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Joint Training Course on Sustainable Water Resources Management in Southern Africa

NEPAD Southern African Water Centres of Excellence

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INTRODUCTION

By adopting in 2002 the Communication on water management in developing countries, a paper setting out EU priorities for development cooperation on water, the EC recognised the crucial role of water resources management for sustainable development. The management of water resources is fundamental to achieve the Millennium Development Goals (MDGs) for which the European Union (EU) has undertaken numerous commitments to accelerate progress in reaching these ambitious targets.

In 2009 the EC established a support project to the AU/NEPAD Water Networks of Centres of Excellence (Water CoE) in Western and in Southern Africa in order to improve the impact of African scientific cooperation, research and development on the water resource sector.

In September 2000 African countries and the international community adopted the Millennium Development Goals at the United Nations Millennium Summit. They identified that water scarcity and related insecurity due to water stress was as one of the sources of the continent's underdevelopment and increasing social and economic decline. Consequently, the first African Ministerial Council on Science and Technology (AMCOST), held in Johannesburg in 2003, established that water science and technology (S&T) would constitute one of the main flagship programmes of the New Partnership for African Development (NEPAD). In 2006, the African Ministers responsible for science, technology and water (AMCOST and African Ministerial Conference on Water, AMCOW) in Cairo (Egypt) committed themselves to establishing the **African Network of Centres of Excellence in Water Sciences and Technology Development**.

Two regional networks now exist and are operational:

The Southern African Network of Water CoE (SANWATCE):

- Stellenbosch University (South Africa) – Secretariat and Hub Coordinator
- International Centre for Water Economics and Governance in Africa (Mozambique)
- University of KwaZulu-Natal (South Africa)
- University of Western Cape (South Africa)
- University of Malawi (Malawi)
- University of Zambia (Zambia)
- University of Botswana (Botswana)
- The Council for Scientific and Industrial Research, CSIR (South Africa)

The Western African Network of Water CoE:

- University of Cheikh Anta Diop (Senegal)- Secretariat and Hub Coordinator
- International Institute for Water and Environmental Engineering (Burkina Faso)
- University of Benin (Nigeria)
- National Water Resources Institute (Nigeria)
- Kwame Nkrumah University for Sciences and Technology (Ghana)

The European Commission provided funding for these two networks, through the Joint Research Centre (JRC), with the objective of enabling Africa to benefit in a more coordinated way from the diversity of scientific and technical institutions and programmes available across the continent. The project's final aim was to improve south to south exchanges and capacity development, strengthening the links between policy and research.

The AU/NEPAD Networks of CoE project was successfully concluded in December 2013. All tasks and deliverables were completed and additional accomplishments have been achieved by the networks. Among the most important results, the SANWATCE network managed to:

- Establishing a network of eight members from five SADC Member States with Stellenbosch University designated as the hub, including developing a business plan;
- Establishing regional institutional relationships such as with ECOWAS and SADC;
- Organizing, with the support Joint Research Centre an international workshop on "Exchange of experiences in water resources management between Africa, China, Latin America and Europe" in October 2012. High level experts on water resources management from four continents exchanged experiences and shared lessons learned on the following topics: water stakeholders' analysis and participation, water resources balance and assessment and water quality and sanitation.
- Contributing to the 9th, 10th and 11th AMCOW General Assembly meetings in Johannesburg (2011) and in Cairo in 2012 and 2013. The AU/NEPAD SANWATCE Secretariat has been delegated by the AMCOW, "to develop a Human Capacity Development Programme aimed at addressing junior professional and technician level capacity challenges in the water sector" (Decision: EXCO/11/2013/CAIRO/17).

One of the programme's tasks was to improve water sector knowledge development and management in the region; consequently the CoEs carried out a need assessment in the two regions identifying skill gaps and defining priorities. The relevant educational material addressing those identified priorities was produced in the form of a "Joint Training Course".

Within the Southern African Network, the exercise of producing training material was based on earlier consultations and studies from a report on Knowledge Management and a Skills and Trainings Needs Assessment study. The result was a short list of training priorities, which finally resulted in the development of 3 Master's degree-level courses. One of the courses is based on the Water Project Tool Kit, available on the AQUAKNOW website.

The rationale behind the training courses

- Conducting a research, including a water stakeholder analysis and needs assessment, on how the Centres of Excellence could effectively provide sector expertise, consultancy and advocacy towards needs in the water sector

Effective water sector policy and development, and sustainable management of water resources must include scientific and technical research specifically directed towards meeting the needs of the African water sector and its stakeholders. In addition there is the necessity to build African human capacities by developing the required expertise and skills for the sustainable management of the available water resources. A study was carried out to identify main skills gaps in the water sector, a summary of which is presented in the table below. This was then followed up with reflection on how the Centres of Excellence could address the needs for sector expertise, consultancy and advocacy for sector development in the region.

Identified skill gaps in the SADC region

- Water and Sanitation Scientists;
- Engineering in multiple sectors (civil, hydrology, process, drainage, irrigation, waste, other);
- Management in multiple sectors (senior & project, accounts, environment,
- Water Treatment Specialists;
- Social Scientists;
- Water Systems/Pipeline Engineers;
- Irrigation/Drainage Engineers / Agronomy (irrigation, soil sciences);
- Conflict Mediation;
- Environmental Law / Climatologists / Foresters / Ecologists
- Coastal Engineering;
- Plant maintenance/operations / Artisans;

With this background information the Centres of Excellence were tasked to address the skills gaps identified in the survey with training courses. It was clear that all gaps could not be addressed in the beginning, but the Southern Africa Network decided as a first step to develop three full Masters level training courses. While the design of the courses is aimed at academic or higher institutional learning environments, their content and modular format do make the courses, or parts of the courses, accessible for practicing professionals in the water sector. The process of selecting the content consisted of a number of communication exchanges followed by a final group consultation held in late 2012. Three course themes and content are summarized hereafter.

Southern African COE Training Course Summaries

Course 1: Groundwater Studies for Southern Africa

The Groundwater course is composed of six main sections. The first two explain the occurrence, movement and hydrogeolical setting of groundwater. Reflecting the importance of groundwater in Southern Africa, the next two sections focus on groundwater exploration, with an emphasis on geophysical techniques. The last two sections address management issues; introducing borehole and well structures, challenges and best management practices, followed by a broader perspective of policy, governance and regulation of groundwater in Southern Africa.

The objective of the course is to provide entry knowledge of groundwater into the water sector for Southern Africa. As such, the course focuses on providing a relevant background on groundwater occurrence, exploration and management. This is supplemented in the closing section with case studies on groundwater policy and current groundwater issues in the region.

Course 2: Water Strategy and Policy in Southern Africa

This course includes an overview of key Strategies on Water and Sanitation in the Southern African region and information about general governance from the SADC regional down to the municipal level, regarding water, energy and sanitation. The focus is on the current principles and views as defined by human rights, constitutions, and declarations accepted by the SADC countries that are discussed. South Africa is central to the course content but students and participants will look at legislative, policy and regulatory contexts and how they vary from a regional as well a local scale.

The course covers the following aspects of water policy and strategy for Southern Africa:

- South Africa as a role player in Southern Africa regarding water and energy
- South Africa as a potential leader in water and energy issues
- South Africa as an example in terms of shared transboundary water resources; notably the Limpopo and the Orange Rivers.
- Shared energy resources: the Cabora-Bassa electricity scheme
- The Mozambique to South Africa gas pipeline
- Shale gas fracturing (fracking) in South Africa

Course 3: Water Project Toolkit Application: Training on equitable, efficient and sustainable management of water resources

The management of freshwater resources and related services is of critical importance to healthy social, economic and political well-being of a society. Access to clean water is vital for the survival of people all other the world. Effective water resource management and developments impacting on water resources are recognised as key components of environmentally sustainable development. The European Commission produced in March 2012 a Water Project Toolkit (WPT) to address these issues. This course develops a strategic approach for the equitable, efficient and sustainable management of water resources and forms the basis for this training. It presents a practical and logical framework of activities based on the involvement of those who use and who manage water, which leads towards improved water governance, and to the development and implementation of integrated water development plans at local, regional and national level.

The first section of the training course introduces challenges and the key concepts behind international development policies and practices of the water sector. The second section focuses on tools and materials useful for developing water sector activities. Theoretical content and practical sessions (exercises, case studies and role playing) are included throughout the course in order to allow participants to experiment with the main concepts presented.

GROUNDWATER STUDIES FOR SOUTHERN AFRICA

EXECUTIVE SUMMARY

The course is composed of six main components. The first two sections of the course explain the occurrence, movement and hydrogeological setting of groundwater. Reflecting the importance of groundwater in Southern Africa, the next two sections focus on groundwater exploration, with an emphasis on geophysical techniques. The last two sections address management issues; introducing borehole and well structures, challenges and best management practices followed by a broader perspective of policy, governance and regulation of groundwater in Southern Africa.

COURSE OBJECTIVES AND OUTCOMES

The course objective is to provide entry knowledge into the groundwater sector for Southern Africa. The content is aimed at Master's Degree level students who have a minimal background in earth sciences and acting professionals in the water sector. As such, the course focusses on providing a relevant background on groundwater occurrence, exploration and management. This is supplemented by a closing section on management of groundwater and current issues on groundwater management in the region.

The course outcome will be for Master's students to gain an overview of groundwater functioning and issues in the Sub Saharan Africa region, which can allow them to make informed and relevant choices for future studies in the groundwater sector, and for professionals in the groundwater sector to obtain the skills and understanding to needed to manage groundwater resources, including strategies for planning and supervising the implementation of highly technical activities. This will be facilitated by having gained an understanding and overview of what constitutes ground water and what constitutes best practices in groundwater management.

ACKNOWLEDGEMENTS

The overall structure and objective of this course has been established with the consultation of Dr. Daniel Nkhuwa (School of Mines at the University of Zambia), Professor Yongxin Xu and Thokozani Kanyere (University of the Western Cape in South Africa), Nico Elema (NEPAD SANWATCE Secretariat), Nora Hanke (NEPAD SANWATCE Secretariat).

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1.1 Occurrence

1.1.1 Hydrological Cycle

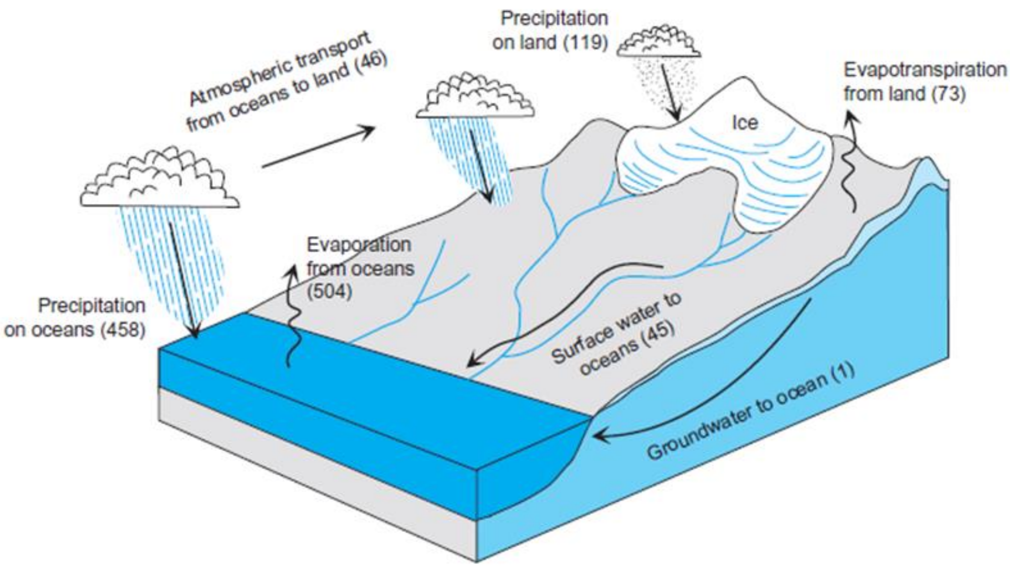


Figure 1 Hydrological Cycle
(Source: Maidment 1993)[1].

Groundwater and surface water are the two reservoirs most used by humans because of their accessibility. Fresh groundwater is about 100 times more plentiful than fresh surface water, but we use more surface water because it is easier to find and use. In the diagram above we see that the majority of the water movement in the cycle occurs over the oceans, including return by precipitation. The remainder of air moisture moves over the land to fall as precipitation.

Driven by energy from solar radiation, water changes continuously both in phases and cycles within these 2 reservoirs. Solar energy drives evaporation, transpiration, atmospheric circulation, and precipitation. Gravity pulls precipitation down to earth and pulls surface water and groundwater down to lower elevations and ultimately back to the ocean reservoir. Evaporation and transpiration are difficult to measure separately, so their combined effects are usually lumped together and called **evapotranspiration**.

Over land areas, average precipitation exceeds average evapotranspiration. The opposite is true over the oceans. On average, more atmospheric water moves from the ocean areas to the land areas than vice versa, creating a net flux of atmospheric water from ocean areas to land areas. The flux of surface water and groundwater from the land back to the oceans maintains a balance so that the volumes in each reservoir remain roughly constant over time. The hydrologic cycle represents only global averages; the actual fluxes in smaller regions and smaller time frames deviate significantly from the average. Deserts, for

[1] Global hydrological cycle. Numbers in parentheses are total global fluxes in thousands of km3/yr.

example, are continental areas where evaporation exceeds precipitation. Conversely, at the cold, rainy coastline of the northwest Pacific, precipitation exceeds evaporation.

The evaporation and precipitation elements of the cycle are the most rapid, while surface water return flow is relatively slower with rivers and streams. The surface water return flow is even more retarded by surface water storage in the form of freshwater bodies such as lakes or ponds (although they are subject also to evaporation), can be held seasonally by snow and ice packs and even longer in glaciers. Relatively, the slowest return flow of water to the oceans is by groundwater flow, and this is affected by the hydro-geological characteristics of the sub-surface.

Water exists in virtually every accessible environment on or near the earth's surface. It's in all forms of flora and fauna, air, glaciers, streams, lakes, oceans, rocks, and soil. The total amount of water on the planet is estimated at 1.4 billion km^3 (UN Water), and its distribution among the main reservoirs is listed below. Much of the total groundwater volume is deep in the earth's crust and too saline for most uses.

1.1.2 Distribution of World Water Resources

Estimate of the World Water Balance

Parameter	Surface area (km^2) X 10^6	Volume (km3) X 10^6	Volume %	Equivalent depth (m)	Residence Time
Oceans and seas	361	1370	94	2500	~4000 years
Lakes and reservoirs	1.55	0.13	<0.01	0.25	~10 years
Swamps	<0.1	<0.01	<0.01	0.007	1-10 years
River channels	<0.1	<0.01	<0.01	0.003	~2 weeks
Soil moisture	130	0.07	<0.01	0.13	2 weeks – 1 year
Groundwater	130	60	4	120	2 weeks – 10,000 years
Icecaps and glaciers	17.8	30	2	60	10-1000 years
Atmospheric water	504	0.01	<0.01	0.025	~10 days
Biospheric water	<0.1	<0.01	<0.01	0.001	~1 week

Figure 2 Estimates of the World Water Balance (Source: Harvey, 2005)

1.1.3 Sub-surface Water

Subsurface waters are divided into two main categories: the near-surface unsaturated or vadose zone and the deeper saturated or phreatic zone (see figure below).

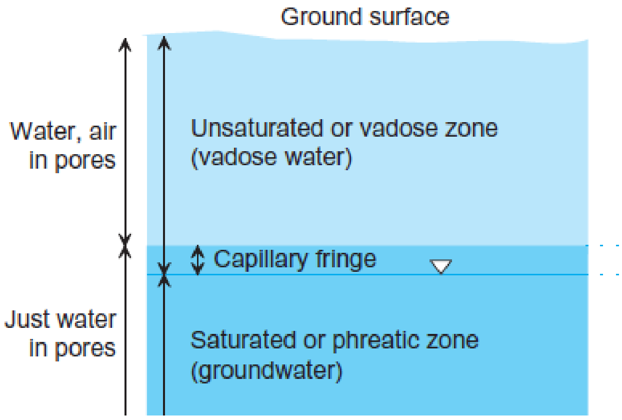


Figure 3 Subsurface Water Zones
(Source: Fitts, 2013)

The boundary between these two zones is the water table, which is technically defined as the surface on which the pore water pressure equals atmospheric pressure. The terms *phreatic surface* and *free surface* are synonymous with *water table*. Measuring the water table is easy. If a shallow well is installed to a depth below the water table, the water level in the well will stabilize at the level of the water table. The water table is often linked to the surface manifestation of geology and can represent a depressed version of topography. Many surface waters are manifestations of the water table – i.e. they represent an exposed water table.

The unsaturated zone or *vadose zone* is defined as the zone above the water table where the pore water pressure is less than atmospheric. In most of the unsaturated zone, the pore spaces contain some air and some water. Capillary forces attract water to the mineral surfaces, causing water pressures to be less than atmospheric. The term vadose water applies to all water in the unsaturated zone. The terms *soil water* and *soil moisture* are also applied to waters in the unsaturated zone, usually in reference to water in the shallow part where plant roots are active.

Below the water table is the **saturated zone** or *phreatic zone*, where water pressures are greater than atmospheric and the pores are saturated with water. The ***capillary fringe*** is a zone that is saturated with water, but above the water table. It has traditionally been assigned to the unsaturated zone, even though it is physically continuous with and similar to the saturated zone.

The thickness of the capillary fringe varies depending on the pore sizes in the medium. Media with small pore sizes have thicker capillary fringes than media with larger pore sizes. In a silt or clay, the capillary fringe can be more than a meter thick, while the capillary fringe in coarse gravel can be less than a millimetre thick. In finer-grained materials, there is more surface area and the greater overall surface attraction forces result in a thicker capillary fringe.

1.1.4 Groundwater

Groundwater refers to water existing in the saturated zone of subsurface water. The strict technical definition of groundwater is any water that is found beneath the surface of the Earth. This definition includes:

- The moisture that is found in the pores between soil grains
- The fresh to slightly saline water, found in saturated geologic units near the surface, which is used for drinking and irrigation
- The extremely salty brines associated with petroleum deposits and deep sedimentary units
- The water found in the lower lithosphere and in the mantle.

1.2 Groundwater Flow

Groundwater is almost always flowing, and the direction of flow is determined by the location of higher groundwater elevation. Note, however, that groundwater does not flow **downhill**; rather, it flows from higher **hydraulic heads** (usually higher water elevation) to lower hydraulic heads. The distribution of hydraulic heads in the saturated zone determines the direction in which the water will flow. The speed with which groundwater flows, also called the **velocity** or **flux**, is determined by the difference in hydraulic head and the **permeability** of the sediment or rock through which it flows. Permeability is a number which describes the ease with which a fluid (like water) will move through a **porous medium** (i.e. a rock, soil, or sediment which has enough pore space to allow water to move through it).

Using hydrostatic principles, it is quite easy to make direct measurements of hydraulic head in the pore water of the saturated zone. All that is needed is a pipe installed into the subsurface. The upper end of the pipe must be open to the atmosphere so that the water surface in the pipe is at atmospheric pressure. At or near the bottom of the pipe, there are holes or slots that allow water to move into the pipe from the surrounding saturated rock or soil. Small diameter pipes like this are called piezometers and larger diameter ones are called wells. If there is no pumping occurring in or nearby the well or piezometer, the conditions of flow are static or *hydrostatic*. Normally groundwater flow is relatively slow; therefore its speed of flow does not affect the position of the hydraulic head. In low hydraulic conductivity materials, there is often disequilibrium between the head in the pipe and the head in the formation. Because water can only flow slowly, it may take anywhere from hours to weeks for enough water to flow through the medium near the pervious section to establish equivalent heads in the pipe and the medium.

1.2.1 Recharge and Discharge

Recharge

Groundwater is a part of the dynamic hydrologic cycle, and water must somehow enter as well as leave the subsurface. Water entering the subsurface is called **recharge**. Recharge to the subsurface is generally through **infiltration** – percolation of surface water (from rain, perennial streams, melting snow etc.) downward into the soil. As the water percolates down through the soil, sediment, and rock, the percentage of the pore space that is filled with water (or the **degree of saturation**) increases until it reaches 100% (i.e. complete saturation).

Recharge rates vary with location at a large scale due to variations in climate and precipitation patterns. Maps of estimated recharge rates show patterns similar to maps of precipitation rates. Precipitation governs the availability of water at the surface, which is key to recharge. In some climates like monsoon climates, recharge is distributed quite unevenly through the year with a rainy season and a dry season. In temperate and polar climates, there is also a strong seasonal variation in recharge, with almost no recharge occurring when and where ground is frozen, and a pulse of recharge when the ground thaws and snow melts. Short-term daily or weekly variations in recharge rates are associated with specific precipitation events.

Infiltration, the precursor to recharge, can occur when precipitation rates exceed evapotranspiration (ET) rates. When ET rates are highest (hot, dry conditions), recharge rates are lower. Outside of tropical latitudes, there is a strong seasonal variation of ET, with highest rates in summer and lowest rates in winter. In these regions, recharge rates tend to be higher in the cool months, except when the ground is frozen.

Topography also influences recharge rates at a more local scale. In humid climates, recharge rates tend to be highest in flat, upland areas and low or negative (groundwater discharging to the surface) in low-lying areas and valleys. In arid climates, the general pattern is quite different. Higher recharge rates tend to be focused in lowlands, ephemeral stream valleys, and alluvial fans, where the occasional precipitation runs off and eventually infiltrates, transpires, or evaporates. On a small scale, subtle topographic variations can focus recharge in low spots where runoff accumulates. For example, in a nearly flat 2.7 hectare field underlain by permeable sands, measured local recharge variations of over 50% corresponded to topographic variations of less than a couple of meters (Delin et al., 2000).

Vegetation is another factor affecting recharge. Forest and shrub landscapes are more effective at transpiring water than grassland or crop landscapes, and thus tend to have lower recharge rates. For similar reasons, areas lacking vegetation have higher recharge rates than vegetated areas. Allison et al. (1990) found that recharge rates at sites in the Murray Basin, Australia, increased by about two orders of magnitude when native deep-rooted eucalyptus vegetation was replaced by shallow-rooted crops.

Under irrigated lands, recharge rates can increase dramatically due to infiltration of excess water (irrigation return flows). In the southern High Plains Aquifer in the U.S., irrigation return flows have increased average annual recharge rates about twentyfold (Alley et al., 1999). In California's Central Valley, predevelopment recharge was greatest during winter months, but now there is an additional pulse of higher recharge during the growing season, thanks to irrigation return flows (Faunt, 2009). Irrigation return flows are now the largest contributor to recharge in the Central Valley aquifer system, and irrigation applies more water to the land surface than precipitation does. Drip irrigation and low-level sprinkling systems are more efficient than older irrigation systems and help minimize return flows.

Where the water table is shallow, transit times from the surface to the water table are short, and recharge rates oscillate up and down in concert with precipitation transients. When the water table is deep, transit times to the water table are long and tend to blur and merge the effects of individual precipitation events at the depth of the water table. Recharge rates at a deep water table tend to be much more uniform than infiltration rates up near the surface.

Urban and suburban development often alters recharge rates. Paving and structures limit infiltration, and runoff is often channelled and routed to distant surface waters, which also reduces recharge. Construction of canals, dams, and reservoirs can have large impacts on recharge. New reservoirs add a new source of high recharge, often lifting water tables in a broad area. Sewer and water lines often leak, becoming new sources of recharge. They also can create permeable conduits, creating new pathways for groundwater migration.

Discharge

While water enters the saturated zone, it must eventually leave it. Movement of water out of the saturated zone is called **discharge**. Natural discharge can be through a spring, into the bed of a stream, lake or ocean, or via evaporation directly from the water table. Pumping of groundwater through **wells** – holes drilled into the ground for the purpose of accessing subsurface fluids – is another way that water discharges from the saturated zone.

1.2.2 Groundwater Discharge to Surface Water Bodies

All water that you see flowing in a stream originates as precipitation, but the water takes various routes to get there. Some runs directly over the land surface to a channel (overland flow). Some water infiltrates a little way and runs horizontally in near-surface soils to a channel (interflow). Some water infiltrates deeply to become recharge and then migrates in the saturated zone to discharge back to the surface at a spring, lake, or stream channel. The portion of stream flow that is attributed to this latter path is called **baseflow**.

If the geologic materials in a stream basin are very permeable, baseflow can be a large part of a stream's discharge. If the materials have low permeability, most precipitation does not infiltrate and baseflow is only a small portion of stream discharge. Baseflow is a fairly steady component of a stream's discharge, maintaining low flows during periods of drought. Flow contributed by overland flow or shallow interflow is called **quickflow** because it gets to the stream channel quickly. Quickflow is more transient and occurs during and soon after precipitation events. Discharges between surface waters and groundwater are not constant over time, but vary as surface water and groundwater levels change in response to precipitation events, floods, and pumping.

In humid climates, there is generally discharge from the saturated zone up into surface waters; such streams are called gaining streams (see figure below). The top of the saturated zone in the adjacent terrain is above the water surface elevation of gaining streams. In losing streams, water discharges in the other direction: from the stream to the subsurface. These situations generally occur in arid climates, where the depth to the saturated zone is great. The base of a losing stream may be above the top of the saturated zone as shown in the right side of the figure, or it may be within the saturated zone. The same process applies to other surface water bodies such as lakes. It is also possible to have one side of the water body have inflow of groundwater to the surface water body while the other side is subjected to outflow from the surface into the groundwater.

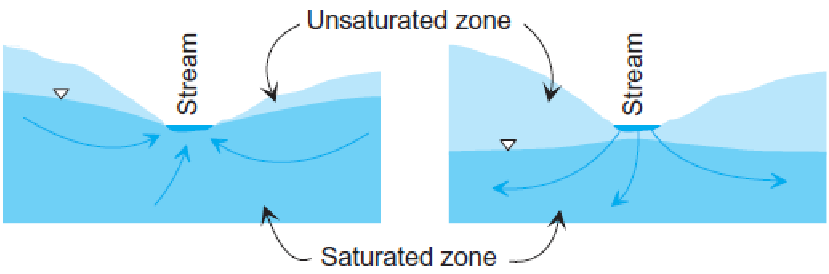


Figure 4 Gaining and Losing Streams
(Source: Fitts, 2013)

Bank storage (river) acts as a buffer of sorts for surface waters. When the surface water stage rises, some of the surface water goes into bank storage, which helps dissipate floods to some degree. When the surface water stage drops, some water exits bank storage and flows into the surface water.

1.2.3 Darcy's Law

In 1856, French engineer Henry Darcy was working for the city of Dijon, France on a project involving the use of sand to filter the water supply. He performed laboratory experiments to examine the factors that govern the rate of water flow through sand (Darcy, 1856; Freeze, 1994). The results of his experiments defined basic empirical principles of groundwater flow that are embodied in an equation now known as Darcy's law.

Darcy's apparatus consisted of a sand-filled column with an inlet and an outlet similar to that illustrated in the figure below. Two manometers (essentially very small piezometers) measure the hydraulic head at two points within the column (h1 and h2). The sample is saturated, and a steady flow of water is forced through at a discharge rate Q [L3/T]. Darcy found through repeated experiments using consistently a specific sand, that Q was proportional to (∝) the head difference Δh between the two manometers and inversely proportional to the distance between manometers Δs:

$$\mathbf{Q} \propto \Delta \mathbf{h_1}, \qquad Q \propto \frac{1}{\Delta s}$$

Obviously, Q is also proportional to the cross-sectional area of the column A. Combining these observations and writing an equation in differential form results in **Darcy's law** for one-dimensional flow:

$$Qs = -Ks\frac{dh}{ds}A$$

Where ***dh*** represents the difference or drop in head or gradient between the two manometers or measuring points, and ***ds*** represents the distance between the manometers as illustrated below:

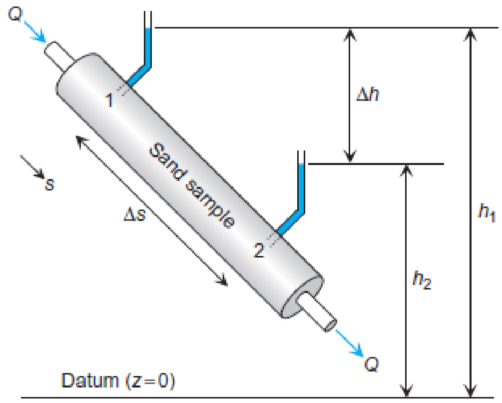


Figure 5 Steady Flow through sand column
(Source: Fitts, 2013)

Qs is the discharge in the *s* direction. The *constant of proportionality Ks* is the hydraulic conductivity in the *s* direction, a property of the geologic medium. Hydraulic conductivity is a measure of the ease with which a medium transmits water; higher *Ks* materials transmit water more easily than lower *Ks* materials.

The minus sign on the right side of this equation is necessary because head decreases in the direction of flow. If there is flow in the positive *s* direction, *Qs* is positive and *dh* = *ds* is negative. Conversely, when flow is in the negative *s* direction, *Qs* is negative and *dh* = *ds* is positive.

Now, consider the units of the entities in Darcy's law. Head *h* and the coordinate *s* both have length units, so *dh*=*ds* is actually dimensionless. The dimensionless quantity *dh*=*ds* represents the rate that head changes in the *s* direction, and is known as the **hydraulic gradient**. The dimensions of *Qs* (discharge) are [L3/T or volume/time] and of *A* are [L2], so the hydraulic conductivity *Ks* is [L/T].

Rocks or soils with small pores allow only slow migration of water while materials with larger, less constricted pores permit more rapid migration. Water traveling though small, constricted pores, must shear itself more in the process of traveling a given distance, than water traveling through larger pores. More shearing in the water causes more viscous resistance and slower flow. Other factors being equal, the average velocity of groundwater migration is proportional to *K*. Hydraulic conductivity is an empirical constant measured in laboratory or field experiments.

Fortunately, Darcy’s law is a physical principle which applies to most groundwater flows. There are a few limitations, however. Darcy’s law can be inappropriate if the medium is too irregular or if the flow velocity is too great in a medium with large pores. Also, Darcy’s law applies to the flow of water, not other liquid flows, which require a different calculation but are still subject to subsurface geological characteristics. In summary the basic idea behind Darcy’s law is this:

- the discharge is driven by a gradient
- discharge is linearly proportional to a gradient
- there is a constant (*K*) of proportionality that characterizes the ease with which water flows through the system (a *conductivity* parameter)

1.2.4 Flows and Aquifer Depths

Most environmental and engineering studies of groundwater are focused on shallow depths within a hundred meters of the surface, but fluid flows deeper in the crust are interesting and quite relevant to oil and gas exploration, mineral exploration, and crustal-scale geologic processes.

With increasing depth in the crust, rock’s porosity and permeability tend to decrease. Also, pore fluids become hotter and more concentrated with dissolved minerals. Deeper than 10 km, the crust has low intrinsic permeability (*k* < 10�20m2) due to high confining pressures and ductile deformation of rock (Person and Baumgartner, 1995). Shallower than 6 km, rock permeabilities are significantly higher and pore fluids can traverse flow paths of continental length scales. The residence times for fluid involved in this upper crustal flow can be of geologic proportions, up to millions of years.

At shallow depths, groundwater flow is driven predominantly by variations in the elevation of the water table surface. This driving mechanism is called *topography-driven* flow because the elevation of the water table usually mimics the elevation of the ground surface. This same driving force can cause large-scale flow patterns where there are continental-scale trends in topography. For example, flow in the upper crust under the great plains of North America is generally from west to east, down the slope of the plains away from the high ground of the Rocky Mountains

1.3 Aquifers

Aquifer is a familiar term, meaning a permeable region or layer in the saturated zone. An aquifer is a geologic unit that can store and transmit a sufficient amount of water supply. The terms aquifer and confining layer are relative descriptors of water-bearing zones or layers in the subsurface. Aquifers are the layers with higher hydraulic conductivity and confining layers (also called aquitards) are the layers with lower hydraulic conductivity. When compared to a marine clay with low conductivity, a glacial till layer might be considered an aquifer. At another location this same glacial till deposit might be considered a confining layer when compared to a sand and gravel layer with a very high conductivity.

Aquifers are the layers that are typically tapped by water supply wells, and aquifers transmit most of the flow towards a given location. Confining layers retard flow and typically transmit relatively little water.

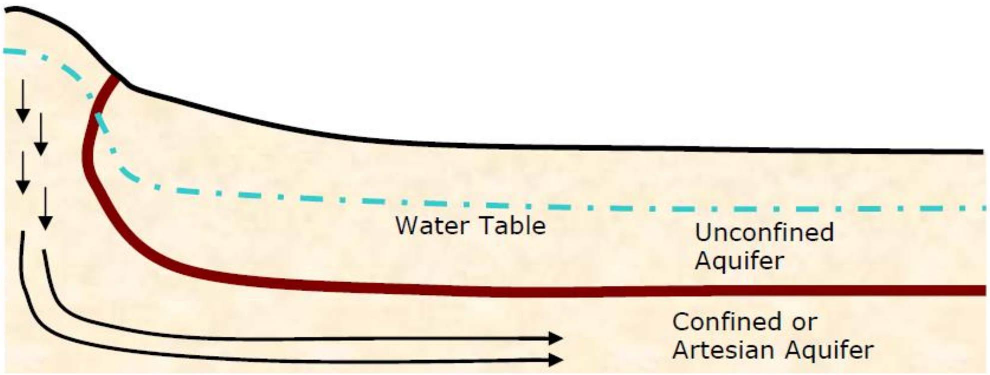


Figure 6 Confining layers
(Source: Harvey, 2005)

The factors that determine if a geologic unit is an effective aquifer include the following:

- The permeability must be high enough that flow can be maintained.
- The aquifer dimensions must be great enough (i.e., there must be a significant saturated thickness) to supply water to a well
- The quality of the water must be good enough for the intended use.

The three basic types of aquifers are – confined, unconfined, and perched (see figure below).

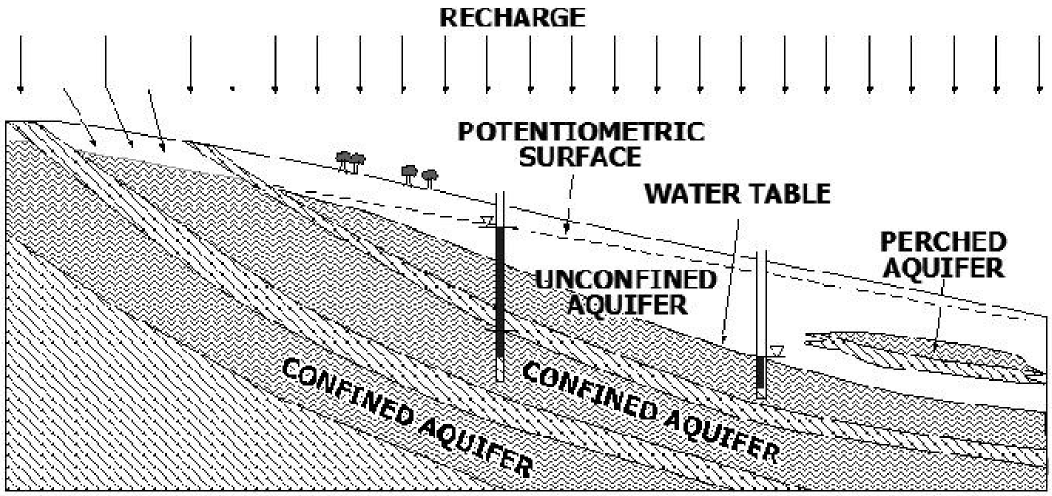


Figure 7 Types of Aquifers
(Source: Uliana, 2012)

1.3.1 Unconfined Aquifers

The most common condition for groundwater is where it is exposed at some point to the surface and atmospheric pressure through openings in the overlying regolith or surface material.

1.3.2 Confined Aquifers

These are aquifers in which groundwater is not exposed to the surface or atmosphere because it is covered above by an impermeable (or relatively impermeable) geologic layer. The aquifer is usually subjected to higher hydrological pressures than atmospheric pressure. Where these aquifers are tapped either with excavation wells or boreholes, water flows upwards, sometimes to the surface (and beyond) forming an **artesian well** (see figure below).

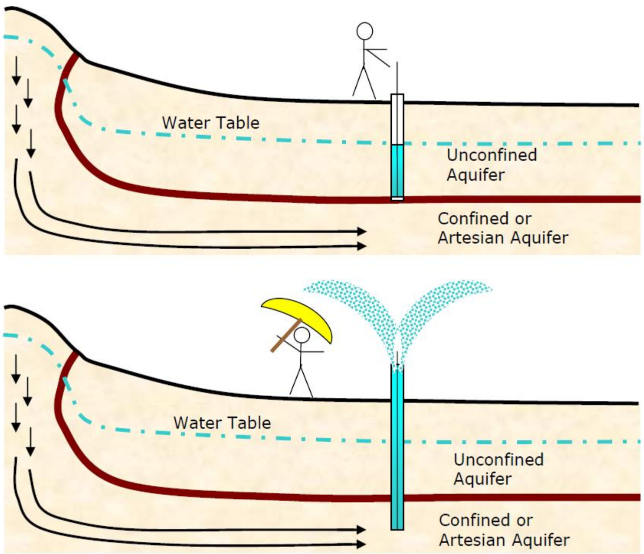


Figure 8 Perched and artesian aquifers
(Source: Harvey, 2005)

1.3.3 Perched Aquifers

As can be seen in the aquifer diagram above, a perched aquifer is a localized impermeable layer within a larger permeable substrate but still remaining above (perched) the unconfined aquifer. This layer acts as a barrier to infiltration to the larger aquifer, resulting in lenses of groundwater perched above the surrounding water table. Perching layers reduce rates of recharge to underlying regional aquifers and redirect subsurface water flow along horizontal flowpaths. Where perching layers outcrop or intersect the ground surface, perched aquifers can discharge water to springs, streams, and wetlands. Where perching layers completely underlie wetlands and lakes, surface-water levels can remain relatively stable even as regional water tables decline.

1.3.4 Key Aquifer Properties

An aquifer performs 2 essential functions – storage and transport. The interstices of the aquifer act as a storage medium but still often remain part of a larger interstitial network. Groundwater is constantly moving through this network of conduits, thus the water only remains in temporary storage. The rate of flow can range from metres per year to metres per day.

Porosity

Porosity is the percentage volume occupied by voids. Porosity is independent of scale. For example, a pile of marbles and a pile of beach balls have spherical shape and differing sizes; the porosities are identical due to the similar shaping. Normally, grains have different sizes and porosity varies with the mix of grain sizes and the range of sorting and composition between large, medium or small size grains.

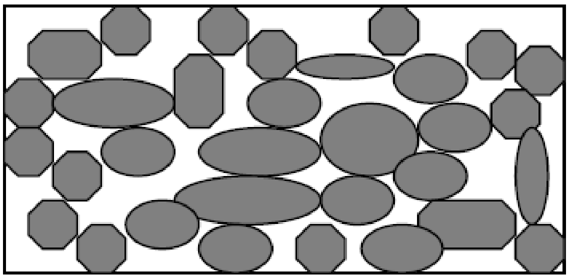


Figure 9 Granular Porosity
(Source: Harvey, 2005)

In the figure above the spaces between the large and medium-size grains may be filled in with very small grains, air, and/or water to form an aquifer. In some cases, water with high mineral content may results in dissolution of minerals in the water and subsequent infilling of the porous spaces with mineral material, thus reducing the porosity of the aquifer.

Primary Porosity

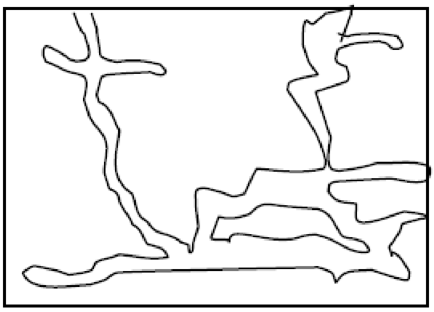
The void space in the rock is formed during deposition of sediments and diagenesis (transition from sediment to sedimentary rock), for example empty space in between sand grains in sandstone. Generally there is greater storage but less flow in primary porosity.

- A function of grain size distribution, also packing (porosity increases with grain size)
- Decreases with depth – compaction and pressure solution

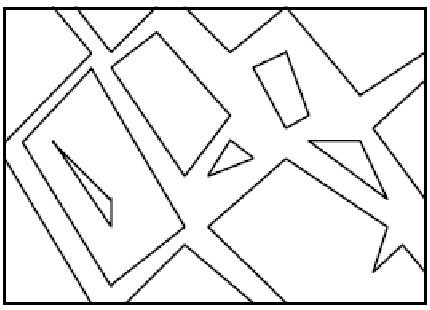
Secondary Porosity

Secondary porosity is the void space formed 'post-diagenesis' from the following geo-chemical and geological processes.

- Dissolution
- Fracture



Dissolution Porosity



Fracture Porosity

Figure 10 Secondary porosities
(Source: Harvey, 2005)

Effective Porosity

We defined the porosity of a rock as the volume of voids over the total volume. However, in real rocks, not all of the porosity is available for fluid flow. Some voids are too small, or the pore throats are too narrow, or some may be isolated from the rest of the rock. The porosity available for fluid flow is called the **effective porosity.** Examples of materials with potentially high total, but low effective, porosity include:

– clay (lots of saturated void space, but fluids do not move)
– vesicular basalts (vesicles are not connected)

Specific Yield

If we saturate a rock and let it drain by gravity, a certain percentage of the water in the pore spaces will be held in by surface tension and narrow pore throats. The fraction that drains is the specific yield (**Sy**) and the fraction that is retained is called the specific retention (**Sr**). More rigorous definitions are:

Sy = volume drained

volume total

Sr = volume retained

Note that **Sy + Sr** = total porosity.

Permeability

Permeability measures the transmission property of the media and the interconnection of the pores. It is related to hydraulic conductivity and transmissivity, or the ease in which a porous media transmits fluid. This characteristic is explained by the relationship known as Darcy's Law.

1.4 Exercises

– Explain why fine-grained granular materials have lower hydraulic conductivity than coarse-grained granular materials.
– Explain why pore water pressures in the unsaturated zone are less than atmospheric pressure.
– What conditions are required in order for water to have an upward component to its specific discharge (*q*) in the unsaturated zone? Assuming a uniform material, what would the vertical profile of water content have to be like?

2.0 Geology and Hydrogeology of Formations

The characteristics of the aquifer are defined in large part by the geological formations in which they are found. These formations will affect the quantity of water as well as the quality of the groundwater. During the solidification and formation of the earth's surface, the skin of the earth was formed with a wide variety of mineral content. With subsequent mechanical processes of erosion by agents wind, water (surface flow, glaciers, oceanic) gravity and chemical (minerals taken up or deposited in solution) the surface is modified. Sedimentary particles are mobilized and deposited, sometimes far from their origins. Generally earth materials are classified in terms of their origins as follows:

2.1 Igneous Rocks

Igneous rocks form by cooling and solidification of a hot molten liquid or magma. This origin is reflected by their texture, which is a mosaic of crystals, arranged in much the same fashion as a flagstone walkway. They can be further classified as *intrusive* and *extrusive*. Intrusive igneous rocks are those that are emplaced into the rocks that surround them, usually as hot magma from deep in the Earth that flows into cracks and fractures of rock closer to the surface, separating and sometimes melting the surrounding rocks on contact. Intrusive igneous rocks are not usually visible at the earth's surface until surface rock cover is eroded away. Extrusive rocks form from lava that flows out of volcanoes, volcanic ash and also lava flows that can arise from deep origin to surface fractures. Basalts and granites are typical igneous rocks. Intrusive igneous rocks are usually coarse grained (composed of large crystals) while extrusive rocks are finer grained. This is linked to cooling time, where intrusive rocks are able to cool more slowly and allow more time for crystal formation.

2.2 Sedimentary Rocks

Sedimentary rocks are composed of hardened, compacted and cemented sediments of sands, silts and clays. The resulting rocks are known as sandstones, siltstones, and shales. Other sediments have more organic origins such as bones and shells of fossil plants and animals, which secrete calcium carbonate, which combine with their skeletons to form limestones. Examples of plant origin sedimentary rocks include coal and lignite from fossilization of plant material deposited in marine environments. The main characteristic of sedimentary rocks is their layering, stratification and bedding which results from a constant depositional environment from air or water transport. Typical depositional environments include sea-floors, river bottoms, beaches or deserts.

2.3 Metamorphic Rocks

Metamorphic rocks are the third major classification, and include the rocks of the other two types which have been altered by heat and / or pressure. They are usually coarse-grained and may show forms of layering similar to sedimentary rocks, but this is in fact due to alignment of the mineral structures which provides a texture known as foliation. Metamorphosis can be caused by wide volume heat and pressure when rocks become buried deep below the earth's surface in a process known as regional metamorphism. It can

also occur from heat by being baked by intruding or overlying magma during intrusions or volcanic activity and this form is known as contact metamorphism.
In terms of hydrogeology we are interested in earth materials which have permeability and porosity which allows for groundwater flow with the processes of recharge and discharge.

2.3.1 Groundwater in Unconsolidated Sedimentary Deposits

Unconsolidated sediments occupy 22% of the land area of Sub Saharan Africa and sustain a rural population of 60 million. They are probably more important than these statistics suggest since they are present in most river valleys throughout Africa. Groundwater is found within sands and gravels. Unconsolidated deposits like sand, silt, and clay usually have their geologic origin as alluvial, marine, or glacial deposits. The coarser deposits, sands and gravels, are among the most porous and permeable of earth materials. Where present, they form important aquifers that have high yields and are easily tapped at shallow depth. Many of these unconsolidated aquifers are in contact with rivers or other surface waters, which adds significantly to their potential yield when pumped.

Most shallow unconsolidated deposits have little cement in them and their porosity and permeability is governed mostly by grain size distribution. The more uniform (well sorted) the grain sizes are, the higher the porosity. The coarser the material, the higher its permeability and hydraulic conductivity is.

Alluvial deposits are common on flood plains and terraces of rivers (see floodplain diagram below). These materials can range from clays to gravels, depending on the turbulence of the water that deposited them. The coarser sands and gravels tend to be deposited in the faster parts of the main river channel, while the finer silts and clays are deposited in stagnant oxbow lakes and beyond the channel during floods. Since the channel meanders over time, the sequence of sediment associated with it also shifts. Meandering channels tend to erode and rework bank materials and cut off big loops from time to time. The result is that a floodplain becomes a complex distribution of former channel sands, levee silts, and floodplain silts and clays.

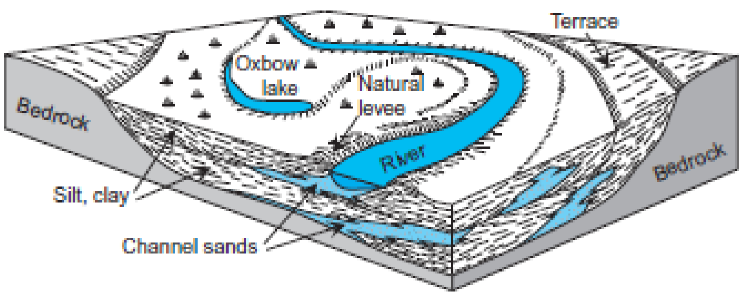


Figure 11 Cross-section view of floodplain (Source: Fitts, 2013)

Alluvium is also common in basins within mountain ranges. Sometimes these basins are closed, sometimes they have an outlet. The figure below illustrates common features of a fault-block mountain basin typical of the basin and range.

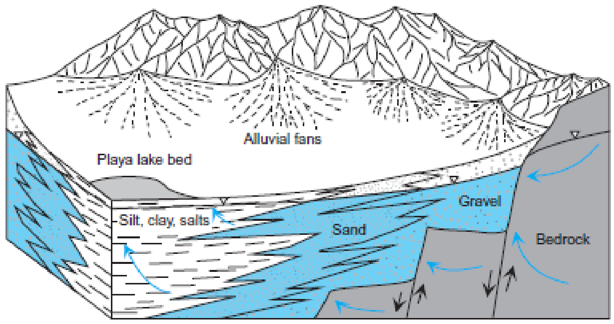


Figure 12 Cross-section view of fault-block basin
(Source: Fitts, 2013)

The alluvium is coarsest at the margins of the basin, where streams deposit sands and gravels in alluvial fans. These streams exit mountain valleys and flow onto the basin alluvium and become losing streams, losing all their discharge to the subsurface before flowing very far.

There is often an ephemeral playa lake in the centre of a closed basin. The alluvium deposited in the lake bed is dominated by silts, clays, and evaporate minerals. The water table is usually closest to the surface in the centre of the basin. During very wet seasons, the water table intersects the surface and the playa lake fills with water. In dry times, the water table drops below the surface and the lake drains and evaporates, depositing salts.

Coastal plains are another setting where there are significant aquifers in unconsolidated deposits. Studies have shown that coastal plain aquifers contain enormous quantities of water which requires optimisation and management to minimize the intrusion of saltwater as a result of over exploitation. Coastal plains and deltas are common on continental margins around the world. The deposits under a coastal plain consist of near-horizontal layers of sediment ranging from sands and gravels to silts and clays. They are deposited in near-shore terrestrial and marine environments. A given layer forms a near horizontal bed as the position of the shoreline and the associated depositional environments slowly progress landward or regress seaward over geologic time.

The stratigraphy of the coastal plain is usually continuous with its submerged portion under the continental shelf. The bedding generally dips gently towards the ocean, and the layers thicken in the down-dip direction. Hydrologically, coastal plains form a thick stack of alternating aquifers (sands and gravels) and aquitards (silts and clays), both of which may be continuous for hundreds of kilometres. Coastal aquifers can also outcrop inland at their up-dip limit, where recharge enters them.

2.3.2 Groundwater in Sedimentary Rocks

A large fraction (approximately 3/4) of the shallow bedrock under of the earth's land area is sedimentary as opposed to igneous or metamorphic. Sedimentary rock sequences can extend for hundreds or even thousands of kilometres, forming huge regional groundwater flow systems. These kinds of sedimentary sequences occur in central North America, central Australia, and northern Africa. Consolidated sedimentary rocks occupy 32% of the land area of Sub Saharan Africa and sustain a rural population of 110 million.

Significant groundwater is found within sandstones and limestones, which can be exploited for urban as well as rural supply. Mudstones however, (which account for about 65% of all sedimentary rocks) contain little groundwater, and careful study is required to develop water for community supply in this environment.

Sedimentary rocks span a huge range with respect to permeability, and these contrasts make for interesting patterns of groundwater flow. Flow in aquifers is mostly parallel to the dip of the layers, but flow in aquitards is mostly normal to the layering, creating leakage between separate aquifers. Shales and salts typically have extremely low permeability and are usually aquitards (confining layers), while sandstones, limestones, and dolomites often have high permeability and are the aquifers.

Sandstones consist of sand grains, often largely quartz, which are cemented together by minerals including quartz, calcite, dolomite, oxides, and clay minerals. Sandstones can have porosity ranging from less than 1% to more than 25%, depending on the degree of sorting in the original sand sediment and the extent of cementation and recrystallization that the sands have experienced. There is a general inverse correlation between depth and porosity in sandstones; depth promotes compaction, recrystallization, and cementation, all of which reduce porosity. Except in highly cemented sandstones, the matrix (primary) porosity and permeability is more significant than the fracture (secondary) porosity and permeability.

Even at a fairly small scale, sandstones are heterogeneous, with variations in permeability that parallel the stratification. As a result, the bulk average permeabilities or hydraulic conductivities of a large volume of sandstone tend to be anisotropic, with higher values parallel to the bedding and lower values normal to the bedding.

Shales and other fine-grained clastic rocks are very common, about half of all sedimentary rocks. Their permeabilities are low, and they usually form the confining layers in a sequence of sedimentary rocks. Although shales transmit water very slowly, large quantities of water can leak though shale aquitards when large areas are considered. Shales often have fairly high porosity, up to 20% or more. The porosity and abundance of shales means that a large amount of water is stored in them. Many important confined aquifers draw much of their discharge from leakage and storage in adjacent shale layers.

Limestones and dolomites are composed primarily of the carbonate minerals calcite and dolomite, respectively. They vary tremendously in their texture and hydraulic properties. Limestones that are shallow and young can have high matrix porosity and permeability, particularly poorly cemented rocks consisting of coarse shell fragments or calcareous sands. When carbonate rocks are buried deeply, their matrix porosity and permeability typically decline due to compression, cementing, and recrystallization. Often the porosity in carbonate rocks is poorly connected, such as pores formed by weathered fossils. When this is the case, the rock has low permeability despite its porosity. In carbonate rocks with low matrix permeability, the fractures provide most of the permeability. There is typically a prominent set of fractures parallel to bedding, in addition to other fracture sets. Fractures in carbonate rock can become much wider when shallow groundwater circulates through them and dissolves calcite and/or dolomite.

Dissolution occurs mostly at shallow depth because shallow, just-infiltrated water has low concentrations of dissolved calcium, magnesium, and carbonate ions, and is very capable of dissolving carbonate minerals. Deeper groundwater usually has high, near-saturation concentrations of these ions, and is unable to continue dissolving carbonate.

2.3.3 Groundwater in Igneous and Metamorphic Rocks

The movement of groundwater through crystalline igneous and metamorphic rocks is one of the least predictable phenomena in all of groundwater science. This is because the porosity of these rocks is very low, and the permeability is usually controlled by an irregular network of small fractures. Crystalline basement occupies 40% of the land area of SUB SAHARAN AFRICA; 220 million people live in rural areas underlain by crystalline basement rocks. Groundwater is found where the rocks have been significantly weathered or in underlying fracture zones. Borehole and well yields are generally low, but can be sufficient for rural demand.

The porosity of most igneous and metamorphic rocks is less than a few percent, and in some it is below 1%. Much of this porosity is in the form of small, unconnected pores between crystals. The pores that conduct fluid flow are the interconnected ones, which in most crystalline rocks are found in fractures. The permeability of most intact, un-fractured crystalline rocks is extremely low, usually orders of magnitude smaller than the permeability of large-scale fractured masses of the same rock.

Fractures, whether they are joints or faults, usually occur in roughly parallel sets, and one rock mass will often have several distinct sets. Some fracture sets develop due to large-scale crustal stresses of tectonic origins. Within tens of meters of the surface, crystalline rock often has a fracture set that parallels the ground surface, called sheeting. Sheeting is caused by unloading that occurs as erosion peels away overlying rock over millions of years. When fractures control the permeability (and hydraulic conductivity) of rock, the permeability will be anisotropic, with higher conductivity parallel to prominent fracture sets. The permeability of a fracture is controlled by its aperture and smoothness, properties that are near impossible to measure at depth.

Many fractures are at least partially filled with precipitated minerals such as iron oxides. Therefore, it is difficult to estimate the permeability of rock masses from measurements of fractures. Large-scale pump testing is a more useful approach to estimating crystalline rock permeability. In general, the density of fractures and the permeability of fractured rock decrease with depth. With increasing depth, the weight of overlying rock increases, and the average fracture aperture decreases. Also, the effects of weathering and erosional unloading are the greatest near the surface. Rock is brittle to many kilometres depth, so although fracture permeability tends to decrease with depth, it can still be significant to depths of several kilometres.

Many extrusive igneous rocks have significant matrix porosity in addition to fracture porosity. When magma cools and crystallizes at or just below the surface, there are often gas bubbles frozen into the rock. Gas bubbles form in magma as it rises to the surface and the pressure within it drops. A good analogy for this process is the formation of bubbles in champagne after opening. If magma cools quickly, the gas bubbles are preserved and the resulting rock has a vesicular texture. Pumice and scoria are very porous rocks formed in this way. Volcanic rocks occupy 6% of the land area of Sub Saharan Africa, and sustain a rural population of 45 million, many of whom live in the drought stricken areas of the Horn of Africa. Groundwater is found within palaeo-soils and fractures between lava flows. Yields can be high, and springs are important in highland areas.

By far the most common type of extrusive igneous rock is basalt. When a large amount of basalt erupts to the surface it tends to form lava flows. Solidified lava is often deformed and fractured by still-flowing lava. Flows often develop a solid skin, which cracks, folds, and breaks up as the underlying molten lava continues moving.

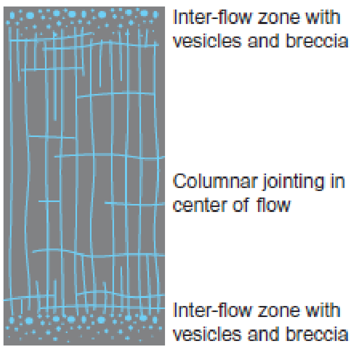


Figure 13 Basalt aquifer characteristics (Source: Fitts, 2013)

This jumbled skin is found at the top of flows for obvious reasons, and on the bottom because the front of a flow advances by rolling over its skin. Generally, the zones at the top and bottom of recent flows are very permeable, due to vesicular lava near the top of flows, jumbled and broken crusts (breccia) on the top and bottom of flows, and sometimes coarse alluvium that is deposited between flows.

In the middle of a thick flow, there is typically columnar jointing, vertical fractures that form as a result of shrinkage during crystallization. The columns are typically smaller than a few meters across, and smaller towards the top of the flow. This gives the centre portion of flows vertical permeability and some horizontal permeability. However, the more porous and permeable interflow zones transmit most of the horizontal flow in a basalt flow sequence. The permeability of basalt flows is strongly anisotropic, with high permeability parallel to the layers.

2.3.4 Hydrogeology and Groundwater Quality

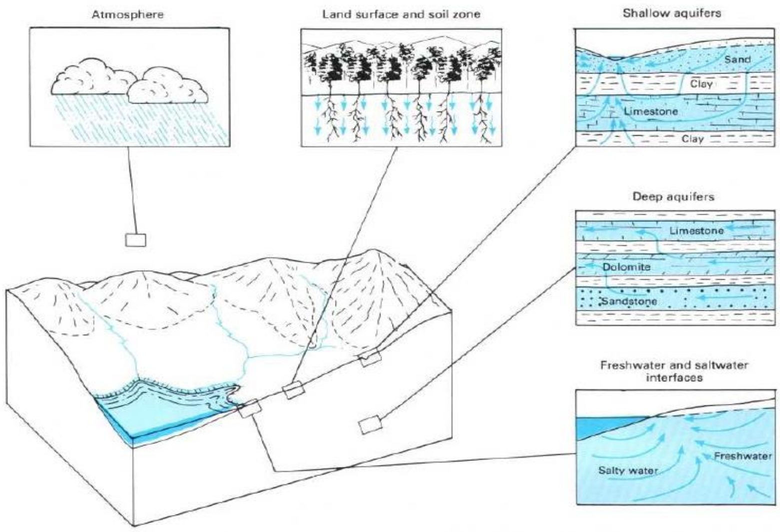


Figure 14 Different groundwater environments within a basin (Source: Heath, 2004)

The chemical constituents of groundwater are determined by the chemical and biological reactions occurring in the zones through which the water moves. Water frequently is referred to as the universal solvent because it has the ability to dissolve at least small amounts of almost all substances that it contacts. Of the domestic water used by man, ground water usually contains the largest amounts of dissolved solids. The composition and concentration of substances dissolved in unpolluted ground water depend on the chemical composition of precipitation, on the biologic and chemical reactions occurring on the land surface and in the soil zone, and on the mineral composition of the aquifers and confining beds through which the water moves.

The concentrations of substances dissolved in water are commonly reported in units of weight per volume. In the International System (SI), the most commonly used units are milligrams per litre. A milligram equals 1/1,000 (0.001) of a gram, and a litre equals 1/1,000 of a cubic meter, so that 1 mg/L equals 1 gram m -3.1

The quality of ground water depends both on the substances dissolved in the water and on certain properties and characteristics that these substances, present in the aquifer, impart to the water. These substances can be both organic and inorganic.

Inorganic Substances

The major inorganic ions in groundwater include sodium, potassium, calcium, magnesium, silica, bicarbonate, sulfate, and chloride. The distribution of these constituents largely depends on the type of geological formations in contact with the groundwater flowing through. Most of them are rarely harmful to health but some may cause physical inconveniences if digested in large concentrations (e.g. sulfate). High concentrations of calcium and magnesium compounds cause hardness of water. For people suffering from diseases of the heart or kidneys, it is recommended to avoid drinking water with high concentrations of sodium. The major ions form the majority of chemical compounds found in groundwater. The summed ion concentration of minerals dissolved in water is referred to as total dissolved solids (TDS). There is no evidence of adverse health effects at TDS levels over 1,000 mg/l, although at about 1,200 mg/l taste problems are likely to arise, and at levels over 1,500 mg/l, gastrointestinal irritation may occur.

Certain minor inorganic constituents may be present in groundwater and may render it unfit for human consumption. Perhaps the two best known examples of such constituents are arsenic and fluoride. Arsenic may be released into groundwater through the reduction of arsenic containing iron hydroxide coatings on sand grains, which are present in some fluvial and deltaic river sediments. A case at hand is the release of arsenic in the sedimentary basin of Bangladesh and neighbouring India (see case study) below. The consumption of groundwater with excessive arsenic levels is toxic and may eventually lead to the loss of limbs, cancer, or death. Fluoride may be present in groundwater by the disintegration and dissolution of igneous and metamorphic rocks containing minerals such as amphiboles and micas. The drinking of groundwater with high concentrations of fluoride may cause mottled teeth and disturb the growth of bones in children. Extremely high concentrations of fluoride are toxic and could lead to death. The recommended limits for arsenic and fluoride are listed in the table below.

Constituent	*Concentration*	*Constituent*	*Concentration*
Total dissolved solids	1,500	Iron	0.3
Arsenic	0.01	Lead	0.01
Cadmium	0.003	Manganese	0.05
Chloride	250	Nitrate	50
Chromium	0.05	Selenium	0.01
Copper	2	Sulfate	250
Fluoride	1.5	Zinc	3

Figure 15 Maximum permissible concentrations of potentially harmful or objectionable substances in drinking water, in mg/l
(Source: WHO Guidelines, 1993)

Organic compounds

In addition to resulting from human activities, organic compounds may be released in groundwater as a result of natural processes. These processes usually take place near the surface in the humus-containing soil, but may also be present in deeper layers where peat, lignite, coal, or even shallow oil deposits are present and in contact with groundwater. Through metabolism, decay, dissolution, advection, and other processes, organic compounds are formed and become part of the groundwater system. Humic acids, pectins, and hydrocarbons, are amongst the natural organic substances occurring in groundwater. In most places, the concentrations of naturally-occurring organic compounds are low and cannot be considered as contaminating groundwater.

Microorganisms

Naturally-occurring microorganisms in groundwater rapidly decrease with depth. There is usually a correlation with the concentrations of organic compounds in groundwater, which also tend to decrease with depth. The few microorganisms found in groundwater pumped from deep wells are usually the so-called chemo-lithotropic bacteria. Nevertheless, groundwater may contain bacteria that play vital roles in oxidation-reduction processes. Well-known examples are:

- the bacteria assisted reduction of carbon dioxide and organic acids into methane,
- the bacteria-aided reduction of sulfate into hydrogen sulfide, and
- the bacteria-based oxidation of dissolved iron and manganese into iron and manganese oxides and hydroxides.

Especially, the last two reactions are known to produce bacterial slimes, which make groundwater less suitable as drinking water, and which also clog well screens and pumping mechanisms.

2.4 Case Study: Arsenic contamination in groundwater in Bangladesh

2.4.1 Problem definition

In Bangladesh, the contamination of shallow groundwater with arsenic has reached critical levels. The Government of Bangladesh became first aware of the problem in 1993, and ever since, reports on illnesses and poisoning by drinking of arsenic-containing groundwater have been increasing. By 1997, the affected areas comprised the western and south western part of the country, and alarming reports were also received from the north eastern part of Bangladesh.

2.4.2 Hydrogeological setting

More than 75 percent of the Bangladesh area is made up of deltaic, alluvial, and marshy deposits (see map below). Residual deposits associated with old land surfaces (II) and areas of consolidated sedimentary rock (I) are located in the isolated central and north-western parts of the country, and in the east, respectively. The deltaic (IV) and alluvial (III) deposits contain numerous layers of sand with occasional gravel, which form good aquifers that are exploited on a large scale by municipalities and smaller communities.

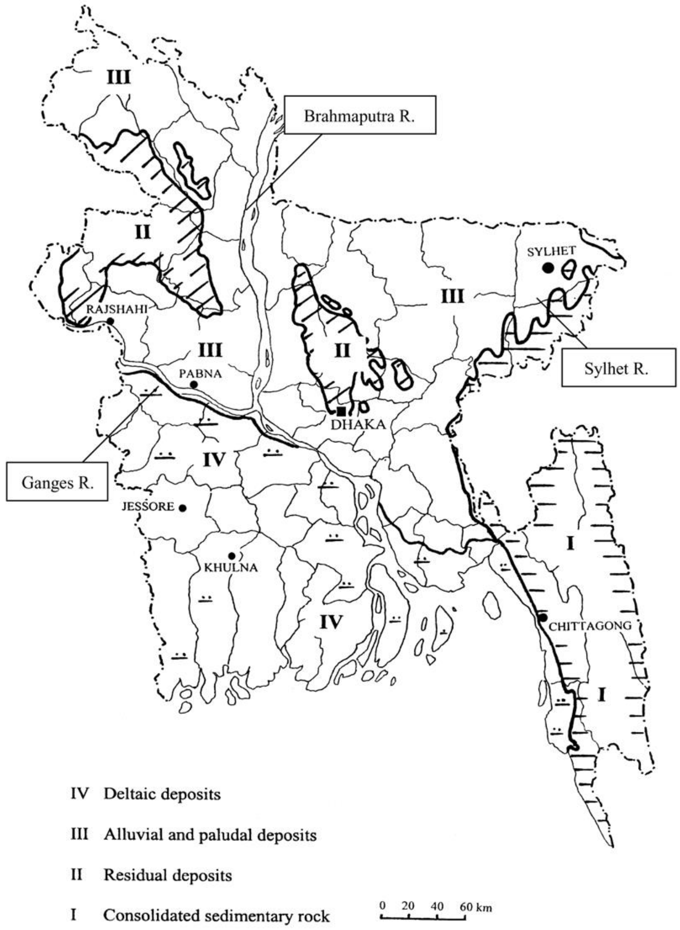


Figure 16 Case Study area and surface geology
(Source: Zaporozec, 2002)

Groundwater, which is pumped from these deposits using deep and shallow wells, contains arsenic that is, supposedly, derived from the arsenic containing mineral-rich sediments deposited in the area by the rivers. The Ganges River appears to be one of the main sources of these sediments. The arsenic contained in the mineral-rich sediments is therefore of natural origin, but there has been speculation that it may have been released into groundwater as a result of human interferences in the area including pumping, dewatering, and reservoir construction.

2.4.3 Investigation and Inventory

The inventory of arsenic-affected areas in Bangladesh has been done on a rather unplanned basis. Water sampling for arsenic has concentrated on wells in communities where a lot of cases of arsenic poisoning caused concern with the local health officers. Understandably, the local and national press has played a role in focusing attention on these communities. The uncoordinated sampling programs have caused the information on arsenic to be only partly available.

An additional systematic groundwater sampling program in the affected areas in Bangladesh was carried out in 1998. A total of just over 2,000 shallow and deep wells were sampled on a municipality basis. Using a suitable geographical grid, 5 to 10 wells per municipality were systematically selected, and subsequently visited. The sampling density varied between 30 and 40 km^2 per sample. A protocol describing geo-referencing procedures, use of water sample collection forms, and bottling techniques was developed and used. Samples collected were primarily analysed by the Department of Public Health Engineering for arsenic, iron, and hardness (DPHE, 1997). Cross-checking of sample analyses was carried out by the British Geological Survey in Wallingford, England. The storage and processing of hydrogeological and hydrochemical data including arsenic was done linked to ArcView for the generation of layers of various parameters which formed a sound basis to present and analyse the results in a professional manner. Results from water quality analyses were overlaid with maps of geological formations.

2.4.4 Conclusions for the Bangladesh basin

One of the essential conclusions related to the groundwater system in Bangladesh was that the arsenic-rich groundwater is confined to shallow geological formations (especially from 20 to 40 m below the land surface), and in particular, to the recent deltaic and alluvial deposits. Groundwater contaminated with arsenic is also positively correlating with low redox potentials (reducing conditions), high iron concentrations, and generally low sulfate concentrations. No direct positive relation exists with groundwater use. Based on these comparisons and the results of sediment samples taken at wells in Bangladesh, the origin of the arsenic in groundwater was mainly attributed to the arsenic-containing iron-hydroxide coating on fine sand, which is deposited in the basin by the large Ganges, Brahmaputra, and Sylhet Rivers. Burial of the sediments causing transfer to reducing conditions stimulated the dissolution of the coatings, which released the arsenic into the groundwater.

2.4 Exercises

- Make one vertical cross-section sketch that shows an *unconfined perched aquifer*, an *unconfined aquifer*, and a *confined aquifer*. Sketch a non-pumping well in the confined aquifer and show the water level in the well. Label each aquifer. Sketch and label the water table where appropriate.
- Consider a coastal plain setting where there are alternating near-horizontal sand layers and silt/clay layers. Describe the typical direction of flow in the sand layers. Describe the typical direction of flow in the silt/clay layers.
- Just by looking at a topographic map of a region with a humid climate, how could you tell if the underlying material is predominantly low conductivity or high conductivity?
- Give an example of a specific location on the earth where you would expect to find very old groundwater (water that had infiltrated thousands of years ago). Explain why you would expect old groundwater there.

3.0 Groundwater Exploration

3.1 Introduction

As discussed in previous chapters, earth materials vary tremendously in their capacity to hold water (porosity) and their capacity to transmit water (hydraulic conductivity). To make intelligent judgements about groundwater requires the best possible knowledge of the distribution of water and geologic materials. The world of groundwater is hidden from view and expensive to explore, so this knowledge is always scant. There are four major categories of exploration techniques that exist:

- Desk Study of hydrogeological maps and reports compiled by government agencies or other sources. These maps can be augmented by topographical maps, vegetation maps, air photos and other forms of remote sensing.
- Formation sampling, which can take the form of excavation or drilling
- Geophysical surveys conducted at the earth's surface.
- Geophysical surveys conducted in existing boreholes

While the initial desk study phase will usually yield a combination of information ranging from regional scale to extremely detailed, it is important to determine as early as possible the nature of the aquifer (s) in the region of interest; specifically whether they are *continuous* or *discontinuous*.

Continuous aquifers are those aquifers in which all points are connected hydraulically through a porous medium (sand, gravel, clayey sand, sandstone, etc*.).*

Discontinuous aquifers are those aquifers in which hydraulic connections are discontinuous and no correlation is possible from one well to another. In these types of aquifers groundwater occurrence is exclusively related to the weathering or fracturing of the rocks and the matrix of the rock is almost completely impervious to regional water flow. This type of aquifer usually occurs in crystalline rocks (igneous or metamorphic) like granite or basalt.

3.1.1 Primary Objectives and Steps

The primary steps in water-well and groundwater exploration are to:

- Locate the best sites for test holes, construction of holes or wells.
- Obtain representative samples of the geological formations penetrated. This should be done in a methodological fashion during the drilling process with all information transmitted into a geological log.
- Do a geophysical log of the completed borehole to augment the geological log.
- Determine the depth to static water level in each borehole drilled or surveyed, or in existing shallow and deep wells or excavations.
- Obtain water samples from potential aquifers to determine the water quality.

3.2 Desk Study Phase of Exploration

The main objective of a preliminary survey is to minimize the cost of groundwater development. Planning a preliminary groundwater survey includes minimizing the total cost of study and implementation of the groundwater development project. It is essential to keep this concept in mind in order to avoid oversizing the study in relation to the expected final groundwater development. The importance of the exploration phase of the project should not be neglected, particularly in areas of discontinuous aquifers where little information is available.

3.2.1 Preliminary hydrogeological survey - methodology

Review existing geological and hydrogeological information

In most countries geological and hydrogeological maps of a scale ranging from 1/200 000 to 1/1 000 000 exist or are in the process of preparation and can provide essential information on aquifers, their extension, their boundaries and their lithology, and on the depth to water level. This information is usually sufficient to determine whether or not the aquifers are continuous within the area considered for water supply project. In many countries publications (e.g. journals or bulletins) are available that address groundwater from a scientific point of view and contain studies of where groundwater exists, its quality and its flow characteristics. While not comprehensive in their coverage, they often represent research or studies that have been done in areas of groundwater shortage or with water quality problems. In combination with boreholes for water purposes, the information that can be derived from mining and petroleum exploration, or geotechnical activities can also provide useful information on subsurface geology and, in some cases, groundwater characteristics such as depth to the water table.

Water well inventory

Information from an inventory of water wells is the basis for a more accurate identification of the aquifer(s) which will then be tapped in the framework of the future groundwater development project. From the data collected on the existing dug and drilled wells it will be possible to establish the hydraulic continuity of the aquifer and to map the depth to water, the distribution of the good wells (the discharge of which exceeds a minimum value admissible for the considered purpose) and water quality. In the case of discontinuous aquifers, the data collected should also include dry wells (dug or drilled) in order to establish a correlation between as many parameters as possible. Well discharge is usually correlated with:

- the nature of the water bearing formation;
- the formation fracture characteristics, if any (from air photo interpretation);
- the distance to important tectonic structures (from satellite imagery and air photo interpretation); and
- the depth of penetration of the wells into the aquifer.

In many countries the installation of boreholes is regulated to varying degrees, and this usually involves the collection of a borehole records or logs which are normally archived and has already been collected by the Service responsible for the Water Resources Inventory. In the best case, the additional field investigations required will be limited to updating the inventory or checking questionable information.

Topographical and Thematic maps

In addition to the classical geological and hydrogeological maps, topographical and even vegetation or other thematic maps can be useful. As has been already discussed, groundwater flow can be influenced by the surface topography. For example, groundwater will generally exist nearer the surface and in larger quantities in valleys rather than in upland areas. Topographic maps also indicate the presence and distribution of surface water resources or surface water drainage characteristics, equally important in arid environments with ephemeral flow. Surface drainage distribution is often indicative of subsurface geology, especially in hard-rock or consolidated sediments where linear fractures and fault lines of subsurface geology interfere with the normal meandering hydrology. Faults, fractures, or sharp changes in geology can often provoke straight lines of flow or sharp changes in direction of surface water flow.

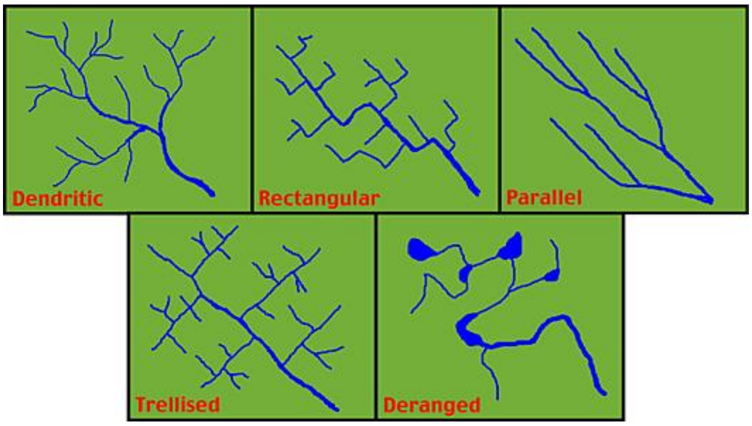


Figure 17 Drainage pattern types
(Source: Pidwirny, 2006)

Trellised drainage patterns tend to develop where there is strong structural control upon streams because of geology. In such situations, channels align themselves parallel to structures in the bedrock with minor tributaries coming in at right angles. Areas with tectonic faults or bedrock joints can cause streams to take on a grid-like or rectangular pattern. Parallel drainage patterns are often found in areas with steep relief or where flow is over non-cohesive materials. Dendritic patterns are typical of adjusted systems on erodible sediments and uniformly dipping bedrock. Deranged drainage patterns are found in areas recently disturbed by events like glacial activity or volcanic deposition. Over time, the stream will adjust the topography of such regions by transporting sediment to improve flow and channel pattern.

Remote sensing methods

Satellite imagery and the digital nature of the satellite image allows for computer manipulations of the image to conform any desired map projection and to enhance or extract specific levels of information. It is therefore advisable, when a high definition of the ground elements is required, to use enhanced imagery especially processed to identify and locate:

- hydrographic networks which may indicate the thickness and characteristics of the weathered zone as well as subsurface tectonic structure,
- vegetation which may give information on shallow groundwater occurrence, and
- lineaments connected with geological structure.

Aerial photographs are of great help for siting new wells in discontinuous aquifers. They are probably the most efficient and cheapest tool (usually much less expensive than satellite imagery) to identify the small tectonic structures which may result in fracture of the bedrock and ground-water occurrence. Moreover the use of air-photos does not require particular skill: the fractured zones of the bedrock are usually clearly visible, sometimes indicated by vegetation alignment (because of the presence of water underground) and occasionally marked by sills or dykes of different intrusive rock types. They are a useful visual complement with topographic and geological maps, especially since aerial photos are subject to scale distortion and difficult to interpret height or altitude.

3.3 Formation Sampling

3.3.1 Excavation

Digging by hand with shovels or hand augers is an inexpensive, but limited, way to sample shallow unconsolidated materials. Usually hand digging can go no deeper than a meter or two. With hand augers that are screwed into the ground, somewhat deeper sampling is possible, particularly in soft sediments. Power excavators (backhoes) can dig deeper than by hand, as deep as four or five meters for the larger ones. A backhoe can dig test pits this deep at a rate of 10 or more per day. This is a good and inexpensive way to map unconsolidated surficial deposits.

With either hand or backhoe excavation, it is difficult to excavate much below the water table, especially in more permeable materials like sands or silts. If a backhoe works fast enough, it can excavate a meter or more below the water table, but it is a race against the clock. Below the water table, the excavation walls and base are usually unstable and they heave or cave in.

3.3.2 Direct-Push Probes

Since the 1980s, a variety of new direct-push exploration methods have been developed. Small-diameter probes and sensors are pushed directly down into unconsolidated materials without drilling out a borehole in advance. Probes generally consist of a small drilling pipe (37–49mm outside diameter) with a cone-shaped tip on it and other instrumentation incorporated just behind the tip. Hydraulic or pneumatic jacks attached to a heavy truck push the probe into the ground with static, impact, or vibrational forces. Probes can be used to measure hydraulic heads and horizontal hydraulic conductivities over the short vertical interval of the screened port, usually less than 2m long. As a probe is driven, it displaces and compresses soil, causing an increase in pore water pressure and head near the tip. When driving stops, pore water flows away from the tip, dissipating excess pore water pressure. The pressure and head eventually return to ambient levels. The rate of pore pressure dissipation is a function of the hydraulic conductivity of the surrounding deposits. Some probes are equipped to make geophysical measurements such as electrical conductivity, which can be used to identify the water table and stratigraphy.

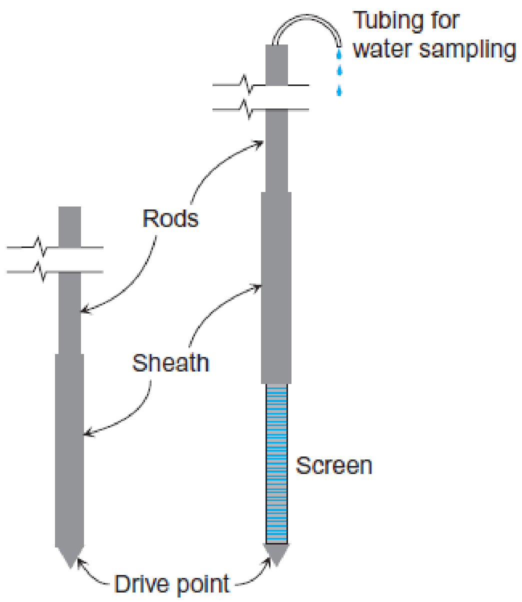


Figure 18 Sampling Probe
(Source: Fitts, 2013)

Above is an illustration of a probe for sampling groundwater. The probe is driven with a sheath covering the screen (left). At the sampling depth, the sheath and rods are retracted, exposing the screen (right).

3.3.3 Jetted Wells

Some shallow, small diameter wells can be efficiently installed in unconsolidated deposits using a method called jetting. A jetted well looks like the groundwater probe shown in the above, with a short screened section behind a drive point. In a jetted well, water is pumped down the centre of the rods, exiting through the screen and sometimes through the drive point. This flow of water softens the deposit allowing the well point to advance.

Jetting is particularly effective in soft sand, silt, or clay materials. Coarser and denser sands and gravels present too much resistance and are not as amenable to this technique. Jetting is usually limited to shallow depths of less than 10 m. When jetting in cohesive clay, the drive point below the screen is usually a vertical blade-like cutting bit with water jets on the sides of the blade. With this type of bit, the drill pipe is simultaneously rotated and lifted up and down in the hole to help cut a straight hole. Jetting does not allow for the effective collection of samples, but in the right materials it is a quick way to install shallow wells which can be used for other evaluations such as depth to water table.

3.3.4 Drilling

Holes hundreds or thousands of feet deep can be made with drilling methods. Drilling creates a hole in either unconsolidated materials or solid rock, with samples being collected as the hole advances. Relatively undisturbed samples can be collected and wells, piezometers, or other instrumentation can be installed in the hole that is drilled. The diameter of drilled holes ranges from just a few centimetres for shallow explorations to a meter or more for large water supply wells. Drilling has great versatility, a relatively high cost, and is widely used for groundwater investigations. The most commonly used drilling methods for groundwater investigations are:

- hollow-stem auger,
- rotary drill, and
- cable-tool or hammer drill.

Hollow-stem augers

These are widely used for shallow environmental and geotechnical investigations. The augers are screwed into unconsolidated deposits by a rotary drilling rig, a powerful truck that can spin the augers while applying downward pressure on them. Various sampling tools and cutting bits may be lowered with a small-diameter drill pipe inside the hollow augers, which typically have an inside diameter of 10 cm. When advancing the hole, a plug bit is lowered to the bottom of the auger to prevent soil from entering the hollow-stem. To take a sample, the plug bit and drill pipe are lifted to the surface while the augers are left in place. The plug bit is replaced with a soil sampler, which is then lowered to the bottom of the hollow-stem and driven into soils beyond the bottom of the auger. This process is typically repeated at specified depth intervals such as every metre.

Hollow-stem augers are limited to unconsolidated deposits, and they work best above the water table in softer materials. Below the water table, especially in uniform sands or silts, soils at the bottom of the hole can liquefy and flow up into the hollow-stem as the plug bit is withdrawn. Another disadvantage of augering is that the zone of soil around the hole is disturbed by the auger flights. This disturbance may affect the results of subsequent hydraulic testing or make it difficult to seal the borehole against contaminant migration.

Sampling Tubes

The two most common methods for sampling unconsolidated materials are the **split-spoon sampler** and the **thin-walled tube**. Both are steel cylinders that are typically ½ metre in length. They are attached to drill rods and driven into intact soils and cores samples as they drill the hole. They are usually used for soil sampling. The tube is lifted out at regular intervals. The tube splits in half lengthwise for inspection and removal of the sample. The tube sampler works in a similar fashion but does not allow for the inspection without removing the sample completely from the core bit.

Rotary Drilling

In **rotary drilling**, the hole is advanced by spinning a drill bit attached to the bottom of a string of hollow drilling pipe. A fluid, which can be mud, water, or air, is circulated down the inside of the drill pipe, out the drill bit, and back up to the surface in the annulus outside the drill pipe. Most rotary test holes are 4 to 6 inches (100 to 150mm) in diameter.

In reverse-circulation rotary drilling, the fluid travels in the opposite direction: down the annulus outside the drill pipe and back up inside the drill pipe. Materials loosened by the drill bit at the base of the hole are swept back to the surface with the return flow of the fluid. There is usually some sort of settling basin at the surface that allows the solids to settle out of the drilling fluid before it is pumped back down the drill pipe.

In unconsolidated materials, an outer casing is often advanced just behind the drill bit to prevent the hole from caving in. Rotary drilling methods generally use an uncased hole when in rock, unless the rock is highly fractured or deformable. The use of water or mud as the drilling fluid keeps fluid pressure on the borehole walls, so it is possible to drill in unconsolidated materials without casing. Drilling mud is slurry of water and suspended clay with other additives. Mud is denser and more viscous than water, so it provides greater insurance against cave-ins and is more efficient at carrying cuttings back to the surface.

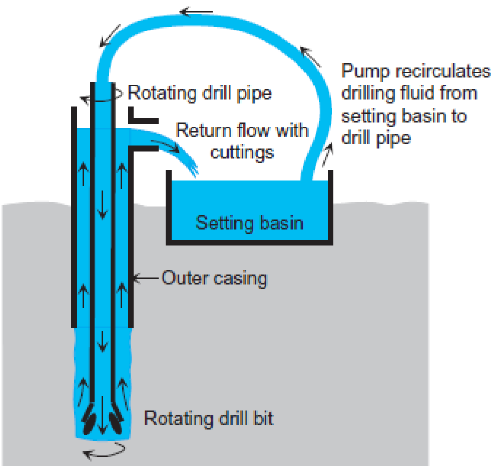


Figure 19 Rotary Drilling
(Source: Fitts, 2013)

Above is a Cross-section of rotary drilling. Drilling fluid flows down the spinning drill pipe, exits at the bit, and returns with cuttings to the surface. The drilling as well as providing a pressure against the borehole walls to prevent collapse, it also forms a borehole wall-cake which also keeps the borehole intact. The viscosity of drilling fluid depends on the mixture of water, additives and to a certain degree the sample material if it is especially fine (fines sands, silts). There are optimal densities or viscosities of drilling fluid that allow for good circulation during the drilling, integrity of the borehole and a consistent delivery of sample materials to the surface.

Sonic drilling is rotary drilling with the addition of high-frequency vibrations transmitted down the drill pipe to the bit. These vibrations can reduce friction on the drill pipe and speed the advance of the drill bit. The operator of the rig can adjust the frequency of the vibration (typically near 100 Hz) to resonate with the drill string and formation for optimal performance.

The bits used for rotary drilling in rock are usually either three-cone roller bits or coring bits. The roller bit chews up the rock and the only samples it affords are chips suspended in the drilling fluid. Coring bits, on the other hand, carve a cylindrical hole, leaving a solid core in the centre. Both types of bits are typically studded with diamond or carbide to abrade and crush the rock that is being drilled.

Cable Tool Drilling

In cable tool drilling, drill bits and samplers are raised and lowered with a cable from the surface. The hole is advanced by dropping a chopping bit repeatedly on the bottom of the hole. Cuttings are removed by dropping a hollow bailer down the hole, which fills up but has a flap that prevents cuttings from falling back out as the bailer is lifted. Unlike rotary drilling, where a string of drill pipe segments must be disassembled and stacked each time a bit or sampler is brought to the surface, bits and samplers can be retrieved quickly with the cable.

3.3.5 Sampling Supervision

The objective of obtaining samples is to obtain information on subsurface geological and hydrological conditions. For the geology, the lithology or the geological record of the types of earth material, the order and thicknesses of deposition, and mineralogical content are important. This requires an ordered and systematic recording of materials as they are excavated, in order to build a correct and accurate record of the subsurface geology. This activity is known as *logging* and resulting profile of the subsurface geology is known as the *lithologic log*.

For shallow excavations and shallow drilling such as with augers or jetting, the logging process is relatively uncomplicated and usually consists of recording for depth and position the excavated unconsolidated materials.

Drilling Supervision

For deep boreholes requiring rotary drilling, more activities require observation and supervision for effective logging. The most common type of lithologic log consists of the driller's description of the geologic character of each formation, the depth at which changes were observed, the thickness of the formation, and the depth to water. Ideally, the driller should collect representative samples at measured depths and at intervals that will show the complete lithologic character of the formations penetrated. Optimally, even for shallow holes up to 50 meters, samples should be taken at least every 2 to 5 meters of depth, unless initial results show frequent changes in lithology. Then, samples should be taken more frequently (every meter). For deeper boreholes up to 100 meters it is feasible to maintain frequent sampling (every 5 meters), but this becomes impractical for very deep boreholes.

The samples usually obtained by various drilling methods consist of cuttings produced by the action of the drill bit. While not entirely representative of the formations penetrated in some cases, they are commonly relied upon in groundwater exploration for identifying the best aquifer materials and determining the size of the screen openings which need to be installed in the borehole casing.

It can be difficult to correlate samples with depth, including major changes in formation, in deep rotary-drilled boreholes due to contamination by materials eroded from the borehole walls and separation of materials coming up a long borehole. This is especially difficult where materials are sedimentary and loosely consolidated. However, if the erosion and separation of sample material is not a problem, a good driller can estimate depth of the obtained sample by calculating the uphole velocity of the drilling fluid and cuttings. If the drilling is being done with a coring drill bit, and the sample material is a continuous representation of geology, it is evidently easy to note the depth.

Awareness of changes in drilling action is also vital in compiling an accurate and informative borehole log. Observations made by the driller should be included in the log, such as rates of penetration. A drilling-time log supplies useful information about the formations encountered, because the character of the material largely determines the rate at which penetration proceeds. Clean sand formations usually drill very rapidly; muddy sand drills more slowly; loose sand drills more rapidly than cemented sand; and tight clay, shale and hard rock drill more slowly than other materials.

Maintaining optimal drilling fluid viscosity is important, and the viscosity should be regularly checked. Viscosity can change due to mixing in of unconsolidated fines in the borehole (becoming thicker) or the drilling into an aquifer, in which case the fluid becomes diluted. In the latter case, a sharp dilution can indicate a water strike which may not be immediately evident from the formation samples; especially if the water discharge is of low capacity, which can occur in aquifers of low permeability.

Sample Collection and Management

The drilling cuttings that arrive at surface are usually collected in a container or basin at the mouth of the borehole as they arrive to surface. This container is regularly emptied and cleaned at intervals corresponding to depths of penetration. The cuttings for each depth sample should be placed in a container that allows them to settle, allowing excess drilling fluid to be poured off. Then the description of the cuttings should be noted carefully, including mineralogical composition, the size and angularity of the particles and cuttings. The latter is especially important, since rounded particles often represent materials hydraulically deposited (streams, water channels) and angular can represent aeolien or wind deposits so common in desert environments; both of which result in different porosities and permeabilities. A small sample of the cuttings is then placed in a container, labelled, and then stored or transported to a laboratory for more detailed grain-size-distribution and lithologic analysis.

3.4 Exercises

- Describe how both direct-push probes and rotary drilling work, in general. Describe the conditions where each of these technologies can and cannot be used.
- Describe two advantages mud has over water as a drilling fluid.
- What are the main benefits of well development?
- What are the general purposes of a well’s filter pack? Above the filter pack, wells often have clay or cement grout seals around the casing. What is the purpose of these seals?

4.0 Geophysical Exploration

4.1 General Geophysical Theory

Geophysical techniques examine variations in the physical structure and composition of the earth's crust. This information may also be gained through expensive drilling programmes or by geological mapping However geophysics is less expensive than drilling and the equipment more portable.

Geophysics does not require surface exposure of outcrop to produce geological information.

Geohydrological investigations often employ surface geophysical techniques during the preliminary stages of a field study. Geophysical methods can provide specific information on the stratigraphy of the local geological environment as well as its aquifer properties. Such stratigraphic information includes the type and extent of surficial material as well as the depth to, and nature of, underlying bedrock. Aquifer properties that can be initially assessed by surface geophysics include the extent of unconsolidated materials and depth to bedrock, the presence and extent of fracturing of bedrock, the presence of water, and the depth to water table. Essentially there are two types of geophysics techniques; those which measure the inherent characteristics of earth materials such as gravity or magnetics, and those which measure the results of applied energy to earth materials such as electrical resistivity or seismics.

4.1.1 Seismic Properties of Earth Materials

Exploration seismology originally developed from earthquake seismology, wherein the seismic energy waves generated from an earthquake were recorded on seismographs at different locations. From this information deductions were made about the earth material between the epicentre (origin of the seismic shock) and the seismograph. This led to the development of modern seismology where a controlled artificial shock wave is applied to the earth's crust and the resulting energy wave or signal is measured by detectors or geophones. Translation of this signal produces a detailed picture of subsurface geology. Seismic methods are widely used for mapping deep layered sediments in oil and gas exploration, location of shallow sedimentary layers and water tables in hydrological investigations and structural site investigations for engineering purposes.

The speed that a seismic wave travels is influenced by the material through which it passes. Generally, the more dense the material, the faster and more easily the energy will be transmitted. Seismics are often used to map bedrock topography and identify features that affect the geohydrological environment. These features include bedrock channels, buried valleys, and structural faults. The degree of water saturation of the aquifer can also affect wave transmission by increasing the density of the earth media and the speed of the wave. In unconsolidated material, the water table registers as a separate layer in the seismic response.

4.1.2 Electrical Properties of Earth Materials

Most soil and rock minerals are electrical insulators and are electrically resistive. However, if conductive earth materials such as metals occur in large enough quantities they can increase the conductivity of the subsurface material. However the main form of electrical conductivity of the subsurface is electrolytic and takes place through moisture-filled pores and passages that are contained within the insulating matrix. Overall, electrical conductivity is determined by porosity and permeability of the soil and rock material, moisture content, the concentration of dissolved electrolytes in the moisture, the temperature and phase state of the water, and the amount and composition of colloids or clay content of the soils.

Electrical Properties of Rocks

Rock material itself rarely acts as a conductor unless it falls in the category of native metals such as copper, gold, or carbon (graphite). Native metals are effective conductors compared to 18 other rock materials because their crystal structure has a more orderly arrangement of metal ions, surrounded by a cloud of valence electrons. This cloud is highly mobile, and the energy required to induce electrical conductivity (movement of electrons) in a metal is relatively small compared to other rock materials.

For most rocks near the earth's surface, the conduction of electricity will be electrolytic conduction through the groundwater contained in the pores of the rocks. The conductive medium will usually be an aqueous solution of common salts contained in the pore structure of the rock or subsurface material. When an electrolyte goes into solution in water the compounds disassociate and move freely about as positive and negative ions until they are impelled by an electrical field.

Depending on rock type and structure, the porosity and the resistivity of different rock types vary. Types of porosity such as intergranular, jointing or fracture induced and vugular (large pores) are a function of the type of material (e.g. sedimentary or volcanic) as well as the structure of the material. The fracture porosity usually results in the highest rock electrical conductivity because of its simple shape. The quality of the water in the material changes with time, altering the water's electrical characteristics. This occurs because groundwater is subject to diagenetic changes during its passage through an aquifer. These changes include such processes as dissolution, hydrolysis, precipitation, adsorption, ion exchange, oxidation and reduction. Once removed from the aquifer, the groundwater is no longer subject to these effects.

The pore spaces of rock materials are not necessarily saturated with electrolytes. Above the water table, near-surface rock materials are only partially saturated in a zone of aeration.

Moisture moves downward through this zone by infiltration, upward as capillary rise, and laterally as groundwater flow. The circulation of moisture in the aerated zone is one important factor in determining near-surface resistivities. Another factor, due to the nature of capillary forces, is that finer grained materials hold more water than coarser grained materials, therefore having a lower electrical resistivity.

There are numerous factors that need to be considered both separately and collectively when attempting to assess a rock aquifer situation. Changes in structure, porosity, or water quality within a region can yield the same electrical characteristics, leading to an incorrect geo-electrical assessment. Rock materials can also affect electrical properties of alluvial deposits by altering the chemical quality of pore water in the alluvial aquifer {e.g. coal or limestone}. They can also affect overall porosity and permeability due to large or small fraction content, and also effect the electrical response with the presence of highly conductive materials such as relocated metals in the alluvium.

Electrical Conductivity of Soils

As with rock materials, the conductivity of soils is primarily electrolytic. Soils are composed of mineral and organic matter as well as water and gas components. The distribution of these components affects the distribution of the electrical conductivity of the soil vertically and horizontally. The clay content in soils has a strong effect on soil electrical conductivity. Sand and silt fractions of the soil are electrically neutral and good insulators, as is completely dry clay. However, the electrical conductivity properties of the clay content changes noticeably when moisture is introduced into the soil. This occurs because the laminar structured and fine texture of clay has a proportionately large surface area. Clay, more easily than sand and silt, retains a film of water and increases its electrical conductivity. As clay becomes increasingly hydrated, the water film surrounding each particle thickens. The retention of water and subsequent swelling of a confined clay body can produce pressures as high as several bars.

Dissolved materials in the soil, often in the form of salts, greatly enhance the electrical conductivity of a soil. Soluble salts in soils consist largely of sodium, calcium, magnesium, chloride and sulphate. The original source for these salt constituents is the primary minerals in the soil. It is not always the situation that sufficient salts can accumulate in situ to form a saline soil. Saline soils also occur in areas receiving salts from other locations, with water being the main carrier.

Irrigation water often brings with it salts, as does a shallow water table rising and falling near the surface. If there is insufficient precipitation, as in semi-arid regions, or if the soil moisture has a relatively high residence time, as in the case of clayey soils, an accumulation of salts occurs with the resulting change in the electrical conductivity of the soils.

4.2 Geophysical Methods

The general theory of the geophysical techniques used in the study is covered in this section. Specifically, the techniques include electrical resistivity, electromagnetics, seismics, ground penetrating radar and magnetics. This section focusses more on the main groundwater geophysics techniques. The two field techniques of electrical resistivity to be discussed include vertical Electrical Sounding (VES) and Horizontal Profiling. For electromagnetics, the techniques of Frequency and Time Domain are covered. The theory of the two main methods of seismics is also discussed in detail.

4.2.1 Electrical Resistivity

The electrical resistivity method is used for studying horizontal and vertical discontinuities in the electrical properties of the subsurface materials. This technique employs an artificially-generated electrical current which is introduced into the ground by two point electrodes at the surface. The resulting voltage (potential difference) that occurs between two additional measuring electrodes at the surface is then recorded.

It is not possible to measure ground resistivity by simply passing an electrical current through two grounded (connected to the earth by low resistance conductors) electrodes and then measuring the resulting voltage at these electrodes. This is a result of contact resistances with the earth being very high. This problem is overcome by measuring the resulting voltage across an additional pair of electrodes through which virtually no electrical current is passing. Earth materials offer resistance to the passage of electrical current from one electrode to another, depending on the nature of subsurface materials. The positioning of the electrodes affects the measurement of the electrical field, with increased spacing between current electrodes resulting in a greater depth of current penetration and greater volumes of earth being measured both vertically and laterally. Resistance is a function of the geometrical configuration of the electrodes and the electrical properties of the ground. Calculations from the measured values of the current output, the resulting voltage or potential difference, and the electrode spacing will give the value of the resistivity, which is measured in ohm-metres.

A discussion is now necessary on the concept of apparent resistivity, written as *pa* where *p* is resistivity and *a* refers to its apparent character. For a given arrangement of electrodes, the electrical field that would be expected in an isotropic or homogenous medium is first determined. This measure is compared to the actual or field measured potential value. One takes the ratio of the measured potential to the theoretical potential as a basic parameter in deriving a mathematical expression for apparent resistivity. One can then solve the equation for resistivity in terms of measured electrical potential, the applied current, and the inter-electrode spacings. These quantities are the index of apparent resistivity, which is a function of the geoelectrical cross-section and the electrode configurations.

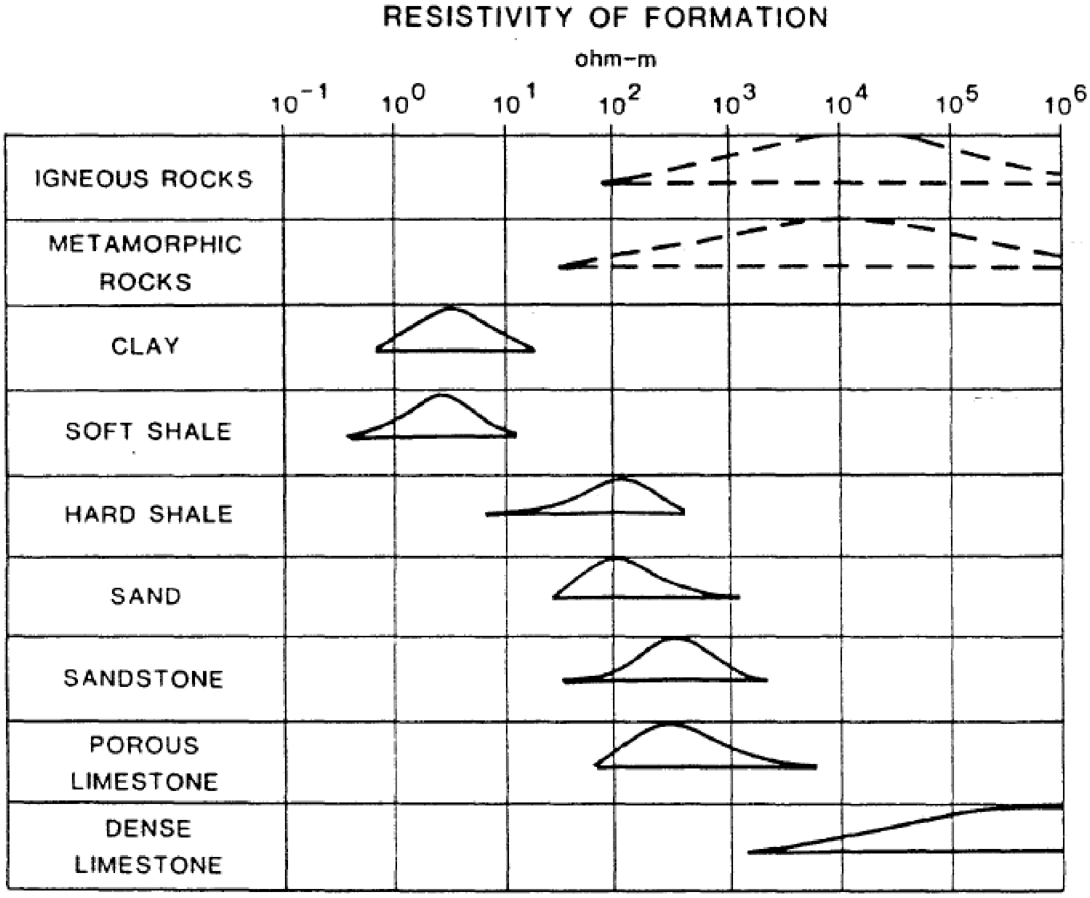


Figure 20 Resistivity of formation
(Source: Mandel and Shiftan, 1981)

The above diagram lists indicative resistivity values in ohm-m for various earth materials. The apparent resistivity will usually fall within the range of the true resistivities of the earth materials being measured in an isotropic medium. However due to the anisotropy of earth materials (they are rarely isotropic or homogenous) the apparent resistivity often rises or falls above or below the true resistivities. Normally, in a homogenous earth medium, the current lines from an electrode will disperse radially, but as they cross boundaries into layers of different resistivities, the lines of current can be seen to diverge. This divergence is often greater if the current lines are passing into a layer of higher resistivity. The thickness of the subsurface layers and the depth of the survey also affect the apparent resistivity response. Horizontal layers or beds near the surface can be surveyed quite accurately if they are relatively thick. With an increase in the depth of the bed and a decrease in the ratio of the thickness of the bed to the depth, it becomes more difficult to isolate the resistivity response of a particular bed unless its resistivity differs noticeably. As a result, apparent resistivity values obtained give more realistic values in shallow surveys which are not affected by layering or depth, and in homogenous earth situations where the effects of anisotropy can be minimized.

Resistivity has been used successfully for groundwater studies and exploration for potential aquifers and groundwater itself. As a preface to drilling, prospecting and exploration with electrical resistivity involves two approaches. One approach is horizontal profiling in which both the current and voltage electrodes are shifted without changing the configuration or distances between the electrodes. Usually a grid or a transect line is established over an area of interest and readings are taken at fixed points. The lateral distribution of the electrical resistivity is then studied at a depth of exploration that remains relatively constant. Recorded resistivity values (in ohm-m) can be plotted to give an image of subsurface variations at the electrical depth of exploration across a horizontal plane, or as a cross-section. Profiling can detect lateral changes in resistivity and is most often used in searching for ore bodies, faults and fault zones, for evaluating sand and gravel deposits, delineating geological boundaries and for finding dipping contacts of different earth materials.

The second method of resistivity prospecting is called Vertical Electrical Sounding (VES) in which the vertical distribution of resistivity with depth is measured. This is done by expanding the current electrode spacing outwards from a point where the voltage electrodes remain at a fixed spacing, resulting in a greater theoretical depth of investigation. Initially the voltage electrode spacing remains unchanged but as the exercise proceeds it may be necessary to increase electrode spacing to obtain a measurable voltage. As the electrical current penetrates deeper it penetrates vertical layers of varying resistivities and with each layer the overall measured response is altered. The measured resistivities are average values for large volumes of earth, with this average taken over increasingly larger volumes of earth as depth of investigation increases. These measurements are plotted graphically (usually on a logarithmic scale) with resistivity a function of current electrode spacing, to form a sounding curve. These curves can be matched with theoretical or master curves to obtain layer thicknesses and resistivity.

As with horizontal profiling, a series of survey points are established over an area in the form of a grid or transect with soundings taken at each point. The resistivity layers interpreted from individual sounding curves can be plotted as a resistivity cross-section chart. The common resistivity values can then be joined together to illustrate subsurface resistivity layering. Resistivity values from a survey grid can also be plotted against given electrode spacings and then contoured to form iso-resistivity curves. This illustrates resistivity highs and lows at selected geo-electrical depths. The effectiveness of Vertical Electrical Soundings is best in simple geologic settings where the geology can be modelled as horizontal layers parallel to the ground surface. As these parameters change, the data acquired becomes more qualitative.

There are many electrode arrays that can be used, but two of the most common are the Wenner and the Schlumberger configurations (see figure below). For both of these arrays the current electrodes are on the outside of the configuration and the potential electrodes are on the inside. The outer current electrodes are schematically termed AB and the inner potential electrodes are termed MN. For the Wenner array the four electrodes are placed in a line at equal distances apart with the inner two electrodes used as the potential electrodes. Instead of equal spacings, the Schlumberger array uses a ratio of current electrode to potential electrode separation that is less than or equal to 1/5.

Figure 21 The Wenner Resistivity Array

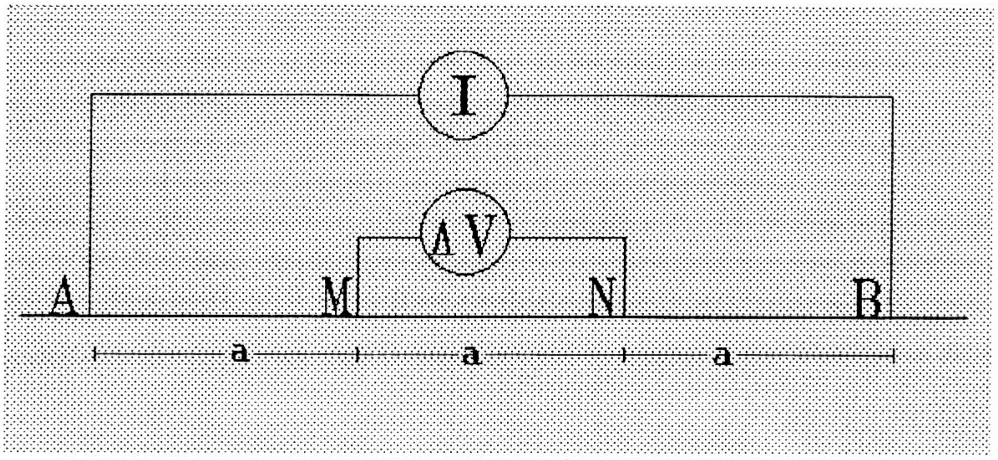
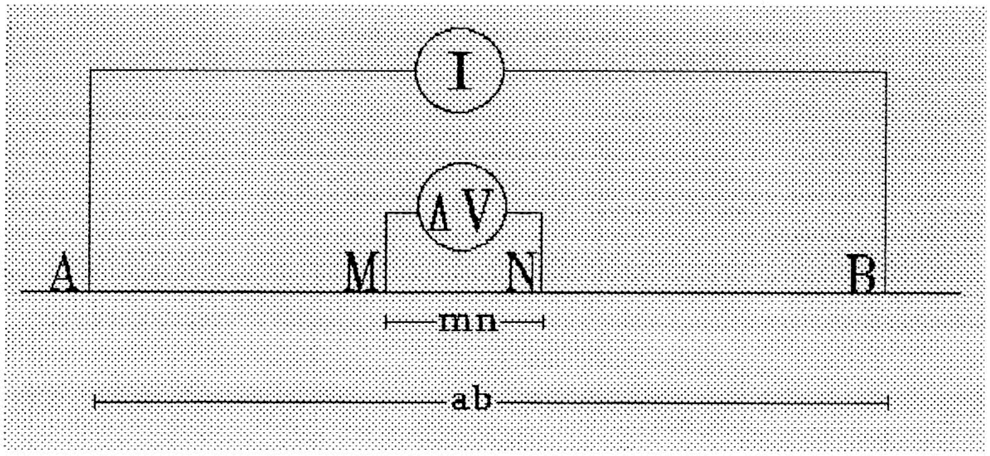


Figure 22 Schlumberger Resistivity Array



(Source: Biedler, 1994)

A & **B** = current electrodes

M & **N** = voltage or potential electrodes

I = ammeter

Δ**V** = voltmeter

a = equal spacing between electrodes for Wenner array

ab = spacing between outer AB electrodes

mn = spacing between inner MN electrodes

The Wenner array, when used for vertical Electrical Soundings, expands with equal separation of all electrodes, requiring all electrodes to be moved during a survey. Initially· the Schlumberger array only requires the movement of the outer AB electrodes. The potential or MN electrodes remain stationary until it becomes necessary to increase the spread between the inner MN electrodes to maintain a measurable electrical potential. This makes the Schlumberger array logistically easier to work with for vertical Electrical Soundings. Another reason the Schlumberger array is favoured over Wenner for soundings has to do with near surface electrode effects. When current or potential electrodes are moved over a resistivity anomaly, the voltage between the potential (MN) electrodes is affected. When the outer current electrodes pass over the anomaly, the result is termed an AB effect and when the inner potential electrodes move over the anomaly the result is termed the MN effect. The MN effect is much larger than the AB effect for both conductive and resistive anomalies. Considering that the purpose of VES is to produce a smooth sounding curve, the array that delivers the least electrode effects is the most favourable.

Depth of Penetration

The effective depth of penetration of the current is important in designing the survey, for it is necessary that the spread of electrodes allows for sufficient penetration of current to the depth of the phenomena to be studied. In the past it was assumed that with the Wenner array there was a close correlation between current electrode spacing and depth penetration. This has proved inaccurate as highly resistive layers can reduce the depth of investigation. For the Wenner array it was suggested that the depth of investigation corresponded to L/3 - a, L being the distance between the outer AB electrodes and a referring to inter-electrode spacing. For the Schlumberger array, depth of investigation was empirically judged to be AB/4.

Later studies have shown that there is a relationship between electrode spacing of current and potential electrodes, and that it may be less than the earlier empirical formulae suggested.

4.2.2 Electromagnetic Method

One of the problems associated with the direct-current resistivity sounding method is its inability to penetrate through a zone of high resistivity. This problem encouraged the development of the magneto-telluric and telluric methods, which measure electrical and magnetic fields associated with induced currents in the earth's subsurface. Magneto-telluric fields are large scale, low frequency natural magnetic fields that exist within and around the earth.

Telluric currents are natural alternating electrical fields that are induced into the earth by the magneto-telluric fields. These natural source methods respond to zones of high electrical conductivity as opposed to zones of resistivity or low electrical conductivity. This aspect of current behaviour allowed for penetration through a very resistive zone where it is difficult to get penetration using galvanic or direct current techniques. The origin of the induction field is an electro-magnetic field, associated with natural phenomena such as thunder storms and solar activity that are propagated over long distances between the earth's surface and the ionosphere. These currents can be measured by setting up two stations and measuring the field signals between them. If the ground is homogenous there is little alteration of the signal. If the geological structure is non-homogenous at either station the current flow will be distorted, registering an anomaly within the electromagnetic field. Transmitters are not required for natural source methods, and the low frequencies of natural sources allow for depths of penetration of the electromagnetic field up to several kilometres.

Natural source methods have some limitations. Electromagnetic noise such as that generated by power lines or by fluctuations in the ionospheric currents in which the required signal strength is not always available can make extraction of useful data difficult. To overcome these difficulties an electromagnetic induction method was developed utilizing a signal frequency and a source geometry that could be controlled by the geophysicist. However there are compromises with a controlled source that include the financial and logistical problems of a transmitter and the expense and difficulty of generating a low frequency signal from a controlled source. The difficulty in generating a low frequency signal means that controlled source electromagnetic (EM) methods are limited in their depths of penetration.

An alternating magnetic field is used as a source and can be generated by passing AC current through a loop or a cable grounded at both ends. The magnetic field corresponds to that of a magnetic dipole perpendicular to the area or plane of the loop (if the loop is horizontal, a vertical magnetic dipole is formed and vice versa).

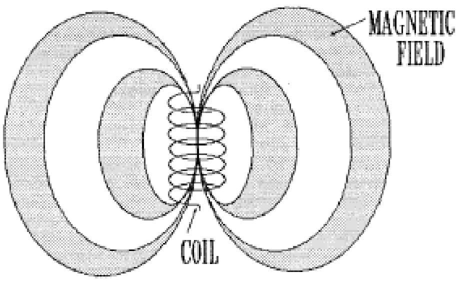


Figure 23 Generation of a primary magnetic field (Source: Biedler, 1994)

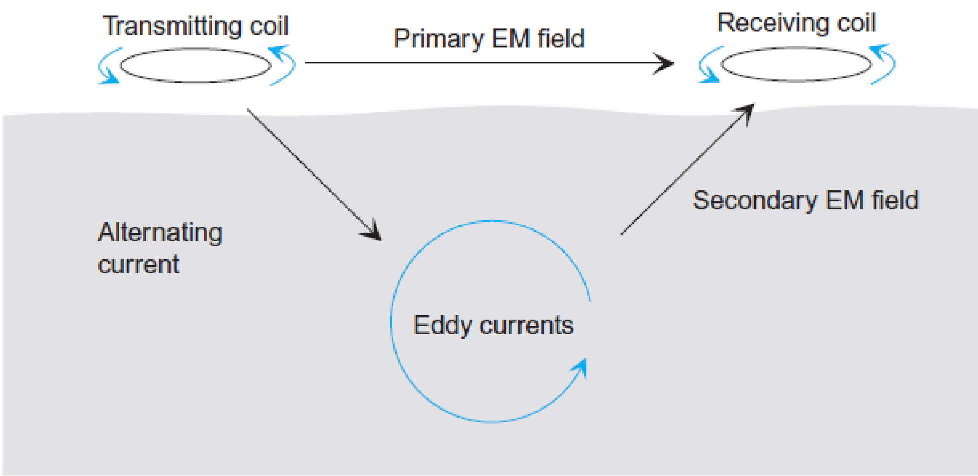


Figure 24 Generation of a secondary magnetic field (Source: Fitts, 2013)

If there is any conductive material within this magnetic field, induction or eddy currents will dissipate into this conductive zone. These eddy currents set up their own secondary magnetic fields which will have the same frequency but not necessarily the same phase as the primary or inducing field. A receiver coil or loop is used to measure the response. The total resultant field measured consists of a primary field due to the source current and a secondary field due to the eddy currents formed around the conductor.

The resultant electromagnetic field contains two oscillatory fields of the same frequency (ie. the frequency of the primary alternating source) but out of step or out of phase with each other. Spatially, the electromagnetic field is characterized by amplitude and phase components. The amplitude is the maximum value that the field strength can attain as it oscillates at a given frequency. Phase refers to the position of the maxima and minima of the signal wave in relation to time, or more specifically, how far into the period of oscillation the signal wave has advanced. When a conductor is subjected to an alternating magnetic field, a voltage of the same frequency as the inducing field is set up in the conductor. This voltage lags behind in signal phase from the inducing or primary field (i.e. it reaches its maxima and minima a portion of period behind the inducing field). Due to a conductor's properties of resistance and inductance (the capability of a conductor to produce voltage), the current in the conductor lags behind the induced voltage and consequently behind the primary field.

The secondary electromagnetic field that is produced from the induced current lags also behind the primary electromagnetic field. The combination of the primary and secondary fields yields a resultant electromagnetic field. This field is what the detecting coil picks up and it differs in amplitude and phase from the primary field. This phase lag is basically a time delay that is equal to lag multiplied by period.

Problems can be encountered with EM systems that use maximum signal coupling between transmitter and receiver. The receiver tends to measure the primary wave as well as the secondary wave induced by the conductor. The primary wave can tend to swamp the secondary signal, so it must be reduced or neutralized. One way this can be done is to introduce into the receiver an artificial signal with the use of a compensating network. The network produces a signal that is the same frequency and amplitude of the primary signal but opposite in phase. This serves to cancel the main primary field and other unwanted signals.

Skin Effect

When the frequency of an AC current is increased in a wire conductor, the current begins to concentrate closer to the wire's surface. This phenomenon is described as the skin effect. This skin effect also occurs in conductors within the earth and determines the effective investigation depth attained with the EM method. The effect depends on the frequency of the current, the conductivity of the subsurface, and the distance between source and receiver. If the conductivity or the frequency is high, the penetration of electromagnetic waves is strongly attenuated. A deeper penetration is acquired by increasing the source/receiver separation or decreasing the frequency.

Electromagnetic (EM) Systems

There are two main types of land-based EM systems; fixed source-moving receiver systems and moving source-moving receiver systems. The fixed source system consists of a stationary controlled source with a receiving coil or set of coils that is moved over a prearranged grid or set of lines relative to the source. The moving source-moving receiver method is characterized by a mobile source (transmitter) as well as a mobile receiver arrangement. The source usually consists of a light-weight portable coil similar to the receiver coil.

The transmitter and the receiver are held at a fixed distance apart and are moved simultaneously over the survey area. Due to the mobility of the system, field work is relatively simple and flexible. The survey need not be bound to stake or grid lines and once anomalies or conductors have been located it is easy to detail the investigation. These characteristics have made the moving source-moving receiver EM systems very popular but there are some constraints.

For practical reasons the coil separation cannot be too great (25-100 metres) with the result that, within the frequency domain approach, the depth of penetration is limited and stray anomalies from near-surface can interfere with deeper source anomalies. Usually the source and receiver are not connected to each other rigidly but are attached by a fixed length of flexible cable, the mid-point of which is regularly used as the observation point. An example of a moving source-moving receiver system is the Geonics series of EM systems manufactured in Canada. The Geonics-made EM-34 is a two-man portable unit in which the transmitter and receiver coils are connected with a reference cable of fixed lengths ranging from 10, 20, and 40 metres. These fixed lengths serve to vary the effective depths of penetration of the primary signal as they are also linked to fixed frequencies. It should be noted the EM instrument measured response of the EM is integrated over the whole depth of investigation, and consequently small or localized variations in conductivity can become lost in the overall EM response.

The orientation of the transmitter coil and the receiver coil affects their sensitivity to subsurface conductors. As previously discussed, the source loop is equivalent to a magnetic dipole at *right angles* to the plane of the loop. This becomes important when one considers the geometry and the orientation of the conductor below surface. As a result of the different orientations of the magnetic fields, the horizontal coil (vertical dipole) will have a greater penetration than the vertical coil of its primary magnetic field and a more sensitive response to apparent conductivity with depth. The vertical coil (horizontal dipole) will be more sensitive to shallower lateral variations in apparent conductivity, producing a different response.

4.2.3 Seismic Methods

Seismic methods are based on the observation of the speed of propagation of elastic waves within rock or other subsurface materials that make up the earth's crust. An artificial shock is created by either detonation of a charge or the use of vibrating and impacting techniques. Detectors, or geophones, are placed at various distances and directions from the source. These are connected to a recording instrument that records the travel time of the waves which are reflected or refracted to the surface.

Three types of waves are produced; two body waves and one surface wave. The surface wave is confined to the region close to the surface. Its amplitude falls off rapidly within a distance from the surface of the same order of magnitude as the wavelength of the disturbance. The body waves travel through the body of the medium and are known as P (compressional and/or primary) waves and S (shear and/or secondary) waves. P waves are faster and result from direct compression, while the slower S waves (also known as shear waves or transverse waves) have a particle motion of energy that is perpendicular to the direction of propagation. The velocities of these two wave types are related to the elastic constants and the density of the medium through which they are travelling. The S wave travels at just over half the velocity of the P wave in most rock materials. It does not propagate in fluids.

Different earth materials have different densities and elastic moduli, which is the ratio of the stress applied to the strain produced on a body. Rocks and rock materials of a relatively high porosity will be poor transmitters of seismic energy and will yield low velocities. The velocity depends on the degree of compaction and cementation, rather than the composition of the sediments. The elastic moduli of these materials increase with compaction, and seismic velocities also increase with depth, providing that the material remains homogenous. The type of cementation, degree of saturation, and the pressure of fluids affect the porosity and therefore the elastic moduli of the earth materials. Saturated earth materials of medium to high porosity will yield high velocities and shorter wave travel-times compared to unsaturated earth materials.

The main objective of seismic surveys remains the identification of different wave-velocity layers, determination of their depth and thickness, and the identification of known or assumed stratigraphic units and structural features. Compressional wave velocities are used to convert with calculation seismic wave travel times into depths and they also give an indication of the lithology of the rock or the nature of pore fluids within the rock. Generally, compressional wave velocities increase with confining pressure. For example sandstone and shale produce a velocity increase with depth of burial and with age due to the effects of progressive compaction and cementation. For many of the sedimentary rocks, compressional wave velocity is related to density, and characteristic velocities have been established (see table below)

ROCK TYPE	COMPRESSIONAL VELOCITY (km/s)
Unconsolidated Materials	
sand (dry)	0.2-1.0
sand (water saturated)	1.5-2.0
clay	1.0-2.5
g1acia1 till (saturated)	1. 5-2. 5
permafrost	3.5-4.0
Sedimentary Rocks	
Tertiary sandstone	2.0-2.5
Carboniferous sandstone	4.0-4.5
Cambrian quartzite	5.5-6.0
cretaceous chalk	2.0-2.5
Jurassic oolites & bioclastic limestones	3.0-4.0
Carboniferous limestones	5.0-5.5
dolomites	2.5-6.5
salt	4.5-5.0
anhydrite	4.5-6.5
gypsum	2.0-3.5

Characteristic compression velocities of earth materials
(Source: Biedler, 1994)

4.2.4 Seismic Reflection and Refraction

The two major seismic methods are reflection and refraction. The refraction method utilizes the principle portion of the wave path as it moves along the interface between two rock layers. The wave path that enters the second layer and moves parallel to the boundary must do so within a critical angle. Seismic waves meeting the boundary with a greater than critical angle of incidence are totally reflected and no energy is refracted into the higher velocity layer. The critically refracted waves moving along the interface within the lower layer create stresses that produce waves that are refracted back up to the upper layer. These waves are known as head waves and they depart the boundary at the critical angle of incidence. Thicknesses of the upper two to three velocity layers can only be determined with refraction where the density of successive layers and the velocity of the shock wave increase with depth.

Travel-time equations form the bases of seismic reflection and refraction methods for determining depth to an interface. The refraction method relies largely on measuring the travel time of the first arrivals of seismic waves at the geophones. Reflected waves occur later and continuously, being more complex to record as they are of smaller amplitude.

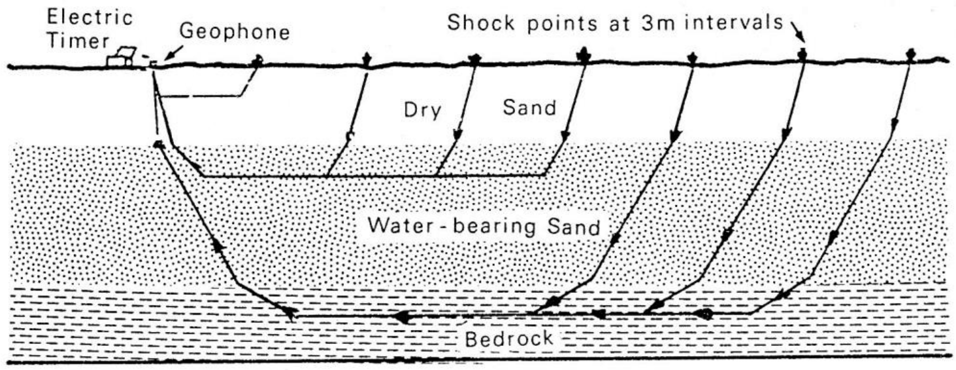


Figure 25 Seismic array for measuring refracted waves in one or more layers

Travel-time graphs are used to determine the velocity of the refracted waves in one or more layers. Travel-time is plotted on the y-axis and source-geophone distance (x) is plotted on the x-axis (see figure below).

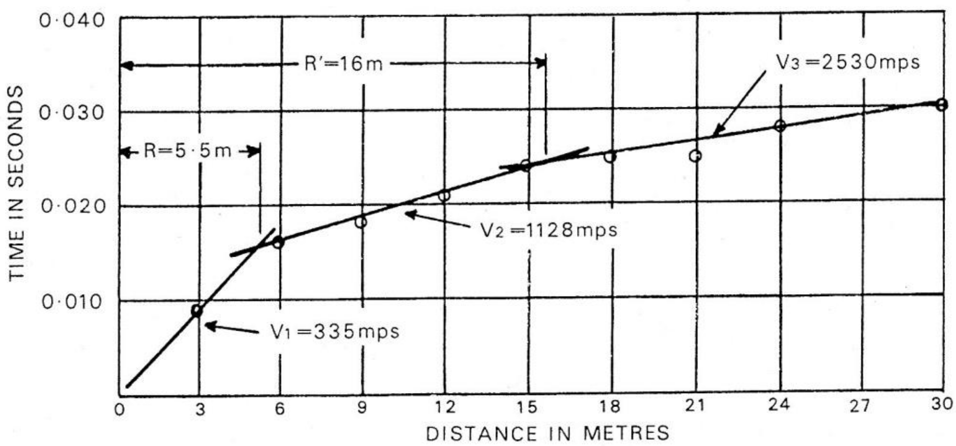


Figure 26 Travel-time graph showing velocities of refracted waves for one or more layers (Source: Griffiths and King, 1981)

The reflection method detects seismic waves that are reflected directly from a subsurface interface where there is change of density and wave velocity (acoustic impedance) of earth materials. There is relatively larger amplitude of reflection signals in comparison to refraction signals generated from the same horizon, meaning that a smaller signal source can be used to generate reflections. The greater amplitude of reflection signals also serves to generate greater detail of overburden structure and bedrock topography. The figure below illustrates the different transmission of reflected and refracted wave paths.

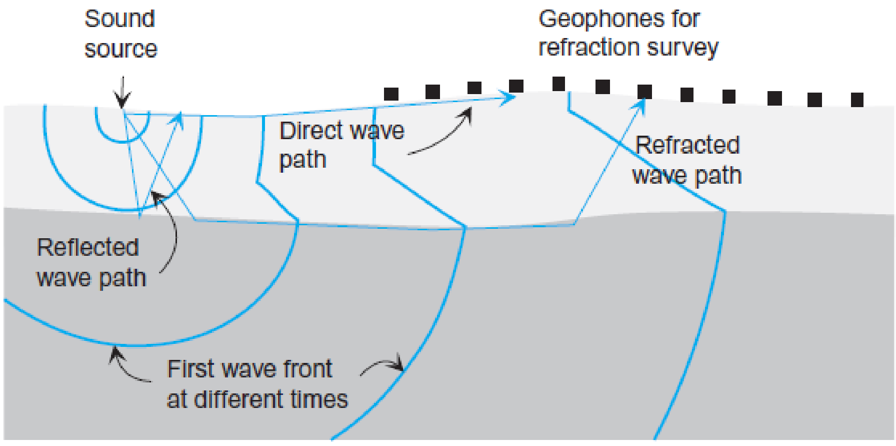


Figure 27 Illustration of reflected and refracted seismic waves (Source: Fitts, 2013)

As with seismic refraction, reflection travel-time graphs are drawn to portray velocity behaviour through the various layers.

The seismic reflection method was developed in the oil and gas industry, which was able to invest in and develop field procedures, digital recording, and computer processing of the data. These methods, however, are still very expensive for engineering, groundwater, and geotechnical applications. As a result, refraction methods have been used almost exclusively in fields where shallow subsurface structural information was required. Refraction methods measure only the time of the first arrival of seismic energy rather than a whole seismic wave train. Seismic refraction surveys can be carried out with relatively simple and inexpensive equipment and are more amenable to shallower surveys, where most engineering, geotechnical, and geohydrological interests occur.

4.2.5 Ground Penetrating Radar

Ground-penetrating radar (GPR) is a technique based on reflection of high-frequency EM waves in the 10–1000 MHz band of the spectrum. A source of radar wave pulses and a receiver are generally built into a single unit that is towed across the ground surface. Like seismic reflection methods, the down-and-back travel times of the reflected pulse are measured.

With estimates of radar wave velocities, the method results in vertical cross-sections that shows reflecting layers or objects at depth. Boundaries where the di-electric properties of the medium change cause GPR waves to reflect back towards the receiver. Good GPR signal reflectors typically occur at the water table in sands and gravels. GPR can probe deeper in materials that have low electrical conductivity (high resistivity); these attenuate the signal to a lesser degree than more conductive materials. The typical limit of penetration is on the order of 20 m, but it can be as much as 50m in dry and frozen materials or as little as 2m in wet clay or silt. In general, the resolution of GPR is a function of the frequency bandwidth of the system. Higher frequency systems get higher resolution but less penetration depth.

4.2.6 Magnetics

Magnetic methods obtain information related to the direction, gradient, or intensity of the Earth's magnetic field. The intensity of the magnetic field at the Earth's surface is a function of the location of the observation point in the primary earth magnetic field as well as from contributions from local or regional variations of magnetic material such as magnetite, the most common magnetic mineral. After correcting for the effects of the Earth's natural magnetic field, magnetic data can be presented as total intensity, relative intensity, and vertical or horizontal gradient anomaly profiles or contour maps.

Interpretation of magnetic surveys generally involves forward modelling or mapping of the anomalies correlating them with other known geologic information. As magnetic signatures depend to a large extent on magnetic mineral content, which is low in most sediments that comprise aquifers, magnetics is not commonly employed for hydrological investigations, but it can be a very powerful technique to locate lateral boundaries of landfills.

Exceptions include mapping subsurface structures (basement topography, faults, or intrusions), provided that a sufficient magnetic signature or contrast exists. In areas where basaltic intrusions occur in the form of subsurface dykes, magnetics can identify barriers to subsurface flow, especially where formations cut across groundwater flow. By knowing in which direction groundwater flow is moving it can be possible to identify borehole sites of higher potential "upstream" of the barrier formations.

4.2.7 Borehole Logging

When a hole is drilled, a geologist will be usually be available to describe the samples and drill cuttings. A compilation of these descriptions along with notes about the rate of drilling, drill fluid losses, etc. make up the geologic log of a borehole. In addition to geologic logs, it is possible to conduct several different borehole surveys. Other than the nuclear radiation methods, these techniques are normally done in an uncased hole. The most common borehole survey techniques are briefly summarized below.

Temperature. A thermometer is towed the length of the borehole, measuring the temperature of the borehole fluid vs. depth. Abrupt changes in fluid temperature often indicate levels where water is entering or leaving the borehole. This is especially useful for locating transmissive fractures in crystalline rock.

Caliper. A caliper drawn through a bedrock borehole accurately measures the diameter of the borehole. The location of fractures can be mapped in this manner.

Borehole imaging. In dry boreholes, the borehole walls can be photographed with optical video cameras specially designed to produce a continuous strip photo along the length of the borehole. In fluid-filled boreholes, similar strip images can be produced using acoustic and electrical imaging. These non-optical methods are more versatile, because they work both above and below the fluid level. Borehole images are particularly useful for characterizing fractures and large openings in rock.

Flow meter. A borehole flow meter is a device that can record the velocity of flow up or down the axis of a borehole. Some use an impeller, some use a heat pulse, and others use electromagnetic sensors. Where water enters or leaves the borehole at fractures or permeable seams, the borehole flow meter will record changing flow velocity in the borehole. Used in conjunction with pumping, it can be used to map the vertical distribution of hydraulic conductivity along a borehole.

Resistivity. Borehole resistivity works on the same principles as surface resistivity, measuring voltage differences in a steady DC electrical field. Usually one of the two current electrodes is in the ground surface near the top of the borehole, and the other is down the borehole in the drilling fluid. The voltage electrodes are placed at different elevations in the borehole. The result of a borehole survey is a vertical profile indicating the distribution of electrical resistance in the formations surrounding the borehole.

Spontaneous potential. In this method, one measures the natural voltage differences between an electrode at the ground surface and one at depth in the borehole fluid. Unlike resistivity methods, there is no induced current—only the ambient electrical field. It can be useful for defining the elevation of lithologic contacts between geological layers.

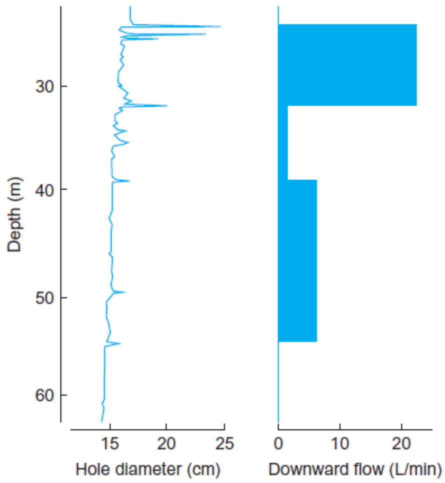


Figure 28 Comparison of a borehole caliper log (left) with a flow meter log (right) (Source: Fitts, 2013)

The figure above shows a comparison of a caliper log and a borehole flow meter log for a borehole in fractured dolomite in Illinois. The flow changes abruptly at fractures that are clearly indicated by the caliper log.

4.3 Designing Geophysical Surveys

The main purpose of geophysical surveys is to locate subsurface structures and if possible to measure the dimensions and physical properties of these structures. Structural and stratigraphic information is sought after in oil prospecting and groundwater surveys, physical properties of subsurface structures is of value for mining exploration, and engineers require information on all of these properties for site. It is important to select the appropriate geophysical techniques for a particular study. Usually a primary geophysical technique is selected and then augmented with additional geophysical methods. For a survey of a groundwater situation, the selection of two or more geophysical methods that measure different parameters is recommended.

The type of information required must also be taken into consideration. If the quality of the groundwater is the focus of the study then seismics, which delivers information only on an aquifer's structural characteristics, would be bypassed in favour of geo-electrical methods. With the use of geo-electrics, a preliminary knowledge of the electrical properties of earth materials and groundwater is necessary.

The second important step in geophysical surveys is site selection. This should be the result of a preliminary assessment of information about the study area. This includes data from maps, air photos, geological reports, borehole logs, as well as data from local administrative sources such as water Boards or other relevant planning and management authorities. Geophysical surveys can be influenced by physical factors. For example, uneven or hilly terrain can interfere with EM data collection where the necessary coplanar transmitter and receiver coil orientations can easily be misaligned. With seismics, situations arise where hydrological boundaries such as the interface between unconsolidated material and underlying weathered bedrock may not be measurable because of similarity in seismic transmission characteristics.

Once the techniques have been chosen and the site established, the design of the field study can be considered. This includes factors such as the physical orientation of the field study and the density of the measuring network. Orientation of the field study refers to the line of direction between the transmitters and receivers of energy for the various geophysical techniques, and should be carefully considered when planning the survey. For example, horizontal profiling with electrical resistivity should be carried out perpendicular to the strike of anomalies or formations being studied in order to obtain the best field distortion.

Regarding sample size and density, there is an optimum number of data points per area, above which the need for more data diminishes, and below which the integrity of the statistical tests or the data portrayal can be compromised. A minimum density of measurements can be determined from initial trial measurements and also from the geophysical and hydrological parameters being measured. Deep Vertical Electrical Sounding surveys, for instance, have a diminishing ability to pick up changes in the resistivity response with increasing depth of investigation. The result is that an increase in the number of soundings will not necessarily enhance the value of data beyond a certain point.

4.3.1 Conceptual Framework of the Survey

To understand the groundwater flow dynamics of alluvial systems, knowledge of the structure of alluvial bodies is important. Techniques such as geophysics are used to facilitate the routine but more expensive methods of obtaining this information (e.g. drilling or excavation). It is important that as much information as possible is acquired on the study area before geophysical techniques are applied. Existing boreholes, surface exposures in the form of road and river bank cuts, and rock outcrop are the main source of geological information. Other aspects of information on the study area important to the geophysical response are the depth to water table and soil or overburden qualities such as salinity. The water table can affect the response of both seismics and geo-electrics, while salinities can affect the geo-electrical properties of earth materials. Once information on the study area is acquired, the geophysical techniques to be assessed can be selected. The selection is done on the basis of the type of information required and the ability of the selected geophysical technique to function within the study area.

The final stage of the study is the assessment of the selected geophysical techniques and/or the data acquired within the study area. The first step is to qualitatively assess the data by comparing the geophysical data to the existing information on the study area. This helps to interpret the data in relation to the geology and hydrogeology of the study area (see figure below). Qualitative assessment includes:

- the contouring of geophysical data and
- the cross-sectional portrayal of the data in data line profiles

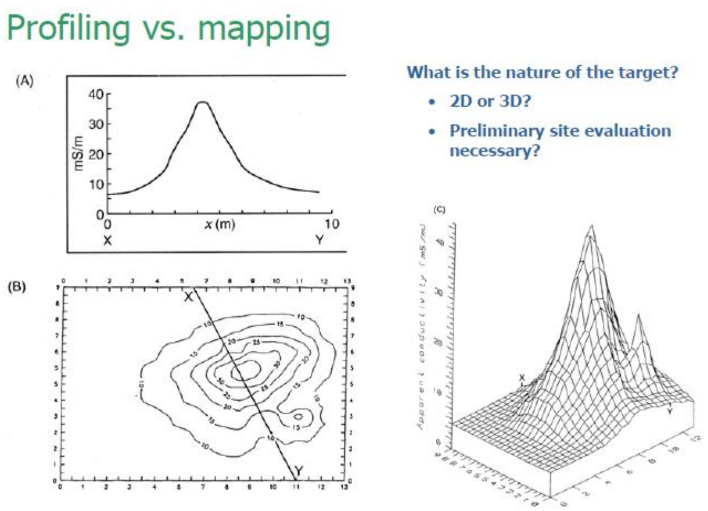


Figure 29 Contouring of geophysical data (2D and 3D) with profile of a data transect (Source: Allen & Fratta)

By studying the data for trends and anomalies it can be seen how closely results accord with information previously collected on the study area. At this point comparisons of the validity of individual geophysical techniques can begin. Vertical Electrical Soundings can be assessed quantitatively by matching the sounding curves of data to a library of theoretical curves or by using computer programs to produce a multi-layered model. There a number of computer software packages available for modelling geoelectrical, magnetic and seismic data. Quantitative assessments can also be done between geophysical data and other collected data such as the depth to water table, "soil" salinities or geological information of the study area. The comparison of geophysical data to borehole data and information is the best method of assessment of geophysical techniques.

4.4 Exercises

- List the geophysical techniques most commonly used for groundwater exploration, explaining what they evaluate and type of earth material characteristics they measure.
- Identify in which conditions the above techniques are less effective

.

5.0 Boreholes and Wells

Many wells are installed to supply water, while others are installed to monitor groundwater levels or quality. The simplest of wells is the dug well, consisting of a large diameter hole dug below the water table. Some dug wells are just that – a deep hole that fills to some level with water. A dug well can be made more stable by lining the hole with porous concrete or masonry. Many modern dug wells are lined with cylindrical concrete pipe sections. One advantage of a dug well is that a large volume of water is stored in the well itself, making it less prone to drying up with a sudden withdrawal. Dug wells are most common in rural, undeveloped areas with limited access to drilling equipment and a shallow water table. Most wells, however, are installed in holes that are created with rotary or cabletool drill rigs. A typical drilled well installation is illustrated schematically below.

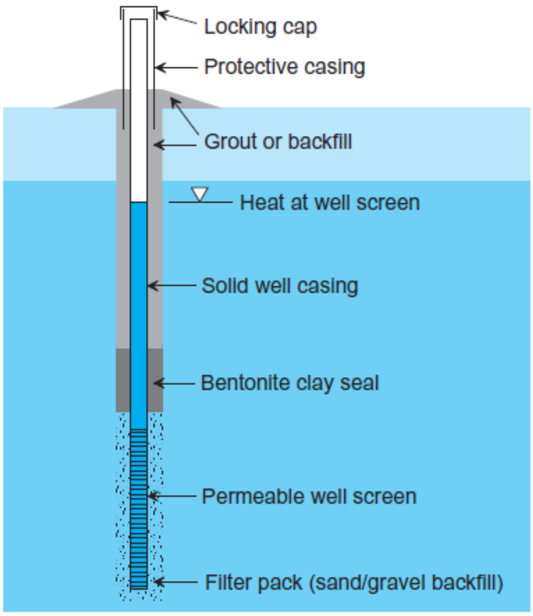


Figure 30 Cross-section in profile of a typical borehole construction (Source: Fitts, 2013)

5.1 Screens

The well consists of a permeable section of casing called the **well screen,** which is connected to a solid casing that extends to the ground surface. Water can flow freely through the screen so that in a non-pumping well, the head within the well casing equals the head in the formation surrounding the screened section of the well.

Water supply wells typically have stainless-steel screens with continuous slots that are made by winding wire around vertical rods (see figure below). Similar continuous-slot screens can be constructed from fiberglass, PVC or other steel alloys. The wire that is wound is usually triangular in cross-section and arranged so that the slots are narrowest at the outer wall of the screen and wider toward the inside of the well. This minimizes clogging of the screen; smaller particles that make it through the outer narrow gap can continue into the well and be removed by the pump.

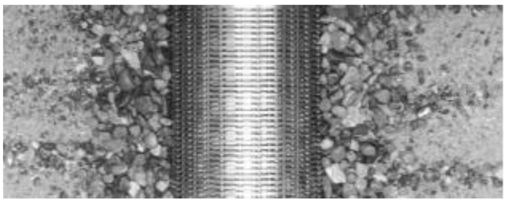
 

Figure 31 Steel screen (left) and pvc screen (right)
(Source: Fitts, 2013)

Below is a figure illustrating a cross-section through the side wall of a wound wire well screen, showing flow into the well and trapping of larger particles outside the screen.

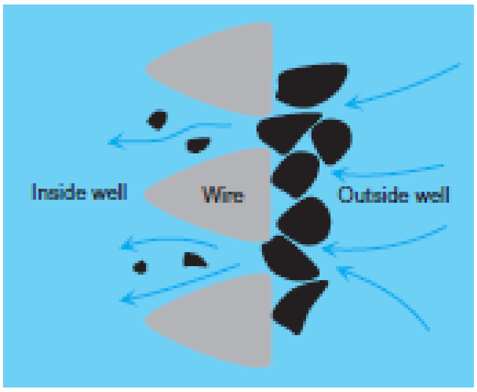


Figure 32 Groundwater flow through screen
(Source: Fitts, 2013)

Observation or monitoring wells that are installed for groundwater hydrology and chemistry investigations are often made with plastic (PVC) casing and plastic screens with thin slots milled into them (see above). Plastic screens are cheaper, less permeable, and weaker than stainless-steel screens, but for most monitoring applications they are adequate. Threaded joints are often used in plastic observation wells to avoid the introduction of organic chemicals found in PVC cements, which could confound contamination monitoring results.

It is important to check the quality of the screen before its installation. Transport can damage the screens and impair the functioning. For slotted or perforated steel casing it is important to verify the stainless steel composition to ensure it has not been substituted by galvanized iron. It is also important that steel casing has not been bent during transport or storage, as this can negatively effect and complicate casing installation. PVC casing and screens must be carefully checked for damage, since they more fragile than steel. PVC is also severely damage by ultraviolet rays and excessive temperature and needs to be well protected from sunlight. Too much exposure weakens the casing structure. Indications of sun and temperature damage include brittleness or easy cracking of casing threads, and change of colour.

5.1.1 Filter Pack

The annulus between the screen and the borehole wall is often backfilled with a granular filter material called **filter pack**, usually sand or gravel. Ideally, the filter pack is more permeable than the formation itself to minimize resistance to flow between the formation and the well. At the same time, the filter pack must also be fine-grained enough that fine particles from the formation cannot be transported through the filter pack and into the well. The grain size of the filter pack must be larger than the screen openings, but small enough to prevent migration of fine particles from the aquifer into the well. In water-supply wells in sand and gravel, a coarse filter pack can be created from the surrounding unconsolidated materials by a process called well development, which removes fine particles from the zone around the well.

Above the screen and filter pack, the annulus between the well casing and the wall of the hole is usually backfilled with a low permeability seal of some sort. Sometimes the seal is cement grout injected via a pipe inserted into the annulus. In other cases, the seal is made of clay, installed by means of pellets of dry clay dropped into the annulus. Usually a very low *K (porosity) clay* such as bentonite is used for this purpose. The seals prevent potentially contaminated surface water from seeping down to the well screen, assuring that the water extracted from the well comes from the screened depth.

When wells are installed in competent bedrock, it is possible to have a well that is just an open hole without casing or a screen in the bedrock, as is shown below. Bedrock wells like this usually have casing through the unconsolidated deposits and into the top of the bedrock. The casing is generally sealed with grout or clay above the bedrock. Wells like this are also developed to remove fine particles from fractures and permeable bedrock near the hole.

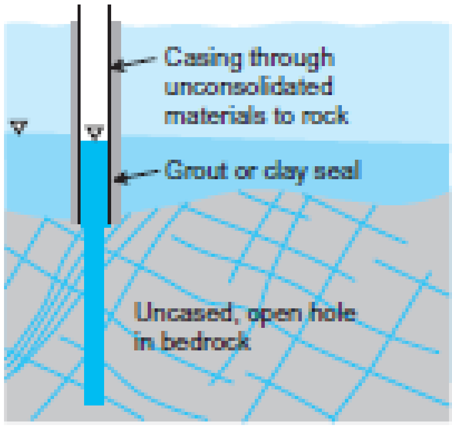


Figure 33 Cross-section in profile of borehole cased at surface and uncased in bedrock (Source: Fitts, 2013)

Small-diameter wells (also called **wellpoints**) can be installed in cobble-free unconsolidated deposits by direct-push or jetting methods. These methods are widely used for temporary shallow construction dewatering wells, and sometimes used for domestic water supply wells. The materials surrounding the screen are the in situ aquifer materials. Development is also helpful for wellpoints, to increase yield of the well and reduce fine sediment in the discharge.

5.2 Borehole Development

Development involves surging water in and out of the well screen to mobilize and suspend fine particles from the formation adjacent to the screen. The well is then pumped for a period to remove the suspended fines. This is repeated until most fines have been removed from the zone around the screen. Surging can be done by jolting a cylindrical solid surge block up and down inside the casing, oscillating the water pressure below the block. In another method, the well is capped and air pressure in the casing is surged up and down. A third method uses a high pressure jet of water sprayed through the screen from inside the well (jetting tool), loosening fines and deposits on the well screen.

A developed well yields greater volume discharge because there is less resistance to flow in the developed zone. However, care must be taken not too use too much force for jetting or air pressure development because it can damage the formation around the screen. It is important that the material around the screen zone settles evenly with a consistent porosity in order for the finer material around the borehole to migrate evenly towards the borehole. Once the material in the formation around the screen settles into place, it should be cleaned or washed of fine material to a certain radial distance from the borehole which is influenced by the hydraulic force of pumping. If the material in the formation settles unevenly, it can leave large pore spaces which will consistently allow the entry of fine material into the borehole.

Well screens provide resistance to flow, and in the case of a high-capacity supply well, it is desirable to reduce that resistance to a minimum. This is done by using screens that have a large ratio of open area to surface area. With wound wire screens as shown above this ratio can be as high as 50%. With PVC screens, and with perforated or slotted steel pipe screens, this ratio is much smaller, more like 10% or less, because there must remain enough pipe structure intact to maintain sufficient strength to avoid buckling or collapse. Screens with larger openings offer less resistance than screens with smaller but are more susceptible to collapse and are less effective for screening fine material. With wound wire screens, another advantage of larger wire and opening size is that there is less metal surface area, thus less corrosion and encrustation of the screen over time. Selecting the well screen opening size usually is a matter of determining the largest opening size that will still prevent the migration of fine particles into the well.

In widely-graded sand and gravel deposits, supply wells often have no filter pack and the formation materials are allowed to collapse directly onto the screen. In such cases, the screen openings are usually chosen to be roughly equal to the median grain size of the sand and gravel. The finer particles are removed by development, while the coarser fraction is retained, creating a permeable filter pack from the native materials. It is essential to do grain size analysis of representative samples of the aquifer in order to design the screen.

If there is uncertainty about the quality of the samples or analysis, the screen opening size should be conservatively estimated at a smaller size. When a screen is placed across stratified aquifers with varying characteristics, different sections of screen may be welded together, with the proper slot size against each stratum. Near the interface of different strata, the screens must be conservatively placed according to their slot size. For example, if coarse sand overlies fine sand, a coarse sand screen should stop well above the interface to be sure that fine sand cannot enter the coarse sand screen.

5.3 Aquifer Tests and Pump Testing

Determining the yield of ground-water systems and evaluating the movement and fate of ground-water quality require, among other information, knowledge of:

- The transmissivity and storage coefficient of the aquifers
- The hydraulic characteristics of the confining beds
- The location and amounts of ground-water withdrawals.

Acquiring knowledge on these factors requires both geologic and hydrologic investigations. One of the most important hydrologic studies involves analyzing the change, with time, in water levels (or total heads) in an aquifer caused by withdrawals through wells. This type of study is referred to as an aquifer test and, in most cases, includes pumping a well at a constant rate for a period ranging from several hours to several days and measuring the change in water level in observation wells located at different distances from the pumped well.

Successful aquifer tests require, among other things:

- Determination of the pre-pumping water-level trend (that is, the regional trend)
- A carefully controlled constant pumping rate
- Accurate water-level measurements made at precisely known times during both the drawdown and the recovery periods.

5.3.1 Drawdown

Drawdown is the difference between the water level at any time during the test and the position at which the water level would have been if withdrawals had not started. Drawdown is very rapid at first. As pumping continues and the cone of depression expands, the rate of drawdown decreases. The recovery of the water level under ideal conditions is a mirror image of the drawdown. The change in water level during the recovery period is the same as if withdrawals had continued at the same rate from the pumped well but, at the moment of pump cut-off, a recharge well had begun recharging water at the same point and at the same rate. Therefore, the recovery of the water level is the difference between the actual measured level and the projected pumping level.

In addition to the constant-rate aquifer test mentioned above, analytical methods have also been developed for several other types of aquifer tests. These methods include tests in which the rate of withdrawal is variable and tests that involve leakage of water across confining beds into confined aquifers. The most commonly used method of analysis of aquifer test data is that for a vertical well pumped at a constant rate from an aquifer not affected by vertical leakage and lateral boundaries. The duration and variability of a pump-test can be indicative of hydrogeological conditions which may only become apparent after longer duration of testing.

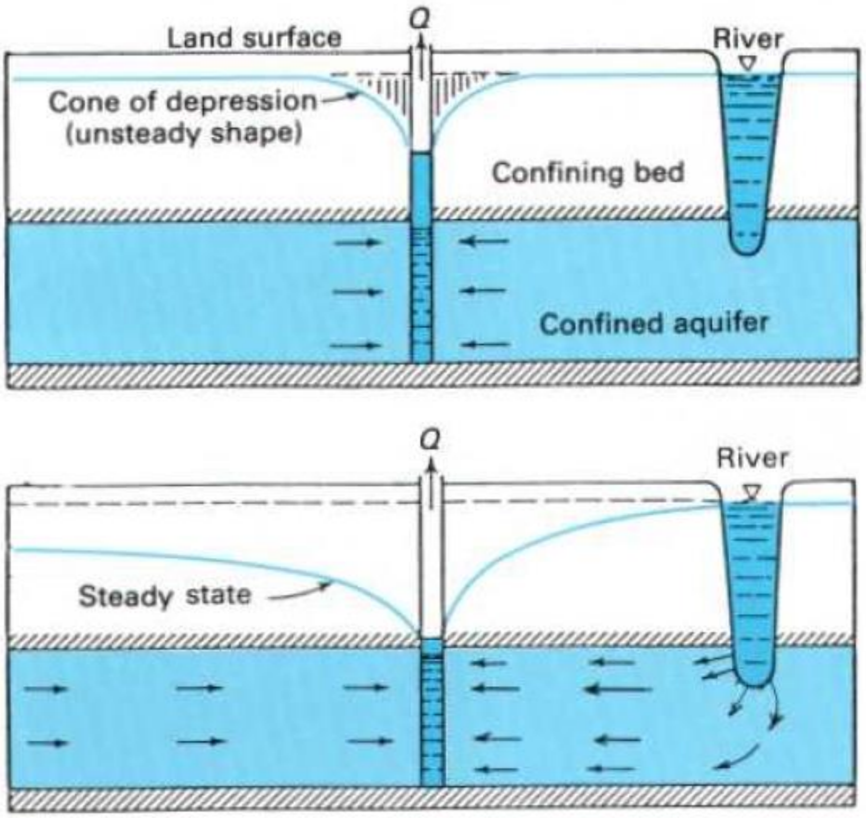


Figure 34 Range and impact of drawdown cones under due to light and heavy abstraction (Source: Heath, 2004)

In the figures above we see that initial pumping produces a conical drawdown of the water table around the borehole known as a drawdown cone. It results from the water in the aquifer being abstracted immediately around the borehole and usually indicates that water is being discharged more quickly than the aquifer can recharge. In the second figure we see that the drawdown cone has now descended into an initial confining bed and is now impacting on the hydrogeological environment of a nearby river.

5.4 Supply Well Protection

Pollution of the environment results from man's activities, and, consequently, except where deep wells or mines are used for waste disposal, it primarily affects the land surface, the soil zone, and the upper part of the saturated (ground water) zone. Therefore, the protection of supply wells includes avoiding areas that are presently polluted and sealing the wells in such a way as to prevent pollution in the future.

Fortunately, most ground-water pollution at the present time affects only relatively small areas that can be readily avoided in the selection of well sites. Among the areas in which at least shallow ground-water pollution should be expected are:

- Industrial districts that include chemical, metalworking, petroleum-refining, and other industries that involve fluids other than cooling water.
- Residential areas in which domestic wastes are disposed of through septic tanks and cesspools.
- Animal feedlots and other areas in which large numbers of animals are kept in close confinement.
- Liquid and solid waste disposal sites, including sanitary landfills, "evaporation ponds," sewage lagoons, and sites used for the disposal of sewage-plant effluent and solid wastes.
- Chemical stockpiles, including those for salt used to de-ice streets and highways and for other chemical substances soluble in water.

In the selection of a well site, areas that should be avoided include not only those listed but also the zones surrounding them that may be polluted by movement of wastes in response to both the natural hydraulic gradient and the artificial gradient that will be developed by the supply well. Rules and regulations intended to prevent future pollution include provision of "exclusion" zones around supply wells, requirements for casing and for sealing of the annular space, and sealing of the upper end of the wells.

5.5 Supply Well Maintenance

The yield of any water-supply well depends on three elements: the aquifer, the well, and the pump. A decline in yield is due to a change in one of these elements, and correction of the problem depends on identification of the element that is involved. This identification in many cases can be made only if data are available on the depth to the water level in the well and the pumping rate. Inability to identify reasons for a decline in yield frequently results in discontinuing the use of the borehole or well supply from the groundwater.

The yield of a well depends on the drawdown and on the specific capacity which is determined during the pump testing of the well and the aquifer. The specific capacity is the yield per unit of drawdown, and, in nearly all pumping wells, it varies with the pumping rate. Therefore, a discussion of decline in yield is meaningful only in terms of the maximum yield.

ANALYSIS OF DECLINES IN WELL YIELD

Identifying criteria	Cause	Corrective action
Decline in available drawdown, --------- no change in specific capacity.	The aquifer, due to a decline in ground-water level resulting from depletion of storage caused by decline in recharge or excessive withdrawals.	Increase spacing of new supply wells. Institute measures for artificial recharge.
No change in available drawdown, ------ decline in specific capacity.	The well, due to increase in well loss resulting from blockage of screen by rock particles or by deposition of carbonate or iron compounds; or reduction in length of the open hole by movement of sediment into the well.	Redevelop the well through the use of a surge block or other means. Use acid to dissolve encrustations.
No change in available drawdown, ------ no change in specific capacity.	The pump, due to wear of impellers and other moving parts or loss of power from the motor.	Recondition or replace motor, or pull pump and replace worn or damaged parts.

(Source: Heath, 2004)

To determine the loss in performance, the original pump test performed and data collected during the original completion of the well serves as the reference point. For optimal management this infers that on-going performance evaluation of the well, both in terms of water quality and quantity, must be done on a regular basis. Inspection procedures, such as pumping tests, should be established and followed in all subsequent inspections, with the results carefully recorded. This includes water quality tests as well. These tests should be done more than once per year in order to observe seasonal variations as well as yearly. This pumping-test data is compared to data from previous tests to assess the performance of the well.

Observations such as a change in the discharge from the pump during the standard pumping period or a slower than usual return to static water level after pumping indicate that the well or the pump is in need of attention. For example, a decline in the discharge capacity of the well can indicate that the well-screens may be plugged or clogged.

In addition to pump-testing, the static or rest-water levels of the wells must be taken regularly and frequently, including those of surrounding wells that may be functioning in the same aquifer. This includes water quality tests as well. The information collected from these regular surveys is more pertinent to the quality of the aquifer, rather than the well. They may indicate how pumping from nearby wells may be affecting the well in question, or whether there is a general change in the hydrological characteristics of the aquifer in terms of quality and quantity.

5.5.1 Major Sources of Well Deterioration

There are five major sources of well deterioration and they generally occur over time, rather than immediately. If there is immediate deterioration of a well, it is almost always the cause of poor borehole construction and incorrect choice of screen, screen position, poor installation of filter pack, structural failure in the casing, improper borehole development, or incorrect pumping rates which may have damaged the local aquifer. The five sources are presented in following.

Reduction in Well Yield

Well yield can be reduced by chemical incrustation or biofouling of the well screen and the formation materials around the intake portion of the well. Deterioration of screen and formation conditions can be alleviated by maintenance procedures (discussed later) but other factors, either man made or natural, can also affect yields. For example a general drop in water table can be the result of climatic trends or from the unregulated and poorly managed installation and/or pumping of nearby wells.

Plugging of the Formation

The formation around the screen can be plugged by fine particles over time, occurring mostly in unconsolidated aquifer formations. During the pumping cycle these fines are mobilized into suspension and will eventually migrate towards the well and the screened or pumping zone. This can also occur in igneous and metamorphic rock, depending on the fracturing environment (size, degree of destruction between fracture faces). In a particularly coarse fractured environment there may be more fine materials produced which can reduce a well to 10 or 20 percent capacity even within a few months of installation.

Onset of Sand Pumping

Some wells seem to always pump a quantity of sand, a condition usually resulting from poor well design or development. Other wells may begin to pump sand after years of service. Localized corrosion of the well screen or casing, or incrustations on a portion of the screen, can permit a higher velocity of flow which in turn allows for sand grains to mechanically erode the screen openings, enlarging them and allowing invasion of fine materials normally screened. Corrosion and encrustation are the usual causes of unexpected sand invasion of the well. However, in sandstones which are well-cemented, the pumping and movement of water into the well may begin to break down the cement matrix, eventually mobilizing sand particles which were consolidated during the original drilling environment.

Structural Collapse of the Well

It is possible to have a structural collapse of the well casing or screen. For metal casings and screens this often results from low-pH (acidic) waters with a high content of total dissolved solids (TDS) and carbon dioxide concentrations which result in electrolytic corrosion which ultimately takes its toll over time. As mentioned earlier, the quality of the casing installed is also important, especially for PVC casing, which may have been weakened or stressed during transport or storage or been exposed to damaging sunlight and UV light.

Pump Condition

Mistakes on the design and construction of the well can cause severe damage to the pump over time. The impellers, impeller housing and pump shaft are particularly susceptible to abrasion and damage during sand pumping. As with metal casing, pumps are also susceptible to corrosion from low-pH waters.

5.6 Well Rehabilitation

Well rehabilitation is defined as restoring a well to its most efficient condition by various treatments or reconstruction methods. The necessity for rehabilitation will depend on the effectiveness *of* the maintenance program and well it has been followed. In some case rehabilitation can be quite major and involve the replacing of casing or screens, but this eventuality can be offset by a regular maintenance program. When the yield of well drops below 75% of its original capacity it can be assumed that a major maintenance is required. However, even major maintenance is seen as being much less expensive than replacement of a well or borehole, unless there has been a collapse or irreparable change to the subsurface aquifer conditions.

5.6.1 Incrustation

This phenomenon is usually determined by water quality. Groundwater normally moves slowly through the earth materials and is in contact with constituent minerals for hundreds or thousands of years. Mineral content can be quite high in the groundwater, which remains in a chemical balance with its surrounding environment. This balance is altered when the equilibrium of the saturated groundwater is chemically or physically disturbed, causing precipitation of the mineral content. The chemical equilibrium is disturbed when the well is pumped, and the greater the drawdown in the well and the aquifer, the greater the disequilibrium will be.

Water with high calcium carbonate content, often derived from limestone aquifer environment, often precipitates mineral deposits or lime scale onto the borehole screen. Other minerals such as iron and manganese can also form deposits on the screen. Iron or ferric oxide often appears as a reddish brown deposit similar to rust. Hydrated iron oxide can appear as a black sludge around the screen. Iron oxide can be deposited in the draw down cone during pumping, filling in the temporarily empty void spaces, eventually reducing void space in the formation. There also exists a bacterium known as iron bacteria, which propagate in concert with iron / manganese content and dissolved organic material such as carbonates. Sludge can rapidly form that quickly blocks the screen area.

Treatment

Prevention of incrustation is not yet an option except for the installation of injection wells around the main production well, into which oxygenated water is pumped, encouraging the precipitation of iron oxide around the injection wells and thus reducing the amount of iron migrating to the production well. Actions can be taken to delay the onset of incrustation including:

- Installation of a screen with a maximum possible exposure area design which reduces the velocity of water movement into the well
- Ensure during installation that the well is developed thoroughly
- Pump at lower rates but for longer periods
- Use a number of smaller boreholes for abstraction rather than a single large diameter borehole
- Maintenance and cleaning of the borehole

For maintenance and cleaning, a sample of the encrusted material is required to determine whether the problem originates from the aquifer and groundwater or the screen itself. Chemical encrustations can be removed by **acid treatment**, which dissolves mineral scale as well as some of the iron deposits which can form. It is important that a professional approach is taken for treatment which requires care in working with essentially dangerous materials and requires special tools. Mechanical methods of treatment also exist in the form of scraping or brushing of cased or solid rock boreholes. Controlled blasting can also be done in un-cased boreholes. After any treatment, the borehole should be redeveloped.

Iron bacteria are a specific problem and it is important that the water well contractor does not introduce this contamination into a borehole during drilling or rehabilitation works. The drill rods, bits and tools should be chlorinated thoroughly to eliminate contamination from previous jobs. Iron bacteria can be treated also be chemical and mechanical means.

5.6.2 Physical Plugging of Screen

As part of the screen becomes plugged, the velocity of water flow in the remaining openings increases, promoting higher mobilization of fine materials and mechanical erosion of the screen openings. Often caused by poor borehole construction, plugging can also result from excessive cycles of pumping. Removing fine materials, especially clays, from the surrounding aquifer is because of their tendency to adhere to each other in a viscous state.

Treatment

The wells can be cleaned by using dispersing agents during a flushing treatment of a well. They serve to separate the fine silt and clay particles, allowing them to be mobilized and flushed out of the well, screen zone and adjacent aquifer formation. Typical dispersing agents are polyphosphates and surfactants. This dispersing agent should be surged or agitated inside the well during the treatment much the same way that the well is developed, with a jetting tool or surging techniques.

5.6.3 Well Failure Due to Corrosion

Well casing and screen failure is often the result of corrosion, a natural process that affects all metals and ultimately can break down their fabricated metal structure. Corrosion can cause screen openings to enlarge and casing to weaken, especially at joints.

Treatment

With corrosion being a natural process, prevention is more effective and is normally undertaken during the installation of the borehole. Casing and screens can be replaced but this may not be an option for unconsolidated sediments or unstable aquifer formations. Stainless steel joints should be used, especially around the screen fittings where water flow velocity is highest. Also, following may years of experience and experimentation, a standard has been developed for competent stainless steel manufactured components, especially for casing. Material components for the borehole should be verified to be up to standard.

5.6.4 Pump Maintenance

Pumps operate often under less than ideal conditions and therefore have a number of maintenance requirements. Indications of pump failure include excessive heating, noise, vibration, or change in energy demand (electrical or fuel and oil). Sand abrasion is one of the most common causes of pump damage, originating from causes already discussed. Cavitation, where the water level above the pump is not sufficient or the flow in the aquifer is lower than the optimal pumping rate of the pump, causes the formation of oxygen vapour bubbles which produces pitting on the pump intake surface. This can occur as a result of over pumping or installation of a pump whose optimal functioning is higher than can be justified by the well. If there is a corrosive element in the water, the impact of cavitation is increased. While pump maintenance is generally a mechanical action, damage to the pump can be reduced by good borehole maintenance and selection of the right pump for the capacity of the well.

5.7 Exercises

- Describe which types of well or borehole problems are caused by improper or incorrect well installation.
- List a borehole or well maintenance program, describing each activity and the reason for its implementation.

6.0 Groundwater Management

6.1 Groundwater Environment in Sub Saharan Africa

Groundwater has proved the most reliable resource for meeting rural water demand in sub-Saharan Africa (SSA). There are four main hydrogeological environments in SSA. Each of these broad categories requires different methods for finding and abstracting groundwater.

- *Crystalline basement* occupies 40% of the land area of SSA; 220 million people live in rural areas underlain by crystalline basement rocks. Groundwater is found where the rocks have been significantly weathered or in underlying fracture zones. Borehole and well yields are generally low, but can be sufficient for rural demand.
- *Volcanic rocks* occupy 6% of the land area of SSA, and sustain a rural population of 45 million, many of whom live in the drought stricken areas of the Horn of Africa. Groundwater is found within palaeosoils and fractures between lava flows. Yields can be high, and springs are important in highland areas.
- *Consolidated sedimentary rocks* occupy 32% of the land area of SSA and sustain a rural population of 110 million. Significant groundwater is found within sandstones and limestones, which can be exploited for urban as well as rural supply. Mudstones however, (which account for about 65% of all sedimentary rocks) contain little groundwater, and careful study is required to develop water for community supply.
- *Unconsolidated sediments* occupy 22% of the land area of SSA and sustain a rural population of 60 million. They are probably more important than these statistics suggest since they are present in most river valleys throughout Africa. Groundwater is found within sands and gravels.

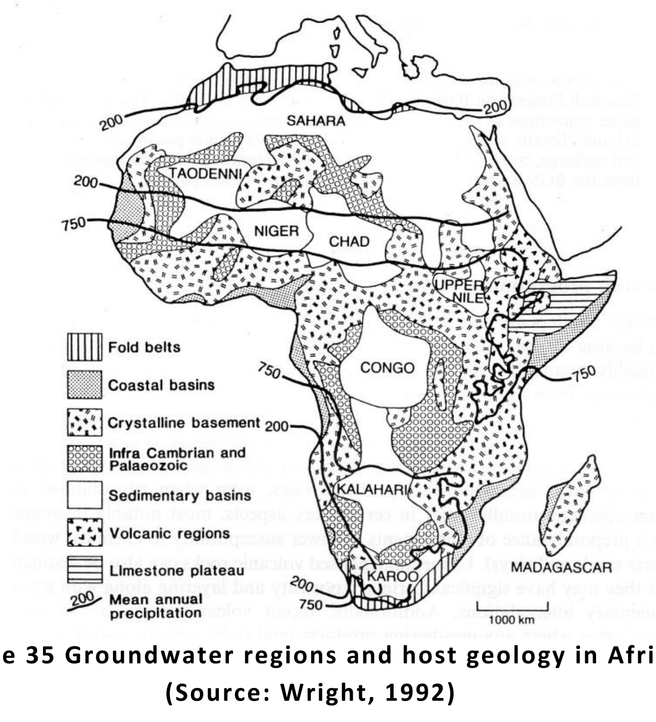


Figure 35 Groundwater regions and host geology in Africa (Source: Wright, 1992)

The figure above illustrates the groundwater regions of Africa. Unconsolidated sediments are found along coastal zones and as top cover in the sedimentary basins.

6.2 Groundwater Demand

The accessibility of groundwater in traditional shallow hand-dug wells, springheads and seepage areas has always controlled the extent of human settlement beyond the major riparian tracts – and the widespread introduction of drilling rigs and water-well pumps from the 1970s enabled further extension of human activity. Today the dependence of rural water-supply on groundwater is undisputable, with the presence of successful water wells allowing the functioning of villages, clinics, schools, markets and livestock posts over very large land areas (the term 'water well' is used for all boreholes, and in smaller number deep hand-dug wells, equipped with pumps).

In recent years important new pressures for groundwater development have been observed, including:

- Rapidly increasing demand for urban water-supply provision at a range of scales – from improving water services in innumerable small (but rapidly expanding) towns to supplementary public and private water-supply sources in large conurbations.
- Growing interest in the prospect of accelerating groundwater use for agricultural irrigation – both for high-value crop production at the commercial scale, and for subsistence horticulture and drought-proofing some staple-crop cultivation.

At present only a small proportion of Sub-Saharan agricultural land is equipped for irrigated cropping, and agricultural groundwater use in particular is extremely limited. Groundwater irrigation has often been beset by operational and/or economic problems, such as import restrictions on water-well equipment, absence of a related service sector, diesel energy costs and supply chains, post-harvest crop handling and transport, and inadequate access to markets. In addition, data scarcity, lack of understanding and poor appreciation of the groundwater resource has inhibited investment.

In parallel with these trends, awareness of the need to conserve groundwater-dependent stream flows and aquatic ecosystems is also increasing. There is a pressing need for investment in drought preparedness at a variety of scales, including the enhanced management of groundwater storage to 'buffer' drought impacts.

6.2.1 Groundwater Data and Information

Traditional institutional separation of surface water from groundwater has created fundamental communication barriers that now extend from technical expertise to policy developers, operational managers and water users. These barriers impede the understanding of the processes and consequences of groundwater-surface water interactions. This is especially challenging in the urban areas, where water consumption tends to be in the order of the number of consumers of water supply, often from groundwater sources, rather than groundwater consumed. Similarly in rural areas, there is a lack of data in rural areas where groundwater wells are not recorded or regulated, leaving a huge gap in the knowledge of groundwater abstraction. There is a clear need for improved data and information collection and dissemination for both rural and urban zones.

Rural Areas

Further mapping and dissemination of groundwater availability data at national and provincial level should be collated with agricultural soils data as baseline planning information to judge the feasibility of investment for irrigation and development. Other recommendations include:

- Incorporating groundwater recharge enhancement into rural development projects where feasible to provide additional 'buffering' storage during drought
- More detailed processing and presentation of hydrogeological information on water-well yield prospects and groundwater resource potential, in areas within 50 km of major market centres, to optimize and regulate private irrigation water-well drilling
- Undertaking multidisciplinary (hydrogeological and agricultural and socio-economic) analysis of successful (and unsuccessful) examples of groundwater irrigation and other consumptions at all scales, so as to build a more robust platform for project design and investment
- Promoting highly focused and closely monitored pilot projects in a variety of hydrogeological and socioeconomic settings to guide cost-effective and sustainable expansion of groundwater-based irrigation and other uses – including the promotion of alternative drilling techniques and pump energy sources, and using private-sector services to sustain initiatives

Urban Areas

In many urban environments the water supply is either from municipal (groundwater origin) sources or local 'in situ' wells. With high levels of economic activity and relatively poor sanitation facilities (often only pit latrines or even less), the risks of at least shallow groundwater contamination are quite high. The most probable future trend will be expansion of low-cost facilities such as water wells (with reticulation to standpipes where feasible) and improved pit latrines for sanitation. Various tools should be developed to facilitate more informed and ordered development of groundwater resources in urban areas including:

- Maps of water-well yield potential, depth to main aquifer horizons, static groundwater levels (as partial indicator of pumping lift), groundwater pollution vulnerability and natural quality hazards
- Order-of-magnitude assessments of groundwater-resource status, levels of sustainability and seriousness of risks associated with persistent excessive abstraction

- Monitoring abstraction and water tables – and making this information easily accessible
- Disseminating protocols requiring rain-water harvesting from rooftops and paved areas with enhancement of aquifer recharge through soakaway pits and avoiding unnecessary soil compaction in the urban environment
- Developing guidelines on groundwater use precautions in relation to potential and actual quality hazards.

6.3 Role of Governments

The emerging developmental agenda in Sub-Saharan Africa will require much greater emphasis on strategic assessment and investment planning for groundwater resources, as a platform for managed groundwater development. This will require strengthening, evolution and, in some cases, reform of the institutional framework for groundwater governance. It will also require achieving a sensible (and in some cases delicate) balance between:

- Promoting (or providing an enabling framework for) much needed groundwater development
- Regulating groundwater abstraction and potentially polluting activities to avoid excessive resource exploitation and subsurface contaminant pressure in critical areas
- Integrating groundwater assessment, development and recharge-enhancement programmes with land-use management.

In many countries, the institutional landscape into which groundwater-resource development, management and protection has to be accommodated is also undergoing substantial change – as the result of a general trend for decentralisation with the formation of river-basin boards and/or agencies primarily to address 'upstream-downstream issues' of major river systems. However, only a minority of these have significant operational capacity and/or actively include groundwater management and protection.

6.3.1 Policy

The integration of groundwater into national policy, such that this resource can make an appropriate and effective contribution to economic development plans (relating to issues like food security, urban services and rural livelihoods) requires developing an adequate cross-sector dialogue within government. This, and accommodating the particular needs of groundwater within the river-basin board/agency structure, makes it absolutely essential for political awareness of groundwater at the highest level. The essential roles of government are best defined legally in terms of certain fundamental concepts, responsibilities and powers as follows:

- **Catchment/aquifer-level resource planning and allocation** – establishing sensible boundaries for resource management, translating national plans to the appropriate territorial level and providing a unified vision of groundwater and surface water resources
- **Land surface zoning for groundwater conservation and/or protection** – making provision for the declaration of 'special control areas', critical in resource terms or especially vulnerable in pollution terms, where exceptional measures can be implemented
- **Groundwater monitoring and information provision** – ensuring appropriate monitoring, together with periodic evaluation of resource status based on open data exchange and information provision
- **Facilitating stakeholder participation and engagement** – the active involvement of groundwater users and potential polluters, and other interest groups being necessary to promote and enforce balanced development and protection on-the-ground
- **Administration of groundwater resource use** – according to the overarching allocation plan and including water-well construction permits, registers, abstraction rights/permits, and resource charging (as appropriate), together with effective sanctions for non-compliance
- **Licensing of ground discharge of wastewater and landfill waste disposal** – subject to conditions that prevent or limit groundwater pollution, with effective sanctions for non-compliance.

However, the institutional capacity required to implement such provisions at local level is rarely achieved because of:

- Serious lack of experienced or well-trained staff in government agencies (and perhaps more generally)
- Inadequate budgets for fundamental activities like water-well registration and groundwater monitoring
- Insufficient attention to priority-setting so as to concentrate on the most critical issues and areas, and to create an 'enabling environment' for management with relevant stakeholders.

Decentralisation and the promotion of demand-responsive approaches to service provision have significant implications for building knowledge of groundwater in Africa. In particular, local institutions - including local government and NGOs - are now tasked with providing technical support for community initiated and managed services. While this move has many benefits and promises greater sustainability, decentralisation has been to the detriment of national databases, national knowledge and control over borehole drilling and construction standards. As a consequence, knowledge of groundwater resources is not growing or even being maintained in much of SSA. Without this knowledge, local institutions risk making poorly informed decisions.

SSA is in the situation where many thousands of boreholes have been drilled in SSA and little knowledge gained from them. As a consequence, the same costly mistakes are made time and again. To gain the same information that could have been routinely collected during on-going drilling requires significant investment in exploratory drilling and testing. Even now, in the new decentralised regime, techniques and methods are available that could be used to collect useful information from on-going drilling. The use of these techniques could allow local institutions to assess the nature of groundwater resources in their areas and, with proper documentation and networking, increase the knowledge base of groundwater in Africa. Budgets for groundwater research in Africa could then be targeted to issues that cannot be addressed by improved data collection from on-going drilling. Such a scenario will only occur with the dissemination of simple techniques in groundwater resource assessment to those involved in rural water supply, and when the benefits of such assessments are seen within individual water projects.

To achieve managed groundwater development it will be necessary for governments to make efforts in:

- **Professional capacity building** – through the provision of training (and training-the-trainers) to develop additional capacity and deploying existing personnel more effectively
- **Stimulating successful private-sector participation** – so as to provide quality contracting services (in water-well siting, construction and maintenance) and/or competent professional consultancy services (in surveying, evaluation and monitoring of groundwater) consistently
- Ensuring that the relevant government agency has the professional capacity and institutional strength to guide and assess the quality of the work commissioned to the private sector.

6.4 Groundwater Policy Case Study Summary: South Africa

A recent case study on groundwater governance in South Africa at national and local levels was done as part of a World Bank economic and sector analysis on "*Too Big to Fail: The paradox of groundwater governance*" (Water Research Commission Report WRC Report No. KV 273/11, 2011) . At the local level, groundwater governance was studied for four highly productive aquifer systems demonstrating various degrees in the implementation of groundwater governance: (i) Botleng Dolomite Aquifer (Delmas area); (ii) Gauteng Dolomites (Steenkoppies and Bapsfontein compartments); (iii) Houdenbrak Basement Aquifer (Mogwadi (Dendron)-Vivo area); and (iv) Dinokana-Lobatse Transboundary Dolomite Aquifer.

6.4.1 Methodology

At the national level, the case study includes an analysis of the policy, legal and institutional frameworks for groundwater provisions, knowledge and capacity availability and gaps and financing arrangements to strengthen groundwater governance. For each aquifer system the governance status was determined based on an evaluation of potential threats. Technical, legal and institutional, cross-sector policy coordination and operational groundwater governance provisions and institutional capacity for implementation were evaluated using a priority list of 20 benchmarking criteria. Management measures were proposed accordingly to strengthen the groundwater governance status. Also the relevance of groundwater governance arrangements for coping with impacts of climate change was reviewed according to a risk-based framework.

The case study builds upon a vast amount of work carried out in recent years on groundwater governance in South Africa. Especially the National Groundwater Strategy which addresses deficiencies in groundwater provisions in the National Water Resource Strategy, the Department of Water Affairs (DWA) Implementation of Dolomite Guideline Project – Phase 1 and a multi-stakeholder workshop proved to be invaluable sources of data and information.

Groundwater governance at national level

- Technical, legal and institutional and operational governance provisions are reasonable but weak for cross-sector policy coordination
- Institutional capacity is weak across all thematic areas except for the technical provisions.

Groundwater governance at local level

- There is similarity in governance provisions for the dolomite aquifers across all thematic areas with the Steenkoppies dolomite aquifer consistently scoring higher
- Basic technical provisions such as hydrogeological maps and aquifer delineation with classified typology are in place for all case study aquifers
- Other governance provisions across all thematic areas are weak or non-existent
- Steenkoppies dolomite compartment scores highest; Bapsfontein dolomite compartment and Houdenbrak basement aquifer score lowest
- Groundwater monitoring is weak and assessment of groundwater resources is poor, both in terms of quantity and quality (e.g. lack of numerical groundwater model)
- There are fair provisions for water well drilling and groundwater use rights but provisions to control groundwater abstraction and pollution are weak (poor compliance monitoring)
- Provisions for establishment of aquifer management organizations are weak or nonexistent
- Cross-sector policy coordination is weak
- From an operational point of view, a groundwater management action plan which includes both water quantity and water quality aspects only exists for the Botleng aquifer but has not been implemented to date

- Institutional capacity across all thematic areas is weak or non-existent except for the Steenkoppies dolomite aquifer where the situation is better.

Climate change adaptation

At national and local level, adaptation measures to climate change are not yet a consideration in planning. Only at the national level an artificial groundwater recharge strategy was developed and awaits implementation.

6.4.2 Recommended management measures

Groundwater management measures are recommended at national level and at local level for each of the case study aquifers to address existing and potential hazards as well as to improve on the effectiveness of existing groundwater governance provisions and institutional capacity.

Most critical are considered (i) the integration of the National Groundwater Strategy into the National Water Resource Strategy (NWRS), Catchment Management Strategies (CMSs) and other strategies, (ii) strengthening of the groundwater related regulatory environment and (iii) strengthening of the institutional capacity, both in terms of existing institutions (DWA) and establishment and operationalising of Catchment management Agencies (CMAs) and Water User Associations (WUAs). Regarding the inadequacy of groundwater expertise we recommend DWA to develop a strategy to augment national GW capacity. Furthermore, investigation and implementation of climate change adaptation measures at local aquifer level are recommended.

Specific recommendations:

- Strengthening and implementing groundwater governance measures should preferably follow a 'parallel track and adaptive approach' within the existing legal and institutional framework. Such an approach would strengthen the said frameworks without disruption, taking cognizance of capacity and willingness to implement.
- Pilot projects in the case study aquifers to improve on the groundwater governance provisions and institutional capacity
- The same methodology which was used in this case study can be applied to identify management measures for other aquifer systems in South Africa such as the Karoo aquifer of Beaufort West.

6.5 Current Regional Issues

6.5.1 Hydraulic Fracturing

One of the most current groundwater issues in the Southern African region is the use of hydraulic fracturing for shale gas exploration. Hydraulic fracturing was developed in the United States of America in the late 1940s to assist in the stimulation of oil and natural gas wells. The number of wells that incorporate hydraulic fracturing increases since oil and gas production is increased by this technique.

Due to present energy shortfall in South Africa, the requirement for new energy sources has gained momentum in recent years. Part of this new focus is on shale gas in Karoo type formations. There are currently a number of companies that have exploration rights to investigate natural gas resources in Karoo type formations. The most interesting aspect of this is that the area available for natural gas development is substantially larger than just the Karoo, with exploration areas covering six of the nine provinces in South Africa. Very little data is available in the public domain on hydraulic fracturing in South Africa.

Geological Setting

Shale gas is defined as gas generated from organic-rich shale. The target gas is methane, which is an energy source and can be used for the production of fuels as in the Mossgas process or as a power source for electricity generation. Methane is a dry gas and represents the final stage of hydrocarbon thermal maturation. Organic-rich shales were originally muds deposited in marine or lacustrine basins, the organic material being derived mostly from algae, spores and pollen. These muds became buried and lithified over tens to hundreds of millions of years and generated various hydrocarbons with increasing depth of burial and increasing temperature. Between 2 and 4 km burial depth, oil is produced, between 4 and 5 km, wet gas is produced and between 5 and 6 km, dry gas, including methane, is produced. Deeper burial results in low-grade metamorphism, the termination of hydrocarbon generation and the formation of graphite from the organic material.

The Fracking Technique

Hydraulic fracturing, or 'fracking', is a method used by drilling engineers to stimulate or improve fluid flow from rocks in the subsurface. In brief, the technique involves pumping a water-rich fluid into a borehole until the fluid pressure at depth causes the rock to fracture.

The pumped fluid contains small particles known as proppant (often quartz-rich sand) which serve to prop open the fractures. After the fracking job, the pressure in the well is dropped and the water containing released natural gas flows back to the well head at the surface. The boreholes themselves are often deviated away from the vertical, into subhorizontal orientations, to ensure better and more efficient coverage of the targeted shale gas reservoir. The fracking fluid also contains small amounts (typically < 2% in total by volume) of chemical additives such as acid to help initiate fractures, corrosion and scale inhibitors to protect the borehole lining and gelling agents to alter the fluid viscosity.

A variety of factors have combined to promote the recent surge in the exploitation of shale gas. Most traditional hydrocarbon reservoirs developed to date have oil and gas located in well-connected pores in the rock. This natural porosity, and related permeability, is often sufficient to allow extraction, but various methods of stimulation have been used over many years to improve the flow rate, including fracking. In shale gas reservoirs, the natural gas is more closely bound to the rock, and sits in a fine scale array of relatively isolated and small pores and cracks. In order to extract this resource, the permeability must be improved by artificial means, and fracking is a popular method.

Environmental Concerns

Injecting large volumes of fluid into the subsurface is not without risk, and recent reports in the media and, to a much lesser extent, in the scientific literature have highlighted the potential for the following:

- earthquakes induced by slip on nearby faults;
- contamination of ground water, and possibly even drinking water, with natural gas and other chemicals;
- emissions of volatile components, such as CO2 or methane, into the atmosphere;
- leakage of contaminated drilling waste fluid from storage ponds.

Tectonic and Geomechanical Risks

Fracking inherently involves *geo-mechanical* risks – i.e. the injection of large volumes of pressurised water at depth will, by design, alter the *in situ* stress state and change the propensity of existing fractures to open or faults to slip, and possibly result in seismic activity (i.e. earthquakes).

Fracking also entails *geochemical* or hydrogeological risks. The key issue is the fate of the water (plus additives) after the fracking has occurred. During fracking there is little direct control on the nature of the permeable fracture network created, and how this new network might then connect to any pre-existing (and potentially undetected) fracture network.

Groundwater Contamination

Whilst potential contamination of ground water with the injected fracking fluid is therefore an important concern, another issue is the fate of the initial drilling fluid (or ‘mud’) used to lubricate the borehole during drilling. The industry as a whole is, however, well versed in conserving drilling mud, and boreholes are lined with metal casing tubes which are then cemented into place. An additional risk is that of the natural gas released by the fracking process entering the ground water, however there has only been one confirmed case of this kind of contamination to date, with natural gas released from a fracking operation entering a shallow aquifer through poor quality casing.

The potential risk to ground water comes from two sources: the injected fluid (water + chemical additives) and the released natural gas. However, a key issue is the exact site of this contamination:

- percolation (advection) or diffusion from the hydraulically fractured formation at depth? or,
- leakage from a defective well bore closer to the land surface?

The figure below shows potential groundwater contamination zones, either measured from existing studies or perceived.

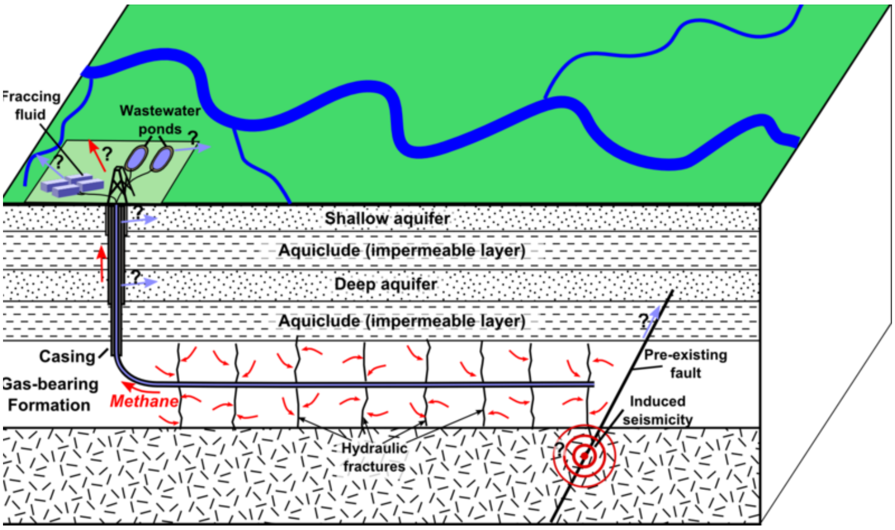


Figure 36 Areas and zones of potential groundwater contamination during fracturing exercise
(Source: Norton, 2011)

A recent review by the University of Aberdeen states that the majority of groundwater contamination events recorded result from casing failure or surface water contamination, and not aquifer contamination, but that this information can also the result from the relatively short time span available for monitoring.

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WATER STRATEGY AND POLICY IN SOUTHERN AFRICA

EXECUTIVE SUMMARY

The course includes an overview of key Southern African Strategies on Water and Sanitation, followed by information about general governance in SADC down to municipal level, regarding water, energy and sanitation. In some instances, the references and examples may only apply to one of the above-mentioned levels but it is mostly the current principles and views as defined by human rights principles, constitutions, and declarations accepted by the SADC countries that are being discussed. The South African perspective is being placed central in this discussion.

This course will indicate the following important aspects of water policy and strategy for the Southern African region

- South Africa as a role player in southern Africa regarding the water and energy
- South Africa as a possible leader in water and energy matters
- South Africa as an example in terms of shared water resources, notably the Limpopo and the orange rivers.
- Shared energy resources: the Cabora-Bassa electricity scheme
- The Mozambique gas pipeline to South Africa (SA).
- Fracking in SA

OUTCOMES AND OBJECTIVES

In this course the importance of the role South Africa plays in the stimulation of the SADC economies will be examined. The course will focus on the differences, and the importance in legislature between countries in the region regarding water and energy. These will be highlighted using case studies on topics mentioned above in this context. Students and participants will look at legislative, policy and regulatory contexts and how they vary from a regional perspective down to a local scale.

TIMEFRAME

The course is designed for a 40 hour window period over 2 weeks, but can also be broken down into short modules.

ACKOWLEDGMENTS

The overall structure and objective of this course has been established with the consultation of Nico Elema (NEPAD SANWATCE Secretariat).

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1.0 INTRODUCTION

The course is structured in such a way as to provide the most relevant and up to date information to the studentsThe history of certain actions and acts are relevant because they were based on mistakes of the past, and this knowledge is important for the future directives and planning. The content of the course aims to be as dynamic as possibleand promotes relevant and up to date discussions in the class.

1.1 Role of regional bodies in implementation of international declarations

Since the late 1990's a number of leading African declarations originated from the Organisation of African Unity (OAU), which played a large role in the transformation of African countries. The OAU influenced many countries in Southern Africa with regards to Human Rights as was the case for South Africa, Namibia, and Botswana. ("OAU/AU Treaties, Conventions, Protocols & Charters," n.d.)

Mandatory reading

In this section the following publications are important for background on relevant international declarations.

Africa regional paper, Bridging Divides in Africa's Water Security: An Agenda to Implement Existing Political Commitments http://www.euwi.net/files/5th_WORLD__FORUM_AFRICA_REGIONAL_PAPER_-_FINA-PRINT_VER_09_M-1_0.pdf

United Nations Universal Declaration of Human Rights (UDHR)

1.1.2 Questions

The following **questions** are to be presented for a class discussion after students have read the above-mentioned articles:

How does the implementation of declarations on an international scale (including SADC) work?

How do we balance regulatory structures and human rights issues?

1.2 National policy at member state level

This section's primary interest is the link between decisions based at the African Union (AU) level, their impact and acceptance, and following down through the institutional hierarchies to the implementation at the member state level. It explores whether such decisions at AU and regional level are ultimately reflected in policies on a national level, including how they are implemented The impacts on national policy will be assessed from:

- a global perspective,
- AU perspective and
- the perspective of any single member state.

The **global perspective**: Africa (and the AU)is expected to conform and align its internal policies to the international agreed-upon principles on human rights.

The **AU perspective**: the AU has no legal right or mandate to force member states to conform to the general agreements of the AU in terms of compliance to their prescribed policies. However the general trend is that countries that are committed to Human rights principles are more inclined to adhere to the AU position in terms of these principles within common law in Africa.

The **local perspective**: For South Africa (as an example of the Member State level), a number of "decisions, declarations and resolutions" are implemented including a focus on climate change and how this will affect Africa's water resources. This is linked to the AU Declarations dealing with climate.

1.3 Sector regulation and governance

The water sector (including the protection and utilization of water resources, both on national and regional level, as well as the provision of water services) is regulated via domestic legislation in the respective SADC countries.

The legislation, which also sets the framework for effective governance, must reflect the African and regional context, but also ensures effective governance at country level.

The main legislative provisions regarding water resources in the South African are as follows:

- the Constitution,
- the National Water Act, Act 36 of 1998,
- the Water Services Act, Act 108 of 1997.

The Constitutional aspects are examined in more detail in Section 8.2. In addition, the main framework legislation on the protection of the environment, the National Environmental Management Act, Act 107 of 1998, plays an increasingly important role as far as the protection of water resources is concerned.

1.4 Local government and participatory processes

In South Africa, local government experiences a general defined commitment to adhere to and implement their Government's decisions and regulations through a participatory process. South Africa is partaking in AU defined initiatives such as monetary policies, trade regulations, and regional economic communities.

Task: Identify programs or activities in South Africa that are reflected in AU declarations, especially those where South Africa clearly declares adherence to.Review their profile and identify participatory processes.

1.5 Case studies

1.5.1 The Limpopo basin as a shared water resource

As South African neighbouring countries became economically more active and agricultural prospects grew, decisions regarding water use and consumption became of crucial importance in order to avoid trans-boundary conflicts in the Limpopo basin. The Limpopo basin spreads over 4 countries: Botswana, South Africa, Mozambique and Zimbabwe. The local South African, Zimbabwean and Mozambican legislature concerning water-use and dam construction is particularly important to these countries' policy makers because water that flows through the Limpopo Basin plays a large role in the livelihoods of people in the region. The recent floods in the lower Limpopo Basin also prompted a regional discussion on the possibility of installing more dams upstream in the Limpopo so that floods could be better managed and the lower part of the basin could be better protected againstfloods.

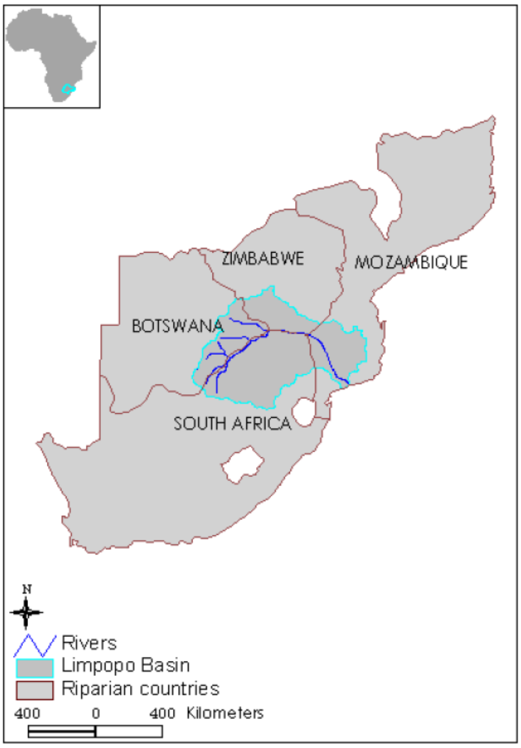

Figure 1 The Limpopo River Basin
(Source: Warner Consultants Ltd, 2007)

The African Network of Basin Organisations (ANBO) originated from the African Minsters Council on Water (AMCOW). The ANBO produced a source book on the state of rivers in Africa with their general geographical and hydrological information, in an effort to facilitate better knowledge and improved governance leading to IWRM on the continent. This document further provides lists of treaties between countries, including a description of the role of Limpopo Watercourse Commission (LIMCOM).

The Mandate of LIMCOM: The objectives of LIMCOM are to advise the Contracting Parties and provide recommendations on the uses of the Limpopo, its tributaries, and its waters for purposes and measures of protection, preservation and management of the river. LIMCOM is a legal authority which advises and provides recommendations to the Limpopo member states on the uses, protection, preservation, and management of the Limpopo and its tributaries. The Commission advises the Contracting Parties on:

- the measures and arrangements to determine the long-term safe yield of water;
- the equitable and reasonable utilization of the Limpopo river to support sustainable development in the territory of all member states.
- all aspects related to the efficient and effective collection, processing and dissemination of data and information
- the development of contingency plans, investigations, and studies (Warner Consultants Ltd, 2007)

Decisions and disputes: Decisions are adopted on the basis of consensus as long as a quorum of three delegations is realized. In the case of a dispute the conflicting parties are required to enter into negotiations. If a solution cannot be reached within six months, the dispute can be referred to the SADC Tribunal. Decisions of the Tribunal are final and binding.

Agreements: The Limpopo Basin is currently being managed on the basis of agreements between the partner countries.

The main issues in the Limpopo basin were identified as the following ("Limpopo River Benchmark Basin," 2013):

- The basin is known for frequent droughts
- The flow of water in the river occurs for only about 40 days during the year in dry periods.
- The water in the river is normally carrying a suspended load of silt and clay.
- Some sub-catchments in the South African side are highly developed economically.

Limpopo basin brief description: The irrigation scheme at Chockwe in Mozambique consists of a very well developed infrastructure, but is often affected by flooding. Apart from the Chockwe scheme, the areas in the neighbouring provinces normally lack expertise in farming, capital resources, training. These areas also do not have access to markets as the farming systems are aimed at supporting mainly households. This situation of on-going political unrest affects economic stability and the ability of farmers to secure a market segment is therefore affected.

Currently the potential for financial investment in South African neighbouring countries, such as Mozambique, is increasing and the utilization of water and energy is therefore on the increase. This increased economic activity also forces a renewed look at the shared water resources between countries.

Lastly, development (industrial, mining, settlements etc.) has an impact on the social, economic, political and environmental situation downstream. This can imply a cross border impact. These situations can in the long run, become potential for conflict unless the differences in water management between countries were not secured through agreements and water management bodies.[2]

This type of study is very important to understand the intricacies for co-existing in the SADC region and to generate an understanding of the differences in water management and governance in the different countries. This includes identifying differences or mis-alignment of legislation between countries, which may also be a source of conflict.

1.5.2 The Orange River

The Orange River is different from the Limpopo river for South Africa in the sense that the origin of the river is in a neighbouring country, namely Lesotho. The mountainous region of Lesotho produces a large flow towards South Africa almost throughout the year. This flow is captured in dams in Lesotho and South Africa and a solid trade and governance agreement exists between these two countries. Apart from Lesotho, the water in this river basin system is also shared with Namibia.

Figure 2 The Orange River Basin (From DWA)

This river system is the most expensive water supply system in South Africa and the only system that generates hydro-electric power for that country.

[2] More about the Limpopo basin can be read at www.arc.agric.za/limpopo.

Orange-Senqu River Basin Commission (ORASECOM): ORASECOM serves as technical adviser to the Riparian Countries on the development, utilization, and conservation of the water resources of the basin. ORASECOM was mandated to develop a comprehensive perspective of the basin, study the present and planned future uses of the river system, and determine the requirements for flow monitoring and flood management. The main objective was the realization of the principle of equitable and reasonable utilization, as well as the principle of sustainable development with regard to the River System.

Organizational Structure: The Council is the highest body of Orange-Senqu River Basin Commission (ORASECOM) supported by a task team of consultants and donors. A permanent secretariat is planned. (Warner Consultants Ltd, 2007)

The Orange-Senqu basin has been selected as one of the target basins of the EU Water Initiative (EUWI). It has presented a portfolio of projects to the EUWI relating to the harmonization of the legislation in the Riparian Countries, the study of trans-boundary aquifers, water demand management, a basin information system, capacity building, and stakeholder participation. The Commission supported the activities that undertook a joint assessment of all the resources of and uses in the basin with the aim of developing an integrated water resources management plan (Warner Consultants Ltd, 2007).

Monitoring: The Parties were required to exchange available information and data regarding the hydrological, hydro-geological, water quality, meteorological, and environmental conditions of the River System. Any Party planning a project, program, or activity with regard to the River System which may have a significant adverse effect upon any one or more of the other parties, or which may adversely affect such River System, must notify the Council and provide all available data and information with regard to the planned project/programme or activity. (Warner Consultants Ltd, 2007)

Decision and disputes: The Council shall make every effort to take decisions on the basis of consensus. No decision of the Council shall be valid unless taken at a meeting attended by at least three of the member delegations. In the event of failure to reach agreement at such a meeting of the Council, the matter shall be made the subject of negotiations between the Parties. Any dispute between the Parties arising out of the interpretation or implementation of this Agreement shall be settled amicably through consultation and/or negotiation between them. In case of a dispute, decisions are transferred to the political level. If a dispute cannot be resolved, the case is referred to the SADC Tribunal whose decisions are final and binding. (Warner Consultants Ltd, 2007)

Agreements: Orange-Senqu basin is currently being managed from 6 treaties since 1986.

The Orange River Project (ORP) was one of the largest and most imaginative projects of its kind in South Africa. The ORP was built to utilize the unused water of the Orange River whichrepresents some 14.1% of the total runoff in South Africa. The main objectives of the project were:

- to stabilize river flow,

- the generation and transmission of hydro-electric power,
- to provide a reliable water supply for users in the Orange river basin, and
- to address water-deficient areas in the Eastern Cape such as the Great Fish and Sundays River valleys.

The Lesotho Highlands Water Project was conceived to supplement the water supply in the Vaal River System. Water is delivered to South Africa by means of the Delivery Tunnel which passes under the Lesotho-South Africa border at the Caledon River. It then passes under the Little Caledon River south of Clarens in the Free State and discharges into the Ash River about 30 km further to the north. The scheme became economically viable when water demands in Gauteng reached levels that could no longer be supported economically by alternative schemes such as the Tugela River-Vaal River pumped storage scheme, which utilized the Sterkfontein Dam, located near Harrismith in the Free State

Further reading: Source Book on Africa's River Basin organisations http://www.inbo-news.org/IMG/pdf/AWRB_Source_Book-2.pdf

1.5.3 The Zambezi and The Cahora-Bassa electricity scheme

The Zambezi River basin covers Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.

Zambezi Water Course Commission (ZAMCOM): The objective of the Commission is to promote the equitable and reasonable utilization of the water resources of the Zambezi watercourse, and their efficient management and sustainable development. The ZAMCOM advises the member states on the planning, management, utilization, development, protection, and conservation of the Zambezi. The Commission also advises on measures necessary to avoid disputes between the member states and assists in the resolution of conflicts. ZAMCOM collects, evaluates, and disseminates information and data relevant to the implementation of the agreements and fosters greater awareness for the efficient and sustainable management and development of the Zambezi among the population. Furthermore, ZAMCOM aims at promoting, supporting, coordinating and harmonizing the management and development of the water resources and the national water policies.

Organisational structure: The Zambezi Watercourse Commission consists of the Council of Ministers, the Technical Committee, and the Secretariat. The Council is composed of one delegate from each member state. A Chairperson and Vice-Chairperson are elected on the basis of rotation. The Technical Committee is made up of three representatives from each member state and is primarily responsible for implementing the Council's decisions and developing the River Basin Management Strategy. The Secretariat is headed by an Executive Secretary and is responsible for the technical and administrative support of the Council.

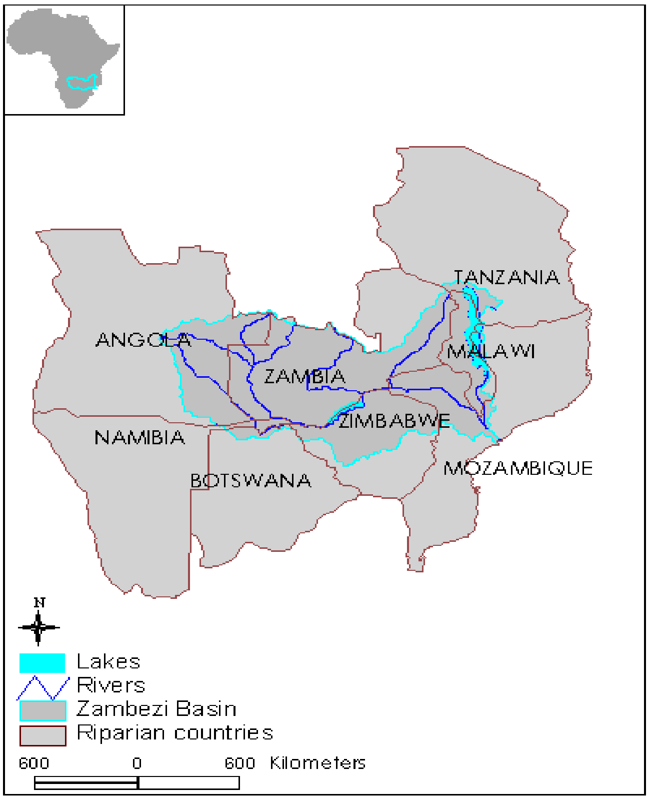

Figure 3 The Zambezi River Basin
(Source: Warner Consultants Ltd, 2007)

ZAMCOM is currently working on the development of an Integrated Water Resources Management Plan for the Zambezi River System, a project already initiated in the 1990s as part of the Action Plan for the Environmentally Sound Management of the Common Zambezi River System (ZACPLAN). ZAMCOM took over the responsibility from the bi-national (Zambia and Zimbabwe) Zambezi River Authority (ZARA).

Decisions and disputes: Decisions are taken unanimously, with two thirds of the member states forming a quorum. In case of a dispute the member states are required to enter into consultations and negotiations. The Council of Ministers may give recommendations. If a dispute cannot be settled, it can be referred to the SADC Tribunal.

Agreements: In May 1984, Mozambique, Portugal and South Africa signed the Cahora Bassa Project agreement.

This scheme was developed in the 1960's and was aimed at supplying electricity to Mozambique and South Africa. The principle reason why this project is important in this study is linked to historical conflicts in Southern Africa and the way in which the electricity supply to South Africa was targeted by forces against the apartheid regime in South Africa.

These case studies are the basis for discussion about the intricacies of international involvement in development of the SADC region.

- Further readings: Cahora Bassa (HVDC) for details of the power scheme based on the dam.

- Germano Vera Cruz, 2007 Mozambique assumes control of Cahora Bassa
- Rendel, Palmer, and Tritton Consulting and Designing Engineers: "Review of the hydrological network, and study of the design of a flood warning system for the Zambezi River". Supplementary report. London: Institute of Hydrology, 1980. Quoted in (Beilfuss & Dos Santos, 2001)
- News: Foreigners try to sabotage Moz dam," 2009 http://www.iol.co.za/index.php?set_id=1&click_id=68&art_id=nw20090505173831242C721082
- Hidroeléctrica de Cahora Bassa Website http://www.hcb.co.mz/eng
- Allen Isaacman and Chris Sneddon, 2003, "Portuguese Colonial Intervention, Regional Conflict and Post-Colonial Amnesia: Cahora Bassa Dam, Mozambique 1965–2002," *Conference on Lusophone Africa: Intersections between the Social Sciences*, Cornell Institute for African Development (May 2003). (Isaacman & Sneddon,

Task: South Africa currently utilizes electricity from the Cahora-Bassa system. From the power generation plant, millions of cubic meter of water runs unused to the sea. South Africa would benefit from the use of this water. How would you propose the South African Government would go about putting this in action in the context of their obligations within the relevant river basin commissions?

1.5.4 The Mozambique gas pipeline

The Mozambique natural gas project was undertaken by SASOL of South Africa and developed into a project that benefited South Africa and Mozambique. In the process the gas fields of Mozambique were developed, a central processing facility was developed in Tamane, and an 860km pipeline was constructed from the gas fields to Secunda in South Africa. The project generated economic growth in Mozambique and pioneered a platform for trade and development between the two countries.

This project is important in terms of actions that shaped compatibility in legislature and governance between the two countries. Projects like this one, which pioneer economic growth and stability, contribute to making countries more interdependent.

1.5.5 Fracking in South Africa

The fracking problem in SA is still very much politicized. The following websites have explicit opinions about fracking and fracking in the Karoo. Please review them in class, find more information, and formulate a collective opinion.

- South African Water Research Commission: http://www.wrc.org.za/News/Pages/HydraulicfracturingintheKarooshouldhaveastrongfocusonenvironmentalprotection.aspx
- Treasure Karoo Action Group: http://www.treasurethekaroo.co.za/fracking-facts

- The Economist: http://www.economist.com/blogs/schumpeter/2012/10/shale-gas-south-africa
- News 24: http://www.news24.com/SciTech/News/Shell-urges-reponsible-Karoo-fracking-20120907
- G Steyl, GJ Van Tonder, L Chevallier - Water Research Commision, Report KV, 2012, State of the Art: Fracking for Shale Gas exploration in South Africa and the Impact on Water Resources. http://www.wrc.org.za/Pages/DisplayItem.aspx?ItemID=9674&FromURL=%2FPages%2FKH_AdvancedSearch.aspx%3Fdt%3D1%26ms%3D20%253b

  Wakeford J., 2012 Socioeconomic implications of global oil depletion for South Africa: vulnerabilities, impacts and transition to sustainability. https://ir1.sun.ac.za/handle/10019.1/71729

Task: From the reading above, suppose that fracking done in SA results in the contamination of internationally shared water resources. What would such a legal procedure entail? Find similar cases in the world and reflect on the legal procedures followed there and whether there are parallels with the African context.

1.6 Questions for discussion

Make a list of issues that should be tabled when the collective use of water from the Limpopo would be discussed between South Africa, Botswana, Zimbabwe, Mozambique and Malawi.

Related to the previous question, can you find instances of communality between the water acts of the different regions, especially member states of Commissions?

Task: Find some of the most relevenat declarations of the AU concerning water and the environment, and transboundary issues, and reflect on the degree to which these AU statements/resolutions have been implemented or are reflected at local level policies and practices.

2.0 ROLE OF REGIONAL BODIES IN IMPLEMENTATION OF DECLARATIONS – PART I

The role of regional bodies like the African Union regarding the implementation of decisions is often limited and responsibilities of member states are difficult to enforce. Regional bodies that assist in the implementation processes are often non-governmental.

The term "declarations" in this section, mainly refers to trans-boundary matters with a specific emphasis on shared resources and human rights issues.

2.1 History and functioning of the African Union – role of Member States

Mandatory reading:

- The African Union: http://www.cfr.org/africa/african-union/p11616 (Hanson, 2009)

Exercise: Please study the reading document and provide a perspective, highlighting the following:

- What are the primary roles of the AU?
- Member countries of the AU?
- Does the AU submit to non-African countries or organisations?
- The role of NEPAD
- Does the AU have a legal body like the International court in The Hague, through which disputes could be settled and through which penalties could be enforced? In short, what is the legal position of the AU?

A historical perspective: In 2002, the Organisation of African Unity (OAU) transformed itself into the African Union (AU). The OAU, founded in 1963 on the principles of state sovereignty and non-interference, drew criticism throughout the 1990s for its lack of intervention as crises unfolded in Rwanda, the Democratic Republic of Congo, and Somalia. Frustration at its ineffectiveness led African leaders, spearheaded by Libyan leader Muammar el-Qaddafi, to launch the African Union, a body with a structure modelled on that of the European Union. Fifty-three countries in Africa are members of the AU. Morocco is the only African country that does not belong. The AU headquarters is in Addis Ababa, Ethiopia.

Some of the objectives of the AU relevant to this course include:

- The African Union seeks to increase development, combat poverty and corruption, and end Africa's many conflicts.
- The AU recognizes the right to intervene in a member state on humanitarian and human rights grounds.
- The Responsibility to Protect.
- Peacekeeping involvement in countries such as Burundi and Sudan[3]

[3] http://www.au.int/en/about/nutshell ("AU in a Nutshell," n.d.)

Vision of the African Union

The values to guide and govern the functioning and operations of the African Union Commission are:

- Respect for diversity and team work;
- Think Africa above all;
- Transparency and accountability;
- Integrity and impartiality;
- Efficiency and professionalism; and
- Information and knowledge sharing.

The Commission will be guided by the following principles:

- Subsidiarity and complementarity with other Organs, Member States and the Regional Economic Communities (RECs);
- Results orientation, feasibility and impact focus;
- Close coordination and cooperation with the RECs;
- Coherence of policies and programmes; and
- A networking approach that takes advantage of available resources through other players.

For further information on the African Union, please readi:

AU Vision and mission: http://www.au.int/en/about/vision ("Vision and Mission," n.d.)

AU strategic plan : http://www.au.int/en/sites/default/files/Strategic_Plan2009-2012.pdf

2.2 Role of Ministerial Councils – focus on AMCOW and AMCOST

African minister's council on water (AMCOW) vision is to promote cooperation, security, social and economic development, and poverty eradication among member states through the effective management of Africa's water resources and provision of water supply services in a bid to realize the 2025 Africa Water Vision. Furthermore its aim is to provide political leadership, policy direction and advocacy in the provision, use and management of water resources for sustainable social and economic development and maintenance of African ecosystems (The African Ministers' Council on Water (AMCOW), 2011).

The African Ministerial Council on Science and Technology (AMCOST) was established in November 2003 under the auspices of the New Partnership for Africa's Development (NEPAD) and the African Union (AU). It is a high-level platform for developing policies and setting priorities on science, technology and innovation for African development. AMCOST provides political and policy leadership for the implementation of Africa's Science and Technology Consolidated Plan of Action (CPA) (The African Ministerial Council on Science and Technology (AMCOST), n.d.).

These two come together in the resolutions of the inter-ministerial dialogue between AMCOW and AMCOST on establishing African network of centres of excellence in water sciences and technology (NEPAD SANWATCE).

These councils share a commitment to establish an African network of excellence in water sciences and technology development through the adoption of criteria and guidelines proposed in the NEPAD document on "Establishing an African Network of Centres of Excellence in Water Sciences and Technology Development: Criteria and Guidelines".[4]

2.3 NEPAD – evolution, role and relevance to water management

The 14th Ordinary Session of the Assembly of the African Union (AU) held in Addis Ababa, Ethiopia, in February 2010 adopted the Decision on the integration of the New Partnership for Africa's Development (NEPAD) into the structures and processes of the AU. This included the establishment of the NEPAD Planning and Coordinating Agency (NPCA) as a technical body of the AU to replace the NEPAD Secretariat. The Assembly mandated NPCA to facilitate and coordinate the implementation of continental and regional priority programmes and projects and to mobilise resources and partners in support of their implementation. It also directed the NPCA to conduct and coordinate research and knowledge management, monitor and evaluate the implementation of programmes and advocate on the AU and NEPAD vision, mission and core values.

Compulsory reading: NPCA Strategic Direction (2010)[5]

2.3.1 What is NEPAD?

The New Partnership for Africa's Development (NEPAD) was developed by the five initial states of the OAU (Algeria, Egypt, Nigeria, Senegal, and South Africa) and formally adopted in July 2001. NEPAD's primary objectives are poverty eradication, sustainable development, and integrating Africa into the global economy. It focuses on establishing partnerships with industrial countries for increased aid, foreign investment, debt relief, and market access. In 2002, NEPAD was placed under the purview of the AU; with a committee reporting annually to the AU Assembly. In March 2007, NEPAD leaders decided the partnership should be integrated into the structures and processes of the AU. This was achieved in 2010 (see above) (Hanson, 2009)

About NEPAD

The New Partnership for Africa's Development (NEPAD), an African Union strategic framework for pan-African socio-economic development, is both a vision and a policy framework for Africa in the twenty-first century. NEPAD in its inception was a radically new intervention, spearheaded by African leaders, to address critical challenges facing the continent: poverty, development and Africa's international marginalisation.

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[4] (http://www.nepadst.org/doclibrary/pdfs/spa_ncewst.pdf) (NEPAD, 2006)

[5] http://www.nepad.org/system/files/NPCA%20Strategic%20Direction%20(Final)%20rev7.pdf (NEPAD, 2010)

NEPAD provides unique opportunities for African countries to take full control of their development agenda, to work more closely together, and to cooperate more effectively with international partners. NEPAD manages a number of programmes and projects in six theme areas. These themes are:

- Agriculture and Food Security.
- Climate Change and National Resource Management.
- Regional Integration and Infrastructure.
- Human Development.
- Economic and Corporate Governance.
- Cross-cutting Issues, including Gender, Capacity Development and ICT.

Historical context: Origins and influences

By the 1970s and 1980s, many African countries were liberated from previous colonial rule, but these were also decades that were characterised by political instability, military coups, one-party governments, dictatorships and the heightened influence of Cold War politics in African affairs. Faced with the onset of an economic crisis – huge foreign debts and declines in social development – and the failure of the international financial institutions' free market policies, African countries tried to reverse these trends by calling for a new international economic order (NIEO) through which they could craft self-reliant, culturally relevant and state-influenced development strategies.

In such a context, African leaders found it necessary to transform the focus of the Organisation of African Unity (OAU) from political liberation to economic development. Hence, throughout the 1980s and 1990s African governments went on to design a series of pan-African development approaches which they felt were relevant to the needs of their people. These initiatives included: the Lagos Plan of Action (1980), the Final Act of Lagos (1980), Africa's Priority Programme for Economic Recovery (1986-1990), the African Alternative Framework to Structural Adjustment Programme (1989), the African (Arusha) Charter for Popular Participation and Development (1990), the Abuja Treaty (1991) and the Cairo Agenda (1994).

Faced with the failures of these plans, a new breed of African leaders entered the 21st century with proclamations of a re-birth for Africa.

It is in this regard that the New Partnership for Africa's Development (NEPAD) is the result of three parallel initiatives. The first is the Millennium Africa Recovery Plan (MAP), led by South African President Thabo Mbeki and unveiled at the World Economic Forum in Davos in January 2001. The second initiative is the Omega Plan, crafted by the President of Senegal, Abdoulaye Wade, and presented to the Summit of Francophone African leaders in Cameroon in January 2001. MAP and the Omega Plan were then combined to give birth to a third initiative the New African Initiative (NAI) which then led to NEPAD in 2001.

All three initiatives shared a common interest in increasing the pace and impact of Africa's development. While these initiatives share common characteristics, there were also differences reflecting the regional and other priorities of the enactors. Compromises had to be made in order to merge the three proposals into one initiative. NEPAD thus reflects the compromises involved in arriving at a single initiative.

Founding member countries of NEPAD included South Africa, Nigeria, Algeria, Egypt and Senegal.

NEPAD was adopted by African Heads of State and Government of the OAU in 2001 and was ratified by the African Union (AU) in 2002 to address Africa's development problems within a new paradigm. NEPAD's main objectives are to reduce poverty, put Africa on a sustainable development path, halt the marginalization of Africa, and empower women. (NEPAD, n.d.-b)

The mechanism for Africa's development – today and tomorrow

Since its initiation, NEPAD has been promoted widely both within Africa and in the industrialised North. NEPAD is now recognised as Africa's development plan by all the governments of the North, and the international financial institutions, and by many international governance institutions like the United Nations. NEPAD is widely seen as the mechanism through which support to Africa's development efforts can be best delivered. Thus, the NEPAD process has come to be accepted not only by African countries and Regional Economic Communities but also by Africa's development partners as the framework mechanism for their development efforts.

2.3.2 Background to the NEPAD Water Centres of Excellence

The NEPAD Water Centres of Excellence vision is to contribute to the improved human and environmental well-being through research and development in water and sanitation.

The first African Ministerial Council on Science and Technology (AMCOST), held in Johannesburg in 2003, decided on water science and technology (S&T) to constitute one of the main flagship programmes of New Partnership for African Development (NEPAD). Thus, in the framework of the NEPAD, the leaders have committed themselves to “ensure sustainable access to safe and adequate clean water supply and sanitation, especially for the poor”. They decided that S&T will play an important role in water development, supply and management and that S&T is crucial for assessing, monitoring and ensuring water quality. The flagship programme should strengthen the continent’s capabilities to harness and apply S&T to address challenges of securing adequate clean water as well as managing the continent’s resources to become a basis for national and regional cooperation and development.

On 22 November 2006, the African Ministers responsible for science, technology and water (The African Ministerial Council on Science and Technology - AMCOST and African Ministerial Conference on Water - AMCOW) met in Cairo, Egypt. By resolution, the delegates committed themselves to establishing an African Network of Excellence in Water Sciences and Technology Development.

2.3.3 The Southern Africa Network of Water Centres of Excellence (SANWATCE)

The Ministerial Mandate, as instituted in Cairo (2006), provides the NEPAD SANWATCE with the following executive mandate:

- Facilitate, and where applicable, conduct selective research on water issues;
- Serve as a Higher Education (PhD; postdoctoral; staff exchange) soundboard to the Southern African Development Community (SADC) region on regional water matters;
- Collaborate with other networks and institutions in specialised areas;
- Set the SADC water research agenda;
- Establish a continental water research agenda which is based on / derived from the SADC regional water agenda.

This can be achieved, amongst other means, through one-on-one engagement with AMCOW and AMCOST though the SADC Technical Advisory Committee, to observe political direction; engage in order to provide evidence-based research.

In 2009, the Southern African Network of Water Centres of Excellence (SANWATCE) was established with an initial eight institutions[6] from SADC countries which include South Africa, Botswana; Mozambique; Malawi and Zambia.

2.4 Questions for discussion

- What do the bodies of NEPAD and AMCOST have as mandate within SADC?
- Can you build an organogram indicating the position regional bodies have in the governance of SADC and identify where their influence is?
- Can you make a link between the African Union and your local municipality?

[6] The initial member institutions are: The University of Stellenbosch – hub and secretariat (South Africa); The International Center for Water Economics and Governance in Africa (IWEGA) (Mozambique; The University of KwaZulu-Natal (South Africa); University of the Western Cape (South Africa); The University of Malawi; The University of Zambia; University of Botswana and The Council for Scientific and Industrial Research (CSIR) (South Africa).

3.0 ROLE OF REGIONAL BODIES IN IMPLEMENTATION OF DECLARATIONS – PART II

The following framework helps breaking down the declaration-policy and regulation:

1 The content of the resolution/declaration

2 Aimed at what level:

a. Regional
b. Country
c. Provincial
d. Municipal
e. Personal

3 To be enforced by

a. AU enforcement measures
b. Ministerial level
c. By the juridical systems of member states

4 For the resolution/declaration to be a mere guiding principle to all levels.

5. The implementation of responsibilities.

Task: Please review the following text content of the Declarations and Statements provided below and categorize the content according to the 4-point framework provided above.

- The Sharm El-Sheikh Commitment for Accelerating the Achievement of Water and Sanitation Goals in Africa
- Declarations of the African Minister's Council on Water (AMCOW)
- 2012 RWSSI AWF Conference Declaration
- 2009 Johannesburg Ministerial Statement
- 2008 eThekwini AfricaSan Declaration

3.1 Sharm El-Sheikh Commitment for Accelerating the Achievement of W&S Goals in Africa

The Sharm El-Sheikh Commitment for Accelerating the Achievement of Water and Sanitation Goals in Africa indicated their commitment as follows:

(a) Increase our efforts to implement our past declarations related to water and sanitation.

(b) Raise the profile of sanitation by addressing the gaps in the context of the 2008 eThekwini Ministerial Declaration on sanitation in Africa adopted by AMCOW.

(c) Address issues pertaining to agricultural water use for food security as provided for in the Ministerial Declaration and outcomes of the first African Water Week.

(d) Develop and/or update national water management policies, regulatory frameworks, and programmes, and prepare national strategies and action plans for achieving the MDG targets for water and sanitation over the next seven (7) years;

(e) Create conducive environment to enhance the effective engagement of local authorities and the private sector;

(f) Ensure the equitable and sustainable use, as well as promote integrated management and development, of national and shared water resources in Africa;

(g) Build institutional and human resources capacity at all levels including the decentralized local government level for programme implementation, enhance information and knowledge management as well as strengthen monitoring and evaluation;

(h) Put in place adaptation measures to improve the resilience of our countries to the increasing threat of climate change and variability to our water resources and our capacity to meet the water and sanitation targets;

(i) Significantly increase domestic financial resources allocated for implementing national and regional water and sanitation development activities and Call upon Ministers of water and finance to develop appropriate investment plans;

(j) Develop local financial instruments and markets for investments in the water and sanitation sectors;

(k) Mobilize increased donor and other financing for the water and sanitation initiatives including national projects and Rural Water and Sanitation Initiatives, the African Water Facility; Water for African Cities programme and the NEPAD Infrastructure Project Preparation Facility, as committed in the G8 Initiatives on water and sanitation;

(l) Promote effective engagement of African civil society and public participation in water and sanitation activities and programmes;

(m) Promote programming that addresses the role and interests of youth and women, given that the burden of poor water and sanitation falls disproportionately on women and children;

(n) Strengthen AMCOW as a key regional mechanism, and other regional stakeholders, as relevant, for promoting cooperation on water and sanitation;

(o) Strengthen AMCOW's initiative on sustainable management of water resources, to implement its roadmap for the African Groundwater Commission;

(p) Strengthen partnership at all levels in our countries and between Regional Economic Communities as well as with the international development agencies and promote public-private partnerships with the view to fast tracking actions towards meeting the MDG on water and sanitation in our continent;

(q) Request AMCOW to annually report on progress made in the implementation of our commitment on water and sanitation with support from regional partners, and to submit these reports for our consideration;

(r) Call on African Ministers in charge of water and finance in collaboration with the African Development Bank and development partners, to hold a meeting of Ministers of Water and Finance to develop appropriate financing policies;

(s) Request the Regional Economic Communities and the Rivers and Lake Basin Organizations to initiate regional dialogues on climate change and its impacts on the water sector with the aim of designing appropriate adaptation measures;

(t) Call upon the G8 to reaffirm at its next Summit in Japan its commitment to fully implement the G8 initiatives on water in Africa, notably the 2003 Evian Plan on Water, to step up their engagement in the sanitation sector and to enter into a strengthened partnership with the AU Member States, through AMCOW, for achieving the Water and Sanitation MDGs.[7]

3.2 Declarations of the African Minister's Council on Water (AMCOW)

3.2.1 RWSSI AWF Conference Declaration 2012

The 2012 RWSSI AWF Conference Declaration was made and was indicated with the following statement.

We hereby:

1. Commit ourselves to mobilize the required resources and make all necessary efforts to achieve the Millennium Development Goal target for water supply and sanitation in Africa, by providing sustainable and improved access to water supply and sanitation to the rural population in particular women and children in Africa within the framework of the Rural Water Supply and Initiative;

2. Call on all African governments to exhibit leadership in ensuring water security and the provision of basic water supply and sanitation services by significantly increasing their budgetary and financial allocations to the sector and by contributing to the RWSSI and AWF Trust Funds;

3. Position achieving water security and access to water supply and sanitation at the centre of African development strategies and to achieve this, call on African governments to prepare plans and financing strategies, improve governance, and strengthen institutional capacities to achieve efficient and sustainable management of the sector;

4. Support the strengthening and scaling up of the African Water Facility by committing resources to enable it accelerate development planning and mobilise investments funds to

[7] Source:(ASSEMBLY OF THE AFRICAN UNION, 2008)

achieve the water security targets of the African Water Vision and Framework for Action for 2025.

5. Coordinate our activities at the regional, national and local levels in accordance with the Paris and Busan commitments and to this effect request the African Development Bank with government, AMCOW and key stakeholders to facilitate the establishment of national and regional coordination and monitoring mechanisms;

6. Consider that the provision of rural water supply and sanitation services and building the water security capacity are core elements of sustainable livelihoods and building adaptive capacity and resilience to climate change impacts, and further consider that the RWSSI and AWF are within the framework of climate change financing mechanisms;

7. Support the effort of the African Development Bank to create green development mechanisms to help African countries attain water security to better respond to climate change challenges and build green economies;

8. Call on all stakeholders to strengthen their communications and knowledge sharing platforms and for AMCOW to strengthen reporting to the AUC on Africa's water challenges and state of development;

9. Call on Governments to strengthen national information and knowledge sharing platforms and monitoring and reporting mechanisms under the leadership of AMCOW in collaboration with partners;

10. Support the implementation of the Programme for Infrastructure Development in Africa (PIDA) Priority Action Plan for trans-boundary water resources projects to foster regional cooperation to achieve water security in Africa;[8]

3.2.2 Johannesburg Ministerial Statement 2009

The Council agreed that in carrying forward the Johannesburg Statement, attention and action should be drawn towards:

- convening meetings of African Water and Finance Ministers, together with development partners;
- establishing a short-term African Water Finance Task Force to make the case for increased finance and to monitor impacts of the current financial crisis on investments in water in Africa;
- accelerating progress on implementing the 2008 eThekwini Declaration, notably through the development of national sanitation and hygiene policies;
- increasing commitment to the AWF to scale up its support for major infrastructure programmes and projects;

[8] Source: (*Partnership for strengthening water security in africa conference on the rural water supply and sanitation initiative & the african water facility*, 2012)

- promoting scaled-up support to country sector reviews, national MDG investment plans and national finance strategies;
- reviewing achievements and mobilizing resources for second and third phase implementation of RWSSI;
- developing a Roadmap to accelerate progress in drinking water and sanitation in Africa, in particular in fragile states where the coverage gaps are greatest, under the aegis of AMCOW;
- encouraging urgent disbursement of implementation funds to support small-scale water management in response to the Africa Food Price Crisis;
- launching and adopting the Pan-African Mechanism for Water Sector M&E framework as a monitoring tool in Africa for water and sanitation;
- planning for AWW-3;
- strengthening engagement with the G8 over implementation of the Evian Action Plan and Joint Statement of the G8-Africa Water Partnership;
- strengthening AMCOW's presence at sub-regional and national levels, including especially regular convening of sub-regional meetings of the AMCOW EXCO and institutionalizing partnerships with regional economic communities;
- adopting special measures to ensure the role and interests of youth and women are incorporated into all water and sanitation policies and programmes;
- assessing the threat of climate change to the variability of water resources and capacity to meet the 2015 MDG water and sanitation targets and put in place adaptation measures; and
- developing and/or strengthening and implementing among riparian countries the water management policies, laws and action plans for the equitable and sustainable use of shared water resources.

3.2.3 Ethekwini AfricaSan Declaration 2008

The Second African Conference on Sanitation and Hygiene (AfricaSan+5) was held in Durban, South Africa from February 18–21, 2008, with firm resolutions to place sanitation and hygiene at the top of the development agenda in Africa.

AfricaSan+5 follows on after the First AfricaSan Conference held in 2002 that helped to formulate a Millennium Development Goal (MDG) specifically for sanitation: to reduce, by half, the number of people without access to basic sanitation and hygiene by 2015. The Second AfricaSan Conference was the climax of a continent-wide process to assess progress, challenges, and lessons towards achieving the sanitation Millennium Development Goal (MDG).

During the three-day event, the delegates agreed on an Action Plan that articulates the critical actions to be further developed, funded and monitored by 2010 in order to put Africa 'back on track' to meet the sanitation MDGs. The African Ministers' Council on Water (AMCOW) was mandated to monitor progress against the national plans and report on progress during the next AfricaSan meeting in 2010. The AfricaSan+5 Conference also marked the formal launch of the International Year of Sanitation in Africa.

At the conclusion, the Ministers signed the eThekwini Declaration in which, among other undertakings, they pledged to create separate budget lines for sanitation and hygiene in their countries and to commit at least 0.5 per cent of GDP.

The AfricanSan Conference was organized under the auspices of AMCOW, and its partners: the African Development Bank (AfDB), the United Nation's Children Fund (UNICEF), United Nations Secretary Generals Advisory Board on Water (UNSGAB), the Water and Sanitation Program, Africa (WSP-Africa), the Water Supply and Sanitation Collaborative Council (WSSCC) and World Health Organization (WHO); and hosts: South Africa's Department of Water Affairs and Forestry (DWAF) and eThekwini Municipality (City of Durban).[9]

3.3 Questions for discussion

– Make a list of key words of the common themes that are contained within the different declarations.

The declarations and activities above bring up many different issues, including that of the principle of public participation. However these declarations do not provide concrete links to local legislation at the member state level.

- Please comment and form an opinion about this 'missing link'. Use participation as a themetic example for reference.

[9] Source: (*The eThekwini Declaration and AfricaSan Action Plan*, 2008)

4.0 REGIONAL DECLARATIONS AND THEIR IMPLEMENTATION

In this section we focus on the implementation of regulations and declarations to provide specific content to be used related to the case-studies provided earlier in this course and the NEPAD initiative.

4.1 SADC Protocol on Shared Watercourses

It was in recognition of the importance of a coordinated approach to utilisation and preservation of water that the SADC member States signed the Protocol on Shared Watercourse Systems at the 1995 Summit in South Africa. This protocol was revised in 2003 and its overall objective is "to foster closer cooperation for judicious, sustainable and coordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration and poverty reduction", contains principles and provisions for water resources management in the region.

General Principles of the Protocol:

The protocol consists of 13 main principles which address the issues of shared watercourses. As well as identifying underlying principles of equity sharing and general, customary and international law relating to management of share water resources, it also addresses functioning issues such as protocols for the collection and sharing of data. This also includes regulatory practices such as the requirement of permits for abstraction and obligations for dealing with hazard events such as pollution or natural disasters such as floods.[10]

4.2 SADC Regional Water Policy (2005)

Policy

The Regional Water Policy for the Southern African Development Community (SADC) is aimed at providing a framework for sustainable, integrated and coordinated development, utilisation, protection and control of national and trans-boundary water resources in the SADC region. This policy is intended to support the SADC Common Agenda of socio-economic development and regional integration and improvement of the quality of life of all people in the region.

The policy was formulated through a highly participatory and consultative process, implemented over a period of 12 months, involving diverse stakeholders including senior government officials from ministries dealing with economics, law, water resources, agriculture, energy, and environment. Other stakeholders included academic and research institutions, private companies, consultants in various disciplines, as well as representatives of local and regional NGOs, and community leaders.

[10] Protocol on Shared Watercourse Systems, 1995 is available at: http://www.africanwater.org/SADCprotocol

This policy includes nine (9) thematic areas, addressing key water resources management issues and challenges:

- Regional Cooperation in Water Resources Management: including policy provisions on water for regional integration and socio-economic development; cooperation in water resources management of shared watercourses; inter-sectoral and international cooperation; and the harmonisation of national policies and legislation.
- Water for Development and Poverty Reduction: containing policy provisions on water for basic human needs and for industrial development; water for food and energy security.
- Water for Environmental Sustainability: containing policy provisions on water and the environment, water quality management, and control of alien invasive species in watercourses.
- Security from Water-related Disasters: including policy provisions covering population protection from water related disasters; disaster prediction, and management and mitigation.
- Water Resources Information and Management: covering data and information acquisition and management; and information sharing.
- Water Resources Development and Management: including policy provisions on a river basin approach; integrated planning; dams and dam management; water demand management; and alternative sources of water
- Regional Water Resources Institutional Framework: including policy provisions covering institutional arrangements at regional and national levels and for Shared Watercourse Institutions (SWCIs).
- Stakeholder Participation and Capacity Building: including provisions focusing on participation and awareness creation; capacity building and training; gender mainstreaming; and research, technology development and transfer.
- Financing integrated water resources management in the region.

Strategy

Currently the Regional Strategic Action Plan for IWR Development and Management is tackling the issues of weak legal and regulatory frameworks, inadequate capacities, poor information acquisition, management and dissemination systems, and low levels of awareness and education. A weak policy framework, lack of effective public participation, and infrastructure that is inadequate and unable to meet the growing demands for service is also to be addressed. The Departments of Water Affairs from member countries will be required to report to SADC on its progress in these areas.

The implementation of the Regional Water Policy will be through the Regional Water Strategy. Existing River Basin Organisations (KOBWA, LIMCOM, ORASECOM, etc.), Catchment Management Agencies (CMAs), Proto-CMAs and or DWA Regional offices will be important means for implementing the policy and strategy, especially on shared watercourses[11].

4.3 SADC Regional Strategic Action Plan III (2011) on Integrated Water Resources Development and Management

Regional Strategic Action Plan III 2011- 2015 (2011)

The Regional Strategic Action Plan on Integrated Water Resources and Development Management III (RSAP-IWRM) is the third five-year action plan of the initial fifteen year plan that was formulated and approved by the SADC summit in August 1998.

The main focus of the plan is primarily to create an enabling environment for joint management of the regional water resources. The RSAP III serves as a work plan to guide development and implementation of activities in the SADC water sector for five years from 2011 to 2015. It covers the strategic areas of water governance, infrastructure development and water management, and calls for the achievement of three strategic objectives to improve the impact of the plan on the ground:

- Capacity development;
- Climate change adaptation; and
- Social development.

The plan incorporates regional policy documents, specific programmes and interventions, institutional arrangements, the financial framework and a monitoring and evaluation plan.[12]

4.4 NEPAD Water Program (Short Term Action Plan, African Water Vision Framework)

What is the water programme?

NEPAD's water programme was developed to address the many challenges on the continent in managing water resources. Among these are the threats posed by drought, floods and climate change.

What is the aim of the programme?

The programme has a Short Term Action Plan (STAP) which is part of the African Water Vision framework which maps strategies through to 2025. The main emphasis of this programme is:

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[11] Full Regional Water Policy is available at: http://nepadwatercoe.org/wp-content/uploads/Regional_Water_Policy.pdf
Source: (SADC, 2005)

[12] Source: http://nepadwatercoe.org/wp-content/uploads/SADC_RSAP-III-Final.pdf
Source: (SADC, 2011)

- The development of national integrated water resources management policies and strategies;
- Addressing climate change including the effects of droughts and floods;
- Meeting the basic water needs of the continent's population;
- Enhancing irrigation and rain-fed agriculture to improve production and food security; and
- Management of trans-boundary water resources to become a basis for national and regional cooperation and development.[13]

[13] Short Term Action Plan is available at: http://nepadwatercoe.org/wp-content/uploads/Project-Implementation-Review-of-the-NEPAD-STAP.pdf

5.0 INTERNATIONAL AND AU INFLUENCE ON NATIONAL POLICIES

This section is aimed to be an open session, discussing the gap between the policies suggested at AU level and their relevance at member state level. It is also aimed at how the policies at member state level may change to align with the AU policy guidelines. There are also various international instruments and international funding aimed at bridging this gap or to bring about the change in Africa to be adaptable to the international tendencies and these instruments are of importance in this section. These instruments include:

- Partnerships (e.g. Cotonou).
- The international support
- The bodies within Africa that facilitates policy.
- The incentives for implementation.

In this section (similar to section 1) the focus is a primary interest in the link between a decision base at AU level and the impact and acceptance through to implementation at member state level. It therefore explores whether such decisions at AU and regional level are adequately reflected in policies on a national level, are indeed implemented and are ultimately reflected in national legislation. The link is assessed from a global perspective, down to AU and then member state perspective.

The **global** perspective: Africa needs to conform to the global trends in the alignment of policies that finds their roots in the general human rights.

The **AU** perspective: the AU has no legal right or mandate to force member states to conform to the general agreements of the AU in terms of compliance to their prescribed policies. However the general trend is that countries that honours their human rights, and has laws imbedded in the general human rights, and refrain from conflict, are more inclined to adhere to the AU prescriptions in terms of common law in Africa.

The **local** perspective: when one compares local governments or municipalities, the more affluent societies tend to accommodate AU decisions better than poorer communities. The same may apply regarding struggling nations in Africa and those that are wealthier.

For South Africa, quite a number of “decisions, declarations and resolutions” were implemented in various ways, of which the most recently important is the focus on climate change and how this will affect the water resources of Africa. South Africa has, through its Department of Science and Technology, instrumented mechanisms for research.

5.1 Functioning and relationship between National Policy and Regional Strategies

Relationships between national policies and regional strategies are difficult to define and very few SADC initiatives on water resource management exist. Where initiatives are underway, they are mostly funded by the European Union (such as the FP7 programme), the World Bank and the United Nations

The AU is instrumental in the formation of partnerships.[14]. The philosophy underpinning Africa’s new partnerships is predicated on specific objectives with pre-determined “Win-Win” outcomes for the mutual benefits of the parties involved. It is based on the principle of trust, equality and mutual respect. It aims at obliterating the age-long pattern of donor-recipient relationship, to one founded on reciprocal obligations and responsibilities. These partnerships are consistent with the clearly defined vision and development strategy of the African Union (AU), with particular emphasis on speeding up industrialization, development of infrastructure, development and acquisition of technology and know-how and development of human capital, all of which are outlined in the Commission’s Strategic Plan and the AU’s NEPAD programme.

These partnerships apply subtle pressure on African institutions and countries to conform to standards, demands and needs of the partners.

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[14] summarized in full in http://www.au.int/en/sites/default/files/Partnerships.pdf (African Union, 2012)

6.0 SANITATION POLICY AT MEMBER STATE LEVEL IN SA

6.1 Introduction

Sanitation is one important aspect imbedded in water policy that is based on the basic human rights of people as mentioned in the Millennium Development Goals. The development of the sanitation principles in South African legislation is also important and therefore the history of the access to basic sanitation will be described in this chapter.

6.1.1 Sanitation in the Millennium Development Goals

The Millennium Development Goals (MDGs) are mainly targeted towards poverty alleviation, health and education, but they do include goals for environmental sustainability. The Millennium goals are targeted at Country's National Governments specifically and filtered through legislation and country specific policy. Goal 7 refers to access to safe drinking water and basic sanitation.

6.1.2 Sanitation in the Southern African Vision

The Southern African Vision for water, life and environment was adopted in March 2000, and aims for "equitable and sustainable utilization of water for social and environmental justice, regional integration and economic benefit for present and future generations". The essence of this vision is carried through the SADC protocol, policy and strategy, as well as in the country specific legislation.

When developing strategies for the management and enforcement of water resources within the Republic of South Africa, the overarching principles and requirements of these international and regional frameworks are ideally to be considered.

6.1.3 Historical Background to South African Situation

Sanitation policy development and implementation in South Africa can be divided into three distinct periods. Firstly, the pre-1994 period before the establishment of a democratically elected government; secondly, the period between 1994 to 2001 during which the new Constitution was implemented and a policy for provision of sanitation services was developed and a delivery programme initiated; and last the period from 2001 onward during which the sanitation policy has been refined and the programme of service delivery accelerated toward meeting the MDG target on sanitation.

Period: Pre – 1994

During this time, the Republic of South Africa was divided into eleven different "homeland" administrative and political areas, the four independent TBVC[15] states, six

[15] Four of the South African Bantustans—Transkei, Bophuthatswana, Venda, and Ciskei (the so-called "TBVC States")—were declared independent, though this was not officially recognised outside of South Africa. Other South African Bantustans (like KwaZulu, Lebowa, and QwaQwa) received partial autonomy but were never granted independence.

self-governing territories and the dominant Republic of South Africa territory, governed by the tri-cameral parliament. In addition, within the ten ‘homelands’ were a number of rural areas that were managed by tribal authorities. This situation resulted in a fragmented approach to service provision with no cohesive strategy, guidelines or support structures to guide the provision of sanitation. Limited or no services were available in the former “black” urban areas and rural areas, and farm labourers and farm schools often had no sanitation services. Where services were provided these were often in a bad state of repair. Despite the lack of capacity in the tribal authorities, assistance for provision of sanitation services was not requested to the authorities. Conversely, the Department of Public Works did not take responsibility for providing these services to avoid interference in the tribal areas. Responsibility for service provision in the rural areas was with the Department of Development, although service provision was characterised by a lack of consultation and buy-in from the stakeholders.

The previous proliferation of institutional structures contributed to the problems faced in providing sanitation services due to: the absence of an institutional framework which established clear responsibilities; the overlapping of institutional boundaries, as well as the exclusion of many areas of great need; a lack of political legitimacy and will; all resulting in a failure to make resources available where they were most needed.

Sanitation service provision was primarily focused on toilet building, sewer systems maintenance, with little consideration given to community needs or health and hygiene education. As a result, those who had inadequate sanitation were forced to continue using the bucket system, rudimentary pit toilets or open defecation. This was compounded by poorly designed or operated sewerage systems.

Groundwater pollution associated with on-site sanitation systems were a major cause of concern at this time resulting in unacceptably high levels of nitrate in the groundwater.

In the early 1990s, it was estimated that about 21 million people did not have access to a basic level of sanitation, which is defined as a ventilated improved pit-latrine or equivalent (DWAF, 2001b).

Period: 1994 to 2001

Addressing the water supply and sanitation backlog was one of the first priorities of the newly elected democratic government in 1994. On 1 July 1994, the new Department of Water Affairs and Forestry was established that consolidated government staff from all parts of the previous structures into one new organisation. In the absence of a coherent policy for water supply and sanitation, the White Paper on Water Supply and Sanitation Policy (DWAF, 1994) was compiled that set out the policy for the new Department with specific regard to these services. The finalisation of the White Paper was identified as a key priority, as well as the development of an integrated implementation strategy for clearing the backlog in support of local government for sanitation provision.

In the execution of this intent, the government embarked on a major investment programme in 1994, aimed at the provision of basic services, primarily in poor rural areas. The Department consulted with a range of stakeholders, which formed the basis for the development of the Community Water Supply and Sanitation (CWSS) Programme. The primary objective of the CWSS programme was to extend the access to basic water supply and sanitation services to all people resident in South Africa.

The Constitution of the Republic of South Africa (Act 108 of 1996) was published in 1996 and assigned the local government the responsibility of providing water and sanitation services access to all. A range of municipal legislation has been developed and implemented since 1994 to transform the local government, including the Local Government Municipal Demarcation Act 27 of 1998, the Municipal Structures Act 117 of 1998, the Municipal Structures Amendment Act 33 of 2000, and the Municipal Systems Act 32 of 2000.

However, in the absence of fully developed local government structures, the Department of Water Affairs and Forestry (DWAF) was mandated to ensure that all South Africans have equitable access to water and sanitation services where local government was unable to carry out this mandate. Targets were set to eliminate the backlog over a ten year period; to provide each individual with at 25 litres of water per day within 200 metres of their home; and, to provide each household with basic sanitation in the form of at least a Ventilated Improved Pit (VIP) latrine.

A National Sanitation Task Team (NSTT) comprising representatives of the national departments with responsibilities for providing sanitation service (i.e. Health, Education, Environmental Affairs and Tourism, Housing, Water Affairs and Forestry, Provincial and Local Government, and Public Works,) and the Mvula Trust was established in 1995 to facilitate an integrated inter-departmental approach. The NSTT's specific objective was to provide a coherent framework for addressing the sanitation backlog. A process of consultation was undertaken with the three levels of government, NGOs, CBOs and other stakeholders, which resulted in the compilation of the Draft White Paper on Sanitation (DWAF, 1996). This policy document formed the basis for the development of the National Sanitation Programme in 1996, which was revised in 1998 (DWAF, 1996 and 1998).

The NSTT launched a new initiative in 2000 to update the 1996 Draft White Paper on Sanitation in the light of legislative developments at both the national and local level that impact on local government service delivery, and to incorporate the experience gained in the implementation of the sanitation programme. Stakeholder inputs were incorporated into the revised draft. Parliament subsequently endorsed the White Paper on Basic Household Sanitation during September 2001 (DWAF, 2001).

Period: 2001 to the Present

The demand for the expansion of municipal infrastructure continued to exceed supply, leading to rising backlogs in some services and limited progress in the elimination of backlogs. Local governments have been extensively restructured to meet these challenges and fulfil its developmental mandate.

At the beginning of 2001 the national backlog of persons without access to adequate sanitation facilities was estimated to be 18 million or 3 million households. The majority of persons falling in this category lived in rural areas, peri-urban areas and informal settlement areas. It is also estimated that up 26% of urban households and 76% of rural households had inadequate sanitation. This backlog was further reduced during the next year by 2.4 million persons.

DWAF, supported and assisted by sanitation role players, has developed and launched a National Sanitation Programme that quickly showed positive results. The Programme focused on the eradication of the sanitation backlog in the rural, peri-urban and informal settlement areas by the year 2010. In addition, eradication of the bucket system (currently estimated at about 428 000 households) was to be achieved by 2007.

These targets were to be met through the provision of two primary deliverables, namely promotion of sanitation, health and hygiene awareness and the provision of a basic toilet facility - and to create an appropriate enabling environment for a community-based approach through training and capacity building elements. Community participation was identified as a key requirement for the success of the implementation programme.

A policy review process initiated in 2002 to address the changes needed to reflect the new local government and municipal financial arrangements. A draft discussion document was compiled to stimulate discussion and debate around key issues and policy options to support the process. The process developed through bilateral meetings with key stakeholders and regional consultation workshops and resulted in the publication of the draft White Paper on Water Services.

Finally The National Sanitation Strategy was published in 2005 in order to take into consideration the latest developments on sanitation in order to provide a coherent approach to sanitation services delivery in South Africa. Successively the Free Basic Sanitation Implementation Strategy was developed to guide Water Service Authorities in providing all citizens with free basic sanitation by 2014.

6.2 Water Service Act (1997)

The Water Services Act 108 of 1997 (Water Services Act) is the primary law relating to the accessibility and provision of water services to households and other municipal water users by local government in South Africa. The Act addresses bulk sanitation, reticulated sanitation and on-site sanitation. More information about this act is developed in chapter 7 section 7.7.[16]

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[16] Water Services Act Interpretative Guide for Sanitation: http://nepadwatercoe.org/wp-content/uploads/WSA_Sanitation_Interpretative.pdf

6.3 The white paper on basic household sanitation (2001)

The White Paper on Water Supply and Sanitation Policy published in November 1994 highlighted the importance of establishing a national sanitation policy. In response to the White Paper, a draft National Sanitation White Paper was published in 1996. Even though the draft White Paper was never formally approved it was the first time that a national sanitation policy had been prepared which addressed the needs of all South Africans. This National Sanitation Policy improves on the initial attempts in 1996 to produce a White Paper and incorporates the knowledge gained in actual implementation of the sanitation improvement programmes since then.

Purpose

Government has a constitutional responsibility to ensure that all South Africans have access to adequate sanitation. The publication of this national White Paper on Basic Household Sanitation policy is an important step in the process of meeting this responsibility and in addressing the problems of inadequate sanitation.

The purpose of this policy document is to:

- highlight the impact of poor sanitation on health, living conditions and the environment;
- articulate government policies on sanitation;
- provide a basis for the formulation of local, provincial and national sanitation improvement strategies aimed at addressing the backlog;
- provide a framework for municipality driven implementation programmes;
- promote greater coherence and co-ordination amongst the different spheres of government and amongst other role players in addressing the sanitation problem;
- ensure that sanitation improvement programmes are adequately funded; and
- put in place mechanisms to monitor the implementation of this policy and sanitation improvement programmes so that corrective action can be taken when necessary.

This policy focuses specifically on the provision of a basic level of household sanitation to mainly rural communities and informal settlements. These are the areas with the greatest need. This policy also deals with the need for an environmentally sound approach to providing sanitation services and addresses the need to protect surface and ground water resources from sanitation pollution through integrated environmental management practices. (DWAF, 2001)[17]

[17] Full document: http://www.dwaf.gov.za/Documents/Policies/SanitationReviewPolicy.pdf

6.4 Draft white paper on water services (2002)[18]

It was considered important that the key goals of the water services sector as a whole be clear. The Water Services White Paper therefore needed to answer questions such as: Why should national government be concerned and active in the area of water and sanitation services? What vision does government have for the water services sector? And, what outcomes does government wish to encourage and facilitate?

This led to the development of the White paper on water services, called **Water is Life, and Sanitation is Dignity**. This Strategic Framework provides a comprehensive review of policies, legislation and strategies with respect to the provision of water services in South Africa, seeking to align them and outline the changes in approach needed to achieve policy goals.

6.5 National Sanitation Strategy (2005)

The National Sanitation Strategy was published in 2005 in order to take into consideration the latest developments on sanitation in order to provide a coherent approach to sanitation services delivery in South Africa. The National Sanitation Strategy had the objective to facilitate the elimination of the sanitation backlog by 2010, and discuss the roles and responsibilities in sanitation delivery, planning for sanitation, funding sanitation, implementation approaches, regulating the sanitation sector, and monitoring and evaluation (SERI, 2011)[19].

6.6 Free Basic Sanitation Service (2009)

The right of access to a basic level of sanitation service is enshrined in the Constitution of South Africa (Act 108 of 1996). Municipalities have an obligation to ensure that poor households are not denied access to basic services due to their inability to pay. However, Municipalities are faced with a challenge of balancing financial resource allocation to the eradication of basic sanitation infrastructure backlog by 2010 and provision of free basic sanitation services to the poor. This target has not been met therefore a revised target has been set for 2014 whereby all people in SA must have access to a functioning basic sanitation facility. The aim of the Free Basic Sanitation Implementation Strategy is to guide Water Service Authorities in providing all citizens with free basic sanitation by 2014.

The strategy is informed by the vision of sanitation for all. For the purposes of the strategy a basic sanitation service is defined as the provision of a basic sanitation facility which is easily accessible to a household, the sustainable operation of the facility, including the safe removal of human waste and wastewater from the premises where this is appropriate and necessary, and the communication of good sanitation, hygiene and related practices. Although there is a broader policy commitment by government to extend the free basic services to all households the policy is largely aimed at poor

[18] http://www.info.gov.za/view/DownloadFileAction?id=68778.
[19] http://www.dwaf.gov.za/dir_ws/wspd/UserControls/DownloadImportFiles.aspx?FileID=64

households for whom free basic services represent a significant poverty alleviation measure.

The strategy adopts the principles that national guidelines should be implemented with local choice. This is aimed at encouraging municipalities to be flexible in the implementation of the strategy locally, to ensure its long-term success. It is also acknowledged that community participation is a key foundation for the sustainable choice of sanitation facilities. The strategy also includes comparative costing of the various sanitation facility options. The technology choice must ensure consumer demand, which implies acceptance of the service level and willingness to pay the tariff, associated with that service level; viability from the point of view of the water services authority and provider, understanding of the environmental impacts of the sanitation choice and the technical feasibility of the facility (DWAF, 2009).[20]

[20] http://www.dwaf.gov.za/dir_ws/wspd/policyinfo.aspx?filen=556

6.7 Policy instruments

6.7.1 Key roles of national, provincial and local government for sanitation provision within the Constitution

In the Constitution of South Africa, local government are tasked with the responsibility for provision of sustainable services to communities, with the support of provincial and national government.

6.7.2 Key legislation with respect to sanitation

The Water Services Act (Act 108 of 1997)

To assist municipalities to undertake their role as water services authorities and to look after the interests of the consumer. It also clarifies the role of other water services institutions; especially water services providers and water boards.

The National Water Act (Act 36 of 1998)

Legislates the way in which the water resource is protected, used, developed, conserved, managed and controlled. It also governs how a municipality may return effluent and other wastewater back to the water resource.

The Municipal Structures Act (Act 33 of 2000)

Provides for the establishment of municipalities in accordance with the requirements relating to categories and types of municipality and to provide for an appropriate division of functions and powers between categories of municipality. The Act allocates the responsibility for water services to the District Municipality or the local municipality if authorised by the Minister of provincial and Local Government.

The Municipal Systems Act (Act 32 of 2000)

Focuses on the internal systems and administration of a municipality. The Act introduces the differentiation between the function of an authority and that of a provider. It also identifies the importance of alternative mechanisms for providing municipal services and sets out certain requirements for entering into partnerships.

The Municipal Demarcation Act (Act 27 of 1998)

Provides criteria and procedures for the determination of municipal boundaries by an independent authority. In terms of the Act, the Municipal Demarcation Board is established to determine municipal boundaries. Section 24 provides that when demarcating a municipal boundary, the Board must aim to establish an area that would enable the municipality to fulfil its Constitutional obligations, including the provision of services in an equitable and sustainable manner, the promotion of social and economic development and the promotion of a safe and healthy environment. The tax base must also be as inclusive as possible of users of municipal services in the municipality. This is important in that rural and urban areas are consolidated, which ensures a more effective use of resources.

The Division of Revenue Act,

Which is enacted annually, gives effect to Section 214(1) of the Constitution that provides for the equitable division of nationally raised revenue among the three spheres of government. The Act for 2002 makes provision for the CWSS as an “Indirect Conditional Grant “ to fund basic level of water services and the implementation of infrastructure projects where municipalities lack the capacity to do so.

The White Paper on Basic Household Sanitation (DWAF, 2001)

Emphasises the provision of a basic level of household sanitation to those areas with the greatest need. It focuses on the safe disposal of human waste in conjunction with appropriate health and hygiene practices. The key to this White Paper is that provision of sanitation services should be demand driven and community-based with a focus on community participation and household choice.

6.8 Funding Mechanisms

Sources of funding for sanitation improvement that are available to local government include the Municipal Infrastructure Grant (MIG) and Equitable Share funding transfers from national to local government, and the revenue collected by the local authority.

6.8.1 Municipal Infrastructure Grants

These are conditional grants for capital investment provided by national government. It is intended to provide capital finance for basic municipal infrastructure for poor households (those with household incomes of below R1 100 per month[21]) and to a limited extent micro enterprises and deserving institutions. Municipalities in the urban renewal and rural development programmes are favoured for support. The Municipal Infrastructure Grant will have an overall target of removing the backlog with regard to access to basic municipal services over a ten year period. The grant will be phased in over a three-year period, through the merger of Consolidated Municipal Infrastructure Programme, the Local Economic Development Fund, the Water Service Capital Grant, the Community Based Public Works Programme and the Building for Sports and Recreation Programme. Individual national line departments will continue to lead the monitoring and support of the implementation in their specific functions and priorities.

6.8.2 The Equitable Share

The Equitable Share is provided by national government to the local government for subsidising operating costs. It was introduced to assist the local government to overcome the burden of service delivery to the very poor.

Where the cost of service delivery exceeds the amount that is billed to very poor households, the subsidy will be used to contribute towards the general operating account of the local authority. This subsidy is an inter-governmental transfer of funds from

[21] 1 Euro = 14.8 South African Rand (2014)

national to local government. However, the Constitution indicates that inter-governmental transfers like the Equitable Share cannot be conditional, which means that local authorities have used the subsidy for other purposes.

6.8.3 Local Authority Revenue

The Local Authorities' own revenue may be used to cross subsidise between "rich" and "poor" households. A broad assessment of municipal income in rural areas, (the areas with the greatest sanitation need), indicates that currently direct cost recovery is only applied to electricity. Any shortfall in the funding for other services is either carried by the service provider or financed with inter-governmental transfers. The total cost of service provision in rural areas with the exception of electricity, is therefore currently subsidised. Cost recovery in many areas remains a matter that requires urgent attention.

The local authority has discretion in deciding on the composition of the service delivery packages, the levels of service and the manner in which these are funded. The Integrated Development Plan is the mechanism for deciding on priorities and for steering and co-ordinating service delivery to avoid duplication of subsidies and the construction of houses without services.

6.8.4 Subsidies

Despite the view of the World Bank that service provision should not be subsidised, the South African government believe that this approach is not justified. Due to the large disparity of rich and poor in South Africa, the average per capita income in South Africa is estimated to be R3 700 per annum, which exceeds the R3 000 per annum that is defined to be the poverty line. South Africa therefore has the resources to subsidise service provision, specifically to the indigent.

Once-off capital subsidies are currently provided for: housing (R15 000 to R17 000 per household); water (R600 to R1 000 per capita), sanitation (R1 200 per household) and rural electrification.

6.9 Information and Education Programmes

A Water, Sanitation and Hygiene (WASH) awareness campaign was launched in collaboration with the United Nations Water Supply and Sanitation Collaborative Council in 2008. The aim of the campaign is to increase hygiene awareness and to promote hygienic sanitation practices. ("Water, Sanitation and Hygiene," 2008)

The Department of Education is also assessing the mechanism of including health and hygiene education on the curriculum in order to maximise education impact on hygienic sanitation practices ("WATER AND SANITATION SERVICE STANDARD, City of Cape Town," 2008).

6.10 Inter Sectoral Approach - Roles and Responsibilities for Providing Services

One of the main obstacles to the effective delivery of acceptable sanitation in the past has been the lack of clarity on the roles and responsibilities of the various role players. The roles and responsibilities of the three levels of government have subsequently been clarified in the White Paper on Basic Household Sanitation.

The *local government* is in the first instance accountable for the provision of sanitation services and, through its Environmental Health Practitioners, to promote health and hygiene awareness and to monitor the health of its communities. The local government must also take responsibility for driving the process set in the White Paper on Basic Household Sanitation at the local level, for creating an enabling environment through its municipal by-laws and for taking responsible decisions on levels of service to ensure that they are both appropriate and affordable. Local government is required to develop an Integrated Development Plan, which is aimed at the integrated development and management of its area of jurisdiction. One component of this plan is a Water Services Development Plan that reviews current service levels and backlogs and sets clear objectives with quantifiable performance indicators. Using these objectives, a domestic sanitation business plan is developed that includes a detailed strategy development process. Councillors and local government officials are encouraged to participate in the development of this coherent strategy and to agree on the priorities and approaches.

Provincial government is responsible for supporting local government in achieving their objectives and ensuring that they perform effectively. Support can be provided in a number of areas, including financial, human resources and technical. In addition, certain provincial departments, such as provincial departments of the environment, local government, education, health and housing are the implementation arm of their national counterparts.

At a *national government* level, there are a number of role players are responsible for sanitation. In accordance with a Cabinet decision, DWAF is responsible for co-ordinating the involvement of national government in the sanitation sector. Other key role players at the national level include the Department of Provincial and Local Government, the Department of Health, the Department of Education, the Department of Housing, the Department of Public Works, The Department of Environmental Affairs and Tourism and the National Treasury.

The Department of Provincial and Local Government is the custodian of the Municipal Systems Act and the Municipal Structures Act. Matters relating to provincial and local government systems fall within this department’s ambit. This includes promoting the development by the municipalities of their Integrated Development Plans, ensuring that provincial and local government have the capacity to fulfil their functions, co-ordination of the provincial and local governments' equitable share and municipal infrastructure grants, and the provision of financial support to sanitation programmes.

The focus of *the Department of Health* is to provide all South Africans with access to affordable, good quality health care. In co-operation with the provinces, the Department of Health has the primary responsibility to creating demand for sanitation services through health and hygiene awareness and education programmes, developing standards and norms relating to health aspects of sanitation and water supply, co-ordinating interventions when a crises poses a regional or national health risk, and providing a systematic approach to the proposition of sanitation facilities in clinics, hospitals and other health institutions.

The Department of Housing is responsible for developing norms and standards in respect of housing development and for co-ordinating the application of the housing subsidies administered by the provincial housing departments. The minimum level of service prescribed for sanitation is a VIP per household, unless the situation, such as soil conditions, dictates otherwise.

The National Department of Education is responsible for the development of curricula, while the provincial departments are responsible for the provision of school facilities, including toilets and other sanitation facilities. The Department of Education, together with the Department of Health, develop curricula, guidelines and other support mechanisms to take up issues relating to health, hygiene and sanitation.

The Department of Public Works acts as the implementing agent on behalf of the national and provincial government departments when facilities, such as schools and clinics, are constructed or rented. The Department has the responsibility in ensuring that adequate provision s made for sanitation facilities in government and public buildings, and ensuring that norms and standards are complied with.

The Department of Environmental Affairs and Tourism is responsible for the protection of the environment. The Department will take primary responsibility for developing policies, guidelines, procedures, norms and standards relating to the impact of sanitation systems on the environment and for monitoring environmental impacts of sanitation systems.

A number of co-ordinating structures have been established at the three levels of government. Co-ordination of sanitation programmes at a national level is through the National Sanitation Task Team (NSTT). In order to achieve greater alignment between sanitation and other municipal infrastructure programmes, the sanitation co-ordination structure will be re-established as a sub-committee of the Municipal Infrastructure Task Team. As the national sphere co-ordinator, DWAF will be responsible for convening the sanitation sub-committee and will ensure participation by all relevant stakeholders.

At a provincial level, Provincial Sanitation Co-ordinating Forums have been established that comprise representatives of the district and metropolitan local authorities and the relevant national government departments, and chaired by provincial representatives.

Co-ordination and integration at the local government level will be the responsibility of the District Municipality or Metro as the Water Services Authority or the local municipality. The Integrated Development Plan is the mechanism for attaining this integration between role players at the local level, as well as between municipalities and their provincial and national government counterparts. Within the Integrated development Plan, the Water Services Development Plan, provides the basis for sanitation provision and operation.

Task

Please review the following document in respect of the preceding text. Find the linkages with the SA bill of human rights and compare this with one neighbouring SADC country and with the AU resolution.

http://www.dwaf.gov.za/Documents/Policies/SanitationReviewPolicy.pdf

7.0 WATER SECTOR REGULATION AND GOVERNANCE LEGISLATION

In countries where the individual rights to access to water are protected by a Constitution, such as in the case of South Africa, governments are obliged to create legislation to conform to such basic human rights. This is not always the case in all African countries where Constitutions do not exist. Countries with Constitutions are also better aligned with the African Union, making it easier for such a country to adopt African Union resolutions.

This section provide an overview of the South African Bill of Rights as stated in the Constitution and related legislation in order to demonstrate how the Constitution reshaped water legislation, and how it could possibly be applied in the rest of Africa.

7.1 The Constitution

7.1.1 The Bill of Rights

Section 24 of the Bill of Rights in the Constitution (Act 108 of 1996) (hereafter referred to as "the Constitution"), reads as follows:

Everyone has the right –

- to an environment that is not harmful to their health or well-being; and
- to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that-
- prevent pollution and ecological degradation;
- promote conservation; and
- secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

The protection and sustainable use of water is part of the environment that must be protected – a duty placed on the state.

Section 24 is one of the human rights enshrined in the highest law of the country, the Constitution. It is written in anthropocentric terms, as one would expect of a provision in a Bill of Rights. Note that it is not the environment itself that gains any rights but the right is vested in the individual. It is therefore a human right of all persons to have the environment protected.

This provision is quite progressive in that the principle of intergenerational equality finds application: it is not only a right of the current generation, but also of future generations, at least in so far as that the current generation has a right to have the environment protected for the benefit of future generations.

Such rights are not absolute – section 24 also allows for development and use of natural resources such as water. This right can also limited in so far as Section 36 of the Constitution allows such limitation in terms of a law of general application to the extent that the limitation is reasonable and justifiable in an open and democratic society based on human dignity, equality and freedom'.

In the context of the subject matter, other basic rights must also be kept in mind, such as the right to equality (see the remarks below on environmental justice in the discussion of the NEMA principles). Of particular importance here is the right to health care, food, water and social security as contained in section 27:

> (1) Everyone has the right to have access to –
>
> - health care service;
> - sufficient food and water; and
> - Social security
>
> (2) The state must take reasonable legislative and other measures within its available resources to achieve the progressive realization of each of these rights.

Both the rights in section 24 and section 27 refer to legislative measures that must be taken to protect these rights. It is at these legislative measures that we will look into more detail in this chapter.

While it is therefore the duty of government to protect these rights, section 38 of the Constitution also provides that a person or group of persons may in their own interest, or the public interest, can approach a competent court for relief, should such a right be infringed or threatened.

7.2 International and regional agreements

International and regional agreements are of high importance in South Africa. These agreements include the United Nations Convention on the Law of the Non-navigational Uses of International Watercourses which deals with the trans-boundary utilization and preservation of both surface waters and ground waters. Similarly the SADC Protocol on Shared Watercourse Systems and the Ramsar Convention on Wetlands are of International Importance especially as Waterfowl Habitat, as already discussed above.

Once such an international agreement has been ratified by South Africa, it becomes binding on the country. It however only creates rights and obligations for the country itself, and none for the citizens of the country. National implementing legislation therefore needs to be passed to give domestic effect to such agreements, where necessary.

Section 231 of the Constitution sets out the respective rights and obligations of the executive and legislative arms of government regarding the adoption of international agreements. The negotiation and signature of all international agreements is the responsibility of the executive, but is binding on the Republic only after approval of both the National Assembly and the National Council of Provinces ("NCOP"). If however, it is an international agreement of a technical, administrative or executive nature, or an agreement that does not require ratification or accession, then such an agreement must simply be tabled in the Assembly or National Council of Provinces ("NCOP") within a reasonable time.

The negotiation and conclusion of international agreements is quite a lengthy procedure requiring inter alia, the State Law Advisors from the Department of Justice and Constitutional Development and from the Department of Foreign Affairs to examine the agreement for consistency with domestic and international law respectively. Thereafter a President's minute is prepared for signature, first by the Cabinet Minister, then by the President. It is then placed before the relevant cabinet portfolio committee before being submitted for parliamentary approval. After the instrument of ratification has been deposited, the treaty or convention is deposited with the Treaty Section at the Department of Foreign Affairs.[22]

Chapter 6 (sections 25 to 27) of the National Environmental Management Act (NEMA, 1998) also contains provisions regarding the adoption of international environmental instruments, and Chapter 10 of the National Water Act deals with international water management should be read by participants of this course.

7.3 Legislative and executive authority of the three spheres of government

The Constitution is also relevant in this context in so far as it determines the legislative and executive authority of the national, provincial and local spheres of government. Section 41 of the Constitution determines that all role players within government and organs of state must adhere to the principle of cooperative governance by, inter alia, coordinating their actions and legislation with one another and avoiding legal proceedings against one another.

National parliament and provincial legislature have concurrent legislative powers in, amongst other things, the environment, agriculture, pollution control, regional planning and development, soil conservation and urban and rural development. Nature conservation also falls within this category, but however specifically excludes national parks, national botanical gardens and marine resources, all of which therefore fall under exclusive national competence.

Some matters falls under exclusive provincial competence and some matters can also be regulated via municipal bylaws. Municipalities may make, consistent with national or provincial legislation, by-laws on matters listed in Part B of Schedule 4 and 5[23]. Part B of Schedule 4 includes municipal public works, storm water management systems in built-up areas and water and sanitation services, to name but a few relevant examples.

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[22] *Practical Guide and Procedures for the Conclusion of Agreements, Office of the Chief State Law Adviser (International law)*, Department of Foreign Affairs. See www.dfa.gov.za

[23] Section 156(2) of the Constitution, Act 108 of 1996.

The executive authority of the three spheres of government is also set out in the Constitution[24], and in a slight oversimplification, is similar to the legislative authority. None of the above must however be seen as watertight compartments (there are various other provisions and principles governing this), but only serves as broad background to the discussion of the most relevant legislation below.

As can be seen from the above, national legislation forms the backbone of legislative provisions dealing with water and related issues, and this legislation is discussed immediately below. What is also clear from the above is that the provincial legislature does not play any substantial role in such matters, while local government do have an important function in this regard. The role of local government structures is examined in more detail in Chapter 8 below.

7.4 National legislation

The South African law relating to water has its roots in four different legal systems, being Roman law, Roman Dutch law, as well as English and American law. The White Paper on a National Water Policy for South Africa was released in 1997 and ushered in a whole new regime relating to ownership of water and the management of water resources with the aim, amongst others to provide for equitable access by all South Africans to water. This lead to the promulgation of the Water Services Act 108 of 1997 as mentioned in chapter 6 and the National Water Act 36 of 1998.

The National Water Act is the primary legislation pertaining to the regulation of water in South Africa and fundamentally changes the notion of private ownership of water and provides that the national government is the public trustee of the nation's water resources and must therefore ensure that the water resources are managed in such a way that take into account, inter alia, the basic human needs of present and future generations. The Water Services Act was enacted to deal with matters such as providing for the right of access to basic water supply, basic sanitation, and the setting of national standards and norms for tariffs.[25]

Task: Read and discuss the case of *Mazibuko and Others v City of Johannesburg and Others 2009 ZACC 28* on the right of access to water[26].

7.5 National Water Act 36 of 1998

7.5.1 A brief history of water law in South Africa

Between 1652 and 1910, the common law gradually changed through a series of decisions, whereby the state began by having the right to allocate water, to a system known as riparian rights.[27] Riparian rights originate in the English common law, whereby

[24] See e.g. sections 99, 125 and 156 of the Constitution.
[25] Morne van der Linde and Loretta Feris, *Compendium of South African Environmental Law*, Second Edition, Pretoria University Law Press, 2010: 335.
[26] http://www.saflii.org/za/cases/ZACC/2009/28.html
[27] This chapter is a summary of Michael Kidd Environmental Law, Reprinted 2008, Juta at page 64 – 69.

water is allocated to land owners around the particular body of water. After the Union, the Irrigation and Conservation of Waters Act 8 of 1912 was passed, which was later replaced by the Water Act 54 of 1956. The Water Act however maintained riparian rights, and water was actually divided into public and private water. Obviously, under this system access to water was not equal for all South Africans.[28]The need for transition from the old Water Act to the new water law was therefore immediately apparent after the Constitution came into effect. It was into this context of inequality that the new National Water Act 36 of 1998 was introduced.

7.5.2 An introduction to the National Water Act 36 of 1998

The National Water Act 36 of 1998 ('the NWA) is a Specific Environmental Management Act ('SEMA') under the National Environmental Management Act 107 of 1998 ('NEMA'), that governs and regulates water. The other implications of this status as a SEMA will be discussed in the next subsection.

The purpose of the NWA is amongst other things to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors meeting the basic human needs of present and future generations, and to promote equitable access to water.[29]

The NWA brought about the following changes to water management in South Africa:

- The government is the public trustee of the nation's water resources, and it is required to ensure that the resources are managed as set out in section 2;
- It is the responsibility of the Minister of Water Affairs to ensure that water is allocated equitably and used beneficial, and in the public interest, while promoting environmental values.[30]

The NWA introduced totally new methods, structures and strategies in order to achieve the aims and purposes of the act. It deals with the following broad subjects:

- Fundamental Principles;
- Water Management Strategies;
- Protection of Water Resources;
- Use of Water;
- Financial Provisions;
- General Powers and Duties of Minister and Director-General;
- Catchment Management Agencies;
- Water Use Associations;
- Advisory Committees;
- International Water Management;

[28] See above note at pages 65-67.
[29] Section 2(a) and (b) of the National Water Act, 36 of 1998 ("NWA")
[30] See section 3 of the NWA.

– Government Waterworks;
– Safety of Dams;
– Access to and Rights over Land;
– Monitoring, Assessment and Information;
– Appeals and Dispute Resolution;
– Offences and Remedies;
– General and Transitional Provisions

7.5.4 Water use

Chapter 4 of the NWA is entitled 'water use'. This pivotal concept in the Act is defined in section 21 to include not only include use of water, but also activities that could impact adversely on water resources, as can be seen below. Water use refers to doing something that has an impact on the water resource, which includes:

– the amount of water in the resource, or
– the quality thereof,
– the environment that surrounds the resource.[31]
– taking water from a water resource:
– storing water
– impeding or diverting the flow of water in a watercourse
– engaging in a stream flow reduction activity contemplated in section 36;
– engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1):
– discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit
– disposing of waste in a manner which may detrimentally impact on a water resource;
– disposing in any manner of water which contains waste from or which has been heated in any industrial or power generation process;
– altering the bed, banks course or characteristics of a watercourse
– removing, discharging or disposing of water found underground it is necessarily for the efficient continuation of an activity or for the safety of people; and
– using water for recreational purposes

[31] Taken from "Application for a License or Registration of a Water Use, a guide to completing registration or license application forms for waste discharge related water uses under the National Water Act (Act 36 of 1998)" published by the Department of Water Affairs and Forestry found at http://www.dwaf.gov.za/Projects/WARMS/Registration/R000218/updatedwasterelatedwateruseregistrationguideNew.pdf

The NWA then specifies that a person must have a license to use water, except in three limited circumstances:

A. permissible water uses (schedule 1)

B. Continuation of an existing lawful water use

C. General authorization (GA)

Schedule 1 (at the end of the Act) lists instances where use of water is permissible without a license, and centres mainly on domestic and small scale water use.

The second scenario is where the water use is a continuation of an existing lawful water use. Existing lawful use means any lawful use of water authorized by or under any law, which took place at any time during the period from 1 October 1996 to 30 September 1998 (i.e. the two years before the National Water Act came into effect). Existing lawful users are still required to register their use in terms of a notice issued under the Registration Regulations.

The third permissible use of water that does not require a license is use of water in terms of a general authorisation issued in terms of section 39 of the NWA. This section allows the responsible authority to authorise water use generally, which is in respect of a specific water resource in a specific geographical area. A general authorisation is an authorization to use water without a license, provided that the water use is within the limits and conditions set out in the general authorisation ('GA'). [32]

Note the following with regard to general authorizations:

- GAs are published in the Gazette in the same way as legislation; and are reviewed on a regular basis;
- GAs apply only to NEW water uses that took place after 1 October 1999 when the Act was fully promulgated.
- GAs describes the conditions under which a water use must be registered.
- The requirements for registration are outlined in the GA that was published in Government Gazette No. 399 and 26187 dated 26 March 2004.

7.5.5 Water management strategies

Section 1 of the NWA defines a water management area as follows:

'water management area' is an area established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources.

[32] This portion is a verbatim summary, taken from the guide entitled "Application for a License or Registration of a Water Use, A guide to completing registration or license application forms for waste discharge related water uses under the National Water Act (Act 36 of 1998)" published by the Department of Water Affairs and Forestry at http://www.dwaf.gov.za/Projects/WARMS/Registration/R000218/updatedwasterelatedwateruseregistrationguideNew.pdf.

Chapter 2 of the National Water Act is entitled 'Water management strategies', and part 1 is entitled 'National Water Resource Strategy'. Section 5 of the NWA provides that the Minister must establish a National Water Resource Strategy in the Gazette, and that it can be established progressively.

Water resources management is a process of accounting for all available water, in order to allocate it efficiently and equitably for utilization, both and for future situations, e.g. catering for floods and drought. The paradigm used for water resources management is Integrated Water Resources Management (IWRM).

Integrated water resources management is a coordinated systemic process of planning and managing water resources together with land and environmental resources.

It takes into consideration the following:

- the volume of available water (surface and groundwater),
- water use (current and expected future),
- water quality (current and ideal),
- international requirements,
- strategic requirements (e.g. power generation),
- environmental requirements and
- social issues as an interdependent system to ensure sustainable, equitable and efficient use.

In order to balance the available resources with the needs and the system requirements, and plan adequately for the future, the process requires detailed and reliable monitoring and information gathering, feedback reporting and regulation. This is captured in the guidelines document of the National Water Resources Strategy (2004), and further developed and detailed per catchment in Catchment Management Strategies (CMS), Catchment Reconciliation Strategies, or Catchment Internal Strategic Perspectives (ISP) where applicable.

The first edition of the NWRS was published in 2004 and set out the 'blueprint' for water resources management in the country for the first time,[33] and is binding on all authorities and institutions exercising powers or performing duties under the NWA. A second NWRS was proposed in September 2012, which sets out the strategic direction for water resources management in the country over the next 20 years, with a particular focus on priorities and objectives for the period 2013 – 2017. It provides the framework for the protection, use, development, conservation, management and control of water resources for South Africa, as well as the framework within which water must be managed at catchment level, in defined water management areas.

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[33] Taken verbatim from "Proposed National Water Resource Strategy 2 Summary" found at http://www.info.gov.za/view/DownloadFileAction?id=173116

Part 2 of chapter 2 is entitled "catchment management strategies", and requires every catchment management to progressively develop a catchment management strategy for the water resources within its water management area. Catchment management strategies must be in harmony with the national water resource strategy.

In as much as it was stated that water is managed nationally, the country has been divided into areas, managed by catchment management agencies, however the management thereof must be carried out in terms of the national water resource strategy.

Establishment and powers of catchment management agencies are set out towards the end of the NWA in Chapter 7. Only two CMAs have so far been established in the whole of South Africa. Section 79(1) provides that a catchment management agency is a body corporate, and has the powers of a natural person of full capacity. A catchment management agency may be established for a specific water management area, after public consultation, on the initiative of the community and stakeholders concerned. In the absence of such a proposal the Minister may establish a catchment management agency on the Minister's own initiative. The provisions of Schedule 4, on institutional and management planning, apply to a catchment management agency.

7.5.6 Water Resource Classification System

Chapter 3 details the protection of water resources in five parts. Part 1 is entitled "classification system for water resources" and provides for the first stage in the protection process, which is the development by the Minister of a system to classify the nation's water resources. The system provides guidelines and procedures for determining different classes of water resources.

Part 2 is entitled "classification of water resources and resource quality objectives", and under this part the Minister is required to use the classification system established in Part I to determine the class and resource quality objectives of all or part of water resources considered to be significant. The purpose of the resource quality objectives is to establish clear goals relating to the quality of the relevant water resources. In determining resource quality objectives a balance must be sought between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other. Provision is made for preliminary determinations of the class and resource quality objectives of water resources before the formal classification system is established. Once the class of a water resource and the resource quality objectives has been determined they are binding on all authorities and institutions when exercising any power or performing any duty under this Act.

The Water Resource Classification System (WRCS) places water resources into different categories called Management Classes. The Regulations for the establishment of the WRCS was published in Government Gazette No 33541, GNR 810 on 17 September 2010. The WRCS is a set of guidelines and procedures for determining the desired characteristics of a water resource, and is represented by a Management Class (MC). The MC outlines those attributes that the DWA and society require of different water resources. The WRCS prescribes a consultative process to classify water resources (Classification Process) to help facilitate a balance between protection and use of the nation's water resources.[34]

The Directorate of Water Resources Classification has been established within the Department of Water Affairs, to develop a National Water Resource Classification System (NWRCS). The Chief Directorate: Resource Directed Measures of the Department of Water Affairs (DWA) is responsible for the classification of water resources in terms of the recently published Water Resource Classification System (WRCS) to ensure that a balance is sought between the need to protect and sustain water resources on one hand and the need to develop and use them on the other. The Chief Directorate: Resource Directed Measures (CD:RDM) of the Department of Water Affairs (DWA) is tasked with the responsibility of ensuring that the water resources are classified in terms of the Water Resource Classification System (WRCS) to ensure that a balance is sought between the need to protect and sustain water resources on one hand and the need to develop and use them on the other..[35]

Part 3 deals with the Reserve, which consists of two parts

- the basic human needs reserve; and
- the ecological reserve

The basic human needs reserve, provides for the essential needs of individuals served by the water resource in question and includes water for drinking, food preparation and personal hygiene. The ecological reserve relates to the water required to protect the aquatic ecosystems of the water resource. The Reserve refers to both the quantity and quality of the water in the resource, and will vary depending on the class of the resource. The Minister is required to determine the Reserve for all or part of any significant water resource. Once the Reserve is determined for a water resource it is binding in the same way as the class and the resource quality objectives.

Section 18 of the NWA provides that the Minister, the Director-General, an organ of state and a water management institution, must give effect to the Reserve as determined in terms of this Part when exercising any power or performing any duty in terms of this Act.

Due to the very complex Reserve determination process, and perhaps a lack of political will, the ecological Reserve has proved difficult to implement.[36] The Reserve is water that is set aside to provide for basic human needs and to protect the water ecosystem. The

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[34] Taken verbatim from "Classification of significant water resources in the Olifant's river Background Information Document" found at http://www.dwa.gov.za/rdm/WRCS/doc/Olifants/OlifantsClassificationBID.pdf

[35] Taken verbatim from http://www.dwa.gov.za/rdm/WRCS/doc/Inception_final_29%20March%2012.pdf

[36] Taken from SciELO, Water SA (Online) Vol 36.No 3. Pretoria Apr.2012 "Balancing resource protection and development in a highly regulated river: the role of conjunctive use" found at http://www.scielo.org.za/scielo.php?pid=S1816-79502010000300018&script=sci_arttext

Reserve is the only right to water in the National Water Act. It therefore has priority over all other water uses.

Some challenges remain to the implementation of these tools provided for in the NWA. The following have not been fully implemented to the extent required by the NWA:

- classification of water resources;
- establishing resource quality objectives; and
- setting an ecological reserve and basic human needs reserve

The Centre for Environmental Rights, in their article *'Stop treading water: What civil society can do to get water governance in South Africa back on track'* note that although some progress has been made, many of these measures have not yet been implemented to the extent required, despite the NWA coming into effect as long ago as 1998. Moreover, in the absence of the necessary monitoring undertaken by DWA, the exact extent of implementation is unclear.

Some of these delays can be ascribed to:

- the complexity of transforming a complex system and achieving the integration of many components of integrated WRM;
- the absence of coordination between key departments, particularly between the DWA, the DEA and
- the Department of Mineral Resources (DMR) – DMR continues to issue coal prospecting licenses in high conservation and critical water-yield areas;
- the fact that many of the tools and implementation strategies are too complicated and resource intensive to implement;
- no clear policy direction on a number of issues, including the roll-out of water management institutions (WMI) and the transformational approaches in water allocation and licensing;
- insufficient capacity, technical skills, experience within DWA, resulting in poor leadership, low morale and severely depleted institutional memory; and
- inadequate financing.[37]

7.5.7 Water pollution under the National Water Act

Part 4 and 5 of Chapter 3 deals with pollution prevention and emergency incidents. Section 19 deals with pollution prevention and in particular the situation where pollution of a water resource occurs or might occur as a result of activities on land.

A person who owns, controls, occupies or uses the land in question is responsible for taking measures to prevent pollution of water resources.

[37] Taken directly from the Centre for Environmental Rights "Stop treading water: What civil society can do to get water governance in South Africa back on track" found at http://cer.org.za/wp-content/uploads/2012/03/Stop-Treading-Water.pdf.

These measures may include measures to:

- cease, modify or control any act or process causing the pollution;
- comply with any prescribed waste standard management practice;
- contain or prevent the movement of pollutants;
- eliminate any source of the pollution;
- remedy the effects of the pollution; and
- remedy the effects of any disturbance to the bed and banks of a watercourse.

If these measures are not taken, the catchment management agency concerned may itself do whatever is necessary to prevent the pollution or to remedy the effects, and to recover all reasonable costs from the persons responsible for the pollution. Note that in the absence of a CMA it is DWA that will have this power, as set out in section 72(1) of the Act.

In terms of section 20, Chapter 3, Part 5 of the National Water Act, 1998, where a water resource is being polluted or is likely to be polluted as result of an emergency incident, for example, where a harmful substance finds its way into a water resource in an emergency incident, any person who is responsible for the incident, owns the substance or was in control of the substance has an obligation to report the incident[38] and take measures to minimize and clean up the effects of the pollution.

The responsibility for remedying the situation rests with the responsible person. According to section 20(2), the 'responsible person' in terms of this section includes any person who:

- is responsible for the incident:
- owns the substance involved in the incident: or
- was in control of' the substance involved in the incident at the time of the incident.

In terms of section 20(3) the responsible person or any other person involved in the incident or any other person with knowledge of the incident must, as soon as reasonably practicable after obtaining knowledge of the incident report to:

- the Department:
- the South African Police Service or the relevant fire department: or
- the relevant catchment management agency

Section 20(4) further provides that the responsible person must also:

- take all reasonable measures to contain and minimise the effects of the incident;
- undertake clean-up procedures:
- remedy the effects of the incident: and

[38] Please refer to "incident" definition in the training lexicon.

– take such measures as the catchment management agency may either verbally or in writing direct the time specified by such institution (the verbal directive must be confirmed in writing within 7 days).

If there is a failure to act and or failure to comply with the directive, or if it is not possible to give the directive to the responsible person timeously the relevant catchment management agency may take the necessary steps to contain and minimize the effects of the incident; undertake clean-up procedures and remedy the effects of the incident and recover the costs from every responsible person jointly and severally. These costs may include but are not limited to labour, administration and overhead costs.

A section 20 directive may be issued by the relevant catchment management agency or the Chief Director of the appropriate Regional Office as delegated by the Minister in terms of section 63. The Minister has delegated the power to issue these directives in terms of section 63.

Non-compliance with a section 20 directive is a criminal offence in terms of section 151(1)(d) and the maximum penalty on a first conviction, as specified in section 151(1)(2), is an unspecified fine or imprisonment for a period not exceeding 5 years or to both such fine and imprisonment. In the case of a second or subsequent conviction, a person may be liable on conviction to a fine or imprisonment for a period not exceeding ten years or to both a fine and such imprisonment. In terms of the Adjustment of Fines Act 101 of 1991, the maximum fine on a first conviction will be R100 000.00, and R200 000.00 in the case of a second or subsequent conviction.

Also see the discussion further below on offences relating to the pollution of water.

7.5.8 Water user associations

Chapter 8 of the NWA deals with the establishment, powers and disestablishment of water user associations ('WUAs'). Although water user associations are water management institutions their primary purpose, unlike catchment management agencies, is not water management.

WUAs operate at a restricted localized level, and are in effect co-operative associations of individual water users who wish to undertake water-related activities for their mutual benefit. A water user association may exercise management powers and duties only if and to the extent these have been assigned or delegated to it. The Minister establishes and disestablishes water user associations according to procedures set out in Chapter 8. An interested person would usually establish a water user association for a particular purpose following a proposal to the Minister, but such an association may also be established on the Minister's initiative. The functions of a water user association depend on its approved constitution, which can be expected to conform to a large extent to the model constitution in Schedule 5. This Schedule also makes detailed provisions for the management and operation of water user associations. Although water user associations must operate within the framework of national policy and standards, particularly the national water resource strategy, the Minister may exercise control over them by giving them directives or by temporarily taking over their functions under particular circumstances.

The following boards will continue in operation until they are restructured as water user associations:

- Existing irrigation boards
- Subterranean water control boards and
- Water boards established for stock-watering purposes

7.5.9 Enforcement under the National Water Act

Part I of Chapter 13 allows authorized persons to enter and inspect property for a number of purposes associated with implementing the NWA. The rights of property owners are protected in that only authorized persons may enter and inspect property; authorized persons must carry a certificate of authorisation and must produce that certificate on request; in certain circumstances notice of entry must be given and the consent of the person owning or occupying the property must be obtained before entry; and in certain circumstances a warrant must be obtained prior to entry. These officials are appointed by the Minister or water management institute, as set out in section 124, and their powers are clearly set out in section 125 of the NWA.

The implications of the NWA's status as a SEMA on the enforcement of the Act are examined further below.

Aside from the administrative enforcement tools (directives) provided for in section 19 and 20, as discussed above, the NWA provides for further administrative enforcement tools in sections 53 and 118.

Section 53, contained in NWA Chapter 4, reads as follows:

> 53(1) A responsible authority may, by notice in writing to a person who contravenes:
>
> (a) any provision of this Chapter;
>
> (b) a requirement set or directive given by the responsible authority under this Chapter; or
>
> (c) a condition which applies to any authority to use water,

direct that person, or the owner of the property in relation to which the contravention occurs, to take any action specified in the notice to rectify the contravention, within the time (being not less than two working days) specified in the notice or any other longer time allowed by the responsible authority.

The responsible authority, in relation to a specific power or duty in respect of water uses, means

(a) *if that power or duty has been assigned by the Minister of Water Affairs to a catchment management agency, that catchment management agency; or*

(b) *if that power or duty has not been so assigned, the Minister of Water Affairs*

The Minister can in terms of section 63(1) delegate his authority, with certain exceptions to:

(a) an official of the Department by name;

(b) the holder of an office in the Department;

(c) a water management institution;

(d) an advisory committee established under section 99; or

(e) a water board as defined in section 1 of the Water Services Act, 1997 (Act No. 108 of 1997).

Chapter 4 deals with water uses and licensing or permissible uses thereof. This could include non-compliance with general authorizations, not registering a lawful water use, and not complying with a determination by a responsible authority of the extent of an existing lawful water use. The person can be directed to take any action to rectify the contravention, within the time (being not less than two working days) specified in the notice or any other longer time allowed by the responsible authority.

If the person, to whom the notice was issued, fails to perform the activity or function, the responsible authority may:

- carry out any works and take any other action necessary to rectify the contravention; and
- recover its reasonable costs from the person on whom the notice was served; or
- apply to a competent court for appropriate relief.

Any expenditure incurred by the responsible authority in doing the above may be recovered from the person concerned to whom the notice was served. In practice this will mean sending an invoice for the costs incurred to the person, and if that person fails to pay, lodging a civil claim in court for payment

Non-compliance with a section 53 directive is a criminal offence in terms of section 151(1)(d) and the maximum sentence on a first conviction, as specified in section 151(1)(2), is an unspecified fine or imprisonment for a period not exceeding 5 years or to both such fine and imprisonment. In the case of a second or subsequent conviction, a person may be liable on conviction to a fine or imprisonment for a period not exceeding ten years or to both a fine and such imprisonment. In terms of the Adjustment of Fines Act 101 of 1991, the maximum fine on a first conviction will be R100 000.00, and R200 000.00 in the case of a second or subsequent conviction.

Section 118, in Chapter 12 dealing with dam safety, provides for control measures for dam and safety risks. The owner of a dam must within the period specified, provide the Minister with any information, drawings, specifications, design assumptions, calculations, documents and test results requested by the Minister; or give any person authorized by the Minister access to that dam, in order to enable the Minister to determine whether that dam is a dam with a safety risk; or should be declared to be a dam with a safety risk; or whether a directive should be issued for specific repairs or alterations to that dam; or whether the owner has complied with any provisions of this Act applicable to that dam.[39] The Minister may declare a dam to be a safety risk,[40] and s/he may also:

- direct the owner of a dam with a safety risk to submit, at the owner's cost, and within a period specified by the Minister, a report by an approved professional person regarding the safety of that dam; or
- direct the owner of a dam with a safety risk to undertake, at the owner's cost, and within a period specified by the Minister, any specific repairs or alterations to that dam which are necessary to protect the public, property or the resource quality from a risk of failure of the dam.[41]

The following definitions in section 117 are relevant:

'dam' includes any existing or proposed structure which is capable of containing, storing or impounding water (including temporary impoundment or storage), whether that water contains any substance or not;

'dam with a safety risk' means any dam:

(i) which can contain, store or dam more than 50 000 cubic metres of water, whether that water contains any substance or not, and which has a wall of a vertical height of more than five metres, measured as the vertical difference between the lowest downstream ground elevation on the outside of the dam wall and the non-overspill crest level or the general top level of the dam wall;

(ii) belonging to a category of dams declared under section 118 (2) to be dams with a safety risk; or

(iii) declared under section 118 (3) (a) to be a dam with a safety risk;

owner of a dam or owner of a dam with a safety risk includes the person in control of that dam;

'task' includes a task relating to designing, constructing, altering, repairing, impounding water in, operating, evaluating the safety of, maintaining, monitoring or abandoning a dam with a safety risk.

[39] Section 118(1)(a)&(b) of the NWA.
[40] Section 118(2) of the NWA.
[41] Section 118(3)(b)&(c) of the NWA.

A section 118 directive may be issued where a dam is declared to be a dam with a safety risk in terms of section 118(3)(a); or where repairs or alterations to a dam with a safety risk are necessary to protect the public, property or the resource quality from a risk of failure of the dam. A directive can only be issued against the owner of the dam with a safety risk. Note the definition of “owner of a dam with a safety risk” referred to above, which includes the person in control of such dam. In the case of the issuing of a directive for a dam with a safety risk, the owner of such dam can be directed to submit, at own cost, within a specified time period, a report by an approved professional person regarding the safety of the dam. In the case of the issuing a directive for specific repairs or alterations for a dam with a safety risk, the owner of such dam can be directed to undertake at the owner’s cost and within a specified period, specific repairs or alterations which are necessary to protect public, property or the resource quality from a risk of failure of the dam.

- Where a dam is declared to be a dam with a safety risk, the Senior Executive Manager: for Policy and Regulation has been delegated to issue this notice.
- To direct the owner of a dam with a safety risk to submit at the owner’s own cost a report by an approved professional person regarding the safety of that dam, the Chief Engineer: Dam Safety Office has been delegated to issue this directive.
- To direct the owner of a dam with a safety risk at the owner’s own cost to undertake specific repairs or alterations to that dam which are necessary to protect the public, property or the resource quality from a risk of failure of that dam, the Manager: Water Use has been delegated to issue this directive.

If the person, to whom the directive was issued, fails to comply with the directive within the timeframe set out in such directive, the Minister or delegated authority may undertake the repairs or alterations and recover the costs from owner, which includes a person in control of the dam. Any expenditure incurred by the Minister or delegated authority in doing the above may be recovered from the person concerned to whom the directive was issued. In practice this will mean sending an invoice for the costs incurred to the person, and if that person fails to pay, lodging a civil claim in court for payment.

Non-compliance with a section 118 directive is a criminal offence in terms of section 151(1)(d) and the maximum sentence on a first conviction, as specified in section 151(1)(2), is an unspecified fine or imprisonment for a period not exceeding 5 years or to both such fine and imprisonment. In the case of a second or subsequent conviction, a person may be liable on conviction to a fine or imprisonment for a period not exceeding ten years or to both a fine and such imprisonment. In terms of the Adjustment of Fines Act 101 of 1991, the maximum fine on a first conviction will be R100 000.00, and R200 000.00 in the case of a second or subsequent conviction.

7.5.10 Offences under the National Water Act

The offences in the NWA are listed in section 151 found in chapter 16 of the NWA:

- Section 151(1)(a) provides that no person may use water otherwise than as permitted under the Act.
- Section 151(1)(b) provides that it is an offence to fail to provide access to any books, accounts, documents or assets when required to do so under the Act.
- Section 151(1)(c) provides that a person who fails to comply with any condition attached to a permitted water use under the Act, shall be guilty of an offence.
- Section 151(1)(d) provides that a person who fails to comply with a directive issued under the Act shall be guilty of an offence.
- Section 151(1)(e) provides that any person who unlawfully and intentionally or negligently tampers or interferes with any waterworks, or any seal or measuring device attached to a waterworks, shall be guilty of an offence. A waterworks includes any borehole, structure, earthwork or equipment installed or used for, or in connection, with water use.
- Section 151(1)(f) provides that it is an offence, under section 151(1)(f), to fail or refuse to give data or information, or to give false or misleading information when required to give information under the Act.
- Section 151(1)(g) provides that a person who fails to register an existing lawful water use when required by a responsible authority to do so, commits an offence.
- Section 151(1)(h) provides that no person may intentionally refuse to perform a duty, or obstruct any other person in the exercise of any power or performance of any of that person’s duties in terms of the Act.
- Section 151(1)(i) provides that no person may unlawfully and intentionally or negligently commit any act or omission which pollutes, or is likely to pollute, a water resource. Pollution is widely defined in section 1 to mean the direct or indirect alteration of the physical, chemical or biological properties of a water resource as to make it less fit for any beneficial purpose or harmful or potentially harmful to the welfare, health or safety of human beings, or to any organisms, or to resource quality or property.
- Section 151(1)(j) provides that no person may unlawfully and intentionally or negligently commit an act or omission which detrimentally affects, or is likely to affect, a water resource.
- Section 151(1)(k) provides that the failure to register a dam with a safety risk, is an offence.
- Section 151(1)(l) provides that no person may commit contempt of the Water Tribunal.
- Section 151(2) provides that any contravention of the above is an offence and provides for an unspecified fine and/or imprisonment not exceeding five years in the case of a first offender. In the case of a second or subsequent conviction, the

prescribed period of maximum imprisonment is ten years. In terms of the Adjustment of Fines Act, the maximum sentences are therefore R100 000 and R200 000 respectively.

Also note that sections 152 and 153 provide for the award of damages in terms of compensation for harm, loss or damage suffered on conviction of an offence under the Act. In addition to these provisions, the offences in section 151(1)(i) and (j) are listed under Schedule 3 of NEMA making the provisions on supplemental orders on sentencing contained in section 34(1)-(4) of NEMA applicable in the case of prosecutions under these offences. This is discussed in more detail further below.

Section 154 contains additional provisions on criminal liability for offences in relation to the employer and employee relationships. In addition, because the offences in section 151(1)(i) and (j) are listed under Schedule 3 of NEMA, additional provisions on criminal liability of employers and directors are applicable in the case of prosecutions under these offences. This is also discussed in more detail further below.

Note that section 156 determines that the NWA binds all organs of state, and therefore includes criminal liability for organs of state.

7.5.11 Appeals and Dispute Resolution

Chapter 15 deals with appeals and dispute resolution, and section 146 establishes the Water Tribunal.

The Water Tribunal hears appeals against certain decisions made by a responsible authority, catchment management agency or water management institution under the NWA. The Tribunal is an independent body, whose members are appointed through an independent selection process, and which may conduct hearings throughout the Republic. A person may appeal to a High Court against a decision of the Tribunal on a question of law. This Chapter also provides for disputes to be resolved by mediation, if so directed by the Minister.

Section 148 of the NWA sets out the appeal process and 148(1) what exactly may be appealed to the Water Tribunal. Section 148(2) provides that an appeal does not suspend a directive given under section 19(3), 20(4) (d) or 53(l); and suspends any other relevant decision, direction, requirement, limitation, prohibition or allocation pending the disposal of the appeal unless the Minister directs otherwise.

7.5.12 Regulations under the National Water Act

Various regulations have been issued under the NWA, which includes:

- Regulations on Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources in Government Notice 704 of Government Gazette 20119 of 4 June 1999 (note that the Department of Water Affairs have requested public comments on this document, and as at November 2010, revised regulations are expected).

- Regulations for the Establishment of the Classification System in Government Notice No. 810 of Government Gazette No. 33541 of 17 September 2010.
- Water Use Registration Regulations in Government Notice No. 1352 of Government Gazette No. 20606 of 1 2 November 1999.
- General Authorizations; Government Notice No. 1160 of 1999 - Establishment of water management areas and their boundaries as a component of the national water resource strategy in terms of section 5(1) of the National Water Act.
- Regulations regarding the safety of dams: Government Notice Number 139, GG No. 35062 of 24 February 2012 in terms of section 123(1) of the National Water Act
- Draft regulations for the establishment of a water resource classification system, Notice No. 999 of 19 September 2008

7.5.13 Challenges remaining in the implementation of the NWA

There are still a number of challenges to the effective implementation and enforcement of the NWA. Firstly, in terms of political aspects of implementing legislation, there is perhaps an argument to be made that the long-term benefits of sustainability and conservation are overlooked due to the short-term pressures of population pressure, aridity and climate change.[42]

In terms of enforcement, there remains some confusion as to the powers of authorized officials. As mentioned above, the NWA is in itself much like framework legislation, and it sets out powers of authorized officials. However because the NWA is also a SEMA, authorized officials who are also EMIs designated to enforce the NWA have two sets of powers in the NWA and NEMA. This may give rise to confusion amongst officials, in terms of which powers and in terms of which legislation they are acting (this is explained in more detail further below). There is also a general discontent that the NWA has not been effectively enforced, and that more can be done in terms of enforcement thereof.

While the national legislation is clear in its intention, the relationships between and lines of responsibility of institutions at the three levels of government are tangled and may prevent successful implementation of the law.

7.6 Discussions and Questions

- Study and discuss the implications of the following case:

Section 19 of the Act was tested in the Supreme Court of Appeal in the matter of Harmony Gold Mining Co LTD v The Regional Director: Free State: Department of Water Affairs and Forestry and the Minister of Water Affairs and Forestry.

[42] Most of the following paragraph is a summary of Fuggle and Rabie Environmental Management in South Africa 2nd ed, Juta 2009 at page 866 – 867.

- Discuss the following statement from the previous section:

"While the national legislation is clear in its intention, the relationships between and lines of responsibility of institutions at the three levels of government are tangled and may prevent successful implementation of the law."

- Read and discuss the provisions contained in Chapter 10 of the Act dealing with International Water Management. Does this adequately provide for the implementation of international and regional treaties or agreements on water management?

Keep in mind the provisions in the Constitution dealing with this, as discussed above and note that in terms of section 108, the Trans-Caledon Tunnel Authority established by Government Gazette No 2631 of 12 December 1986, and replaced by Government Notice 277 in Government Gazette No 21017 dated 24 March 2000, the Komati Basin Water Authority established by an agreement dated 13 March 1992 with the Kingdom of Swaziland, and the Vioolsdrift Noordoewer Joint Irrigation Authority established by an agreement dated 14 September 1992 with the Government of Namibia must be regarded as being bodies established as international water management bodies.

Additional reading:

- Centre for Environmental Rights "Stop treading water: What civil society can do to get water governance in South Africa back on track" found at http://cer.org.za/wp-content/uploads/2012/03/Stop-Treading-Water.pdf
- Fuggle and Rabie "Environmental Management in South Africa" 2nd ed, Juta 2009 at page 442-443, 630-640 and 861 – 867.
- Guide to the National Water Act" published by the Department of Water Affairs and Forestry.
- Statement on the release of the Experts' Report on the Management of Acid Mine Drainage in the Witwatersrand" on the Department of Water Affairs website, or http://www.info.gov.za/speech/DynamicAction?pageid=461&sid=16506&tid=28815
- 'Acid mine drainage in Johannesburg' at http://www.greenpeace.org/africa/en/News/news/Acid-Mine-Drainage/
- 'Water management Institutions Overview' by the DWA at http://www.dwa.gov.za/documents/publications/WMIoverview.pdf.
- Chapter 14 (p. 425 -448) in *Environmental Law in South Africa* by Jan Glazewski, Second Edition, Butterworths, 2005.

7.7 Water Services Act 108 of 1997

7.7.1 The purpose and aim of the Water Services Act

While the provision of water services is an activity distinct from the development and management of water resources, water services shall be provided in a manner consistent with the goals of water resource management.[43]

While the NWA is therefore concerned with the management and conservation of water resources, the Water Services Act 108 of 1997 ('the WSA') provides a regulatory framework for local authorities to supply water and sanitation services in their areas. This is done by establishing local governments as water services authorities. The WSA therefore is concerned with the abstraction, transferring, treatment and distribution of water and sanitation to users, and the removal of waste water and sewerage.[44]

Section 2 of the WSA states that the objectives of the WSA is to provide for-

- the rights of access to basic water supply and the right to basic sanitation necessary to secure sufficient water and an environment not harmful to human health and well-being;
- the setting of national standards and of norms and standards for tariffs in respect of water services;
- the preparation and adoption of water services development by water services authorities;
- a regulatory framework for water services institutions and water services intermediaries;
- the establishment and disestablishment of water boards and water services committees and their powers and duties;
- the monitoring of water services and intervention by the Minister or by the relevant Province;
- financial assistance to water services institutions; to provide for certain general powers of the Minister;
- the gathering of information in a national information system and the distribution of that information;
- the accountability of water services providers; and
- the promotion of effective water resource management and conservation.

The South African Constitution provides that everyone has the right to have access to, among other rights, sufficient water, and the State must take reasonable legislative and other measures, within its available resources, to achieve the progressive realization of

[43] Principle 27 of the Fundamental Principles.

[44] Paragraph summarised from Jan Glazewski *Environmental Law in South Africa*, Second Edition, Butterworths, 2005: 449.

these rights. This is the mandate of the WSA. Note that the NWA and the WSA are closely related.

7.7.2 Institutions under the Water Services Act

As far as institutions under the WSA are concerned[45], the focal point of the Act is the water services authority, which is defined as any municipality responsible for ensuring access to water services. These authorities are obliged to take reasonable measures to ensure sufficient, affordable, economical, and sustainable access to water resources, as is set out in section 11(1) of the Act. Section 13-18 also requires them to prepare draft water services development plans to ensure that water services are constantly being developed, monitored and reported.

A water service provider is a water service authority who may enter into contracts with the private sector to provide water services. Chapter 6 of the Act provides for Water Boards to provide services to other water service institutions within its service area. Examples of these include Rand Water in Gauteng and Umgeni Water in KwaZulu-Natal. While the boards may provide water services directly to consumers, the local authorities' obligations and responsibilities are retained in terms of section 30 of the Act. The Act also provides for water service committees which can be established by the Minister in those areas where a water services authority is not able or willing to function.[46]

7.8 National Environmental Management Act 107 of 1998 (NEMA)

The National Environmental Management Act, Act 107 of 1998 ('NEMA') has introduced a new and comprehensive underlying legal framework to give effect to the environmental rights contained in section 24 of the Constitution. It stipulates environmental management principles and prescribes detailed procedures for co-operative governance as well as fair decision making and conflict management. Another core objective is that of integrated environmental management based on the requirement of environmental authorisations for certain listed activities. It also aims to ensure that South Africa meets its international obligations in terms of international environmental instruments and provides for measures to ensure effective compliance and enforcement, including novel provisions on judicial matters.

NEMA also introduced specific environmental management Acts ('SEMAs'), which regulate specific aspects of the environment.47 Of relevance here is the fact that the National Water Act was added to the list of SEMAs in section 1 of NEMA, with effect from 11

[45] This part adapted from Jan Glazewski *Environmental Law in South Africa*, Second Edition, Butterworths, 2005: 449.

[46] See Chapter 7 and section 5 of the Act.

[47] The current SEMAs deal with the subject matter of protected areas, biodiversity, air quality, waste, integrated coastal management and water.

September 2009.48 It is important to note that many provisions of NEMA have general application, while others only apply to the enforcement of NEMA itself and the SEMAs. Part 2 of Chapter 7 creates the Environmental Management Inspectorate (EMI), whose duties and powers are limited to the enforcement of NEMA and the SEMAs. Provisions on awards to informers, the cancellation of permits at conviction, prescriptions as to the handling of seized items and the regulation of admission of guilt fines, also only apply to NEMA and the SEMAs.49 Chapter 9 also deals exclusively with the administration of NEMA and the SEMAs.

NEMA will not be discussed in detail here, but it is important to note that the above means that a person designated as an EMI can also be designated to enforce the NWA in terms of the powers of EMIs in NEMA. In practice officials from the Department of Water Affairs have not been designated as such, but some senior EMIs from the Department of Environmental Affairs have been designated to enforce all SEMAs, which therefore includes the NWA.

7.9 Other applicable legislation

It must be acknowledged and noted that various other legislation also plays a role in water management. Examples include the Mountain Catchment Areas Act 63 of 1970 and the Conservation of Agricultural Resources Act 43 of 1983 ('CARA") and the regulations promulgated in terms of that Act. CARA is administered and implemented by the National Department of Agriculture, which is responsible for the management of agricultural practices and soil conservation within the Republic. CARA includes provisions relating to wetlands and watercourses.

As is clear from the above discussions, municipalities, forming the local government structures, have a big role to play in the provision of the relevant services, and by-laws of such institutions has a major role in accommodating this.

[48] Section 3 of the National Environment Laws Amendment Act 44 of 2008 with effect from 11 September 2009 – GN 902 in GG 32563 of 11 September 2009.

49 See section 34A-34G of NEMA

8.0 LOCAL GOVERNMENT: A CASE STUDY

As is clear from previous chapters, municipalities, as local government structures, have a big role to play in the provision of the relevant services, and their role in terms of the Constitution, national policy, NWA and WSA is crucial in the delivery of water and sanitation to users.

The legislative and executive authority of the three spheres of government, including that of local government, was discussed under chapter 8.1 above. A recent judgment provides some perspective on what is sometimes seen as the very limited role of municipalities in this regard.

In the recent unreported case of R A Le Sueur and Others v Ethekwini Municipality and Others[50], the applicant contested the municipality's authority to legislate on environmental issues, with reference to an amendment to the Ethekweni Town Planning Schemes (referred to as D-MOSS, the Metropolitan Open Space System) to introduce split zonings by a council resolution adopted in 2010. The applicants were unsuccessful and in its finding that the municipality can legislate on environmental matters, the court inter alia said that the constitutional obligation in Section 72 of the Constitution on the State to protect, promote and fulfil the rights in the Bill of Rights clearly puts such an obligation on local government as a sphere of government, and therefore the protection offered by section 24 apply to all three spheres of government.

While the 'environment' falls under Part A of Schedule 4 and 'municipal planning' falls under Part B of Schedule 4, 'the framers of the Constitution did not intend thereby to allocate legislative powers amongst the three spheres of Government in hermetically sealed, distinct and water tight compartments. The court then referred to various national legislation that places an obligation on municipalities with regard to environmental matters, inter alia section 23(1)(c) of the Municipal Systems Act that contains a 'clearly legislative mandate from national legislature in regard to environmental matters'. The court comes to the conclusion that it is impossible to separate environmental and conservation concerns in town planning practice from a 'municipal planning' perspective. A further basis for this conclusion is the applicability of the environmental management principles in Chapter 1 of NEMA to the actions of all organs of State, therefore including local government structures. The court's conclusion was that municipalities are entitled to regulate environmental matters from micro level for the protection of the environment' and are in fact authorized to legislate in respect of environmental matters to protect the environment at the local level and that the D-MOSS Amendments in no way transgress or intrude upon the exclusive purview of the National and Provincial governance in respect of environmental legislation.'

[50] High Court of South Africa, Kwa-Zulu-Natal, Pietermaritzburg, Case No. 9714/11. Judgment by Gyanda J. Heard on 14 November 2012, undated judgment. This case will be discussed in an upcoming Juta publication and this summary based on a discussion by Phil Snijman and Trafford Petterson.

While this decision was with reference to the subject matter of the environment, and not water specifically, keep in mind that the term 'environment' includes water resources, and that the same principle with regard to the role of municipalities in the protection of the environment, also will apply to water related matters. While a municipality is mainly tasked with water and sanitation services, and can legislate on this via by-laws, that does not mean that a municipality can ignore the obligation to protect water resources, and must take this obligation into account when e.g. creating bylaws or making decisions on planning issues.

Discussions:

- Based on the above discussion of the Le Sueur case, does this open the way for a bigger role for municipalities in water management?
- As far as enforcement of water related legislation is concerned, municipalities currently only play a role in the enforcement of bylaws dealing with water and sanitation services, but section 124(1) of the NWA allows the Minister or a CMA to appoint 'any suitable person' as an authorized person under the Act. This seems to imply it can also be officials from other organs of state, such as municipalities. In addition, municipal officers can be appointed as EMIs, implying they can also be appointed to enforce the NWA.

Significant delay in the appointment of EMIs in the local government sphere remains a cause of concern, and while the first municipal intakes for EMI training completed their studies in December 2007, the appointment process itself however only commenced in 2012. Discuss whether municipalities should play a bigger role in the enforcement of the NWA with the following questions in mind:

- Are municipal officials in a position to perform this function as they are already enforcing the water and sanitation services legislation?
- Do municipalities have the necessary resources to fulfil this function?
- Are the various participatory processes adequate?

LEXICON

- "Agricultural use" means use of water for irrigation purposes.
- "Aquifer" means a geological formation which has structures or textures that hold water or permit appreciable water movement through them.
- "Basin" means drainage basin.
- "Basin State" means a State part or all of whose territory is within a drainage basin.
- "Domestic Use" means use of water for drinking, washing, cooking, bathing, sanitation and stock watering purposes.
- "Drainage Basin" means a geographical area determined by the watershed limits of a system of waters including underground waters flowing into a common terminus.
- "Emergency situation" means a situation that causes, or poses an imminent threat of causing serious harm to Basin States and which results suddenly from natural causes, such as floods, landslides or earthquakes or from human conduct.
- "Estuary" means a partially or fully enclosed body of water which is open to the sea permanently or periodically; and within which the sea water can be diluted, to an extent that is measurable, with fresh water determined from land.
- "Incident" includes any incident or accident in which a substance pollutes or has the potential to pollute a water resource; or has, or is likely to have, a detrimental effect on a water resource.
- "Industrial use" means use of water for commercial, electrical power generation, industrial, manufacturing and mining purposes
- "Member State" means a State which is a member of SADC, party to this protocol.
- "Navigational use" means use of water for sailing whether it be for transport, fishing, recreation or tourism.
- "Pollution" means the direct or indirect alteration of the physical, chemical or biological properties of a water resource.
- "Riparian Land" means land contiguous to, abutting on or overlying waters of a stream, lake or aquifer or land through which a watercourse passes.
- "Riparian State" means a State through whose territory or along whose border a watercourse passes.
- "Riparian habitat" includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and a with a frequency sufficient to support vegetation of a species with a composition and physical structure distinct from those of adjacent land areas.
- "Shared watercourse system" means a watercourse system passing through or forming the border between two or more basin states
- "Water resource" includes a watercourse, surface water, estuary and aquifer.

- "Watercourse State" means a State in whose territory part of a watercourse system is situated.
- "Watercourse system" means the inter-related hydrologic components of a drainage basin such as streams, rivers, lakes, canals and underground water which constitute a unitary whole by virtue of their physical relationship.
- “Wetland”’ means land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

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EQUITABLE, EFFICIENT AND SUSTAINABLE MANAGEMENT OF WATER RESOURCES – WATER PROJECT TOOLKIT APPLICATION

EXECUTIVE SUMMARY

The management of freshwater resources and related services is of critical importance to healthy social, economic and political wellbeing of a society. Access to clean water is vital for the survival of people all other the world. Effective water resource management and developments impacting on water resources are recognised as key components of environmentally sustainable development. The European commission produced in March 2012 a Water Project Toolkit (WPT) to address this issue. This document develops a strategic approach for the equitable, efficient and sustainable management of water resources and forms the basis for this training.

This course presents a practical and logical framework of activities based on the involvement of those who use and manage water, which leads towards improved water governance, and to the development and implementation of integrated water development plans at local, regional and national level.

The first part of this training (Section 1 to section 5) introduces challenges and the key concepts behind international development policies and practices of the water sector. The second part (section 6 to section 7) is more focus on useful tools and materials to develop water activities. Theoretical content and practical sessions (exercises, case studies, role playing, etc.) are mixed trough the training to allow the participants to experiment the teachings.

COURSE OBJECTIVES & OUTCOMES

Audience

Master student and Sector professional

Courses Overview

This open source course seeks to explore methodologies and tools developed and used by the European Commission for the development of water activities. It has three main objectives:

- To provide a comprehensive framework for all activities relating to water resources development.
- To facilitate the application of sustainable water management in national and sub-national policies, programmes and projects.
- To formalize skills, tools and methods necessary for water development activities: planning, identification, formulation, implementation and evaluation

Course Outcome

After completing this course the students will be able to:

- Identify and describe key challenges for the development of water activities
- Explain the difference between water management and water governance
- Build a European project proposal
- Fill in a Logical Framework
- Realize a Stakeholder Analysis
- Facilitate and assist with the planning, coordination and implementation of water activities.

ACKOWLEDGMENTS

The overall structure and objective of this course has been established with the consultation of Nico Elema (NEPAD SANWATCE Secretariat).

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1.0 RATIONALE AND KEY CONCEPTS

The water crises of the 21st century is in many ways a crisis of governance; a crisis of the failure of our institutions to manage our resources for the wellbeing of humans and ecosystems. This chapter focuses on establishing principles that are of relevance to dealing with water challenges. These principles provide an operational philosophy and framework for sector development in areas relating to water resources management and service delivery.

Part I of this training opens on six broad types of challenges: Availability of the natural resource, access to basic services, food security, water use for energy, water in urban areas and international cooperation on water. Then policy principles for the equitable, efficient and sustainable management of water resources are described and illustrated with several case studies. Finally, chapter 5 closes on the concept of water governance with the presentation of characteristics and examples of good governance activities.

Part II of this training is designed to enable trainees to put the principles presented in Part I into effect. The chapters contain a description of Project Cycle Management (PCM), whose phases provide a time-line and project process framework in which to apply the principles and checklists of key challenges and potential responses. These are grouped according to both the PCM phases and the water challenges identified in the first part of the training. Then, the course focuses on the Logical Framework Approach (LFA). It is an analytical and management tool which is used by most multilateral and bilateral aid agencies, international NGOs and by many partner governments. It is a core tool used within Project Cycle Management.

1.1 Water resources management: the challenges

Environmental stresses imposed by population growth, urbanisation, industrialisation and climate change have become a prominent theme of international concern, especially since the 1992 Earth Summit in Rio de Janeiro. One of the most affected of the natural resources is that of freshwater. Demands upon the world’s supply of freshwater resources are increasing the threats and risk to both the quantity and quality of a natural resource essential to human life, health, social and economic activities. These risks to water resources have raised political attention which has been translated into political commitment, within and between countries, for the protection of this vital resource. Growing concerns related to climate change highlight the urgency of the freshwater situation. Climate change impacts are expected to affect populations directly by more frequent extreme events such as floods and droughts, rising sea levels, changes in the seasonal distribution and amount and type of precipitation such as snow and rain, Climate change is also expected to impact on the storage components of the Water Life Cycle such as glaciers, snow pack and groundwater via recharge.

The Intergovernmental Panel on Climate Change (IPCC), established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), is an intergovernmental body with the aim to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences. Relevant reports produced by the IPCC and others cover all continents and regions, with focus on developing regions such as Africa, Asia, Latin America and the Caribbean and South East Asia where most vulnerability to climate change is perceived. To provide a framework within which nations can act in concert to address climate change, the United Nations hosted the formation of a Framework Convention on Climate Change (UNFCCC). Article 4, paragraph 1(e) of the United Nations Framework Convention on Climate Change commits Parties to develop appropriate and integrated plans for coastal zone management and water resources management for the protection and rehabilitation of areas affected by drought, desertification and floods. While the initial focus of the Convention has been on CO_2 emissions, the importance of water has been working its way firmly onto the international agenda.

1.1.1 Availability of fresh water resources

There are large differences between regions and countries regarding the availability of fresh water resources, especially those in temperate and tropical zones. The majority of countries in the Middle East and North Africa can be classified as having absolute water scarcity today (Figure 1) while in Sub-Saharan African the water scarcity is more related to the economic situation (lack of human, institutional and financial capacities).

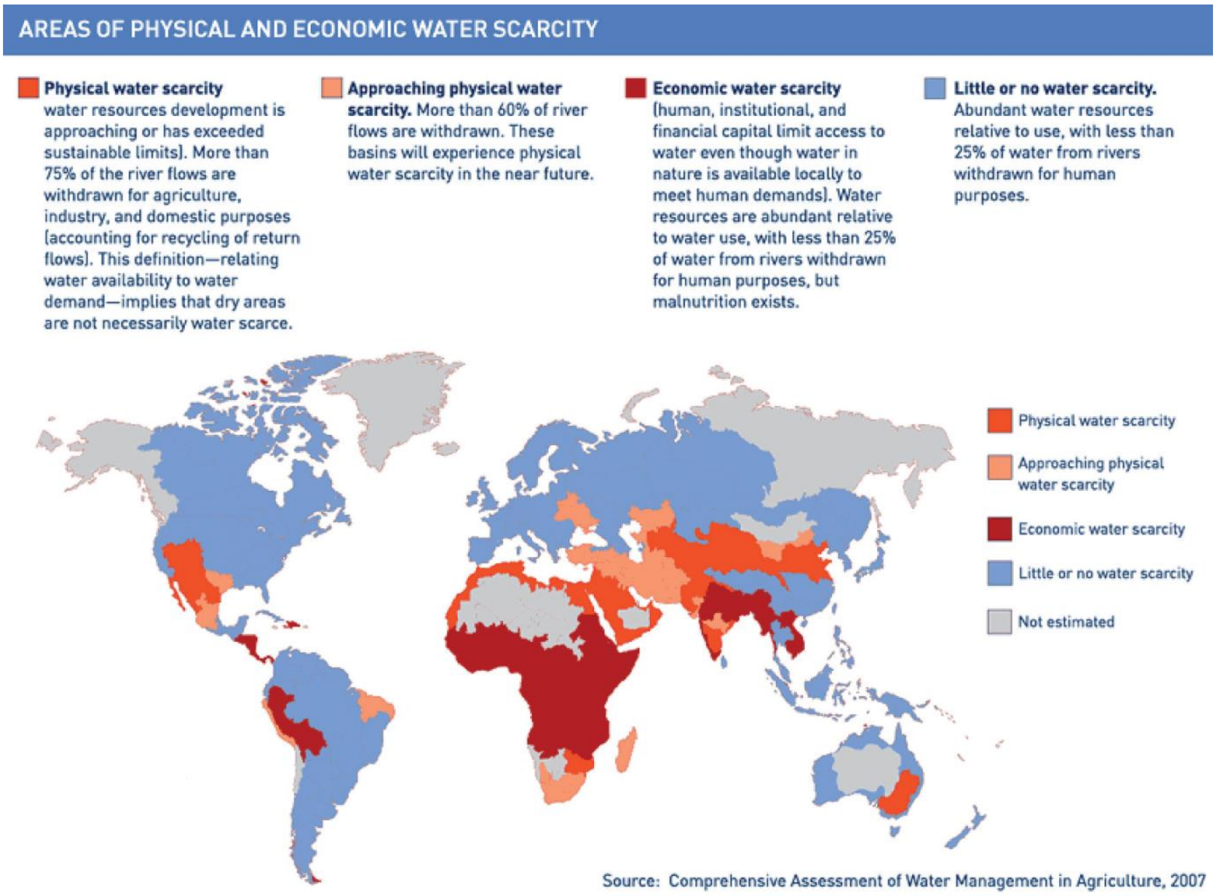


Figure 1 Areas of physical and economic water scarcity (source: IWMI, 2007)

Hydrologists typically assess scarcity by looking at the population-water equation. An area is experiencing water stress when annual water supplies drop below 1,700 m3 per person. When annual water supplies drop below 1,000 m3 per person, the population faces water scarcity, and below 500 cubic metres "absolute scarcity".

Water scarcity is defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully. Water scarcity is a relative concept and can occur at any level of supply or demand. Scarcity may be a social construct (a product of affluence, expectations and customary behaviour) or the consequence of altered supply patterns - stemming from climate change for example.

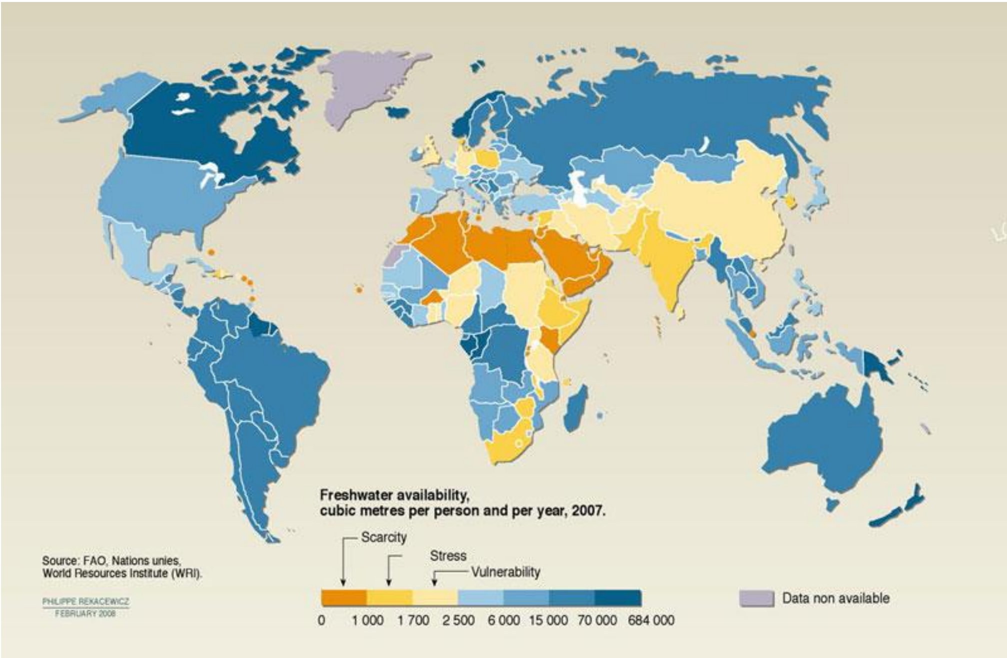


Figure 2 freshwater availability, cubic metres per person and per year, 2007 (source: UNEP 2007)

Did you know?

- Around 700 million people in 43 countries suffer today from water scarcity.
- By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions.
- With the existing climate change scenario, almost half the world's population will be living in areas of high water stress by 2030, including between 75 million and 250 million people in Africa. In addition, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people.
- Sub-Saharan Africa has the largest number of water-stressed countries of any region.

As shown in figure 3a and 3b, according to a joint study by the International Food Policy Research Institute and Veolia water (2011), the water stress, intended as percent of total renewable water withdrawn, is supposed to increase dramatically in the countries with a stronger projected economic growth such as China, India, South Africa and USA. According to the same study the population living in water short areas will increase by 90% by 2050.

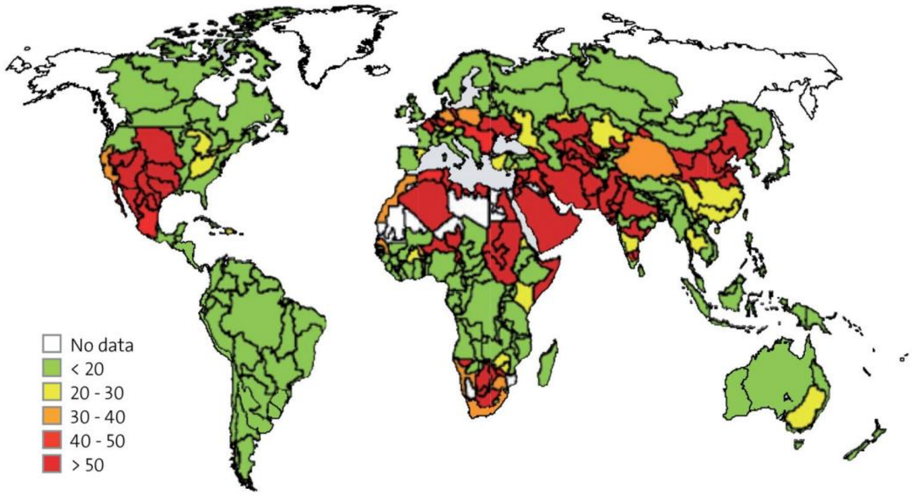


Figure 3a Water stress in 2010
(Source : IFPRI et al., 2011).

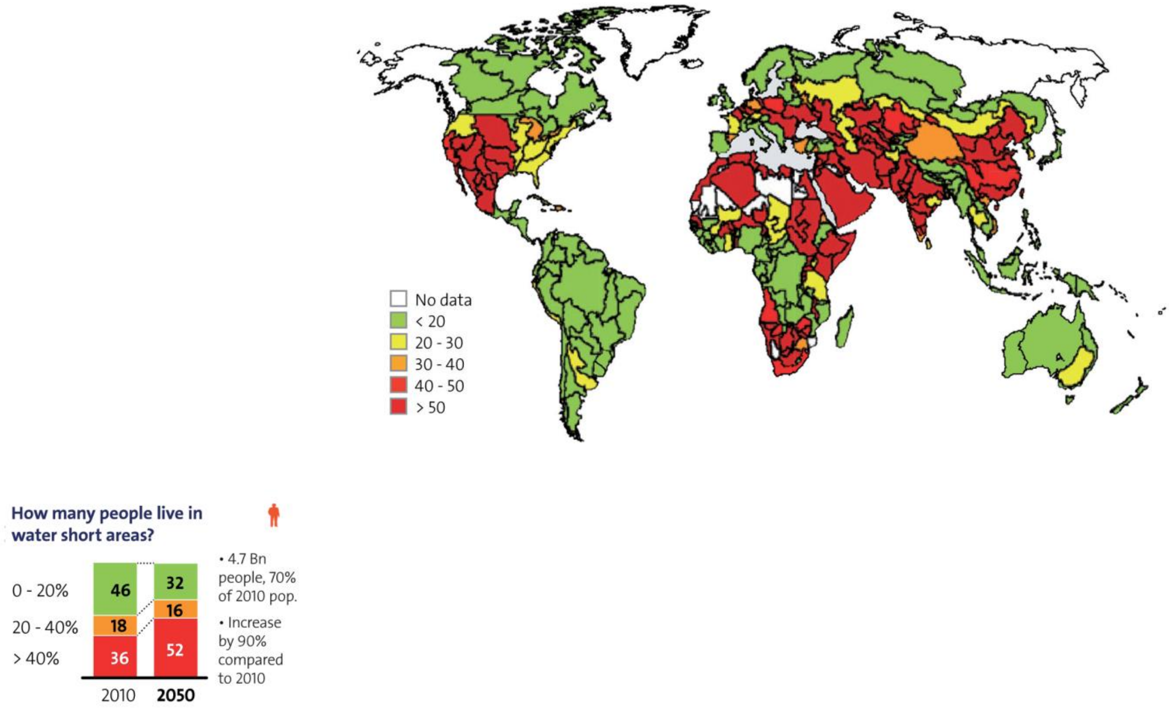


Figure 3b Water stress in 2050
(Source : IFPRI et al., 2011).

Some major urban centres already face serious water shortages compounded by water pollution crises, the latter often originating from water-dependent and water-impacting agricultural and industrial activities. Questions relating to water resources management and usage cut across many economic and social sectors, including agriculture, fisheries, industry, urban development, energy, environment, tourism and public health. Integrated Water Resources Management (IWRM) principles and concepts are presently used to manage competition between users and even to mediate in disputes over access to water resources and its use.

With increasing economic and demographic demands coupled with climatic change stresses, the prospect of increased competition and serious disputes within and between states and sectors over water resources in the not-too-distant future become more conceivable.

The lack of an integrated approach to the management of water resources has led in the past to isolated investments in water-related activity, some of which have inadvertently resulted in negative consequences on other users or on the environment.

At the national level, activities are designed to develop and support a co-ordinated water resource management strategy within the national sector framework. The main purpose of such a strategy will be to ensure sustainable water resources use and development for all water-related sectors in the various regions of the country in order to minimize competition. Where weather disasters such as drought or floods occur more frequently than historically usual, this strategy must also incorporate environmental risks and disaster preparedness.

Some water-related activities can be multipurpose. Linked to dams are activities such as power supply, recreational use and flood control. All of these uses will be reconciled within WR activities. This is also the context in which the demands of energy production (hydropower), water for recreation purposes or the need for flood control will be jointly considered.

An integrated approach is equally essential to enable higher levels of authority to set limits on activities where the implementation may neglect a broader view. Consequently, decision makers require access to adequate information such as resource quantity and quality, consumption and demand in order to make informed decisions on policy, allocation, investment and cost-recovery in parallel with other issues which have a direct impact on sustainable socio-economic development.

Water resources interventions are less likely to address infrastructure but will more often consist of studies and analyses to promote institutional strengthening. Issues to be addressed include: policy and legislation regarding ground and surface water, transboundary planning and negotiation, river basin planning and management (including the interaction between water and land use), environmental management, optimum allocation of responsibilities for resource management, designing regulation of the water sector (e.g. for service providers), and the management of water resource competition.

Possible activities related to Water resources management:

- Studies into water and land-use patterns
- Hydrogeological/hydrological surveys and data collection
- Allocation of responsibilities in River Basin Organisations
- Ecosystem protection/conservation
- Regular reviews of water policy, laws and the regulatory framework
- Development of national water standards
- Development of data collection and monitoring systems
- Cross-sector planning in hydropower and navigational uses of water
- Needs and methods for flood control /drought prevention
- Conflict resolution concerning water uses and upstream/downstream user

EUROCLIMA-Agua (2010-2013)

The region of Latin America represents one of the most significant sources of renewable water in the world, accounting for some 30% of the global total. The spatial distribution of water resources, however, varies considerably across the continent. The considerable disparity in regional distribution, the need for cross-border management and the variability brought about by Climate Change mean that for Latin America water is one of the key strategic and political elements for stability and sound governance in the region.

Within this context the EUROCLIMA project was identified between the Latin American (LA) governments and the EU at the last LA-EU Lima summit. The project's aim is to help improve the knowledge of Latin American decision-makers and scientists regarding the impact of climate change in the region, and so facilitate integration of the issue within sustainable development strategies. Government representatives of the 18 beneficiary countries play a fundamental role in guaranteeing synergies and promoting the impact of results in decision-making.

Relevant to the water resources planning context, one of the ongoing activities within EUROCLIMA is the "Analysis of the variability and frequency of components of the Water Balance in Latin America". A group of LA experts supported by the EC is analyzing the variability and frequency of the components of the Water Balance at the regional level (precipitation, temperature and evapotranspiration).

One of the expected outcomes is the characterization of the variability in terms of the frequency of occurrence of extreme events, which would in turn serve as the basis for establishing the risk of disasters caused by extreme hydro-climatic events. This approach furthermore complements and enriches the efforts made with the International Hydrological Programme (IHP: http://www.unesco.org.uy/phi/aqualac), for the development of National Water Balances in Latin America, which will provide data for decision-makers in response to the effects of variability and climate change. It is similarly expected to strengthen networks for cooperation in the sector within the region and with the European Union towards sound scientific based sustainable water resources policies.

Adapted from: www.euroclima.org

1.1.2 Access to clean water and sanitation

A Human right?

Water's special character of being essential to health as well as a key component in social and economic activities, has resulted in a special cultural status and consequently a special position in public policy. Freshwater resources have traditionally been regarded as something to which all members of the human community have rights to access. Access to clean water – and sanitation - is considered by many current international agendas and platforms as a basic human right, indispensable for leading a healthy and dignified human life. Most existing water supply systems are the result of public investments for social improvement, and as such are invariably subsidized. The use of water in the various social and economic contexts has typically either been unregulated by tariffs, or at most very low-cost; the contributions by consumers usually not able to cover the costs of operation and maintenance.

There are important implications of subsidies and cost recovery in an era of water stress, among which are water profligacy and wasteful practices, or mismanaged water services and infrastructures. In the face of water shortages and environmental concerns, discussions in some international fora have called for water to be regarded as a social and public good and not to be available for the marketplace. However, regardless of where the responsibility of management is placed, costs must be met to ensure sustainability of services. There can be a clear distinction between the rights-based "value" of water and the value as represented by charges or tariffs for different consumer groups, but herein lie the roots of a dispute. The view which upholds water as a commodity to be bought and sold, in which the community and especially its poorer members might thereby lose their rights, cuts across deeply held beliefs and long-established ideologies, now upheld in some areas that access to water is a human right.

On 28 July 2010, through Resolution 64/292, the United Nations General Assembly explicitly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realisation of all human rights. The Resolution calls upon States and international organisations to provide financial resources, help capacity-building and technology transfer to help countries, in particular developing countries, to provide safe, clean, accessible and affordable drinking water and sanitation for all.

Some progress has been made in getting the rights recognised. Some countries have included the right to water and sanitation in national legislation and used it as a guide for developing national policies.

- In some cases, countries have explicitly adopted legal provisions recognizing the right to water and sanitation as human rights including: DRC, Ecuador, Kenya, Nicaragua, South Africa, Uganda, Uruguay, etc.
- In other cases, governments have not adopted an explicit provision, but have adapted its legal framework for the implementation of the right to water and

sanitation and/or have developed policies focused on extending coverage to members of vulnerable and marginalized groups and creating water services which are affordable for all, for example: France, Peru, The Netherlands, Zambia.

Millennium Development Goals

Formally acknowledging water, as a human right, and expressing the willingness to give content and effect to this right, may be a way of encouraging the international community and governments to enhance their efforts to satisfy basic human needs and to meet the Millennium Development Goals.

In September 2000, building upon a decade of major United Nations conferences and summits, world leaders came together at United Nations Headquarters in New York to adopt the United Nations Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets - with a deadline of 2015 - that have become known as the Millennium Development Goals. These MDGs were adopted by 189 nations and signed by 147 heads of state and government.

The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty rates to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world's countries and all the world's leading development institutions. They have galvanized unprecedented efforts to meet the needs of the world's poorest.

Figure 4 The eight Millennium Development Goals (MDGs)

These indicators are followed up by the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation, which is the official United Nations mechanism tasked with Millennium monitoring progress towards the Development Goals relating to drinking-water and sanitation (MDG 7, Target 7c: *"Have, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation"*). The assessment of this target is by measuring the proportion of population using an improved drinking water source and using an improved sanitation facility.

Inequity in access

The fulfilment of population's basic needs for access to a supply of safe drinking water and a safe disposal of human waste, remain important parts of today's social and economic challenges. There has been some progress towards satisfying these two basic needs, but the challenge still remains today, with 900 million persons not having access to safe water and 2.6 billion people who do not have access to adequate sanitation facilities (WHO, 2011).

In 2008, the UN General Assembly declared the year 2008 the International Year of Sanitation, the goal being to raise awareness and to accelerate progress towards the MDG target to reduce by half the proportion of the 2.6 billion people without access to basic sanitation by 2015. Given the current technologies, approaches and skilled human resources, the targeted goal is in principle reachable. The present estimated cost to halve the proportion of people without basic sanitation by 2015 is estimated at USD $10 billion.

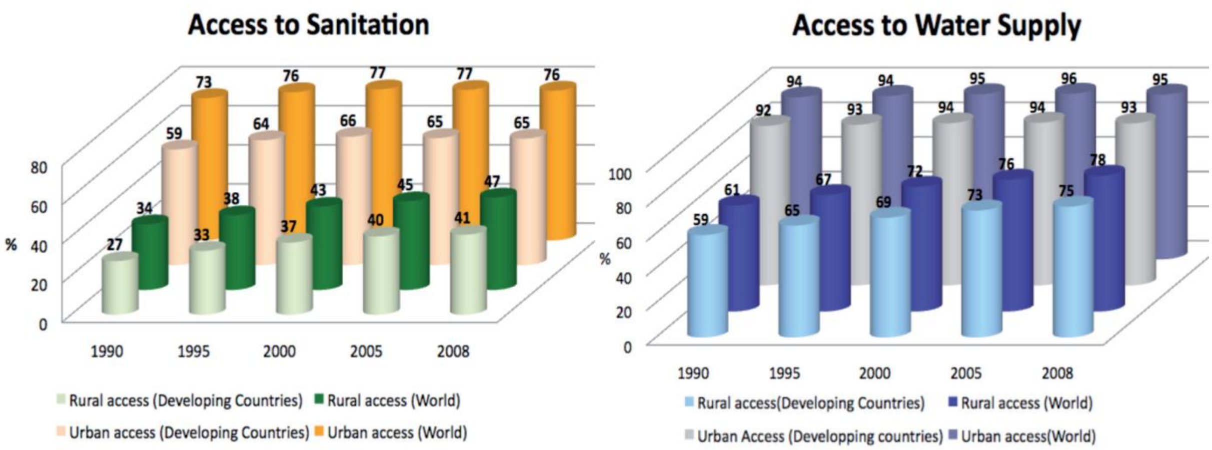


Figure 5 Inequity in access to sanitation and clean water.
(Source: JMP, 2012).

Calls for increased prioritization in development cooperation for drinking water supply and sanitation systems have been more frequently repeated in recent years.

In spite of its shortcomings in meeting its set quantitative targets, the Water Decade - at least at the non-technical level - did succeed in changing the perception of the international development community concerning cooperation in domestic water supplies and public health initiatives. The Water Decade highlighted the then-existing shortcomings in policy and practices. These included:

- Over-emphasis on costly and sophisticated (inappropriate) technology, which produced services beyond the capacity of management bodies to maintain and sustain;
- Lack of a sense of ownership by service stakeholders and users and the consequent neglect of services;

- Lack of gender analysis and recognition of the role of women in water-transport, plus their influence in domestic water quality and hygiene;
- Insufficient emphasis on environmental sanitation, on health education and hygiene promotion to enable uneducated service users to appreciate the implications of water and waste disposal for family health;
- Need for cost-effectiveness in all areas of activity in order to use scarce resources wisely.

The latter is being reinforced more and more by best practices which include more efficient techniques of water storage and transportation, greater efficiency in water use in industry and agriculture, and promoting behavioural change among water consumers to minimize excess consumption, wastage and water loss.

Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection. The importance of water, sanitation and hygiene for health and development has been reflected in the outcomes of a series of international policy forums. These have included health-oriented conferences such as the International Conference on Primary Health Care, held in Alma-Ata, Kazakhstan, in 1978. They have also included water-oriented conferences such as the 1977 World Water Conference in Mar del Plata, Argentina, which launched the water supply and sanitation decade of 1981–1990, as well as the Millennium Development Goals adopted by the General Assembly of the United Nations (UN) in 2000 and the outcome of the Johannesburg World Summit for Sustainable Development in 2002

Water related diseases are primarily the result of poor access to sufficient quantities of clean water and are also usually related to environmental conditions. Problems due to water scarcity are on the increase, and at the present global pattern consumption; two out of three persons will be living under water stress conditions by year 2025. However, as has already been mentioned, poor access can also be linked to poverty, poor services, security issues and extreme events. Water related diseases are often associated with the aftermath of natural disasters such as earthquakes and floods.

Disease	Morbidity (episodes/year)	Mortality (deaths/year)
Diarrhoeal diseases	1,000,000,000	3,300,000
Intestinal worms	1,500,000,000	100,000
Schistosomiasis	200,000,000	200,000
Malaria	400,000,000	1,500,000
Total burden/year	3,100,000,000	5,000,000

Table 1 Selected Water-Related Disease Morbidity and Mortality (Source: Gleick, 2002).

Water diseases can be categorized with Environmental Classifications:

- Faecal-Oral
- Water-Washed (or water-scarce)
- Water-Based
- Water-Related Vectors

Faecal-oral diseases are the result of pathogens transmitted by human excreta and then ingested. They can be water-borne or water-washed. The result is infection of the intestinal tract which can cause extreme illness and death. The diseases can be diarrheal or dysentery type with cholera, shigela and amoeba; can include enteric fevers such as typhoid; or also include hepatitis A, polio or leptospirosis.

For ***water-washed diseases*** the quantity of water is often more important than the quality and there are strong links between personal and domestic hygiene and these illnesses. They include skin and eye infections such as skin sepsis, scabies, fungal skin infections and trachoma/blindness.

Water-based diseases are those where the pathogen spends part of its life-cycle in an aquatic animal such as a water snail (e.g. bilharzia) or infections is by a parasitic worm that requires an aquatic intermediate host in the life-cycle (e.g. guinea worm).

Water-related vectors carry diseases that are spread by insects that breed in water bite near water. Examples of diseases spread by insects breeding near water include malaria (anopheles mosquito), dengue and yellow fever (aedes mosquito), and onchocerciasis or river blindness (simulium black fly). Insect vectors that bite near water include the glossina tsetse fly which transmits trypanosomiasis or sleeping sickness. Malaria is by far the most important disease, both in terms of the number of people annually infected, and whose quality of life and working capacity are reduced, and in terms of deaths. Worldwide, some 2000 million people live in areas where they are at risk of contracting malaria. The total number of people infected with malaria is variably estimated to range between100 to as many as 200 million, with between 1 and 2 million deaths per year, with almost 90% of the cases in Africa.

Securing the microbial safety of drinking water supplies is based on the use of multiple barriers, from catchment to consumer, to prevent the contamination of drinking water or to reduce contamination to levels not injurious to health. Safety is increased if multiple barriers are in place, including protection of water resources, proper selection and operation of a series of treatment steps and management of distribution systems (piped or otherwise) to maintain and protect treated water quality. The preferred strategy is a management approach that places the primary emphasis on preventing or reducing the entry of pathogens into water sources and reducing reliance on treatment processes for removal of pathogens.

Disinfection is of unquestionable importance in the supply of safe drinking water. The destruction of pathogenic microorganisms is essential and very commonly involves the use of reactive chemical agents such as chlorine. Disinfection is an effective barrier to many pathogens (especially bacteria) during drinking-water treatment. Residual disinfection is used to provide a partial safeguard against low-level contamination and growth within the distribution system.

Typical Activities for providing basic services

- Rural water supply and sanitation
- Water supply and sanitation for low-income urban and peri-urban communities
- Base-line studies and data collection from beneficiary localities, including: Knowledge, attitude and practice studies, gender issues, capacity and willingness-to-pay for recovery of costs for operations and maintenance, appropriate levels of technology for water and sanitation
- Establishment of local Water Committees Programmes for management of services and promotion of public health and hygiene
- Capacity-building for local authorities, community organisations or NGOs who will be involved in managing the services

Worm eradication in Northern Ghana (2007-2011)

Access to clean drinking water and proper sanitation is a continuing challenge for many people living in Ghana. Not only does this result in the occurrence of preventable water-borne diseases, but it also has a particular impact on women who must spend hours every day fetching water and on children who unduly miss school due to illness or to help their mother. In Ghana, guinea worm disease, a parasitic illness contracted through drinking contaminated water, has been affecting populations for as long as anyone can remember. Ghana is one of the four remaining countries (all in sub-Sahara Africa) where the disease still persists.

The project benefits from collaboration from a number of partners, requiring emphasis on co-ordination mechanisms'. These include the government of Ghana, the European Commission which is funding 75% of the project and UNICEF.

The principal aims of this project are to reduce guinea worm cases by 90%, reduce reported cases of diarrheal disease among children under 5 by 40% and finally increase sanitation coverage by 35%. The programme also seeks to increasing access to and the use of sustainable drinking water by undertaking district specific feasibility studies on factors affecting water delivery and financing options and stakeholder interventions.

Since the beginning of the project in 2007 up until 2010 some positive results occurred. In fact, the annual number of guinea worm cases fell from 3 358 to 8 (99%), 236 water schemes serving a total population of 147 916 people were created, more families could live in more hygienic environments and enjoy access to and use of improved sanitation facilities and finally a considerable number of women and children were finally relieved from the burden of fetching water and have more time to go to school or spend time with family.

Adapted from: EC case study, 2011

1.1.3 Water and Food

Food security and agricultural development are closely linked to water resource availability and quality, and the increasing population and demand on food supplies means that many countries are interested in expanding their arable lands by irrigation. It is not only the demand for food; many developing economies also have a high agricultural component as their main economic activity for family-based livelihoods, local markets and export. Finally, a number of developing countries have a policy of agricultural autonomy in order not to rely on agricultural imports. Thus we arrive at agriculture as a population, economic and security priority. In many of these countries, irrigation is the main consumption of water, sometimes as high as 70%. It is no surprise that efficiency in the use of water in irrigation is a critical consideration and that the construction and repair of reservoirs, distribution systems and the development and application of water-efficient technologies and crops are priorities.

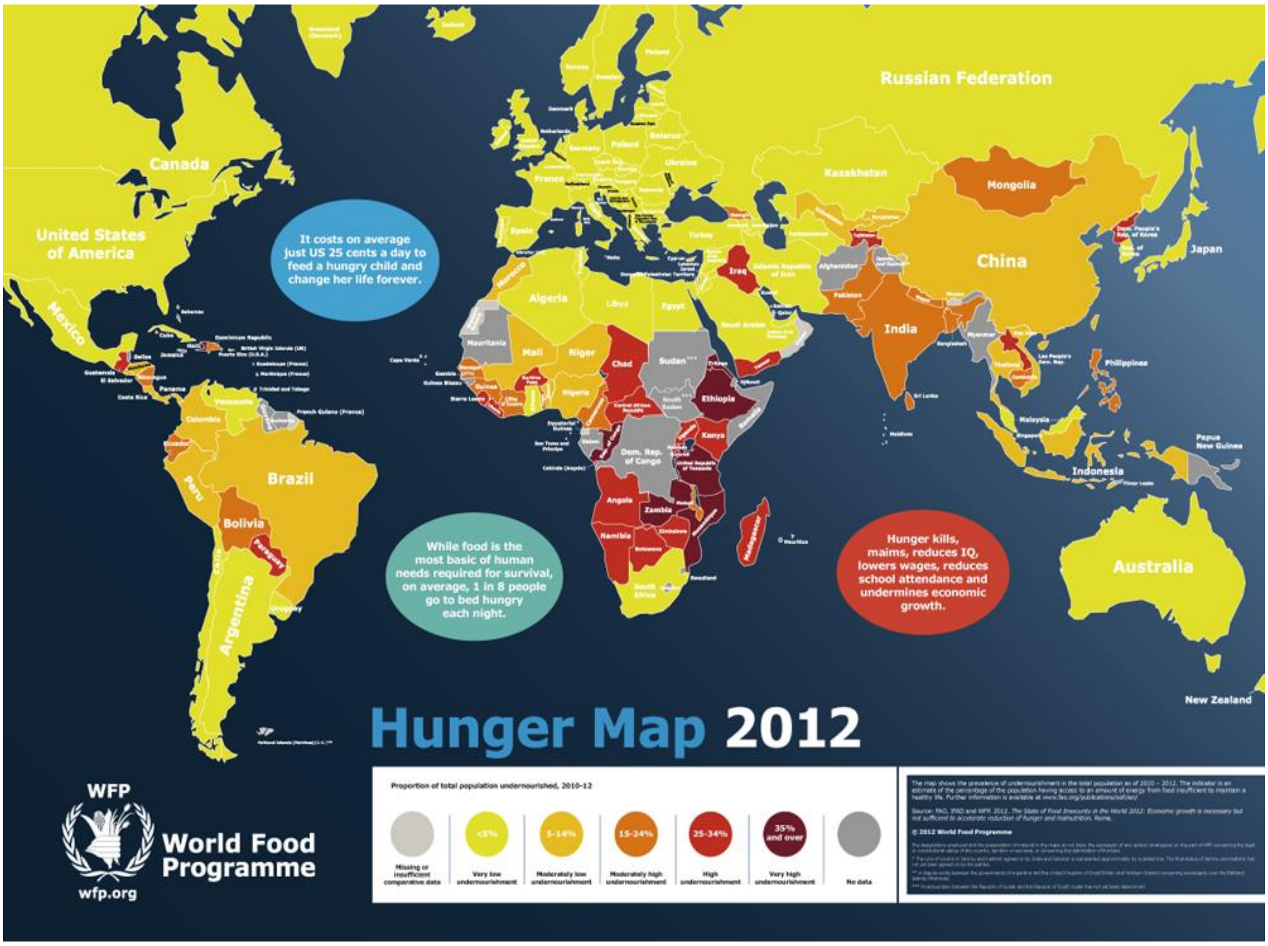


Figure 6 Hunger Map 2012,
(Source: World Food Programme 2012)

There is enough water available for our global future needs, but this world picture hides large areas of absolute water scarcity, which affects billions of people, many of whom are poor and disadvantaged. Major changes in policy and management, across the entire agricultural production chain, are needed to ensure best use of available water resources in meeting growing demands for food and other agricultural products.

While water use in agriculture accounts for more than 75% of water consumption in the developing world, in the developed world the sectors of industry and even energy are having very strong impacts on water consumption and more specifically water quality. With the promotion of economic development as a solution to poverty in some developing countries, such as many in Asia, there will also occur an increasing evolution of the water consumption profile which will be less agricultural and more industrial.

This evolving profile of water usage will differ among the world regions as a result of their available resources. Water withdrawal as a percentage of renewable water resources varies from a minimum of 1% for Latin America to a maximum of 51% in the Near East and North Africa, as shown in Table 2.

	Total renewable water resources (km³)	Irrigation water requirements (km³)	Water requirement ratio	Water withdrawal for agriculture (km³)	Water withdrawals percentage of renewable water resources
Latin America	13409	45	24%	187	1%
Near East and North Africa	541	109	40%	274	51%
Sub-Saharan Africa	3518	31	32%	97	3%
East Asia	8609	232	34%	693	8%
South Asia	2469	397	44%	895	36%
90 developing countries	28545	814	38%	2146	8%

Table 2 Comparison agricultural waters vs. water resources.
(Source : FAO Aquastat, 2011)

Concern for world food security is growing and the productivity of agriculture will have to be increased to meet the increasing demand for food. Since 2006, developing countries have leased from 15 to 20 million hectares of farmland to foreign companies, investment funds and foreign governments with a turnover between 20 and 30 billion dollars, but not all of this land is allocated towards food production. While alternative economic land use could bring new opportunities to local populations, they could also over-ride important local issues such as priorities for land allocation or even unresolved land ownership issues. These competing land-uses also impact directly on water consumption and therefore water management requirements.

In the past, many irrigation projects have inadequately taken into account environmental impacts. The importance of drainage for irrigation return flow, soil salinity control and the prevention of water-logging of soils were ignored. Similarly, the adverse environmental impacts of surface abstraction (e.g. Aral Sea for cotton exploitation) or over-pumping of ground water resources for irrigation have not always been factored into the planning for agricultural activities.

This highlights the need for a sustainable and also consultative management process which takes into account due consideration of local populations' land and water needs, ownership issues, environmental issues, the competing demands of other sectors, and the future challenges of climate change. While Governments have a vested interest in promoting foreign investment, they also must balance this with the responsibility to address the needs of the population and maintain an agenda of good resource management.

In Asia, the tendency is for the rehabilitation and modernization of existing systems to take precedence over the development of new schemes. In Africa, community based schemes were the usual scale applied and have long been the focus of agricultural development there. However the advent of larger commercial agricultural projects is becoming more common in both regions, including for economic cash crops such as cut flowers or bio-fuels.

Water resources management for agriculture purposes must also take into account prevailing conditions, livestock needs, and grazing practices and impacts. Assessing the demand must include not only competition between agriculturalists and pastoralists but also other contemporary users. Depending on the scale of the activity and, where technically appropriate, the optimization of existing small-scale systems and irrigation practices to improve irrigation efficiency is preferred over new, large-scale irrigation schemes given all the environmental and other difficulties attendant on macro-interventions. The use of surface and groundwater resources in combination, if effectively managed and not over-abstracted, can contribute to seasonal buffers and promote more reliable irrigation services in arid and semi-arid areas.

While infrastructure will remain important in project design, institutional, social, economic and capacity-building issues will be equally so. An understanding of gender roles and support for women farmers, community management needs, participative management and above all informed decision-making are increasingly recognized as important aspects of managing agricultural irrigation activities.

As competition between water users increases, there will be pressure to reduce the volumes absorbed by irrigation, at least for crops of relatively low social and economic value. At the same time, demand for food and higher agricultural yields will continue to rise. Thus the challenge is to raise crop production while consuming less water and operating within a more restrictive financial and economic regime. The social challenge which has often arisen is a tendency to increase agricultural efficiency by applying larger scale irrigation and cropping techniques which can reduce water consumption and increase production but not cost-effectively at the family-holding or small community scale. In choosing a strategy for improving agricultural activity, trade-offs may need to be made between the pursuit of large-scale efficiency over smaller-scale economic stability. These types of choices should be taken in an informed manner and made with the consultation and participation of all key stakeholders.

Measures to reduce water consumption, cost recovery and demand management will therefore be important concerns of programme and project activity in agricultural area. As with the previous challenges, the need for re-orienting or restructuring Government agencies involved in agricultural water use and management is likely to be an important component in project design. The involvement of the private sector as a partner in construction or management of schemes is likely to be a recurring theme, as will the management role of Water User Associations, Farmers Associations or other expressions of civil society. The scale of the project or the management issue to be addressed will also reflect to what degree the relevant River Basin Organisation may become involved.

In order to achieve a global food and nutritional security, commitments and investments are needed:

- To produce more nutritious food with less water: Innovative technologies are required to ensure a greener and more sustainable food production.
- They are needed to: Improve crop yields;
- Implement efficient irrigation strategies;
- Reuse of drainage water and use of water of marginal quality;
- Produce smarter ways to use fertilizer and water;
- Improve crop protection;
- Reduce post-harvest losses;
- Create more sustainable livestock and marine production.

To focus on human capacities and institutional framework: Agricultural development in the least developing countries (LDCs) lies mainly in the hands of smallholders, a large majority of whom are women. Therefore, new institutional arrangements are needed that centralize the responsibility for water regulation, yet decentralize water management responsibility and increase user ownership and participation.

To improve the value chain: From production, post-harvest handling, processing, retailing, consumption to distribution and trade, efficient water and food recycling strategies can be addressed. It can help secure environmental water requirements when reuse of treated water is not culturally acceptable for other uses.

<u>Typical project activities for agricultural development</u>

- Development of agricultural sector policy on irrigated farming and pastoral consumption
- Small-scale systems for irrigation
- Flood control measures
- Drainage, return flow and prevention of water-logging
- Credit programmes for smallholder irrigation
- Rehabilitation/modernization of irrigation systems
- Establishment of Farmer User Groups and Participatory Irrigation Management
- Research and application of technology for improving irrigation efficiency

Sugar cane and cash crops in Pakistan

Sugarcane and cotton cash crops play an important role in Pakistan's economy. The impact that these crops have on the environment due to their maximum consumption of water classifies them as 'water thirsty' crops. To produce 1 kg of cotton lint 10 000–17 000 litres of water are needed. These are also crops on which a substantial amount of agrochemicals is used.

The main goal of this EC supported project is to provide sustainable sources of clean freshwater to support the livelihoods of poor communities in Pakistan. It aims to create a mechanism to increase water availability and reduce pollution by decreasing the amount of water and agrochemicals used in sugarcane and cotton production.

This is achieved by:

- Developing and implementing appropriate 'on farm' better management practices
- Conducting farmer training and training of trainers for extension work
- Establishing farmer field schools in Faisalabad and Bahawalpur
- Working closely with research centres, target farmers, extension services and NGOs

The project activities have led to a reduction of water (30%) and pesticide (60%) usage for sugarcane and cotton crops, while improving the financial situation of small-scale farmers through increased profits and decreased input costs. The establishment of farmer field schools and farmer training of trainers has enabled the farmers not only to adopt better management practices but also promote and disseminate these to other fellow farmers. Formal collaboration has been made with different stakeholders such as the Punjab Agriculture Department, the Ministry of Food, Agriculture and Livestock (MINFAL), the Kissan Welfare Association (KWA), the Punjab Irrigation and Drainage Authority (PIDA). Working closely with government, research institutes and nongovernment partners throughout the project is a key to the long-term sustainability of the project.

Adapted from: EC case study, 2009.

1.1.4 Water and Energy

The growth of industrial and manufacturing processes which depend on water cannot be left out of the management picture. It is expected that the annual water volume used by industry will rise from 752 km3/year in 1995 to an estimated 1,170 km3/year in 2025 i.e. about 24% of total freshwater withdrawal worldwide (UNESCO water portal).

Among all industrial sectors, the energy sector is the largest water consumer. The interdependence between water and energy is fundamental. All water operations require energy; for conveyance, storage, treatment or distribution; and all energy production and generation requires large volumes of water for extraction, cooling, refining, and electric power generation. As a consequence, water and energy systems and operations must be planned together or there will be negative consequences.

Water is involved at many points in the process of producing electricity:

Electricity Generation – Most of power plants require cooling, a traditionally water-intensive process. These types of power plants are called thermoelectric because they use a heat source to produce steam for generating electricity. Hydroelectric power plants use water in a different way, converting the energy of falling water into electricity by passing it through turbines.

Fuel Extraction and Production – Water is a critical resource for the drilling and mining of natural gas, coal, oil, and uranium. In many cases, fuel extraction also produces wastewater, as is the case with natural gas wells, oil wells and coal slurry ponds.

Fuel Refining and Processing – Oil, uranium, and natural gas all require refining before they can be used as fuels – a process that uses substantial amounts of water.

Fuel Transportation – Water is used to transport coal through slurries -- pipelines of finely ground coal mixed with water -- and to test energy pipelines for leaks.

Emissions Control – Many thermoelectric power plants emit sulphur, mercury, particulates, carbon dioxide, and other pollutants which require pollution control technologies. These technologies also require significant amounts of water in their operation.

With world electricity demand increasing, exploitation of the considerable potential for hydropower generation in many developing countries is an attractive prospect. Hydropower is currently the most common form of renewable energy and plays an important part in global power generation. Worldwide hydropower produced 3 288 TWh, just over 16% of global electricity production in 2008. The overall technical potential for hydropower is estimated to be more than 16 400 TWh/yr.

Globally, around 20% of the world's hydropower potential has been developed. Countries which have actively developed hydropower use around 60% of their potential. Numerous other countries have a huge amount of untapped hydropower potential in the regions of Latin America, Central Africa, India and China. As shown by figure 6 and 7 China is the leading hydropower producer, followed by Canada, Brazil and the United States. Together these territories generate 44% of all hydroelectric power. Fifteen territories do not use hydroelectric power. These territories are generally either relatively small islands or Middle Eastern oil producers with low rainfall.

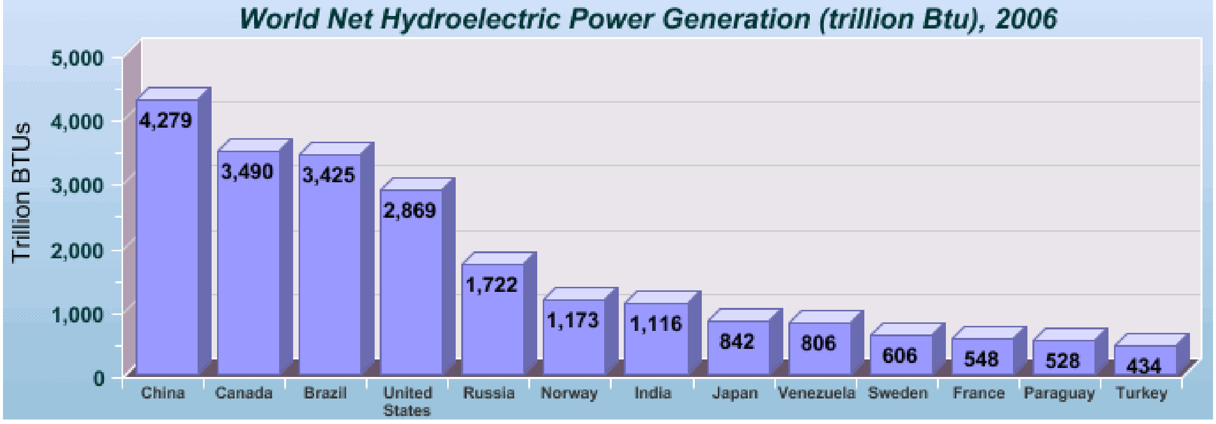


Figure 7 World Net Hydroelectric Power Generation (trillion Btu), (Source : EIA, 2006)

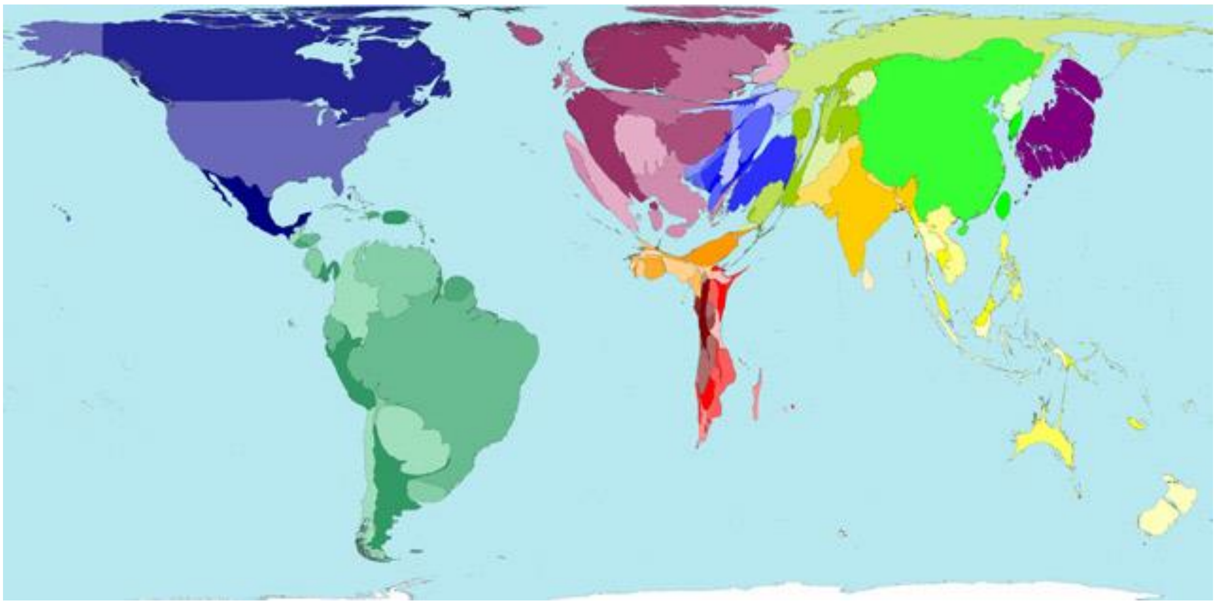


Figure 8: Hydroelectric power production per country, (Source : World mapper, 2006)

Large hydropower projects can adversely affect development in certain regions and have unwanted social and environmental impacts. On the other hand, they can also do much to promote human development in a way that is socially equitable, environmentally sustainable and economically viable. Deployment of hydroelectric power production, if undertaken in a responsible and equitable way, can significantly contribute to lowering greenhouse gas emissions. Its associated infrastructure development can help countries to managing water scarcity / flood protection / irrigation and thus, help countries cope with extreme events related to climate variability. However, adverse environmental and social effects of large hydroelectric projects could undermine the positive impacts of these projects.

The World Commission on Dams has set **two** objectives:

1) to review the development effectiveness of large dams and assess alternatives for water resources and energy development;

2) to develop internationally acceptable criteria, guidelines and standards, where appropriate, for the planning, design, appraisal, construction, operation, monitoring and decommissioning of dams. These objectives comprise, but are not limited to, the following general aspects:

- avoiding and minimizing impacts on ecosystems, livelihoods, health and cultural (and religious) heritage,
- analyzing needs and options on the basis of many different criteria (multi-criteria analysis)
- improving the livelihoods of people displaced and affected by projects,
- ensuring compliance with the compensatory measures,
- applying the principles of corporate environmental and social responsibility and accountability[51],

A harmonized approach should help ensure the sustainability and environmental integrity of the large hydropower project activities.

Development of hydropower requires an enabling institutional and legal framework with clear legislation, regulations and guidelines. This process needs to be developed in an open and cooperative way, involving stakeholders at all levels. Key elements to be considered are:

- the protection plans for water resources,
- the management plan for water resources,
- the industrial concession,
- the watercourse regulation,
- the water resources law.

In many cases, the legal framework shall include provision for mitigation measures of permanent socio-economic uplift for the population directly affected.

The strategic role of hydropower is defined at national and regional level. Its development requires an enabling environment that includes adequate resources, knowledge and skills across multiple levels of stakeholders. Hydropower project value is defined by the so called "triple bottom line" i.e. the combination of environmental, social and economic benefits generated by each project. Environmental and social impact assessments must therefore be integrated in the planning process and its full impact must be taken into account in the whole process.

Key constraints are:

- High capital costs,
- Lack of capacity throughout the industry and client countries,
- Weak regulatory and policy frameworks,

[51] In accordance with recital 15 of Directive 2004/101/EC.5

- Limited collection and/or weak analysis of hydrological data, and other environmental factors such as geology.
- Social impacts are mainly linked to involuntary displacement of communities and breakdown in community cohesion affected by plant and reservoir construction, especially ethnic communities in remote areas.

To mitigate these impacts it is important to identify the potential socio-economic impacts of projects through social impact assessments and the development of appropriate planning, monitoring and adaptation strategies for affected populations.

Water conflicts may arise on transboundary rivers between upstream hydropower use and downstream irrigation and/or hydropower use. Conflicts arise as upstream water release does not necessarily coincide with seasonal irrigation needs of the downstream riparian user. To avoid any conflict, hydropower needs to be implemented only on the basis of the results of international, independent expert examination so that the volumes and regimes of watercourse of these rivers are not upset and the ecological situation in the region will not be aggravated. Several agreements are already in place e.g. Plan of Action of the Zambezi river (ZACPLAN), Orange-Senqu River Basin Commission (ORASECOM), Lake Chad basin commission (CBLT).

In terms of scale, small scale hydropower systems as a renewable and clean energy option, used extensively in the past for shaft power, and in modern times for electricity generation, should not be overlooked. Small hydro is a good decentralized option to supply energy and alleviate poverty. If properly installed, it can be a clean energy option based on indigenous resources, and can be reliable and affordable when appropriate technologies and approaches are used for its implementation, operation and management. It can be economically and socially viable, using local materials and capabilities for installation. It also has a much lower impact on the social and physical environment. As with large scale hydro, the small scale initiatives require a policy environment that includes development agencies, through international cooperation, and governments to put in place policy arrangements to facilitate activity.

Possible project activities related to hydropower

- Hydro meteorological/hydro-geological surveys
- River profile studies
- Site evaluation for ranking study of potential hydro-power projects
- Cross-sector planning in hydropower and navigational uses of water
- Social and environmental impacts of hydropower project, including competition among water users
- Development of data collection and monitoring systems
- Topographic surveys, Geological site investigations
- Ecosystem protection/conservation

Some illustrative project examples are presented below:

Project example – EU China River Basin Management Programme

Despite China's enormous economic success, the country still faces considerable environmental challenges, particularly problems of water shortage, water pollution, soil erosion and deteriorating water ecology. The Chinese leadership shows great concern over this and has given directives to improve the situation. Water legislation and an institutional framework for implementation of the laws are being put in place.

The concept of integrated river basin management is an integral part of China's water law. China and Europe share a common concern over the environment. To assist each other in taking responsibility for sustainable economic and environmental development within the context of Chinese-European cooperation, the EU-China River Basin Management Programme has been formulated and is presently being implemented. It is hoped that some of the lessons of how advances in Europe have been achieved, what has worked, and what has not worked, can, together with facilitating technologies, be transferred to China to help manage the transition of river basin management practices.

The main objective of this project is to attain sustainable management and use of China's water resources compatible with current social economic and natural global change as well as to establish integrated river basin management practices in the Yellow and Yangtze River basins that are environmentally sustainable and address global environmental concerns as well as those of the local population. These practices will be replicated in other regions of China.

- A dialogue platform between Europe and China as well as links with the EU Water Framework Directive has been established to allow exchange of ideas on policy and management of major river basins water resources.

-Technical assistance provided to facilitate river basin planning training, exchange visits and internships; conferences, workshops and forums; research, studies and surveys

-Soil erosion control measures undertaken in poor mountainous areas in the upper Yangtze River Basin River Basin

-Increased efficiency of use of natural and local resources due to the installation of biophysical structures and to other interventions.

Adapted from EC case study, 2010.

Mini-Hydropower Schemes for Sustainable Economic Development in Indonesia (1999 to 2008)

Indonesia has insufficient supplies of electrical power. This lack of energy supply limits the country's development of businesses, social infrastructure and services. However, Indonesia is a water rich country and against the background of rising oil prices on the world markets and the removal of large state fuel subsidies in Indonesia, mini-hydropower is becoming increasingly attractive as a competitive energy option.

In this context the GIZ project aimed at generating energy supplies through mini-hydropower plants in Sulawesi, Java and Sumatra areas. The purpose was to improve local economic cycles able to generate additional income to cover the costs of the mini-hydropower stations.

The results up to 2008 have been:

85% of the electromechanical equipment was produced locally as a result of technical training provided in respect of adapted mini-hydropower solutions.

- Creation of employment opportunities.

-Exports to eight countries in Asia, Africa and Europe evidence the quality and competitiveness of Indonesian mini-hydropower equipment.

-More than 100 installations of 7-250 kW used the standard design introduced by the project, supplying some 20,000 households, small-scale entrepreneurs and public utilities in Indonesia with clean energy.

-Compared to diesel generators, these mini-hydropower plants bring a reduction in CO2 emissions of more than 4,000 tonnes per year.

The project also advised on the formulation and exemplary implementation of a law regulating the feeding of energy into the public grid. It ensured that NGO's and Indonesian universities were involved in the project to ensure that the technical competencies were consolidated locally and to assure the sustainability of the program access to funding sources was taken into account thanks to the creation of financing models based on more commercial lines.

Adapted from: GTZ, 2008.

1.1.5 Water and cities

Half of humanity now lives in cities, and within two decades, nearly 60 per cent of the world's people will be urban dwellers. Urban growth is most rapid in the developing world, where cities gain an average of 5 million residents every month. The exploding urban population growth creates unprecedented challenges, among which provision for water and sanitation have been the most pressing and painfully felt when lacking.

Two main challenges related to water are affecting the sustainability of human urban settlements: the lack of access to safe water and sanitation, and increasing water-related disasters such as floods and droughts. These problems have enormous consequences on human health and well-being, safety, the environment, economic growth and development. The lack of adequate water and sanitation facilities leads to health issues such as diarrhoea, malaria and cholera outbreaks. Though water supply and sanitation coverage increased between 1990 and 2008, the growth of the world's urban populations jeopardizes those results. While between 1990 and 2008 1052 million urban dwellers gained access to improved drinking water and 813 million to improved sanitation, the urban population in that period grew by 1089 million people.

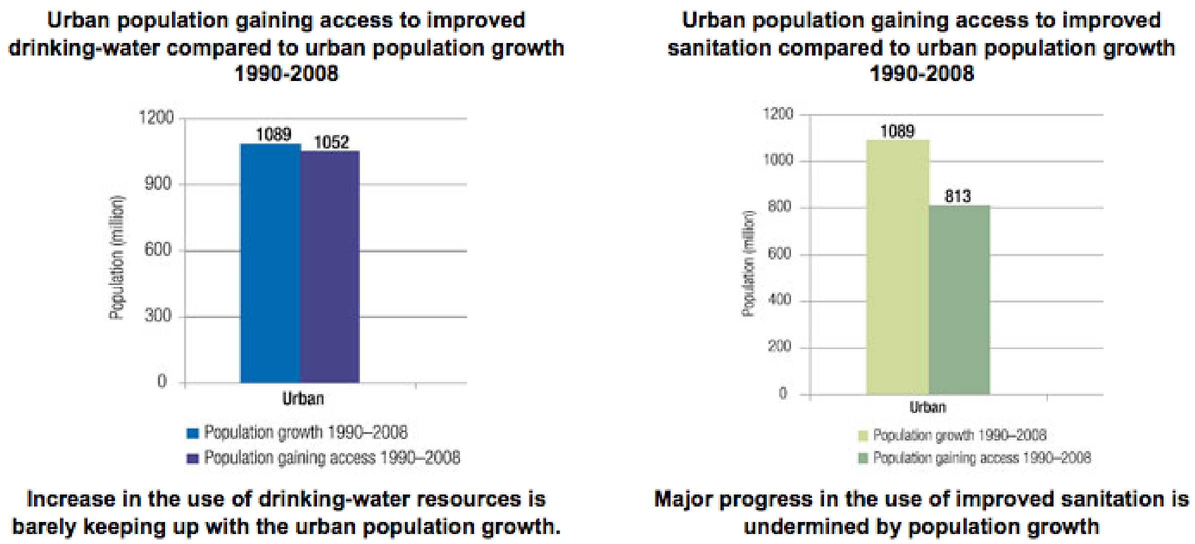


Figure 9: Progress on Sanitation and Drinking-Water: update 2010. (Source: WHO/UNICEF JMP. 2010)

An estimated 96% of the urban population globally used an improved water supply source in 2010, compared to 81% of the rural population. This means that 653 million rural dwellers lacked improved sources of drinking water.

Globally, 79% of the urban population used an improved sanitation facility in 2010, compared to 47% of the rural population.

Major water- and sanitation- related activities undertaken within the municipal areas are usually under the auspices of the Municipal Authorities and with their support and facilitation. These Authorities will inevitably have an important role, if in some cases primarily a regulatory one, in basic services schemes for low-income urban and peri-urban areas. But in basic services schemes, especially where informal or illegal settlements are concerned, community groups are usually the key operators of services. The municipal water and wastewater services are primarily capital-intensive types of programmes and projects with more sophisticated technology and maintenance requirements as compared with Basic Services schemes.

Programmes and projects include water supply, sewerage, waste water management, and management of waste from a wide range of industrial, manufacturing and domestic consumers. Given the rapid rate of urbanisation in many developing countries, one area of concentration will be the development of additional water sources (see also WR). The increasing distance of intakes from urban settlements, for example, is contributing to the escalation of costs and creating a growing awareness of the need for efficiency and a change in water consumption habits. Rehabilitation and repair of existing systems, including the reduction of wastage from leaking pipes and reservoirs, is an important area of activity. Optimal use of existing systems, including water efficient technologies, is the preferred option to the installation of new systems.

Water quality is also as important as managing the transport elements of water supply. Municipal Services are responsible for wastewater treatment and control of upstream and downstream pollution. In many coastal areas, especially in arid and semi-arid regions, the prevention of seawater intrusion into over-exploited coastal aquifers is becoming a major issue in many developing country cities and towns. Changing water use habits to include recycling and re-use of water, and other water saving strategies are being seen as having as strong an impact as that of improved technology in optimizing water use. Cost recovery, regulation and demand management will be key elements of programme and project design.

The institutions, types of agencies and the allocation of responsibilities involved in provision and management of water and sanitation services should be subject to more scrutiny. There is likely to be more frequent involvement of private sector companies or public/private partnerships in the management of programmes and projects. Reforms of the institutional and regulatory frameworks for the provision and maintenance of services, increasing the efficiency of investment and cost recovery may also be the focus of programmes and projects.

A wide range of stakeholders, many with considerable vested interests, may need to be involved; especially if investments are required for establishing a preferred level of provision usually above that of basic services. These processes require a good participation supported by awareness raising for informed choices and decisions in order that solutions are not too technically sophisticated or costly; but instead are efficient and appropriate.

Typical municipal water services

- Wastewater treatment plant, taking into account industrial uses
- Municipal sewerage installations
- Regulation and review of costs and cost-recovery
- Re-orientation/retraining of municipal water authority staff
- Development of private sector partnerships in service management/extension
- Rehabilitation of existing systems, maintenance and leakage control

Water supply and sanitation project in Maputo

In 2005, Mozambique launched a water supply and sanitation project in its capital city, Maputo. The Greater Maputo sanitation provision is grossly inefficient, as in most cities in sub-Saharan Africa: most people do not have access to a hygienic toilet; less than a half of the population has access to adequate drinking water and 48% of the population lives in absolute poverty.

In this context the project aims to rehabilitate water supply infrastructure, reduce water loss and wastage and extend services to the outer fringes of the metropolitan area of Maputo. By 2014, the target is to raise the number of people served, particularly the most disadvantaged, from 670,000 today to nearly 1.5 million.

The project consists of an interesting blended financial mechanism with a mix of grants from the ACP-EU Water Facility, the Dutch government and French Development Agency, a loan from the European Investment Bank (EIB) and a strong national support from the Mozambican Government. The Maputo water supply project is implemented by the public asset-holding company FIPAG (Fundo de Investimento e Patrimonio do Abastecimento de Agua).

The project had four specific objectives:

(i) To increase installed production capacity to ensure constant supply to the 730 000 people presently connected to the existing water supply system (currently the system does not provide a 24-hour supply) and increase the population served by the international operator by 467 000 people in 2010 and by an additional 145 000 by 2014;

(ii) To improve the system's performance by reducing unaccounted for water (so-called unmetered water or UFW) from 60% to 40%;

(iii) To expand the water supply in the poorer areas on peri-urban areas with the support of small local private operators, in order to extend services to an additional 110 000 people;

(iv) To improve the promoter's capacity and financial sustainability, which will contribute to the improvement of water services in all cities under the promoter's responsibility.

The key positive socio-economic benefits will be the result of the improvement of services to the currently served population and the extension of services to areas currently not served. Without the project, the extension of improved services would be blocked and the deterioration of existing services expected, as installations are working beyond design capacity. To ensure the realisation of socio-economic benefits the project focuses on meeting the populations' needs, with respect to

-the selection of service and income levels to respect affordability,

-the encouragement of participatory management structures, especially for shared water supply services (standpipes), strengthening the sense of ownership in local communities.

A key impact of the project is the reduction of the time spent by families on long distance water collection. Water collection is generally the responsibility of women and young girls; the project should free time for them to engage in productive or educational activities generating substantial additional wealth and increasing the likelihood of girls receiving formal education. The project will also create opportunities for women to participate in water committees and other community-based organisations and so contribute to a fairer gender balance in the management of water services.

A second significant impact is on health. Access to safe water is a dominant factor in the A second significant impact is on health. Access to safe water is a dominant factor in the reduction of cholera and other water-borne diseases. In Maputo, studies show there are cholera cases every year and an epidemic every three years. In peri-urban areas there are an average of 3 000 cholera cases per annum, while diarrhoea cases are estimated at about 63 000 per annum. The project is expected to significantly reduce morbidity from these diseases.

The economic analysis of the project, including consideration of direct and indirect benefits (tariffs paid by people for different services in different areas, as well as the value of time saved, of reduced morbidity from waterborne diseases, and of induced economic activity) shows a satisfactory and robust Economic Internal Rate of Return according to the EIB.

Adapted from: EIB, 2006.

1. 1.6 Water and International cooperation

International development cooperation

A number of concerns, in addition to those surfacing as a consequence of the Water Decade, have subsequently exerted a significant influence on international thinking about water. Some - such as environmental stresses, water scarcity, climate change and potential conflict - have already been touched upon. Others need to be mentioned here in the context of a path to a new international consensus on water.

In recent years, economic, environmental and 'common good' perceptions of water resources have come to assume greater importance. Concerns over poverty reduction, democracy and human rights have increased the emphasis on equity and participatory approaches. According to the Development Assistance Committee (DAC) definition, aid to water supply and sanitation includes water resources policy, planning and programmes, water legislation and management, water resources development, water resources protection, water supply and use, sanitation (including solid waste management) and education and training in water supply and sanitation. Aid for water supply and sanitation has increased since 2006; for the period 2006-2007, the DAC countries' bilateral annual aid commitments to the water supply and sanitation sector was of USD 4.7 billion. The bilateral aid to water increased at an average annual rate of 19% for the period 2002-2007 whereas multilateral aid rose over the same period in about 11% annually.

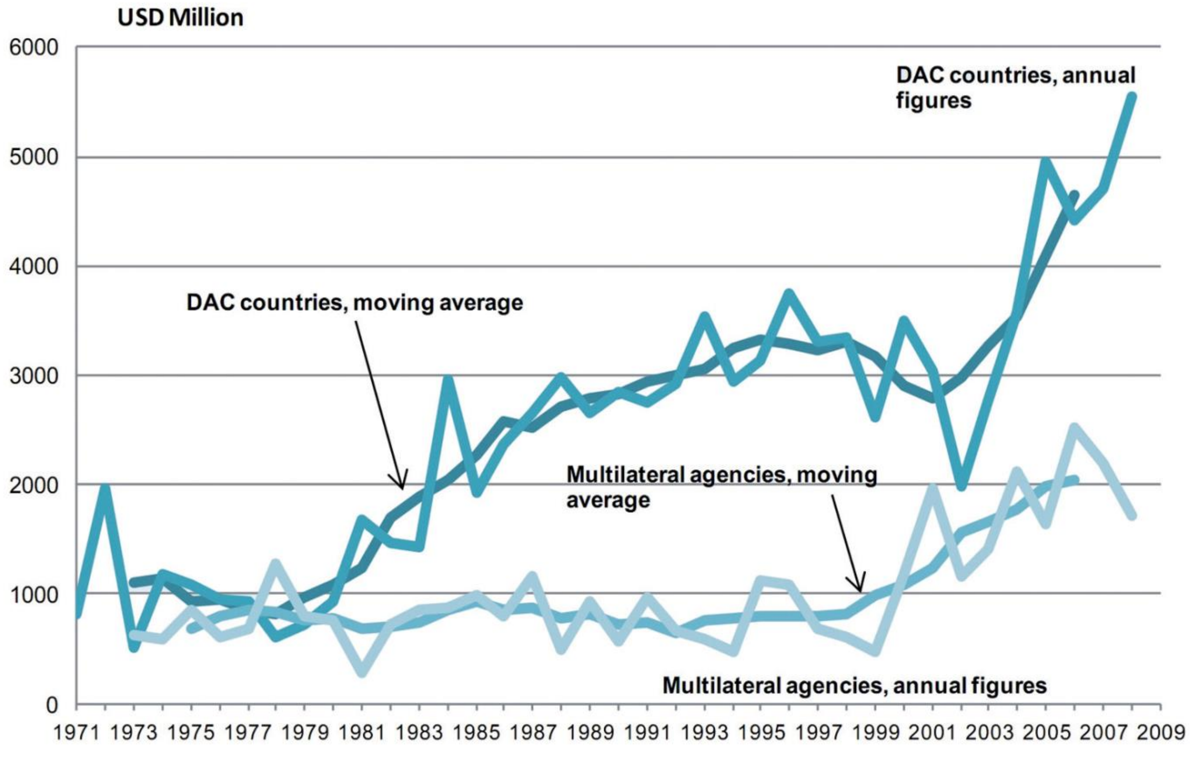


Figure 10 Trends in aid to water supply and sanitation 1971-2009, 5-year moving averages and annual figures of commitments, constant 2008 prices.
(Source: OECD-DAC, 2010)

The poor achievement of objectives and goals within development cooperation, coupled with similar shortfall of results associated with structural adjustment programmes, prompted a systemic analyses of the context and modalities of development cooperation overall. The need to improve efficiency and cost-effectiveness in the application of Official Development Assistance (ODA) resources, both from the perspective of intended beneficiaries and from that of donors, became compelling for pragmatic reasons (such as financial) as well as an evolving geopolitical and ideological framework.

The Paris Declaration of 2005 is one of the major steps in recent years to address these ODA shortcomings. It was endorsed by over one hundred Ministers, Heads of Agencies and Senior Officials who committed their countries and organisations to increase efforts in harmonization, alignment and managing aid for results, with a set of actions and indicators to be monitored (OECD, 2005). It laid down a practical, action-orientated roadmap to improve the quality of aid and its impact on development. The Declaration is organized on five principles:

- ownership,
- alignment,
- harmonization,
- managing for results,
- mutual accountability;

It contains twelve indicators to monitor progress in achieving results and its aim is to create stronger mechanisms for accountability.

Transboundary cooperation

The principle of Integrated Water Resources Management has led to the promotion of the river basin as the logical geographical unit for its practical realisation; notably by the EU, the World Bank and other Development Funding Agencies. The river basin offers many advantages for strategic planning, particularly at higher levels of government, though difficulties in their application should not be underestimated. Groundwater aquifers frequently cross catchment boundaries and, more problematically, river basins rarely conform to existing administrative entities or structures. To attempt to address these challenges, a number of river basins around the world are the focus of river basin organisations whose membership is usually composed of by a wide range of stakeholders from different sectors, levels and geographic representation. Although river basin organisations should not be seen as a panacea, they do provide a sound geographical basis for integrated water management.

In many parts of the developing world, major rivers traverse two or more countries and their transboundary character complicates the practicalities of river basin management. Water sharing between states which host major rivers such as the Ganges, Nile, Jordan and Mekong is an important political and strategic issue for the states concerned. Historically there are numerous examples of projects designed to meet national objectives but which ignore their impacts on the river basin as a whole; not acknowledging potential conflicts of the needs of downstream users other national or sub-national states. The 1997 Convention on the Non-navigational Use of International Water Courses provides a basis for establishing common user rights and obligations along transboundary rivers and a framework for the management of international river basin systems (UN, 2005). The importance of mechanisms for promoting river basin cooperation is now widely recognised as is illustrated by the creation of the International Network of River Basin Organisations (INBO) forum for international transboundary policies.

Approximately 276 transboundary river basins were listed worldwide, which provide water to 3 billion people in 148 countries. These rivers cover around 45% of the globe's surface and represent 60% of the world surface water. Another 445 transboundary aquifers feed approximately 2 billion people, that is 80 % of the world population depending on shared water resources.

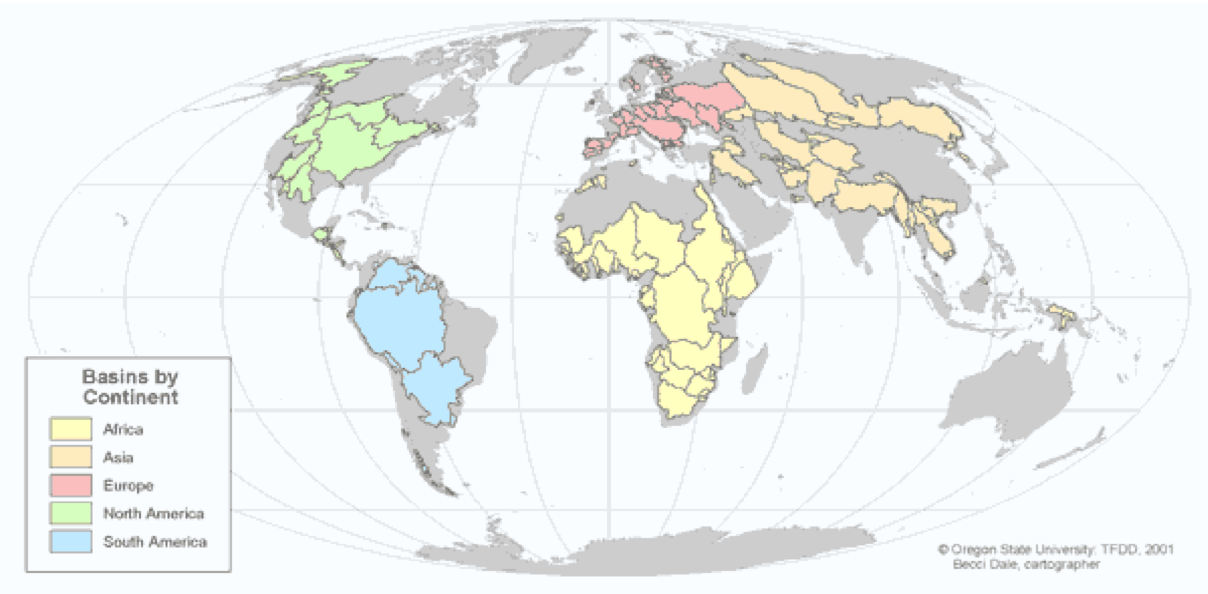


Figure 11 World transboundary river basins,
(Source: Oregon State University, 2001)

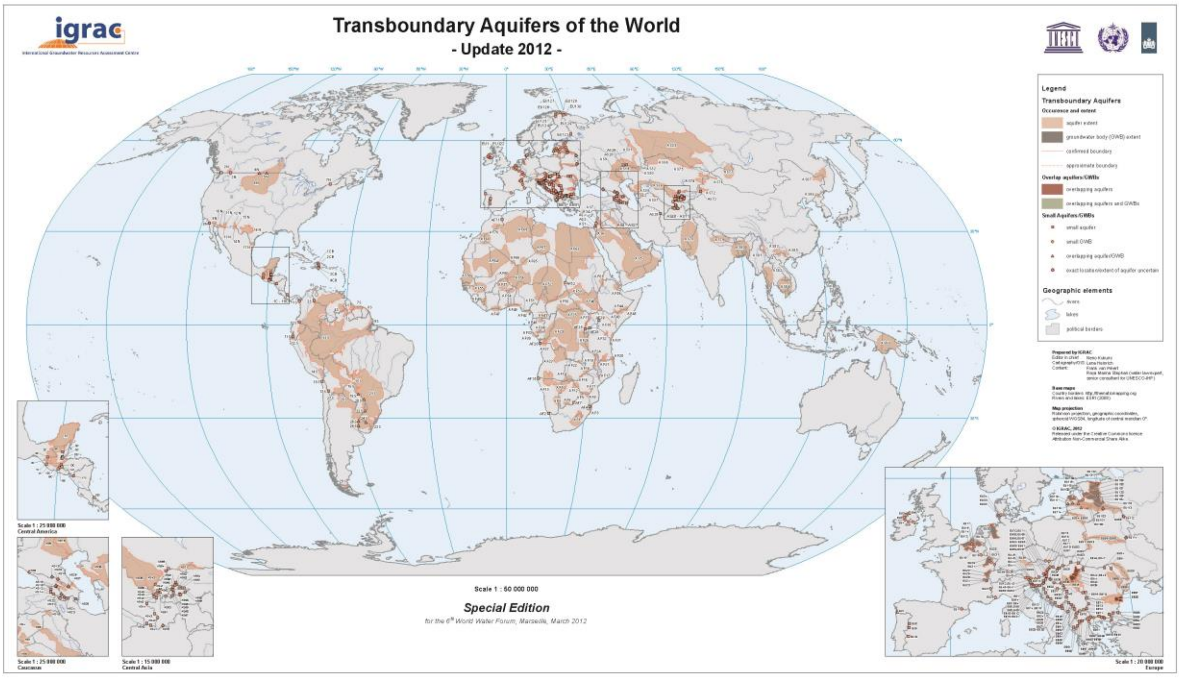


Figure 12: World transboundary aquifers,
(Source : Igrac, 2012)

Today, these basins have not yet all been subject to a basin management approach. 30 % of rivers and less than 5 % of aquifers have already implemented projects or at least created an institutional cooperation. Cooperation among the riparian countries to better manage water resources and the environments in these basins, in the interest of all users and all sectors, is becoming imperative as the pressure on water resources is increasing because of the global changes, which are intensifying. There is a need for coordinated water development at river basin scale and for the implementation of river basin organisations.

River basin organisations provide a mechanism for ensuring that land use and needs are reflected in water management - and vice versa. Experience has varied dramatically in the ability of these organisations to achieve IWRM. Their functions vary from water allocation, resource management and planning, to education of basin communities, to developing natural resources management strategies and programs of remediation of degraded lands and waterways. They may also play a role in consensus building, facilitation and conflict management

The form and role of a river basin organisation is closely linked to its historical and social context. Key characteristics of sustainable river basin management are:

- Basin-wide planning to balance all user needs for water resources and to provide protection from water related hazards;
- Wide public and stakeholder participation in decision-making, local empowerment;
- Effective demand management;
- Agreement on commitments within the basin, and mechanisms for monitoring those agreements;
- Adequate human and financial resources.

Experience shows that all RBOs evolve with time and we see their composition and duties adapted from time to time reflecting the real needs of the moment.

Successful river basin organisations are supported by:

- An ability to establish trusted technical competencies;
- A focus on serious recurrent problems such as flooding or drought or supply shortages, and the provision of solutions acceptable to all stakeholders;
- A broad stakeholder involvement, catering for grassroots participation at a basin-wide level (e.g. through water forums);
- An ability to generate some form of sustaining revenue;
- The capacity to collect fees, and attract grants and/or loans;
- Clear jurisdictional boundaries and appropriate powers.

Typical transboundary water activities:

- Transboundary diagnostic analysis
- Data exchange through the implementation of information systems
- Signature of transboundary agreements
- Common water infrastructure such as waste water treatment or dams
- Educational materials
- Capacity building activities
- Public consultation

Following is an example of a well-established river basin commission:

The Mekong River Commission

International aid agencies first direct involvement in international river basin goes back to 1957 with the UN implication in the creation of the Mekong Committee. This regional committee was set up by the governments of Cambodia, Lao PDR, Thailand and Vietnam. Its aim was to jointly manage the shared water resources and economic development of the Mekong River through scientific investigations and some water resources projects. It managed through all these years to promote international dialogue and cooperation in a region characterized by war.

Today's Mekong River Commission, although not exempt from criticisms, represents a clear example of a shift in water basin planning and international relations. China and Myanmar although not full members of the commission, are considered as dialogue members giving voice to all the countries of the Mekong River basin.

Since 1995 the Commission implemented many programs such as the Basin Development Plan, the Water Utilization Program, the Environment Program, the Flood Management Program, the Capacity-Building Program, the Agriculture, Irrigation and Forestry Program, the Fisheries Program, the Navigation Program and the Water Resources and Hydrology program.

This basin organization initiated an institutional framework for integrated watershed management and for a regional cooperation on water resources providing a useful model for other international basin. Moving towards a new level of maturity, in early 2011 the Commission endorsed two key strategies, the Integrated Water and Related Resources Management (IWRM)-based Basin Development Strategy, and the 2011-2015 Strategic Plan, that shape a more comprehensive and new direction for the Agency.

The IWRM-based strategy provides regional and transboundary perspectives for basin development planning, representing over a decade of collaboration between Member Countries on their shared understanding of the river's opportunities and risks associated with development.

Meanwhile, the strategic plan for the 2011-2015 period will support the implementation of this strategy as well as providing a platform for the MRC's plan to decentralize core functions of the MRC Secretariat to the national level.

The hydrological, environmental and political implications of China's intent to construct dams on the upper Mekong River and the 12 to be built planned Dams in the lower Mekong River are the current challenges that the Commission will have to face in order to prove how basin cooperation can be successful with regard to water management.

Adapted from: Jacobs, 2002 & The Mekong River Commission Vision, 2011

2.0 WATER MESSAGE GAME

This game is an application of the game theory. It has been developed by UNESCO PCCP programme. It shows the importance of the politician decisions on a water body and the difficulties to build trust among stakeholders.

Divide a group into two sub-groups. These two groups will communicate with each other through messages written on paper, which are exchanged simultaneously through a neutral facilitator. In a total seven rounds, messages are exchanged.

No other means of communication are allowed, except after rounds 3 and round 6, when each group may decide to negotiate with the other party and nominate a negotiator. However, this negotiation can only proceed if both groups decide to negotiate.

The messages that are exchanged concern the use of a shared water body such as a lake or an aquifer. Each message round starts afresh, and is independent of any message sent earlier. In explaining the message game below, the two groups are called "Us" and "Them". For each round of negotiation, we send a message: either XX or XY or YY.

Possible messages:

XX = We invest fully in water supply infrastructure (e.g. dams), as a result our water use may increase to the full; and therefore our economic growth will be high.

XY = We do not invest in water supply infrastructure (e.g. dams), as a result the increase of our water use is constrained, and therefore our economic development.

YY = We invest moderately in water supply infrastructure (e.g. dams), but we also invest in water demand management; our water use may increase moderately but securely; and therefore our economic development.

Each group message (either XX or XY or YY) is combined with the message of the other party (them). These two messages form a combination. The combined result of our and their messages (Us and Them)are:

Message Score Explanation

Us Them Us Them

XX XX = (-20) (-20) We both lost: we both invested heavily, our water demand increased, but there is not sufficient water.

XX XY = +20 (-20) We invested, got our water and achieved economic growth; they lost as we took all the water and they did not invest.

XX YY = +40 (-40) We invested and got even more water, because they also invested in demand management; they lost much because despite of their investments they had little water.

XY XX = (-20) +20 We lost as they took all the water and we did not invest; they invested, got their water and achieved economic growth.

XY XY = 0 0 We both gained nothing.

XY YY = +20 (-20) We won, because we did not invest yet we gained some extra water because they invested in water demand management; they lost: they invested while we took their water.

YY XX = (-40) +40 We lost much because despite of our investments we had little water; they invested and got even more water, because we also invested in demand management.

YY XY = (-20) +20 We lost: we invested while they took our water; they won, because they did not invest yet they gained some extra water because we invested in water demand management.

YY YY = +20 +20 We both invested in supply schemes and demand management, we both achieved moderate but sustained economic growth; therefore we both won.

Summary of scores

To determine our points for each transaction, combine the two messages and refer to the table below.

Message		Score	
US	THEM	US	THEM
XX	XX	-20	-20
XX	XY	+20	-20
XX	YY	+40	-40
XY	XX	-20	+20
XY	XY	0	0
XY	YY	+20	-20
YY	XX	-40	+40
YY	XY	-20	+20
YY	YY	+20	+20

			OUR RESULTS		THEIR RESULTS	
Round	Our message	Their message	Our result this round	Our cumulative score	Their result this round	Their cumulative score
No. 1						
No. 2						
No. 3						
No. 4			*× 5*		*× 5*	
No. 5						
No. 6						
No. 7			*× 10*		*× 10*	

Conclusion:

As a first conclusion, the professor may ask the participants to share *their* first *impression.*

- *What did they retain?*
- What was difficult?
- What they would do differently?

Then the professor can highlight four points:

- **The interpretation of the objectives:**

No directive has been clearly express at the beginning of the game. It's interesting to analyse the different position took by the group to either protect the water body or focus on economic growth.

- **The interpretation of the messages**

The groups exchanged piece of paper with the chosen message: XX, XY or YY. No further explanation was allowed on the paper. The groups may have misinterpreted the decision taken by the others.

- **The importance of communication**

Communication is key in a good negotiation. The two negotiation opportunities are important moment for the groups to compare their vision. It's interesting to analyse the decision taken after the negotiation. How communication influenced the groups?

- **The value of trust**

It is difficult to make a deal if there is no trust between counterparts. It is a key success factor for water negotiation. How the groups have created a mutual confidence and constructive cooperation?

3.0 IWRM PRINCIPLES

3.1 Exercise to introduce IWRM concepts

Form:

- Groups of 6 seated at different tables
- Group work facilitation, 1 facilitator per group who take notes on discussion
- One big wall space for presentation with headings

Professor responsibilities:

- Directions for group work
- Interpretation/leading discussion on results

Process (30 min):

- Brainstorm in groups on what IWRM means to them (25 min)
- Each group gets cards and marker pens
- The group writes key words and concepts that they feel are part of or explain IWRM on cards (5 min)
- if no discussion one facilitator will prompt groups to think of the values, principles, processes and purpose of IWRM

Output/Presentation/Reporting (30 min):

- One group is asked to post their cards on a wall. Groups then post their cards in clusters according to whether it is a value/principle, foundation/structure, process or purpose of IWRM (or other).
- Groups should be instructed to post cards close to similar cards posted by other groups.
- Facilitator interprets/presents results examining the values/principles, foundations/ structures, processes and purposes of IWRM. This should flow into the presentation on IWRM that follows on from working session.

3.2 Introduction to IWRM

IWRM is an empirical concept, which was built up from the on-the-ground experience of practitioners. Although many parts of the concept have been around for several decades - in fact since the first global water conference in Mar del Plata in 1977 - it was not until after Agenda 21 and the World Summit on Sustainable Development in 1992 in Rio that the concept was made the object of extensive discussions as to what it means in practice. The Global Water Partnership's definition of IWRM is widely accepted. It states: 'IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.'

The basis of IWRM is that the many different uses of finite water resources are interdependent. High irrigation demands and polluted drainage flows from agriculture mean less freshwater for drinking or industrial use; contaminated municipal and industrial wastewater pollutes rivers and threatens ecosystems; if water has to be left in a river to protect fisheries and ecosystems, less can be diverted to grow crops. There are plenty more examples of the basic theme that unregulated use of scarce water resources is wasteful and inherently unsustainable.

IWRM strategies are based on the four Dublin Principles presented at the World Summit in Rio de Janeiro in 1992:

1/ Fresh water 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 is a public good and has a social and economic value in all its competing uses.

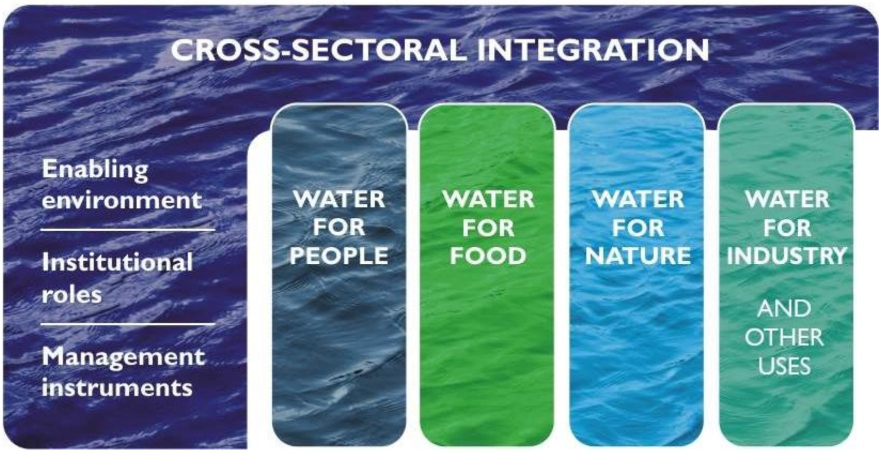
While the core principles provide a basis for water-related policy, they are relatively remote from practitioner realities and offer little guidance for resolving the dilemmas and difficulties experienced in their practical implementation. Therefore, as part of the development of a strategic approach, and to aid administrative management and implementation of water-related policy, the Water Project Toolkit presents a series of policy principles applicable at the programming and project level. These are as follows:

- Institutional and management principles
- Social principles
- Economic and financial principles
- Environmental principles
- Information, education and communications principles
- Technological principles.

These headings reflect the wider range of issues essential for effective water resources management. Many of these principles are inter-related and interlinked.

Sound water resources management affects development activity in economic, productive, infrastructural and social sectors. Concerns outside an immediate programming and project environment – such as sustainability of the resource over the long term, protection of water-dependent ecosystems, sustainability of service management, and enhancement of the wider urban or rural environment – need to be taken into account. The positive implications of adopting a broader strategic approach to water cannot be underestimated. More governments are implementing a range of practical changes which are integrated and respond effectively to the core principles of the new consensus. Activities at the macro-level (integrated water resources management, water policies, legislation, and institutional change) and at the micro-level (user participation or community-level operation and maintenance) are given more weight proportionately compared to technical activities. Technological issues such as construction, which previously dominated programme strategies, still remain critical components but are now regarded as one set of considerations among many.

Figure 13: IWRM and its relation to sub sectors



(Source: GWP, 2010)

The policy principles are cross-cutting and applicable to all types and aspects of water-related activities – from surveys, to human resources development or construction of installations – whatever their physical, social or economic setting. Such principles form a foundation for a strategic approach that will facilitate clear thinking on objectives and actions.

Integrated Water Resources Management (IWRM) is an iterative, evolutionary and adaptive process with no definitive start and end point. Implementing IWRM processes means working in cycles that can be compared to a management Cycle. UNESCO conceptualized this process as a 'spiral' (figure 13), which permits immediate action, builds understanding, develops local capacity and creates ownership.

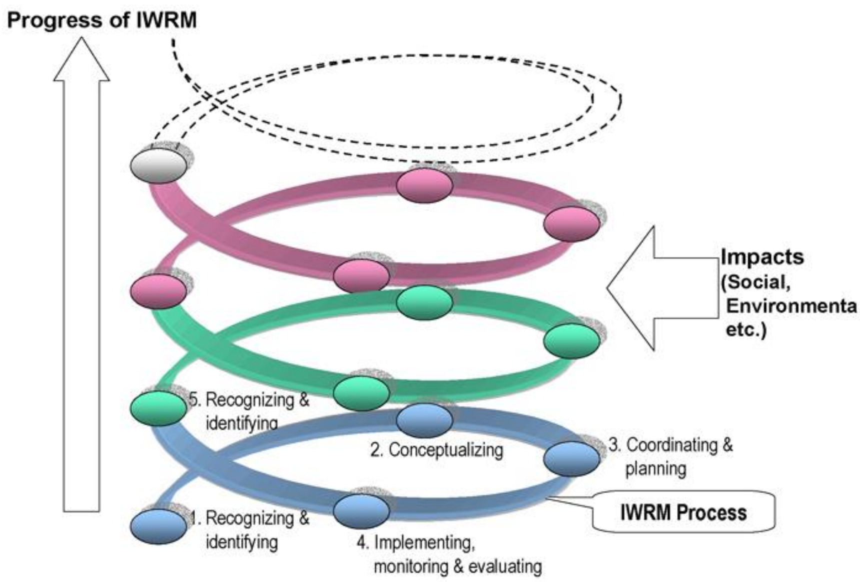


Figure14: IWRM Spiral concept model,
(Source:Unesco 2009)

3.3 Institutional and management principles

- **Roles of government and official bodies at all levels should be clearly defined and areas of responsibility officially established.**
- **The structures and systems of management should be designed in such a way as to facilitate involvement by the responsible authorities at different levels.**
- **Involvement of user organisations and the private sector, public – private and/or public/public partnerships should be encouraged.**
- **Ongoing capacity building is needed within institutions and for participant groups at all levels.**

Roles of government and official bodies at all levels should be clearly defined and areas of responsibility officially established

Management and service delivery functions need to be clearly identified and institutional responsibilities demarcated. Governments should provide a sound legal and policy framework for water resources management and facilitate service extension and provision. Governments are responsible for establishing and overseeing regulatory bodies; these bodies must be independent, transparent, accountable, and empowered to enforce regulations. All uses of water (environmental as well as consumption), and the roles of institutions involved in managing resources and providing services, need to be enshrined in law. Service and quality criteria need to be similarly established within a regulatory framework.

At national level, governments have a responsibility to develop an integrated water policy, meeting the needs of the various users within the limits of available financial and environmental resources. While financial resources can be quantified with financial tools, the geographical and hydrological nature of water resources needs to be taken into account; catchment areas have been adopted as the most effective scale of management for overall water resources (surface, subsurface and recharge).

Effort should be made to verify that water policy is coordinated with other policies that have implications for water use – such as those for agriculture, health, industry, energy, environment and urban development. To this end, a system of co-ordination among those responsible in the different sectors at national level is needed. An effective coordinating body will enable competition between water uses to be resolved, in accordance with the national policy and agreed water resources development plan. While such coordinating bodies are not easily created within government structures or administrations, river basin organisations have been used as the platform to facilitate a coordinated approach to management.

One model for achievement of an integrated strategy the Sector Wide Approach (SWAp), which provides a framework for collaboration, harmonization and analysis that promises to lead to more effective implementation and delivery of water services and better integrated management of water resources. SWAp aims to deliver these benefits by providing a methodology for assessing the sector, which systematically considers all the interrelated factors that influence performance and sustainability. SWAp is wide because it recognizes that success depends on a coordinated response where no single actor is likely to be able to deliver all that is needed. But an efficient SWAp is no wider than it needs to be. SWAPs have been slow to develop in the water sector, since the sector is more complex than other sectors such as education and health where the sector wide approach is more developed. At the same time a successful sector wide approach brings many benefits to the water sector precisely because the complexity of the sector requires multi-stakeholder dialogues, collaboration and coordination, and participation by all stakeholders including the state, the private sector and civil society

Some lessons from the water sector SWAp in Uganda

While there is still room for improvements in rural water and sanitation services in Uganda, it is worth considering some of the key factors that led to a relatively successful transition to a SWAp:

- The Ministry of Finance led a process of achieving better targeting of sector investments, by developing sector budgets based on government priorities and using good sector performance monitoring information.

- Donors were keen to reduce transaction costs and harmonize their sector funding, through a basket fund, coordinated by Government.

- The Danida RUWASA 2 project in a number of districts with institutional funding for the districts was in effect a pilot, learning what was required at district level for a nationwide SWAp; the same project also utilized the comparative advantages of NGOs and the local private sector.

- Increased capacity in national water sector organisations to do the strategic planning for decentralisation of water and sanitation and the design and implementation of the SWAP.

- Establishment of a national Sector Working Group who were willing and able to coordinate sector performance monitoring Progress has since been hampered by a lack of capacity at district level, which has been in part due to the creation of increasing numbers of districts.

Source: Note prepared by Kevin Sansom, Delta Partnership.

Example of a water SWAp in Malawi

The objective of a Sector Wide Approach (SWAp) is for the Government of Malawi and its partners to work in a coordinated way regarding policy, strategy and spending. It also increases coherence between spending and results. In practice this means that there should be better coordination between the sub-sectors in terms of financial allocations, as well as spending in the districts. The Irrigation, Water and Sanitation SWAp is one of 16 sector working group that are developing SWAPs in Malawi. The sector working groups are arranged in line with the 5 themes under the Malawi Growth and Development Strategy (2006-11).

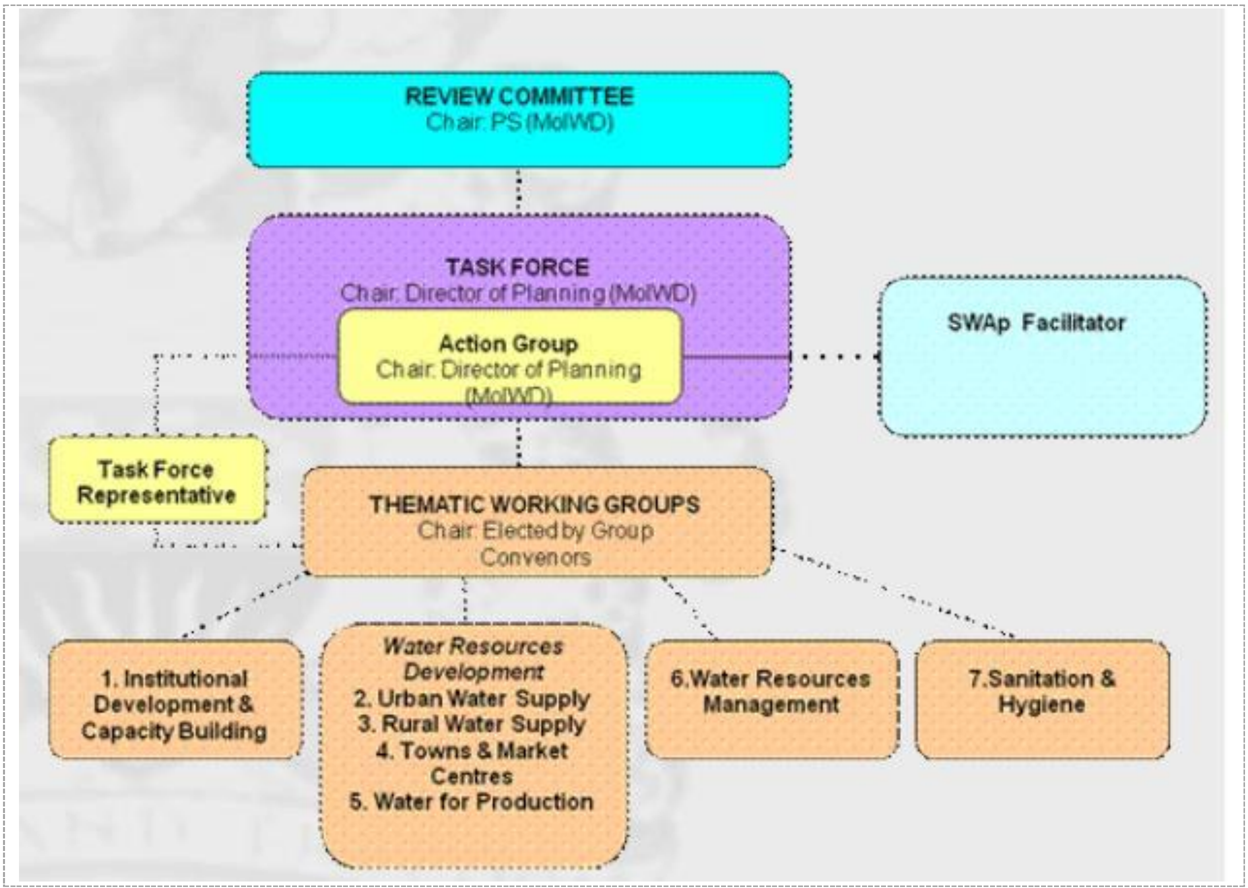


Figure 15 Water SWAp Governance Structure in Malawi

Many countries still implement water codes or water legislation that are outdated and are not always relevant to the challenges of today. They often do not take into account integrated water resources management and conservation, nor have they always been established through a participatory process. New laws, ratification and implementation of national and even international agreements coupled with enforcement procedures are required. As far as possible, they should be formulated permissively rather than restrictively to enable application without undue cost and administrative burden. One approach to reduce these burdens is by decentralizing the various types of decision-making to the lowest, most appropriate, administrative tier. However, even though faced with challenges, costs and burdens, common references and minimum standards are still required and should always form the basis of new legislation, regulation and codes.

The structures and systems of management should be designed in such a way as to facilitate involvement by the responsible authorities at different levels

Participation by all stakeholders is essential for successful water management and usage. Structures and practices of the responsible authorities therefore need to be designed to facilitate participation of the various categories of users including all major groups (equity mainstreaming) as follows:

- Water companies,
- Industries,
- Small and Medium Enterprises,

- Farmers,
- Domestic consumers,
- Energy utilities,
- Fisheries organisations,
- Transport organisations,
- Nature conservation organisations

The contribution of civil society organisations who represent cross-cutting categories such as gender or education must also be included.

Responsibilities for water-related services and resource management need to be decentralized to the lowest appropriate administrative level according to the concept of subsidiarity; this allows the contributions of the various parties to be optimized. However, the necessary tools, capacity development incl. training and funds must first be allocated so that the resources are available for responsibilities to be fulfilled. Where responsible bodies have centralized and hierarchical command structures, they are often inadequately geared to consultation and interaction with stakeholders, especially users down to the community or household level. In such cases, organizational transformation may be necessary. On the one hand, functional responsibilities are best devolved to officials and bodies close to the realities of the situation, including local authorities, private and public companies and NGOs/ CSOs able to facilitate participation of users in decision-making, planning etc. On the other hand, the role of the public authority as regulator, facilitator and moderator is to develop an organizational culture that is outward-looking, to facilitate timely communication with all stakeholders. Therefore it is important that the division of responsibilities is well thought out and that decentralization does not become an automatic option that results in divesting central authorities of core responsibilities. The need and added value of capacity building to address administrative challenges is often a strong complement to redesigning management strategies for the central level and outwards.

Involvement of user organisations and the private sector, public – private and/or public/public partnerships should be encouraged

Partnerships with the private sector and or/public / communal sectors need to be encouraged and facilitated; this is especially relevant as government authorities decentralize progressively their responsibilities for the provision of services. In this context, the private sector is deemed to include informal or civil society groups involved in water services or management, such as Water User Associations, Committees or Farmer Associations.

The roles of the private sector actors will vary according to social, economic and environmental circumstances, but they should all be subject to regulation. A suitable relationship between public and private sectors needs to be defined which promotes the efficient operation of the facilities and collection of user fees while at the same time guarantees access and affordability to all users. Delivery of services and construction of installations may be organised through service providers which, whether publicly or privately owned and operated, can be autonomous, but still supervised and regulated by authority. At

the same time, vulnerable populations – the under-served and underprivileged – need to be protected from exploitation by service providers operating largely for profit, since this sector of the population have little or no direct (consumer) influence. The principles of transparency, integrity, solidarity and equity are effective where all people and stakeholders are aware of their rights while at the same time acknowledge their responsibilities. Access to information allows users to make informed choices and to more effectively participate in the governance processes of water management and services.
Government-run water authorities and utilities companies can facilitate the transfer of technology to a wide range of private sector actors by promoting the development of local water supply, wastewater disposal and irrigation manufacturing and service industries. These industries can be large or small-scale and able to cater to the needs either of major publicly financed schemes or micro-projects and private consumers.

Public-private partnerships (PPP) aim to combine the respective strengths of public and private partners. PPP projects are planned, financed and implemented jointly. The Private sector involvement is expected to achieve development policy objectives via the introduction of technological innovations, job creation, and improvement of production or delivery processes and thus contribute to the Millennium Development Goals. The Public sector involvement optimally maintains ownership and responsibility to ensure water services are equitably delivered and transparently managed. PPP schemes have faced some setbacks in the recent years mainly due to a lack of governance in the PPP process, including a lack of transparency compounded by unclear definitions of roles and responsibilities.

The Public-Public Partnerships (PUPs) involve two or more public authorities or organizations collaborating to improve the capacity and effectiveness of one partner in providing public water or sanitation services. PUPs should not be considered as an approach which is opposed to PPPs but rather as an alternative for achieving improvements in water management.

Lesson learnt from Constanta Water and Wastewater Project, Romania

Affordability constraints require that an imaginative approach is taken to tariff-setting and reliable economic and customer information to allow options for tariff structures to be evaluated, using financial modelling.

-PPP agreement lengths must balance financial returns to investors, customer tariffs, investment programmes, and risk allocation factors.

-Legislation and election cycles should be considered early in project planning.

-Local authorities may have to be prepared to support legislation enabling PPP solutions.

-Selection and award criteria must be clearly formulated and emphasize desired outputs.

-Commission funded investments in the public sector are capable of being converted into PPP programmes provided the Commission is included at an early stage and its funding criteria are adequately addressed.

-Where there is no complete regulatory framework and the concession is regulated by contract, there is an inherent risk that political imperatives, for instance price pressures, conflict with the principles of good regulation founded on proper process.

-The dual role of the public partner (County) as shareholder in New Co and as public authority signing the contract with the concessionaire must be carefully monitored

Source: EC Resources book on PPP case studies, Jun 2004

Ongoing capacity building is needed within institutions and for participant groups at all levels.

Capacity building, especially the development of human resources, the enhancement of skills, the adoption of up-to-date thinking, and improvement of the knowledge base, are needed in many institutions responsible for water resources management and services. Capacity building should extend to all levels of an organisation and to as wide a selection of stakeholders as is necessary. If a more active role in service design and implementation is envisaged for water users, the capacity of intermediary bodies, such as NGOs and local councils, may also need to be enhanced. This can include training in technical and organizational activities which allows actors to be able to make more effective decisions in management or maintenance as required.

An emphasis on 'software', as opposed to 'hardware', components of water-related projects requires that an orientation towards capacity building in these areas should be built into project design. Interpersonal skills such as communication, negotiation and leadership, as well as knowledge of project management, or environmental and public health activities are equally as important as the functional skills relating to building and managing installations. With the right encouragement and training, engineering staff can adopt more of a partnership approach to service delivery rather than a proprietary attitude towards schemes. However it is also important to understand that for capacity building on skills and knowledge to succeed, there will be required a minimum of resources and materials, or hardware, in order to realize the benefits of these skills. The point of balance between hardware and software is often in a process of movement and requires regular review by the management to ensure the best combination of the two.

Malawi: Ensuring sustainability in IWRM processes

Description

Development interventions requiring policy changes take time. Yet, while a development intervention is on-going, the people involved often change. This poses the risk of losing the experiences and lessons acquired along the way. To ensure sustainability and avoid the loss of knowledge when new governments are elected and key decision and policy-makers change, specific steps are needed to strengthen institutional memory over time. The IWRM process needs to be institutionalized among relevant organisations and across government departments.

Actions taken

The Malawi Water Partnership solved the issue of institutional memory by involving as many high-level decision-makers as possible. Early on in the process the Malawi Water Partnership organised awareness raising workshops for all senior civil servants which are the permanent secretaries in charge of water related sector ministries. Each of these permanent secretaries then briefed their ministers on the initiative.

As a result of this approach, the national IWRM Programme benefited from sustained institutional memory at higher political levels. When the minister in charge of water was changed, there was no loss of knowledge as the new minister already knew about the programme. For example, in one case the permanent secretary responsible for gender affairs participated in an IWRM planning workshop arranged by the Malawi Ministry of Irrigation and Water Development with support from the Malawi Water Partnership. A few weeks later the President appointed the permanent secretary from the Ministry of Gender as the new permanent secretary for the Ministry of Water. When a delegation from the Malawi Water Partnership went to see her to discuss the IWRM programme, she confidently supported the initiative, with which she was already familiar.

Lessons learnt

Institutional memory enhances the sustainability of development interventions during and after initial development efforts. Therefore a comprehensive and coherent plan to ensure institutional memory should be developed and implemented at the start of an IWRM Planning process.

Source: GWP, Toolbox case studies

3.4 Social principles

- **A sufficient supply of water and an adequate means of sanitation are basic human needs to which everyone should have access**
- **Users have an important role to play and their involvement should be fostered via a participatory approach**
- **Gender implications should be examined and taken into account at all stages of the planning and implementation process**
- **Mainstreaming HIV/AIDS in the water sector**

A sufficient supply of water and an adequate means of sanitation are basic human needs to which everyone should have access

Water is a fundamental social resource since it is essential for human health and life itself. It is also an economic resource and a fundamental component of economic activities such as agriculture, fisheries or industrial activity, upon which the populations' livelihoods depend. Water shortages or excesses, drought and flood-prone environments have profound implications on these activities and thus for human well-being. Poverty reduction, quality of life and equity considerations therefore need to be seen as priorities in the conceptualization and planning of activities relating to water.

The lack of safe water and sanitation in many poorer parts of the developing world is a cause of continuing concern especially for those un-served or under-served and who are most at risk from water-related diseases. It is therefore important to prioritize the extension of basic water and sanitation services to the population in both rural and urban areas. Sanitation is often neglected, although it is as important for health impacts as is access to clean water. Equal priority should therefore also be given to sanitation, whether it is community, domestic, or waste water management, an equal emphasis with water supply in the provision of essential services.

Definitions of access to sanitation and water (i.e. distance to the supply and personal security) and adequate coverage (i.e. per capita served) need to take into account the type of the installations and their use, as well as willingness and ability of users to pay. The ability of households to access water in sufficient quantity for their needs and to have access to improved sanitation are important determinants of their capacity to adopt hygienic behaviour and participate in measures for controlling water-related diseases.

The management of water as a collective/ public good is often an integral part of community life and is deeply embedded in social, cultural and livelihood strategies and behaviours. An understanding of attitudes and practices regarding water use, human waste and solid waste disposal at the household and community level, whether for economic or domestic activity, is critical to formulation of all strategies and activities intended to provide sustainable and appropriate services.

A critical review of domestic water supply schemes should pay attention to the quality of water/water safety at the point of supply, in the method of transport and finally for storage and use at the household or user level in the context of domestic hygiene. WHO water quality standards can be applied at all points of the collection, distribution, storage and use process.

Presentation of the WHO Water quality Guidelines

One of the main roles of WHO is to establish international norms to protect human health. Since 1958, as part of its activities on drinking water and health, the Organization has published – at around ten-year intervals – several editions of International Standards for Drinking water and subsequently, the Guidelines for Drinking-water Quality.

The basic and essential requirements to ensure the safety of drinking water are a "framework" for safe drinking water, comprising health-based targets established by a competent health authority, adequate and properly managed systems (adequate infra-structure, proper monitoring and effective planning and management) and a system of independent surveillance.

A holistic approach to the risk assessment and risk management of a drinking-water supply increases confidence in the safety of the drinking water. This approach entails systematic assessment of risks throughout a drinking-water supply—from the catchment and its source water through to the consumer—and identification of the ways in which these risks can be managed, including methods to ensure that control measures are working effectively.

In support of the framework for safe drinking water, the Guidelines provide a range of supporting information, including microbial aspects, chemical aspects, radiological aspects and acceptability aspects.

Users have an important role to play and their involvement should be fostered via a participatory approach

The involvement of users in water management is central to the development of water and waste management services. This can include:

- The provision of community labour in the construction of schemes,
- Decision-making about siting installations,
- Collection of tariffs,
- Operation and maintenance.

In low-income areas or small population groups such as villages, this involvement is likely to be through community-based organisations such as water user or management committees.

The extent of community involvement in the management of water supply or sanitation services will vary with the context, the technical design of the installed systems, and the resources available at community level. Both the capacity and the limitations of community involvement need to be taken into account. Long-term sustainability of facilities in low-income communities cannot be guaranteed without a strong sense of community responsibility and ownership.

Implementing a community-based approach involves training of field and administrative staff in participatory techniques, gender and equity and adopting a flexible approach to project implementation. Local knowledge – traditional or otherwise - cultural values, indigenous practices, lifestyles and habits relating to water management and their application need to be analysed, respected and, where possible, supported.

Egypt: The role of water users' associations in reforming irrigation

Description

Egypt's water resources are severely constrained. This calls for increasing the water use efficiency by improving irrigation management practice, as the agriculture sector is the main user of water resources. Much of the irrigation infrastructure is elderly and in need of rehabilitation. The irrigation improvement program (IIP) is one of the large-scale projects to help Egypt to sustain its ambitious development plan. The program involves a combination of technical changes and infrastructure investment, together with institutional and organizational changes in the way irrigation water is managed. Of key importance, Water Users' Associations playing a major role in decision-making and the operation and maintenance of the pumps and mesqas (irrigation ditches) by themselves, with minimal assistance from the Irrigation Advisory Service (IAS) staff. The fundamental change introduced by the irrigation improvement is to replace individual farmer pumping at multiple points along the mesqa by collective single point pumping. In addition to the above primary aims, there are many other aspects to the project, including intensive training for water users, the IAS, and all levels of personnel involved to the top of the ministry; special studies and seminars, workshops to help the execution of such a program.

Lessons learned

- The new program has been built on the experience of earlier irrigation programs; there is a body of knowledge that has been tested and piloted which provides underlying strength to the new reforms.
- In order to increase the efficiency as well as the performance of the system, user's participation in the management is a must since their decisions and ideas have a great impact on the operators and the modernization process of the systems would assure the sustainability of the system.
- Increased crop production and achievement of real water savings in the system is dependent on the awareness and understanding of both users, and operators and managers of the system.
- Increasing the capacity of users, operators and managers require intensive training. Now in Egypt the new generation has accepted the concept of user's participation in the management and the Ministry of Water Resources and Irrigation has legalized the formation of water users association.

Source: GWP, Toolbox case studies

Gender implications should be examined and taken into account at all stages of the planning and implementation process

The central role played by women, especially in the developing world, in the provision, service management and husbandry of water, primarily in the domestic, small and medium enterprises (SME) and small holding farms, is widely recognized. Women's participation and gender issues should be accorded special consideration in relation to water management and use.

In both rural and urban environments, much time and energy is spent by women and girls in water-hauling; time and energy that cannot be devoted to other family or economic activities. Consequently water resources management is an important factor in determining women's availability to participate in these activities. Gender implications need to be considered at all stages of the planning and implementation of water-related activities, with consideration given to the different social, economic and cultural roles assigned to both men and women. Not only do gender implications of proposed interventions have to be considered, but women users and beneficiaries of services should participate in defining those implications. Given existing power and responsibility structures within families and communities in many parts of the world, a targeted effort is often required to enable women to take a meaningful role in the consultation and decision-making process relating to water and waste disposal.

In many traditional cultures, women's perceived roles in water resources management are often for carrying and storage of domestic supply. Domestic hygiene, whether it is care of children or food preparation, is also usually regarded as the woman's responsibility. Issues such as the location and the ownership of installations; knowledge of operations and maintenance procedures; and membership of Water Committees or similar bodies are often allocated to men. The absence of women from decision-making in water resources management and service delivery is essentially inequitable, and severely hinders the possibility of realising good domestic and public health, food management and quality of life programme objectives.

Because of their domestic roles, women are also logical key candidates for educational activities concerning water use and hygiene behaviour. However, men should also be included since their attitude towards – for example – hygienic disposal of human waste and their willingness to pay for services or installations may be decisive within the household and community.

Mainstreaming HIV/AIDS in the water sector

For People Living with HIV (PLHIV) their suppressed immune systems make them highly vulnerable to any disease that may be carried by unclean water and sewage. HIV affected people also need more than average amounts of clean water (Ngwenya and Kgathi, 2006). As a matter of fact, large amounts of water are essential for purposes of hydration, taking medicines, maintaining personnel hygiene, washing personal articles and clothing.

Unfortunately, PLHIV often have reduced access to clean water and basic sanitation: despite their greater need, they are also often subject to stigma and discrimination that limits their access to otherwise readily available clean water and sanitation facilities (Magrath, 2006).

Women usually carry out almost all water-related activities (UN Secretariat, 2007). The fatal disease is therefore a considerable burden for girls who are responsible of fetching water and taking care of PLHIV. – often while HIV-infected themselves (GCWA, 2006). Inadequate water and sanitation make home-based HIV care extremely burdensome and time consuming. Furthermore HIV-positive mothers need clean water for the preparation of formula milk for their babies (USAID, 2008).

At project level attention shall be given to internal and external mainstreaming which are often interlinked to each other. The former focuses on the reduction of sector employees' susceptibility and vulnerability to infection and on giving support to those already infected by HIV, including workplace policies and guidelines that regulate day to day activities. Related activities often consist of preventive education, treatment, care and support. External mainstreaming refers to actions such as developing partnerships between government departments/ministries, and between the public sector, the private sector and civil society. It also promotes considering HIV/AIDS as a development issue that has implications in all areas of policy making, insufficient access to water and sanitation, current health and hygiene education. It adequately addresses issues of best practices and the search for methods to assist individuals, households and the community at large to cope with the impact of HIV/AID.

The IRBM project on the Okavango

Angola, Botswana, and Namibia agreed in 1994 to establish the Permanent Okavango River Basin Water Commission (OKACOM) to promote coordinated, regional water resources development objectives for the Okavango river basin, while addressing the legitimate social and economic needs of these three riparian states.
OKACOM and its technical advisory body will implement the Okavango Integrated River Basin Management project (IRBM) in collaboration with government ministries, non-governmental organizations in the basin, communities, regional academic and research institutions, businesses and local governments that use and manage the resources in the Okavango River Basin.
Three components make up IRBM:

- Organizations' ability to manage river basin resources enhanced;
- Information systems for biodiversity and natural resource management improved, and;
- Improving community management and local governance of natural resources.

These three components combine to strengthen regional capacity for improved management of selected river basins. Incorporated with these three components are three crosscutting themes:

- Highlighting HIV/AIDS within the basin,
- Ensuring the participation of women and disadvantaged groups, and
- Promoting the participation of the private-sector.

3.5 Economic and financial principles

- **Water has an economic value and should be recognised as a social and public good**
- **Charging tariffs for water services is an important component of any strategy for sustainability**
- **"Demand management" should be used in conjunction with supply provision**

Water has an economic value and should be recognised as a social and public good

Recognition of freshwater as a finite resource has led to the emergence of the principle that water is a social and public good but one to which a price for provision services connected to it can be attached. The application of this principle becomes increasingly critical as water becomes scarcer. However, this principle should not over-ride the social imperative of providing a basic supply of safe water for every human being.

Applying an economic value to water can require the attachment of different values linked to different uses of water. These values will vary from setting to setting depending upon the user population, although it is invariably the case that survival and public health uses will be of high value; whereas recreational uses are often comparatively lower value. Where water is scarce, it is often good management to discourage low-value uses. The objective of reallocating sufficient water from low-value to high-value purposes should be investigated as an alternative to, or in parallel with, developing new sources of supply. In this context, the use of water markets can be appropriate. Some estimates of high and low-value uses of water may benefit from considering the importance of "virtual water" i.e. the non-evident water embedded in imported food crops, and "water foot printing". However water foot printing remains largely an accounting process, and elements of environmental and ecological responsibility as well as governance principles need to be included in evaluating the water resource.

Allocation of values to water uses helps in the following areas: balancing scarce resources with increasing demand; focusing attention on reduction of wastage and loss; conservation of the resource; and shifts in consumption towards higher value uses.

Virtual Water Concept

Virtual water content: The virtual-water content of a product (a commodity, good or service) is the volume of freshwater used to produce the product, measured at the place where the product was actually produced (production-site definition). It refers to the sum of the water use in the various steps of the production chain.

The virtual-water content of a product can also be defined as the volume of water that would have been required to produce the product at the place where the product is consumed (consumption-site definition). We recommend to use the production-site definition and to mention it explicitly when the consumption-site definition is used.

The adjective 'virtual' refers to the fact that most of the water used to produce a product is not contained in the product. The real-water content of products is generally negligible if compared to the virtual-water content.

Excerpt from Globalization of water: Sharing the planet's freshwater resources, Hoekstra A.Y, 2011

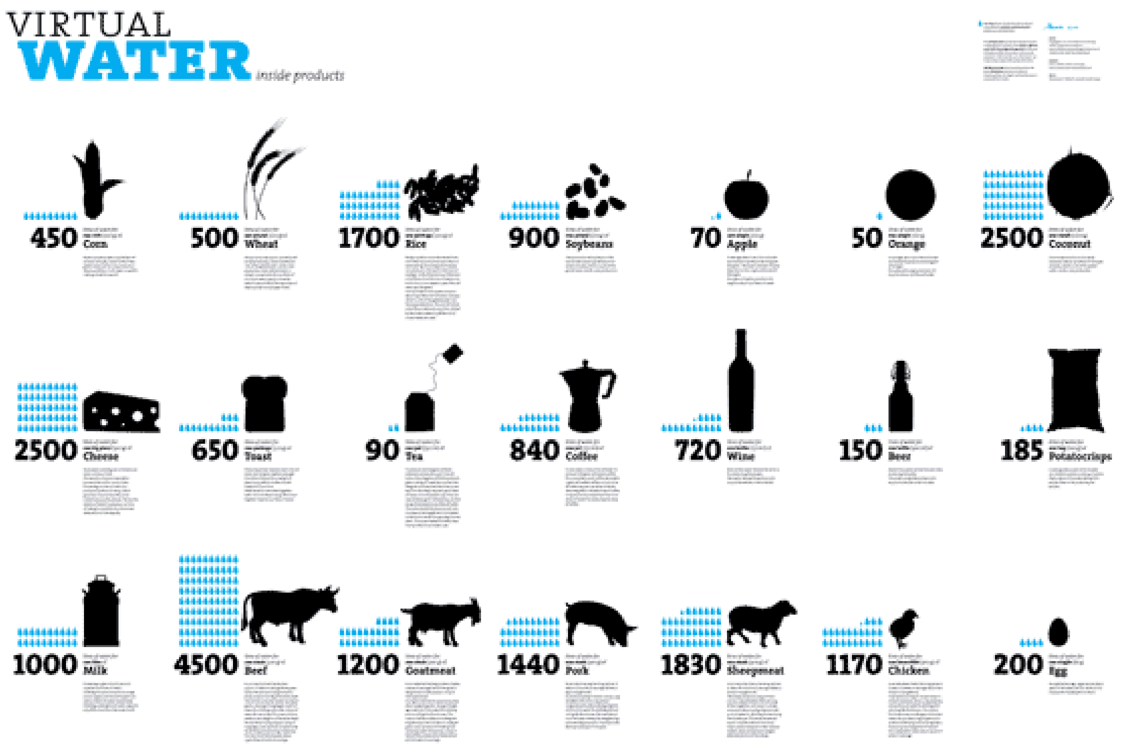


Figure16:The water footprint of product
(Source: ads from The Virtual Water Project based on the Water Footprint Network' publications.)

Charging tariffs for water services is an important component of any strategy for sustainability

Charging for water services (water supply, irrigation and wastewater disposal and re-use) is essential in order to generate funds for operating, maintaining and investing in systems; ensure that scarce supplies are allocated to essential purposes; and serves as a signal to users that a real financial value can be applied to the resource. Theoretically, a service which provides water to customers should not do so for free, even to the poorest customer. However, this principle poses a dilemma: how to provide a basic service to those who are extremely poor and yet ensure cost recovery, especially in areas where the costs of water extraction and delivery are high and/or continually mounting due to pressure on the resource.

Some basic solutions exist. For households' consumption, a certain minimum volume necessary for basic needs can be provided at an affordable price, with higher-level volumes subject to higher tariffs (solidarity principle / cross subsidizing). This will ensure that higher levels of consumption are not subsidized. Public subsidies are legitimate when applied to achieve certain social benefits (for example, provision of supplies to the underprivileged and under-served). However, these subsidies need to be transparent, targeted, and budgetary practical and sustainable (for example, covered by surpluses generated elsewhere).

The weighted average of the tariffs should be high enough to recover, at a minimum, recurrent operations and maintenance costs. Where water charges have been increased for this purpose, the aim should be to raise them progressively, and with due regard for continuing to meet basic needs and to the full marginal cost (equivalent to the average incremental cost of future supply) in order to also generate resources for expanding or modernizing the system. Industrial water tariffs need to take into account the volume of water they extract, and the volume and quality of water returned to public water bodies. For example, OECD members have accepted the principle that 'polluters pay'*:* those who dispose carelessly of wastewater should be charged for their actions.

If the tariff structure is progressively higher for increased consumption levels, they provide an incentive to conservation. Higher tariffs also generate extra resources for expanding services, although the practicalities of recovering costs for service installation and extension will depend on conditions (physical and socio-economic) operating in a given setting. The same principles apply to wastewater disposal and management.

"Demand management" should be used in conjunction with supply provision

Demand management seeks to maximize the usage of a given volume of water, by curbing inessential or low-value uses through price or non-price measures. In water-scarce areas, it is necessary to gain political support for demand management over supply-led solutions (the latter referring to solutions which are based on indefinite expansion of services and supplies).

A number of demand management measures can be considered, including market-based incentives such as water tariffs, pollution charges, water markets, water banking; and non-market incentives, such as leakage control, restrictions, quotas, norms, licenses and promoting re-use and recycling practices Alternative technologies, such as promoting dry sanitation methods of water conservation, can also contribute. All options need to be systematically identified and appraised. These appraisals need to be conveyed to the end-users and local authorities so informed choices can be made, leading to effective demand driven solutions.

In its policies towards key sectors such as industry and agriculture, a government and the population should be made aware of the potential negative impacts from developing water-intensive industries or agriculture in regions where water is scarce and estimates of different water values suggest that it should be applied to other uses.

Water Demand Management in Jordan

Ministry of Water and Irrigation in Jordan started to implement the Water Demand Management policy with process of data collection from Jordanian water sector units depending on the customers billing data, none revenue water, population, Investments Programs and other sources of available information. The billing data reflects the real water consumption for each consumer as total, consumer type, residential, commercial, industrial, and sorted per governorate. Based on the data available and with cooperation with the water utilities in Jordan, WDMU and IDARA Project has conducted several types of surveys, to identify and classify the water usage on the micro level, faucet, kitchens, showers, toilets and classified per sector.

Based on the analysis from the data collected, MWI has developed a set of programs to be implemented to meet the water demand management goals in the water strategy and to achieve the most efficient water use in Jordan.

The following table presents the proposed efficiency program distributed on difference sectors (customer classes)

Customer Class	Program Name
Residential	Toilet Trim Replacement, Residential
Residential	Showerhead & Faucets Retrofitting, Residential
Education	Toilet Trim Replacement, Education
Education	Faucets Retrofitting, Education
Governmental	Toilet Trim Replacement, Government Offices
Governmental	Faucets Retrofitting, Government Offices
Residential	Faucets Retrofitting, Worship
Touristic	High Efficiency Toilet , Hotel (via Performance Contract)
Touristic	Showerhead & Faucets Retrofitting, Hotel (via Performance Contract)
Commercial	Toilet Trim Replacement, Commercial
Commercial	Faucets, Commercial Office
Touristic	High Efficiency Toilet , Hotel (via Performance Contract)
Touristic	Showerhead & Faucets Retrofitting, Hotel (via Performance Contract)

Table 3 Water Demand activities in Jordan
(Source: MWI of Jordan 2012)

3.6 Environmental principles

- **Water-related activities should aim to enhance or to cause least detrimental effect on the natural environment and its health and life-giving properties.**
- **The allocation and consumption of water for environmental purposes should be recognised and given appropriate value.**
- **Environmental changes should be monitored so that improvements can be encouraged and detrimental impacts minimized.**
- **Climate change**

Water-related activities should aim to enhance or to cause least detrimental effect on the natural environment and its health and life-giving properties

Water-related activities need to be planned and implemented with due regard for all their environmental implications. Programmes and projects requiring the disruption of water flows can reduce the productivity of aquatic ecosystems, necessitate resettlement of affected populations, and devastate fisheries and grazing lands. Pollution degrades water supplies and increases the costs of water treatment. Integrated river basin management can provide a solution for surface waters since it allows all competing interests to be taken into account for one water-defined environment.

The protection of aquifers from pollution and over-exploitation should be addressed. This is especially important since the effects of mismanagement are not immediately visible and can thus be overlooked. The use of fossil groundwater must be avoided.

Water resource management systems should take into account the implications of all development activities related to the environment. These include industrial, commercial and agricultural development which lead to discharges that endanger water quality; changes in land use, such as road construction, mining or forestry activities; settlement and cultivation of floodplains and other riverine environments; and the impacts of freshwater use and pollution on estuaries and coastal zones.

Water resource management objectives therefore must be carefully balanced against parallel long- and short-term development objectives. Water issues must be taken into account in (urban) planning policies (for example avoiding settlement on floodplains). Every effort should be made to capitalize on better knowledge of the water environment derived from historical as well as recent experience. With climate change impacts and environmental extreme events arriving in shorter cycles, historical knowledge becomes more relevant. Integrating the environment into the planning activity is the desirable strategy. Technical methods using local materials, and bio-control of vegetation and disease vectors, have environmental advantages and build on natural capacities for pollution control and regeneration within ecosystems.

Lake Victoria: Junction of land degradation, biodiversity loss and water resources management in Kagera and Nyando catchments

Description

Over the last 50 years the Lake Victoria and its watersheds have undergone rapid ecological changes. Currently, major environmental threats in the Lake Victoria Basin (LVB) include unsustainable agriculture and deforestation in the catchments. This has resulted to sedimentation and proliferation of aquatic plants in the lake, most notably phytoplankton and an increase in water hyacinth mainly originating from the Kagera river basin. The threats facing the lake have caused considerable hardship for the population depending on it for their livelihoods and have also reduced the biodiversity of the lake's fauna and flora. More than 80% of the population in LVB is engaged in agricultural production and the basin forms a significant part for agriculture and livestock keeping that maintain the livelihoods of small-scale farmers. Deforestation coupled with bad agricultural practices has exacerbated the problem of sedimentation in the lake. As a result, soil erosion in prime agricultural areas within the catchments causes food productivity losses.

In Kagera and Nyando catchments there is also persistent land degradation accompanied by serious loss of biodiversity with impacts on the agro-ecosystems thus affecting the livelihoods of local people who largely depend upon the natural resources for their living. As the main contributor of water inflow into Lake Victoria, the Kagera River is a major source of sediment and phosphorus flow into Lake Victoria. Of the eleven main rivers draining into Lake Victoria from Kenya, the Nyando river basin has the highest average slope and sediment transport capacity. Floods in the Kano plain have become more severe and frequent as the river gradually losses its ability to buffer environmental variability.

Action taken

The riparian countries of LVB through the East African Community (EAC) and its protocol for sustainable management of the LVB have developed an action plan for management of the entire lake and its catchments across sectors. In 2003, the EAC signed a Protocol for Sustainable Development of LVB. The Protocol has played a crucial role in the establishment of an institutional framework for better management of the LVB. Under the protocol, Lake Victoria Basin Commission (LVBC) was formed as an apex institution responsible for all the management initiatives in the LVB. Other important management bodies involved in the LVB include Nile Basin Initiative (NBI) and the Nile Equatorial Lakes Subsidiary Action Programme (NELSAP) focusing on the promotion of economic growth, eradication of poverty and a reversal of environmental degradation.

This case study provides an insight into watershed management in the Kagera and Nyando catchments by illustrating the link between policy formulation and actual implementation and enforcement.

Lessons learned

- Policy framework and formation of institutions in LVB was driven by the EAC and a new institutional framework under the LVBC has provided a platform for coordination and the formation of strategies for catchment management. However, the coordination and exchange of information is mainly at top levels.
- There is a clear relationship between poverty and environmental degradation reflected by the inability to adopt and undertake conservation measures by majority of the people. Most people in the basin are struggling for basic needs of life and the thought of conservation is far from obtaining those needs.
- Although significant progress has been made in formulating land management policies and the promotion of land management practices, their practical application at subsistence level still remains low. This is due to inadequate extension services to reach the small-scale farmers much remains to be done for scaling up and translating the policies into concrete actions at the micro watershed level.
- Formation of village watershed committees is crucial to act as mediators among stakeholders, especially local communities within a catchment and the government agencies at district level. It makes the management plans well rooted in the local communities in a catchment. Involvement of local communities through watershed committees also enables the use of local knowledge and resources in developing cost-effective plans and to increase the acceptability of these plans among stakeholders.
- Use of incentives creates a more positive attitude to conservation among framers and pastoralists and helps accelerate conservation. Application and wide adoption of incentives in the catchments helps to encourage subsistence farmers to take conversation measures which in turn prevents land degradation in the basin.

This case study was adapted from a Master's thesis Kenge James Gunya: Participatory watershed management to decrease land degradation and sediment transport in Kagera and Nyando catchments of Lake Victoria basin (Linkopings University, 2009) – GWP Toolbox

The allocation and consumption of water for environmental purposes should be recognised and given appropriate value

Programmes and projects for the development, management and use of water mostly entail modifications to the natural environment in order to improve the quality of human life. Certain water-related activities, such as flood control and drainage schemes, have as part of their central purpose an environmental objective.

Maintenance of the natural water environment is important both for its intrinsic value and for supporting life. Water has an "in-stream" value for fish but also supports co-existing aquatic eco-systems. Eco-systems in wetlands and coastal zones depend on a certain volume and quality of water for their sustainability. Rivers and wetlands function as wildlife reserves, navigation routes, and areas for recreation. They also help to support natural biodiversity. In order to plan water use priorities it must be accepted that areas such as wetlands "consume" large quantities of water through evaporation. All uses, consumptive and non-consumptive, have to be considered for their ecological value and not automatically regarded as secondary to human and economic priorities.

Environmental changes should be monitored so that improvements can be encouraged and detrimental impacts minimized

Effective systems to monitor environmental changes throughout a project cycle and beyond will be required. Appropriate expertise is needed from the outset to ensure that environmental aspects are properly assessed. Care should be taken to adopt systems that allow flexibility of action where some environmental costs may have to be accepted in exchange for greater social and economic benefits.

Emphasis on environmental considerations is particularly appropriate in water-stressed areas, where the environmental and other implications of using alternative sources of supply – surface as opposed to groundwater, for example – need to be assessed. The inextricable connections between land and water management need to be recognised; land use and soil quality have a major influence on water flow and water quality, and vice versa.

Focus on Participatory Environmental Monitoring

"Participatory Environmental Monitoring" can be defined as monitoring approaches that develop partnerships of multiple stakeholders for efficient, effective and socially inclusive monitoring. Participatory monitoring recognises the central role that local people play in planning and managing their use of the environment.

Three forms of participatory environmental monitoring can be distinguished, although there are overlaps:

- Methods based on the visualisation techniques of Participatory Rural Appraisal
- Methods that use oral testimony to uncover patterns of environmental and social change
- The adaptation of methods of ecological assessment to make them more accessible to local people

There are several common key principles:

- Monitoring objectives must be clear
- The expectations and information needs of all stakeholders must be understood
- The end-users and uses of the information must be identified
- The monitoring process must provide real benefits for local people
- Participation should extend beyond indicator identification into design of data collection methods and decision on information uses.
- Negotiations between different categories of local people may be important

Source: FAO Livestock and environment Toolbox

Climate change

According to the Intergovernmental Panel on Climate Change (IPCC, 2008) "Freshwater resources have the potential to be highly impacted by climate change, and human societies and ecosystems will both feel the consequences". Climate change is expected to increase the frequency and magnitude of extreme events such as floods and droughts, and changes in the seasonal distribution and amount of precipitation. It is evident that more attention needs to be given to adaptation measures and building resilience throughout the water sector. As with other aspects of water resources management, the principles of IWRM are important for addressing climate change and water. All sectors who utilize or impact on water resources must also contribute to addressing climate change discussion on mitigation and adaptation.

The greatest impact due to climate change will be on the world's poorest people, who are most vulnerable to their surrounding environment (e.g. subsistence or small scale agriculture, small stock farmers) for their survival, or the poor in urban and peri-urban environments whose population's capacity and resources to adapt are very limited, making them extremely vulnerable. It is thus critical that climate change and risk management are integrated into water governance and development cooperation. From the perspective of the EC, the mainstreaming of climate change into development cooperation addresses four main objectives (EuropeAid, 2009):

- Identifying and avoiding harmful direct and indirect environmental impacts of programmes and projects in the different co-operation sectors, which can undermine sustainability.
- Recognizing and realising opportunities for enhancing environmental conditions, thereby bringing additional benefits to development and economic activities and advancing environmental issues that are a priority for the EC.
- Promoting improved environmental dialogue with partner countries, based on the technical, economic and social arguments in favour of a more environmental approach to policies and programmes.
- Identifying potential risks of a project or programme by assessing its exposure and sensitivity as well as response capacities in place to deal with existing or anticipated climate variability and change.

Climate change adaptation measures aim to offset negative impacts but also to take advantage of positive ones, where they exist. Adaptation should not be seen just as a constraint and an additional financial and economic burden. In almost every sector, climate change intensifies already existing problems. Climate-related concerns may provide the impetus needed to implement many of the environmental and developmental 'best practices' previously neglected and in this way make programmes and projects both more effective and more sustainable.

Climate Change in the SADC region

In 2012 the Southern African Development Community (SADC) launched a programme on Climate Change Adaptation and Mitigation in the region. The main goal of the Climate Change Adaptation (CCA) Strategy is to improve climate resilience in Southern Africa through integrated and adapted water resources management at regional, river basin and local levels.

The objective is to promote further the application of integrated water resources management as a priority tool to reduce climate vulnerability and to ensure that water management systems are well adapted to cope with increased climate variability.

The implementation of the Strategy is achieved mainly through the SADC Regional Strategic Action

Plan (in its current third phase: RSAP III). The RSAP is the official SADC programme for the Water Sector and is therefore the de facto implementation plan for the Strategy. The CCA Strategy was designed in alignment with the RSAP III strategic areas, which are:

1. Water Governance

2. Infrastructure Development

3. Water management

Within each of these strategic areas the RSAP III provides a coherent set of activities to contribute to the achievement of three strategic objectives: i) capacity development, ii) climate change adaptation and iii) social development. Under climate change the RSAP calls for the achievement of three operational objectives:

1. Develop a common understanding on the risks and impacts of climate change;

2. Increase water storage capacities to improve climate resilience;

3. Reduce the risks and impacts associated with climate change.

Text adapted from "Climate Change Adaptation In SADC, A strategy for the Water Sector, 2011.

3.7 Information, education and communication principles

- **A sound information and knowledge base is needed for effective actions within all water-related activities.**
- **Education is a vital component of water-related schemes if health and life enhancement benefits are to be achieved and sustained.**
- **Communication and awareness building are essential ingredients in all forms of water resources management**

A sound information and knowledge base is needed for effective actions within all water-related activities

Many developing countries lack sufficient data on the hydrology of their surface water resources, the groundwater resources and overall water quality. Without a full range of scientific information concerning climate and the ecosystem, it is not possible to evaluate the resource, balance its availability against demand, or reach scientifically-informed management decisions in key areas of water policy. Thus, the development of a water resources knowledge foundation and information data base is a precondition for any effective water policy.

Government authorities and agencies involved in water-related activities need proper information in order to function effectively. This information includes data on technologies, strategies, approaches, organizational models, and management information of all kinds. Data collection systems need to be established, and integrated with one another, so that activities can be continuously monitored, impacts be assessed and adjustments made.

Surveys and research projects are needed to generate and collect socio-cultural and economic as well as usual technical data. Where projects are intended to benefit low-income communities, prior information is needed about attitudes and practices surrounding water supply ownership, access and use, and traditional methods of waste management. Effective hygiene promotion depends upon thorough knowledge of existing water-and sanitation-related behaviours and beliefs. Baseline data on the prevalence of water-related diseases is also an important aid to needs identification, on-going monitoring and useful for post-intervention evaluation of public health impacts.

Transboundary data exchange

Most integrated water projects now include the development of monitoring and information systems. Information systems are common tools for information sharing and data harmonization across the basin. They are online platforms gathering technical data on the basin (qualitative and quantitative data, mathematical models, maps, etc.). An information system consists of software (an architecture filled with databases) and hardware (one central server and national servers in each country). For example, the Guarani Aquifer implemented the Guarani Aquifer System Information System (SISAG), the Danube Danubis and the Mekong the Fisheries Information system providing data on Mekong fishes.

Many basins set monitoring networks in order to monitor water quality and/or quantity. The Nile Transboundary Water Quality Monitoring Network (WQM) and the Danube Trans-National Monitoring Networks System (TNMN), for instance, are constituted of networks of sampling stations monitoring water quality along the river, the harmonization of monitoring procedures, laboratory equipment and capacity building. The International Commission for the Protection of the Danube River (ICPDR) also set a Danube Accident and Early Warning System (AEWS) and a Danube Basin Alarm model (DBAM) which are internet and GSM based systems sending alerts in order for experts to take preventive or responsive measures to pollution or other environmental threats.

Education is a vital component of water-related schemes if health and life enhancement benefits are to be achieved and sustained

Demand for water in low-income communities is associated with survival interests, and improving quality of life with a reduction of time and labour spent by men, women and children in water-related tasks. Beneficiary definitions of social well-being relating to water may not coincide with those of donors and programme agencies, whose principal concerns are usually linked to public health (or in economic improvement schemes such as irrigation for agricultural use). There is usually a higher demand for water supplies than for sanitation, although sanitation is often more essential to control water-related diseases. Therefore, education and awareness-raising of the linkages between unsafe water, inadequate excreta disposal, and disease should be integral to all schemes. This should not just be limited to low-income communities, since there are some water-related diseases which easily traverse the poverty line. Education and information programmes for sanitation and personal hygiene may sometimes need to be targeted towards women, given their special role in household water management and use. Children and teachers can also be targeted by school-based programmes.

Education is similarly needed in the environmental implications of water-related activities in the agricultural sector. Farmers need to learn the value of water and the importance of water saving in irrigation, as well as implications of irrigation and use of chemicals and fertilizers on water quality. Without an understanding of the essential need and purpose of water resources management, user group participation in management decisions, especially in negotiations over competing user groups, cannot be obtained; and if obtained, cannot effectively contribute.

Communication and awareness building are essential ingredients in all forms of water resources management

The accepted best practices in water resources management and the delivery of services include extensive awareness-building among political leaders and decision-makers, professionals and academics, donors and members within civil society such as NGOs. Initially this consensus was largely limited to members of the international water-associated community, but this has now become commonly accepted practice at national levels.

Communication mechanisms, in the form of educational activity and public awareness and information campaigns, are tools regularly used to increase community-level understanding of the linkages between water and health, to manage demand for water-related services, and generate motivation and impart skills for service maintenance. Awareness-raising also reaches down to the level of users to create a climate favourable for community management of water supply and sanitation systems, local participation, good operation and maintenance, collaborative systems of cost-recovery and household management.

Orange-Senqu River **Awareness Kit**

The Orange-Senqu River Commission (ORASECOM) created in 2011 the **Orange-Senqu** River **Awareness Kit** (2011) – is an information and knowledge management tool for the Orange-Senqu River basin, to support capacity development and the sustainable management of the environment and resources within the basin. Included within the Orange-Senqu RAK are self-learning resources, supported by interactive visualisation tools, maps, documents and Google Earth layers. The intended audience for the Orange-Senqu RAK is the broad spectrum of stakeholders in the Orange-Senqu River basin, including government agencies, river basin managers, Non-Governmental Organisations (NGOs), educational establishments and the general public, as well as the international community.

Several river basins developed similar activities as the Nile, Mekong, Kunene and Limpopo basin.

Source: http://www.orangesenqurak.com/

3.8 Technological principles

- **A balanced approach towards 'hardware' and 'software' components of projects should be adopted**
- **Choice of technology should be governed by considerations of its efficiency, appropriateness, cost, and suitability for local conditions**

A balanced approach towards 'hardware' and 'software' components of projects should be adopted

Providing a reliable supply of water for domestic or agricultural purposes requires careful attention to 'hardware', suitably balanced by attention to 'software' aspects. Technological innovation and adaptation are integral to many of the water-saving measures, service extensions and system improvements urgently required. Technical issues largely determine the costs of a given water-related project, and thus remain of paramount importance.

The present water-related project cycle can, in many settings, still be characterised as 'build, breakdown, rebuild'. Where the technology deployed is beyond the level of the users' capacity to maintain, operate or cover costs, the prospects of sustainability of the service are equally beyond reach. Thus the development and use of water resources including waste management infrastructures or irrigation works needs to take technological considerations, as well as local management capacities and community resources into account.

Technology itself needs to be applied within an integrated framework. A project designed to provide a new supply of water should, for example, take into account requirements for disposal, treatment or recycling of run-off and used water. Irrigation works should take into account the potential for soil degradation, return flow problems, mobilization of pollutants from agriculture or other water-related health hazards such as standing water and vectors for water-related diseases.

Choice of technology should be governed by considerations of its efficiency, appropriateness, cost, and suitability for local conditions

Technical solutions need to be selected according to criteria which include efficiency, appropriateness, cost and their potential for adaptation to the local environment. The desired approach can be summarised by the term 'appropriate modern technology ', which captures elements of capacity for operation and maintenance as well as cost-efficiency (see part 3). There have been numerous examples of poor project outcomes due to the selection of costly and inappropriate technology, whose infrastructure and management systems have fallen into disrepair because maintenance was too difficult, or of projects which have resulted in unanticipated environmental damage.

Infrastructure projects have too often imported technology from industrialized countries unsuited to the physical, economic and social conditions in which the system is being applied. While awareness of this issue has grown considerably in recent years, the application of best practices is not yet consistently applied due to lack of resources or capacity linked to insufficient priority being placed on appropriate levels of technology. Professional technical and social advice is useful to guide the choice of technology – whether it is to be 'high-tech' or 'low-tech'. For example the choice of materials should receive careful consideration regarding health security of users, impact on supplying the resources, as well as their environmental suitability. Technical decisions must take into account the social, institutional and economic context within which infrastructure will be maintained. Long-term affordability and sustainability often hinge upon the choice of technology, type of abstraction and methods of delivery. Thus, critical social and economic considerations about the viability of a technology in a given setting should not be ignored. As a general rule, technologies should not burden operators or tie them into costly and unreliable supply strategies; and finally consideration should also be given to the prospects of technology transfer and capacity building at the local level, be it supply or manufacture.

To facilitate cost-effective operation and maintenance, upgrading technologies are being introduced for the first time that permit well-judged and carefully stepped development are desirable, especially in settings where systems, services or specific technologies. These can be developed by incorporating indigenous technologies and local knowledge, scaled-down versions of larger systems or considering alternative choices for water and sanitation services.

To facilitate effective operation and maintenance, availability of spare parts, and appropriate training of operatives including local community workers – men and women- the standardization of technology being applied is of high importance in order to reduce fragmentation of a strategy. These issues can be addressed within the regulatory framework of water resources management.

India: Actual scope for improving water productivity in irrigated agriculture in Andhra Pradesh

Description

India is the world's major irrigating country with the major share of the water resources being used for irrigation. The demand for water from the non-agricultural sectors is growing rapidly, causing an increased pressure on available water resources. The national and state governments of India currently face huge challenges in water management.

Agricultural production in the southern state of Andhra Pradesh is mainly concentrated in the densely populated catchments of the Krishna and Godavari rivers. The state is facing water related problems like interstate water disputes on reservoir releases, inequity in canal water distribution in irrigation commands, over-exploitation of groundwater resources in rain-fed agriculture, degradation of wet lands, salt-water intrusion in coastal regions and shortages in drinking water supply for Hyderabad.

Action taken

The FAO - funded joint applied research study in farmers´ fields was initiated and facilitated by Alterra – IWRM (the Netherlands) and the State Agricultural University in Hyderabad. The aim of the study is to generate and disseminate knowledge as well as build research capacity on improved agricultural water productivity of canal and tank irrigation systems. Also, the objective is to strengthen strategic partnerships among research institutions, policy makers, line departments, NGOs and Water User Associations.

Eight pilot areas throughout Andhra Pradesh were selected for the study. Local NGOs together with local project staff living in the villages are facilitating the participatory involvement of the pilot area farmers.

The project included both technical and non-technical measures. In addition, a very important goal is to support the development and design of innovative production systems to make more effective use of natural resources. An integral part of the project is to support institutional capacity of local authorities in implementing these approaches.

Achievements

Results and products developed so far are:

- improved on-farm crop and water management packages tested in the pilot areas resulting in overall higher water productivity;
- up-scaling of pilot area results through remote sensing: canal water savings up to 40% can be realized in Krishna Western Delta;
- participatory irrigation water management implemented in a canal command: water savings up to 30% realized;
- participatory irrigation water management implemented in a tank command: there are no longer water disputes among farmers; tail-enders have sufficient tank water; groundwater is now regarded as strategic reserve; increase of cropped area up to 30%;
- introduction of sub-surface drainage systems to combat deltaic environmental degradation and salinisation: increase of water productivity up to 50%.
- Water Technology Centre was established within the State Agricultural Unviersity in Hyderbad where the expertise obtained from the project has been clustered; one of its activities is conducting annual training courses on improved water productivity technologies.
- The state government is now in the process of up-scaling elements of the pilots area results to larger canal commands in Andhra Pradesh
- The state Irrigation Department has already incorporated newly introduced design procedures on discharge measurement structures in its new irrigation projects.

Lessons learnt

- Pilot demonstrations and capacity building are a prerequisite for promoting improved water management practices to all stake holders
- Considerable time was required to build mutual trust between stakeholders and project staff
- Water User Associations can effectively employ improved water management practices
- The project achievements served as a model for tank irrigation improvement, for aspects such as technical, managerial and participatory

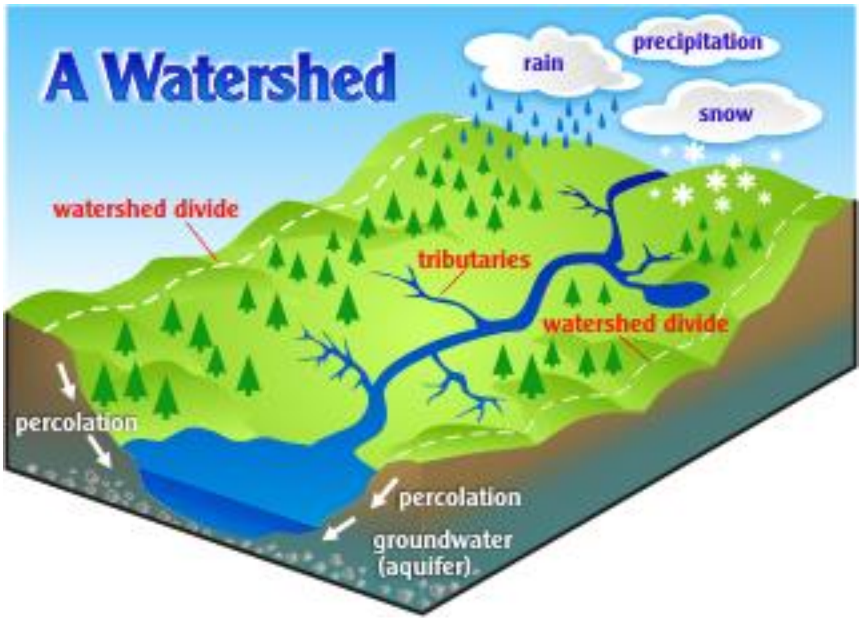
Source: GWP, Toolbox case studies

4.0 ROLE-PLAY ON WATER GOVERNANCE

Objective

- To understand the responsibilities of all stakeholders involved in water management.
- To have a better knowledge of each other's concerns.
- To reach a solution via negotiation
- To raise awareness on the complexity of environmental issues related to the water resources

Description



This game is designed to bring different stakeholders together at a broad watershed level and build a common Integrated Water Resource Management.

The group will be divided in 6 groups representing the stakeholders. Each group will have a representative. And the instructor or trainer will moderate and facilitate the debate between them.

6 stakeholders are involved in this watershed

- Citizens
- Farmers
- Tourism organisations
- Paper industries
- Private water operators
- Mayors

5 phases:

1- Preparation: Allocation of roles to each participants (5min)
2- Definition: per group, each stakeholder will determine (20 m)

- His water uses and needs

- The impact of his uses on the environment

3- Installation: collectively the 6 stakeholders will define (1h)

- An inventory of water resource available on the watershed

- The require infrastructures for the water supply and waste water treatments

- A common regulatory framework to protect the water resources (general principles of eco-citizenship and rules applicable to specific cases)

- The financial mechanisms required to maintain these infrastructures (Who's paying for what?)

4- Role playing: 2 specific situations (50h)

Drought: there is not enough water for each stakeholder. How the water should be allocated?

Polluted estuary: where the pollution is coming from? Who should pay to restore the water quality within the watershed?

5- Analyse and conclusion (15m)

-Feedback from participants

-5 key functions:

Planning: common objectives, needs and means

Role definition: role and responsibilities

Participation: inclusive debate and common solutions

Regulations: common documents to which stakeholders refer

Financings: implementation and maintenance of the activities

5.0 WATER GOVERNANCE

5.1 Introduction on Water Governance

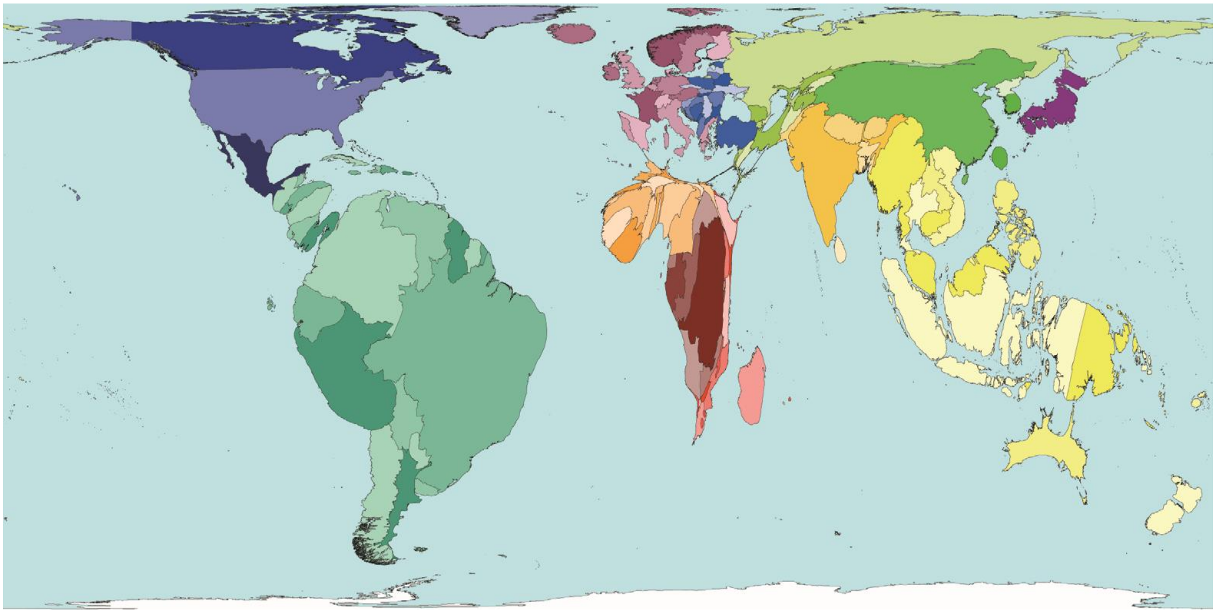


Figure 17 Fresh Water resources
(Source: World mapper)

Nine countries concentrate 60% the world fresh water resources: Brazil, Canada, China, Colombia, United States, Indonesia, Peru and Russia.

While Asia concentrate almost 60% of the world population, the continent dispose of 30% of the fresh water resources available on earth. At the opposite, Amazonia represent 0,3% of the world population but holds 15% of the world fresh water resources.

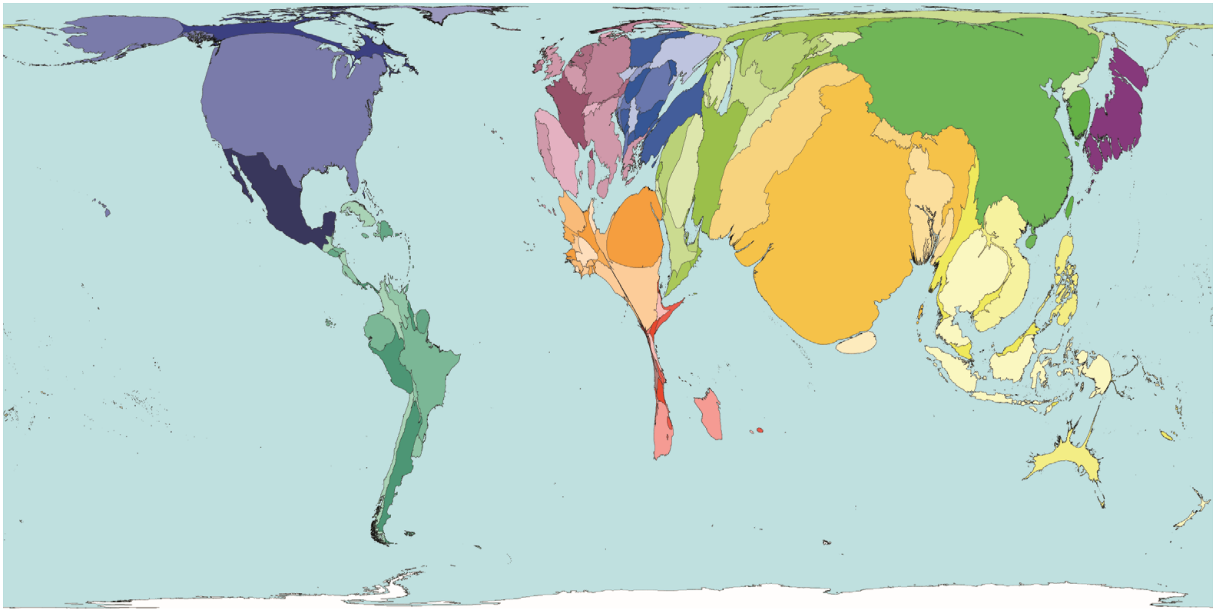


Figure 18 The fresh water uses,
(Source: World mapper)

China, India and the United States are the highest consumers of water. These are also the territories where the most people live. But water consumption per person is about three times higher in the United States than it is in India and China.

When we compare the two maps we can see that a country as Congo has fresh water resources available but it doesn't use it. The water crisis is increasingly about how we, as individuals, and as parts of a collective society, govern the access to and control over water resources and their benefits.

Within the crisis context, how do we determine:

- Which uses will get water first?
- In which quantity?
- With what quality?
- When water should be delivered?
- How?
- At what price?

To answer all these question, there is a need to determine the processes of decision-making and the processes by which decisions are implemented (or not implemented). In another term, there is a need of governance.

Water governance is the set of systems that controls decision making with regard to water management and water service delivery. Simply put, water governance is about who gets what water, when and how. Such decisions often contain a profoundly political element, particularly where there is a competition for limited water resources. As a result, systems of water governance usually reflect political and cultural realities at national, regional and local levels.

There is a growing understanding that governance of water resources and water services functions more effectively within a system which enables broad participation by civil society, including community based organizations, NGOs, private enterprise and the media, networking to support and influence government, including local government. In practice, this means that forums where stakeholders discuss and come to conclusions need to be strengthened, or even established, at different levels and steps need to be taken by government to ensure that these "stakeholder platforms" play a prominent and active role in systems of water governance.

As competition for water intensifies, it becomes more and more difficult to find simple technical solutions to water-related problems. Increasingly, solutions involve trade-offs between benefits and costs for different groups, which require management of demand and enforcement of regulations. These tradeoffs have much better chance of being accepted if they are identified and implemented as part of a system of improved local water governance that is focused on addressing problems and improving service delivery, and if stakeholders are actively involved on these processes.

Effective water governance requires a policy environment that promotes decentralisation, and the combined commitment of relevant government departments and civil society actors, including the private sector. Although there is no single model for effective water governance, the water project toolkit is based on four fundamental principles:

- **Accountability** (reporting etc.), according to which policymakers must prove to stakeholders that public goods are being managed properly,
- **Participation** of all the actors in the sector and their ownership of governance processes,
- **Inclusion** of all actors in the sector, particularly the most vulnerable, such as women and children, who have the same rights as other stakeholders,
- **Transparency** in financial management, the award of contracts and the results obtained as well as providing easy access to information.

Integrated Water Resource Management (IWRM), defined earlier in the document, is the approach that implements governance measures aimed at conserving and ensuring the sustainability of water resources.

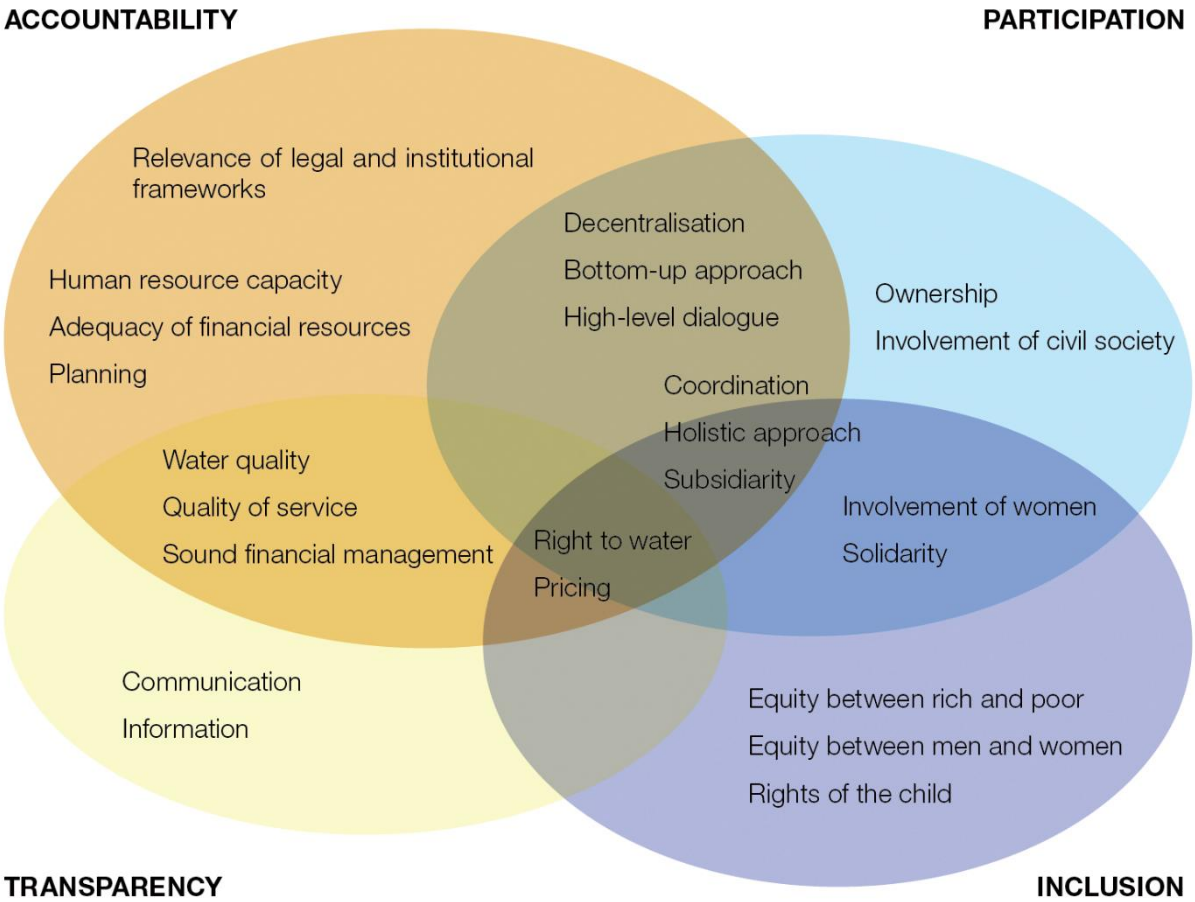


Figure 19 IWRM aspects in relation to the 4 governance principles (Source: EC,2009)

Stakeholders' participation in the Niger River Basin

The starting point for thought on the participation of the civil society in the Shared Vision process for sustainable development of the Niger basin was the invitation sent by the Niger Basin Authority (NBA) to regional organizations and associations for them to participate in a workshop gathering the nine basin countries in January 2005.

A study for the identification and characterization of the water users of the Niger basin was then coordinated by "Eau Vive" and the International Secretariat for Water. Its findings were presented at the First Regional Forum for users of the basin resources, in February 2006 in Fada-Ngourma in Burkina Faso.

For the first time, this step brought together the civil society organizations of the Niger basin to discuss matters of general interest with the States and partners. Several resolutions of the NBA

Council of Ministers eventually led to a regional coordination of the Niger Basin users, based on countries' national coordination. Regional coordination, which is represented in some NBA official bodies, especially works on the impacts of large dam projects in the basin.

Source: Handbook for Integrated Water Resources Management in the Basins of Transboundary Rivers, Lakes and Aquifers, INBO 2012

5.2 Stakeholder analysis

Since governance is the process of decision-making and the process by which decisions are implemented, an analysis of governance focuses on the formal and informal actors involved in decision-making and implementing the decisions made and the formal and informal structures that have been set in place to arrive at and implement the decision.

Government is one of the actors in governance. Other actors involved in governance vary depending on the level of government that is under discussion. In rural areas, for example, other actors may include influential land lords, associations of peasant farmers, cooperatives, NGOs, research institutes, religious leaders, finance institutions political parties or the military. At the national level, in addition to the above actors, media, lobbyists, international donors and multi-national corporations may play a role in decision-making or in influencing the decision-making process.

Effective stakeholder dialogue depends on having all appropriate stakeholders involved in the stakeholder platform – i.e. the people and institutions that need to become engaged if water governance is to improve. It is essential to identify these stakeholders, and to discover their stake in water management. The end users of water and some of the most significant institutions (such as the water providers, local government or key devolved bodies) can be thought of as key stakeholders who must be involved in the process if it is to be successful.

They are not 'more important' than other groups or individuals but without them the process will not work. They must remain involved institutional stakeholders (e.g. a water users' association –WUA) and whether they have the capacity to become involved in stakeholder dialogue.

Because water's nature as both a social good to which people have a right and an economic good which has a value, stakeholder analysis needs to look at three broad groupings:

- Main social groups (men, women; poorer, better off) who may have a right to water
- Main water-user groups (farmers; domestic users, industrial users, etc.)
- Main institutional stakeholders including private sector water providers, local NGOs/CBOs, local government and politicians

A usual first step of a stakeholder analysis is to achieve a stakeholder mapping in order to identify primary, secondary and key stakeholders.

- Primary stakeholders: This category comprises those whose main livelihood or interest is ultimately affected (either positively (beneficiaries) or negatively (e.g. those involuntarily resettled).
- Secondary stakeholders: Those whose interests are related to the project in a less immediate way than as the primary stakeholders, for example suppliers of project inputs.
- Key stakeholders: those who have the capacity to influence the project outcomes, but who are not themselves directly affected by it, for example legislators and officials.

Among the different existing tools to conduct stakeholder analysis (such as potential analysis, organizational landscapes, Venn diagrams, "field analysis", each with more specific purposes, the stakeholder analysis matrix and SWOT analysis are among the most widely used by donors.

In using any of these tools, the quality of information obtained will be significantly influenced by the process of information collection. In this regard, the effective use of participatory planning methods and group facilitation tools can help ensure that the views and perspectives of different stakeholder groups are adequately represented and understood.

Stakeholder analysis matrix

As illustrated in the table below, the stakeholder analysis matrix describes:

- the basic characteristics of the stakeholders
- their interests and how they are affected in the problem/potential project
- their capacity and motivation to bring about change
- the possible action to address their interest

Stakeholder and basic characteristics	Problems (How affected by the problem(s)	Interests (and possible actions to address it)	Potential (Capacity and motivation to bring about change)
Fishing families: X families, low income earners, small scale family businesses, organised into informal cooperatives, women actively involved in fish processing and marketing	Pollution is affecting volume and quality of catch Family health is suffering, particularly children and mothers	Maintain and improve their means of livelihood Support capacity to organise and lobby Implement industry pollution control measures	Limited political Influence given weak organisational structure Keen interest in pollution control measures
Industry X: Large scale industrial operation, poorly regulated and no unions, influential lobby group, poor environmental record	Some concern about public image Concern about costs if Environmental regulations enforced	Maintain/increase profits Raise their awareness of social and environmental impact Mobilise political pressure to influence industry behaviour Strengthen and enforce environmental laws	Have financial and technical resources to employ new cleaner technologies Limited current motivation to change
Households: X households discharge waste and waste water into river, also source some drinking water and eat fish from the river	Aware of industrial pollution and impact on water quality Health risks	Want access to clean water Want to dispose of own waste away from the household	Potential to lobby government bodies more effectively Appear willing to pay for improved waste management services Limited understanding of the health impact of their own waste/ waste water disposal
Local government Etc.			

Table 4 Stakeholder analysis matrix. (Source: EC 2012)

The type of information collected, analysed and presented in the columns of such a matrix can be adapted to meet the needs of different circumstances. For example, additional columns could be added to specifically deal with the different interests of women and men, or to underline linkages between stakeholders.

SWOT analysis

SWOT analysis (strengths, weaknesses, opportunities and threats) is used to analyse the internal strengths and weaknesses of an organisation and the external opportunities and threats that it faces. It can be used either as a tool for general analysis, or to look at how an organisation might address a specific problem or challenge.

The quality of information derived from using this tool depends (as ever) on who is involved and how the process is managed – it basically just provides a structure and focus for discussion. This information is most often represented in a matrix format as in the example below:

Strengths	Weaknesses
– Grassroots based and quite broad membership – Focused on the specific concerns of a relatively homogenous group – Men and women both represented – Provide a basic small scale credit facility	– Limited lobbying capacity and environmental management skills – Lack of formal constitutions and unclear legal status – Weak linkages with other organisations – Internal disagreements on limiting fishing effort in response to declining fish stocks
Opportunity	**Threats**
– Growing public/political concern over health impacts of uncontrolled waste disposal – New government legislation in preparation on Environmental Protection largely focused on making polluters pay – The river is potentially rich in resources for local consumption and sale – New markets for fish and fish products developing as a result of improved transport infrastructure to nearby population centres	– Political influence of industrial lobby groups who are opposed to tighter environmental protection laws (namely waste disposal) – New environmental protection legislation may impact on access to traditional fishing grounds and the fishing methods – that can be employed

Table 5 SWOT analysis,
(Source: EC, 2012)

The success or the failure of SWOT rests on the skills of the facilitator, and the willingness of stakeholders to follow and accept the logic – even if this subject abandoning an objective or activity.

Exercise: Fill a SWOT Analysis:

Step 1: On a large piece of paper create a matrix with four divisions: strengths, weaknesses, opportunities, and threats.

Step 2: Clarify the objective. SWOT is most useful when related to a specific objective or activity such as improving the powers of a water user association, or improving the operation of maintenance performance of a department.

Step 3: Identify the strengths, weaknesses, opportunities and threats affecting the objective.

Strengths are internal factors helpful to achieving the objective (e.g. well trained staff)

Weaknesses are internal factors harmful to achieving the objective (e.g. poorly motivated staff)

Opportunities are external factors helpful to achieving the objective (e.g. government support)

Threats are external factors harmful to achieving the objective (e.g. insufficient funding)

Step 4: Use the SWOT to access the likelihood of achieving the objective. Assess whether the objective is realistic by asking:

- *How can we use each strength?*
- *How can we stop each weakness?*
- *How can we exploit each opportunity?*
- *How can we deal with each threat?*

Bear in mind that the SWOT analysis may show that the objective is unrealistic and should be modified or abandoned.

5.3 Stakeholder participation

Concerning participation, in the past few decades participatory development has been in vogue for development programmes worldwide. This trend is the result of the notable failures of coercive ‘top-down’ projects introduced in developing countries during the 1970s to ‘80s (Choguill et al., 1993). In the quest to legitimize development programmes and make them more sustainable, the idea of a ‘bottom-up’ approach appeared. In the nineties, participatory methods became the new way of pursuing development programmes, but without losing the bottom up approach.

With particular reference to the water sector, the participatory approach can be defined as one of the main development principles related to sustainability both from the point of view of Integrated Water Resource Management (IWRM, Dublin 1992) policies and from water sector governance (GWP, DfID 2009, EC 2010 etc.). Concerning IWRM, the Dublin principles (1992) state that water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

In the same way, at sector level, participation is one of foundation principles of the Sector Wide Approach that through the joint dialogue process (government, technical and financial partners, other actors in the sector) allows the government to define and implement its sector programme.

At the community level the purpose of participation is to gather information in a non-extractive way and involve the stakeholders in the policy making and policy implementation processes. This will mean having to:

- Stimulate the community to identify the causes of its problems and collective aspirations;
- Facilitate communication with the community;
- Help the community to identify resources, experiences, and potential improvement;
- Identify interests and conflicts; and
- Motivate communities to develop self-reliance in project development and management

Participation may take on various forms, and occur in varying intensities depending on the nature of the activity and the roles and responsibilities of the people and groups involved. Community members or groups may simply be required to contribute labour or some cash inputs, or be represented on a management committee, or take on full management and decision making responsibilities and authority.

The nature, scale and scope of the project will influence the level of participation that is practical and possible, as will a realistic assessment of skills and capacity among participating communities and groups. Building such capacity is often a specific objective of participatory approaches.

Four levels of intensity might be distinguished (they are not mutually exclusive):

- ***Information sharing.*** This is the minimal level of ‘participation’ and often consists of little more than keeping people informed – i.e. a one-way flow of information.

- ***Consultation.*** Consultation means that there is a two-way flow of information – a dialogue. However, this dialogue may not necessarily impact on decision making.
- ***Delegated power.*** Participation reaches a higher level when it involves individuals or groups (particularly those who are usually excluded) in actually making decisions. They have the authority and responsibility to take action.
- ***Citizen Control.*** The highest level of participation is achieved when people take it on themselves to initiate new actions. To do so indicates a significant level of self-confidence and empowerment and the establishment of organizational and management capacity.

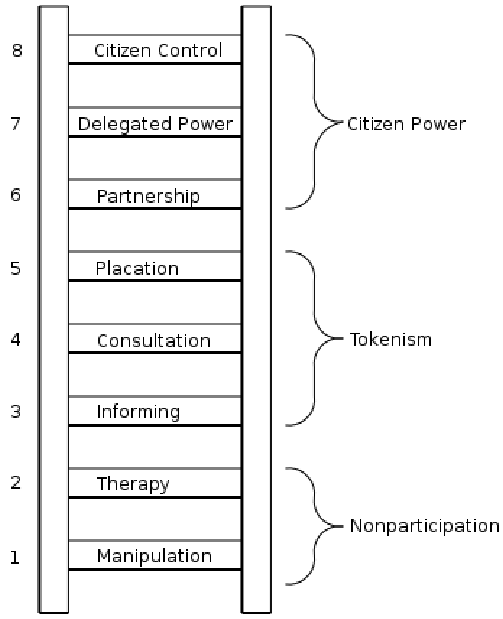


Figure 20 The ladder of citizen participation
(Source: Arnstein, 1969)

The decision to involve the stakeholders in water management should be understood as a real benefit for water projects. Public participation is one of the key factors for the success of development efforts. It allows:

- **Better ownership, involvement and implementation of projects.**

Public participation is a means to increase the ownership and involvement of the public in water projects. It makes people understand and respect the final decisions on projects. As communities often are the beneficiaries, they need to understand the necessity of preserving water resources because they have the capability to impact it.

- **Local solution meeting local needs.**

Communities are in the best position to identify resource-related problems, trace back the causes of those problems and propose possible local solutions they themselves can implement. Participatory techniques can be used to generate an understanding of community perspectives of resource issues, such as the health of the river, use of resources,

resources that are declining, causes of problems, existence of local resource management rules and institutions and possible solutions to problems.

During the year 2006, local residents, businesses, municipal representatives and other stakeholders from seventeen Jordanian, Palestinian and Israeli communities involved in the Friends of the Earth Middle East (FoEME) **Good Water Neighbors Project** on the Jordan River, met on a regular basis to discuss and define the primary environmental concerns faced by their communities. With the assistance of a local planner, community residents worked cooperatively to map out environmental threats and start developing first ideas that could constitute sustainable solutions.

Emek Hefer community in Israel, for example, identified three primary environmental issues:

- Untreated wastewater disposal
- Untreated solid waste dumping
- Mosquito outbreak

Several solutions were identified and implemented by the community such as the construction of water treatment facilities, water testing, the construction of a "Green Basin Cross Border Park", public awareness campaigns on recycling, an incentive system for the reduction of household waste or a cross border study of the mosquito problem.

- **Avoidance of conflicts**

Public participation allows stakeholders to express their views regarding social and environmental conditions in their communities and helps them to understand the views and perspectives of others. Conflicts can be prevented by making sure everyone has a word concerning what affects their lives. When done at an early stage of decision-making, it may prevent or mitigate conflicts and adverse environmental consequences with transboundary impacts. An important building block is the development of consensus between these groups and the development of a shared understanding of the issues. While agreement or consensus might not be possible on every issue, understanding other people's perspectives is a useful starting point.

On the Okavango Every River Has Its People Project, socio-ecological surveys were carried out in Botswana and Namibia. Questionnaires and focus group discussions were passed in the riparian communities of the two countries asking basin communities what they knew about the resource, their priority issues, and propositions of solutions to these problems. These surveys allowed identifying that the communities from Botswana thought that Namibian people were stealing all their water during six months of the year when it actually came from the monsoon phenomena. Thanks to the survey, not only did they realize that their perception was wrong, but they could share their seasonal difficulties with upstream communities.

- **The use of indigenous knowledge**

People living by the river have a considerable store of knowledge about it. They might possess or be able to gather information that cannot be gathered scientifically such as habits, seasonal changes or modification of the ecosystem behaviour. As they live by the resource, they can access proxy data easily on the ground. As those data are informal or oral, they need to be translated in analyzable terms. Indigenous Knowledge is particularly crucial to understanding situations within community set-up especially when subsequent measures are to operate with the set-up.

People can also identify and address environmental threats at an early stage, saving time, energy, and scarce financial resources in the long run. They can control resource uses by identifying violations of applicable laws.

The size of the Mekong Basin and the diversity of its fisheries make it an almost impossible task to study certain trends concerning the fish, particularly migrations, solely by conventional scientific methods (fish tagging, scientific speculations, satellites, etc.). These methods are complicated and very costly. So the Fisheries Programme team decided to seek the knowledge of local fishers through the approach called "Traditional Ecological Knowledge (TEK)". The research Institutes in the four countries and the project team interviewed local fishers and asked them to show the species they had seen on a poster displaying the diverse species of the basin. Selected fishermen were required to take note of the fish they caught (number, size, species, net size, etc.) and report the information in logbooks in exchange for financial compensation. These methods do not allow a high level of precision but it has two major advantages: it is cost-effective and it promotes the participation of local populations.

Mekong fishermen, once they had understood the benefits of sustainable fishing, started pursuing on their own initiative illegal fishermen who were using dynamite or too-small nets.

However, it is not yet automatically considered as an inherent dimension of any sustainable development process. The actual practice of participatory approaches still faces certain challenges and problems. Two major obstacles to public participation can be highlighted.

- **Initial mistrust of the population**

It is very common for the population to be initially reluctant towards water projects. When seeing project stakeholders for the first time, they often fear for their lands to be taken or for illegal activities to be controlled.

- **Cost and duration**

Public participation activities are long and costly. They require time in order to question a sufficient number of people and collect their views. Insights then need to be analysed and incorporated in the project design.

Cameroon: Challenges in Kumbo community to improve water supply management

Description

The Kumbo water supply system initiated in the late 1960's and completed in 1972 has a complex ownership claim. On the one hand, it is claimed to be a Nso ethnic community water scheme realised with the financial support of the people of Canada through the efforts of an elite of Nso. Others consider it as a government-owned scheme considering the provisions of the national legislation relating to water supply, and the technical and diplomatic role of the Government of Cameroon in the construction and mobilization of financial resources from the Canadian government.

In 1984, a presidential decree institutionalized state operation of all urban water supply systems under the then Cameroon National Water Corporation (French abbreviation SNEC). It would appear this paradigm was of concern to several individuals due to non-involvement of locals in the management structure of SNEC. However, real trouble started when the Kumbo Council was billed for water consumed at public standpipes. This was compounded by the subsequent disconnection of over 60 public stand pipes and what the Nso people considered as deteriorating services, and escalating water tariffs which forced the citizenry to return to unprotected stream sources for their daily water needs.

There has also existed for over thirty years a conflict over the use of catchment area by the locals and the municipal water supply system management. This has been principally due to the forceful ejection of the locals from their farmland by the paramount traditional authorities.

Action taken

In April of 1991, in the light of the political upheavals in the Cameroon, a locally orchestrated campaign led to the forceful expulsion of SNEC from Kumbo in October of 1991. A community based local institution, the Kumbo Water Authority (KWA), under the chairmanship of the traditional ruler, with support from the elites, was created to manage the Kumbo Water Supply. This structure had problems of legality (in the light of national legislation for water management) that were compounded by regular conflicts in, and a litigation case over the catchment area that threatened the sustainability of Kumbo municipal water supply. Thus, following the 2004 decentralisation laws in Cameroon, GWP Cameroon worked with the Kumbo Urban Council and facilitated the transfer of management of the Kumbo Water Supply system to the Kumbo Urban Council.

Key outcomes

The locally managed KWA has re-opened all public taps, extended coverage and introduced a differential water tariff structure. Moreover, the Kumbo Urban Council has formally taken over the Kumbo Water Authority, and integrated it within its management structure. This has resulted in the establishment of an inclusive and participatory community water governance structure for the KWA that involves key stakeholders like the landowners in the catchment area. The KWA is currently engaged in participatory protection and conflict resolution over the catchment area. Findings from public interviews (Voxpop) suggest that there is an increase in the willingness to pay for services due to the provision of more reliable services and better communication between KWA and the population, especially those of the catchment area.

Key lessons

This case study elucidates how deteriorating drinking water supply service delivery can trigger community mobilization leading to a complete take-over and management of the system by local communities. Furthermore, it shows the importance of participatory management in resolving water catchment conflicts and improved cost recovery. Command and control decision-making paradigm and deteriorating drinking water supply services can be triggers for social and political instability, as well as sources of water related conflict. Community based organisations can be platforms to enhance participatory governance for efficient and effective management of water resources and conflict resolution.

Source: GWP, Toolbox case studies

5.4 Transparency and accountability

Conditions for good water governance require participation, accountability, and transparency in order to achieve successful economic, social and environmental outcomes. This requires transparency and accountability from both formal and informal sectors associated with water management: be they governments, private sector, or non-governmental organisations.

The responsible authorities, their partners and water users need to have confidence in their management systems and operating procedures. This can be addressed with training and information to promote the necessary understanding, but this is not always viable at all levels for all procedures to all stakeholders. Some elements of management may always remain internal but they must always be accessible. A balance needs to be struck between flexibility and accountability.

Consequently all financing and auditing procedures must be transparent. Tariff systems, systems of financial and quality control need to be rigorous in order to avoid the mismanagement or misapplication of funds that can be associated with large-scale investments in major construction works but also are relevant at village level water supply committees.

Information management helps to ensure that decision-making is legitimate, transparent, effective and efficient. It is about handling information from different sources in a way that optimizes access by all who have a share in or a right to access that information. It is about knowing what information to gather, knowing what to do with information when you get it, knowing what information to pass on and knowing how to value the resultant use of the information.

Historically, information management was largely limited to the management of libraries and documents (books, files, maps etc.) and retrieval of information was based predominantly on filing or cataloguing systems. Although such systems continue to be used, computers, other electronic devices and the Internet have revolutionized access. This technology enables large amounts of information to be stored and shared effectively, efficiently and rapidly. The key challenge for the water sector is to ensure that these ever more powerful and sophisticated systems are designed and managed for the ultimate benefit of all stakeholders, especially the marginalized. Millions of people lack access to computer and the Internet and as with most technologies, there is a high risk that the benefits will be captured by powerful and dominant elites. Effective information management involves the establishment and management of an information base, whether PC based or as paper-based filing system.

The Challenge of water management over large areas has resulted in an increasing use of geographical information systems (GIS) which bring enormous benefits in terms of accuracy and comprehensiveness, even though they also introduce new human and financial resource challenges.

Water data and information exchanges are taking place at three levels:

- Exchange of *technical information (*resource uses, pollution pressures, related ecosystems, risk assessment and financial challenges) among basin stakeholders.
- *Internal communication* with in an organisation or the project team,
- *External communication* towards the public at the local, national, regional and international scale.

The constitution of a common knowledge base and the development of tools to facilitate data exchanges is often the first step for cooperation and an indispensable preliminary before initiating a common management of the basin. Data exchange and transparency has two major benefits:

- **A shared vision**

A shared vision of the issues and priorities at stake in the basin cannot exist without a clear and straightforward communication among its stakeholders. Usually there are widely disparate levels of understanding about the functioning of a system depending upon the situation of the various stakeholders and their access to information. All stakeholders must share appropriate environmental, social and economic baseline data about the functioning as well as the present and future pressures likely to be placed on the basin system. These elements are an essential prerequisite for the achievement of joint strategic planning and effective management. It contributes to providing a framework for future actions that will be undertaken by decision-makers, water managers and populations to manage the basin.

A shared vision is also fundamental in order to ensure the sustainability of complex water projects. Many basins are now emphasizing this interrelation by developing “shared vision” projects and Programmes. In 2003, the Nile Council of Ministers agreed that a shared vision could be legitimized by action on the ground that could benefit the peoples of the Nile Basin. The resulting Shared Vision Projects have generated a wealth of knowledge products, best practices, practical tools, strategic and analytical frameworks as well as policies and guidelines that promote an integrated and comprehensive approach to water and related resources management and development. On the Niger basin, the development phase of a Shared Vision process for the sustainable development of the River Niger Basin was initiated in September 2002.

- **Lessons learned from existing experiences**

Any action or project is formative for those who undertook it. Nevertheless, this knowledge must be made explicit, formalized and promoted if it is to be disseminated to others. Formalizing the lessons learned from existing practices and experiences allows improving the quality of future actions by sharing knowledge and know-how. Stakeholders concerned by this process are varied: they can be within a country (among people, basin organizations, water managers and other concerned institutions), among countries belonging to the same basin and among basins. An increased sharing and knowledge exchange between these stakeholders is indeed crucial for the reinforcement of cooperation, and for the improvement of surface and groundwater project and operations management.

The focus for those efforts encompasses wide recommendations from strategic to operational and methodological aspects. They can be related to many crucial areas of interest such as risk management, flood and drought prevention, funding mechanisms, integrated information systems, planning methods, training and capacity development. They must include not only key success factors but also difficulties and issues faced in the management of the projects and the resource. Most importantly, they must be communicated through short and clear messages. Usually lessons gained from existing experiences are gathered in numerous and long reports that are never reopened once closed. Efforts should be made to systematically formalize lessons learned, offering opportunities for participants to exchange experience and transfer knowledge and good practices among them.

Several aspects constitute obstacles to data exchange and transparency.

- **Data Availability**

In many basins, quantitative and qualitative information regarding water resources is incomplete or lacking. Certain aspects, such as the quantity of water available, are unknown while some others, such as water uses, are based on mathematical estimates.

On the Senegal River for example, little is known about the basin. L'Organisation pour la Mise en Valeur du Fleuve Sénégal (OMVS) has signed a number of conventions with professors and researchers. Each of their universities has a water centre but none of them is gathering the data. The OMVS is trying to gather existing data in order to support decision-making. But in many sectors, like water quality for instance, data is not available. Moreover, the OMVS does not have any data on the Guinean part of the river, even though the country is located upstream and has a major impact on downstream riparian states.

- **Data Accessibility**

Of the data available, most is not accessible because:

- Some is in the form of hard-copy reports, limiting its circulation,
- Published articles are not easily accessed due to lack of subscriptions,
- Information on internet is not easily accessed because of lack of adequate internet access or connectivity problems,
- Knowing that the data exists at all may be difficult,
- Owner of data has to be prepared to share it if it is not already in public domain.

- **Data Quality**

In some cases, the quality of the data itself is suspect. Low quality data can lead to inefficiencies and poor decisions that can have severe financial and social impacts. Thus, the field of data and information quality is an active area of research.

- **Reluctance of the countries to share information**

Some countries are not in favour of water data transparency. They associate it with a lack of sovereignty and wish not to divulgate quantitative or qualitative data. Data ownership is still often considered as a high-level strategic issue.

On the Guarani Project for instance, the Brazilian Ministry of Environment decided to develop its own Information System, called SIAGAS, while an Information System was already being developed for the project. 62% of the aquifer relies upon the Brazilian territory, meaning that Brazil also possesses by itself 62% of the data on the aquifer (respectively, the extent of the aquifer in Argentina is of 21%, Paraguay 8% and Uruguay 3%). The Brazilian government knew that an information system was developed by the project. Assumptions can be made that they thought that the project system wouldn't be done and that they could be the one gathering and managing the data of all countries or that they might thought they could sell their data and/or information system to the project.

In some cases, this refusal hides shortcomings of the countries regarding the quantity and quality of their data.

- **Financial sustainability of monitoring networks and information systems**

Many monitoring networks and information systems are being developed in complex water projects, particularly in transboundary basins. One of the main issues related to those tools is their (financial) sustainability. Once the project that implemented them ends, water keep needing to be sampled regularly, data to be entered into the system, databases to be updated, etc. All these operational activities have a cost. Countries need to pledge to maintain such activities after the end of the project.

The Nile Water Quality Monitoring Network experienced difficulties in being maintained after the closing of the Nile Transboundary Environmental Action Project. The implementation and completion report of the project highlighted that Nile Basin countries should be committed to sustain the networks technically and financially but that they needed support in order to enable production and sharing of data. By the end of the project, only one or two countries out of nine had sent data to NTEAP.

- **Staff turnover**

Complex water projects last several years. One phase usually stretches over 3 to 5 years. During that time, members of the project team and other stakeholders involved in the project might leave and be replaced. This turnover creates instability for the management of the project since some information and knowledge generally gets lost in the process.

Another difficulty linked to staff turnover is related to consultants. The hiring of many different short-term consultants and the variety of their working methods can be hard to manage and can lead to a loss of time and data.

- **The Science-Policy Interface**

Scientists are looking at generating knowledge while decision makers are looking for concrete and fast results. This discrepancy in expectations, timescales and vocabulary can be detrimental for water project.

Volta river basin: Water management through multi-level participatory governance and community projects

Description

The Volta River Basin in West Africa has a surface area of approximately 400,000 km2 across six countries: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, and Togo. The basin is divided into four major sub-basins: the Black Volta, the White Volta, the Oti and the Lower Volta. The Volta Basin is home to nearly 19 million people. The Volta basin is an important asset for the livelihoods of the people and development of the riparian countries.

The Volta River Basin faces enormous development challenges. Poverty and increasing population pressure have led to the extensive exploitation of natural resources contributing to water scarcity, land degradation and the siltation of river channels. Despite the fact that most of these challenges call for basin-wide responses, the Volta River remained one of the few transboundary watercourses in Africa without an international treaty and without a basin-wide coordination mechanism. Limited consultation and coordination between Burkina Faso and Ghana combined with uncoordinated policies and development initiatives were serious threats to the sustainable management of Volta Basin. The basin had no formal legal and institutional arrangements to manage disputes over resources. Tensions between Burkina Faso and Ghana stemmed from misconceptions about the causes of climate variability and changes in flow patterns of water resources.

Action taken

The Water and Nature Initiative (WANI) and partners have worked with riparian states in the Volta basin to improve water governance and water management practices. WANI, through a project supported the setting up of local, national, transboundary and regional governance frameworks to improve the management of water resources in the Volta Basin focusing on Burkina Faso and Ghana. This has resulted in multi-scale participatory governance frameworks for joint management of water resources and improvement of livelihoods through riverbank protection schemes. This has complemented and helped to facilitate large-scale government and donor initiatives that have supported the establishment of the Volta Basin Authority. The Volta Basin now has a number of legal tools, knowledge and capacity to sustainably manage its shared water resources at local to transboundary levels.

As a response to development challenges in the Volta Basin, WANI also launched a project "Improving Water Governance in the Volta River Basin" to demonstrate change in water governance and management. WANI and partners aimed to improve water governance through consensus on key water management principles and to institutionalize coordination mechanisms. If effectively and fully taken into consideration, these policies offered a good basis for reaching an agreement for the equitable and sustainable management of the Volta River. In both Ghana and Burkina Faso, the adopted legal and institutional frameworks for the management of water resources promoted integrated basin management, equitable access, water for nature and international cooperation.

Lessons learned

Although water laws and institutions for managing water resources were in place in both Ghana and Burkina Faso, the implementation of IWRM principles were not fully demonstrated and there is still a lack of regulatory processes or mechanisms to manage the basin water resources.

While the willingness to discuss transboundary issues was present, the lack of baseline knowledge of the basin and the absence of major water users in decision-making processes and governance frameworks limited the riparian countries' ability to manage the water resources sustainably.

Alignment of activities with national priorities and linkages with government policy processes are needed for larger-scale impacts. When national interests are positioned with regional initiatives such as basin authorities, which have the political hardware and infrastructure to support transboundary collaboration, water resources governance can become a reality at multiple scales and across national boundaries.

Stakeholders and partners are more willing to participate when they see tangible results and improvements in their everyday lives such as income generation schemes, water supply facilitation and conflict reduction. Addressing some of the issues that are important to the community helps considerably in gaining trust and a commitment to engage in wider governance issues and initiatives.

Building a local knowledge base with good data and information systems is important in deciding the most efficient allocation of resources. Such a tool is key thorough understanding of the relationships and scenarios within the basin such as water availability, trends, demands and conflicts, and can then lead to better management decision making.

Source: GWP, Toolbox case studies

5.5 Inclusion

Poor and marginalized people are by their nature not well represented in existing management structures or other platforms. They often lack the time or resources to play an active role in processes. Poor women are often too busy in the house to attend meetings. In some cases there is active resistance to including marginalized people who may be seen by other groups as 'outsiders' or as not having a legitimate stake in the process. Identifying the poorest and most marginalized people in a community is often the single most important step that can be taken towards inclusion and presents special challenges. A feature of exclusion is that marginalized tend to be invisible – overlooked and ignored in development processes.

The Eldis poverty portal suggest as a methodology that deals with the identification of the poor and marginalized to use wealth ranking. This tool helps classify the population into socio-economic strata; based on locally specific criteria and using culturally appropriate terms. The main steps of wealth ranking are:

Step 1: Identification of criteria.

Criteria for identifying the poorest and most marginalized need to be identified. These can be formal indicators (such as household income), but should ideally also include qualitative indicators based on people's own perceptions.

Step 2: Identification of the poorest.

Once an agreed set on criteria has been identified these should be used to identify where the poorest and most marginalized live, and how many people are in this category. In situations where the poor and marginalized live in particular areas, mapping can be useful tool to identify and illustrate this.

Step 3: Mapping access to resources.

Group discussions and semi-structured interviews with poor and marginalized people, and with other wealth groups, service providers and other stakeholders can be used to map access to resources by the poorest and most marginalized, with a particular focus on actual and potential barriers to access. This should include mapping access to water resources and services, as part of assessing and a RIDA (Resources, Infrastructure, Demand and Access) analysis, and also mapping access to other resources and services such as income, education, employment and healthcare.

Step 4: Involvement.

Based on the identification of the poorest and most marginalized, identify a strategy for their involvement in the process. This strategy must tackle issues such as:

- Representation in meetings and workshops,
- Ensuring that such representation is legitimate and appropriate,
- Tailoring materials to the needs of less educated people,
- Working separately with the most marginalized (particularly poor women) so that they are not intimidated,
- Developing specific programmes for capacity development, and
- Identifying suitable financing mechanisms such as subsidized loans, micro-credit etc.

The Paris Declaration on Aid Effectiveness stresses the importance of results-oriented frameworks to improve aid effectiveness and to assure better pro-poor outcomes. To this effect, different tools are available, such as Poverty Impact Analysis (PIA), Poverty and Social Impact Analysis (PSIA), Social Impact Analysis (SIA).

PIA is a tool based on a balance of qualitative and quantitative information, on existing information sources that can assist in identifying the consequences of an envisaged project and in providing a basis for harmonization as it uses a standardized set of matrices.

Poverty and Social Impact Analysis (PSIA) studies how the impact of policy reforms on the welfare is distributed on different stakeholders groups, primarily on the poor and vulnerable groups. Its overarching objective is to promote evidence-based policy choices, by explicitly including poverty and social impacts in the analysis of policy reforms, and to build country ownership of policies by informing a public debate on the trade-offs between policy choices. PSIA can be used for analyzing the link between policy reforms and their poverty and social impacts, design mitigating measures and risk management systems.

Social Impact Analysis (SIA) "includes the processes of analyzing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions. Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment".

There are five main elements of social development to consider in the water projects. These are:

- The cultural features and implications of water use;
- The perceived needs of all those affected by changes in policy and by new projects;
- Inclusion of all members of society, particularly those who may be disadvantaged by poverty, or by their status in society;
- Recognition that the roles and needs of women and men may be different, but that they should have equal status in society, and that equal participation and benefit for women and men is a pre-requisite for a successful project;
- Encouragement of the participation of all stakeholders in the development process and the eventual empowerment of communities.

Cultural issues with regard to water are especially sensitive. There may be beliefs and behaviours associated with water use to which strong religious or customary value is attached. There may also be differences in attitudes between women, children and men. These differences are more easily exposed by participatory methods of enquiry, and in the first instance by discussing with women and men separately.

Case study Lake Victoria Murray Darling Basin Australia

This will be a case study of the successful resolution of an eight years conflict between water management agencies (and the various stakeholders that benefit from water extractions) and Aboriginal or Indigenous people in the region of Lake Victoria, one of the major storages in the southern section of the Murray Darling Basin. In 1994 the Murray Darling Basin Commission emptied the lake in order to undertake repairs for the first time since the original natural lake on that site was enlarged in the 1920s. This revealed a large number of exposed graves in the bed of the lake. The regional Aboriginal community immediately demanded that the storage be permanently decommissioned so that the graves could be treated appropriately. Against these demands the water agencies backed by their state governments argued that this was an essential storage for the operation of the water distribution agreement between the southern states, South Australia, Victoria and New South Wales.

The resulting controversy took the storage offline for eight years and caused severe dislocation. In earlier decades the Aboriginal demands would have been ignored but in the changed political climate of the 1990s that was not possible. Eventually through the use of facilitators and the influence of the wider political context a new management plan was negotiated that achieved most of the water management objectives of the previous operating system but which also satisfied Aboriginal concerns. Under the plan the graves were protected through a four million dollar restoration program undertaken using Aboriginal labour and directed by Aboriginal consultants. A crucial policy change was that instead of filling the lake and holding it full at the beginning of winter for release in summer it was now to be filled for only short periods. This allowed the lower inner slopes of the lake to be vegetated with plants able to survive short inundation, thereby further protecting the graves and improving environmental conditions. Aboriginal representatives were also placed on the storage management board. A significant factor which made it imperative to reach a negotiated solution which satisfied all stakeholders was that this situation is likely to recur elsewhere in the Murray Darling Basin.

Aboriginal people have lived, died and been buried along its rivers for at least twenty to thirty thousand years and it is a certainty that there are many graves elsewhere. The negotiation of an acceptable compromise for Lake Victoria provides a well developed and tested response of wider relevance.

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Focus on Gender

The promotion of gender equality and women's rights is not only a crucial goal in itself, as a matter of fundamental human rights and social justice, but is also a *sine qua non* for achieving all development goals. As a matter of fact gender equality is key to achieving the MDGs.

Gender denotes the social roles of women and men as opposed to their biological difference. Access to socially valued and valuable resources is unequal, and is normally biased in favour of men. Women generally have less access than men to training, land, secure employment and leisure, as well as to the political process. Already in 1979, the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW), adopted by the UN General Assembly defined what constitutes discrimination against women and set up an agenda for national action to end such discrimination. Unfortunately such discrimination still widely persists.

Gender mainstreaming is a strategy aimed at achieving gender equality. The EC *Toolkit on Mainstreaming Gender Equality in EC Development Cooperation* (2004) defined this in order to mainstream gender equality in development cooperation programmes and related activities the following steps are essential:

- Statistics disaggregated by sex and qualitative information on the situation of women and men must be obtained for the population in question. This information is required not only at project/programme beneficiary level, but also at the macro and meso levels.
- A gender analysis should be conducted with regard to the gendered division of labour, access to and control over material and non-material resources, the legal basis for gender equality/inequality; political commitments with respect to gender equality; and the culture, attitudes and stereotypes which affect all preceding issues. Gender analysis should be conducted at the micro, meso- and macro-levels.
- Gender analysis of a programme or project concept should reveal whether gender equality objectives are articulated in the initial idea, whether or not the planned activity will contribute to or challenge existing inequalities, and whether there are any gender issues that have not been addressed.
- During the identification and formulation phases, gender analysis contributes to the identification of entry points for actions that will be needed in order to meet gender equality objectives.
- A gender-sensitive monitoring and evaluation system should also be in place from the design phase onwards, including the establishment of indicators to measure the extent to which gender equality objectives are met and changes in gender relations achieved.

Without identifying such differences, it is not possible to devise policies that meet the specific needs of women and men and address existing inequalities.

The development of gender planning techniques such as the use of gender-disaggregated statistics and task analysis in which female and male tasks are defined, responds to the need to allow for gender differences in the planning and implementation of programmes and projects.

Gender planning methodology identifies several roles of women as household and domestic managers; economic producers (e.g. in farming); and community leaders. It also identifies two crucial distinctions in gender interventions: projects which address women's needs, by improving existing work methods and relieving their domestic and farming burdens; and projects which address such strategic needs as equality with men, improved status and access to resources.

Gender analysis and the PSIA/ PIA /SIA should seek to identify the allocation of tasks to women and men, and to measure time and burdens in relation to women's and men's activities, and to calculate the likely benefits and losses to both women and men.

In Turkey, Multi-Purpose Community Centers (ÇATOMs) were initiated by the South-eastern Anatolia Project to alleviate poverty in poor neighbourhoods. Women and young girls received trainings on income generating activities such as handicrafts, machine knitting, cutting-sewing, furniture, felt processing, stone works, silversmith works, textiles, toys, souvenirs, soap making, cloth dyeing, hair dressing or cooking. The manager of these training centres for women had numerous difficulties to convince the husbands to let their wives participate in ÇATOMs. To do so, she had to demonstrate to them evidence of economic effectiveness.

In Turkish and Kurdish traditions, women do not need to know how to read or write in order to take care of the children and the house. It is by explaining that a good hygiene can limit healthcare expenses or that training in sewing, hair dressing or embroidery will allow them to bring additional income to their household that ÇATOM employees and volunteer workers managed to attract women. Other trainings offered by ÇATOMs include reading/writing, computer, mother and child education, birth Control and health (reproductive, hygiene, mother health, child health, etc.).

Water for inclusive growth and development

While access to water for basic needs is acknowledged as a right, it is an accepted fact that water is inextricably linked to growth and development. Furthermore, for certain areas of the developing world (such as Sub-Saharan Africa), certain concepts brought up by IWRM such as the integration of the different uses have been coupled with a new impulse promoting Water for Growth and Development (WfGD). This combination is giving as much weight to economic growth as principal reducers of poverty in development as it does to MDG targets for basic services such as food security, household poverty and access to electricity. The concept of WfGD has been developed particularly in Africa, where African Ministerial Conference on Water (AMCOW) Ministers have since 2008 been embracing the concept. It is being recognised that in developed countries the focus on water management and operation is important and certainly needed, but that for the least developed countries the lack of recognition of the significance of investments in water infrastructure has serious consequences. For securing water and achieving economic development and growth, a minimum level of water infrastructures is required.

Whether a country should invest in water management and operation or in infrastructures therefore clearly depends on its local situation and its level of water sector development, blanket prescriptions of course are not the answer to complex economic, social and environmental realities.

At the same time poor countries must not see infrastructures as a Panacea. This could result in some unsustainable and catastrophic results; investments must not only be addressed in building infrastructures but also in developing in parallel sound institutions and sustainable, equitable and environmental sound solutions.

The contribution that water can make to growth and development as a whole is important; consequently the World Water Council (WWC) (2011) developed an “effective investment framework”. This framework aims at improving financing measures in the African continent taking into account three key institutional levels - local, national and regional- as well as three interdependent “securities”- human security, economic security and water security. To achieve the best possible investment actions for sustainable development and growth the WWC suggests that the three securities must intersect with the three cited institutional levels.

One of the most advanced experiences in WfDG is in South Africa where, since 2009, a Water for Growth & Development Framework is under implementation. Key points include the centrality of water to all South African sectors and the necessity of taking a cross-sector approach to ensuring water security and balancing water interests.

This push towards growth in development is also defined by the EU in its communication “Agenda for Change” adding the concept of inclusion, affirming that “Inclusive and sustainable economic growth is crucial to long-term poverty reduction and growth patterns are as important as growth rates. To this end, the EU should encourage more inclusive growth, characterized by people’s ability to participate in, and benefit from, wealth and job creation. The promotion of decent work covering job creation, guarantee of rights at work, social protection and social dialogue is vital. Development is not sustainable if it damages the environment, biodiversity and natural resources and increases the exposure/vulnerability to natural disasters”.

6.0 PROJECT MANAGEMENT APPROACH

The concepts presented in the first part of this course provide a framework of policy principles and programming contexts for water related interventions. Planners, officials, practitioners and development workers are expected to use them as a guide for decision-making. The second part is designed to enable trainees to put the principles into effect.

The following chapter contains a description of Project Cycle Management (PCM), whose phases provide a time-line and project process framework in which to apply the principles and checklists of key challenges and potential responses. These are grouped according to both the PCM phases and the water challenges identified in the first chapter.

Then, the course focuses on the Logical Framework Approach (LFA). It is an analytical and management tool which is used by most multilateral and bilateral aid agencies, international NGOs and by many partner governments. It is a core tool used within Project Cycle Management.

6.1 Description of Project Cycle Management (PCM) Approach

6.1.1 - Project approach

The Oxford English Dictionary defines “project” as “An individual or collaborative enterprise that is carefully planned and designed to achieve a particular aim.

Projects can vary significantly in their objectives, scope and scale. Smaller projects might involve modest financial resources and last only a few months, whereas a large project might involve many millions of Euro and last for many years.

However, disregarding its specific characteristics:

- **Projects have a purpose**: projects have clearly-defined aims and set out to produce clearly-defined results. Their purpose is to solve a “problem”, and this involves analyzing needs beforehand. Suggesting one or more solutions, it aims at lasting social change.
- **Projects are realistic**: their aims must be achievable, and this means taking account both of requirements and of the financial and human resources available.
- **Projects are limited in time and space**: they have a beginning and an end, and are implemented in a specific place and context.
- **Projects are complex**: projects call on various planning and implementation skills, and involve various partners and players.
- **Projects are collective**: projects are the product of collective endeavour. They are run by teams, involve various partners and cater for the needs of others. A project should have a clearly defined coordination, management and financing arrangements.
- **Projects are unique**: all projects stem from new ideas. They provide a specific response to a need (problem) in a specific context. They are innovative.
- **Projects are an adventure**: every project is different and ground-breaking; they always involve some uncertainty and risk.

- **Projects can be assessed**: projects are planned and broken down into measurable aims, which must be open to evaluation.
- **Projects are made up of stages**: projects have distinct, identifiable stages.

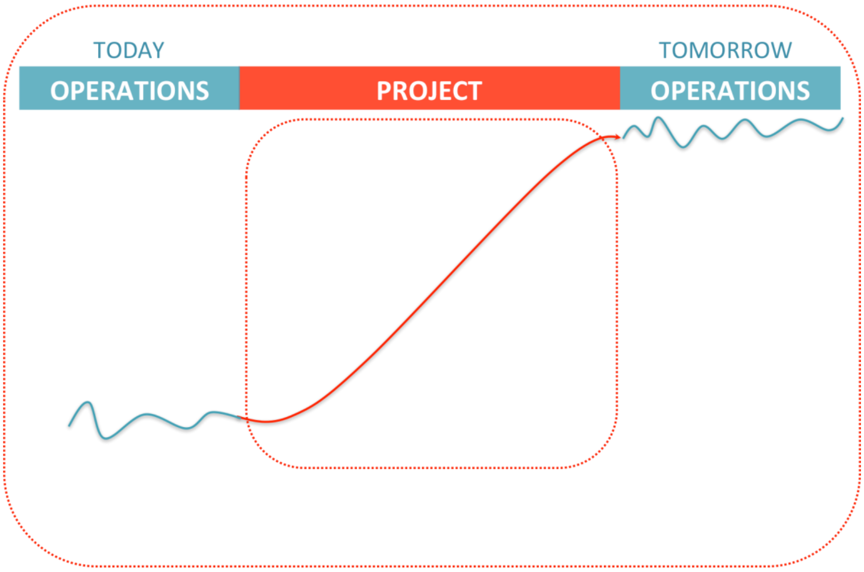


Figure 21: Project as transition
(Source: Hassenforder, Daniel, Noury, 2012)

A water project (or water programme) is always a transition between a present unsatisfactory situation and a future one, considered as a better one. Hence, the role of the project phase is to identify, to clarify, to produce and to deliver the resources and means that will be necessary to make the future expected situation possible. A project is a development phase that will generate new capacities in a basin.

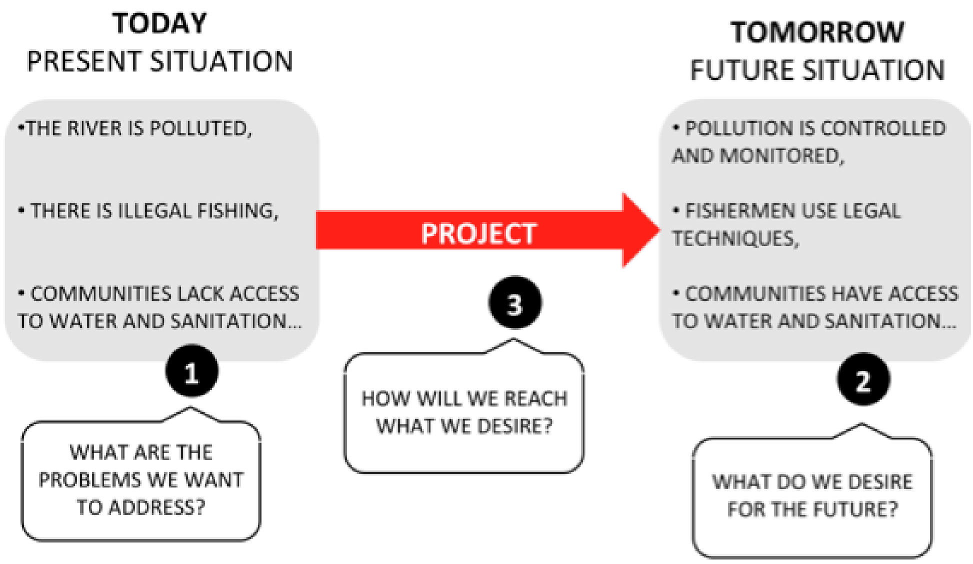


Figure 22 From the present to the future situation,
(Source: Hassenforder, Daniel, Noury, 2012)

Among all the problems and needs that are revealed in a river basin, only some will be addressed. Priorities must be set. One of the strategic roles of project decision-makers is to establish development orientations and priorities for the basin. Once the broad strategic mission is defined, projects and programmes are launched in order to address the specific issues considered as strategic. As a matter of fact, each project and/or programme is the expression of a desired vision for the future. Projects and programmes represent means to provide chosen solutions to a given problem - considered as a strategic priority - among all of the solutions which were possible. Hence, projects must be totally aligned with the strategic mission that is defined.

Examples of projects could include:

- A health service reform and expansion project, implemented primarily by the Ministry of Health of the partner government and with financial support of other donors, costing Euro 30m over 10 years;
- An emergency relief project, coordinated by the UN and implemented through International NGOs, costing Euro 5m over one year;
- Business promotion projects, providing grants to non-profit organizations of up to Euro 200,000 over a maximum time line of 2 years;
- City waste water treatment building project, using a contracted project manager, costing Euro 50m over 5 years;
- A regional food security training project, focused on the provision of technical assistance and training services, costing Euro 2m over 3 years; or
- An election monitoring project, conducted primarily by staff from the EC and its member states, costing Euro 600,000 over 5 months.

In order to accommodate this kind of diversity, it is important that project cycle management systems support the application of standard working modalities/rules in a flexible manner.

A well-formulated project should derive from an appropriate balance between the National's development policy priorities and the donor's development priorities. Within the scope of these policy priorities, the executive arms of government or nongovernmental agencies formulate under a programme, the broad areas of work required to implement policy decisions. Programmes, like projects, may vary significantly in scope and scale. The definition of what a programme is depends essentially on how the responsible authority (ies) chooses to define it.

For example, a programme may:

- Cover a whole sector (e.g. Water Sector Programme);
- Focus on one part of the Water sector (e.g. a Capacity Building Programme);
- Be a 'package' of projects with a common focus/theme (e.g. SADC-EU university links programme); or
- Define what is essentially just a large project with a number of components.

In line with international thinking on the water sector, development is seen nowadays as a process to which sector programmes and projects contribute; sector programmes and projects alone do not themselves necessarily constitute development. A project can be effectively executed in technical terms, but if it is not in line with national policies and plans or with social, economic or environmental realities, it may end up as a costly and unsustainable implementation exercise.

Concerning the macro level of the national policies and strategies, a coherent project management cycle, in order to increase its chances of bringing sustainable benefits to its target groups, has to take into account the sector building blocks and in particular the following elements:

- **Sector policy and strategy:** a sector policy is a statement of a government's long-term vision (ten years or more) for the sector, setting out the government's objectives for that period. The sector policy also specifies the institutional aspects (roles of different actors in the sector, division of responsibilities, financing, etc.), sets out the main principles of service management (state control, private operator etc.) and the priority action areas (geographical areas, maintenance or extension of the network) and explains which legal and regulatory decisions are deemed necessary. The sector strategy action plan, also known as the master plan, describes how, in terms of the physical and financial execution, the government intends to implement sector policy over a medium-term perspective (3-5 years). It may be necessary to set intermediate targets or priorities to meet policy objectives;
- **The sector budget and its expenditure perspective:** these two must form the financial expression, on an annual and multi-annual basis, of the sector strategy. They are drawn up in conjunction with the sector strategy and on the basis of the available resources in the sector;
- **A sector coordination framework**, through which the sector policy, action plans and budget are reviewed and updated.

Together with those three core elements, there are also two key components: the **monitoring system** and the **institutional capacity**. These two components are of equal importance and often pose major challenges for the sustainable development of the sector. Monitoring systems are common weak points, which can be detrimental to future management and programming, and call into question the use of sector budget support as a financing modality. As regards to institutional capacity, capacity building assistance must be targeted by a good needs assessment but often involves most national partners.

The general relationship between policies, programmes and projects is illustrated in the figure below

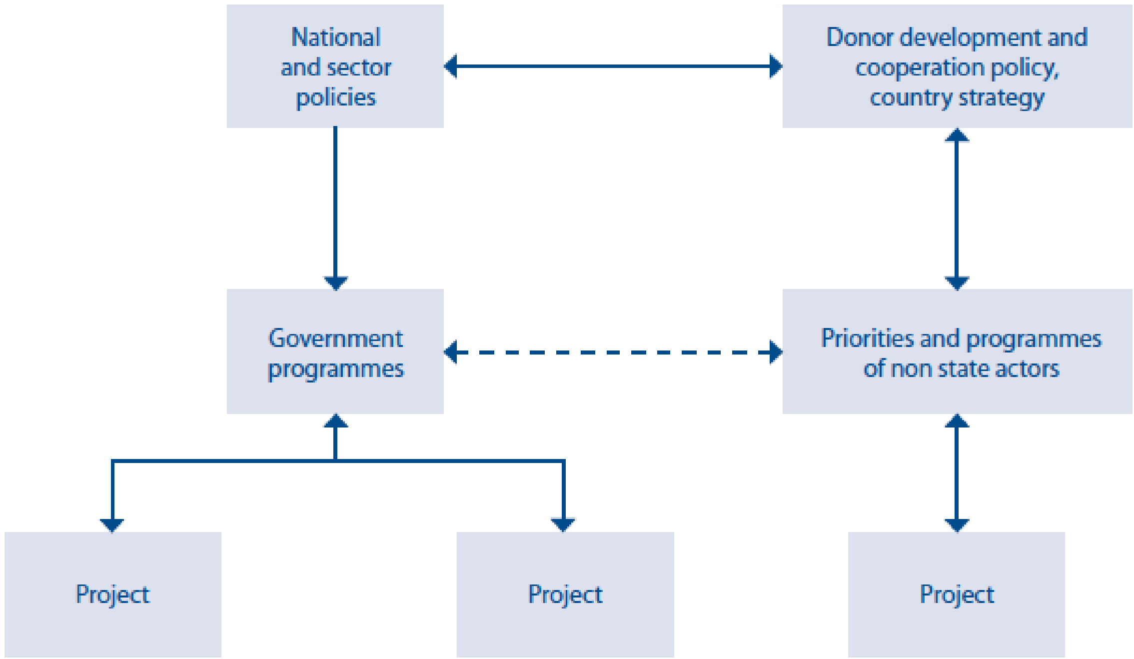


Figure 23 Policy, programmes and projects
(Source: EC, 2011)

Project objectives should therefore contribute to national and sector policies wherever a public sector activity is being supported. The articulation of projects into programmes contributing to broader policy objectives requests coordination mechanisms between the programmatic planning of donor's support/external assistance and the planning and budgeting of national resources. Actually, foreign assistance programming mechanism should be aligned and complementary to the programmatic planning and budgeting process of the national resources.

The Volta Basin Authority

The strategic objectives of the Volta Basin Authority (VBA) are:

- *Strengthening of policies, legislation and authorities,*
- *Strengthening of the knowledge on the basin,*
- *Coordination, planning and management,*
- *Communication and capacity-building of all stakeholders,*
- *Strengthening of VBA operational functions.*

Several programmes and projects were launched, they have to be in line with the above strategic objectives, and they have to contribute efficiently to them:

- *Volta-Hycos: implementation of an hydrological cycle observing system,*
- *GEF Volta: addressing priority regional transboundary issues and problems,*
- *GLOWA Volta: scientific sound Decision Support Resources for the authorities in the region*
- *IWRM Volta EU: IWRM development in Volta basin countries,*
- *Observatory: Tool to monitor, understand, correct, anticipate and inform about water trends,*
- *Project for Improving Water Governance in the Volta basin (PAGEV): strengthening bilateral cooperation between Burkina Faso and Ghana,*
- *Challenge Programme on Water and Food (CPWF): small rainwater reservoir development and maintenance.*

Concerning the project level, to contribute effectively to development throughout the entire project management cycle, a process of dialogue with stakeholders and beneficiaries is needed in order to foster:

- **Ownership:** From a user-beneficiary perspective, the project is viewed as the creation of assets over which they hold responsibility and will yield sustainable benefits after funding has ceased.
- **Stakeholder involvement**: ownership cannot be created without the involvement throughout the project cycle of all actual or potential stakeholders whether they are individuals, groups or organisations that have an interest in the project. Beneficiaries and implementing organisations are generally the most important stakeholders, but others of significance can include faith-based organisations, NGOs, traders, developers, the private sector and agencies concerned with complementary or competing activities in the programme or project environment. Stakeholder interests may therefore be positive or negative towards the project. Effective PCM needs to take account of stakeholder interests at every phase of the project cycle, and make adjustments accordingly.
- **Participation**: the above elements entail an overall concept: the need for participation. Much water-related development activity depends heavily for its success on active and real participation by the intended beneficiaries. It is recognised that effective participation, as opposed to an exercise in consultation or a communications campaign, can be a long process with less easily predictable results. However participation is regarded as a vital component of the stages of identification and formulation, and should be present to some degree in other stages of the project cycle.

Weaknesses of the project approach

The project approach has been at ‘the cutting edge of development’ for many years, primarily because it has helped meet the accountability requirements of donors. However, significant problems with the ‘classical’ donor-controlled project approach have also become increasingly evident, namely:

- Inadequate local ownership of projects, with negative implications for sustainability of benefits;
- The huge number of different development projects, funded by different donors each with their own management and reporting arrangements, has resulted in large (and wasteful) transaction costs for the recipients of development assistance;
- The establishment of separate management, financing and monitoring/reporting arrangements has often undermined local capacity and accountability, rather than fostering it; and
- The project approach has encouraged a narrow view of how funds are being used, without adequate appreciation of the 'fundibility' issue.

The concept of ***fundibility*** of aid resources highlights the fact that donor funded projects can simply allow partner governments to re-direct their own financial resources to other purposes (assuming that governments would have spent their own money on the project(s) even if the donor funding was not available). For example, donor funding of Euro 100m to the Water Sector of a particular country could allow the partner government to then use (or 'divert') Euro 100m of its own resources (which it otherwise would have had to allocate to Water) to fund other uses (e.g. internal security or Health expenditures).

Exercise - Every River has its people Project – Okavango

The Every River Has Its People Project (ERP) is a unique initiative on shared river basin management approach implemented in the Okavango River Basin, which transcends three countries (Angola, Botswana & Namibia) funded by the Swedish International Development Agency (SIDA). The project facilitates community participation in the Permanent Okavango Commission (OKACOM), a tripartite agreement between Angola, Botswana and Namibia and has been running since 1999, with the second Phase having started in August 2004 and ends in February 2007. There will be a five-year strategy implementation starting 2007 to 2012.

The Association for Environmental Conservation and Rural Development (ACADIR), Kalahari Conservation Society (KCS) and Namibia Nature Foundation (NNF), therefore, are respectively implementing the project.

Step 1: Divide the class in small groups and ask them to imagine projects activities to answer these objectives:

-To promote the sustainable management of natural resources in the Okavango River Basin for the benefit of basin residents and states

-To foster exchange between the inhabitant of the Okavango river basin.

-To promote and facilitate the participation of communities and other local stakeholders in water resource management and decision-making.

Step2: Each group presents its activities

<u>Step3:</u> Presentation of the activities implemented by the project

Knowledge production:

- *Socio – economic studies*
- *Technical report*

Awareness

- *Project website*
- *Educational material*
- *Workshops*
- *School visits*

Local projects generating income:

Ecotourism, craft, Operation Roaming Rhino, trophy hunting, bird guides, mukoro trails…

Networking

- *Basin Wide Forum, a transboundary committee comprised of 10 local representatives from each state*
- *Transboundary field visits*

6.2 Project Cycle Management Approach

The European Commission introduced project Cycle Management (PCM) in the early 1990's to improve the quality of project design and management and thereby to improve aid effectiveness.

PCM developed out of an analysis of the effectiveness of development aid undertaken by the OECD Development Assistance Committee during the late 1980's. Evaluation findings indicated that a significant proportion of development projects had performed poorly, and identified a number of causes:

- Poor project planning and preparation
- Many projects not relevant to beneficiaries
- Risks were insufficiently taken into account
- Factors affecting the longer-term sustainability of project benefits were ignored
- Lessons from past experience were rarely incorporated into new policy and practice

Project Management (PM) methodologies in use around the World are definitions of project management processes aiming at standardizing and improving the quality of the project management lifecycle. Quality of the projects can be defined in terms of the relevance, feasibility and effectiveness of the impacts of the investment, including how well they are managed.

A project management methodology consists of process groups and control systems. The PM methodology aims at organising the project cycle structure and defining not only the content of each phase but also how it can be best accomplished.

Typically all project management methodologies imply a flow similar to the "Plan-Do-Check-Act" cycle with phases which are linked together by results – the result of one phase should become the input of another. Although, the way of defining the phases of a project can be subjective and often based on organizational procedures, each project management methodology approach should include well defined phases and the transition from one work phase to another should naturally involve the transfer of some sort of deliverable (a document, piece of software, invoice, report, an approval by committee, etc.)

The word 'project' as used in this course, should be interpreted as broadly as possible including sector planning. The term 'project' is primarily used for convenience and simply means the collection of related activities for which a contribution is provided to meet a specified objective.

Different project management methodologies have been adopted by several agencies such as the Asian Development Bank (ADB), the World Bank (WB), the European Commission (EC), and national governments. In particular, the EC has produced a "Project Cycle Management" (PCM) manual, which has been subsequently adopted by other development partners as one of the systems for project development, funding and evaluation (EC, 2004).

As mentioned, the way of defining the phases of a project can be subjective and often based on organizational procedures. In the case of the EC PCM, the project cycle presents five phases: Programming, Identification, Formulation, Implementation and Evaluation.

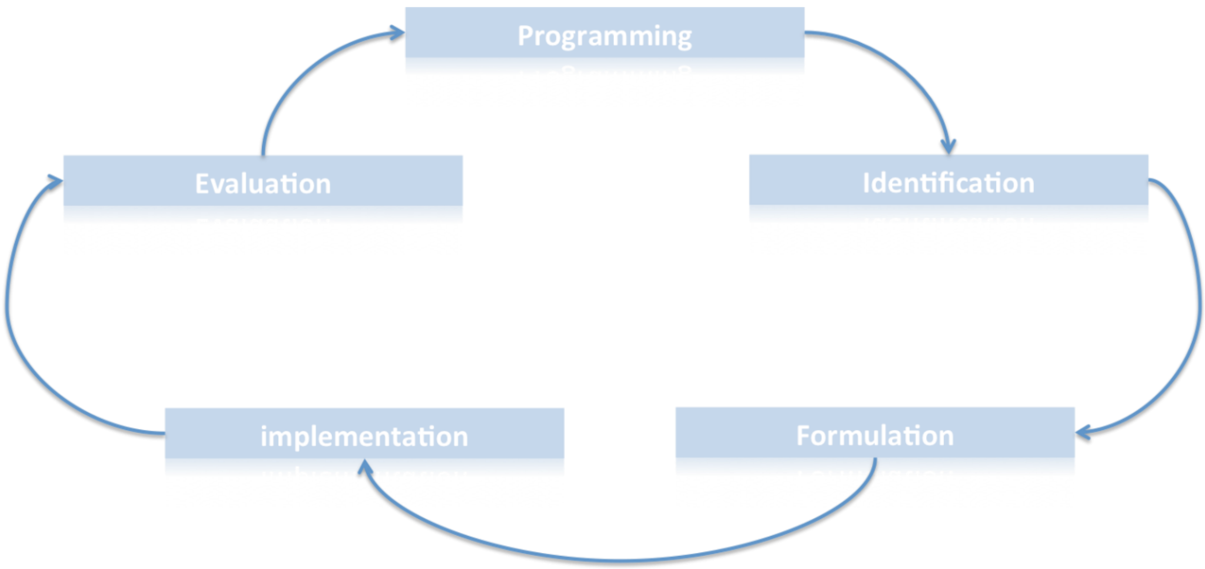


Figure 24 European Commission Project Cycle
(Source: EC, Water Project Toolkit 2012)

In the case of the World Bank the phases would be similarly the following: Identification- Preparation- Appraisal- Approval- Implementation - Completion- Evaluation. The World Bank phases are slightly more numerous, and this depends on the interest for highlighting some parts of the project management phases. The WB "Completion" phase, for example, can be found within the EC PCM "Implementation" phase. Besides these methodological procedural differences, the PCM approach is constructed around the idea of carefully planned phases leading logically from one to another with mechanisms of assessment and verification.

Within all institutions the cycle shares three common themes:

- The cycle defines the key decisions, information requirements and responsibilities at each phase.
- The phases in the cycle are progressive – each phase needs to be completed for the next to be tackled with success.
- The cycle draws on evaluation to build experience from existing projects into the design of future programmes and projects.

Four Key principles have been identified by PCM practitioners to improve the quality of judgment and decision making at all stages of the project cycle. These key principles interpreted from a perspective of sector development are:

- Projects are supportive of overarching sector policy objectives;
- Projects are relevant to an agreed-upon strategy and to the real problems of target groups/beneficiaries;
- Projects are feasible, meaning that objectives can be realistically achieved

within the constraints of the operating environment, the given budget and the capacities of the implementing organisation; and

- Project benefits generated are likely to be sustainable.

These four principles are important measures of the quality of the project, and should provide information for judgements and decisions of managers and advisors, not only during the planning stage, but at all moment during the project cycle when amendments and course corrections are indicated.

A particular mention is to be given to the last principle “sustainability”. In order to foster the sustainability of the benefits generated, a careful analysis of the other three principles is fundamental. Sustainability is in fact a delicate issue depending on the coherence with the overarching sector policy objectives, the ownership and the alignment with the target groups needs and capacities and a realistic feasibility assessment. The list of over-ambitious failed projects is long.

To support the achievement of these aims, the PCM:

- Requires the active *participation* of key *stakeholders* and aims to promote local ownership;
- Uses the Logical Framework Approach (as well as other tools) to support a number of key assessments/analyses (including *stakeholders*, problems, objectives and strategies);
- Incorporates key quality assessment criteria into each stage of the project cycle; and
- Requires the production of good-quality key document(s) in each phase (with commonly understood concepts and definitions) to support well-informed decision-making.

The phases of the project cycle can be described as follows:

During the **Programming** phase, the purpose is to assess the main objectives and priorities of the sector, and thus to provide a relevant and feasible programming framework within which programmes and projects can be identified and prepared. The programming phase consists of an analysis of the situation at national and sector level to identify problems, constraints and opportunities. For the identified priorities, strategies are formulated based on the analysis and that take into account lessons learned. Programming helps to: establish what other activities are on-going and/or planned in the water sector, which are the sources of financing and in what areas; review existing water sector development policy; consider water-related activity across all development sectors; and identify the key areas for water-related projects.

During the **Identification** phase, ideas for projects and other development actions are identified and screened for further study. This involves consultation with the intended beneficiaries of each action, an analysis of the problems they face, and the identification of options to address these problems. The purpose of this phase is to:

Identification

- Identify project ideas that are consistent with the sector national framework, the sector strategy, the sector programme (if existing) and partner development priorities;
- Assess the relevance and likely feasibility of these project ideas consulting stakeholders (beneficiaries in particular) and other sector partners;
- Assess the possibility of overlapping and other criticalities with other projects or programmes in the sector
- Prepare a project identification document summarizing the results of the ideas and the financial aspects; and
- Determine the scope of the further work required for individual projects during the formulation stage.

During the **Formulation** phase, relevant project ideas are developed into operational project plans. Beneficiaries and other stakeholders participate in the detailed specification of the project idea that is then assessed for its feasibility and sustainability. The purpose of the project formulation stage is to:

Formulation

- Confirm the relevance and feasibility of the project ideas as proposed in the identification phase;
- Prepare a detailed project design, including the management and coordination arrangements, financing plan, cost-benefit analysis, risk management, monitoring, evaluation and audit arrangements; and
- Prepare a proposal including all the documents above mentioned to be submitted to the funding organisation or to the government.

During the **Implementation** phase, the project is mobilized and executed. This may require the tendering and award of contracts for technical assistance or works and supplies. During implementation, and in consultation with beneficiaries and stakeholders, project management assesses actual progress against planned progress to determine whether the project is on track towards achieving its objectives. If necessary the project is re-oriented to bring it back on track, or to modify some of its objectives in the light of any significant changes that may have occurred since its formulation. The implementation stage of the project cycle is in many ways the

Implementation

most critical; as it is during this stage that planned benefits are delivered. All other stages in the cycle are therefore essentially supportive of this implementation stage.

The purpose of the implementation stage is to:

- Deliver the results and contribute effectively to the overall objective of the project;
- Manage the available resources efficiently; and
- Monitor and report on progress of activities.

Evaluation

During the **Evaluation** phase, the funding agency and partner country make an “assessment, as systematic and objective as possible, of an on-going or completed project, programme, strategy or policy, its design, implementation and results. The evaluation scope can include the time period, funds spent, geographical area, target groups, organizational set-up, implementation arrangements, policy and institutional context and other dimensions to be covered by the evaluation. Identifying discrepancies between the planned and actual implementation of the interventions are among the main results of an evaluation.

The evaluation purpose will be in line with the learning and accountability function of evaluations such as:

- Contribute to improving sector policies, strategies, procedures or techniques;
- Consider a continuation or discontinuation of a project/programme;
- Accountability for expenditures to stakeholders and tax payers;

Amongst the most important objectives of an evaluation, the OECD-DAC cites:

- To ascertain results (output, outcome, impact) and assess the effectiveness, efficiency and relevance of a specific development intervention;
- To provide findings, conclusions and recommendations with respect to a specific policy, programme etc.

Exercise: The Project Cycle

Per small groups, complete the following table to describe the project cycle that operates for water projects.

Project Cycle Phases	Input	Activities	Outcomes
Programming			
Identification			
Formulation			
Implementation			
Evaluation			

The following activities have been suggested in the Water Project Toolkit (EC, 2012)

Project Cycle Phases	**Input**	**Activities**	**Outcomes**
Programming	National policies and strategies, Regional policies, Sector assessment studies, Sector plans, Evaluation of policies, strategies and sector program, Demand analysis and resource assessment, Economic, Financial, social institutional and Envt analysis.	Identify key stakeholders and assess their needs, interests and capacities, Identify and analyse the priority of development problems, Identify development objectives, Identify a strategy for a possible intervention.	An indicative sector programme with: Global objectives Financial issues for each development area Specific objectives and expected results for each area How cross cutting issues are taken into consideration Programmes / projects to be implemented in pursuit of these objectives, including the targeted beneficiaries

Identification	Framework established during programming phase Results from sector study Results of participative consultations Sector financing strategy National sector policy	Assessment of policy and programming framework; Stakeholders analysis; Problem analysis; Assessment of other on-going and planned initiatives; Preliminary objectives analysis; Preliminary assessment of resource and cost parameters; Preliminary assessment of project management, coordination and financing arrangements; Preliminary assessment of economic/financial, environmental, technical and social sustainability issues.	Policy and programme context, Stakeholder analysis, Problem analysis, including scope of cross-cutting issues, Lessons learned and review of other on-going or planned initiatives; Preliminary project description; Indicative resource and cost implications; Indicative coordination management, Preliminary assessment of economic/ financial, environmental, technical and social sustainability; Follow-up work plan for the Formulation stage.
Formulation	Project identification document defining key components of the proposed project; Terms of Reference for detailed project design studies; Other assessments documents	Confirm consistency with the policy and national programming framework; Stakeholder analysis; Problem analysis; Complementarities with other on-going and planned initiatives; Strategy assessment; Objective hierarchy assessment; Assessment of resource needs and cost requirements; Assessment of management, coordination and financing procedures and arrangements	A Final project proposal; Terms of Reference/Technical and Administrative Provisions for implementation. The main information elements that should be available by the end of Formulation (in order to effectively guide and support implementation) are: -Situation Analysis/Key Assessment; - Project Description; -Management Arrangement; -Feasibility and

		Assessment of monitoring, evaluation and audit arrangements; Sustainability and risk assessment, including economic/financial, environmental, technical and social	Sustainability
Implementation	Quality criteria and standards; Logframe matrix; Work programme schedules; Risk management matrix Checklists for planning short-visits; ToR; Contractual documents.	Monitoring and regular review; Planning and re-planning; Reporting; On-going assessment.	Operational work plans Periodic but regular progress report Specific reviews/ study reports; Completion reports (at the end).
Evaluation	ToR for the evaluation mission; Logframe matrix; Monitoring reports; Annual plans; Evaluation Report format.	Identifying the specific needs for the evaluation; Designing the evaluation; Briefing the evaluation; Ensuring the production of high quality report.	ToR designing the evaluation work; Inception report; Draft Evaluation report; Final evaluation report.

6.3 Project Water Toolkit Checklist

The application of the strategic approach entails identifying problem areas and appropriate responses at every stage of the project management cycle. Thus the main content of this part of the course consists of checklists to assist users to put into practice the policy principles at each of the different stages of the project management cycle.

The students should bear in mind at all times that these checklists are not meant to be exhaustive, but to act as pointers towards strategies and actions. Each situation, each problem area and any stage of the PCM, not to mention the course of any project, is subject to so many variables that to produce a definitive set of checklists would not be possible, efficient nor practical.

The whole emphasis of the Water Project Toolkit is to avoid prescription, but instead to facilitate a questioning mode of project development, in which sensitivity to changing trends, local variety of economic, social and environmental circumstances, and especially the input derived from stakeholder and user participation, can be reflected.

> *For each recommendation, the Water Project Toolkit developed a full range of questions that should be asked at any water project manager. These are available on: http://www.aquaknow.net/fr/water-project-toolkit*

PROGRAMMING

Checklists have been developed corresponding to the following four steps in the programming process.

Step 1: Alignment to national sector framework;

- *Water resources development and management must be assessed with regard to alignment with the national sector framework of the country.*
- *Ensure that programmes do not conflict with other national / sector activity.*

Step 2: Assessing the capacity of recipients to adopt and manage programmes;

- *A water resources sector programme can only be effectively implemented if the sector governance is adequate and if there is the required capacity existing within the sector, especially for the government, in order to handle the institutional, technical and financial aspects.*
- *Concerning sector funding in particular, there are a number of mechanisms for the provision of development partner support (including grants and loans). If and when this external assistance is envisaged, it is important to identify the most suitable funding mechanism during the sector-programming phase and to ensure adequate local funding is available.*

Step 3: Assessing the needs of the water sector;

- *Some countries may be fully aware of water resources issues and make appropriate plans whilst others are unaware or take a shorter-term view of needs and responses.*
- *Support to programmes and projects should be demand-driven, fully lead by the country and developed with stakeholders and the target groups.*
- *In formulating any programme or action plan for water resources, care is needed to*

avoid contradictions between water-related sector policies and limit unnecessary competition for water resources such as those for agriculture, energy, health, education, transport, and environmental policies.

- *Policies established by the government should be developed in consultation with the various stakeholders to ensure that competing or conflicting interests are reconciled as far as possible and that the policy is acceptable to all interests.*

Step 4: Identifying the priority Focus Areas for support

- *It is important to identify which Focus Area(s) is/are most in need of support. This priority setting should fit within an overall sector programme based on responses to the earlier key issues.*
- *An adequate knowledge base is crucial to reasoned planning and decision making on water resources development and management.*

IDENTIFICATION AND FORMULATION

In the Identification and Formulation phases, each programming context is handled separately since lessons and recommendations differ between focus areas activity. In other phases, lessons and recommendations are generic, and the same set of checklists applies in every focus area activity.

These focus area activities are referring to the water challenges presented in the first chapter:

1/ Availability of the natural resource,

2/ Access to basic services,

3/ Water and food security

4/ Water use for energy,

5/ Water in urban areas.

Water Resources activities

IWRM Principles	Identification	Formulation
Inst[al] & Man[t]	*- The lack of an integrated policy environment at the national level can lead to inefficient allocation of water resources and poor investment decisions.* *- Fragmented planning functions and agency responsibilities lead to sector-based project-by- project development and inter-sector conflict.* *- Transboundary water resource issues are critical to water resource availability in many countries.* *- Neglect of legal aspects during strategy formulation can lead to an untenable legal framework for sound resource management.* *Disregard for stakeholder participation and too much emphasis on top-down planning tend to produce poor results.*	*- Water Resources Management is a continuous process which needs to adapt to external factors, such as changes in policy, economic climate and development objectives.* *- Effective inter-sector and inter-agency planning is essential for an integrated approach.* *- Changes in transboundary water management can have a major impact on proposed projects.* *- Water-related planning can become ineffective if the outputs and recommendations are not ratified and acted upon by the appropriate bodies.* *- Incorporating stakeholders' needs and views into WATER RESOURCES helps to foster a sense of ownership.* *- Requirements for capacity-building and training must be addressed during project formulation.* *- Management information systems providing indicators of performance are essential for efficient project implementation and monitoring*
Social	*- National and regional social development goals should be integrated with water resources policies if key objectives are to be achieved.* *- Disregard for the social context of water use and a lack of consultation with stakeholders can result in inappropriate interventions.*	*- Water resource planning should be integrated with social development goals.* *Developing a community-based approach is likely to increase ownership and commitment to sustainability.*
Econ and Fin	*- A sense of the economic value of water is necessary to balance scarce resources with increasing demand, reduce wastage and encourage conservation.* *- Policies for allocation of water resources within and among sectors should promote economic efficiency and encourage higher-value uses.* *- Water is a scarce resource and demand management measures offer a means to augment existing supplies and conserve*	*- Economic analysis of the project should reflect the economic value of water in all its competing uses.*

	resources.	
Environmental	*- Environmentally sound water resource development and management relies on an integrated policy framework.* *- Water is an essential natural resource and should be planned and managed within the context of an overall natural resource management strategy.* *- A lack of baseline data can make it difficult to assess the potential environmental impact of interventions and may lead to unplanned degradation.*	*- Environmentally sound solutions rely on managing and mitigating adverse impacts within an overall resource management strategy.* *- Interventions to bring benefits to one user group or sector can have adverse impacts on water availability for user groups downstream.* *- Environmental monitoring is necessary to ensure mitigation measures are effective and to identify unforeseen impacts.*
Inf, Edu & com	*- Water resource assessment and planning is an inter-disciplinary process that relies on a broad knowledge base as a pre-condition for effective planning.* *- Communication between government agencies and other stakeholders is necessary if water-related development interventions are to be relevant.* *- Without an understanding of water resource management issues, important stakeholders are unable to contribute effectively to planning.*	*- Effective WATER RESOURCES relies on good data collection and analysis on all aspects of water-related information including socio-cultural, economic, and environmental.* *- Education and awareness-raising are key methods of enabling stakeholders to contribute effectively to the planning process.*
Technological	*- Assessment of surface and groundwater resources, their allocation and use is a precondition for planning water resource management.* *- Effective planning relies on a wide range of tools to enhance the knowledge base and understand linkages between physical and non-physical processes.* *- Hydrological and hydro-geological information form the basis of water resource assessments. High quality data is needed for reliable assessments.*	*- Hydrological and hydro-geological data should be selected to contribute to efficiency, ease of O & M, and capital and operating costs.*

Basic Service activities

IWRM Policy Principles	Identification	Formulation
Inst[al] & Man[t]	*- Basic service activities should be consistent with an integrated national water policy, and WHO standards.* *- Effective inter-agency and inter-sector planning is essential.* *- Maximum stakeholder participation is essential for an effective project, from the earliest possible stage.* *- A sound legal basis is required for effective delivery of Basic Services (BS),* *BS projects have traditionally focused on design and construction and tended to neglect O&M (operation and maintenance)and management. New policies may seek to transfer responsibility for O&M to the private sector or user groups.* *- Capacity building for government institutions and user groups is required to support new initiatives.* *- Management information systems in which both users and service providers have confidence are essential for improved operational efficiency.*	*- Changes in policy objectives and economic factors since the identification phase, and recent lessons from previous projects, should be taken into account.* *- Effective inter-sector and inter-agency planning should be facilitated by the project.* *- Effective stakeholder participation requires that their views and needs help to shape the design of the project.* *- Sustainability of BS requires that responsibility for a significant share of management and O&M be devolved to users, within a suitable organisational structure.* *- Requirements for training and capacity-building, identified in the feasibility study, must be addressed in project formulation.* *- Management information systems in which both users and service providers have confidence are essential for operational efficiency*
Social	*- BS initiatives should be integrated with social development goals and policies.* *- BS projects can bring great health and quality of life benefits to communities, but without taking into account existing user norms, they can be underused or even abandoned.* *- A community-based approach helps to ensure a sense of ownership of the project by the stakeholders and user groups.* *- Women have a central role in BS projects, not only as primary users, but to manage water resources. Their participation at all levels of planning is needed.*	*- Development of BS projects may disrupt traditional user rights to water and land.* *- Development of BS can require significant changes in social and cultural norms and habits, especially with regard to sanitation.* *- Improved BS schemes can also lead to increased inequalities between different social groups.* *- A community-based approach is more likely to ensure ownership and sustainability of services by the users.* *- Given the centrality of water to women's daily lives, measures are required to ensure the effective participation of women in project planning and design.*

Econ and Fin	*- The economic value of water is an integral part of BS.* *- Charging for services is needed to generate funds for future investment and to ensure maintenance. However, the concept of water as a free resource can be difficult to overcome.* *- Where possible, demand management through both market and non-market measures should be incorporated into projects.* *- Projects must demonstrate financial viability and accountability.*	*- The economic value of water must be reflected in BS schemes.* *- Charging for services is needed to generate funds for future investment and promote the idea of water as a valuable commodity.* *- A balanced approach between supply augmentation and demand management is required.* *- Projects must demonstrate financial viability.*
Environmental	*- Environmental damage may result because insufficient time and money is invested in collection and analysis of baseline data.* *- BS projects often bring changes in water use.*	*- Projects in BASIC SERVICES often bring changes in land and water use.* *- Accurate baseline data collection and informed analysis are the keys to minimising environmental damage* *- New sanitation schemes may cause disposal problems.*
Inf, Edu & com	*- The development of a BS knowledge base is a pre-condition for development of services. This requires effective data collection and monitoring procedures.* *- Without an understanding of the principles of BS schemes, stakeholder participation is weakened.*	*- An adequate knowledge base is a pre-condition for development of BS programmes. This requires effective data collection and monitoring procedures.* *- Education and awareness raising targeted at BS agency staff and users is needed to ensure an understanding of principles and participatory approaches.*
Technological	*- Appropriate technological solutions should be selected according to criteria that include efficiency, ease of operation, capital and operating costs, and the management capacity of the users.*	*- Appropriate specification and design of hardware for BASIC SERVICES depends on complete and reliable information.* *- The design of hardware and specification of operating rules must minimise detrimental impacts on the environment.* *- Engineering solutions should take account of the material and technical resource base available to operating agencies and users.*

Agricultural activities

IWRM Policy Principles	Identification	Formulation
Inst[al] & Man[t]	*- "A" activities must be consistent with an integrated national water policy setting out the legal and policy framework for service provision.* *- Fragmented planning functions and agency responsibilities lead to sector-based, project-by project development and potential inter-sector and inter-agency conflict.* *- Stakeholder participation can help resolve conflicts of interest and promote user ownership of projects.* *- Agencies have traditionally focused on project design and construction and neglected operation and maintenance. Policy may now be to transfer responsibility for O&M to the users.* *- Capacity building for government staff and user groups may be required.* *- Management information systems in which both users and service providers have confidence are essential.*	*- Changes in policy objectives and economic factors may influence predicted project benefits; lessons from other AGRICULTURE projects should be taken into account.* *- Effective inter-sector and inter-agency planning should be facilitated by the project.* *- Ensure that commitment to stakeholder participation is effectively implemented so that the views and needs of stakeholders help shape the project.* *- The sustainability of systems requires that users shoulder significant responsibility for O&M and management of systems, within a suitable organisational structure.* *- Requirements for training and capacity building, identified in the feasibility study, must be addressed in project formulation.* *- Management information systems in which users and service providers have confidence are essential.*
Social	*- Agricultural water use and management initiatives must be integrated with the social development goals of the region.* *- A community-based approach is more likely to ensure ownership of the project by the intended beneficiaries.* *- In many regions women are responsible for production decisions and contribute significant field labour. Measures are required to ensure women's effective participation in project planning and design.*	*- Development of irrigation, drainage and flood control works may disrupt traditional user rights to land and water resources.* *- The provision of irrigation can lead to increased inequalities between different social groups.* *- A community-based approach is more likely to ensure ownership of the intervention by the intended beneficiaries.* *- In many regions, women are responsible for certain production decisions and contribute significantly to field labour.*
Econ and Fin	*- The economic value of land and water must be reflected in A actions.*	*- The economic value of water must be reflected in activities relating to A.*

	- Charging for services is needed to generate funds for future investment and promote efficient water use. *- Where possible, demand management, through both market and non-market measures, should be incorporated into projects.* *- Projects must demonstrate economic benefit and financial viability.*	*- Charging for services is needed to generate funds for future investment and promote water allocation to higher-value uses.* *- Where possible, demand management, through both market and non-market measures, should be incorporated into projects.* *- Interventions must demonstrate economic benefit and financial viability* *- Financial viability is critical to successful irrigated agriculture for both farmers and service providers.*
Environmental	*- Environmental damage may result because insufficient time and money are invested in collection and analysis of baseline data.* *- A activities often bring major changes in land and water use.*	*- Environmental damage may result because of insufficient time and money are invested on the collection and analysis of baseline data.* *- AGRICULTURE activities often bring major changes in land and water use.*
Inf, Edu & com	*- The development of a knowledge base grounded in effective data collection and monitoring procedures is essential for both local and basin-level plans.* *- Education and awareness-raising, targeted at agency staff and farmers, are needed to develop user participation in decisions over competing user group needs.*	*- Knowledge, based on effective data collection and monitoring procedures, is a pre-condition for development of AGRICULTURE programmes.* *- Education and awareness raising targeted at agency staff and users are needed to develop user participation and reach decisions over competing user group needs.*
Technological	*- Engineering solutions must take account of environment and physical characteristics; needs, resources and skills of users; capital and operating costs and markets.* *- The objective should be to use modern but appropriate technology*	*- Appropriate specification and design of hardware for water control and management can only occur when there are reliable estimates of resources.* *- The design of hardware and specification of operating rules must minimise detrimental impacts on the environment.* *- Engineering solutions should take account of the material and technical resource base available to the operating agencies and the users.* *- Simplicity and operational flexibility must be incorporated in the operating environment.* *- Sustainability requires that maintenance needs are identified and agreements for the technical performance of installations reached with agencies and farmers.*

Hydropower activities

IWRM Policy Principles	Identification	Formulation
Inst^{al} & Man^{t}	*- The lack of an integrated policy environment at the national level can lead to inefficient allocation of water resources and poor investment decisions.* *- Fragmented planning functions and agency responsibilities lead to sector-based project-by- project development and inter-sector conflict.* *- Transboundary water resource issues are critical to water resource availability in many countries.* *- Neglect of legal aspects during strategy formulation can lead to an untenable legal framework for sound resource management.* *- Effective inter-agency and inter-sector planning is essential.* *- A sound legal basis is required for effective delivery service,* *- Capacity building for government institutions and user groups is required to support new initiatives.* *- Stakeholder participation can help resolve conflicts of interest and promote user ownership of projects. Management and institutional structures should facilitate the participation of all interested parties.*	*- Hydropower projects needs to adapt to external factors, such as changes in policy, economic climate and development objectives.* *- Effective inter-sector and inter-agency planning is essential for an integrated approach.* *- Changes in transboundary water management can have a major impact on proposed projects.* *- Incorporating relevant stakeholders' needs and views into hydropower development is essential.* *- Requirements for capacity-building and training must be addressed during project formulation.* *- Effective hydropower planning relies on good data collection and analysis on all aspects of water-related information including socio-cultural, economic, and environmental.*
Social	*- National and regional social development goals should be integrated with water resources policies if key objectives are to be achieved.* *- Disregard for the social context of water use and a lack of consultation with stakeholders can result in inappropriate interventions.* *- A community-based approach helps to ensure a sense of ownership of the project by the stakeholders and user groups.* *- Energy / hydropower initiatives must be integrated with the social development goals of the municipality.* *- Community involvement by stakeholders and users is more likely to ensure project success.*	*- Hydropower planning should be integrated with social development goals.*
Econ and Fin	*- A sense of the economic value of water is necessary to balance scarce resources with increasing demand, reduce wastage and encourage conservation.* *- The economic value of water is an integral*	*- Economic analysis of the project should reflect the economic value of water in all its competing uses.*

	part of hydropower. *- Projects must demonstrate financial viability and accountability*	
Environmental	*- Environmentally sound water resource development and management relies on an integrated policy framework.* *- Water is an essential natural resource and should be planned and managed within the context of an overall natural resource management strategy.* *- A lack of baseline data can make it difficult to assess the potential environmental impact of interventions and may lead to unplanned degradation.* *- Hydropower projects often bring changes in water use.*	*- Environmentally sound solutions rely on managing and mitigating adverse impacts within an overall resource management strategy.* *- Interventions to bring benefits to one sector can have adverse impacts on water availability for upstream and/or downstream users.* *- Environmental monitoring is necessary to ensure mitigation measures are effective and to identify unforeseen impacts.*
Inf, Edu & com	*- Water resource assessment and planning is an inter-disciplinary process that relies on a broad knowledge base as a pre-condition for effective planning.* *- Communication between government agencies and other stakeholders is necessary if water-related development interventions are to be relevant.* *- The development of a energy / hydropower knowledge base is a pre-condition for development of services. This requires effective data collection and monitoring procedures.*	
Technological	*- Hydro-meteorological information forms the basis of hydropower assessments. High quality data is needed for reliable assessments.* *- Appropriate technological solutions should be selected according to criteria that include efficiency, ease of operation, capital and operating costs, and the management capacity of the users.* *- Technical knowledge forms the basis of all good design.*	

Municipal services activities

IWRM Policy Principles	Identification	Formulation
Inst[al] & Man[t]	*- MS activities should be consistent with a national integrated water policy, and institutions' functions and responsibilities clearly identified.* *- Effective inter-agency and inter-sector planning is essential.* *- Maximum stakeholder participation is essential for an effective project and should be involved at the earliest possible stage.* *- MS projects have traditionally focused on design and construction aspects and neglected operation, maintenance and management.* *- Participation of the private sector can be important in the efficient delivery of municipal water and wastewater services.* *- Capacity building for government and/or municipality staff and user groups is required to support new initiatives.* *- Management information systems in which both users and service providers have confidence are essential for improved operational efficiency.*	*- Changes in policy objectives and economic factors may influence predicted project benefits. Lessons from previous projects in MS should be taken into account.* *- Effective inter-agency and inter-sector planning should be facilitated by the project.* *- Effective stakeholder participation needs to be implemented with the views and needs of stakeholders shaping the form of the project.* *- Projects should aim for effective public-private sector partnership in service delivery.* *- Requirements for training and capacity-building must be addressed in the project formulation phase.* *- Management information systems in which both users and service providers have confidence are essential for operational efficiency*
Social	*- Municipal services initiatives must be integrated with the social development goals of the municipality.* *- MS projects can bring great health and social benefits to urban areas. But without taking into account users' norms and needs, projects can be underused.* *- Community involvement by stakeholders and users is more likely to ensure project success.*	*- MS projects must conform with social development goals.* *- Full involvement by stakeholders and users is more likely to ensure project success.* *- Effective provision of MUNICIPAL SERVICES should take account of the needs and roles of women.*
Econ and Fin	*- The economic value of water is an integral part of MS.* *- Charging for services is necessary to generate funds for future investment and to ensure maintenance and long-term financial viability.* *- Demand management through both market and non-market measures should be used in conjunction with supply provision; in water-*	*- The economic value of water must be recognised as an integral part of any municipal water and wastewater project.* *- Charging for services is needed to generate funds for maintenance, management, future investment and service spread.* *- Demand management, through both market and non-market measures, should be*

	scarce areas, demand management should take priority over supply-led solutions. *- Projects must demonstrate financial viability and accountability*	*incorporated into projects.* *- Projects must assess financial risks and demonstrate accountability.*
Environmental	*- Environmental damage may result because insufficient time and money is invested in collection and analysis of baseline data.* *- Municipal services often have adverse effects on water use, particularly groundwater*	*- Environmental damage may result because insufficient time and money is invested in collection and analysis of baseline data.* *- MS projects often bring changes in water use.* *- Municipal wastewater schemes present disposal problems.*
Inf, Edu & com	*- The development of a water and wastewater knowledge base is necessary and requires effective data collection and monitoring procedures.* *- Education and awareness-raising targeted at municipal staff, stakeholders and users should be used to strengthen stakeholder participation*	*- The development of a water and wastewater knowledge base is a pre-condition for successful project implementation and service delivery.* *- Education and awareness raising among municipal staff and other stakeholders on MS principles is needed to facilitate participation and exchange.*
Technological	*- MS should be technically efficient, using appropriate modern technology that is adapted to suit local, physical, economic and social conditions.* *- Technical knowledge forms the basis of all good design.*	*- Appropriate modern technology must be utilised to suit local physical, economic, social, and environmental conditions.*

IMPLEMENTATION

For all phases of the project cycle other than programming, checklists have been prepared in the same format, to allow the user of the Water Project Toolkit examine key points likely to arise in the preparation and implementation of projects, alongside possible responses. Lessons and recommendations are grouped according to the set of problems statements within the framework of IWRM principles, starting with Institutional and Management principles and proceeding through all categories and principles.

IWRM Policy Principles	Implementation
Inst[al] & Man[t]	*- Management information systems may need revision if the nature or scopes of the project are revised during implementation.* *- Changes in the structure of implementing agencies may weaken (or improve) their capability to implement the project or programme.* *- Measures to improve inter-sector and sector coordination planning may meet with resistance, thereby hindering implementation.* *- Sustainability of services requires that users and operators understand and fulfil their responsibilities for O&M.* *- There is a danger that training and capacity-building measures, defined at formulation, are cut back during implementation or are ineffectual.*
Social	*- The financing proposal may identify effective women's participation and other social issues as central to the project's success.* *- Intervention may disrupt traditional user rights to land and water resources and lead to increased inequalities between stakeholders.* *- Where a community-based approach is used the community may want to modify the scope of the project during implementation.*
Econ and Fin	*- Changes in economic factors occurring between financing and implementation may require revision of the project.* *- Long-term financial sustainability must be ensured during implementation.* *- Coordination of fund contributions is essential to avoid wastage of resource and project delay.*
Environmental	*- Environmental damage may result because adverse impacts were previously unrecognised or inadequate resources provided for mitigating measures.*
Inf, Edu & com	*- Information obtained from project monitoring should be used to shape and direct the implementation process.* *- Provision of information and clarity of procedure are necessary for conflict resolution between different stakeholder interests.*
Technological	*- Where construction quality is poor or equipment is badly specified, systems may fail prematurely and maintenance costs will be high* *- Technology that was judged appropriate at the design stage may prove in-appropriate as implementation proceeds.* *- Technological and construction aspects usually represent the major capital cost items.* *- Hydro-meteorological information forms the basis of water / hydropower assessments. High quality data is needed for reliable implementation.*

EVALUATION

As for the implementation phase, lessons and recommendations are grouped according to the set of problems statements within the framework of IWRM principles, starting with Institutional and Management principles and proceeding through all categories and principles.

IWRM Policy Principles	Evaluation
Inst[al] & Man[t]	*- Sustainable hand-over of infrastructure and equipment depends on the training of users and organisations who are allocated responsibility for O&M and management of services.* *- Projects must have sufficient flexibility in their design, implementation schedule and subsequent operation to permit adjustments to be made.* *- Provision should be made for effective inter-agency and inter-sector planning. If this was weak, lessons should be learnt for the future.* *- The project should have been formulated and implemented in a way that ensured effective stakeholders involvement and participation.*
Social	*- Ownership by stakeholders and user groups of services provided by the project is essential in ensuring sustainability.* *- Evaluation must determine to what extent intended social development has been achieved and what unexpected impacts may have occurred.*
Econ and Fin	*- The economic and financial sustainability of the project depends on the avoidance of inappropriate subsidies and effective cost recovery* *- Projects must demonstrate economic benefit and financial accountability if they are to be sustained over the long term.*
Environmental	*- Environmental damage may result because insufficient time and money is invested in collection and analysis of data during and after*
Inf, Edu & com	*- Evaluation should determine whether the knowledge base was adequate and whether recommendations for improved data collection have been implemented.* *- Public education, awareness raising and free availability of information to all stakeholders facilitate the sustainability of water projects.*
Technological	*- In evaluating the appropriateness of technology and its influence on the wider results of the project, the accuracy of underlying data is critical.* *- Technological solutions must be acceptable to the target users and compatible with the environment.* *- Sustainability of infrastructure and equipment can only be achieved if the technical and financial requirements for maintenance are met.*

7.0 PRESENTATION OF THE LOGICAL FRAMEWORK TOOL

7.1 Overview of the Approach

Project planning and management tools provide the practical mechanisms by which relevance, feasibility and sustainability can be achieved. The core tool used within PCM for project planning and management is described **Logical Framework Approach** (LFA).

The LFA is an effective technique designed to improve and streamline projects, making them more effective in realising their development objectives, including that of producing sustainable benefits. The LFA is used by most governments, multi-lateral and bi-lateral aid agencies, international NGOs, etc. to prepare sector development plans and/or project proposals. It is the principal tool used for project design during the identification and formulation phases of the project cycle. In addition to its role during programme and project preparation, the LFA is also a key management tool during implementation and evaluation. It provides the basis for the preparation of action plans and the development of a monitoring system, and a framework for evaluation

Stakeholders should be involved as fully as possible, which requires teamwork and strong facilitation skills on the part of project planners.

The LFA helps to:

- Analyse an existing situation, including the identification of stakeholders' needs and the definition of related objectives;
- Establish a causal link between inputs, activities, results, purpose and overall objective (vertical logic);
- Define the assumptions on which the project logic builds;
- Identify the potential risks for achieving objectives and purpose;
- Establish a system for monitoring and evaluating project performance;
- Establish a communication and learning process among the stakeholders, i.e. clients/ beneficiaries, planners, decision-makers and implementers.

Originally developed and applied in science (NASA) and the private sector (management by objectives) for the planning and management of complex projects, the Logical Framework Approach was first formally adopted as a planning tool for overseas development activities by USAID in the early 1970s. Since then it has been adopted and adapted by a large number of agencies involved in providing development assistance. They include the British DFID, Canada's CIDA, the OECD Expert Group on Aid Evaluation, the International Service for National Agricultural Research (ISNAR), Australia's AusAID and the German GIZ. With its 'ZOPP'-version (Ziel-Orientierte Projekt Planung) GIZ has put particular emphasis on the participation of stakeholders in the application of the approach. EC requires application of the LFA and preparation of the Logframe as a part of EU funding applications.

The *Logical Framework Approach* (LFA) is a core tool used within Project Cycle Management.

- It is used during the ***identification*** stage of PCM to help analyse the existing situation, investigate the relevance of the proposed project and identify potential objectives and strategies;
- During the ***formulation*** stage, the LFA supports the preparation of an appropriate project plan with clear objectives, measurable results, a risk management strategy and defined levels of management responsibility;
- During project/programme ***implementation***, the LFA provides a key management tool to support contracting, operational work planning and monitoring; and
- During the ***evaluation*** and ***audit*** stage, the Logframe matrix provides a summary record of what was planned (objectives, indicators and key assumptions), and thus provides a basis for performance and impact assessment.

A common problem with the application of the Logical Framework Approach (particularly the preparation of the matrix) is that it is undertaken separately from the preparation of the other required project documents. This then results in inconsistency between the contents of the Logframe matrix and the description of the project contained in the narrative of the main documents. The application of the LFA should come first, and then provide a base source of information for completing the required PCM documents.

As for any instrument of project cycle management (for more details on project cycle management please refer part 3 of this guide), there can be advantages and limitations of using LFA. They can be summarised as follow:

Advantages

- It ensures that fundamental questions are asked and weaknesses are analysed, in order to provide decision makers with better and more relevant information.
- It guides systematic and logical analysis of the inter-related key elements which constitute a well-designed project.
- It improves planning by highlighting linkages between project elements and external factors.
- It provides a better basis for systematic monitoring and analysis of the effects of projects.
- It facilitates common understanding and better communication between decision makers, managers and other parties involved in the project.
- Management and administration benefit from standardized procedures for collecting and assessing information.
- The use of LFA and systematic monitoring ensures continuity of approach when or if original project staff is replaced.
- As more institutions adopt the LFA concept it may facilitate communication between governments and donor agencies. Widespread use of the LFA format makes it easier to undertake both sectorial studies and comparative studies in general.

Limitations

- Rigidity in project administration may arise when objectives and external factors specified at the outset are over-emphasised. This can be avoided by regular project reviews where the key elements can be re-evaluated and adjusted.
- LFA is a general analytic tool. It is policy-neutral on such questions as income distribution, employment opportunities, access to resources, local participation, cost and feasibility of strategies and technology, or effects on the environment. LFA is therefore only one of several tools to be used during project preparation, implementation and evaluation, and it does not replace target-group analysis, cost benefit analysis, time planning, impact analysis, etc.
- The full benefits of utilizing the LFA can be achieved only through systematic training of all parties involved and methodological follow-up.

The LFA provides no magic solutions, but when understood and intelligently applied, is a very effective analytical and management tool. However, it is not a substitute for experience and professional judgment and must also be complemented by the application of other specific tools (such as Institutional Capacity Assessment, Economic and Financial Analysis, Gender Analysis, and Environmental Impact Assessment) and through the application of working techniques which promote the effective participation of stakeholders.

The process of applying the analytical tools of LFA in a participatory manner is as important as the documented matrix product. This is particularly so in the context of development projects, where ownership of the project idea by implementing partners is often critical to the success of project implementation and to the sustainability of benefits. Effective teamwork is critical.

Drawing up a Logframe has two main stages, ***Analysis*** and ***Planning***, which are carried out progressively during the Identification and Formulation phases of the project cycle:

There are four main elements of the ***Analysis Stage***, namely:

- Stakeholder Analysis, including preliminary institutional capacity assessment, gender analysis and needs of other vulnerable groups such as the disabled (profile of the main 'players');
- Problem Analysis (profile of the main problems including cause and effect relationships);
- Analysis of Objectives (image of an improved situation in the future); and
- Analysis of Strategies (comparison of different options to address a given situation)

This analysis should be carried out as an *iterative learning process*, rather than as a simple set of linear 'steps'. For example, while stakeholder analysis must be carried out early in the process, it must be reviewed and refined as new questions are asked and new information comes to light.

In the ***Planning Stage*** the results of the analysis are transcribed into a practical, operational plan ready to be implemented. In this stage:

- The Logframe matrix is prepared, requiring further analysis and refinement of ideas;
- Activities and resource requirements are defined and scheduled, and
- A budget is prepared.

This is again an iterative process, as it may be necessary to review and revise the scope of project activities and expected results once the resource implications and budget become clearer. Figure 16 summarizes the two main phases of LFA.

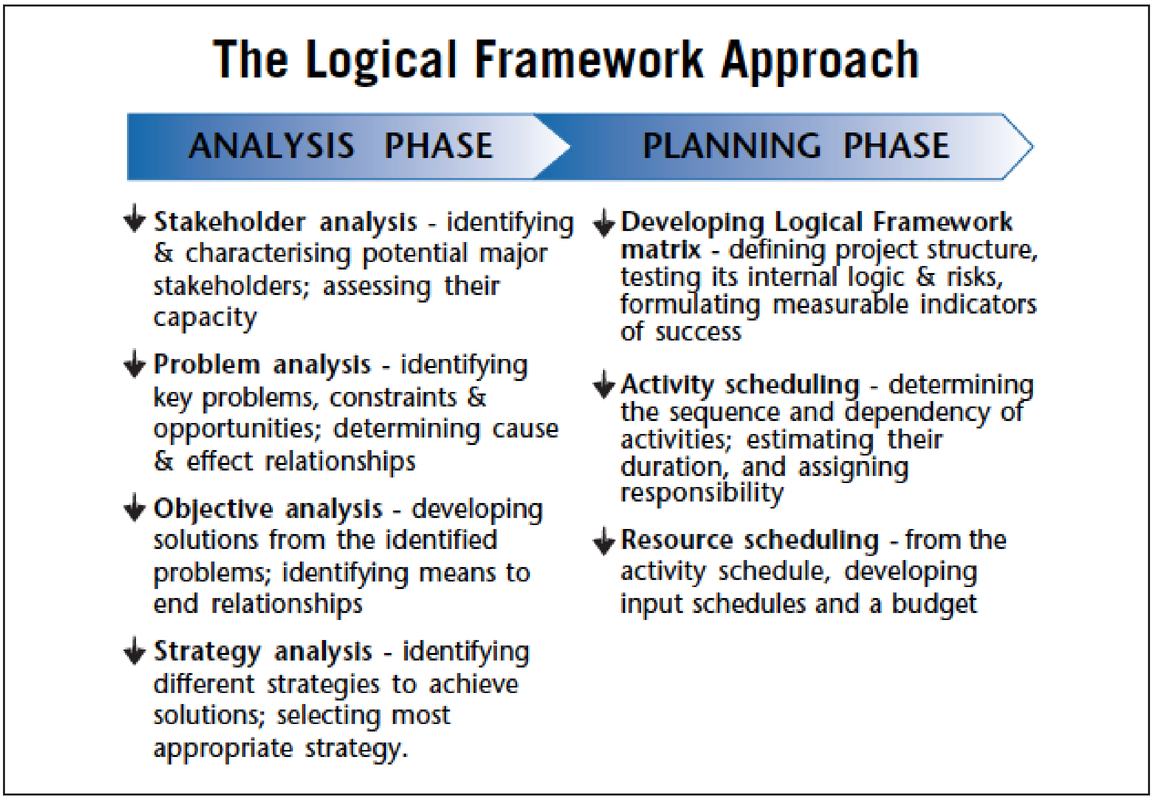


Figure 25 The two main phase of LFA
(Source: EC, 1999)

7.2 Logical Framework Approach – Analysis Stage

7.2.1 Preparatory analysis

Prior to initiating detailed analytical work with stakeholder groups (often requiring field work), it is important that those involved in the identification or formulation of projects are sufficiently aware of the policy, sector and institutional context within which they are undertaking their work. Key documents that should be referenced would include the EC's Country Strategy Papers and relevant Partner Government development policy documents, such as their Poverty Reduction Strategy and/or Sector Policy documents.

The scope and depth of this preliminary analysis will depend primarily on how much information is already available and its quality. In general, it should not be the work of each individual project planning team to undertake 'new' analysis of development/sector policies or the broader institutional framework, rather they should access existing information and then work to ensure that the development of the project idea takes account of these elements of the operating environment.

7.2.2 Stakeholder analysis

Any individuals, groups of people, institutions or firms that may have a significant interest in the success or failure of a project (either as implementers, facilitators, beneficiaries or adversaries) are defined as 'stakeholders'. A basic premise behind stakeholder analysis is that different groups have different concerns, capacities and interests, and that these need to be explicitly understood and recognized in the process of problem identification, objective setting and strategy selection.

The key questions asked by stakeholder analysis are therefore 'Whose problems or opportunities are we analyzing' and 'Who will benefit or loose-out, and how, from a proposed project intervention'? The ultimate aim is to help maximize the social, economic and institutional benefits of the project to target groups and ultimate beneficiaries, and minimize its potential negative impacts (including stakeholder conflicts).

There are a variety of tools that can be used to support stakeholder analysis. Two have been presented in the governance chapter under stakeholder analysis paragraph. Another one is described here:

Visual models of leadership and coordination

Relations between stakeholders in a complex system can be very difficult to summarize effectively. However, an underlying understanding of these relationships does not need to be captured to develop strong stakeholder platforms. One method is to build up diagrams or models of the systems, showing the main actors, the main link between them (for example reporting or information sharing), and the relative strength or weakness of the actors in relationship to each other. Such diagrams may be complex but are often better at catching the relationships than written descriptions. There are no hard and fast rules for developing models – different approaches work for different facilitators and different groups. The main aim is to capture the dynamic web of relationship in a way recognizable to all stakeholders.

Step 1: Actor identification. All stakeholders, especially key stakeholders should be identified within the model. The first step is to identify actors and their links with each other.

Step 2: Developing model(s). Start to work out the linkage between different actors in terms of:

- Information sharing
- Reporting
- Lines of responsibilities
- Permission

Use different means to identify the relative strength/importance of actor (larger symbols, stars, underlining text)

Use different type of lines to identify different relationships between them, and an arrow to reflect the direction of such relationships or information flows. It is important to maintain clarity as to what part of the system the model represents – for example a model of relations around domestic water supply may be different to a model around irrigation

Step 3: Share and discuss models. Models are useful in as much as they capture perceptions and understanding and allow these to be shared and discussed. The single criterion for judging such models is: does it advance our understanding of what needs to be done to achieve our objectives? If the answer is no, the model needs further development.

Step 4: Capture and document. Models should be captured – for example by taking a digital photograph – and stored as part of process documentation

This tool has been developed based largely on the RAAKS “leadership and coordination” tool.

7.2.3 Problem analysis

Problem analysis identifies the negative aspects of an existing situation and establishes the '*cause and effect' relationships* between the identified problems.

It involves three main steps:

- Definition of the framework and subject of analysis;
- Identification of the major problems faced by target groups and beneficiaries (What is/are the problem/s? Whose problems?); and
- Visualisation of the problems in form of a diagram, called a "problem tree" or "hierarchy of problems" to help analyse and clarify cause–effect relationships.

The problem analysis identifies the negative aspects of an existing situation and establishes the 'cause and effect' relationships between the identified problems. In many respects the problem analysis is the most critical stage of project planning, as it then guides all subsequent analysis and decision-making on priorities.

Brainstorming exercises with stakeholders are best suited for the problem analysis. It is essential to ensure that "root causes" are identified and not just the symptoms of the problem(s).

The problems identified are arranged in a 'problem-tree' by establishing the cause and effect relationships between the negative aspects of an existing situation. Depending on the complexity of the situation to be addressed by the project, preliminary technical or socio-economic studies or assessments might be useful.

The main output of a problem tree exercise is a diagram that creates a logical hierarchy of causes and effects and the links between them.

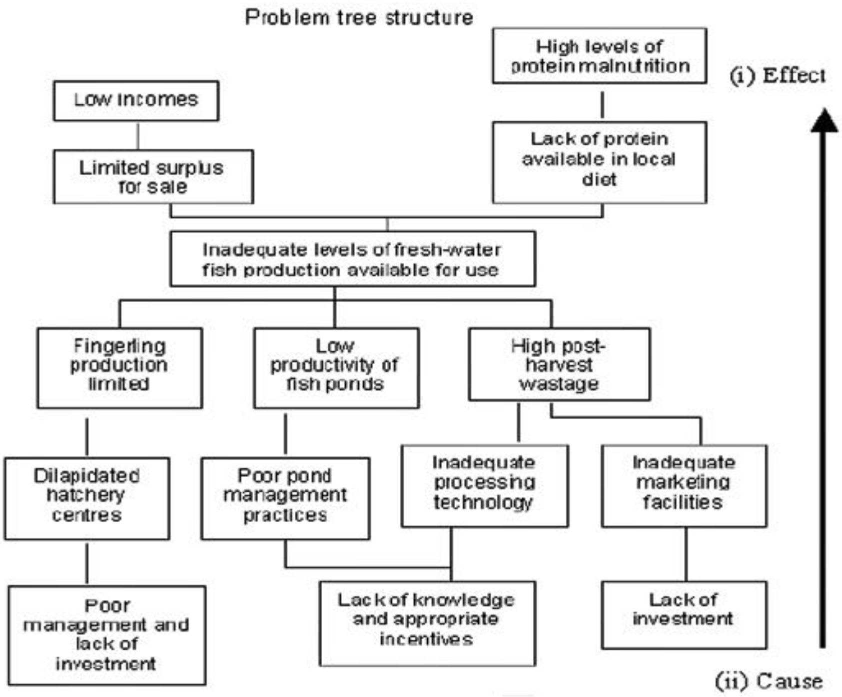


Figure 26 Problem tree after sorting causes and effects, (Source: ECDPM & DSI/AI)

Exercise: Problem tree analysis

Creating a problem tree that illuminates a situation calls for skills facilitation, as well as plenty of time. It is crucial that there is good representation of Stakeholders during problem tree sessions to achieve a shared understanding of water related issues. There may be considerable differences of opinion and perceptions between different stakeholders.

Step 1: Start with a brainstorming session on the major problems (or potential problems) impeding the achievement of the desired vision. Together with the group, choose a starter problem.

Step 2: Draw a tree and write the starter problem on the trunk. If you want to look at more than one problem, then you will need to draw one tree per problem.

Step 3: Encourage people to brainstorm on the causes of the starter problem. To ensure that a few people do not dominate, give each person three to five blank cards and ask everyone to write down one idea per card.

Step 4: To focus on the root causes of the problem, discuss the factors that possibly contribute to it. Write these causes on sticky notes. This task is made easier by continually asking the question Why? for each of the causes identified. Keep asking Why? until you have reached the basic root cause of the problem.

Step 5: Connect the notes with lines to show linkages between the causes. These connections become the roots of the tree.

Step 6: Follow the same procedure to determine the effects/impact of the problem and write the primary effects on the branches of the tree.

7.2.4 Objective analysis

When the stakeholders have identified the problems that the project shall contribute to eliminating, it is time to develop the objectives, to make an objective tree/analysis. If care has been taken on the problem analysis, the formulation of objectives shall not result in any difficulties. The objective analysis is the positive reverse image of the problem analysis.

The analysis of objectives is a methodological approach employed to:

- Describe the situation in the future once identified problems have been remedied;
- Verify the hierarchy of objectives; and
- Illustrate the means-ends relationships in a diagram.

The ‘negative situations’ of the problem tree are converted into solutions and expressed as ‘positive achievements’. These positive achievements are in fact objectives, and are presented in a diagram of objectives showing a means to ends hierarchy.

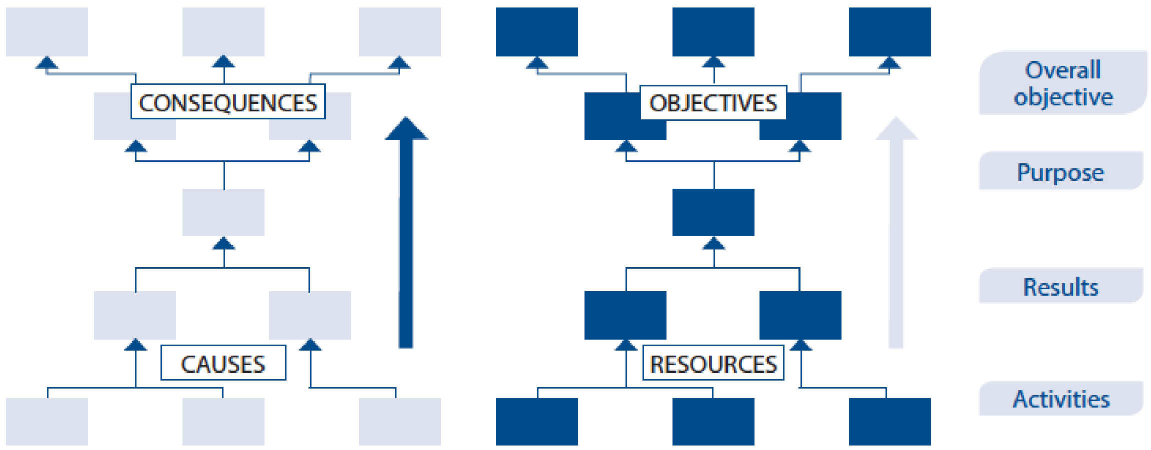


Figure 27 Problem tree and Objective tree,
(Source:EC, 2011)

It is a tool to aid analysis and presentation of ideas. Its main strength is that it keeps the analysis of potential project objectives firmly based on addressing a range of clearly identified priority problems.

Exercise: Objectives analysis

From the following problem tree conduct objective analysis by establishing an objective tree

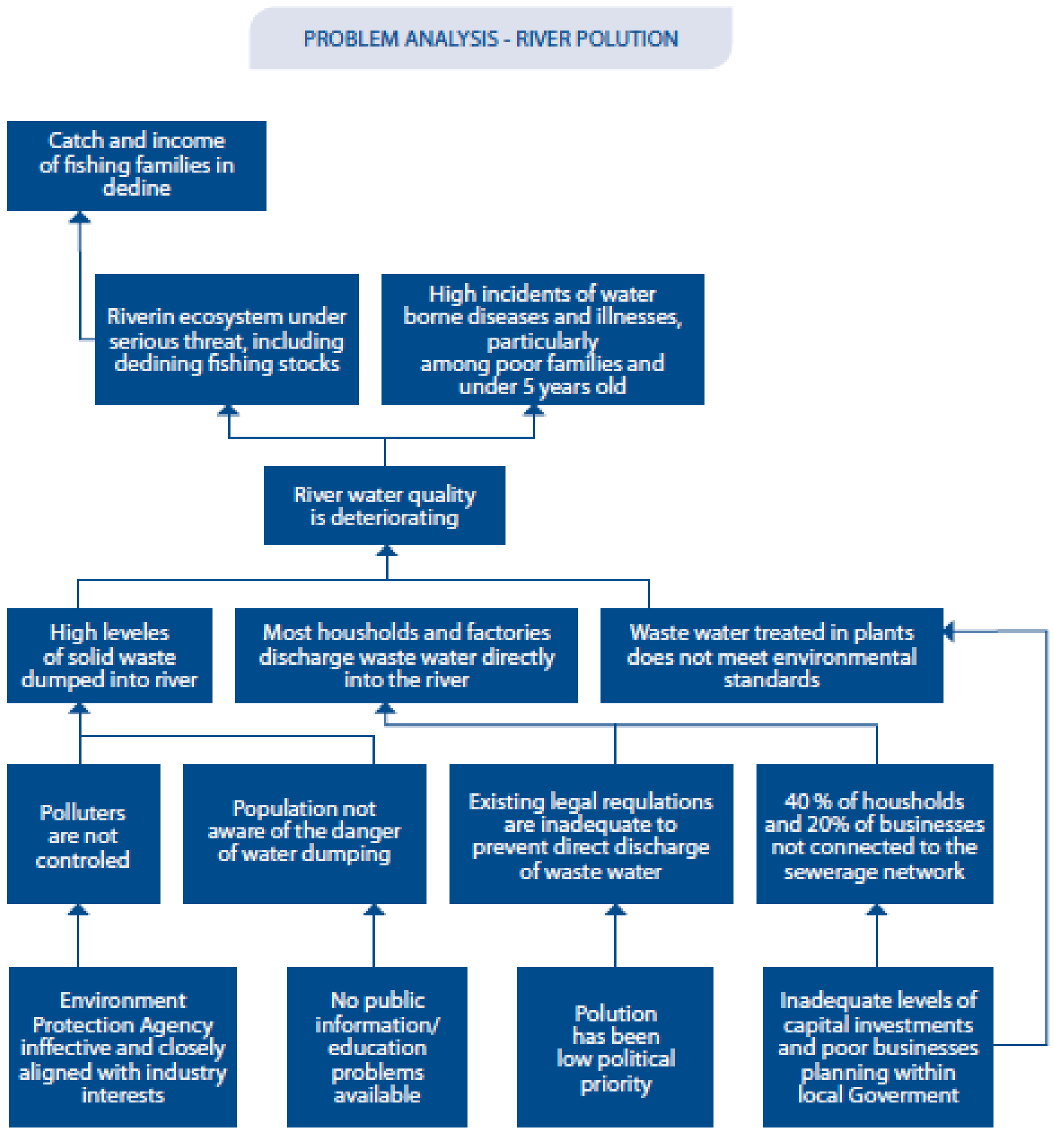


Figure 28 Problem analysis -River pollution
(Source: EC, 2011)

Step 1: Reformulate all negative situations of the problems analysis into positive situations that are desirable, realistically achievable

Step 2: Check the means-ends relationships to ensure validity and completeness of the hierarchy (cause-effect relationships are turned into means-ends linkages)

Caution: Every cause-effect relationship does not automatically become a means-end relationship.

Step 3: Work from the bottom upwards to ensure that cause-effect relationships have become means-ends relationships. If necessary:

- *revise statements*
- *add new objectives if these seem to be relevant and necessary to achieve the*
- *objective at the next higher level*
- *delete objectives which do not seem suitable or necessary*

Step 4: Draw connecting lines to indicate the means-ends relationships.

Proposed solution:

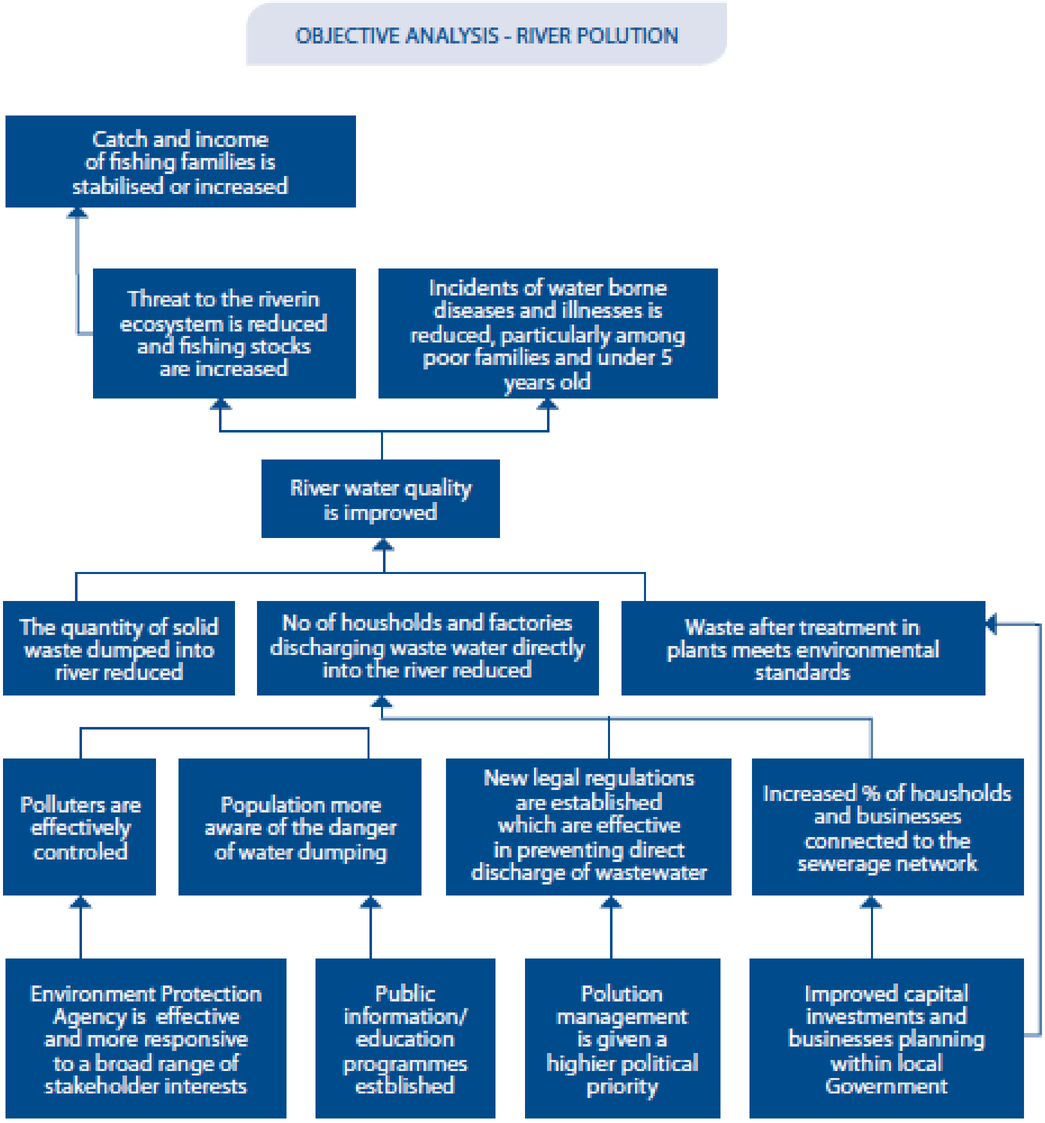


Figure 29 Objective analysis – river pollution (Source:EC, 2011)

7.2.5 Strategy analysis

The purpose of this analysis is to identify possible alternative options/strategies, to assess the feasibility of these and agree upon one project strategy.

The Objective Tree usually shows different clusters of objectives that have an inherent means-end linkage. Out of these possible strategies of intervention the most pertinent and feasible one is selected on the basis of a number of criteria, including relevance, likelihood of success, resource availability, etc.

This analytical stage is in some respects the most difficult and challenging, as it involves synthesizing a significant amount of information and then making a complex judgment about the best implementation strategy (or strategies) to pursue. In practice a number of compromises often have to be made to balance different stakeholder interests, political demands and practical constraints such as the likely resource availability.

Nevertheless, the task is made easier if there is an agreed set of criteria against which to assess the merits of different intervention options.

Possible key criteria for strategy selection could be:

- **Strategic**: Expected contribution to key policy objectives (e.g. such as poverty reduction or economic integration, complementarily with other on-going or planned programmes or projects
- **Social/distributional**: Distribution of costs and benefits to target groups, including gender issues, socio-cultural constraints, local involvement and motivation.
- **Financial**: Capital and operating cost implications, financial sustainability and local ability to meet recurrent costs, foreign ex-change needs.
- **Economic**: Economic return, cost-benefit, cost effectiveness.
- **Institutional**: Contribution to institutional capacity building, Capacity and capability to absorb technical assistance
- **Technical**: feasibility Appropriateness, use of local resources, market suitability.
- **Environmental**: Environmental impact, environmental costs vs. benefits

These criteria should be considered in relation to the alternative options and roughly assessed, e.g. high/low; +/-; extensive/limited. Using these criteria will help to determine what should/can be included within the scope of the project, and what should/cannot be included.

In the example shown on the previous exercise, the objective tree can be separated into two strategies: a waste strategy and a wastewater strategy. In this case, a choice has been made to focus the project primarily on a wastewater strategy, due to:

- Another planned project working with the implementing agency,
- The positive cost-benefit analysis of improving waste-water treatment plants and implementing cost recovery mechanisms for extending the sewerage network,
- The enthusiasm of Local Government to improve its ability to plan and manage waste-water disposal systems;
- Indicative budget ceilings, which require a choice to be made regarding priorities for EC support.

Those objectives which fall under the strategy of intervention are selected to elaborate the hierarchy of objectives in the first column of the Logframe matrix. Objectives at the top of the objective tree are translated into the overall objective, while those objectives further down the tree need to be converted into purpose and results statements.

7.3 Logical Framework Approach – Planning Stage

7.3.1 Logical Framework Matrix

The Logical Framework Matrix (or more briefly the Logframe) consists of a matrix with four columns and four (or more) rows, which summarize the key elements of a project plan, namely:

- The project's hierarchy of objectives (Project Description or Intervention Logic);
- The key external factors critical to the project's success (Assumptions); and
- How the project's achievements will be monitored and evaluated (Indicators and Sources of Verification).

The typical structure of a Logframe Matrix is shown in the figure below:

Logic of intervention	Objectively Verifiable Indicators	Sources of Verification	Assumptions
Overall Objective			
Purpose 1. 2.			
Results 1.1 1.2... 2.1			
Activities 1.1.1 1.1.2 1.2.1 2.1.1...	Means	Costs	
			Preconditions

Figure 30 Typical Logframe matrix,
(Source : EC, 2011)

Overall Objective:

The overall objective is the higher-order objective that you are seeking to achieve through this project, often in combination with others. It usually relates to a programme or a sector. Very often a group of projects will share a common overall objective statement.

Since the Overall Objective/Goal describes the anticipated long-term objective towards which the project will contribute (project justification). It is to be expressed as 'To contribute to.....`;

Purpose

The purposes, also called specific objectives, must be formulated as an expression of a desire for the future, an end-state. Purposes are much more specific than a goal and must be stated in terms of a particular result to be achieved, a future completed action. They should not be formulated as means or processes. When an overall objective guides stakeholders of the entire project, the specific objectives target more specifically stakeholders involved in a given sector. Objectives are usually stated in specific terms and through a short and clear sentence.

Each purpose is a necessary, but not sufficient, contribution to the Overall objective's achievement.

Results

Results/outputs are expressed as the targets which th project management must achieve and sustain within the life of the project (WHAT do you want the project to achieve). Their combined impact should be sufficient to achieve the immediate purpose. They are to be expressed in terms of a tangible result 'delivered/produced/ conducted etc.'

Activities

Activities are expressed as processes, in the present tense starting with an active verb, such as 'Prepare, design, construct, research …..'. Avoid detailing activities; indicate the basic structure and strategy of the project. Activities define HOW the team will carry out the project.

Objectively Verifiable Indicators

OVI show the important characteristics of the performance standards expected to be reached in terms of quantity, quality, time frame and location. The word "objectively" implies that indicators should be specified in a way that is independent of possible bias of the observer.

Source of Verification

The source of verification (SOV), also called means of verification, should be considered and specified at the same time as the formulation of indicators. This will help to test whether or not the indicators can be realistically measured at the expense of a reasonable amount of time, money and effort. Indicators for which we cannot identify suitable means of verification must be replaced by other, verifiable indicators.

Assumptions:

Assumptions are external factors that have the potential to influence (or even determine) the success of a project, but lie outside the direct control of project managers.

They are the answer to the question: "What external factors may impact on project implementation and the long-term sustainability of benefits, but are outside project management's control?"

Project Description	Indicators	Source of Verification	Assumptions
Overall objective: The broad development impact to which the project contributes – at a national or sectoral level (provides the link to the policy and/or sector programme context)	Measures the extent to which a contribution to the overall objective has been made. Used during evaluation. However, it is often not appropriate for the project itself to try and collect this information.	Sources of information and methods used to collect and report it (including who and when/how frequently).	
Purpose: The development outcome at the end of the project – more specifically the expected benefits to the target group(s)	Helps answer the question 'How will we know if the purpose has been achieved'? Should include appropriate details of quantity, quality and time.	Sources of information and methods used to collect and report it (including who and when/how frequently)	Assumptions (factors outside project management's control) that may impact on the purpose-objective linkage
Results: The direct/tangible results (good and services) that the project delivers, and which are largely under project management's control	Helps answer the question 'How will we know if the results have been delivered'? Should include appropriate details of quantity, quality and time.	Sources of information and methods used to collect and report it (including who and when/how frequently)	Assumptions (factors outside project management's control) that may impact on the result-purpose linkage
Activities: The tasks (work programme) that need to be carried out to deliver the planned results *(optional within the matrix itself)*	*(sometimes a summary of resources/means is provided in this box)*	*(sometimes a summary of costs/budget is provided in this box)*	Assumptions (factors outside project management's control) that may impact on the activity-result linkage

Figure 31 Information contain in the Logframe matrix, (Source: EC, 2004)

The preparation of a Logframe matrix is an iterative process, not a just a linear set of steps. As new parts of the matrix are drafted, information previously assembled needs to be reviewed and, if required, revised. Nevertheless, there is a general sequence to completing the matrix, which starts with the project description (top down), then the assumptions (bottom-up), followed by the indicators and then sources of verification (working across). The sequence of completion can be illustrated as follow:

Project Description	Indicators	Sources of verification	Assumptions
Overall objective 1	8	9	
Purpose 2	10	11	7
Results 3	12	13	6
Activities 4 *(optional inclusion in the matrix)*	*Not included*	*Not included*	5 *(optional inclusion in the matrix)*

Figure 32 Sequence of completion, (Source: EC, 2004)

Case study: The Nile Transboundary Environmental Action Project (NTEAP)

According to the information found in the text below completed with your personal assumption try to fill the Logical Framework Matrix for the NTEAP Project

1/ Project Fact Sheet

Project Title: Nile Transboundary Environmental Action Project (NTEAP)

Phase 1: Mid Oct - Dec 2003 (start up phase)

Phase 2: 01 Jan - 30 May 2004 (preparatory period)

Phase 3: June 2004 – Dec 2007 (Implementation phase)

Duration: 5 years

Project Budget: 43,6 million USD

Beneficiary countries: Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, South Sudan, Tanzania, Uganda, and Eritrea (observer)

Implementing Agency: UNDP, World Bank

Executing Agency: NBI through UNOPS

2/ Nile river basin

Source: White Nile: Victoria Lake (Uganda); Blue Nile: Tana Lake (Ethiopia)

Delta: Alexandria in the Mediterranean Sea (Egypt)

Confluence Khartoum (Soudan)

Length: White Nile: 5 584 km (from Victoria Lake) or 6 695 km (from its furthest tributary, the Ruvyironza river in Burundi); Blue Nile: 1 529 km

Total Surface of the basin: 3 349 000 km2

Countries located **in the basin: 11 countries*:*** Burundi, DR Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, South Sudan, Tanzania, Uganda

Population located on the basin: 160 million people

Main tributaries: Bashilo, Beles, Dabus, Didessa, Dinder, Jamma, Muger, Blue Nile, Walaqa, White Nile

The Nile Basin covering close to 3 million square kilometres faces significant environmental problems related to water resources and land degradation compounded by poverty and population growth and lack of awareness. Furthermore, large-scale flooding and periodic devastating droughts are very severe problems in most of the Basin. Although countries of the Nile basin have been struggling to address these challenges individually, cooperative actions and regional approach were found to be appropriate ways of addressing the environmental problems facing the Nile basin.

Elements of Complexity:

- *The size: over 3 million Km2, shared by 10 countries;*
- *high population pressure;*
- *food insecurity;*
- *extreme poverty;*
- *political instabilities;*
- *limited understanding of the biophysical resources;*

3/ Presentation of the project

The Nile Trans-boundary Environmental Action Project (NTEAP) is one of the seven projects under the Nile Basin Initiative (NBI) Shared Vision Program (SVP). Its objective is to provide a strategic environmental framework for the management of the transboundary waters and environment challenges in the Nile River Basin. The project will improve the understanding of the relationship of water resources development and the environment in the basin, and provide a forum to discuss development paths for the Nile basin with a wide range of stakeholders.

NTEAP aims to:

- Increase regional cooperation in environmental and water management fields.
- Increase basin-wide community action and cooperation in land and water management.
- Increase the number of basin-wide networks comprising of environmental and water professionals therefore increasing the number of experts knowledgeable on the environment
- Create a greater appreciation of river hydrology and more informed discussion of development paths.
- Expand information, knowledge base and know-how on land and water resources available to professionals and Non-Governmental Organizations (NGOs) in the riparian countries.
  Create greater awareness of the linkages between macro/sectoral policies and the environment.
- Greater awareness and increased capacity on transboundary water quality threats.

The project hopes that by the end of its life cycle, the following will have been achieved:

- Improved communications and knowledge management
- A functioning river basin model,
- Local level conservation initiatives supported through micro grants, enhanced public awareness, networking of secondary schools, universities and research institutions, with an enhanced understanding of transboundary soil erosion

- Improved cooperation and capacity in wetlands management and enhanced national capacities in water quality monitoring.

NTEAP has 5 components:

- *Institutional Strengthening to Facilitate Regional Cooperation;*
- *Community-Level Land, Forests and Water Conservation;*
- *Environmental Education and Public Awareness;*
- *Wetlands and Biodiversity Conservation;*
- *Basin Wide Water Quality Monitoring*

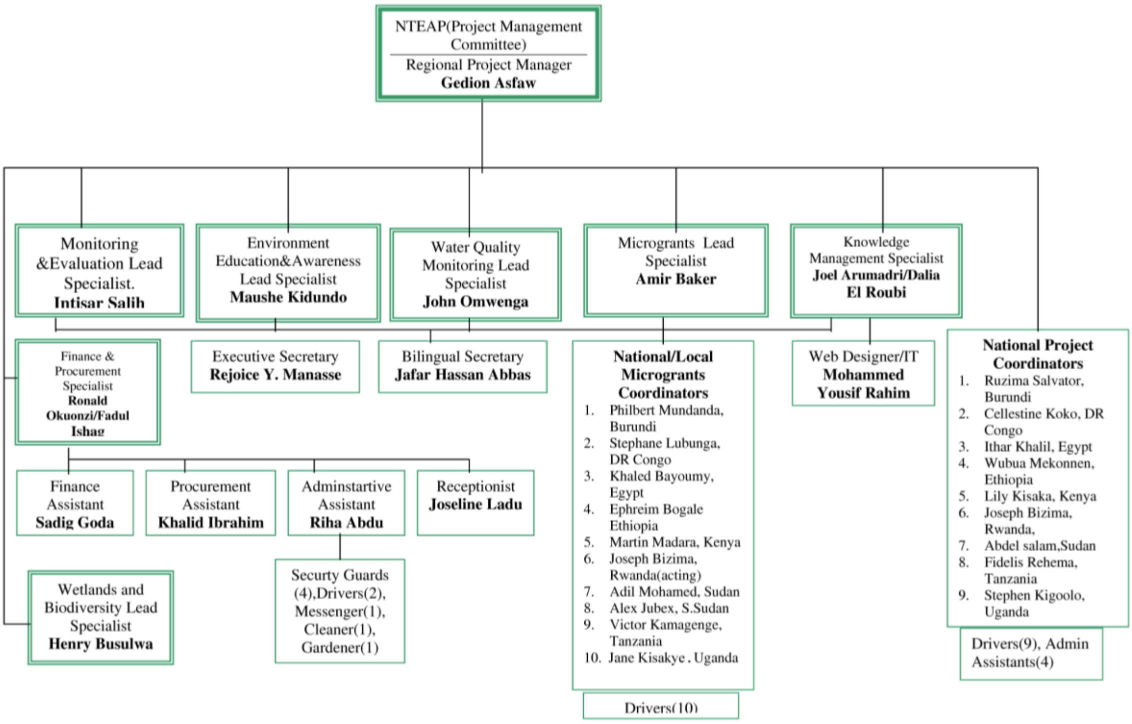
4/ Main outputs of the project

Nile Trans-boundary Environment Action Project (NTEAP) has made considerable progress, mainly in institutional capacities development, awareness creation, communities' skills development, and water quality monitoring.

Major achievements include:

- *Completion and dissemination of Nile River Awareness kit (NRAK) including French version,*
- *Micro-grants fund release agreement signed for 85 projects in nine countries with a total of US$1.95(bringing the total to 175 projects and US4.0 mill commitments);*
- *36 schools projects and 21 NEPs under implementation,*
- *185 practitioners trained on EE&A concept,*
- *Soil erosion studies to inform Micro Grants completed in Ethiopia, Rwanda and Sudan.*
- *Established a network of expertise and themes.*
- *180 secondary schools teachers trained on project-based learning concept,*
- *36 school environmental projects with community link implemented,*
- *Formed a regional Water Quality Working group including representation of South Sudan.*
- *9 masters exchange students from NBI countries participated in exchange program,*
- *Capacity strengthened in all the countries in Water Quality Management (equipment's, operational manuals, sampling stations, parameters and procedures).*
- *Baselines are being developed through a network of national experts and have been completed in many of the Nile Basin countries*

5/ NTEAP Organisation



The Logical framework matrix below is the official NTEAP Logframe extracted from NTEAP – project Completion report Volume II Annexes – December 2009. Do not hesitate to ask your student to comment.

Results	Indicators	Assumptions & Risks
Goal: To ensure efficient water management and the optimal use of the resources		
Impact : Improved quality of the environment in the Nile Basin	Frequency /density of indicator species	Political leadership and economic stability of riparian countries will favor development and cooperation
	Water quality of the Nile (measured by levels of pesticide pollution ,volume of invasive species and turbidity)	
	Soil erosion rate (tons per hectare)	
Project Objective		
To increase cooperation & capacity in NB countries through the provision of strategic environmental framework of actions and engagement of stakeholders for the management of transboundary waters and environmental challenges in the NB		NB countries are willing to reach consensus and share information and stakeholders are willing to collaborate with the project
Outcome 1. Institutions strengthened to facilitate regional collaboration	Transboundary EIA guidelines for use by NBI investment programs developed Policy recommendations on Basin environment protection formulated and submitted for consideration in at least two countries Environment function of the NB permanent institution defined through a consultative process	

	Nile Basin Development Forum in 2008 defines the environmental issues and priorities for the Basin Nile Cooperative Framework ratified with specific references to wetlands conservation (co-financed catalytic outcome	
Outputs		
1.1 Institutional setup for project implementation established	PSC,PMU & 9 national offices established & functioning	
1.2 Knowledge management and communication tools produced	1.Quarterly newsletters published in 5 languages, 2.Website established and updated regularly (No. of hits per year) 3. IT infrastructure at the PMU and 9 countries established and functioning. 4. library established, equipped and connected to the NBI cyber library 5. multimedia communication tools developed	Adequate institutional arrangements are available in each country to manage TB micro grants program in a transparent manner
1.3 River basin model system developed	RBM developed integrated in the DSS	National working groups are willing to jointly share
1.4 Strategic Environment Framework provided	Guidelines for EIA for the SAPs produced	

	&submitted for approval	information with counterparts from other riparian countries
1.5 Transboundary desk studies of macro & sector policies & environment completed	Policy recommendations formulated and submitted to PSC.	
1.6 M&E system in place	Monthly, quarterly, semi annual, annual, field visits , surveys and review reports produced and disseminated to respective partners	
Outcome 2: Improved capacity of the Nile Basin communities to demonstrate and adopt viable approaches to integrated natural resources management across GEF focal areas	3 pilots identified for up scaling and 10 identified for replication during the project lifetime.	
Outputs		
2.1. Capacities of NGOs and CBOs on addressing environmental threats enhanced	No. of professional women and men trained on the Nile environmental threats across the basin.	
2.2. Viable options for community level actions to address Nile environmental threats (in accordance to the relevant GEF focal areas)	A minimum of 200 projects, of which 10% targeting women groups, implemented by communities across the basin. At least 8 universities in 6 NBI countries approved and adopted the environmental modules based on Nile environmental threats	
2.3 Soil erosion micro grants studies completed	Number of MG Projects addressing soil erosion issues approved in all NB countries	

Outcome 3: Environmental Education Improved and Public awareness enhanced	Environmental campaigns and schools award programs adopted and institutionalized at national levels in at least 6 NBI countries.	
Outputs		
3.1 Public awareness on Nile Environmental Threats enhanced in NB countries	1. At least 2 environmental awareness programs delivered in at least 5 countries 2. Awareness material on 5 selected Nile Environment threats produced and disseminated across the basin	
3.2. Networks of secondary schools for projects based learning established and functioning in NB countries	At least 60 % of the participating schools adopt project based learning (environmental modules and school projects).	
3.3. Networking established among universities and other research institutions	1. At least 2 junior faculty or graduate students exchanged in at least 6 countries. 2. Training modules developed and adopted in at least 6 universities	Wetlands and other priority transboundary sites selected for studies and for pilot initiatives are accessible
Outcome 4 : Enhanced Capacity for conservation and management of wetlands and their biodiversity	Strategic approach to wetlands management in the basin with key actions, steps and responsibilities developed.	

	Management plans for at least three selected wetlands developed and under implementation.	Commitments among the riparian to agree on common monitoring approaches and to share water quality information
Outputs		
4.1. Regional cooperation is enhanced and capacity for conservation and management of wetlands and their biodiversity improved	Regional network/working group established and functioning	
	National level wetlands management networks established and functioning in all NBI countries	
	Training program on wetlands management developed in 2 languages	
4.2. Understanding and awareness of the roles of wetlands in supporting sustainable development is improved	Ecological& economic studies on wetland roles in sustainable development conducted	
	National baseline surveys carried out and regional synthesis report written up	
4.3 Train in Wetlands management according to needs	Over 50 officers on wetlands management trained across the basin	
	Awareness programs conducted in 9 NBI countries	

4.4. Pilot initiatives in support of capacity building and wetland management plans implemented	Transboundary wetlands management plans prepared for three selected sites	
	Wetlands inventory carried out and the results mapped on a GIS platform	
Outcome 5. Increased capacity and awareness on water quality monitoring in the NB countries	Transboundary water quality monitoring network established and operational	
	Water quality monitoring data exchange agreement to be annexed to the NBI information sharing protocol formulated approved by the WQM WG.	
Outputs		
5.1 Regional working group established	Strategy to operationalize Water quality monitoring network developed and finalized	
5.2. Awareness on WQ issues increased in NBC at all levels	Awareness materials on water quality monitoring produced &disseminated in all Nile basin countries	
5.3.Data exchange mechanism developed	Regional WQ manuals and uniform data reporting formats developed and used in at least 4 countries	

5.4 Capacity of selected labs in each country improved	Water quality testing kits provided and training in WQ measurements provided to focal laboratories	
5.5 Biological monitoring tools pilot tested in the Nile basin	At least 2 biological monitoring demonstration sites selected and tools pilot tested in at least 2 countries	
5.6. Critical evaluation of progress undertaken and recommendations for follow up action formulated	The way forward in transboundary WQM developed	

7.4 Activity and resources scheduling

Once the Logframe matrix itself is complete, it is then possible to use the identified Activities (which may or may not be actually included in the matrix itself) to further analyse issues of timing, dependency and responsibility using an activity scheduling (or Gantt chart)

The format can be adapted to fit with the expected duration of the project in question and to the level of detail that it is useful and practical to provide. The first year's Activities may be specified in more detail (i.e. showing the indicative start and finish of Activities to within a week or month of their expected timing) while subsequent years scheduling should be more indicative (to within a month or a quarter).

A European Commission step-by-step approach to the preparation of a detailed activity schedule can be followed:

Step 1 – List Main Activities

The main Activities identified through the Logframe analysis are a summary of what the project must do in order to deliver project results. These can therefore be used as the basis for preparation of the Activity Schedule which helps to specify the likely phasing and duration of key activities.

Step 2 – Break Activities Down into Manageable Tasks

This step may not be appropriate until Financing is approved and the project implementation phase has commenced. The purpose of breaking Activities down into sub-activities or tasks is to make them sufficiently simple to be organised and managed easily. The technique is to break an Activity down into its component sub-activities, and then to take each sub-activity and break it down into its component tasks. Each task can then be assigned to an individual, and becomes their short-term goal.

Step 3 – Clarify Sequence and Dependencies

Once the Activities have been broken down into sufficient detail, they must be related to each other to determine their:

- S*equence* _ in what order should related Activities be undertaken?
- D*ependencies* -_ is the Activity dependent on the start-up or completion of any other Activity?

Step 4 – Estimate Start-up, Duration and Completion of Activities

Specifying the timing involves making a realistic estimate of the duration of each task, and then building it into the Activity Schedule to establish likely start-up and completion dates. However, it is often not possible to estimate timing with great confidence. To ensure that the estimates are at least realistic, those who have the necessary technical knowledge or experience should be consulted.

Step 5 – Summarize Scheduling of Main Activities

Having specified the timing of the individual tasks that make up the main Activities, it is useful to provide an overall summary of the start-up, duration and completion of the main Activity itself.

Step 6 – Define Milestones

Milestones can provide the basis by which project implementation is monitored and managed. They are key events that provide a measure of progress and a target for the project team to aim at. The simplest milestones are the dates estimated for completion of each

Step 7 – Define Expertise

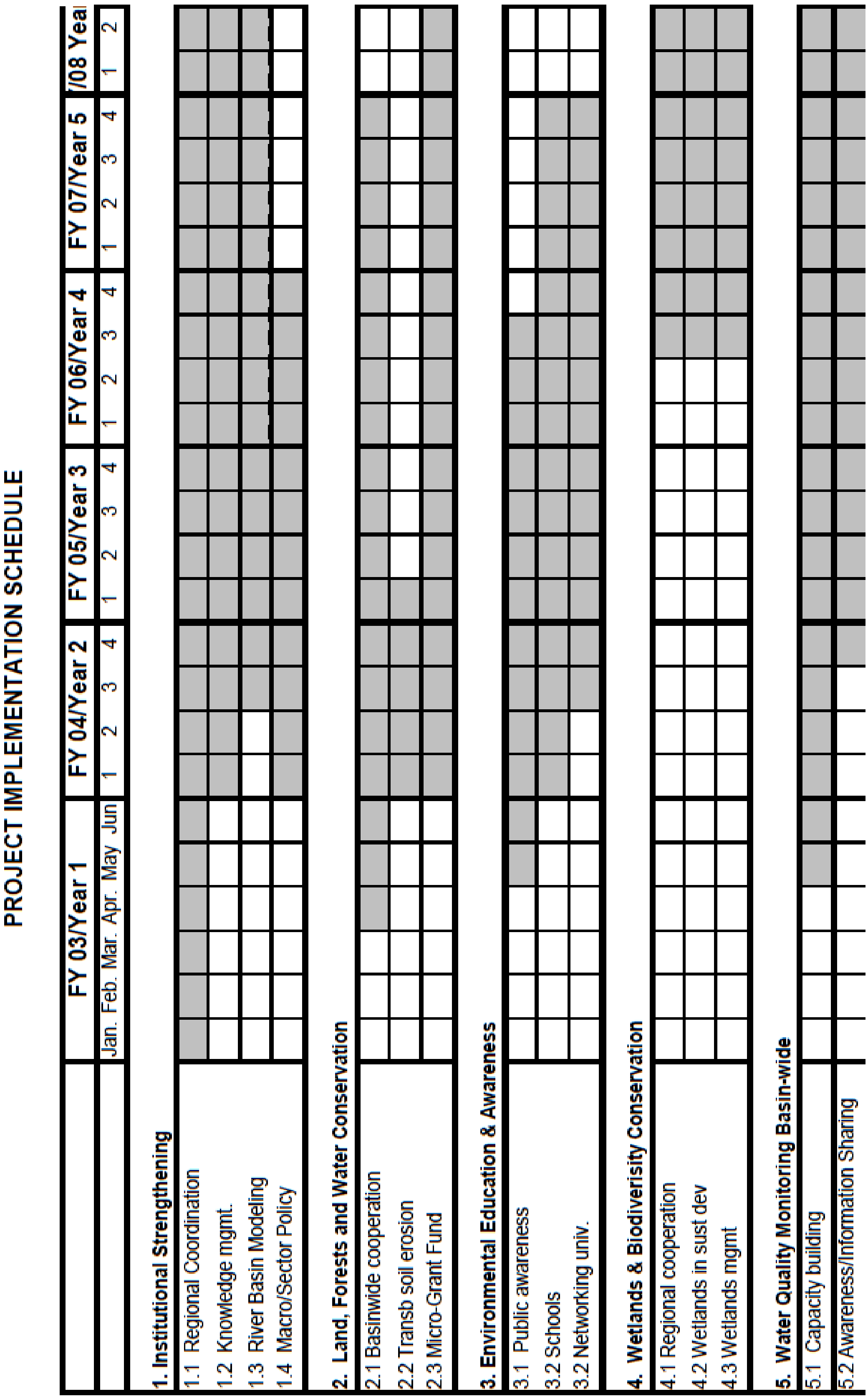
When the tasks are known, it is possible to specify the type of expertise required. Often the available expertise is known in advance. Nonetheless, this provides a good opportunity to check whether the action plan is feasible given the human resources available.

Step 8 – Allocate Tasks Among the Team

This involves more than just saying who does what. With task allocation comes responsibility for achievement of milestones. In other words, it is a means to define each team member's accountability to the project manager and to other team members.

Task allocation should therefore take into account the capability, skills and experience of each member of the team. When delegating tasks to team members, it is important to ensure that they understand what is required of them. If not, the level of detail with which the relevant tasks are specified may have to be increased.

Figure 33 NTEAP Project Implementation Schedule
(Source: NBI, 2009)



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Abstract

Within the framework of the EC support project to the NEPAD Water Centres of Excellence one the project's tasks was to improve water sector knowledge development and management in the region; consequently the CoEs were requested to develop relevant educational material in the form of academic training courses. Within the Southern African Network, the exercise of producing training material was based on earlier consultations and studies from a report on Knowledge Management and a Skills and Trainings Needs Assessment study. The result was a short list of training priorities, which finally resulted in the development of 3 Master's degree-level courses, namely: Ground water studies for Southern Africa; Water strategy and policy in Southern Africa; Equitable, efficient and sustainable management of water resources – water project toolkit application.

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