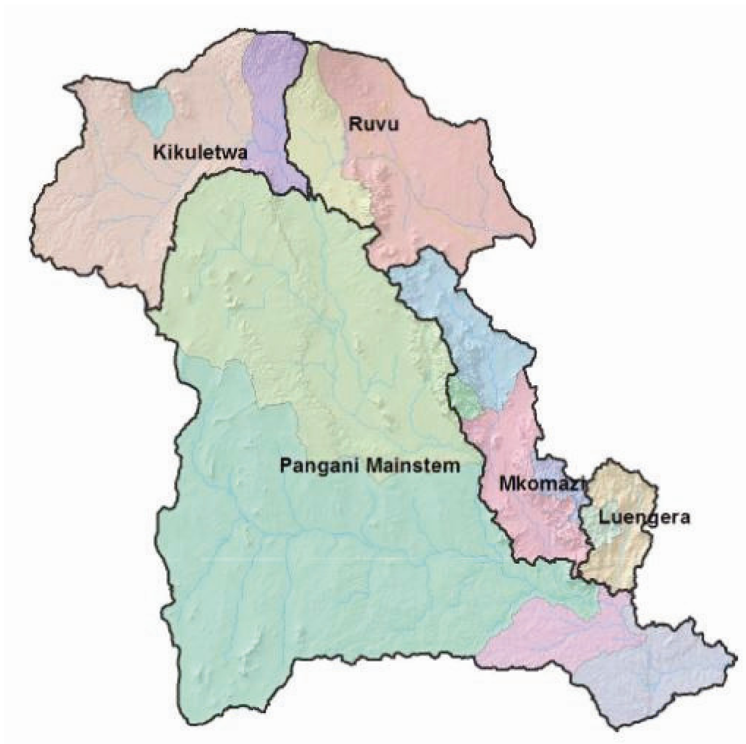
IUCN WATER AND NATURE INITIATIVE

PANGANI BASIN WATER BOARD[1]

PANGANI RIVER BASIN FLOW ASSESSMENT



Task 5 Report

An assessment of understanding and knowledge gaps

Final Report

J. King, C. Brown, A. Joubert, J. Turpie, B. Clark and H. Beuster

June 2008

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Task 5 Report

An assessment of understanding and knowledge gaps

Final Report

June 2008

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EXECUTIVE SUMMARY

Introduction

The Pangani Basin Flow Assessment (FA) is an initiative of the World Conservation Union (IUCN) and the Pangani Basin Water Office (PBWO) that brings together a core team of Tanzanian specialists in a range of river-related, water-allocation and policy-making disciplines and an international team of flow-assessment specialists from Southern Waters Ecological Research and Consulting and Anchor Environmental Consultants. Their task is to develop an understanding of the hydrology of the Pangani River Basin, the flow-related nature and functioning of the river system and the links between the river and the social and economic value of the river's resources. They then have to create scenarios of possible basin management/development pathways into the future for consideration by the water authorities and other stakeholders.

The project is divided into a series of ten tasks, as follows: Task 1: Hydrology, Task 2: Study area delineation and site selection, Task 3: Health assessment of the river and estuary, Task 4: Baseline socio-economic assessment, Task 5: Synthesis of understanding of the river systems and its economies and identification of major gaps, Task 6: Specialist Studies, Task 7: Creation and evaluation of scenarios, Task 8: Practical application of scenario evaluation by National Core FA Team, Task 9: Final Reporting, Task 10: Awareness raising at the basin and national level.

This report describes activities undertaken in Task 5, the aim of which is to create an awareness of the links between flow, the river ecosystem and its users, and the trade-offs to be made between water development and natural-resource protection. Part of this task includes developing an understanding of the water-related ecological and economic systems of the Pangani Basin based on work completed on the project to date (Tasks 1-4), identification of gaps in this understanding, and development of Terms of Reference for specialist studies to address these gaps.

The main activities related to this task were completed at the PBWO in Moshi, Tanzania, from 6 to 10 November 2006, involving all members of the FA team.

Key flow-related changes that have occurred in the Pangani Basin

Key flow-related changes that are evident in the river system were identified as follows:

- modified channel and habitats, particularly in the Kikuletwa river (dries up in dry season) and in the mainstem downstream of NYM dam (loss of floods and swamps);
- reduction in water quality (sediment accumulation upstream of NYM dam, pollution);
- decrease in fish abundance and diversity, particularly in Lake Jipe (due to extensive growth of macrophytes and a drop in lake level), the Kirua swamp (due to flood attenuation by NYM dam) and downstream of Pangani HEP station (due to intermittent releases);
- fishery created in NYM reservoir but this is now also declining in response to increased abstractions upstream of the dam that result in lower water levels in the reservoir;
- loss of floodplain vegetation in the Kirua swamp (flood attenuation) and invasion of exotic plants into the riparian zones (due to decrease in flow);
- substantial loss of goods and services historically provided by the river.

Changes associated with the estuary were:

- reduction in mean annual runoff entering the estuary, changes in the seasonality of freshwater flows, and a reduction in flood frequency;
- reduction in coarse sediment carried down by the river, with concomitant impacts on the state of the mouth and channel form;
- an increase in fine sediment (silt) carried down by the river, resulting in an increase in muddiness and anoxic sediment conditions;
- a reduction in water quality, principally a reduction in oxygen concentrations and an increase in the concentration of various inorganic nutrients;
- a reduction in the abundance and diversity of estuarine fauna and flora and in goods and services delivered by the estuary (e.g. fish and agricultural production).

Changes associated with the socio-economic conditions in the basin were:

- erosion of value provided by aquatic resources (e.g. fish) particularly at the Kirua swamps, the estuary, Lake Jipe, and Nyumba ya Mungu Dam;
- erosion of benefits provided by aquatic resources, thus reducing the ability of households to spread risk and to use the river as a safety net after shocks such as loss of employment or death of a breadwinner.

Conceptual frameworks

A conceptual framework (Figure E.1) was developed that would aid planning at a basin level. This outlines the context of the Pangani Basin Flow Assessment within integrated flow management of the basin:

The process starts with the selection of a range of possible development or other water-management scenarios known or contemplated for the Pangani Basin, for which flows are simulated using the basin hydrology models. Responding to this and using a number of purpose-built tools, the effects of flow changes on ecosystem health and the delivery of ecosystem good and services can be predicted, as can the effects on peoples' livelihoods and national and local economies. Using these predictions, trade-offs between development and protection of the river system's resources can then be considered by decision-makers and other stakeholders in the search for an optimal water-allocation solution. This optimal trade-off, finally decided upon by the decision-makers, could be defined as a Basin Development Plan, against which individual proposed developments could then be assessed.

Development and population of FA tools

The Pangani Basin was divided into a series of hydrologically discrete zones, for which the purpose-built FA tools (models) will be developed in the next phase of the project. Each will describe the relationship between flow or water levels and a particular water-related aspect of the basin:

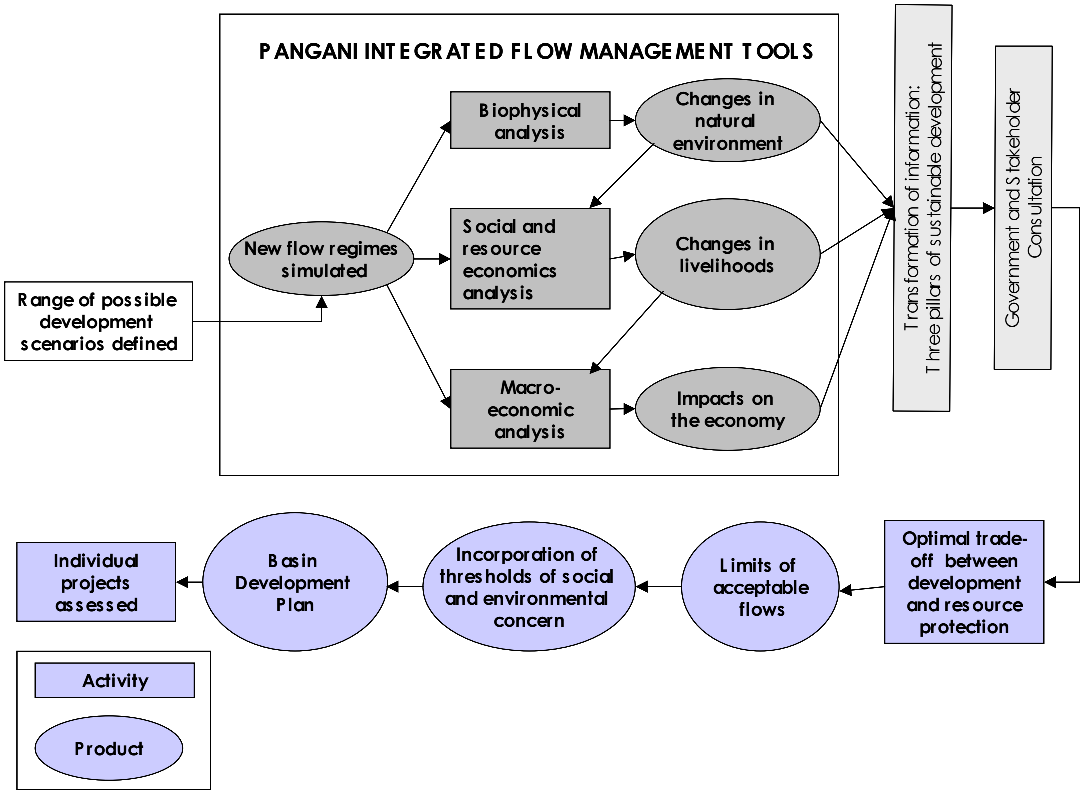

Figure E.1 Conceptual framework for planning at the basin level

- River ecosystem FA Tool;
- Kirua Floodplain FA Tool;
- Lake ecosystem FA Tool;
- Estuary FA Tool;
- People's livelihoods FA Tool;
- Hydropower FA Tool;
- Macro-economics FA Tool.

The FA tools will aid analysis of the development scenarios, providing predictions of ecological, economic or social change linked to each, for decision-makers to consider. Defined steps for the flow of data into and out of each tool have been developed, and team members responsible for each have been identified.

Identification of specialist studies for Task 6
Members of the project team compiled a list of all specialist studies they felt were necessary to provide a better understanding of the Pangani system and its users, and which were possible within the time limits of the project. Nineteen specialist studies were identified as important. As available funds for specialist studies were limited, these were prioritised for funding in terms of how urgently the knowledge was needed, and their importance to this flow assessment and to Integrated Water Resources Management (IWRM) generally in the Pangani Basin. Other issues considered in the prioritisation process included whether or not it would be possible to derive good value from a desktop study only, the estimated number of person days required to complete each study, the total duration of the project, and whether

capacity to do the study was available in Tanzania or would have to be sought elsewhere. A final priority list of eight projects was created:

1. A macroeconomics study that can provide a detailed overview of the water-related economy of the Pangani River Basin, and the contribution that this area makes to the national economy.
2. Hydraulic assessment of the water levels (or depth) and inundated areas in Lake Jipe, Nyumba ya Mungu, and the Kirua swamps associated with different antecedent river flows and seasonal variations in aspects such as evaporation.
3. Assessment of the relationships between water level and/or flow and fishery production for the major fisheries of the Pangani River Basin.
4. Assessment of the links between flow and distribution, biology and life history of key fish and invertebrate species of economic or subsistence value in the Pangani River system.
5. Assessment of the links between flow and the distribution, biology and life history of key plant species of economic or subsistence value in the Pangani River system.
6. A basin-wide assessment of past and present water quality of the Pangani system
7. Assessment of the likely impacts of climate change on the hydrology of the Pangani Basin.
8. Enhanced understanding of the variation in hydropower generated under different flow scenarios.

Funding from Pangani Basin Flow Assessment resources was available for seven priority studies. PBWO and IUCN published advertisements in the Tanzanian press publicising the studies, referring interested readers to a website with detailed Terms of Reference, and inviting proposals from interested consultant researchers. An evaluation committee consisting of PBWO and IUCN staff evaluated the proposals and the selected consultants were subsequently contracted to conduct the studies.

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1 INTRODUCTION

1.1 Introduction

Large water-resource developments or excessive water abstraction affect the flow, water chemistry, sediment and temperature regimes of aquatic ecosystems, and, as a knock-on effect, their fauna and flora. These changes also affect the people dependent on the rivers. Impacts can be reduced by manipulation of flow releases from impoundments for maintenance of the downstream river, or by regulation of water abstractions, or both (Brown and King 2000).

Aquatic ecosystems can be managed to be at different levels of condition, from pristine, through various stages of change, to serious degradation (King 2004). The functioning and characteristics of the systems change with a change in condition, as does their socio-economic value.

Within the Pangani River Basin, appropriate trade-offs between benefits provided by the aquatic ecosystems in the basin and the benefits provided through off-stream water use such as irrigation and hydropower should be decided upon by the decision-makers with input from other stakeholders in the basin. These trade-offs may be different for each sub-basin; for instance, sub-basins with conservation areas may place more emphasis on good river condition than those primarily used for food production. For each sub-basin, the level of ecosystem condition that is decided on, with its corresponding flow allocation will become the Environmental Flow for the aquatic ecosystems in that sub-basin.

The trade-offs are analysed by examining the predicted consequences of a range of scenarios describing the potential future management of the catchment and its water resources. Flow Assessments describe the consequences of different management scenarios, and by doing so offer options for consideration by decision-makers. The Assessments do not make recommendations of what the water allocation to any sector should be. This final trade-off is done by the relevant decision-makers.

The Pangani River Basin Flow Assessment Initiative (FA) is a joint initiative of the World Conservation Union (IUCN) and the Pangani Basin Water Office (PBWO). It brings together a national team of specialists in a range of river-related, water-allocation and policy-making disciplines and an international team of flow-assessment specialists from Southern Waters Ecological Research and Consulting and Anchor Environmental Consultants to develop an understanding of the hydrology of the Pangani River Basin, the nature and functioning of the river system and the links between the river and the social and economic value of its resources (see Basin Delineation Report for details). The project commenced in August 2005.

1.2 Project aims

The objectives of the Flow Assessment are to:

- generate baseline data of the condition of the Pangani River system against which the impact of water-related decision-making can be monitored in future;
- enhance the understanding among PBWO and Ministry of Water (MoW) staff of the relationship between flow, river health and the people who use the river;
- create an awareness of the trade-offs to be made between water development and natural-resource protection though consideration of a number of scenarios;

- develop simple tools to help guide flow management and water allocations in the Pangani Basin;
- build capacity that will enable PBWO to act as a nucleus of expertise for FA-related work in other areas;
- support the National Water Policy (NAWAPO 2002) and the National Environmental Management Act (EMA 2004).

1.3 Project tasks

The project is divided into ten tasks, as follows:

Task 1:	Hydrology.
Task 2:	Study area delineation and site selection.
Task 3:	Health assessment of the river and estuary.
Task 4:	Baseline socio-economic assessment.
Task 5:	Synthesis of understanding of the river systems and its economies and identification of major knowledge gaps.
Task 6:	Specialist Studies.
Task 7:	Creation and evaluation of scenarios.
Task 8:	Practical application of scenario evaluation by National Pangani FA Team.
Task 9:	Final Reporting.
Task 10:	Awareness raising outside the National Pangani FA Team.

This report addresses Task 5.

1.4 Task 5

Tasks 1-4 have together allowed development of an understanding among the team of the present day relationships between flow, river health and the people who use the river.
Tasks 5 and 6 build on this foundation. They aim to further enhance understanding of the river ecosystem and its users, and to create an awareness of the trade-offs between water development and natural-resource protection that need to be made. This will lead to the development of simple tools to help guide flow management and water allocations in the Pangani Basin. To this end:

- o Task 5 focuses on developing an understanding of the ecological and economic systems through discussion among the team.
- o Task 6 comprises a series of specialist studies, identified in Task 5 as being important to fill key information gaps.

Task 5 encompasses the following:

1. Assessment of the Hydrology Basin Report, the State of the Basin Report, the Ribver Health Assessment, the Estuary Health Assessment and the Baseline Socio-economic Assessment in order to identify and evaluate the key flow-related changes that have occurred over time in the basin.
2. Development of simple conceptual frameworks for predicting flow-related changes.
3. Identification of priority topics for more in-depth investigation and development of a set of discipline-specific questions to focus the in-depth investigations.
4. Development of a short list of specialist studies that is feasible within the Scope of Work for the project.
5. Identification of specialists and mentors to provide expert input on these selected studies.
6. Development of Terms of Reference (ToRs) for selected specialist studies.

1.4.1 Approach for Task 5

The main activities related to Task 5 were completed at the PBWO in Moshi, Tanzania, from 6 to 10 November 2006. The week was divided into several work sessions as follows:

Day 1:	Presentation and discussion of draft River and Estuary Health Assessments and Socio-economic Assessment, and the draft State of the Basin Report.
Day 2:	Identification of priority research topics and selection of topics for specialist studies.
Day 3:	Compilation of Terms of Reference for specialist studies, with budget allocations. Practice sessions for Team presentations to Pangani Basin Water Board (PBWB).
Day 4:	Review and changes to Terms of Reference for specialist studies. Presentation on suggested framework for Pangani flow assessments
Day 5	Forward planning. Presentations to the PBWB. Report writing.

This document reports on these activities. Its main purposes are:

- to introduce conceptual frameworks of the flow of data and activities that will aid water-resource planning at the basin and project levels;
- to detail the Terms of Reference for Specialist Studies in Task 6.

1.5 Participants in Task 5 Workshops

Members of the team present during part or all of the week of Task 5 are listed in Table 1.1.

Table 1.1 Participants in Task 5 Workshops

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2 KEY RIVER-RELATED CHANGES THAT HAVE OCCURRED IN THE BASIN

Tasks 3 and 4 were situation assessments of the health of the river and estuary, and the socio-economic situation in the basin that could be related to the river. The main findings from measurements, observation anecdotal information were as follows.

2.1 Rivers

Modified channel and habitats:

- Kikuletwa upstream of Chemka and Rundugai Springs dries up in low flows due to water abstraction for crops.
- Constant flows (loss of floods) downstream NYM dam.
- Disappearance of Kirua swamps due to dampening of flood peaks by NYM dam.

Water quality:

- Sediment accumulation upstream of NYM dam.
- Increase in water uses by increasing human population along the river has increased water pollution. This is a reflection of settlements, agriculture and livestock keeping (e.g. Wahoga chini, Kifaru, Hale and Himo towns).

Fish:

- Decrease in fish abundance and diversity after extensive growth of macrophytes in Lake Jipe in response to a drop in lake level.
- Decrease in fish abundance in Kirua swamp and relative increase in NYM reservoir in response to drop and increase in water levels respectively.
- Decrease in fishery downstream of Pangani Falls HEP Dam due to intermittent releases.

Vegetation:

- Loss of floodplain vegetation in Kirua swamp in response to decreased flooding frequency.
- Introduction of exotic plants in the riparian zones of Pangani, Mkomazi, Ruvu and Luengera rivers in relation to decrease in flows.

2.2 Estuary

- a reduction in mean annual runoff reaching the estuary;
- changes in the seasonality of freshwater flows reaching the estuary;
- a reduction in flood frequency;
- a reduction in coarse sediment carried down by the river, with concomitant impacts on the state of the mouth and channel form;
- an increase in fine sediment (silt) carried down by the river, resulting in an increase in muddiness and anoxic sediment conditions;
- a reduction in water quality, principally a reduction in oxygen concentrations and an increase in the concentration of various inorganic nutrients.

These impacts have collectively had a serious negative impact on the health of the estuary, resulting in a reduction in the abundance and diversity of fauna and flora in the system, and a reduction in goods and services delivered by the estuary (e.g. fish and agricultural production).

2.3 Socio-economics

It is estimated that the total gross value of aquatic resources to households in the Pangani River Basin is between Tsh 8.7 and 2.9 billion per year (US$ 7 – 10 million). However, it is evident that the value provided by aquatic resources has already been substantially eroded. Rivers in the highlands are no longer perennial, and fish have reportedly disappeared from these. The Kirua swamp has been reduced to a fraction of its former size due to cessation of flooding, and with it has been lost a valuable fishery, leaving households in the area even more vulnerable and poor than they were before. Fishers at the Pangani estuary report that catches there have declined, and some believe this is due to reduction in freshwater inputs. Even at Lake Nyumba ya Mungo, a reservoir that largely replaced a natural wetland, fisheries have reportedly declined due to low water levels as well as over-fishing. At Lake Jipe, the fishery was all but exterminated by high nutrient levels leading to encroachment of the lake by emergent vegetation. Thus the capacity of the aquatic systems in the basin to provide value to households has been compromised. Any restoration of them that would be possible in future management plans would provide an increase in social services to poor rural households in the basin.

3 CONCEPTUAL FRAMEWORKS FOR BASIN PLANNING

Integrated Water Resource Management (IWRM) is a relatively new approach to water management that aims to meet the three primary requirements of sustainable development: ecological integrity, social justice and economic development. To achieve this, a number of options for any anticipated water-management activity (development of a river system or rehabilitation of a degraded one) are identified and described in terms of the full range of positive and negative ecological, social and economic impacts each would generate. These detailed options should be made available to government and other stakeholders in an accessible format, so that a fair and equitable decision can be made on the way forward. The first two sections of this chapter outline conceptual frameworks for planning at the basin and project level, followed by a framework for the flow of data to achieve the objectives given in the two planning sections. These frameworks guide planning, but not implementation, which would need further structured organisation in order to realise the objectives decided upon in to the planning process.

3.1 Planning at a basin level

Figure 3.1 illustrates a possible conceptual framework for planning at the basin level. It places the Pagan Basin Flow Assessment in context within the bigger picture of IWRM of the basin. Planning is seen as a process of identifying what society may need in the future in terms of water-related goods and services; modelling the impact of each of these needs in terms of impact on river flow; predicting the consequences of changing flows on river health, livelihoods and both local and regional economies; and transforming this technical information into a form accessible for government and other stakeholders. Decisions can then be made on a management pathway into the future.

The individual boxes in Figure 3.1 are explained in Sections 3.1.1 to 3.1.15.

3.1.1 Range of possible development scenarios defined

List all water developments known or contemplated for the Pangani Basin over the next 30 or more years, and describe or estimate their water-related details to the extent possible. Include any options for introducing water demand management, improving present water use from existing schemes, and rehabilitating degraded systems. Use this knowledge to choose a number of development/rehabilitation scenarios that between them encompass all possible management pathways to the future.

3.1.2 New flow regimes simulated

Using the hydrology models all ready set up for the basin, simulate the future flow regime for each scenario at the daily time-step, for points along the whole Pangani system.

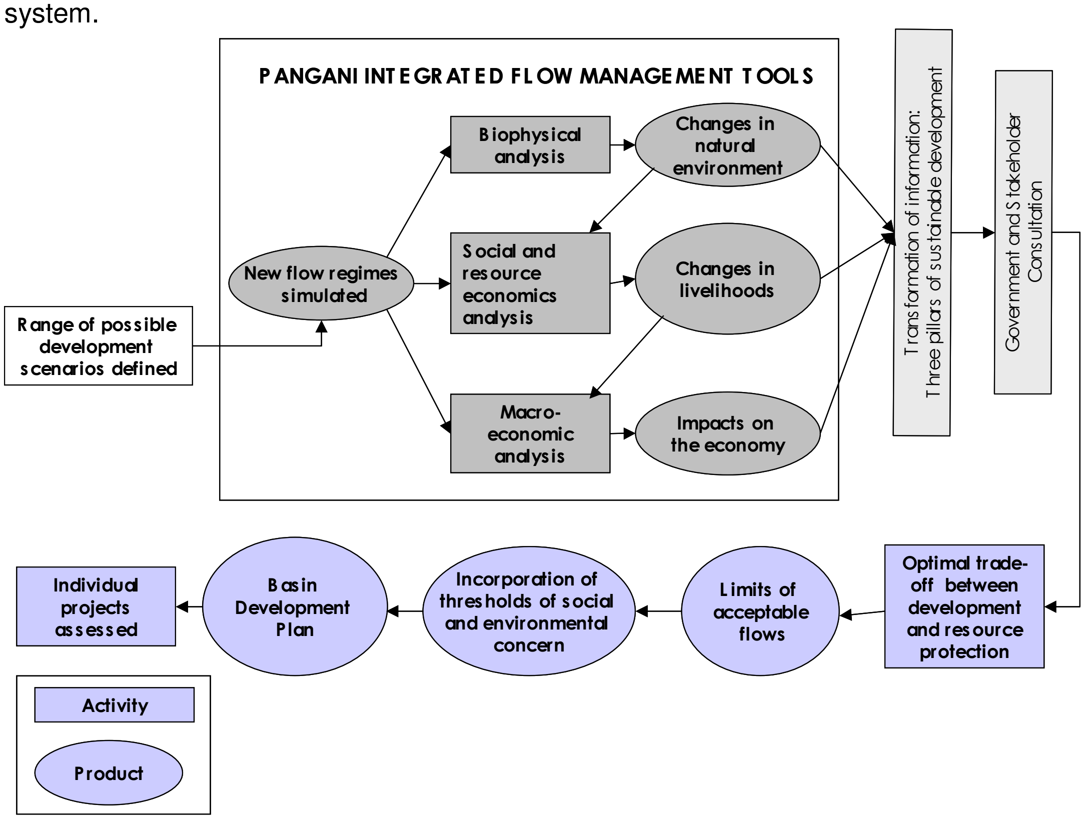

Figure 3.1 Planning at the basin level

3.1.3 Biophysical analysis

Use preliminary research (such as, in this project, the state of the river and estuary reports; specialist reports; international literature searches) to populate custom-built databases for the river and estuary with a first generation of ‘flow-response couplets’. Each of the couplets predicts how some ecosystem indicator linked to river flow could change with a specific flow change defined by the set of development scenarios. Indicators could be, for instance, abundance of fishes, a water-quality variable such as salinity, or a plant community on the banks. The first generation flow-response couplets can be amended with time as new research improves our understanding of the system.

3.1.4 Changes in the natural environment

Analyse each simulated flow regime (from Section 3.1.2) in terms of what flow changes from present it would cause and what change from present it would trigger in all of the indicators. The full set of relevant flow-response couplets is automatically chosen within the database and outputted as a set of descriptions about how the ecosystem could change. This is summarised by experienced river and estuarine ecologists. In most cases water developments will cause some measure of degradation to the ecosystem, which could translate into a loss of biodiversity or deterioration in water quality. Thus, in most cases, these changes will represent a cost of the development.

3.1.5 Social and resource economics analysis

Use any available knowledge (in this project, the socio-economic report; specialist reports; international literature searches) to populate a custom-built database with people-river resource relationships.

3.1.6 Changes in people's livelihoods

Feed changes in the natural environment (Section 3.1.4) through to the social database (Section 3.1.5), which outputs predictions of how ecosystem changes will affect resource use and livelihoods. This is summarised by an experienced resource economist. In many cases, ecosystem changes will result in a reduction in river resources for people, and this would represent a cost of the development.

3.1.7 Macro-economic analysis

Complete a macro-economic analysis of the current value of all uses of the water including river resources, and of multiplier effects.

3.1.8 Impacts on the economy

Define the effect on the national, regional and local macro-economies of each of the development scenarios. As well as improving these economies, many of the effects could lead to improvements in peoples' livelihoods, and so may be seen as benefits of the development. On the other hand, some of the local negative effects of resource degradation may filter through to affect the wider economic structure of the region.

3.1.9 Transformation of information: the three pillars of sustainable development

The outputs to this point are detailed and technical, and thus not in a form suitable for easy understanding of the main messages. Transformation of the information into accessible language in a summary form is a vital step to facilitate its use by government and other stakeholders in the basin. The information is summarised as three streams of information reflecting the three pillars of sustainable development: ecological integrity, social justice and economic development.

3.1.10 Government and stakeholder consultation

The summary information on each scenario is prepared for consideration by the Pangani Basin Water Board and other stakeholders. Each scenario represents a possible path to the future, and each will have different levels of benefits and costs. Other stakeholders can also evaluate the scenarios and feedback to government those that are acceptable and unacceptable to them. Different scenarios will probably be acceptable to different stakeholders.

3.1.11 Optimal trade-off between development and resource protection

Taking into consideration all stakeholder inputs, the government decides on the development path for the basin/country that represents the optimal trade-off between protection of river resources and livelihoods, and development.

3.1.12 Limits of acceptable flows

The scenario(s) that define the optimal development path represent flow regimes that need to be maintained in the river system. The outer boundaries of these flow regimes can be described as a series of rules/guidelines for the required flow maintenance. This can be used to identify how much ‘development space’ remains in the Pangani Basin – or indeed, if this has already been exceeded.

3.1.13 Incorporation of thresholds of social and environmental concern

Within the band of acceptable flows, many different kinds of development might still be planned. To ensure that these do not unwittingly cause unforeseen impacts, ‘bottom line’ thresholds of concern should be identified against which they are checked. Such thresholds could include, for instance, an X percent reduction in the estuarine fishery, a Y percent increase in river-related diseases or the crossing point of some economic threshold.

3.1.14 Basin Development Plan

Based on Section 3.1.11-3.1.13, a basin development plan could be drawn up that takes into account the ‘development space’ available, where it is located within the basin, and local, regional and national needs.

3.1.15 Individual projects assessed

With the basin development plan defined, individual development projects can be assessed in terms of whether or not they adhere to it (see Figure 3.2).

3.2 Planning at a project level

Once planning at the basin level has been concluded and the Basin Development Plan, or similar, has been established then proposed projects can be assessed against this on a project-by-project basis.

Figure 3.2 illustrates a possible conceptual framework for planning at the project level, illustrating the context of the Pangani Basin Flow Assessment within the bigger picture. The process begins with identification of a possible water management activity (development or rehabilitation), which is assessed in terms of whether or not it complies with the Basin Development Plan. If it does, its impacts are then predicted using the FA Tools, and assessed by government and other stakeholders in much the same way as the earlier process (Figure 3.1). The individual steps are described in Sections 3.1.1-3.1.10.

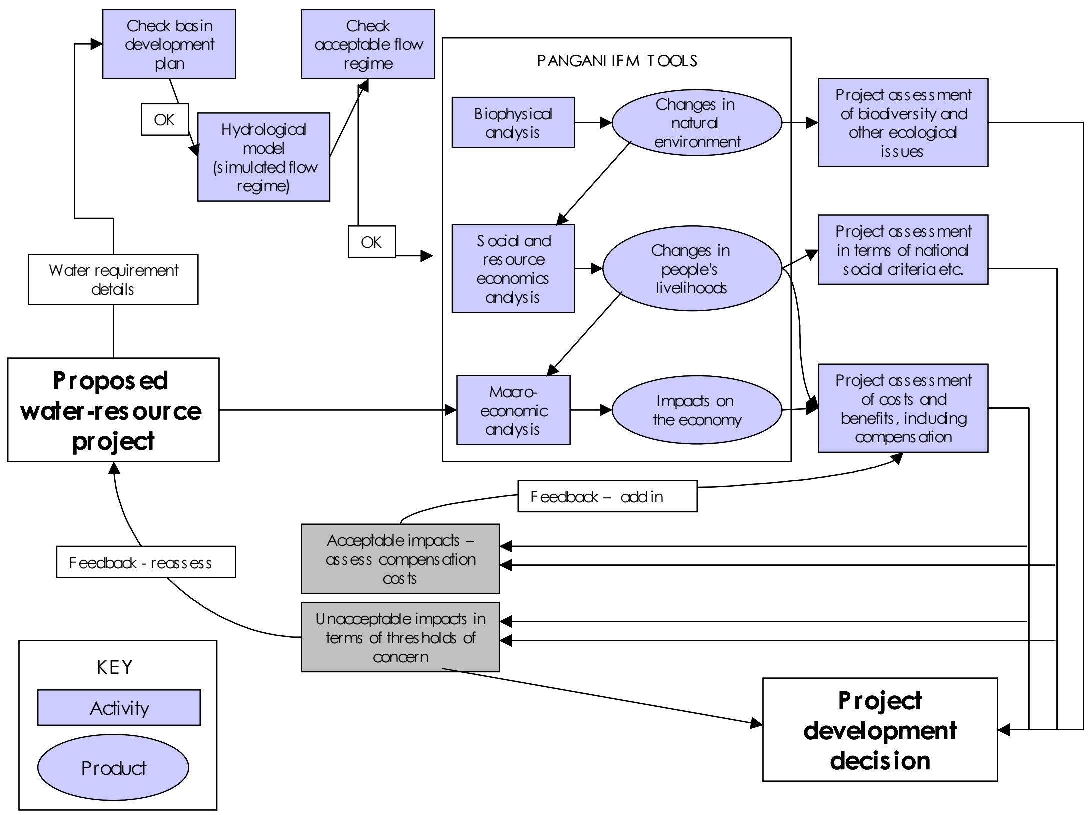

Figure 3.2 Planning at the project level

3.2.1 Details of proposed project

For proposed water-resource developments above a size to be determined by the Pangani Basin Water Board details are provided of the implications in terms of water requirements.

3.2.2 Check with basin development plan

The project is assessed in terms of adherence to the Basin Development Plan.

3.2.3 Simulate flow regime and assess

The flow regime of the complete river system with the scheme in place is simulated using the basin hydrology model, and assessed in terms of compliance with the limits of acceptable flows.

3.2.4 Predictions of change

The Pangani Integrated Flow Management Tools are employed to predict the ecological, social and macro-economic costs and benefits of the development.

3.2.5 Project assessment of biodiversity and other ecological issues

Predicted changes to the river ecosystem are assessed in terms of national commitments to multilateral environmental agreements (e.g. UNCBD, UNFCCC, UNCCD, Ramsar Convention) as well as national policies, legislation, strategies and plans in relevant sectors (e.g. water, energy, agriculture, environment).

3.2.6 Project assessment of social goals

The impact of the changing river resources on peoples' livelihoods is evaluated in terms of relevant social criteria such as millennium development goals, poverty reduction (www.povertymonitoring.go.tz/documents/mkukuta_main_eng.pdf), local development priorities and health criteria.

3.2.7 Project assessment of costs and benefits, including compensation

The macro-economic impacts of the development are evaluated in terms of national and regional economies or other relevant criteria. For compensation – see Section 3.2.9.

3.2.8 Unacceptable impacts in terms of thresholds of concern

Ecological and social impacts deemed unacceptable in terms of the thresholds of concern identified in the basin management plan require re-assessment and perhaps re-design of the proposed project, or possibly rejection (Section 3.2.10).

3.2.9 Acceptable impacts – assess compensation costs

Any project of the size being considered will cause some ecological change to the river system and may have social impacts also. If the social impacts include loss of river resources, the costs of these could become the subject of compensation. Any compensation costs would feedback into the macro-economic analysis (Section 3.2.7).

3.2.10 Project development decision

Based on the three streams of information, on the ecological, social and economic implications of the proposed project, a decision is made on whether or not to proceed with development and under what conditions.

3.3 Modelling process and data management

The large boxes in Figure 3.1 and Figure 3.2, and possibly their preceding boxes, represent the Pangani Flow Assessment activities. Complex processes and tools for data collection, processing, analysis and interpretation are necessary in order to provide the predictions of change shown in the figures. The flow of data has to be carefully planned to ensure the right information in the right format is available at each stage of the Flow Assessment.

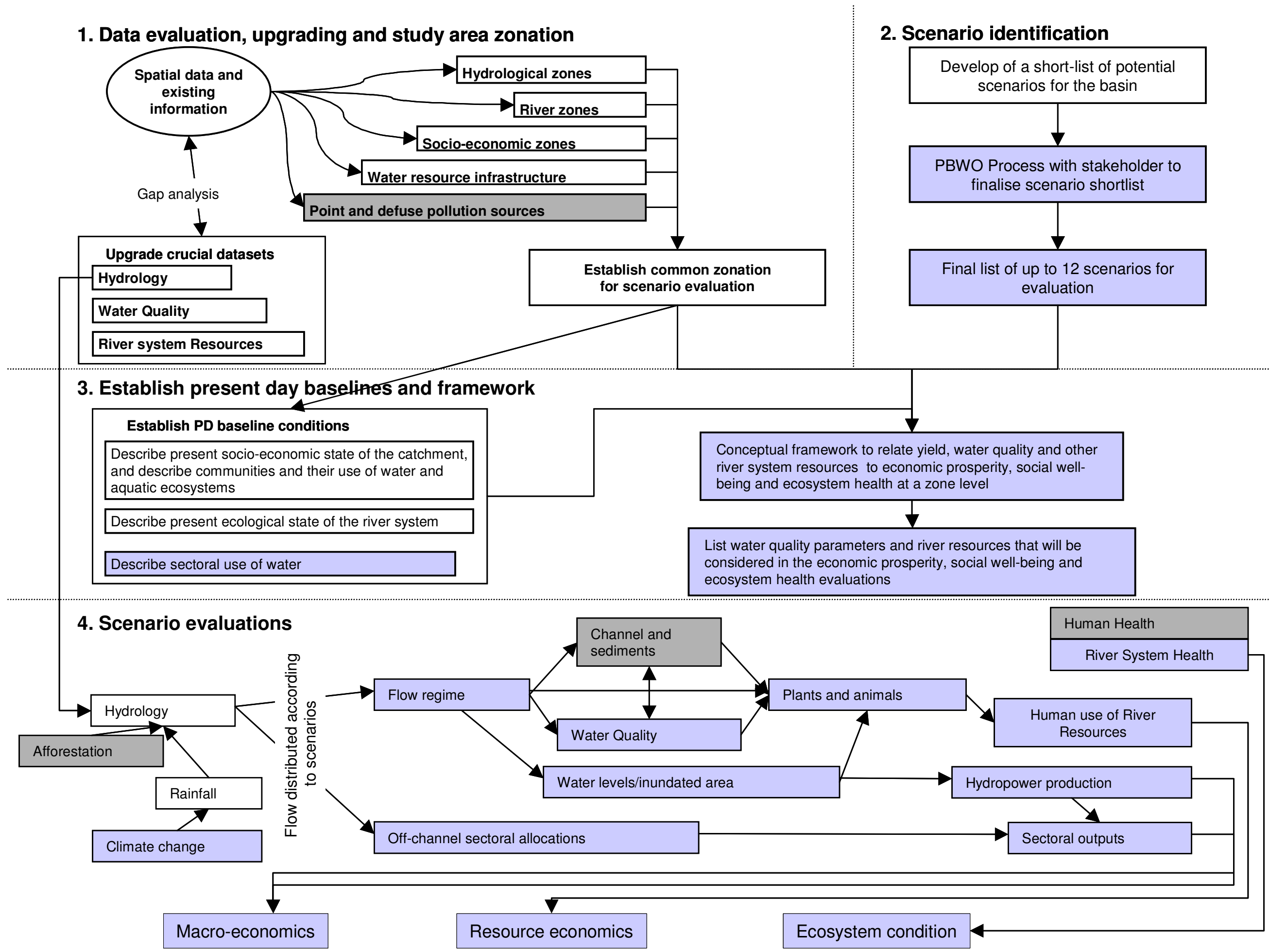

Figure 3.3 Conceptual framework of the flow of data

illustrates the conceptual framework created for the flow of data. The top two sections of Figure 3.3 represent Tasks 1 and 2; the next section down covers Tasks 3, 4 and 5; and the bottom section Tasks 5 to 10. The details of each box are provided in the following sections.

3.3.1 Evaluate existing spatial data

Relevant existing data and information on the Pangani Basin were sourced and assessed for major data gaps.

3.3.2 Upgrade crucial data sets

The hydrological data drive the whole of the integrated flow assessment. A major project activity was to review and upgrade them, and to develop hydrological models for the basin. This resulted in a Pangani Basin Hydrology Report. Another extremely important data set is that on water quality, but a comprehensive upgrade was not undertaken at this stage. Yellow blocks have not been addressed at that point in the process.

3.3.3 Establish a common zonation for use in the integrated flow assessment.

Information on the hydrological and biophysical nature of the river system, the social groupings in the basin and the existing water-resource structures were used to establish a common set of biophysical and socio-economic zones along the river system. Predictions of ecological, social and economic change, gleaned from study sites, would be extrapolated within each zone. The Basin Delineation Report contains the details.

3.3.4 Identify scenarios

A workshop with stakeholders in March 2006 led to identification of a set of 12 scenarios representing a wide range of possible development trajectories for the basin. The Scenario Selection Report refers. The PBWO, in consultation with stakeholder groups, will finalise the list of scenarios for use in the rest of the project.

3.3.5 Establish baseline (present day) conditions

A river health assessment, estuarine health assessment and social assessment were completed between May and October 2006, leading to three reports. The fourth baseline assessment required is that on the water-related economics of the basin, which will form part of the macro-economic specialist study (see steps 11-12).

3.3.6 Develop a conceptual framework for the Integrated Flow Assessment

This appears as Figure 3.1 and accompanying text in Section 3.1.

3.3.7 Develop a conceptual framework for data flow

This appears as Figure 3.3.

3.3.8 Improve the hydrological data set

Data on how climate change could affect rainfall and evaporation in the basin will be provided through a special study. A similar study on the affects of afforestation or deforestation on river flow was proposed but not prioritised for the current project. From this activity the basin hydrology models will be able to simulate the future flow regime linked to each development scenario either with or without climate change included.

3.3.9 Biophysical analysis

The biophysical analysis for any one scenario indicated in Figure 3.1 and Figure 3.2 will be triggered by the simulated flow regime. The River, Floodplain, Lake and Estuary FA Tools (Section 4) will produce predictions of resulting ecosystem changes in terms of the channel, water quality, fish, invertebrates and riparian vegetation. Specialist studies on water quality, hydraulic modelling of standing water bodies (Lake Jipe, NyM reservoir, Kirua Floodplain), and important fish and invertebrate species will enhance knowledge of the system and thus the quality and confidence level of the predictions. A specialist study identified but not prioritised in this project was one on channel geomorphology and sediment dynamics. For this and other areas where there will be few local data or little knowledge, predictions will be based on the international literature and known trends in river change. The result of this activity will be an output on predicted ecosystem change as illustrated in Figure 3.3.

3.3.10 Social analysis

The information on changes in the river and its resources will be analysed in the Livelihood FA Tool (Section 4.5) to predict the social impacts. The output will be predictions of how changing river resources affect local livelihoods. The groups of resources considered in the analysis are wild foods, reeds and sedges (*Phragmites* and *Cyperus*), grasses, palms (*Hyphaene* and *Phoenix*), wood (for timber, poles and fuel), waterbirds, fish (including *Synodontis, Tilapia, Chanos, Valamugil, Clarias, Plotosus, Labeo, Barbus* & eels), crabs and Penaeid prawns. Due to limitations of the study, wild foods, grasses, woody species and birds are not dealt with at the species level.

3.3.11 Information on the hydraulic relationship between flow and inundation levels

Information on the hydraulic relationship between flow and inundation levels of NyM will be used in a specialist study on the implications of each scenario for hydropower generation. This will be fed into the larger body of information on sectoral use of water under each scenario and will itself feed into the macro-economic analysis (Macro-economic FA Tool – Section 5.7). The output will be an economic analysis of all of the impacts of the development, including benefits to local and national economies, losses or gains in terms of river resources, and multiplier effects.

3.3.12 Information to decision -makers

The stream of information on the economic, environmental and social aspects of the scenarios will be prepared in accessible form for consideration by government and other stakeholders. Aspects of human health were identified as important but could not be covered in this project.

3.3.13 Summary

The tools and processes described in this chapter outline the way in which an FA approach supports sustainable development, through providing a comprehensive array of information on the costs as well as the benefits of any planned water management activity. The process should be an integral part of IWRM, with the ecological and social implications of development/rehabilitation given the same weight and attention as the economic and engineering aspects. We envisage the process being followed and the tools set up for each drainage basin, after which any scenario of interest can easily be investigated to show its costs and benefits. In a basin where the process has not been done, it should be started at the earliest stage of development/rehabilitation planning, so that the favoured scenario can be chosen BEFORE dam design or similar happens. Schemes should be designed to meet the flow and other requirements of the chosen scenario and not the other way round as presently happens in almost all parts of the world. This latter course has led to schemes being designed and built, and only afterwards do the detrimental costs of flow changes become apparent. The FA approach helps avoid this situation.

4 DEVELOPMENT AND POPULATION OF FA TOOLS

The framework for the flow of data as depicted in Section 3.3 can be translated into a series of purpose-built FA tools or models that will facilitate the data analyses required at each stage. In the lowest section of Figure 3.3 arrows show the flow of information from the hydrological module through various physical, chemical and biological modules, to the HEP, social and economic modules. Each of these steps needs a tool to accept the information from the previous module and convert it into a prediction of change within the receiving module. In this chapter, we focus on the tools that are being developed for the Pangani for this purpose. The tools are represented pictorially in Figure 4.1.

The flow of information begins with the WEAP model, which is the hydrological model that simulates the flow changes for each scenario (Beuster *et al.* 2006). The simulated flow regimes it produces are taken up in three different ways:

- simulated daily flows are used by the 13 River FA Tools to predict river ecosystem changes at 13 points along the river system; they are also used by the Kirua Floodplain Tool to predict flooding and biological responses on the floodplain;
- simulated monthly summarized flows are taken up by the Lake, Estuary and HEP Tools, which do need the fine detail of daily flows, to predict changes in each of these;
- the simulated total supply of water is taken up by the Macro-economic FA Tool to predict the wider economic implications of the flow changes, including the positive impacts in terms of, for instance, increased areas of irrigated crops or security of supply to urban areas.

The information from the river, estuary, lake and HEP tools feeds into the Livelihoods FA Tool, which provides information on social impacts such as household incomes and general wellbeing. The full suite of tools provides the information required to make decisions within a sustainable-development approach. The middle set of tools in Figure 4.1 provides information on ecological integrity; the bottom left tool on economic development and the bottom right tool on social justice.

One important set of project activities, to be done leading up to and within Task 7, will focus on ensuring that the various tools can provide data and knowledge in a form that receiving tools can use (see Chapter 5).

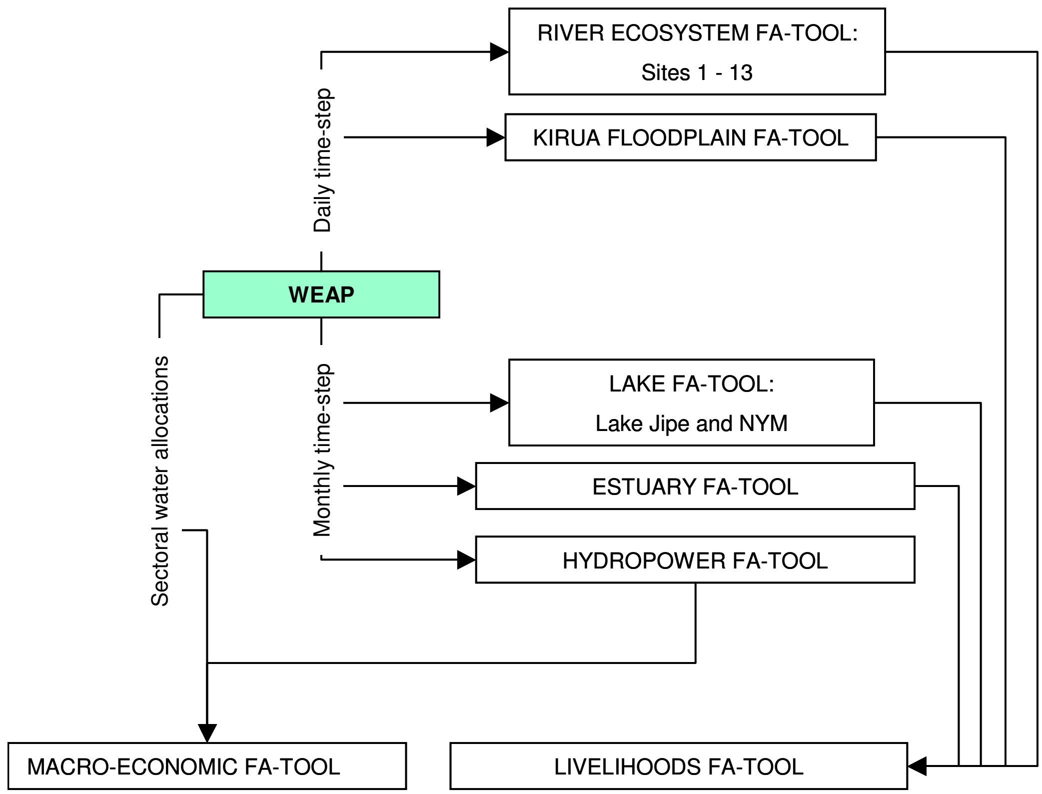

Figure 4.1 Conceptual framework of the suite of FA tools required to facilitate the data analyses inherent in the data flow in Figure 3.3

This section discusses the plan for development of each of these tools and their population with the data that will be used in scenario predictions. The responsibility for procurement/development of two of these tools has been out-sourced as part of the Task 6 Specialist Studies. The suite of tools to be developed by the FA team is:

- River ecosystem FA Tool.
- Kirua Floodplain FA Tool.
- Lake ecosystem FA Tool.
- Estuary FA Tool.
- People's livelihoods FA Tool.
- Hydropower FA Tool (Outsourced – see Section 6.3).
- Macroeconomics FA Tool (Outsourced – see Section 6.3).

4.1 River FA Tool

It is envisaged that there will be one FA Tool for each of the important river zones in the Pangani Basin, encompassing most of the river sites established in the Delineation Phase of the project (Figure 4.2 and Table 4.1).

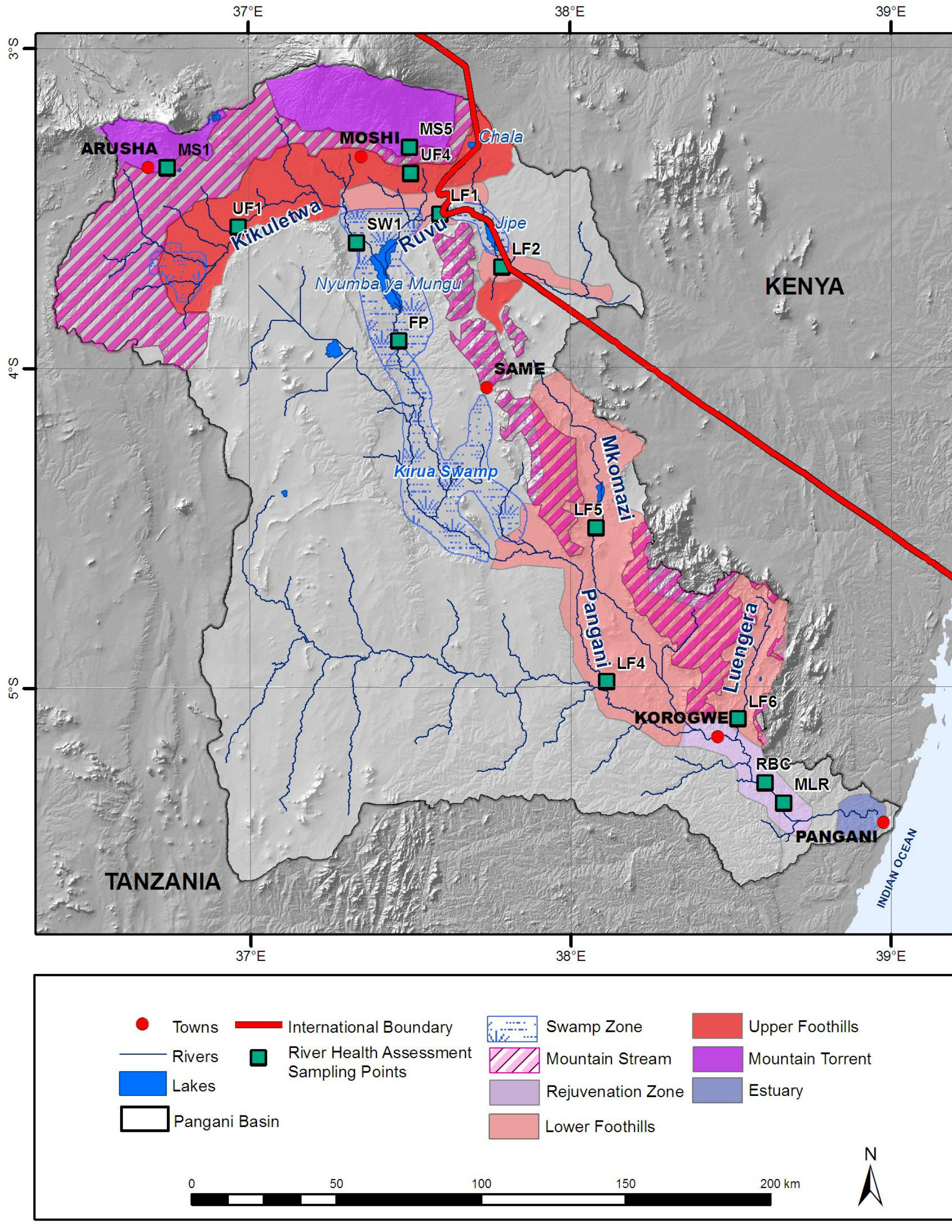

Figure 4.2 River zones

With the exception of the Mountain Torrent Zone, each zone is represented by at least one river site. At this stage, however, the key river sites targeted for FA Tools are R 1, 2 and 3, R 5 and 6, and R 8-13, i.e., a total of 11 sites. R7 is omitted because there are insufficient rainfall or flow data for the hydrological system model to be able to simulate hydrological data for these sites; thus, as hydrological (flow) data are the starting point of each scenario, scenarios cannot be created for these sites.

Table 4.1 Study sites within the Pangani Basin selected for the river health assessment

Site No.	River system	River name at reach	Coordinates	Location Description	River Sub-zone
R1 (MS1)		Nduruma R.	3°22'24.24"S 36°44'51.06"E	U/S of Nduruma chini	Mountain Stream
R2 (UF1)	Kikuletwa R.	Kikuletwa R.	3°33'28.17"S 36°58'05.61"E	Wahoga chini (gauging station)	Upper Foothill
R3 (SW1)		Kikuletwa R.	3°38'23.62"S 37°18'16.72"E	Upstream Nyumba ya Mungu	Swamp
R4 (MS5)		Ona R.	3°18'36.51"S 37°30'04.37"E	Samangai - Kimatoloni bridge	Mountain Stream
R5 (UF4)	Himo R.	Himo R.	3°23'29.55"S 37°30'14.94"E	At Himo town, upper bridge (gauging station)	Upper Foothill
R6 (LF1)		Ruvu R.	3°31'08.98"S 37°34'03.63"E	At Kifaru, upstream of the bridge	Lower Foothill
R7 (LF2)	Muraini R.	Muraini R. (Mvuleni R.)	3°41'09.24"S 37°47'16.74"E	Upstream Jipe (at bridge)	Lower Foothill
R8 (FP)		Pangani R.	3°54'57.67"S 37°28'01.5"E	Kirua swamp	Swamp
R9 (LF4)		Pangani R.	4°59'02.02"S 38°06'47.91"E	Mkalamo village (at the bridge)	Lower Foothill
R10 (RBC)	Pangani R.	Pangani R.	5°18'05.22"S 38°36'26.68"E	Mwakinyumbi (Hale town downstream)	Rejuvenation Zone
R11 (MLR)		Pangani R.	5°21'53.31"S 38°39'57.74"E	Jambe village	Mature Lower River
R11A*[2]		Pangani R.	4°30'07.83"S 38°04'53.31"E	Jambe village	Lower Foothill/ Rejuvenated Bedrock Cascade
R12 (LF5)	Mkomazi R.	Mkomazi R.	5°06'02.03"S 38°31'25.07"E	Downstream Kalimawe dam (at Bendera)	Lower Foothill
R13 (LF6)	Luengera R.	Luengera R.	3°22'24.24"S 36°44'51.06"E	Kwamndolwa – old Korogwe	Lower Foothill

The steps in the development and population of the river ecosystem FA tool are given in Table 4.2. It is envisaged that this tool will be based on the principles of DRIFT (**D**ownstream **R**esponse to **F**low **T**ransformations; King *et al.* 2003). The central rationale of DRIFT is that different aspects of the flow regime of a river elicit different responses from the riverine ecosystem. Thus, changes in a particular element of the flow regime will affect the riverine ecosystem differently than will removal of some other element. Data and knowledge on the links between flow and the physical, chemical and biological nature of the river system can be captured and used to predict how flow changes would result in ecosystem changes.

DRIFT is essentially the data-management tool for these predictions, allowing data and knowledge to be used to their best advantage in a structured way. Within DRIFT, component-specific methods are used to derive the links between river flow and river condition.

DRIFT assumes:

- o it is possible to identify and isolate the elements of the flow regime from the historical hydrological record (e.g. floods of a specified magnitude that inundate riparian tree communities, or dry-season low flows that maintain connectivity of flow along the river);

[2] Additional site added during wet-season river health assessment

- it is possible to describe the probable biophysical consequences of changes in any one of these elements of the flow regime, in isolation;
- once these biophysical consequences have been described, it is possible to combine them in various ways to describe the overall impact on river condition of a range of different potential flow regimes;
- once the potential changes in river condition have been described, it is possible to describe their implications for people's livelihoods (Section 4.5).

Table 4.2 Steps in the development and population of the river FA tool

Step	Action	Comments
1	Divide the flow regime into ecologically relevant components.	See Section 4.1.1.
2	Obtain list of important river resources from socio-economists.	From the Social Assessment Report.
3	Establish key supporting ecosystem components for each river resource.	See Section 4.1.2.
4	Incorporate key flow-related changes identified from Task 3 (see Section 2).	This involves cross-checking the lists of ecosystem components identified in Steps 2 and 3 and including any key changes not yet incorporated.
5	Develop the river database templates according to Steps 1, 2 and 3 above.	Incorporate the flow components determined in Step 1 and the ecosystem components identified in Steps 2, 3 and 4.
6	Determine relationships between key supporting river components and changes in flow-regime components.	These relationships will be developed from a wide array of sources including, but not necessarily limited to: - Task 6 specialist studies on fish and plants; - international ecological literature; - the results of FA projects for other river ecosystems.
7	Populate the river databases for each selected river site.	To be explained in more detail in Task 7.

4.1.1 Division of the flow regime

The first of the main assumptions in the process is that it is possible to identify and isolate ecologically relevant elements of the flow regime from the historical hydrological record. Thus, one of the first steps in the process, for any river, must be to **identify the ecologically most important flow categories**. For the Pangani River Basin it is expected that this division will be driven by:

1. seasonal variations;
2. variations in low flows and flood flows.

The climate in the Pangani Basin is characterised by two rainy seasons:

- the short rains, which start in approximately October and continue through to December, and;
- the long rains, which start in approximately March and continue through to June.

Thus a possible division of the flow regime could be along these lines (Figure 4.3).

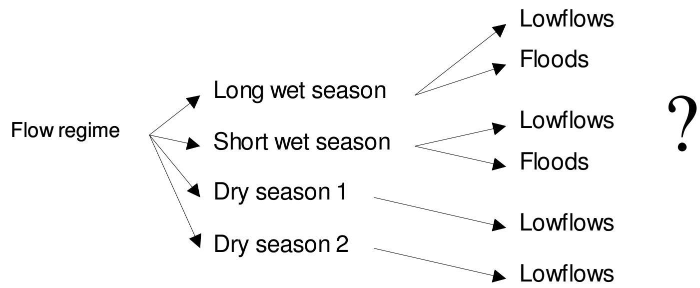

Figure 4.3 Possible division of a typical flow regime of a river in the Pangani Basin into flow seasons

These rainy periods are mirrored by the annual hydrographs of many of the rivers, which show a bi-modal pattern of elevated flows lagging slightly behind the rainfall with the extent and timing of this pattern differing between hydrological zones.

Thus, as a further step in division of the flow regime, the seasonal division of the flow regime was determined through evaluation of the annual hydrographs for each of the major hydrological zones in the basin:

- Kikuletwa River
- Ruvu River
- Pangani at Kirua
- Pangani upstream of Mkomazi
- Lower Pangani River (and estuary)
- Mkomazi River
- Luengera River

Only present-day hydrographs are available for the Pangani at Kirua and upstream of Mkomazi, but it is anticipated that their naturalised flow regimes would show a similar pattern to that on the upstream reaches, that is, for the Kikuletwa and Ruvu. Nevertheless, present day flows downstream of Nyumba ya Mungu (Figures 4.4 and 4.5) were checked to assess if they show a seasonal division that is incompatible with a division based on natural characteristics, which they did despite the influence of Nyumba ya Mungu.

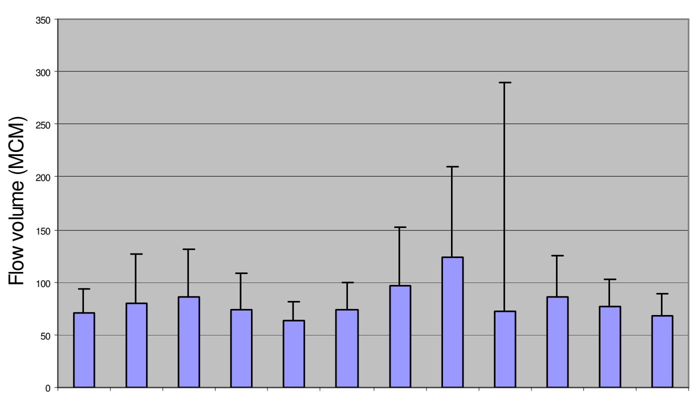

Figure 4.4 Pangani Mainstem at Kirua. Present day annual hydrograph for 1D8C – immediately downstream of Nyumba ya Mungu

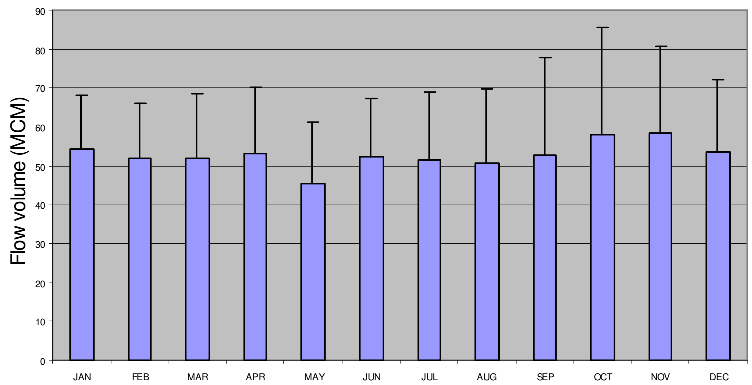

Figure 4.5 Pangani River immediately upstream of the confluence with the Mkomazi River. Present day annual hydrograph for 1D10.

Suggested seasonal divisions of the flow regimes of each of these sub-basins, based on their hydrological records, are given in Table 4.3. Seasons are numbered sequentially based on the hydrological year, i.e., starting in October.

Table 4.3 Suggested seasonal divisions of the flow regimes of the hydrological sub-catchments

Sub-catchment	Wet 1	Dry 1	Wet 2	Dry 2	Comments
Kikuletwa	November-January	February-March	April-June*	July-October	Wet 2 characterised by flood events
Ruvu	November-January	February-March	April-June*	July-October	
Pangani @ Kirua	November-January	February-March	April-June*	July-October	
Pangani u/s Mkomazi	November-January	February-March	April-June*	July-October	
Lower Pangani River and estuary	October - December	January-February	March-June	July-September	Both Wet 1 and Wet 2 characterised by flood events
Mkomazi River	November-January	February	March-May*	June-October	Wet 2 characterised by flood events
Luengera River	October-November	December - March	April-June*	July-September	

4.1.2 Establishing key supporting ecosystem components for river resources

In order to describe the changes in a particular river resource in response to flow, information may be required for other ecosystem components that play a key role in supporting the resource under consideration. For instance, before the consequences of a reduction in dry-season low flows for a fish can be predicted, it may be necessary to first consider the effects of the flow on the following:

- o water levels, depths and wetted area;
- o water velocity;
- o temperature;
- o salinity concentrations;
- o habitat quality (e.g., riffle embeddedness);

- o inundation of marginal vegetation;
- o extent of instream vegetation;
- o potential food for the fish.

Some of these will be more important than others in determining the eventual outcome for the fish, and not all will be addressed in the Pangani Basin Flow Assessment. However, the most important of these supporting relationships will need to be included in the FA Tool(s).

4.2 Kirua Floodplain FA Tool

It is envisaged that there will be separate FA Tools for the Kirua Floodplain and for the river as it passes the floodplain (the latter is discussed in Section 4.1).

Table 4.4 Steps in the development and population of the Kirua Floodplain FA tool

Step	Action	Comments
1	Identifying water losses incurred	This information will be supplied by the hydrologists.
2	Obtain list of important river resources from socio-economists.	Social Assessment Report
3	Establish the magnitude of flow that will inundate Kirua Floodplain to different extents, and the manner in which this inflow distributes itself across the system	The establishment of these relationships form a Task 6 Specialist Study (see Section 7.3).
4	Develop the Kirua Floodplain database templates according to Steps 2 and 3 above.	Develop the template to incorporate the flow components determined in Step 1 and 3 and the ecosystem components identified in Step 2.
5	Establish relationships between inundation levels and frequency, and fish catches	These relationships will be developed from a wide array of sources including, but not necessarily limited to: - the Task 6 specialist studies on fisheries, fish and plants; - international ecological literature; - the results of FA projects for other floodplain ecosystems.
6	Establish relationships between inundation levels and floodplain plant biomass	
7	Populate the Kirua Floodplain databases based on the relationships determined in Steps 3, 4 and 5 above.	To be explained in more detail in Task 7.

4.3 Lake FA Tool

It is envisaged that there will be two lake FA Tools: one for Lake Jipe and a second for the reservoir at Nyumba ya Mungu. It is anticipated that the nature of the tool for the lakes will be similar to that for the floodplain (Section 4.2) in that the driving physical variable that will be considered is lake levels. The relationship between inflow (and releases in the case of NYM) and lake levels form the subject of one of the task 6 Specialist Studies (see Section 7.3)

Table 4.5 Steps in the development and population of the Lake FA tool

Step	Action	Comments
1	Determine the relationship(s) between inflow (and releases in the case of NYM) and lake levels, taking account of climatic variations.	This establishment of these relationships form a Task 6 Specialist Study (see Section 7.3).
2	Develop lake templates according to Steps 1 and 2 above.	Develop the template to incorporate the flow components determined in Step 3.
3	Establish relationships between lake levels and fish catches.	Establishment of these relationships forms a Task 6 Specialist Study (see Section 7.4).
4	Populate lakes databases for the NYM and Lake Jipe based on the relationships determined in Steps 2 and 3 above.	To be explained in more detail in Task 7.

4.4 Estuary FA Tool

It is envisaged that there will be one FA Tool for the Pangani Estuary, encompassing all of the sites Identified during the Estuary Health Assessment surveys (Figure 4.4).

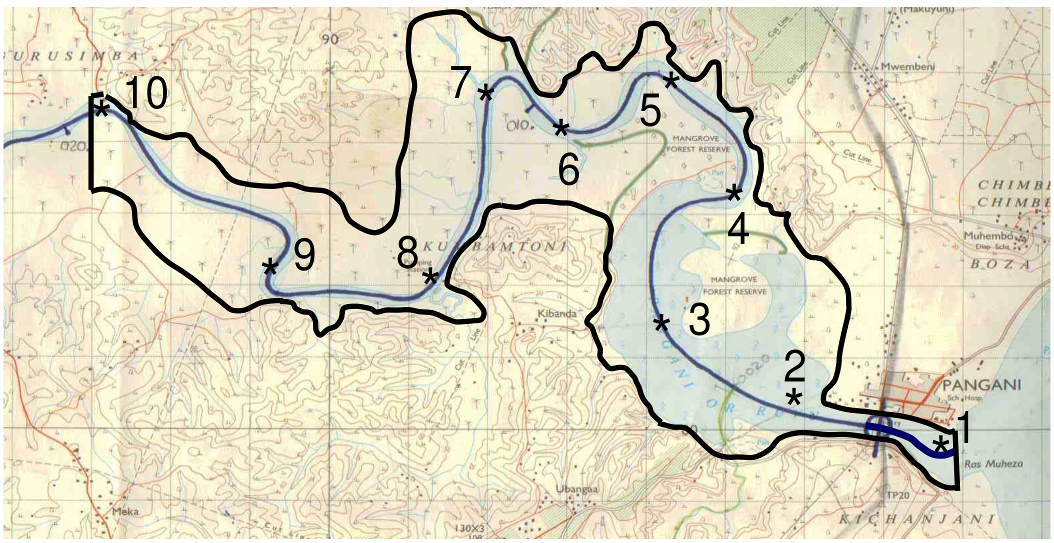

Figure 4.4 Locations of the ten sampling sites in the Pangani estuary with downstream, upstream, and lateral boundaries of the estuary marked

The steps in the development and population of the estuarine ecosystem FA tool and the rationale for each step are essentially the same as those for the river (described in Section 4.1) and are not repeated here. Similarly, division of the flow regime for the estuary follows a similar procedure to that for the river sites (described in Section 4.1.1 above). An examination of the flow regime at the head of the estuary revealed that there is a period of elevated flow between October to December corresponding to the short rains that occur in the upstream Pangani basin (Wet 1), another period of elevated flow with accompanying flood peaks between March and June (Wet 2, and two low flow periods January-February (Dry 1) and July-September (Dry 2).

Supporting ecosystem components for the estuary resources that may be affected by changes in flow (and can hence affect distribution or abundance of biota in the system) are similar to those identified for the river, and would include for example:

- salinity
- oxygen concentration
- concentration of inorganic nutrients
- water velocity
- turbidity
- extent of inundation
- habitat quality (e.g., mean sediment particle size)
- food availability.

Not all of these are equally important for all resources but most will need to be included in the FA Tool(s) in order to fully evaluate the effects of changes in flow on the estuarine ecosystem and the delivery of good and services from it. A summary description of the steps to be followed in the development and population of the Estuary FA tool is provided in Table 4.6.

Table 4.6 Steps in the development and population of the Estuary FA tool

Step	Action	Comments
1	Identify water losses incurred	This information will be supplied by the hydrologists
2	Obtain list of important estuary resources from socio-economists	This information will be obtained from the socio-economic team
3	Establish relationships between inundation levels and frequency and availability and abundance of key resources	Task to be completed by the estuary team
5	Develop estuary database templates according to Steps 1 and 2 above	Task to be completed by the estuary team
6	Determine relationships between key supporting ecosystem components and changes in flow regime components	Task to be completed by the estuary team
7	Populate estuary databases	Task to be completed by the estuary team

4.5 People's livelihoods FA Tool

The aim of the Livelihoods FA Tool is to determine changes in household income in different parts of the study area as a result of changes in water supply and the supply of ecosystem products that result from changes in water allocation and flows. The main inputs will be the percentage change in the resources or resource groups shown in Figure 4.5. The effect of change in abundance of resources on household income will depend on demand and supply characteristics that will have to be estimated. Changes in water supply will need to be translated into a change in agricultural output, taking limiting factors such as land into account. Given the data limitations, the tool will be simple and will not take complex issues such as health impacts and impacts of changes in the regional or national economy on household well-being into account. It should, however, be possible to add these at a later stage.

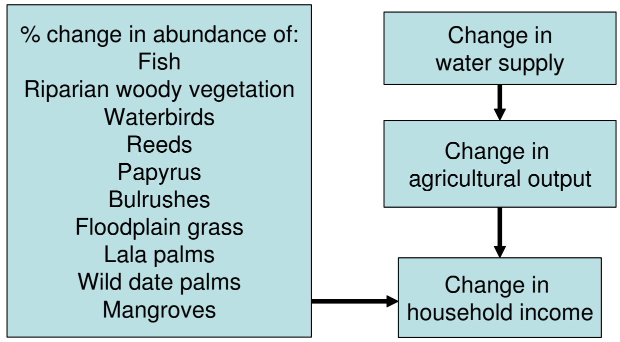

Figure 4.5 Schematic of the main inputs and outputs of the livelihood assessment tool

The steps in the development and population of the Livelihoods FA Tool are described in Table 4.7.

Table 4.7 Steps in the development and population of the Livelihoods FA tool

Step	Action	Comments
1	Estimate the relationships between water supply and agricultural outputs	This will be based mainly on inputs from the specialist study. Water for livestock is only considered in the case of stall-fed livestock.
2	Estimate the relationships between resource abundance and household use and income	This will be based mainly on inputs from the specialist study
3	Develop a spreadsheet model using these relationships	
4	Obtain details on the change in amount of water supplied to small-scale farmers with each scenario	
5	Obtain percentage change in each of the resources for each zone in the study area for each scenario from the relevant ecologists	
6	Populate the spreadsheet model and obtain the outputs	
7	Provide outputs to the macroeconomic model as required	The macro-economist to provide details.

5 FORMAT AND FLOW OF DATA BETWEEN FA TOOLS

Section 4 noted that the process of creating and using tools to predict flow-related changes to rivers and people is complex. In that chapter, the tools that will be used within the process were outlined. In this chapter, further information is given on how the data will flow from tool to tool.

The information is provided in Table 5.1 to Table 5.7, which list the input and expected output data for each of the FA Tools and an initial indication of the format of those data. The tables will need to be evaluated by the specialists responsible for each discipline to ensure that:

For data required FROM their discipline:

- o they are aware of who requires data from them;
- o the tool they are using/developing will be able to provide the data;
- o the data will be available for them in the required format;

For data required FOR their discipline:

- o the specialists responsible for providing the data are aware that the data are required from them and are able to provide such;
- o the tool they are using/developing will be able to provide the data;
- o the data can be passed on in the required format.

5.1 Input/output data for the River Ecosystem FA Tool

Table 5.1 lists the anticipated inflow and outflow data for the River ecosystem FA Tool, and where possible the required/expected format for those data.

Table 5.1 Anticipated inflow and outflow data for the River ecosystem FA Tool

<table>
<tr><td colspan="5">Input data</td></tr>
<tr><td>Data description</td><td>Format</td><td>From</td><td>Providing specialists</td><td>Where</td></tr>
<tr><td>Naturalised and present day flow sequences</td><td rowspan="2">Daily data for > 30 years.</td><td rowspan="2">WEAP</td><td rowspan="2">Beuster, Lugomela</td><td>River sites identified in Section 4.1</td></tr>
<tr><td>A modified flow regime for each scenario</td><td>At applicable river sites identified in Section 4.1</td></tr>
<tr><td colspan="5">Output data</td></tr>
<tr><td>Data description</td><td>Format</td><td>To</td><td>Receiving specialists</td><td>Where</td></tr>
<tr><td>Changes in identified river resources</td><td>Percentage change in abundance relative to present day</td><td>Livelihoods FA Tool</td><td>Turpie, Hepelwa</td><td>River sites identified in Section 4.1. Extrapolation to social zones by socio-economic team</td></tr>
<tr><td>Changes in water quality parameters</td><td>Percentage change in present day concentrations</td><td>Estuary FA Tool</td><td>Clark, Benno, Salum, Lukambuzi</td><td>Riv 13</td></tr>
<tr><td>Estimates of overall river condition</td><td>Rated on a scale of A-E (see State of the Basin Report)</td><td>Scenario evaluation results</td><td>Brown, King, Kaaya, Materu, Benno</td><td>River sites identified in Section 4.1</td></tr>
<tr><td>Flow regime for achievement of a given overall river condition</td><td>Modified daily flow sequences in DRIFT format. Also relevant Flow Duration Curves and information on the timing, magnitude and duration</td><td>WEAP</td><td>Beuster, Lugomela</td><td>River sites identified in Section 4.1</td></tr>
</table>

5.2 Input/output data for the Kirua Floodplain FA Tool

Table 5.2 lists the anticipated inflow and outflow data for the Kirua Floodplain FA Tool, and where possible the required/expected format for those data.

Table 5.2 Anticipated inflow and outflow data for the Kirua Floodplain FA Tool

Input data				
Data description	Format	From	Providing team specialists	Where
Relationship(s) between flood events and inundation extent and duration in the Kirua floodplain	Lookup tables or a reactive database.	Hydraulics model	Hydraulics Specialist Study	Kirua floodplain
Naturalised and present day flow sequences	Daily data for > 30 years.	WEAP	Beuster, Lugomela	Kirua floodplain
Modified flow regimes based on changes outlined in the Scenarios				Kirua floodplain, if applicable
Output data				
Data description	Format	To	Receiving team specialists	Where
Changes in identified river resources	Percentage change in abundance relative to present day	Livelihoods FA Tool	Turpie, Hepelwa	Kirua floodplain
Estimates of overall floodplain condition	Rated on a scale of A-E (see State of the Basin Report for explanations)	Scenario evaluation results	Brown, King, Kaaya, Materu, Benno	Kirua floodplain
Flow regime for achievement of a given overall river condition	Modified daily flow sequences in required format. Also relevant Flow Duration Curves and information on the timing, magnitude and duration	WEAP	Beuster, Lugomela	Kirua floodplain

5.3 Input/output data for the Lake FA Tool

Table 5.3 lists the anticipated inflow and outflow data for the lake FA Tool, and where possible the required/expected format for those data.

Table 5.3 Anticipated inflow and outflow data for the Lake FA Tool

Input data				
Data description	Format	From	Providing team specialists	Where
Lake levels linked to the modified flow regime for each scenario	Time series of water levels (depths)	Hydraulics model/WEAP	Hydraulics specialist/Hydrologist	Lake Jipe and Nymba ya Mungu
Output data				
Data description	Format	To	Receiving team specialists	Where
Changes in fish catch	Percentage change relative to Present Day	Livelihoods FA Tool	Turpie, Hepelwa	Lake Jipe and Nymba ya Mungu
Estimates of overall lake condition	Rated on a scale of A-E (see State of the Basin Report for explanations)	Scenario evaluation results	Brown, King, Kaaya, Materu, Benno	Lake Jipe and Nymba ya Mungu
Flow regime for achievement of a given overall river condition	Modified daily flow sequences in DRIFT format. Also relevant Flow Duration Curves and information on the timing, magnitude and duration	WEAP	Beuster, Lugomela	Lake Jipe and Nymba ya Mungu

5.4 Input/output data for the Estuary FA Tool

Table 5.4 lists the anticipated inflow and outflow data for the Estuary ecosystem FA Tool, and where possible the required/expected format for those data.

Table 5.4 Anticipated inflow and outflow data for the River ecosystem FA Tool

Input data				
Data description	Format	To	Providing team specialists	Where
Naturalised and present day flow sequences	Monthly data > 30 years.	WEAP	Beuster, Lugomela	Head of the estuary
Water quality parameters	Percentage change in present day concentrations	Estuary FA Tool	Brown, King, Kaaya, Materu, Benno	Riv 13
Output data				
Data description	Format	To	Receiving team specialists	Where
Changes in identified estuary resources	Percentage change in abundance relative to present day	Livelihoods FA Tool	Turpie, Hepelwa	Estuary as a whole
Estimates of overall estuary condition	Rated on a scale of A-E (see State of the Basin Report for explanations)	Scenario evaluation results	Clark, Salam, Lukambuzi, Benno, Materu,	Upper and lower estuary as a whole
Flow regime for achievement of a given overall estuary condition	Modified monthly flow sequences in DRIFT format. Also relevant Flow Duration Curves and information on the timing, magnitude and duration	WEAP	Beuster, Lugomela	Head of the estuary

5.5 Input/output data for the Livelihoods FA Tool

Table 5.5 lists the anticipated inflow and outflow data for the Livelihoods FA Tool, and where possible the required/expected format for those data.

Table 5.5 Anticipated inflow and outflow data for the Livelihoods FA Tool

Input data				
Data description	Format	To	Providing team specialists	Where
Percentage change in the abundance of important fish species (e.g. tilapia and catfish)			Rivers and estuary teams	Rivers, Nyumba ya Mungu, Lake Jipe, Kalimawe Dam, estuary
Percentage change in the abundance of fish, crabs and prawns			Estuary team	Pangani estuary
Percentage change in the abundance of woody riparian vegetation			Rivers team	All rivers
Percentage change in the abundance of reeds, bulrushes, papyrus and lala palms and wild date palms			Rivers team	All freshwater ecosystems
Percentage change in abundance of mangroves			Estuary team	Estuary
Percentage change in abundance of coconut palms			Estuary team	Estuary
Absolute and percentage change in the water allocated to small scale farmers	To be advised by PBWO.		PBWO	Socio-economic zones
Output data				
Data description	Format	To	Receiving team specialists	Where
Changes in average household income	Tshs per year	Scenario evaluation results	Turpie, Hepelwa	Average for each zone.
Changes in aggregate value of resource use	Tshs per year	Macro-economic FA Tool	Whole Team	By zone and for basin

5.6 Input/output data for the Hydropower FA Tool

This study has been outsourced and the preliminary inflow and outflow data provided in Table 5.6 will be reviewed and updated by the appointed specialist.

Table 5.6 Anticipated inflow and outflow data for Hydropower FA Tool

Input data				
Data description	Format	From	Providing team specialists	Where
A modified flow regime for each scenario	Monthly data > 30 years.	WEAP	Beuster, Lugomela	Into NYM, Hale and Pangani Falls
Lake levels linked to the modified flow regime for each scenario	Time series of depths.	Hydraulics model/WEAP	Hydraulics specialist/Hydrologist	NYM
Output data				
Data description	Format	To	Receiving team specialists	Where
Optimal power generation for the flow regime for each scenario	KW per hour. Firm yield.	Macro-economics FA Tool	Appointed specialist	NYM, Hale and Pangani Falls
Release schedules for optimal power generation	To be determined through discussion with appointed specialists	WEAP (and eventually through to River FA Tool).	Beuster, Lugomela, Brown, King	

5.7 Input/output data for the Macro-economics FA Tool

This study has been outsourced and the preliminary inflow and outflow data provided in Table 5.7 will be reviewed and updated by the appointed specialist.

Table 5.7 Anticipated inflow and outflow data for Macro-economics FA Tool

Input data				
Data description	Format	From	Providing team specialists	Where
Amount of water available for off-channel use	Not known at this stage.	WEAP	Beuster, Lugomela	In socio-economic zones
Scenario off-channel sectoral allocations	Not known at this stage.	Scenarios	Stakeholders	In socio-economic zones
Optimal power generation for the flow regime for each scenario	To be determined through discussion with appointed specialists.	Hydropower FA Tool	Appointed specialist	NYM, Hale and Pangani Falls
Output data				
Data description	Format	To	Receiving team specialists	Where
Contributions to GDP per sector	Not known at this stage.	Scenario evaluation results	Whole team	In socio-economic zones

6 IDENTIFICATION OF SPECIALIST STUDIES FOR TASK 6

6.1 Identification of topics

Members of the project team were requested to assist in compiling a list of all specialist studies they felt were necessary to provide a full understanding of links between freshwater flows, ecosystem functioning and goods and services derived from the Pangani Basin. Nineteen specialist studies were identified as being important:

1. A macroeconomics study that could provide a detailed overview of the economy of the Pangani River Basin, and the contribution that this area makes to the national economy.
2. Assessment of the likely impacts of climate change on the hydrology of the Pangani Basin.
3. Assessment of the links between biology and life history of key plant species of economic or subsistence value and freshwater flow in the Pangani River system.
4. Assessment of the current status of the riparian buffer zone, and the need for improved management and rehabilitation.
5. Assessment of the links between biology and life history of key fish and invertebrate species of economic or subsistence value and freshwater flow in the Pangani River system.
6. Assessment of the prevalence and condition of habitats for important fish species in the Pangani Basin, and flow required to maintain these habitats.
7. Assessment of the relationships between water level and/or flow and fishery production for the major fisheries of the Pangani Basin.
8. Enhanced understanding of the variation in hydropower generated under different flow scenarios.
9. Assessment of the relationships between water inputs and value added from crop production (crop per drop).
10. Assessment of the impacts of changes in water quality on river resource productivity.
11. Assessment of the impacts of changes in water quality on goods and services derived from Pangani Basin.
12. A basin-wide assessment of sediment inputs, transport and fates in the Pangani system.
13. A basin-wide assessment of past and present water quality of the Pangani system
14. A basin-wide assessment of links between river flow and human health in the Pangani system.
15. Assessment of the use of aquatic invertebrates as bio-indicators in long-term monitoring.
16. Assessment of the effects of de- and afforestation on flow regimes and groundwater reserves in the Pangani Basin.
17. Assessment of the impact of groundwater abstraction on the flow regime of the Pangani Basin.
18. Assessment of the water levels (or depth) and inundated areas in Lake Jipe, Nyumba ya Mungu, and the Kirua swamps, associated with different antecedent river flows and seasonal variations in aspects such as evaporation.
19. Development of a hydrodynamic model that could elucidate links between changes in freshwater flow and mouth state, and changes in water quality and water movement in the Pangani estuary.

6.2 Prioritisation of topics

Available funds for the additional specialist studies for the Pangani Basin Flow Assessment are limited and so the identified specialist studies were prioritised for funding in terms of how urgently each needed to be completed, their importance to this flow assessment initiative, and to Integrated Water Resources Management (IWRM) generally in the Pangani Basin. Other issues considered in this process included whether or not it would be possible to derive good value from a desktop study only, the estimated number of person days required to complete each study, the total duration of the project in months, and whether capacity to do the study was available in Tanzania or whether assistance of international experts would be required. Ratings assigned to each project in terms of the categories listed above are presented in Table 6.1.

Table 6.1 List of specialist studies ranked in accordance of priority with criteria and other issues considered in the ranking process.

Priority	Study Number	Specialist study	Scheduling (**N**ow/**L**ater)	Relevance to this EF study (1-3)	Relevance to IWRM (1-3)	Desktop (Y/N)	Person days	Duration (months)	Tanzanian /International
1	1	Macro-economics study	N	3	3	Y	25	3	T
2	2	Climate change	N	3	3	Y	20	3	I
3	18	Hydraulic links between flow and water levels/inundated area at key locations	N	3	3	Y	20	5	
4	7	Links between fisheries catch and effort and water levels and flow	N	3	3	Y	10	3	T
5	13	Basin-wide water quality assessment	N	3	3	Y	42	5	I/T
6	8	Hydropower and dam operation- constraints and issues	N	3	3	Y	20	3	T
7	5	Flow links with key fish and invertebrate species	N	3	0	Y	5	5	T
8	3	Flow links with key vegetation species	N	3	0	Y	10	5	T
9	19	Hydrodynamics of the estuary	N	3	3	Y	63	5	
10	16	Effects of de- and afforestation on flow	N	3	3	Y	52	5	T
11	10	Water quality and river resource productivity	N	3	3	Y	15	2	I
12	11	Water quality and goods and service provision by the river	L	0	3	Y			
13	4	Riparian vegetation health and management assessment	L	1	3	Y			
14	14	Links between river flow and human health	L	2	3	N			
15	15	Use of aquatic invertebrates as bio-indicators	L	2	3	N			
16	17	Impact of groundwater abstraction on river flow	L	2	3	N			
17	12	Basin-wide assessment of sediment fluxes	L	3	3	Y*			
18	9	Links between crop production and water input	L	3	3	Y			
19	6	6. Prevalence and condition of habitats for fish	L	3	0	N			

*some ground truthing required

In Table 6.1 the project numbers (left hand column) correspond with those in the full list of projects in Section 6.1. The number of days required to complete each project were estimated for the ten highest ranked projects only.

6.3 Specialist studies selected for Task 6

Once all specialist studies had been ranked in terms of their importance and potential contribution to the Pangani Basin Environmental Flow Assessment Initiative, an estimated number of person days required to complete the ten highest ranking projects was assigned. Using a rough estimate of between $300-500 per person day, it was clear from this exercise that available funds set aside for the specialist studies would be sufficient to fund only a small number of these projects. Eight study topics were prioritised, as below. The water-quality study was envisioned to be a significant undertaking requiring 42 days of work across an annual cycle. It was agreed that the required time and human-resource inputs for a successful water-quality study placed it outside of the current project's resources and that additional funding for such a study would be sought when the opportunity arose. The remaining seven studies were within the project budget. PBWO and IUCN published advertisements in the Tanzanian press publicising the studies, referring interested readers to a website with detailed Terms of Reference, and inviting proposals from interested consultant researchers. Seventeen proposals were received. An evaluation committee consisting of PBWO and IUCN staff evaluated the proposals and selected consultants to undertake the work. These consultants attended a briefing in Dar es Salaam in February 2007 on the larger Flow Assessment project and how their studies would fit into this. Consultants were subsequently contracted to conduct the priority studies.

The priority list of projects for which detailed Terms of Reference (Section 7) were developed is as follows:

1. A macroeconomics study that can provide a detailed overview of the economy of the Pangani River Basin, and the contribution that this area makes to the national economy.
2. Hydraulic assessment of the water levels (or depth) and inundated areas in Lake Jipe, Nyumba ya Mungu, and the Kirua swamps associated with different antecedent river flows and seasonal variations in aspects such as evaporation.
3. Assessment of the relationships between water level and/or flow and fishery production for the major fisheries of the Pangani River Basin.
4. Assessment of the links between biology and life history of key fish and invertebrate species of economic or subsistence value, and flow in the Pangani River system.
5. Assessment of the links between biology and life history of key plant species of economic or subsistence value and freshwater flow in the Pangani River system.
6. A basin-wide assessment of past and present water quality of the Pangani system
7. Assessment of the likely impacts of climate change on the Pangani Basin.
8. Enhanced understanding of the variation in hydropower generated under different flow scenarios.

7 TERMS OF REFERENCE (TORS) FOR TASK 6 SPECIALIST STUDIES

7.1 General Introduction for all ToRs

The Pangani Basin Water Office (PWBO) and the World Conservation Union (IUCN) are implementing the Pangani River Basin Management Project, which is supported by the IUCN Water & Nature Initiative, UNDP/GEF and the European Union. The project has several components that will provide technical information and establish participatory processes to support water allocation in the basin.

The Pangani River Basin Flow Assessment (PRBFA) is one of the primary activities that will provide technical information to support water allocation. Its objective is to synthesise present knowledge of the river systems and its users and, in line with the new Tanzanian water policy, to create management tools that will help promote an integrated approach to future water-development and water-allocation decisions. Creation of the tools depends on a substantial investment in new understanding of the links between river flow, the quality of goods and services provided by the river, and the lives and livelihoods of the river users.

Over the last few months, a team of Tanzanian and international specialists has begun this process by synthesising present knowledge and writing a series of reports. These are:

- Hydrology of the Pangani River Basin
- Basin Delineation Report
- Scenario Selection Report
- River Health Assessment
- Estuary Health Assessment
- Social Assessment.

These have led to identification of a series of specialist studies that are needed to further enhance understanding of the river system and the people of the basin. The studies will be done in the first half of 2007, each producing a report designed to aid development of the management tools. This Terms of Reference is for one of the specialist studies.

7.2 Terms of Reference: Macroeconomic study

7.2.1 Nature of the work

The PRBFA study will entail the evaluation of ecological, social and economic consequences of different possible future scenarios with regard to the allocation of water among different water user sectors and the environment. This study will provide baseline information on the economy of the Pangani Basin and will provide the means to evaluate the impacts of alternative water allocation scenarios on the regional and national economy. The study will be largely a desktop study, but is expected to involve some primary data collection, particularly for the agricultural-economics aspects. The study will build on other studies that have described the use of water and the economy of the basin e.g. Pamoja 2003, Turpie et al. 2003, outputs of the socio-economic component of this project, and an ongoing study to develop the water accounts for Tanzania. The study will also make use of the findings of another specialist study that has been commissioned on hydropower generation. The consultant must have access to an appropriate and up-to-date macroeconomic model.

7.2.2 Objectives

The objectives of the study will be as follows:

- To provide a detailed overview of the economy of the Pangani River Basin, and the contribution that this area makes to the national economy.
- To quantify the relationships between water supply and sectoral outputs at a micro and macro-scale
- To provide a working, user-friendly model with which to evaluate the regional and national economic consequences of changes in water allocation, which would take changes in agricultural, hydropower and fisheries production into account, as well as any other important water user sectors.

7.2.3 Tasks

Task 1: Attend briefing meeting

Attend a Briefing Meeting with the PRBFA team leaders in order to:

- be briefed on your role in the project;
- be briefed on the use to which data generated from this study will be put;
- agree on the format of the data generated from this study;
- finalise the layout and Table of Contents for the final report.

Task 2: Baseline description

Provide a detailed overview of the Regional economies of the Pangani River Basin area, and the contribution that these regions make to the national economy.

Task 3: Describe and quantify relationships between water supply and sectoral outputs

This task should seek to elucidate the relationships between water supply and sectoral outputs (production and direct value added) for the agricultural and hydropower sectors in the basin. The agricultural analysis should include small scale agriculture and the major large-scale or commercial irrigation crops (including coffee, sugar and sisal among others). This will involve collection and analysis of empirical data. Information on hydropower output will be supplied by another study, and need only be summarised in this study. The outputs of this task should be used in the following task.

Task 4: Provide means for analysis of water allocation scenarios

This task will involve providing a spreadsheet model for the estimation of impacts of changes in sectoral outputs due to changes in water allocation in the basin on the regional and national economy. At least twelve previously defined scenarios (see Scenario Selection Report) will be modelled. The different measures produced (e.g. contribution to gross national product, employment, income to poor households etc) should be explained. This task will require use of an existing input-output model, preferably a social accounting matrix.

7.2.4 Deliverables

The following deliverables are required:

1. A report on the economy of the basin in the context of the Tanzanian economy.
2. A report on the relationships between water resource allocation and sectoral outputs, written up in scientific style (introduction, methods, results,

discussion, references). In the discussion, the report should also look beyond the water to shilling relationship and describe the structure of the economy, distribution of wealth and short and medium term opportunities for growth and how changes in water allocation could effect the lowest, median and highest income percentiles in the population.

3. An annotated spreadsheet model for calculation of macro-economic impacts of different water allocation scenarios for the Pangani River Basin

Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.

7.2.5 Timing

Briefing meeting	30 January 2007
Development of relationships	1 February 2007 – 30 April 2007
Hand-over of relevant data	31 May 2007
Report	31 May 2007
Revisions completed	30 June 2007

7.2.6 Budget

The total budget allocated to this project may not exceed US$12,000.

7.2.7 Qualifications required

The team should include an agricultural economist and a macro-economist. The agricultural economist should perform the analysis of the agricultural sector in Task 3, providing outputs specified by the macro-economist. The macro economist is the project leader and responsible for the project deliverables.

7.3 Terms of Reference: Hydraulics study

7.3.1 Nature of the work

Within the Pangani River Basin, trade-offs between benefits provided by the aquatic ecosystems and the benefits provided through off-stream water use such as irrigation and hydropower will need to be decided by the stakeholders. The trade-offs will be analysed by examining the potential consequences of a range of scenarios regarding the future management of the catchment and its water resources.

As part of these trade-offs the impacts on the fisheries and plants associated with the various dams, lakes and floodplains in the basin will need to be considered. For these resources, the primary determinant of abundance is the water level (or depth) and inundated area in Lake Jipe and Nyumba ya Mungu associated with different inflow regimes. For the floodplain, the primary determinant of fish and plant abundance is the timing and extent of inundation. This project is aimed at providing the necessary hydraulic information.

It is acknowledged that relatively few data exist on which to base such an assessment, and that the relationships developed will be preliminary and may require testing over time.

7.3.2 Objectives

The objectives of this study are to:

- Develop a conceptual understanding of the roles that surface water inflows and groundwater recharge play in maintaining water levels in Lake Jipe and the Kirua floodplain.
- Undertake a preliminary assessment of the water levels (or depth) and inundated areas in Lake Jipe associated with different antecedent river flows and seasonal variations in aspects such as evaporation.
- Liaise with the dam/HEP modeller to provide an indication of the water level (or depth) and inundated area in Nyumba ya Mungu associated with different inflow regimes.
- Undertake a preliminary assessment of the magnitude of flows that will inundate Kirua Floodplain and the manner in which this inflow distributes itself across the system.

7.3.3 Tasks

Task 1: Briefing meeting

I. Attend a Briefing Meeting with the PRBFA team leaders in order to:
   a. be briefed on your role in the project;
   b. be briefed on the use to which data generated from this study will be put;
   c. agree on the format of the data generated from this study;
   d. finalise the layout and Table of Contents for the final report.

Task 2: Collection and review of pertinent data

I. Liaise with PBWO and other relevant authorities to source relevant data such as:
   a. Pangani River Training Project (Nyumba ya Mungu to Kirua Swamp; available from PBWO);
   b. channel cross-sections, where available and applicable;
   c. stage rating curves (streamflow to stage curve), where available and applicable;
   d. vegetation, soil and landuse maps;
   e. precipitation, temperature and pan evaporation data.
   f. dam level records, spring and borehole discharge records, and geohydrological maps.

II. Source relevant remote sensing data.

III. Liaise with PBWO hydrologist to source relevant hydrological data.

Task 3: Develop the relationships between water level (or depth) and inundated area in Lake Jipe associated with different inflow regimes

a. Review analytical approaches available for characterizing the flow/stage/inundation relationship at critical locations with respect to the availability of data, required outputs and desired timeframe:
b. Select an appropriate analytical approach.
c. Calibrate and check.

Task 4: Develop the relationships between water level (or depth) and inundated area in Nyumba ya Mungu associated with different inflow and release regimes

I. Liaise with the dam/HEP Modeller to ascertain the extent to which models that s/he has at her/his disposal would meet the requirements of predicting water level and inundation areas with different inflow regimes for Nyumba ya Mungu.

II. If the dam/HEP Model is not able to provide the required information:
   a. Select an appropriate analytical approach.
   b. Calibrate and check.

Task 5: Determine the magnitude of flows that will inundate the Kirua floodplain and the manner in which this inflow distributes itself across the system

I. Review analytical approaches available for characterizing the flow/stage/inundation relationship at critical locations with respect to the availability of data, required outputs and desired timeframe.

II. Select an appropriate analytical approach.

III. Calibrate and check.

IV. Illustrate using maps and/or satellite images the inundated area associated with different magnitude flood events, in particular the naturalised 1:1, 1:2, 1:5, 1:10, 1:20 and 1:50 year flood events.

V. Provide the area (km^2) of the inundated area associated with the different magnitude flood events, in particular those listed in IV.

Task 6: Provide required information for up to 12 flow scenarios

I. For up to 12 flow scenarios:

II. Provide water levels at Lake Jipe and Nyumba ya Mungu.

III. Provide inundated area of Kirua Floodplain.

Task 7: Produce a Report

Write a short report that:
   a. describes the approaches used;
   b. describes the relationships developed;
   c. summarises the outputs.

7.3.4 Deliverables

The following is a summary list of the project deliverables.

Technical reports:

1. Final Report.

Software/data:

1. A conceptual description of the relative roles that surface water inflows and groundwater recharge play in maintaining water levels in Lake Jipe and the Kirua floodplain.
2. Analytical approach for determining water level (or depth) and inundated area in Lake Jipe associated with different inflow regimes.
3. Analytical approach for determining water level (or depth) and inundated area in Nyumba ya Mungu associated with different inflow and release regimes.

4. Analytical approach for outlining magnitude of flows that inundate Kirua Floodplain and the manner in which this inflow distributes itself across the system.

Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.

7.3.5 Timing

Briefing meeting	30 January 2007
Development of relationships	1 February 2007 – 30 April 2007
Hand-over of relevant data	31 May 2007
Report	31 May 2007
Revisions completed	30 June 2007

7.3.6 Budget

The total budget allocated to this project may not exceed US$ 6,000.

7.3.7 Qualifications required

The minimum qualifications for the position are a post-graduate degree in Hydraulic Engineering, Geohydrology or an associate field, proven experience in developing generalised discharge/inundation relationships for large systems with few data, and good written and spoken English.

7.4 Terms of Reference: Fisheries

7.4.1 Nature of the work

This will be a desktop study of the relationships between water level or flow and fishery production for the major fisheries of the Pangani River Basin. The relationships derived in this study will be used to predict changes in fish catches that could occur as a result of different water allocation scenarios in the Pangani River Basin.

7.4.2 Objectives

The objective of the study is to derive the relationships between water level and fishery production that will be used to predict changes in catches in Nyumba ya Mungu, Lake Jipe, Kalimawe Dam and the Pangani estuary under different flow and water-level scenarios.

7.4.3 Tasks

Task 1: Briefing meeting

Attend a Briefing Meeting with the PRBFA team leaders in order to:

- be briefed on your role in the project;

- be briefed on the use to which data generated from this study will be put;
- agree on the format of the data generated from this study;
- finalise the layout and Table of Contents for the final report.

Task 2: Source relevant data

1. Source all existing historical and seasonal data on fish and crustacean catches and effort at Nyumba ya Mungu, Lake Jipe, Kalimawe Dam and the Pangani estuary.
2. Source historical data or modelled data on water levels and flows for the same localities and times, the modelled data to be requested in the required format from the team hydrologist. Water level data for Nyumba ya Mungu and Lake Jipe are available from the Pangani Basin Water Office.
3. Standardise the data as necessary.

Task 3: Quantify relationships between water level or flow and fishery outputs

This task will involve quantitative analysis of fishery outputs in relation to water level or flow and fishing effort, and any other relevant parameters, such as gear type or season, using simple or multiple regression analysis or linear modelling as appropriate. The analysis will generate predictive relationships that can be used in scenario analysis.

Task 4: Report writing

The findings will be written up in a report, which will discuss the empirical findings in relation to anecdotal and other previous descriptions of these relationships. The report will also discuss the reliability of the data and the predictive equations produced.

7.4.4 Deliverables

The following deliverables are required:

4. Excel data sheets and any other electronic files providing all the data obtained for the study and showing the empirical analyses.
5. A report on the quantitative relationships between water level and fishery production.

Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.

7.4.5 Timing

Briefing meeting	30 January 2007
Development of relationships	1 February 2007 – 1 April 2007
Hand-over of relevant data	30 April 2007
Report	30 April 2007
Revisions completed	31 May 2007

No extensions on deadlines will be given.

7.4.6 Budget

The total budget allocated to this project may not exceed US$3,000.

7.4.7 Qualifications required

An MSc or PhD degree in Zoology. Experience in analysis of fishery and hydrological data. Proven numeracy skills.

7.5 Terms of Reference: Fish and Invertebrates

7.5.1 Nature of the Work

This is a desktop study designed to provide essential information on the links between life history, breeding and feeding habits of key fish and invertebrate species of economic or subsistence value in the Pangani River system (river, lakes and estuary), and the timing and/or magnitude of freshwater flows in the system, and hence likely effects of past and future alterations in flow on the abundance and distribution of these species in the basin. As such, it will contribute to the FA study by providing information on the likely effects of different flow scenarios on the health of the system and the environmental goods and services derived from the system.

7.5.2 Objectives of the Study

The objectives of the study are:

- to describe the relationships between the timing and magnitude of freshwater flows in the Pangani system and the biology and life history characteristics of its key fish and invertebrate species;
- to use these relationships to infer what the historic abundance levels and distribution patterns were for these species in the Pangani catchment (where such information is lacking);
- to predict how abundance and distribution patterns may change in the future under altered flow patterns.

7.5.3 Tasks

Task 1: Briefing meeting

1. Attend a briefing meeting with the PRBFA team leaders to be briefed on
   a) Your role in the project;
   b) The use to which data generated from this study will be put;
   c) The format of the data generated from this study;
   d) The layout and Table of Contents for the final report.

Task 2: Literature survey

1. Research conducted to date for the Pangani River Basin Flow Assessment has yielded lists of fish and invertebrate species:
   1. occurring along the Pangani system (see River and Estuary State of the Basin Reports), and;
   2. of economic or subsistence value in the Pangani system (available in the Socio-economic State of the Basin Report).

   These lists should be combined to provide a list of fish and invertebrate species of greatest relevance. The lists should be checked to ensure that no species of social or ecological importance have been missed, and amended where necessary. Any proposal to add or delete species from the list should be motivated for and cleared with the PRBFA team leaders.

2. The resultant list of species should be grouped into fish and invertebrate assemblages showing longitudinal zonation in the catchment.
3. For each assemblage identified in (2), key species should be selected that will become the focus of subsequent investigations of life histories. The number of key species identified should be evenly spread between the assemblages and should be between ten and fifteen species in total. The selected key species should be ones that show clear linkages between life-history traits and flow/water levels. At least four longitudinal zones should be recognised.
4. The species assemblages identified and their associated key species (with motivations) should be provided to the PRBFA team leaders for discussion and agreement before proceeding with Task 2b. *See Timing*.

Task 2b: Literature survey

1. For each species on the list, an international literature search should be conducted to ascertain aspects of its biology and life-history attributes that are linked to flow or water levels, and other flow-related variables (such as, possibly, water chemistry or total suspended solids). Where applicable, local literature should take precedence; otherwise international literature on the same species should be used. Failing that being available, literature on a similar species, the genus, family, growth form or other relevant attribute should be used to infer relationships with flow.

Task 3: Conceptual Model Development

1. Develop conceptual models explaining how each of the selected key species is likely to respond to changes in the timing and magnitude of different aspects of the freshwater flow regime of the Pangani system. The aspects of the flow regime to be considered will be provided to you by the PRBFA team leaders.

Task 4: Report preparation

1. Prepare a report summarising all available information referred to in Task 2 and conceptual relationships developed in Task 3 above, highlighting probable links between the timing and magnitude of freshwater flows in the Pangani system and the flow-related requirements and life-history characteristics of each species.
2. Indicate in the report how changes in the timing or magnitude of flows have already, or may in the future, affect the abundance or distribution of each species. It must be explicitly stated in the report where such relationships have actually been demonstrated or where they are hypothesised.

7.5.4 Deliverables

A report that includes the following:

- a list of key fish and invertebrate species of economic, subsistence or ecological importance in the Pangani system, with an explanation of the rationale used in selecting these species (including the main

riverine, floodplain, lake and estuarine fish species, main estuarine invertebrates and keystone ecological species),
- a summary of information on the important flow-related biological and life history characteristics of each species (or other relevant taxon where such information is limited),
- conceptual models explaining links between magnitude and timing of flows and abundance and distribution of the key species in the Pangani system.

Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.

7.5.5 Timing

Briefing meeting	30 January 2007
Draft Table of Contents	31 March 2007
Species assemblages and key species with justification	30 April 2007
Early draft with literature review, methods and early results	30 June 2007
Final draft and all relevant data	31 August 2007
Receive reviewer's comments	30 September 2007
Submit final report	15 October 2007.

7.5.6 Budget

The total budget allocated to this project may not exceed US$3,000.

7.5.7 Qualifications for the Post

The study should be undertaken by an experienced fish biologist with an MSc or PhD degree in Zoology, with proven experience working with riverine fish and invertebrates, and good written and spoken English

7.6 Terms of Reference: Vegetation

This is a desktop study designed to provide essential information on the links between the biology and life history characteristics of key plant species of economic or subsistence value in the Pangani River system (river, lakes and estuary), and the timing and/or magnitude of freshwater flows in the system, and hence likely effects of past and future alterations in flow on the abundance and distribution of these species in the basin. As such, it will contribute to the FA study by providing information on the likely effects of different flow scenarios on the health of the system and the environmental goods and services derived from the system.

7.6.1 Objectives of the Study

The objectives of the study are:

- to describe the relationships between the timing and magnitude of freshwater flows in the Pangani system and the biology and life-history characteristics of its key plant species;

- to use these relationships to infer what the historic abundance levels and distribution patterns were for these species in the Pangani catchment (where such information is lacking);
- to predict how abundance and distribution patterns may change in the future under altered flow patterns.

7.6.2 Tasks

1.1.1.1 Task 1: Briefing meeting

I. Attend a briefing meeting with the PRBFA team leaders to be briefed on:
   a. Your role in the project;
   b. The use to which data generated from this study will be put;
   c. The format of the data generated from this study;
   d. The layout and Table of Contents for the final report.

1.1.1.2 Task 2: Literature survey

I. A preliminary list of plant species of economic or subsistence value in the Pangani system has been created from research conducted to date for the Pangani River Basin Flow Assessment. This list needs to be checked to ensure that it includes species of greatest relevance and that no species of social or ecological importance have been missed. Any proposal to add or delete species from the list should be motivated for and cleared with the PRBFA team leaders.

II. For each species on the list, an international literature search should be conducted to ascertain aspects of its biology and life-history attributes that are linked to flow or water levels, and any other water-related variables (such as, possibly, water chemistry or total suspended solids). Where applicable, local literature should take precedence; otherwise international literature on the same species should be used. Failing that, literature on a similar species, the genus, family, growth form or other relevant attribute should be used to infer relationships.

Task 3: Conceptual Model Development

I. Develop conceptual models explaining how each of the selected key species is likely to respond to changes in the timing and magnitude of different aspects of the freshwater flow regime in the Pangani system. The aspects of the freshwater flow regime to be considered will be provided to you by the PRBFA team leaders.

Task 4: Report preparation

I. Prepare a report summarising all available information referred to in Tasks 2 and conceptual relationships developed in Task 3 above, highlighting probable links between the timing and magnitude of freshwater flows in the Pangani system and the flow-related requirements and life-history characteristics of each species.

II. Indicate in the report how changes in the timing or magnitude of flows have already, or may in the future, affect the abundance or distribution of each species.
III. It must be explicitly stated in the report where such relationships have actually been demonstrated or where they are hypothesised.

7.6.3 Deliverables

A report that includes the following:

- o a list of key plant species of economic, subsistence or ecological importance in the Pangani system, with an explanation of the rationale used in selecting these species (minimum 15 species, including the main reed, sedge and palm species used, important aquatic food and medicinal plants; and keystone ecological species);
- o a summary of information on the important flow-related biological and life-history characteristics of each species (or other relevant taxon where such information is limited);
- o conceptual models explaining links between magnitude and timing of flows and abundance and distribution of the key species in the Pangani system.

Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.

7.6.4 Timing

Briefing meeting	30 January 2007
Development of relationships	1 February 2007 – 30 April 2007
Hand-over of relevant data	31 May 2007
Report	31 May 2007
Revisions completed	30 June 2007

7.6.5 Budget

The total budget allocated to this project may not exceed US$3 000.

7.6.6 Qualifications for the Post

The study should be performed by an experienced botanist with an MSc or PhD in Botany, with proven experience working with and aquatic and riparian plants, and good written and spoken English.

7.7 Terms of Reference: Climate Change

7.7.1 General

The Pangani Basin Water Office (PWBO) and the World Conservation Union (IUCN) are implementing the Pangani River Basin Management Project, which is supported by the IUCN Water & Nature Initiative, UNDP/GEF and the European Union. The project has several components that will provide technical information and establish participatory processes to support water allocation in the basin.

The PBWO and IUCN require technical information on expected climate change impacts in the Pangani Basin to inform two components of the project:

A: Flow Assessment Component: the modelling of river flows under a variety of water allocation scenarios

B: Community Participation Component: the development of general training and awareness-raising materials about climate change

It is thought that one study can generate the necessary information to inform both of these project components on expected climate change impacts. The different project components and expected tasks and deliverables are described below.

A: Flow Assessment Component

With national and international partners, the PBWO and IUCN have begun a Pangani River Basin Flow Assessment (PRBFA). The objective is to synthesise present knowledge of the river systems and its users and, in line with the Tanzanian water policy, to create management tools that will help promote an integrated approach to future water-development and water-allocation decisions. Creation of the tools depends on a substantial investment in new understanding of the links between river flow, the quality of goods and services provided by the river, and the lives and livelihoods of the river users.

Over the last few months, a team of Tanzanian and international specialists has begun this process by synthesising present knowledge and writing a series of reports. These are:

- Hydrology of the Pangani River Basin
- Basin Delineation Report
- Scenario Selection Report
- River Health Assessment
- Estuary Health Assessment
- Social Assessment.

These have led to identification of seven specialist studies that are needed to further enhance understanding of the river system and the people of the basin. A study on expected climate change impacts has been identified as a prerequisite to assist the development of water management tools.

7.7.2 Nature of the Work

This is a desktop study designed to provide essential information on the likely impacts of climate change on the freshwater flows in the Pangani River Basin.

Hydrological and system models have been configured and calibrated for the Pangani River Basin using 15 monthly sub-catchment rainfall sequences (prepared from 63 rainfall stations in the catchment), water use estimates and regionalised evaporation and evapo-transpiration estimates. These models have been used to produce long-term (76 year) current day and 'naturalized' flow sequences at a number of key points in the system as well as estimates of system yield. Additional flow sequences need to be prepared by modifying the existing long-term monthly rainfall sequences and evaporation estimates using downscaled projections from General Circulation Models (GCMs) or Regional Climate Models (RCMs) and running these through the existing Pitman hydrological model to derive modified 'natural' streamflow sequences, which can then be inputted into a system model to examine impacts on system yield.

The incumbent will be expected to work closely with PBWO Basin Hydrologist, Dr George Lugomela.

7.7.3 Objectives

The overall objective of the study is to examine likely impacts of climate change on river flow sequences and system yield for the Pangani Basin.

The specific objective of this specialist assignment is to model scenarios of local climate variability due to global climatic change, and to use the projected climate changes to modify the "no change", 76 year long, monthly sub-catchment rainfall sequences, and average monthly evaporation values that serve as input to the hydrological catchment model that has been configured and calibrated for the Pangani Basin. Three climate change scenarios over the Pangani Basin are required:

- an average of regional model output or a median model;
- a relatively dry model for the region;
- a relatively wet model for the region.

Change projections must be sufficiently detailed to describe changes to annual precipitation, the present bi-modal distribution of monthly rainfall totals, and provide a reasonable indication of spatial variability over the basin. The spatial resolution of GCMs will be too coarse to provide this, and the use of Regional Climate Model(s) will be required. To provide an envelope of projected change, and to validate predictions, the results of the selected regional model should be compared with the results of at least one other model. The second set of predictions can be derived from statistical downscaling of a GCM, or from another RCM.

The PBWO Hydrologist and members of the Pangani River Basin Flow Assessment team will use the modified rainfall sequences, average monthly evaporation values, and the existing calibrated hydrological model to generate modified stream flow sequences and to assess impacts on water availability. Close communication between the two modelling groups will be required to ensure that the climate change modelling outputs are consistent with, and can be incorporated into the water resources assessments.

7.7.4 Tasks

Task 1: Briefing meeting

I. Attend a briefing meeting with the PRBFA team leaders to be briefed on:
   a) Your role in the project.
   b) The use to which data generated from this study will be put.
   c) The format of the data generated from this study.
   d) The layout and Table of Contents for the final report.

Task 2: Literature and data review

a) Undertake a literature review of available information on existing General Circulation and Regional Climate models to identify which model(s) are best suited to the Pangani Basin and surrounding region, and what downscaling techniques should be used to provide data suitable for incorporation into the existing hydrological and system models developed for the Basin;
b) Liaise with the PBWO Hydrologist and officials from the Tanzanian National Climate Change Committee (NCCC) to check that findings from this study are in agreement with work done in this field to date.

Task 3: Preparation of Climate Change Scenario Data

a) Develop three climate-change estimates (relatively dry, average/median, relatively wet) based on application of a RCM and/or statistical downscaling of GCMs.
b) Modify the "no change", 76 year long, monthly sub-catchment rainfall sequences, and average monthly evaporation values that serve as input to the hydrological catchment model
c) Prepare the modified sequences in a format suitable for incorporation into the Pangani Basin hydrological model.

Task 4: Preparation of flow sequences using Pitman Hydrological model

a) Prepare modified 'naturalised' flow sequences for the Pangani Basin using the Pangani Basin hydrological model, monthly rainfall data, and regionalised evaporation and evapo-transpiration estimates under altered climate scenarios.

Task 5: Assess impacts of water yield

a) Run the modified 'naturalised' flow sequences through the WEAP system model developed for the Pangani Basin to examine impacts on water yield for the system.

<u>Please note that proposals are only solicited for Tasks 1-3, as Tasks 4 and 5 will be undertaken by the PRBFA team.</u>

7.7.5 Deliverables

- Modified long-term monthly sub-catchment rainfall sequences and monthly average evaporation values incorporating climate change projections.
- Report on likely impacts of climate change on the quantity, and spatial and temporal distribution of precipitation in the Pangani Basin.
- Description of climate scenario and models used to generate these scenarios.

Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.

7.7.6 Timing

Briefing meeting	30 January 2007
Development of relationships	1 February 2007 – 30 April 2007
Hand-over of relevant data	30 April 2007
Report	30 April 2007
Revisions completed	31 May 2007

B. Community Participation Component

With national partners, the PBWO and IUCN will develop two training modules for a program to strengthen the capacity of Water User's Associations in Pangani Basin. One training module will be on aspects of Integrated Water Resources Management (IWRM) and the provisions of the national policy, legislations and strategy documents to guide water management in Tanzania. The other training module will be on expected climate change impacts in Pangani Basin and possible climate change adaptation strategies. This special study will provide information on expected climate change impacts in Pangani Basin to inform the training module on climate change.

7.7.7 Tasks

Through literature research and modelling (see previous component of these ToRs), the consultant is expected to generate the following information:

1. Information on current ("base-line") climate conditions for the Pangani Basin. Note that the basin is not homogeneous with respect to climate and the summary should describe the several different climatic zones in some detail. Climate conditions should include temperature, rainfall, broad vegetation types and a general description of the suitability of the zones for agricultural and pastoral livelihoods. Maps should support the description of climatic zones.

2. Information on how the climate in Pangani Basin has changed in recent geological and historical times

3. Information on how the climate in Pangani Basin is expected to change in the future, in the short (3-25 years), medium (25-75 years), and long term (75-150 years).

7.7.8 Deliverables

- A 15-25 page technical report for a general audience (educated non-specialist, define terms, avoid jargon) that:
    a. Summarizes the information generated on current climate conditions (#1 above)
    b. Summarizes the information on past climate conditions (#2 above)
    c. Summarizes the climate predictions in the short, medium and long-term (#3 above)
    d. Building on the description of climate predictions, describes the suitability of the different climate zones to agricultural and pastoralist livelihoods as well as urban expansion
    e. Discusses the implications of climate change predictions on current land and water use activities

f. Provides supporting maps of climate zones in Pangani Basin
g. Provides up to 10 short, concise key messages on climate change in Pangani Basin
h. Provides a general description for non-specialists of the methods used to arrive and the past and future climate descriptions

7.7.9 Budget for Total Study

The total budget allocated to this project may not exceed US$ 12,000.00.

7.7.10 Qualifications required

Minimum qualifications required for the position are a postgraduate degree in hydrology or an associated field, proven experience in working with hydrological models, experience analysing and working with data from climate change models, and good written and spoken English.

7.8 Terms of Reference: Hydro-electric Power (HEP) Model

7.8.1 Nature of the work

Within the Pangani River Basin, trade-offs between benefits provided by the aquatic ecosystems and the benefits provided through off-stream water use such as irrigation and hydropower will need to be analysed by decision-makers. The trade-offs will be evaluated by examining the potential consequences of a range of scenarios regarding the future management of the catchment and its water resources. Clearly an important component of the information required to understand these trade-offs is the variation in hydro-electric power (HEP) generated with different flow regimes.
To this end, for each of the HEP Stations (Nyumba Ya Mungu, Hale and Pangani Falls) on the Pangani River, a dam-operation/HEP model is required in order to:

- determine reservoir levels for different inflow regimes;
- assess the effects of upstream flow regimes on hydropower generation (firm power generation and total energy production) from Nyumba ya Mungu, Hale and Pangani Falls.

The person responsible for providing this information to the PRBFA team will be expected to:

- have access to and be familiar with TANESCO-sanctioned dam-operation/HEP models for Nyumba ya Mungu, Hale and Pangani Falls;
- work with the Pangani River Basin Flow Assessment (PRBFA) team to provide the required information as and when scenarios are evaluated.

7.8.2 Objectives

The objectives of this study are to:

- provide an indication of dam-levels at Nyumba ya Mungu for different flow scenarios to the PRBFA biophysical models;
- provide input to the PRBFA macro-economic model on firm power generation and total energy production for different flow scenarios.

7.8.3 Tasks

Task 1: Briefing meeting

1. Attend a Briefing Meeting with the PRBFA team leaders in order to:
    a) be briefed on your role in the project;
    b) be briefed on the use to which data generated from this study will be put;
    c) agree on the format of the data generated from this study;
    d) finalise the layout and Table of Contents for the final report.

Task 2: Source and configure dam-operation/HEP models for Nyumba ya Mungu, Hale and Pangani Falls

1. Liaise with TANESCO officials and PBWO to source appropriate, TANESCO-sanctioned, dam-operation/HEP models for Nyumba ya Mungu, Hale and Pangani Falls.
2. Establish the HEP operating rules and power generation targets that are currently in use.
3. In discussion with TANESCO, establish the likely future development path of hydropower installations in the Pangani River Basin by TANESCO
4. Ensure that the models are correctly configured and utilise these to produce best estimates of:
    a) dam levels at Nyumba ya Mungu for different upstream flow regimes;
    b) hydropower generation (firm power and total energy) from the existing system (Nyumba ya Mungu, Hale and Pangani Falls) for different upstream flow regimes;
    c) hydropower generation from a likely future system for a likely future flow regime.

Task 3: Liaison with PRBFA Hydrological Modellers, Biophysical Modellers and Macro-economist

5. Liaise with the PRBFA Hydrological Modellers in order to:
    a. discuss and agree on the timing and nature of the hydrological flow sequences to be provided for the calculation of reservoir balances, firm power and total energy production;
    b. ensure that the data received from the modellers will be suitable for use in the dam/HEP model;
    c. generate the required dam/HEP information for 12 future flow scenarios.
    d. Liaise with the PRBFA Biophysical Modeller in order to:
    e. discuss and agree on the timing and format of the data on firm power and total energy production to be provided to her/him;
    f. ensure that the data on dam levels are in a format that can be incorporated into the biophysical model.
6. Liaise with the PRBFA Macro-economist in order to:
    a. discuss and agree on the timing and format of the data on firm power and total energy production to be provided to her/him;
    b. ensure that the data generated in I can be incorporated into the macro-economic model.

Task 4: Produce a Report

I. Provide a short report, which:
   i. describes the dam/HEP model and its parameters;
   ii. outlines conditions for its use;
   iii. details its outputs.

7.8.4 Deliverables

The following is a summary list of the project deliverables.
Technical reports:

1. Final Report.

Software/data:

1. Dam levels at Nyumba ya Mungu and hydropower generation (firm power and total energy) at all HEP stations for:
   i. up to 12 different flow regimes and the present water infrastructure system;
   ii. a likely future flow regime and a likely future hydropower infrastructure configuration.

> *Note: The source of all information used in the report must be clearly referenced by indicating the author and date of the publication in the text and by providing a full reference to the material in a list of references at the end of the report. Copies of all reference material used should be included with the final report.*

7.8.5 Timing

Briefing meeting	30 January 2007
Sourcing and preparation of the HEP model	1 February 2007 – 30 April 2007
Liaison with PRBFA Modellers	30 April – 31 May 2007
Hand-over of hydropower data generated	June 2007 - to be discussed see Task 3
Final Report	30 June 2007
Revisions to report	31 July 2007

7.8.6 Budget

The total budget allocated to this project may not exceed US$5,000.

7.8.7 Qualifications required

The minimum qualifications for the position are a post-graduate degree in Engineering or an associated field, proven experience in calculating hydropower yields, previous experience with data exchange in inter-disciplinary projects, a good working relationship with TANESCO, and good written and spoken English.

8 References

Beuster, J., Howard, G.J. and G.V. Lugomela. 2006. IUCN Water and Nature Initiative. Pangani Basin Water Office Pangani Flow Assessment Initiative. Hydrology and System Analysis, Volume 1 of 2: The Hydrology of the Pangani River Basin. Report prepared for Southern Waters Ecological Research and Consulting and Anchor Environmental Consultants by Emzantsi Systems.