# Experiences and Lessons Learned Brief For Lake Naivasha

**Prof. Eric Odada Dr Robert Becht and Ms. Sarah Higgins**

## 1. Introduction.

Lake Naivasha is a shallow basin lake situated 80 kilometres Northwest of Nairobi in the Kenyan Rift Valley. The recent developments around the lake constitute an interesting case for natural resource management that will be discussed in this brief.

The lake contains fresh water supporting a rich ecosystem with hundreds of bird species, papyrus fringes full of hippos, riparian grasslands where waterbuck, giraffe, zebra and various antelopes graze, dense patches of riparian acacia forest with buffaloes, bushbuck and other creatures, beautiful swampy areas where waterfowl breed and feed and at the same time magnificent views of the nearby volcanoes. Local fishermen depend on the lake for fish and crayfish. The lake is situated in a semi-arid zone but after the rainy seasons the fragile soils of the surrounding hills and the valley bottom produce grass where the pastoral Maasai bring their herds for dry weather grazing. The herds (cattle, goats etc) depend on the lake and various watering points for water.

Just west of the main lake is Lake Sonachi, a small paradise on its own. Sonachi (or Crater Lake as it is often known) is in the caldera of a small volcano with its own microclimate. A dense forest covers the steep walls of the crater. High biomass production has been recorded in this highly alkaline lake, which often hosts flocks of flamingos.

Lake Naivasha has no surface outlet and the natural change in water levels over the last 100 years is more than 12 metres. Within just a few months the water level can change several metres causing a shift of the shoreline of several kilometres. These dynamics adds an extra dimension to the riparian ecosystem as well as to the water resource management issues.

Back in the colonial days large cattle ranches occupied the bottom of the rift valley. South of Lake Naivasha there was a large sisal plantation. The lake water was used only to irrigate small acreages of fodder crops, provide water for cattle and to grow vegetables. Large areas of papyrus were cleared and converted into agricultural land. When the water levels were receding, between the 1930s and 1950s, the Colonial Government was reluctant to give out water abstraction permits.

In 1929 the Naivasha landowners had organized themselves into the Lake Naivasha Riparian Owners Association (LNROA). In 1933 the land below the arbitrary chosen lake level of 6,210 ft asl (1892.8m asl) was put into the custody of the landowners, under the LNROA, but no permanent structures were allowed to be built on this land. This proved to be a wise move as it has protected the riparian/shore line from degradation. In the late 1950's when the water levels of the lake started to rise after a couple of decades of falling levels, the Administration began designing complex diversion schemes: water was to be transferred to Lake Elmenteita to the North and to Kedong valley to the South. Luckily these plans never came to fruition. Around 1990 the LNROA became more proactive, and in 1998 changed its name to Lake Naivasha Riparian Association (LNRA) and opened itself to a wider membership by instituting associate membership. In 1999, the LNRA's 70th anniversary, the organisation

received the prestigious RAMSAR Wetlands Conservation Award in the NGO category for their conservation work on the lake.

The first large abstraction of the lake occurred when the pipeline from the Naivasha basin to Gilgil and Nakuru town became operational in 1992. During the 1970s there was little irrigation, mainly fodder crops. Then, in the early 1980's, one vegetable grower decided to switch, successfully, to production of cut flowers. This decision has changed the rules of the game.

The permeable and fertile soils, low rainfall, reliable supply of good quality water, good climatic conditions, availability of cheap labour, and easy access to Nairobi Airport, are the ingredients of a booming flower-dominated horticultural industry around the shores of the lake.

Since the first flower farms started in the early 1980's there has been a fairly constant increase of the area under flowers. Then in the late 1990s the flower farms started to mushroom and this process is still continuing, causing considerable concern as to whether the lake can sustain this increase.

The horticultural developments caused a shift in the land ownership and population around the lake. Before the horticultural developments the population was mainly composed of people who where born along the shores of the lake or were attracted by its peace and beauty. Since the 1980's the entrepreneurs moved in, bought or rented land, and started growing commercial flowers for export. It was the old establishment, those who had lived all or most of their lives in Naivasha, that realized that the paradise may be lost if the lake was not appropriately managed. The LNRA became the vehicle that started the lake management process in the late 1980s. The energy, diplomacy and stamina of two LNRA members, the Chairman and Honorary Secretary have been instrumental in starting the process and keeping it going. During this period a rather dormant stakeholder organisation with a long colonial history changed into an active organisation aiming at a sustainable development of the lake. The LNRA undertook the following activities: sensitising their members and others on environmental issues; they compiled and summarized the research that had been carried out over the years into one document (Goldson, 1993); encouraged researchers to investigate the lake; started to develop a management plan and sectoral codes of conduct; started to network and lobby in order to achieve their goals. Consequently, the old riparian agreement became a powerful instrument for the protection of the government owned riparian zone.

The large commercial growers felt that the direction the LNRA had taken was not in line with their commercial interests and so a small group of large flower farms established the Lake Naivasha Growers Group (LNGG). Conflicts between LNRA and LNGG arose and were reconciled, which is all part of the consensus building process and the process towards a more institutionalised form of management. The result is that both groups are now working together for the benefit of the lake.

The first important achievement was the designation of Lake Naivasha as a Ramsar site in 1995. As a consequence, the Kenya Wildlife Services (KWS), the custodian of Kenyan Ramsar sites, became an important and influential partner with the LNRA. In 1996, the stakeholders agreed on the Management Plan and the Government of Kenya officially approved the Plan. This was the start of the implementation phase of the Plan. The Lake Naivasha Management Implementation Committee (LNMIC) was then formed and charged

with executing the Plan. It draws its members from various relevant government and non-government stakeholder organisations.

The LNMIC has no executive powers and no budget allocated to it. It has to work through, and with the official government institutions with some limited support from wetlands oriented projects and NGO's. At the same time the number of problems to be addressed are manifold and many important parameters are still unknown.

The population has increased tremendously resulting in a proliferation of unplanned settlements around the lake. These settlements are without basic amenities such as water, sanitation and waste disposal programmes. The lack of water in these settlements forces residents to go to the lakeshore for domestic water, laundry and livestock watering. The area is being denuded through felling of trees for firewood and over-grazing by livestock, thus causing erosion. There is a major issue of human/wildlife conflict; and wildlife is being snared on a large scale for meat and skins.

The rapid developments caused concern, resulting in many speculations on the complex relationships between resources and resource users, and consequent disputes.
Conservationists argued that the commercial farms are ruthlessly empting the lake whereas commercial growers counter that the lake levels were much lower in the 1950s, before agricultural activities began. The lake is intimately linked to a very productive aquifer but the inter-relationships are complex. Farmers pumping groundwater claim that they do not exploit the lake. Many unsubstantiated claims are made about: the amount of abstractions; the effect of deforestation; the river sediments silting up the lake; the effect of agrochemicals used by the horticultural farms as well as the smallholders in the upper catchment; the unplanned urban and slum development; the effect of cattle watering at the lakeshore; the relationships between agrochemicals; over-fishing, introduced species and biodiversity; the effect of untreated sewage discharged into the lake; the effect of the geothermal plant just south of the lake; and many many more.

In 1996 the LNRA asked the Ministry of Water Development to study the water balance and the water related environmental impacts. This study was carried out in close collaboration with ITC-International Institute of Geo-Information Science and Earth Observation, in the Netherlands. The collaborative studies continue today and the Ministry has stationed a hydrologist in Naivasha who is monitoring the water resources. Leicester University/Earthwatch have been studying the aquatic ecology of the lake since 1985. The lake has also been the focus of research by many Kenyan researchers from local and overseas universities, the Kenya Marine and Fisheries Research Institute (KMFRI), KWS and Kenya Agricultural Research Institute (KARI).

The problems of the dissemination of scientific work among laymen and the integration of scientific work in the management process are well known and not unique to Kenya. Nevertheless, the research on the water, environment, socio-economy and ecology has helped to resolve a number of resource disputes and conflicts and allows the LNMIC to make rational decisions.

The main issue, however, of how a multimillion-dollar booming horticultural economy could exist within a Ramsar site, became more quantifiable.

Over the past six years, from the moment the LNMIC became operational, many factors have facilitated the implementation. Over a long period Kenyans had unsustainably exploited their

natural resources, long-term planning was virtually absent and law enforcement was poor. Somewhere around the year 2000 the tide changed and an enabling environment for natural resources management started to emerge.

The Environmental Management and Co-ordination Act (1999) and the Water Act (2002) provided the operational framework for National Environmental Management Authority (NEMA) and the Water Management Authority (WMA). The first is now operational whereas the latter is still in the process of being established and the concept of Integrated Water Resources Management (IWRM) is being incorporated. The LNRA took a more holistic approach realising that the RAMSAR site could not be protected without addressing the problems in the whole lake basin. They involved more and more stakeholders and sectoral Codes of Conduct were operationalised in the Management Plan. The Growers Group who originally were mainly concerned with access to water and land primarily for horticultural production, also appreciated that natural resources are finite, and that over exploitation would damage the whole flower industry. Furthermore, in their main export market in Europe, environmentally friendly production is an asset. The LNGG adjusted their earlier position and became a more active partner in the lake management, working together with LNRA on resource issues, like land tenure, abstraction rates, agrochemical control, and water availability. The LNGG employed a horticultural expert who actively promotes the introduction of water conservation and environmentally friendly production techniques, and the importance of water abstraction monitoring, among their members. Many (large) farms have now voluntarily installed water meters.

Several commercial growers realized that reduced water usage could come from innovative techniques and better irrigation management. They have started applying computerized irrigation systems with soil moisture sensors, and have moved away from overhead sprinklers to more efficient drip irrigation systems. Coco-peat is used to improve soil characteristics, while geothermal energy is used to increase $CO_2$ and in climate control of greenhouses. Roof runoff is stored and artificial wetlands have been constructed to treat waste water.

The LNRA started to put together an inventory of their resources in close cooperation with the officials of various Ministries. A politically important achievement was a temporary ban on fishing that was enforced with the cooperation of the commercial fishermen something unheard of before.

At the present time , the Ministry of Water Development & Management is seriously (re) assessing abstraction permits, and the pricing of water is being seriously discussed. Both LNRA and LNGG feel that no more abstraction licences should be issued for the time being.

The Chairman of the LNRA wrote: “I believe that we were also fortunate to have the ideal conditions of climate, soils and water for flower-growing. For all its potential to destroy the lake, the industry is contributing greatly to sustainable utilisation of such a valuable resource. In absence of the industry, I believe more abuse and more fragmented development would have occurred and would have been more difficult to contain” (Enniskillen, 2002).

The management of Lake Naivasha is complex. Many issues remain to be addressed and resolved. However, if the management process that started some 10 years ago maintains its present direction/course, Lake Naivasha may become a famous example of Integrated Water Resources Management, where a profitable economy and a Ramsar site co-exist.

## 2. Background.

### 2.1 Biophysical features.

#### 2.1.1 General Setting

Lake Naivasha (0. 45ºS, 36. 26ºE), altitude 1890, lies on the floor of Africa's Eastern Rift Valley and covers approximately 140 $km^2$. It is the second-largest freshwater lake in Kenya. It is one of a series of 23 major lakes in the Eastern Rift Valley – eight in central Ethiopia, eight in Kenya and seven in Tanzania – spanning latitudes from approximately 7º N to 5º S. The overall climate of the Eastern Rift Valley is semi-arid, the exception being the regions of central Ethiopia and central Kenya. All but three of these Eastern Rift Valley lakes are alkaline or saline. Lake Naivasha is unique within the central latitudes of the valley, and indeed within the Kenyan series of lakes (from north to south are Turkana, Baringo, Bogoria, Nakuru, Elmenteita, Naivasha, Magadi ) in being fresh, with a mean conductivity of around 250 µS/cm.

**Figure 1: Map of Lake Naivasha**

#### 2.2.3 Geology

Lake Naivasha is situated on the bottom of the Kenyan rift valley. The rift valley is one of the major geological structures extending from Jordan to Southern Africa. The rifting is caused by the drifting apart of the eastern and central part of the African containment and is associated with extensive volcanism. In Kenya, large areas of phonolitic and basaltic flood lavas were deposited. Rifting started during late Miocene and large volumes of Pliocene ignimbritic tuffs erupted within the depression in the central part of the rift. These rocks included the Mau and Kinangop tuffs now constituting the flanks of the rift. After this the real graben was formed and the large rift faults now constitute the many scarps. The major rifting period was followed by a period of grid faulting of the valley floor associated with intensive volcanism. Since the rift valley is internally drained, all erosional material is deposited on the valley floor. Lakes were present in the valley and the size varied with the climatic conditions. During the Pleistocene and Holocene the volcanic complexes around the lake were formed. The rest of the area is filled with a complex system of lavas and pyroclastic materials interfingering with lacustrine, deltaic and fluviatile sediments. In the Naivasha area the thickness of the volcanic series is some 6 kilometres. The tectonics of the area is relatively simple. The graben is defined by a series of North-South trending step faults. The bottom of the rift has a gridded fault system.

#### 2.2.4 Geomorphology.

The lake Naivasha basin comprises 3 distinct catchments that drain into the Northern part of the lake: the Malewa (1750 $km^2$), the Gilgil (420 $km^2$) and the Karati (70 $km^2$)
Many small basins with a total size of 1000 $km^2$ drains the southern and western part of the basin. The Nyandarua (Aberdares) range to east rises to an elevation of almost 4000 m asl. Lake Naivasha, the lowest area has an elevation of 1887 m asl. The flanks of the rift to the east (Mau escarpment) rise to 3100 m asl.

Broadly the following geomorphologic units can be distinguished:
The mountainous Nyandarua and Kipiri basaltic volcanic complexes, the Kinangop and upper Malewa plateaux, the rift valley floor, the mainly pyroclastic Logonot, Ol Karia and Eburru volcanic complexes and the Gilgil river basin which is a highly dissected volcanic complex.

### 2.2.5 Soils

Sombroek et al (1980) indicate that the distribution of the soils in the area is complex and influenced by intensive variation in relief, climate, and volcanic activities and the underlying rocks. The soils in lake Naivasha basin, classified according to the FAO legend (1974) are; calcic gleysols, ando-haplic pheozems, gleyic cambisols, ando-calcic regosols, lithosols, and calcic xerosols, from the lacustrine plain through the volcanic plain to the volcanic hills respectively. Classified soil on the lacustrine deposits as very well-drained eutric cambisols and that generally the soils in the study area have high supply of phosphorus, calcium and magnesium. The potassium levels are high while those of nitrogen and carbon are low. The sand fraction of the soils is composed of small pumice grains causing very special hydraulic characteristics.

### 2.2.6 Climate.

The basin lies within the range of the Intertropical Convergence Zone (ITCZ). Mt. Kenya and the Nyandarua range capture moisture from the monsoon winds casting a significant rain shadow over the Lake Naivasha Basin. The rainfall distribution has a bi-modal character. The long rains from April to June and the short rains during October and November.

**Figure 2: Rainfall distribution**

The long-term spatial distribution of the rain varies from some 600 mm at Naivasha town to some 1700 mm at the slopes of the Nyandarua Mountains. The Kinangop plateau experiences a yearly rainfall of 1000 mm to 1300mm.

The rainfall is very localized with very little correlation between the events.
Rain starts usually in the afternoon. The graph below shows the hourly rainfall distribution in the Nyandarua mountains (Mutubio gate). The rain intensities can be very high reaching 100 mm/hour. The interannual variability of rainfall is high with a mean of 600 mm/year, 10% of the years receive more than 900 mm or less than 450 mm.

**Figure 3: hourly rainfall distribution picture**

The graph below shows the cause of the fluctuations in shallow East African lakes. The long cycles with wetter or drier conditions occur regionally and are the driving force behind the lake fluctuations. In Naivasha the days are warm but rarely hot and the nights are cool. In the higher parts of the basin there is regular frost of a few degrees below zero.
At Naivasha town the maximum temperature is 37º and the minimum 5º Celsius. The mean is around 16ºC. At the top of the Nyandarua mountains the average temperature is 8º, the maximum 17ºC and the minimum 3ºC below zero. The central Kinangop plateau has a mean, maximum and minimum temperature of 12ºC, 28ºC and -1º C, respectively.

**Figure 4: Cumulative deviation from the mean rainfall picture**

The relative humidity is quite high in the basin. The higher parts experience very frequent fog during the night and the morning. This may play an important role in the water balance due to "fog-stripping" and reduced evaporation during the morning hours but has so far never been subject to research.

The open water evaporation of lake Naivasha is approximately 1720 mm / year.

### 2.2.7 Hydrology and the water balance.

The lake is fed by two perennial rivers, the Malewa and the Gilgil, discharging 80% and 20% of the total inflow respectively. The Karati drains the area east of the Lake is ephemeral and flows approximately 2 months per year. The area south of lake Naivasha does not produce much runoff reaching the lake. To the west the drainage from the Mau Hills and Eburu infiltrates the ground before it reaches the lake.

The Gilgil River discharges an elongated north-south trending, highly dissected basin, receiving an average rainfall of 900 mm/year. The hydrology of this basin has not been studied.
The Malewa River receives its water to a large extent from the Nyandarua and Kipiri mountains and their foothills. The mountains support a deep-seated groundwater flow system that provides, via numerous springs and seepage zones, the very dependable base flow (dry weather flow) of the Malewa. The Kinankop Plateau and the flat area in the northern part of the basin only contribute to stream flow during the rainy seasons.

Both the Malewa and the Gilgil rivers yield water of excellent quality. The Electric Conductivity (EC), a proxy for Total Dissolved Solids (TDS), may change very rapidly in a few hours but the mean EC for both rivers is around 100 μS/cm. Like all natural water in the area the sodium content is relatively high.

The lake fills a shallow depression with gentle slopes, so an increase in lake levels greatly increases the lake surface area and consequently increases evaporation. The lake shows a very dynamic behaviour that is shown in the figure below as well as water levels calculated from hydrometeorological data. The amplitude of the lake levels over the last 100 years was some 12 metres. The water levels of the lake respond to long-term wet and dry climatic cycles. The yearly variations of the water levels are superimposed on these long-term variations.

**Figure 5: Lake Levels 1990-2000**

The fluctuations of the lake have attracted the interest of both scientists and water managers. In 1948, Mr. Tetley an Hydraulic Engineer in Nairobi wrote: " The lake reached its next highest peak in 1917 and since that year (1917) to April 1946 the level had a drop of about 37 feet; its area shrank from say 86 square miles to less than 33 square miles and it lost about fifteen sixteenth of the volume of water all in 29 years" .

Verschuren (2000) has studied the lake levels over the past 1000 years and has identified 4 periods where the lake went (almost) dry but also periods with higher levels than present.

Lake Naivasha actually consists of three lakes. The Crescent Lake which is the deepest part of the lake (18m depth) can be connected to the main lake, depending on lake levels. Oloiden is a smaller lake at the south end of the Lake and, depending on lake levels, can be distinct from the main lake. The Crater Lake or Sonachi is located on the southwestern part of the lake and is independent from the main lake. The main lake is shallow (max. 8m).

The lake has no surface outlet and still has good water quality with an EC of approximately 300ms/cm. For decades it has been recognized that only an underground outflow can explain the freshness of the lake. The groundwater levels and the isotopic composition of groundwater indicate that this flow is both to the north and to the south. A small part of the groundwater evaporates and will escape in the form of fumaroles in the geothermal areas; the

remainder of the water is flowing into lake Magadi and lake Elementeita. One should realize that it takes thousands of years before the water arrives at these lakes.

The lake it self can be considered as a groundwater outcrop of a very good shallow aquifer that is draining into a deeper aquifer system that carries the water towards the terminal lakes. The groundwater system around the lake is complex and has important management implications that will be discussed later. In general the water flows away from the lake with the exception of the west-side where an inflow from the Ndabi plains exits.

The water balance of the lake has been established using a water balance model (Mmbuie, 1999). The water balance is calculated for the period 1934 – 1983 and therefore represents the period before the large-scale abstraction began.

**Table 1: Lake Naivasha Water Balance**

### 2.2.8 Biosphere

Little natural vegetation is left in the catchment. The headwaters of the Malewa, the main water source for the lake, are situated in the Aberdare National Park and the adjoining gazetted forest. The vegetation consists of humid Afro-montane forest and bamboo. Fog is very frequent and may play a role in the water balance. The Kinankop and Bolosat Plateau were large grassland plains in the past. An estimated 30% is now covered with maize or vegetables and many fast growing tree species. The upland areas are largely covered by tree-savannah landscape and dry land forest. Remnants of this forest can still be seen on the escarpment. The bottom of the rift valley was an open savannah landscape in the past.

Lake Naivasha supports unique habitats particularly the fringing papyrus swamp and associated freshwater biodiversity. The ecosystem comprises three chemically distinct water bodies, the main freshwater lake itself, a more alkaline and sometimes connected Oloidien, and a crater lake, Sonachi.

The littoral zone is inhabited by macrophytes that provide suitable habitats for fish feeding and breeding, and mulch for invertebrates. Although species composition has changed over time, the dominant floating species are *Cyperus papyrus*, *Eichhornia crassipes* (exotic), *Pistia stratiotes, Salvinia molesta* (exotic), *Wolffia arrhiza* and *Nymphaea* (water lilies). Submerged plants include *Potamogeton schweinfurthii, P. pectinatus, P. octandrus, Najas pectinata, N. caerulea, Ultricularia reflexa,* and *U. gibba.* The areas of submerged macrophytes vary considerably, but the littoral zone comprises about 1/3 of the lake. This habitat exerts great influence on the biology and chemistry of the lake, and the plants are also responsible for the richness of the bird population.

Water lilies almost disappeared in the 1980s and this was thought to be caused by the introduced crayfish and accidentally introduced Coypus. The papyrus is considered the most important plant of Lake Naivasha. It occurs in the shallow water of the lake edge and on land where sub-surface soil is saturated. It almost completely surrounds the lake, forms floating islands on the lake and can be found up to 5 kms up the Malewa River. It acts as an efficient silt and nutrient filter and is capable of recycling excess nutrients. It forms an important habitat for fish (where submerged or floating) and wildlife such as birds, hippo and buffalo, which use it as safe refuge and feeding area. The amount of papyrus in the lake has varied tremendously as a consequence of fluctuating water levels, fires, and, in some cases, human encroachment.

One hundred and forty three (143) phytoplankton taxa are recorded in the lake, and these include the species *Microcystis, Lyngbya, Oscillatoria* and *Melosira*. The photosynthetic rate is about 5 mg $O_2/m^3/d$ in the open lake (50 mg Chl.-a/$m^3$). Most productivity is in the top 3m of the lake. The more alkaline Oloidien and Sonachi lakes are more productive and *Spirulina* is significantly present. The main zooplankton genera are Cladocera, Copepoda and Rotifera. Zooplankton biomass is positively correlated with chlorophyll a (algal) concentrations, because zooplankton feed on the phytoplankton. Twenty eight taxa of invertebrates have been recorded associated with the macrophyte beds.

Before 1925 the small-toothed carp *(Aplocheilichthys antinorii)* and *Barbus amphigramma* were the only fish species in the lake (paucity probably due to historical episodes of the lake drying out). By 1962, probably as a direct result of the introduction of the largemouth bass the *A. antinorii* has disappeared. The present fish population is made up of introductions by man. These species are the large-mouth bass (*Micropterus salmoides)*, introduced from the USA in 1927, 1951 and 1956, *Tilapia zillii* (1956 from Lake Victoria - the introduction contained *Oreochromis leucostictus*, which is now the most numerous fish ahead of the bass), and other tilapiine species which are not encountered today. Three cyprinodonts, *Gambusia, Poecilia* and *Lebistes*, were introduced to control mosquitoes. The exotic rainbow trout (*Onchorhynchus mykiss*) occasionally strays into the lake from the River Malewa, while *Barbus amphigramma* migrates between the lake and the river. The Louisiana red swamp crayfish (*Procambarus clarkii*) was introduced in 1970 as a food source for the bass.

The main food source for fish fry is zooplankton (60%) and chironomid larvae, followed by algae and detritus. Larger Bass depend on crayfish, fish fry and frogs. Juvenile fish exert predation pressure on the zooplankton in the littoral zone, whereas in the open waters the zooplankton remain relatively untouched. On their part the fish are a source of food for numerous piscivorous birds such as the fish eagles, ospreys, cormorants, kingfishers, herons and pelicans, and also support an important fishery that is a source of income and animal protein for the human population around the lake and in nearby towns.

The Naivasha Thorn, or Yellow Fever Tree (*Acacia xanthophloea*) is the dominant terrestrial tree species and forms the woodland around the lake. It is an important habitat for birds and other wildlife, and the undergrowth provides an important buffer against erosion and helps to prevent silt and nutrients getting to the lake. Many animals are to be found on the shores of the lake, in the acacia woodland and the neighbouring national parks and sanctuaries, including hippopotamus (a population of over 600), waterbuck, buffalo, giraffe, eland, zebra, Thomson's and Grant's gazelles, bushbuck, duikers, mongooses, otters, various snakes and rodents as well as the occasional leopard. The River Malewa delta comprises Acacia woodland before giving way to papyrus swamp.

Lake Naivasha regularly supports more than 20,000 water bird congregations, with a mean of 22,000 (1991-1997). The riparian, papyrus and littoral macrophyte zones provide safe haven, foraging and breeding ground for many resident and migrant bird species, as well as other wildlife such as the Hippo, Waterbuck and Buffalo. The woodland within the ecosystem provides habitat for the globally threatened Grey-crested Helmet-shrike (vulnerable). Another globally threatened bird found in the site is the Basra Reed Warbler (near-threatened), a winter visitor and passage migrant whose exact status is unknown. There are regionally threatened species both as regular visitors and residents e.g. Great Crested Grebe (critical), Maccoa Duck (endangered), African Darter, Great Egret, Saddle-billed Stork, White-backed Duck, Baillon's Crake and African Skimmer (all vulnerable). The

riparian/papyrus habitat supports certain endemic species such as Papyrus Gonolek and White-winged Swamp-Warbler.

### 2.2 Political and Socio-economic Features of Development and Conservation.

The Lake Naivasha basin covers two Districts, Nyandarua and Nakuru. Many activities of the Government Ministries are decentralized to district level and thus complicate an integrated catchment approach. Development plans are written for Districts (District Development Plans) cross-cutting basin boundaries.

Most land within the Ramsar site is privately owned. The land below the riparian boundary is government land given in custody to the riparian landowners. No permanent structures are allowed.

The Naivasha basin occupies a large part of the traditional pastures of the pastoral Maasai. However, after colonisation by the British, the basin became part of so-called white highlands, the areas where only European settlers were allowed to own land. The higher parts were mainly used for wheat and cattle, the bottom of the rift valley for cattle and around lake Naivasha sisal, Lucerne and vegetables were grown. After independence mainly Kikuyu's occupied the parts suitable for rainfed agriculture. The land tenure in the bottom of the rift valley remained largely unchanged. Therefore there is still a lot of land around the lake owned by Kenyans of European origin. The fishermen community is mainly Luo.

Since the 1940s irrigated Lucerne north of the lake has been used as fodder for dairy cows. The area between Lake Naivasha and Lake Nakuru (80 kilometres to the northwest) is mainly used as cattle and game rangeland. South of the lake are open rangelands where the Maasai graze their livestock during the dry seasons and closer to the lake edge there are many irrigated floriculture ventures. The areas to the west and east of the lake which receive higher rainfall are mainly occupied by smallholders growing maize, vegetables and pyrethrum. There are also some larger grain farms.

As a result of the introduced fish species, a fishing industry has sprung up and black bass, tilapia and crayfish are commercially exploited. Recently, as a result of excessive fishing pressure, the fish stock became so depleted that a yearlong ban had to be imposed to redress the situation and an annual closed season is now in force during the fish-breeding season.

Lake Naivasha is a tourist destination, although not a major one. There are two small national parks (Hells Gate and Longonot) in the vicinity of the Lake and the Aberdare National Park close by. The beauty of the area, the extent of the bird and wildlife, the proximity to Nairobi, and the many hotels, home-stays and campsites at all budgetary levels attract many local and overseas visitors. In 1998 some 40,000 tourists visited the lake and its surroundings.

In 1982 the KenGen Ol Karia geothermal power plant, situated 7km south of the lake, became operational, producing some 45Kw of power. In 2002 an independent power producer started production in an adjacent area, producing 12 KW. In 2003 a second KenGen generation station will be commissioned and will produce 65KW of power.

In the early 1980s the first flower farm started and in a period of twenty years the flori- and horticultural area has increased from close to zero to some 4,000 ha. Growers now produce at least 25 varieties of flowers (roses, spray carnations, gypsophila, alstroemeria, eustoma,

etc) and vegetables (peas, baby corn, beans) for the export market. All of these are irrigated from lake, river or groundwater.

The economic return per cubic metre of water applied on a crop ($ per drop) varies tremendously. The figures below are based on an analysis carried out in 2000 (ITC, Saheed, 2001).

**Table 2: Economic return per cubit Meter**

The industry employs some 25,000 people directly and a multiple of this are indirect beneficiaries depended, both as dependents and service providers. The population around the lake increased from some 25,000 to 250,000 within 15 years (Enniskillen, 2002).

Based on the 1999 census, the Central Bureau of Statistics reports the population of Naivasha Urban Core as 32,000 and Naivasha Municipality as 115,000 persons.

A demographic internet source (www.library.uu.nl/wesp/populstat/Africa/kenyag.htm) gives the following data. The explosive developments around the lake are associated with many conflicts and disputes.

**Table 3: Population of Naivasha**

**Figure 6: economy vs environment picture**

## 3. Biophysical environment

### 3.1 Water balance.

A model simulating the monthly lake levels based on inflow, rain and evaporation records is operational for the period 1932-2000. This model was programmed as an Excel spreadsheet. The graph shows that water levels can be accurately predicted by the model and the departure of the calculated and measured curve starting around 1983 is thought to be caused by the basin wide abstraction. The abstraction as calculated from this model is 60 MCM.
In order to study the lake water balance in conjunction with the groundwater reservoir around the lake. The lake-groundwater system was modelled using a groundwater-modelling programme of US Geological Survey (ModFlow). The predictive results of this model were not better than for the spreadsheet model. However, this model allows studying the effect of groundwater abstractions on the lake levels and it can be linked to groundwater quality models in order to study the transport of pollutants around the lake.

**Figure 7: Lake Model Simulation**

The figure above shows the result of a simulation of 60 MCM since 1932. If the climatic conditions of the 1940's are repeated and the lake surface area would reduce to 30 $km^2$ as compared to the present 120 $km^2$. The model has been calculated with the underground outflow as the main calibration parameter. The outflow is 55 MCM or some 25% of the inflow. The amount outflow that is flowing towards the north (Elmenteita) and southwards has long been a subject of debate. A water balance study covering the Southern rift valley from lake Magadi to lake Nakuru indicated that some 15MCM flows towards the north.

In 2000 the estimated total abstraction was calculated as 60 MCM. This basin wide abstraction causes a drop of 2.5 metres of the lake water level.

The area under irrigation and water consumption of the irrigated crops is in the process of being re-assessed. The table and map below (Table 4) give the preliminary area based on a March 2003 satellite image and September 2003 fieldwork.

**Table 4: Area Under Irrigation**

**Figure 8: Area Under Irrigation**

Groundwater plays a more important role than realized by the stakeholders and management.

- It controls the efficiency of irrigation
- It contains as much water as the lake
- It transports pollutants
- It affects the lake levels
- It feeds the geothermal reservoirs
- It causes the lake to be fresh

The outflow towards the south causes over-irrigation to be a net loss while pollutants are moving away from the lake. In the north, where groundwater is recirculating due to groundwater exploitation, the excess irrigation will recharge the aquifer as are the pollutants. The large groundwater reservoir renders the system relatively inert and thus long-term planning of lake management is important.

### 3.2 Water quality and aquatic ecology.

Several authors have reported on the water quality and aquatic ecology of the lake. The oldest, although not complete, analyses dates back to the 1920. The natural water quality is mainly driven by the solutes input and the variations in lake levels. The Total Dissolved Solids (TDS) increase in times of receding lake levels and decrease after floods. Irrigation from the lake will decrease the TDS whereas irrigation from the rivers will increase TDS levels. So far no disturbing trends have been detected. (Chaweepan Suangkiattikun, ITC, 2003).

**Figure 9: Long Term EC**

Total P is one of the elements determining the trophic status of a lake. The following data has been collected from literature (Abiya, 1996), (Kitaka, 2000), (Munoz Villers, ITC, 2002)
The high values of 1997 are explained by the high runoff in that year. In 1990 Kitaka took a series of samples over several months with a mean value of 10µg/l. The source of Abiya's data is unknown. Time series data on nitrogen ($NO_3$ and ammonia) has not been found.

**Table 5: Total Phosphorus runoff into L. Naivasha**

The 2001 ITC data set shows there is a considerable temporal and spatial variation in the soluble P ($PO_4$) and Nitrogen data. The two surveys both have over 100 points well spread over the whole lake, and were carried out only one week apart. The concentrations of chlorophyll-a have increased from around 30 µg $l^{-1}$ in 1982 to 110 µg $l^{-1}$ in 1988, and reached 178 µg $l^{-1}$ in 1995 (LNRA, Internal Report). McLean (ITC 2001) used 8 chlorophyll-a values obtained from Humble (1998) with values ranging between 0.01 and 0.08 µg/ l. Most likely the large difference can be explained by the reporting units (factor 1000 between µg/l and mg/l). Harper and Mavuti (1990) report an increase from 20 µg/l in 1982 to 130 µg/l in 1987.

The N/P ratio is 2.1 (McLean, ITC, 2001) and as a consequence nitrogen is the limiting nutrient.

**Table 6: Temporal and spatial variation in the soluble P ($PO_4$) and Nitrogen data.**

Certainly the large horticultural farms and the many smallholders in the upper catchment have an effect on the lake water quality. However, the trophic status of the lake is still acceptable.

Kitaka and Harper (2003) classify the lake as eutrophic (1998-99) and hypertropic after the El Niño floods (97-98) and state that the tropic status of lake can be explained by the input from the Malewa only

Visibility varies with site and ranges between 5 cm and 150 cm Secchi depth. It is lowest in the north swamp area where suspended sediment is brought in by the rivers. Low visibility can also be caused by algal growth. Algal blooms have been observed, albeit infrequently.

Very few analyses are available on pesticides in the lake water. Gitahi (2003) reports that organochlorines could be detected in black bass and crayfish. No organophosphates were detected in the same samples. Based upon farm data the total load has been calculated.
The reduction of the Papyrus fringe has been dramatic (Everard and Harper, 2003).

**Figure 10: Area under papyrus**

Many stakeholders consider siltation of the lake a large threat. A bathymetric survey of 1957 has been compared with a survey in 2001 (Rupasinga, 2002). There are no indications that the sedimentation process is accelerating yet.

The fish catch varied substantially over the last 40 years. The graph below shows data compiled by the LNRA.

**Figure 11: Fish Catch**

An issue of major concern is whether an "ecological switch point" exists. This is a phenomenon where an ecosystem (irreversibly) switches from one stable state to another.
Aquatic ecologists speculate that this point has been passed a long time ago, when alien species were introduced in the lake. The introduction of the Louisiana crayfish has especially changed the original submerged macrophyte dominated ecosystem into a rather poor macrophyte ecosystem. Smart (2002) concludes that *P. clarkii* (crayfish) could well have accounted for the observed elimination of native plant species in Lake Naivasha; the cyclical nature of populations of submerged plant species and of *P. clarkii* in inverse proportion to each other lead us to hypothesise that *P. clarkii* is a `keystone' species in the lake ecosystem.
Under the present lake stresses the occurrence of a next switch point is unlikely.

A new threat may emerge from the accidental introduction of common carp in 2001.
Britton (2002) concludes that further work is necessary on the fish population to monitor if *C. carpio* does successfully reproduce and establish in the lake. If this does happen, monitoring of the fauna and flora of the whole lake will need to be continued as the species can be very destructive in their foraging activities among the lake benthos. *C. carpio* is considered a pest species in many countries, including Australia and South Africa, due to their negative impact on water turbidity and macrophyte growth, and there are eradication programmes designed to remove them totally from aquatic eco-systems.

## 4. Management Environment.

### 4.1 Lake Management Programme and Processes.

To understand the management environment of Lake Naivasha we have to discuss the many formal stakeholder and informal stakeholder groups with their mandates, objectives and interrelationships as well as the many obvious and less visible conflicts, disputes and disagreements.

#### 4.1.1 Stakeholders

*Lake Naivasha Riparian Association (LNRA).*

This organisation was founded in 1929 by the riparian owners as the Lake Naivasha Riparian Owners Association (LNROA). Several descendents of the founding members still live around the lake. In 1932 the LNROA signed the Foreshore Rights of Riparian Owners with Government, giving the owners the right to use the exposed land below the boundary *ALWAYS PROVIDED that the ordinary occupation in these premises shall be deemed to mean only the right of access to water the right of grazing and the right of cultivation.* Sixty years later this boundary still plays a very important role. Persons buying/owning land around the lake automatically became members of the Association. The Association was not particularly active until 1986 when a new and dynamic Chairman was elected. It was then that the members started to realise that the newly booming floricultural developments had the ability to put the future of the lake at stake.

The LNRA started a process of lobbying, awareness building, networking and data collection to counter the degradation of the lake by the ongoing activities. In 1993 a report was commissioned by the LNRA summarizing the knowledge on the lake (Goldston,1993). In these days the "Foreshore Rights" was the only legal document protecting at least the immediate surroundings of the lake. In 1993 the LNRA started the process of drawing up a Management Plan for the Lake, which would have the support of all sectors, and which was based on voluntarily adopted sectoral codes of practice under an overall management strategy. In 1996 the Management Plan was adopted by the membership and subsequently by the District Development Committee in Nakuru and thereafter by the Government as the official Management Plan for Lake Naivasha.

In 1995 as a result of initiatives by the LNRA, the Kenya Government (GoK) nominated Lake Naivasha as its second Ramsar site, however, this is only the area within the road around the lake. The GoK reaffirmed the LNRA's Management Plan as being the Government's official Management Plan for its Ramsar site. KWS are the custodians, on behalf of the Government of wetlands in general and Ramsar sites in particular, and this process received their full backing and support throughout. The Management Plan is implemented by the Lake Naivasha Management Implementation Committee (LNMIC) (see below) under terms of reference that have been established and agreed with KWS. The Committee consists of local and national organisations, including one international group - IUCN. The LNRA, having initiated the management process and played a central role throughout, remains a key member, but the LNMIC membership is intended to be representative of more of the stakeholders' interests consistent with administrative and decision-making efficiency, whilst at the same time being a firmly - locally-based initiative.

In 1998 the Lake Naivasha Owners Association (LNROA) changed its name to Lake Naivasha Riparian Association (LNRA) and became more open to other stakeholders than the

original landowners by allowing associate membership. It is still however primarily an association of individuals or companies which hold land title or legal responsibilities in the area. In 1999 the LNRA celebrated its 70th anniversary and also received the prestigious Ramsar Wetland Conservation Award, presented in Costa Rica at the 7th Ramsar Conference of Parties.

At present the LNRA has some 140 individual and corporate members. If employees, other workers, and dependents are included, the Association can be considered to represent at least some of the interests of perhaps 100,000 people. In order to allow more persons to become members, the fee is kept low and thus the organisation is continuously short of funds. The Association receives some support from conservation oriented NGO's. The Association employs one person full-time with a background in aquatic ecology and has one Peace Corps volunteer working for them. If funding allows small projects are executed.

*Lake Naivasha Growers Group (LNGG)*

This group was founded some 10 years ago by a small group of large commercial flower growers and as such does have considerable influence and unofficial power. The membership fee is based on the number of employees, and with some 25,000 persons employed by LNGG members, this generates a steady flow of income. The LNGG started as a response to the conservation ambitions of LNRA, but has changed its stance. The large farms are now concerned that in the long-term they will be negatively affected by overexploitation of the lake's resources, and they also realize that their European customers want "clean" or "eco- products" that come from a protected environment. Labour and social conditions, including the working environment, health and safety factors, and gender equity are also increasingly of concern to European customers, and the Kenya Flower Council (KFC) (see below) has responded to this with a Code of Practice. The LNGG employs its Code of Conduct for its members which is also included as part of the Management Plan for the Lake. A horticultural consultant is employed on a part time basis advising farms on social and legal issues, conservation measures, better pest control and irrigation management. The group carries out audits among their members to ensure that they comply with their Code of Conduct and the Lake Naivasha Management Plan. Several of the larger farms have looked at ways of improving their impact on the environment by using integrated pest management to cut down on pesticides and using constructed wetlands to treat their waste water.

*Kenya Wildlife Services (KWS)*

As an owner of riparian land, KWS has been a long-time LNRA member. KWS is also the official custodian of all Ramsar sites in Kenya. They are also the managers of the area's National Parks.

*Lake Naivasha Fishermen's Co-operative Society*

This society represents the small-scale commercial fishermen on the lake and works in conjunction with the Fisheries Department.

*The Government of Kenya and Local Administration*

The Government through several of its ministries and local authorities have a legal and constitutional stake, as well as legitimate interests, in the lake. The Fisheries Department is

responsible for managing the fish stock and the Ministry of Water Development & Management is responsible for water management issues. Other government institutions are Local Authorities (LA) at District and Divisional level, Naivasha Municipal Council, Nakuru District Development Committee and District Environmental Committee.

*Power Generating Companies.*

KenGen is a parastatal power company operating just south of the Lake. OR Power is a new private power provider. Lake water recharges the geothermal field.

*IUCN*

Is a member of LNMIC but has no further activities in the area.

*Lake Naivasha Management Implementation Committee (LNMIC).*

This committee has the mandate to implement the management for KWS but has until today no official status nor legal power although the process of gazettement under the Environmental Management & Coordination Act (EMCA) is far advanced. The members are nominated representatives of various organisations and subcommittees of LNMIC. The LNMIC has no formal budget.

Although the LNMIC has no direct jurisdiction it can to a certain extent influence policy decisions and measures through its members.

Full members:

- Lake Naivasha Riparian Association (LNRA)
- Kenya Wildlife Service (KWS)
- World Conservation Union (IUCN)
- Ministry of Water Development and Management (MoWD&M)
- Ministry of Environment, Natural Resources and Wildlife.
- Fisheries Department (Ministry of Livestock and Fisheries Development)
- District Commissioner, Nakuru
- Naivasha Municipal Council
- Kenya Power Generating Company (KENGEN)
- Ministry of Lands and Settlement
- Ministry of Agriculture and Rural Development
- Lake Naivasha Fishermen's Co-operative Society

Co-opted members

- Water Bailiff
- The Chairmen of the Sub Committees for:
  Tourism, Eburru Forest, Livestock, Biodiversity Monitoring, Water

Apart from the stakeholders discussed above and represented in the LNMIC there are others such as:

- The large farms. Most large farms are members of both LNRA and LNGG. As seen above, the interests of the two organisations are not always compatible. Moreover, some five large companies around the lake employ thousands of people and have exports worth millions of Dollars, and as such can be seen to constitute a stakeholder group on their own. Several of these large farms provide recreational, sports, medical and educational facilities (schools, hospitals) for their workers and families. These

large farms also play an important role in introducing water- and environmentally-friendly technologies.

- The labour force employed by the large farms, and the trade unions which represent some of them. With about 25,000 employees, this is the largest stakeholder in terms of numbers of people, but with proportionally the least effective influence; for instance, no trade union is present in the LNMIC. In the Kenyan press, however, the working conditions (salaries, exposure to pesticides, working conditions) are regularly discussed.
- Indigenous Biodiversity and Environmental Conservation. A rather vague group mainly concerned with access to the lake.
- Upper catchment population is highly significant in that it is indirectly responsible for maintaining the inflow into the rivers, the lake, and the aquifers. Whatever soil, woodland, and land management activities the upper catchment dwellers do, it will eventually affect the system hydrology. They utilise water for domestic and livestock, as well as for farming, and sediments and agrochemicals from the upper basin end up in the lake. This stakeholder group is also not represented in the LNMIC, except by GoK ministries and Las.
- Wood loggers. Legal and illegal logging affects the hydrological regime and increases erosion. Many people depend on forest products for their livelihood, even though many activities are illegal.
- The (Maasai) pastoralists living south and west of the lake use the lake as a water point, especially during drought periods. This group is also not directly represented and feels it is not benefiting much of the developments in the area. They feel that their health and environment are affected by gases escaping from the geothermal power plants.
- Knowledge Institutes. Several universities and institutions such as Egerton University, Moi University, Nairobi University, Kenya Marine and Fisheries Research Institute, Leicester University / Earthwatch and the International Institute of Geo-Information Science and Earth Observation (ITC) regularly carry out research in the lake basin.
- Social & Environmental Certification Organisations (i.e. MPS).
- Kenya Flower Council (KFC), advising their members on farm management, labour standards, and environmental policies. KFC has set up a 'silver standard' covering workers' pay, conditions, and health & safety (to reach ILO conventions), and some environmental conditions; whereas their 'gold standard' demands higher levels of environmental performance. The Fresh Produce Exporters Association of Kenya (FPEAK), which covers vegetables and flowers, utilises weaker guidelines.
- International customers for flowers and vegetables, especially in Europe, are increasingly purchasing not just eco-products like organically-grown vegetables, but are also concerned with 'Fair Trade' issues such as wage rates, working conditions especially for women, child labour, health and safety for workers working with pesticides, housing and social standards, etc.
- Media in Kenya and outside, especially environmental journalists.
- Agro-companies (seeds, agro-chemicals).
- Tourist Industry, although this is not a major player in the area. There are two small National Parks in the vicinity of the Lake and the Aberdare National Park on the eastern watershed, and a number of hotels, home-stays and campsites.
- Internationally influential environmental and civil society organisations (WWF & IUCN).

An important consideration, which is not always openly aired, is the cultural and ethnic differences between stakeholders. A large proportion of the commercial farms is operated and owned by Europeans. The whites again can be divided into descendents of colonial landowners, and more recent entrepreneurs attracted by the business opportunities the area offers. The large dairy enterprise and meat farms are run by old UK-Kenya aristocrats and Italians By the end of the 19th century, at the start of British colonial times, the area was populated by the pastoral Maasai, but now the major part of the population in the area belong to the Kikuyu. The fishermen are Luo people migrated from Lake Victoria.

### 4.1.2 Conflicts

A summary of the most important conflicts is listed below. A differentiation is made between technical conflicts (facts based) and institutional/social conflicts (conflicts of interest and Relational issues).

**Technical conflicts**

These conflicts are mainly related to disputes about the interrelations between natural resources, the allocation of these resources, and the humans exploiting them. Many factual disagreements in the past have been solved by research, and the issues below can be seen as priorities for further research and analysis.

Factual disagreements:

- Disputes about the exact effect of abstractions on the lake level and how much can be safely abstracted.
- On the size of the irrigated area and the total abstraction taking place in it.
- Some environmental groups claim that the lake is polluted by agro-chemicals.
- Disagreements on the contribution of pollution from the upper catchment versus the large farms.
- Lake water users think that up-catchment abstractions are considerable.
- Fishermen claim that the reduced lake levels caused by abstractions decrease the catch, that agrochemicals reduce catch, and that fish (fry) are pumped out of the lake during water abstraction.
- Parties do not agree on the definition of sustainable water exploitation.
- Growers using groundwater claim that they are not exploiting the lake's water resource.
- Conflicts arise because of the uncertainty of who has legal abstraction permits and who not. It is speculated that many users abstract more than their permit allows.
- The riparian land delimited by the riparian boundary is government property under the custody of the riparian landowners. No permanent structures are allowed inside this boundary, although there is some dispute as to what constitutes permanent structures. The boundary is defined by the 6210ft asl (1892.8m asl) lake level contour. Some are in doubt as to exactly where this boundary is located.
- Disputes over the relationship between the lake level and lake level dynamics.
- Disputes over the ecological functioning of the lake and its surroundings.
- The effect of the geothermal plants on the environment (lake levels, water quality and the effect of the emitted gases on the environment and people).

**Institutional and social conflicts**

These conflicts are of a legal, administrative, financial, social, or institutional order.

Relational Issues:

- Water users blame Forest Department and (illegal) wood loggers for mismanaging the Forest Reserves and thereby diminishing water yields and increasing erosion, causing an accelerated fill of the lake.
- Existing game and cattle corridors have been closed by agricultural land. More generally, access to the lake has been closed off.
- The labour force has claims that it is exploited and underpaid.
- Does the LNRA Management Plan really consider the interests of all stakeholders? or is it more the product of a group of environmentally-sensitised Whites (Wazungu)?
- Conflicts between media and stakeholders. The news on Naivasha is more often negative than positive.
- Some farms do not respect the official riparian zone.

**Conflict of Interest:**

There are conflicts between different socio-economic groups pursuing different goals:

- The main conflict is certainly between environmental groups who want to protect the lake and its catchment from over-exploitation and the commercial growers intending to maximise their output.
- Nakuru town wants more water for its urban water supply which would critically damage the Lake.
- The tourist industry would like a natural landscape setting.
- The Maasai claim historical traditional rights to the area and access to the lake to water their cows.
- The large cattle farm claims that it has used the local natural resources in an environmentally-friendly manner producing meat and milk for millions of Kenyans, instead of destroying the environment like the flower growers have done.
- Fishermen consider the use of agro-chemicals in the large-scale horticultural industry as a threat.
- Does the ordinary Kenyan or the Kenyan state benefit from this economic boom, or only a happy privileged few in the area?.
- If water would be priced, who would benefit from the revenues? (government or local stakeholders or both)?

### 4.1.3 Programmes and Processes

**There has never been a government project or programme directly addressing the management of the lake.** The LNRA and the GoK have received small grants from various organisations, but the investments in the lakes management are limited.

The responsible government organisations are lacking funds, means, and sometimes the interest to seriously address and solve the problems. Until very recently water and environmental law was basically a copy of the law established during colonial days and unable to cope with modern land and water management issues.

A water abstraction permit has always been required but in practice every request was honoured. In any case, many users are abstracting either without a permit at all, or above the limit set by the permit. Two new laws have recently been passed by Parliament: Environmental Management and Co-ordination Act (1999) and the Water Act (2002). The National Environmental Management Authority (NEMA) and the Water Management Authority (WMA) have the mandate to implement and enforce the new laws.

It was the combination of the many problems listed above, the lack of Government intervention (thus a management vacuum), combined with the visionary and strong leadership of LNRA, that allowed the LNRA to rise as a strong stakeholder organisation addressing the many pressing issues.

A process that took some 15 years saw the evolution, from a small group of LNRA members concerned with the future of the lake, through a process of drafting the long-term vision, lobbying, networking, solving disagreements among the stakeholders, consensus-building, awareness-raising, and reconciliation into the present form of lake management.

The milestones in this process were:

- Report on the scientific knowledge and outline of "the way ahead" (1993)
- Preparation and official adoption of the Management Plan (1995) and as a consequence the installation of the LNMIC.
- Reconciliation between the LNRA and the LNGG (+/-1999)
- Co-hosting a scientific conference on shallow tropical lakes (1999)
- Declaration as a Ramsar site (1999)
- Temporary ban on fishing indicating that policies can be enforced (2002)

At present the cornerstones of the Lake Management are the Management Plan and the implementing and executing organisation, the LNMIC.

**Lake Naivasha Management Plan**

The Management Plan was written by a Steering Committee consisting of LNRA members, representatives of the Government and NGO's. It is a dynamic document that has already been updated twice (carried out by the LNMIC) since its inception as knowledge increases and circumstances and laws change.

*The objectives of the Management Plan:*
The prime objective of the Management Plan is to manage existing human activities in the lake ecosystem through voluntarily adopted sustainable wise use principles to ensure the conservation of the freshwater resource and associated biodiversity.

*Secondary objectives are:*

- To promote and encourage the major contribution made to the national economy;
- To maintain, conserve and, where necessary, restore the natural beauty and biodiversity of the lake;
- To achieve consensus, an understanding of and support for the Management Plan through voluntarily adopted codes of practice and dialogue;
- To facilitate public access, tourism and research activities whilst at the same time respecting the private ownership of surrounding land;
- To immediately adopt practices on which there is consensus based on current knowledge and to adopt others as the Plan is updated in the light of new information from the monitoring programme.

*Measures envisaged by the Plan*

The principal immediate measures envisaged by the Management Plan are to:

- Require that all developments within the Ramsar Site first be subjected to Environmental Impact Assessment (EIA) and approval (the Ramsar Site however is spatially limited to the area immediately around the lake)
- Strengthen the water abstraction licensing procedures and the enforcement of them;
- Establish metering of abstractions and monitoring the use of water;
- Promote efficient use of water;
- Protect and where necessary re-establish the papyrus fringe around the lake and allow its natural growth;
- Maintain and where necessary restore to a natural state a minimum 100 meter buffer zone on the land side of the papyrus edge or from the shoreline where no papyrus exists;
- Disallow the reclaiming of flooded land, intensive irrigated agriculture, and building of permanent structures, below the lake level in 1906 (6210ft contour);
- Establish sources of revenue to fund the management plan;
- Establish direct representation on appropriate regulatory bodies of local and central administration;
- Establish accepted sectoral codes of practice;
- Influence a reversal of adverse activities in the watershed;
- Implement a technical study of the full water budget and support a study of an alternative source of water for Naivasha.
- Implement monitoring, education and awareness programmes;
- Establish contingency planning for natural and man-made disasters.

*The Sectoral Codes of Conduct (CoCs) incorporated in the Management Plan.*

- Lake Naivasha Growers Group
- Power Producers (KenGen)
- Lake Naivasha Tourist Group
- Fisheries Industry
- Livestock and Dairy Industry
- Wildlife
- Naivasha Municipal Council

**The present management process**

The LNMIC, responsible for implementation of the Management Plan, meets on average every six weeks. Agreed action points are delegated to the individual members. The direct contact for day-to-day business, visitors, enquiries, etc., is the very active Honorary Secretary; the Chairman handles higher-level contacts.

Since the LNMIC has no executive power it can only exert its decisions through its members. The LNMIC can put pressure on the members representing the Government to enforce laws or to take action but the final authority remains with the various government institutions. It can also motivate members to adopt certain practices. Measurable targets are not (yet) part of the process.

The Officers of the key Government Departments such as the Fisheries, Forest and Water Departments are supported to execute their duties. Subcommittees address the problems in special sectors such as Biodiversity, Water, Horticulture (LNGG). Technical information is

provided by the subcommittees, Ministries, LNGG, researchers or individual specialists. The LNRA, with support of LNGG, facilitates the LNMIC with a Geographic Information System (GIS) with a detailed photographic coverage of the Ramsar Site, the riparian boundary and the cadastral map linked to a database with details of the landowners.

The LNGG sub-commissioned a Hydrological Status Report. This report gives a fairly complete overview of water related issues, data availability, and advice on water resources management issues and policies (Rural Focus, 2002). Also a user-friendly version of the Water Balance Model of the lake (ITC, 1999) has been prepared and as such is now in local ownership. A regular Newsletter informs interested parties on news, progress, etc.

### 4.2 Reduction of Lake Stresses

The reduction of lake stresses is taken very seriously and is one of the key duties of the LNMIC. A lot of credit goes to LNGG and some of the large farms. Members of the LNGG consider that it is very important for them that the profit level of the well-managed farms is sufficient to make social and environmental investments.

Farms are implementing or experimenting with new technologies and management practices:

- Hydroponics - closed circulation systems using the locally available pumice as substratum
- The use of coco-peat and compost to improve soil characteristics
- Biological pest control and biodegradable pesticides
- Artificial wetlands for natural wastewater treatment
- Storage of roof runoff from greenhouses
- Sophisticated irrigation systems with soil tension meters and the latest irrigation technology
- The use of geothermal steam: for energy for heating greenhouses during the night, for enhanced plant growth using $CO_2$ and $H_2S$, and for sterilising crops and the growth medium without the need for fumigation.
- Monitoring water abstractions.
- A shift from open field crops to shaded growth, or greenhouses, thus reducing evaporation losses
- High temperature incineration of dangerous wastes
- Plastic recycling
- Multiple use of crops: baby corn for export, the stems/leaves as fodder
- Reducing area under cultivation while intensifying output per area
- Hospitals, schools, housing, social clubs for the employees.

These large innovative pioneer farms play an important role in showing the other farms the possibilities and advantages of these innovations. Technical innovation may serve an economic as well as an environmental purpose. The extra capital investments needed for hydroponics are earned back by higher productivities, no fumigation and lower agrochemical inputs in a very short period.

### Other Interventions to Reduce the Stress on the Lake

Salvinia has been on the lake since 1962 and by the early 1970s it had become a major ecological problem as it covered a large portion of the lake. After chemical control failed, a

biological control agent *Cyrtobagus salviniae*, a host-specific insect, was introduced and by the early 1990's had effectively reduced the Salvinia cover to insignificant levels. Water hyacinth was noted on the lake in 1988, but the conditions on the lake are not conducive to its rapid spread. Two host-specific biological control agents, *Neochetina bruchii* and *N. eichhornia,* have been introduced and been effective in containing the weed.

Naivasha Municipal Council is in the process, with German and Japanese assistance, to reduce the nutrient load on the lake by upgrading the sewage network and treatment plant.

KenGen is injecting the condensed steam back into the geothermal reservoir.

The Ministry of Water Development & Management has carried out a detailed water abstraction point survey, has stationed an hydrologist and a Water Bailiff in Naivasha to monitor resources and demand, is training a water police force to prosecute illegal abstractors, is actively supporting hydrologic and environmental research, and has upgraded the monitoring network.

The Fisheries Department and the Kenya Marine and Fisheries Research Institute now actively monitor fish stocks, prosecute poachers, and manage the stock by periodic fishing bans. The licensed fishermen themselves enforce the closed fishing seasons.

The LNMIC/LNRA and LNGG have been engaged in the following activities:

- Preservation of the riparian (shoreline) strip
- Promoting use of safe, degradable pesticides
- Enhanced (collaborative) fishery management
- Control of water uptake
- Minimising fertiliser use
- Preventing the introduction of alien species
- Proper urban planning and development
- Promoting sustainable tourism
- Monitoring of resource status and development activities
- Forest conservation, erosion control, watershed management
- Environmental Impact Assessment and Environmental Audits

### 4.3 Environmental Status

Overall the lake is still in a fairly healthy state. The spatial and temporal dynamics of the water quality parameters and the unknown details of historic data render the detection of trends difficult.

The main stresses on the lake are summarised as:

- Water abstraction
- Agrochemical and sewage pollution
- Destruction of riparian habitat (papyrus)
- Over fishing
- Erosion / siltation

Regarding the abstraction and pollution of the lake an ongoing discussion is the relative contribution of the floricultural industry including its labour force, versus the rest of the basin.

The recent introduction of sophisticated irrigation systems and better irrigation management has certainly led to a reduction in water use. This is (partly) offset by an increase of the area under irrigation for flowers and horticulture. The basin wide abstractions have caused a drawdown of the mean lake level of some 2.5 meters.

**Figure 12: Basin wide abstractions effect on the mean lake level**

Due to the physical conditions around lake Naivasha the risk of agrochemicals ending up in the lake is rather limited. The change to environmentally-friendlier pest control and better irrigation management certainly has a positive effect on the water quality of the lake. The contribution of the hinterlands is likely to be higher than the contribution of the farms around the lake. To reduce the sediment and the pollution loads from the upper catchment a lot of work has to be carried out on educating farmers in watershed conservation techniques and IPM (integrated pest management). Very little has been carried out so far, but WWF will start a project in the upper catchment. The water quality parameters of lake Naivasha are still at an acceptable level.

The improper use of riparian land is being reduced. Transgressors of the riparian boundary have been summoned to stop their activities. In one part of the lake papyrus burning remains a problem.

Overfishing has been a major concern lately. A ban on fishing has already been issued twice in the last 2 years, and therefore the fish stock is assumed likely to recover.

The siltation of the lake has 3 sources: the sediment inflow through the main rivers, the semi-arid area around the lake with flash floods, and atmospheric deposition. In some areas south of the lake wind erosion is a serious problem due to overgrazing and improper land management; part of the wind-blown material is deposited in the lake. So far, there is no evidence that the lake is seriously threatened by siltation.

## 4.4 Enabling Environment

### The LNMIC and LNRA

The lake management institution (LNMIC) is operational. It is the result of a 10 year long process of lobbying, networking, awareness and consensus building, and individuals effort without the assistance of a "financed project". The institution is likely to be sustainable given the fact that it strongly linked to an organisation (LNRA) that was founded more than 70 years ago. However, the financial situation of the LNRA and LNMIC is poor, given the fact that no structural support exists, and the memberships fees of the 140 members are not set high enough to cover the ambitions of the organisation. The LNMIC is only weakly supported by a team of professionals who advise on developments and threats, by collecting and analysing data. As a result the lake management is rather ad-hoc and not based on in-depth analysis of the system.

The main stakeholders seem to be firmly embedded in both LNRA and LNMIC. However, among the average Kenyan (Wananchi) the organisation still has the perception of a "white" and elite club of conservationists and big businesses. The inclusion of the main non-represented stakeholders like the Maasai pastoralists, the upper-catchment population, and the workers and employees of the farms, would be necessary to introduce these other stakeholders' needs and concerns, and thus change this image. Most likely the WWF will start with a project in the upper-catchment soon and through this project that part of the population may get a voice in the process.

Better relations with the press could also help to change the perceptions. It is noticeable that the stories always address same issues in a negative way: the floricultural industry emptying and poisoning the lake, causing low fish stocks and underpaying their labour force.

Another negative image of LNMIC is that the meetings are not public and the records are confidential. The Newsletter of the LNRA only vaguely covers the real management problems the committee is facing and usually address lighter issues like a new bird species that has been seen or the arrival of a new staff member in one of the Institutes.
It would be positive if the management process, their goals, success stories and failures, would be more effectively communicated to the general public.

**The Management Plan**

The main weakness of the Management Plan and also the new Water Act is that it does not quantify sustainability and define sustainable abstractions. The Management Plan stresses the importance of an accurate water balance. The water balance model is accurate enough for management purposes. However, it cannot answer the question of what would be the sustainable abstraction of the lake. Every abstraction from the basin will result in a lowering of the mean water level in the lake. How much drawdown is socially, economically and ecologically acceptable is an economic and political, rather than a hydrological question.

**Policy Context and Monitoring**

The new Government of Kenya, in office since the beginning of 2003, seems to take water issues seriously. The new laws on water and environment provide a good framework for Integrated Water Resources Management. The two new institutions, the National Environmental Management Authority (NEMA) and the soon-to-be Water Management Authorities (WMAs) should have close links to the LNMIC, something that is not yet the case. For many years the LNMIC has asked to be gazetted as a member of the Water Apportionment Board, so far without success.

Once the WMA is in place for the Lake Naivasha basin it is likely that the water users will pay for their abstractions. These funds could lift the management of the lake to a higher level.
Due to cooperation between the government, LNRA/LNGG, and research institutes, the lake is reasonably well monitored. The monitoring situation is certainly much better than in the rest of Kenya. However, the monitoring system is not systematic and structural. Improvements are necessary; besides, the technical aspects of Water Resources Management are a costly affair. At present collection of water data is carried out by MoWD&M and research institutes.

The formal policy of the Government regarding data is that the user pays. Notwithstanding that data collection is expensive, selling it for too high a price will cause the data not to be

used at all. The official price of the hydro-meteorological data set is some $50,000, resulting in the data not being optimally used.

**Research and Data for the Lake Basin**

The amount of data and research on the basin is rather overwhelming. The lake levels have been regularly monitored since 1909 and a few older observations exist. The rainfall for Naivasha town is available since the beginning of the 20th century. The area is well covered with rainfall stations (65 of which 35 are operational). Other climatic variables such as pan evaporation, radiation, wind speed, temperature etc, are also available.

The discharge records of the Malewa river (main inflow) start in 1932. Several upper basin discharge stations monitor flow. Hundreds of rain, surface, lake and groundwater samples have been taken and analysed for chemical, biochemical, suspended sediments and isotopic composition. The oldest lake water analysis dates back to 1923. The bathymetry of the lake has been carried out in 1923, 1958, 1983, 1991, 1997 and 2001. An aerial survey was carried out for the first time in 1948 and several times after. A series of satellite images starting in 1976 shows the land cover changes and land use developments in the basin. The geology has been mapped out in detail for the geothermal projects. Some 80 deep (>1000 metre) wells have been drilled in the geothermal areas. Around the lake many wells have been drilled giving information on the shallow hydrogeological conditions and groundwater quality.

Detailed inventories exist on water abstraction points and water consumption. Researchers have collected data on vegetation cover, biodiversity, aquatic ecology and fish stocks.

The early research was primarily carried out by the colonial administration but from 1960 onwards the lake has attracted a steady stream of researchers who produced 100's of articles, Master and PhD thesis, reports and posters.

The Ministry of Water Development and Management (MoWD&M), Kenya Wildlife Services (KWS), Kenya Marine and Fisheries Research Institute (KMFRI), KENGEN, LNRA, and Kenyan and foreign universities are actively involved in research on the lake and there is in general a good spirit of cooperation and data sharing.

Research is mainly sponsored by Earthwatch, Shell, Kenyan Ministries and Institutes and local farms.

**World Lake Vision**

Finally, an attempt to measure the performance of the lake management in the light of the World Lake Vision.

1. *Harmonious relationship between human needs and nature is essential for the sustainable use of lakes.*
The stresses on the lake and its basin are large, especially abstraction. At this moment it is difficult to judge whether the lake management will control the situation, or the economic interests are so strong that unsustainable exploitation occurs.

2. *A Lake Basin is a logical starting point for planning and management actions for sustainable lake use*.

The LNMIC has only a mandate in the Ramsar site, the lake and its direct surroundings. However, it seems that the LNMIC is currently adopting a more holistic IWRM/ Lake Vision approach. However, Government organisations are organised according to administrative boundaries that dissect the lake basin.

3. *A long-term preventive approach directed to preventing the causes of lake degradation is essential.*
The process described in this brief was a reaction to ongoing activities, and therefore *sensu stricto*, not preventive. However, the LNMIC attempts to apply the precautionary principle. Certain reactions to stresses, especially those related to groundwater, require very long planning horizons (20 – 30 years). It is not certain to what extent LNMIC realizes this.

*4. Policy development and decision making for lake management should be based on sound science and the best available information.*
As already discussed, the integration and utilisation of scientific information remains a problem. Funds to bring the available data and knowledge to "local ownership" and carry out more research are not available but are being sought. Because a professional level supporting the management level is lacking, the available information is not adequately used.

5. *The management of lakes for their sustainable use requires the resolution of conflict among competing users, taking into account the needs of present and future generations, and of nature.*
The LNRA has achieved a lot, through an ongoing process of conflict resolution. The most important achievement certainly is that now the commercial growers (LNGG) support the management plan. Other conflicts remain, like the wish of Nakuru town to draw more water from the basin (inter-basin transfer).

6. *Citizens and other stakeholders should be encouraged to participate meaningfully in identifying and resolving critical lake problems*.
This is a continuing process around lake Naivasha. But more stakeholders need to be involved and represented in the decision-making and management, like in the LNMIC.

7. *Good governance, based on fairness, transparency and empowerment of all stakeholders, is essential for sustainable lake use.*
In this final item there is room for improvement. Not all stakeholders are involved and the decision making process is not transparent. The Management meetings are not public and the records confidential. No formal mechanism exits to inform the citizen on decisions and policy.

## 5. Lessons Learned and Recommended Initiatives

One does necessarily need a project in order to introduce lake management. A few committed individuals may initiate the process and keep it going. Moreover, a management vacuum amongst the different officially-responsible authorities has created the opportunities for local (management) initiatives.

The presence of a healthy economy as the regional context seems to have influenced the protection of the lake in a positive way. The capital needed to introduce environmentally-friendly water conservation measures is available. Due to the large capital investments in horticulture, which are relatively tied to the Kenyan economy, there is a strong interest in

sustainability from the private commercial sector. Technically-innovative production techniques and systems are both economically and environmentally interesting.

Ramsar status/ designation has also helped to enhance awareness on the need to conserve the natural resources.

In many other project-supported lake management programmes, large amounts of money were spent on data collection and analysis. This may be carried out more cost-effectively if the lake managers team up with Ministries and knowledge institutes. However, dissemination of scientific information and the use of such information by the management remains problematic.

Although, research can solve many technical issues concerned with data interpretation and some of the institutional conflicts, the underlying conflicts of interest will still remain. Community participation is therefore a vital element particularly for a lake like Naivasha where most impacts emanate directly from competition over the use of resources, and human settlements. In general, there is need to entrench the policy on community involvement into resource management.

Consensus building is essential in such community-driven conservation programmes, so that all stakeholders can be moving in tandem in the same direction. At the same time, consensus building takes a long time and can often significantly slow the management processes needed to deal with urgent problems. However, even acknowledging the need for community participation and consensus building, the enforcement of the new national laws incorporating modern environmental and water management concepts is an absolute requirement.

Funding remains a major challenge for community groups interested in wetland / lake basin conservation. The fact that there are a considerable number of wealthy enterprises around the lake and dependent on the sustainability of its resources, may negatively affect the willingness of donor agencies to finance a project.

Having an accepted and ratified Management Plan and an Implementation Committee is not enough to carry out the complex lake management. The LNMIC is composed of rather senior representatives of various stakeholders spending only limited time on their duties. The organisational layer below the Committee is not present. There is no operational team of professionals in the fields of water resources management, natural resources management, regional planning, and aquatic ecology engaged full-time in collecting and analysing data to support the management process, set priorities and measure results. This is an important omission.

Structural and strategic discussions on what is sustainability, on how the water should be allocated between different farms and sectors, on how to optimise economic output and at the same time conserve the environment, how upstream-downstream relations could involve the population of the upper catchment, or, what do if a series of serious drought years occurs, are issues that seem to be too complex and too political to be yet addressed by the LNMIC.

The main author learned the following lessons during involvement in research over many years in Lake Naivasha:

- Willingness to cooperate, trust, and share data and resources are more important than signing MoUs and agreements
- Pooling resources is cost-effective

- Dissemination, communication of research results to the stakeholders and decision-makers is very difficult, and therefore old myths concerning the lake system turn out to be persistent.

**Recommended Initiatives**

In spite of the official nature of the Management Plan it is still necessary to institutionalise the Plan and its Implementation Committee under the Environmental Management and Co-ordination Act (1999). This will enable the Implementation Committee decisions to carry more weight for improved management effectiveness, and in the final analysis, if the principle of voluntarily adopted practices fails, to allow them to enforce their decisions through the established legal mechanisms.

It is essential that the LNMIC becomes a full member of the Water Apportionment Board.

One of the priority activities should be the introduction of water charges. The revenues should be used for basin management and not seen simply as an extra income for the government. The pricing mechanism should focus on lake management: minimizing environmental damage while maximizing social and economic output and an equitable distribution of the resources. Issuing of (new) abstraction permits should also consider the large differences in economic return of different irrigated crops. Tradable water rights may be considered as a future option.
Introduction of water pricing also encompasses a danger. The control over the revenues may introduce power struggles by the many organisations claiming a stake in the lake management, paralysing the progress in integrated lake management towards sustainable goals.

Ideally, the whole process of data collection, updating the databases, analysis and interpretation, the use of the simulation models and the GIS, should be transferred from the research institutes to local ownership. A Lake Naivasha Management Centre, where officials of different government institutions and scientists work together and share equipment, data and knowledge, to the benefit of the LNMIC could be a new goal. The revenues of the water charges could be used to establish and maintain such a centre.
Establishing such a Centre would mean a considerable investment in capacity building and education.

Over the last 30 years a tremendous amount of data has been collected by the government and Kenyan and foreign researchers. A large part of this information is available at the Documentation Centre of the LNRA. However, given the variety of topics and the amount of material, it is impossible to overview or appreciate its full content. The LNMIC could be assisted in this task if a Scientific Committee would be attached to LNMIC to advise on relevant policy matters. This Committee could be composed of researchers who seriously study the lake and a few experts in Lake and Wetlands Management and/or IWRM.

**Epilogue.**

Around lake Naivasha we find a unique set of conditions.

- A highly profitable booming horti- and flori-cultural industry depending on a protected lake/wetlands.

- A well-established and strong stakeholder organisation. An accepted Management Plan and an Implementation Committee.
- An abundance of scientific research on various aspects of the ecosystem and the socio-economy.
- An, in general, environmentally conscious stakeholder community and enterprises that do not want to put their future at stake by overexploiting the lake.
- A positive change in attitude by the government towards natural resources management.
- The large farms not being opposed against water charges as long the process is transparent and (part of) the revenues are invested in the lake basin.
- Cooperation between LNRA/LNMIC, LNGG, Government Institutions and research institutes.
- The lake is a Ramsar site.
- The lake and its management receive a lot of national and international interest

All conditions are present for Lake Naivasha to become one of the first basins in Africa with a sustainably managed lake according to Lake Vision and IWRM principles.
The present actors in the management process deserve support to take the last institutional, technical and financial hurdles.

## 6. References.

LNRA, (1993). A three phase environmental impact study of recent development around lake Naivasha

LNRA,(1995,1999). Lake Naivasha Management Plan

LNGG, (2002), Hydrological Status Report (prepared by Rural Focus and ITC)

Harper, et al, 2003. Lake Naivasha, Kenya. (21 papers submitted at the conference Science and sustainable management of shallow tropical waters),Hydrobiologia 488. Kluwer, Netherlands

Enniskillen (2002). The Lake Naivasha Management Plan – consensus building to conserve an international gem. Hydrobiologia 488 (Dev. Hydrobiol. 168): 123-128.

Kitaka, N. (2000). Phosphorus Supply to a Shallow Tropical Lake and its Consequences - Lake Naivasha, Kenya. PhD Thesis, University of Leicester.

ITC, 1997-2003. MSc theses addressing water, environment, soils, socio-economics of the Lake Naivasha Basin. (Available on CD or at www.itc.nl/library)

Harper, D.M., K.M. Mavuti and S.M. Muchiri (1990). Ecology and management of Lake Naivasha, Kenya, in relation to climatic change, alien species' introductions, and agricultural development. Environmental Conservation Vol. 17, No. 4.

Clarke, M.C.G. ,et al, (1990). Geological, vulcanological and hydrogeological controls on the occurrence of geothermal activity in the area surrounding Lake Naivasha, Kenya. Ministry of Energy, Kenya.

Åse, L.E. ,et al, 1986. Studies of Lake Naivasha, Kenya, and its drainage area. Stockholms Universitete naturgeografiska Institutionen 106 91 Stockholm.

Gitahi, S.M., D.M. Harper, S.M. Muchiri, M.P. Tole and R. N. Ng'ang'a (2002). Organochlorine and organocphosphorus pesticide concentrations in water, sediment, and selected organisms in Lake Naivasha (Kenya). *Hydrobiologia* 488 (Dev. Hydrobiol. 168).

Sombroek, et al (1980). Soil map of Kenya.

Smart Andrew C, (2003).Feeding of the exotic Louisiana red swamp crayfish, Procambarus clarkii (Crustacea, Decapoda), in an African tropical lake: Lake Naivasha, Kenya. Hydrobiologia 488 (1/3) p.129-142

Britton, R (2002). Investigations into the fish population of Lake Naivasha, Earthwatch Project. (http://salmonriver.com/sort/fishnaivasha.html)