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Review on *riverwater* ***resource monitoring*** and ***allocation planning*** in the Lake Naivasha Basin, Kenya

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Abstract

This research aims to clarify how the river water balance and abstraction regulations of the Lake Naivasha basin Water Allocation Plan (WAP), are in line with the real situation and how it potentially impacts river water abstractors and the successful implementation of the WAP itself. This is done through comparison of the WAP Flow Duration Curves (FDCs) with newly composed FDCs of recent years. The results show that if the abstraction regulations would in theory already have been applied in the years 2005-2009 river abstractions for domestic and irrigation purposes would have been restricted respectively up to 84% and 89% of the time in a year compared to values of respectively 20% and 5% as indicated for an average year by the WAP. Although it is recognized that the research methods, same as used for the WAP itself, are subject to many uncertainties, the direction of impact is clear. The current water resource monitoring methods do not give reliable outcomes on which proper water allocation planning can be based. The question therefore to be asked and thought over by policy makers is if the current model used for river water allocation planning is suitable for doing this properly.

Keywords: *Water Allocation Plan, river water resource monitoring, abstraction regulations, environmental flow, Lake Naivasha basin, Kenya*

Preface

"…Choosing to save a river is more often an act of passion than of careful calculation…"

As David Bolling said in his book How to Save a River (1994). In the case of the Lake Naivasha basin there are both rivers and a lake in need of passionate action to improve the riverine and lake ecosystems, and water supply functions towards livelihoods and commercial activities. This bachelor thesis research report, about the rivers in the Lake Naivasha basin, is nevertheless full of calculations; whether they are careful enough I leave for the opinion of the reader. This research is a follow up on an internship done in 2010 in the Lake Naivasha basin in Kenya, as the internship research was all about water abstraction, this research is more about water availability in the rivers. The aim of this report is to give interested people a better insight how the river water balance and abstraction regulations in the recently and officially launched Water Allocation Plan are in line with the current reality and how they potentially impact river water abstractors.

I would like to thank the people that cooperated in the fieldwork in the middle of 2010. Special thanks to WRMA for the cooperation and sharing of data, and to Dominic Wambua, Jackline Muturi and Kimnje Tito for the great time together in the field and in the river! I would also like to thank SNV for the logistic support. Further thanks to Gert Jan Veldwisch for the clear supervision and his infinite patience in waiting for the results.

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Acronyms

CMS	Catchment Management Strategy
LaNaWRUA	Lake Naivasha Water Resource Users Association
LANBUWRUA	Lake Naivasha Basin Umbrella Water Resource Users Association
MWI	Ministry of Water and Irrigation
RGS	Regular Gauging Station
SCMP	Sub-Catchment Management Plan
SNV	SNV Netherlands Development Organisation
SRO	Sub-Regional Office
WAP	Water Allocation Plan
WAS	Water Abstraction Survey
WRMA	Water Resource Management Authority
WRUA	Water Resource User Association
WSTF	Water Service Trust Fund
WWF	World Wide Fund for Nature

1 Introduction

The Lake Naivasha basin, situated in the African Eastern Rift Valley floor, contains the second-largest freshwater lake in Kenya, which is an internationally renowned Ramsar site. Unlike most other Ramsar sites in Kenya, Lake Naivasha is also feeding a large horticultural industry with its water resources (WWF, 2011). In and around the lake and it's feeding rivers the ecosystem, livelihoods and commercial activities are all strongly relying on an adequate water supply. The lake has been and still is under intensive investigation and debate on how the lake's environmental quality and requirements can be maintained whilst still supporting the livelihoods and commercial activities in the basin with an adequate water supply (WWF, 2011) (WAP, 2010) (Rural Focus, 2006) (Becht, Odada, & Higgins, 2003) (Becht & Harper, 2002).

An important step in this investigation and debate is the development of a Water Allocation Plan (WAP), which was initiated back in 2004 (Rural Focus, 2006) by stakeholders around the lake and the Water Resource Management Authority (WRMA). A consultancy company financed by commercial irrigators has been doing thorough research on the social and technical aspects of the water resource system in the Lake Naivasha basin; a revised and "final" version of the WAP was finished in September 2010 (WAP, 2010). The WAP concedes that one of the challenges was insufficient and up to date information on the availability and use of water in the basin as a whole. It proposes basin-wide abstraction surveys and hydrological, water use efficiency and demand management studies. The water abstraction survey (Jong, 2011) was finished in June 2010 and gives proper indications on abstraction volumes from the different water resources. The water abstraction survey also indicates that the main challenge facing WRMA and the Water Resource Users Associations (WRUAs) in the Naivasha basin is bringing water users into legal compliance to the water legislative framework as stipulated by the Ministry of Water and Irrigation (MWI) and WRMA (Water Act, 2002) (WRM Rules, 2007). The current situation is that many water users do not have a permit to abstract water, and if they have, compliance to the permit conditions in terms of over-abstraction or over-allocation is often lacking (Jong, 2011). The aim of the WAP is to act as a tool to improve on this, and to finally be able as WRMA and the WRUAs to better manage the water resources on the long term as well as in water scarce periods wherein water use conflicts are likely to arise because of competing claims between the ecosystem, livelihoods and commercial activities (WAP, 2010).

1.1 Topic delineation

The focus of this report is on river water allocation planning as described by the WAP, with putting most emphasizes on allocation planning during water scarce periods and on the methods and data used in developing these river water allocation planning rules.

The river water balance in the WAP (ANNEX I), which provides boundaries for water allocation that assist in protecting the Environmental Reserve from over allocation of the resource, builds on historical water discharge data (Rural Focus, 2006); the importance of accurate, reliable and up-to-date information on river water discharges is high for policy makers and the water users involved, because the available water for permitting and regulation of water abstraction is based on certain flow thresholds established from naturalised Flow Duration Curves (FDCs). For example the WAP prescribes that below a certain river discharge, no abstraction for irrigation is allowed anymore, with even lower river discharges abstraction for domestic purposes is also restricted. The current water balance in the WAP is based on naturalized stream flow data from ±1940 – 1980. My hypothesis is that the probability on certain river water discharges has changed, with higher peak flows and longer periods of low flow, compared to the 1940 - 1980 timeframe, mainly because of land use changes, wherein indigenous forest and open woodland have been converted into rain-fed smallholdings. Also through population growth and immigration more buildings and roads have emerged in the Naivasha catchment area, all leading to a quicker runoff of rainwater (WWF, 2011) (Were, 2008) (Time line land use images can be found in ANNEX III). Also climate change may have contributed to a shift in the probability of stream flow amounts. This report aims to examine if the probability of stream flow amounts has changed compared to the period of 1940 – 1980, and if so what the consequences are for the current and future water allocation planning in the Lake Naivasha basin.

The consequence of the above hypothesis in relation to the WAP and the river water users is for example that abstraction for irrigation will be restricted more severe than the WAP indicates. The WAP indicates a probability of 80% of the time of the year that they are allowed to abstract water, but with longer periods of low discharge this probability of 80% can decrease significantly.

1.2 Research background

1.2.1 Political

The political background from which the WAP originated is both in a change in the institutional structure (Olum, 2008) and in the adoption of a new Water Act in 2002 (Water Act, 2002). In these water reforms, some important changes are that the management boundaries are based on drainage boundaries instead of administrational boundaries. WRUAs are formed to create platforms of stakeholder participation, and to improve implementation and enforcement of the water legislative framework at field level. Another important change is that water users need to pay for the amount of water abstracted. The most important change in relation to the research topic is the allocation of water to the environment (Water Act, 2002) (WRM Rules, 2007). The Guidelines for Water Allocation (WRMA, 2009) defines the environmental reserve for streams and rivers as follows: "The reserve quantity shall not be less than the flow value that is exceeded 95% of the time as measured by a naturalised flow duration curve at any point along the watercourse".

The underlying justification for allocation of water to the reserve is stated as follows in the WAP: "The reserve may not be violated in terms of either quantity or quality or both. This primarily affects those that rely directly on the water resource for their water supply. Violation of the reserve can be considered as a violation of someone's basic human right." (WAP, 2010).

Furthermore it is also stated that the reserve commands the highest priority in terms of water allocation. This implies that in the context of a severe drought even domestic water supplies may need to be rationed. According to this a correct quantification of the reserve flow is very important, on one hand it states that the reserve is a human right, but on the other hand it states that also domestic supply can be restricted to protect the reserve. With reserve flow figures based on the old flow data huge differences in legal water availability between up and downstream users in the Lake Naivasha system are suspect to happen.

1.2.2 Cross disciplinary research

The research consists mainly out of technical analysis on the probability of river water flows, but the political and social disciplines are strongly linked. The current dominant approach, to water allocation planning comes from the political sub-system and the effects of decision making are being experienced in the social system. In fact the technical discipline is only to support the political discipline with information on resource availability. What to do with this information is a fully political question (Rural Focus, 2006). At this point the transfer of knowledge between disciplines becomes very interesting, politicians are putting their trust in a technical approach towards water allocation. This has different consequences for the different water abstractor groups in the Lake Naivasha basin.

I recognize the cross-disciplinary character of the WAP regulations and the proposed research. Despite this recognition, the results from the research as presented in this report are mainly of a technical character. Due to limitation in time it was not possible to include much of the social and political issues related to the research topic. The reports can serve as an input for more cross-disciplinary research and as input for discussions about water allocation planning in the political and social disciplines.

1.3 Problem Statement

Pulling the introduction and research background together, the following concise problem statement is composed.

"The actual impact of river water abstraction regulations during low flow conditions as laid out in the Lake Naivasha basin Water Allocation Plan, on "legal" water availability for the different users is currently unknown, but seems to be more severe than the Water Allocation Plan indicates. The extent of this negative impact is not known. If the extent is significant, then it will have negative consequences for both commercial and domestic abstractors as well as for successful implementation and enforcement of the Water Allocation Plan."

1.4 Objectives

The purpose of the research is to look if the hypothesis that river flows have significantly changed in relation to the WAP water balance is true, and what the extent of impact is of this change on the river water abstractors. Furthermore the output of the research can make WRMA and the concerned water users in the catchment aware of the implications of the current WAP abstraction regulations during low flows.

1.5 Research Questions

1.5.1 Main research question

"What is the actual impact of the current WAP river abstraction regulations during low flow on the reliability of water supply, for river water abstractors in the Lake Naivasha basin, Kenya".

1.5.2 Sub questions

1. For which Regular Gauging Stations (RGS) in the Lake Naivasha basin are the gauge reading data sets sufficient complete and reliable to execute the water resource availability analysis?

2. What are the rating curve equations for the regular gauging stations selected in sub question 1?

3. What are the Flow Duration Curves (FDC) at the selected RGS's and what is the extent of the yearly variance in the FDCs?

4. How do the FDCs used in the WAP differ from the newly composed FDCs?

5. What is the impact on the reliability of water supply, when comparing the newly composed FDCs with the WAP abstraction regulations?

1.6 General background information

1.6.1 Study Area

The Lake Naivasha basin or catchment is a sub-catchment within the Rift valley in Kenya (Figure 1). The Lake Naivasha basin covers an area of approximately 3400 km^2. With altitudes between 3080 m.a.s.l. in the upper catchment and ± 1887 m.a.s.l. at lake level.

Three types of landscapes can be identified in the Naivasha catchment: the Kinangop plateau, the Mau escarpment, and the Rift Valley floor (ANNEX IV).

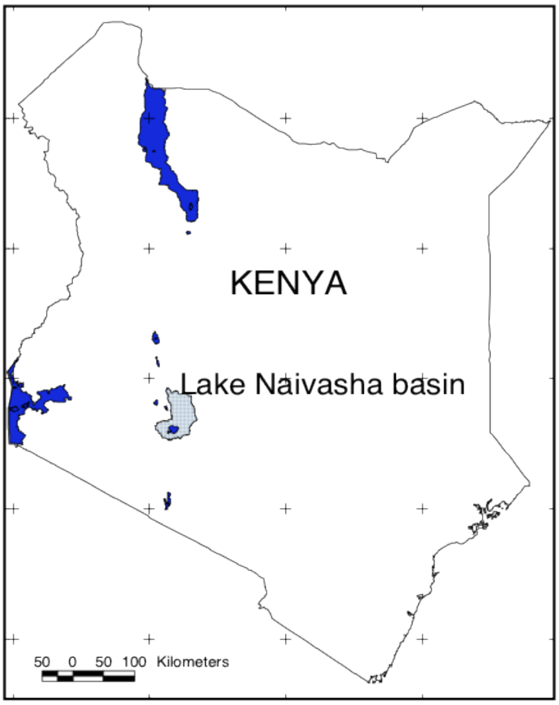

Figure 1: Lake Naivasha basin in Kenya *(source: WWF Naivasha)*

1.6.2 Climate

The climate is humid to sub-humid in the highlands and semi-arid in the Rift Valley. The mean monthly maximum temperature ranges between 24.6°C to 28.3°C. And mean monthly minimum temperature between 6.8°C and 8.0°C. The average monthly temperature ranges between 15.9°C and 17.8°C. The monthly distribution of precipitation within the basin is governed by the movement of the Inter Tropical

Convergence Zone. This results in two rainy seasons (April-May and October-November). The other major factor determining rainfall is the topography and the direction of the prevailing trade winds, which result in orographic rainfall. In the case of Lake Naivasha, the Nyandarua mountain range (Abadares (ANNEX IV)) to the east of the lake captures most of the rainfall. The mean annual rainfall ranges from about 1350mm in the Nyandarua mountains / upper catchment to about 600mm in the rift floor / Naivasha town (Rural Focus, 2002).

1.6.3 Hydrology

Lake Naivasha is a freshwater lake with a mean surface area of approximately 140 km^2. The two main rivers draining the catchment and entering the lake from the north are the Malewa (drainage area 1,700 km^2), which accounts for ±80% of the surface inflow and the Gilgil (drainage area 420 km^2) contributing almost 90% of the remaining surface inflow. A third river named Karati is seasonal and flows for about two months during the wet season. A schematic drainage pattern of the Lake Naivasha basin can be found in ANNEX VI. River inflow and precipitation into the lake amounts to 85%, subsurface recharge amounts to the remaining 15% of the total inflow into the lake.

1.6.4 Water use

The water use in the area is largely defined by the land use within the catchment. The main land use within the catchment is agriculture (ANNEX III), which includes irrigated crop farming (horticulture, vegetables, fruits) around the lake (HQ image in ANNEX V) and mixed farming (wheat, maize, potatoes, beans and sunflowers) on the rain-fed slopes of the escarpment. Next to these irrigation purposes, water is also used for domestic purposes and geo-thermal activities. Major issues within the catchment in relation to water use include effects of climate change, degradation of catchment areas due to increased agricultural practices and declining river flows.

1.6.5 Institutional framework

The institutional framework as shown in Figure 2 is the situation from 2002 on, when the Water Act (2002) was gazetted. Before 2002 policy formulation and implementation fell both under the ministry (Olum, 2008). The Water Act (2002) separates water services and water resource management into two different institutional bodies as shown in Figure 2. WRMA as manager of the water resources is appointed with water allocation, catchment protection and conservation, water resource assessments and conservation, delineation of catchment areas, gazetting water protected areas, protection of wetlands, gazetting water schemes to be state and community owned, establishing Catchment Management Strategies (CMS) and the collection of water use and effluent discharge charges (WWF, 2011).

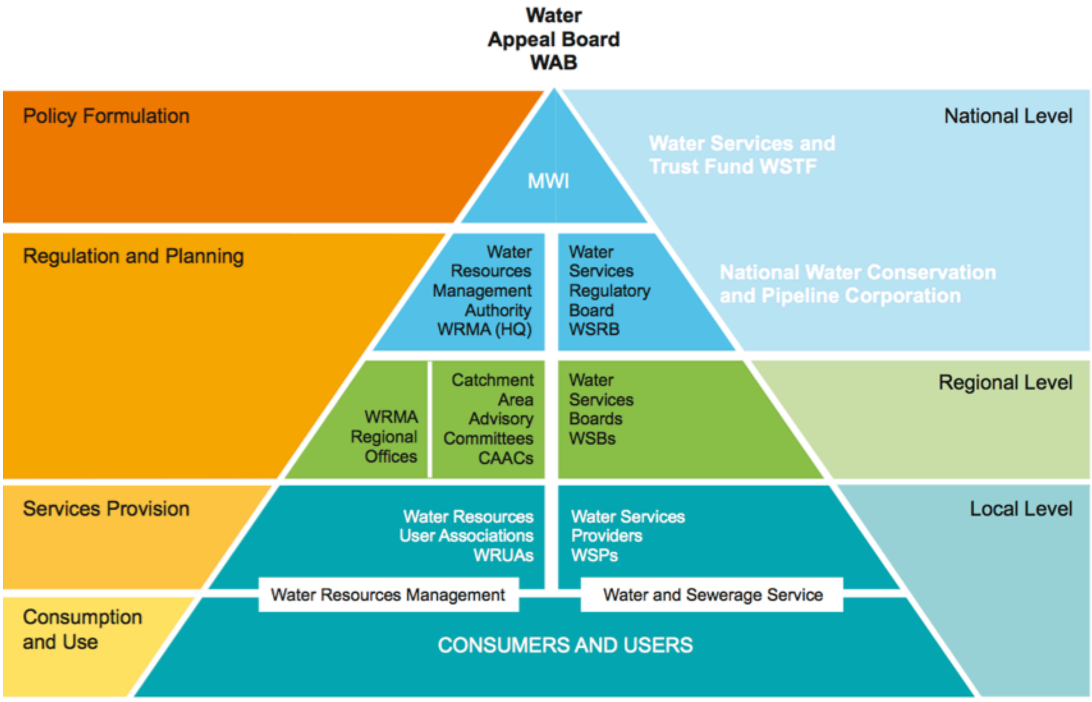

Figure 2: Institutional framework on water issues *(source: Olum, 2008)*

The sub-regional WRMA office for the Lake Naivasha basin is located in Naivasha town. And falls under the regional office of the Rift Valley catchment area located in Nakuru, which on its hand reports to the headquarters of WRMA in Nairobi. The WRMA regional offices are supported by catchment area advisory committees (CAAC), which are made out of a range of stakeholders within each catchment. The CAAC meets regularly to discuss water management issues in the catchment and to advise on water allocations and specific water permit applications (WWF, 2011). WRUAs are established under the hospice of WRMA to support WRMA in local management of the water resources and to enhance the local driven water management. All waters users (groups) should be represented as members of the WRUAs. A typical WRUA in Kenya manages the water resources of an area of 200 km2. A formal registration process is required before a WRUA can officially work together with WRMA. The WRUAs are intended to be involved in identification and registration of water users, assisting WRMA in monitoring water use, conflict resolution, and the co-operative management of water resources and it's riparian and catchment areas. A WRUA specific Sub-catchment management plan (SCMP) supports in this and enables the WRUA to apply for finances from the Water Services Trust Fund (WSTF). The Lake Naivasha basin contains 12 WRUAs with varying degrees of capacity (WWF, 2011).

2 Concepts and Theories

The Water Act (2002) has set out a framework for water allocation planning for commercial, livelihood and ecological purposes. In the Guidelines for Water Allocation (2009) the specific method used in Kenya are explained. This chapter introduces the theories and concepts behind water allocation planning. Furthermore this chapter elaborates how these concepts and theories are used in Kenya in relation to water allocation planning and how they will be used in this research.

2.1 The social-technical character of water management

Achterkamp (2009) talks about water management as a socio-technical phenomenon. And argues that the social-technical concept in irrigation water management as described by Mollinga (1997) and Bolding et al. (2000) can be extended to a catchment scale. In this sociotechnical approach the focus is on the interrelations between water, water technologies, water users, the resulting agro-ecologies and water networks. In terms of interdisciplinarity in this socio-technical approach the investigation of a water system requires insights into its technical, socio-economic, organizational and political elements (Achterkamp, 2009) (Mollinga, 1997). The complexity in a catchment water system is even increasing due to uncertainty on the long-term, putting this in the light of sustainable river and lake management wherein valid and reliable long term info is required which is often lacking, a special management approach is required to cope with the imperfect knowledge of the complex water systems. The old management approaches that viewed an ecosystem as a stable linear system with less variability are not sufficient to deal with the water- and related ecosystem complexity (Pollard, du Toit, & Mallory, 2009). Adaptive management is better suitable to deal with high complexities, because it has the ability to change management practices based on new insights and experiences. With adaptive management a systematic process that continuously improves on management policies and practices by learning on outcomes of earlier implemented management strategies (Pahl-Wostl, 2007). In adaptive management it is recognized that time and resources are insufficient to fully understand water management problems, but that it is required to take actions without this full understanding of the water system, to be able to address emerging problems such as, in the case of Lake Naivasha basin, the high pressure on the water resources and declining ecosystem quality.

2.2 Water Allocation Planning

2.2.1 Environmental flows

Environmental flows are volumes of water purposefully left in or released into rivers, lakes or reservoirs, to maintain or restore particular ecological values (Young, 2004). A concept for providing an ecologically sound water regime is required in this. In the case of a lake the water regime is known as the depth and in time variations in the depth of the lake. A change in depth changes the surface area, shoreline length and so the aquatic habitat of the lake, furthermore physical and chemical processes are also affected by the lake depth, which on their hand further affect the ecological conditions of the lake (Young, 2004). In the case of rivers the water regime is constructed out of the discharge and the variability of the discharge through time. The variations or changes in discharge impact the flow depths, flow velocities, wetted perimeter, which on their hand alter the nature and extent of the aquatic habitat in rivers, with inclusion of the physical and chemical processes (Young, 2004).

In a situation wherein a lake and rivers are connected the importance of the lake and river water regimes interact with each other. From the lake perspective this includes environmental constraints on: (environmental) releases or lake levels, downstream abstractions/diversions from lake releases, abstractions/diversions from contributory rivers or their connected groundwater's (Young, 2004). Temporal variability is known as an important aspect of environmental flows, usually as also in the Lake Naivasha basin case the environmental flows are like a water allocation, because of the volumetric flow consequence indicated as environmental flow requirement. Young (2004) indicates that there is a rarity in environmental flow allocation in lake basin management. It is a new concept in river basin management, in lake basin management it is clearly only just emerging. Next to this Young (2004) also indicates that for the Lake Naivasha basin case, compared to other lake basins, the institutional and legal framework is (potentially) strong, formalisation of water allocations is reasonable, water balance quantification is good and stakeholder involvement is strong. A weakness on the policy process in general mentioned by Young (2004) is that most of the time no investigation on specific environmental benefits of environmental flows is done. In the policy process the general reasoning is that over abstraction has the potential to harm the ecosystem and the related human well-being. The WAP is currently under implementation in the Lake Naivasha basin, the reserve flow regulations prescribe that in the rivers at least the flow that is equaled 95% of the time of the year according to a naturalized flow duration curve, should be left in the river as environmental flow. The concept of a flow duration curve will explained further one in this chapter.

2.2.2 Allocations for consumptive uses

Water allocation is the process of specifying or quantifying the volumes of water available for, or used by "consumptive uses". In lake basin management this refers to volumes of water used in the contributing catchment as well as volumes used or released from the lake itself. These consumptive uses include irrigation, industrial uses and domestic water supply. Lake basin management is both about land and water management, but the focus is often on the major water body / lake and it's functions towards (non-) consumptive uses. These functions are depending both on water quality and quantity, although for non-consumptive uses water quality is usually the limiting factor and for consumptive uses it is usually water quantity (Young, 2004). According to Dinar et al. (1997) the criteria for water allocation can be ranging from complete control by government to a mixture of market and government allocation. The most prominent forms of water allocation are; marginal cost pricing, user based allocation, water markets, and public water allocation. In Kenya water is allocated through a public (administrative) water allocation process. The criteria guiding on water allocation are prescribed by the responsible government institutions MWI and

WRMA in the Water Act (2002) and WRM Rules (2007) and specific for the Lake Naivasha basin in the WAP (2010).

2.2.3 Allocation principles in the Lake Naivasha basin

The Guidelines for Water Allocation (2009) and the WAP (2010) describe the allocation principles used in the Lake Naivasha basin. It states that the allocation of water from a water body should take into consideration four demands on water (Figure 3), namely:

1. The portion of the water resource required to meet ecological demands which forms part of the Reserve.
2. The portion required to meet basic human needs (BHNs) which forms the second part of the Reserve. Basic human needs have been quantified in the WRM Rules as 25 l/person/day.
3. The portion of water for which commitments have been made in international treaties and water transfers;
4. The portion of water that can be allocated to individual uses by means of a permit.

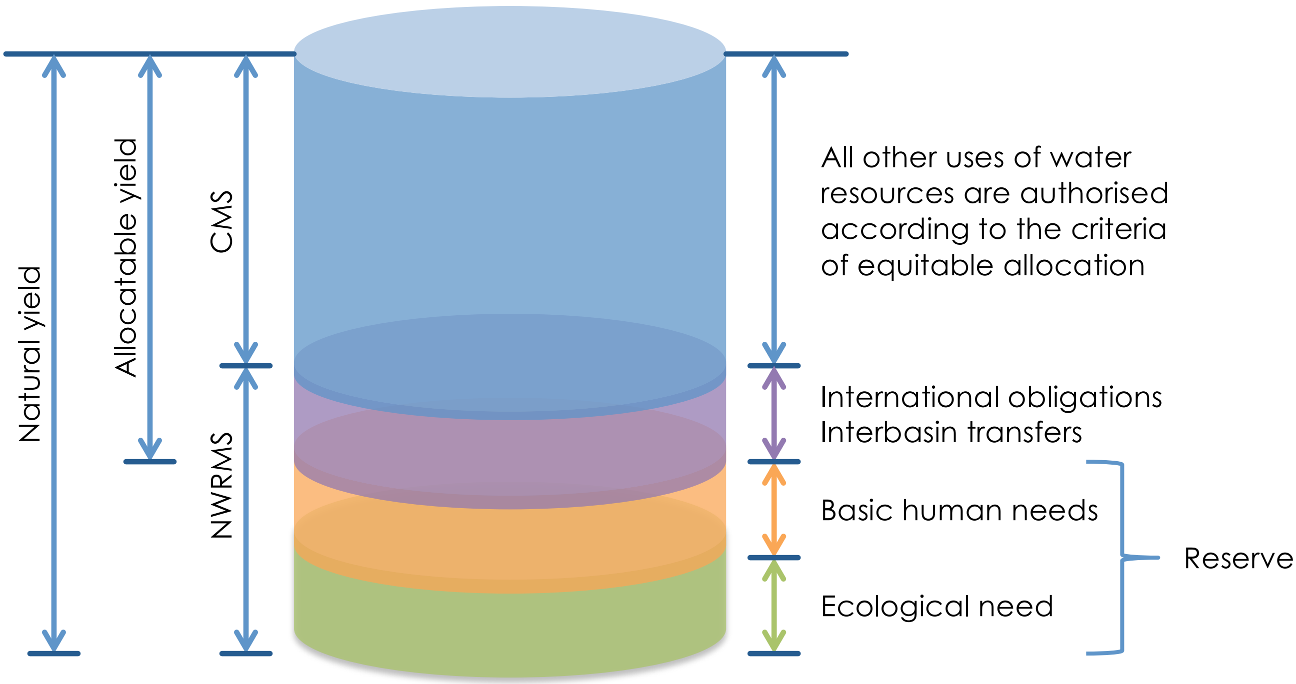

Figure 3: General considerations in water allocation (WRMA, 2009).

A more comprehensively description on the allocation principles used in the WAP can be found in ANNEX II. The main points of these principles are that the finite and valuable water resources in the Lake Naivasha basin are vulnerable to over-allocation, over-abstraction and degradation, which implies that there is a tangible risk to the environment, economy and social well being if the WAP is not complied with. The precautionary principle implies that preventive action is required even in the face of uncertainty, that the burden of proof can be shifted to the proponents of an activity, that alternatives to potential harmful actions need to be explored and that a provision for public participation in decision-making is required. Furthermore the principles state that the reserve commands the highest priority, and that in the context of a severe drought even domestic supplies may need to be rationed. Equity between environmental, livelihood and commercial benefits should be maintained although equity has often different meanings for different stakeholders. The WAP should minimise social and economic disruption, implementation of the WAP or future changes should allow for a transition period for stakeholders. Future revisions to the WAP are required because of changing situations and the current inadequacy of some information. This requires stakeholder participation in which negotiation and respect between different stakeholders and sufficient time and fora for discussion and negotiation should be arranged.

2.3 Water resource monitoring

The technical concepts on which the thresholds for the reserve flow, and water availability for consumptive uses as described above are based will be explained in this paragraph.

The method used in the Lake Naivasha basin to monitor river water resources is based on the empirical measured relationship between water height and discharge at a specific cross section in the river. This relationship is visualized in a rating curve line graph (Figure 4), in which the water height is plotted on the vertical-axis and the related discharge, obtained through field measurements at various discharge rates, on the horizontal-axis. This rating curve can also be expressed by a formula, namely;

$$Q = C(H_w - H_0)^n$$

In which:

In which:	Q	= Discharge in m^3/s
	C	= constant factor
	H_w	= Measured water height
	H_0	= Water level at which $Q = 0$
	n	= constant factor

With this formula the discharge at any given water height can be calculated. Most of the time the C and n constants are ranging the whole water height range with enough accuracy, but it is also possible that within certain water height ranges different values for the C and n constants are required for a correct calculation of the discharge. This depends on the shape of the cross section and what the vegetation cover and structures on the flood plains are. These C and n constants can also change over time as the cross section in the river may change over time.

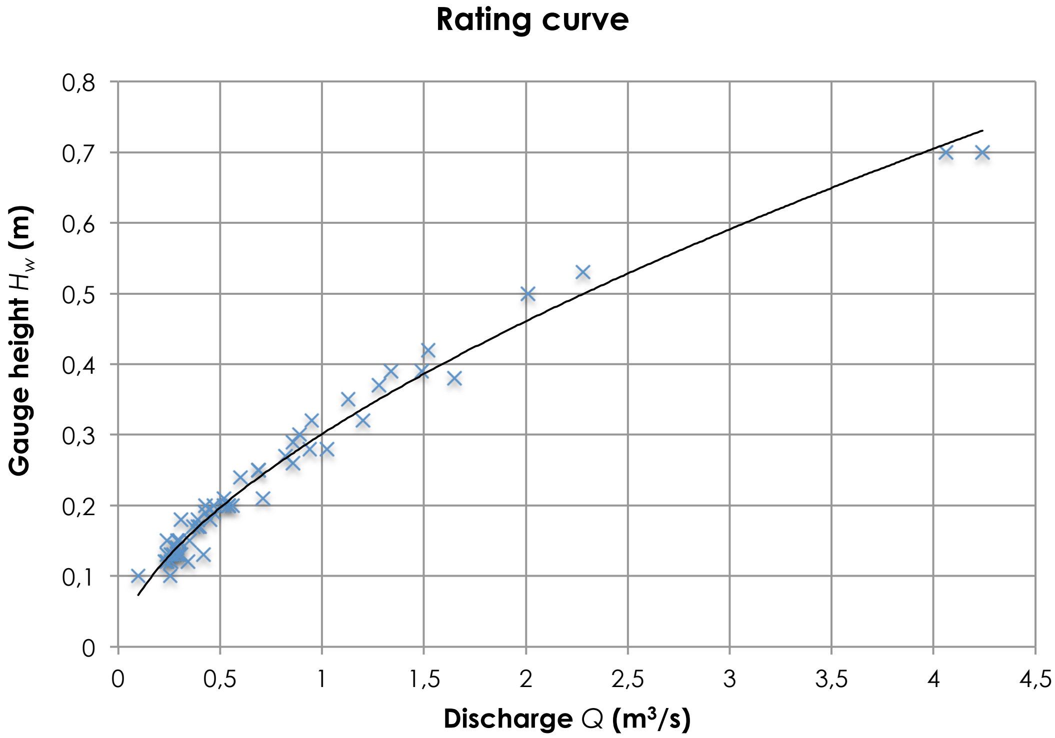

Figure 4: Example Rating Curve

With daily water level data the discharge can be calculated on a daily basis, or at any other given timescale bigger than this as long as the water level data is sufficient.

2.4 Flow duration curves

A (stream) flow duration curve illustrates the relationship between the frequency and magnitude of stream flow. The flow duration curve illustrated the percentage of time a given stream flow was equaled or exceeded during a specified period of time (Figure 5) (Vogel & Fennessey, 1995). Flow duration curves have a long history in the field of water resource engineering and have been used to solve problems in water quality management, hydropower, instream flow methodologies, water-use planning, water allocation planning, flood control, river and reservoir sedimentation, and for scientific comparisons of stream flow characteristics across watersheds (Vogel & Fennessey, 1995). The flow duration curve exemplifies the old Chinese proverb that “one picture is worth a thousand words” because of its ability to summarize and condense a large amount of historical stream flow variability information into a single simple graphic image (Vogel & Fennessey, 1994).

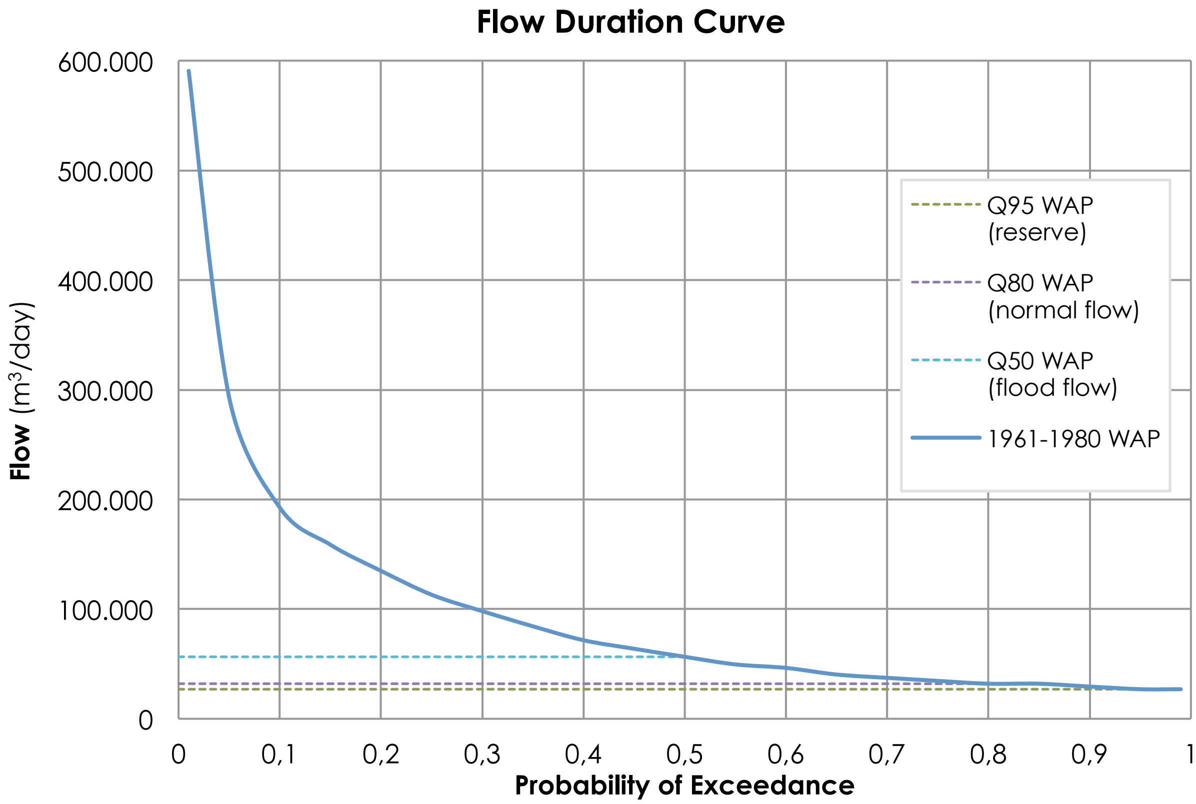

Figure 5: Flow Duration Curve (WAP, 2010)

2.5 Reflection on water resource monitoring methods

Although flow duration curves have a long and rich history in hydrology, they are sometimes criticized because, traditionally, their interpretation depends on the particular period of record on which they are based (Vogel & Fennessey, 1994). Using this period of record specific information for decisions making and water allocation planning, is always bound to the inevitable assumption that the future situation is likely to be the same as the period of record. Of course it is recognized by water resource managers and engineers that this is not the case, but the incorporation of future changes is very hard with this method. In the case of the Lake Naivasha basin the decision is made to use the period of record from ± 1940 – 1980, because during this period the data was relatively complete and reliable and the river flow wasn't influenced by much water abstraction yet, so a naturalized flow duration curve could be determined.

Still the water resource monitoring methods used in the Lake Naivasha basin are build on many hypothesizes. As also argued by Savenije (2009) who claims that a hydrological model is not a tool but rather a hypothesis, and that no good models exist but that one should try to develop better ones suited to local situations. At each point in the construction and analysis of the model and data as explained in the two previous paragraphs it is important to realize the statement Savanije makes. In summary the causal relationships in the research are as follows.

1. At different "gauging stations" (schematic figure in ANNEX VI) daily water level data is collected, manual and sometimes with an automatic recorder.
2. Rating curves have been established and checked for these different gauging stations, through several discharge measurements (Boiten, 2008).
3. Linking the daily water level data with the site specific rating curve, gives the daily stream flow data (Boiten, 2008).
4. A probability analysis of the stream flow over a certain period gives the flow duration curve for that certain period (Vogel & Fennessey, 1994) (Vogel & Fennessey, 1995).
5. The WAP river abstraction regulations are based on flow duration curves based on historical flow data (within period of 1940-1980) These curves can be compared to the curves calculated under 4, using different periods of time.

At and between these steps the hydraulic relationships are clear and evident, the quality of the input data therefore determines to a large extent the quality of the output data. The steps 1 and 2 are essential in this, especially the water level data is often incomplete and the reliability of the data is also not very high. The rating curves have been established a long time ago, normally it is needed to check and update if required on a regular basis, this is only sparsely done. In that sense the outcome of the research in my opinion gives at first insights in the direction of the change and secondly with less reliability it gives information about the extent of the change. This is also because the hydrological processes are reduced to a very small scale and single processes at a single spot in the river; in reality the hydrological system has different components that influence the river discharge, such as rainfall distribution, abstraction, land use, aquifer recharge, constructions in the river etc. these elements are not included in the research to complement or check the research. Rather the output of the research indicates a change in these elements.

The research does make sense according to the WAP regulations, because they are based on exactly the same principles or hypothesizes according to Savenije (2009). Looking to it from that perspective this is the only way to compare the actual figures with the WAP regulations. Going a step further with the aim to give better inputs for the WAP regulations, better data and models are required. For example currently in the flow duration analysis no difference is made between wet and dry season and yearly variance, by doing so a more comprehensive analysis can be given on the reserve flow, which can be used for water allocation planning.

3 Methodology

This section of the report describes the methodology used for doing the research. It explains on data collection, analysis and presentation and finally addresses the limitations of the research methodology. The research is a case study in the Lake Naivasha basin the study is only done within the boundaries of this area and aims to give empirical evidence from the field in relation to water allocation planning and regulation.

3.1 Data Collection

During my internship from April – July 2010 I was engaged in the Water Abstraction Survey (Jong, 2011). Next to this, I collected data on water resource availability that is used in this research. As explained in the concepts and theories, daily water level data for each gauging station and stream flow measurements are required to monitor the water resource availability. The manual read daily water level data is collected from the WRMA offices in Naivasha and Nakuru and supplemented with data from the field visits to the gauge readers. Also data from automatic water level recorders was downloaded at some stations during the fieldwork. The stream flow measurement data is collected initially from the WRMA office in Nakuru; this is further supplemented with data available at the WRMA Naivasha office and trough field measurements done in cooperation with WRMA Naivasha and SNV. Additional data on rating curve equations for the gauging stations in the Lake Naivasha basin was obtained from the ITC institute in Enschede, the Netherlands.

3.2 Selection of gauging sites

As shown in ANNEX VI there are several gauging stations in the rivers feeding Lake Naivasha. In the WAP (2010) the stations used in the river water balance (0) are the 2GB1 River Malewa station, 2GC4 Turasha river station and the 2GA3 and 2GA6 Gilgil river stations. These stations are used because of their downstream river position in the water network. Yet, also for the stations: "2GB4 Wanjohi river, 2GB5 Malewa river, 2GB7 Malewa river, 2GC5 Nandarasi river, 2GC7 Turasha river, 2GC10 Mkungi river" a flow duration analysis is made (Rural Focus, 2006). In the analysis the stations 2GB1, 2GB4, 2GB5 and 2GC7 are included, for the other 2GB and 2GC stations analysis was not possible due to bottlenecks in the data. The 2GA stations are also not analysed due to a time constraint.

3.3 Data Analysis

The data is first analysed on its validity in terms of completeness and reliability. This was done through checking on gaps in the data and through comparison with other data and cross comparison between gauging stations. This already encountered into some limitations. The next step in the analysis was to construct flow duration curves with data and to compare them with the WAP flow duration curves and related regulations. This analysis is done in Microsoft Excel. The analysed data is mainly presented in graphs.

3.4 Research Limitations

The most important limitations / uncertainties of this research are as follows, while some of these are also included in the discussion at the end of this report:

- Water level data completeness and reliability:
  Incomplete records; daily records or complete months / years are missing. Gauging sites are sometimes not properly maintained and reading below a certain water level cannot be possible because of siltation. Gauge readers are not paid in time, consequence is sometimes that they do not deliver reliable work.

- Rating curve availability and reliability in relation to recent water level data:
  Rating curves used are mainly based on old flow measurements, moreover the flow measurements themselves carry already a substantial uncertainty factor (Boiten, 2008).

- Distant research:
  No check up field visits were possible, and it was hard to get supplementary data.

- Time constraints

- Limited insight in exact methods used for calculating WAP FDCs; makes comparison more difficult.

4 Results

4.1 Selection of gauging stations

The Water Abstraction Survey (Jong, 2011) shows that out of the 247 river abstractions in the Lake Naivasha basin 84 (34%), 108 (44%) and 55 (22%) are from respectively the 2GA Gilgil, 2GB Malewa and 2GC Turasha drainage units (Annex VI). Although the number of abstraction points in the 2GA Gilgil drainage unit is comparable to the other drainage units, the amount of water abstraction is small compared to the other the 2GB and 2GC drainage units (Figure 6).

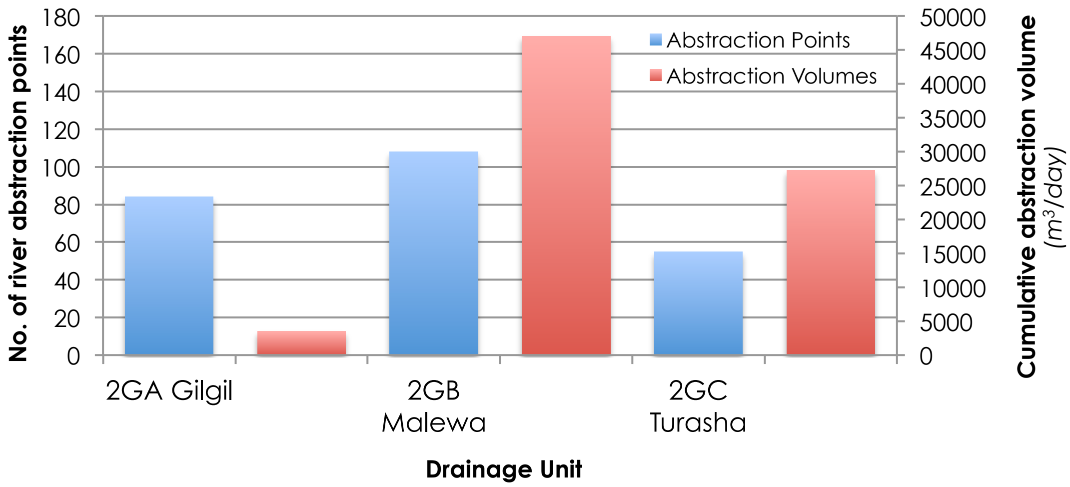

Figure 6: Comparing river abstraction- points and volumes between the different drainage units (Jong, 2011)

The regulations on river water abstraction focus merely on quantity of the remaining flow in the river and finally into the lake (WAP, 2010), the 2GA Gilgil drainage unit seems to be less relevant in the analysis for this report. The total river abstractions in the 2GA Gilgil drainage unit sum up to only 5% of the total river abstraction in the basin. But although the amounts might be small, local impact on river water abstractors by the abstraction regulations can still be large.

ANNEX VI shows a schematic overview of the water resource monitoring network in the Lake Naivasha basin. In the WAP the stations 2GB1 (last station in Malewa river before it drains into the lake) and 2GC4 (last station in Turasha river before confluence with Malewa river) are taken as most important stations in the water allocation and abstraction regulation process (WAP, 2010).

4.1.1 Water level data completeness

In the selection of the stations suitable for analysis firstly the water level data completeness is analyzed. The figure in ANNEX VII shows the daily manual water level reading completeness on a monthly basis for the year 1931 till 2010. This figure gives also a good insight in the data completeness of the period of record used for composing the flow duration curves used in the WAP. From the figure it can be derived that many water level data is missing.

For suitable analysis it is decided that at least a data completeness of 80% is required. Looking to the period from 1990 till now for the stations: 2GB4 Wanjohi river, 2GB5 Malewa river, 2GB7 Malewa river, 2GB8 (2GB7new), 2GC4 Turasha river, 2GC7 Turasha river, 2GA3 Gilgil river and 2GA6 Little Gilgil have all data available for periods stretching from 1 – 5 consecutive years. The main data shortcoming is at the most important gauging station namely 2GB1 River Malewa. It has data for 1998 and 2001 but next to that manual read data is lacking. Diver data is available for 2GB1 for the period of 2008-2010 but the required adjustment for atmospheric pressure is a bottleneck in using this data. Because the analysis in this report is focusing on the impact on river water abstractors it is not necessarily required to have long consecutive periods of record. A single year of data can already be used to see what the WAP regulations impact could have been. Still the data incompleteness for all stations makes it very difficult or maybe even impossible to analyze if there is a change or trend in the river discharges for the period of 1990-till now compared to the WAP period of record.

4.2 Rating curve availability and validity

The second step after selecting the gauging stations that do have “sufficient” data for analysis is the determination of the rating curves. The rating curves are required for the conversion of water level readings into discharges. This section presents the results on the rating curve determination and give some comments on the credibility of the determined rating curves. A list of rating curve equations for the Lake Naivasha basin RGS stations is acquired from the ITC, Faculty of Geo-Information Science and Earth Observation (ITC, 2010). This list is used to supplement and crosscheck the own calculated rating curves. A recent report on low flow monitoring and the assessment of the RGS status by WRMA (2011) gives information on the working status of the different RGS in the Lake Naivasha Basin. Another recent report about the water resource data availability in the Lake Naivasha basin (MWI, 2010) indicates that none of the RGS stations in the Lake Naivasha basin has it’s rating curve equations revalidated for the year 2000 to date. This makes the determination of rating curves with the few data available a difficult but worthwhile exercise.

4.2.1 2GB1 Malewa River

Figure 7 shows the empirically found rating curve for 2GB1, the rating curve parameters differs a bit from the ones generated by ITC (C=25,96; n=1,821), but this ITC rating curve is from the year 1951 and on. Earlier equations (ITC, 2010) show n values that are closer to the n value in the graph. Especially in the high end the rating curve tends to underestimate the flow for a given gauge height. Podder (1998) has calculated through cross comparison with other gauging stations a similar C value but a slightly higher n value, this makes that the curve from Podder does not underestimate the flow during high flow, but does so during low flow. The problem in this is that a weir controls the channel at 2GB1 and while the natural channel is also very rectangular, one n value for the whole range of flows seems not to be sufficient in creating a good rating curve. Yet this has not much impact on the analysis, which focuses more on the low flows.

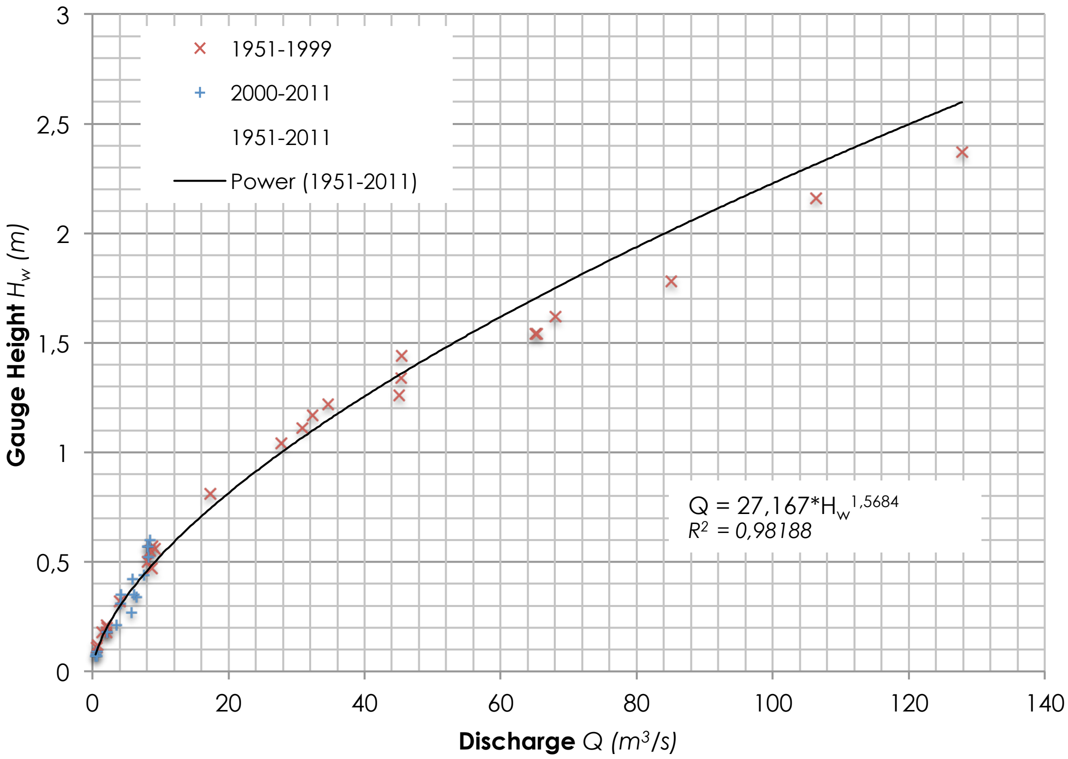

Figure 7: Rating curve showing the relationship between the gauge height and discharge at the 2GB1 gauging station in the Malewa River (x and + markers represent a flow measurement Source: WRMA / MWI)

4.2.2 2GB4 Wanjohi River

In Figure 8 the empirical found rating curve for the 2GB4 station is shown. The curve shows the relationship between the gauge height H_w and the discharge Q. The flow measurements are from the period of 1961 till present, the more recent measurements fit well to trend line, which indicates that the rating curve parameters have not changed much over time. The ITC (2010) rating curve shows only slightly different parameters for the rating equation of the 2GB4 station. In the standard format of $Q=C*(H_w-H_0)n$, ITC (2010) indicates C=5,891, n=1,506 l and H_0=0. Because no measurements are done at H_w> 0,8 m, the equations is only valid below a H_w of 0,8 m. The WRMA (2011) report indicates that the station is still working properly, but that more flow measurements are needed to ensure the validity of the rating curve equation.

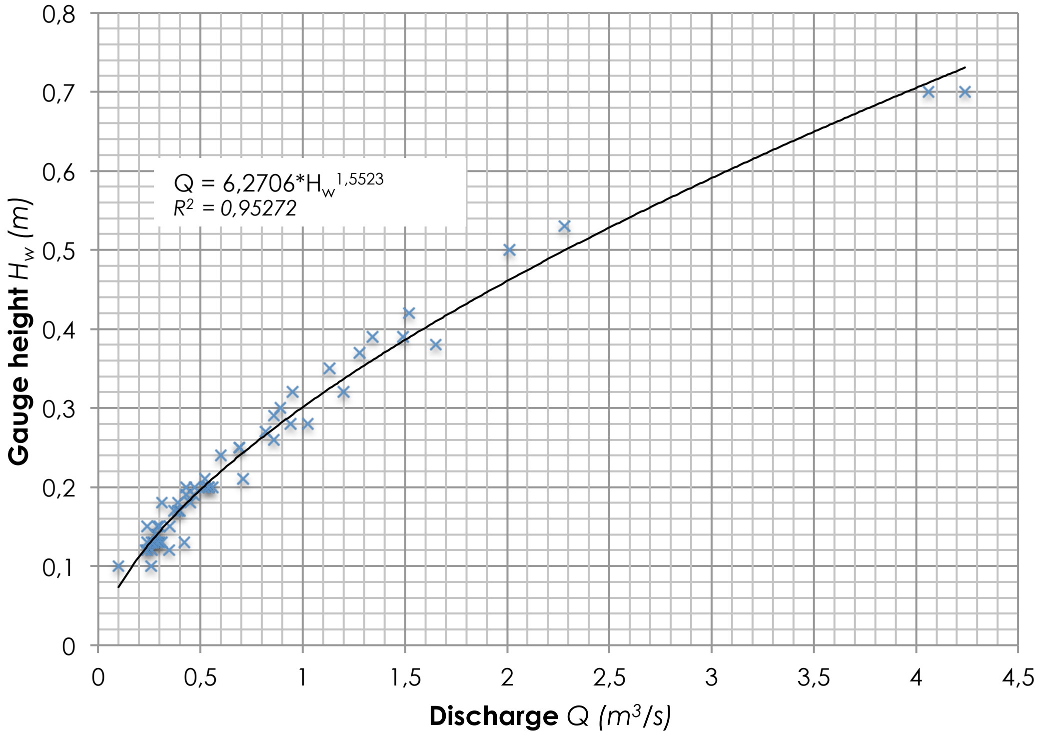

Figure 8: Rating curve showing the relationship between the gauge height and discharge at the 2GB4 gauging station in the Wanjohi River (x markers represent a flow measurement Source: WRMA/MWI)

4.2.3 2GB5 Malewa River

In Figure 9 and Figure 10 the empirical found rating curves for the 2GB5 station are shown. The curves show the relationship between the gauge height H_w and the discharge Q. The flow measurements are from the period of 1961 till present. Podder (1998) has also studied the stage discharge relation for the 2GB5 station and already indicated that a different rating

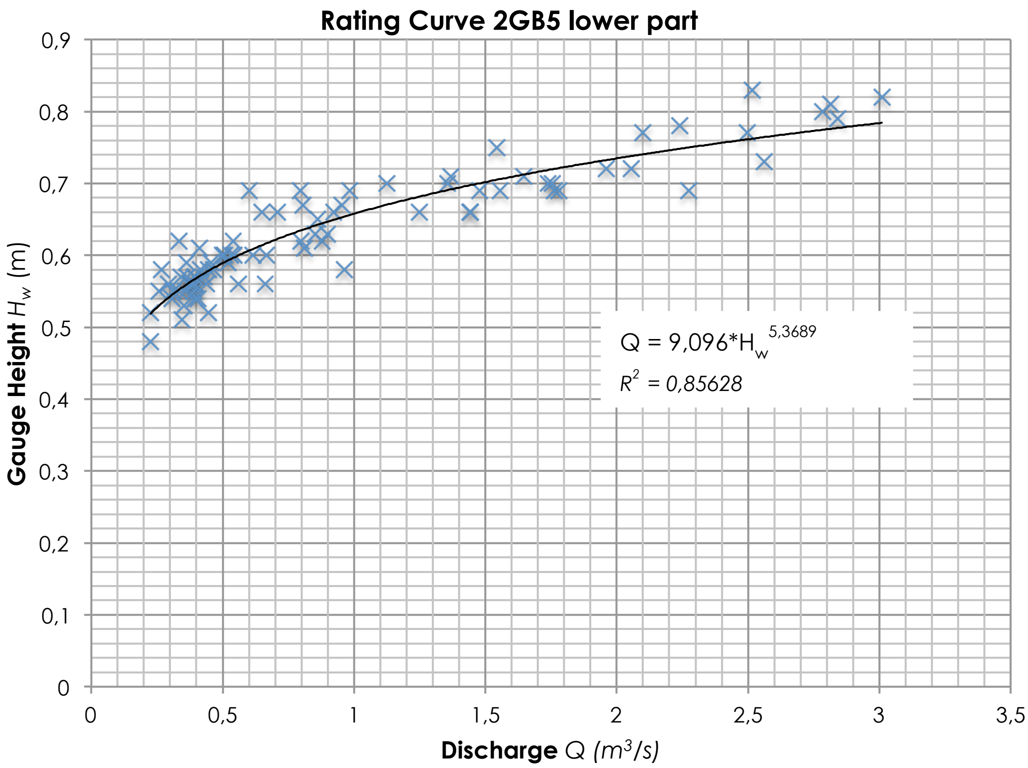

Figure 9: Rating curve showing the relationship between the gauge height and discharge at the 2GB5 gauging station in the Malewa River for the low-end discharges (x markers represent a flow measurement Source: WRMA/MWI)

curve for the lower and upper part of the flow regime were required. For both curves Podder (1998) calculated almost the same values. Through cross comparison with the 2GB1 and 2GC4 station he found out the upper part curve is reliable but that the lower part curve is not completely reliable.

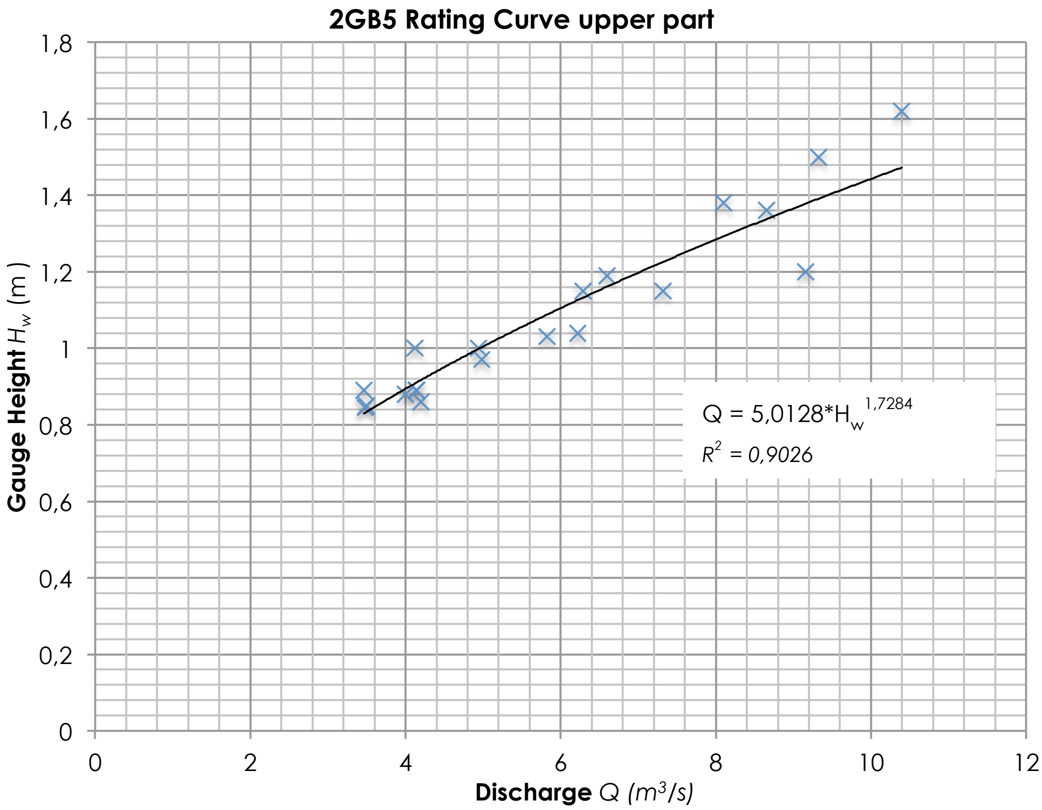

Figure 10: Rating curve showing the relationship between the gauge height and discharge at the 2GB5 gauging station in the Malewa River for the high-end discharges (x markers represent a flow measurement Source: WRMA/MWI)

4.2.4 2GC7 Turasha River

In the upper part of the Turasha river the 2GC7 gauging station is located There is hardly any abstraction from the river before this point as indicated in the Water Abstraction Survey (Jong, 2011). This makes this station interesting because the effect of abstraction can be excluded. The rating curve is shown in Figure 11 and consist out of two parts.

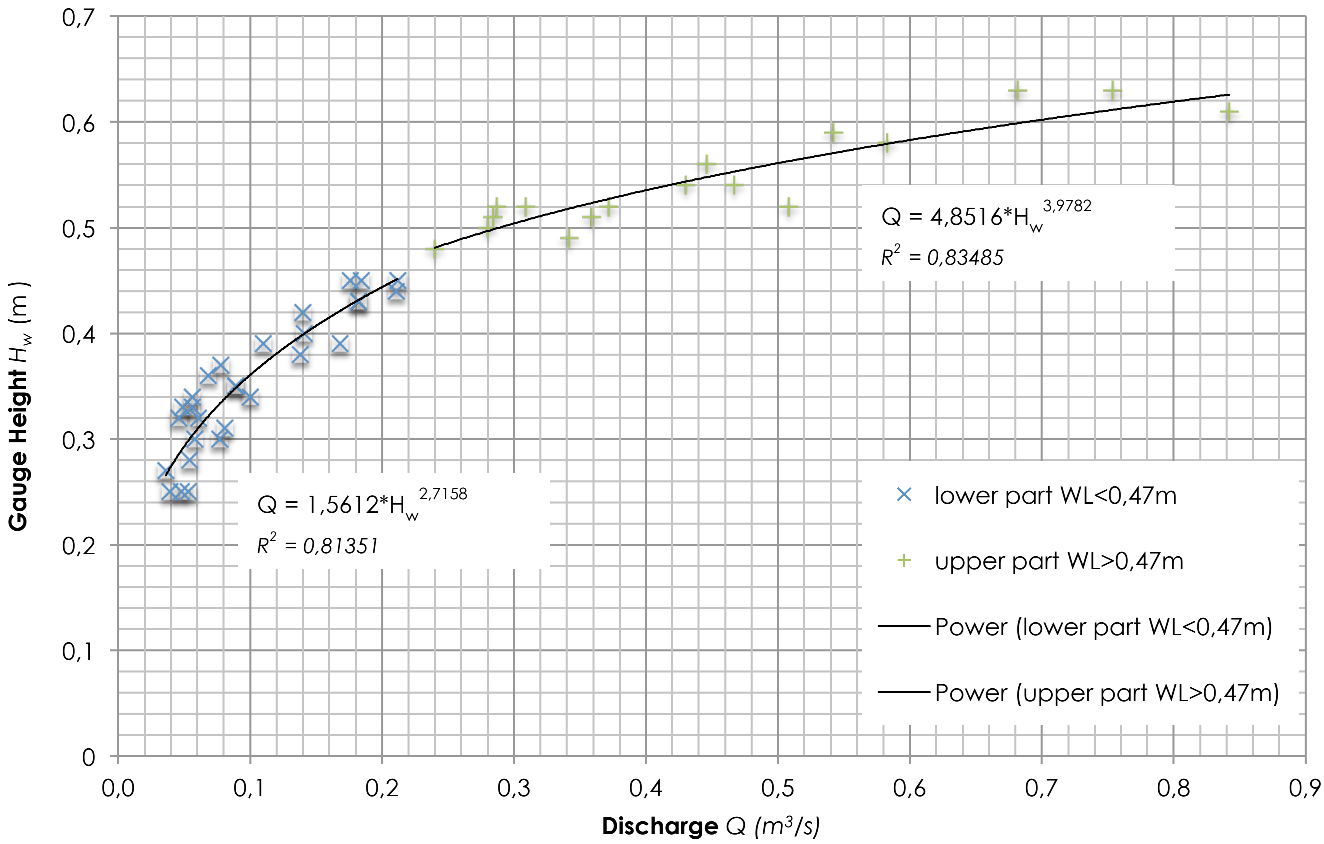

Figure 11: Rating curves showing the relationship between the gauge height and discharge at the 2GC7 gauging station in the Turasha River (x and + markers represent a flow measurement Source: WRMA/MWI)

4.3 Flow Duration Curves Comparison

Combining the rating curves and water level data, makes it possible to generate discharge time series, which is needed to create the Flow Duration Curves (FDCs). This paragraph answers the sub research questions; *"What are the Flow Duration Curves (FDC) at the selected RGS's and what is the extent of the yearly variance in the FDCs?"* and *"How do the FDCs used in the WAP differ from the newly composed FDCs?"*. The above paragraphs already indicated the availability and credibility of the water level data and rating curves. Below graphs are shown with the newly composed and the WAP FDCs for each RGS, these are compared in and between stations. These graphs also show the regulative flow thresholds (Q95, Q80 and Q50) derived from the WAP FDC. This makes it possible to quickly analyze and compare the regulative flow thresholds with the newly composed FDCs. A check run is also done with the rating curves used in this report for the WAP period.

4.3.1 2GB1 Malewa River

Figure 12 shows single year FDCs for the years 2008 and 2009, comparing these FDCs with the WAP FDC and the related Regulative flow thresholds (Q-flows) it can be seen that the 2008 and 2009 single year FDCs are beneath the WAP FDC in the low and normal flow section. This indicates that the time of low flow in the years 2008 and 2009 was longer compared to the probability curve of the WAP. The extreme example in this is that in Figure 12 can be seen that the Q80 threshold is only exceeded 30% of the time in the year 2009. On the other hand the beginning of the year 2010 was very wet as can be seen in the figure.

The main bottleneck in composing the flow duration curves for 2GB1 was the diver data, because no comparison was possible with manual readings, to check if the correction for atmospheric pressure was valid during the whole time series, because they were simply not available, this makes the water level data unreliable. Together with a rating curve of which is not known how credible it is, it is not possible to add too much weight to Figure 12.

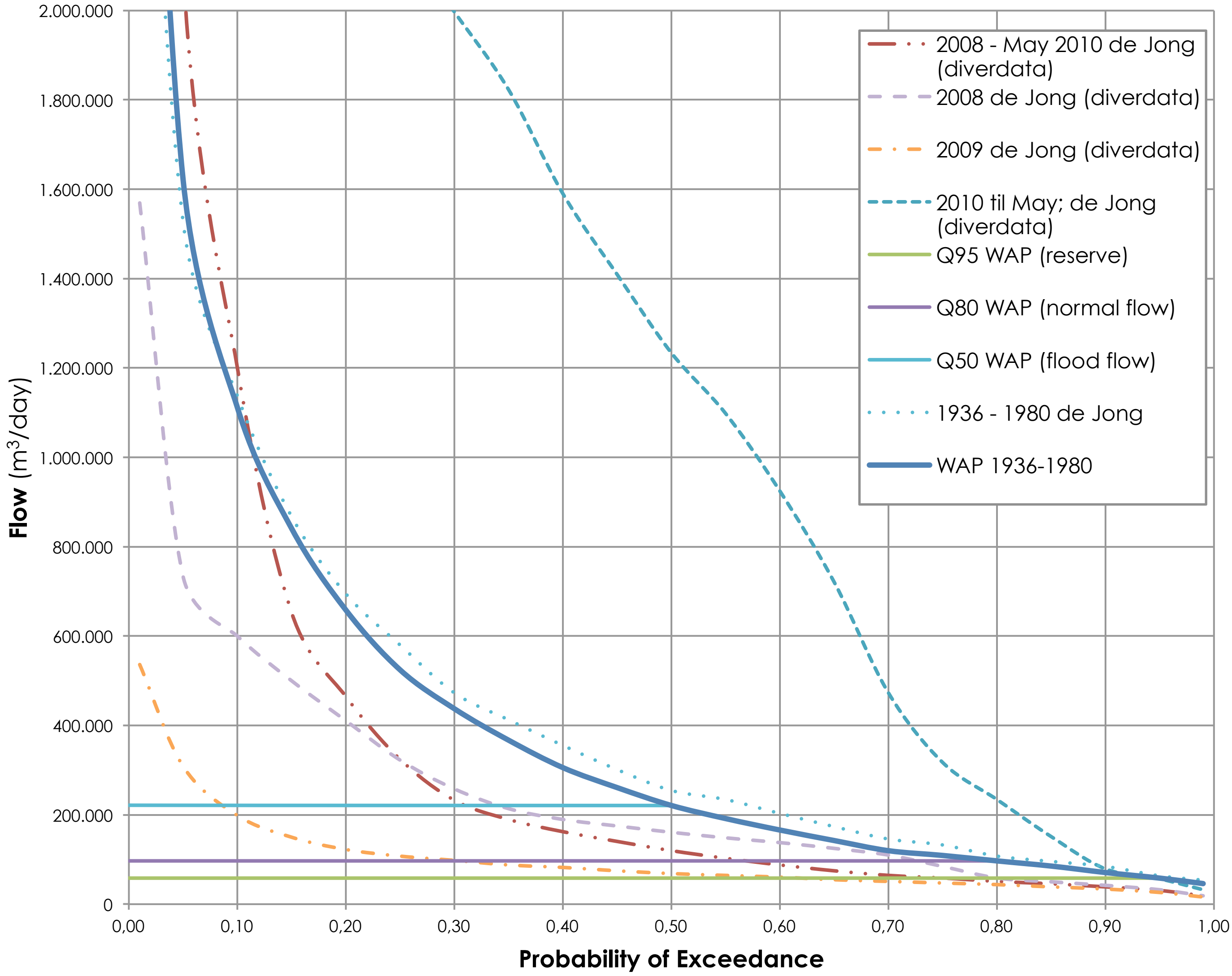

Figure 12: 2GB1 WAP and newly composed (de Jong, Source WRMA) FDCs and regulative flow thresholds (Q-Flows).

4.3.2 2GB4 Wanjohi River

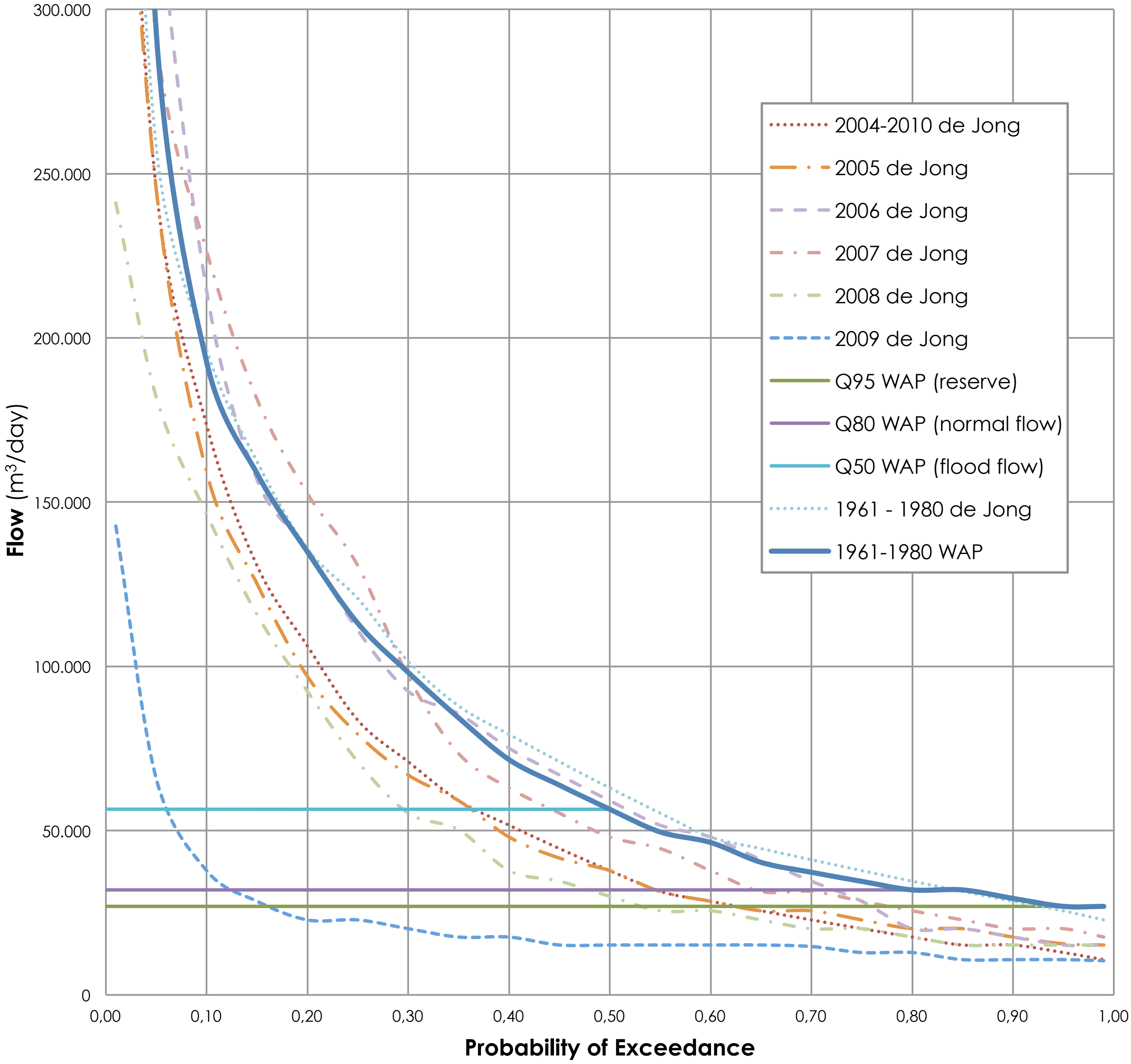

Figure 13: 2GB4 WAP and newly composed (de Jong, Source WRMA) FDCs and regulative flow thresholds (Q-Flows).

Figure 13 shows that the WAP FDC and the newly composed FDC for the WAP period are very similar this indicates that the input data for the WAP FDC (water level and rating curve) are similar to the data used in the newly composed FDCs. The graph shows new single year FDCs for the years 2005-2009, comparing these FDCs with the WAP FDC and the related Regulative flow thresholds (Q-flows) it can be seen that the new single year FDCs are all beneath the WAP FDC especially in the low flow section. This indicates that the time of low flow in the years 2005-2009 was longer compared to the probability curve from the WAP. For example; only above the Q80 flow threshold farmers are allowed to abstract water for irrigation. This means that on average 80% of the time farmers are allowed to do so according to the WAP hydrological records. Looking to the year 2009 it can be seen that the 2009 FDC crosses the Q80 threshold at the percentile of 0,12 this means that in

2009 only 12% of the time farmers were allowed to abstract water for irrigation if the WAP regulations would have been in use at that time. Also in the year 2009 abstractions for domestic use would have been restricted 84% (intersect with Q95) of the time of the year. For the other years this ranges from 40-20% of the time in a year compared to 5% indicated by the WAP regulations.

4.3.3 2GB5 Malewa River

The WAP FDC and de newly calculated FDC for the WAP period, differ slightly, as can be seen in Figure 14, this can be because in the newly calculated FDC two rating curves are used. It is not known how this is done in the WAP version. The Y-axis in Figure 14 is cut at 800.000 m³/day, to get a larger scaling of the low flows. Out of the nine single years FDC shown three show more flow than

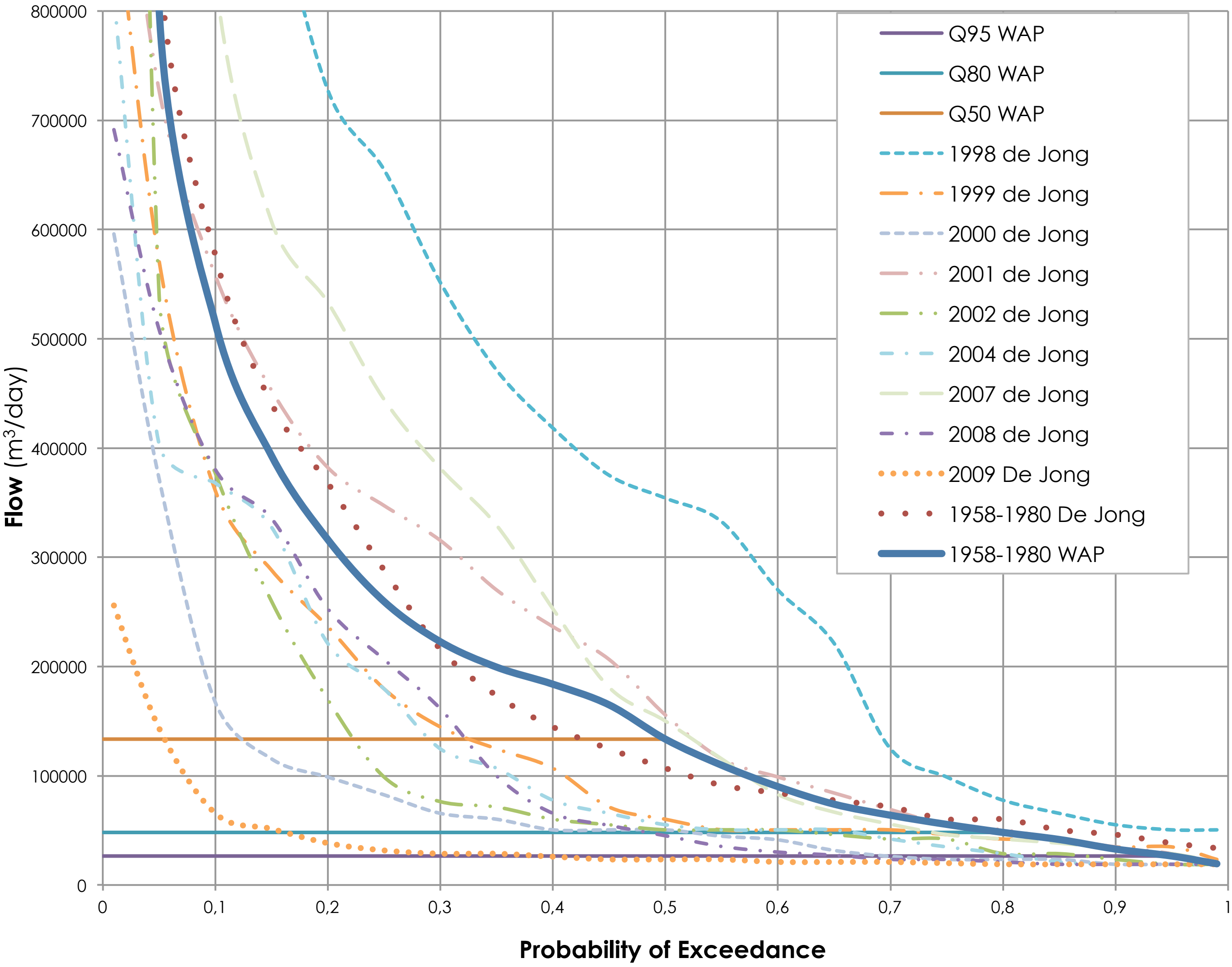

Figure 14: 2GB5 WAP and newly composed (de Jong, Source WRMA) FDCs and regulative flow thresholds (Q-Flows).

the WAP FDC the other six all indicate less flow in the river, with the extremes in the year 2009 and 2000.

A remark that has to be made is that during low flow the gauge in 2GB5 cannot be properly read anymore, because it is silted. This can also be traced back in the discharge series, which do not go beneath this reading threshold. The consequence for the analysis is that during dry years the low flow will most probably even lower than indicated in the FDCs.

4.3.4 2GC7 Turasha River

The flow duration curves in Figure 15 for the 2GC7 station do not show the same extreme differences compared to the WAP FDC as indicated for the 2GB1 and 2GB5 stations, this difference might be allocated because there is no river abstraction before 2GC7, yet the variability in river discharge is still huge. And the single year curves differ a lot from the WAP curve, with a dominant direction into more time with lower discharges.

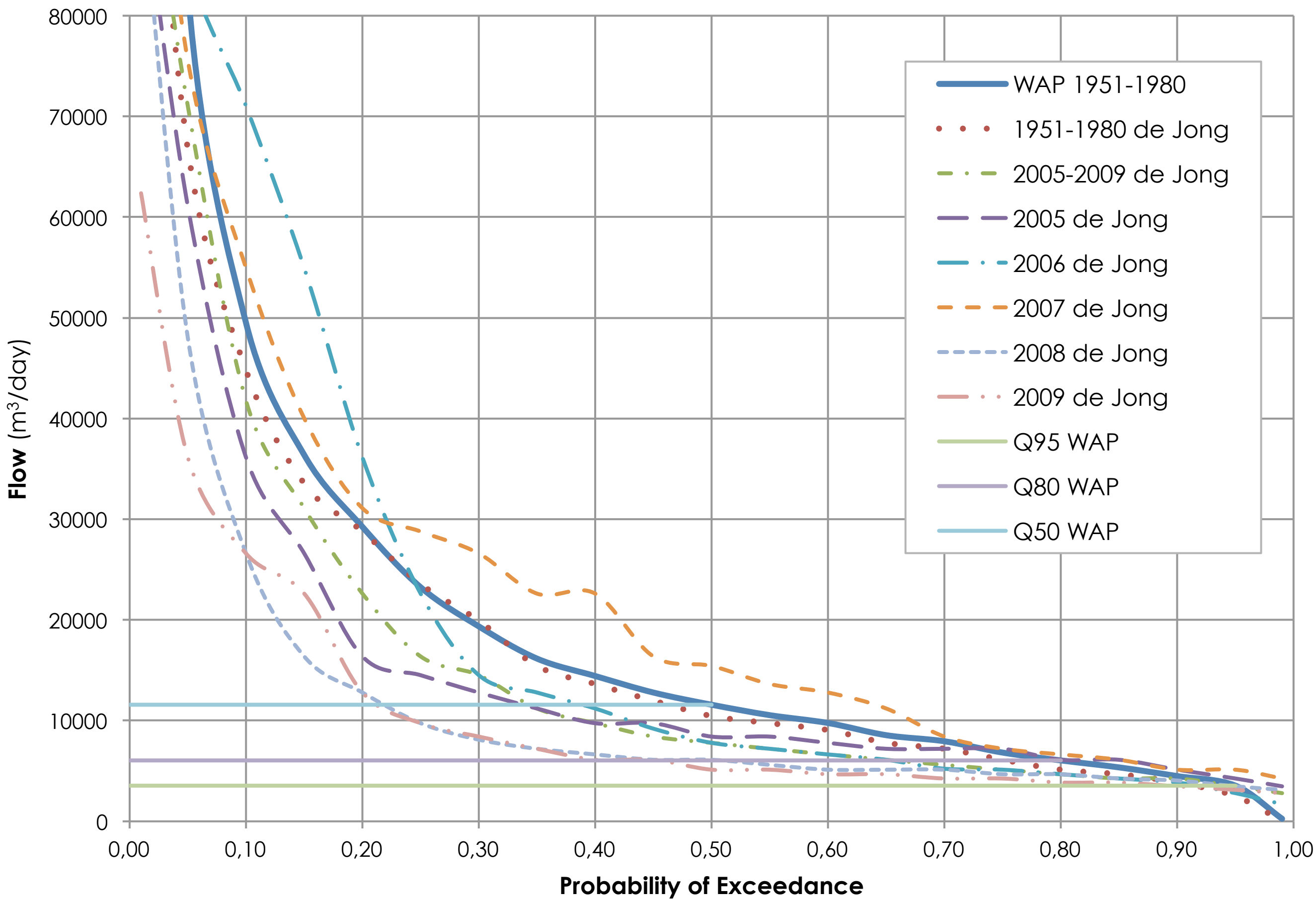

Figure 15: 2GC7 WAP and newly composed (de Jong, Source WRMA) FDCs and regulative flow thresholds (Q-Flows).

4.3.5 Cross comparison between gauging stations

Flow duration curves of the 2GB1, 2GB4, 2GB5 and 2GC7 gauging stations are shown above these flow duration graphs show a load of information, this paragraph tries to summarize the important information and to compare these summarized information between the stations. To do so the time that the flow equals or exceeds the WAP Q50/80/95 is plotted for the years 2005 till 2009 on a percentage scale (Figure 16, Figure 17 and Figure 18). In an average year within the WAP data period the columns would have extended exactly to the Q50/80/95 threshold or in this graphs to 50/80/95%, which are indicated by the orange lines. What can be seen at a first glance from the graphs is that this does not happen in almost all cases for the four stations during the years 2005 till 2009. Beneath the Q80 threshold farmers are not allowed to abstract for irrigation, the striking fact is that for the years 2008 and 2009 this threshold is only reached between ± 10% and 70%. Same accounts for the Q95 threshold which would have imposed that in years like 2008 and 2009 domestic abstraction would also have been extensively restricted if the WAP regulations would have been in place already. It can be concluded that the impact on the reliability of "legal" water supply for river abstractors, when comparing the newly composed FDCs with the WAP abstraction regulations, is significant, in terms of a much less reliable water supply.

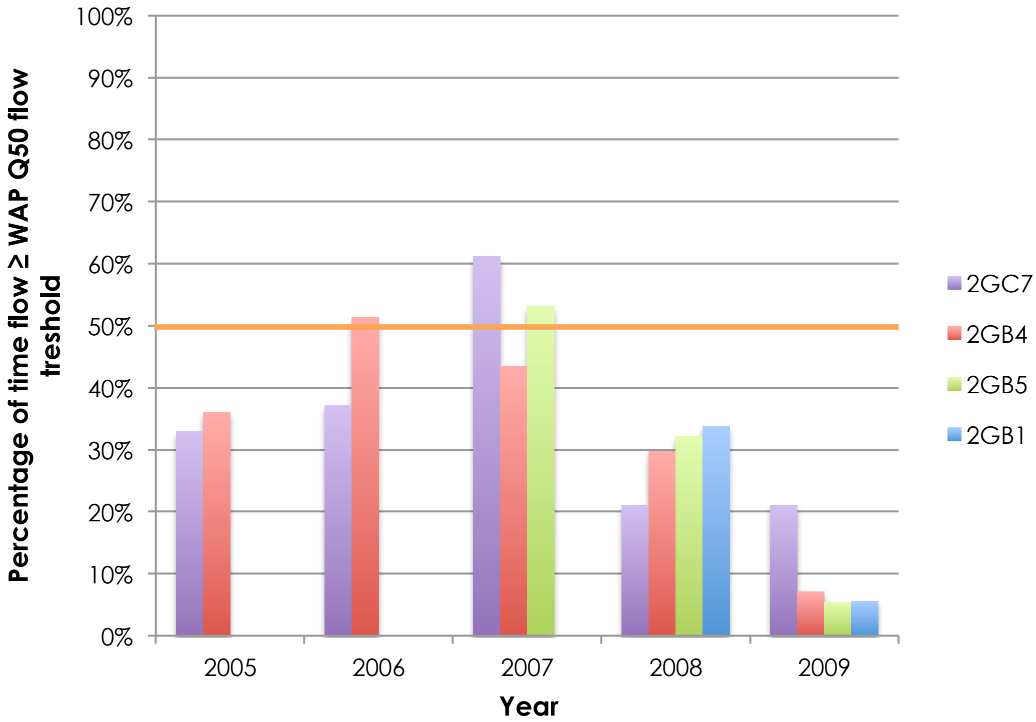

Figure 16: Percentage of time river flow equals or exceeds the WAP Q50 flow at the stations 2GB1, 2GB4, 2GB5, 2GC7

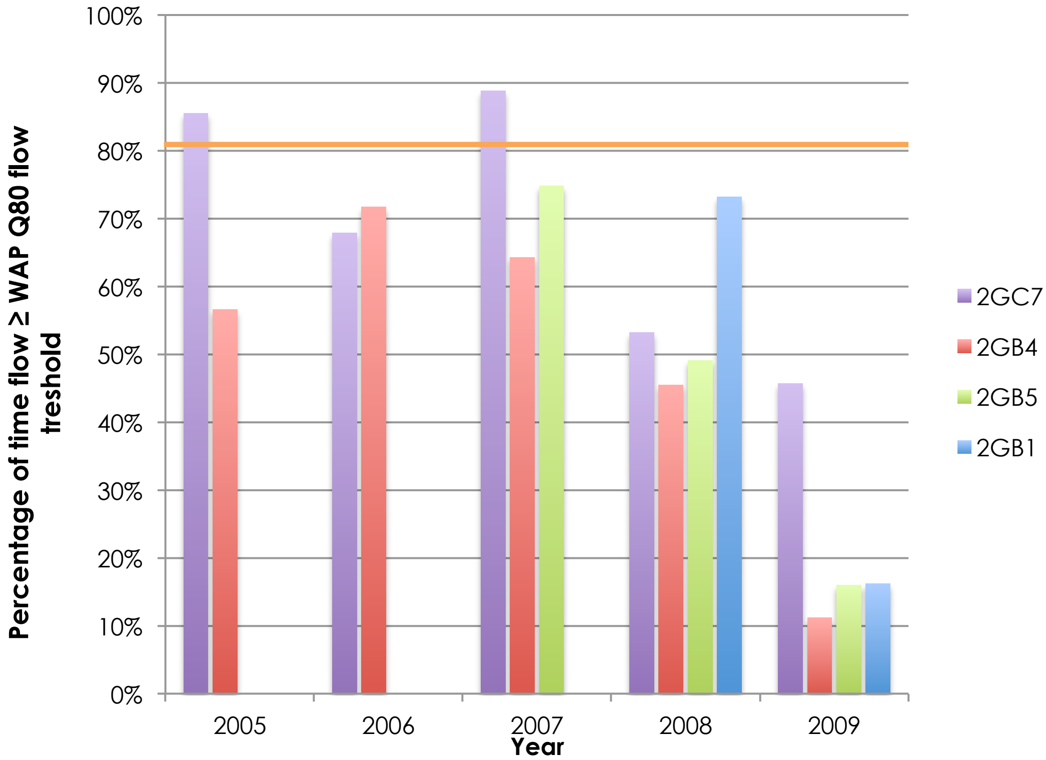

Figure 17: Percentage of time river flow equals or exceeds the WAP Q80 flow at the stations 2GB1, 2GB4, 2GB5, 2GC7

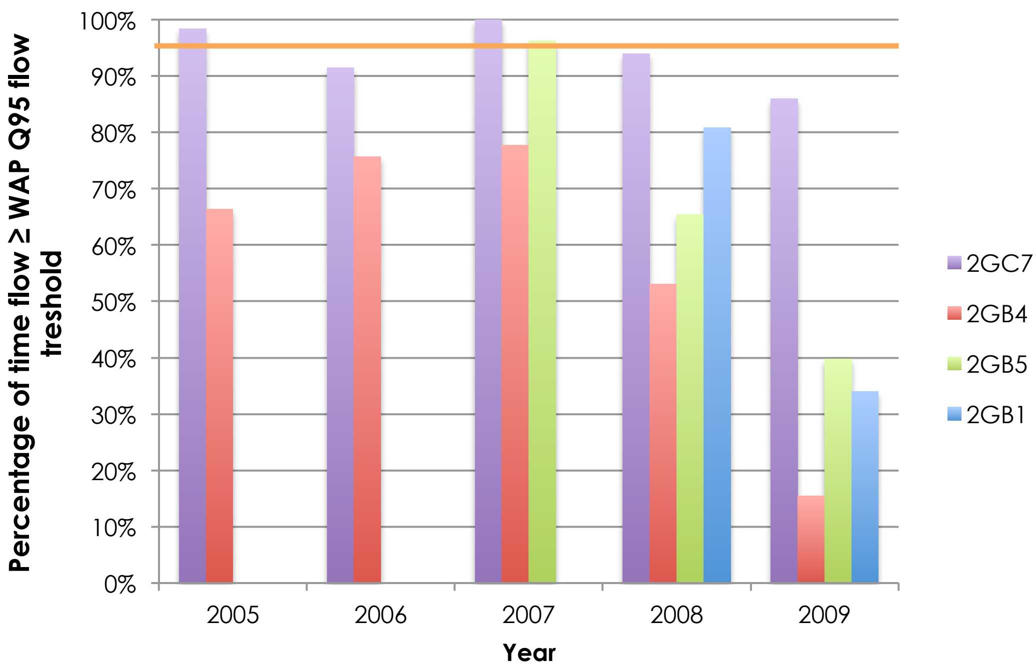

Figure 18: Percentage of time river flow equals or exceeds the WAP Q95 flow at the stations 2GB1, 2GB4, 2GB5, 2GC7

4.4 Comparing the WAP with water abstraction data

A recent report about water abstraction in the Lake Naivasha basin (Jong, 2011) gives some interesting insights on what's actually happening around river abstraction and data that can be compared with the WAP river water balance.

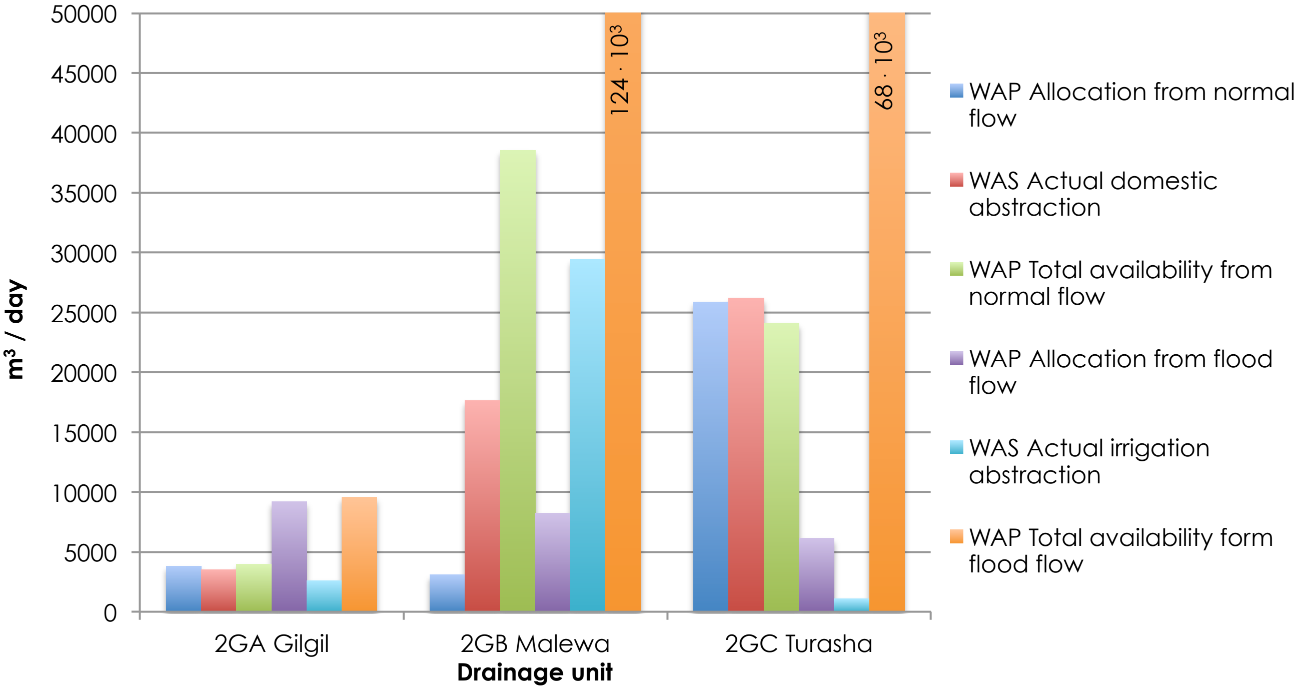

Figure 19: River water abstraction data compared to the allocation and availability as indicated by the WAP for normal and flood flow (Jong, 2011).

Figure 19 shows the river water balance from the WAP, the meaning of normal and flood flow is as follows: "normal flow = Q80 flow threshold minus Q95; flood flow = Q50 – Q80". The normal and flood flow availability is derived from the 2GA3 and 2GA6, 2GB1 and 2GC4 WAP FDCs for respectively the 2GA Gilgil, 2GB Malewa and 2GC4 Turasha drainage units (ANNEX I and ANNEX VI). The WAP allocation columns are about what the WAP indicates as being allocated this is based on old records from the Ministry of Water and Irrigation.

The old allocation data is not in line with the actual abstraction as indicated by the water abstraction survey. Figure 20 explains more about the reason behind this; a lot of abstraction is not under permitting. Out of the *(48+38+26)* 112 river abstractions with some legal status only 10 abstraction points do have a valid permit, which allows to really abstract water. Only 2,6 · 10^3 m^3/day is abstracted under these valid permits out of a total river abstraction of 78 · 10^3 m^3/day (Jong, 2011). Figure 19 indicates that

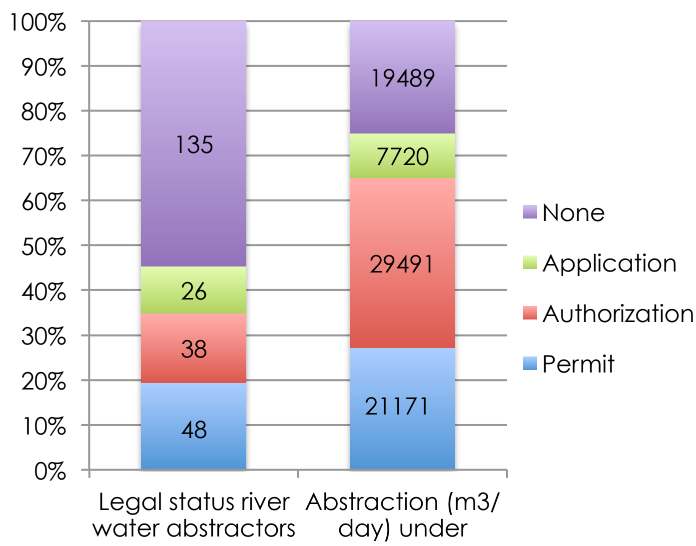

Figure 20: Legal status of river water abstractors and river abstraction amounts under the different legal status (Jong, 2011).

according to the WAP normal and flood flow availability, enough water is still available to give out permits for the abstractions currently without a valid permit, if they also comply to other required conditions. Only domestic abstraction from normal flow in the Turasha river has reached it's limits according to the WAP FDC. This is different from the actual situation in the last years as shown in the results in the previous chapters, which show that river abstraction would have been strongly regulated. The analysis above shows that the current WAP river water balance only limitedly represents the actual state of the river flow regime and availability of water for further allocations.

5 Discussion

5.1 Discussion on results uncertainties

The first conclusion from the results seems to be fully in line with the hypothesis that the probability on certain river water discharges has changed in the Lake Naivasha basin rivers compared to the 1940-1980 timeframe, and that this is especially manifested in the longer periods of low flow. Yet there are a lot of uncertainties in the methods and data used to get to this conclusion. As already mentioned earlier in this report Savenije (2009) says that no good hydrological models exist, and that caution is required to rely too much on hydrological models. This is fully experienced in this research, it is also not the aim of this research to claim that the water resource monitoring results presented are correct, the many problems and hurdles experienced during the research rather underline the statement of Savenije and lead more to a concluding question if the method/model used for river water allocation planning in the Lake Naivasha basin is suitable for doing accurate water allocation planning. Yet the same methods are used to come up with regulations for water allocation planning in the Lake Naivasha basin and therefore it is very relevant to know where the uncertainties in the results are encountered and what the extent is of uncertainties created by data incompleteness and model failure, which is rather difficult to quantify.

The model used in creating the flow duration curves needs reliable input data, in the case of the Lake Naivasha basin a lot of daily water level data is missing, or the reliability of it is questionable. The rating curves, are largely based on old data, of which the reliability is also not known. In the meantime the gauging sites have changed which leads to minor or maybe also bigger changes in the rating equations for a specific monitoring point. The few discharge measurements done in this research were not sufficient to fully overcome this problem. Other difficulties encountered are that the data processing and analyzing is a time consuming process, in which time was really a limiting factor. Also the fact that processing and analysis was done in the Netherlands made that acquiring supplementary data and check ups in the field where not possible.

A main bottleneck in the analysis was also that for the WAP FDCs with the reference period of 1940-1980 there was much less abstraction from the river than for the FDCs created in this report. In the WAP the FDCs are based on the so-called naturalized stream flow, with zero or very little abstraction, this is in line with the Guidelines for Water Allocation (WRMA, 2009). As shown elsewhere (De Jong 2011) the current abstraction is large in the Wanjohi and Upper Malewa river, also in the Turasha river a dam abstracts a huge amount of water each day. This implies that FDCs with a lot of river abstraction will have a higher probability on low flows than FDCs without river abstraction (This accounts for the 2GB1, 2GB5 and 2GB4 stations. Still if the abstraction as indicated by Jong (2011) is added on top of the FDCs most yearly FDCs will still be beneath the WAP FDC. In the case of 2GC7 there is currently no upstream abstraction according to Jong (2011). Yet the new yearly FDCs are significantly below the WAP FDC as can be seen in the previous chapter.

The two most important gauging stations used in the WAP are 2GB1 and 2GC4, for 2GB1 only little water level data was available, for 2GC4 it was not possible at all to come up with correct new FDCs. This is unfortunate especially for the comparative analysis, because the stations 2GB1, 2GB5 and 2GC4 together can be used to check whether daily or yearly flow summation are correctly in line with each other (see ANNEX VI). Calculating this for the WAP FDCs; 2GB5 and 2GC4 together have a 13% higher yearly discharge volume than 2GB1, unless there is a lot of outflow to groundwater from the Malewa river between the stations this is in theory not possible, and shows again the shortcomings of the model used in water allocation planning.

There is not much research to be found that emphasizes on the same specific topic apart from the WAP research. It was therefore also not possible to do a necessary and critical check on the results of the research presented in this report.

5.2 Reflection on WAP abstraction regulations

The question already mentioned in the previous paragraph: "If the method/model used for river water allocation planning in the Lake Naivasha basin is suitable for doing proper water allocation planning?" is a very relevant question in light of the many hurdles experienced in getting to the results of this research and also because of the results themselves. The WAP has been officially launched at the 9th of August 2011 (KFC, 2011), which is on itself a milestone in Kenya's water resource management, but this in itself does not guarantee a successful implementation. In my opinion the WAP river abstraction regulations are built on highly uncertain data, which limitedly reflects the actual situation, is only to some extent interdisciplinary grounded, and somewhat inflexible or non-adaptive. Regarding the latter Pollard et. al (2009) indicate that the opposite is necessary to cope with the complexity in a catchment water system, wherein valid and reliable long term info is lacking. I realize that time and resources are insufficient to fully understand the water management problems, and that it is required to take actions without this full understanding. Preventive action is required even in the face of uncertainty, the burden of proof can be shifted to the proponents of an activity as indicated as a key principle in the WAP (WRMA, 2010). Because of the above mentioned reasons I do believe that it will be difficult to effectively implement the WAP.

The following will explain more on this, firstly as showed in the results, the abstraction regulations as they are now will have huge impact on river water abstractors, and a 90 day storage to overcome dry periods as the WAP prescribes as necessary is not sufficient in this. The chance that river water abstractions with the purpose both in domestic or agriculture will need to be restricted for more than three months is quite high, if the regulations are enforced this will lead to conflicts between up- and down-stream users and in the case of the Lake Navaisha basin mainly between river and lake water abstractors. This will have a counterproductive effect on the building of effective water management in the whole basin that requires cooperation and understanding between up- and down-stream users. It is a political decision whether to stick to current WAP FDCs based on the old data or to adapt the flow regulations more to the actual flow regime. Additionally not much is known about the real environmental benefits in relation to the reserve flow regulation, it is likely to happen that upstream users will claim that the downstream lake users, who came up with the plan, only want the abstraction regulations to make sure that as much water as possible is flowing to the lake.

Secondly the abstraction regulations are very inflexible in the light of climate / precipitation variations in the area in and between years. Only one fixed threshold is clear and easy to understand, but does not reflect the high variability in the system. It is therefore necessary to ask the question whether a fixed reserve threshold is required for the river and lake ecosystem as in reality the flow regime might have had long periods of low flow when there was not much abstraction yet. The old management approach that viewed an ecosystem as a stable linear system with less variability is not sufficient to deal with the water- and related ecosystem complexity (Pollard, du Toit, & Mallory, 2009). Further research on this is recommended.

Thirdly the current status of the water resource-monitoring network is bad and daily discharge status updates do not exist. Thus it is unknown when the Q80/95 regulative thresholds are reached. Furthermore many water abstractors do probably not (yet) know about the regulations and there is no system in place to communicate the discharge status. The WRUAs have to play a big role in this but there is a long way to go before they will be able to do the above things.

Last to mention is that the abstraction regulations are not interdisciplinary grounded. As far as I understand the formation of the WAP, it has been build on mainly technical and political foundations in which the downstream lake water users had and have the biggest voice. No proper consultations with the upstream water users on what the abstraction regulations would encompass in reality have been done. During implementation of the WAP abstraction regulations this will most probably lead to a lot of questions and opposition from upstream water users.

A recent article (4-9-‘11) in the Daily Nation (Mbaria, 2011), a renowned newspaper in Kenya, talks about the WAP as being recognized as essential by stakeholders in the combat against the decay of the river and lake ecosystem as well in ensuring a proper water supply to commercial and livelihood activities. It is always risky to take over from second hand sources, but in the article John Philip Olum, WRMA’s chief executive, says that: “the WAP particularly promotes the interests on ‘weaker’ groups like pastoralists, smallholders, as well as the wildlife depending on the lake for survival”, and he says: “efficient water utilisation, combined with the restrictions the Plan places on how much water can be drawn would ensure the water is available for everyone”. The outcomes of this research raise questions regarding the correctness of these statements, as it seems that the WAP is not really favouring smallholders or upstream river water abstractors, and that the regulations may fail to ensure that water is available for everyone.

6 Conclusions & Recommendations

It can be concluded from the results that the actual impact of the current WAP river abstraction regulations during low flow on the reliability of legal water supply, for river water abstractors in the Lake Naivasha basin is substantial, when taking the years 2005-2009 as main reference. Abstractions with the purpose in irrigation would have been restricted to abstract water for 30 – 90% of the time in a year, compared to the average of 20% as indicated by the WAP. For abstractions with the domestic purposes this ranges between 4 – 84% compared to the average of 5% as indicated by the WAP. These numbers should not be seen as absolute figures, in the light of the uncertainties as discussed in the previous chapter. The outcome of this research in the first place provides insights in the direction of the change in river flow regime and secondly with less reliability it gives information about the extent of the change. The above accounts for river abstractors in the whole river Malewa catchment as the analysis has taken place for the stations 2GB1/4/5 and 2GC7.

The other conclusion that can be drawn is that the river water balance (ANNEX I) and abstraction regulations for river water abstractors as laid out in the WAP are built on too many uncertainties, limitedly reflect the actual situation, are somewhat inflexible and limited in their interdisciplinary grounding, as explained in the results and discussion. Although there is an urgent need for action in water allocation planning in the Lake Naivasha basin, because of the decay of the water eco system, the current river abstraction regulations will struggle to contribute to combat this, and they are difficult to be implemented and enforced effectively.

The WRMA could benefit from overthinking the WAP river water balance river and abstraction regulations in light of the findings of this study. WRMA could further adapt their policies to the actual situation in collaboration with the WRUAs in the basin. Environmental or reserve flow as it is coming forward in the WAP is putting emphasizes only on quantity problem. Other perspectives on environmental flows that are emerging around the world are worth to take into consideration. It can be constructive in this to do research whether the high variability in river flow regime as shown in the results of this report was also of the same extent and frequency for the data period used in the WAP.

Furthermore the actual situation on legal status of the river water abstractions as shown in the results need to be improved first, before it is possible to effectively start implementing abstraction regulations. This requires the WRMA and the WRUAs to take a position on what to do with abstractors without a permit and a strategy on how to bring abstractors without a valid permit into legal compliance.

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ANNEX I. River water balance WAP

Table 1: Water Balance WAP; availability vs. Allocated resources[1]

	GILGIL RIVER			TURASHA RIVER	MALEWA RIVER
Station Number	2GA3	2GA6		2GC4	2GB1
Station Name	*Gilgil*	*Little Gilgil*	*Gilgil Total*	*Turasha*	*Malewa*
Catchment Area (km²)	151.38	21.78	370.26	723.37	1,563.31
					FLOW THRESHOLDS (m³/**day)**
Q95	259	1,210		39,658	58,320
Q80	3,974	1,469		63,763	96,854
Q50	13,133	1,901		131,674	220,838
					RESOURCE AVAILABLE FOR ALLOCATION (m³/**day)**
Reserve	259	1,210	1,469	39,658	58,320
Normal Flow	3,715	259	3,974	24,105	38,534
Flood Flow	9,159	432	9,591	67,911	123,984
					RESOURCE ALLOCATED IN PERMITS[2] **(m³/day)**
Reserve					
Normal Flow			3,819	25,890	3,076
Flood Flow			9,212	6,161	8,225
					RESOURCE BALANCE FOR FURTHER ALLOCATIONS (m³/**day)**
Reserve			1,469	39,658	58,320
Normal Flow			155	-1,785	35,458
Flood Flow			379	61,750	115,759

The above table indicates an over-allocation of the normal flows for the Turasha river, while all other rivers show a positive balance. In reality it is known that the Giligil River and parts of the Malewa river experience periods of very low flow, in which the Reserve is not being respected. This indicates that with respect to the rivers both over abstraction and over allocation are factors causing violations of the Reserve.

[1] Source: Rural focus (2006) Development of a Water Allocation Plan for Naivasha Basin, Phase 1 Report, Technical Options.

[2] Based on old permit records from MWI, In (Jeng, 2011) the Water Abstraction Survey results indicate different numbers on permitted and actual abstractions.

ANNEX II. WAP underlying principles

This section sets out the principles agreed as part of the WAP. These principles can serve to guide the decisions that need to be made in cases where the WAP lacks sufficient detail.

1. The water resources are *finite and valuable*. This implies that there are insufficient resources to meet ever-increasing demands and therefore choices will have to be made on who should be allocated the resource and on what conditions. The value of the resource implies that the resource should be allocated for beneficial use;

2. The water resources are *vulnerable* to over allocation, over abstraction and degradation. This implies that there is a tangible *risk* to the environment, economy and social well being if the WAP is not complied with. It is in the public interest to adopt and comply with the WAP to set in place a controlled mechanism for the allocation and abstraction of water resources.

3. The *precautionary principle* implies that decisions can or indeed must be made even where information is incomplete in relation to;
    - Taking preventive action in the face of uncertainty;
    - Shifting the burden of proof to the proponents of an activity;
    - Exploring a wide range of alternatives to potential harmful actions;
    - Providing for public participation in decision-making.

4. Revisions to the WAP are contingent on *stakeholder participation*. Participation of water users requires proactive steps to ensure that disadvantaged groups are informed and able to articulate their concerns and interests;

5. *Water use conflicts* cause social and economic disruption. Inequitable allocation or access to the water resources provides fertile ground for water use conflicts. The WAP seeks to mitigate conflicts by setting out a framework agreed by the stakeholders for water allocation and abstraction;

6. *The Reserve* commands the highest priority in terms of water allocation. This implies that in the context of a very severe drought, even domestic water supplies may need to be rationed;

7. *Equity*. This is difficult to define precisely as it can often have different meanings for different stakeholders. Essentially equity implies that there should be a fair balance between environmental, livelihood and commercial benefits. Additionally it implies that new water users should be eligible for water allocation, depending on the priority attributed to their needs.

8. The WAP should minimise *social and economic disruption*. This implies that changes that need to be implemented to bring compliance to

the WAP or future changes in the WAP should provide for a transition period to enable social and economic adjustments to be made. Essentially this implies that existing lawful and beneficial use of the water should not be quickly, arbitrarily or unnecessarily curtailed;

9. Revisions to the WAP require *negotiation and respect* between different stakeholders. The process of negotiation requires informed and mandated representatives of stakeholder groups and adequate time and fora for negotiation to take place;

10. There is a need for *future revisions* to the WAP. The development of the WAP is made in the context of the priorities, understanding and information available at the present time. As better information and understanding is gained, or priorities change, then the WAP should be revised to reflect these developments.

ANNEX III. Land use change images

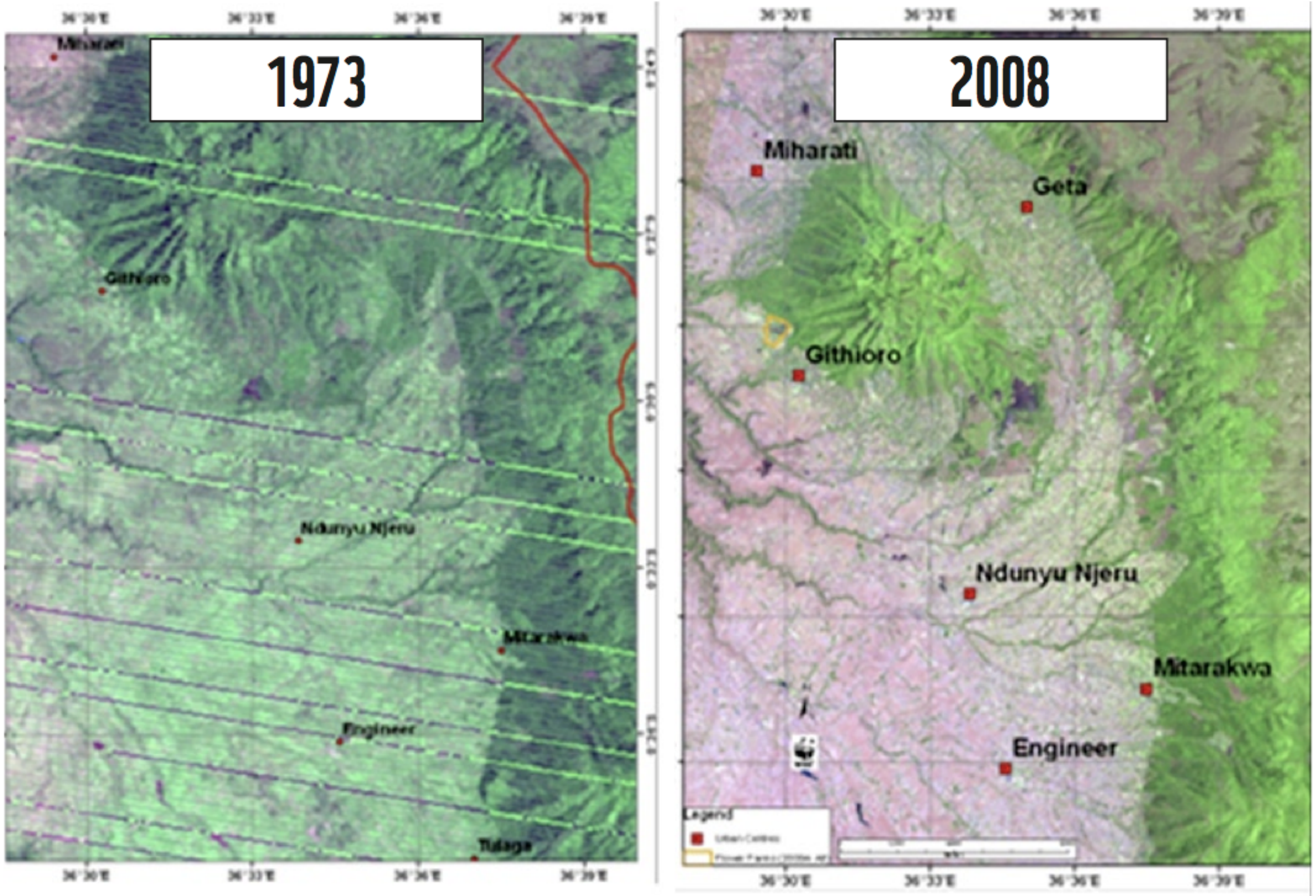


Figure 21: Land use changes Naivasha catchment area (north east part) (WWF, 2011, p. 6).

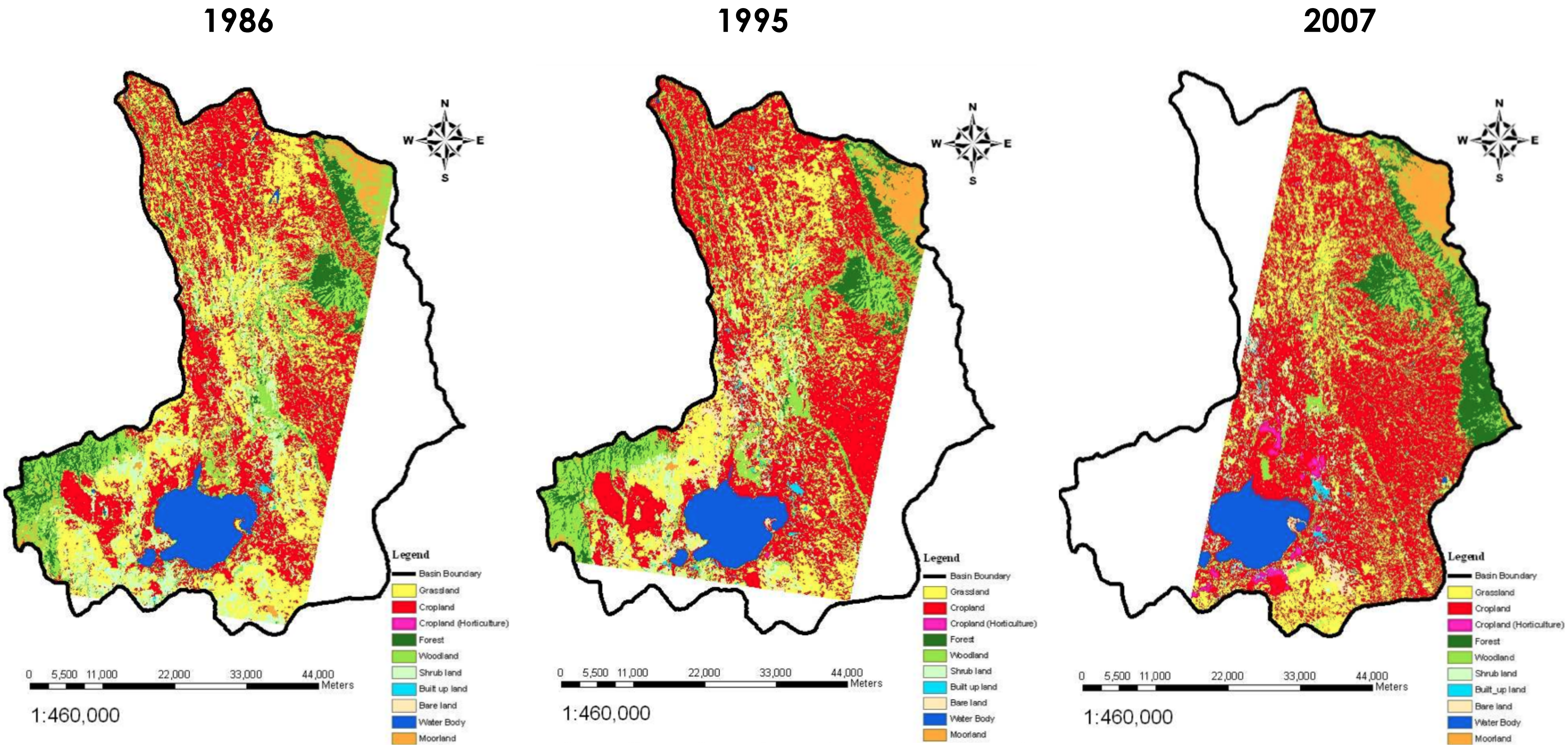
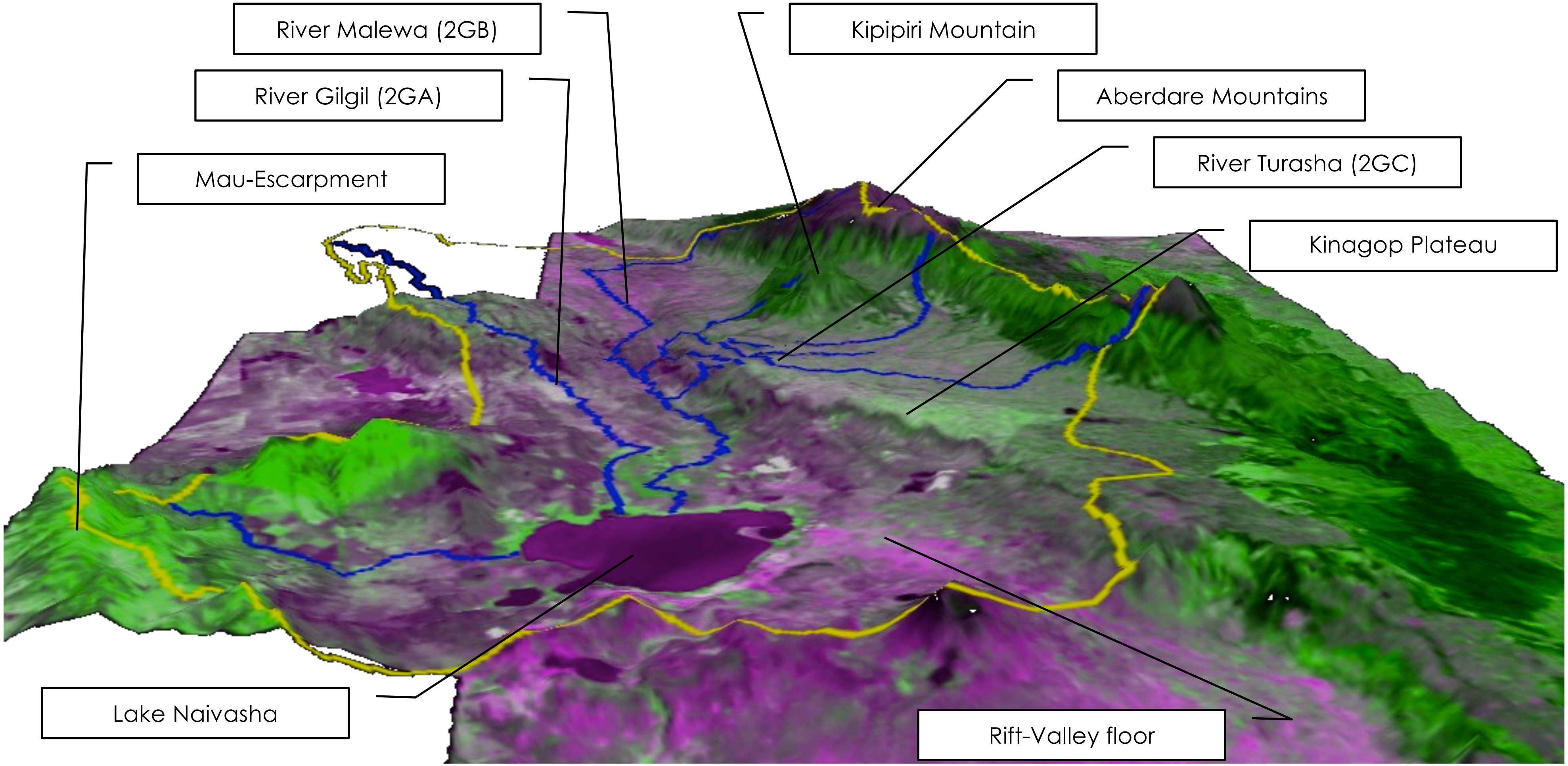


Figure 22: Land cover change, extracted from Landsat TM ('86 & '95) and ASTER ('07) images (Were, 2008, pp. 22-24).

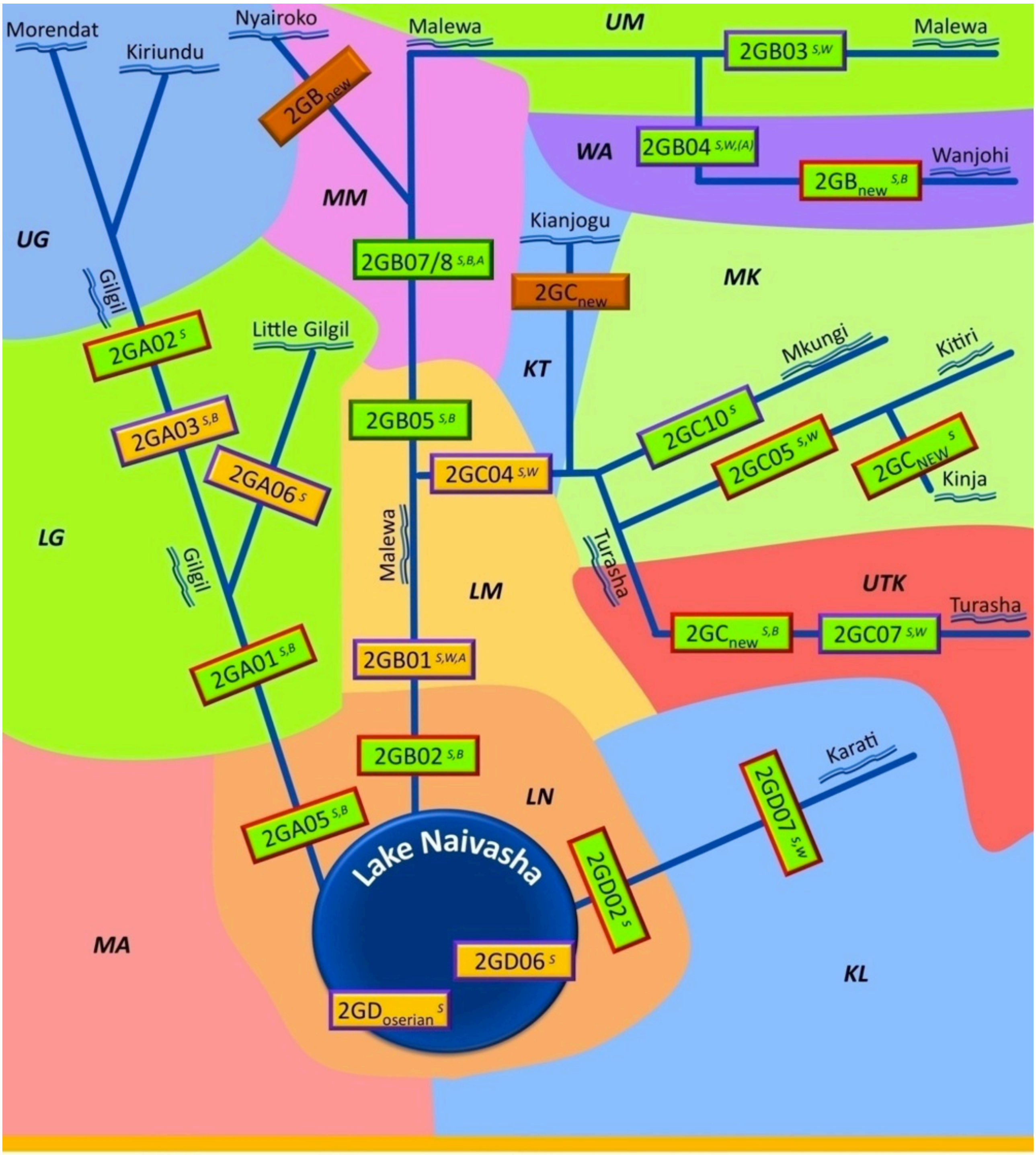
ANNEX IV. 2D image of the basin



Source: WWF Naivasha

ANNEX V. HQ image of Lake Naivasha + Riparian Area

ANNEX VI. Schematic drainage pattern Lake Naivasha Basin



Schematic drainage pattern showing the Regular Gauging Stations (RGS) in the different WRUAs* of the Lake Naivasha Basin

** WRUA areas are not representive in size and shape*

= Data +

= Data +/-

= Data –

= Used in WAP

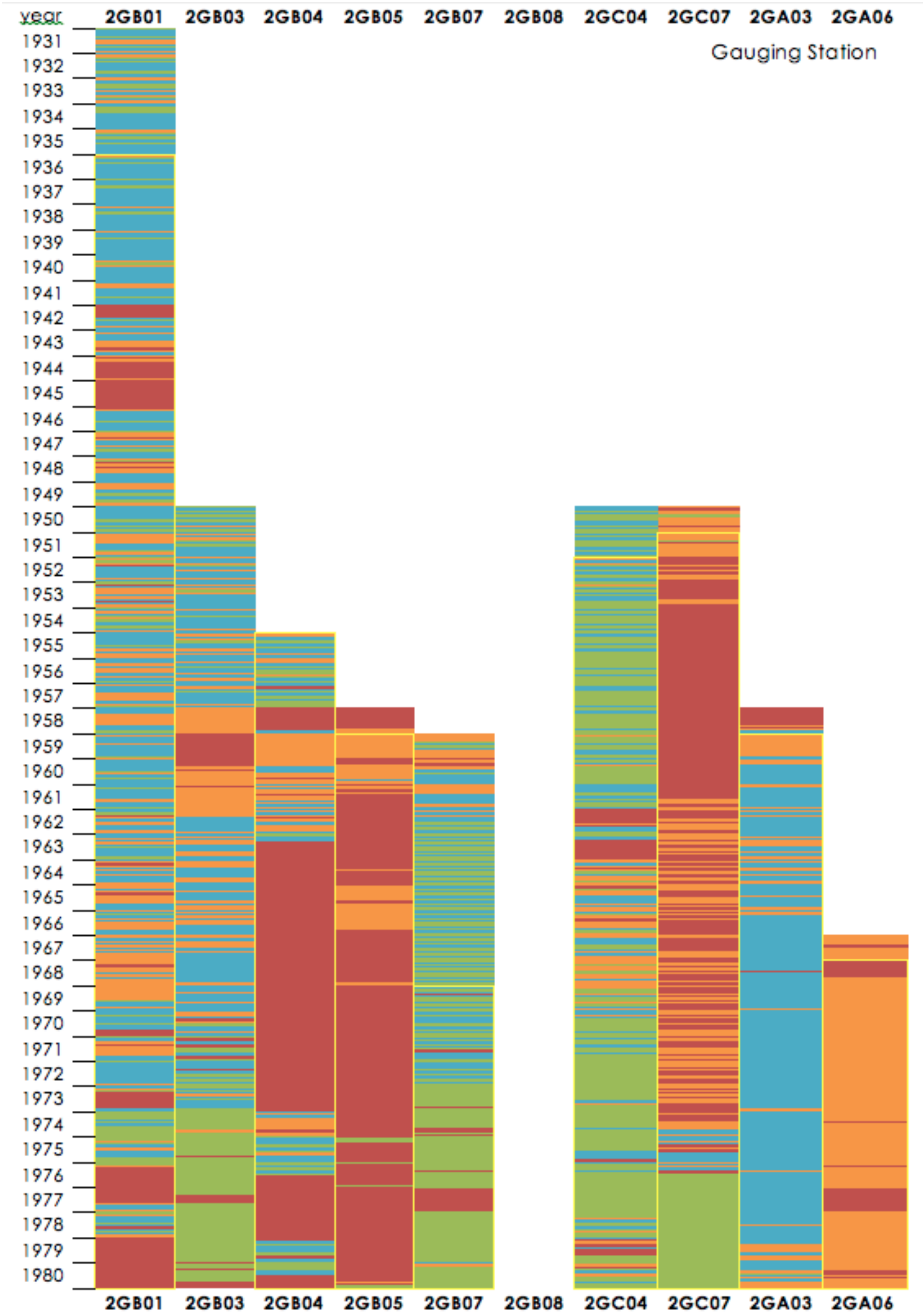
= Not used in WAP

= Yet to install

S	*= Staff*	*UG*	*= Upper Gilgil*	*UTK*	*= Upper Turasha Kinja*		
W	*= Weir*	*LG*	*= Lower Gilgil*	*MK*	*= Mkungi Kitiri*		
B	*= Bridge*	*WA*	*= Wanjohi*	*KT*	*= Kianjogu-Turasha*		
A	*= Automatic water level recorder*	*UM*	*= Upper Malewa*	*KL*	*= Karati Longonot*		
		MM	*= Middle Malewa*	*MA*	*= Mariba*		
		LM	*= Lower Malewa*	*LN*	*= Lake Naivasha*		

Thomas de Jong (2010)

ANNEX VII. Water level data completeness



Legend

Colour Code	Data Completeness
	100%
	> 80%
	40% - 80%
	< 40%

	Data record period used in the WAP