

TWINBAS



TWINBAS

Twinning European and third countries' river basins for development of integrated water resources management methods

An EC FP6 research project

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Final Report

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1. Summary

A key feature of Integrated Water Resources Management (IWRM) is that solutions are no longer analysed from the perspective of only one area, e.g. water availability. Instead, problems in different water fields are analysed in a coherent manner. The central objective of TWINBAS has been to fill gaps in knowledge and methods in order to enable implementation of a harmonised IWRM approach that addresses the European Water Initiative. TWINBAS has been funded by the EC 6th Framework Programme.

By twinning five river basins: the Okavango in southern Africa, the Biobío in Chile, the Nura in Kazakhstan, the Norrström in Sweden, and the Thames in the U.K. and tying together water researchers with key expertise on these rivers, a critical mass of experience and knowledge has been mobilised.

The work within TWINBAS was initiated in January 2004 and has been completed in June, 2007. Work has been conducted within nine work packages, each resulting in a final work package report:

- WP1 History, current status and stakeholder structures
- WP2 Monitoring
- WP3 Public participation
- WP4 Hydrological modelling and water abstraction
- WP5 Pollution pressure and impact analysis
- WP6 Classification of water bodies
- WP7 Change effects and vulnerability assessment
- WP8 Economic analyses
- WP9 River basin management plans

All reports are available on the project's web site (www.twinbas.org).

With the exception of the Okavango, the five basins fall in a relatively narrow band of area, from 13,000 km² for the Thames, to 57,600 km² for the Nura. The Okavango basin, the only international river basin, is a different order of magnitude with an area of 390,000 km². In terms of topography, all basins have relatively mountainous upstream catchments and lowland plains, with the Biobío rising to an altitude of 2,000 m above sea level with permanent glaciers. Exceptions are the Okavango and the

Nura basins, which terminate not in the sea but in wetlands with areas 30,000 km² and 2,600 km² respectively. Regarding climate, all basins are temperate, with the exceptions again being the Nura basin which is semi-arid, and the Okavango basin which is tropical upstream while the delta is in a semi-arid zone.

In terms of anthropogenic factors, four of the five basins have populations around 1 million, though the Okavango basin as the largest in area has a much lower population density. In contrast the Thames has a population around 13 million. The Norrström and the Biobío are developed for hydropower, which is a major potential along with irrigation in the Okavango. The Nura basin is heavily exploited with large withdrawals for agriculture, and industrial and domestic supply, the latter also being significant in the densely populated Thames basin.

Industrial, domestic and agricultural pollution are problem areas in the four basins which are developed, i.e. the Norrström, Biobío, Nura and Thames. The terminal wetlands in the Nura and Okavango basins are particularly sensitive to possible future exploitation of water resources upstream and climate changes, to excess nutrients from upstream agricultural development, and to dams reducing the supply of sediment. The twinned river basins differ widely in the extent and availability of existing data, and monitoring infrastructure. Some complementary monitoring efforts have been carried out in TWINBAS, although the project could not cover e.g. the gaps in hydrological data for the upper Okavango and large parts of the Nura. Monitoring included rainfall and water level gauging stations in the Okavango delta, Mercury measurements and bathymetric measurements in the Nura, and nutrient and metal measurements in Norrström.

The experience from the public participation process is very positive and TWINBAS has, by close collaboration with stakeholders in each basin and each partner country, significantly contributed to the transfer of research results and methods to major stakeholder institutions in the countries of the twinned river basins.

One of the key issues that was widely recognised within work in the Nura was the need for structural re-organisation within the public water sector. More effort might be made by Kazakhstan to ensure that other methods are adopted to ensure stakeholder participation than concentrating so much on establishing RBCs. The directors of

management authorities need to be more accountable to the stakeholders.

There is at present a lack of dependable information tools and communication mechanisms for the management planning process in the Okavango delta. The provision of government services to the communities of the delta is inadequate due to lack of communication, no action taken on previous raised issues, lack of feed-back from government departments, and consequently little or no influence on decisions from the local communities. There is a need for monitoring and targeted research, with data and results readily available to all stakeholders.

Involvement of farmers and the Federation of Swedish farmers in the Norrström contributed significantly to better modelling results. These findings are highly relevant to the continued work with farmer involvement in the efforts to reduce eutrophication of lakes as well as the Baltic Sea.

Development of improved hydrological modelling was an important task in all basins except the Thames, being a reference case, in order to provide an adequate basis for the pollution pressure and change impact analyses. The application of the integrated hydrology model Mike SHE for the Okavango delta significantly improved the understanding of the water cycle of the delta. The possibility to cross-validate the GVAWA and Pitman models results improved the understanding of the upstream hydrology, but the breakdown of the gauging station from the 1970's and onwards have put limitations to the validation of the models. The water balance modelling for the terminal wetlands and lakes of the Nura river has given a first scientifically based identification of ecologically sustainable input flow for the wetlands. The SWAT hydrological modeling implemented in the Biobío resulted in a good general model performance and thus could be used in WP 7 for climate change impact assessment on monthly flow rates. In Norrström the accuracy produced using SWAT was good for daily values, allowed improved nutrient leaching assessment.

The diverging problems dominating the river basins require different tools for assessment of pollution pressure, which was the subject for WP5. Pollution pressure is high for the downstream parts of the Biobío river, while pressure is low in the Okavango basin. Nura river is suffering from severe pollution of mercury, and Norrström from high agricultural nutrient loads. Methods to analyse the impacts, i.e. the ecological/biological effect of the pressure (fish

reproduction, ecosystem modified etc.) had to be tailored to be relevant to the the different basins.

Increased Mercury concentrations above safe levels were found in river fish up to 200 km downstream of the source of the pollution. Risk assessment results confirmed that the consumption of contaminated fish from the river is the most important exposure pathway for the local population, and dose-response-modelling indicated a strong link between the Mercury body burden in the riverine population and fish intake. In the Biobío a general theoretical assessment of the potential and current deviation from reference conditions was made by combining results from an inventory of main pressure types with a water body classification obtained from WP6. The sediment transport risk mapping conducted now allows for a spatial prioritisation of future actions. For the first time in Biobío ecological impact of current hydropower operation has been demonstrated through application of a fish habitat model.

Pollution pressure is marginal in the Okavango system. The development in WP 5 focussed on sediment transport and its potential impact on the delta. The simulated impact of potential hydropower developments in the upstream river basin shows that bed level changes will take place with substantial erosion in the downstream of the Okavango River. After around 100 years, the changes will have an impact on the bed levels near the apex of the delta. Pressure modelling capacity developed for Norrström, makes it is possible to get more detailed information on eutrophication dynamics. The modelling results have a high accuracy for phosphorus when compared to measurement data, and good although somewhat lower accuracy for nitrogen. A conclusion of the model application is that further development requires denser soil characteristics data and flow-proportional nutrient measurements. The results of SWAT modelling significantly improved with additional detailed information from farmers.

The water body classification and categorisation effort in WP 6 represents a preliminary risk assessment. The results will steer further characterisation, including the development of a targeted and efficient monitoring system, and as a starting point for the development of measures ensuring a cost-effective approach to water protection. The WFD categorisation process earlier implemented in the Thames river basin was used as a guide in several of the basins. In Kazakhstan, for the first time, water bodies of the Nura River Basin

have been classified according to the WFD methodology, and protected areas and recreational sites have been documented. In Chile, where available resources and baseline information are limited, emphasis was put on the establishment of a water body typology for the rivers of the Biobío River Basin, and other surface water categories may be addressed in future research efforts.

In Sweden, neither a classification of ecological status nor a risk categorisation for the Norrström River Basin was made under the framework of the TWINBAS project, in order to avoid confusion with the on-going work of the District Water Authority. In the Okavango classification work was focussed on the Delta wetland. Wetlands are a category not explicitly included in the WFD natural surface water body classification, and so the WFD was not adopted. An ecosystem approach to wetland management was used, classifying the delta according to hydrological characteristics mainly associated with seasonal flooding frequencies.

Forcing behind changes in a rivers water resources are both climatic and antropogenic in nature. The work package looked at the potential changes that might occur in all the basins in 50 and 100 years time.

There were wide variations in between the catchments. In the case of the Norrström in 50 and 100 years time it was shown that there is expected to be an increase of precipitation and temperature and significant changes in agricultural land use. Substantial reductions in nutrient leaching from arable land in Norrström can be anticipated as an effect of climate change and management practices adapting to climate change. River Nura is expected to see no climatic driven change in its water resources but will have a very rapid rise in population due to inward migration to the new capital city, the result of which could have catastrophic effects on the water resources available to the internationally important terminal wetlands. For Biobío, analysis of hydrological impacts of future precipitation scenarios all indicated reduced river discharges for the future. This further accentuates the urgent need for a more integrated approach towards water resources management, as reduced river discharges can further increment the impact of planned development options for the basin. Modelled climate change and societal development for the Okavango basin results in significantly decreased permanently inundated area. The combination of

upstream water resources developments and climate change produces adverse effects in terms of the volume and spread of water and sediment in the delta. Sediment transport volumes are greatly reduced, with implications for the entire hydrological and biological functions of the delta.

WP 8 focused on economic analyses and since the main pressures in the five basins differ, diverging approaches to the economic analysis was taken. Both the Okavango and the Nura terminate in internationally important wetland sites. The analyses for these two basins therefore focused on the potential impacts on the wetlands presented e.g. by future land use changes, water extraction plans and climate change. For the Nura, the analysis clarified that if only local benefits of maintaining the wetlands are considered, other uses of the Nura water are more beneficial, but if the international ecological value of the wetlands are taken into account, the benefits of sustaining the wetlands clearly outweigh other alternatives.

Economic values associated with the Okavango Delta include consumptive and non-consumptive uses. The values are dominated by non-consumptive uses for tourism and consumptive uses e.g. harvesting of natural resources, contributing about 2% to the GNP of which 31 accrues to low income elements of society. Economic effects caused by hypothetical changes in hydrological regimes resulting from climate change were also investigated for the Biobío river. In the Norrström basin where nutrient inputs from agricultural activities represent the biggest pressure on water quality, the economic analyses concentrated on calculating the benefits and costs for eutrophication mitigation.

Rather than providing examples of RBMPs as was initially planned, WP9 was revised in collaboration with major stakeholders to cover the identification and assessment of possible and prioritised actions to achieve environmental objectives, as an input to future official RBMPs. Hence, the work reported here is a first step in the river basin management planning process. The advanced state of river basin management and the abundance of management plans in the Thames basin, has enabled it to demonstrate and contribute examples of good practice to the other TWINBAS basins in order to encourage improved management approaches.

In collaboration with major stakeholders in the Biobío basin a strategy for future water management was identified, including among others the following actions: better compatibility

between the economic activities and environmental issues; improved environmental monitoring; fully implemented water quality standards; financial sustainability in water resource management through subsidies and other incentives; institutional reforms including more effective regulatory authorities; and the creation of river basin organisations.

The institutional structure for sustainable water resource planning in Kazakhstan is lacking and, although there is clear awareness of the need for change within the sector, institutional inertia and vested interests limit the potential for implementing a sustainable river basin management plan. Therefore, the first step in the development and implementation of a sustainable water resource management plan for the Nura basin has to be institutional and legal reform in this sector. At this stage, specific tools for assessing the efficiency of actions and measures for the Nura basin are not needed. What is needed, instead, is a set of targets against which the development of water resource management action plans can be assessed, and improved monitoring against which the effectiveness and success of those plans can be measured.

The Okavango Delta Management Plan (ODMP) has borrowed from the Ramsar Planning Guidelines and the Ecosystem Approach to wetlands management. The ownership of the ODMP process is premised on participatory mechanisms, associated with international stakeholders and building partnership basin-wide. The ODMP planning process has proven to incorporate the main elements and concepts in the WFD RBMP process. However, the delta cannot be considered in isolation as many of the pressures on it are likely to come from developments in the upper basin in Angola, where there is a lack of firm data and information. TWINBAS has highlighted the need for an integrated approach to water planning and management: emphasis must be on international cooperation in the management of the whole basin, from the upper basin in Angola to the terminal delta in Botswana.

For reduction of eutrophication in the Norrström basin, changed management practices and wetland installations are efficient measures. The farmers generally accept the need for further actions to reduce diffuse pollution. They require detailed information on cost-effectiveness of measures on a level that could not be produced in TWINBAS, to be able to take a position on whether to go ahead

with implementation for their property, supported by Government incentives. However, the modelling approach, including detailed information from farmers on soil conditions and current management practices, has proved to be a feasible way to initiate collaboration with the farmers regarding action implementation. The approach needs to be scaled up from the study area to the basin or region.

Overall project conclusions:

- In spite of diverse existing structures for water management in the twinned river basins all partners found the European Water Framework Directive a good framework for development of methods and tools for implementation of integrated water resources management.
- TWINBAS has by collaboration with the major public stakeholders in each basin and each partner country significantly contributed to the transfer of research results and methods to major stakeholder institutions in the countries of the twinned river basins.
- Twinning has significantly raised the competence level of the third country partners, as well as that of stakeholders and end-user water authorities in all countries. In some areas, the European partners have benefited from ambitious development work carried out by third country partners. Language difficulties and the efforts needed for translation and basic technological support have required more resources than anticipated, but the general conclusion of the consortium is that the advances clearly outweigh these difficulties.
- Advances in research and knowledge have been achieved in several fields, such as improved hydrological modelling and pollution pressure modelling, methods for and results on impact of climate and societal change on water flow and pollution, as well as improved knowledge on the economics of water use and action cost-effectiveness. Throughout the project and with increased intensity in the second half, stakeholders from 'grassroots' to national authorities have been involved in discussions on research methods, results and abatement measures.

2. Introduction

The central objective of TWINBAS has been to fill gaps in knowledge and methods in order to enable implementation of a harmonised integrated water resources management (IWRM) approach that addresses the European Water Initiative. By twinning five river basins, two in Europe and three in Africa, NIS and Latin America and tying together water researchers with key expertise on these rivers, a critical mass of experience and knowledge has been mobilised. A key feature of IWRM is that solutions are no longer analysed from the perspective of only one area, e.g. water availability. Instead, problems in different water fields are analysed in a coherent manner.

An important part of the objective has been to build the capacity to carry out IWRM in all the five river basins, building on European approaches to water resources management with the Water Framework Directive in focus, as well as on third countries expertise and experience. To reach the strategic objectives of TWINBAS, a number of research tasks on hydrology, modelling of pollution flow, impact assessment, socio-economics, scenario analyses and action efficiency have been carried through. Based on existing analysis on climate change the effects on the hydrological regime, on water availability and water quality have been modelled, and the ecological, societal and economical consequences analysed.

For all these activity areas, the goal has been to bring knowledge to a level where IWRM can be implemented for the five twinned river basins: Okavango (Angola, Namibia, Botswana), Nura (Kazakhstan), Biobío (Chile) Thames (UK) and Norrström (Sweden) (Figure 2-1). The nature and width of the gaps in knowledge vary between the different case study rivers and, therefore, the research required has been specific to each basin.

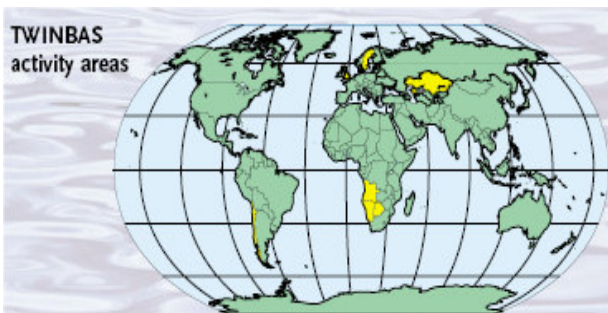


Figure 2-1. Twinbas activity areas are marked in yellow.

With the exception of the Okavango, all basins fall in a relatively narrow band of area, from 13,000 km² for the Thames, to 57,600 km² for the Nura. The Okavango Basin, the only international river basin, is a different order of magnitude with an area of 390,000 km². In terms of topography, all basins have relatively mountainous upstream catchments and lowland plains, with the Biobío rising to an altitude of 2,000 m above sea level with permanent glaciers. Exceptions are the Okavango and the Nura Basins, which terminate not in the sea but in wetlands with areas 30,000 km² and 2,600 km² respectively. Regarding climate, all basins are temperate, with the exceptions again being the Nura Basin which is semi-arid, and the Okavango Basin which is tropical upstream while the delta is in a semi-arid zone.

In terms of anthropogenic factors, four of the five basins have populations around 1 million, though the Okavango Basin as the largest in area has a much lower population density. In contrast the Thames has a population around 15 million. The Norrstrom and the Biobío are developed for hydropower, which is a major potential along with irrigation in the Okavango. The Nura Basin is heavily exploited with large withdrawals for agriculture, and industrial and domestic supply, the latter also being significant in the heavily populated Thames Basin.

Industrial, domestic and agricultural pollution are problem areas in the four basins which are developed, ie the Norrstrom, Biobío, Nura and Thames. The terminal wetlands in the Nura and Okavango Basins are particularly sensitive to possible future exploitation of water resources upstream and climate changes, to excess nutrients from upstream agricultural development, and to dams reducing the supply of sediment. The twinned river basins differ widely in the extent and availability of existing data, and monitoring infrastructure. For some basins, a large amount of measurement data is already available, but significant data gaps were identified for others. The most extensive monitoring efforts were required for the Okavango basin and the Nura, but also in Norrström a two-year monitoring programme has been carried out.

Work has been conducted within nine work packages, each resulting in a final work package report. Most of the reports have been made available to the public through publication on the project's web site (www.twinbas.org). The work

within TWINBAS was initiated in January 2004 and has been completed in June 2007.

3. Work Package activities and results

3.1. WP1 – History, Current Status and Stakeholder Structures

The objectives of work package 1 were to collect and document current knowledge including scientific literature on the status of the river basins regarding hydrology, water quality, user demands, user conflicts, political structures and policies. Furthermore, an important objective of was to identify all stakeholder groups and to record the history of the river basins and the human activities in them according to the perspective of all stakeholder groups.

The water sector is often fragmented, with many institutions being involved in water management at various levels, but not always working in a coordinated way. This situation is particularly a problem in the third country basins. In the European basins new water authorities with an overall responsibility and a needed legal framework is now being formed under the Water Framework Directive.

In many cases, the absence of water quality and emission standards is a problem when looking towards sustainable and integrated management plans. These are interesting topics for twinning activities involving experts and representatives of authorities.

The river basins of TWINBAS display significant differences in terms of problems related to hydrological regime, water quality, management structure etc. The basins are described in the following sections.

3.1.1. Biobío

The Biobío Basin (24,371 km²) is the third largest Chilean river basin. Located between 36°45'-38°49' S and 71°00'-73°20' W, it stretches from the continental divide in the *E* to the Pacific Ocean in the *W*. It is influenced by the temperate and Mediterranean climates from South and Central Chile, has a pronounced seasonality in precipitation patterns (winter rains), and an exceptional value in terms of biodiversity (endemism). Its water

resources are of strategic importance for Chilean development: in 2005, the basin provided ~30% of all electricity of the Inter-Connected System SIC, which covers the energetic demand of 43% of the national territory and 93% of the population. At present, ~200,000 ha of agricultural lands are being irrigated within the basin, and 13% of the mean Biobío summer discharge is to be deviated to the Itata Basin to the *N*. The river network itself also serves as a receiving body for wastewaters from cities and industries (*the basin is the centre for the Chilean forestry industry, i.e. both plantations and pulp mills*). Near the river mouth, Concepción - one of Chile's biggest cities - depends almost completely on Biobío for drinking water (Figure 3.1-1).



Figure 3.1-1 Biobío river and the city of Concepción

Development in the Basin is fast and ongoing, but it needs to consider society's increasing environmental consciousness, which is reflected in the recent changes in legal and institutional settings. A major challenge for water management in the Basin is to trigger the transition from a sectorial to an integrated approach, and the establishment of an equilibrium between ecosystem and societal needs, in a context of increasing environmental change.

Two of the main institutional players in water management in Chile are the General Water Directorate DGA and the National Environmental Commission CONAMA, regionally represented through DGA Biobío and CONAMA Biobío. Some of the most important legal tools for basin-level water resources management are the Water Code and the new Secondary Water Quality Standard. However, at the start of TWINBAS, a legal framework for basin-level integrated water resources management (IWRM) did not exist. Only recently, the plan for a "National River Basin

Strategy” (to be implemented through CONAMA) was launched.

Climate variability and change, combined with the projected increase in industrial activity and water demand, holds the potential to generate new, or intensify existing conflicts between water users and uses in the Basin. Reduced water availability would affect irrigation, hydropower generation and dilution capacity of the river. This may further impact water quality and thus limit the potential for future investments; it would also further impact ecosystems and cause additional costs for drinking water production and civil society.

Together with the limitations of the current institutional and legal framework, many knowledge gaps still hamper the implementation of an IWRM approach. In this context, through TWINBAS, Academics and in particular the EULA Centre – with multiple years of work on Biobío- can and need to play an important role in the provision of results from research which is relevant for policy and decision-making. Considering Biobío’s strategic importance, giving priority to this basin in the implementation of the National River Basin Strategy can be recommended.

It is in this sense that TWINBAS can deliver an important contribution by giving special attention to those priority knowledge gaps that are not being addressed by other planned or ongoing initiatives: Hydrological and water allocation modeling tools, together with current and plausible future land/water use and climate change scenarios, can be highly useful to provide information to stakeholders which allow for better decision making. Erosion and sediment delivery modeling may be an important starting-point for addressing non-point source pollution issues, which are expected to become increasingly important in the Basin as point-sources are gradually being treated. Very little information is currently available on the potential impact of hydropower operation on the native, often endemic fish species of the Biobío Basin. Application of these modeling tools departs from a general analysis on availability and quality of required input data sets (time series and GIS layers), and from the implementation of a basin georeferenced database. Information collected for the database can be further analyzed in a review of impact and scope of recent/planned modifications in the legal framework, and to plan additional, future monitoring efforts.

3.1.2. Nura

Kazakhstan is a Central Asian country with a transitional economy, which after the post Soviet era depression, now has an explosive rate of economic development. This is placing increased pressure on all the countries water resources but no more so than in the Nura catchment. The Nura River lies in north central Kazakhstan and is characterised by very cold winters and warm dry summers, precipitation is only about 300 mm with runoff only occurring at the time of spring snow melt. There is no usable groundwater except in river gravels. It is the only seasonal river in the whole of central Kazakhstan. The perennial nature is caused by the river entering a large old glacial moraine in the upper catchment before emerging 15 km downstream. Mean annual flow which occurs near Astana is $20 \text{ m}^3\text{s}^{-1}$, but it shows high seasonable variability. The River has three cities, one of which has the Worlds largest steel works. The river terminates in the large internationally important Kurgaldzhino wetland, a RAMSAR site. Unfortunately because of the arid nature of the climate the water resources are in great demand for domestic, industrial and agricultural use which poses an ongoing serious threat to the long term sustainability of the wetlands.

The threat to the wetlands has increased dramatically in the past few years with the transfer of the capital city to Astana in the lower catchment. This resource rich country has a booming economy and Astana is rapidly expanding exponentially, as is its demand for more water. As a result a large washed out reservoir is being constructed on the Nura to guarantee cities water supply in the summer.

Unfortunately the hydrology and abstraction and basin transfer schemes of the Nura Basin are poorly understood, an issue that is severely hampered by very poor data that is totally inadequate to manage the system. The Institutional arrangements for gathering data and water resource management is very disjointed and under resourced, a legacy of USSR central planning. As a result it would not be possible to develop a sustainable management plan for the water resources of the catchment until there has been institutional reform in the public water sector. The Government has made a start and has introduced a new legal water code, that is compliant with most aspects of the EU water directive, but its implementation at the water management level has a long way to go before it becomes a reality. The intervention of TWINBAS

was therefore very timely, and the work packages described below, within the resources available, have addressed many of the issues that need to be resolved if the water resources of the River Nura are to be sustainably managed.

3.1.3. Okavango

The Okavango River rises as the Cubango in south east Angola. After 600 km the river forms the boundary with north east Namibia for a distance of 400 km, here joined by its largest tributary, the Cuito. It enters north west Botswana, forming the terminal delta in the Kalahari sands, with a maximum flood area around 15,000 km². The total area of the basin in Southern Africa is 400,000 km². Being the largest wetland in the world, the delta is under serious threat from climate changes and surface and ground water resources developments both in the delta and in the catchment upstream.

To date there has been little human interference in the basin, largely owing to civil strife negating the opportunity for development in the upstream basin, and the realisation that interference in the delta would have major environmental consequences. With peace settling on the region, there is strong pressure for water resources development in the basin, which is seen as the greatest threat to the sensitive environment in the delta.

Following Botswana's accession to the Ramsar Convention in 1997, twelve government departments have cooperated to prepare a management plan for the delta. A critical issue is that international collaboration is assured, and the upstream countries in the basin share the philosophy behind the management plan, and respect its provisions.

The International Waters Unit and Department of Water Affairs of the water ministry is represented on the international Okavango River Basin Commission (OKACOM). Other key stakeholders in the delta are the Department of Wildlife and National Parks, Department of Tourism, Ministry of Agriculture, Department of Town and Country Planning, Tswana Land Board and District Land Use Planning Unit, and North West District Council.

As the world's largest and most prestigious wetland, the Okavango Delta is the subject of a large number of research activities and publications. Little effort is taken to coordinate this research, which tends to focus on specific sectors

(hydrology, vegetation, wildlife, etc) in specific areas of the vast delta. Harry Oppenheimer Okavango Research Centre (HOORC), an academic centre of the University of Botswana, is endeavouring to play a greater role in coordinating research, with specific focus on management planning activities.



Figure 3.1-2 Delta environments – panhandle, upstream perennial swamps, seasonal flood plains, and downstream occasionally flooded

3.1.4. Norrström

The Norrström River Basin covers an area of 22,600 km², representing some 5% of the area of Sweden. The basin includes two of country's largest lakes: Mälaren, which has an area of 1000 km², and Hjälmaren, which covers approximately 500 km². The number of people living in the area is approximately 1.2 million. In the Norrström basin, forests and mires dominate the landscape and cover about 70% of the surface area. The basin is commonly divided into 12 tributaries, all with outlets in Lake Mälaren. Administratively, the Norrström basin belongs to 31 municipalities, and is part of six different counties. The surface water in the Norrström basin is divided into 356 rivers at a total length of 2900 km. In addition to this, there are 790 lakes of a total area of 2780 km² (Figure 3.1-3).

Lake Mälaren provides drinking water to 1.5 million people and is also the recipient of the wastewater from the surrounding cities and industries. Lake Mälaren is both an important transport route for oil and chemical products and an appreciated recreational resource. Both the lake itself and its tributaries have been stepwise dammed since 1943.

The major problem in the Norrström basin is nutrient transport, which causes eutrophication both

in smaller rivers and lakes as well as in Lake Mälaren and in the Baltic Sea. Since parts of the basin have a long tradition of mining, problems concerning heavy metal pollution also occur. The substance of ore residues varies but usually contains high levels of arsenic, lead, copper or zinc.

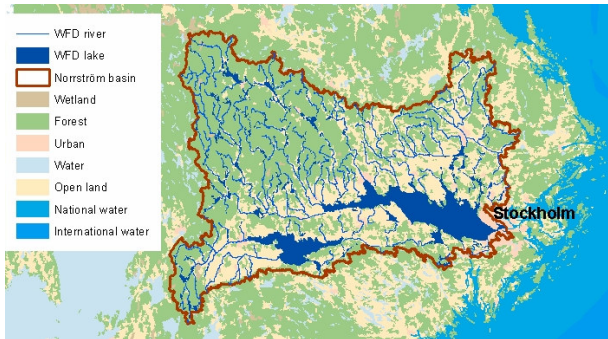


Figure 3.1-3 Rivers and lakes in the Norrström basin according to WFD definitions.

The major point sources in the Norrström basin include mining sites, domestic wastewater

treatment plants and industries. There are also small point sources such as rural households, fish farms and pleasure boats that are of importance for nitrogen and phosphorus. Since eutrophication is the main problem within the Norrström basin, the focus within the TWINBAS project has been on the collection and analysis of point source emission data for nitrogen and phosphorus. However, emission data concerning copper, cadmium, zinc and mercury have also been collected.

3.1.5. Thames

The Thames River Basin covers an area of 13,000 km², representing some 4% of the area of the United Kingdom. However, it houses a population of over 12 million people (one fifth of the UK's population), and generates more than a quarter of the GNP. The western parts of the basin are predominantly rural, with towns concentrated along motorway corridors. In the northern and south-eastern parts, urban land uses predominates, although considerable areas of rural land remain. The eastern part is dominated by Greater London which is heavily urbanised. The basin contains 5330 km of main river and 896 km² of floodplain, and is rich in rivers, canals, lakes and flooded gravel pits, many of which are home to a range of wildlife (Figure 3.1-4).



Figure 3.1-4 Upstream Lambourn tributary of Thames (top left); middle reaches of Thames at Wallingford (lower left); lowest downstream station at Teddington Weir (right)

The Thames basin receives an average of 690 mm rainfall per year, compared with a national average of 897 mm. This makes the basin one of the driest parts of the UK. The mean runoff is approximately 260 mm per year, with 85-90% occurring from October to March. Approximately 55% of the runoff in the Thames basin is abstracted, of which 85% is used for public supply and the remainder by agriculture and industry. Much of this is returned to the river at some point for reuse further downstream. During the summer months there is no water surplus for approximately 80% of the basin. During the winter months, there is currently a surplus. For groundwater sources, approximately 50% of the basin has no surplus.

In the Thames basin, approximately 55% of the mean annual runoff of 260 mm is abstracted from surface (~60%) and groundwater (~40%) sources, equating to about 5000 MI per day. Some 85% of this is for public supply, and 15% for direct use by agriculture and industry. Of the water put into public supply, households use half, and industry a quarter; the remaining quarter is largely lost through leakage from the distribution system. On average each person in the basin uses 156 l of water per day compared with the national average of 150 l per day, an increase of 10% over the past decade. Principal industrial and agricultural uses include cooling water for power generation, water for manufacturing, sand and gravel extraction, fish farming and cress growing, plus 20 MI per day for spray irrigation concentrated in the summer months. Much of the water abstracted is purified and returned to the river at some point for reuse further downstream, and during dry summer months, many river flows can consist of over 90% treated sewage.

Beginning with the Industrial Revolution, the Thames has had a history of pollution, particularly in the London area. Successive campaigns have been aimed at improving water quality: firstly gross organic pollution and latterly nutrient enrichment. However, whilst river water quality may be improving, groundwater pollution is an progressively more important issue with nitrate concentrations in groundwater across the Thames basin continuing to increase slowly. The tidal Thames is now cleaner and healthier than it has been for nearly 200 years and supports a wide variety of wildlife including 119 species of fish, though through and downstream of London it is still particularly contaminated with pollutants.

The demand on land and water for homes, offices and other developments already creates intense pressure on the natural environment and stress on the basin's water resources and waste disposal capacity. Forecast growth in population and number of households, plus the predicted impacts of climate change, mean that effective and sustainable management of the water resources of the Thames River Basin is becoming increasingly important.

3.2. WP2 – Monitoring

Setting up operational monitoring programmes constitutes a major step of the WFD process and also the general IWRM process. Prior to this the applicability of the European list of priority substances and other priority hazardous substances needs to be analysed for the twinned river basins.

The specific objectives of work package 2 have therefore been

- to identify, collect and describe the available monitoring data for the five river basins,
- to produce a list of priority substances for each of the five rivers, and
- to produce a complementary monitoring programme adapted to the conditions and problems of the river basin in question.

The data collected in this work package was essential for carrying out other project tasks, e.g. hydrological modelling (WP4), pollution pressure and impact analysis (WP5), classification of water bodies (WP6), and vulnerability assessment (WP7).

The monitoring programmes have been adapted to the specific conditions and problems of the individual river basins, giving due consideration to

the priority substances that were identified for each basin.

3.2.1. Biobío

Locally obtained monitoring data are important for enabling researchers and decision-makers to apply theoretical knowledge on e.g. meteorological, hydrological, hydraulic and water quality processes to local conditions: field measurements, combined with theoretical knowledge, may allow researchers and decision-makers to quantify effects, check status or compliance, and gain insight in the characteristics of cause-effect relationships. As such, they allow for better management decisions.

In this context, TWINBAS foresees for the implementation of monitoring efforts in the case study basins. However, it is also a fact that for many places in the world, important amounts of data may already exist: these have typically been generated by individuals and organizations in the context of numerous past projects, studies and other initiatives. They may be dispersed over a large number of institutions or even be held by private persons.

For this reason, the EULA TWINBAS team considered it to be essential to collect, analyze, harmonize and store in a structured way those existing data sets which are relevant to the project activities, before the issue of additional monitoring efforts is addressed.

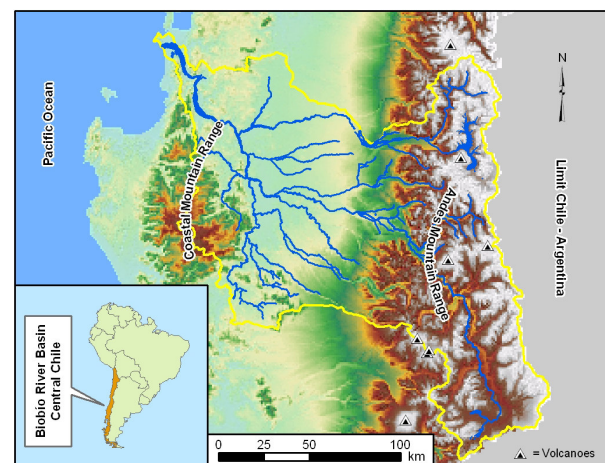


Figure 3.2-1 Location of Biobío

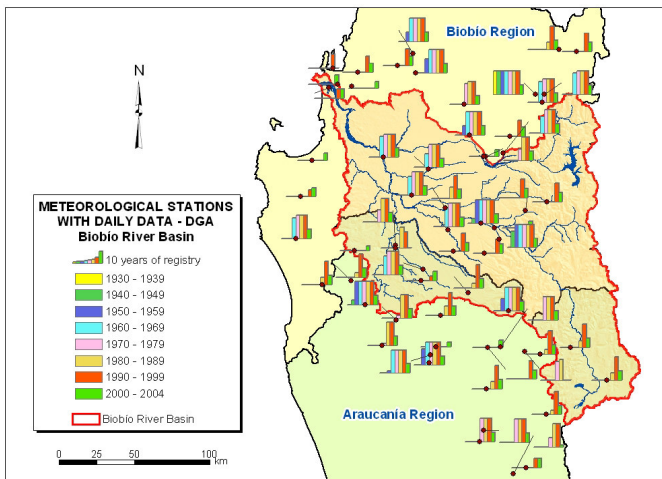


Figure 3.2-2 DGA's daily rainfall time series available for the Biobío and Araucanía Region

Existing meteorological data sets for Biobío have thus been gathered from the Chilean General Water Directorate (DGA), the Chilean Meteorological Directorate (DMC), private forestry companies, the University of Concepcion (UdeC) as well as from EULA itself. Data from the > 80 available stations (mainly daily precipitation and for some stations also min/max temperatures) were collected. For some stations, time series go back as far as 1900; more typically, they are about 20-30 years long. Two important characteristics of the meteorological data set collected for Biobío are: (i) the large amount of data gaps in the time series; and (ii) the almost complete absence of measuring stations at higher elevations (Coastal Mountains; Andes), i.e. precisely where the most important contributions to the Basin water balance occur. The former conclusions are highly relevant as they limit possibilities for basin-scale analyses or model applications. Installation of additional stations in the Mountainous part of the Basin is highly recommended.

Hydrological data (water levels, discharges) are generated through DGA's network of fluviometric stations and are contained in DGA's "*Banco Nacional de Aguas*". Data from 42 traditional stations (*daily time steps*) were available for Biobío, with the oldest time series going back to 1914. At present, 27 stations are still operational; 12 fluviometric and 2 lake level stations have recently been equipped with *satellite transmitters* and now provide measurements at hourly intervals. Data gaps in the time series are also frequent here.

Three main physico-chemical water quality monitoring programmes exist for Biobío. These

correspond to the ongoing (i) "*Programa de Monitoreo del Biobío*" (PMBB), financed by private companies and executed by EULA; (ii) the official DGA monitoring programme and the (iii) monitoring done by the Endesa hydropower company. In addition, at the end of 2004 results from a private study requested by CONAMA/DGA in the framework of the development of the Secondary Water Quality Standard for Biobío became available.

In a first stage, collected data sets (time series together with relevant GIS layers for the Basin) were screened and structured in a georeferenced database for the Basin, and made available for the activities under other work packages. More recently, the ArcHydro data model is being implemented, and transfer of collected Biobío datasets to a geodatabase is being undertaken. The new structure will initially be tested at EULA; transfer to the data-generating/holding government institutions can be considered at a later stage.

In addition to the former, under WP02 a list of priority substances was established based on a screening of opinions amongst experts at EULA. As existing (non-TWINBAS) monitoring efforts are currently ongoing, and a new official water quality monitoring programme for the Biobío Basin is to be implemented in the near future under the Secondary Water Quality Standard for Biobío (2WQS), no important additional monitoring was undertaken under TWINBAS. Instead, available data sets and knowledge were used by EULA to support the development of the 2WQS for Biobío (coordinated by CONAMA and DGA).

3.2.2. Nura

The River Nura terminates in the internationally important terminal Kurgaldzhino wetlands and Lake Tengis which together constitute the core of the Kurgaldzhino RAMSAR site (Figure 3.2-3). At the start of the project there was little or no information of the hydrology of the wetlands or the contribution that the River Nura discharge contributes to the long term sustainability of the wetlands. The monitoring programme was therefore designed to establish a database that would form a sound basis for the development of a monitoring programme. The results of the work are summarised below.

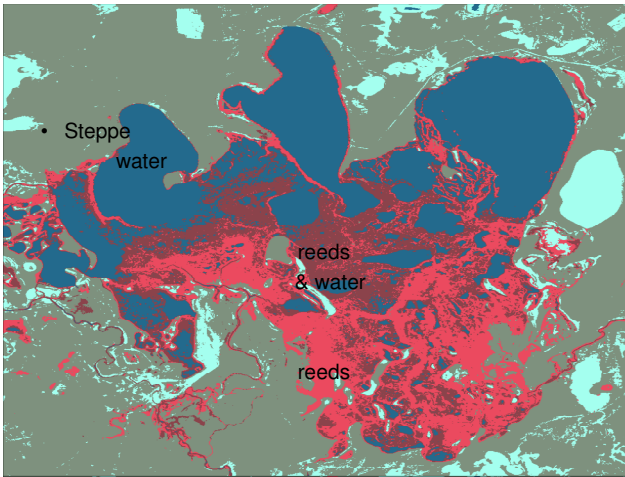


Figure 3.2-3 Classified LANDSAT 7 image of Kurgalzhino Wetlands

The project carried out a Sonar/DGPS hydrographical survey of the three main lakes of the wetlands. The three main northern lakes proved to be flat bottomed lakes between 1.5 and 2.5 meters deep, each one separated from each others by dense reeds. The differences between the surface levels of the lakes were only between 10 to 20 cm, but the three lakes constitute the deeper parts of a large lower basin lake. The areas of the lower lake basin less than about 1.5 meters deep were colonized with vast reed beds and accumulated reed debris.

The River Nura enters the wetlands in the South East of the wetlands 7 meters higher than the main lake complex. The topographic survey showed that the wetlands fall 7 m in the first 7 kilometres through a series of drops. Each drop is created by reed development. Hydrographical survey data, observational survey and satellite imagery showed that the morphology of this area of wetlands was developed by reeds growing out from the edge of the lake either side of the main channel. During flood periods suspended sediment is trapped in the fringing reeds and over time a levy is built up. These reed based levies extend further and further into the lake with water decanting over the sides until the velocity of the stream at the end declines to a level where sediment is deposited on the lake bed, and the velocity is such that reeds can establish and a terminal closure levee builds over time. The levee progressively gets higher over the years until in the end a flood breaches it and the process starts again developing a new channel. The sediment free water that passes over the levee then passes slowly through reed beds until it begins to gather in collector channels and the river starts

again at a lower level. The final result is a vast reed wetland that spreads across the floodplain of the Nura River, with a complex series of channels and ponds at different levels all of which are surrounded by extensive reed beds.

The UNDP wetland project installed level monitoring stations throughout the wetlands. The project established their height and coordinates by DGPS. Cross sections of gauging stations on the River Nura were also surveyed to allow them to be re-calibrated.

Lysimeters were installed in the reed beds to aid the estimation of evapotranspiration from the reeds and open pans were installed in the lake to help establish lake evaporation, unfortunately wave action limited the use of the pans.

Mercury levels were monitored in the biota of the River Nura from Temirtau to the Terminal wetlands. Mercury levels in the hair of the people living in the Nura floodplain that are most at risk from mercury toxicity was also measured. All mercury levels were elevated, although only a few were just above accepted “safe” norms, but even then there were not excessively high and not cause for alarm. The ongoing remediation programme is expected to reduce the risk.

The River Nura needs improved gauging and measurement throughout the catchment if the water resources are to be effectively managed.

3.2.3. Okavango

Data have been collected for research, constrained in time and space. Often these results can only describe the processes taking place in the locality and at the time the study was conducted. However, the nature of the delta imposes logistic difficulties in the collection of data: travelling into the Delta takes days, and wild animals pose a serious threat to staff visiting the stations.

Five meteorological stations are located along the margins of the delta. Within the delta, eight data collection platforms (DCPs), measure rainfall and water level, with two recording a range of climatic parameters. At 73 locations water levels have been monitored sporadically. Discharge has been measured at around 30 stations with around 15 still monitored monthly.

Groundwater monitoring is restricted to a small number of the boreholes around Maun in the south for the purpose of abstraction. These data show the

combined impact of seasonal recharge from flooding and abstraction, but do not reveal the overall pattern in the delta. Water quality parameters are analysed for supply purposes.



Figure 3.2-4 Kwihun Automatic Water Level Recorder

Cross sections of main channels are available from discharge measurement stations (20), and from surveys conducted in the course of research studies (30). Owing to the nature of the terrain and difficulties with access, it is difficult to determine the precise topography of the delta. A topographical model has been prepared with a resolution of 30m

An improved hydrological monitoring system is presently being implemented by the Department of Water Affairs. In total, four climate stations are proposed in addition to the three presently operated by DMS, 13 automatic rain gauges and 27 automatic water level stations. A new water quality monitoring system has been designed under Twinbas.

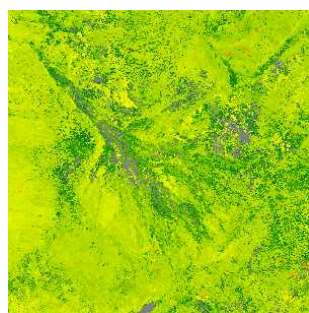
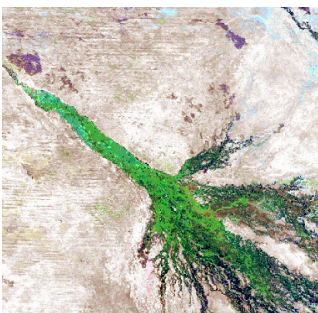


Figure 3.2-5 Landsat (left) and MODIS (right) images of Delta. Remote sensing provides valuable information on the state of the Delta

The challenge for sustained economic growth and poverty alleviation to meet the objectives of the EUWI and the MDGs in Southern Africa is closely associated with sustainable use of natural resources and better management of the environment. Water resource management is recognised as critical to

development in the Upper Okavango, but the value of the data on which decisions are based is less well appreciated, with a decline in data collection and management in recent years. Consequences include a lack of real-time data for monitoring the progress of droughts and floods, and insufficient long-term data for the design of water-related schemes and for the integrated management of large multinational Okavango basin.

A more coherent approach to data collection and institutional reform are needed to acknowledge the importance of hydrometry and data management within, and by, the national hydrological and meteorological agencies in Angola and improve the current limited ability to collect the data needed for water resources management. The need for re-establishment of an adequate hydrometric network in the Upper Okavango, funded by the Angolan government and/or international donors, has been highlighted by the TWINBAS project.

3.2.4. Norrström

The Norrström river Basin is one of the most studied areas in Sweden, much because of its location in a densely populated area with its outlet to the Baltic Sea in Stockholm. Monitoring is rather extensive in the basin, and Lake Mälaren and its tributaries are generally very well investigated.

The primary source of meteorological and hydrological data is SMHI (Swedish Meteorological and Hydrological Institute). Data concerning water quality is available from a number of sources referring to different monitoring programmes: SLU (Swedish University of Agricultural Sciences) is data host for the national monitoring programme initiated by the Swedish EPA. Data from regional monitoring programmes and recipient control monitoring programmes is available from the county councils or from the water associations. The municipalities host their own monitoring programmes or are responsible for recipient monitoring programmes. This data is in some cases available from county councils. Detailed data of higher accuracy is available from monitoring programmes co-ordinated by SLU on five small agriculture dominated areas in the basin.

Within TWINBAS three areas were early identified where existing information is insufficient and complementary monitoring is needed: 1) *Nutrient losses from agricultural land in the immediate surroundings of Lake Mälaren*, 2) *Losses of heavy metals from agricultural land*, and 3) *WFD-*

priority substances / persistent organic compounds. Focus has during the project been on nutrients and in response to these monitoring needs, three small streams in agricultural land near Lake Mälaren were selected for measurements of nutrient losses from agricultural land. Two other agricultural areas



Figure 3.2-6 Monitoring locations in the L. Mälaren river basin. Fånö, Ståholm and Sundbyholm

were selected to also include analysis of metals.

The monitoring program included monthly water quality sampling at three streams in separate subbasins (Fånö, Ståholm, and Sundbyholm). Previous studies in the Norrström river basin had shown that agricultural lands are the largest contributors of both nitrogen and phosphorous and the three study streams are located in subbasins with high agricultural levels.

3.2.5. Thames

The Thames basin is one of the most densely monitored river basins in the UK; parts of the basin, particularly tributaries of special interest like the Pang and the Lambourn, have amongst the most spatially intensive and highest quality hydrological networks in the country (Figure 3.2-7).

Long records exist for the Thames for most hydrometeorological variables.

The primary sources of meteorological data for the Thames basin are the Agency and the UK Met Office, though CEH also has 42-year rainfall records and 10 years weather station records from its own meteorological site and past research projects. The Thames basin is covered by two weather radars: Chennies and South Downs, which provide 5-minute rainfall data on a 2 km x 2 km grid. The radar data are used primarily for flood forecasting purposes.



Figure 3.2-7 Automatic weather station in Pang catchment of Thames (left); Lambourn tributary at Shaw gauging station. The biological GQA is based on macro-invertebrates, such as the larvae of insects (e.g. mayfly, caddis fly) and snails, shrimps and worms, and is the closest measure of status currently available for the biological quality element of the WFD's ecological status classification scheme.

The Agency is the main organisation responsible for the rivers of the Thames basin. There are about 150 gauging stations in the basin, and at most of these water levels are recorded at sub-daily intervals and daily mean flows are derived. The main trunk of the Thames has eight ultrasonic gauges which have proved very successful, but the rest of the network is dominated by structures (weirs) to measure flow. The majority of the gauged flow data for the Thames basin is artificially influenced by abstractions or discharges upstream. Abstractions and discharges are also monitored by the Agency. The network is reasonably stable, though periodic reviews are undertaken to check for redundancy. The earliest gauges date from 1883 at Kingston on the Thames and at Fields Weir on the Lee tributary. A non-continuous record from 1841 exists for Wendover Springs. The mean flow at Kingston is about $80 \text{ m}^3 \text{ s}^{-1}$.

Hydrogeological information are collected and held by both the Agency and the British Geological Survey, including main well records covering water level and groundwater chemistry and abstraction licence data.

River water quality is assessed using a survey called the General Quality Assessment (GQA) scheme. This measures four aspects of quality: biology, chemistry, nutrients and aesthetic quality. Quality is monitored at about 7000 sites representing 40000 km of rivers and canals.

The chemical GQA looks at chemical water quality in terms of dissolved oxygen, biochemical oxygen demand and ammonia. The nutrients scheme

measures the average concentrations of phosphate and nitrate in rivers. Perceptions of the quality of a river are usually based on sight and smell, and so the aesthetics scheme measures aspects such as litter on the banks and in the river, sewage-derived waste, the colour and smell of the water, etc.

Water industry-specific information e.g. water use figures, is held by the water companies themselves. In the Thames basin, the main operator is Thames Water.

The information is used to help formulate and update Local Environment Agency Local Plans (LEAPs) which are management plans for identifying, prioritizing and solving local environmental issues, and River Basin Management Plans (developed under the WFD) to identify any changes in water quantity that are required to achieve a healthy aquatic ecosystem in the Thames basin.

3.3. WP3 – Public Participation

To ensure the effective implementation and achievement of the objectives of water management, EU member states have to encourage active involvement and ensure consultation and access to background information. The process of public participation is specified in Article 14 of the Water Framework Directive (WFD):

- Active involvement in all aspects of the implementation of the WFD by stakeholders;
- Consultation in three steps of the planning process by the general public;
- Access to background information by the general public.

Access to background information and consultation are the lowest levels of public participation and is a core requirement of public participation. The government makes documents available for written comments, organises public hearings or actively seeks the comments and opinions of the public through, for example, surveys and interviews. Active involvement is a higher level of public participation, considered as best practice. Stakeholders are invited to contribute actively to the planning process by discussing relevant issues and their possible solutions.

Based on Article 14 as described above, the objectives of this work package have been:

- To develop a consistent and efficient structure for stakeholder involvement, consultation and public access to information, taking into account the prevailing cultural, socio-economic, democratic and administrative traditions, and addressing poverty and gender issues.
- To develop process guidelines for identification of users and stakeholder water requirements that are transferable to other river basins in the regions of the case studies.
- To evaluate the applied methods during the process and in final evaluation report.

3.3.1. Biobío

A communication plan was produced in 2003, including definitions of existing and expected future stakeholder conflicts within the Biobío River Basin. Since then important changes have taken place, both regarding the environmental conditions, and political, institutional and social arrangements.

During the last two years, CONAMA has conducted workshops for stakeholders in three separate areas of interest:

1. The formulation and implementation of the “Secondary Water Quality Standard for the Biobío River” (2WQS), that involved stakeholders at two levels in two consecutive processes:

The first during the formulation of the Standard with participation of the most important water users – that is, the forest industry, pulp mills, agriculture represented by irrigation committees, chemical industry, oil refinery, the drinking water producer ESSBIO, and others.

The second during the formal process of Public Participation consisting of a 60 days period where all interested stakeholders were entitled to formulate observations to the proposal. These observations were taken into account before the final consolidation of the standard. One full day workshop including presentation and discussion was held in that timeframe. It is worth mentioning, that this is a common practice, structured by law applying to every process of standard formulation in Chile and therefore well-known to the population. Besides the workshop, the public was informed in newspapers and on the internet.

Results: A socially accepted and known Quality Standard for the waters in the Biobío Basin, a key

stakeholder map containing specific interests, and a non formal approach scheme between stakeholders.

2. The integrated river basin management perspective, specifically related to the TWINBAS project: on this topic a series of workshops and seminars were conducted basically with the aim to inform different stakeholders about the ongoing research and its current results and to enhance awareness of possible consequences of climate change and water scarcity within the river basin.

Results: Better common understanding of the concept of River Basin, enhanced awareness of the importance of Integrated River Basin Management and better knowledge of the current environmental, social and economic situation of the Biobío River Basin and its strategic importance for the nation's energy production.

3. Special importance was put on the educational sector, both at basic, junior and university levels. Under the proposal of Education for Sustainability, Teacher Training Courses were held for 100 teachers, as well as a School competition to create a logo and a slogan for the Biobío River.

Results: Putting into practice, cross curricular units of "Water and Sustainable Development" and in this way the construction of an available database of best practices regarding water education. Design of a logo and slogan for the river.

Lessons learned:

The different stakeholder interests are strong and in general a comprehensive knowledge of the river basin concept is weak.

It is much more viable to approach integrated water management through an initial concrete proposal regarding water use or quality, than to start setting up an administrative framework, different to the existing power structure.

Pilot experiences of integrated river basin management are more likely to succeed in smaller basins with less strategic importance.

In the case of Chile the sustained, ongoing effort conducted by various governmental and academic institutions has resulted in a Policy for Integrated River Basin Management, that must prove its efficiency during the coming years, and therefore

needs the support from the international water community to succeed.

3.3.2. Nura

From early on in this work it became apparent that although the national Kazakhstan Water Code specifies that there has to be stakeholder participation it has not yet been adopted. Management is controlled by the National Water Committee and the major stakeholders had no concept of each others plans. For example, the Kurgaldzhino park authorities had no idea that substantial amounts of water were to be extracted for the new Capital city of Astana while non of the stakeholders other than the park authority knew that on signing the RAMSAR convention to allow the site to become a RAMSAR site, has an undertaking that the State will ensure its sustainability (Under the USSR it was a RAMSAR site but with the foundation of Kazakhstan re-registration was needed).

The project carried out discussions with most of the major stakeholders to establish each others perception of water management and their plans for future abstraction. The information formed the basis for structuring a workshop in Astana. Although the original concept was to explore what form of stakeholder participation might be appropriate the main outcome of the workshop turned out to be mainly educational, with participants learning for the first time what each others plans and aspirations for the use of the River's water resources are. Not surprisingly this created considerable heated debate. At the end of the stakeholders meeting many of the participants agreed that a more effective mechanism was needed to engage them in the planning process, not least to enable them to temper their ambitions with the available water resources.

Three of the stakeholders came to the international workshop in Stockholm. The main value of this workshop was that a) many of the problems they face also occur in other countries, and b) there are different ways of doing things in different countries all of which are aimed at the same outcome.

We produced a paper on the new legal Water Code in Kazakhstan, which is compliant with the EU water Directive, on what legal and institutional reform would be needed to bring about the full implementation of the water code to ensure sustainable water resource management in Kazakhstan. The paper also looks at models used

by other countries to ensure compliance with the code and to ensure public participation.

The second workshop in Kazakhstan aimed at developing a mechanism for improving public participation, either along a new approach or one similar to those adopted in other countries, however, at the end of the conference it was clear that there are many real obstacles that need to be overcome before effective stakeholder participation can take place.

One of the key issues that was widely recognised was the need for structural re-organisation within the public water sector. A memorandum was written for Government outlining an organisation structure that could better meet the Governments Goals and objectives than the present structure.

3.3.3. Okavango

There is at present a particular lack of dependable information tools and communication mechanisms for the management planning process in the delta. Considerable work is required to develop and implement these. While hydrology is recognised as being fundamental to the behaviour of the delta, it is also necessary to develop a sound understanding of ecological, social and economic conditions, and linkages among these.

In many respects, stakeholders in Angola hold the key to the sustainability of the Okavango Delta, in terms of managing the waters flowing in to the delta. A special effort was made by TWINBAS to identify the stakeholders in the upstream basin, and assess their views and possible future actions.

Participation in the planning process commenced an early stage, with traditional council (kgotla) meetings held in 33 settlements. Lessons learned was the provision of government services to the communities of the delta is inadequate due to lack of communication, no action taken on previous raised issues, lack of feed-back from government departments, and consequently little or no influence on decisions from the local communities.

Local land users have profound knowledge based on lifelong experience, and as such are better informed than the technical experts, but they do need more information and technical knowledge, through educational workshops, to contribute meaningfully. There is a need for a central data and research institution, focussing on well targeted research, with data and results readily accessible to all stakeholders.

Given the fundamental importance of water to the environment of the Okavango Delta, two stakeholders' consultation workshops related to water resources were held in February 2005 and June 2006 accompanied by bilateral meetings with each stakeholder, to broaden the scope for an effective information exchange. In summary, the response of the stakeholders to the information provided on water resources issues was positive on the whole meeting their needs.

3.3.4. Norrström

The approach outlined in the communication plan for Norrström was to identify and get acceptance for a programme of measures using an iterative communication process based on meetings with a working group of farmers and point source stakeholders, with large meetings at crucial points, and for IVL to provide scientifically-based analyses of the effects of the measures discussed at these meetings. This approach was developed in collaboration with major stakeholders and would be an operational test of the official Water Authority process, with IVL participating. It should be noted that agricultural leaching was in focus, since domestic treatment plants and other point sources have advanced treatment facilities and contributes less to nutrient pollution than the agricultural sector. The downstream parts of rivers Sagån and Svartån were selected cases.

However, it proved difficult to engage the farmers, individual property owners as well as the local representatives of the Federation of Swedish farmers. The reason for this was found to be; 1) The notion among farmers that they have already implemented measures to reduce leaching of nutrients but are still seen as environmental 'villains', and 2) the fact that the Federation of Swedish Farmers (LRF) did not entirely support discussions on mitigative actions at this stage, since modelling of nutrient leaching did not take into account information from each farm, and thus could give misleading results for individual farmers or groups of farmers.

After a series of meetings between IVL and the main stakeholders the approach was revised. Based on this approach IVL collected detailed information on management practices and soil characteristics from each farmer in a selected area, the catchment of Lillån, a tributary to Sagån with a size of appr. 200 km². Information was collected through visits and personal interviews (Figure 3.3-1). The

modelling was re-iterated with this data and the results evaluated in comparison with modelling results that used commonly available soil data and statistics on fertiliser use and management practices. With this more detailed basis, effects and cost-effectiveness of measures were then analysed.



Figure 3.3-1: One of the farms in the study area. The area is dominated by large farm properties, often 300 ha or more in size.

The main conclusion of the results were that the farmers and LRF were right; local detailed data is required in order to provide accurate modelling results and possibilities to analyse effects of relevant measures (also excluding measures that have already been implemented). These findings are highly relevant to the continued work with farmer involvement in the efforts to reduce eutrophication of Swedish lakes as well as the Baltic Sea.

To support future stakeholder involvement, IVL developed a webtool for dissemination of information on the status of water bodies, to provide a discussion forum, information on the WFD and links to stakeholders (Figure 3.3-2). This work was mainly done in TWINBAS, and finalised in TWINLATIN.

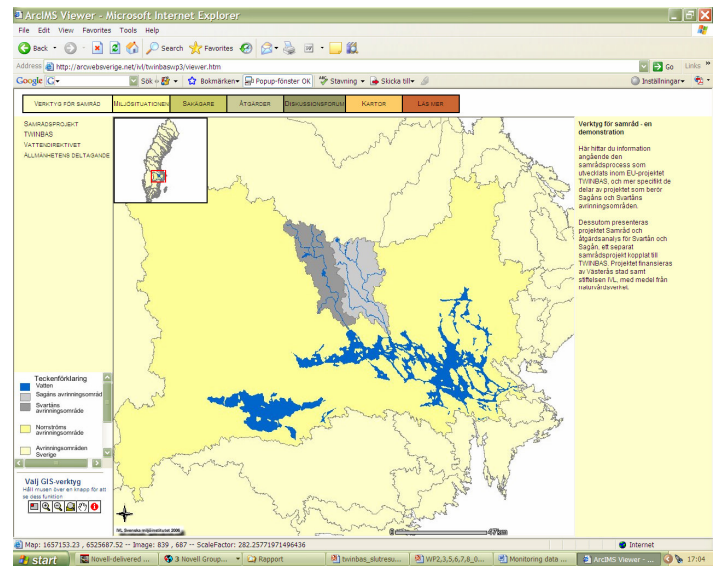


Figure 3.3-2 Webtool interface. The developed webtool provides descriptions of catchments, status of water bodies, information on the WFD process, links to stakeholders, and a discussion forum.

3.3.5. Thames

Some of the techniques from the Environment Agency's stakeholder participation toolkit were used in the NERC LOCAR (Lowland Catchment Research) programme^{1,2}, studying water resource issues in the English chalk lowlands and involving the Pang and Lambourn catchments of the Thames River Basin. In these catchments, groundwater is an important source of water, and Winter rainfall is important to top up aquifers and maintain low flows in streams in Summer. However, in recent years, several streams have dried up in Summer, and fish and plants have been adversely affected. It is believed that changes in land use and agricultural practices have altered the patterns of movement of sediments and chemicals. LOCAR investigated the interactions between surface and groundwater, and the interactions of animal and plant life with stream chemical and sediments.

Public participation activities in the Pang and Lambourn catchments of the Thames basin during the LOCAR programme were limited by the resources available, but included:

¹ Douglas, I. (Ed). 2006a. Integrated Catchment Research – Science for lowland river management: Achievements and Applications. NERC, Swindon, UK.

² NERC. 2006b. Go with the flow – Science to help manage our lowland rivers, now and in the future: Highlights from the Lowland Catchment Research programme (LOCAR). NERC, Swindon, UK.

- Project Team comprising representatives from the project funders, researchers, the catchment service team and the Agency
- Stakeholder Forum in the form of an internal project team within the Agency who are the primary stakeholder
- Meetings in person with landowner to negotiate access their land to install monitoring equipment and visit sites to download data
- Presentations by the Project Steering Group to interested stakeholder groups
- Website providing a source of information, though largely for researchers
- Brochures describing the project aimed at the interested general public

LOCAR was driven by scientific curiosity, the requirements of the WFD, and a commitment to deliver science that will contribute to national needs. Perspectives of the success of LOCAR varied between different stakeholder groups. Water researchers saw it as a model project in which scientists from different disciplines worked together to provide water managers with the knowledge they need. Indeed, the water regulators (e.g. the Environment Agency) found the results to show that the processes controlling water and pollutant movement were far more dynamic than previously thought, providing invaluable scientific underpinning to help develop required regulatory frameworks, whilst the water industry (e.g. Thames Water) found the results to provide sound science on which to base investment decisions in identifying and developing new environmentally sustainable yet cost effective water sources for drought-prone southern England. Other water users (e.g. farmers) could see how an action on part of the catchment could create impacts elsewhere, and that sustainable management of the land and water go together. Local communities felt that the project had given them a new understanding of the significance of their river. The Project Team felt that earlier stakeholder involvement may have improved the relevance and integration of some of the science.

The LOCAR outcomes directly address key needs of the Environment Agency's Integrated Catchment Science Strategy but, though relevant to policy, must be translated effectively to be useful in practice, particularly at different scales. However, much of the knowledge gained through LOCAR is

generic and widely applicable to large areas of England and other countries.

3.4. WP4 – Hydrological Modelling and Water Abstraction

Accurate hydrological modelling is a necessary basis for all IWRM phases. The scope of the hydrologic and water resources analysis of a river basin ranges from the hydrologic cycle, the water balance, the propagation of flood waves through controlled reservoirs and over flood plains, the variation in soil moisture content, the variation in ground water levels, and the supplies to various users. Additional significant features may be the sediment transported through the system, and the transport and decay of pollutants in the system.

The range of processes involved, and their differing data types and the time scale of phenomena, means that there is no one model type suitable for all applications. Thus several categories of models have been developed under TWINBAS, incorporating various features in the 5 river basins (Table 3.4-1).

The diversity of tasks required to be accomplished by water resources analysis in the basins means that none of the basins is covered by a single model. Two of the basins, Norrström and Okavango, are covered by two different model types, while the Biobío has three types. While the Okavango Delta model integrates the hydrologic processes with channel and flood plain flow, water resources allocation is not incorporated.

That certain features have not been incorporated in a model do not mean that the results are not useful, rather it should be understood that some processes are not well understood, and compromises have been made in the analytical process, the consequences of which have to be understood in terms of the accuracy of the results. In general, it can be said that all the models applied are useful in terms of the purpose which they are intended to serve.

Table 3.4-1 Overview of the used models.

BASIN	Norrstrom	Okavango Upstream Pitman	Okavango Upstream GWAVA	Okavango Delta	Biobío	Nura
Model Type	Hydrology: Distributed Hydraulics: Kinematic	Lumped conceptual Rainfall-runoff	Distributed hydrology and water resources	Integrated hydrology Full hydrodynamics	Lumped conceptual rainfall-runoff Hydraulics: Kinematic	1) Mass Balance 2) Sensible heat balance 3) Risk
GIS Linkage	Model input and output in ArcGIS	Model input and output in GIS	-	Model input and output in GIS	Model input and output in ArcView	1) no 2) ERDAS/GIS
Resolution	50 metres Daily	24 catchments Monthly	55km Monthly	1 km ² 4 hours	272 catchments Daily	1) input option 2) 40 m 3) N/A
User Interface	ArcView interface to data	GIS front end	-	Comprehensive structures GUI	ArcView interface to data	1) Data base
Input data Quality	Good	Poor	Poor	Poor	Good for modelled basin	1) poor 2) very poor 3) good
Calibration	Good	Good	Fair	Water Balance: Good Discharge: Poor	Good for modelled basin	1) impossible 2) excellent 3) fair
Limitations	Lacks hydraulic structure controls	-	Coarse resolution	Vegetation and channel development not well understood	Empirical parameter estimation not based on regional data	1) Lack of data
Applications	Development scenarios and climate change	Water resources scenarios and climate change	Water resources scenarios	Water resources scenarios and climate change	Land use and climate change impact on water resources	1) see above 2) Calculate water loss from terminal wetlands 3) Establish Hg risk

While a set of principles formulated with the participation of the stakeholders in the basin is the foremost requirement for effective integrated river basin management, quantitative analysis is essential to put these principles into practice. Those bearing the responsibility for managing river basins as a whole, or in part, need to be aware of the realistic potential of models, and their demands on good quality data and human resources.

3.4.1. Biobío

A better understanding of basin hydrology and its relations to (i) climate, climate variability and change, and (ii) the spatially variable nature of physical basin characteristics, in particular land use and land use dynamics, is urgently needed in order to enable sound decision-making with respect to the

multi-purpose, integrated management of water resources in the Biobío Basin.

Rainfall-runoff models can be highly useful for analyzing - in a quantitative way - the relationships between (e.g.) mean monthly river discharge, land use and climate. They can be combined with Decision Support Systems (DSS) for scenario modelling on the analysis of water allocation, quality and demand. However, due to the complexity of both hydrology and water use systems in Biobío, a considerable amount of research questions need to be addressed before an operational, basin-scale DSS can be provided and applied. Restricted availability of measured meteorological data sets -especially at higher elevations- and the lack of important, previous experiences on the application of hydrological models at the scale of meso- or macro-basins in

Chile further makes that progress in the development and implementation of such a model needs to be phased, and priorities are to be established.

For these reasons, detailed modelling of the hydrology for the entire Biobío Basin was not attempted under TWINBAS. Instead, a hydrological modelling application was developed by EULA for the Vergara Basin, a subbasin of Biobío with a total drainage area of approx. 4,265 km². The selection of Vergara was based on the availability of good measurement data sets for this sector of the Biobío Basin, which allow for adequate model calibration and validation. This step is essential before the model is applied at a larger spatial scale, or to sectors/subbasins where irrigation and/or snowmelt contributions may be important. Input time series consisted of daily precipitation and min/max daily temperatures, i.e. data sets typically available for most Chilean Basins, so the used approach can also be extended beyond the Biobío Basin itself. Under WP04, the application built for the Vergara subbasin was made using the SWAT model. SWAT disposes of good user manuals and a Graphical User Interface embedded in ArcView 3.2, which can facilitate future transfer of the modeling application to interested stakeholders/end users in the Basin (e.g. the Chilean General Water Directorate DGA).

The modeling process implemented by EULA itself consisted of a sensitivity analysis, followed by a calibration process in which time series from the period 1998-2002, observed at 4 internal control points, were used. Model performance was evaluated using 5 statistical indicators, including the Nash-Sutcliffe criterion “EF”. Validation was performed using time series from 1994-1999. During both calibration and validation, a good general model performance was obtained for reproducing monthly discharge rates in the Vergara Basin (EF from 0.51-0.96 and from 0.66-0.86 for calibration and validation, respectively).

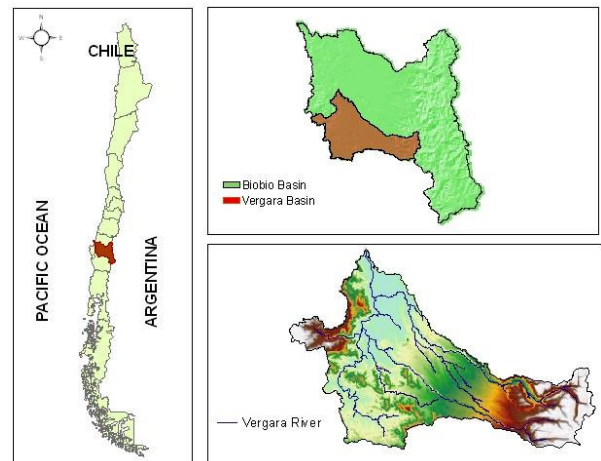


Figure 3.4-1 Location of the Vergara subbasin within the Biobío Basin

Under its current form, the model thus already constitutes a useful tool for water balance analyses and scenario impact assessment, and it has been consequently used under WP07. However, additional research will still be required in order to further improve, amongst other aspects: (i) the representation of peak discharges; (ii) the modeling of daily discharge rates; (iii) the representation of spatial variability of rainfall; (iv) model parameterization (e.g. SCS Curve Number) specifically for Chilean soil and land use conditions; (v) the explicit description of land use dynamics, especially for modeling longer periods of time.

Additional progress beyond the status described in the WP04 report was and is being obtained through ongoing PhD research at EULA (e.g. *snowmelt contributions*) and through a collaboration established with the University of Ghent, Belgium (undergraduate thesis work; *land use dynamics, rainfall fields*). Opportunities have been, and are currently being sought, for extending the modeling approach to the remaining part of the Basin, and for combining the rainfall-runoff tool with a water demand/allocation Decision Support System. This will allow to further evaluate how the allocation process can be optimized under changing conditions of availability, demand, environmental awareness and legal/institutional settings in the Basin.

3.4.2. Nura

The River Nura is the main water supply for the cities of Karaganda and Temirtau, is the main water supply for the cities of Karaganda and Temirtau, and is a secondary source for the new capital city of Astana. The river terminates in the internationally important Kurgaldzhino wetlands and Tengiz lake in the west of the catchment (a RAMSAR site).

The rapid development of Astana and the consequent explosion in water demand means there is an urgent need to assess the impact on the Kurgaldzhino terminal wetlands. Unfortunately the upstream river data was poor, and discharge data from the inter-basin Irtysh Karaganda Canal and industrial and irrigation abstraction data appears to be very unreliable and unusable. In addition the runoff from the region is almost entirely from snowmelt. Unfortunately the data needed for reliable calculation of run-off from snowmelt was totally lacking. The result is that it is not possible realistically to model the river. A mass water balance for the wetlands based on total surface runoff was not possible as only the River Nura which contributes about half of the runoff to the wetland is gauged. The contribution of the River Nura to the annual water balance of the wetlands was therefore established by comparing its discharge with mean annual water loss from the wetlands.

A revised methodology was developed and tested for establishing the annual evapotranspiration from the vast reed beds of the wetland system, using Landsat 7 data and a sensible heat balance approach to estimate real time evapotranspiration. The method that we developed uses the Monin-Oberkhov length as a keystone to the calculation. When tested on a fully-instrumented irrigated cotton field the results indicated that the methodology was highly reliable at establishing evapotranspiration. When applied to the reed beds the mean annual established evapotranspiration was calculated as 1.2 times that of potential evapotranspiration. Annual mean evaporation from open water was established from calculated potential evaporation multiplied by a K_c of 1.05.

The results show that to maintain the present surface area of the wetlands and Tengiz lake requires a mean annual catchment runoff of 1265 million m^3 per year of which 386 million m^3 per year is for the wetlands.

The mean annual runoff from the River Nura into the wetlands is 284 million m^3 per year, corresponding to a mean flow of the Nura of $9 m^3 s^{-1}$.

Plans are being discussed to abstract up to $20 m^3 s^{-1}$ of water from the Nura River for the development and greening of Astana. Since the mean annual flow from the Nura River that presently reaches the terminal wetlands is just under $9 m^3 s^{-1}$, this would not only kill the wetlands. Put simply, the loss of $1 m^3 s^{-1}$ inflow from the Nura is equivalent to losing a surface area of wetlands of $46 km^2$. Abstracting more water from the River Nura is therefore not compatible with the RAMSAR convention. It is therefore of the utmost importance that the Kazakhstan government takes steps to ensure sustainable management of the water supply to the wetlands.

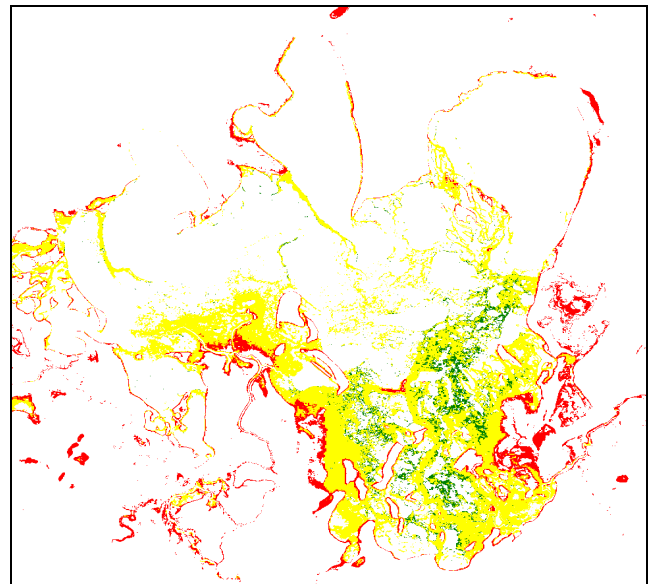


Figure 3.4-2 Illustration of special distribution of evapotranspiration rates in reeds in the Kurgaldzhinskiy wetland established from Landsat data collected in September, classified into 3 classes for illustrative purposes, (Red = < 4mm/day, Yellow = 4 to 4.6 mm/d and Red=>4.6)

3.4.3. Okavango

The Global Water AVailability Assessment (GWAVA³) model was used to estimate current water resource availability in the Okavango basin over a baseline period 1961-1990. The approach employs a gridded probability distributed rainfall-runoff model (PDM⁴) operating, in this case, at 0.5 degree resolution (approximately 50 × 50 km i.e. 161 grid cells) to estimate water supply. Superimposed is the water demand network which estimates water abstractions, returns, transfers and the influence of structures such as reservoirs. The PDM model parameters are fixed according to the soil texture and land cover, or optimised by calibration against observed flows. Good quality long flow records exist in the lower reaches of the Okavango at Rundu (1945 to 1999) and Mukwe (1949 – 1998), but for suitable sites in the upper basin there is, on average, just 10 years of data per station. However, flows for the 1961-90 baseline are generally well reproduced in the basin, in terms of both the mean annual runoff and the pattern of monthly flows.

GWAVA's outputs include mapped indices of water availability (in terms of supply v demand) across the basin. Figure 3.4-3 (top) shows a simple ratio of annual water supply to demand, the cells shaded blue indicating a plentiful supply of water exceeding demand, tending to red when supply is equal to, or, less than demand. The lower Figure captures the monthly variation of supply over the 30-year period and compares it to monthly demand. This provides a picture of the basin sensitive to changes in supply and demand, with blue cells having sufficient water to meet demand, and red cells experiencing insufficient supplies to meet demand and therefore experiencing water stress.

GWAVA enables a consistent methodology to be applied across a region at a resolution that captures the spatial variation in water supply and demand. Key outputs of the model are comparisons of supply and demand made at the grid cell basis,

through a set of indices to take account of the annual and inter-annual variability in water supply.

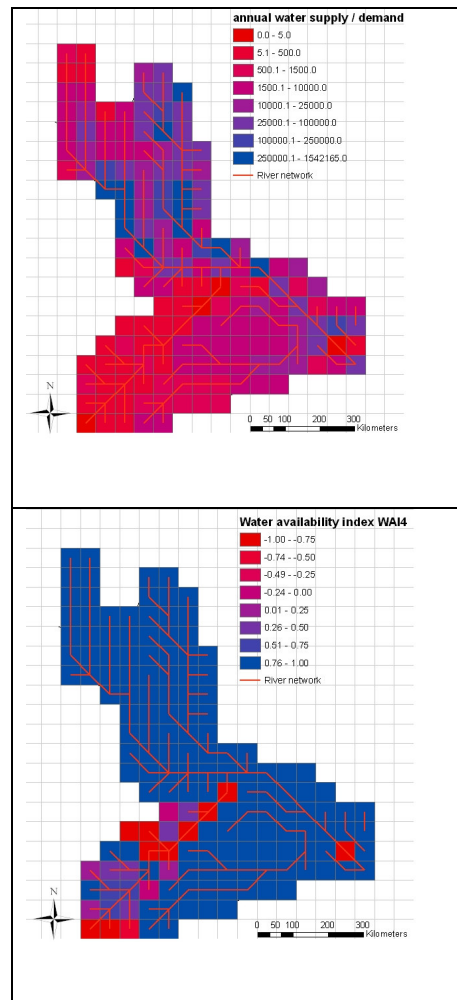


Figure 3.4-3 Water availability index for the baseline period

The hydrology of the delta is extremely complex, with surface water flows through channels and swamps, evaporation from open water and soil, uptake of water by vegetation from the surface water and soil moisture and transpiration from the leaves, infiltration to ground water and ground water flows (Figure 3.4-4). Given the need to represent the combined hydrologic processes of evapotranspiration, surface and ground water, including sediment transport, the only solution identified was to develop an integrated hydrologic model, covering evapotranspiration, surface and subsurface water movements. All the components are fully integrated through dynamic flow couplings, and a full accounting of the water balance data for the surface-vegetation-atmosphere transfer, surface and sub-surface zones.

³ Meigh, JR, McKenzie, AA and Sene, KJ. 1999. A grid-based approach to water scarcity estimates for eastern and southern Africa. *Water Resour. Manage.*, 13, 85–115.

⁴ Moore, RJ. 1985. The probability-distributed principle and runoff production at point and basin scales. *Hydrol. Sci. J.* 30(2), 273–297.



Figure 3.4-4 Papyrus in Okavango (left) Part of the main river bed (right).

Input data describing the hydrologic conditions are required at the boundary of the model domain, being the outline of the delta, and the climatic conditions over the delta. Topographic data are required for the entire model area, and for the main river channels through the delta.

In many cases, hydrologic and water resources models are set up by national or international specialist institutes for the local authority. While the models may be targeted at a specific immediate need, the models usually are valuable for longer term use and further development. The local authority then has the option of training its own staff to take over the model when the present application ends, relying on outside assistance or some combination of the two.

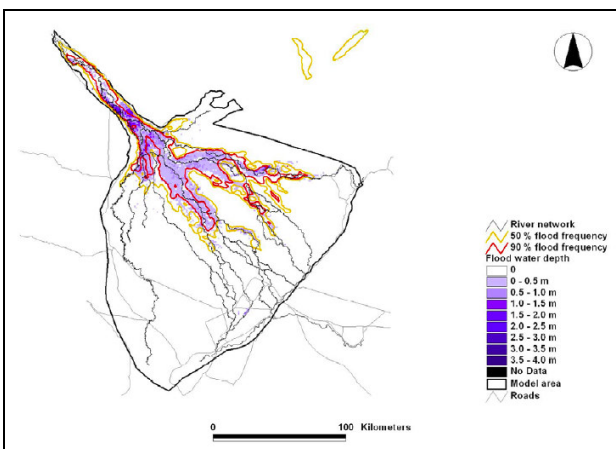


Figure 3.4-5 Calibration against minimum flood extent Year 2000.

The delta is among the most complex hydrologic systems anywhere, and the hydrologic model is similarly and necessarily among the most complex (Figure 3.4-5). A Modelling Unit has been established by DWA, well equipped with computers and training aids. A three pronged approach was taken to the technology transfer with a) A series of formal courses in the different aspects of model set up and application, b) On-the-job training, whereby the DWA staff learn by doing, working alongside the consultants setting up and especially applying the model, c) Overseas

training – options were an intensive course at an international hydrology institute, or MSc courses in water resources.

3.4.4. Norrström

The work package objective for the Norrström basin was to develop and validate hydrological modelling on a scale and detail sufficient for identification of actions addressing nutrient pollution on a local level. The development work in Norrström consisted of two main parts.

The model approaches earlier applied in Norrström did not account for the hydrologic processes that occur in the soil layer and the dynamics between the unsaturated and saturated zone. A new hydrological model was required for this, and it should be GIS-based to allow use of the available GIS data for land use, elevation, soil type etc. Thus, development and application of a fully distributed hydrological GIS based model⁵, was carried out for a test area, river Kölstaån, 110 km². The results were promising (Figure 3.4-6) and the model provides a module for meso-scale modelling of hydrology and nutrient transport.

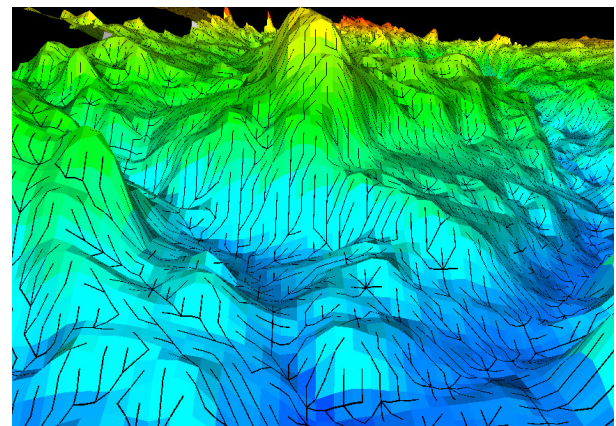


Figure 3.4-6 Flow network derived from the digital elevation model. Each grid cell in the area is connected to the outflow via the flow network. The streams are derived from the flow network.

For analysis of local measures to reduce nutrient leaching however, a tool capable to model agricultural leaching with more detail is required. Therefore, the second part of modelling activities included application of the existing AvSWAT 2000 model and adjustment for Swedish conditions (AvSWAT - Soil & Water Assessment Tool,

⁵ Westerberg, 2005. Development and application of a GIS-based hydrologic model. MSc thesis, Department of Earth Sciences, Uppsala University.

Arcview version). SWAT is a physically based model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in complex watersheds with varying soils, land use and management conditions. It works with hydrological response units (HRUs) as the basic geographic unit, often with sizes around 50 hectares, although depending on the heterogeneity of the landscape.

SWAT was adjusted for Swedish conditions and calibrated for Sagån (Figure 3.4-7), one of the twelve main tributaries in Norrström. Nash-Sutcliffe model efficiency was between 0.6-0.7 for different validation periods and gauging stations, which is a good level of accuracy. With this basis, SWAT was implemented also for Svartån, and later in WP 5 for three additional tributaries Figure 3.4-8).

The need for more precise and cost-effective abatement efforts set new requirements on hydrological and nutrient transport models. Assessments need to be diversified in space and in time and should identify “hot spots” and high-risk fields. Therefore, physically based semi- and fully distributed hydrological models have an important function.

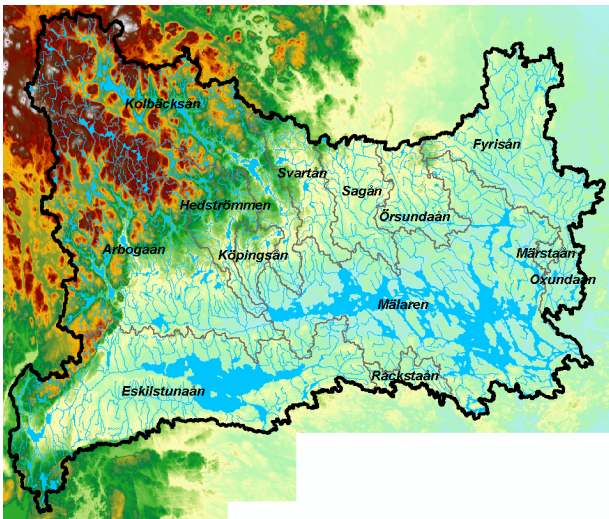


Figure 3.4-7 The twelve main tributaries in the Norrström river basin

AvSWAT Water flow simulations showed good agreements with measured daily values and could probably be further improved by inclusion of better input data such as denser soil characteristics data. Due to the high number of parameters and the model complexity, calibration of the model is however a time-consuming task which requires expert knowledge.

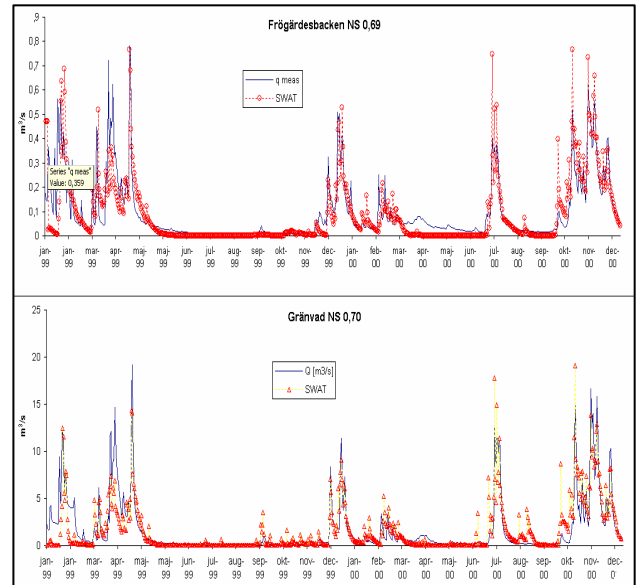


Figure 3.4-8: measured vs. AvSWAT simulations of flow at two validation gauging stations in Sagån.

3.5. WP5 Pollution Pressure and Impact Analysis

Characterisation and risk assessment of water bodies within the river basins is a major task in IWRM. One of the main parts of the characterisation is analysis of pollution pressure and impact.

Acquisition of surface water pollution pressure data not already available in partner databases was a first phase. Pollution pressure is high for the downstream parts of the Biobío river, while pressure is low in the Okavango basin. Nura river is suffering from severe pollution of mercury, and Norrström from high agricultural nutrient loads.

The diverging problems dominating the river basins require different tools for assessment of pollution pressure. Methods to analyse the impacts, i.e. the ecological/biological effect of the pressure (fish reproduction, ecosystem modified etc.) need to be tailored to be relevant to the ecosystems in the region of the case study.

3.5.1. Biobío

Focus for the analysis of pressures and impacts in Biobío was put on surface water bodies, category “rivers”. This is the component which is (i) most affected by human activities; and (ii) the object of recent modifications to the Chilean Legal Framework (*Secondary in-river Water Quality Standard for Biobío (2WQS)*). The selection of

actions under WP05 was based on locally determined priorities, i.e. previously identified knowledge gaps that are not being addressed by other planned or ongoing initiatives (see also WP01).

Principles from the “*Driver, Pressure, Status, Impact, Response*” (DPSIR) analytical framework described in EC WFD Guidance Document No. 3 were applied to make a preliminary, general analysis of pressures and impacts. This was combined with results from WP06 in order to obtain a general, theoretical assessment of the potential current status of the different river water body types in the Basin, and can be used to evaluate the adequateness of the spatial coverage of monitoring programmes, or for orienting complementary research.

In addition, more specific, detailed pressure-impact analyses such as the modelling of land use impacts on erosion and sediment delivery, and the modelling of hydropower operations impact on aquatic habitat availability were also addressed under WP05.

As a result, a series of thematic maps were produced which illustrate type, magnitude and spatial patterns of the principal human activities and associated pressures in the Basin. Under a simplified approach, pressure layers were mathematically combined (expert judgement) in order to obtain a preliminary, spatially explicit indication of potential impacts, based on the cumulative presence of pressures. Combination of these results with the water body typology established under WP06, allows to: (i) get an overview of the spatial patterns of cumulative pressures; (ii) identify, for each WP06 water body type, the presence of river reaches which may currently still present reference conditions (*to be used for establishing reference data in future monitoring efforts*); (iii) check if reaches currently under “high risk” are included in current or future monitoring programmes (e.g. *planned 2WQS monitoring*).

Erosion and sediment delivery to water bodies is considered to be the maximum exponent of non-point source pollution within the Basin. Together with sediments, nutrients and pesticides can also reach the river system. From this perspective, the spatially and temporally explicit modelling of erosion and sediment delivery is a good starting point for addressing non-point source pollution. The Universal Soil Loss Equation was applied under a GIS approach. Thematic maps of rainfall

erosivity, soil erodability, land use/cover factor and slope/flow concentration effects were prepared and mathematically combined to provide a theoretical assessment of spatial and temporal variability of erosion in the Basin. From this approach, erosion was identified as a critical problem in ~45% of the Basin’s surface area. A simplified approach (“*sediment delivery ratio*”) was used to assess impact of erosion on water bodies. Opportunities for validation of results need to be sought for in future works. Information obtained through the modelling approach can then be used and cross-checked with monitoring results in order to establish priorities for mitigation under the implementation of 2WQS.

To evaluate impact from hydropower operation on fish habitat, an aquatic habitat model (“CASiMiR”) was applied to a 2-km Biobío river reach. Habitat availability and suitability was assessed for 2 native fish species under a “pre-“ and a “post-dam” hydrological summer regime. Results showed serious impacts from especially hydropeaking on habitat, mainly in terms of reduced availability and suitability, and rapid shifts in spatial location. The importance of additional research on habitat preferences of native species can be stressed. Major attention to the impacts of hydropower operation may need to be considered for future licensing, if conservation of aquatic biodiversity is set forward as a desire of Chilean Society.

Results under WP05 by no means pretend to be complete. They constitute a first step in a large, dynamic and ongoing process. However, considerable advances in the knowledge about the general status of pressures and impacts in the Biobío Basin have been achieved under TWINBAS. These provide an important input for future work, and can already be used for the definition of preliminary adaptive management plans.

3.5.2. Nura

The 978 km long River Nura is the main river of the central Kazakhstan region. It rises in the mountains and flows westward through the heavily industrialised Karaganda region, before passing the new capital city Astana, and on to the terminal lakes. The main water quality problems of the Nura stem from present and former industrial activities in the Karaganda region. Upstream of Karaganda, there are no known point sources of pollution.

The main water quality problem is caused by a severe case of mercury pollution which occurred at the city of Temirtau, approximately 20 km west of Karaganda. An acetaldehyde plant operated in Temirtau for more than 40 years and discharged mercury-containing wastewater to the river. Emissions have mostly ceased since the 1990s, but the river sediments and floodplain downstream of Temirtau remain highly contaminated. About 300 km downstream of Temirtau lies the new capital city Astana, with a rapidly expanding population and increasing water demand. A link canal between the Nura and the smaller Ishim River is intended to supply additional water to Astana, although some concerns remain over the upstream mercury spill, and a project to clean up the Nura in the most polluted section has recently been initiated by the World Bank. About 150 km south west of Astana, the Nura discharges into the Kurgaldzhino wetlands and Lake Tengiz, one of the most important wetland sites in Central Asia.

Most of the river Nura can be classed as low or moderately polluted (characteristic contaminants are petroleum products, phenols, ammonia nitrogen, nitrites, nitrates, and sulphates), except for the section between the main effluent canal at Temirtau and Rostovka which is heavily polluted by mercury from former industrial activities. Further upstream the waters are very clean and downstream, the river is only marginally impacted by agricultural activity and waste discharge

The river bed between Temirtau and Rostovka is thought to contain between 3 – 8 t of Hg, with additional large deposits of mercury on the river banks (could be over one hundred tonnes). Downstream of the Intumak reservoir which acts as a settling pond for contaminated particles, river water quality is much improved, but during the flood period, small amounts of mercury can get transferred with flood water several hundred kilometres downstream.

Mercury is a highly bioaccumulative contaminant, and increased Hg concentrations were found in river fish up to 200 km downstream of the source of the pollution although the main danger to human consumption is between Temirtau and Rostovka (see Figure 3.5-1).

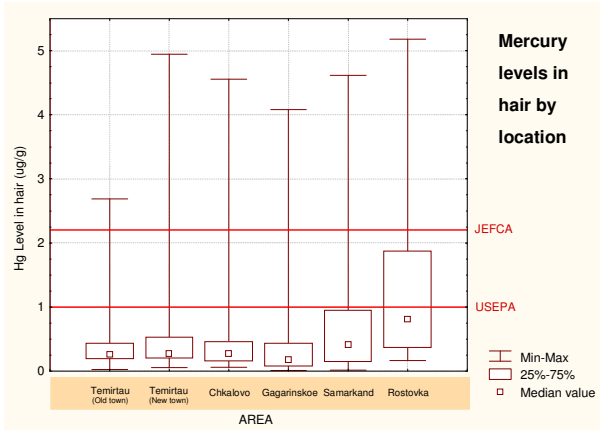


Figure 3.5-1 Mercury body burden of the local population, by residential area.

Risk assessment results confirmed that the consumption of contaminated fish from the river is the most important exposure pathway for the local population, and dose-response-modelling indicated a strong link between the Hg body burden in the riverine population and fish intake. However, although risk modelling indicated that quite a large percentage of the population in the Temirtau area are at risk. Despite the widespread mercury contamination of Temirtau and the river valley below town, hair sampling showed that although mercury levels were elevated in the people living in the riverine environment of the Nura they were not as high as initially predicted by a level 2 risk model. The work showed that this was most likely the result of the mercury being associated with powerstation flyash that had also been discharged into the river as the ash is able to bind it quite tightly.

A project is about to start to dredge the most polluted section of the Nura but continued monitoring of groundwater, surface water and biota will be required as past experience has shown that Hg levels in fish may remain elevated for a considerable period of time, and a public information campaign may be advisable to discourage people from fishing.

The methylation risk in the Intumak reservoir and downstream river reaches still needs to be assessed.

3.5.3. Okavango

Upper Okavango

The Upper Okavango basin has remained predominantly undeveloped and un-monitored until recently, but is expected to change in the future as the population of the basin is predicted to increase,

as are demands for associated water for domestic supply and irrigated agriculture. A number of potential sites for water storage and hydropower generation have already been identified. Another effect of increasing population will inevitably be land use change, particularly arising from deforestation, which could increase erosion and, hence, sediment delivery to the downstream delta. However, the hydropower dams may trap much of the sediment. Climate change could also impact significantly on water availability in the basin.

It is anticipated that pollution pressures will increase over time, due to growing population (i.e. increased waste) and agricultural development (i.e. increased use of fertilisers). However, this is likely to have limited impact on water quality in the near future due to the dispersed nature of the pollution, and a possible buffering effect by the hydropower dams.

Pollution pressure and impact analysis activities in the Upper Okavango were limited by the lack of firm data and information on changing pressures. However, the qualitative water quantity pressures were used to quantify a series of possible development scenarios in the upper basin (i.e. proposed hydropower schemes, expansion of irrigated areas, and population growth causing an increase in domestic water demand) for use in WP7 to assess the impact of possible change scenarios of water availability.

Delta

The Okavango Delta is formed by sediments carried from the basin in Angola and Namibia. Coarser particles are distributed as bed load in the channels, while suspended and dissolved substances are distributed by overland flows, across flood plains and swamps. Significant shifts in the distribution of flows appear to occur at a frequency around 50 years caused by neotectonic events.

The Hydrologic Model with sediment transport was applied to assess the impact of a) Major hydropower dams in the basin, b) Clearing channels blocked by vegetation, c) Dredging of main channels, and d) The combined impact of upstream water resources developments and climate change.

The long term development of the delta depends on the supply of sediment. The construction of hydropower dams will limit the supply of sediment to the delta. When the supply of sediment stops, the upstream bed of the Okavango River erodes rapidly. This erosion will migrate downstream

until it reaches the apex of the delta proper. From the present trend, this would take over 100 years.

An analysis of the impact of clearing channels show that the peak flow and sediment transport may increase by a factor of six leading to local erosion. Declining transport volumes downstream creates a backwater effect, declining flows and the channel becoming again blocked by encroaching vegetation.

In 1991 dredging of the main channel started to increase water supply to the diamond mines some 300km downstream. However, this was abandoned due to national and international environmental concerns. The dredging works would have increased the outflow from the delta by around 40%.

The combination of hydropower dams and irrigation schemes, increased water abstraction and climate change produces the most adverse scenario. The inflows to the delta decline by 55%, and the permanently flooded area in the Delta declines from 4,776 to 346 km². The marked decline in the inflows from the upstream basin results in greatly reduced sediment transport volumes, from around 400,000 to 50,000 m³ at the entrance to the Delta proper.

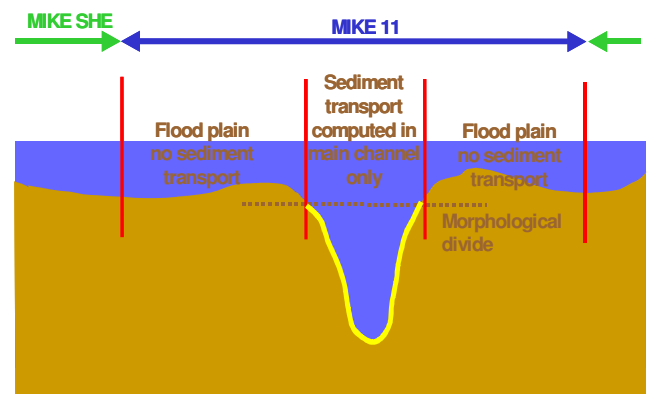


Figure 3.5-2 Particulate sediment transport is mainly confined to the main channels in the Okavango Delta

3.5.4. Norrström

For the Norrström basin the WP 5 objective was to develop methods allowing improved assessment of the nutrient pollution pressure on Lake Mälaren. Eutrophication is the main water quality related problem in the basin.

Building on the improved hydrological modelling methods developed in WP 4 with Svartån and

Sagån catchments as case areas, SWAT was used for hydrological and nutrient pressure modelling in five additional tributaries: Örsundaån, Köpingsån, Hedströmmen, Kolbäcksån and Arbogaån. For the latter two, hydropower dam regulation data proved to be inaccessible. Nutrient transport and source apportionment modelling with focus on agricultural leaching was thus implemented and validated for the other five tributaries. This included GIS-database set-up including monitoring data, emission inventories addressing point sources, calibration and validation of hydrological modelling and nutrient transport modelling

With the adaptation of SWAT to Swedish conditions, agricultural leaching of nutrients can be modelled with significantly improved dynamics and geographic detail.

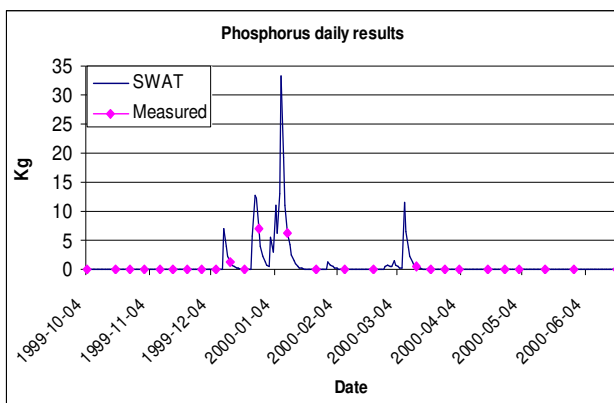


Figure 3.5-3 Results from SWAT modelling. Transport in kg for the days when measurement data on concentration and flow was available during the validation period.

The modelling results for the days when nutrient concentration and flow was measured (once every month at most stations) showed a high accuracy for P as well as N. SWAT daily modelling results as an average per month are more accurate than conventional averaging of monthly monitoring data for annual load values (Figure 3.5-3).

With the detail in dynamics and geographic resolution provided by SWAT, the main limitation to the modelling accuracy is now that generally only monthly or bi-weekly nutrient monitoring is carried out. Flow-proportional monitoring supporting the modelling calculations would further improve the modelling. Based on these TWINBAS findings, flow-proportional monitoring is now implemented in TWINLATIN.

Yet, with this improved modelling capacity, the farmer stakeholders as described in WP 3 – Public participation, argued that local data from farmers

on management practices and soil conditions should be collected and used in the modelling instead of GIS soil data and regional statistics on management practices (e.g. fertiliser use per ha), in order to ensure high accuracy as a basis for discussions on measures. Following these recommendations from farmers, such data was collected by interviews with farmers in a small catchment, Lillån, 200 km², and used in the modelling. This further improved the modelling accuracy compared to monitoring data. Thus, to provide an accurate basis for discussions on measures of programmes, local data on management practices and soil conditions from farmers is needed (Figure 3.5-4, Figure 3.5-5).

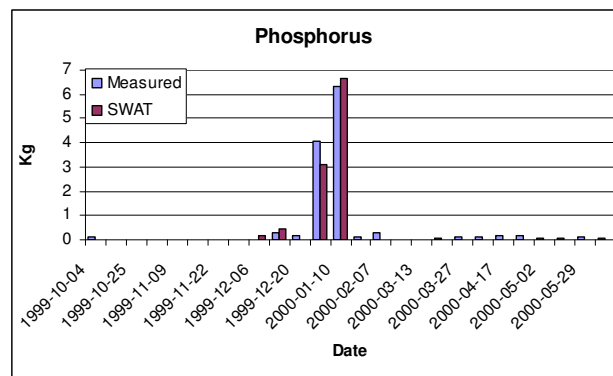
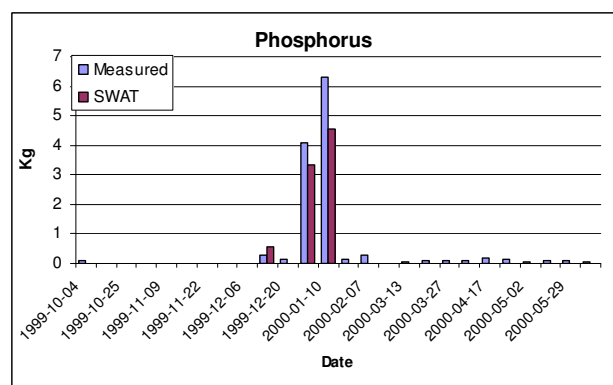


Figure 3.5-4 Modelled and measured P transport from the Frögårde sub-catchment. Above: With data from soil maps and regional statistics on e.g. fertiliser use. Below: With local data from farmers on soil conditions fertiliser use etc. Note the very high leaching during snowmelt

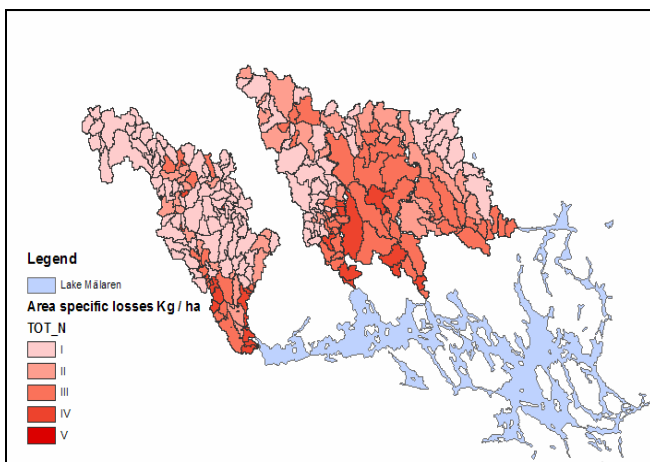
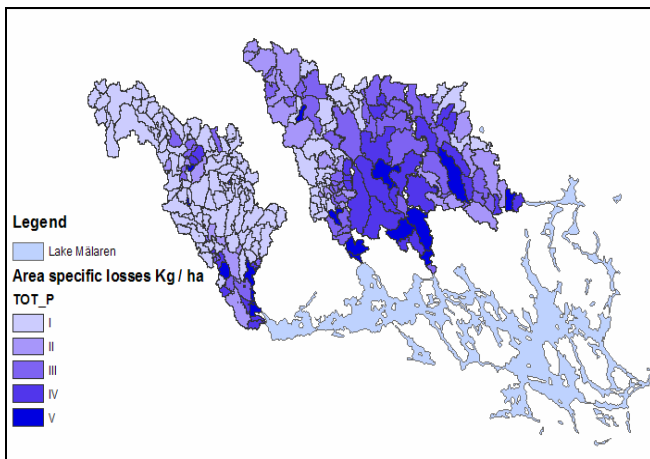


Figure 3.5-5 Area losses for the five tributaries modelled using AvSWAT, classified according to the classification system of the Swedish EPA. The agricultural areas close to lake Mälaren are all in classes 4 and 5, with high and very high losses.

3.6. WP6 – Classification of Water Bodies

Environmental objectives are set to protect users and uses of water from the effects of pollution and to protect the water environment itself from especially dangerous substances. The Water Framework Directive introduces new broader ecological objectives designed to protect, and where necessary restore, the structure and function of aquatic ecosystems.

The basic management unit for setting environmental objectives is the water body. A water body is a distinct, significant and relatively homogenous element of water. Water bodies can be grouped in different categories, such as rivers, lakes, wetlands, coastal waters, transitional waters (estuaries) and groundwaters. The WFD requires characterisation of both surface water and

groundwater water bodies, and identification of the specific pressures on each water body. Identification and spatial delineation of individual water bodies within each category, by differentiating the various types on the basis of their natural characteristics, enables their environmental status to be accurately described. The WFD also requires registers of areas requiring special attention to protect their surface waters or groundwaters, or to conserve habitats and species that depend on those waters. The environmental objectives that need to be achieved under the WFD are summarised in Table 3.6-1:

Table 3.6-1 WFD environmental objectives for surface and groundwater water bodies.

	Environmental objective
Surface waters	Achievement of good ecological status and good surface water chemical status by 2015
	Achievement of good ecological potential and good surface water chemical status for HMWBs* and AWBs*
	Prevention of deterioration from one status class to another
	Achievement of water-related objectives and standards for protected areas
Groundwaters	Achievement of good groundwater quantitative and chemical status by 2015
	Prevention of deterioration from one status class to another
	Reversal of any significant and sustained upward trends in pollutant concentrations and prevent or limit input of pollutants to groundwater
	Achievement of water-related objectives and standards for protected areas

*HMWB – heavily modified water body; AWB – artificial water body

The status of each water body is determined by comparison with desired reference conditions, usually specified as the ecological status of a water body free from anthropogenic influences. Therefore, within each category, water bodies are grouped according to their physical, chemical, biological, morphological and hydrological

characteristics, and type-specific reference conditions are established. Based on the reference conditions, each water body is classified as having a high, good, moderate, poor or bad ecological status. Once actual or potential environmental problems have been identified, in terms of the risk of not achieving good status by 2015, cost-effective protection and improvements measures can be designed and implemented, as a component of successful river basin planning. Risk assessments, and river basin management plans, should be updated periodically as knowledge of the risks to the status of the water environment improves through modelling and targeted monitoring.

The conceptual adaptation and application of the WFD approach to water body classification is more advanced in some of the TWINBAS basins than others:

- The analysis has largely been completed in the UK.
- In Kazakhstan, for the first time, water bodies of the Nura River Basin have been classified according to the WFD methodology, and protected areas and recreational sites have been documented.
- In Chile, where available resources and baseline information are limited, emphasis was put on the establishment of a water body typology for the rivers of the Biobío River Basin, and other surface water categories may be addressed in future research efforts.
- In Sweden, neither a classification of ecological status nor a risk categorisation for the Norrström River Basin was made under the framework of the TWINBAS project, in order to avoid confusion with the on-going work of the District Water Authority.
- In Southern Africa, classification work was focussed on the Okavango Delta wetland. Wetlands are a category not explicitly included in the WFD natural surface water body classification, and so the WFD has not been adopted.

3.6.1. Biobío

Under WP6, a river water body typology was established for the Biobío Basin, using a methodology inspired on the procedures for

implementation of the EC WFD (2000/60/EC), but further adapted to local conditions.

For this purpose, the Biobío Basin was subdivided in 1,100 analytical units, called water bodies. Both artificial and natural water bodies were identified, and protected areas or areas requiring special attention (*e.g. presence of drinking water intake points*) were mapped.

The “System A” classification scheme which is documented in Annex II of the WFD was then applied under a modified form. Modifications were based on the input provided by local experts. The basic GIS information layers used for establishing the typology were: (1) elevation; (2) soil type (*instead of geology*); and (3) drainage area. In agreement with the specifications given in Annex II of the WFD, and taking into consideration the recommendations and suggestions for class limits of local experts, the following parameters were selected for use in the classification process: (i) mean elevation of the reach-specific drainage area (4 classes); (ii) percentage of the total upstream drainage area with snowmelt contribution (2 classes); (iii) total upstream drainage area (4 classes); (iv) dominant soil type within the reach-specific drainage area (7 classes).

Based on this procedure, a large number of water body types were generated for the Biobío Basin. Such a large number may be desirable in the case of evaluating potential diversity of ecosystem/macrobiodiversity types, but is unpractical if the typology is to serve as input for, *e.g.*, the establishment and control (or revision) of a differential water quality standard (*i.e. standards in function of spatially variable reference conditions*). For this reason, the total number of river water body types in the Basin was reduced to 14, through the application of cluster analysis.

By means of the analysis of the cumulative presence of the pressure types identified under WP05, a set of representative elements from each water body type can then be selected, for which it can be reasonably assumed that “natural” or (close to) “reference” conditions still occur at these sites. These water bodies can then be analyzed in the field, in order to set reference conditions which may then allow to further evaluate the current status at other sites belonging to the same river body type. The indicator of cumulative pressures used under WP06 was derived from the combination of the following thematic data layers: (i) how unspoiled the land cover is in the reach-specific drainage area; (ii) how unspoiled the land

cover is in the total upstream drainage area for a given reach; (iii) local presence of irrigation channels; (iv) local population density; (v) local and upstream presence of flow regulations.

Outcome from this process was used to establish 5 “probability classes” of water bodies presenting reference conditions. As a result from this exercise, it could be seen that only 5, respectively 7 Biobio Basin river water body types still have representative elements (*i.e. individual water bodies*) classified under “high”, respectively “good” probability of presenting (close to) reference conditions. For these types, it can still be possible to establish type-specific reference conditions through field monitoring. For most other types, however, monitoring efforts will need to be combined with expert judgement and/or modeling, if reference conditions are to be deduced.

In addition to the selection of sites for reference monitoring, the developed approach thus also allows for a first screening on potential status of water bodies at the Basin level. As was already indicated under WP05, the identification of important cumulative pressures associated to a given water body may serve for identifying water bodies potentially under risk. This information can now be combined with the outcome from past monitoring (*i*) to identify gaps in ongoing or future monitoring efforts, or (*ii*) for the periodic revision of Secondary Water Quality Standards and associated monitoring efforts.

3.6.2. Nura

Out of a total of 44 classified river reaches and water bodies in the basin, four are ‘at risk’ and one is at high risk. The four river bodies designated as ‘at risk’ are the Nura, the Sherubainura, and the Karakengir and Sokur rivers. The Nura below Samarkand reservoir is heavily impacted by mercury and waste water from industrial enterprises. The contaminant status of the Nura carries associated risks of polluting the alluvial aquifer. Upstream areas of the Nura are relatively pristine, and diffuse pollution insignificant. Point source pollution pressures are however significant in the Karaganda region. The river quality is very poor in the section below Temirtau but this is expected to improve after clean-up programme that is presently being implemented to remove the mercury polluted sediments. This is scheduled to start in spring 2008. Regular surface water quality monitoring for mercury will be needed during and

after these works. The water quality in winter below the Temirtau sewage outfall is also low as there is little natural flow to dilute the nutrient load.

For ease of comparability the water quality has been classified the same as the Thames River Basin which was used as a blueprint for the preparation of the classification maps for the Nura. As a result this has been the first time a Kazakhstan river has been classified according to the methodology stipulated by the Water Framework Directive. However the River Thames has a strong well documented database on which to base the classification, the input data for the Nura leaves a lot to be desired in all respects and the visually pleasing presentation of the classification could lead the reader to place more trust in it than the input data warrants

The WP6 Maps were presented to all interested stakeholders at a Seminar held in the capital of Kazakhstan, Astana on 6 September 2006. At the end of the project, the maps will be given to the Ministry of Environmental Protection of the Republic of Kazakhstan.

3.6.3. Okavango

The WFD does not set environmental objectives for wetlands in the same way that it does for other surface water bodies. However, wetlands form an important component of two of the TWINBAS river basins, the Nura and the Okavango which both terminate in inland wetlands.

The Okavango Delta is significant in size and possesses a remarkable biodiversity. Large parts of the human population in and around the delta still depend directly on the utilisation of natural resources of the Delta for subsistence. Fishing, hunting, livestock grazing, flood plain cultivation and collection of raw materials for building, fuel, and the production of handicrafts are important elements of the local economy.

The outstanding natural beauty and abundant wildlife resources form the basis of a fast growing tourism industry, which is offering alternative employment opportunities to people in the rural communities of Ngamiland District. In addition, Wildlife Management Areas cover an area of 13,000km² of the delta. Community Based Natural Resource Management practices provide a conducive environment for the sustainable utilisation of the natural resources, linking socio-economic development with natural resource management.

Among the Ramsar Convention identified wetland systems the Okavango Delta comprises three of the above systems, namely lacustrine, palustrine and riverine. Each of these systems interfaces with the others, and with related habitats fringing the wetland proper. Given the importance of a holistic approach to the investigation, understanding and management of the wetland, and the continuum of environments at the land-water interface, the area is extended to include two additional fringing habitats: terrestrial wetland – fringing the normally or frequently flooded areas, receiving flood water from overspill from an average seasonal upstream flood, terrestrial dryland – occupying the remainder of the alluvial fan, but rarely flooded under the present climate and flow pattern, and generally only from local rainstorms which are slow to drain.

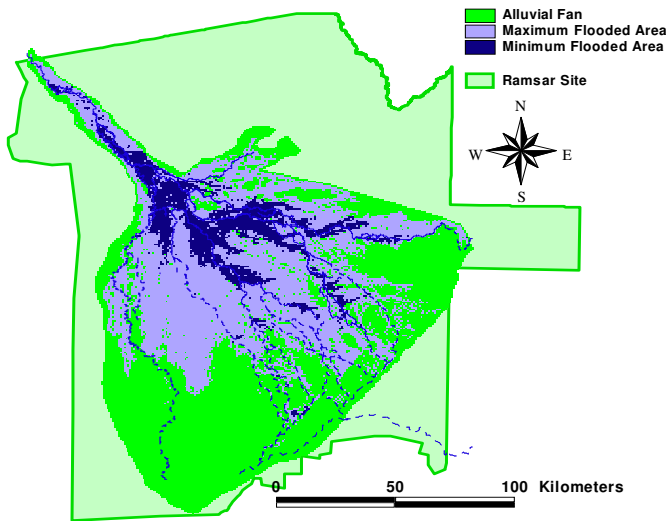


Figure 3.6-1 Okavango Delta Areas

3.6.4. Norrström

In Sweden, waters can be protected as in nature reserves or national parks. Areas can also be of national interest regarding nature protection and outdoor life, for example. In addition to this, there is also a general protection of biotopes in the agricultural landscape. Water areas with high values have also been identified in the inventories of forest biotopes and in the national inventory of wetlands. Within TWINBAS all protected areas in the Norrström basin were documented and included in the GIS database.

The Lake Mälaren and Lake Hjälmaren basins are classified as nitrogen-sensitive areas and the whole

of Sweden is classified as sensitive to discharges from phosphorous.

The maps in Figure 3.6-2 - Figure 3.6-4 show a selection of the protected areas:



Figure 3.6-2 Natura 2000 sites

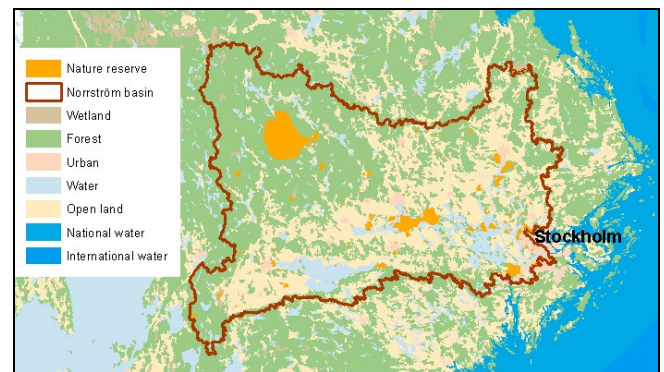


Figure 3.6-3 Nature reserves

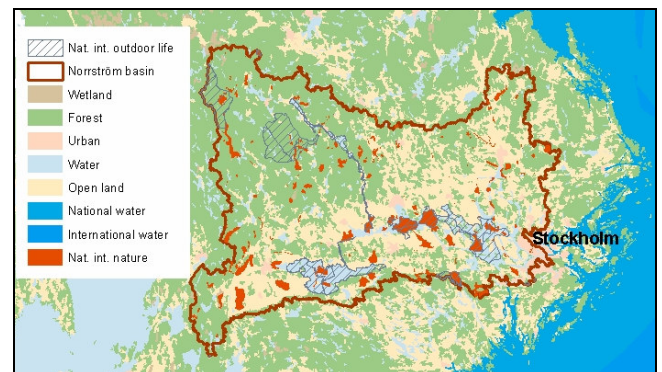


Figure 3.6-4 Areas of national interest for outdoor life and nature protection

In discussions with the Water authority of the district, it has been agreed that the project shall not produce a separate classification of water bodies, but instead use the official classification produced by the Water authority. This is to avoid confusion. However the water authority has not been able to finalise the ecological status classification so that it could be used in TWINBAS. The classification would have been used to choose waters at risk for analysis of abatement actions. Instead, the analyses

of abatement actions have been done in a case area selected by expert judgement.

The selected area, again Sagån, is a major contributor of nutrients to lake Mälaren, and has sufficient input data for assessment of abatement actions in terms of chemical efficiency and cost-effectiveness.

3.6.5. Thames

In the Thames River Basin, 449 river water bodies, 46 lake water bodies, 7 transitional and 3 coastal water bodies, various artificial water bodies and heavily modified water bodies, and 45 groundwater water bodies were identified. A register of 101 drinking water protected areas, areas for the protection of economically-significant species, 17 recreational waters, 10 nutrient sensitive areas and 23 conservation areas was also established.

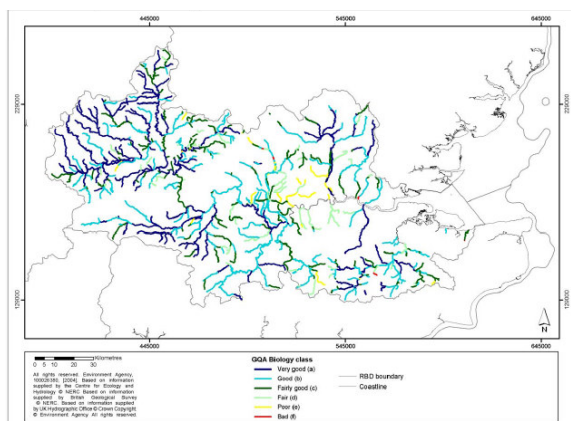


Figure 3.6-5 Thames River Basin GQA biology assessment (reproduced with written permission of the Environment Agency for England and Wales⁶)

Reference conditions for the water bodies were based on the Agency’s biology GQA (General Quality Assessment) classification system (Figure 3.6-5). This uses macro-invertebrates, such as the larvae of insects (e.g. mayfly, caddis fly) and snails, shrimps and worms. Macro-invertebrates are used because they are found in virtually all rivers, they do not move far and they respond to water pollutants as well as to physical damage to their habitat. The survey measures the difference between the macro-invertebrates found in the river and those expected if the river was unpolluted and undamaged. The biology GQA provides a partial assessment of the aquatic ecology in terms of macro-invertebrates but is the closest measure of status available for the biological quality element of the WFD’s ecological status classification scheme. Results from the LOCAR programme suggest that

this conventional biological assessment of river ecological quality is inadequate and a new ecosystem-based approach is needed.

Of the river water bodies at risk of not achieving good status, diffuse pollution accounts for around 90% and morphological pressures around 70%. Both point and diffuse source pressures are significant for lakes. Morphological pressures cause all three coastal waters and all seven transitional waters to be at risk. Point source pressures are also significant in transitional waters, and diffuse pollution in coastal waters. Diffuse source pollution pressures and abstraction pressures are significant for groundwater bodies, accounting for around 90%, and 40%, respectively, being at risk of not achieving good status (Figure 3.6-6). Diffuse pollution is strongly linked to land use activity, with agriculture a major, though declining, source. However, current understanding of the relationship between pressures and impacts for diffuse pollution from non-agricultural activities is less well known, highlighting the need for future research to strengthen awareness of such links.

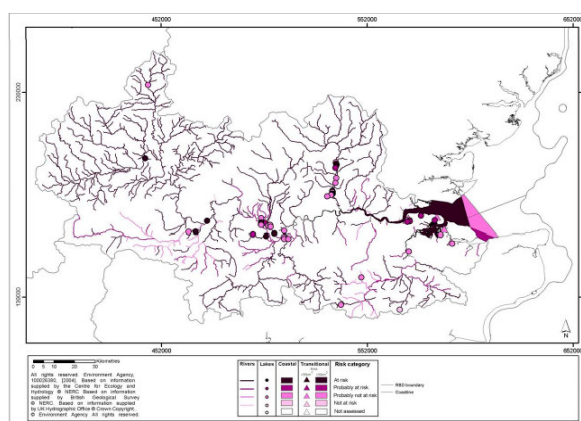


Figure 3.6-6 Surface water bodies at risk from diffuse source pollution pressures in the Thames River Basin (reproduced with written permission of the Environment Agency for England and Wales⁶)

The majority of point pollution sources in the Thames basin are licensed and closely monitored and controlled by the Agency, and do not cause any damage to the water environment. In contrast, diffuse pollution pressures on river water bodies account for around 90% of them being at risk of not

⁶ Defra. 2005a. Maps to support the Summary report of the characterisation, impacts and economic analyses required by Article 5: Thames River Basin District. Crown copyright 2005.

(<http://www.Defra.gov.uk/environment/water/wfd/pdf/thamesmaps.pdf>)

achieving good status, and are also significant for lakes, groundwater bodies and coastal waters. The Agency's current surface water monitoring programme is designed mainly to assess the impacts from point source pressures, and knowledge of diffuse source impacts at a national scale is less than that for point sources. Abstraction and flow regulation pressures are clearly linked to economic activities e.g. household and economic growth will affect the level of water demand. The most important abstractors in the Thames basin are water companies, followed by the electricity industry.

The water body classification requirements of the WFD will allow the Agency and stakeholders in the Thames River Basin to take a more holistic and integrated approach to water management and the improvement of aquatic environments. The proportion of water bodies identified as being "at risk" may increase in the future as further risk assessment work (including data from targeted monitoring) improves confidence in the risk to those waters.

3.7. WP7 – Change Effects and Vulnerability Assessment

The various hydrologic and water resource models described in WP4 show considerable innovation and diversity in their respective approaches to change effects and vulnerability assessment. The forces behind the changes that are anticipated are:

- Land use – primarily to forests and agriculture
- Water resources – primarily the continued development of irrigation and hydropower, and also domestic and industrial supplies; and the pollution loadings arising from the developments
- Climate change based on predictions from Global Climate Models of temperature and precipitation changes

The outputs from the model analyses are generally changed patterns of river flows. Additional outputs available from certain models are impacts of pollutants and sediment transport, and the impacts on subsurface waters, reflecting the problem areas and corresponding needs of the respective basins.

The key strength behind all good models of river systems is a holistic approach. The analysis of river basins is complex, involving many different

aspects: climatic, geographic, socio-economic and structural interventions. A river basin needs to be managed and hence analysed as a whole. The largest uncertainty in the analysis relates to the climate change parameters. Different climate change models show considerable variations among their outputs, even to the extent of disagreement on whether for example precipitation is increasing or decreasing. A further major uncertainty lies in the degree to which the hydrologic and ecosystems will adapt to the changes; and also the degree to which human societies will adapt and endeavour to mitigate the adverse impacts of climate change, as well as supply shortages.

With the capability to separate the impacts of increasing water demands from climate change, hydrologic models have a vital role to play in addressing the solutions to the overall problems arising in river basins with increasing pressure on available water resources. Major socio-political decisions concerning water resources are being made, and more critical decisions will be required in future. It is imperative that these decisions are based on the best well founded information on the quantity and quality of the waters available.

The full report from WP7 presents different approaches to the analysis of river basins with wide ranging climatic, topographic and demographic parameters. As such it provides a useful reference document for further work in this area. The technology is for most purposes well developed. The greatest need here is to place the technology in the hands of the people closest to the problems, in the river basins, which requires more usable models and human resources development. The other pressing need is for more extensive and more reliable hydrologic data.

3.7.1. Biobío

One of the most important aspects of future water management in the Biobío Basin will be the adequate allocation of water resources between different users. Limited availability of resources during summer, together with an ever increasing demand and the potential impacts of land use and climate changes may lead to increased vulnerability and new or intensified conflicts between stakeholders:

Important changes related to human use have been taken place or are expected in the basin in the near future: (i) the Laja-Diguillin canal - with a capacity to transfer ~13% of the mean Biobío summer flow

to a neighboring basin - becomes operational; (ii) further expansion of the forestry plantations area; (iii) 100% increase in productive capacity of pulp and paper mill industry in the Basin; (iv) changes in legal framework: modifications to Chilean Water Code and implementation of Secondary Water Quality Standard.

The location of Biobío in a climatic transition zone makes it particularly vulnerable to climate variability and change. In order to assess the potential exposure of the water resources sector to future conditions of water availability and quality under plausible future climatic and land use conditions, the following approach was used:

Performance of the hydrological model for the Vergara Subbasin (see WP04) was further tested at EULA through a double validation exercise, using time series from 1992-99 and 1975-82 together with representative land uses for both periods based on information from 1995-98 and 1979. Five maps representing plausible future land use scenarios were developed, based on both a simple approach and a logistic regression analysis. Simulated regional output from 7 General Circulation Models under 6 different emission scenarios was obtained by applying the MAGICC-SCENGEN tool (v4.1). Spatially correlated stochastic precipitation time series generated for 5 local meteorology stations (F. Meza, PUC - Santiago de Chile) were perturbed based on the results from MAGICC-SCENGEN. Both reference and perturbed series were used in the hydrological model to evaluate impact of potential climate change on annual and monthly discharges in the Vergara Basin.

For the improved, double validation modelling exercise, the Nash-Sutcliffe Efficiency Criteria for both modelled periods ranged from 0.80-0.90 and 0.74-0.88, respectively. This indicates that the model, under its current form, is capable of adequately reproducing observed monthly flows under different conditions of meteorology and land use. However, no clear conclusions could be obtained yet on the explanatory power of the model with regard to impacts of land use changes on monthly discharge rates (additional research required).

Results from MAGICC-SCENGEN for the year 2050 indicated possible ranges in mean annual temperature and precipitation changes between + 0.6 and + 1.8 °C, and between -0.1 and -30.0%, respectively. From the hydrological modelling application, elasticity values ($[\% \text{change in mean annual discharge}] / [\% \text{change in mean annual}$

precipitation]) between approx. 1.5 – 1.8 were obtained. This indicates that impact of climate change on water resources availability would be proportionally higher than what would be expected from the projected changes in precipitation rates. Monthly discharge rates for return periods from 1-30 years were graphed for both reference and climate change scenarios, and can be used as background information by stakeholders to assess individual or collective vulnerabilities.

Reduced flows as a consequence of climate change may further also negatively impact water quality, especially in the case of point discharges. Changes in intra-annual precipitation patterns within the Basin still need to be analyzed. Downscaled results from RCM runs in Latin-America are currently becoming available and can be used in future research. Research under TWINBAS mainly focused on the “exposure” component of the vulnerability of human society to climate change. Additional attention will need to be given in future efforts to the evaluation of local or national adaptive capacity, in order to enable an adequate overall evaluation of vulnerability, and propose actions to further reduce this vulnerability. First steps in this direction are currently being undertaken through ongoing work at EULA. For this purpose, outcome from WP07 research was presented during the TWINBAS final public participation workshop, and an inquiry on sectorial vulnerability was applied. Results from TWINBAS will also be presented and disseminated during an IPCC-TGICA specialist workshop to be held in June, 2007.

3.7.2. Nura

Because of the high economic value of water in this arid region the water resources of the Nura Basin are highly vulnerable. The towns of Karaganda, Temirtau and Astana are sited in the catchment. With Kazakhstan’s vast oil wealth being tapped, the growth of the new capital of Astana and its environs is explosive. This and the political will to green the city in this arid area is posing a grave threat to the internationally important terminal wetlands (a RAMSAR site), a threat not seen since that experienced in the 1960s with the implementation of the Soviet ‘Green Lands Policy’. Because of the isolated and remote nature of the terminal wetlands green tourism is very small-scale, and hence even with the best environmental economic practices it is not possible to make an economic case for supplying water to the wetlands

that will stand up against the economic case associated with its use to develop the capital city and its green spaces.

The mean annual discharge of the River Nura at Astana is $20 \text{ m}^3 \text{ s}^{-1}$, but due to losses from large in-stream depression lakes this falls to half when it reaches the terminal wetlands.

The work shows that climate change is likely to make little impact on the water resources of the basin, but plans are being discussed to abstract up to $20 \text{ m}^3 \text{ s}^{-1}$ of water for Astana. It is clear that abstraction of half this would result in the effective drying of the Kurgaldzhino wetlands. Abstraction of an additional 1 or $2 \text{ m}^3 \text{ s}^{-1}$ might be possible but only if all other water development in the region was frozen and a rational plan was put into place sustainably to manage its effect on the terminal lake and wetland system.

The results of the project indicate that without an effective water resource management plan the scope for additional sustainable abstraction is negligible. The project has been working towards developing a sustainable water resource management plan, but until an effective institutional and legal structure is introduced it is impossible to develop and implement a river basin plan.

There is a River Basin Organisation in name but it lacks the power, legal status, personnel skills and finances to have a significant effect on water resource management.

The Irtysh-Karaganda canal is capable of making up any local shortfall in water resources, and this is often cited as a reason not to worry about lack of water. However, these statements are made without a rational sustainable water resource management plan for the basin, and as pointed out earlier this option would only be feasible with huge government capital and annual operating subsidies from Government.

This project has brought the issues into the political arena, but the implementation of a sustained water resource management plan from the Nura Basin is some way away from becoming a reality. In fact a project is already underway to develop the Intumak reservoir to allow Astana to abstract more water in the dry summer months. Hence, the threat to the wetland must be considered severe.

On a brighter note Kazakhstan is a transitional nation that is rapidly changing from a centrally planned to a free market economy and many

changes have taken place. There is a political will that the water sector becomes sustainably managed but the transition from the old ineffective management structures has to overcome a considerable amount of institutional inertia and vested interests.

3.7.3. Okavango

Upper Okavango

In WP4, the Global Water Availability Assessment (GWAVA³) model was used to estimate current water resource availability in the Okavango basin over a baseline period 1961-1990. GWAVA's outputs include mapped indices of water availability (in terms of supply v demand) across the basin, and allow assessment of the impacts on water resources of change scenarios (climate, land use, etc), and also enable water managers to evaluate the impacts in their basins in a wider context. In WP7, a series of possible development scenarios in the basin were applied to the GWAVA model to provide an indication of the impact of these possible change scenarios of water availability, and on flows entering the delta at Moheumbo.

The results from the population and water demand scenarios showed that, if considered individually, increased abstractions for water supply and irrigation have relatively little impact on annual flows with a reduction of less than 1.5% on dry season flows by 2025. A potential Namibian water transfer scheme could reduce dry season flows by some 3%, although this represents an extreme case of water abstraction.

The scenario of potential hydropower development in the Upper Okavango impact the pattern of flows entering the delta, with annual volumes being reduced by between 1% and 9%. If all of the schemes are realised then the flood flows could be reduced by 17%. However, if many of these are run-of-river schemes rather than dams, the impact on flow regime will not be substantially affected.

The climate change results from the various models highlights the uncertainty in the long-term predictions for the basin, as illustrated in the figure which shows the flows entering the delta at Moheumbo in 2050. By 2080 there is general declining trend in river flows, but the degree to which this happens is much less clear and, as temperatures warm, enhancing potential

evaporation, dry season flows are reduced even further.

The model outputs reveal that understanding of hydrological processes in the upper basin and movement of water in the lower basin prior to entry into the delta can be further improved. However, the results provide a baseline for longer-term strategic planning of water resource development and alert river basin managers and policy makers to emerging problems. This will contribute to the collaborative exchange of IWRM research policy and practice within and between river basins, thereby addressing relevant objectives of the EUWI and MDGs.

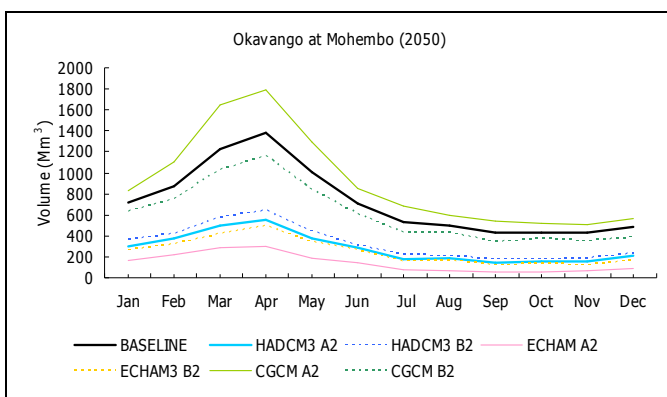


Figure 3.7-1 Changes in flows at Mohembo for 3 GCMs under the A2 and B2 SRES scenarios

Delta

The entire Delta ecosystem depends on the spatial and temporal distribution of water, and is at risk from adverse changes to the hydrologic regime of the delta. The hydrological impacts arising from the scenarios analysed by the Integrated Hydrologic Model are briefly summarised as follows.

- (1) The basin and delta are presently in a near natural state. To date, land use changes and abstractions from the basin upstream and the delta have a minimal impact on the delta as whole.
- (2) With environmentally sensitive operation, the potential dams in Angola with a combined storage approximately equal to the annual delta inflow do not have a major impact on the waters of the delta. There is no net water consumption, and little water is stored in dry years, with correspondingly small releases in the dry period.
- (3) Upstream irrigation in Namibia and Angola has a significant impact. The permanent

flooded area is reduced by 40% in dry years.

- (4) Present and future surface and ground water abstractions from the delta are minimally significant, amounting to 0.3% and 0.5% of the inflow respectively. Under future conditions, the seasonal flooded area by around 70km², or 0.6%.
- (5) Projected climate change has severe impact, reducing both inflows from upstream and rainfall over the delta, and increasing temperature and the rate of evapotranspiration. The permanently flooded area is reduced by 68%, from 2,770km² to 900km².
- (6) The combined water resources developments with climate change have the most severe impact on the delta. The flooded area declines from a maximum of 14,424km² to 4,685km², and the minimum from 2,770km² to 145km².

Other threats to the delta relates to fencing erected to prevent contact between cattle and wildlife in order to avoid spreading of diseases. Tsetse flies have been virtually eradicated by aerial spraying. While the direct environmental impact of the spraying appears to be minimal, it has as intended allowed humans and their livestock to encroach on the delta.

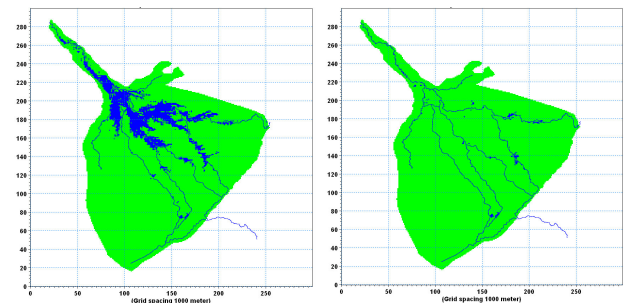


Figure 3.7-2 Permanently flooded area of the Okavango Delta in present situation during dry years (left – 2,770km²) compared to scenario with developed irrigation and Climate Change in the Okavango Basin and Climate Change (right – 145km²).

3.7.4. Norrström

The work that was conducted within WP 7 for the Norrström area focused on the two river basins Sagån and Svartån. Both basins are located north of Lake Mälaren. Agriculture dominates the southern parts of the basins close to lake Mälaren, and forest the northern parts. Modelling and assessment of the

effects of future climate scenarios on hydrology, land use and leaching of nutrients expert estimates need to be used for a number of change effects, e.g. the effect of changed temperature and precipitation on agricultural management practices. To do this a great deal of effort was made to gather expert estimations, to look at management practices in regions with a climate similar to the modelled future climate in Norrström and on identifying the planned or foreseen development of both rural and urban development. Modelled future climate data was delivered from SMHI's regional climate model. The approach was as follows:

1. Decide which of IPCC's future climate scenarios that was to be modelled, and to process suitable climate data from SMHI for input to SWAT.
2. Collect planned or foreseen urban and rural development., including technical regulations regarding wastewater discharge, urban development and household wastewater treatment.
3. Estimate changes in land use and management of agricultural management practices corresponding to the changed future climate.
4. Processing gathered information and adapting to the IPCC scenarios. Modelling the different SWAT scenarios .

Two of IPCC's scenarios were chosen: scenario A2 and B2. These were chosen to represent the worst and best case scenario of the future climate development, where the B2 represents the best scenario. By using scenarios for the present situation and future reference scenarios (where the climate variables as well as agricultural management dates were altered) as well as future scenarios adapted to IPCC scenarios, the outcome resulted in data showing the future development of pollution pressure.

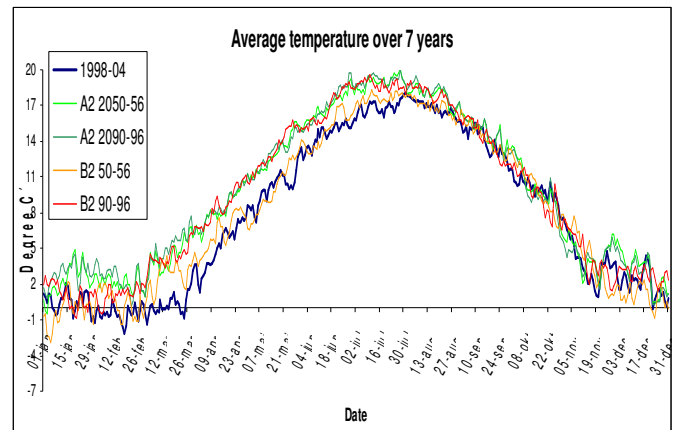


Figure 3.7-3. Temperature over the year as an average of 7 years for a baseline period and four scenarios.

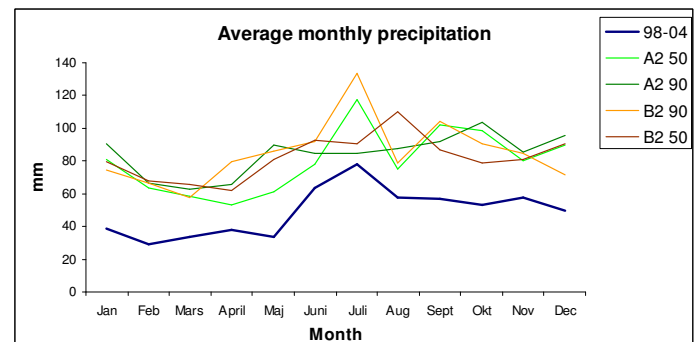


Figure 3.7-4. Monthly precipitation over the year as an average of 7 years for a baseline period and four scenarios.

The modelled results reveal that the future pollution pressure will decline. The trend is the same in both IPCC scenarios and also the reference scenarios show a decline in pollution pressure. The major landuse changes with regard to changes in nutrient leakage are the increased use of autumn sown crops and increased use of energy crops. Changed agricultural management to less tillage in autumn and spring fertilization instead of autumn fertilization also have an effect on the leakage. Except from these changes the changed climate had a big impact in the modelled scenarios. Along with a warmer climate and increased precipitation the model simulates reduced snowmelt leaching peaks, an increased crop growth and yield together with increased nutrient uptake. Considering the SWAT model set up and its physical approach, the trend shown in the decreasing leakage from agricultural land can be said to be reliable, if the predicted climate change will prove to come close to future reality.

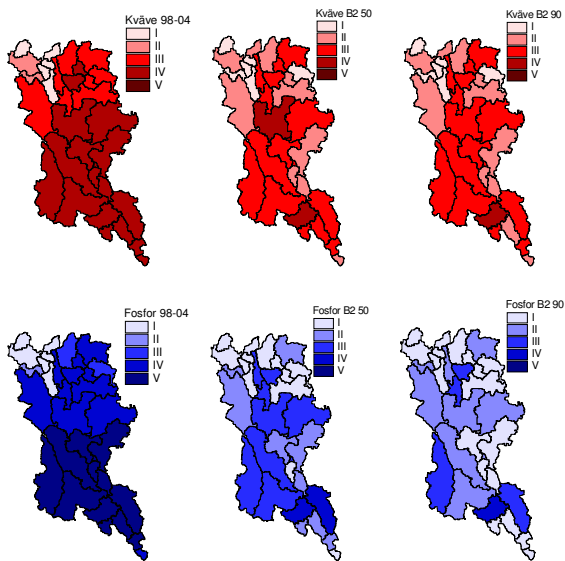


Figure 3.7-5 The figures above show the modelled area specific losses (kg / ha) for both Nitrogen (red) and Phosphorus (blue) for the Sagån river basin. The figures show from left to right: actual situation 1998-2004, IPCC B2 adapted scenario for the period 2050-2056 and IPCC B2 adapted scenario for 2090-2096.

3.8. WP8 – Economic Analyses

The objectives of this work package were to develop means for a thorough analysis of the economy of water use and cost recovery for water services, as well as institutional set-up for water services in the river basins, and to provide this analysis for the river basins. Furthermore, a baseline scenario, should be developed to identify gaps between this scenario and international, national or provincial goals, and the economic consequence of the gap. The feasibility and efficiency of different policy instruments that could be used to reach water availability, water quality or socioeconomic goals, or to bridge the gaps between goals and baseline scenario should also be assessed. Finally, an analysis of the economic effect of the modelled scenario changes from WP 7 should be provided.

In each of the five basins, a different approach to the economic analysis was taken, depending on what were considered to be the main pressures. The **Okavango** and the **Nura** are similar in that they both terminate in internationally important wetland sites. The analyses for these two basins therefore focused on the potential impacts on the wetlands presented e.g. by future land use changes, water extraction plans and climate change. Economic effects caused by hypothetical changes in hydrological regimes resulting from climate

change were also investigated for the **Biobío** river. In the **Norrström** basin where nutrient inputs from agricultural activities represent the biggest pressure on water quality, the economic analyses concentrated on calculating the benefits and costs for eutrophication mitigation.

3.8.1. Biobío

The general objective of this study is to design and apply a calculation methodology, which allows performing an economical assessment of the water quality standard implementation in the basin water for different hypothetical scenarios of weather changes. This assessment must be performed through the cost-benefit analysis. The specific objectives to obtain the general objective are:

- Characterize the economics of the basin related to the water quality.
- Design a calculation model which allows assessing the economic effect of different scenarios for future climate and the use of water resources in the Biobío basin, under the current legal framework (focused on the Secondary Standard).
- Test the methodology with a hypothetical change on the hydrological regime and available flows in the basin, evaluating the economic impact of the Water Quality Standard. Methodology must be developed in such a way that later it can be applied using the result of the hydrological modeling of the sub-basin of Río Vergara, and results of other sub-basins in the Biobío which can be modeled in the future (compatible with the hydrologic model).
- Describe the efficiency of different instruments of policy which adjust to the Río Bío Bío basin, and the economic effects of the development of climate and human change scenarios.

In this way, to do the economic analysis in the context of this study, the impacts of the implementation of the secondary water quality standard on the main economic activities of the Biobío basin were identified and evaluated in two scenarios: The first one, considering the current situation of concentration of quality parameters and their projection five years from now, considering also the level of current flows or historical averages and therefore, assuming there will be no important changes in climate that may alter these flow levels,

which corresponds to **no climate change situation**; and the second one, analyzing the current parameter concentrations and how these may be altered in the projection, assuming the presence of hypothetical climate changes affecting the flow levels significantly, thus evaluating the economic effects in the production activities of the basin; which corresponds to a **climate change situation**.

By relating the economic effects caused by hypothetical variations of changes in hydrological regimes in the Biobío basin, we can see the existence of important impacts. The social NPV (Net Present Value) indicator shows a negative and inverse ratio about increments in flow level, because as the flow increases the social NPV becomes more negative; and a positive and direct ratio about flow decreases, because the social NPV increases progressively as there are more decreases in the flow level. This leads to conclusions related to the regional incorporation of a better integrated management of this water resource on the regulatory drawings, because this would allow the implementation of policies and key actions leading to prevent negative economic impacts when there are negative climate scenarios.

Also, to achieve progress in the integrated management of water resources, it is fundamental to determine a clearer administration regarding the functions and responsibilities for institutions taking part in the administration of water resources, a more efficient and effective administration is required that is able to integrate all participants, without producing double functions nor controversy when taking decisions, when these decisions depend on several institutions, therefore it is relevant that strategic management is in charge of only one functional unit responsible for delegating the corresponding responsibilities to other entities, through a systemic approach with continuous feedback, expedite information flow both ways.

A policy about water resources must clearly propose protection and conservation of different river ecosystems in the country, to ensure maintenance of biodiversity of different ecosystems and resource quality. This requirement is a key objective to achieve maintenance of hydrological basins, as well as sustainability of nature and development, moreover if strong economical impacts of hypothetical climate changes in the Biobío basin have been discovered in this study.

3.8.2. Nura

This project provides an economic analysis of the water allocation problems specific to the River Nura and the decision making and allocation problems inherent in the Nura Basin and how they might differ from those of other basins. The Nura has very specific characteristics and problems which make the immediate transfer of policy recommendations inappropriate without careful analysis of the underlying structure.

Underlying all decisions and calculations there is a great importance of uncertainty. Usually, this is handled by the method of 'Certainty Equivalence' where an uncertain variable such as future river flow, or water required for maintenance of eco-systems are replaced by their expected value, and then Cost Benefit Analysis proceeds as usual. An example of this is the economic analysis that underlies the World Bank's Nura Mercury Clean-Up project. However, the expected value that arises from state variables representing economic and ecological variables, taken under the appropriate probability distribution, is not the same as the value when those state variables take their expected value but with certainty. The probability distribution that underlies the Nura Basin makes this divergence large. However to do this requires getting inside of the stochastic structure of decision making and evaluation, and so analysis is rather technical, and has a similar structure to that of modern stochastic financial economics. By doing this, it was possible to see how the Social Price of Water, underlying the European Union's Water Framework Directive, relates to the Precautionary Principle and the timing of decisions when little is known about either the ecology, or the future economics of the basin. The question of Sustainable Use of the River Basin, when the damage caused by water withdrawal policies happen some time in the future, is strongly influenced by uncertainty and variability. Thus, it can be seen how the variability of flow in different basins of different countries with different time preference generates different local and international valuations for environmental damages.

In summary it is clear that the Nura river's international terminal Wetlands, which are a key link in the Central Asian Flyway and contains many endangered species' despite its RAMSAR status, even with the best environmental economics available it is not possible to make an economic case for the wetlands that can compete with the

economic case for the development of Astana. It is therefore essential that strategic decisions on water allocation have to be made at the highest level if the wetlands are to have a future. The situation is made worse by the uncertainty associated with potential future ecotourist development

3.8.3. Okavango

Direct use values associated with the Okavango Delta Ramsar site include those generated by non-consumptive tourism, hunting tourism, household livestock production, household crop production, and household harvesting and processing of natural resource products. The values are overwhelmingly dominated by those generated by tourism, which takes place in the central zone, and which contributes P401 million annually to the GNP. Eighty percent of the tourism direct value is from non-consumptive activities. Ninety percent of tourism is attributable to the actual wetland. Agriculture contributes P42 million annually to the GNP. 93% of this is from livestock, and only 3% of it is derived from the wetland itself. Household harvesting and processing of natural resources contributes P29 million annually to GNP. Fifty three percent of this derived from the wetland.

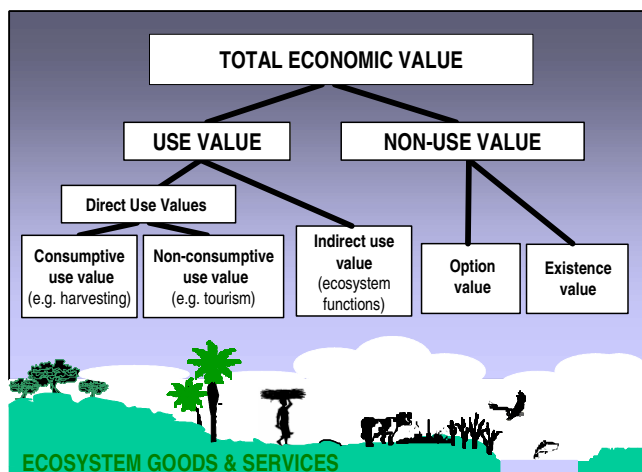


Figure 3.8-1 The classification of ecosystem values that make up total economic value of the Okavango Delta.

The Ramsar site contributes to livelihoods of its people through profits (both cash and in-kind) from agricultural and natural resource use, through wages and salaries in the tourism sector and from rentals and royalties in the tourism sector. Poor households in the study area benefit from profits amounting to P99 million, from wages and salaries amounting to P102 million, and from rentals and royalties amounting to an estimated P25 million. The wetland contributes less than 3% of profits, but

nearly all the wages and royalty benefits. Of the direct contribution made to the national GNP by the Ramsar site (P472 million per annum) 31% accrues to low income elements of society.

The likely effect of future land use options on direct use values were examined for three options. These involved the currently proposed land use plan, a second option with emphasis on the expansion of agricultural lands, and a third option with emphasis on protection of the natural assets of the delta. The currently proposed plan, which gives emphasis to complementary land use and wise use of the resources, emerged as the most economically efficient. The likely effects of external factors, involving water extraction plans and climate change predictions were tested in two further scenarios. These factors, particularly climate change, will reduce the size and value of the Ramsar site considerably. Attention should be given in planning to any possible ways of ameliorating these effects.

3.8.4. Norrström

Socio-economic data for the water districts Sagån and Svartån as well as for the municipalities Sala, Norberg and Västerås was collected to analyse the impact of household, industry and agricultural sectors impact on water quality. Further, information related to the "water" institutions activities in the Västmanland County in general and the 3 municipalities in particular were studied. Based on this information socio-economic analysis of implementing measures to achieve a sustainable management of the river basin was carried out. The study area was the Svartån and Sagån watersheds within the Norrström water basin where the agricultural sector is the larger emitter of nutrients leading to eutrophication of the lake Mälaren as well as the Stockholm archipelago. However, other sources of eutrophication such as households are briefly discussed. Further, water pricing and water scarcity issues are not included based on the fact that these issues have no high relevance in the area.

Cost benefit analysis has been conducted to shed light on the cost effective measures in order to diminish leaching of nutrients to water courses. Using the SWAT model, estimations of emissions are made for a baseline and other scenarios for a time span of 50 and 100 years including different measures such as construction of buffer zones and Salix production to analyse their costs effectiveness. To estimate the benefits of lower

eutrophication, results based on contingent valuation studies by means of benefit transfer were used to conduct a cost benefit analysis.

The results from different scenarios i.e., the A2 and B2 scenarios for the periods 2050_56 as well as 2090_96 show that the assumed management in the agricultural sector to comply with the regional goals is cost effective and ranges between 2 Euro/kg and 44 Euro/kg being the average costs to reduce emissions of N and P. However, the average annual costs for a farmer are considerable and range between 511 Euro in the A2 scenario for the coming 100 years and 2093 Euro in the B2 scenario for the coming 50 years. The variation in costs depends mainly on the level of replacement of other crops by Salix.

Table 3.8-1 Sagån and Svartån: Emissions reduction to watercourse relative to 1998-2004 (relative to baseline).

Sagån				
	A2 scenario		B2 scenario	
Scenario	P%	N%	P%	N%
2050-56 base	-46	-12	-46	-9
2050-56	-68 (-22)	-36 (-24)	-68 (-23)	-35 (-26)
2090-96 base	-57	-9	-61	-9
2090-96	-74 (-17)	-34 (-25)	-76 (-15)	-38 (-29)
Svartån				
	A2 scenario		B2 scenarion	
Scenario	P%	N%	P%	N%
2050-56 base	-43	-21	-48	-18
2050-56	-54 (-11)	-34 (-13)	-60 (-12)	-39 (-21)
2090-96 base	-59	-20	-59	-23
2090-96	-75 (-16)	-41 (-21)	-75 (-16)	-46 (-23)

When it comes to cost benefit analysis the general finding is that the discounted benefits for both the

coming 50 years and the coming 100 years are much higher than the discounted costs for the respective period. When considering the population of Sagån and Svartån for instance, the net present value for the A2 scenario and the coming 50 years is estimated to 119 Euro. There are, however, a number of uncertainties in this analysis. There are uncertainties related to the results in each scenario that are based on the assumptions included in the SWAT model. Other uncertainties are related to the estimation of benefits for the coming years. Yet, the implications of the assumptions in the A2 and B2 scenarios on the socio-economic issues would be marginal based on the fact that where the polluter sectors are relatively small e.g., Sweden, reduction of N emissions has marginal structural effects on other sectors.

3.8.5. Thames

A large number of activities contribute towards multiple pressures in the Thames basin, putting many water bodies in the basin at risk of not achieving the environmental objectives and good ecological status required by the WFD. The economic analyses for the Thames basin^{7,8}, provide an overview of the socio-economic importance and dynamics of water uses in the basin, and summarising work to identify driving forces and pressures and establish a baseline scenario including forecasts of population, households, output and employment.

Population and households in the basin are expected to grow at rates of 0.7% and 1% per annum, respectively. This growth has implications for public water supply abstractions and sewage discharges, and for floodplain development. The most important abstractors in the basin are water companies. Abstraction of water for public supply, industry and agriculture has a significant impact on the status of water bodies. Water companies are already the most significant abstractors in the basin.

⁷ Defra. 2005b. Summary report of the characterisation, impacts and economic analyses required by Article 5: Thames River Basin District. Crown copyright 2005. (<http://www.defra.gov.uk/environment/water/wfd/pdf/thamesext.pdf>)

⁸ Defra. 2005c. Article 5 economic analysis of water use supporting document: Thames River Basin District. Crown copyright 2005.

(<http://www.defra.gov.uk/environment/water/wfd/economics/pdf/thamesecon.pdf>)

Eight water companies operate in the Thames basin, servicing 5.5M households and 441,000 businesses. They supply 4325 ML of water per day at an annual cost of £817M (unit cost £0.63/m³), and take away 3171ML of sewage per day at an annual cost of £710M (unit cost £0.62/m³). The water companies pay licence fees to the Agency for the water they abstract to use and the discharges they make.

The electricity industry is the second largest abstractor and output in this sector is expected to grow. The transport sector, one source of diffuse pollution, makes up an important part of the basin's economy and is also expected to grow. However, in the agricultural sector, which is currently the most significant contributor of diffuse pollution in the basin, there is expected to be a slight slow down of agricultural intensification, in parallel with the growth of organic farming and reform of Common Agricultural Policy. An estimated £50M of water companies' annual costs are incurred dealing with diffuse pollution, and an estimated £122M are associated with mitigating their own environmental impacts. In total (£172M) this equates to an estimated 85% of their environmental damage costs. Cost recovery is achieved through revenue from water company customers.

In many cases, there is more than one measure or programme of measures which could be used to meet the good ecological status objective, and also more than one delivery mechanism for implementing it. A cost-effectiveness analysis will enable judgements to be made about the most cost-effective combination(s) of measures that could be implemented in order to assess whether programmes of measures are disproportionately expensive and to ensure that the least cost is incurred for maximum benefit.

Results of a cost effectiveness analysis, including environmental costs and benefits, and assessment of disproportionate costs, to be carried out as components of an ongoing collaborative research programme into integrating economics into river basin planning, will provide inputs to decision-making and public participation processes in the development of programmes of measures for water bodies at risk of not achieving good status in the Thames basin, and RBMPs.

3.9. WP9 River Basin Management Plans

The WFD aims to establish a holistic approach to managing the water environment, based on river basins, and integrating water quantity with quality considerations, the latter based on an ecological classification system. In addition to contributing to sustainable management and development of the water environment to ensure a better quality of life, now and in the future, greater integration should help to avoid unnecessary duplication of effort, ensure that there are no contradictions between the objectives and the priorities shown in the different plans, achieve greater transparency of objectives and priorities among stakeholders, whilst ensuring that individual statutory obligations can still be met, and maximise cost-effective approaches to meeting multiple objectives⁹.

River basin management plans (RBMPs), which set out specific objectives and the measures to achieve them, are the key planning documents to achieve this aim. The RBMPs must be in place by 2009 and must be reviewed and updated every 6 years after that. The RBMPs are informed by a programme of cost-effective actions or combinations of actions to achieve the WFD's environmental objectives by 2009, based on monitoring and analysis of the river basin's characteristics, and the identification for each water body of any discrepancy between its existing status and that required under the WFD. The programme of measures should consider:

- Proposals for modification of the current procedures for licensing abstractions and consenting discharges.
- Basic measures required to implement EU Directives to protect water bodies in the river basin district i.e. Bathing Water, Birds, Drinking Water, Major Accidents, Environmental Impact Assessment, Sewage Sludge, Urban Wastewater Treatment, Plant Protection Products, Nitrates, Habitats, Integrated Pollution Prevention and Control.
- Any pricing measures, or other economic/fiscal instruments, intended to

⁹ Department for Environment, Food and Rural Affairs (Defra). 2002. *Directing the flow: Priorities for future water policy*. Crown copyright 2002.

provide incentives to encourage more sustainable and efficient use of water.

- Supplementary measures if the above are not sufficient to meet WFD requirements e.g. abstraction and emission controls, negotiated environmental agreements, codes of good practice, demand management measures, efficiency and re-use measures, artificial recharge of aquifers, re-creation and restoration of wetlands, construction projects, desalination plants, rehabilitation projects, education projects, research projects.
- In exceptional cases, additional measures may be needed e.g. for international river basins.

These programmes of measures setting out the actions to be taken to secure WFD objectives must be in operation by 2012, and the environmental objectives achieved by 2015, by which time the RBMP for the next period will be in place. The reasons for taking a long-term view in this process are that the drivers for change are often of a long-term nature (e.g. climate change and land use), that there are many long-term impacts on the water environment (e.g. it takes many years to reverse pollution in groundwater and pollution from nutrients such as phosphates), that the substantial investment in the changes needed requires long time scales for both planning and execution, and that behavioural change is likely to take time to be fully achieved (e.g. by households to reduce water use, or by farmers to address diffuse pollution). Therefore, river basin management planning is necessarily an iterative process, with many of the activities repeated in the next cycle, though informed by the results of the last cycle.

The WFD basic management unit for river basin management is the river basin district. A river basin district may be a catchment or a group of catchments, and for international rivers, such as the Okavango basin in Southern Africa, the river basin district will transcend national boundaries. The RBMP developed for each river basin district will form the basis if achievement of water quality protection and improvement, and will include a programme of measures. However, although the primary aims of the WFD are environmental, RBMPs should also take economic and social needs into account, in line with the principles for sustainable development. To enable this, the involvement of all basin stakeholders is a key

requirement of the river basin management planning process.

3.9.1. Biobío

An important percent of Chilean GDP is generated by activities associates with the Biobío River Basin. Activities like hydropower generation, forestry, pulp mill, petrochemical industry, irrigated land, etc.

Since the nineties the Biobío river basin, especially its authorities and academic sector (e.g. DGA, EULA, CONAMA, CONAF and others) has worked at different levels and with different degrees of success in the integrated water resources management.

Currently the Government of Chile works on the development of the **National Strategy for Integrated Management of River Basins**, which is one of the pillars of the Environmental Policy of this government. One of the reasons why this issue is included in the presidential program is precisely the existence of the TWINBAS project and the awareness of its importance at professional and directive levels.

The National Strategy proposes an implementation process by steps starting with three minor Pilot River Basins, one in the Biobío Region, namely the Itata River Basin.

The different discussions with stakeholders show the important problems of the Biobío River Basin, these points are very important for the management of the basin in order to recommend the future actions.

RBMP in the form of reduced priority list of actions or combinations of actions, discussed with stakeholders. Include problem areas where no agreements can be reached or identified and list all compromises required:

- A) Requirement of more information of river basin
 - a) Include the season variation of some parameters like turbidity, suspended solids, conductivity and color.
 - b) Definition of actual and future scenery: in this context, it is necessary to define current scenery that includes the projects with an Environmental Qualification Resolution.
 - c) Include in the normative process other parameters with environmental regional

information, like: DQO, total nitrogen, total phosphorous, AOX, pentachlorophenol.

B) Considerate of Biological parameters in the monitoring programs.

Activities like pulp and paper have an impact on aquatic biota. This is an alert condition for the Biobío River Basin.

C) The normative process must include all sections of the river.

D) Technical and economical issues: Any action on the Biobío River Basin implicate social and economical impacts, for this reason it is very important to make social and economical studies to determinate the costs and benefits of different actions proposed; for the population that require water with quality, for the new industrials projects and for the State in relation to inspection and environmental monitoring.

E) The futures compromises are the following:

- a) The stakeholders will participate in water management decision
- b) Co-operation and co-ordination between various ministries and organisations

The most important future actions and agreement acceptable to all parties are:

- New industrial projects that require water from Biobío River Basin
- Implementation of the secondary norm of quality for the Biobío River.
- A better environmental monitoring on the Biobío River Basin.
- Territorial planning in the Biobío River Basin.
- Develop a management with compatibility between economical activities and environmental issues
- For any future action it is necessary that the state has a key role in the use, management and water resources development of the Biobío river
- Develop mechanisms for achieving financial sustainability in water management systems, for example subsidies and others incentives.
- Institutional reforms and better efficiency of regulatory authorities and to encourage the creation of river basin organisations.

Many different lessons can be achieved from the TWINBAS work; the main one being that it is of extreme importance to delimit the different Stakeholder Roles in the design and implementation of the RBMP.

By definition: It is the role of the State to make decisions, to implement them and to secure their enforcement.

By definition: Academic, and other studies to support decisions or to feed monitoring programs are infinite.

At this stage of the development of RBMPs in the Biobío River Basin, investment in awareness campaigns, education, stakeholder co-ordination initiatives, etc. are the most important actions towards improved water management.

3.9.2. Nura

There is not an effective mechanism of water resource management and planning in Kazakhstan that would ensure sustainable use of the Nations water resources. As a result it is not surprising that the institutional organisation of the river Nura would not be able to implement a sustainable River Basin Management plan if one were to be developed. In fact a report was produced in 2004 outlining a plan for the management of rivers water resources but unfortunately there is not an institutional structure or the resources available that could develop a plan and implement it. However, reform is rapidly taking place in all sectors in Kazakhstan and the water sector is no exception. The Government recently adopted a New Water code that is fully compliant with the EU Framework Directive. However, considerable institutional change and capacity building is needed before it can become a reality.

The key issues that need to be addressed if the water resources of the river Nura are to be sustainably managed are:

- Development and implementation of a legal and institutional framework to give River Basin Authorities the powers and responsibilities to develop, implement and monitor water basin management plans along the lines proposed in the full TWINBAS final report and extended in this report,

- Major reform in the public water sector capable of meeting the needs of effective river basin management
- Provision of an adequate funding mechanism that will allow the river Basin authorities to independently operate
- Provision of adequate staffing and training provided
- A strategy for a sustainable water resource management plan adopted
- A performance monitoring system in place

Many recognise the need for change but not surprisingly change takes time and resources.

In terms of monitoring the sustainability of the Kurgaldzhino wetlands, permanent well maintained gauging stations are needed on the Rivers Nura at Almas and the Kulan-Uptes, where they enter the wetlands, and permanent monthly level gauges need to be installed and monitored monthly throughout the wetlands. These will provide the data against which the effectiveness of water management can be assessed.

The project there opted not to dwell on the development of another management plan but to look at institutional issues. The project produced a Memorandum for the Government of RK outlining a possible way forward.

3.9.3. Okavango

The existing diverse and complex nature of the Okavango Delta in terms of its natural resources; its wide range of users and uses; its multiple managers (both in and outside government and including communities); and an array of national laws, policies and guidelines as well as regional and international conventions, agreements and protocols are all factors that dictate the need and determine the context for an integrated management planning process for the Okavango Delta. The main threats to the biodiversity and unique ecological function of the Delta relating to hydrology addressed under Twinbas are water resources developments in the basin upstream, water resources developments within the delta, and potential climate change over the basin including the delta.

The ODMP planning process started in 2003 and borrowed from the Ramsar Planning Guidelines and the Ecosystem Approach to wetlands management. The ODMP is anchored on the main principle of strengthening ownership through accountability and the active participation of all stakeholders both during development and implementation of the plan. The ownership of the ODMP process is premised on participatory mechanisms, association with international stakeholders, building partnerships at all levels

Overall Goal of the Okavango Delta Management Plan:		
to integrate resource management for the Okavango Delta that will ensure its long-term conservation and that will provide benefits for the present and future well being of the people, through sustainable use of its natural resources"		
Thematic Areas	Strategic Goals	Strategic Objectives
Institutional	To establish viable management infrastructure and tools to sustainably manage the delta resources at local, district, national and international (River Basin) levels.	To establish viable management institutions for sustainable management of the Okavango Delta ecosystem
		To improve the regulatory framework for sustainable management of the Okavango Delta ecosystem.
		To raise public awareness, enhance knowledge and create a platform for information exchange and learning about the Okavango Delta ecosystem.
Physical	To ensure that the Okavango Delta (and its associated dry lands) continues to deliver present-day ecosystem services and products for the benefit of all organisms dependant on it.	To maintain and conserve the biotic and abiotic status of the Okavango Delta as well as their interaction
		To maintain and restore the Okavango Delta wetland habitats and ecosystem
Socio-Economic	To sustainably use the delta resources for improvement of livelihoods of all stakeholders that are directly and indirectly dependent on the ecosystem products and services of the Okavango Delta (and associated dry lands) in an equitable way	To sustainably use the Okavango Delta wetland resources for the long term benefit of stakeholders dependant on it
		To improve livelihoods of the Delta stakeholders through improved socio-economic opportunities

The preparation of the ODMP has been organised in 10 components with the various relevant line-ministries responsible for implementation. The Twinbas project has primarily contributed to two components, providing information and support for monitoring under the Research and Data Management component, and developing the main features of the Hydrology and Water Resources Component in close cooperation with Department of Water Affairs as the implementing agency. The implementation of the ODMP has started in 2007. A Monitoring and Evaluation (M&E) plan has been developed to track the implementation of the ODMP.

The ODMP Integrated Hydrologic Model has been developed and implemented in a Hydrological Modelling Unit within Department of Water Affairs in their Headquarters in Gabarone. Staff at the unit has been trained to be able to maintain the modelling system and use it during the further implementation of the ODMP. Copies of the modelling system have been set-up at the DWA Office in Maun for their use in collaboration with the local ODMP Secretariat in Maun during the implementation of the ODMP.

In the Okavango River Basin, TWINBAS has highlighted the need for an integrated approach to water planning and management. The delta cannot be considered in isolation as many of the pressures on it are likely to come from developments in the upper basin in Angola, as described under WP5, where there is a lack of firm data and information. Emphasis must be on international cooperation in the management of the whole basin, from the upper basin in Angola to the terminal delta in Botswana.

3.9.4. Norrström

The most important water quality problem in the Norrström river basin is by far the eutrophication of Lake Mälaren, to which the tributaries in the basin transport nutrients. The contribution of point sources and rural households is fairly easily assessed and, therefore, the development tasks within the project have been concentrated on improving the dynamic modelling of nutrient leaching from agriculture and identifying a cost-effective programme of measures leading to a reduction of nitrogen and phosphorus from agriculture.

The environmental regional goals for the Norrström River Basin require an emission reduction of 30% for nitrogen and 20% for phosphorus, relative to the levels of 1995, by the year 2010.

The study area was for budget reasons limited to a sub-basin in the Sagån tributary; Frögärdesbäcken and parts of Lillån, but can be generalised to large parts of the Norrström basin.

The cost-effectiveness is presented as the costs per ha for each measure, divided by the effect, that is kg reduced P or N. In **Error! Reference source not found.** the cost-efficiency results are presented.

The actions recommended in this list have been presented to the DWA (District Water authority) and the County Board. These stakeholders have stated that the results are valuable and will be used in the process of identifying a programme of measures for the water district, due in 2008 following the EU WFD.

An actor that will undoubtedly play a major role in the practical implementation of actions in Sagån-Svartån, most likely also with a financial responsibility, is Västerås City, who now integrates the TWINBAS results in its planning process. The way forward currently discussed would be to launch a follow-up project where technical solutions and costs are analysed in detail for wetland installations and agricultural management practice measures, in collaboration with the farmers in the area. When such a detailed inventory of technical solutions (concerns wetlands), costs and locations is in place, farmers and other stakeholders will be able to take a position regarding these plans. Their general attitude towards these actions is however currently positive, since detailed data provided by them have been used in the modelling as well as in the selection of measures.

It is clear though, that the governmental (EU) funding currently available for environmental measures in the agricultural landscape (e.g for wetlands, buffer zones, pasture) does not cover costs to 100% and therefore needs to be strengthened, as well as widened to include the management practice measures that are currently not supported but are clearly cost-effective in this region. The farmers are currently under considerable economic stress and many of them will not survive forced measure implementation if it is not fully financed, and they state that they will not be able to bear any further cost on a voluntarily basis.

Table 3.9-1 Measures and cost-efficiency results for the measures modelled in the Lillå report (ranking does not take into account administrative costs & subsidies.)

Measure	Euro per ha per year	Effectiveness Kg N or P / ha	Euro per kg reduced N	Euro per kg reduced P	Rank	Admin. costs & subsidies
Wetlands	500	256-277 kg N 29-32 kg P	1.85	15-17	1	0.5-1(P)
Riparian buffer zones	42-63	1.7 kg N (40 %) 0.5 kg P (73 %)	25-37	84-126	2	110 (P)
Catch crops	38	0.9 kg N 0 kg P	42		3	6.3 (N)
No Autumn preparation		0.8 kg N 0.01 kg P	50	400	4	8.4 (N)
Energy crops – Salix	333	3.4 kg N 0.61 kg P	97	528	5	100 (P)
Reduction of use of fertilisers		No change in short term			6	

3.9.5. Thames

In the Thames River Basin, the three priority basin-wide concerns, in light of the pressures on water bodies identified in WP8, relate to the future water resource supply, particularly during drought events, to flood risk (Figure 3.9-1) and to water quality. Proposed actions to address these issues now and in the future are presented in the Environment Agency’s Five-Year Plan¹⁰.

Use of the water resources of the Thames basin must take the needs of both people and the environment into account. Currently, in Summer, surface water throughout the basin is fully utilised by existing abstractions and environmental needs. Limited groundwater resources are available from the basin’s aquifers, but many are at or approaching full utilisation. This situation will become more challenging in the future with pressures from more people, houses and businesses in the basin, combined with more frequent and severe drought events predicted as an impact of climate change.

¹⁰ EA. 2006. Improving the environment where you live - Creating a better Thames: Our five year plan 2006-2011. Environment Agency, Bristol, UK. (http://www.environment-agency.gov.uk/commodata/acrobat/localcontributions_1362000.pdf)

For water resource supply, the Plan requires the Agency to continue to work closely with the public to use water more efficiently, and with water companies to meet the water demand needs of both people and the environment, control leakage and develop new resources as necessary.

In the Thames basin, development on floodplains to satisfy the demand for suitable land for homes, offices and businesses has put many people, properties and services at risk from flooding. There are estimated to already be over 180 km of flood defence embankments along the course of the Thames. Flood defence functions in the basin account for nearly half of Environment Agency expenditure and staff, making it a priority issue now and in the future when a predicted impact of climate change is more frequent and severe floods. For flood risk, the Plan requires the Agency to work closely with planners and developers to ensure that inappropriate development in the floodplain stops, and that it can be used as a storage area for flood waters as is its natural purpose. The Environment Agency must also continue to improve its own systems for flood warning, and to maintain existing, and construct new, flood defences.



Figure 3.9-1 Thames in flood at Wallingford in January 2003 (photo: RAF Benson)

Good water quality is essential for both people and the environment. Water quality issues in the Thames basin fall into two main areas: waste water treatment and agriculture. The water quality of rivers in the Thames basin has improved steadily over the last 40 years, and is generally good, but it is now under pressure from the growing population with its waste disposal needs, land use particularly agricultural land use, and climate change. Diffuse pollution caused by the runoff from farmland of chemicals into rivers and groundwater is of particular concern. The WFD provides an integrated approach to maintaining and improving water quality across the Thames basin in the future. For water quality, the Plan requires the Environment Agency to work closely with water companies, developers and farmers to reduce point and diffuse pollution problems from urban and rural runoff and waste water throughout the basin.

The periodic reassessment carried out by the Environment Agency in preparation of its 5-year Plan will inform the WFD river basin planning process in the Thames basin. The latest series of consultations will create a wider awareness of the challenges facing the water environment and the ways in which they can be tackled, and will culminate in the production of a first RBMP for the Thames basin in 2009.

The advanced state of river basin management and the abundance of management plans in the Thames basin, has enabled it to demonstrate and contribute examples of good practice to the other TWINBAS basins in order to encourage improved management approaches.

4. Conclusions

In spite of diverse existing structures for water management in the twinned river basins, all partners found the European Water Framework Directive a good framework for development of methods and tools for implementation of integrated water resources management.

TWINBAS has through collaboration with the major public stakeholders in each basin and each partner country significantly contributed to the transfer of research results and methods to major stakeholder institutions in the countries of the twinned river basins.

Advances in research and knowledge have been achieved in several fields, such as improved hydrological modelling and pollution pressure modelling, a system for categorisation typology for third countries water bodies with implementation methodology, methods for and results on impact of climate and societal change on water flow and pollution, as well as improved knowledge on the economics of water use and action cost-effectiveness. Throughout the project and with raised intensity in the second half, stakeholders from grassroots to national authorities have been involved in the project work, in discussions on research methods, results and abatement measures.

Twinning has significantly raised the competence level of the third country partners, as well as that of stakeholders and end-user water authorities in all countries. In some areas, the European partners have benefited from ambitious development work carried out by third country partners. Language difficulties and the efforts needed for translation and basic technological support have required more resources than anticipated, but the general conclusion of the consortium is that the advances clearly outweigh these difficulties.

The analyses of current status and stakeholder views in Work Package 1 underlined the significant variability among the five river basins in terms of water quality and availability problems. In short, the main problems were:

- Okavango river - vulnerability of the delta to change in the hydrological regime.
- River Nura - Mercury pollution in parts of the river valley and vulnerability of the terminal wetlands to planned water abstraction.

- Biobío river - industrial pollution and diffuse sources, hydropower operation schemes and irrigation stakeholder conflicts.
- Norrström basin - eutrophication mainly due to agricultural nutrient leaching.
- Thames river - water abstraction and water overuse, pollution.

In terms of data availability the twinned river basins differ widely. The most extensive monitoring efforts are required for the Okavango basin and the Nura. Some complementary monitoring efforts have been carried out in TWINBAS, although the project could not cover e.g. the gaps in hydrological data for the upper Okavango and large parts of the Nura. Monitoring included setting up hydrological gauging stations in the Okavango delta, sediment transport measurements in the entrance to the delta, Mercury measurements and bathymetric measurements in the Nura, and nutrient and metal measurements in Norrström.

Public participation

In general, the experience from the public participation process is very positive and TWINBAS has, by close collaboration with the major public stakeholders in each basin and each partner country, significantly contributed to the transfer of research results and methods to major stakeholder institutions in the countries of the twinned river basins.

It is much more viable to approach integrated water management through an initial concrete proposal regarding water use or quality, than to start setting up an administrative framework, different to the existing power structure. Pilot experiences of integrated river basin management are more likely to succeed in smaller basins with less strategic importance. In the case of Chile the sustained, ongoing effort conducted by various governmental and academic institutions, including an ambitious public participation process to which TWINBAS contributed, has resulted in a Policy for Integrated River Basin Management.

One of the key issues that was widely recognised within work in the Nura was the need for structural re-organisation within the public water sector. More effort might be made by Kazakhstan to ensure that other methods are adopted to ensure stakeholder participation than concentrating so much on establishing RBCs. The directors of

management authorities need to be more accountable to the stakeholders. This will encourage transparency, and therefore accountability, and lead to an increase in the quality of the governance. By seeking to improve governance, the standing and value of the RBC can only increase.

There is at present a lack of dependable information tools and communication mechanisms for the management planning process in the Okavango delta. The provision of government services to the communities of the delta is inadequate due to lack of communication, no action taken on previous raised issues, lack of feed-back from government departments, and consequently little or no influence on decisions from the local communities. There is a need for monitoring and targeted research, with data and results readily available to all stakeholders.

Involvement of farmers and the Federation of Swedish farmers in the Norrström contributed significantly to better modelling results. These findings are highly relevant to the continued work with farmer involvement in the efforts to reduce eutrophication of Swedish lakes as well as the Baltic Sea. The improved knowledge on pollution pressure and abatement actions has been taken up by County Boards and the District Water Authorities, and will strengthen the basis for the programme of measures to be identified in Norrström, as well as in other basins.

An investigation of the stakeholder participation activities practised in the Pang and Lambourn catchments of the Thames basin revealed that six of the ten techniques promoted by the Environment Agency had been implemented in some form. The perceptions of the project and its success varied between the different stakeholder groups depending on their priorities. Furthermore, it was felt that earlier stakeholder involvement may have improved the relevance and integration of some of the science emphasising that stakeholders should be actively involved from project inception, though the level of participation will depend very much on the time and budgetary resources available.

Hydrological modelling and water abstraction

The application of the integrated hydrology model Mike SHE for the Okavango delta has significantly improved the understanding of the water cycle of the delta and provided advances in possibility to realistically predict changes in the delta hydrology caused by upstream changes or climate change. The

possibility to cross-validate the GVAWA and Pitman models results improved the understanding of the upstream hydrology, but the breakdown of the gauging station from the 1970s and onwards have put limitations to the validation of the models. Therefore the hydrological input to the delta, and thus also the hydrological cycle in the delta, is still associated with considerable uncertainties.

The water balance modelling for the terminal wetlands and lakes of the Nura river has given a first scientifically based identification of ecologically sustainable input flow for the wetlands. The modelling is based on bathymetric data collected in the project and potential evapotranspiration calculated from monthly climate data and vegetation factors from lysimeter studies. The identified level clearly shows that the planned abstraction of water to the capital Astana will dry out large parts of the unique RAMSAR wetlands. A sensible heat balance approach to estimate ET from satellite data was modified and used to determine ET from the terminal wetlands of the Nura.

The SWAT hydrological modelling implemented in the Biobío resulted in a good general model performance and thus could be used in WP 7 for climate change impact assessment on monthly flow rates. In Norrström accuracy was good for daily values, allowed improved nutrient leaching assessment SWAT constitutes a useful tool for hydrological analyses and scenario impact assessment, providing physically-based and semi-fully distributed model results. Due to the high number of parameters and the model complexity, calibration of the model is however a time-consuming task which requires expert knowledge.

Those bearing the responsibility for managing river basins as a whole, or in part, need to be aware of the realistic potential of models, and their demands on good quality data and human resources. While not offering any hard and fast conclusions on model types and proprietary modelling systems, TWINBAS will, by describing and discussing the application of a range of hydrologic and water resources models to very different natural and institutional environments, be of value to river basin managers.

Pollution pressure and impact

Different approaches have been applied in the basins for assessment of pressure and impact based on local availability of data. In the Biobío a general theoretical assessment of the potential and current deviation from reference conditions was made by

combining results from an inventory of main pressure types with a water body classification obtained from WP6. Sediment transport risk mapping conducted now allows for a spatial prioritisation of future actions. For the first time in Biobío ecological impact of current hydropower operation schemes have been demonstrated through application of a fish habitat model

Most of the river Nura can be classed as moderately polluted except for the section between the main effluent canal at Temirtau and Rostovka which is heavily polluted by mercury from former industrial activities. Increased Mercury concentrations above safe levels were found in river fish up to 200 km downstream of the source of the pollution. Risk assessment results confirmed that the consumption of contaminated fish from the river is the most important exposure pathway for the local population, and dose-response-modelling indicated a strong link between the Mercury body burden in the riverine population and fish intake.

Pollution pressure is marginal in the still pristine Okavango system and is considered to remain so for the foreseeable future with little development in the basin. However, the potential impact on the sediment inflow to the delta from possible hydropower developments have been assessed. The simulated impact of potential hydropower developments in the upstream river basin shows that bed level changes will take place from the upstream Panhandle with substantial erosion. After around 100 years, the changes will have an impact on the bed levels near the apex of the delta. Clearance of channel blockages results in a temporary increase in sediment transport with accelerated deposition downstream of the cleared reach. This will ultimately lead to a reduction in flow, and vegetation encroaching once again.

Pressure modelling capacity developed for Norrström, makes it possible to get more detailed information on eutrophication dynamics. The modelling results have a high accuracy for phosphorus when compared to measurement data, and good although somewhat lower accuracy for nitrogen. A conclusion of the model application is that further development requires denser soil characteristics data and flow-proportional nutrient measurements. The results of SWAT modelling significantly improved with additional detailed information from farmers. SWAT is suitable for areas where agricultural leakage is of specific importance, while simpler and more generalistic modelling tools can be used elsewhere in a basin.

Classification of water bodies

The water body classification and categorisation effort in the TWINBAS basins represents a preliminary risk assessment. The results will steer further characterisation, including the development of a targeted and efficient monitoring system, and as a starting point for the development of measures ensuring a cost-effective approach to water protection. The categorisation process earlier implemented in the Thames river basin was used as a guide in several of the basins.

In the Biobío River Basin, a theoretical framework guided by the EC WFD was established for defining a typology for the river water bodies based on reference conditions, as a basis for ecological status classification. These results can be used to review the secondary quality standards for Biobío in the future.

For Norrström, on request of the District Water Authority, neither a classification of ecological water status nor a risk categorisation for the Norrström River Basin was made in the TWINBAS project. This was to avoid confusion with the ongoing water authority work.

The water bodies in the Nura River Basin have, for the first time, been classified according to the ecological status as stipulated by the WFD, using the maps supporting the summary report of the characterisation, impacts and economics analyses required by Article 5 Thames River Basin district as a blueprint. Adoption of the water body classification requirements of the WFD in the Nura River Basin has been a pioneering exercise that will inform future river basin management plans.

In the Okavango, classification work was focussed on the delta wetland due to lack of data and problems with accessibility of upstream areas. Wetlands are a category not explicitly included in the WFD natural surface water body classification, and so the approach of the WFD was not adopted. Therefore an ecosystem approach to wetland management has been used, classifying the delta according to hydrological characteristics mainly associated with seasonal flooding frequencies.

Change effects and vulnerability

Forcing behind changes in a rivers water resources are both climatic and anthropogenic in nature. The work package looked at the potential changes that might occur in all the basins in 50 and 100 years time.

There were wide variations between the catchments. In the case of the Norrström, in 50 and 100 years time it was shown that there is expected to be an increase of precipitation and temperature and significant changes in agricultural land use. Substantial reductions in nutrient leaching from arable land in Norrström can be anticipated as an effect of climate change and management practices adapting to climate change. The work showed that river Nura is expected to see no climatic driven change in its water resources but will have a very rapid rise in population due to inward migration to the new capital city, the result of which could have catastrophic effects on the water resources available to the internationally important terminal wetlands. For the Biobío, analysis of hydrological impacts of future precipitation scenarios derived from seven different GCMs for six SRES marker scenarios all indicated reduced river discharges for the future. This further accentuates the urgent need for a more integrated approach towards water resources management, as reduced river discharges can further increment the impact of planned development options for the basin. Modelled climate change and societal development for the Okavango basin results in significantly decreased permanently inundated area. The combination of upstream water resources developments and climate change produces the most adverse scenario in terms of a reduced inflow and spread of water and sediment in the delta.

Economic analyses

Economic values associated with the Okavango Delta include consumptive and non-consumptive uses. The values are dominated by non-consumptive uses for tourism and consumptive uses e.g. harvesting of natural resources, contributing about 2% to the GNP of which 31 accrues to low income elements of society.

Significant impacts have been identified for hypothetical changes in hydrological regimes in the Biobío basin,. However the methodology developed for this purpose should be further extended using process-based tools.

Kurgaldzhino, the terminal wetlands of the Nura, are very sensitive to disturbances in flow. With the uncertainties existing in terms of future effects of reduced flow, the Precautionary Principle should be used, i.e. nothing should be done to take water out of the river before more information is available. This conclusion however depends on cost and benefit parameters that are used for the basin, e.g. if only local values are counted, or if international

values associated with the RAMSAR classification are considered. The calculation of the international social price enabled a calculation of the economic cost of ecological catastrophe for the wetland system of 0.5 euros per m³ (2000 prices) When this was added to the operating cost, the conclusion of a World Bank Study that 90% of projected Astana water demand could possibly be met from diverting water from the River Nura with a cost of \$0.07/m³ compared to the cheapest alternative of \$ 0.17/m³, would be reversed if environmental costs are included in both prices.

The results from different scenarios applied to Svartån and Sagån in Norrström, i.e. the IPCC A2 and B2 scenarios for the periods 2050-56 as well as 2090-96, show that the assumed management in the agricultural sector to comply with the regional goals is cost effective and ranges between 2 and 44 Euro per kg being the average costs to reduce emissions of N and P. However, the average annual costs for a farmer may be considerable. These costs range between 511 Euro in the A2 scenario for the coming 100 years and 2093 Euro in the B2 scenario for the coming 50 years. The variation in costs depends mainly on the level of replacement of other crops by Salix. The cost benefit analysis shows that the discounted benefits for both the coming 50 years and the coming 100 years are higher than the discounted costs for the respective period.

River basin management plans

Rather than providing examples of RBMPs as was initially planned, this work package was revised in collaboration with major stakeholders to cover the identification and assessment of possible and prioritised actions to achieve environmental objectives, as an input to future official RBMPs. Hence, the work reported here is a first step in the river basin management planning process, and would in practice be re-evaluated as information is continually improved and identified gaps in the knowledge base are filled, ultimately leading to a more integrated approach to future water management. The advanced state of river basin management and the abundance of management plans in the Thames basin, has enabled it to demonstrate and contribute examples of good practice to the other TWINBAS basins in order to encourage improved management approaches.

Future actions in the Biobío basin, agreed by and acceptable to major stakeholders include: improved territorial planning; better compatibility between the economic activities and environmental issues of

concern in the basin; improved environmental monitoring on the Biobío river and its tributaries; fully implemented water quality standards; the development of mechanisms to achieve financial sustainability in water resource management systems, through subsidies and other incentives; institutional reforms including more effective regulatory authorities; and the creation of river basin organisations.

Farmers in the Norrström river basin generally accept the need for further actions to reduce diffuse pollution. They require detailed information on cost-effectiveness of measures on a level that could not be produced in TWINBAS, to be able to take a position on whether to go ahead with implementation for their property, supported by Government incentives. However, the modelling approach, including detailed information from farmers on soil conditions and current management practices, has proved to be a feasible way to initiate collaboration with the farmers regarding action implementation. The approach needs to be scaled up from the study area to the basin or region.

The institutional structure for sustainable water resource planning in Kazakhstan is lacking. Although there is clear awareness of the need for change within the sector, institutional inertia and vested interests limit the potential for implementing a sustainable river basin management plan. Therefore, the first step in the development and implementation of a sustainable water resource management plan for the Nura basin has to be institutional and legal reform in this sector. What is needed, at this stage is a set of targets against which the development of water resource management action plans can be assessed, together with improved monitoring against which the effectiveness and success of those plans can be measured.

The Okavango Delta Management Plan (ODMP) has borrowed from the Ramsar Planning Guidelines and the Ecosystem Approach to wetlands management. The ownership of the ODMP process is premised on participatory mechanisms, associated with international stakeholders and building partnership basin-wide. The ODMP planning process has proven to incorporate the main elements and concepts in the WFD RBMP process. However, the delta cannot be considered in isolation as many of the pressures on it are likely to come from developments in the upper basin in Angola, where there are a lack of firm data and information. TWINBAS has highlighted the need

for an integrated approach to water planning and management: emphasis must be on international cooperation in the management of the whole basin, from the upper basin in Angola to the terminal delta in Botswana.