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Contribution to OECD Country Programme for Kazakhstan - Activity 1: Strengthening the Role of Multi-Purpose Water Infrastructure

INTERIM REPORT, DRAFT FINAL

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ACKNOWLEDGMENTS AND DISCLAIMER

The current project is part of the activity on “Economic Aspects of Water Resource Management in EECCA Countries: Support to the Implementation of the Water Resources Management Programme in Kazakhstan”, which is implemented in 2015-16 under the Kazakhstan and OECD cooperation agreement and the OECD Country Programme for Kazakhstan developed and approved in March 2015.

This Interim Report has been prepared to inform and facilitate the National Policy Dialogue (NPD) on Water Policy in Kazakhstan conducted in cooperation with the European Union Water Initiative (EUWI) and facilitated by the OECD EAP Task Force and UNECE.

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The authors of this report are Dr. Jesper Karup Pedersen and Mr. Mikkel A. Kromann (both COWI) with inputs from Ms. Assel Kenzheakhmetova and Dr. Anatoliy Ryabtsev (both local experts) and also Dr Aditya Sood (IWMI). Mr. Michael Jacobsen (COWI) has provided quality assurance.

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However, the analysis, statements and any eventual errors and material omissions are solely the responsibility of the authors.

The views presented in this report are those of the authors and can in no way be taken to reflect the official opinion of the Government of Kazakhstan, the European Union (EU), the Government of Norway, the OECD or of the governments of the EU and OECD member countries.
## ABBREVIATIONS AND TERMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Akimat</em></td>
<td>District, municipality or region (province) administration</td>
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<tr>
<td>CAPEX</td>
<td>Capital expenditure</td>
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<tr>
<td>CWR</td>
<td>Committee on Water Resources</td>
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<tr>
<td>EAP</td>
<td>Environmental Action Programme</td>
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<tr>
<td>EECCA</td>
<td>Eastern Europe, Caucasus and Central Asia</td>
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<td>EUWI</td>
<td>European Union Water Initiative</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GWP</td>
<td>Global Water Partnership</td>
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<tr>
<td>HES</td>
<td>Hydro-Electric Station</td>
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<td>ICOLD</td>
<td>International Commission on Large Dams</td>
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<td>IMCC</td>
<td>Inter-Ministerial Coordination Council</td>
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<td>IPR</td>
<td>Intellectual property right</td>
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<tr>
<td>IWMI</td>
<td>International Water Management Institute</td>
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<tr>
<td><em>Kazvodhoz</em></td>
<td>State enterprise “Kazakh Water Management”</td>
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<tr>
<td>MPWI</td>
<td>Multi-Purpose Water Infrastructure</td>
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<tr>
<td>m³/s</td>
<td>Cubic metres per second</td>
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<tr>
<td>NPD</td>
<td>National Policy Dialogue</td>
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<td>OECD</td>
<td>Organization for Economic Development and Cooperation</td>
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<td>OPEX</td>
<td>Operational expenditure</td>
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<tr>
<td>Rayon</td>
<td>Administrative unit of a region; also referred to as &quot;district&quot;</td>
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<td>WSI</td>
<td>Water security index</td>
</tr>
<tr>
<td>WSS</td>
<td>Water supply and sanitation</td>
</tr>
</tbody>
</table>
# CONTENTS

1 Introduction  1

2 Methodology  5
2.1 MPWI  5
2.2 Typical services  5
2.3 Methodology, Component 1  6

3 Shardara MPWI  11
3.1 Pilot area  11
3.2 Schematic  16

4 Model Runs, Preliminary Findings  20
4.1 Two modules  20
4.2 Remaining data  26

5 Identified Actions  28

6 International Experience  31
6.1 Selection criteria  31
6.2 Candidate case studies  32
6.3 Template  35

7 Next Steps  37
7.1 Data  37
7.2 List of indicators  37
7.3 Expert Workshop  37
7.4 Component 3  38
Annex A  References
Annex B  Institutions Visited and Persons Met
Annex C  Mission, April 2016
Annex D  Data
Annex E  Model Design
Annex F  Case Studies, Example
1 Introduction

Purpose

The current Interim Report (or Assessment Report) has been prepared within the framework of the project “Strengthening the role of multi-purpose water infrastructure in ensuring the water, food and energy and ecosystems security, as well as in shifting to the inclusive green economy and sustainable development of Kazakhstan” (also referred to as “Strengthening the role of Multi-Purpose Water Infrastructure”), launched by the OECD with financial support from the Government of Kazakhstan, European Union and OECD EAP Task Force. The project was entrusted COWI A/S (henceforth COWI) in late Q1 2016. The purpose of the current report is to present key results till date, thereby providing information about progress made and status of the project. Furthermore, the report informs about next steps to be taken till project finalization. It has been prepared by COWI with input from International Water Management Institute (IWMI). The focus is on Components 1 and 2 of the project; most attention is paid to Component 1.

Long procurement procedure

Due to a long procurement procedure the project started almost five months later than planned. However, as of today, the project is only one month behind the original time schedule. It is expected that the project will be carried out in accordance with original time schedule from late August 2016.

Activities till date

Although the procurement procedure had not been completed by then, the Consultant participated in the NPD Working Group meeting in December 2015. In the following months the field work was launched, so that the Project team held a mission to the pilot area and launched data collection as soon as the pilot area was identified and the contract was properly signed. The Shardara reservoir and accompanying multi-purpose water infrastructure (Shardara MPWI) was identified as the pilot area by the Committee on Water Resources (CWR) in Q1 2016, approximately a month before the procurement procedure was finalized.

A mission to Astana, Shymkent and Shardara was held in April 2016. Subsequently, data collection was carried out, possible actions and development scenarios addressing the Shardara MPWI development needs identified, schematic developed, model design made, model implementation (or model runs) carried out to assess the economic impact of the Shardara MPWI, and relevant international experience identified. These activities have been carried out during April-May 2016 and continued in June. It is estimated that as much as 90% of all data needed for implementing the project have been successfully collected by now.
Box 1-1 Project at a glance

In January 2015, the OECD and Kazakhstan signed a cooperation agreement under which the OECD Country Programme for Kazakhstan was developed and approved in March 2015. It includes an activity on “Economic Aspects of Water Resource Management in EECCA Countries: Support to the Implementation of the Water Resources Management Programme” which will be implemented in 2015-16. The present project is part (Activity 1) of this action.

It is implemented through the NPD on water policy in Kazakhstan in cooperation with the CWR and the Chair of the NPD Inter-Ministerial Coordination Council (IMCC). Main beneficiaries of the project are the Ministry of Agriculture, CWR and Kazvodhoz, which is the state enterprise responsible for water management in Kazakhstan and refers to CWR; CWR is subordinated to the Ministry of Agriculture. However, other government bodies in Kazakhstan (at all levels), as well as the various IFIs and donors active in Kazakhstan, may benefit from the project.

Focus of the project is on Multi-Purpose Water Infrastructure (MPWI).

One key objective is "to help Kazakhstan stakeholders to identify options for increasing economic and financial returns from a selected MPWI thus reducing demand for extending water infrastructure, including the associated amount of capital investment and state support". Insofar as such options (or improvements of existing systems and water infrastructure) may affect food and energy security and also ecosystem services and flood and draught management, another key objective is to "show how to maximise the contribution from a MPWI to greater levels of water, food and energy security", so that lessons learnt from the pilot case may be "replicated and implemented to other existing or planned MPWI projects in Kazakhstan".

The project consists of four components: Component 0: Inception; Component 1: Assessment; Component 2: International experience; and Component 3: Conclusions and recommendations. It will be completed by the end of 2016.

Source: Project’s Terms of Reference.

Key results In brief, key results till date are the following within Components 1 and 2:

› Component 1

› Pilot area identified;

› Draft final schematics developed;

› Relevant infrastructure identified;

› Virtually all data collected;

› Model design developed;

› Model run carried out;
Draft final list of actions to increase contribution of the MPWI to economic development and water, food and energy security developed.

Component 2

Draft final list of criteria for selection of case studies to illustrate relevant international experience outlined;

Draft final list of case studies prepared;

Draft final template for reporting of case studies developed.

Consultations and assistance

In order to finalize the abovementioned draft final results, the Consultant needs to consult with representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC. Furthermore, the Consultant needs assistance from the main beneficiaries in collecting remaining data and prepare for an assessment of the economic impacts of implementing the actions agreed upon.

Throughout the report requests for such consultations and assistance are highlighted by red colour. With regard to consultations a deadline is provided.

Organisation

The report consists of six chapters in addition to the current one:

Chapter 2 provides a definition of MPWI, highlights the typical services a MPWI provides and presents the methodology applied when implementing Component 1 (methodology applied with regard to Component 2 follows from Chapter 6);

Chapter 3 presents the pilot area identified, including existing infrastructure, and presents the draft final schematic;

Chapter 4 presents the preliminary findings based on the initial model run carried out and highlights remaining data that have to be collected;

Chapter 5 puts forward the draft list of actions identified;

Chapter 6 reports on progress made within Component 2, highlighting selection criteria, case studies and template for reporting proposed;

Chapter 7 informs about the envisaged next steps to be taken till project finalization.

In addition the report contains six annexes. Annex A lists the references used. Annex B provides an overview of institutions visited and persons met. Annex C contains information about the mission carried out in April 2016 to Astana, Shymkent and Sharda with the purpose of launching data collection. Annex D provides an overview of data collected till date. Annex E presents the design design of the model to be developed to make a solid economic assessment of Sharda MPWI and economic impacts of actions taken by key stakeholders. Finally, Annex F provides an example of reporting of a case study regarding a selected MPWI in India using the draft final template presented in Chapter 6.
### 2 Methodology

This chapter provides a definition of MPWI, highlights the typical services a MPWI provides and presents the methodology applied when implementing Component 1.

#### 2.1 MPWI

Increasingly, water infrastructures are used for more than one purpose. Hence, the term MPWI has emerged. It may be defined in different ways. In this project, the definition provided in a forthcoming OECD publication is used. It states, that MPWI “encompasses all man-made water infrastructure, including dams, dykes, reservoirs and water distribution networks, which are used or may be used for more than one purpose”. Please note that water infrastructure may be multi-purpose by design or by practice. In many cases, the water infrastructure has been designed for one purpose but is used for more than one purpose today.

The multi-purpose nature of the water infrastructure has several implications. One implication is that it makes investment decisions more difficult insofar as the impacts of an investment is multi-faceted. In the words of a recent publication on water, food and energy security: “Investments intended to promote water security must increasingly address interrelated challenges with solutions that achieve multiple objectives (...). The multipurpose nature of many water-related investments makes it important to assess the full range of risks and rewards in a given location, and to determine the most cost-effective interventions for managing multiple, often interrelated, risks; while also capitalizing on opportunities for investment.”

#### 2.2 Typical services

While irrigation or hydropower generation constitutes the most important purpose and accompanying service of most MPWIs, other services prevail. Among these are flood control, drought mitigation, drinking water supply, water supply for

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1. OECD (forthcoming).
industry needs, commercial fisheries, recreational activities, and transport and navigation. Each service has its stakeholders and economic impacts.

Direct and indirect economic impacts

The economic impacts of a MPWI and its services may be divided into direct and indirect economic impacts. The indirect economic impacts (also referred to as externalities) may be positive or negative. An example of a positive indirect economic impact is the job creation following the development of commercial fisheries in a reservoir designed for irrigation. An example of a negative indirect economic impact is the decrease in water for irrigation in spring and summer for farmers downstream due to the construction of a hydropower plant upstream.

Most important is that the indirect economic impacts have to be taken into account when preparing and assessing investment projects in relation to MPWI.

2.3 Methodology, Component 1

Computer-based model

Component 1 is focused on the economic assessment of a pilot MPWI. The methodology proposed in the project proposal submitted by the Consultant to the OECD envisaged development of a dedicated computer-based model for economic assessment of the MPWI – that is, of present situation of the MPWI and possible actions to increase its contribution to the national and regional economy, as well as to greater levels of water, food and energy security.

Five tasks

The methodology applied when implementing Component 1 consists of five consecutive tasks. The tasks are:

› Task 1: Schematic;
› Task 2: Identify actions and indicators;
› Task 3: Collect and assess data;
› Task 4: Construct scenarios and storylines;
› Task 5: Analyze results and facilitate dissemination.

In the following these tasks are dealt with – one by none.

Actions, scenarios and storylines

By way of introduction it is, however, worth emphasizing that actions, scenarios and storylines are key in the methodology. They are important regarding data collection and model design, they are important regarding analyses, and they are important regarding dissemination and facilitation of the policy dialogue linked with investment planning. The terms are defined below.

3 For more information, see OECD (forthcoming) and Branche, E. (2015).
2.3.1 Task 1: Schematic

Aim
This task, which is quite time consuming - since various data and information, including maps, have to be studied and competent experts need to be consulted, often in an iterative process – is aimed at developing a schematic to be used for the assessment and development of an appropriate model design.

Two issues
Two issues are high on the agenda in connection with this task: identification of existing water infrastructure and water resources and delineation of planning zones.

2.3.2 Task 2: Identify actions and indicators

Aims
This task is aimed at identifying relevant actions aimed at increasing the contribution of the MPWI in question to the national and regional economy, as well as to greater levels of water, food and energy security, and also at identifying accompanying indicators to be used when evaluating the actions. Relevant actions include, among others, investments, whereas relevant indicators are, among others, economic indicators, cf. Chart 2-1.

Chart 2-1 Selection of actions and indicators

Actions
- Investments
- Operations
- Taxation
- User charges

Indicators
- Economic
- Financial
- Physical
- Social

Evaluation of actions

Actions
The actions will enhance economic and financial returns from the existing MPWI in question, increase water, food and energy security through greater water use efficiency and improved flood management. Examples of possible actions are:

› Investments in improved conveyance systems to reduce water losses;

› Investments in improved on-farm water application systems;

› Management of reservoirs for alleviating flood and drought risks;

› Investments in reservoirs and hydro power;

› Investments in thermal power generation.

These actions can then be compared to other actions, such as no actions (or Business-As-Usual) or the building of additional large-scale water infrastructure implying significant capital expenditure.
Indicators

The indicators shall describe developments in various topics, such as economic welfare, public budget impact, water, food and energy security, flooding security, employment and other economic benefits and impacts on the national economy – and, hence, facilitate the evaluation and comparison of economic impacts of various actions.

Examples of present indicators in the model are:

- Economic welfare by sectors (e.g. energy and agriculture) and planning zones;
- Value added by sectors and planning zones;
- Detailed descriptions of infrastructure investment costs including cost drivers, unit costs and total operating and capital expenditure.

Scope

The scope of the task is the identification of the 5-10 most important actions and 5-10 most important indicators. It is our experience that more actions and indicators will make the assessment much harder to compile and disseminate.

2.3.3 Task 3: Collect and assess data

Aim

The aim of this task is to collect and, not least, assess data relevant to the actions and indicators identified, as well as to the general entry data needs by the model.

Key task

It is the key task in the sense that all other tasks depend on the successful outcome of this task. It is, as a rule, very time consuming (the current project is no exception). Furthermore, it is an iterative process where the Consultant is very much dependent on assistance from key local stakeholders.

2.3.4 Task 4: Construct scenarios and storylines

Aim

The aim of this task is to construct and analyse storylines and scenarios. It implies, among others, finalisation of the model and execution of model runs.

Scenario

A scenario consists of a set of specific assumptions regarding selected actions. A very simple scenario will contain one and only one action, which is compared with a no action scenario (Business-As-Usual, BaU). In some cases, it can be attractive that scenarios contain multiple actions – e.g. in the case, where two actions are expected to affect each other. Assuming we have two actions: Obviously, there should be a scenario with both actions enabled, but it will remain interesting also to compare with the two scenarios containing only each single action, as well as the no action scenario. The time horizon of a scenario has to be decided upon.

Storyline

A storyline is simply a group of inter-related scenarios. Each storyline is aimed at telling a specific story, highlighting certain developments, changes and impacts. The order of the scenarios in the storyline is of utmost importance to the storyline.
The scenarios and storylines will be simulated in the model developed and compiled into a result spreadsheet. This sheet contains the storylines, which shows how the indicators develop with the introduction of various combination of actions.

Chart 2-2 below illustrates what storyline consisting of 8 scenarios that have been constructed on the basis of 3 actions may look like. The Y axis may concern economic welfare by sector (in billion KZT).

In sum, synergies and interactions between various actions and impacts of these may be presented in a comprehensive way. Changes in economic welfare, employment, agricultural output, energy production, etc. can easily be traced.

Scenarios and storylines will be developed on the basis of model runs. It is foreseen that there will be a need for further changes in storylines and hence new model runs as main beneficiaries of the project and the OECD study the scenarios and storylines developed.

It is strongly suggested to limit the number of scenarios to a maximum of 30 and the number of storylines to 6.

2.3.5 Task 5: Analyze results and facilitate dissemination

The aim of this task is to analyse the results of the model runs and the storylines and scenarios developed and documented – and, especially, to compare indicators and explain results, thereby facilitating the dissemination of findings and results of the assessment carried out throughout Component 1.

The analysis of the results will revolve around the 6 storylines. In particular, it will highlight certain impacts and address various questions.
Impacts

By impacts is meant effects of various investments and policies, especially those related to water use efficiency and water, food and energy security (by sectors and planning zones) on the following economic parameters, among others:

› Production value;
› Production volume;
› Tax revenues and subsidy expenses;
› Water deliveries and losses;
› Water productivity in agriculture (e.g. m³ water per quantity or value of crop);
› Employment (agriculture only; not considering indirect employment in, for instance, food processing).

Questions

Possible questions to address are many. They include the following:

› How does the costs of improved refurbishment and maintenance of conveyance canals (leading to lower losses) balance with the increased crop production coming from additionally available water? What are the other impacts?
› How does increased investments in urban water distribution systems (leading to lower losses) balance with the increased crop production coming from additionally available water? What are the other impacts?
› How does increased investments in reservoir capacity (leading to higher water consumption possibility in dry years and possibly higher energy production) balance with increased crop production in dry years coming from additionally available water? What are the other impacts?
› How does increased flood safety margins in reservoirs impact agricultural production in dry years due to lower dry year water availability? What are the other impacts?
› How does investments in collector-drainage systems improve salinity conditions and agricultural output, and how does this balance with the increased income? Which other impacts?
› What are the costs (in terms of lost agricultural output) of increasing allocations of water to nature? Other impacts?
› What are the impacts of climate change on agricultural and energy output? Other impacts?
3 Shardara MPWI

The purpose of this chapter is to provide data and information about the Shardara MPWI. It presents the pilot area identified, including existing infrastructure, and presents the draft final schematic.

3.1 Pilot area

As already mentioned in the introduction, the Shardara reservoir and accompanying multi-purpose water infrastructure was identified as the pilot area for this project by the CWR in Q1 2016. The reason for this is the importance of the Shardara reservoir and the whole of the Aral-Syr Darya basin for the national and regional economy, as well as the fact that the water infrastructure in this area is, in fact, very complex.

Map 3-1 Aral-Lower Syr Darya basin, including Shardara reservoir

Source: Committee on Water Resources (2015).
It is worth emphasizing that the pilot area, in this project referred to as Shardara MPWI, encompasses not only the Shardara reservoir. In fact, it encompasses water resources and water infrastructure in the whole Aral-Lower Syr Darya basin insofar as the analyses to be carried out will address impacts and questions linked with areas downstream of the Shardara and also Koksaray reservoirs, cf. Map 1-1. However, when it comes to actions, focus is on water infrastructure in and around the Shardara reservoir, including Koksaray reservoir.

3.1.1 Key features

80% from outside

One key feature of the Aral-Lower Syr Darya basin is that about 80% of the water flow comes from outside Kazakhstan. Hence, the water flow of the Syr Darya river is and will continue being determined not only by natural factors of runoff formation, but also changes in water intake, return water and mode of operation of reservoirs in the neighboring countries Kyrgyz Republic, Tajikistan and Uzbekistan.

Multi-purpose

Another key feature is that the water infrastructure Shardara reservoir and the whole of the Aral-Lower Syr Darya basin has become more and more multi-faceted over the years. Originally, the Shardara reservoir was designed for irrigation. Today, it offers various other services, most notably hydropower generation, flood control, commercial fisheries and support to livestock. In future, it is likely it will offer even more services, including diverse recreational activities.

3.1.2 Infrastructure

Brief information

This sub-section provides brief information about the infrastructure in the Shardara MPWI encompassing not only the Shardara reservoir as already mentioned above. It encompasses a part of the Syr Darya above the Shardara reservoir and, especially, the parts of the Syr Darya below the Shardara reservoir.

Reservoirs

There are two reservoirs in the pilot area, Shardara reservoir and Koksaray reservoir.

The Shardara reservoir, which was constructed in 1967, is used for irrigation of agricultural lands in South Kazakhstan and Kyzylorda regions, and hydropower. Reservoir length is 80 km and width is 25 km, and surface area is 783 km². Its maximum volume is 5.2 km³ (design storage capacity), whereas the actual volume taking into consideration effects of sedimentation is 4.7 km³. Annual release from reservoir is 10 km³. Up to 1 km³ is delivered to Kyzylkum canal. 1 km³ is left as dead volume. Evaporation is accounted to 850 mln m³. Current hydropower capacity is 100 MW. Currently, the four existing turbines are being replaced; it will increase hydropower capacity to 126 MW. The head amounts to 26 m.

The Koksaray reservoir is located 160 km downstream of Shardara reservoir. It was constructed in 2011 and has been operated to accumulate surplus of winter hydropower flow from the upstream countries in order to prevent floods. In summer

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the water from Koksaray is released to support the irrigation in downstream areas. The reservoir volume is 2.3 km$^3$ on average; design volume amounts to 3 km$^3$.

Furthermore, there is a number of smaller hydropower stations in the pilot area. In Kyzylorda region, Kyzylorda hydro units and Kazalinsk hydro units facilitate operation of irrigation systems.

**River sections**

Syr Darya river flows from Uzbekistan are measured at Kokbulak hydropost, at the Kazakh-Uzbek border. Up to Sharda reservoir it is regarded as Syr Darya middle. The additional inflow on the territory of Kazakhstan to Syr Darya middle is delivered by Keles river and canal system from Uzbekistan.

Downstream the Sharda reservoir the river is referred to as Syr Darya Lower. Lower Syr Darya receives the inflow from Arys’ river. Koktobe hydropost (388 km from Sharda reservoir downstream point) serves as the ‘border’ between the two regions, South Kazakhstan region and Kyzylorda region.

Kazalinsk hydropost registers the start of the Syr Darya delta at 1459 km below from Sharda reservoir. The distance from Kazalinsk hydropost to the Northern Aral Sea is about 180 km.

**Lakes**

The water from Sharda reservoir is released in case of emergency winter flooding and periodically during the year (upon request or approval from Uzbek side) to Arnasai lakes in Uzbekistan. The lakes emerged after the catastrophic 1969 flood when excessive water was released to the Arnasai Depression. From February 1969 to February 1970 some 21 km$^3$ of excessive water (amounting to some 60% of the annual run-off of Syr Darya river) were released and accumulated in the new man-made lakes.

There is often practice that the drainage water is collected in artificial lakes where specific ecosystems emerge. In Kyzylorda region such type of lakes are: Telikul (collect up to 1 km$^3$ annually), Kashkansu, Bozkol bay and Makpal. To support some of them the environmental flows are maintained. Kamystybas and Akshatau lake/wetland systems are regarded part of the Syr Darya delta.

**Agricultural zones**

Agricultural lands associated with Syr Darya Lower are split between the two regions as follows:

› South Kazakhstan region
  
  › Kyzylkum area, irrigated with Kyzylkum canal and pumping stations, with total area of 86,000 ha.

› Kyzylorda region
  
  › Togusken area, irrigated with Kelintobe canal, total area is 34,000 ha;
  
  › Zhanakorgan-Shieli area, irrigated with Shieli and Kamystyvak canals, total area is 45,000 ha;
Further agricultural lands in South Kazakhstan region are:

- Kyzylorda area, irrigated with Kyzylorda canal and Aitek canal, total area is 115,000 ha;
- Kazalinsk area, irrigated with Kazalinsk canal, total area is 37,000 ha.

Further agricultural lands in South Kazakhstan region are:

- Associated with Syr Darya Middle
  - Makhtaaral is fed mainly from Uzbekistan via Dostyk canal; however, in the situations of high importance the water is pumped also from Shardara reservoir, total area is 147,000 ha.
- Agricultural lands associated with Chirchik and Keles rivers (Syr Darya Middle basin, flow generated in Uzbekistan)
  - CHAKIR is fed with water supplied via canals from Uzbekistan, total area is 66,000 ha.
- Agricultural lands associated with Arys’ river (Syr Darya Lower basin):
  - In the ARTUR irrigation zone Arys river flow is consumed via the canal and reservoir system. Total area is 204,000 ha. Drainage water is released to Shoshkakol lake.

Please note that the agricultural zones of Syr Darya Lower are subject to analysis within the current project insofar as, for instance, investments made in and around Shardara reservoir may impact on agricultural zones of Syr Darya Lower.

Canals

Total length of the main canals in South Kazakhstan region amounts to 475 km, while total length of the extended system (main canals and canals linking irrigation zones) amounts to 666 km\(^5\). The far most important canal in the region is the Kyzylkum canal. It is 106 km long (27 km lined) with a maximum flow of capacity 200 m\(^3\)/sec. Another important canal is Dostyk interstate canal that takes water from the Syr Darya river in Uzbekistan and delivers it to South Kazakhstan region (113 km long with a flow of 230 m\(^3\)/sec).

Total length of the main canals in Kyzylorda region amounts to 943 km, while total length of extended system amounts to 2318 km. In Kyzylorda region the majority of canals is unlined; only 5-10 percent of the canals are lined.

\(^5\) In irrigation, a main canal refers to a main distribution canal of the irrigation system. It supplies water from a river, reservoir or canal to irrigated lands by gravity flow. It has larger capacity compared to other canals. In South Kazakhstan region the capacity of main canals varies from 200 m\(^3\)/sec to 4.5 m\(^3\)/sec (small river Sairamsu). In Kyzylorda region the capacity of main canals varies from 226 m\(^3\)/sec to 20 m\(^3\)/sec. Please note that all data in this section are canal design data.
The main canals in Kyzylorda region are:

- The Kelintobe canal is 88 km long with a flow of 102 m³/sec;
- The Shieli canal is 181 km long with a flow of 120 m³/sec;
- Kyzylorda canal system, including the Aitek canal, is part of the Kyzylorda hydro facilities. The left side area is irrigated from the main canal (406 km long with a flow of 226 m³/sec), whereas the right side area is irrigated with two branches of the canal (50 km long with a flow of 110 m³/sec – and 78 km long with a flow of 60 m³/sec);
- Kazalinsk canal, which is unlined, is part of the Kazalinsk hydro facilities. The left side area is irrigated from one part of the canal (99 km long with a flow of 100 m³/sec and (unlined), whereas the right side area is irrigated from another part of the canal (39 km long with a flow of 85 m³/sec).

In addition, there are two old riverbeds in Kyzylorda region, which may be considered a special type of canals insofar that they may be used for diverting water from flooding. One is Zhanadarya (577 km long), another is Kuandarya (380 km long). Zhanadarya is situated above Kuandarya.

| Drainage and return water | The collector-drainage system is, as a rule, outdated and of poor quality. In Shardara rayon (South Kazakhstan section of Syr Darya Lower), some 25% of the vertical drainage systems of the region is located, and none is repaired. Only 300 mln m³ are returned to Syr Darya from Shardara rayon out of 677 mln m³ of water used for irrigation in 2015. In South Kazakhstan regions 724 mln m³ out of 3 km³ used for irrigation are returned to the collector-drainage systems, and 2.5 mln m³ are returned back to Syr Darya. Seepage and evaporation accounted for 631 mln m³ in 2015. Often the water from fields is released into external collectors. The maximum level of return water in Kyzylorda region reach only 31 % of irrigation water pumped into the canal. |
| Drinking water | Syr Darya Lower water users include drinking and technical water supply. The main consumers are: villages along Syr Darya river, Kyzylorda city (however, the transfer to groundwater source is in place), Kazalinsk town (7,000 people). Drinking and technical water to Shardara town (30,000 people) is delivered from Shardara reservoir (1.2 mln m³ annually). Groundwater for drinking purposes is used extensively in both regions. In general, the Syr Darya water quality is not adequate to meet drinking water standards. Thus, even in the rayons (administrative units of a region) adjacent to surface |

The Kamystykak canal (30 km long with a flow of 20 m³/sec) is not a main canal, although it is important.
water source of Syr Darya river, the group water pipes which supply water from groundwater sources are constructed.

According to a very preliminary data assessment carried out 1.7 mln people in South Kazakhstan region consume groundwater for drinking and technical needs.

Fisheries

The Shardara reservoir is also used for commercial fisheries, including fish farming; there is one fish factory. Currently, it is being discussed whether to grant fishing rights to individuals.

Water intakes to serve fishery exists throughout the Aral-Syr Darya basin.

3.2 Schematic

Top priority

Much attention has been paid to the development of the schematic, which is a key element for hydro economic analysis and modelling of the MPWI. Therefore, it has been a top priority of the Project team to construct a solid schematic. The schematic defines the geographical areas, river sections and pieces of main infrastructure, which can be explicitly analysed by the analytical model, and for which results can be reported.

Basis

The basis for constructing the schematics has been the draft list of actions together with collected data and information on data availability, since elements that are not explicitly described in the schematic cannot be analysed explicitly.

Key considerations

Key considerations regarding the schematic has been that the schematic should:

› in sufficient detail accommodate available data on irrigated agriculture in terms of e.g. crop structure and irrigation techniques;

› allow for explicit description of selected key pieces of infrastructure, e.g. selected canals and reservoirs;

› allow for analysis of various diversions of water across country borders.
Notes: 1) Comprises Kazalinsk district. 2) Comprises Kyzylorda, Syr Darya, Zhalagash and Karmakshy districts. 3) Comprises Shieli and Zhanakorgan districts. 4) Comprises all districts in South Kazakhstan region, but Suzak district (not a part of the catchment area to Syr Darya and, hence, not included in the schematic), Shardara district (separate planning zone in the schematic), Sayragash and Kazygurt districts (separate planning zone in the schematic) Makhtaraal district (separate planning zone in the schematic) and parts of Arys’ and Otrar districts. 5) Comprises Sayragash and Kazygurt districts. 6) Shardara district and parts of Arys’ and Otrar districts. 7) Comprises Makhtaraal district.

Source: COWI, based on data and information collected.

Planning zones

The proposed schematic is composed of 7 agricultural planning zones, three in Kyzylorda region and four in South Kazakhstan region, cf. Error! Reference source not found.. The planning zones describes water use for irrigation and leaching (based on crop choice and irrigated area), as well as drinking water supply (based on urban and

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Chart 3-1 Proposal for schematic
rural population and coverage rates). The relevant conveyance canals are attached to each planning zone for describing water losses in water conveyance.

River sections, etc. The schematic also describes seven river sections and two large reservoirs. Further, ground water use in the Shardara planning zone is shown in the schematic. In the case that analysis of ground water use is relevant in other zones, such use can easily be added to the schematic.

The ARTUR planning zone covers a large and complex system of canals and reservoirs. As such this zone can be said to be the most simplified in the schematic. In case that relevant opportunities for analysis arise (e.g. pumping of irrigation water) and requires a more detailed description of the ARTUR zone, the schematics will be revised accordingly. Other comments from stakeholders, or new actions on the draft list may also lead to minor revisions of the schematic.

Outstanding issue An outstanding issue to be resolved is the treatment of irrigated pastures and water use for livestock. The project team is currently considering various options for explicitly modelling this type of agricultural activity, so related actions and consequences can be simulated with the model and analysed.

Request to stakeholders Representatives of the Ministry of Agriculture, CWR and Kazvodkhaz, as well as other members of the NPD IMCC are kindly requested to provide comments on the schematic, if any, by September 1, 2016 via the CWR (Mr Yerdos Kulzhanbekov, E.Kulzhanbekov@msh.gov.kz). Besides, the Project team will reach out to selected representatives of the main beneficiaries on this issue. The purpose of this is to ensure that key stakeholders may subscribe to the schematic.
4 Model Runs, Preliminary Findings

Purpose
This chapter presents the preliminary findings based on the initial model run carried out and highlights remaining data that have to be collected. It includes assessment of the present situation, An economic assessment of possible actions will be implemented at next stages of project implementation.

4.1 Two modules
Two key modules have already been completed and are fully operational. These are:

› a module for economic assessment of the current situation within irrigated agriculture;

› a module for producing (calculating) the water mass balance using the entry data collected.

Further, a number of modules are almost completed. These concern simulation of crop choice (i.e. changes in crop mix) and production; water releases, abstractions and water use; financial consequences of actions etc. Remaining work concerns mainly of structuring of the collected data so that it fits correctly into the model data structure, programming of actions and reporting of results.

Preliminary findings
Some interesting preliminary findings have come from the analysis of historical data on irrigated agriculture, land and water use, and economic performance of the agricultural activities. They are presented below.

Land use, Kyzylorda region
Kyzylorda region’s agricultural activities tend to focus on the production of particularly rice and to some extent fodder crops, cf. Chart 4-1. Rice is virtually not produced in the districts of South Kazakhstan region. Here the districts Makhtaraal and Shardara tend to focus on cotton, while grains, fruits, vegetables and melons are more prevalent in ARTUR and CHAKIR planning zones.
Land use, by planning zones: Kyzylorda’s agriculture focuses on rice and fodder crops

Irrigation water use in the planning zones in Kyzylorda region is almost exclusively going to rice production, cf. Chart 4-2. The reason is that rice is the crop with the highest “irrigation norm” (per ha), which is many times higher than those of most other crops.

The prevalence of rice strongly contributes to the Kyzylorda region to consume 59% of total irrigation water in the combined use in the two regions, even though it has only 30% of the irrigated area, according to the data collected so far.

Agricultural income

The net income from agriculture is also very focused on rice in the Kyzylorda region, and fruits and vegetables in South Kazakhstan region, cf. Chart 4-3. For rice, this is no surprise since this crop is so prevalent in Kyzylorda region. For fruits and vegetables, the high net income indicates that fruits and vegetables are among the most profitable crops when measured in term of net income per hectare. The net income is defined as crop value (ex farm price) minus cultivation costs (also...
including wages). Kyzylorda region receive 41% of the combined income from agriculture in the two regions, while South Kazakhstan region receives 59%.

The data collected indicates that the production costs for fodder crops exceed the value of these crops (in Chart 4-3 this makes fodder crops appear as a negative contribution to income).

**Chart 4-3** Agricultural net income, by planning zones: it is focused on rice, fruits and vegetables

The project team is reviewing this finding through quality assurance process.

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7 Another option is considered for calculating the net income from agriculture: prevailing price for respective crop at local market (from market prices survey by Statistical agency) minus cultivation, transportation and storage costs (also including wages).
Profits by area

Vegetables, fruits and rice are the most profitable crops when measuring the profits (net income) in relation to the irrigated area, cf. Chart 4-4. Melons are also somewhat profitable, while cotton, grains and fodder seem barely profitable (or even loss making for farmers) according to the data collected.

Chart 4-4  Profits by area and crop: vegetables, fruit and rice is most profitable measured per hectare

Source: Output chart produced by the model.
Profits by water use

However, rice becomes among the least profitable when instead measuring net income per cubic metre of irrigation water used. This comes as another consequence of the relatively large irrigation norm for rice. Fruits and vegetables are still the most profitable, cf. Chart 4-5.

Chart 4-5 Profits by water use (crop) and planning zone: rice becomes among the least profitable when measured by net income per cubic metre of irrigation water

Source: Output chart produced by the model.
For comparison, Chart 4-6 provides information about water use productivity for key crops in the planning zones. It follows that water use productivity is particularly high for fruits in Makhtaraal.

**Chart 4-6: Water productivity, by crop and planning zone**

![Chart showing water productivity by crop and planning zone]

Source: Output chart produced by the model.

**Changes in crop mix?**

This observation immediately raises the following question: If water is in short supply, why not shift production away from thirsty crops like rice with a low net income (low value-added) per cubic metre of water used, to crops such as vegetables and fruits with higher income per amount of water used?

The answer is – however – much less simple. Rice production is particularly prevalent in Kyrgyz region, while fruits and vegetables are grown only in limited quantities here. If it was really that easy and profitable to shift away from rice towards fruits and vegetables, chances are that it would have been done already. So is there another explanation of the low prevalence of the very profitable fruits and vegetables in Kyrgyz region?
One explanation might be transportation costs and market size. South Kazakhstan region has a number of larger cities, and is located not that far from the large city of Almaty. Hence, the distance to large markets for fruits and vegetables is limited. On the contrary, Kyzylorda region is more remote and sparsely populated, and there is a longer distance to larger population centres. The large distances (eventually complemented by the lack or poor quality of regional roads and/or the lack of storage facilities) are likely to cause both high transportation costs as well as high losses of the fresh produce. Conversely, rice is much easier to store and transport. This makes it a better crop for more remotely located areas (not considering its larger water needs).

4.2 Remaining data

Overview

This section provides an overview of remaining data. The Project team will take action on this in July 2016. Annex D provides brief information about data collected. Some remaining data have high priority (priority A), whereas others have a slightly lower priority (priority B). Hopefully, all priority A remaining data may be collected by the end of July 2016.

Request to stakeholders

Representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC are kindly requested to provide the Project team with assistance in collecting the remaining data. The Project team will contact selected representatives of the main beneficiaries on this issue.

4.2.1 Financial data for infrastructure (priority A)

OPEX

In order to assess public finances in a business-as-usual situation as well in situations with extended investments, there is a need for some sort of estimate of the operational costs of reservoirs and main canals and collectors (OPEX).

In order to limit the amount of detailed data going into the model, it is preferable to have dedicated data for only the pieces of infrastructure that we plan to analyse in detail, e.g. the Kyzylikum canal.

Rough numbers

For the infrastructure not analysed directly, rough numbers of the unit cost (e.g. per kilometre of canal) is sufficient. It will probably be necessary to categorise the cost of canal maintenance according to canal capacity (in m³/s), e.g. in some intervals, like 0-15 m³/s; 15-40 m³/s; 40-100 m³/s; 100-200 m³/s; >200 m³/s.

Also, it might be useful to distinguish between a “gradual improvement” investment program and a “full rebuilding” investment program.

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8 These intervals are defined somewhat arbitrarily. Please advise if other intervals make better sense.
4.2.2 Water supply and industrial water data (priority B)

There is a need for data on water supply and population, categorised by urban and rural population and by connected and unconnected, preferably by district.

Data on daily water use (litres/capita/day) and estimation of losses in the drinking water system are required. So are data on the share of drinking water returned to the river system and some estimate of how the various districts are hydraulically linked to the river systems.

Furthermore, there is a need of information on losses from pipes and – if possible commercial losses. Preferably, the losses should be by district, but more aggregated data are also usable.

Industrial water use figures are needed.

4.2.3 Irrigation by crop (priority B)

Monthly data

A piece of data still missing is the irrigation by crop distributed by month.

It does not need to be on a m³/ha basis, simple percentage distribution of the irrigation norm across the relevant norms will do fine as well.

Another twist on this data need could also be if there is variation in the planting and harvesting time of the different crops.

4.2.4 Evapotranspiration by month (priority B)

Monthly data

Crop irrigation norms per year have been collected, but there is a need to calculate crop evapotranspiration per month. Preferably, mm/ha for each crop, but the share of irrigation norm by month is also fine, if data on mm/ha are not available.

4.2.5 Crop markets (priority B)

Food security

In order to improve the model, the Project team will collect additional data on the share of crop production that is consumed on the local market (district/planning zone or regional market). This will be very useful for indicators on food security.

4.2.6 Selected canals/areas with pumping (priority B)

Pumping conveyance

There is a need to collect data and information on energy used for pumping conveyance of irrigation water in planning zones, where pumping is prevalent. Such data may allow for analyses of the cost element linked with pumping.
5 Identified Actions

Purpose
This chapter puts forward the draft list of identified actions aimed at increasing the contribution of the MPWI in question to the national and regional economy, as well as to greater levels of water, food and energy security in Kazakhstan as a whole.

South Kazakhstan region
By way of introduction, it is worth mentioning that it is proposed focusing on actions in South Kazakhstan region only, when developing and finalizing the list of actions. These actions will, however, have impacts on Kyzylorda region, and these impacts will be dealt with in the analyses and different model runs.

Three types
The draft list of actions is divided into three types of actions:

› demand side actions;
› supply side actions;
› risk management actions.

Each type may include both capital investment and “soft” measures (institutional, regulatory, R&D etc.). However, it is foreseen that most of the actions finally selected and agreed upon will involve an investment element and, hence, may be presented in terms of CAPEX.

Few, but important
The draft list of actions include a few, but important actions:

› Demand side actions

› Investment in more efficient irrigation techniques (both better practices and investments in hardware), including possible more water in Kyzylorda region;

› Reducing water losses in WSS systems;

› Metering water use and introduction of improved irrigation water tariff system combining fixed tariff (per ha) and volumetric tariff (per cbm);
Conversion of land and water use into pastures to support re-establishing and increasing meat production and processing, and leather & fur industries;

Consider options to shift from pumping water to delivery by gravity (specific intakes have to be considered; only not to Makhtaraal; demand for both water and energy will be affected).

Supply side actions

Increase strategic water storage capacity (e.g. by increasing the height of the dam to intercept and accumulate more water during winter flood and spring flood; note that amount of winter flood depends on Kyrgyz actions):

- Shardara reservoir; and/or
- Koksaray.

Kyzylkum canal refurbishment focusing on the whole canal or only on the unlined parts of the canal (restoration to reduce water losses);

Reduce the length of an existing canal, while at the same time increasing water productivity of the still existing canal;

Consider options for increasing supply of groundwater for irrigation in certain areas (e.g. distant parts of Kyzylkum canal) and use solar-powered pumps (it would be important to avoid over-depletion of groundwater; maybe even address salinity problems in this way; this may require changes in legislation);

Adaptation of infrastructure to climate change (to be developed).

Risk management actions

Flood protection canal on the right bank of Shardara reservoir so that excessive water could bypass urban settlements downstream the Shardara reservoir (Variant No 1);

Consider using excessive water for re-charging ground water reserves during flooding and then using the ground water in dry seasons.

Impacts

For each action the impacts on water allocation and economic welfare will be assessed using the model together with an overview of assessed increase in investments and financing.

Request to stakeholders

 Representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC are kindly requested to provide comments on the above draft final list of actions by September 1, 2016 via the CWR (Mr Yerdos Kulzhanbekov, E.Kulzhanbekov@msh.gov.kz). Besides, the Project team will
reach out to selected representatives of the main beneficiaries on this issue. It is crucial that key stakeholders may subscribe to the final list.
6 International Experience

Purpose

This chapter concerns Component 2 of the current project, whereas the above chapters dealt with Component 1. It provides information about the draft final list of criteria for selection of case studies to illustrate relevant international experience and provide valuable information to key stakeholders in Kazakhstan, draft final list of case studies and draft final template for reporting of case studies.

6.1 Selection criteria

Relevant

This section presents the draft final list of criteria for selection of case studies. The repository of case studies developed will act as a set of relevant international experiences which would inform future management practices in case of Shardara reservoir in Kazakhstan. The key word here is “relevant”.

Overall criterion

There are more than 24,000 multi-purpose dams and water distribution networks globally. The overall criterion is that case studies will be selected to represent conditions similar to (or as close as possible to) Shardara reservoir - and that there will be at least 2 case studies from Asia, Africa, EU, OECD regions and 5 from EECCA countries.

Specific criteria

The following specific criteria for case study selection are proposed:

› **Water supply to the reservoir**: In case of Shardara, water is supplied from Syr Darya River, which is a transboundary river. This has implications on water availability in the reservoir (and hence its operations) as the government of Kazakhstan does not have full control on the source of water for the reservoirs. Effort will be made to select the case studies, wherever possible, that include reservoirs with transboundary rivers as their source of water.

› **Water use from the reservoir**:

› **Transboundary use**: Shardara reservoir borders Kazakhstan and Uzbekistan. The water from the reservoir is shared between the two countries thus making it a transboundary water use system. Effort will be made to include cases with similar situations but it may be difficult to find 15-20 of such cases.
Water users: Water from Shardara is predominantly used for hydro-power generation and irrigation. It also provides flood protection benefits. Case studies with similar water users will be selected.

Physical Characteristics:

Surface Area and Storage capacity: Reservoirs selected will be of size similar to the scale of Shardara reservoir.

Degree of Regulation: This is defined as ratio between the storage capacity and the water inflow. The reservoirs selected will have similar degree of regulation as that of Shardara reservoir.

Climatic Conditions: Reservoirs in climatic zone similar to that of Shardara will be selected as case studies.

Water Security Index: Water supply and water demand depend upon availability of water resources and population within a region. A simple water security index – per capita water availability – will be used as a criterion to filter out reservoirs that are not similar to Shardara. If it is not possible to meet this criterion in some region, it will be ignored.

Request to stakeholders Representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC, are kindly requested to provide comments on the above selection criteria, if any, by September 1, 2016 via the CWR (Mr Yerdos Kulzhanbekov, E.Kulzhanbekov@msh.gov.kz). Besides, the Project team will reach out to selected representatives of the main beneficiaries on this issue.

6.2 Candidate case studies

15 case studies On the basis of the above selection criteria, a draft list of case studies have been prepared, cf. Table 6-1 overleaf. They are all similar to Shardara MPWI in terms of source of water (trans-boundary river), physical characteristics (storage capacity etc.), climatic conditions (incl. water stress index), and the mix of water uses.

Request to stakeholders Representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC, are kindly requested to provide comments on the draft list of case studies, if any, by September 1, 2016 via the CWR (Mr Yerdos Kulzhanbekov, E.Kulzhanbekov@msh.gov.kz). Besides, the Project team will reach out to selected representatives of the main beneficiaries on this issue. It is envisaged that the case studies will be completed during July-September 2016 using the template agreed upon (see Section 6.3), so that they may be presented at the Expert Workshop in September 2016 (see Chapter 7).
### Table 6.1 Candidate case studies: international experience

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<th>Upstream countries</th>
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<th>Water use (minor)</th>
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<th>Climatic condition</th>
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<td>Rio Tonto</td>
<td>Yucatan</td>
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</tbody>
</table>
6.3 Template

Draft final

A draft final template for reporting of case studies have been developed, cf. Table 6-2. An example of what the template will look like when filled in is provided in Annex F.

Table 6.2 Draft final template, Case studies

<table>
<thead>
<tr>
<th>Flag of country</th>
<th>Map 1 (e.g. region in country)</th>
<th>Map 2/Picture (close-up)</th>
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<tbody>
<tr>
<td>Owners, including asset ownership</td>
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<td>Physical characteristics (volume, surface area, residence time, etc.)</td>
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<td>Key water uses:</td>
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<td>Irrigation (maybe in terms of figures):</td>
<td>Hydropower; Flooding; Others</td>
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<tr>
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<td>Stakeholders</td>
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<td>Brief history</td>
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<tr>
<td>Business model, including cost recovery</td>
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<tr>
<td>Negative externalities</td>
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<tr>
<td>Future plans</td>
<td></td>
<td></td>
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<tr>
<td>Sources of information</td>
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</tbody>
</table>

Request to stakeholders

Representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC, are kindly requested to provide comments on the draft final template, if any, by September 1, 2016 via the CWR (Mr Yerdos Kulzhanbekov, E.Kulzhanbekov@msh.gov.kz). Besides, the project team will reach out to selected representatives of the main beneficiaries on this issue. It is, as already mentioned, envisaged that the case studies will be completed during July-September 2016 using the template agreed upon.
### Next Steps

#### Purpose
This chapter simply informs about the envisaged next steps to be taken till project finalization, thereby ensuring alignment of expectations.

#### Data

##### Collection
Remaining data will be collected as stated in Section 4.2.

##### Access
In August 2016, the Project team will pay much attention to the access to data collected. Data will be made public available as soon as the model is made available to the public (as part of Component 3 to be completed in September-December 2016). It is important to do this in a way which enjoys full support of all parties involved.

#### List of indicators

##### Indicators to assess actions
In order to evaluate actions identified and agreed upon a list of indicators have to be developed and agreed upon. The Consultant will provide the main beneficiaries of the project with such a draft list in August 2016.

#### Expert Workshop

##### Dates identified
It has been tentatively agreed by the Committee on Water Resources and the Consultant to carry out the Expert Workshop on September 15-16, 2016. It will discuss and assess interim results of the two activities implemented under the aforesaid “Support to the Implementation of the Water Resources Management Programme in Kazakhstan”, including the activity (or project) on MPWI.

##### Objectives
The objective of the expert workshop will be to discuss interim results of this project and agree upon the list of actions to be modelled and assessed in the final report.
Draft program

The draft program looks as follows:

Day One

- MPWI project, highlighting results of model runs regarding actions and accompanying scenarios; a separate discussion is how to ensure that the model could and should be used for facilitating cross-sector and cross-levels of government national policy dialogue on nexus issues;
- International experience with MPWI, including a presentation about Israel (in-kind contribution of Israeli delegation to the OECD).

Day Two

- State Support Project;
- Short presentation of other tools on nexus and nexus-related SDGs, including Eis for WRM (other than state support); FEASIBLE model and some other instruments.

Location and invitees

The workshop will be held in Astana. List of invitees is to be prepared in July 2016, so that invitations may be sent out before summer vacation.

Consultations

In the period till the workshop the Consultant will consult with representatives of the Ministry of Agriculture, CWR and Kazvodkhoz, as well as other members of the NPD IMCC about key findings to ensure that they are fully in line with policy goals of the Government of Kazakhstan and prevailing expertise within, not least, the Ministry of Agriculture.

7.4 Component 3

In the wake of the Expert Workshop

Following the Expert Workshop the Consultant will work intensively on Component 3, focusing on analyses, dissemination and preparation of Final Report. This the Consultant will do in close cooperation with the main beneficiaries and OECD.

Selected issues

A few issues will be dealt with as part of Component 3, including:

- **Glossary.** A glossary on terms used in the project and also the model will be developed.
- **Reach out.** In close cooperation with main beneficiaries and OECD it will be discussed how to reach out to international stakeholders active in water management in Kazakhstan.
- **Model.** A separate issue is where and how to make the model available in the public domain. In this connection it may be considered developing a user-friendly interface allowing the user to run the model without having license to software used.
Annex A

References


Committee on Water Resources (2015): Various water management schemes in case of surplus water in Kyzylkum (Схема вариантов водоотведения в катастрофические по водности многоводные годы избыточных расходов в пески Кызылкум; in Russian).


Annex B  Institutions Visited and Persons Met

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yerdos Kulzhanbekov Tursynbekovic</td>
<td>Senior Expert, Committee on Water Resources, Ministry of Agriculture</td>
<td><a href="mailto:E.Kulzhanbekov@msh.gov.kz">E.Kulzhanbekov@msh.gov.kz</a></td>
</tr>
<tr>
<td>Arman Orazovic Ajmenbetov</td>
<td>Deputy General Secretary, Committee on Water Resources</td>
<td>P: 8 (717) 2374598 E: <a href="mailto:ao_lawyer@bk.ru">ao_lawyer@bk.ru</a></td>
</tr>
<tr>
<td>Nazgul Saduova</td>
<td>Head of Unit, Committee of Housing and Communal Utilities, Ministry of National Economy</td>
<td>P: 8 (717) 2741815 E: <a href="mailto:na.saduova@economy.gov.kz">na.saduova@economy.gov.kz</a> E: <a href="mailto:742775@mail.ru">742775@mail.ru</a></td>
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<tr>
<td>Saule Zhadrina</td>
<td>Senior Expert, Committee of Housing and Communal Utilities, Ministry of National Economy</td>
<td>-</td>
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<tr>
<td>Meirbek Egenov</td>
<td>Director, Kazvodkhoz, South Kazakhstan Branch</td>
<td><a href="mailto:ugvodhoz@mail.ru">ugvodhoz@mail.ru</a></td>
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<tr>
<td>Tolkyn Balpikov</td>
<td>Deputy Director, Kazvodkhoz, South Kazakhstan Branch</td>
<td>P: 8 (701) 7422528</td>
</tr>
<tr>
<td>Karl Albertovic Anzelm</td>
<td>Head, South Kazakhstan Hydrogeological Agency, Committee on Water Resources</td>
<td>P: 8 (701) 3767923 P: 8 (705) 4374321 E: <a href="mailto:ggmeak55@mail.ru">ggmeak55@mail.ru</a></td>
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<tr>
<td>Meirzhan Yusupbekovic Esanbekov</td>
<td>Deputy Head, South Kazakhstan Hydrogeological Agency, Committee on Water Resources</td>
<td>P: 8 (778) 6600973 E: <a href="mailto:meyr_1984@mail.ru">meyr_1984@mail.ru</a></td>
</tr>
<tr>
<td>Abdukhamid Urazkeldiev</td>
<td>Chief Engineer, Yuzhvodstroi</td>
<td><a href="mailto:urazkeldiev@mail.ru">urazkeldiev@mail.ru</a></td>
</tr>
<tr>
<td>Polatbaj Zhumataevic Tastanov</td>
<td>Deputy Head, Department of Agriculture, Akimat of South Kazakhstan region</td>
<td>P: 8 (725) 2512170 E: <a href="mailto:dsh_uk@mail.ru">dsh_uk@mail.ru</a></td>
</tr>
</tbody>
</table>
Annex C  Mission, April 2016

This annex contains information about the mission carried out in April 2016 to Astana, Shymkent and Shardara with the purpose of launching data collection.

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<th>April 18, 2016, Astana</th>
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<table>
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<td>Local Kazvodkhoz (water resources and infrastructure management in South Kazakhstan)</td>
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<tr>
<td>Aral-Syr Darya Basin Inspection</td>
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<tr>
<td>South Kazakhstan Hydrogeology and Melioration</td>
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<tr>
<td>Akimat of South Kazakhstan region</td>
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<tr>
<td>Department of Agriculture</td>
</tr>
<tr>
<td>Energy and Utilities Department</td>
</tr>
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</table>

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Shardara reservoir</td>
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<tr>
<td>Kyzylkum canal operation</td>
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</table>
Annex D  Data

This annex provides an overview of the data collected within the period of April-May 2016 and continued in June.

D.1  Water mass balance

It has been discussed and agreed with the hydrology specialists from Aral-Syr Darya Basin Inspection to select the following years for project analysis:

› 2010 – Wet year
› 2012 – Normal year
› 2015 – Drying trend (2017 forecasted as dry), so that data can be adjusted.

Annual water balance data (including seepage and evaporation, environmental flows) were provided for the river sections (Aral-Syr Darya Basin Inspection):

› Middle Syr Darya (from Kokbulak hydropost to Shardara reservoir)
› Shardara reservoir water mass balance
› Lower Syr Darya South Kazakhstan section (from Shardara reservoir to Koktobe hydropost)
› Lower Syr Darya Kyzylorda section (from Koktobe hydropost to North Aral Sea). No more detailed split by Kyzylorda river sections was provided.

As advised by Basin Inspection and Water Committee of the Ministry of Agriculture there is no available record of the monthly data for water balance.

Retrospective monthly data for the period of 70s, 80s and 90s are available. But it presents certain difficulties to extrapolate the years with similar hydrological conditions due to significant change in land use and ageing infrastructure.

Data on monthly releases from Shardara reservoir has been obtained.

D.2  Schematic

The schematics presented in Chapter 3 was compiled on the basis of schematics of specific river sections received from the Basin Inspection and Kazgiprovodkhoz Institute – and consultations with selected experts.

D.3  Land use

Information on land use (for the specified hydrological years) in South Kazakhstan region was summarised by the South Kazakhstan Hydrogeology and Melioration
Expedition (reports to Water Committee): land use data derived from water supply analysis and the data provided by the Department of Agriculture in the Akimat of South Kazakhstan region. The data detail land use by crops in the agricultural zones defined in Chapter 3. It also provides information on water use by agricultural zone and by main crop.

Information on land use in Kyrgyz region is given for rayons, so that it will need to be aggregated by the agricultural zones indicated in Chapter 3. It also provides information about water use by crops.

D.4 Land quality

Thanks to the South Kazakhstan Hydrogeology and Melioration Expedition the solid data were obtained for the level of land salinization, groundwater level and mineralization in the South Kazakhstan region – in specific agricultural zones.

For Kyrgyz region the regional data were obtained from Kazvodkhoz in Kyrgyz: the level of land salinization, groundwater level and mineralization.

D.5 Crops

Crop productivity and irrigation norms data are available for every rayon in Kyrgyz region / for every agricultural zone in South Kazakhstan region. Actual yields information is not available and can be calculated based on land use and productivity (yield information is also available in Stat.gov.kz, but not detailed to fit the project needs).

For South Kazakhstan region the crop prices and detailed production costs were provided; for Kyrgyz region the additional request has been made to the Water Committee.

D.6 Irrigation infrastructure

The general information on canal systems and collector-drainage systems was obtained from the South Kazakhstan Hydrogeology and Melioration Expedition under the CWR. Specific information was provided regarding the Kyzykum canal use. Data on the general condition (depreciation level) of some infrastructure elements were provided; however, no CAPEX and OPEX were specified (these data is pending additional data request; alternatively, the comparative review from the IDIP-2 feasibility study may be used to assess the situation). The available data include irrigation methods by area and efficiency associated with their use.

D.7 Water users

As mentioned above the data on water consumption in each irrigation system of South Kazakhstan region is available for analysis; however, no specification by irrigation zone is given in Kyrgyz region.
Fishery needs in total are specified as separate component in water balance. However, more detailed (by agricultural zone) information per water intakes for fishery needs has been requested for Kyzylorda region.

Environmental needs in total are specified as separate component in water balance. However, more detailed data on water intakes (by agricultural zone) for environmental needs has been requested for Kyzylorda region. Certain assumptions have been made following information obtained about the availability of lakes due to drainage-collector systems.

Regarding water supply data for drinking purposes and industrial sector in South Kazakhstan region: the majority of urban and rural settlements use groundwater. The relevant data request was made to Energy and Utilities Department within the Akimat of South Kazakhstan region (it is responsible for some rayons) to complete the mapping of water supply sources and consumption (Yuzhvodstroi responsible for group water pipelines provided the data for 6 rayons).

The data for water users in Kyzylorda regions has not been provided till date.
An ©ñss E  Ì©ödël Ðíëññíë

This annëx provides a brief description of the model, tentatively named WHAT-IF (Water, Hydropower and Agriculture – Ímpact and Feaisible), which it is proposed to apply on this ññject.

E.1  Ërief överview

Target

The model calculates economic welfare as the sum of ññsumer and producer surplus under a Marshallian demand function. The model's objective function is the maximisation of this economic welfare.

Scope

The model is a bottom-up technical/economical optimisation model, which simulates the ñ defenses of various stakeholders in a river basin. Broadly speaking there are three types of model decision variables:

› Land use and crop choices: The farmers must decide which crops to plant on which irrigated areas

› Reservoir management: Monthly discharges must be decided in order to balance the need for irrigation water with the need for hydropower

› Irrigation choices: The crops planted must be irrigated with whatever water there is available, possibly less than their optimal evapotranspiration, leading to reduced crop yields

Model principles

The optimisation happens subject to a number of constraints, which mimics real world limitations in physical responses. For instance, crop production is a function of land and water used, hydropower produced depends on the water level in the reservoir, the modelled flow of water must obey a mass balance restriction etc.

Key assumptions and sensitivity analyses

The limitations in physical responses are guided by data on agriculture, hydrology, energy, environment and other water use. Selected pieces of data are supplemented by scenario assumptions chosen by the model user. These reflects various possible actions available to the decision makers, e.g. investments in new infrastructure, changed taxation or operation of various facilities. Scenario assumptions can also be other circumstances, e.g. climate change. Sensitivity analysis with systematic variation to critical assumptions are performed by production additional scenarios.

Goal function and constraints

The objective function is enclosed in the model's welfare module. The objective function counts the economic welfare of the various economic activities described by the model. The objective function works together with a number of constraints that limit the choices regarding the decision variables (e.g. you cannot use more water than you have). The constraints are organised in modules:

› Hydrological mass balance module: Flow of water through rivers and reservoirs respecting flow constraints of the user defined river system
› **Agricultural module:** Farmers’ optimization of which crops to grow and how much water to apply given constraints on water and land use

› **Energy module:** Energy production by hydro power stations, optimization of the timing of reservoir discharge choice, and the economic value of the energy measured as the costs of the thermal energy production it replaces

Each of these modules are implemented in a numerical optimization model as constraints to a maximization problem. As the optimization problem is solved with respect to all constraints, the model will account for an integrated solution taking into consideration all effects modelled.

**Fiscal impacts**

As part of reporting fiscal impacts are separately accounted for. Accounting is made for all relevant taxes, subsidies, as well as profits/losses in public and semi-public companies providing energy and water infrastructure services. Hence, investments and change of service levels in MPWIs are accounted for.

**Overview**

The chart below illustrates the interactions of the various parts of the model.

*Chart E-1  Overview of the model*

Source: COWI.
### E.2 Model Design and Operations

#### Capabilities and application
The model is applicable to economic and financial analysis of an MPWI and its contribution to economy and to the water, food and energy security, i.e. weighing costs and benefits of water use in different sectors, as well as simulating how actions, changed policies, and new investments within one sector affects both that sector as well as other sectors.

#### Architecture and algorithms
The model is a bottom-up optimization model accounting for carefully selected technical and economic/financial details within agriculture, hydrology and energy. The economic welfare is defined as the sum of consumer and producer surplus for energy and agricultural markets under a Marshallian demand function. The model can thus be labelled as a partial equilibrium model with a sophisticated description of hydrology and agricultural and energy production.

#### Adaptability
Furthermore, the model user have a high degree of detailed control with the objective function. Among other things, the user can design scenarios such that only agricultural surplus is counted, while energy surplus is not counted. Such a scenario would give a result that illustrates what happens when energy considerations are not taken into account. Conversely, agricultural surplus can be ignored and only energy surplus could be optimised. Such a scenario would show the effects of ignoring agriculture in the reservoir discharge decisions. It is also possible to assign different weights to agriculture and energy, thus making various mixes of consideration to each sector.

#### Computing requirements
The model will run very well on any decently modern standard pc, e.g. on a Pentium i3 the model will solve typically within 10 to 60 seconds, depending on problem size and other technical considerations. Faster equipment will speed up the process further. The memory requirements are negligible compared to modern equipment (i.e. below 50-100MB RAM).

#### Data needs
Compared to e.g. hydrological models, this model relies on a relatively sparse data set. A river might be split into only a few sections (e.g. 5), and agriculture is represented by agricultural planning zones (e.g. around 5) with a limited number of crops (e.g. 5-10). Water flows are accounted for on a monthly basis for only a few representative year (e.g. "dry", "normal" and "wet").

#### Plug-and-play capability
The model will run more or less out-of-the-box, provided that the user has a working version of the numerical simulation software tool GAMS installed. Also, MS Excel and MS Access installations are required for the model to function. The model is provided as a zip-file and can be placed anywhere on the user's pc.

### E.3 User interface

#### Input data
The model input data is entered into a MS Excel spreadsheet containing 10-15 tables depending on the delineation and scope of the model. Typically, each table has 10-15 rows and 10-15 columns (that is tables with input data are quite observable and manageable). Typically, these tables will initially be filled out by the Consultant, but then can be inspected and changed by any model user.
### Scenario assumptions
Additionally, scenario assumptions are entered into another MS Excel spreadsheet also containing 10-15 tables with additional assumptions. These sheets typically contain rather simple information, such as economic and financial rates of return, assumed sensitivities for various prices, user financing, investment policies, reservoir operation behaviour etc.

### Assumptions organised as "policies"
All the assumptions are organised in so-called "policies". These could be e.g. baseline and alternative policies for investments in canals, reservoirs, irrigation equipment etc.

### Scenarios combine policies
The scenarios are defined by the user as combinations of various policies. The definition of scenarios can be done using a graphical user interface in the MS Excel sheet. The interface contains various drop down menus for policy selection, as well as various buttons for running simulations, and creating, copying and deleting scenarios.

### Summarised and thematic result sheets
The results are presented in a third spreadsheet. The main findings are summarised in an overview fact sheet containing a few tables and charts showing the most important results. Additionally, around 10 thematic sheets gives a more detailed presentation of the various themes, such as water flows, energy production, agriculture, reservoirs etc.

### Scenarios presented in storyline
In the result spreadsheet, the scenarios are presented in so-called storylines as described in Chapter 2.

### Model result as indicators
The storylines is used for all indicators presenting model results. Indicators are e.g. change in economic welfare, energy and agricultural production, water use and water efficiency etc. Because of the storyline concept, it is also rather straightforward to compare developments in different indicators along the implementation of the storylines different policies.

### E.4 Accessibility
One important consideration of the modelling efforts in this project is that the methodology, calculations and data should be accessible and reproducible for any interested party. It is the hope that this will enhance the participation of both key and minor stakeholders, during and after project implementation, thereby enhancing understanding of this type of analysis and its results. In order to achieve this, the model, its input data, assumptions made and model results should be as freely accessible as possible.

### Key users
Envisaged key users are Ministry of Agriculture, CWR and Kazvodkhoz, other ministries, universities and research institutes.

### Open source model ownership
The model consist of the input, scenario and result spreadsheet as well as around 15 plain text files containing the GAMS code for the model. All these files are...
provided on an Open Source basis using the GNU General Public License (GPL) version 3.0.  

No restrictions on use, modification or redistribution …

This means that any author of model code or modification owns his/her own contribution, but that no restrictions can be placed on use, modification and distribution of either model nor modifications. It is required that modifications are also distributed under the GNU GPL 3.0 license. This will ensure that the model in any of its versions will remain Open Source, and that no party can restrict the use, modification and redistribution of the model.

… but private changes can still be kept private

It is – however – not required that modifications are published and distributed. In other words, if someone wants to keep his/her modifications private this is permitted by the license. The license only requires that if the model or modifications are distributed, the distributor cannot restrict the receiver’s use, modification or re-distribution of modifications of the model. However, once the changes to the model are distributed to other parties, they are also to be considered Open Source.

Data ownership

Most of the data to be used in the model are likely to be owned by various government agencies and other parties. Since the model is not very useful without data, it is important for the accessibility that the used data can be distributed to stakeholders and other interested parties. In order to distribute the data alongside with the model, data distribution permission must be granted by the data owners.

Public domain data

In many cases, the data has been placed in the public domain (e.g. on a website), and in this case the data can be freely redistributed alongside with the model, typically by quoting the website precisely, and by indicating any changes made to the data. The data providers will typically have some sort of redistribution policy, which this project will have to comply to.

Private data

In other cases, the best available data may be owned by organisations that e.g. sell the data for profit or for other reasons cannot share the data. If it is not possible to get permission from the data owners to freely redistribute the data, other paths must be sought. Possibly, redistribution may be permissible if the data is aggregated or transformed in other ways. If it is not possible to get permission for redistribution, the data simply cannot be used in this project without jeopardising the accessibility of the project. In this case, it is preferable to use own assumptions based on the best freely available data.

Assumption ownership

The assumptions are a part of the works delivered by the Consultant to the Client and is as such owned by the Client. To further the accessibility of the analyses, the Client can choose to distribute the assumptions (i.e. the scenario spreadsheet

---

9 http://www.gnu.org/licenses/gpl-3.0.html

10 The delineation – or scope of intellectual property rights (IPR) – between the model (which also include the input, scenario and output spreadsheets) and its data and assumptions are clearly marked inside the spreadsheets using various formatting. Generally, "formulas" are considered as "model", while "raw numbers" are considered as "data". The model spreadsheets also include meta information tables for describing data IPR.
data) as placed in the public domain, with a Creative Commons license\textsuperscript{11}, or similar.

**Result ownership**

As with the assumptions, the results (i.e. the data inside the result spreadsheet) are also a part of the works delivered from the Project team to the Client. Since the results can be calculated by using the model, input data and assumptions, it is not strictly necessary for maximum accessibility that the results are placed in the public domain or similar. If not placed in the public domain, it can be adequate to license the results data with no restrictions on redistribution, but with restrictions on modification and quoting, e.g. a Creative Commons license with a "No-derivative" clause.

**E.5 Other administrative issues**

**Initial and operational costs**

The model itself has no initial nor operational costs. As Open Source it is provided free of charge. The same goes for the selected dataset and assumptions, which are to be provided under permissive and cost-free license terms.

**License costs**

The main part of the model is coded in the GAMS numerical programming and optimization language. The data and results are kept in MS Access and MS Excel. To run do simulations with the model, the user will need a license for the GAMS system, as well as for MS Excel and MS Access. The GAMS license costs are 3,200 USD for a base system and 3,200 USD for an appropriate solver (the non-linear solvers CONOPT, MINOS5 and IPOPT have previously been confirmed to work with the model). The GAMS license\textsuperscript{12} is perpetual, but as a point of departure it is attached to a specific person. Costs for MS Excel and MS Access may vary depending on the user's country.

**Server location/costs**

Previous experiences has shown that it is possible to place a version of the model on a server connected to the Internet and let users create run scenarios on this server, and download the result spreadsheets. This option is not included in the present project.

\textsuperscript{11} https://creativecommons.org/licenses/
\textsuperscript{12} https://www.gams.com/sales/commercialp.pdf
Annex F  Case Studies, Example
**Hirakud Lake**

**Owners, including asset ownership:** Government of Odisha State

**Physical characteristics (volume, surface area, residence time, etc.)**
- **Volume:** 8,141 MCM (original) / 5,896 MCM (revised in 2000)
- **Surface Area:** 500.7 km² / 743 km²
- **Residence Time** (Average length of time water stay in a reservoir): 23.1 %
- **National Water Security index:** 1,618 (m³/inhab/year)
- **Climatic condition:** Tropical wet
- **Transboundary users:** not applicable (n.a)

**Key water uses:**

<table>
<thead>
<tr>
<th><strong>Irrigation:</strong></th>
<th><strong>Hydropower:</strong></th>
<th><strong>Flood &amp; drought risk management:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The project provides 1,556 km² of kharif (monsoon) and 1,084 km² of rabi (spring) irrigation in districts of Sambalpur, Bargarh, Bolangir, and Subarnpur in the state of Orrisa.</td>
<td>The dam has a capacity to generate up to 307.5 MW of electrical power through its two power plants. Power House I is located at the base (toe) of the main dam section and contains 3 x 37.5 MW Kaplan turbine and 2 x 24 MW Francis turbine generators with a total installed capacity of 259.5 MW. Power Station II is located 19 km (12 mi) southeast of the dam at Chipilima. It contains 3 x 24 MW generators.</td>
<td>The construction of the dam has alleviated periodic droughts in the upper drainage basin of Mahanadi River as well as flooding in the lower delta regions which subjected in crop damage. The dam controls flooding of Mahanadi delta by regulating 83,400 km² of Mahanadi drainage. Provides flood protection to 9500 km² of delta area in districts of Cuttack and Puri.</td>
</tr>
</tbody>
</table>
**Goods and services provided**
- Irrigation water supply
- Hydropower generation
- Flood protection
- Water & electricity for the downstream industries (Paper mills, Drinking water, Aluminium, Rice mills, cement production, sugar mills)

**Stakeholders**\(^6\):

<table>
<thead>
<tr>
<th>Primary users</th>
<th>Agricultural Department</th>
<th>Alliances</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Big farmers</td>
<td>- Agricultural Technology Management Agency (ATMA)</td>
<td>- Farmers Union</td>
</tr>
<tr>
<td>- Small farmers</td>
<td>- Soil testing laboratory, Sambalpur</td>
<td>- Civil society</td>
</tr>
<tr>
<td>- Marginal farmers</td>
<td>- Organic farming unit</td>
<td>- Citizen forums</td>
</tr>
<tr>
<td>- Agricultural laborers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Youth and women (farm and industrial workers)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State agencies dealing with water</td>
<td><strong>Panchayati Raj &amp; Representatives</strong></td>
<td><strong>Academicians &amp; Environmentalists</strong></td>
</tr>
<tr>
<td>- Water Resources Department</td>
<td>- Panchayati Raj Institutions (for village level governance and conflict resolution)</td>
<td>- Individuals</td>
</tr>
<tr>
<td>- Irrigation Administration</td>
<td></td>
<td><strong>Media</strong></td>
</tr>
<tr>
<td>- Command Area Development Agency</td>
<td></td>
<td>- Print and audio-visual media</td>
</tr>
<tr>
<td>- Pani Panchayats (Water Users Associations(WUA) to manage irrigation water)</td>
<td>- Fishermen</td>
<td></td>
</tr>
<tr>
<td>- Soil Conservation Department</td>
<td>- Fishing co-operatives</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>- Fishermen</td>
<td></td>
</tr>
<tr>
<td><strong>Industries</strong></td>
<td>- Companies</td>
<td></td>
</tr>
</tbody>
</table>

**Brief history**

Since 1868 there have been as many as 39 floods in the Mahanadi Delta as well as significant periodic droughts in the upstream of Mahanadi \(^2\). Such floods and droughts necessarily caused insecurity to humane life and property and had a demoralising effect on the inhabitants and shatter their enthusiasm to improve the land \(^2\). The dam was constructed to address the issues of floods in the Mahanadi delta and to benefit from controlling the Mahanadi for multi-purpose use. The work started on 15\(^{th}\) March 1946 and was ended on 13th January 1957. Power generation along with agricultural irrigation has started in 1956, achieving full potential in 1966 \(^1\). The Hirakud dam & reservoir has been viewed as a symbol of India’s postindependence developmentalism.

**Business model, including cost recovery**\(^6\)

The total capital cost of the project is Rs. 1000.2 million (in 1957). The cost recovery was not specified at the beginning of the commissioning of the reservoir. The focus was on benefiting the downstream communities while protecting the Mahanadi coastal communities from flooding. However, several policies have been implemented to streamline the utilization of the Hirakud reservoir.

Until 1990, water utilisation from the dam was mainly for hydropower generation and irrigation. Industrial water use was minimal during that period. Hydropower generation was prioritised. Since flood control was the major purpose of the project. A rule curve
committee in 1988 was appointed to lower the water level of the reservoir during the monsoon period as near to the dead storage level as possible for flood control.

After 1990 there had been new water policies which set new priorities for water use for different sectors.

- River Board Act, 1956
- State Water Policy, 1994
- The Orissa Pani Panchayat Act and Rule, 2002
- State Water Plan, 2004
- Pani Panchayat Act, 2005
- The State Water Policy, 2007

These acts notify the management strategies and tariffs to be paid to the government for the utilization of Hirakud reservoir and its water. The Odisha State Water Policy, 2007 has set priorities for water allocation with drinking water being the first, followed by environment, irrigation, and power, with the industry being accorded the fifth priority. In 2004, a new reservoir fishing policy was developed by the state, which increased the leasing tariff and brought in provisions.

**Key challenges**

- Overcoming the substantial mass agitation, anti-Hirakud dam campaign which started in 1945 when the construction decision of the dam was announced[2] The progress of the project has been far behind the schedule during construction phase which has resulted in enhanced capital cost, interest charges, and delayed returns. [2]
- Developing compensation strategies for the displacement of village communities. [2]
- The conflict between the farmers in the Hirakud command and the Government of Odisha over the allocation of water from the reservoir to industries. [6]
- The limited storage of the reservoir in relation to the size of its catchment has substantial effects of Hirakud’s flood control objectives to the reservoir water allocation [6]
- Conflict between industries and agricultural community regarding the water allocation strategies [6]
- The hydrologic impact of climate change is likely to result in decreasing performance and annual hydropower generation for the Hirakud reservoir. Mean monthly storages are likely to decrease in future scenarios. In many scenarios for 2075-95, the reservoir is unable to get filled by the end of the monsoon in October [6]
- High silt flows into the Hirakud reservoir due to the considerable deforestation in the upper catchment area. [6]
- Over half a century after the construction of the dam, its catchment, reservoir, and command have undergone considerable economic and ecological changes. These changes have significantly affected water use and availability, both in terms of quality and quantity, as well as inflows into and outflows from the dam. [6]
- Illegal fishing has lead to the overexploitation of fish resource in the reservoir [6]
- Direct flow of polluted water from upstream due to industrial effluent degrades the water quality of the reservoir [6]
- Navigation in the reservoir which was an initial objective has still not materialized [6]

**Positive externalities**

- The dam is the longest earthen dam and the reservoir is one of the largest artificial
STRENGTHENING THE ROLE OF MULTI-PURPOSE WATER INFRASTRUCTURE

- Sufficient supply of water from reservoir for the drinking and sanitation purposes
- The reservoir is a destination for migratory birds from Caspian Sea, Lake Baikal, Aral Sea, Mongolia, Central and South East Asia and Himalaya region
- The water released by the power plant irrigates another 4360 km² of culturable command area in Mahanadi delta
- Hirakud reservoir comprises of a fishery with an annual average yield of 6.6 kg/ha (151.54 MT in 2004/05). Where the fish catch comprise of 40 commercial fish species with a 239 kg catch per unit effort (CPUE).

**Negative externalities**

- The construction of the dam has affected 249 villages, 22,144 families which of significant individuals were displaced which has resulted in severe livelihood crises, health hazards, and diseases made them victims in their initial period of self-resettlement
- The rates of compensation were much less than the market value
- It is argued that the Hirakud dam has submerged more lands and displaced more people than estimated in the feasibility report
- The electricity generation from the dam is only 62.24 % of the original claims
- Irrigation lands are 55.85 % from the initially targeted irrigation lands
- Most post-Hirakud floods have been attributed to the mismanagement of reservoir operations
- With the growing number of industries after the reservoir commissioning, the concentration of contaminants, especially mercury, chlorine, fluoride, and fly ash in the reservoir water has also increased, affecting the fish diversity and catch significantly
- The reduced inflow, increase in uptake by industries from specific locations, increasing siltation and changing spatial spread with seasons.
- Poor water allocation strategies and regular canal repairing processes results in shortages of irrigation water time to time
- Insufficient environmental flow

**Specific regulations**

Since the main objective of the Hirakud dam was flood control, whereas irrigation and hydropower generation were secondary. To make the reservoir a more economical one, the dam planners designed it as a multipurpose project which would provide other benefits.

To meet multiple needs, it is required to keep the water level in the reservoir as low as possible in the monsoons so that flood water could be stored and discharged in a regulated manner. Also, the dam would have to be filled to its Full Reservoir Level (FRL) by the end of the monsoon so as to provide water for irrigation, drinking, and hydropower generation.

For managing reservoir operations throughout the year to control floods and assure the availability of water in the reservoir at the end of the monsoon for other purposes, a rule curve committee is responsible for raising and lowering reservoir levels in specific periods.

**Future plans**

- Underwater scans have been conducted at Hirakud Reservoir to quantify and analyze the crack in the dam in order to continue with treatments for the cracks.
- Discussions are ongoing to commission a specific study on the overall evaluation of the performance of the Hirakud project, it's socioeconomic and environmental impacts.
There are plans to systematically revisit the decisions made during reforming displaced communities, consult all relevant stakeholders through a multi-stakeholder consultation, review earlier decisions and their implementation, keeping equity and justice at par if not above economic and efficiency considerations. [6]

Sources
5. http://www.newindianexpress.com/states/odisha/2nd-Phase-Hirakud-Dam-Scanning-Begins/2016/03/20/article3336765.ece
7. GRAND Database