Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
Governments of Botswana, Lesotho, Namibia and South Africa

UNDP-GEF
Orange-Senqu Strategic Action Programme
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ORASECOM
Frequently Asked Questions

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UNDP-GEF
Orange-Senqu Strategic Action Programme

ORASECOM Frequently Asked Questions

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with contributions from the ORASECOM Secretariat, the UNDP-GEF Project und utilising previous research of ORASECOM and its ICP supported projects.

This report has been issued and amended as follows:

Revision	Description	Date	Signed
0	Draft for review and discussion by ORASECOM Secretariat and other stakeholders.	13 May 2011	JCP, mor
1	Incorporating initial comments from CTT members, as well as general editing.	10 Nov 2011	JCP, mor

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UNOPS

Contents

Why Frequently Asked Questions?

To become informed participants in the development of ORASECOM's basin-wide IWRM plan (and the NAPs and a basin-wide SAP of the UNDP-GEF Project. which contributes to this exercise) most stakeholders will need to learn the basics regarding ORASECOM. Few will know the extent of the Orange-Senqu Basin and the infrastructure in the Basin that is used to deliver water across the system. Fewer still will understand the basic science concepts underlying TDA identified issues and the socio-economics of the basin.

In its meeting on 13 April 2011, the ORASECOM Communication Task Team acknowledged the need to expand its communications efforts to provide information to the public about ORASECOM and it work. The Team supported the development of a short list of basic topics for materials, which could be further expanded in the form of "FAQs - Frequently Asked Questions" or "Fact Sheets". These topics included:

- ORASECOM: What is it? Who is involved? Why was it formed? Structure, contacts.
- What is the UNDP-GEF Project? The TDA-NAP-SAP process.
- The Orange-Senqu River Basin: What is it? Geographical area? Infrastructure in the basin? (How many dams, a map). Basic socio-economic data of the basin? Priority issues.
- Climate Change and its potential impact in the basin?
- The Basin's hydrological cycle, what are the dynamics of water use – demand and supply in the basin, environmental flow requirements?
- Land use and land degradation in the basin. Alien invasives.
- Aquatic health of the river system. Water quality issues?

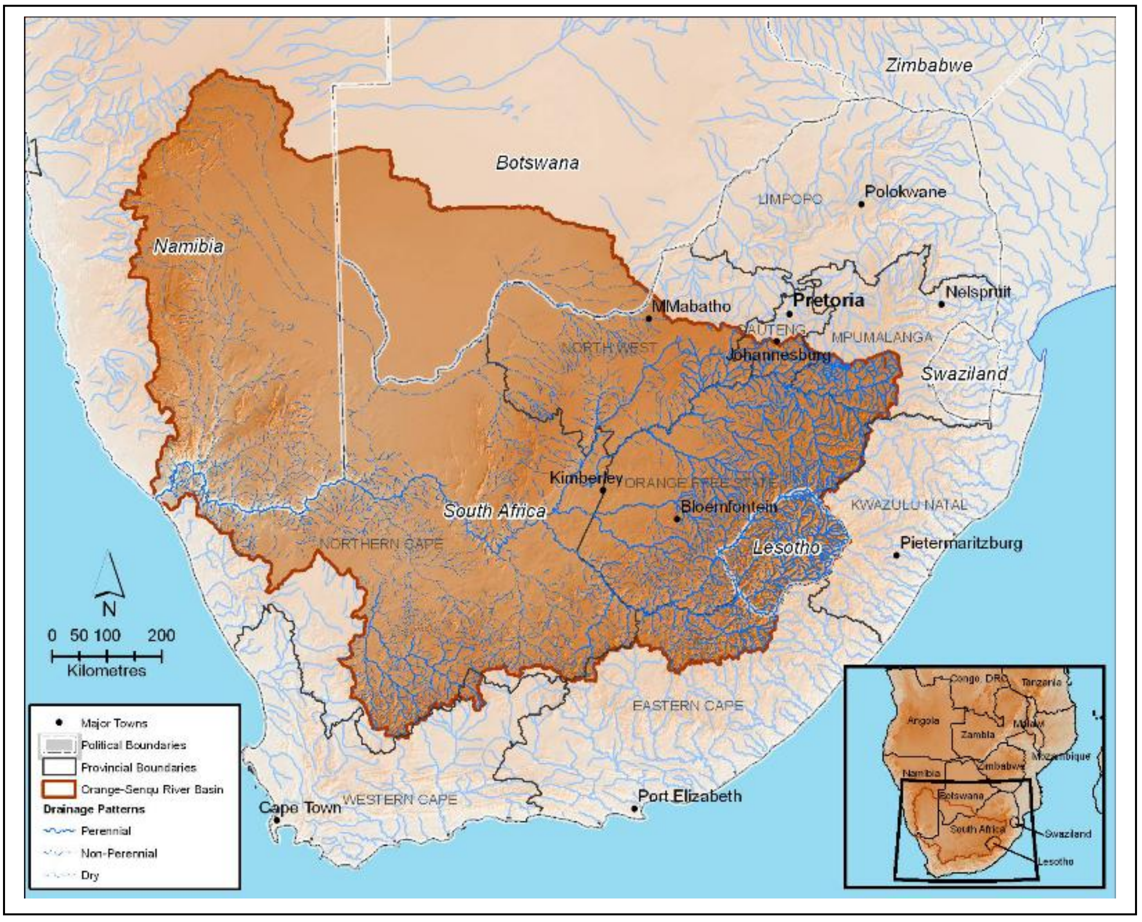
Clearly the Orange-Senqu River Awareness Kit (RAK) offers technically superior information on the above questions. The problem is that to answer with these questions via the RAK, one must wade through a lot of information, some of it dauntingly technical and in a language that is not always simple or clear. The questioner also needs to have access to a computer or the internet and time to search the RAK. The FAQs will be a series of presentations of bulleted facts relevant to a given question based on the above topics. The purpose is almost as much a "point of purchase sales" marketing tactic as it is stakeholder education: ORASECOM gets promoted and the reader gets a quick fact fix on a particular topic. The questions will provide some of the information required by both a general audience and a stakeholder who is asked to participate in the TDA-NAP-SAP development process.

In print format the Fact Sheet would be one side of A4, contain no more than 10 bulleted statements or facts on one of the listed topics and could possibly have graphics, perhaps a map, on the reverse side. The Fact Sheets would be printed for distribution at events. As well, they should be available for downloading from the website.

1. What is ORASECOM?

- The Orange-Senqu River Commission (ORASECOM) was established by the Governments of Botswana, Lesotho, Namibia and South Africa through the "Agreement for the Establishment of the Orange-Senqu Commission" on 3 November 2000 in Windhoek to promote equitable and sustainable development of the resources of the Orange-Senqu River.

- The agreement stipulates: (1) the Commission is an international organisation; (2) possesses both an international legal personality with the capacity to enter into international agreements and a legal personality within the legal systems of each of the countries; (3) agreements in force prior to the Agreement are unaffected by the Agreement; and (4) any number of the countries can establish among themselves river commissions with regard to any part of the River System, but any such commissions would be subordinate to Orange-Senqu River Commission.



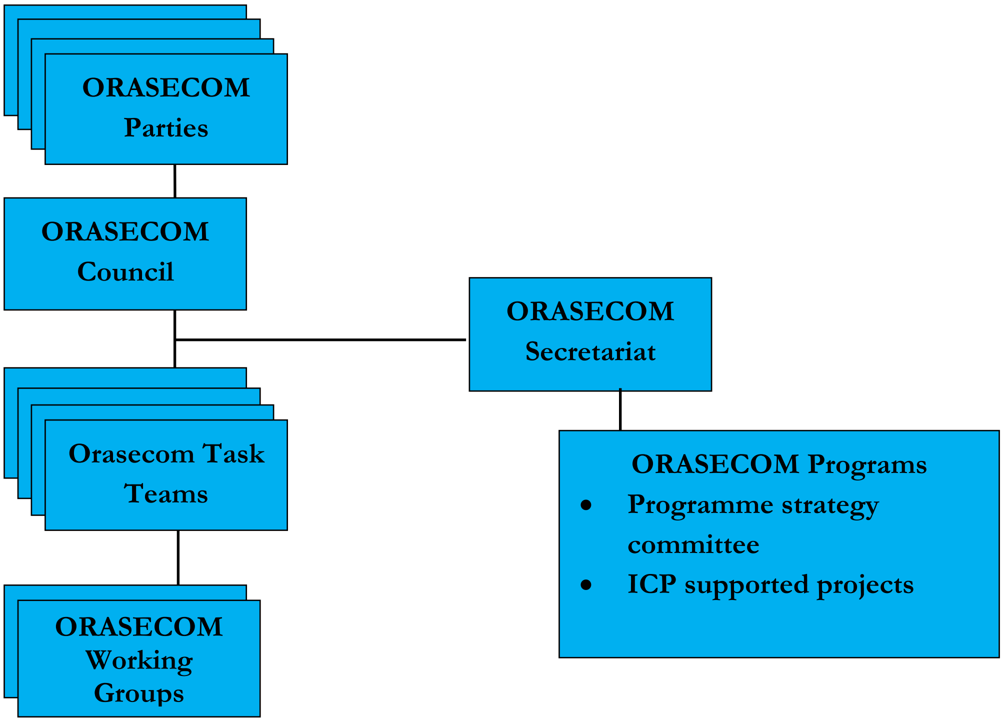
The Orange-Senqu River System and the four countries party to ORASECOM

2. What is the structure of ORASECOM?

- The highest body of ORASECOM is the Council consisting of delegations from each country, which is supported by various Task Teams who manage projects, and by a Secretariat. The Council serves as technical advisor to the Parties on matters related to development, utilisation and conservation of water resources.

- The Secretariat was established in 2004. The Republic of South Africa agreed in August 2006 to host the Secretariat. The Secretariat's role includes:

    - Coordinating ORASECOM activities and implementing ORASECOM decisions;
    - Serving as a repository of information related to the Orange-Senqu River Basin;
    - Acting as a focal point for ORASECOM with all external parties;
    - Performing ORASECOM administrative functions;
    - Conducting communications and promotions for ORASECOM
    - Developing and managing programmes and projects;
    - Mobilising resources.



The organisational structure of ORASECOM.

3. What are the functions of ORASECOM?

- The main purpose of ORASECOM is the realisation of the principle of equitable and reasonable utilisation, as well as the principle of sustainable development, with regard to the river system. The executive functions remain with the relevant water authorities of the four member states.

- The following functions are assigned to ORASECOM:

    - A secretariat function related to administration, financial control and technical back-stopping to the Commission to facilitate its functions.
    - A management function related to the provision of support to the joint management of those projects in the basin that are under the auspices of the Commission.
    - A coordination function related to harmonising development activities in the basin and facilitating the participation of all stakeholders in the activities of ORASECOM.
    - A communication function related to the maintenance of a comprehensive database on the basin, with a view to enabling transparent dialogue between the Commission, the scientific community, NGOs and other stakeholders.
    - A screening function related to ensuring the execution of decisions made by the Commission and the assessment of proposals for new activities submitted by a variety of outside interests.

- In operational terms, it is the Secretariat that guarantees these functions are carried out.

4. What activities have ORASECOM and the Secretariat been engaged in?

- ORASECOM and its Secretariat receive financial support from the basin States. International Cooperating Partners (ICPs) have also provided support to develop measures and frameworks that strengthen ORASECOM's legal, institutional and organisational structures. Various activities funded by ICPs and coordinated by the Secretariat include the conducting of basin studies to determine existing conditions, the development of an Integrated Water Resource Management (IWRM) Plan for the Basin and the formulation of procedures for dispute resolution.

- ICP projects implemented in support of ORASECOM and coordinated by the Secretariat include:

    - The development and implementation of a Strategic Action Programme (SAP) for the Orange-Senqu River Basin as well as related National Action plans (NAPs) in the four basin States implemented by the Global Environment Facility (GEF) through UNDP. The aim is to improve the management of the basin's trans-boundary water resources through IWRM approaches and create a transition towards adaptive management strategies.

    - The German GIZ has been actively involved with the SADC Water Sector and national water institutions, in the development of strategic action programmes and policy reviews. It is presently addressing a 6-year programme on trans-boundary water management in the SADC which specifically focuses on the Limpopo and the Orange River Basins to help in the development of their basin organisations and their secretariats. It will also tackle the problem of harmonising water policies and laws in the region. Another GIZ project, with a total duration of 9 years, plans to help increase co-operation between the region's river basin organisations.

5. What is IWRM?

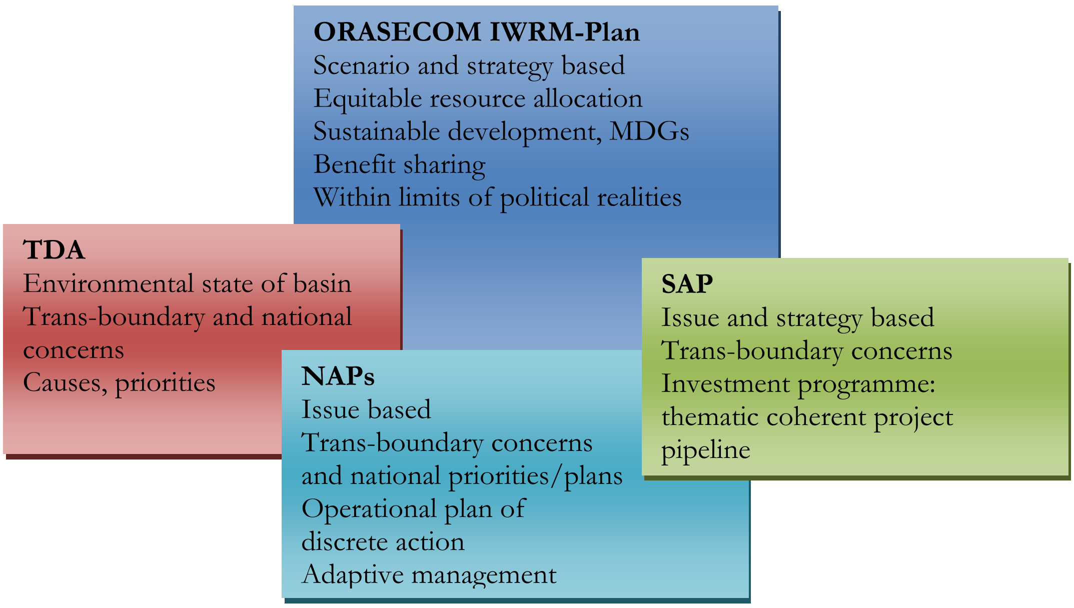
- The approach proposed within Integrated Water Resources Management (IWRM): *"Promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"* (GWP 2000).

- *"The IWRM approach helps to manage and develop water resources in a sustainable and balanced way, taking account of social, economic, and environmental interests."* (GWP 2003).

- IWRM is designed to coordinate actions across multiple sectors involving a range of stakeholders at local, national and international levels.

- With support from GIZ, French-GEF, the European Commission and the UNDP-GEF, ORASECOM is developing a single, harmonised basin IWRM Plan based on a series of steps that include the compilation of a Transboundary Diagnostic Analysis (TDA), country-based National Action Plans (NAP) and a basin-wide Strategic Action Plan (SAP). The development of this Plan is in line with the international harmonisation agenda according to the Paris and Windhoek Declarations and the Accra Agenda for Action (AAA). This is the first such plan in the SADC region, leading the way for other river basin organisations.

TDA-NAPs-SAP-IWRM



6. What is trans-boundary water resources management?

- A river basin represents a unified hydrologic and geographic unit, which supports a holistic perspective on river basin management.
- River Basin Organisations (for example, ORASECOM) have been promoted as the most appropriate means to manage water resources under some form of supranational authority. This supports the approach of Integrated Water Resource Management (IWRM), which has been proposed under international water law.
- Trans-boundary river basin organisations provide a framework for managing water resources across national boundaries. Other critical institutional responses to address some present-day water challenges include commitment to international treaties, effective national water laws and regulations governing access and use of water, and creation of a knowledge-base for basin managers to make informed decisions.
- At the international level, UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Convention) provides a framework and principles to guide basin level agreements. Within the Southern African Development Community (SADC), trans-boundary water management needs to be understood in the context of riparian nations' membership to SADC.
- The Revised SADC Protocol on Shared Watercourses (Revised Protocol) is an example of a legal instrument at the regional level stipulating rules and regulations for members of SADC. At the basin level, the Orange-Senqu River Basin Commission was the first basin commission to be formed with reference to the Revised Protocol.

7. How does ORASECOM provide protection for biodiversity in the Basin?

- ORASECOM is in place to harmonise national laws with the SADC Protocol and relevant regional policies, i.e., the SADC Regional Water Policy and the SADC Regional Water Strategy (SADC 2006; SADC 2005) to protect biodiversity in the Orange-Senqu River Basin.

- The ORASECOM Agreement contains a number of provisions that protect the basin and its biodiversity (UNDP-GEF 2008).

- Specific environmental clauses in the agreement include:

  - the obligations to "protect and preserve the River System" (Article 7.12),
  - "prevent, reduce and control pollution of the River System that may cause significant harm to one or more Parties, including harm to the environment, or to human health or safety, or to the ecosystem of the River System" (Article 7.13),
  - "protect and preserve the estuary" (Article 7.14) and
  - "prevent the introduction of species, alien or new, that have a detrimental effect to the ecosystem of the watercourse" (Article 7.15).
- Conservation of biodiversity and water in general is enshrined in existing bilateral agreements and treaties between countries.

- The Orange-Senqu River Basin States are parties to a number of other relevant international environmental agreements, which concern the protection and conservation of biodiversity:

  - Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).
  - Convention on Biological Diversity (CBD).
  - Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention).
  - UN Framework Convention on Climate Change and Kyoto Protocol (UNFCCC) non-Annex I.
  - United Nations Convention to Combat Desertification (UNCCD).
  - At a national level, guidelines to protect aquatic ecosystems are available in South Africa (DWAF 1999, 1999a).

8. What are the national policies of countries in the basin to protect water quality?

- Policies and other institutional arrangements that deal with water quality management of surface and groundwater resources exist to different degrees in the riparian countries of the Orange-Senqu River Basin. A recently completed study by ORASECOM (2007) identified the existing institutional and policy issues pertaining to water quality management in the Basin.

- Botswana has water quality standards set by the Botswana Bureau of Standards for the protection and control of quality water supplies for various uses. The Botswana Bureau of Standards (BOBS 2000) water quality guideline, known as BOS 32:2000 (BOBS 2000), applies to domestic water use.

- In Lesotho, urban water supply and sanitation falls under the Water and Sewage Authority (WASA), while the Department of Rural Water Supply attends to rural water issues. The provision and use of water is governed by the Water Resources Act, No 2 of 1978 and the Water Resources Regulations of 1980. The Department of Water Affairs under the Ministry of Natural Resources has the mandate to oversee the water quality and quantity aspects of Lesotho's water resources. However, WASA and LHDA monitor basic water quality determinants for the various water sources such as dams, transfer pipelines and treatment plants. Lesotho has national water quality standards, although they are less stringent that the WHO guidelines.

- In Namibia, water management falls under the Department of Water Affairs (DWA) within the Ministry of Agriculture, Water and Forestry. Water quality management is the responsibility of the Directorate of Resource Management (DRM), while the quality of domestic supplies is the responsibility of the Namibian Water Corporation (Namwater), commercial parastatal (government owned), set up to provide bulk water to municipalities, industry and mines in the country. The national water quality standards for Namibia are the same as the WHO standards.

- In South Africa, one of the most important milestones in the revision of the Water Law in South Africa was the publication of the White Paper on a National Water Policy for South Africa. This document set out overarching policy principles regarding water resource management. These principles were later included in the National Water Act (Act No. 36 of 1998) (NWA) that addresses both water quality and quantity. The South Africa Water Quality Guidelines, Volumes 1 to 7 are used for maintaining water quality for a variety of uses.

9. What is the Orange-Senqu River Basin?

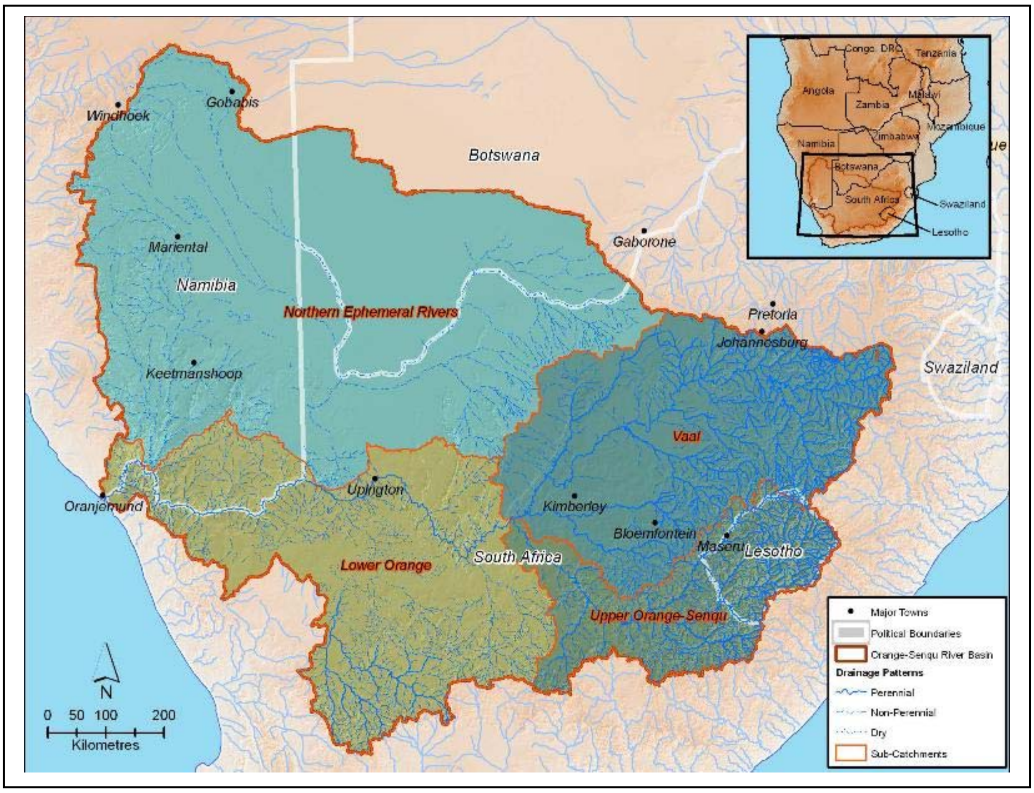
- The Orange-Senqu River Basin is a diverse landscape, from the temperate mountains of the Kingdom of Lesotho and the grasslands and savannah of central South Africa and southern Botswana, to the Nama Karoo and Succulent Karoo of western South Africa and southern Namibia. The Orange-Senqu River Basin contains the following sub-basins.

- The Upper Orange-Senqu River sub-basin consists of the Senqu, Upper Orange and Caledon basins. The sub-basin extends from the source of the river to the Orange-Vaal confluence. The sub-basin includes the main rivers draining the Kingdom of Lesotho, namely the Makhaleng, Mohokare and Senqu Rivers.

- The Vaal River sub-basin consists of the Kalkfontein, Riet, Modder, Rustfontein and Krugersdrift Rivers..

- The Lower-Orange River sub-basin consists of the sub-basin downstream of Upper Orange-Vaal confluence comprising the Ongers, Hartbees, Sak and Brak Rivers and streams adjacent to Molopo river to the north.

- The Northern Ephemeral Rivers comprise the Fish River and the Molopo-Nossob sub-basin (including the Kuruman and Auob Rivers).



10. What is climate?

- Climate is perhaps the single most important driver with respect to determining the amount, distribution and to some extent, the availability of water in the environment. The temporal and spatial distribution of water, the intensity of precipitation, and temperatures all drive elements of the hydrologic cycle and many other physical and chemical processes that shape the landscape.
- The climate of the Orange-Senqu River Basin varies significantly along the path of the river from the temperate climes of the Lesotho mountains through dry grasslands and savannah to the arid landscapes of the semi-desert Nama and Succulent Karoo regions.
- Climate is the overall pattern of weather conditions in a place or region, including both predictable seasonal changes in each year, and extreme weather conditions and events over a longer span of time. Climate descriptions and classifications for an area must therefore be based on long-term events and statistics. A region's climate and weather are a function of elevation, topography and landforms, and the amount and movement of heat and moisture in the atmosphere.
- Meteorology is the interdisciplinary scientific study of the atmosphere that focuses on the processes and forecasting of observable weather events and patterns. These events are impacted by numerous variables including temperature, air pressure, and water vapour, and how these interactions vary in time and space. Meteorological processes affect the formation and occurrence of rainfall, the formation of clouds, and evapo-transpiration, all of which play significant roles in the hydrologic cycle.

11. What is the climate of the Orange-Senqu River Basin?

Climate and geography are key to the presence and survival of ecosystems. Geology determines the shape of the landscape (or geomorphology) and the minerals in rocks contribute to the formation of soils in a region; and the climate determines the amount of moisture in the environment and the erosion processes that take place there. The significant variations in altitude, relief and geography create variations in climate within the Orange-Senqu River Basin.

Regional climate is the primary driver in the definition of terrestrial eco-regions, hence the climate of the Orange-Senqu River Basin is usually discussed in terms of these regions:

- The mountainous terrain of the Maloti Mountains of Lesotho, and the relatively temperate climate, define the ecosystems and to a large extent the livelihoods possible in this region.
- The undulating dry grasslands of the southern Highveld are a climatic and geographic transition zone from the mountainous region.
- The western region of southern Africa contains three desert systems, characterised by harsh arid conditions:
    - The Succulent Karoo – rainfall occurs with almost equal improbability throughout the year.
    - The Nama Karoo - receives mainly summer rainfall and comprises a number of different vegetation types.
    - The Southern Kalahari – consists of deep wind-blown sand, which produces little or no run-off from rainfall.

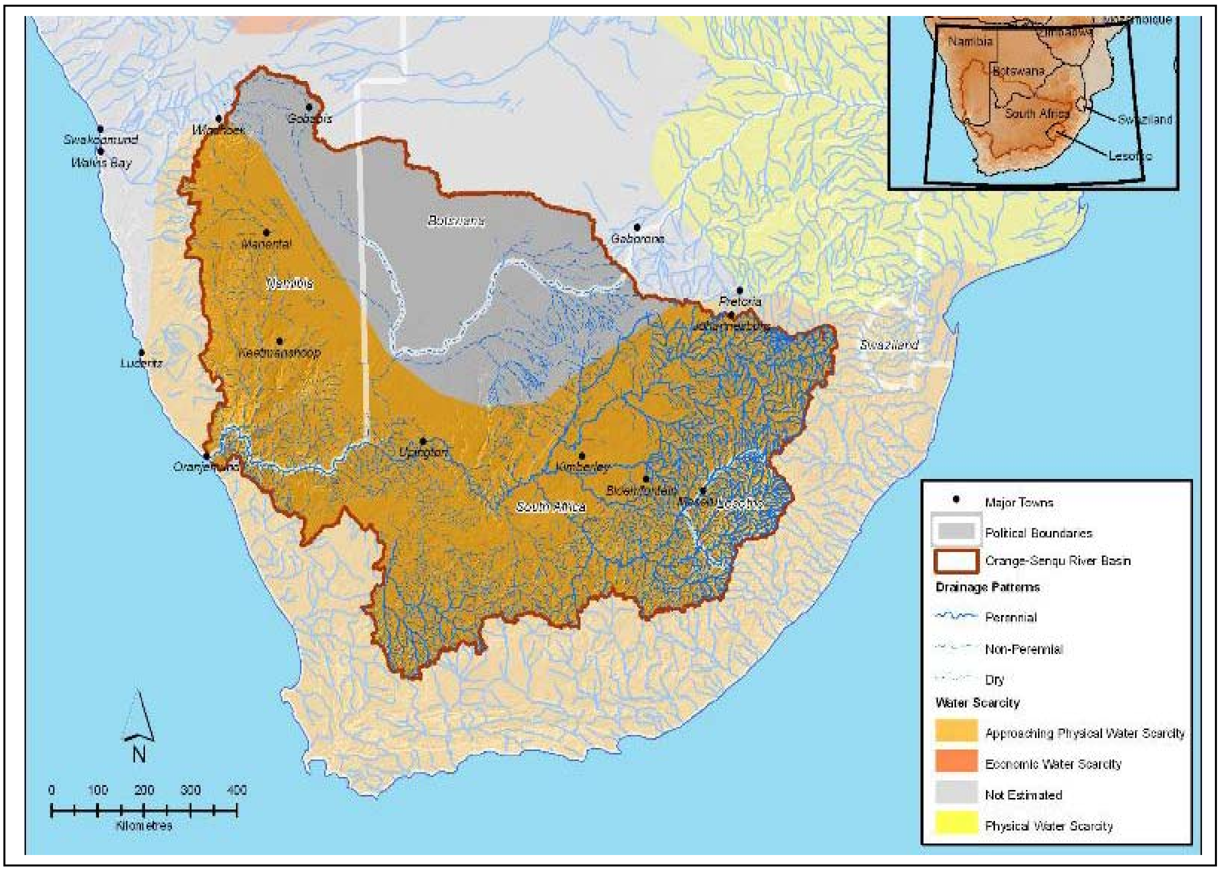
With a mean annual precipitation of approximately 400mm, the Orange-Senqu River Basin is considered well-watered by southern African standards. However, its water resources are nonetheless finite and are affected by severe climatic variability.

The mean annual precipitation at the summit of the Maloti-Drakensberg escarpment in Lesotho and South Africa is 1,600 to 1,800mm, decreasing sharply westward to only 45mm at the Orange River Mouth. Furthermore, rainfall in the western part of the basin is highly variable. Variability of precipitation in low-rainfall regions is a critical factor in understanding the climate, as it helps explain the natural year-to-year situation and to an extent the scarcity of water resources.

High average temperatures across most of the basin result in high evaporation rates, especially in the arid and semi-arid west of the Orange-Senqu River Basin. This, combined with low rainfall, results in an average water deficit of approximately 1,900mm per year in the middle reaches of the Orange River and approximately 2,600mm per year in the western parts of the lower Orange-Senqu River Basin.

12. How scarce is water in the Basin?

- Due to increasingly high demands on water for agricultural and industrial use, the water resources of the Orange-Senqu River Basin are at a critical stage. Options exist for addressing this, however, the Orange-Senqu River System is reaching a state where obtaining more water becomes increasingly expensive and produces diminishing returns.
- The UN World Water Assessment Programme identifies two types of water scarcity: **physical water scarcity** where demand or withdrawals exceed or are close to exceeding water availability and **economic water scarcity** where even though water may be naturally present, human, institutional and financial issues put limits on the access to clean water.



- As can be seen from this map, although data is not available for the ephemeral river basins the northern portion of the Orange-Senqu River basin, the majority of the basin is approaching physical water scarcity.

13. How will Climate Change affect the Basin?

There is growing consensus among scientists and politicians that the global climate is changing. The main impact of these changes on humans and the environment is the availability and quality of water and increased exposure to weather-related natural disasters (World Water Assessment Programme 2009)..

The climate changes reflect a general increase in global temperature and changes to the composition of the atmosphere, which in turn cause changes in precipitation, temperature and other atmospheric and weather-related patterns.

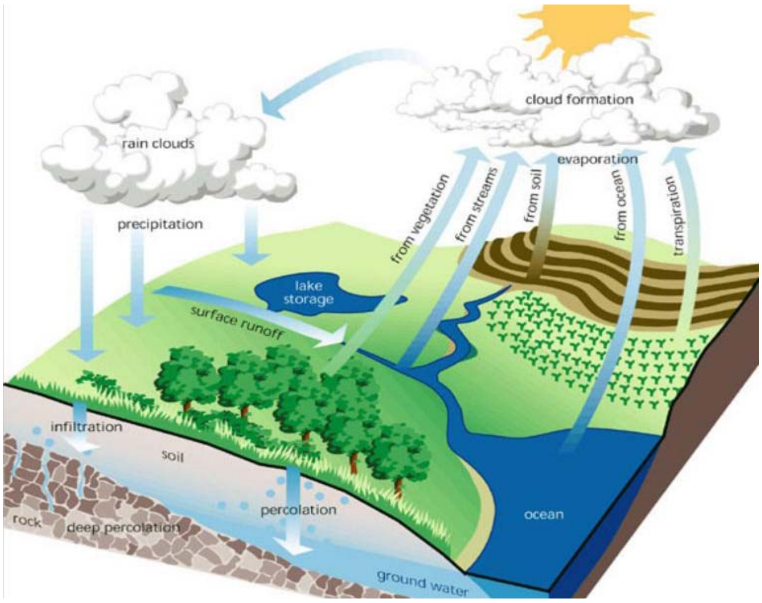
The ultimate result is ongoing change in catchment rainfall-runoff processes and the availability of water, which will have a profound effect on ecosystems and the communities that rely upon them.

There is growing evidence of changes in temperature, precipitation and streamflow over many parts of southern Africa. Research findings support the International Panel on Climate Change (IPCC 2008) findings that temperatures have increased by between 0,2°C and 2,0°C between 1970 and 2004. These temperature changes will have profound effects, both direct and indirect, on hydrology and water resources.

Large parts of southern Africa are expected to experience some of the most variable rainfalls and streamflows in the world, presenting major challenges to managers of water resources. In fact, the IPCC has identified southern Africa as one of the regions of the world most vulnerable to anticipated climate change impacts.

14. What is the hydrological cycle?

- The two most important aspects of climate are precipitation and temperature. Patterns of precipitation -the timing, amount, and form - and the range of temperatures characteristic of a region, affect the growth of vegetation, the development of soils, changes in landforms, animal life, and the availability of water.
- The 'hydrologic cycle' describes the circulation of moisture in all physical states and situations. Aspects of the hydrologic cycle critical to climate include: precipitation, evaporation and transpiration.
- Precipitation is the condensation of atmospheric moisture forming either rain or ice or snow which then falls to the Earth's surface. When precipitation reaches the Earth's surface it is absorbed into the soil or it forms runoff and drains into rivers or other water bodies.
- Evaporation refers to the loss of water from the surface of the earth, streams, rivers and water bodies and from soil and plant surfaces. Liquid water changes into vapour, driven by both sunlight and aerodynamic effects such as wind and varying humidity.
- Transpiration is a loss of water through a plants stomata and lenticels into the atmosphere.
- Evapo-transpiration is the combined process of evaporation from the Earth's surface and transpiration from vegetation. The amount of evapo-transpiration occurring in an area is determined by meteorological factors such as wind, air humidity, solar energy, latitude, lapse rate, etc.



15. Why do we need dams?

- Water is a fundamental human need and required to support all life. A lack of clean water leads to the spread of diseases, and creates hardship for humans, animals and the environment. Access to water also brings economic benefits and improvements to living standards. It is therefore vital that governments efficiently distribute clean water to all citizens.

- Water infrastructure consists of man-made structures and facilities used to abstract, retain, treat, convey and deliver water to users, and to collect, transport, treat and dispose of wastewater. Typical infrastructure includes: groundwater well-fields, water supply schemes, sewage treatment facilities, dams, river water abstraction works, inter-basin transfers (bulk transfers), and canals. Dams and associated structures are critical elements of the water management system and supply network in the Orange-Senqu River Basin, as they allow for the storage, distribution and the transfer of water to the water scarce parts of the basin. In certain areas they also allow for the generation of hydropower.

- Southern Africa is a water scarce region with an erratic rainfall distribution pattern, which in recent years has led to frequent droughts - local, national and regional. Managing water is therefore particularly vital to both the population and the economy.

16. What are the major dams in the basin?

- There are currently three major dams in **Lesotho**, the Katse, Mohale and Muela dams, all are part of Phase 1 of the Lesotho Highlands Water Project. The Katse Dam, the highest in Africa at 185 m., is the major dam in the Senqu River catchment. Located on the Malibamutso River, Katse Dam is the key to the LHWP. The Mohale Dam, a major storage element of the LHWP, is located on the Senqunyane River. The dam is approximately 145m high with a total capacity of 947Mm^3. The Muela Dam and Hydropower Plant were completed in Phase 1A of the LHWP. The dam's hydroelectric power station supplies the needs of Lesotho

- Hardap and Naute dams, two of the largest dams in **Namibia**, are located in the Orange-Senqu River basin which falls inside Namibia. These dams are used for urban and irrigation supply. The Naute Dam located on a tributary of the Fish River, supplies water for urban consumption to Keetmanshoop. The dam has a full storage capacity of 84 Mm^3. The Hardap Dam located on the Fish River supplies water for urban consumption to Mariental. The dam has a full storage capacity of 294 Mm^3.

- Major dams in **South Africa** in the Orange Senqu Basin include Gariep, Vanderkloof, Vaal, Grootdrai, and Bloemhof dams. The Gariep Dam is the largest reservoir in South Africa with a total storage of approximately 5,500 M^{m3} and a surface area of more than 370k^{m2} at full capacity. The Vanderkloof Dam is 130km downstream of Gariep Dam on the Orange River. It is the second largest reservoir in South Africa, storing over than 3,200 Mm^3. The Vaal Dam is located on the Vaal River about 56 km south of Johannesburg. At its maximum, the Vaal Dam can store 2 536 M^{m3} with a surface area of approximately 320 k^{m2}, making it a relatively large and shallow reservoir. The Grootdraai Dam is situated in the upper reaches of the Vaal River. It has a catchment area of 8,195k^{m2} and a maximum supply capacity of 364 Mm^3. The Bloemhof Dam is situated on the Vaal River, downstream of Vaal Dam, approximately 2 km upstream of the town of Bloemhof. At maximum supply, the capacity of Bloemhof Dam is 1,269 M^{m3} with a surface area of 223km^2 - a very large and shallow reservoir.

17. What is the Orange River Project?

- The Orange River Project (ORP) was launched in 1962 (promoted as "Taming a River Giant") and aimed at promoting and stabilising irrigation along the Orange River and in the eastern Cape, as well as to generate hydro-power, supply water to towns and industries, and to limit flood damage (Conley and Van Niekerk 2000).

- According to the Department of Water Affairs (DWA) South Africa, the Orange River Project was intended to increase the value of South African agricultural production and provide for a large number of irrigation farms. By promoting economic activity and development in the areas directly involved in the project, it was envisioned to counteract the migration of the rural population to the cities by creating stable farming communities. An additional objective of the project was to create recreation facilities in the centre of the interior and promote tourism. Finally, the project was intended to level off and moderate flood peaks in the course of the river, and so safeguard riparian communities and irrigation schemes downstream.

- Two main storage reservoirs were constructed: Gariep Dam and Vanderkloof Dam. The Gariep Dam forms the largest reservoir in South Africa with a capacity in excess of 5,000Mm^3 while the Vanderkloof Dam forms the second largest, storing over 3,200Mm^3 (DWAF 2009).

- The Vanderkloof Dam is currently the last main storage structure on the Orange-Senqu River, and effectively controls the flow of water along the 1,400km stretch of river between the dam and Alexander Bay on the Atlantic Ocean. The water is mostly used for agriculture.

18. What is the Lesotho Highlands Water Project?

A project was proposed in the 1950s to gravity feed water from the highlands of Lesotho to the Vaal region through a diversion tunnel (Conley and Van Niekerk 2000) and to generate hydroelectric power. Negotiations took place over about 30 years between the Governments of Lesotho and South Africa.

The Lesotho Highlands Water Project (LHWP) Treaty, signed in 1986, sets out the quantities of water to be delivered, calculation of royalties, and provisions for cost sharing. The stated objectives of the project are to (ORASECOM 2007):

- Transfer surplus water from the Lesotho highlands to South Africa in exchange for royalties
- Generate hydroelectric power in Lesotho
- Promote economic development in both States.

Phase 1 of the LHWP has been implemented (see below Box) and the South African and Lesotho governments have recently signed a Memorandum of Understanding to proceed with Phase 2.

The Lesotho Highland Water Project (LHWP) - Phase 1

Phase 1A

- the 185m high Katse Dam
- the intake structure capable of handling 70m^3/s
- the 45 km long transfer tunnel from Katse reservoir to the Muela reservoir
- the Muela Dam and hydro-power station
- the 37km long delivery tunnel from the Muela reservoir to the Vaal River basin.

Phase 1B

- the 145m high Mohale Dam
- the 32km long transfer tunnel from the Mohale reservoir to upstream of Katse Dam
- the 15m high Matsoku Diversion Weir
- the 5.7km long transfer tunnel from the Matsoku Weir to Katse Dam.

Currently, LHWP Phase 2 includes the construction of a 165Mm^3 capacity dam at Polihali, in the Mohotlong district. This new dam would consist of two major reservoirs, enclosed by a 145m high dam wall. Planned for construction just downstream of the confluence of Khubelu and Senqu Rivers, Polihali Dam will be connected to Katse Dam via a transfer tunnel. Water transferred from Polihali to Katse will contribute to the bulk transfer of water to the Vaal River basin via the Ash River. Construction is expected to start in 2012, with water transfer estimated to begin in 2018/19.

19. What aquatic habitats exist in the basin?

- **Rivers.** Rivers and streams differ from other aquatic habitats in their shape and hydrology, which is dominated by flowing water and often varies seasonally. Significant shifts in habitats and biological communities also occur over the length of rivers.
  - The distribution of fish and other aquatic organisms in rivers and streams depends on the environmental conditions they prefer or require. Oxygen levels in streams are usually sufficient for fish, and temperatures are generally similar at the surface and the bottom. However, other habitat features– stream substrate, current strength, water depth, aquatic vegetation, etc. – can vary over small distances in a watercourse, providing a range of habitats for different fish species.
  - The Senqu River flows from its source near Thabana Ntlenyana (at 3,482 meters) in Lesotho, becomes the Orange River upon entering South Aftica, traverses central and western South Africa and finally joins the Atlantic Ocean near Alexander Bay. Along this 2,300km journey, several major tributaries feed the main river.
- **Wetlands.** Wetlands are areas where the water table is at or near the surface, or where the land is covered by shallow water for long enough to result in water tolerant vegetation and altered soils. Wetlands are neither truly terrestrial nor truly aquatic, and are often transition zones linking land and water environments.
  - The wetlands of the Lesotho highlands and the Orange River Mouth are of particular interest due to geographic location, their importance to the hydrology and the ecological integrity of the catchment.
- **Lakes.** Lakes are defined as permanent water bodies greater than 0,25ha in surface area and more than 2 m deep. Lakes vary in morphological features, such as depth, extent of shoreline, basin shape, and basin geology. They also vary in their surrounding vegetation, climate, and river inflows and outflows.
  - There are no natural lakes in the Orange-Senqu River Basin, but the numerous dams provide aquatic habitats that to a large extent mimic those found in lakes – a large body of deeper water, with slow flow, temperature gradients and a different sediment and nutrient profile compared to rivers.

20. What is the function of wetlands in the Orange-Senqu Basin?

The water and wetland resources of the Orange-Senqu River, provide numerous socio-economic development benefits to the riparian states, including:

- Flow regulation. Besides serving as sources of streams, wetlands also regulate flow and attenuate floods.
- Erosion control. Plants in marshes and swamps hold the soil and trap sediments in their roots. Well-vegetated rivers and floodplains are excellent flood wave absorbers.
- Flood plain farming. The deposited sediments and the variations in flooding create fertile soils that can be used to support subsistence floodplain farming.
- Plant and animal products. The nutrients in the wetland environment of the basin support diverse plant and animal species. Wetlands are principal habitats for fish species, providing cover as well as suitable breeding and feeding grounds.
- Conservation. The rich biodiversity and natural beauty of wetlands make them an important focus for conservation. Protected areas make up 4.7 % of the Orange-Senqu River Basin (WRI 2008). Many of the national parks and conservation areas in the basin are wetlands which support large numbers of wetland birds of diverse species.
- Tourism and recreation. The wetlands sustain flow in the basin and support fish biodiversity. As a result tourism and fishing activities within the wetlands, as well as in the main river system and reservoirs, is very common.
- Groundwater Recharge. Depending on the soil, geology, and landscape of a wetland ecosystem, wetlands can contribute to groundwater recharge if water can filter down to the groundwater system.
- Water Quality. Wetlands play an important role in improving surface water quality by filtering out suspended material (e.g., organic or inorganic sediments) and by retaining nutrients and pollutants.

21. What factors affect the health of aquatic ecosystems?

- Pioneer alien species out-compete indigenous species for space, nutrients and sunlight.

- Dams, inter-basin transfers, hydro-electrical flow releases, irrigation and mining abstraction: change flow regimes or hydrology.

- Pollution from mines and return flows from irrigation reduce water quality, including nutrient build-up and salanisation.

- Reduced flood regime and modified seasonal flows result in geomorphologic modification of the river channel due to lower flows, resulting in less or no scouring of rivers.

- Continued deterioration of riparian and in-stream vegetation leads to:
  - An increse in floating aquatic plants because of reduced flow
  - Changes to the shape of the wetted perimeter of the river channel causing banks to dry out, temporary exposure of unprotected banks and bank collapse
  - A reduced flow which benefit pioneer reeds such as the Common Reed (*Phragmites australis)* leading to increased distribution and patch size of reeds thereby accumulating sediments, blocking channels and resulting in large disturbances when washed out during large floods.
  - A loss of indigenous trees and gallery forest in the riparian belt because of reduced floods (moisture), reduced seed dispersal, more frequent hot fires because of increase in reed beds and less cooling effect as previously moist riverbanks are drier
  - An increase in agricultural encroachment into the riparian belt because of reduced flooding and waterlogged soils
  - Invasion by alien vegetation, notably Mesquite (*Prosopis spp.)*, exacerbated by a loss of indigenous vegetation and disturbance (e.g., through fires and agricultural activities)
  - Changes in species composition and abundance as a result of fertilizers and salts draining into the river, with for example Common Reed *(P. australis)* and Wild Tamarisk *(Tamarix usneoides*) increasing and having a negative effect on safsaf willow, Kaapse wilger or Cape Willow *(Salix mucronata)*.

22. What is the threat from invasive alien species?

Environmental threats to the Senqu and the Orange in South Africa have been widely presented in the country's state of the environment reports. Reports have provided information on potential invasive species (along with endemic species) for South Africa and Lesotho respectively. The recently completed study by ORASECOM through UNDP and GEF (UNDP-GEF 2008) reported on the existence and trans-boundary character of alien invasive species and their effects on the Orange-Senqu River Basin ecosystem. Alien invasive species within the Orange-Senqu River Basin can be broadly grouped in two categories: aquatic and riparian.

The most common aquatic invasive species include:

- *Eichhornia crassipes*, widely known as water hyacinth, is a non-native plant in the region. It has spread from the upper-middle parts of the Vaal to areas near the confluence with the Orange River in recent years and invasions of the Lower Orange River are a distinct possibility (UNDP-GEF 2008). *Eichhornia crassipes* is also present in Botswana but the impact is not yet significant.
- *Azolla filiculoides*, known as Water Fern, has also invaded sections of the Upper Orange-Senqu River and its tributaries. Effects of invasion by this plant are similar to that of crassipes although its distribution is limited to the upper catchments (UNDP-GEF 2008).
- The introduction of two trout species *(Salmo trutta and Oncorhynchus mykiss)* to the upper reaches of the Orange-Senqu River Basin in South Africa and Lesotho has affected populations of indigenous minnow species in these areas (UNDP-GEF 2008).
- *Arundo donax L.*, the giant reed or Spanish reed, is found in the Lower Orange River and in the Fish River downstream of the Hardap Dam in Namibia (Bethune et al. 2004).

Riparian vegetation has been notably disturbed along the Orange-Senqu River and most of its tributaries. The former dominance of riparian woody species such as Cape willow *(Salix mucronata)*, buffalo thorn *(Ziziphus mucronata)*, wild olive *(Olea europaea)* and white karee *(Rhus viminalis)* have been compromised through a combination of:

- Clearing for small-scale alluvial mining.
- Wood collection for fuel and building material.
- Agriculture on the river banks.
- Colonization by alien species.

Institutions in South Africa, particularly CSIR, South African National Biodiversity Institute (SANBI) and Department of Water Affairs (DWA), monitor and undertake research on aquatic ecosystems. Some of these studies have confirmed that the riparian areas of all Southern African rivers have suffered from invasion by alien plant species.

Tributaries of the Orange such as the Vaal and the Senqu Rivers originate in wetter regions and alien species are frequently a greater problem in these areas. Typical riparian invasive plants are the woody plant species *Acacia dealbata* (Silver wattle), *Acacia mearnsii* (Black wattle), *Poplus sp.* (Grey poplar), *Eucalyptus spp.* (Blue gum), *Melia azederach* (Syringa), *Jacaranda mimosifolia* (Jacaranda) (UNDP-GEF 2000), and P*rosopis glandulosa* (Mesquite).

Consequences of invasive species include.

- A reduced aesthetic "sense of place", affecting the tourism potential of the Basin.
- A decrease in available water as a result of high water use by alien plants.
- Increased flood peaks as a result of degraded wetland and riparian systems.
- Increased cost of water as water quality and availability is harmed.
- Costs associated with eradication of invasive species.
- A decrease in production potential of land.

23. How do ecology and biodiversity interact with water resources management?

In broad terms, Ecology is the scientific study of how organisms interact with each other and with their environment. Aquatic ecology includes the study of these relationships in all aquatic environments, including oceans, estuaries, lakes, ponds, wetlands, rivers, and streams.

The physical characteristics of aquatic habitats affect both the type and variety of organisms (biodiversity) found. Organisms in a particular environment are directly affected by its characteristics, such as nutrient concentrations, temperature, water flow, and shelter. Only those best adapted to these conditions, and best able to use the available resources, will thrive. Interactions between organisms also matter, as predation and competition for resources affect species abundance and diversity. In turn, the organisms in an environment can influence some aspects of their environment. Understanding aquatic ecosystems and the interaction between organisms and their environment can help manage human effects better.

Aquatic ecosystems include all forms of life within a waterbody including fish and aquatic invertebrates, along with related communities such as riparian vegetation.

To maintain a healthy aquatic environment, the overall health of the system should outweigh the demands of any one user. When humans impound river water, the downstream flow regime changes – and adequate base flow downstream is essential to ecosystem integrity. The amount and timing of water releases is often a complicated planning decision that must balance conflicting demands.

24. What is the biodiversity of the Basin?

Biodiversity refers to the species diversity of the flora and fauna found in an ecosystem and can be used as an indicator of its health. Abundant biodiversity may represent health in one ecosystem, while in another the ecosystem may be optimal when occupied by only a few endemic species. Human activities, water quality and invasive species can alter and threaten the biodiversity of an ecosystem and thus the overall integrity of the ecosystem.

The Orange River basin is an extraordinarily geographically and biologically diverse system originating in the highest point in southern Africa at 3,482 m above mean sea-level, and flowing westwards for over 2 300 km to its mouth at the Atlantic Ocean. Its upper catchment falls within both the rainiest and coldest parts of southern Africa, while its lower reaches cross the driest and hottest areas of the region.

From an ecological perspective, the basin system is one of the most modified in southern Africa. The amount of water actually reaching the Orange River Mouth is less than 50% of the natural runoff (11,600 Mm^3/a: ORASECOM 2007). The is due to extensive water use in the Vaal River basin, mainly for domestic and industrial purposes including mining and irrigation, as well as transfers out of the river. The transfers are for use both inside and outside the basin in the lower sections of the Orange. A number of dams have been constructed in the catchment, and abstraction and transfer systems have marked effects on the biodiversity of the Orange River system.

To determine to what extent biodiversity is being affected in the basin, biodiversity indicators in the form of endemic flora and fauna are monitored. The most common biodiversity indicators of the basin are summarised in the table below (WRI 2008), based on information obtained from SADC, the International Union for the Conservation of Nature (IUCN), the World Resource Institute (WRI) and Ramsar.

Biodiversity indicators and distribution in the Orange-Senqu River Basin	
Number of Fish Species	24
Number of Fish Endemics	70
Number of Amphibian Species	42
Number of Ramsar Sites	5
Number of Wetland-Dependent IBAs	7
Number of Endemic Bird Areas	2
Percent Protected Area	4

Biodiversity Hotspots

Conservation International maintains a list of internationally recognised biodiversity hotspots. The distribution of these hotspot areas is show in the map below. As can be seen from this map, the three primary hotspots in the region are:

- Cape Floristic Region.
- Maputaland - Pondoland Albany Region.
- Succulent Karoo.

All of these hotspots are found along the southern and western fringes of the Orange-Senqu River Basin, with only minimal coverage of Maputaland - Pondoland Albany Region and Succulent Karoo within the basin itself.

25. How rich in endemic species is the basin?

The Orange-Senqu basin is home to a wide variety of endemic species (endemism means that a species is not naturally found anywhere else). Botswana has more than 900 species of mammals, amphibians, birds and reptiles, and 0.8% of these are endemic to Botswana (Mongabay.com 2009). Some 30.2% of the country is protected, three times the sub-Saharan Africa average of 10.9% (Earth Trends 2009). Recent studies show that Lesotho has 2 961 documented plant species and at least 132 species of *Thallophytes*: algae and fungi. The total number of endemic plant species is estimated at 27, plus one endemic subspecies. Lesotho also has a variety of fauna: there are 63 mammal species recorded in the country. The majority of Namibia's endemic species are found along the western edge of the escarpment, in the transition zone between the Desert, Karoo and Savannah biomes. Another hotspot is the Succulent Karoo biome found in southern Namibia; the harsh conditions of the arid environment have forced flora and fauna to adapt, creating an abundance of endemic species.

South Africa has the third highest level of biological diversity in the world, with 7.5% of the worlds vascular plants, 5.8% of the world's mammal species, 8% of the world's bird species, 4.6% of the world's reptile species, 16% of marine fish species and 5,5% of the world's recorded insect species (DEAT 2009).

In South Africa alone, there are 582 protected areas (160 private reserves and 422 areas under national, provincial or local authorities, DEAT 2009). The 422 formally protected areas cover some 6% of the land surface area. Although the extent to which viable populations are conserved in such areas is not known, about 74% of plant, 92% of amphibian and reptile, 97% of bird, and 93% of mammal species of South Africa are estimated to be represented (DEAT 2009).

26. What Ramsar sites exist in the Basin?

The Ramsar Convention (The Convention on Wetlands of International Importance, especially as Waterfowl Habitat) is an international treaty for the conservation and sustainable utilization of wetlands. The convention was developed and adopted by participating nations at a meeting in Ramsar, Iran on 2 February 1971. The Ramsar List of Wetlands of International Importance now includes 1,847 sites (known as Ramsar Sites). Five Ramsar sites have been identified and accorded conservation status in the Basin:

- The Orange-Senqu River Mouth drains into the Atlantic Ocean, only occasionally when it is not blocked by sand-bars. The 2 000ha site was named a Wetland of International Importance (according to the Ramsar convention) in 1991 and is home to up to 60 bird species, an appreciable number of which are Red-listed species (http://www.iucnredlist.org/), including the Cape Cormorant, Damara Tern and Hartlaub's Gull. (Bethune 2007; UNDP-GEF 2008). Due to its location at the mount of the Orange-Senqu River, the Orange River Mouth Ramsar site is shared by Namibia and South Africa.

- The second Ramsar site is the Seekoeivlei Nature Reserve, as the largest wetland in the African Highveld it supports a large number of local and migratory birds (SAWCP 2009a). The Nature Reserve is found in the floodplain that drains into the Klip River and eventually into the Vaal River.

- The Barberspan Nature Reserve covers 3 118 ha of which 2 000 ha is water. The Barberspan is the largest of a series of grass pans in the fossil Harts River basin. Other pans exist in the area but are non-perennial (SAWCP 2009b). 320 bird species have been spotted at the pan and it is important to the maintenance of several rare and endangered animals and plants.

- Lets'eng-la-Letsie is a source of the Quthing River in Lesotho that contributes 3% of the total flow to the Senqu River (DWA 2003). The Lets'eng-la-Letsie wetland consists of a man-made lake resulting from a small dam built on the Mohlakeng River. The area was declared a protected area in 2001 because of its importance as a tributary to the Orange-Senqu River system, its high natural mountain biodiversity and the relatively undisturbed state of the high mountain wetland.

- Blesbokspruit is one of the larger wetlands found in the highveld region of South Africa. Situated very close to the Orange-Senqu River Basin boundary, near the town of Springs in Gauteng Province, Blesbokspruit is approximately 1600 m above mean sea level.

Blesbokspruit is seen as having a high conservation value, specifically due to its water purification functions in a region affected by industrial and domestic effluents.

27. What is water quality?

Water quality is often characterized in terms of the concentration of different chemicals in the water. What determines “good” or “bad” water quality depends on the purpose of the assessment—for example, water with naturally elevated concentrations of some metals may be unsafe to drink, but still suitable for industrial uses. Assessment involves comparing measured chemical concentrations with natural, background, or baseline concentrations, and with guidelines established to protect human health or ecological communities.

Beyond use of water for drinking, cooking and sanitation, humans use waterbodies as convenient sinks for the disposal of waste – domestic, industrial and agricultural. These uses degrade water quality and can have severe environmental impacts, difficult to alleviate even with treatment.

Three primary forces affect southern Africa’s freshwater environment, in all of the basin states:

- Geographic and climatic conditions - low rainfall, high evaporation rates and low run-off availability (except Lesotho).
- Development – including rapid urban population growth, requires economic activity, which leads to increased water demand and pollution.
- Policy on water resources – policy decisions on management strategies have a direct impact on water quality.

28. How do we measure water quality?

Water-quality monitoring and analysis is multi-faceted and complex; best understood by dividing characteristics into the following four sets:

- Physical
- Chemical
- Biological.

Physical

The commonly measured physical characteristics are temperature, colour, taste, odour and turbidity. These can be subjectively evaluated through use of our five senses. Quantitative measurements require special instruments to accurately measure temperature (ºC), dissolved oxygen (DO) and the conventional variables: pH, total dissolved solids (TDS), electrical conductivity (EC), and total suspended sediment (TSS).

Chemical

Dissolved materials and ions occur naturally in water because of mineral dissolution from weathered rocks and soils. The most common positively charged chemicals found in natural waters are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}). Several other chemicals are present and essential to sustaining life in aquatic systems. Nutrients such as nitrogen (N) and phosphorus (P) are needed by aquatic organisms, but at high concentrations can degrade ecosystems through eutrophication. Metal ions, similarly, are essential to biological processes at low concentrations but can be toxic at higher concentrations.

The most important negatively charged ions, anions, found in natural waters are chloride (Cl^{-}), sulphate (SO_4^{2-}), bicarbonate (HCO_3^{-}) and carbonate (CO_3^{2-}), which also originate from dissolution of rock and soil minerals. These anions play an important role in buffering water and also impact the solubility of many cations. The ability to neutralise acids is termed alkalinity and is mainly due to the presence of bicarbonate and carbonate.

Industrial discharge from base metal mines (copper, lead and zinc) and other industrial activities can impair the chemical water characteristics if they are not regulated.

Biological

Biological water characteristics are used to describe the presence of microbiological organisms and water-borne pathogens. Many organisms can cause illness when directly consumed by humans and animals. Micro-organisms and waterborne pathogens generally enter rivers and lakes via the release of untreated or partially treated sewage. Many waste water treatment plants located in the basin produce and discharge effluent that does not meet national discharge standards. Non-compliance may be a result of inadequate management and maintenance of sewage treatment facilities, or if the facility is operated beyond design capacity resulting in discharges of raw or partially treated sewage into the river systems.

Achieving a water quality standard that will not harm aquatic organisms, and is safe for human consumption is a challenge throughout much of the basin. This is especially true for rural areas (e.g., Momba et al. 2006, Hodgson and Manus 2006). Water borne diseases such as dysentery, cholera, typhoid, gastro-entertitis and hepatitis are the primary cause of disease and poor health in the SADC region (SADC 2009). Bilharzia and malaria are other waterborne diseases that persist in the SADC region. Water polluted with ecoli and fecal coliform used for bathing and drinking are principal pathways of infection. The WHO guideline for faecal coliform is 0cfu/100mL and this is exceeded in both 2007 and 2008 at a Department of Water Affairs (DWA) South Africa monitoring station at the Vaal Dam (40-50cfu/100mL).

29. How do humans impact water quality in the basin?

The water quality in the Orange-Senqu basin is highly variable due to a combination of natural and human factors. The Senqu River system generally provides high quality water, thanks to a relatively undeveloped mountain catchment, and the natural filtering effects of the wetlands of the Lesotho highlands. However, water quality generally deteriorates as the river moves downstream, receiving a variety of inputs from agriculture, industry and urban/rural domestic sources, in addition to the natural discharge of sediments common to all rivers.

The key trans-boundary water quality issues in the Orange-Senqu River Basin are: salinity, eutrophication, microbiological organisms and water-borne pathogens, heavy metals, persistent organic pollutants (POPs), and to a lesser extent, temperature changes. Although there is localised pollution in the catchment from acid mine drainage and radio-nuclides, no actual pollution of trans-boundary significance are ascribed to these two sources of pollution.

The gradual increasing of catchment area and possible flow quantities from source to mouth affects water quality along the entire length of the river.

A summary of human influence along the Orange-Senqu River Basin:

- The Upper Orange-Senqu River region generally experiences minimal impacts from industry and mining activities, as there are very few facilities in this region which is dominated by rural communities rather than urban centres (DWAF 2004).
- The Vaal and Upper and Lower Orange sub-basins all include major South African urban and industrial centres: the main gold mining region, parts of the Highveld coal fields, some of South Africa's power stations and significant areas of dryland and irrigation agriculture.
- Water quality in the Lower Orange River is severely impacted by upstream developments, including urban, industrial and agricultural activities. Salinity in the Lower Orange River is elevated due to the transfer of water out of the basin, which reduces the dilution of saline irrigation return flow to the river (DWAF 2004).

30. What is eutrophication?

Eutrophication results from the presence of high concentrations of nutrients, which can lead to excessive biological growth, usually algae. While eutrophication is a natural process in the aging of some freshwater ecosystems, artificial (human-induced) eutrophication can degrade water quality and threaten aquatic species. High levels of algae can decrease the penetration of sunlight through the water column, preventing photosynthesis by submerged plants. Algae may release compounds with bad odour and tastes, or toxic effects. In addition, the death and decay of algae can reduce concentrations of dissolved oxygen. These changes can affect the diversity of plants, animals, and other aquatic organisms, and also interfere with human uses of water.

31. What is nitrate poisoning?

Nitrate poisoning of cattle is a problem throughout the basin. The WHO guideline for human health recommends that drinking water should not exceed levels of 100mg/L and should ideally be below 50 mg/L. Recent studies have shown that excessive levels (40mg/L), or higher, can be dangerous to human health and can cause *methamoglobinaemia*, also known as blue baby syndrome, in infants. Blue baby syndrome occurs when nitrate is converted to nitrite in the baby and inhibits the distribution of oxygen in the baby's blood. If not identified and treated this condition can be fatal. These serious effects are not restricted to humans. Nitrate poisoning of cattle has resulted in devastating losses across southern Africa. In 2000, 356 heads of cattle died on Ghanzi River in the Ghanzi-Karakubis area in Botswana. Nitrate levels have been detected above 500mg/L in the southern Kalahari. Nitrate poisoning is not contagious, but because of the misconception that it is, farmers are often not able to sell their cattle when it is suspected.

Nitrate can be found naturally in the environment, but for the most part is a result of human activities and pollution from point sources. Improperly treated wastewater infiltrating into the groundwater source is one of the main sources of nitrates. Once nitrates become abundant in a groundwater source their removal is usually impossible without the application of expensive technology.

32. What is the problem with metals in water?

A number of metals, such as manganese (Mn), zinc (Zn), and copper (Cu), are essential to biochemical processes that sustain life. However, these same metals, and a variety of others, can be toxic to aquatic organisms at certain concentrations. Repeated exposure to even low (non-acutely toxic) concentrations can eventually result in toxic effects. Metals can be toxic to humans as well, if they are ingested directly in water, or if they accumulate in organisms that are higher in the food chain and are consumed by humans (Järup 2003).

Dissolved metals are generally more bioavailable and toxic than metals bound in complexes with other molecules or adsorbed to sediment particles. The toxicity and bioavailability of many metals depends on their oxidation state and the form in which they occur. These characteristics of metals—oxidation state, form, solubility, and toxicity—are influenced by chemical characteristics of water such as pH, dissolved oxygen levels, and hardness ($CaCO_3$ concentration).

Sources of Metals

Metals occur naturally in aquatic ecosystems due to weathering of rocks and soils. Erosion and sedimentation can introduce metals into an aquatic ecosystem, although the fate of metals introduced with sediments depends on the chemical characteristics of the water. Other sources of metals include effluent from wastewater treatment plants, industry, and mining operations, and sewage or soils contaminated by previous industrial activity. Metals may be introduced into the atmosphere through burning and ore smelting, and can be deposited in surface waters. Mercury is particularly susceptible to bio-accumulation as methyl mercury, and in high concentrations presents a risk to human health. A common pathway for the accumulation of mercury is by eating fish that have been exposed to high levels of the metal.

Metal contamination occurs in various areas along the Orange-Senqu and can make water toxic to both aquatic biota and humans. Toxicity depends on the type of metal, the chemical interactions of the metal with other metals and the presence of organic compounds which may increase the availability and spread of the toxic metal. The flow rate and volume of water, the physical make-up of sediments, water temperature, pH and salinity also impact how toxic a metal is in a given environment (Davies and Day 1998).

Heavy metals include cadmium, copper, nickel, zinc, chromium, arsenic, mercury, lead, etc. These metals are persistent in the environment and can be bio-accumulated in aquatic organisms. The main sources of metal pollution in the Orange-Senqu are industries and mines through direct discharges of effluent, and diffuse seepage and runoff from polluted areas and waste dumps. There are many industrial sources of metal pollution and waste disposal sites in the Vaal triangle area of the Upper Vaal. They produce a cocktail of metal pollution which contaminate runoff and impact both surface and groundwater sources. Metal contamination also originates from urban storm water runoff from roads, parking areas and other impervious surfaces, ending up either in waste water treatment plants, or directly in the river. Toxic metals are also associated with some pesticides (Heath and Claasen 1999).

Sources of metal pollution from industry

Metal	*Source*
Cadmium	Laundrettes, electroplating workshops, plastic manufacturing, pigments, enamels, paints
Chromium	Alloys, preservatives, dying and tanning activities, metal coatings
Copper	Electronics, plating, electrical wires, paper, textiles, rubber, printing, plastic
Iron	Galvanizing, electroplating, polishing
Lead	Fuel additive, batteries, pigments, roofing, fishing weights
Zinc	Domestic wastes, galvanizing, batteries, paints, fungicides, textiles, cosmetics, pulp, paper mills, and pharmaceutics
Nickel	Alloys, electroplating, nickel-cadmium batteries, laundrettes, paints
Mercury	Dental practices, clinical thermometers, glass mirrors

33. What are POPs?

Of all the pollutants released into the environment every year by human activity, persistent organic pollutants (POPs) are among the most dangerous. POPs are either used as pesticides, in industry, or generated unintentionally as by-products of various industrial/combustion processes.

POPs are toxic, causing an array of adverse effects, including death, disease, and birth defects among humans and animals. Effects may include cancer, allergies and hypersensitivity, damage to the central and peripheral nervous systems, reproductive disorders, and disruption of the immune system. Some POPs are also considered to be endocrine disrupters, which, by altering the hormonal system, can damage the reproductive and immune systems of exposed individuals as well as their offspring; endocrine disrupters can also have developmental and carcinogenic effects.

These stable compounds can persist for years or decades before breaking down. They circulate globally through a process known as the 'grasshopper effect'. POPs released in one part of the world can, through a repeated (and often seasonal) process of evaporation and deposition, be transported through the atmosphere to regions far away from the original source.

POPs are also problematic because they concentrate in living organisms through bioaccumulation. Though not soluble in water, POPs are readily absorbed in fatty tissue where concentrations can become magnified by up to 70,000 times the background levels. Fish, predatory birds, mammals, and humans are high up the food chain and so absorb the greatest concentrations. When they travel, POPs travel with them. As a result of these two processes, POPs can be found in people and animals living in remote regions such as the Arctic, thousands of kilometres from any major POPs source.

The agricultural use of POP-containing pesticides such as Aldrin, DDT, Dieldrin and Heptachlor has been prohibited in all basin States.