AGRICULTURE RECONSTRUCTION AND DEVELOPMENT PROGRAM FOR IRAQ

STRATEGY FOR WATER AND LAND RESOURCES IN IRAQ
Phase 1 Project Completion Report
Volume 3 - Annexes 1 - 15

October 2006

This publication was produced for review by the United States Agency for International Development. It was prepared by Development Alternatives, Inc.

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Annex 1 - Review of Phase 1 Data Sets

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List of Contents

Page

Preface P-1

Chapters and Appendices

1 Introduction 1-1
- 1.1 Structure of this Annex 1-1
- 1.2 Identifying What Data is Needed for Planning Studies 1-3
  - 1.2.1 The 'Facts' Data Sets 1-3
  - 1.2.2 Data on Needs 1-3
  - 1.2.3 Information on Opportunities 1-4
- 1.3 Data Collection 1-4
  - 1.3.1 Approach 1-4
  - 1.3.2 Claromentis 1-5

2 Data Compilation and Checking 2-1
- 2.1 The Data Repository 2-1
- 2.2 Generic Quality Control Procedures 2-1

3 Data Assessments 3-1
- 3.1 Introduction 3-1
- 3.2 Topic Areas Subject to Limited Review 3-1
  - 3.2.1 Water Control Infrastructure 3-1
  - 3.2.2 Meteorological Information 3-1
  - 3.2.3 River Flow and Reservoir Operation Data 3-2
  - 3.2.4 Population Statistics 3-2
  - 3.2.5 Environmental Information 3-2

4 Agriculture and Irrigation 4-1
- 4.1 General 4-1
- 4.2 Summary of information received from the Ministry of Agriculture: 4-1
- 4.3 Further Information Requested 4-2
  - 4.3.1 General 4-2
  - 4.3.2 For Each Major Irrigation Scheme 4-2

5 Groundwater 5-1
- 5.1 Introduction 5-1
- 5.2 Data Received 5-1
  - 5.2.1 Ministry of Water Resources (Baghdad) Data 5-1
  - 5.2.2 Sulaymaniyah Governorate Data 5-3
  - 5.2.3 Erbil Governorate Data 5-4
  - 5.2.4 Other Sources 5-5
- 5.3 Further Data Requirements 5-5

Preliminary

5.3.1 Where is groundwater used? 5-5
5.3.2 What is groundwater used for? 5-6
5.3.3 Planning new wells 5-6
5.3.4 Record keeping 5-6
5.3.5 Groundwater level monitoring 5-7
5.3.6 Problems with the wells 5-7
5.3.7 Recharge estimation 5-8
5.3.8 Other information required 5-8

6 Water Supply Information 6-1

6.1 Existing Municipal Water Supplies (Information and Data) 6-1
6.1.1 Data from the Ministry of Municipalities and Public Works 6-1
6.1.2 Mini Master Plans 6-1
6.1.3 New Eden Project Information 6-3
6.1.4 Information from the Reconstruction Project in Southern Iraq 6-3
6.1.5 Analysis of Data 6-4
6.1.6 Industrial Water Supplies 6-6
6.1.7 Existing Wastewater Collection and Treatment Facilities 6-6

6.2 Further Information Needs 6-7
6.2.1 General information 6-7
6.2.2 Existing Water Supply Systems 6-7
6.2.3 Present Consumption Data 6-8
6.2.4 Industrial Water Supplies 6-8
6.2.5 Water Quality 6-9
6.2.6 Wastewater 6-9

7 Hydropower Information 7-1

7.1 Data Received 7-1

7.2 Further Data Requested 7-1

8 Water Quality and Pollution Information 8-1

8.1 Surface Water Quality Data 8-1

8.2 Groundwater Quality Data 8-3

9 Opportunities Data 9-1

9.1 Information Received 9-1

9.2 Further Information Required 9-1

10 Recommendations 10-1

10.1 Data Sharing Arrangements 10-1

10.2 Quality Control of Data 10-1

10.3 Further Data to be Collected 10-1

Appendix A Original Data Request A-1

Appendix B Record of Discussions with the Groundwater Studies Centre B-1

Preliminary

Figure 1.1: SWLRI Planning Approach 1-2
Figure 2.1: Generic Quality Control Process 2-3
Figure 9.1: Sample List of Potential Projects from the MoWR Web Site 9-3

Table 1.1: Where to Find Information in this Annex 1-1
Table 1.2:Status of Documents of Claromentis (end September 2006) 1-5
Table 5.1: Well Cards by Governorate 5-2
Table 6.1: Planning Criteria for Basrah Demand Forecast 6-2
Table 6.2: Suggested Long Term Planning Criteria 6-4
Table 6.3: Summary of Data on Existing Water Supplies 6-5
Table 6.4: Sewage Treatment Plants in Four Southern Governorate 6-7
Table 8.1: Availability of Water Quality Data Series for River Monitoring Points 8-2

Preliminary

Preface

This Annex contains an incomplete data review reflecting the status of the preparation of the Phase 1 Completion Report at mid August 2006 when the project was put on hold.

The status of hydrometric data for the rivers of Iraq and operational data for the major hydraulic control structures is the subject of a separate annex: Annex 17.

Preliminary

1 Introduction

1.1 Structure of this Annex

Data collection and review has been one of the major activities in Phase 1. The present Annex briefly recapitulates the approach to this important activity and then describes the status of data collection, identifies outstanding data, and discusses the quality of the information received.

Figure 1.1 shows the overall planning approach adopted for the SWLRI project to emphasise the initial data collection, and to highlight that the development and testing of models and analytical tools and the comparison of alternative interventions were both expected to lead to further information needs.

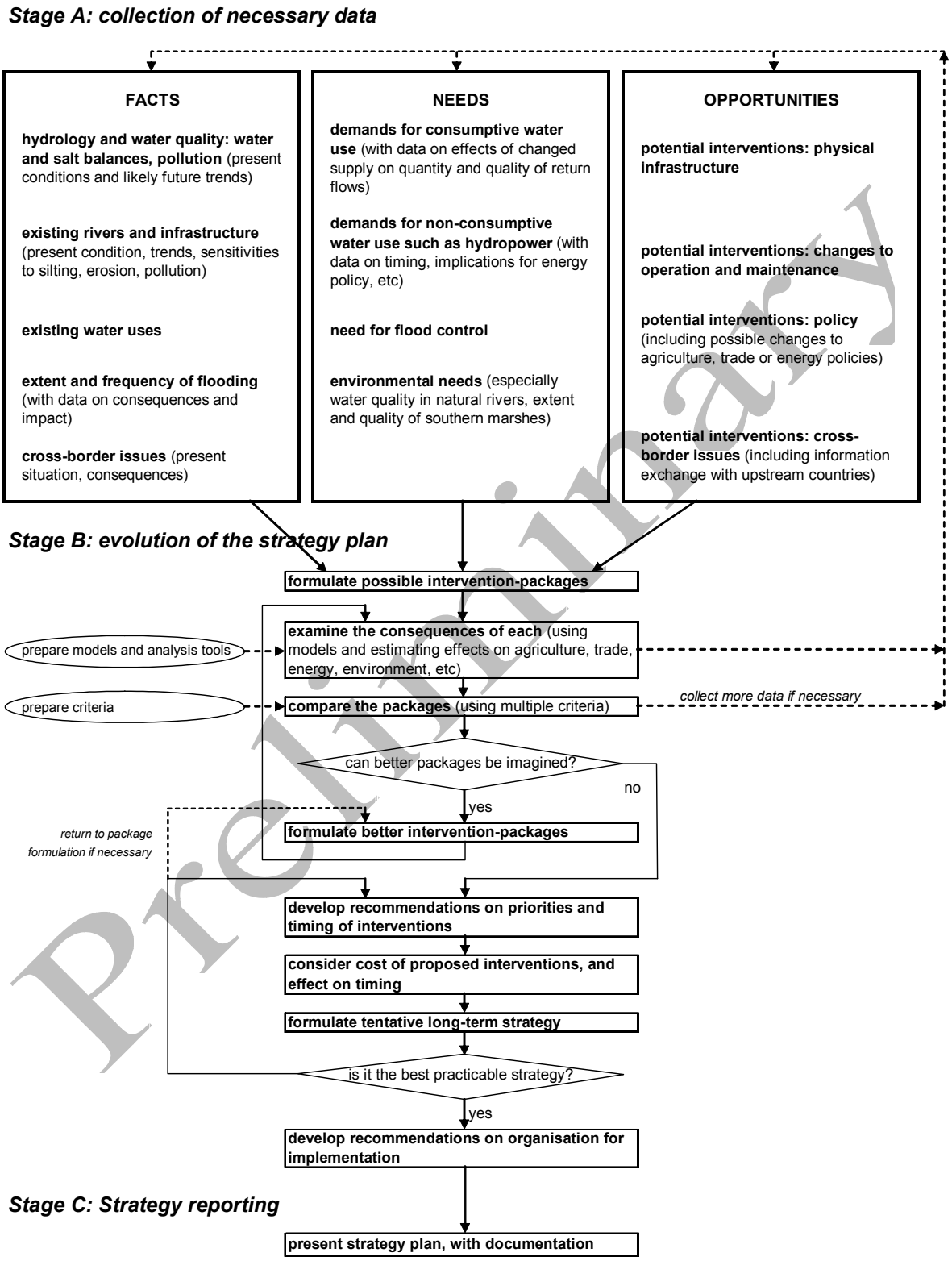
Table 1.1 provides some guidance on where to find material in this Annex. It should be noted that further data assessment is reported in Annex 17.

Table 1.1: Where to Find Information in this Annex

Subject	Location
Data requested from the ministries	Sections 1.2 and Appendix A, Sections 4 - 9
Data repository on Claromentis	Section 2.1
Quality control procedures	Section 2.2
Meteorological data	Section 3.2.2
River Flow data	Section 3.2.3 and ANNEX 17
Water flow in canals and drains	Section 3 and Section 4.3
Major hydraulic infrastructure	Section 3.2 and ANNEX 17
Agricultural information including water use	Section 4
Groundwater information	Section 5
Population	Section 3.2.4
Environmental information	Section 3.2.5
Water supply and sanitation information	Section 6
Water quality and pollution information	Section 8
Hydropower information	Section 7
Opportunities (potential projects)	Section 9
Recommendations	Section 10

Preliminary

Figure 1.1: SWLRI Planning Approach



Preliminary

1.2 Identifying What Data is Needed for Planning Studies

There are several types of information that need to be compiled to provide the basis for strategic planning of water and land resources:

1. **Inventories** which list and map the location of physical infrastructure (dams, boreholes, canals, drains, pumping stations etc), and monitoring points. The inventories should be 'live' and reflect the number and status of facilities in the country as they are now, and in some cases as they were in the past.

2. **Time series records** of river, canal and drain flows, water quality, population details, agricultural production statistics etc. These should be regularly updated at a frequency to suit the type of data.

3. **Areal features** of the natural environment and anthropogenic activities (soil type, forestry, land classification, population distribution, cropping patterns, urban areas, seasonal flooding, salinisation, etc). When linked to remote sensing and to GIS areal information can be obtained and presented in many ways that contribute to the strategic planning process.

4. The **planning framework**. Details of national aspirations as expressed in government policies and legislation that provide the context for strategic planning for the water and agriculture sectors. Included in this are the policies and plans for other sectors (energy, health, trade etc) that are linked directly or indirectly to the water and agriculture sectors. The water sector cannot be considered in isolation and up to date information on the activities in other sectors will be needed.

5. **External pressures**: economic status and relations, migration, international relations, climate change, international commodity prices, etc.

The following sections discuss the requirements in relation to the three data sets referred to in Figure 1.1: facts, needs, and opportunities.

1.2.1 The 'Facts' Data Sets

All the data types and examples listed above are associated with the 'facts' data. The General Scheme reports provided guidance as to what should be collected in order to support the planning process. The consultants prepared a preliminary list of the required data to describe the baseline situation in terms of natural and man made elements. This list is reproduced in Appendix A. In addition ministries were asked to update various tables from the General Scheme – this particularly applied to agricultural data. Throughout the need for geo-referenced data was emphasised so that the maximum use could be made of GIS and mapping tools.

1.2.2 Data on Needs

Needs data is more likely to be synthesised than measured so that compilation of this data set is more a matter of analysis of other data than the collection of actual records.

Preliminary

Consumptive water uses (for agriculture, industry, or potable water) are not generally monitored with sufficient frequency or accuracy to make the data very practical for planning studies. In particular, records where available are usually for bulk abstraction and can be very difficult or impossible to disaggregate. Therefore the needs data is typically built up using standard procedures and aggregated to give the estimated bulk demand. This process calls for other data from the 'facts' category. For example in order to estimate irrigation water requirements for a whole scheme it is necessary to know what crops are being or are to be grown and over what area, the planting and harvesting dates, design meteorological conditions, land preparation requirements, and irrigation efficiency allowances etc. If the estimate is for a future planning horizon then the cropping pattern, the land preparation requirements and the irrigation efficiency could all be different depending on government policies, and projected changes in the socio-economic situation.

1.2.3 Information on Opportunities

Opportunities represent possible actions or interventions for MoWR and other ministries to budget and programme for, and to implement in the short, medium or long term horizons. They represent potential calls on the national budget in the near and longer term and as such need to be prioritised for the water and agriculture sectors as a whole. Opportunities cover an exceedingly wide range of possibilities from new studies to actual construction, from policy change to capacity building and training, etc.

It has been agreed to use a main planning horizon of 30 years, with greater detail for the next 5 years and some strategic consideration of the longer outlook beyond 30 years. The planning process is designed to be periodically updated in a rolling manner, for instance every 3 to 5 years.

1.3 Data Collection

1.3.1 Approach

The Phase 1 Scope of Work described the intended approach to the data collection activity:

'The consultants will rely on the Iraqi ministries and other institutions for nearly all data collection work. Much of the necessary data is already available on paper or in electronic form, and the institutions will need to make staff time available to find it, collect it, collate it in convenient form, and transmit it to the team members abroad. Counterpart staff assigned to this work will need not only time but also the necessary authority to obtain data from people and offices that keep it; they will thus need strong support from senior levels in the ministries.'

'Information will be entered into electronic files of appropriate format by the data collectors wherever possible, and where this is not practicable it will be sent on paper to the analysts for entry into data files.'

Preliminary

The data collection exercise started with a long list of typical data required for strategic planning and a large number of data proforma developed by the consultants. Each ministry was provided with a copy of the General Scheme Stage 2 report on CD so that they could see what data had been presented and how it had been used in the development of the strategy that was described in the report. It was made clear during discussions with ministry staff that the SWLRI project was initially seeking the same type of data as had been collated and presented in the General Scheme Stage 2 report in order to undertake a similar strategy development study. The feedback loop where the exercise of developing and testing models and analytical tools identifies new data requirements to be met (see Figure 1.1) was also emphasised from the start.

Monthly data collection meetings were held to provide an update on progress. In September 2005 each ministry nominated a Data Collection Leader who was given the responsibility for providing the link point between his ministry and the consultants team.

1.3.2 Claromentis

At an early stage in the project it was decided that a web-based collaboration system was essential to the proposed data collection activities, and would be a tool for helping to build strong links between the stakeholders and to provide opportunities for other ministries to benefit from the project's activities.

Claromentis, was selected to act as the project data repository and email system. To encourage participation and eventual data sharing Claromentis has been designed to give each ministry a secure extranet area which has been customised for them. In this area set aside for them each ministry is able to manage its own data.

At the end of Phase 1 there were over 13,000 items loaded onto the system (September 2006), the majority of which are items of data. The following table shows document quantity based on application type:

Table 1.2:Status of Documents of Claromentis (end September 2006)

Application type	Documents Quantity
Unknown Document Format	513
RAR-compressed Archive	2
ZIP-compressed Archive	193
Microsoft Word Document	505
Microsoft Excel Document	2652
HTML (HyperText Markup Language)	55
CompuServe Bitmap Image	1
JPEG Image	9570
Text Document	11
Adobe PDF (Portable Document Format)	206

At the end of Phase 1 ARDI handed over the role of Claromentis Administrator to an IT specialist from MoWR and the hardware was transferred to Baghdad.

Preliminary

2 Data Compilation and Checking

2.1 The Data Repository

Most of the items submitted by the ministries to the SWLRI team were hard copy that subsequently had to be scanned, hence the preponderance of JPEG images in the Claromentis data repository (Table 1.2). The Phase 1 Scope of Work had envisaged that a much higher proportion of the data would be provided in digital format such as Microsoft Excel spreadsheets, tables in Microsoft Word or text files. As a consequence the ARDI team to support the data collection exercise was both expanded and kept in place for considerably longer than originally anticipated to cope with the workload of scanning and uploading images. The scanned image format, while useful for storing information, does not allow the data to be analysed directly.

Given the security problems that have affected the country the simple fact of creating an electronic record of such a large body of original paper data records is a very valuable precaution to safeguard the data. Therefore the ARDI team have scanned all material handed over to them by the ministries even when in some cases the material may not have been of immediate relevance to the SWLRI Unit.

The scanned data sheets have been uploaded to Claromentis either by the relevant ministry or by the ARDI team. The data has been reviewed remotely by other members of the ARDI team and comments, questions and further data requests have been passed back to the ministry Data Collection Leaders via email, occasional telephone conversations, and more importantly through the regular data collection meetings.

Many of the queries back to the ministries related to the lack of geo-reference information. In many cases it is necessary to know the location of sites where data has been recorded. This has generally been given as a description and grid references are required to make more effective use of this information.

Data was also requested and received from other project teams. Such data has not been subject to any further checking.

2.2 Generic Quality Control Procedures

The nature and extent of the quality control checking depends on the technical field. It was recognised that in the time frame of Phase 1 it would not be possible to complete full quality control on all the many data types required for strategic planning. However, procedures should be put in place to ensure that routine QC was established and standards were as high as possible.

In all cases the data must be finally signed off as ‘acceptable’ before it can be accepted as part of the strategy database. MoWR must have the final say in this as the principal end users. A staged approach to acceptance was proposed and was discussed at the January 2006 Steering Committee meeting. Some of the concepts, familiar to those with experience of working within Quality Assurance systems, such as keeping an ‘audit trail’ with individuals signing off their work were the subject of considerable debate. The conclusion was that introducing QA procedures identifying individuals would have to be a gradual process.

Preliminary

In reality it is highly desirable that QC of data should be undertaken by the ministry that is providing the data to the SWLRI Unit. For example, the Ministry of Municipalities and Public Works has experienced engineers who can, and should, review the data on water treatment works capacity and performance, and decide upon appropriate design criteria for consumption for different types of consumer. The SWLRI Unit does not have staff with the same experience and therefore should not be attempting to QC data without discussions with the data provider.

With this in mind a generic staged QC process is described below that can be adapted to suit the particular characteristics of the data under examination. For example, the QC procedures for hydrometric data (meteorological, river level and flow, groundwater level) are well established with specialised software to aid the process (HEC's DSS software) and so will differ from the QC procedures appropriate to checking agricultural crop statistics. The use of DSS, and the QC exercise on the hydrometric data that was used to develop the Tigris-Euphrates ResSim model, are fully described in Annex 17.

The generic QC process is outlined in Figure 2.1.

Preliminary

Figure 2.1: Generic Quality Control Process

Receipt of Incoming information
Who from?
What format is it in (spreadsheet, word, GIS layer, JPEG etc)?
Where is it stored on Claromentis?
If hard copy, where is it stored, and when does it have to be returned by?
Does it need scanning? All pages? If not all, identify which to be scanned.

NON-TECHNICAL CHECKING – Level 1
After scanning
Check all original pages have been scanned and are legible
Where is the scanned version stored on Claromentis? – this is now the original, 'raw' data

Conversion to digital format (by Optical Character Reader or typing in)
Check that the data entered matches the original
Where is the digital file stored on Claromentis? – if this matches the scanned version exactly it is also the original 'raw' data

TECHNICAL DATA CHECKING/REVIEW – Level 2
Initial review to identify suspicious data – *record suspicions in note form*

- Do the daily values sum to give the monthly value?
- Do the monthly values sum to give the annual value?
- Are units of measurement clear and any conversion factors correct?
- Plot graphs (if appropriate)
- Compare to previous years for same data
- Compare to any equivalent data received from another ministry or seen in a technical reference or report
- Pass the data and all checking records *plus your notes* to a senior officer for review

Senior review to advise on additional checks, or to correct any mistakes made in the checking process.
If suspicions remain: contact the originating ministry data collection leader, or directly to the department responsible for the data if known
Request them to QC the data set themselves (they should have internal procedures for QC and they also have the specialists for that particular data type who can give an expert opinion on the reliability of the data) – *check the digital file 'out' on Claromentis*
If they withdraw the data and reissue a corrected data set – *upload revised data file and Claromentis will record the version change. Add a note to the old file version to say why superseded*
If they confirm the data as reliable – SWLRI Unit must make a judgement
If they are unwilling to assist – SWLRI Unit must make a judgement

SWLRI UNIT ACTION
How important is this particular data set?
If needed for current work to progress – SWLRI Unit must adjust or revise the data
If not essential – *check the file back in on Claromentis unchanged and alter the meta field to record that the information is still under suspicion*

ADJUSTING OR REVISING THE DATA – Level 3
If the data is of a very specialised nature the SWLRI Unit should seek expert advice (within the MoWR, local experts, or consultants)
Otherwise the senior staff member will need to use their skill/experience to adjust or revise the data – *recording what changes were made and why*
Check the revised file onto Claromentis so that a new version is created and add a to the note field the reason for the changes and who made them and when.

Preliminary

3 Data Assessments

3.1 Introduction

The assessments described here review the collected data only in terms of their suitability for the needs of the SWLRI Unit for its planning activities. The descriptions are by field rather than by ministry because a number of data types are collected by more than just one ministry – water quality data is an example being collected by at least three ministries. Where the data is highly relevant to the development of the Tigris-Euphrates Water Management System Model the detailed review is presented in Annex 17.

Geo-referenced data was sought at the outset because of the ease with which erroneous data can be identified once it is plotted especially if plotted against a satellite image or topographic map background. It was apparent at an early stage that geo-reference (grid reference) information was rarely available and that there was a reluctance to share any available GIS information. The GIS strategy, discussed in Section 4.3 of the Main Report, took a different approach by providing training and other support to the GIS capabilities of individual ministries to geo-reference their own data and to be responsible for the quality control process.

3.2 Topic Areas Subject to Limited Review

These have been subject to only limited review for the following reasons:

- Fully described in Annex 17
- Data received from another project and therefore deemed to have already been reviewed
- Little data received to review

3.2.1 Water Control Infrastructure

Information describing the major water control infrastructure has been collated and checked by HEC and the MoWR in the course of developing the Tigris-Euphrates ResSim model (see Annex 17).

Information on the status of irrigation schemes is however incomplete. For example, no GIS layers of irrigation schemes and their associated control structures and pumping stations were available and the ARDI consultants have started the task of developing these essential maps for the MoWR GIS Section to complete – this will depend on obtaining geo-references for most of the structures. During the Study Visit in June 2006 the MoWR visitors attempted to improve upon the scheme status data sets and progress was made. This is an area where the SWLRI Unit need to press for complete data.

3.2.2 Meteorological Information

Most of the meteorological information obtained during Phase 1 was transferred from another ARDI component the AEZ (agro-ecological zones) pilot project with the Ministry of Agriculture. The data was not separately reviewed for SWLRI because it had already been assessed and accepted for use by the AEZ project.

Preliminary

3.2.3 River Flow and Reservoir Operation Data

HEC have carried out a comprehensive assessment of the available data in collaboration with staff of MoWR. This is reported in detail in Annex 17. Their assessment covered all the data types required to build and test the Tigris-Euphrates WMSM, but only for locations relevant to this model or the pilot ResPRM model of the Diyala basin.

3.2.4 Population Statistics

These were obtained as expected from several sources, many of which were consultants' reports. The SWLRI Unit should liaise with the Ministry of Planning and Development Cooperation to ensure that such parameters as estimated growth rates that SWLRI will be using are consistent with those used by MoPDC. The checking undertaken during Phase 1 of the data obtained has been limited to cross checking between sources, the national 10 yearly census being taken as the most reliable source.

Population and housing data has been received from the Ministry of Planning and Development Cooperation which includes the following:

- Total population for years 1957,1965 and 1970 to 2004
- Population broken down into total urban and total rural for each governorate for 1997 and 2004.
- Numbers of housing units and households broken down into urban and rural for 1997
- Numbers of housing units and households for each governorate for 1997.

Historic data indicates a past growth rate of about 3% per annum. Growth appears to have been fairly uniform. This rate of growth is used by the Ministry of Municipalities and Public Works to project future populations. The mini Master Plan for Basrah indicates that the Ministry of Planning projects future populations at a growth rate of 2.25% per annum to 2010 and 2.0% per annum thereafter.

3.2.5 Environmental Information

The main sources of information collected on environment in Iraq are UNEP, the Marsh Restoration Program and the New Eden Project. All of these have used experts from the local universities to provide material on habitats and species of interest. The future of the southern marshes is obviously a key issue for the strategic studies to be undertaken by the SWLRI Unit but there appears to be a considerable body of recent data from other projects to work from. Obtaining good data covering the period before the draining of the marshes is more problematic.

Dealing with the potential impacts of project opportunities put forward by the ministries (Section 9) will be an important task for both the Ministry of the Environment and for the SWLRI Unit. The ARDI team therefore discussed with the Ministry of Environment aspects of environmental legislation and procedures for assessing the potential impacts. The following series of questions were raised with the Ministry of the Environment to clarify these issues.

Preliminary

(i) Legislation

In order to understand the process for environmental management in both the development and operation of projects/facilities, it is necessary to understand the legal framework within which the Ministries are expected to operate. Although some standards have been identified for specific environmental parameters have been identified and uploaded into the Claromentis system, there is still a lack of clarity to us on the overall legislative framework.

Environmental Impact Assessment

In most countries there is a defined statutory Environmental Impact Assessment (EIA) process, which defines what projects require an EIA, what is expected contained within an EIA, responsibility for making decisions on the EIA process and a mechanism for making decisions on what is acceptable for new development projects.

Increasingly common is the requirement for Strategic Environmental Assessment, to incorporate environmental parameters into levels of planning which are higher than specific projects (e.g. development plans and long term programmes).

Based on discussions with delegates visiting the UK it appears that there is a process which involves environmental directorates within each governorate, however the details of this process are unclear, and it appears likely that this process will be reformed as the Ministry of Environment develops as an institution.

Questions:

1. Is there an existing formal process for the approval of projects, which takes into account environmental factors?
2. Are there any parameters for defining which projects/plans/programmes require an environmental assessment?
3. Is it possible to receive translated versions of any current legislation that addresses this process
4. Are the Ministry of Environment currently reviewing/developing such processes and if so is it possible to see their current drafts/thoughs on these processes?

Environmental Standards

In order to determine the significance of particular environmental impacts of proposed programmes of works and individual projects, it is necessary to understand the statutory requirements for particular environmental parameters. Some standards for water quality have been received, however it would be of great value to understand other limits set either by law or through other recognised standards (such as the World Health Organisation guidelines)

Preliminary

Questions:

1. For the following environmental parameters, how are acceptable limits defined for development projects?
    a. Protected areas (e.g. are there particular areas which are protected from environmental harm under national or international law – for example National Parks or Nature reserves)
    b. Protected Species (nationally and internationally)
    c. National monuments/archaeological features
    d. Water quality
    e. Noise
    f. Air Quality
    g. Soil Quality (e.g. soils of high agricultural value or limits for particular chemicals)
    h. Aesthetic quality (e.g. natural beauty)

Environmental Policy/Aspirations

In the case of the short term it is recognised that it may not be possible to address environmental impacts to the level which may be expected in many other countries, due to the urgent need and scale of reconstruction and rehabilitation required. In order for development proponents (such as the ministry of water resources) to set realistic targets for environmental management issues, it may be necessary to set short term environmental priorities and longer term environmental aspirations.

Questions:

1. Have any of any of the ministries created a set of environmental priorities which should be addressed in the short term?
2. Other than those identified for the short term, have longer term environmental aspirations been identified which should be considered in strategic planning?

(ii) Institutional Framework

Decision Makers

In order for the Environmental Assessment process to be effective (at both strategic and project levels) it is common for development proposals to be reviewed by a governing body in order to make a decision on the acceptability of the project.

Preliminary

Questions:

1. With a typical development project put forward by a ministry such as an irrigation project proposed by the Water Resources Ministry. What other bodies have influence on the decision to build the project?
2. Are environmental permits/approval required to begin construction and if so who issues such permits? (e.g. local authorities or national bodies)
3. If such permits/approvals are issued, are conditions attached to permits to set acceptable environmental limits for projects? (e.g. can be built as long as discharges to water contain less than a particular concentration of a chemical)

Regulators

Where environmental limits are set it is important to ensure that monitoring and measurement is carried out to determine if the limits are to be broken. It is assumed that the development proponent is ultimately responsible for this monitoring during construction and that the operator would be responsible in the longer term.

Questions:

1. Is the above assumption correct?
2. What agencies exist to regulate conditions applied to development projects?
3. Is auditing undertaken to determine if conditions are being met?
4. What actions are taken if conditions are not met?

Non Governmental Organisations?

In many systems non-governmental organisations play a key role in providing independent guidance on the acceptability of development projects and in some cases there is a statutory requirement for consultation with such bodies to ensure that the interests they represent are not adversely affected by a development programme or project.

Questions:

1. Are any NGO's consulted on development projects?
2. What environmental NGO's exist in Iraq?

Human Resources

Although it is possible for non-environmental specialists to contribute to the Environmental assessment process, there may be occasions where it is necessary for specialist environmental expertise to be used to assess particular problems.

Preliminary

Questions:

1. Who conducts environmental assessments? (e.g. Ministries, regulating bodies, consultants, universities etc)
2. Are there any competence requirements for environmental specialists to conduct assessments in Iraq (e.g. Register of Environmental Impact Assessment specialists?)
3. Which ministries have specialist environmental expertise?
4. Where expertises are not present in a particular ministry, where are they found? (e.g. do ministries employ expertise from universities, consultancies etc?)
5. Are any capacity building programmes in place to increase environmental skills within relevant ministries?

(iii) Environmental Parameters

In order to obtain an understanding of the key environmental issues in Iraq it is necessary to gather technical datasets on individual environmental parameters. Although the response to questions in section 1.2 of this note will increase our understanding of environmental aspirations and therefore influence what datasets are needed, the following are considered to be desirable (note that water quality data has not been included as this is requested elsewhere in the project)

Questions:

1. What data is available for fisheries in Iraq?
   a. Can data on all commercial fisheries species (large scale and small scale be provided)
   b. What information is available on non-commercial fisheries which are used on a local scale (e.g. informal fishing to supplement dietary needs of families)
   c. Information is needed on migratory patterns and routes. Published information appears to be scanty regarding the migration patterns and routes for the species in the rivers, tributaries and marshes. Can we get this information from local people or NGOs?
2. Is it possible to provide a schedule, including geographical locations of protected sites, including
   a. Ecologically sensitive sites such as wetlands or nature reserves
   b. Protected species
   c. Archeologically/culturally sensitive sites
   d. Any other protected areas?
3. Soil pollution data (e.g. land degraded by pollution from industry or military activity)?
4. Air quality data (particularly for urban areas)?
5. Land Use Data?

4 Agriculture and Irrigation

4.1 General

Agricultural data has been provided by the Ministry of Agriculture generally excluding the northern governorates, data from these has been provided by the Kurdistan Regional Ministry of Agriculture and Water Resources. The information from these two sources is difficult to compile into single data sets for the entire country because different parameters or different record periods have been supplied. In the planning context there is a need to develop an understanding of trends over time in the choice of crops, planted area for each crop, and yield (production). Some of the data is suitable for such trend analysis on a governorate basis.

There is at present no data on crop production from individual irrigation areas.

There is no data on the quantity and quality of irrigation return flows from individual schemes.

4.2 Summary of information received from the Ministry of Agriculture:

1. Comparison between 1971 and 2001 of:

   - Number of farms by governorate (unclear if these are private farms or farms rented from government)
   - Area of farms by governorate (suggested that this data may be unreliable as it shows a decrease in area over this time whereas due to sanctions restricting imports, the area probably increased)
   - Area of land cultivated in summer by crop (rice, cotton, sunflower and potatoes)
   - Area of land cultivated in winter by crop (wheat, barley)
   - Area of land used for production of fruit and date palms
   - Number of cows, buffalo, sheep, goats, camels

2. For each governorate by crop for winter and for summer for each year from 1995 to 2003:

   - Production (tonnes x 100)
   - Area cultivated (donums x 100)
   - Yield (kg/donum)

   Summary table of the above

3. Production, area cultivated and yields for each year from 1971 to 2001 for the whole country (excluding Kurdish area) for irrigated and rainfed areas (where applicable) for the following groups and crops:

   - Important crops (wheat, barley, rice, yellow corn, white corn)
   - Beans etc (maize, haricots, broad beans, chick peas, lentils, oats)
   - Oil crops (sesame, sunflower, linen/flax, pistachio, soya, safflower)
   - Industrial crops (cotton, tobacco, sugar cane, sugar beet)
   - Animal feed (alfalfa, berseem, other)
   - Vegetables (winter, summer)

Preliminary

- Spring potatoes, autumn potatoes, onion, garlic

4. Area cultivated by governorate for rainfed and irrigated areas from 1971 to 2002 (also 1990 to 2002).

5. Summary of land use for agriculture including:

- Cultivatable land
- Cultivated land (seasonal, perennial, irrigated, rainfed)
- Grassland
- Forest

4.3 Further Information Requested

In order to develop needs and opportunities data for the agricultural sector, and in particular for irrigated agriculture, the following questions were put to the MoWR and MoA:

4.3.1 General

1. Are there subsidies:
   i) for the irrigated agriculture sector;
   ii) for general agriculture.

2. For each region, has the area under irrigation over the last 5 years;
   i) increased;
   ii) decreased;
   iii) remained steady.

3. Are the methods and facilities for storage and distribution of crops adequate?

In addition, the following general questions were put forward:

- Is there a desire to improve irrigation efficiency by using different irrigation techniques?
- Is the main target to achieve economically/financially sustainable schemes?
- How important is food security?
- How important is employment generation?
- Would any new projects require World Bank (or other international donor) finance?

4.3.2 For Each Major Irrigation Scheme

1. Is the scheme fully operational? If not is this because of:

   a) lack of water;

Preliminary

i) all year;
ii) certain times of the year;

b) problems with water quality;
i) all year;
ii) certain times of the year;

c) shortage of land;
i) because of soils;
ii) because of salinity/drainage;
iii) because of flood susceptibility;
iv) because of erosion;
v) because of sand dunes;

d) is there any subsurface drainage, if so is it;
i) fully operational;
ii) partially operational;
iii) not working;

e) shortage of people;
i) all year;
ii) certain times of the year;

f) lack of capacity;
i) due to initial design;
ii) due to deterioration;
iii) is rehabilitation required;

g) trend – over the last five years has the irrigated area;
i) increased (give reasons);
ii) decreased (give reasons);
iii) remained approximately the same.

2. Are there any records to allow estimates to be made for irrigation efficiency as:
a) conveyance losses;
i) for unlined canals;
ii) for concrete lined canals;
iii) any other form of lining.
b) infield application efficiency.

3. Is there scope for expansion? If not which of the points under (1) represents the constraint.

4. How is the scheme currently managed:
a) by the state;
b) by the farmers;
c) by private companies;
d) other.

5. Operation and maintenance.
a) How is O&M controlled?
b) How is O&M paid for (water charges)?
c) Is it effective?

6. What is the current land-tenure situation:
a) do farmers own the land?
b) can agricultural land be brought and sold?
c) do farmers have traditional rights (usufruct)?

7. What are the constraints on improving yields:

Preliminary

a) water;
b) availability of other inputs (seeds, fertilizers, herbicides, pesticides);
c) seasonal labour;
d) salinity/water logging;
e) other.

8. How are the cropping patterns selected?

Preliminary

5 Groundwater

5.1 Introduction

Two Governorates – Sulaymaniyah and Erbil – provided most of information due to the fact that groundwater development has been most intense there from 2000 onwards. The development was a result of an FAO initiative. The MoWR provided about 3,600 scanned well cards – short descriptions of basic well data including coordinates, total depth, static water level, pumped water level, an outline lithology and some basic water quality parameters.

The Groundwater Studies Centre of the MoWR is currently undertaking work to install and operate a nationwide monitoring system. However, it is still not clear what is being monitored in 2006 and what had been monitored in the past, although there is rather more information for Erbil and Sulaymaniyah than elsewhere.

The MoWR GIS centre appears to have a number of geological and hydrogeological features mapped including well locations, presence of saline groundwaters, and water table depth, but these have not been made available in digital format for the ARDI team to perform independent checking.

5.2 Data Received

The information received from various sources and stored on Claromentis can be broadly divided into four main categories:

- Ministry of Water Resources, Baghdad
- Ministry of Agriculture and Water Resources, Sulayimaniyah
- Ministry of Agriculture and Water Resources, Erbil
- Data from other sources

5.2.1 Ministry of Water Resources (Baghdad) Data

Most of this information is in the form of electronically scanned well cards, short descriptions of basic well data. They have been recorded in Arabic although some contain English entries.

The categories of information provided by well cards include the following:

- Name of the well
- Governorate, project
- Coordinates (geographical)
- Total depth of the well
- Static water level (SWL)
- Pumped water level

Preliminary

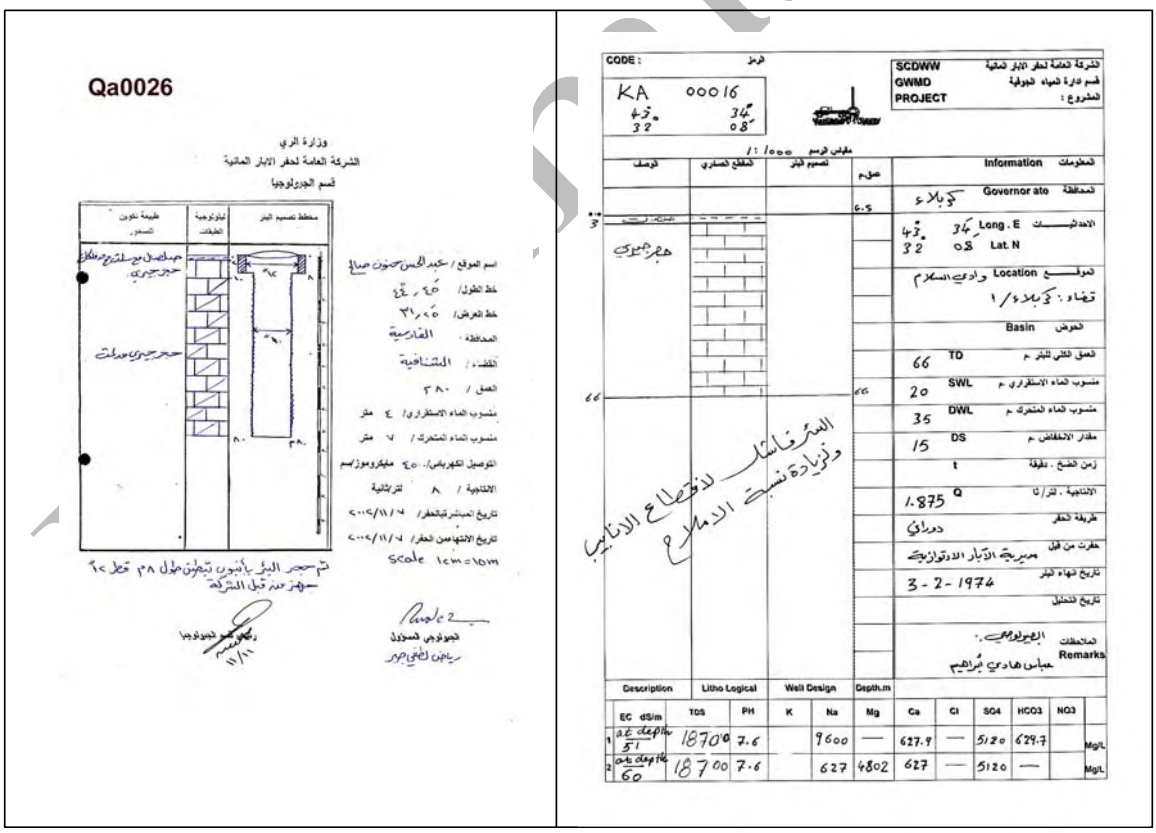
- Outline of encountered lithology
- Basic water quality parameters

Claromentis contains about 3600 well cards at present. The number of cards per governorate is shown below:

Table 5.1: Well Cards by Governorate

Governorate	Number of well records at MW
Al-Anbar	1041
Al-Muthana	563
Al-Najaf	646
Babel	132
Basrah	742
Dyala	9
Karbala	471
Qadsya	27
Total	**3631**

Some examples of well cards are shown below:



5.2.2 Sulaymaniyah Governorate Data

Groundwater and related information sourced from the Sulaymaniyah Governorate is tabulated below:

Information source	Type of information
Ministry of Agriculture and Water Resources, Sulaymaniyah, Deep Well Program Annexes	Groundwater level data, well depths, aquifer properties, pump rates
Ministry of Agriculture and Water Resources, Sulaymaniyah, Drillers Diaries	Approx locations, depths, casing, lithologies and drawdowns (with pumping) for wells
Ministry of Agriculture and Water Resources, Sulaymaniyah, Static Water Level Records	Water level data and charts, mainly for period 2000-2001
Ministry of Agriculture and Water Resources, Sulaymaniyah, p10	Average GWLs August 2000 to July 2001. Q and duration of pumping tests for April-July 2001
Ministry of Agriculture and Water Resources, Sulaymaniyah, Vol 1 and 2 annexes	Geological maps, cross Sections, stratigraphical columns, hydrogeological Maps
Ministry of Agriculture and Water Resources, Sulaymaniyah, Well Survey Cards	Well cards showing lithology and location of wells
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Parts of FAO project
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Average monthly rainfall, temp, pressure, evap 1992 - 1999
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Rainfall, windspeed temp
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall for years 2001-2002 for different raingauges
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Monthly rainfall data 2000-2004 for Kifri
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall for years 2002-2003 for different raingauges
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall for years 2001-2004 for different raingauges
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall for years 2001-2002 for different raingauges
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall, Humidity, Wind, Evaporation and Temp for 11 months of 2004 at Darbandikhan Dam
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall, Humidity, Wind, Evaporation and Temp for 3 months of 2003 at Darbandikhan Dam
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall data (2002-2003)
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall data (March 2005) for a number of districts
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Daily Rainfall data for different locations, range of dates from 2000 +
Ministry of Agriculture and Water Resources, Sulaymaniyah, p11	Daily rainfall, wind, pressure, temp etc data for different months and locations in 2000-2002 in Sulymaniah
Ministry of Agriculture and Water Resources, Sulaymaniyah, p11	Monthly rainfall data in Kifri for Nov01 to April03, Monthly rainfall data in Kalar for October 00 to May 01
Ministry of Agriculture and Water Resources, Sulaymaniyah, p12	Monthly rainfall data for different stations from Sep01 to May 02
Ministry of Agriculture and Water Resources, Sulaymaniyah,	FAO Drilling Training Course 2002 Documents (including certificates and contents list for acheivements report)
Ministry of Agriculture and Water Resources, Sulaymaniyah,	Groundwater levels and well/aquifer information for certain wells. Levels not plotted.

Preliminary

Ministry of Agriculture and Water Resources, Sulaymaniyah, page 7	Well logs
Ministry of Agriculture and Water Resources, Sulaymaniyah	Statistical reports of deeps wells monitoring team (includes well location, depth, no of monitoring visits undertaken) + deep overall summary report

5.2.3 Erbil Governorate Data

Groundwater and related information sourced from the Erbil Governorate is tabulated below:

Type of information	Example	Electronic format
Pumping test data	"Long December" "Sort pump test Hamza 10"	Time and WL data in excel and word. Charts in excel.
Groundwater level data	"MW fluct of Erbil to 7 july"	Date and WL data in Excel with charts
Summary GW Reports	"The monthly report of july 7 2001"	Word
Contour Maps	"Contour map max only August 8.SRF"	Some appear to be ISIS files.
Pumping test data	"long test - july"	Time and WL data in excel and word. Charts in excel.
Average Daily Pumping Rates	"Monitoring Pumping Rate2 - feb"	Word
Groundwater level data	"Mwfluct of Erbil in Feb.2002"	Date and WL data in Excel with charts
Groundwater level data - summaries	"Monitoring Wells, Summary 5 - feb"	WL and Date - some in word, some in excel
Summary GW Reports	"The monthly report of April.4"	Word
Contour Maps		Surfer files
Pumping test data	"Banaman No.1 chart.xls"	Time and WL data in excel and word. Charts in excel.
Groundwater level data	"Flactuation February 03"	Date and WL data in Excel with charts
Average monthly GWL levels + Well depth + Geological formations + Pumping rates and durations	"monitoring monthly summeryñ1.xls", "Monitoring Pumping Rate.doc"	Summary tables in word and excel
Summary GW Reports	"The monthly report of August. 2003.doc"	Word
Contour Maps	"CONTOUR MAP OF MINIMMUM GWL IN ERBIL BASIN ONLY JULY 03.GRD"	Surfer files
GWL database	"data swl"	Excel spreadsheet containing WLs for all (?) wells in Erbil from 2000 -2003
GWL Summary sheets	"MONITO~3.XLS", In folder "GWL Summary sheets"	Excel spreadsheets with max and min GWLs for month, altitude, aquifer type, well code, Q

Preliminary

5.2.4 Other Sources

Information was also sought from various other sources. Some GIS information – at a national scale – was obtained informally from researchers who have conducted investigations on Iraqi groundwater in the past.

Other information was sourced from the GIS section of the MoWR but it is believed that more potentially valuable information is still available at this particular source.

Groundwater summary maps are also available from the recently published Geology of Iraq [Jassim, Goff, 2006], but these are only available as raster (jpg) files..

5.3 Further Data Requirements

In order to further understand the activities of the Groundwater Studies Centre at MoWR, and to clarify a number of points relating to the data then received, a series of questions were formulated and sent to Dr Sadik, Director of the Groundwater Studies Centre, and these were then followed up directly by telephone conversation with Dr Sadik. The record of this latter discussion is contained in Appendix B.

The questions posed were as follows:

Key questions:

- What tasks are the Groundwater Studies Centre currently undertaking?
- What monitoring of water levels and salinity is undertaken?
- Databases or GIS systems – are they in use for storing information?
- Planning groundwater abstractions/new wells – what is the decision-making process?

These questions are expanded in more detail below.

The text in boxes contains questions which require answering to further develop needs and opportunities. The bullet points outside the boxes summarized the ARDI team's understanding of the situation prior to any clarifications from Dr Sadik.

5.3.1 Where is groundwater used?

- Groundwater use in Iraq is small in proportion to surface water, but is more important in rural areas. It may be the only practical source of water in large areas of the country.
- There is a perception that groundwater is currently used mainly in the northern governorates including Erbil and Sulaymaniyah.
- Groundwater also used where surface water is not readily available, e.g. in Najaf, Anbar and Muthanna governorates
- There are wells located in other governorates
- Both deep (up to 150 m depth) and shallow hand dug wells are used

- Are there recent estimates of groundwater use for irrigation and drinking purposes?
- Are there differences in well ownership between sites/governorates?
- What are the proportions of private and public users?
- Has groundwater use increased; decreased or remained steady over last 5 years (for each region where groundwater is used)?

Preliminary

5.3.2 What is groundwater used for?

- Both agriculture and for drinking water

- Do the wells pump 24 hours a day or only for parts of the day?
- Do the pump hours vary for deep and shallow wells? Are the variations recorded?
- What flow rates are obtained? How do they vary? Are they recorded?
- If the water is used for agriculture, what area is irrigated per well?
- Who owns, maintains, updates abstraction records?

5.3.3 Planning new wells

- New wells deeper than 20 m require a permit to be granted by the Director of Groundwater for each Governorate (Muhabir)
- The new well must be more than 500 m from an existing well for the permit to be granted
- The Ministry of Water Resources examines hydrogeological maps for the area which contain information about the salinity, depth to water table and hydrogeology
- Permission to drill will then be granted
- Following the drilling a well permit must be completed and sent back to the Director of Groundwater. This contains a geological log, the location of the well and various measurements including static water level and water quality.
- We understand that the Groundwater Studies Center is currently undertaking a special study to perform a General Assessment Report, examining the renewability, quantity and quality of groundwater resources.

- Apart from the 500 m distance, what other criteria are used to determine if a permit will be granted?
- Are the proposed well locations georeferenced?
- Is the water required by the well assessed in relation to the potential resources available? How?
- What work has been undertaken by the Groundwater Studies Center on their special study to perform a General Assessment Report, to examine the renewability, quantity and quality of groundwater resources? How are the renewability, quantity and quality being assessed? What is the current progress on the study? When is it to be completed?

5.3.4 Record keeping

- The deep well permits are scanned and held as pdfs by the Director of Groundwater for each Governorate.

- Is there a central and/or regional (for example governorate-based) database of all the wells?
- How many deep and shallow wells are there? Per governorate?
- What pieces of information (database fields) are being populated?
- What information is stored in paper format and what is stored in electronic format?
- What is the proportion of paper-based information to electronic? Can you provide estimates?
- Is record collecting and keeping mandatory?
- Who is responsible for recording and record-keeping?
- Are there differences in record-keeping practices between deep and shallow wells?

Preliminary

5.3.5 Groundwater level monitoring

- We understand that the Groundwater Studies Centre is currently undertaking work to install and operate a nationwide monitoring system.
- We are unclear about exactly what is being monitored at present, and in the past, and where.
- We understand that in Erbil there may be around 15 to 25 years of monitoring data available – we are not sure exactly what has been being measured and where.

- What monitoring has been undertaken in different governorates and what is the current status?
- Is there an existing network of monitoring wells?
- Are both pumped wells and wells without pumps monitored?
- When water levels are measured where is the information stored? Is it held in a database? By who – the governorate or ministry?
- Have any studies been undertaken to recommend monitoring strategies and procedures?
- Are these studies being implemented? Where?
- What work has been done so far by the Groundwater Studies Centre in relation to the monitoring network? Has a system been designed? Has any equipment been installed as part of this work?

5.3.6 Problems with the wells

Salinity

- Groundwater salinity is increasing in many areas

- Which areas are salinity-affected?
- Is the salinity routinely measured in the wells?
- If so how often and what is the basis of the monitoring regime?
- Where is it measured?
- Where and how is the data stored? Electronically (in a database?)
- Are changes in salinity over time being measured? What trends have been observed? Which areas of Iraq are showing increases in salinity?

Falling Groundwater Levels

- There were four years of drought between 1999 and 2002.
- These caused the groundwater levels to fall
- Since 2002, the amount of water recharging the aquifer has not been sufficient to allow the water levels to rise back up again. The levels are continuing to fall due to increased demand.
- The average abstraction exceeds the recharge

- When groundwater levels fall are the pumps lowered and/or boreholes deepened?
- Which areas were affected by drought?
- What was the magnitude of groundwater level decrease between different areas/governorates?
- Were sustainable yields determined for public and private sources?
- Is recharge/replenishment routinely assessed, if so what methods are used?

Sewage

- Erbil has problems with sewage contaminating groundwater

Preliminary

- Are maps available showing the locations in Erbil particularly affected by sewage contamination of groundwater?
- What is the source of the sewage? Is it a treatment works, septic tank, soakaway etc?
- Are there any guidelines about the location of new wells in relation to sewage?
- Are there problems with sewage contamination in other places in Iraq?

Other Pollution Issues

- Is there a groundwater pollution prevention strategy applicable to oil extracting and processing facilities?
- Has vulnerability of groundwater resources been assessed at a national or regional scale?
- Is zoning strategy considered and/or applied to groundwater supplies?
- What are the analytical determinands routinely used to assess groundwater pollution?
- Is the laboratory infrastructure capable of dealing with analytical demands resulting from groundwater pollution studies and routine monitoring?
- Has there been an international cooperation aimed at groundwater pollution studies in Iraq?
- Are there corrosion and scaling problems associated with groundwater, if so which areas are affected?
- Can you describe past and current pollution control practices in Iraq? Is polluter-pays principle applicable?
- Is the data on land use available at a national or regional scale? If so is it transferred to GIS systems?

5.3.7 Recharge estimation

- Have any recharge assessment studies been done in Iraq? Can you provide references or copies of reports?

5.3.8 Other information required

- What is the status of education in groundwater resource assessment and management? Are there university courses covering groundwater topics in Iraq?
- Can you provide an estimate of the number of groundwater specialists in Iraq?
- Are there public or private consulting firms engaged in groundwater exploration, assessment and management?
- Who is the key fund provider for groundwater exploration?
- Is research funding available for groundwater problems in Iraq?
- Recharge dams – have there been any studies or is there any anecdotal evidence into whether they have been successful? Are there siltation and/or salinisation problemes associated with existing recharge dams?
- We understand more recharge dams are being planned in the north – how are the cost/benefits being assessed?
- Is there a consistent pricing policy for groundwater resources? If so can you describe / provide references to its key elements?
- Are there state subsidies to develop or manage groundwater resources
- Are you aware of trans-boundary issues related to groundwater resources? (for example, borders with Turkey, Iran, Kuwait)

6 Water Supply Information

6.1 Existing Municipal Water Supplies (Information and Data)

6.1.1 Data from the Ministry of Municipalities and Public Works

The Ministry of Municipalities and Public Works (MMPW) has provided a list of water treatment plants, wells and compact units for 15 governorates. There is no equivalent data for the three Kurdish governorates of Dohuk, Erbil and Sulaymaniyah. Data for each facility include location given by coordinates, planned output, actual output and numbers of people served. From discussions with MMPW it is understood that the list is probably far from complete, although it is believed to be the most comprehensive list available. There is a reasonable correlation between the number of water treatment plants in the list and those recorded in specific plans for individual governorates, but the number of compact units (CUs) varies widely. It appears that CUs are put in by various organisations without any real coordination or record keeping

A weakness of the MMPW list is that it does not indicate which town(s) each treatment plant serves, nor the source of water for each works. There are coordinates for the location of each works, but these are unreliable, and in any case the treatment plant does not necessarily serve the area in which it is located, or the source of raw water may be far from the works.

Analysis of per capita consumption (pcc) from data for outputs and people served in the MMPW list shows a very wide range with many anomalous figures, e.g.

- For water treatment plants, the calculated pcc varies from 24 to over 10,000 litres per person per day (lpcd).
- The variation is even more extreme for CUs.
- In 8 governorates (over half of those for which data are supplied) the average pcc is 333 lpcd for all works. The governorates with this figure throughout are Al Anbar, Baghdad, Basrah, Diyala, Maysan, Muthanna, Qadisiyah and Salah al Din. We assume that 333 is a target figure for supply, and population served is calculated from measured/estimated works output or actual output is calculated backwards from population served.

6.1.2 Mini Master Plans

Water supply mini master plans have been or are being prepared for the governorates of Basrah, Erbil and Sulaymaniyah and copies have been provided. A wastewater plan has been prepared for Karbala and copy of that has also been provided. Further plans are due to be completed for water supplies to, Najaf, Diwania and Kirkuk

Despite their name, these plans appear quite comprehensive, although their coverage varies. That for Basrah covers the whole governorate with the focus on the municipality of Basrah, whilst those for Erbil and Sulaymaniyah cover the governorate except for the main towns of Erbil of Sulaymaniyah. The wastewater mini master plan for Karbala is only for the main town.

A very brief outline of the planning criteria used and water requirements for each plan is given below.

Preliminary

(i) Basrah

The basic demand criteria used for Basrah were as shown below.

Table 6.1: Planning Criteria for Basrah Demand Forecast

Location	Level of Service Factors (l/c/d)				
	Domestic	Commercial	Industrial	UfW	Total
Basrah	300	30	30	72	432
Towns with industry	200	30	30	52	312
Towns without industry	200	30		46	276
Rural	200			40	240

There is no indication whether these figures are average or peak daily demands. It is assumed that they are peak figures as they are used to establish capacity requirements.

The population of the governorate is projected to rise from 1,761,000 in 2003 to 3,375,000 in 2025, using a growth rate of 3% per annum in line with that used by MMPW. Applying the above figures for per capita water demands to the projected population gives a present total peak daily water demand of about 650,000 m^3/d rising to 1,167,400 m^3/d by 2025.

The mini master plan examined seven options for meeting this demand and recommended a combination of conventional treatment of water from the River Tigris at Al Quorna and desalination of water from the Shat al Arab in Basrah. It is proposed that normally 40% of the water will come from Al Qorna and 60% from the Shat al Arab. The different supplies will be blended to give a potable supply meeting Iraqi and WHO guidelines.

(ii) Erbil

The population of Erbil is expected to grow from its current level of about 1,600,000 to 2,900,000 by 2025. This is a growth rate of 3% per annum. The urban centres, outside the city of Erbil itself, have a present population of about 250,000 and this is projected to rise to 437,520 by 2025.

The overall per capita demand for people in the district centres is taken to be between 360 and 390 l/d and applying these figures to the population forecast gives a total demand rising to 160,216 m^3/d by 2025. The total demand from sub-district centres is forecast to be 52,861 m^3/d by 2025. No water demand figures are given for rural areas, although it is noted that about 28% of the total population of the governorate are classified as rural.

Proposals for development of water supplies generally anticipate increases in abstractions from existing local sources, which are a mixture of springs, rivers and groundwater.

Preliminary

(iii) Sulaymaniyah

The population of Sulaymaniyah is expected to grow from its current level of about 1,800,000 to 3,300,000 by 2025. This is a growth rate of 3% per annum. The urban centres, outside the city of Sulaymaniyah itself, have a present population of about 257,000 and this is projected to rise to 464,171 by 2025.

The overall per capita demand for people in the district centres is taken to be 360 l/d and applying this figure to the population forecast gives a total demand rising to 167,101 m^3/d by 2025. The total demand from sub-district centres is forecast to be 521,972 m^3/d by 2025. No water demand figures are given for rural areas, although it is noted that about 20% of the total population of the governorate are classified as rural.

Proposals for development of water supplies generally anticipate various new surface water and groundwater sources. Sources will generally be local to the communities supplied.

6.1.3 New Eden Project Information

The reports provide data on existing systems and estimates for the development of water and sanitations systems. Although costs are given, there are no projections of water demand or lists of schemes in the main report.

The criteria for water demand assessment are given in the report as follows:

- Governorate headquarters 450 lpcd
- District capitals 360 lpcd
- Rural communities 250 lpcd

These are similar to those used in the mini master plans and were agreed with MMPW. They are assumed to overall peak day demands, including an allowance for unaccounted for water (UfW).

6.1.4 Information from the Reconstruction Project in Southern Iraq

As part of its work on the reconstruction project in Southern Iraq, Mott MacDonald has worked on water sanitation projects in Basrah, Thi Qar, Al Muthanna and Maysan governorates. As part of this work, outline plans were prepared for the development of water and sanitation systems in these four governorates in 2004.

The figures in the table below were used as an initial guideline for assessing water requirements and the adequacy of existing systems.

Preliminary

Table 6.2: Suggested Long Term Planning Criteria

Item	Per capita water demand (l/day)	
	Urban areas with developed internal plumbing systems	Rural areas with limited internal plumbing systems
Household demand	160	120
Non-household demand (industry, commerce, institutions, etc.)	40	20
Total consumption	200	140
Unaccounted for water	67	47
Total water requirement (average day)	267	187
Total water requirement (peak summer day)	335	237

The figures in the above table assume unaccounted for water is 25% of water production, which is a reasonable, but certainly not demanding target. The average per capita household consumption assumes a reasonably careful use of water and is based the normal requirements for household use. The figures used are also similar to figures which Mott MacDonald has recently used for a master plan for Oman. The summer peak assumes a 40% increase in average household demand, reflecting the extremes in temperature, and a 10% increase in non-household demand.

6.1.5 Analysis of Data

The following table summarises the data in the MMPW lists for 15 governorates and provides comparisons with data from other sources.

Preliminary

Table 6.3: Summary of Data on Existing Water Supplies

Governorate	Actual capacity from MMPW list (m3/d)				Population 2004	Capacity per person (l/d)	Capacities from other sources (m3/d)		
	WTP	Well	CU	Total			New Eden	Mini MP	MM 2004
Al Anbar	326,561		96,240	422,801	1,328,776	318			
Babil	71,760		26,256	98,016	1,493,718	66			
Baghdad	235,591		113,460	349,051	6,554,126	407			
Baghdad municipality	2,208,000		113,000	2,321,000					
Basrah	476,206		371,540	847,746	1,797,821	472	850,000	555,600	n/a
Diyala	308,465		65,050	373,515	1,418,455	263			
Karbala	215,270		30,720	245,990	787,072	313			
Al Tamim (Kirkuk)	383,140	7,000	30,840	420,980	854,470	493			
Maysan	56,314		89,640	145,954	762,872	191	271,656		197,000
Al Muthanna	83,138		16,920	100,058	554,994	180			86,000
Najaf	257,300		21,140	278,440	978,400	285			
Ninawah	603,217	22,059	62,068	687,344	2,554,270	269			
Qadisiyah	210,352		39,185	249,537	911,641	274			
Salah al Din	228,930		54,060	282,990	1,119,369	253			
Thi Qar	108,340		116,832	225,172	1,472,405	153	308,000		129,000
Wasit	174,300		52,794	227,094	971,280	234			
Total	5,946,884	29,059	1,299,745	7,275,688	23,559,669	309			

Notes:

1 Population data from Ministry of Planning figures

2 New Eden : new Eden Master plan for Integrated Water resources Management in the Marshlands Area, April 2006

3 Mini MP : Drinking Water Supply Mini Master Plan, CH2M Hill/Parsons, 2005.

4 MM 2004 : Data from Mott Macdonald's outline plans for the four southern provinces, 2004.

Preliminary

Although only limited comparisons between different data sources are available, it is clear that there are wide differences in several places where such comparisons are possible. The New Eden Project generally gives significantly higher figures than the MMPW list, whilst the Basrah Mini Master Plan and the Mott MacDonald data from 2004 appear generally to give low figures.

In some cases, the differences may be due to the coverage of the reports e.g. Mott MacDonald's work was focussed only onthe main towns. Another possible source of error is the number of operating hours assumed each day. The data in the New Project reports is given in m^3/hour, and the figures in the table above assume 24 hours per day operation and make no allowance for outages. We understand, however, that some works operate only in daylight hours.

The data from the MMPW list indicates that average per capita supply capacity is just over 300 lpcd, but varies widely between governorates from a low of 66 lpcd in Babil to a high of 472 in Basrah. The figures suggest that the overall supply capacity in many governorates should be adequate to maintain at least a good basic level of service to most of the population. However, reports suggest that this is rarely the case due to a variety of reasons including inequitable distribution of water, high levels of leakage, frequent loss of supply due to loss of power, and reduced operating hours due to security problems.

About 18% of the total capacity is from compact units (CUs). These are prefabricated steel plants with a limited lifespan, perhaps only 10 years. The New Eden Project reports record the condition and performance of the works and many CUs are classified as 'poor' in both respects. It is likely that a major programme of replacement of these plants with more robust conventional plants will be required in the coming years.

6.1.6 Industrial Water Supplies

A limited amount of information has been received from the Ministry of Industry and Materials. Tabulated data collected describes each industrial water user, the source of the water, the volume used, the volume discharged and a description of the discharge location. There are 107 records, but not all have complete information. Unfortunately the list does not indicate what units are used for measurement of abstractions and discharges, nor the location of the industry, although a separate list gives longitude and latitude references for a few companies. There are several major water consumers with private supplies in the chemical, petroleum, iron & steel, sugar refining and cement industries.

6.1.7 Existing Wastewater Collection and Treatment Facilities

Data on wastewater systems is only available from other reports. In general, piped sewerage schemes serve district headquarters but are limited in extent and wastewater treatment plants serve only parts of the major towns and often perform poorly if at all. Many house have septic tanks but these are often badly maintained and rarely emptied, and much wastewater is discharged to open drains. The situation on sewage treatment in the four southern provinces has been complied from reports on the New Eden Project and from the work of Mott MacDonald in 2004. The situation is summarised in the table below.

Preliminary

Table 6.4: Sewage Treatment Plants in Four Southern Governorate

Governorate/town	Capacity (PE)	Remarks
Basrah		
- Hamdan WWTP, Basrah city	400,000	Poor condition, partial treatment only
- Khur al Zubair	100,000	Not working
Thi Qar		
- Nasariyah	85,000	Not working
- Ali Askan Al Sinaie	10,000	Acceptable
Maysan		
- Amarah	150,000	Acceptable
Al Muthanna		
- Samawah	n/a	Two works dedicated to residential complexes only

We understand the situation in the four southern provinces is not atypical and clearly the collection treatment and disposal of wastewater in an environmentally acceptable way will require massive investment.

6.2 Further Information Needs

6.2.1 General information

Basic socio economic information is required to assist with assessing demands in various locations:

Additional data required:

i. Population data, including major urban areas and urban/rural split by governorate

ii. Numbers of houses with internal plumbing and flush toilets in urban and rural areas, by governorate.

6.2.2 Existing Water Supply Systems

We have a list of treatment plants, wells and compact units for 15 governorates. The title of the spread sheet states it is 'for all governorates', but there appears to be no data for three governorates. The missing governorates appear to be the three northern governorates covering the Kurdish Region.

It is not known what town(s) each treatment plant serves. It would be helpful to identify water supply systems. These may be for individual towns or in some cases several towns served as part of a single system.

There are some anomalies in the data e.g. if we calculate per capita water consumption we get an enormous range of values (0 to 15,724 lpcd). There are clearly many unrealistic figures at the extremes of the range. Furthermore, in some provinces most, if not all, WTPs provide a per capita supply of 333 l/day. It is assumed that in these cases either output has been worked back from population served or vice versa.

Preliminary

Additional data required on existing water supply systems:

iii. Lists of water treatment plants and wellfields for the three northern governorates

iv. Source of water for all treatment plants.

v. Towns/water supply system served by each water treatment plant

vi. Details of water treatment processes

vii. Clarification as to how the actual output and population served have been calculated and how the quality of data might be improved

viii. Details for distribution pipework (lengths and condition) for each water supply system/town.

ix. Numbers of consumer connections in different categories (households, industry, government, etc.) to each system and/or in each town.

6.2.3 Present Consumption Data

Present consumption levels by different types of consumers and water losses are the basis of future planning. At the present we have very little data. As noted above, the list of water treatment plants/CUs/wells gives anomalous data on consumption levels. We appreciate that few supplies are presently metered and good data may not generally be readily available.

Additional data required on present consumption and production:

x. Breakdown of water consumption between household and non-household (industrial, commercial, institutional) customers, and unaccounted for water (leakage and other losses). Ideally we would like this by water supply system, but any information would be useful.

6.2.4 Industrial Water Supplies

We have a list from the Ministry of major industrial water supplies but some key information is lacking.

Additional data required on industrial supplies:

xi. Location of each industry listed.

xii. Units for volume of water used.

Preliminary

6.2.5 Water Quality

We have readings from nine governorates for June 2005 (maximum, minimum and average values). Our main interest will be in salinity, and we would like some indication of annual variation and perhaps long term trends, if available.

Additional data required on water quality:

xiii. Annual maximum, minimum and average values for the main water quality parameters (TDS, Turbidity, pH, Ca, Mg, Alkalinity, Cl) for all water supply systems.

xiv. Trends in salinity over the past 10 years say where data is available.

6.2.6 Wastewater

The coverage of sewerage and wastewater treatment facilities obviously lags well behind the provision of public water supply systems and major investments will be needed in the future. We have no information on existing municipal wastewater treatment plants.

We have a list of industrial discharges but there are no units for volume discharged and the final discharge point is not clear (several say discharge to storage)

Additional data required on wastewater collection and treatment facilities:

xv. A list of existing wastewater treatment plants - location, design capacity, actual dry weather flow, treatment process and discharge point.

xvi. Lengths of the sewerage network in each town, numbers of connections.

xvii. Industrial wastewater – location of works, units for volume discharged and final discharge point

Preliminary

7 Hydropower Information

7.1 Data Received

The collected data was almost complete and was used successfully to build and test a workbook for hydropower energy and power calculations. The data set would have been complete but for some untidy scanning which meant that the static head values for a number of installations were missing. This missing information has been requested.

The installed capacity, annual energy generation, annual hours of generation, static head values and expected capital costs have been obtained for the 7 existing and 68 potential hydropower stations in Iraq. These figures were obtained from a spreadsheet provided by the Ministry of Energy in Iraq. This data is assumed to be current and accurate; however there is limited information available regarding the assumptions used to create these estimates. It is uncertain when the cost estimates were developed and these could have changed substantially. It is assumed however that for cost comparison purposes this data is sufficient. The assumed operating rules are also unclear and may be driven by demand for irrigation flows. The level of consideration for the interaction of these issues is unclear and could have a substantial impact on costs and benefits associated with the hydropower schemes. With these issues in mind, the data from the table has been used to give an indication of some of the possible scenarios for hydropower development in Iraq from now until 2030. As the accuracy of the input data is improved, the scenarios can be updated and more accurate conclusions can be reached.

7.2 Further Data Requested

Details of studies and plans from the Ministry of Energy were needed which showed the plans for rehabilitation, upgrading, and new schemes to meet projected electricity demand by sector in the short and long term future. The ARDI consultants also wanted to review the energy sector study (covering all types of generation) and planning documents and so determine how to include hydropower in the Phase 1 efforts for strategic water resources planning.

Preliminary

8 Water Quality and Pollution Information

8.1 Surface Water Quality Data

Sample data for a number of stations on the river system was available. However, grid reference information was lacking, causing difficulties in correlating data from General Scheme with data sheets provided by ministries.

The map below shows recent sampling sites and the table the relationship to the General Scheme measurement points (neither source of information giving grid references).

شكل 1.4 يبين مواقع محطات الرصد على المصادر المائية في العراق

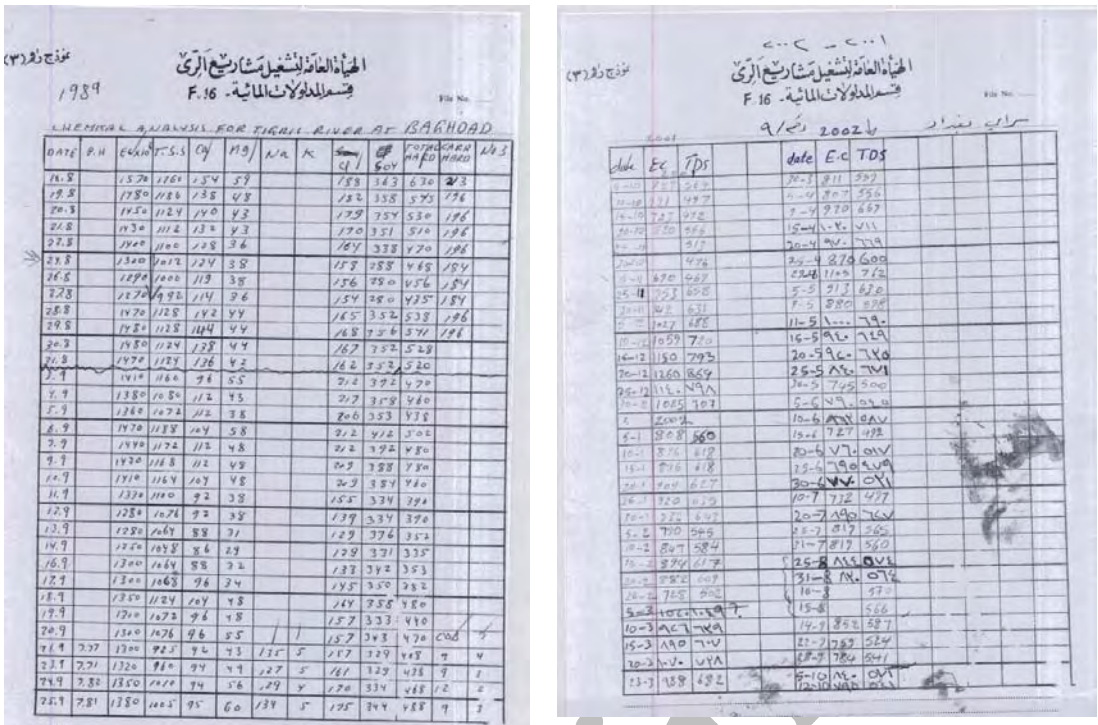
Ref: General Scheme of Water Resources and Land Development in Iraq
Volume VII - Water and Land Conservation Book 1
Water Quality Data for 1978

Site no.	Description	River	Table no.	Corresponding station(s)
0	Tusan	Tigris	2.8	
1	Mosul (U/S and D/S)	Tigris	2.8	T7, T8, T9
3	Eski Kalak	Greater Zab	2.13	
5	Fatha	Tigris	2.9	T12
6	Dokan Reservoir	Lesser Zab	2.13	L22
7	Lesser Zab	Lesser Zab	2.13	L23, L24
8	Samara (U/S and D/S)	Tigris	2.9	T14
9	Adhaim Mouth	Adhaim	2.13	T16
11	Baghdad (U/S, Within, D/S)	Tigris	2.11	T22, T23
12	Derbendi Khan Reservoir	Diyala	2.13	D13, D14
13	Usptream of Baquba	Diyala	2.14	D15
14	Diyala Mouth	Diyala	2.14	D17
15	Kut (U/S and D/S)	Tigris	2.12	D26, D27
16	Amarah	Tigris	2.12	T30
18a	Al Khaim (Syria Border)	Euphrates	2.15	E1
18	Haditha	Euphrates	2.15	E2, E3
19	Ramadi	Euphrates	2.15	E5
20	Thar-thar Euphrates Canal	Euphrates	2.15	E6
21	Hindiyah (U/S and D/S)	Euphrates	2.16	E9, E10
??	Shinafiyah	Euphrates	2.16	
22	Samawa	Euphrates	2.17	E15
23	Nasirriyah (U/S and D/S)	Euphrates	2.17	E18, E19
24	Qurna	Euphrates	2.17	E20, E21
??	Qurna	Shat al Arab	2.18	SH1
??	Basrah (U/S and D/S)	Shat al Arab	2.18	SH2
??	Fao	Shat al Arab	2.18	SH3

Hand-written water quality record sheets were received for various monitoring points on the Tigris and the Euphrates.

The data was provided as scanned copies of original data sheets. There was a clear deterioration over time with more comprehensive records for earlier periods as shown by the two sample sheets from Baghdad below.

Preliminary



Sample data sheets from 1989 (left) and 2002 (right)

The periods of data covered in the records are shown in the following table. The time interval between samples varied between the monitoring stations, and also over time at each station varying between monthly data and as frequent as daily data for some periods of record, although there are extensive periods of missing data. The lengths of the data sets shown below are for the salinity or conductivity data records although further data series are present at most sites for other water quality parameters. This inconsistency in sampling frequency has consequences for the suitability of the data for some uses.

Table 8.1: Availability of Water Quality Data Series for River Monitoring Points

River	Location	Period of Record
Tigris	Srai Baghdad	1971-2000
	Amara	1977-2002
	Baghdad	1979-1990
	Mosul	1971-2001
	Samarra Barrage	1974-2001
Shat al Arab	Al Qurna	1971-1990
Euphrates	Al Hindiah Dams	1971-1998
	Al Ramady Dams	1971-2001
	Al Samawah	1973-2002
	Di Qar	1978-2002

Preliminary

None of the monitoring points was given a grid reference to show precisely where the sample had been taken. In fact 23 other record sheets were available but the gauging locations were not clearly identified on the sheets.

These monitoring points are all on the main river systems. No data has been collected during Phase 1 that relates to the water quality in lakes and reservoirs, or any measurements giving the quality of waters in the canal and drainage systems. Information on the quality of drainage returns is of particular interest for agricultural planning and the lack of data is surprising.

The lack of water quality data was a constraint to the development of models during Phase 1. There is more discussion of these issues in Annex 11.

8.2 Groundwater Quality Data

There was very limited information received from the Ministries on groundwater quality.

Preliminary

9 Opportunities Data

9.1 Information Received

The limited data on opportunities was reviewed with the visiting MoWR staff in May/June 2006 as part of the process of developing the Iraqi multi-criterion decision model (MCDM).

The data available came from three sources:

- The MoWR web site (downloaded February 2006)
- Two lists, one for MoWR and one for MMPW, prepared during the period of the CPA administration – these were provided through IRMO
- A list of some 12 projects in all sectors provided by the Ministry of Planning and International – this contained three water sector projects including Bekhme Dam

The MoWR web site contains a number of lists of potential projects according to a proposed year for start of implementation. There are a total of 262 projects listed ranging from the supply of computers, through rehabilitation works, to major multi-purpose dams and new irrigation and drainage systems. Figure 9.1 presents the spreadsheet from the web site for the year 2005 to illustrate the format and level of detail available.

The CPA period documents present a relatively small number of major schemes set out in a format to be presented to potential donors, it is understood that these two documents were prepared for an intended donor conference that was never held.

These lists were discussed with the MoWR visitors. From these discussions it appeared that most of the projects had been proposed at the time of the General Scheme Stage 2 (Russian report, 1982) and had not been taken further since then. This suggested that a major exercise would be required to check the existing engineering designs, to revisit the economic analyses, and to prepare environmental impact assessments and any other studies that might be required if the project were to be considered a candidate for international donor financing (e.g. World Bank safeguards policies).

9.2 Further Information Required

By June 2006, it was clear that there were still significant gaps in the information received, which required filling before comprehensive needs and opportunities data sets could be developed. A special meeting of the Data Collection Leaders was held in Baghdad on 19th June at which the ARDI team raised the following issues:

1. **Policies and likely direction of development in each sector** – needed to guide the preparation of the strategy and at this stage needed to help the ARDI consultants develop appropriate tools for subsequent strategy development.
2. **'Opportunities' (proposed projects) for ministries** – needed to include in the scenarios of possible alternative short and long term strategies. The ARDI consultants needed to know what projects were currently under study and how to access the information being prepared by the study teams

Preliminary

Each of these points is described in more detail below.

(i) Policies and likely direction of development in each sector

It was recognised that the delegates to the meeting might not be in a position to provide guidance on their ministry's existing policies, and more importantly on likely directions in the future. The key question for the MoWR SWLRI Unit and the ARDI consultants was how to obtain this information – a mechanism was needed that could deliver at least preliminary information to guide the ARDI team by the end of June at the latest.

Examples of the issues of concern to the consultants include:

- Charging for water use – what is current thinking on charging consumers the 'real' cost of their water use including agriculture and power. Do the ministries involved consider higher water charges in their future planning exercises?
- Food security – how is this viewed now, and in the future? To what extent should food security drive agricultural production?
- Hydropower – what role should it play in the future for electricity generation?
- Environment – what value should Iraq place on environment now and future? How are social needs and environmental needs to be weighed against each other in the short term, and in the longer term?
- Employment and poverty reduction – to what extent should projects that create agricultural employment be favoured as meeting socially desirable goals?
- Health targets eg access to clean drinking water, provision of safe sewage disposal

(ii) Opportunities

Each ministry was requested to make a list of ongoing studies, or recently completed studies, of projects and to name a direct point of contact for the SWLRI Unit and the ARDI consultants to talk to about the studies. It was suggested that it would also be useful to have a contact in each ministry's own section responsible for developing their plans for future developments. These names would be in addition to the Steering Committee Delegate and the Data Collection Leader, and would help to speed up the process of gathering the right information on opportunities.

Preliminary

Figure 9.1: Sample List of Potential Projects from the MoWR Web Site

Projects 2005

Project Title	Ministry ID	PMO ID	LOCATION(GOVERNORATE)	Description	Total Estimated Project Cost	SDate	EDate
Al Hindiyah Barrage	Barrage-004		Babylon	Al Hindiyah barrage is one of the 4 barrages with hydropower and it has 4 regulators upstream respor	$969,000	06/01/2005	8/31/2005
Al Kufa and Al Abasiya Regulators - Rehabilitation	Reg-001	W-R-WR-Dam-276	Najaf	Rehabilitation of regulators which water to supply local irrigation systems. To maintain water levels up	$888,000	02/01/2005	7/31/2005
Al Kut Barrage Complex	Barrage-006		Kut	The Barrage serves to maintain the water surface for the Gharaf. Rehabilitate gates from various bar	$3,000,000	06/01/2005	8/31/2005
Arar Dam Construction	Dam-032	W-R-WR-Dam Rural-183	Anbar	Construction of earth fill dam on Wadi Arar in the western desert. Dam would be 1,300 meters in leng	$8,752,000	01/01/2005	8/31/2008
Badoosh Dam (Phase II)	Dam-008		Ninewa	Phase II includes adding hydropower generaton to the dam. Elevate dam level to 256 m to store .5 bil	$35,000,000	02/01/2005	7/31/2006
Construction of 30 projects for protection of river bank erosion	IR-009		Suliamaniyah	Construction of 30 projects for protection of river bank erosion	$500,000	06/01/2005	11/30/2005
Construction of 40 water collection tanks	IR-004		Suliamaniyah	Construction of 40 water collection tanks. Tanks will store spring water at night for distribution during t	$400,000	04/01/2005	6/30/2005
Construction of 5 drainage projects	IR-008		Suliamaniyah	Construction of 5 drainage projects	$4,000,000	06/01/2005	11/30/2005
Construction of Komospan Dam	Dam-020		Duhuk	Construction of Komospan Dam for irrigation, hydropower, water storage purposes. Earth fill dam = Ir	$10,000,000	01/01/2005	6/30/2007
Dam Program Project Security	Dam-034	W-R-WR-Dam-093	Nationwide	Provide appropriate level of project security, system-wide. Provide full time armed security at all of the	$1,421,000	05/01/2005	7/31/2005
Falluja Barrage Rehabilitation	Barrage-007	W-R-WR-Dam-274	Anbar	Falluja Barrage controls the elevation of the water for 6 major irrigation systems. There has been no r	$1,776,000	01/01/2005	3/31/2005
Horan 1/2 Dam Construction	Dam-017	W-R-WR-Dam Rural-181	Anbar	Construction of earth fill dam on Wadi Horan in the western desert. Dam would be 650 meters in leng	$1,859,000	01/01/2005	6/30/2007
Irrigation improvement by using drip systems	IR-007		Suliamaniyah	Irrigation improvement by using drip systems	$3,000,000	04/01/2005	6/30/2005
Irrigation improvement by using sprinker systems	IR-006		Suliamaniyah	Irrigation improvement by using sprinker systems	$2,600,000	01/01/2005	3/31/2005
Kalar Reclamation Project	Major-014	W-R-WR-Major-219	Suliamaniyah	Rehabilitate existing irrigation network (lining of canals, other related structures). Irrigation is by pump	$7,000,000	06/01/2005	11/30/2006
Kassara Cross Regulator Rehabilitation	Reg-008	W-R-WR-Dam-255	Missan	Rehabilitate cross regulator to restore safe operations, raising upstream water levels and regulating d	$3,997,000	02/01/2005	7/31/2005
Kirkuk (Contract 24) - Various Projects	Major-002	W-R-WR-Major-202	Salah al-Din	Improve land production in this region; provide water resource; improve decreasing ground water leve	$14,282,000	01/01/2005	3/31/2005
Mahrut (Phase I)	Major-008	W-R-WR-Major-208	Diyala	Improve land production in this region; provide water resource; improve decreasing groundwater level	$15,988,000	01/01/2005	3/31/2005
Mandali Dam Construction	Dam-009	W-R-WR-Dam Rural-190	Diyala	Construction of earth fill dam at Mandilee in the eastern region. Approximate storage capacity equals	$4,441,000	01/01/2005	8/31/2007
Muthanna Reclamation Project	Major-010	W-R-WR-Major-205	Muthanna	The aim of the project is to raise the agricultural productivity and supply food to the farmers as well as	$28,565,000	01/01/2005	3/31/2007
Reestablish Professional & International relationships	Cap-018		Nationwide	Ministry of Water Resources employees have had very few opportunities over the past two decades t	$250,000	06/01/2005	8/31/2005
Rehabilitation of Delmage Project - Various Projects	Major-036		Wassit	Project is for irrigation and drainage lands in Wouthern Iraq. Includes lining of concrete canals, also fi	$10,000,000	01/01/2005	6/30/2005
Shamiya Barrage Rehabilitation	Barrage-002	W-R-WR-Dam-263	Najaf	The barrage crosses the Shamiyah River. Rehabilitate weir to restore safe operations, raising upstrea	$888,000	03/01/2005	5/31/2005
Tubal Dam Construction	Dam-031	W-R-WR-Dam Rural-182	Anbar	Construction of earth fill dam on Wadi Tubal in the western desert. Dam would be 490 meters in leng	$6,972,000	01/01/2005	6/30/2009
Well Drilling Equipment	Equip-008		Nationwide	The following equipment is needed: 30 well diggineg machines 300,000m pipes for lining wells 50 sin	$15,000,000	03/01/2005	03/01/2005
Western Gharraf Reclamation Project	Major-019	W-R-WR-Irrigation and Drainage-209	Wassit	The project includes construction of complete irrigation and dranaige networks, including structures, p	$26,646,000	01/01/2005	6/30/2005

Largest by cost	$35,000,000
Smallest by cost	$250,000

Western Gharraf Reclamation Project – Description Field in Full

The project includes construction of complete irrigation and drainage networks, including structures, pumping stations for irrigation, drainage and earthworks. Earthworks includes land sloping and shaping to ensure proper declination. The irrigation network includes the construction of main and minor canals. Feeder canals will be lined with 5-10 centimeters of concrete, and will divide the field in to irrigation units of about 12 – 24 acres. Upstream regulators will be constructed at different canals, as well as falls, minor weirs and vehicles and pedestrians bridges. A pumping station will be constructed to raise water from the Shatt Al Gharaf to the main canals. Construction of the drainage network will include main and minor drains, collecting drains and field drains (perforated PVC). Drainage construction will also include intersecting canal structures as well as drainage pumping stations to raise the water from the main drains to the Al Gharaf big drain. • The lands of this project locate within Wassit & ThiQar governorates, and to the right side of Shatt Al Gharaf in the area between the north of Al Kut city borders ,and in the south of Al Refai˜city & to the east of Al Gharaf river & to the west of Al Gharaf big drain. • The source of irrigation from Al Gharaf River which is gravity branched from Tigris River- the upstream of Al Kut barrage with drainage about 63 M3/Sec. • The drainage of the project lands goes to Al Gharaf big drain which flows into the main outfall in the north of Al Nasiriya city. Irrigation network: • It includes executing main & minor canals & also feeding canals which is lined with concrete and have the thickness of (5- 10 cm), and also dividing the field in to irrigation units of about (30-60) acres. • Executing irrigation structures including executing up stream regulators of different canals , and also control structures , and regulating distributing water between canals and it includes: cutting regulators , falls, minor weir, structures of intersecting culverts with roads, railway, oil piping (if there is any) and vehicles & pedestrians bridges. • Executing irrigation pumping stations , these stations raise water from Shatt Al Gharaf to the main canals in some above sectors with executing service structures for the stations operators. Drainage network: It includes executing main & minor drains, collecting drains, and the covered field drains by using plastic piping of (100 cm) (PVC), also executing drainage structures like drains outfalls, and also executing structures of intersecting canals with the drains and roads, and executing drainage pumping stations to raise the water of some main drains to Al Gharaf big drain with executing service structures for the stations operators, and also developing Al Gharaf big outfall to the main outfall. Leveling works: It includes making leveling for the lands of irrigation units by raising high areas and filling low areas in a proper declination which correspond with the nature of the area.

Preliminary

10 Recommendations

10.1 Data Sharing Arrangements

Data is fundamental to the planning process and it is essential that efforts are made to build on the improving culture of openness to data sharing that Phase 1 has strongly promoted, preferably by establishing formal protocols.

The Data Collection Leaders proved very useful to the ARDI and SWLRI staff allowing them to focus their efforts more effectively. It is recommended that the role of Data Collection Leader is retained (possibly under a new title) into Phase 2.

During Phase 1 it became apparent that there was some data that needed to be collected at governorate or district level. The mechanism for passing data requests from the SWLRI Unit to say governorate level needs to be considered. At present all requests are routed through the Data collection Leader but they may not have the authority to direct governorate staff to provide the data.

During Phase 1 the Claromentis system proved an effective route to get data transferred between ministries. This depends upon the security settings and permissions that are set by the Claromentis Administrator. It is recommended that increased access should be allowed where possible.

The situation in the upper catchments is of great interest to Iraqi planners. How to get data from the upstream neighbours as a matter of routine is something that needs to be explored. Presentations during the shorter study visit covered case studies on promoting transboundary data sharing.

10.2 Quality Control of Data

This is linked to previous section, in that QC of data should be undertaken by the home ministry not by the SWLRI unit who have neither the resources nor the experience to do this as well as it could, and should, be done by the home ministry.

In the case of GIS activities, the concept from the start has been that the MoWR should assist the other ministries to provide reliable geo-referenced data to the SWLRI unit by training them and by setting standards for QC procedures. Every opportunity was taken to reinforce this message and while it is too early to say whether the approach has been successful it seems to be the right model for the future because it should be sustainable.

10.3 Further Data to be Collected

The process of building and testing the models and analytical tools during Phase 1 has highlighted the fact that in most cases other information is still required in order to be able to complete the testing and to make full use of the Phase 1 tools in the future. Two examples have been selected to show where the lack of information available in Phase 1 has been a constraint: the use of the Iraq Multi-criterion Decision Model (Section 5.2), and the water quality model (Section 5.4).

Preliminary

Another particular area is the need for agricultural data records for individual irrigation schemes rather than just accumulated figures for administrative regions. This would allow the link between water supplied and actual yield of crops to be fully explored.

Preliminary

Appendix A Original Data Request

The Work Plan, discussed and agreed in Amman 7-9 June 2005, outlined a two phase approach with the 14 month Phase 1 concentrating on data compilation and the development of tools for use in strategic planning. This document is intended to start the process of data compilation. It provides a very long list of information that would be useful for strategic planning – not all of which may be available at this time. The list is almost certainly incomplete so comments, additions or deletions would be welcome.

Details of Information Requirements

Scene Setting
Detailed overview of infrastructure:

Maps showing all major waterways, ideally as time series eg map of systems in 1960s, 1970s, present.

Maps showing irrigated areas, on and off stream reservoirs, water supply intakes, offtakes and discharges, canal and drain systems

Surface Water Data (Rivers - canals and drains see I&D data)
(Note much of this information has already been collected by MoWR with HEC on the marshlands restoration project)
Gauging station (GS) locations (grid reference)
Date of opening and closing of GS
Method of measurement (automatic water level recorder, 3xday staff gauge, cableway etc)
Suitability of site: full range? Stable control? Bypassed during floods? etc
Indication of reliability (poor/medium/good) with justification
Daily mean discharges (m^3/s) for full period of record at each gauging station
Annual maximum instantaneous water level and discharge
All GS rating curves (current and past with dates and water level ranges for application)
All current meter measurements taken to calibrate rating curves (date of measurement, water level, discharge)
All GS channel sections (all topographic records for each site)
Water level records – required if rating curves suspect and discharges need reprocessing.
History of major river engineering works (dates, locations, consequences) including temporary and permanent diversions, provision of storage.
Details of seasonal water management practices.

Use of the data: water availability, flood and drought flows, peak flood levels, check on reliability of rating curves and therefore flow estimates, estimate of any rehabilitation/upgrading needed.

Groundwater and Spring sources
Location of monitored springs (grid reference)
Location of piezometers (grid reference)
Aquifer characteristics: stratigraphy, permeability, transmissivity, storage, hydrochemistry
Regional and subregional geological reports and maps
Hydrogeological reports and maps
Piezometer drilling records – depth, location of screen, drilling logs
Water level records from piezometers
Discharge records from springs
Borehole drilling records – depth, diameter, depth of casing, screen details, logs
Borehole locations (grid reference), pump type and characteristics, yield

Preliminary

Pump test records
Records of groundwater pollution
Details of groundwater pollution monitoring

Use of data: water availability, seasonal water table movement, drought water levels, estimate any rehabilitation/upgrading needed for monitoring network.

Water Quality information
Location of *routine* monitoring points for both surface and groundwaters (grid reference)
- Method of sampling and immediate treatment of samples to be taken to a laboratory
- Field test procedures
- Laboratory procedures
- Records of Parameter values eg sediment, salinity, total dissolved solids, chemical analysis etc

Location of temporary or project monitoring points (grid reference)
- Method of sampling and immediate treatment of samples to be taken to a laboratory
- Field test procedures
- Laboratory procedures
- Records of Parameter values eg sediment, salinity, total dissolved solids, chemical analysis etc

Details of laboratories carrying out water quality sampling (name, ministry or local authority name, location, range of parameters that it is equipped to test for, etc)

Reservoirs
(Note much of this information has already been collected by MoWR with HEC on the marshlands restoration project)
Date construction started, date filling completed
Design and current purpose of reservoir
Storage volume/Area/Elevation curves
Spillway details, dam height, dead storage allocation, outlet details, offtake arrangement details
Operating rules/procedures
Organisation responsible for reservoir operation
Authority responsible for providing operating rules/capacity to override rules

Regulating Structures
Date construction started and finished
Details of gates etc
Function
Capacity
Operational records
Operating rules/procedures
Current status of mechanical, electrical and civil works. Is it fully or partially operable?
Is water control achieved at present?

Data for: assessing rehabilitation/upgrading of structure, investigate operating rules

Irrigation & Drainage Systems
Irrigation system boundaries (geo-referenced)
Drainage system boundaries (geo-referenced)
Water user associations (area covered, date formed)
Reuse of drainage water
Details of water management systems (monitoring - where, how, and how often), method of communication of operational information
Number of farms overall and by size

Preliminary

Population directly dependent on irrigation system for majority of their income (farmers, truck drivers, local traders, support services, resident family members) – approximate population of local towns/villages is an acceptable proxy.
Design reports and feasibility studies (bibliography and location where copies obtainable (if known))

Pumping stations (fixed installations)
Location (grid reference)
Command area – design
Lift
Date construction started and finished
Energy supply
Details of installed capacity and type of pump(s)
'passport'
Current status of mechanical electrical and civil works

Small mobile pumping plant
Estimate of numbers
Capacity of typical unit
Energy supply

Regulating structures
Location (grid reference)
Date construction started and finished
Design capacity
Energy supply
Notional hydraulic characteristics
Operator's records (flow/setting)
Current status of mechanical electrical and civil works

Flood Management
Levees: location, type, nominal protection level (elevation), condition
Escapes: location of intentional breaches and escape canals
Planning regulations (zoning) and accepted return period for design (eg urban areas the target for defence works could be from all floods up to 100 year flood)
Current forecasting and warning practice
Historical flooded areas (focus on Baghdad and other population centres)
Records of damage caused by flooding (monetary value and year)

Policies: Past, Current, and under development by sector
Trade (including import/export)
Agriculture
Melioration
Water supply and sanitation
Water charges
Licensing of abstractions for surface or groundwater
Water user associations
Environment – water quality, wildlife, sustainability
Energy especially policies on role of hydropower
Transport especially policies on role of inland waterways
Industry
Institutional structures – roles of ministries, state organisations, local government, private companies/organisations

Preliminary

Legal Agreements, Treaty obligations
International basins
Transboundary water related agreements eg Shatt al Arab
Environmental standards (including water quality)
Bibliography of all current legislation affecting water and the water-related environment

Public Water Supply and Sewage Disposal
Demography and spatial distribution of population
Socio-economic data (income levels)
Numbers of houses with full piped water/flush toilets
Numbers of houses with septic tank
Demand forecasts
Urban and rural population (past and forecast)
% population with access to treated drinking water
% population served by distribution systems
% of distribution system requiring rehabilitation
% population served by sewage systems
% of sewerage system requiring rehabilitation
location of potable water treatment works (grid reference)
type of water treatment at each works
Each works: abstraction from what? and where is intake or borehole (grid reference)
Water quality at intake and after treatment (range of values)
Water quality problem areas and their extent
location of sewage treatment works (grid reference)
type of sewage treatment at each works
Each works: discharge to what? and where is outlet (grid reference)
water quality of effluent (range of values)

Industrial Water Use and Discharges
Estimate of usage provided through public water supply systems
Demand forecasts
location of industrial user (grid reference)
type of industry and nature of use of water
Discharge to what? And where is outlet (grid reference)
water quality of effluent (range of values)
Details of any on-site effluent treatment
Water quality problem areas and their extent

Industrial Water Use and Discharges
Estimate of usage not provided through public water supply systems
Demand forecasts
location of industrial user (grid reference)
type of industry and nature of use of water
Each intake: abstraction from what source? and where is intake or borehole (grid reference)
Water quality at intake (range of values)
discharge to what? And where is outlet (grid reference)
water quality of effluent (range of values)
Water quality problem areas and their extent

Land/Agriculture
Land use (current and trends)
Irrigated lands
Cropped area by crop type and district

Preliminary

Crop water requirements including land preparation/leaching needs
Agricultural production statistics by district and by crop
Constraints to land development options eg maps showing steep slopes, areas subject to serious soil erosion, areas subject to salinisation, areas subject to seasonal flooding
Details of any studies on constraints (bibliography)
Land condition: salinity level, depth to water table, quality of shallow groundwater
Agricultural drainage: presence/absence, type of system, conditions (functioning/ barely functioning/not functioning)
Livestock numbers estimates by district and type (current and trends)
Details of agri-processing plant (eg sugar refinery location, capacity, current production level)

Energy Sector
National generation capacity kWhr by year and maximum load kW
Annual pattern of load
Daily pattern of load (winter and summer separately)
List of power stations by region with installed capacity and type
Projections of future power demand
Transmission system description

Hydropower Installations
Location
Installed capacity and when installed
Type of turbines, turbine characteristics
Is it a multipurpose reservoir/barrage? If so what is the priority of the needs of power generation compared to the other uses?
Operating rules
Operating records (discharges, power generated eg monthly)

Channel Morphology
Known problem areas for erosion/deposition
Navigation routes and target depths
Number/capacity of dredgers
Annual volume of dredging by river reach
Annual cost of dredging
Cross sections with date of survey

Navigation
Location and physical characteristics of locks
Location of ports/docks
Locking arrangements
Estimates of traffic (past and current)
Value of cargo transported
Operation costs (boat running costs, cost of maintaining locks, wharves etc)
Forecast traffic and cargo
Estimated volume of cargo transported by land
Proportion of annual cargo transported carried by water
List constraints to navigation and proposed measures

GIS (geo-referenced in accordance with coordinate system to be used throughout the project)
Satellite imagery for base mapping
Rivers/lakes geo-referenced
Administrative boundaries
Hydrologic and hydrogeologic sub-basin boundaries

Preliminary

Meteorological Information
Location of synoptic, agrometeorological and rainfall stations
Periods of record
Indication of reliability
Parameter values: temperature, humidity, wind, sunshine, evaporation

Economic Aspects
Tariff for power
Water charging structures
Cost information for engineering works to build up cost estimates for potential development or rehabilitation packages
Agricultural prices (inputs and outputs), subsidies.
Taxes and duties affecting water users (municipal, rural, industrial)
State guaranteed price arrangements

Environment
Boundaries of any designated nature reserves, Ramsar sites etc
Details of studies eg Marsh Restoration
Red data species or habitats
Shatt al Arab and obligations to Gulf water quality

Upstream Countries
(such information as can be obtained from published sources or informal contacts)
Planned developments on rivers draining to Iraq
Policies for development in water sector
Studies on developments
Studies on environmental impact of planned developments

Institutional Structures
Government organisation structures as affects water/agriculture/environment sector
Details of rights enjoyed by Government national and local and its agents to act in these sectors
Chain of command and reporting for operation of water related infrastructure
Chain of command and reporting for monitoring of water resources and their use ie where is monitoring data processed and where is it stored (locally/centrally etc)

References/Studies etc
Updating of the preliminary list of relevant papers, studies etc circulated at the Amman meeting on completed or ongoing projects
Schedule of proposed project support eg plans of various UN agencies described by the UNESCO representative at the Amman meeting.

Preliminary

Appendix B Record of Discussions with the Groundwater Studies Centre

Preliminary

Preliminary

Record of Meeting/Discussion

Project Title	Strategy for Water and Land Resources in Iraq	**Division**	WER
Subject	Groundwater Studies Centre	**Project No.**	208465
Location	Teleconference – Cambridge - Baghdad	**Date of Meeting**	16/06/06
Present	Dr Sadik (DS), Groundwater Studies Centre	ARDI:	
		Milo Simonic	
		Charles Jones	
		Cat Watts	
		Clare Wilson	

Recorded by	**Distribution**
CHW	Present, plus Alison Stuck, Neil Morris, Peter Halifax, Andrew Paskins, John Prytherch, Phil le Gouais

Item	**Text**	**Action on**
1 0	Introductions	
1 1	Introduction to the Groundwater Studies Centre • Established 2 years ago • Part of the Ministry of Water Resources • Role: improving data collection and water resources management	
1 2	4 specific projects being undertaken at present: 1. Collection of data • Information is being collected on wells, geology, hydrological data • A database is being established • Producing maps on scale of 1: 1 million *ARDI would like to know more about the database that is being set up and the maps that are available.*	DS
	2. Nationwide Monitoring Network • At present there is no countrywide monitoring network in place • Monitoring has been undertaken on a short term basis for specific projects (e.g. the FAO work). Some existing monitoring is being continued? • A new monitoring network is currently being designed • The first year of this work has comprised the delineation of the aquifers, their condition, and fluctuations in water level – this will determine the monitoring network that will be designed • 15 aquifers have been delineated, of which five or six are the main ones. • The delineation has been completed for the desert (formation and thickness) and has been started in other areas. • The focus has been to start on areas where aquifers are already exploited, and then extend the work. • Maps have been produced • Approximately 300 monitoring wells will be established.	

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Record of Meeting/Discussion Continuation Sheet

Project No. 208465 **Date of Meeting** 16/06/06

Item		Text	Action on
		• Work is being funded by Ministry of Water Resources *ARDI will review the monitoring data we have already, and then contact Dr Sadik regarding gaps* *We would like to see the maps of the desert, and aquifers that have been delineated* 3. Eco-Agricultural Zoning • Maps being produced that relate to the susceptibility of groundwater and its suitability for agriculture • Presentation made to SWRLI steering group meeting about this project • 40 areas identified as suitable (?) • Iraq divided into five regions, three of which defined as suitable (?) • Study plans are being defined for selected areas. • Survey undertaken on 1:250 000 scale. • Certain areas in the north not covered yet, but these have been examined in the FAO report. 4th project?	
2	0	Outputs • No reports produced yet for the projects listed above • However, some proposals have been sent to funding agencies, but have not yet been successful in obtaining funding. • E.g. proposal for Diyala Basin – to try to get groundwater used as a resource • Comment – more use of groundwater in the north will save surface water in the south and improve water quality.	
3	0	ARDI outputs • Dr Sadik suggested Diyala and Lower Zab basin as appropriate pilot areas that he is already working on (note – river basin areas, not governorates)	MM to include at least one of these areas as a pilot
4	0	GIS data • There is a GIS centre in the Directorate, but the Groundwater Studies Centre staff need training – they have put forward a proposal for future capacity building. • GIS was used as a tool in the agriculture work – AEZ mapping. • Some training has already been undertaken.	
5	0	Groundwater Studies Centre staffing • 12 people • Many have long experience • Mainly hydrogeologists and geophysisists	
6	0	Groundwater modelling • Three or four people in Centre trained in modelling	

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Record of Meeting/Discussion Continuation Sheet

Project No. 208465 **Date of Meeting** 16/06/06

Item		Text	Action on
		• There is a 2-d 1982 groundwater model of Erbil (Dr Sadik involved) • In 2005 they agreed to construct a new model of Erbil, but there is a present lack of resources • Dr Sadik knew of approximately ten groundwater models that had been developed.	
7	0	Estimating recharge • They do some water balance calculations to estimate recharge, and then check them, e.g by using isotope data for Kerbala. • Keen for ARDI to provide advice in recharge estimation	
8	0	Well drilling • Noted that the drilling of abstraction wells is not covered by the Groundwater Studies Centre, and they do not hold information on what wells are in existence	
9	0	Irrigation return water • No studies undertaken by Groundwater Studies Centre, but some work may have been done by the College of Engineering.	
10	0	Claromentis – SWRLI extranet • ARDI to investigate obtaining access to Claromentis for Dr Sadik	

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Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Geographic Information System and Databases Strategy for Developing Planning Tools

GN 02

August 2006

GN 02 Rev 0

This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note describes the strategy for further development of GIS and databases prepared by the consultants in collaboration with Mr Mudher of the Ministry of Water Resources GIS Section.

Preliminary

Report Issue and Revision Record

Rev	Date	Description
P1	August 2006	Preliminary when Phase 1 curtailed

List of Contents

Page

Chapters and Appendices

1	Introduction	1
2	Standardisation of Software	2
3	GIS Standards and Structure	2
4	Data Exchange Mechanisms	4
5	Reliability of Data	4
6	map products for planners	4
7	Evaluating Training Needs	4
8	Evaluating Hardware and Software	5
9	Developing Mutual Professional Support Mechanisms	5

Appendix A	Suggested Map Products	A-1

Preliminary

Acronyms

ARDI	Agricultural Reconstruction and Development in Iraq project
GIS	Geographic information system
IT	Information technology
MoWR	Ministry of Water Resources
SWLRI	Strategy for Water and Land Resources in Iraq
USAID	United States Agency for International Development

Computer Software Packages and Specialist Terminology

ArcGIS	GIS software from ESRI
Claromentis	Web-based collaboration system from Claromentis Ltd
HEC-ResSim	Reservoir operation software from the HEC
SQL	Standard Query Language
WMSM	Water management system model for Iraq built using HEC-ResSim

Preliminary

1 INTRODUCTION

1.1.1 Maps and GIS tools are extremely important in strategic planning. Not only are they actively used by the planners but they are a vital component of the extremely important task of selling the resulting plans to others: politicians, other ministries, and the general public.

1.1.2 At the start of the SWLRI project in July 2005 GIS capacity was limited to a few small centres, the largest of which was the GIS Section within the MoWR. From the start the SWLRI team have emphasised the value of using maps and GIS tools to assist in strategic planning work. In February 2006 the first GIS Cluster meeting was held with representatives of 11 ministries in Erbil to raise awareness of the potential of GIS tools and to start a collaborative process by which all ministries contributing to SWLRI Phase 1 would develop their GIS capability and move towards adoption of common standards to facilitate future exchange of data.

1.1.3 This document presents a strategy for developing and maintaining a suite of GIS tools and map products for use by the SWLRI Unit, and for establishing formal mechanisms for sharing expertise and exchanging data.

1.1.4 The strategy addresses the following topics:

- Agreement on standard software
- Appropriate structure for information
- Identification of data exchange mechanisms and quality control processes to ensure the reliability of data being exchanged
- Evaluating training needs at each of the participating ministries
- Evaluating hardware and software needs at each ministry
- Developing mutual professional support mechanisms.

Preliminary

2 STANDARDISATION OF SOFTWARE

2.1.1 The data being collected by and on behalf of the SWLRI Unit needs to be arranged in a structured predefined manner. The MoWR standard software is ArcGIS from Esri software. This is a comprehensive suite of applications that has gained worldwide recognition and is in use in many government organisations in many countries.

3 GIS STANDARDS AND STRUCTURE

3.1.1 Geo-referenced information held within ArcGIS is generally held in the following formats:

1. Shape Files. These are individual data layers that are stored as points, lines or polygons. Shape files generally comprise one type of information for instance well locations could be stored as points; agricultural areas could be stored as polygons.
2. GeoDatabases. These are effectively collections of shape files contained within a Microsoft Access (Jet) or SQL database. Again, these may comprise point, line or polygon information. Geodatabases allow GIS administrators to create complex interrelations between datasets and aid in the management of the GIS system.
3. Raster Data Sets are usually large data files containing information such as satellite or aerial photography or map scans.
4. Databases with a Geo-referenced component. Access, SQL or another database source can contain data such as latitude and longitude. Generally used to store point information, the coordinates are usually stored in decimal degrees.

3.1.2 All of the above information has to be based on a standard projected coordinate system. Most of the data within Iraq has so far been projected to WGS 1984 UTM Zone 38N. Iraq actually covers 37N, 38N and 39N, and it is possible to use all projections within ArcGIS files, but it does introduce a level of complexity that may lead to a number of errors if not administered correctly. 38N covers Baghdad and is a very good compromise projection for all information. This standard has to be agreed by all ministries, not least those in Erbil and Sulymaniyah, who lie outside of the 38N area.

3.1.3 Storage locations and naming conventions are important too when producing a GIS strategy. These need to be formulated before construction of the databases commences. The structure of the GIS system is very important. A suggested structure is to arrange data by function rather than ministry or information storage method. Water based GIS systems developed in other countries have divided the information up into five areas:

1. Supply sources, or available resources, layers. These comprise features such as river diversion points, wells, desalination plants, imported water, water treatment plants. These layers are usually point or polygon features within geodatabases.
2. Demand centres layers. These comprise features such as population centres, industrial areas, forestry, agriculture and exported water. Power stations and

Preliminary

dams are also to be included within these layers. As with supply layers, these layers are usually point or polygon features within geodatabases.

3. Conveyance layers. These comprise features such as canals, drains, water pipelines both for supply and for waste. These layers are usually line features within a geodatabases.
4. Geographic inventory layers. These layers comprise information such as river/lake and sea, rainfall distribution and soil areas. These layers are usually utilised when performing analyses or creating comprehensive maps for use in areas such as agriculture or transportation. These layers are invariably stored as polygon or point survey information.
5. Source data layers. These comprise source information and are usually utilised when building up the previous 4 layer types. These layers could be satellite information of varying type, aerial photography or scanned survey maps. These are usually stored as raster information, manipulation and editing of these layers is difficult, so they are usually used for reference.

Preliminary

4 DATA EXCHANGE MECHANISMS

4.1.1 At the start of SWLRI there was a considerable variation in the extent of digital GIS usage between ministries with the MoWR being in the vanguard. The methods of data exchange being developed between SWLRI and the ministries must therefore provide for both electronic and paper formats, and the flexibility to change as GIS usage becomes more widely adopted with time.

5 RELIABILITY OF DATA

5.1.1 By adopting generic standards for data quality control the ministries can ensure that all spatial information being exchanged is reliable having passed through a number of checking procedures with the originating organisation.

5.1.2 The generic standards should be developed by the MoWR GIS Section which has already considerable experience of creating and maintaining GIS products. They should then be disseminated through the mechanism of the Cluster Meetings.

5.1.3 Other ministries should then review the generic procedures and compare them to existing procedures used by their technical staff. They should then develop their own local ministry standard procedures and disseminate them to other participants through the Cluster Meetings.

6 MAP PRODUCTS FOR PLANNERS

6.1.1 It is most important that the GIS specialists in the various ministries maintain a regular dialogue with the planning staff both within their own ministry and with the SWLRI Unit. The needs of the end users must be the driver for the GIS work.

6.1.2 Preparing geo-databases can be very time consuming and it is therefore important that the GIS work is prioritised so that the most urgently needed products can be delivered to the planners as quickly as possible. Part of the dialogue with the end users should be about the time frame for delivery and the resources needed to complete the activity.

6.1.3 Some suggested map products that would benefit the SWLRI Unit are listed in Appendix A.

7 EVALUATING TRAINING NEEDS

7.1.1 Capacity building in GIS at each of the participating ministries is an important part of the development of strategic planning activities.

Preliminary

7.1.2 The initial GIS Cluster meeting in Basra raised the issue of training for GIS staff. Many of the ministries have software and hardware but have few or no trained staff. It was suggested that an introductory course on GIS would be valuable to several of the ministries.

7.1.3 A second higher level of GIS training for MoWR themselves would also prove beneficial. The MoWR GIS department is already ahead of other ministries in its capabilities, and SWLRI provides it with a new remit to deliver its services to others outside its own ministry. A role of this type requires a highly effective team of well trained GIS professionals that are able to deliver accurate mapping information at a high rate. Advanced GIS training courses would certainly facilitate this.

7.1.4 During SWLRI Phase 1 a number of courses were held and the lessons learned should be fed back via the Cluster Meetings to allow for continuous improvement of the training opportunities.

7.1.5 Training needs and the merits of particular forms of training should be re-evaluated every year.

8 EVALUATING HARDWARE AND SOFTWARE

8.1.1 For some ministries the issues are what equipment and software are required to set up a GIS section, for others such as MoWR the issue is of keeping abreast of improvements in technology and software versions.

9 DEVELOPING MUTUAL PROFESSIONAL SUPPORT MECHANISMS

9.1.1 The Cluster Meetings have played an important role in bringing GIS professionals and those with an interest in taking up the subject together to focus on raising standards in map and GIS products. These should be continued and held quarterly.

9.1.2 A technical discussion forum should be established on Claromentis so that ministries' GIS and other interested parties can develop question and answer postings to share knowledge around the group.

9.1.3 The valuable centre of expertise at the MoWR should be exploited by other ministries for ongoing technical support. This may require financial arrangements to be agreed between ministries and the MoWR.

9.1.4 Iraqi experts in GIS such as Mr Mudher of the MoWR should be used where appropriate to lead training courses.

Preliminary

Appendix A Suggested Map Products

This appendix contains a list of some of the map products that would be useful for the activities of the SWLRI Unit. It is indicative only and is intended to prompt the GIS teams in the various ministries, and particularly that of MoWR, to put forward additional ideas for map products for the SWLRI Unit to consider.

Map product and suggested use	**Layers needed**
Agro-climatic zones and irrigated areas *To determine which set of crop water requirements to use for a particular irrigation area*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Irrigation scheme boundaries – formal schemes
	Irrigation area boundaries - traditional
	Agro-climatic zones (General Scheme Stage 2)
Iraq WMSM computation points and irrigated areas *To determine which irrigated areas are associated with which WMSM computational point when preparing scenarios*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Irrigation scheme boundaries – formal schemes
	Irrigation area boundaries - traditional
	Main canals
	Main drains
	Dams
	Barrages/weirs
	Pumping stations (irrig & drainage)
	Nodes and other computation points in ResSim
Hydrometric network and/or water quality monitoring network *To show where monitoring takes place. Could add Nodes for ResSim layer to show where calibration points fit with the model structure*	National borders
	Governorate boundaries
	Watersheds (main river basins)
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Dams
	Barrages/weirs
	River gauging stations
	Water quality routine monitoring sites
Climate monitoring network *To show where monitoring takes place. Could add layers for any climate parameter, eg:* *Average annual rainfall, temp etc*	National borders
	Governorate boundaries
	Watersheds (main river basins)
	Main rivers
	Lakes

Preliminary

Map product and suggested use	**Layers needed**
Average winter season rainfall, temp etc *Average December rainfall, temp etc* *Or one of the agro-climatic zone layers*	Reservoirs
	Sea
	Major town names and scaled symbol
	Raingauges
	Climate stations
	Agro-meteorological stations
Groundwater monitoring network *To show where monitoring takes place*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Geological formations
	Hydrogeological characteristics
	Major town names and scaled symbol
	Piezometers
	Water quality routine monitoring point
Monitoring within irrigated areas *To show where level/flow and water quality are monitored within the canal and drain networks to assess water use and return flows*	National borders
	Governorate boundaries
	Watersheds (main river basins)
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Irrigation scheme boundaries – formal schemes
	Irrigation area boundaries - traditional
	Main canals
	Main drains
	Dams
	Barrages/weirs
	Pumping stations (irrig & drainage)
	Level/flow gauging stations
	Water quality routine monitoring sites
Hydropower schemes (existing and proposed)	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Dams
	Barrages/weirs
	Hydropower installations
Water supply and sanitation infrastructure	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol

Preliminary

Map product and suggested use	Layers needed
	Water Treatment Plant
	Area served by each WTP
	Wastewater Treatment Plant
	Area served by each WwTP
Groundwater development *Could be combined with a layer showing water table depth*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Geological formations
	Hydrogeological characteristics
	Major town names and scaled symbol
	Boreholes
	Water wells
	Springs
Irrigated agricultural production by crop and by governorate *Could show other crops, other seasons, average over last 5 years, individual years* *Could show rainfed agricultural production by crop and by governorate and could add layer for season rainfall amount*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Cultivated area – wheat (winter season)
	Harvested area – wheat (winter season)
	Yield – wheat (winter season)
	Production weight – wheat (winter season)
	Production value – wheat (winter season)
Irrigated agricultural production by crop and by scheme or area *Could show other crops, other seasons, average over last 5 years, individual years*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Irrigation scheme boundaries – formal schemes
	Irrigation area boundaries - traditional
	Cultivated area – wheat (winter season)
	Harvested area – wheat (winter season)
	Yield – wheat (winter season)
	Production weight – wheat (winter season)
	Production value – wheat (winter season)
Map of saline or water logged soils *Could combine with crop yield to show where soil conditions restrict yield compared to other areas*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Soil type
	Major town names and scaled symbol
	Irrigation scheme boundaries – formal schemes

Preliminary

Map product and suggested use	Layers needed
	Irrigation area boundaries - traditional
	Piezometers
	Water quality routine monitoring point
Navigation infrastructure *Could combine with a layer showing volumes of traffic or weight of cargo transported*	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Navigable river reaches
	Major town names and scaled symbol
	Locks
Areas where no development can take place	National borders
	Governorate boundaries
	Main rivers
	Lakes
	Reservoirs
	Sea
	Major town names and scaled symbol
	Protected areas (environment)
	Restricted areas
	Cultural / heritage sites

Note: The list above is far from exhaustive.

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Opportunities Data Set
Guidance Note on Data Requirements

GN 05

August 2006

GN 05 Rev 0

This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note presents the proposed overall approach to the development of the Strategy for Water and Land Resources in Iraq (SWLRI), both in Phase 1 and thereafter.

Preliminary

Report Issue and Revision Record

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List of Contents

Page

Chapters and Appendices

1 The Planning Approach 1

2 What are 'Opportunities'? 2

3 What Level of Preparation is each Opportunity at? 2

4 How will Opportunities be Treated in the SWLRI Planning Approach? 3

5 What is Needed from each Ministry? 3

Appendix A SWLRI Opportunities Report Format A-1

A.1 Sample Reporting Format A-1

A.2 Worked Example A-2

List of Figures

Figure 5.1: The Planning Approach 4
Figure 5.2: Project Cycle Concept (Source World Bank) 5

Preliminary

1 THE PLANNING APPROACH

1.1.1 Figure 5.1 presents a diagrammatic representation of the proposed overall approach to the development of the Strategy for Water and Land Resources in Iraq (SWLRI), both in Phase 1 and thereafter. The approach has the following particular features:

1. It emphasises a distinction between facts and needs: facts about the present state of the country's water resources and its physical infrastructure (both natural channels and man-made infrastructure), and on the other hand needs and desires for water use, flood control and environmental conditions.

2. It emphasises, alongside facts and needs, a third data set concerning **opportunities for the future**; these include not only potential physical interventions like completing the Bekhme Dam but also policy changes like a shift to different crops on irrigated land, a changed way of using hydropower stations within the national energy sector, or a different way of interacting with upstream countries.

3. It emphasises interventions (as defined in point 2 above), and packages of interventions, as units of the planning process.

4. It emphasises the iterative nature of the evolution of a strategy plan.

1.1.2 The diagram divides the planning work into three functional stages and also emphasises the iterative nature of the planning process. Its Stage B begins with the formulation of possible packages of interventions, using the set of opportunities prepared at Stage A, and also the preparation of models, analysis tools and comparison criteria. These will include not only technical but also social, economic and environmental considerations. They will then be used to examine the consequences of each hypothetical package of interventions (which may be quite complex because of the nature of Iraq's interconnected rivers, canals, reservoirs and groundwater) and to compare them. The next step is to consider whether at least some of the packages are useful and well-packaged, and if appropriate to revisit the formulation step and develop new packages in the light of the analysis so far; this is followed by a repeat of the examination and comparison steps. During this iterative process it may prove necessary to go back and seek additional data.

1.1.3 Acceptable packages proceed to the stage of formulating the strategy, which is in effect a prioritised set of intervention-packages, and this again is iterative. The formulation will make use of the earlier analyses of individual intervention-packages, and repeat them if necessary to refine the strategy. Costs will be considered, to ensure that the timing of interventions is balanced from year to year to match the available or probable human and financial resources.

Preliminary

2 WHAT ARE 'OPPORTUNITIES'?

2.1.1 Opportunities represent possible actions or interventions for MoWR and other ministries to budget and programme for, and to implement in the short, medium or long term horizons. They represent potential calls on the national budget in the near and longer term and as such need to be prioritised for the water and agriculture sectors as a whole. Opportunities cover an exceedingly wide range of possibilities from new studies to actual construction, from policy change to capacity building and training, etc.

2.1.2 Each ministry has its own ideas for future activities in the short and longer term to fulfil its particular mandate and contribute to national development. Water and land issues may feature only indirectly or as a minor component in the projects planned by some ministries but these projects might have consequences for the water sector and so are relevant to the SWLRI planning process.

2.1.3 Projects identified by all the ministries contributing to SWLRI are to be collated to build up the opportunities data set.

3 WHAT LEVEL OF PREPARATION IS EACH OPPORTUNITY AT?

3.1.1 From an initial idea to completion of any project is a staged process. It is common for the stages to be described in terms of the project cycle. Figure 5.2 illustrates this concept as it is used by the World Bank. A key stage in the cycle is 'identification' when an idea is first formulated into a project concept, then reviewed against wider objectives and also checked for internal consistency against the particular criteria that the ministry or donor has chosen to apply. As the project progresses through the first half of the project cycle it is more closely defined and improved. Since SWLRI is about planning for the future the opportunities data set should contain all proposals that have yet to secure funding and start implementation.

3.1.2 As it will be necessary for the SWLRI team to compare ideas that are different stages in the project cycle some form of brief standardised report will be required. This may be based on the World Bank's Project Information Document format. The SWLRI team will complete this in consultation with the ministry concerned.

3.1.3 Where projects are at an advanced stage of preparation it will be important to review the background studies, particularly environmental impact assessments. For ideas that are at a very early stage the process of preparing the standardised report with the ministry may itself help to bring the idea forward.

3.1.4 A sample format for this standardised report is given in Appendix A. A blank form and a partially completed example are given to illustrate the concept.

Preliminary

4 HOW WILL OPPORTUNITIES BE TREATED IN THE SWLRI PLANNING APPROACH?

4.1.1 The SWLRI Unit will use the opportunities data set, and also invite and welcome suggestions from all stakeholders, to distil out a manageable set of packages for the initial comparisons.

4.1.2 After the consequences of various potential intervention-packages have been worked out, the next step will be to compare the packages. It is proposed to use a form of multi-criterion analysis, which should be systematic and transparent so that decision-makers can understand how the recommendations have been arrived at. The analysis will be based on criteria that are developed with the stakeholders.

4.1.3 A key process at the end of the first round will be to review how the process worked in all aspects and to provide feedback to the stakeholders.

5 WHAT IS NEEDED FROM EACH MINISTRY?

5.1.1 The SWLRI Unit need to assemble a **long** list of opportunities covering the whole spectrum of water and land activities in order to start the planning process and demonstrate the modelling tools.

5.1.2 A start has been made by reviewing material on the International Reconstruction Fund Facility for Iraq web site www.irffi.org. However, these are just the proposals that have formally been put forward to the particular donors associated with this fund, and are therefore all at an advanced stage in preparation.

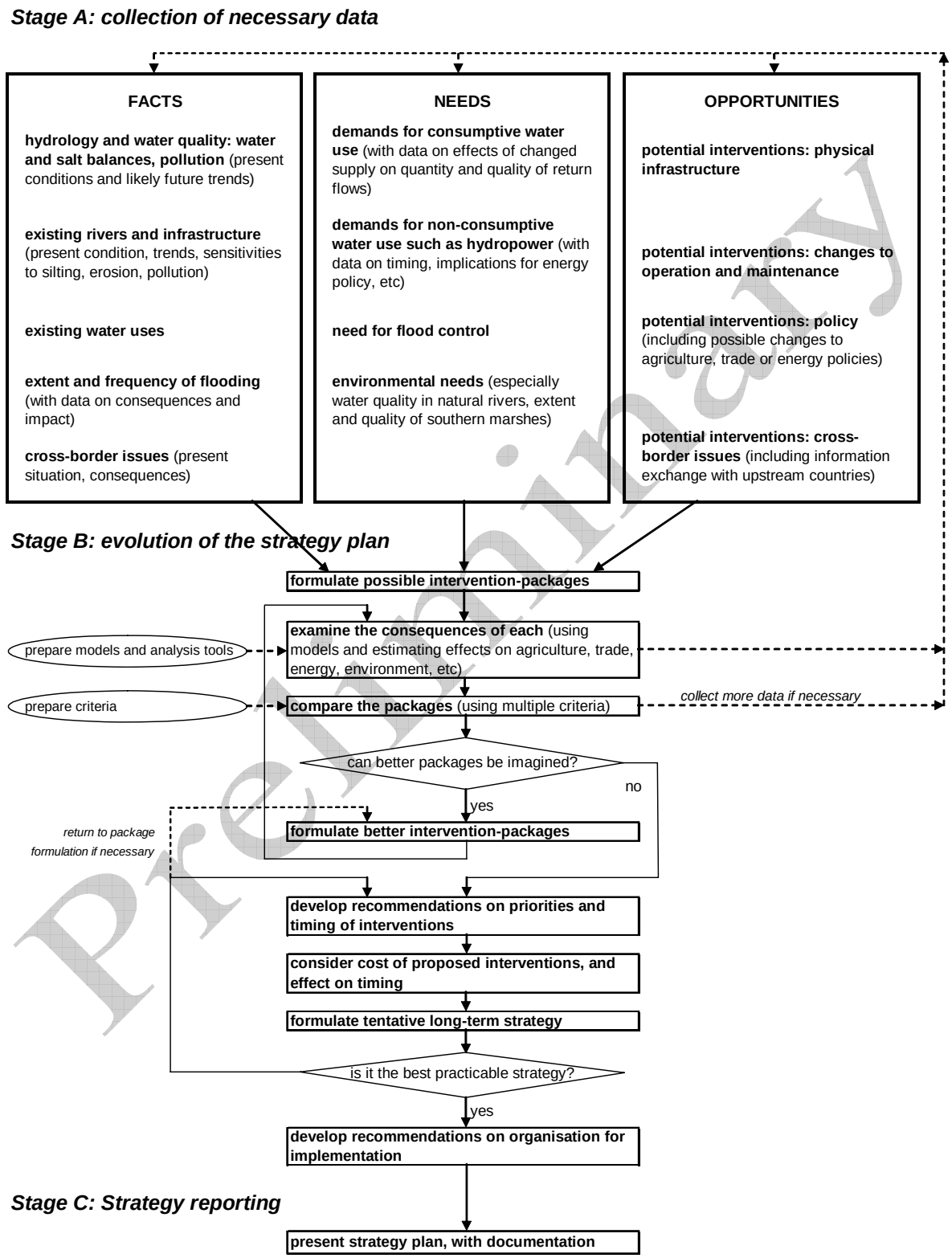
5.1.3 The SWLRI Unit requires from each ministry a list of projects, proposals, concepts, and possible ideas prepared by their own planning teams which can be construed as 'opportunities' that relate to water and land. To facilitate this process each ministry will be asked to nominate a point of contact in their planning team, and may be offered assistance in the data compilation if this is required.

5.1.4 The report format illustrated in Appendix A identifies the **supporting information** about each opportunity that is required by the SWLRI team. References for all studies and surveys related to the project proposals are requested from the ministries in order to provide a clear picture of the previous work done to prepare the project, and to ascertain the stage of the proposal in the project cycle. The brief standardised report format has a two page summary of *Basic Information about the Proposed Project* and *Supporting Information* (see Appendix A for template and example). The reporting format, a Word document, accompanying this guidance note is available to assist the ministries in providing the requested supporting information. While the format illustrated in Appendix A would be particularly useful, the ministry can discuss other formats if that is their preference.

Preliminary

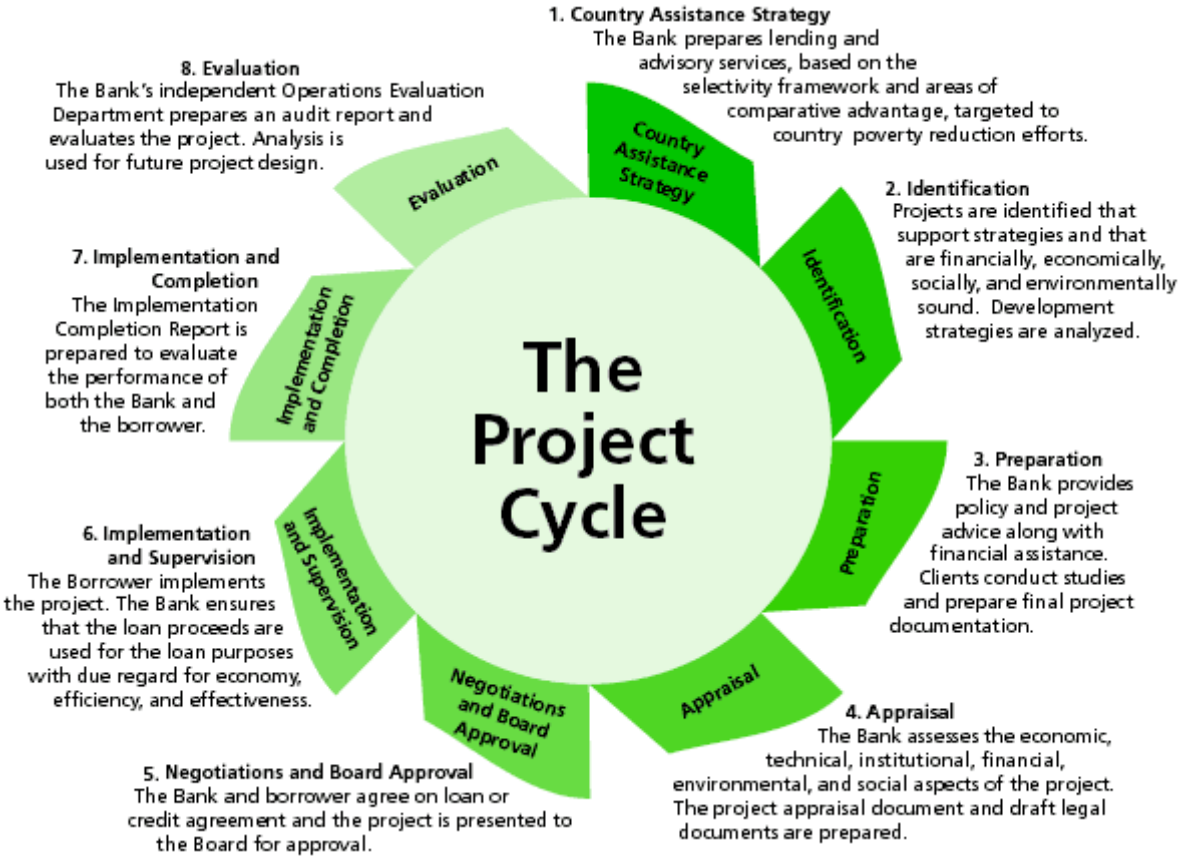
5.1.5 Ministries can also put details of their 'opportunities' directly onto their own area on Claromentis in any format of their choice.

Figure 5.1: The Planning Approach



Preliminary

Figure 5.2: Project Cycle Concept (Source World Bank)



Prelim

Appendix A SWLRI Opportunities Report Format

A.1 Sample Reporting Format

Sample reporting format loosely based on World Bank Project Information Document.

A worked example is given in Section A.2.

Preliminary

Basic Information about the Proposed Project

		Please complete all sections
Project Name		
Project Description		
Location		
Category of proposal *(strike out categories which do not apply)*		Monitoring/field investigations Study Design Construction Training/capacity building Institutional/legal Socio-economic Environmental Safety Other ……..
Implementing Agency		
Estimated duration		
Target start date		
Estimated international contribution ($)		
Estimated counterpart costs ($)		
Source of funds if known *(if a potential source of funding has been identified please specify)*		
Organisation putting forward the proposal *(ministry, department, and contact person in the event of queries)*		
Date received by SWLRI Unit		
SWLRI ID code		

Supporting Information *(To be completed by ministries)*

Note:
N/A – Not applicable for this project proposal

Stages in preparation of this project	**Completed**	
	Y, N, N/A	**Year**
Strategy study		
Pre-feasibility study		
Feasibility study		
Detailed design study		
Procurement (Tender Docs)		
Environmental Impact Assessment		
Surveys/field investigations		
Institutional analysis		
Training needs assessment		
Other eg World Bank Safeguards		

Reference documents and maps *(extend list if more documents are available)*			
No.	**Year**	**Author**	**Title**
1			
2			

To be completed by SWLRI Unit

Record of data collection and review *(date and/or actions)*							
No.	Requested from ministry	Date Received	If required: Returned	Reviewed	If required: Translated	If required: Scanned	Upload
1							
2							

1 Key development issues and relation to national priorities

2 Proposed objective(s)

3 Description

3.1 Project scope and area

3.2 Project components

4 Implementation Strategy

4.1 Target beneficiaries

4.2 Implementation arrangements

4.3 Alternative implementation strategies

5 Safeguard policies that might apply (World Bank guidance)

Tick boxes where applicable:

Applicable?	Safeguard Policy: If applicable, how might it apply
[ ]	Environmental assessment
[ ]	Natural habitats
[ ]	Pest management
[ ]	Involuntary resettlement
[ ]	Indigenous people
[ ]	Forests
[ ]	Safety of dams
[ ]	Cultural property
[ ]	Projects in disputed areas
[ ]	Projects on international waterways

Environmental Assessment Category[1]:

[ ] A [ ] B [ ] C [ ] To be determined

If 'To be determined', state what steps will be taken to determine category.

6 Risks

6.1 Factors that may cause delay at the outset of the project

[1] World Bank categories:
Category A – Proposed project is likely to have significant adverse environmental impacts that may affect an area broader than the sites subject to physical works. A full Environmental Impact Assessment should be prepared examining the project's potential negative and positive environmental impacts.
Category B – Proposed project potential impacts are less adverse than those for a Category A project. An environmental assessment is required but may be narrower in scope than that for a Category A project.
Category C – Proposed project is likely to have minimal or no adverse environmental impacts. No additional environmental assessment is required.

6.2 Factors which could over time cause major delays or prevent achievement of the projects outputs and objectives

7 Inputs

7.1 Resources required

7.2 Preliminary estimate of funding requirements

Appendix A Supporting information

(Location maps etc)

A.2 Worked Example

Partial worked example based on information from the Ministry of Water Resources web site.

Preliminary

Basic Information about the Proposed Project

		Please complete all sections
Project Name and Ministry ID		DIWANIYA SAFFIYA RECLAMATION PROJECT Major-029
Project Description		Construction of a complete irrigation and drainage system to improve land productivity in this region
Location		Euphrates river basin to the south of Baghdad city about 200Km and it goes along the 2 sides of Shatt Al Diwaniya
Category of proposal *(strike out categories which do not apply)*		Monitoring/field investigations Study Design Construction Training/capacity building Institutional/legal Socio-economic Environmental ~~Safety~~ Other ……..
Implementing Agency		Ministry of Water Resources
Estimated duration		30 years
Target start date		2006
Estimated international contribution ($)		
Estimated counterpart costs ($)		
Estimated total project cost ($)		$37,305,000 (estimated in 2005)
Source of funds if known *(if a potential source of funding has been identified please specify)*		Not known
Organisation putting forward the proposal *(ministry, department, and contact person in the event of queries)*		MoWR web site
Date received by SWLRI Unit		
SWLRI ID code		

Example using information from the Ministry of Water Resources web site downloaded February 2006

Supporting Information *(To be completed by ministries)*

Stages in preparation of this project	Completed	
	Y, N, N/A	Year
Strategy study	Y	1982
Pre-feasibility study		
Feasibility study		
Detailed design study		
Procurement (Tender Docs)		
Environmental Impact Assessment		
Surveys/field investigations		
Institutional analysis		
Training needs assessment	N/A	
Other eg World Bank Safeguards		

Reference documents and maps *(extend list if more documents are available)*			
No.	**Year**	**Author**	**Title**
1	1982	Solkhozpromexport	General Scheme for Water Resources and Land Development in Iraq
2			

To be completed by SWLRI Unit

Record of data collection and review *(date and/or actions)*							
No.	Requested from ministry	Date Received	If required: Returned	Reviewed	If required: Translated	If required: Scanned	Upload
1		Aug 05	N/A				Y
2							

1 Key development issues and relation to national priorities

The agriculture sector has a potential to contribute more to the country's economic development by raising rural incomes and boosting non-oil exports. Irrigation is vital for improving productivity in the sector.

2 Proposed objective(s)

Improve land productivity in this region; provide water resource; improve decreasing groundwater level; increase food production; provide increased work opportunities, provide initial requirement for local industry; and improving the quality and quantity of the livestock production.

3 Description

3.1 Project scope and area

The project includes the construction of a complete irrigation and drainage system. The irrigation network is divided into three parts, each irrigated by a main canal, as follows: 1. MC1 canal, 17,800 hectares, left side of Shatt Al-Diwaniya, 1 pumping station 2. MC3 canal, 48,600 hectares, left side of Shatt Al-Diwaniya, 1 pumping station 3. MC2 canal, 87,000 hectares, left side of Shatt Al-Diwaniya, 1 pumping station. The drainage network comprises of 2 main drains, MD1 (on the left side of the project) and MD2 (on the right side of the project). MD1 goes to the Rumeitha drain (D3) at km 26.400 via pumping station; the length of this drain is about 42.120 km and it serves about 37,000 Hectares. MD2 goes to the Euphrates eastern drain at km 40.300 via pumping station; the length of this drain is about 58.100 km and it serves about 57,750 hectares. The project locates in Euphrates river basin to the south of Baghdad city about 200KM and it goes along the 2 sides of Shatt Al Diwaniya – from the north of Al Diwaniya to Al Najmi canal which is branched from the left of Shatt Al Diwaniya –The south of Al Hamzah city. Shatt Al Diwaniya which is branched from Shatt Al Hilla tails is considered the main source of irrigation in the project's area.

3.2 Project components

A. Irrigation network : According to the proposal of developing irrigation network of Al Diwaniya – Shafi`ya project, this project is divided into 3 parts each part is irrigated by a main canal, and as the following: • The 1st part: It is irrigated by the canal (MC1) for a net area which is about (31880) acres and it locates to the left side of Shatt Al Diwaniya. • The 2nd part: It is irrigated by the main canal (MC3) for a net area which is about (113608) acres and it locates to the left side of Shatt Al Diwaniya also. • The 3rd part: It is irrigated by the main canal (MC2) for a net area which is about (202960) acres and it locates to the right side of Shatt Al Diwaniya. In addition to the above canals, this network includes minor feeding & distributing canals lined with concrete.

B. Drainage network: The proposed drainage network for the project comprises of 2 main drains– one of these drains is on the left side of the project, & this main drain is called (MD1), the other one is on the right side, & it is called (MD2). The drainage of the drain (MD1) goes to Al Rumeitha drain (D3)at the kilometer (26,400) via pumping station , the length of this drain is about (42,120) KM into which many minor & collecting drains flow , and it serves about (31435) hectares . The drain (MD2) serves net area about (49049) hectares, its drainage goes to Euphrates eastern drain at the kilometer (121) via pumping station to raise water at the kilometer (40,300), its length is about (58,100)KM into which many minor & subsidiary drains flows.

4 Implementation Strategy

4.1 Target beneficiaries

Farmers, and their dependents, that live and work in the project area. The local economy will also benefit.

4.2 Implementation arrangements

Ministry of Water Resources

Ministry of Agriculture – extension activities, etc….

4.3 Alternative implementation strategies

5 Safeguard policies that might apply (World Bank guidance)

Tick boxes where applicable:

Applicable?	Safeguard Policy: If applicable, how might it apply
[X]	Environmental assessment
[X]	Natural habitats
[X]	Pest management
[ ]	Involuntary resettlement
[ ]	Indigenous people
[ ]	Forests
[ ]	Safety of dams

Applicable?	Safeguard Policy: If applicable, how might it apply
[ ]	Cultural property
[ ]	Projects in disputed areas
[X]	Projects on international waterways

Environmental Assessment Category[1]:

[X] A [ ] B [ ] C [ ] To be determined

If 'To be determined', state what steps will be taken to determine category.

6 Risks

6.1 Factors that may cause delay at the outset of the project

Outstanding studies of safeguards issues to satisfy donor regulations and procedures.

6.2 Factors which could over time cause major delays or prevent achievement of the projects outputs and objectives

Previous policies of keeping food prices artificially low led to a drastic decline in agricultural production. Success of the project will depend on policy reform to reduce subsidies and adopt a free market. Adequate support for farmers both during the transition to market based and to take up new practices, extension services need to be enhanced. Formation of water user associations and their development may delay progress towards sustainable O&M.

[1] World Bank categories:
Category A – Proposed project is likely to have significant adverse environmental impacts that may affect an area broader than the sites subject to physical works. A full Environmental Impact Assessment should be prepared examining the project's potential negative and positive environmental impacts.
Category B – Proposed project potential impacts are less adverse than those for a Category A project. An environmental assessment is required but may be narrower in scope than that for a Category A project.
Category C – Proposed project is likely to have minimal or no adverse environmental impacts. No additional environmental assessment is required.

7 Inputs

7.1 Resources required

Further studies? Give details eg Environmental Impact Assessment

7.2 Preliminary estimate of funding requirements

Total estimated project cost - $37,305,000 (2005)

Appendix A Supporting information

Map showing location of proposed project

Location Map

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Multi-criterion Decision Analysis and Models
Introductory Explanation

GN 01

August 2006

GN 01 Rev 0

This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note gives an introductory explanation of Multi-criterion decision analysis (MCDA), a set of methods which aims to help decision makers when they are faced with several, sometimes conflicting, objectives.

Preliminary

Report Issue and Revision Record

Rev	Date	Description
P1	August 2006	Preliminary when Phase 1 curtailed

Preliminary

List of Contents

Page

Chapters and Appendices

1	Introduction	1
2	The Importance of Transparency	2
3	Screening, Ranking, Thresholds and Dominance	3
4	Methods of Multi-criterion Decision Analysis	4
5	Uncertainty and Incomplete Information	5
6	The Weighted-Average Model	6
7	How the Model Can Be Used for Prioritising Investments	15
8	International Experience with MCDA	19
9	References	20
Appendix A	Forms	A-1
A.1	Form for drafting scoring rules	A-1
A.2	Form for recording scores and the reasoning behind the choice of score	A-2

List of Figures

Figure 1: An Example of a Value Tree	7
Figure 2: An Example of a Quantitative (Numerical) Scoring Rule	8
Figure 3: An Example of a Qualitative (Verbal) Scoring Rule	10
Figure 4: Estimated budgetary room for the next six years	15
Figure 5: Position after provisional allocations to four projects	17

List of Tables

Table 1: An Example of a Table to Compute and Present the Results of the Model	12

Abbreviations

MCDA	multi-criterion decision analysis
MCDM	multi-criterion decision model

Preliminary

Preliminary

1 Introduction

1.1.1 Multi-criterion decision analysis (MCDA) is a set of methods aimed at helping decision-makers faced with several objectives which sometimes conflict with each other. This appendix seeks to explain briefly the nature and main features of MCDA, to give references to more detailed information, and to describe one particular type of multi-criterion decision model (MCDM).

1.1.2 In general, a decision-making problem or situation will usually involve:

- A number of alternative courses of action (called alternatives, projects, schemes, plans, options, variants, interventions or packages);
- A number of objectives or criteria;
- A number of stakeholders: one or more persons or groups of people to whom the criteria matter to some degree.

1.1.3 Decision-guiding methods that cover more than one objective or criterion can be complex or simple. A large body of literature has built up, a good summary being in Belton & Stewart 2002, while a briefer account, with reference to water resources, is in Snell 1997[1]. Applications to dams and water resources are described in WCD 2000, and recent theoretical refinements are set out in ISMCDM 2006.

1.1.4 In many situations there is a distinction between the decision-makers, who represent (perhaps imperfectly) all the stakeholders, and on the other hand one or more facilitators or analysts, who help the decision-makers to set up whatever methods or models are being used. These facilitators or analysts form a sort of secretariat to the decision-makers: they administer the model, advise on methodology, do the routine collection and handling of necessary data about projects and options, and keep the records of reasons for decisions. They do not take the decisions.

1.1.5 This Guidance Note begins with general concepts and a very brief review of available methods, then Section 6 introduces a model suitable for allocation of public sector investment funds, and Section 7 describes how it could be used. Some information on experience with MCDM is in Section 8.

Preliminary

[1] The field is referred to under several names, like multi-criteria analysis, multi-criterion decision support, or multi-attribute analysis. Methods are variously called multi-criterion decision aids, multi-criterion decision models, or multi-criterion decision support systems.

2 The Importance of Transparency

2.1.1 If decision-makers do not understand the analysis by which their decisions are guided, they are unlikely to "own" the decisions, and the decisions are unlikely to be effectively implemented. Similarly, if other affected people or groups are not clearly informed of the reasoning behind a proposal, they cannot give it effective consent nor act to improve it. Once a decision has been made, it usually has to be explained and defended to a wider audience, so that a process of communication and persuasion must follow the decision-making. So a decision aid must often serve as an instrument not only of analysis but also of communication and persuasion. Therefore one of its most important characteristics must be transparency. If an analyst collects, processes and analyses information, he must then present a clearly argued case to the decision-makers and other people who are to be consulted. All these people must understand the analysis well enough to influence it, asking the analyst to modify it until they are comfortable with it, so that its results are their decisions, not those of the analyst. A non-transparent analysis can hide undeclared priorities and biases in a "black box" which is either not described at all or described in impenetrable technical jargon; such an approach is not conducive to good decisions that will be followed through and implemented.

Preliminary

3 Screening, Ranking, Thresholds and Dominance

3.1.1 Screening and ranking are two basic and complementary processes used to reduce a long list of conceivable courses of action or alternatives to one preferred alternative, or to a preferred set of alternatives that matches a budget or any other constraint.

- **Screening**, by analogy with a sieve that lets some items through and holds others back, is the simpler: an alternative is either accepted or rejected at a screening phase. It might be rejected by being shown to be totally unacceptable under just one criterion (this is referred to below as a veto), or just by falling below some threshold based on one or several criteria.

- **Ranking** is more subtle than screening in that alternatives are not merely sorted into two classes, the accepted and the rejected, but are placed in order of merit, by whatever measure of merit or preference is being used.

3.1.2 If the degree of the decision-makers' preferences between alternatives is known, then presentation of a ranked order involves a loss of information. For example, suppose three alternatives A, B and C achieve the values 8, 5 and 9 respectively, on some merit or preference scale. One can say that the respective ranks are 2, 3, 1, or that the rank order is C, A, B. Either way one is omitting significant information, namely the fact that the preference for C over A is by only one unit of preference, while A is preferred to B by a margin of three units.

3.1.3 If one alternative is preferred to another under every single criterion, the first is said to dominate the second. It is usually not wise to reject all dominated alternatives before analysing tradeoffs[2].

Preliminary

[2] Belton & Stewart 2002: Section 4.1, page 83.

4 Methods of Multi-criterion Decision Analysis

4.1.1 There are three main groups of methods for MCDA, or multi-criterion decision models (MCDMs)[3]:

- *Value measurement* theory arrives at a number or index value for each alternative, which represents the overall degree of preference for that alternative in the eyes of the decision-makers, using several criteria simultaneously and dealing explicitly with tradeoffs between criteria.

- *Satisficing methods* take one criterion at a time and use it to screen a list of alternatives, then apply another criterion to screen among the remaining alternatives, until a decision guide is reached. Tradeoffs between criteria are not explicitly handled. This is more a description of how people sometimes make decisions with limited information than a recommended method, though it can be useful for initial screening of a large number of alternatives.

- *Outranking methods* extend the concept of dominance to analyse pairs of alternatives to see if one is preferable (outranks the other) strongly, or weakly, or if preference between the two is indeterminate.

Preliminary

[3] Belton & Stewart 2002: Sections 4.2 and 4.3 for value measurement theory, Section 4.4 for satisficing, and Section 4.5 for outranking. Section F.5 of Snell 1997 has a longer list.

5 Uncertainty and Incomplete Information

5.1.1 Decision-makers never have complete and precise information about the available alternatives or their merits under various criteria, nor about the relative importance of the criteria. As well as partial information, there are usually divergences between the preferences or value judgements of the different decision-makers or stakeholders. Any kind of MCDA, to be useful for real decisions, must deal with these uncertainties and divergences[4].

5.1.2 Some experts have developed ways of using fuzzy set theory and rough set theory (lower and upper bounds) to deal with uncertainty, while the satisficing and outranking approaches have their own internal ways of dealing with it[5].

5.1.3 A common and useful way of dealing with uncertainty is to do sensitivity tests. After a model or computation has been set up with the most likely value of each important input parameter, it can be re-run with different values to see what difference each change makes. This can guide the iterative improvement of the model, and if decision-makers are involved at successive stages it can help them to formulate their preferences clearly and to reach a consensus view[6]. The iterative process is described further in Section 7 below.

Preliminary

[4] A discussion of uncertainty in this context is in Section 3.4.4 of Belton & Stewart 2002.

[5] Belton & Stewart 2002: Section 4.6.

[6] Belton & Stewart 2002: Section 5.1 includes the remark that “the learning and understanding which results from engaging in the whole process of analysis is far more important than the numerical results”, and “the process is a constructive one, helping decision-makers to build a model of their values”.

6 The Weighted-Average Model

6.1.1 Among the various methods and models for MCDA, one is preferred here because of its simplicity and transparency, although it can handle complex problems with large numbers of competing alternatives. It is called the additive model within multi-attribute value theory, or the weighted-average model[7]. It is particularly suitable for handling tradeoffs between criteria, for large numbers of alternatives, and for situations where new alternatives may from time to time be added to the list. Because of its simplicity it is easy to explain to decision-makers and other stakeholders.

6.1.2 To set up a model (a MCDM) of this kind it is necessary to define a set of criteria and to assign a relative importance weight to each one. The model also needs a value function or scoring rule for each criterion, and in practice the formulation of the scoring rule provides the precise definition of the criterion. The scoring rule describes how a score is assigned to each alternative under each criterion, usually on a scale from zero to 100 with 100 at the preferred end of the scale. The model operates on a set or long-list of alternatives, each of which is assigned a score under each criterion.

6.1.3 Once these elements are in place (the set of criteria, their weights and scoring rules, and the list of alternatives), the model works by computing an overall merit index value for each alternative. The index value of an alternative is simply the weighted average of its scores under the individual criteria, using the criterion importance weights. When the merit index values have been computed, the alternatives can, if desired, be ranked and sorted to give a priority list, those with high index values at the top of the list. This prioritised list can then be used to draw up investment programmes to match annual budgets or other constraints.

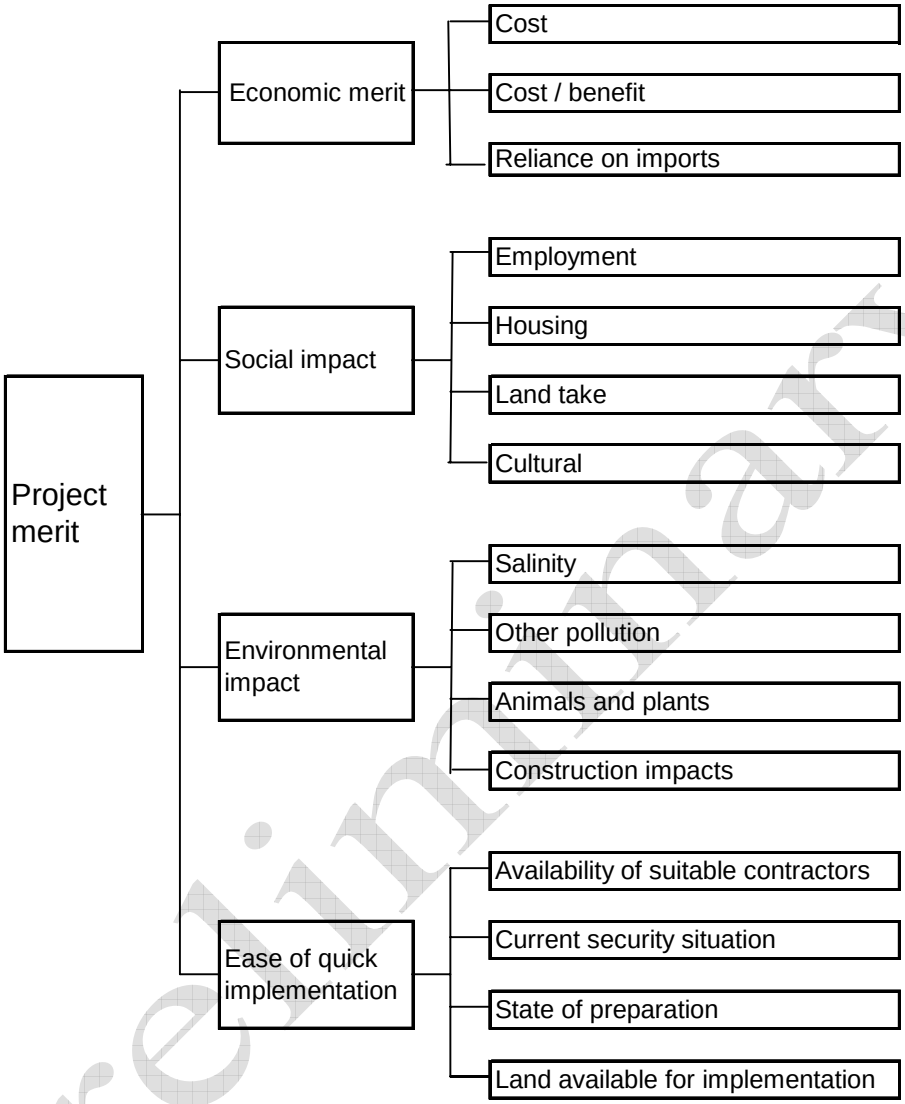
6.1.4 The two setting-up processes, weighting and scoring, are not independent of each other, and the whole model needs to be developed in an iterative manner, trying out early versions with real alternatives, before it gives a good representation of the decision-makers' preferences and value judgements.

6.1.5 A useful device for developing a set of criteria and their importance weights is a 'value tree', which describes a hierarchy of objectives grouped at two or more levels[8]. Figure 1 shows an example of a value tree that might be used for guiding decisions about irrigation projects that compete for limited funds.

[7] Belton & Stewart 2002 Chapter 5; Snell 1997 Section 5.4. Multi-attribute value theory is sometimes called multi-attribute utility theory.
[8] Belton & Stewart 2002, pages 66, 80-81, and 139-141.

Preliminary

Figure 1: An Example of a Value Tree



Preliminary

6.1.6 This one has three levels, though in practice a criterion can be subdivided at a fourth level. The fifteen third-level criteria are grouped into four groups at the second level, which makes the model easier to develop, to use and to explain than if the fifteen criteria had been shown directly contributing to the first-level objective.

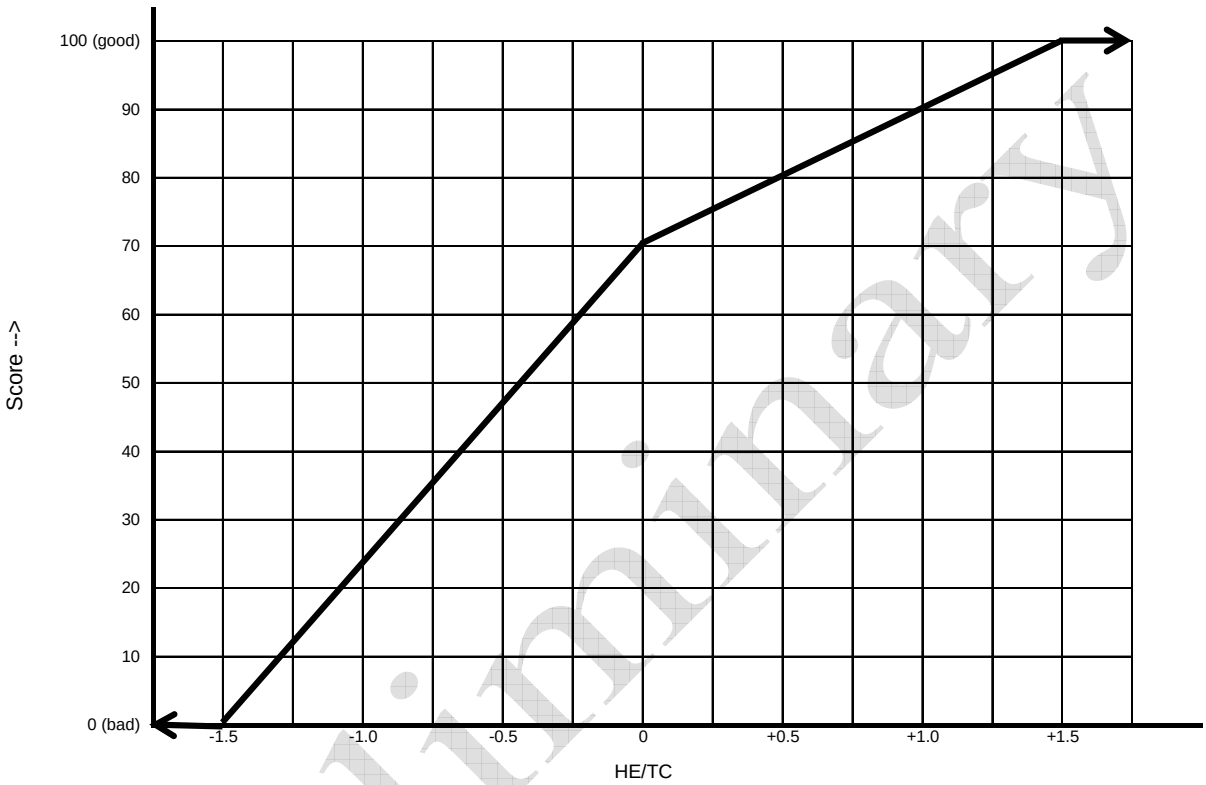
6.1.7 A value tree embodies a set of criteria. The next element needed is the scoring rules whereby each alternative (each irrigation project in this example) is assigned a merit score under each criterion. These are usually of two kinds; quantitative ones and qualitative ones.

6.1.8 A quantitative scoring rule uses a numerical parameter describing each alternative under each criterion, and sets out, usually graphically, how the scores are derived

from the parameter values. The example in Figure 2 shows a rule using a simple parameter whose definition is explained underneath the diagram.

Figure 2: An Example of a Quantitative (Numerical) Scoring Rule

Scoring rule for: **SOCIAL: Housing**



HE = Housing Equivalents

2 bedroom house	=	1	HE
4 bedroom house	=	1.5	HE
School	=	20	HE
Pump station	=	0	HE
Railway line	=	0	HE
Hospital	=	0	HE

TC = Total Cost of Intervention (US$m)

Note: Houses to be destroyed - negative
Houses to be developed / saved from destruction or abandonment - positive

Preliminary

6.1.9 The impact of a particular intervention (or project) on housing is expressed in terms of “housing equivalents” (HE), which provides a series of weighting factors to allow the derivation of a single number to represent a summation of a variety of building types. However, the value of HE is taken to represent the general impact on the existing population. In order to provide a basis for comparison of different interventions the derived value of HE is divided by the total cost of the intervention. The scoring rule allocates a value of 70 to any intervention that would not involve the destruction of any buildings (and thus the moving of any people). The scoring rule recognises that some types of intervention could make a positive contribution to the housing stock, either by sustaining a current situation (which would otherwise deteriorate) or by providing new houses. The steeper gradient for the negative HE

part of the graph recognises the undesirability of moving people out of existing houses.

6.1.10 This example shows how non-linear decision-maker preferences can be used in the model. The "reliance on imports" criterion (taken as the value of imports as a proportion of the cost of the intervention) in the above value tree would be expressed in a quantitative rule of this sort, but the lines would slope the other way, since an intervention that relies more on the use of local resources is preferred. Again there could be slope changes and cut-off values: there is no need for a rule to be linear. Non-linear rule curves can be smooth rather than made up of straight lines as in this example.

6.1.11 A qualitative scoring rule uses the same 0-to-100 merit scale, but the score is chosen subjectively for each alternative using the verbal markers as guidance. In the example in Figure 3 there is a neutral score, but this is not necessarily the case for all criteria. A rule like this can first be formulated in general terms, as here, and while it is being used more verbal markers can be written in at suitable scores to help people to remember how the scale has been used, and to score all alternatives consistently.

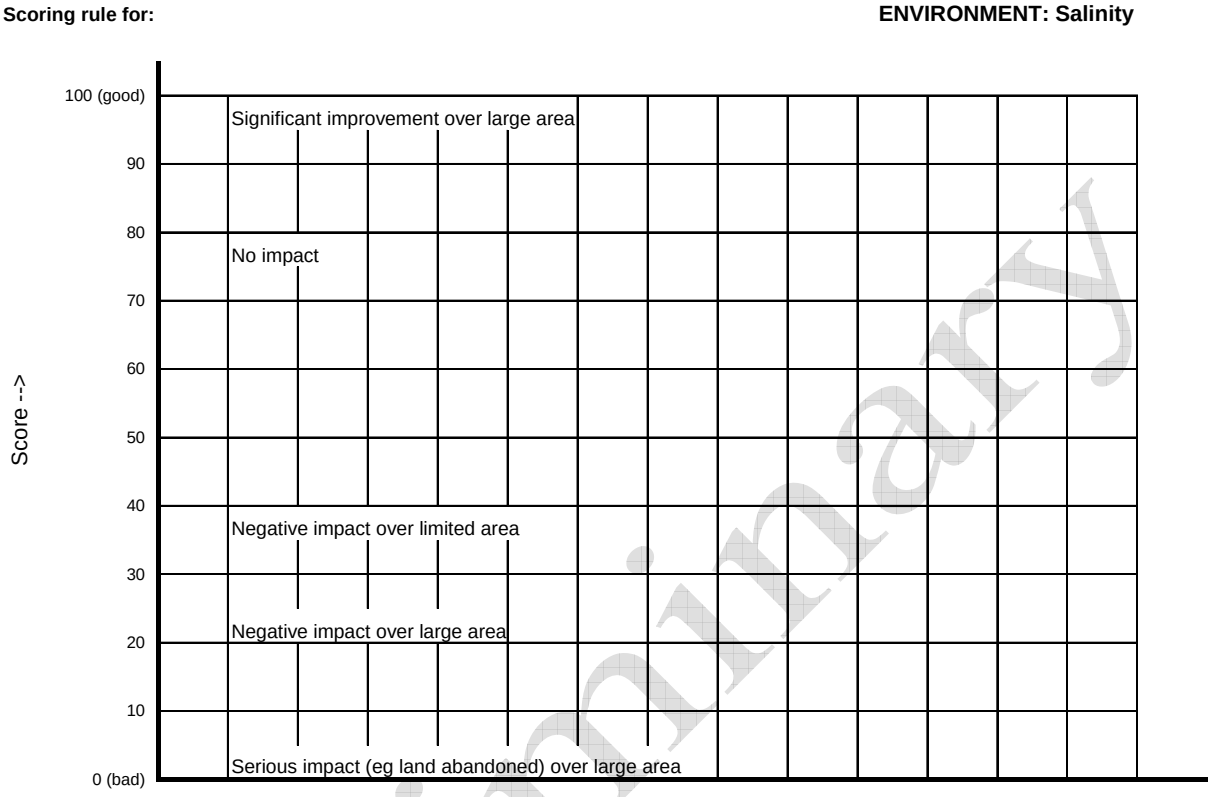
6.1.12 In this second example the score of zero can be used to indicate a veto, since a project that resulted in a serious impact over a large area, no matter how favourably it looked under other criteria, would be unacceptable. The model can also be operated without vetoes. Any individual criterion can be used just for ranking, or just for screening with a veto, or for both[9].

6.1.13 It is advisable, when setting the scores for the various alternatives, to keep a record of the reasoning behind the decisions, so that people can come back later and be reminded why a certain score was set. Simple standard forms are suitable. This is helpful when setting scores for a new set of alternatives at a later date. A set of such record sheets contributes to the definition of the scoring rule, forming an informative complement to the simple expression of the rule as shown here.

Preliminary

[9] The use of vetoes in effect applies a satisficing process. The sort of MCDM that operates entirely by satisficing, using threshold values, without scoring and weighting, has several disadvantages relative to the weighted-average model with vetoes. It is described in Section 4.4 of Belton & Stewart 2002.

Figure 3: An Example of a Qualitative (Verbal) Scoring Rule



6.1.14 The criterion weights should be set in discussion between a range of stakeholders or decision-makers, sometimes with the help of a facilitator. It is generally best to begin by agreeing which is the most important criterion and giving it an initial weight of 1, and then to discuss the weight to be given to the second most important criterion relative to that. The weight is not just people's intuitive idea of the importance of the criterion, but must be assessed by asking what interval on one criterion would be seen as a fair trade-off against a standard interval (such as the full range 0 to 100) on another criterion[10]. That is why the scoring rules should be developed and agreed before assessing the weights. Usually the weight of the most important criterion should not be more than 5 times that of the least important, since a greater ratio would give the least-weighted criterion very little influence on the overall merit index; an exception can be made when criteria with small weights have vetoes[11].

Preliminary

[10] This is called the 'swing weight method'; Belton & Stewart 2002, Section 5.4.2.

[11] Belton & Stewart 2002: Section 5.4.5: criterion weights should be checked by sensitivity tests on a few alternatives.

6.1.15 The final step in setting up a weighted-average model is the table, generally a spreadsheet, where the scores for each alternative are set out against each criterion, and the overall merit index is computed as the weighted mean. The example in Table 1 shows the criteria from the above value tree applied to an imaginary list of alternatives, using an imaginary set of weights and scores.

Preliminary

Table 1: An Example of a Table to Compute and Present the Results of the Model

A: ALTERNATIVES IN ORIGINAL LIST ORDER

Criterion group:	economic merit			social impact				environmental impact				ease of quick implementation				multicriterion index for ranking					rank or veto	ranking without vetoes	
group weight:	30%			30%				20%				20%				group contributions				overall merit index			
Criterion:	Cost	Cost / Benefit	Reliance on imports	Employ-ment	Housing	Land take	Cultural	Salinity	Other pollution	Animals and plants	Construct-ion impacts	Availability of suitable contractors	Current security situation	State of prepar-ation	Land available for implement ation	economic merit	social impact	environ-mental impact	ease of quick imple-mentation				
criterion weight:	5%	20%	5%	7%	10%	8%	5%	10%	3%	3%	4%	8%	4%	4%	4%	max 30	max 30	max 20	max 20	100		index	rank
Alternatives:	(relative merit scores under each criterion are from 1 to 100: a score of zero means a veto)																						
project A	70	65	50	35	50	60	40	50	80	80	30	100	70	100	100	19.0	14.3	11.0	18.8	63.1	2	63.1	3
project B	70	40	30	50	70	30	50	30	50	0	20	100	80	100	100	13.0	15.4	0.0	19.2	0.0	vetoed	52.9	7
project C	50	55	90	50	50	50	50	70	90	50	50	100	40	60	100	18.0	15.0	13.2	16.0	62.2	3	62.2	4
project D	95	80	50	55	50	55	60	50	25	60	35	50	70	100	20	23.3	16.3	9.0	11.6	60.1	4	60.1	5
project E	20	35	60	25	85	70	45	20	70	35	50	50	50	100	100	11.0	18.1	7.2	14.0	50.3	6	50.3	9
project F	85	60	45	50	90	30	35	40	45	75	50	100	70	0	100	18.5	16.7	9.6	0.0	0.0	vetoed	59.6	6
project G	75	50	15	80	70	70	100	60	50	90	70	100	70	100	100	14.5	23.2	13.0	18.8	69.5	1	69.5	1
project H	80	90	80	70	60	50	80	50	75	30	55	0	50	100	100	26.0	18.9	10.4	0.0	0.0	vetoed	65.3	2
project I	75	25	70	15	20	65	70	60	25	50	85	50	70	100	100	12.3	11.8	11.7	14.8	50.5	5	50.5	8

B: ALTERNATIVES IN RANKED ORDER

Criterion group:	economic merit			social impact				environmental impact				ease of quick implementation				multicriterion index for ranking					rank or veto	ranking without vetoes	
group weight:	30%			30%				20%				20%				group contributions				overall merit index			
Criterion:	Cost	Cost / Benefit	Reliance on imports	Employ-ment	Housing	Land take	Cultural	Salinity	Other pollution	Animals and plants	Construct-ion impacts	Availability of suitable contractors	Current security situation	State of prepar-ation	Land available for implement ation	economic merit	social impact	environ-mental impact	ease of quick imple-mentation				
criterion weight:	5%	20%	5%	7%	10%	8%	5%	10%	3%	3%	4%	8%	4%	4%	4%	max 30	max 30	max 20	max 20	100		index	rank
Alternatives:	(relative merit scores under each criterion are from 1 to 100: a score of zero means a veto)																						
project G	75	50	15	80	70	70	100	60	50	90	70	100	70	100	100	14.5	23.2	13.0	18.8	69.5	1	69.5	1
project A	70	65	50	35	50	60	40	50	80	80	30	100	70	100	100	19.0	14.3	11.0	18.8	63.1	2	63.1	3
project C	50	55	90	50	50	50	50	70	90	50	50	100	40	60	100	18.0	15.0	13.2	16.0	62.2	3	62.2	4
project D	95	80	50	55	50	55	60	50	25	60	35	50	70	100	20	23.3	16.3	9.0	11.6	60.1	4	60.1	5
project I	75	25	70	15	20	65	70	60	25	50	85	50	70	100	100	12.3	11.8	11.7	14.8	50.5	5	50.5	8
project E	20	35	60	25	85	70	45	20	70	35	50	50	50	100	100	11.0	18.1	7.2	14.0	50.3	6	50.3	9
project B	70	40	30	50	70	30	50	30	50	0	20	100	80	100	100	13.0	15.4	0.0	19.2	0.0	vetoed	52.9	7
project F	85	60	45	50	90	30	35	40	45	75	50	100	70	0	100	18.5	16.7	9.6	0.0	0.0	vetoed	59.6	6
project H	80	90	80	70	60	50	80	50	75	30	55	0	50	100	100	26.0	18.9	10.4	0.0	0.0	vetoed	65.3	2

6.1.16 If there is a hierarchy of criteria, as in the example value tree in Figure 1, it is usefully informative to show also the index contributions from the different groups, so that one can use the table to see and explain why one alternative outranks another. For instance, it may do so because of high scores in the environmental and quick-implementation groups, despite a relatively low economic score.

6.1.17 In the upper part of Table 1 the index values and ranks have been computed, but the alternatives are still in their original list order. The lower part shows the same results but with the alternatives sorted into rank order, which is more convenient for some purposes. The overall merit index values give more information on the outcome than the ranks do. It can be seen that the best project, G, is preferred by a considerable margin over the next-best one, project A, while the margins separating projects A, C and D are smaller. The margin between project D and the next worst one, I, is very wide.

6.1.18 Study of the group contributions show that project G was preferred above projects A, C, and D because of its high rating in the social and environmental groups, despite having lower economic merit that any of those. A sensitivity test shows that it would have needed a large shift of weight away from social and environmental criteria, towards economic ones, to reverse that preference.

6.1.19 The table also shows the operation of vetoes. Project B was vetoed because of some very severe impact on ecosystems, project F was vetoed because its tender documents were not ready, and project H because there was considered to be no chance of attracting a competent contractor. So long as these vetoes stand, these projects cannot be selected for funding. But it is useful to know which of them is most worth looking at to see if it can be modified and the veto can be lifted, if not immediately then in time for next year's allocation round (the iterative allocation process is described further in the next section). The two extra columns on the right of the table help with this. They show what the index values and ranks would have been in the absence of the vetoes. Project H would have been ranked second, mainly because it has the highest economic merit in the whole list. This indicates that it would be worth while to make a big effort to overcome the problem about contractors for that one. Project F, without its veto, would still only have been ranked sixth (or fifth if H were still vetoed), so there would probably not be much point in making a big effort to finish its tender documents in time for the current year. Project B would have been ranked very low even without its environmental veto, and a quick sensitivity test shows that even if its ecosystems score were neutral, about 50, it would still rank seventh. So it would be difficult to make a case for spending a lot of effort to redesign it quickly to avoid the ecological impact.

6.1.20 This discussion illustrates how a transparent model of this kind can yield a great deal of useful information quite easily, and can facilitate discussion among decision-makers, with or without help from their facilitators. Once the model is set up and the ranking is computed with the chosen scoring rules and criterion weights, is it advisable to conduct a number of sensitivity tests with the decision-makers, leading

Preliminary

to discussion and probably some adjustment to scores or weights until the working of the model is judged to be a fair representation of the consensus judgements of the relevant parties. A sensitivity test on a single score or weight takes only a few seconds and the change can be projected on a screen, undoing and redoing it to watch what difference it makes. A change to a scoring rule takes longer because all the candidate alternatives have to be scored again.

6.1.21 There will probably be arguments and disagreements at this stage, especially the first time a new model is used, but this is better than merely arguing about a list of alternatives without any such structure.

6.1.22 A weighted-average model as described here can handle quite complex problems, for instance up to twenty or more criteria and hundreds of alternatives if needed, without losing its essential simplicity and transparency. The examples given here are only illustrations.

Preliminary

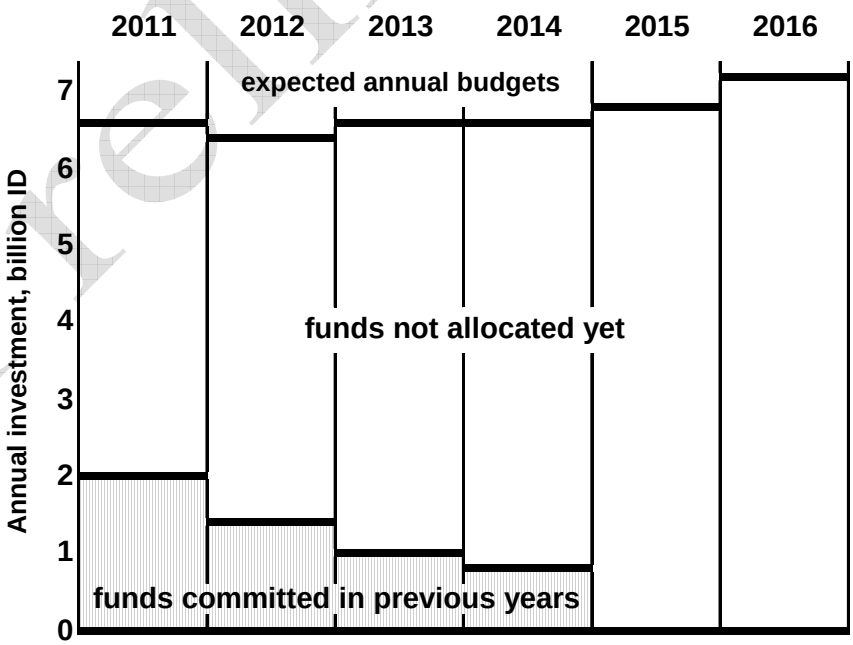
7 How the Model Can Be Used for Prioritising Investments

7.1.1 A model of this sort is sometimes used just to select one preferred alternative among many ways of achieving a single purpose. But this Guidance Note and the above imaginary example, concern its use for prioritising alternative investments that are competing for a limited budget. This section describes how such resource allocation can be done.

7.1.2 The model is intended to be used as part of a routine annual cycle of fund allocation, alongside a policy of commitment funding. (This means that once a multi-year alternative, project or contract has been started in a particular year, the funds for all its years are fully committed.) The starting-point is

- a model, at least tentatively agreed among the decision-makers;
- a list of alternatives, all being candidates to start in the next year, with their scores;
- a set of budget ceilings for the next few years, noting any funds already committed by earlier decisions so as to determine the remaining 'budgetary room' for each future year (as illustrated).

Figure 4: Estimated budgetary room for the next six years



Preliminary

7.1.3 The normal steps of the process then are:

1. The model is computed with the full list of alternatives, and when it has ranked them they are sorted into rank order as shown in the lower part of Table 1 above.

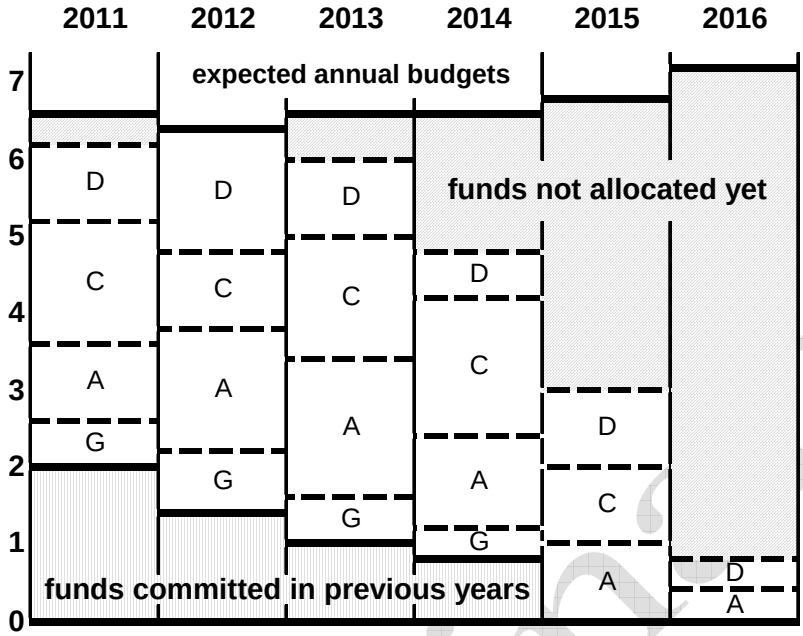
2. The analysts and decision-makers review all the features of the model, especially its scoring rules and weights. Although they resulted from a consensus earlier, the decision makers may reasonably wish, after seeing what priorities they result in, to adjust them a little. Adjusting weights, or individual scores of particular alternatives, is quick to do and the results can be displayed during a meeting and discussed. As mentioned above, changing a scoring rule takes much longer, since all alternatives have to be re-scored with the new version of the rule, and criterion weights may have to be reconsidered in the light of the new scale; such model changes would have to be done by the analysts separately and presented to a later meeting of the decision-makers. This iterative process can take some time, especially in the first year that a new sort of model is used, but after a few years the model should settle, and people should become more adept at managing it, so the iterative process should get quicker and easier.

3. The analysts and the decision-makers then begin the allocation of funds by provisionally allocating funds to the highest ranked alternative (ignoring vetoed ones), provided there is room in the future budgets for all its years of implementation.

4. This is repeated for the next highest alternative, remembering that some of the 'budgetary room' has already been committed to the higher one, and so on until the budget ceiling of one of the future years is reached. (This is illustrated here for the imaginary example, assuming that the second year's budget is full after four projects have been inserted.)

Preliminary

Figure 5: Position after provisional allocations to four projects



5. If that ceiling has been reached because of a particularly large requirement by one alternative in one year (project D's second-year requirement in the illustration), the remaining list of alternatives is inspected to see if, by dropping one of the projects already selected, some slightly lower ranking alternative can be inserted to give a better overall fit to the whole set of budget ceilings. This involves some compromise, since a lower-ranked alternative will be included and a higher-ranked one omitted, but if there seems to be good reason to do this a consensus may be reached; the omitted one will stand a good chance of being funded next year, especially if its year-by-year investment schedule can be smoothed or spread to make it fit in better (it might even be rescheduled straight away and resubmitted for selection, perhaps getting back into the current allocation batch). It is generally better that the first year of the planning period should be filled first, not the second as illustrated here, since this will leave a more convenient budgetary room for next year's allocation process.

6. Either after or alongside that adjustment process, the provisional investment list for the next year is inspected to see if the balance of alternatives between regions or provinces is reasonable. This can involve a number of pragmatic, social or political criteria such as the desire to keep a reasonable flow of work in each region, or to promote development in a particular region faster than the merits of its alternatives would normally justify. Because they concern the volume of investment in a region (or perhaps in a category of alternatives), rather than the separate merits of single alternatives, these criteria have to be applied at this stage, not inside the prioritising model. The process should be transparent, and once agreement has been reached on some compromise the reasons for it should be recorded, before people move on to something else and begin to forget them.

Preliminary

7. At the conclusion of this process there will be an agreed investment programme for the first year of the plan period (normally the year following the meetings), a new set of commitments for subsequent years, and a record of the reasons for all the scoring, weighting and allocation decisions.

8. During the implementation of the investments in the following year, some small re-allocations may be desirable, if some projects spend funds a little faster or slower that was planned, but this should be done in a disciplined way, for instance using small contingency allowances within the project budgets.

9. All remaining alternatives, including vetoed ones, can stay on the candidate list for possible selection in the next year's allocation round, unless some are seen to have so little merit that they should be abandoned altogether.

10. Now attention can turn to the alternatives that were not selected. This is where the last two columns of the example in Table 1 become useful. The index values and without-veto ranks show which alternatives are most worthy of attention in preparation for next year's allocation round. In particular they show which of the vetoed alternatives might be worth-while if a way can be found to avoid their vetoes next time. In the case of pragmatic vetoes like those relating to lack of tender drawings this may be quite easy to do within in a few months, and if there are many such vetoed alternatives the ranking will indicate which ones to attend to first. There may be some other alternatives which, although not vetoed, achieved low ranks but, with guidance from their scores and ranking, can be improved in time for the next round. So this veto-free ranking helps to guide the allocation of study and preparation effort in the run-up to the next year's allocation process.

7.1.4 Like the preparation of the model, this process for its use must be transparent, and the reasons for all decisions should be recorded. Some of the above steps give considerable opportunity for subjective, political or even irrational motives to be applied. Some political, region-specific or project-specific reasoning may be fully justifiable, and the point here is that a transparent process ensures that it does need to be explicitly justified and recorded. This should help to maintain efficient allocation of resources, in the broad national interest.

Preliminary

8 International Experience with MCDA

8.1.1 Systematic multi-criterion models have been used to guide decisions of many sorts in many countries over the last few decades. There is an extensive literature on the subject, and some very sophisticated mathematical techniques are constantly under discussion among academics and practitioners[12]. The Consultant has experience of using the simple weighted-average model to prioritise investments for water quality improvement projects in China, and for selecting project type and location in UK, while on another occasion (water pollution control) a different sort of model was chosen because of the nature of the problem. The literature contains references to models in use for national master planning in Norway and for Canada's hydropower and defence sectors[13].

Preliminary

[12] The literature up to about 2001 is well reviewed and referenced in Belton & Stewart 2002, Professor Belton having been the editor of the relevant journal for some years while Professor Stewart is now the president of the International Society on Multiple Criteria Decision Making. Current debate can be seen in the abstracts of the association's 2006 conference (ISMCDM 2006).

[13] WCD 2000, page 74; ISMCDM 2006, page 88.

9 References

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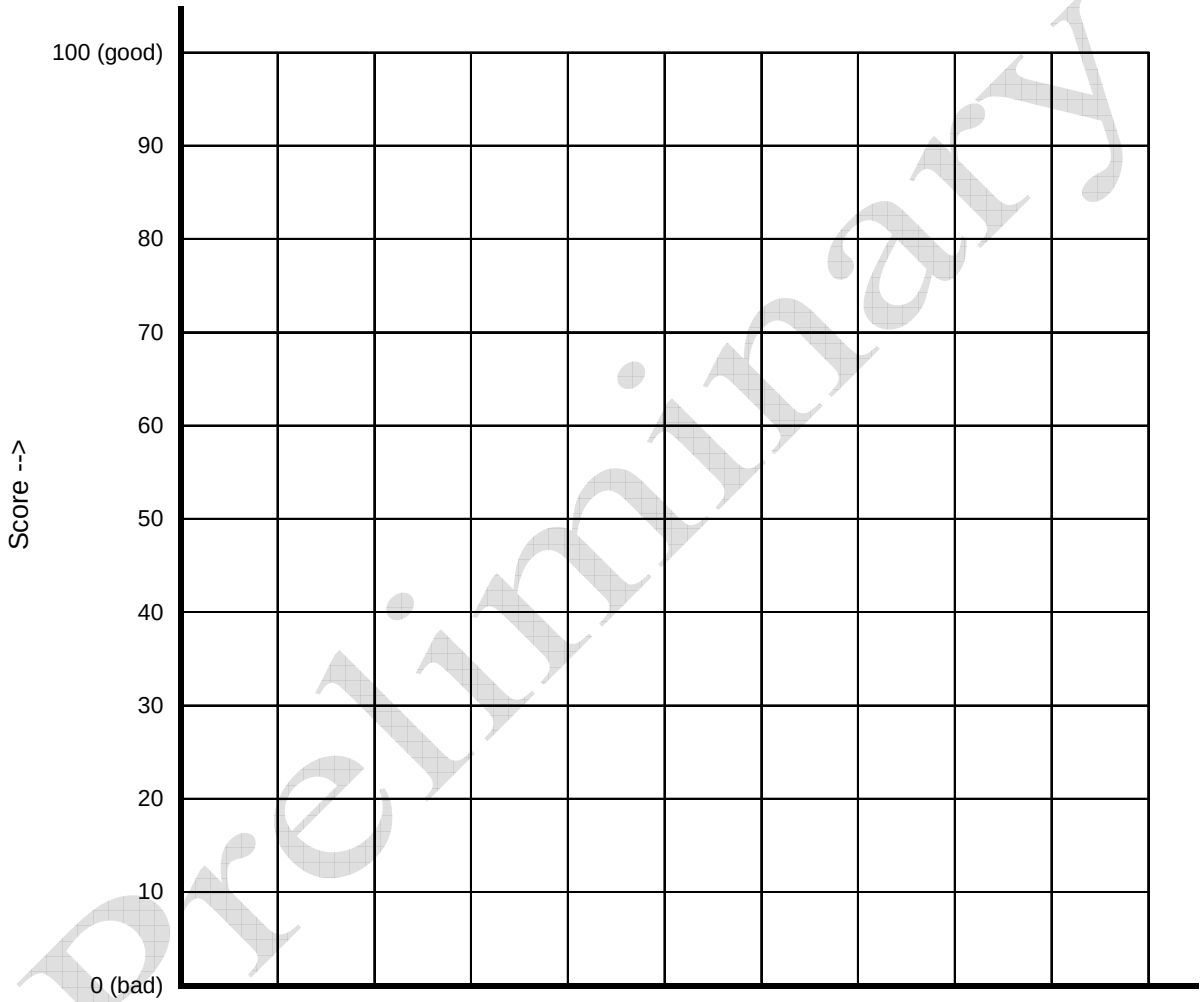
Preliminary

Appendix A Forms

A.1 Form for drafting scoring rules

Multi-criterion Decision Model
scoring rule for:



Preliminary

A.2 Form for recording scores and the reasoning behind the choice of score

PROJECT: ----------

CRITERION (Second Level): ----------

CRITERION 1 (Third Level): ---------- SCORE: [ ] %

COMMENTS:

STUDY NEEDED? [ ] Y/N	DETAIL:

CRITERION 2 (Third Level): ---------- SCORE: [ ] %

COMMENTS:

STUDY NEEDED? [ ] Y/N	DETAIL:

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Introduction to Cost Benefit Analysis

GN 09

August 2006

GN 09 Rev 0

This document was prepared under the Agriculture Reconstruction and Development Program in Iraq, Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note introduces cost benefit analysis for engineers and planners who lack a formal training in economics.

Preliminary

Report Issue and Revision Record

Rev	Date	Description
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List of Contents

Page

Chapters

1 Introduction 1
- 1.1 A set of tools for guiding decisions 1
- 1.2 A common unit of measurement 2
- 1.3 Main stages of a cost-benefit analysis 2

2 Quantifying and valuing costs and benefits 4
- 2.1 With- and without-project situations 4
- 2.2 Shadow pricing 5

3 Resources and time 6
- 3.1 Time preference 6
- 3.2 Discounting 6
- 3.3 Indicators and their calculation 7
- 3.4 Choice of indicator 7
- 3.5 Sensitivity tests 8

4 Worked Example 9

Preliminary

1 INTRODUCTION

1.1 A set of tools for guiding decisions

1.1.1 We all make decisions every day. Consciously or not, before deciding on a course of action we often ask ourselves 'is it worth it?'. When we do that we are using cost-benefit analysis. Having formulated a possible course of action (a project) we assess the cost it will incur and the benefits it will bring, balance the one against the other, perhaps consider other influences, and then decide: 'is the benefit worth the cost?'. So cost-benefit analysis (CBA) is above all a set of tools for guiding decisions.

1.1.2 To use CBA quantitatively for the guidance of a decision there are a few basic steps in every case

1. Define the decision, normally between a possible course of action and its alternative
2. Fix, at least tentatively, the decision criteria
3. Estimate the cost of taking that course of action
4. Estimate the benefits that it would bring
5. Weight up the costs and benefits by means of some quantitative indicator
6. Consider uncertainty and the range of possible outcomes
7. Apply the criteria
8. Consider the CBA alongside other relevant decision guides like environmental aspects
9. Make the decision

1.1.3 Although CBA is a tool for guiding decisions it is seldom the only guide to a particular decision. Most decisions are made on several criteria, some of which may be unacknowledged and never explicitly presented. Examples are:

- Regional policy (a political desire to develop some regions)
- Social policy (a political desire to favour some groups of people like disadvantaged minorities)
- Environmental criteria

Preliminary

- Self interest
- Habit
- Risk aversion.

1.2 A common unit of measurement

1.2.1 In order to ask 'is the benefit worth the cost?' in any quantitative way we need to have the cost and the benefit expressed in some sort of common unit of measurement. Since costs are most easily and normally measured in terms of money it is usual, although not essential, to use money as the common unit of measurement.

1.2.2 In many kinds of CBA the unit is not really money because some kind of economic or social pricing has been used rather than ordinary financial or market prices, but the unit is still called by the name of a currency; this can cause confusion so careful labelling and explanation should always be provided.

1.2.3 When the various costs and benefits are of different kinds the processes for putting the two into a common unit of measurement are called valuation methods. When the costs and benefits occur at different times the relative value of resources at different moments has to be taken into account by discounting.

1.3 Main stages of a cost-benefit analysis

1.3.1 To provide a framework for later discussion the main activities in a CBA are listed below (for an economic analysis).

- Define the decisions that are to be guided. When the analysis concerns a project it must be precisely defined which can usually best be done by defining its purpose and then the with-project and without-project situations.
- Define the group of people whose point of view is to be applied
- Decide the criteria and parameters such as:
    - Project life, or period to be used for analysis
    - Discount rate
    - Categories of benefits and costs (some things can be treated as either positive benefits or as negative costs)
    - Adjustments: shadow pricing, omission of transfer payments etc

Preliminary

- Calculate the economic benefits attributable solely to the decision or the project for each year of its life, ie the incremental benefit (the benefits of the with-project situation minus any benefits that would arise in the without-project situation).
- Calculate the economic costs:
    - Initial (capital) costs
    - Recurrent (annual) cost
    - Replacement costs, eg replace pumps in years 16, 31 etc; in each case incremental cost is the with-project cost minus without-project cost for each year of the project life.
- Formulate the net benefit stream
    - List the benefits and costs year by year for the whole analysis period
    - Calculate the net benefit (benefit minus cost) for each year
- Carry out the arithmetical economic analysis ie discount the benefit and cost (or net benefit) streams and calculate indicators
- Carry out sensitivity tests
- Assess other benefits or costs that have been excluded from the CBA
- Report the whole analysis.

Preliminary

2 QUANTIFYING AND VALUING COSTS AND BENEFITS

2.1 With- and without-project situations

2.1.1 The key to correct and complete identification of costs and benefits is the definition of the with- and without-project situations. These are projections into the future with all the usual difficulties and uncertainties of estimating and forecasting.

2.1.2 The without-project situation, sometimes equivalent to the do-nothing scenario, is not usually the same as a continuation of the present situation.

2.1.3 Part of the work of defining the with-project and without-project situation is to consider whether a project's outputs add to total production of the relevant goods, or substitute for (displace) goods that would have been produced or provided anyway. If the latter is true the effects on the other providers of the goods may need to be considered too.

2.1.4 CBA takes three forms according to the point of view being examined.

2.1.5 A person, a commercial organisation or a state organisation operating on quasi-commercial lines may be interested in the financial benefits compared with the financial cost – which comes from the budget they hold.

2.1.6 However, when deciding on national projects, the efficiency of resource use is more important than the financial impact on a particular organisation.

2.1.7 Where account is to be taken of achieving certain social goals, social CBA is employed. In this, some costs and/or benefits are given a weighting to increase or decrease their impact on the CBA calculations, in accordance with criteria established prior to the CBA. In summary:

Whose point of view	Type of analysis	Main criterion
Commercial organisation	Financial analysis	Money
Whole economy	Economic analysis	Efficiency
Region		
Nation		
'society'	Social analysis	Equity
Whole human race		

2.1.8 In an economic CBA any cost borne by a member of the nation should be included even if there is no money payment made, as in the case of family

Preliminary

labour, and also any benefit enjoyed for which nothing is paid. Since no money changes hands these items would not be included in a financial CBA.

2.2 Shadow pricing

2.2.1 In an economic CBA there may be costs and benefits to include that have no market and thus there is no financial price, while others may have prices which, because of say market distortions, do not reflect their true value to the defined group of people on whose behalf the project is being analysed. Special valuation techniques must be used, referred to as shadow pricing.

2.2.2 The usual method is to start with financial prices and apply a factor which converts a value in financial prices into a value in economic prices. The factor being the shadow price factor (SPF). The SPF may give a higher economic price or a lower economic price than the financial price.

2.2.3 When goods or services appearing in a CBA as costs or benefits are traded in a relatively free market with few distortions, the market prices are a relatively good guide to willingness to pay and are usually used in an economic CBA unchanged (SPF=1). When they are not so traded, the economic price can either be estimated directly by finding out what people would be willing to pay if there were an effective market, or by taking the distorted real market price and adjusting it by shadow pricing.

2.2.4 The opportunity cost of something is what we have to forego or give up in order to obtain it. For example, in a rural area the use of unskilled labour on road-building is related to its seasonal use in agriculture. At harvest-time the opportunity cost to the nation of using an unskilled labourer for a day on the road is the value of the forgone work he might have been doing in the fields, quite a high value. However, the loss of his normal activity in the quiet season to spend a day working on the road might be if little or no value. The SPF could then be adjusted seasonally from say 1 at peak times like harvest down to 0.3 for slack times.

Preliminary

3 RESOURCES AND TIME

3.1 Time preference

3.1.1 Humans have a time preference. When considering using resources or enjoying benefits, we are not indifferent to timing. Most of us prefer jam today to jam tomorrow.

3.1.2 A benefit in the future is valued less than a benefit now. Equally a future cost is of less concern than a cost borne now.

3.1.3 The cost or benefit now is called the Present Value (PV) and now is considered to be year zero. At some time in the future, year 'n' the same cost or benefit has a Future Value (FV), so that there is a stream of costs or benefits over time each with a different FV. The formula is:

3.1.4 $PV/FV_{Year\ n} = 1 / (1 + r)^n$ where 'r' is the time preference or discount rate

3.2 Discounting

3.2.1 Discounting is the arithmetical process of converting value statements referring to one moment in time to their equivalent value statements referring to another moment in time. Excel spreadsheet functions will do the calculation for you.

3.2.2 Discounting deals with the time value of resources or effects of any kind. Usually it is applied to money or to an economic or social value that is expressed in monetary units by some valuation technique. It can however be applied to anything whose value needs to be assessed at different times. For instance it is common to discount the annual volumes of water delivered by a water supply scheme so as to produce a discounted total volume which can be compared with a discounted total cost in a cost-effectiveness analysis.

3.2.3 The outcome of a CBA may depend on the choice of discount rate. This rate is not related to inflation rates; it is however related to the balance between consumption and saving/investment. Selecting a discount rate is therefore a specialised task; however, as the rate should only change slowly with time it is normally possibly to use a rate recommended by the national central bank (or equivalent organisation). On some internationally financed projects a specific discount rate will be required for the analysis.

Preliminary

3.3 Indicators and their calculation

3.3.1 Discounting can be used to calculate indicators which describe the relative merit or desirability of projects or options being studied. The most basic are the Net Present Value (NPV) and the benefit-cost ratio (B/C).

3.3.2 The starting point for both is to list the costs and the benefits by year and to discount both series. This gives the total discounted costs C and the total discounted benefits B. Then NPV is the difference between them, B – C, and the benefit-cost ratio is the ratio between them, B/C.

3.3.3 Discounted costs and benefits many years in the future become very small – especially at high discount rates. The length of time used should be the design life of the project, typically 25-30 years but sometimes 50 years or so.

3.3.4 The internal rate of return (IRR) is the discount rate at which the NPV is equal to zero and the B/C ratio is equal to one.

3.3.5 Because the NPV and B/C values depend on the discount rate it must e stated when they are quoted, eg 'the NPV is $10 million at a discount rate of 9%'.

3.4 Choice of indicator

3.4.1 If the analysis is to be used to decide whether or not to implement a certain project an indicator is normally compared with a pre-determined threshold value which determines whether a course of action is acceptable or not. This is normally a test discount rate.

3.4.2 To choose between projects that are mutually exclusive for technical reasons the criterion should be maximum NPV with an appropriate discount rate. Maximising any other indicator may lead to a wrong decision especially when the competing projects vary widely in size.

3.4.3 When ranking projects that are competing for a limited resource (usually funding) the B/C should be used, with the projects ranked in descending order of B/C ratios.

Preliminary

3.5 Sensitivity tests

3.5.1 Sensitivity tests are ideal for investigating and reporting on uncertainty due to the inherent difficulty of estimating and forecasting with limited information.

Preliminary

4 WORKED EXAMPLE

Preliminary

Calculation of Internal Rate of Return and Net Present Value ($ million)

Year	Without project (WO)			With project (WP)						Marginal values (WP - WO)	
	Agricultural benefits	Pump O&M	Total benefits	Capital	Drain O&M	Agricultural benefits	Downriver benefits	Total benefits	Net Benefit	Total costs	Total benefits
1	31.55	1.22	30.33	9.62		31.55		21.93	-8.40	8.40	0.00
2	34.37	1.22	33.15	13.39		34.37		20.98	-12.17	12.17	0.00
3	38.59	1.22	37.37	9.62	0.46	39.59		29.51	-7.86	8.86	1.01
4	41.40	1.22	40.18	9.62	0.46	43.51		33.43	-6.75	8.86	2.11
5	42.81	1.22	41.59	9.62	0.46	47.43		37.35	-4.24	8.86	4.62
6	44.22	0.83	43.39		1.57	51.35	1.03	50.81	7.41	0.75	8.16
7	45.63	0.83	44.80		1.57	60.50	1.03	59.95	15.15	0.75	15.90
8	45.65	0.83	44.82		1.57	61.42	1.03	60.87	16.05	0.75	16.80
9	45.67	0.83	44.84		1.57	62.34	1.03	61.79	16.95	0.75	17.69
10	45.69	0.83	44.86		1.57	63.26	1.03	62.71	17.85	0.75	18.59
11	45.71	0.83	44.88		1.57	64.17	1.03	63.63	18.74	0.75	19.49
16	45.82	0.83	44.99	4.81	1.57	68.77	1.03	63.41	18.42	5.56	23.97
17	45.84	0.83	45.01	4.81	1.57	69.69	1.03	64.33	19.32	5.56	24.87
18	45.86	0.83	45.03	4.81	1.57	70.60	1.03	65.25	20.21	5.56	25.77
19	45.88	0.83	45.05		1.57	71.52	1.03	70.97	25.92	0.75	26.67
30	45.95	0.83	45.12		1.57	74.28	1.03	73.73	28.61	0.75	29.36

Discount rate 10%.

Preliminary

Illustration of a series of sensitivity tests against the baseline (derived above).

			EIRR	NPV at 10%	B/C ratio	Total costs (NPV)	Total benefits (NPV)
Baseline case			**24%**	**75.3**	**2.64**	**45.85**	**121.12**
Switching value - capital costs	**+**	**167%**			**1.00**		
Switching value - net benefits	**-**	**62%**			**1.00**		
Switching value - with project benefits	**-**	**15%**			**1.00**		
Switching value - without project benefits	**+**	**19%**			**1.00**		
Sensitivity analysis		**Assume**					
Non saline soil crop yields	**-**	**50%**	**14%**	**11.8**	**1.26**		
Capital cost	**+**	**50%**	**17%**	**53.4**	**1.78**		
Capital cost	**-**	**50%**	**40%**	**98.7**	**5.25**		
Drain O&M cost	**+**	**100%**	**22%**	**66.2**	**2.19**		
No pump costs saved			**23%**	**74.7**	**2.58**		
No downriver benefits			**23%**	**70.2**	**2.53**		

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Technical Report Series

Possible Water Allocation Model

TR 05

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This document is one of a series of technical reports published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The technical report provides an overview of a simple water allocation model which is a tool for examining the trade-offs between meeting water needs from scarce water resources.

Preliminary

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List of Contents

		Page
1	Introduction	4
2	Water Allocation model	4
2.1	Constraints	4
2.2	Handling multiple periods	5
2.3	Watercost matrix	5
2.4	Slack matrices	5
2.5	Shadow prices	6
2.6	Key inputs and outputs	6
2.7	Model Operation	6
Appendix A	Simple Water Allocation Model	A-1

Preliminary

Preliminary

1 INTRODUCTION

1.1.1 This note outlines the philosophy behind our simple water allocation model, as provided in the simple water allocation model (see Appendix A).

1.1.2 The model is designed to provide a spreadsheet tool for examining the trade-offs between meeting water needs from scarce water resources. The model requires that we put capacities and costs on the various water supply and transport options and that the needs can be specified in terms of absolute quantity (Bcm) requirements.

1.1.3 The model uses a Linear Programme (LP) solver (What's Best) to find the least cost mix of water supply options that meets all the water requirements, subject to not breaching any constraints regarding capacities of water supply options and transport routes. In terms of the spreadsheet, the optimiser finds a set of values in top (water) matrix which produces the minimum value for the sum of products of this matrix and the second (watercost) matrix, and which does not breach any constraints.

Deployment of water resources: Bcm

WATER	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs	Capacity of supply scheme	Bcm despatched
dam 1	0	10	40	0	10	51	139	0	**250**	250
dam 2	49	40	0	100	0	0	11	0	**200**	200
dam 3	0	0	0	0	20	99	0	0	**145**	119
dam 4	0	0	0	0	30	0	0	0	**75**	30
well 1	51	0	0	0	0	0	0	49	**100**	100
well 2	0	0	0	0	20	0	0	0	**60**	20
well 3	0	0	0	0	20	0	0	0	**90**	20
desal 1	0	0	0	0	0	0	0	71	**100**	71
desal 2	0	0	0	0	0	0	0	0	**85**	0
Total need	**100**	**50**	**40**	**100**	**100**	**150**	**150**	**120**	1105	810
excess supply	0	0	0	0	0	0	0	0		
Shadow price	39	39	39	38	40	41	47	68		

2 WATER ALLOCATION MODEL

2.1 Constraints

2.1.1 The two fundamental sets of constraints are that the amount of water despatched from each source cannot exceed the capacity and that the sum of water despatched towards a specific need equals the need total. It is unlikely to exceed it, as this would imply that a water source was free.

2.1.2 There will typically be many additional constraints and these can be in many forms. The model here for example, provides minimum and maximum despatch constraints, whereby floors and caps are set on water flows from a particular source to a need. A variant of this kind of constraint are percentage diversity constraints on demand and supply. This would reflect the practice of users and suppliers seeking to diversify their portfolios,

Preliminary

although this may not be a so important in a country which is trying to meet just basic needs.

2.1.3 There is lots of scope for devising alternative constraints, however, those which link the value of one cell in the water matrix to another can introduce non-linearities, unless this is done through an unconditional formula link, i.e. one with no "if" statements.

2.1.4 It is also possible to fix values in the main water matrix (i.e. exclude certain cells from the optimisation).

2.2 Handling multiple periods

2.2.1 In this example the model is solved for a single period (a year), however, it would be possible run additional periods. This can done either as part of a multi-period solve, whereby the optimisation allows trade-offs between periods, or alternatively run as a series of separate solves covering discrete time periods, in which case results from one solve are fed through to successive periods.

2.2.2 The former is easier to handle and has the advantage of allowing an optimisation over a multiple period time span. This would in principle allow the model to choice optimal capital expansion plans. It does of course assume that investors are blessed with perfect foresight. Solving over an extended period means that any shadow values calculated reflect the changes in value to the system over the whole time horizon. If the problem become very large, (i.e. the main matrices become very large or there are many and complex constraints) then the only solution (within an Excel framework) may be to run the model as a series of solves.

2.3 Watercost matrix

2.3.1 The watercost matrix here is meant to reflect the annual operating costs in this case built up from a basic cost and a transport cost. It is clearly possible to develop much more sophisticated cost build up and even to have costs altering with level of water despatched – although this can be complicated.

2.4 Slack matrices

2.4.1 There are a number of slack matrices and arrays which show the value of comfort margin between constrained magnitudes of value in the water matrix

Preliminary

and the solved values. These values will always be non-negative, assuming that the model has been solved an a feasible solution has been returned.

2.5 Shadow prices

2.5.1 A shadow price is the delta in the total system cost from an incremental relaxing or tightening a constraint. This means that the shadow price will tend to have a positive value only when the constraint is binding, i.e. when the slack variable is zero. Otherwise the shadow price is zero.

2.5.2 The model here shows two sets of shadow prices, one relating to the marginal cost of meeting each water need and one relating to the value of having an additional unit of water from each supply source option.

2.5.3 It is a relatively straightforward task to add shadow price indicators to test the value of relaxing any binding constraint, for example regarding diversity or maximum flow rates on particular routes.

2.6 Key inputs and outputs

2.6.1 The key inputs variable are:

- Water requirements by end-use and region
- Availability and cost of water from each supply source
- Transport costs (loss rates) for getting water from each source to each end-user point
- A volume restriction on flows.

2.6.2 Key output variables are:

- Water flows between each source and end-user point
- Total system costs and average unit cost
- Shadow price of water for each need
- Value of extra capacity for each water supply option
- Shadow price of relaxing constraints on allocation.

2.7 Model Operation

2.7.1 Model users should only change cells highlighted in yellow or beige. The so-called adjustable cells in the Water matrix have a blue font can be changed but the values will be overwritten when the model is re-solved. The model is

Preliminary

solved by executing the solve from the drop-down What's Best menu bar (assuming What's Best is installed).

2.7.2 A free trial version of What's Best is available from www.lindosystems.com.

Preliminary

Appendix A Simple Water Allocation Model

Preliminary

Simple water allocation tool

Deployment of water resources: Bcm

WATER	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs	Capacity of supply scheme	Bcm despatched	Spare capacity	min take	excess over min	Value of extra capacity
dam 1	0	10	40	0	10	51	139	0	**250**	250	0	**100**	150	17
dam 2	49	40	0	100	0	0	11	0	**200**	200	0	**50**	150	12
dam 3	0	0	0	0	20	99	0	0	**145**	119	26	**30**	89	0
dam 4	0	0	0	0	30	0	0	0	**75**	30	45	**30**	0	0
well 1	51	0	0	0	0	0	0	49	**100**	100	0	**20**	80	3
well 2	0	0	0	0	20	0	0	0	**60**	20	40	**20**	0	0
well 3	0	0	0	0	20	0	0	0	**90**	20	70	**20**	0	0
desal 1	0	0	0	0	0	0	0	71	**100**	71	29	**0**	71	0
desal 2	0	0	0	0	0	0	0	0	**85**	0	85	**0**	0	0
Total need	**100**	**50**	**40**	**100**	**100**	**150**	**150**	**120**	1105	810				
excess supply	0	0	0	0	0	0	0	0						
Shadow price	39	39	39	38	40	41	47	68						

Cost of using water resources: £m/bcm

WATERCOST	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs
dam 1	22	22	22	22	23	24	30	120
dam 2	27	27	28	26	34	30	35	125
dam 3	43	42	41	51	42	41	50	140
dam 4	47	47	48	48	47	51	55	145
well 1	36	40	45	39	39	39	50	55
well 2	45	50	43	43	42	46	56	71
well 3	46	46	46	46	43	45	58	83
desal 1	66	66	65	66	66	66	67	68
desal 2	75	76	76	76	76	76	77	78

Add-on delivery/processing costs

COSTBUILDUP	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs	**Basic production cost**
dam 1	2	2	2	2	3	4	10	100	**20**
dam 2	2	2	3	1	9	5	10	100	**25**
dam 3	3	2	1	11	2	1	10	100	**40**
dam 4	2	2	3	3	2	6	10	100	**45**
well 1	1	5	10	4	4	4	15	20	**35**
well 2	4	9	2	2	1	5	15	30	**41**
well 3	3	3	3	3	0	2	15	40	**43**
desal 1	1	1	0	1	1	1	2	3	**65**
desal 2	0	1	1	1	1	1	2	3	**75**

Total cost being minimised	Average cost per unit
29480	36.40

Preliminary

Delivered cost of water despatched

DELCOST	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs
dam 1	0	22	22	0	23	24	30	0
dam 2	27	27	0	26	0	0	35	0
dam 3	0	0	0	0	42	41	0	0
dam 4	0	0	0	0	47	0	0	0
well 1	36	0	0	0	0	0	0	55
well 2	0	0	0	0	42	0	0	0
well 3	0	0	0	0	43	0	0	0
desal 1	0	0	0	0	0	0	0	68
desal 2	0	0	0	0	0	0	0	0
max	36	27	22	26	47	41	35	68

Minimum despatchs

MINDESPATCH	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs
dam 1	0	0	0	0	0	0	0	0
dam 2	0	0	0	0	0	0	0	0
dam 3	0	0	0	0	20	0	0	0
dam 4	0	0	0	0	0	0	0	0
well 1	25	0	0	0	0	0	0	0
well 2	0	0	0	0	0	0	0	0
well 3	0	0	0	0	0	0	0	0
desal 1	0	0	0	0	0	0	0	0
desal 2	0	0	0	0	0	0	0	0

Slacks

	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs
dam 1	0	10	40	0	10	51	139	0
dam 2	49	40	0	100	0	0	11	0
dam 3	0	0	0	0	0	99	0	0
dam 4	0	0	0	0	30	0	0	0
well 1	26	0	0	0	0	0	0	49
well 2	0	0	0	0	20	0	0	0
well 3	0	0	0	0	20	0	0	0
desal 1	0	0	0	0	0	0	0	71
desal 2	0	0	0	0	0	0	0	0

Maximum despatchs

MAXDESPATCH	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs
dam 1	55	999	999	999	999	999	999	999
dam 2	999	999	999	999	999	999	999	999
dam 3	999	999	999	999	999	999	999	999
dam 4	999	999	999	999	999	999	999	999
well 1	999	999	999	999	999	999	999	49
well 2	999	999	999	999	999	999	999	999
well 3	999	999	999	999	999	999	999	999
desal 1	999	999	999	999	999	999	999	999
desal 2	999	999	999	999	999	999	999	999

Slacks

	power need in area A	power need in area B	power need in area C	irrigation need in area A	irrigation need in area B	irrigation need in area C	industrial water needs	Household water needs
dam 1	55	989	959	999	989	948	860	999
dam 2	950	959	999	899	999	999	988	999
dam 3	999	999	999	999	979	900	999	999
dam 4	999	999	999	999	969	999	999	999
well 1	948	999	999	999	999	999	999	0
well 2	999	999	999	999	979	999	999	999
well 3	999	999	999	999	979	999	999	999
desal 1	999	999	999	999	999	999	999	928
desal 2	999	999	999	999	999	999	999	999

Diversity constraints
on demand
on supply

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Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Preparing Farm Budgets

GN 10

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This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note describes procedures for the calculation of farm budgets for use in economic analyses.

Preliminary

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List of Contents

Page

Chapters and Appendices

1	Introduction	1
1.1	The Place of Farm Budgets in Economic Analyses	1
1.2	Financial and Economic Analysis	1
1.3	With- and without-project situations	2
1.4	Shadow pricing	2
2	Requirements	4
2.1	Data Requirements - Arable	4
2.2	Data Requirement – Livestock Enterprise	5
2.3	Additional Information for Economic Analysis	6
3	crop budget	10
3.1	Financial	10
3.2	Economic	11
4	Arable farm budget	12
5	livestock enterprise budget	13
5.1	Dairy Unit	13
6	Example of with- and without-project analysis	16

Preliminary

1 INTRODUCTION

1.1 The Place of Farm Budgets in Economic Analyses

1.1.1 This note presents a step by step approach to the preparation of farm budgets for both seasonal crops and livestock enterprises. The methodology is based on the following two documents.

- Cost-Benefit Analysis for Engineers and Planners, Snell M J, 1997, ISBN: 0 7277 2587 4
- Strategy for Water and Land Resources in Iraq, 'Guidance Note 09: Introduction to Cost-Benefit Analysis', August 2006

1.1.2 The document describes both financial and economic farm budgets and how to consider what is an appropriate future scenario for the farm enterprise.

1.2 Financial and Economic Analysis

1.2.1 Cost-benefit analysis (CBA) takes three forms according to the point of view being examined.

1.2.2 A farmer, a commercial organisation or a state organisation operating on quasi-commercial lines may be interested in the financial benefits compared with the financial cost – which comes from the budget they hold.

1.2.3 However, when deciding on national projects, the efficiency of resource use is more important than the financial impact on a particular organisation.

1.2.4 Where account is to be taken of achieving certain social goals, social CBA is employed. In this, some costs and/or benefits are given a weighting to increase or decrease their impact on the CBA calculations, in accordance with criteria established prior to the CBA. In summary:

Whose point of view	Type of analysis	Main criterion
Commercial organisation – here THE FARM	Financial analysis	Money
Whole economy	Economic analysis	Efficiency
Region		
Nation		
'society'	Social analysis	Equity
Whole human race		

Preliminary

1.2.5 In an economic CBA any cost borne by a member of the nation should be included even if there is no money payment made, as in the case of family labour, and also any benefit enjoyed for which nothing is paid. Since no money changes hands these items would not be included in a financial CBA.

1.3 With- and without-project situations

1.3.1 The key to correct and complete identification of costs and benefits is the definition of the with- and without-project situations. These are projections into the future with all the usual difficulties and uncertainties of estimating and forecasting.

1.3.2 The without-project situation, sometimes equivalent to the do-nothing scenario, is not usually the same as a continuation of the present situation.

1.3.3 Part of the work of defining the with-project and without-project situation is to consider whether a project's outputs add to total production of the relevant goods, or substitute for (displace) goods that would have been produced or provided anyway. If the latter is true the effects on the other providers of the goods may need to be considered too.

1.4 Shadow pricing

1.4.1 In an economic CBA there may be costs and benefits to include that have no market and thus there is no financial price, while others may have prices which, because of say market distortions, do not reflect their true value to the defined group of people on whose behalf the project is being analysed. Special valuation techniques must be used, referred to as shadow pricing.

1.4.2 The usual method is to start with financial prices and apply a factor which converts a value in financial prices into a value in economic prices. The factor being the shadow price factor (SPF). The SPF may give a higher economic price or a lower economic price than the financial price.

1.4.3 When goods or services appearing in a CBA as costs or benefits are traded in a relatively free market with few distortions, the market prices are a relatively good guide to willingness to pay and are usually used in an economic CBA unchanged (SPF=1). When they are not so traded, the economic price can either be estimated directly by finding out what people would be willing to pay if there were an effective market, or by taking the distorted real market price and adjusting it by shadow pricing.

Preliminary

1.4.4 The opportunity cost of something is what we have to forego or give up in order to obtain it. For example, in a rural area the use of unskilled labour on road-building is related to its seasonal use in agriculture. At harvest-time the opportunity cost to the nation of using an unskilled labourer for a day on the road is the value of the forgone work he might have been doing in the fields, quite a high value. However, the loss of his normal activity in the quiet season to spend a day working on the road might be if little or no value. The SPF could then be adjusted seasonally from say 1 at peak times like harvest down to 0.3 for slack times.

1.4.5

Preliminary

2 REQUIREMENTS

2.1 Data Requirements - Arable

2.1.1 Before starting the calculations it is necessary to assemble the following data:

- Characteristics of the farm type
  - Size of farm (ha)
  - Scale of enterprise (family, small, medium, large)
  - Ownership (farmer owner, tenant farmer, cooperative, etc)
  - Type of enterprise (arable, livestock, mixed)
- Crops to be grown, including details of the seed variety
  - Area to be cultivated under each crop
  - Yield per hectare of main crop product (eg grain)
  - Yield per hectare of crop by-product (eg straw)
- Farming operations for each crop
  - Land preparation: labour and machinery required and when
  - Sowing: labour and machinery required
  - Fertilizer applications: labour and machinery required
  - Pesticide/herbicide applications: labour and machinery required
  - Harvest: labour and machinery required
  - Transport from field: labour and machinery required
  - Handling: labour and machinery required
  - Storage: labour and machinery required
- Unit rates for crop production inputs
  - Labour cost rate per day (hired labour: skilled, unskilled)
  - Seed cost
  - Fertilizer cost (for each type applied)
  - Pesticide/herbicide cost (for each type applied)
  - Machinery costs (tractor and more specialised equipment)
  - Transport costs (fuel etc)
  - Miscellaneous eg bags for grain
  - Storage costs
  - Rent if applicable
  - Water charges or costs for pumping
- Value of product in the local market
  - Price per standard unit of measure for main and by-products

Preliminary

2.1.2 Appendix A contains proforma for the collection of the necessary agronomic data from the Ministry of Agriculture.

2.2 Data Requirement – Livestock Enterprise

2.2.1 Before starting the calculations it is necessary to assemble the following data:

- Characteristics of the farm type
  - Size of farm (ha)
  - Scale of enterprise (family, small, medium, large)
  - Ownership (farmer owner, tenant farmer, cooperative, etc)
  - Type of enterprise (arable, livestock, mixed)
  - Primary product for livestock enterprise (eggs, dairy, meat, wool)
- Livestock to be kept, including details of the herd/flock composition
  - Herd/flock size and composition
  - Yield of main product
  - Yield of by-products
- Crops to be grown for feed, including details of the seed variety
  - Area to be cultivated under each crop
  - Yield per hectare of main crop product (eg grain)
  - Yield per hectare of crop by-product (eg straw)
- Crop operations and costs as in Section 2.1.
- Farming operations for each type of livestock and product
  - Milk production: labour and machinery required
  - Egg production: labour and machinery required
  - Wool production: labour and machinery required
  - Veterinary activities: labour and machinery required
  - Slaughter: labour and machinery required
  - Transport from farm: labour and machinery required
  - Handling: labour and machinery required
  - Storage: labour and machinery required
- Unit rates for production inputs
  - Labour cost rate per day (hired labour: skilled, unskilled)
  - Feed cost (if bought in rather than grown on the farm)
  - Veterinary costs (for each type applied)
  - Machinery costs (tractor and more specialised equipment)
  - Transport costs (fuel etc)
  - Miscellaneous eg bags, boxes, bottles etc

Preliminary

- Storage costs
- Rent if applicable
- Value of product in the local market
- Price per standard unit of measure for main and by-products

2.2.2 Appendix A contains proforma for the collection of the necessary agronomic data from the Ministry of Agriculture.

2.3 Additional Information for Economic Analysis

2.3.1 Shadow price factors have to be estimated where necessary.

Table 1: Basic parameters and prices

All in Iraqi Dinars (ID) at 1986 constant prices, domestic pricing system				
Official exchange rate		x.xx ID/US$		East Gharraf FS
Shadow exchange rate factor		1.15		
Shadow exchange rate		x.xx ID/US$		
Discount rate		8%/year		
Good	*Unit*	*Financial price*	*Economic price*	*Shadow price factor*
Investment inputs				
Imported materials				1.10
other materials				1.00
Skilled labour				1.10
Unskilled labour				0.60
Machine use				1.20
Agricultural inputs				
Seed				
Maize	kg	0.35	0.35	
Fertilizer				
N	kg	0.06	0.12	
P	kg	0.12	0.24	
K	kg			
Agro-chemicals	ID			
Seed treatments		20	40	
Weedkiller		1.6	3.2	
Pesticide treatments		1.8	3.6	
Machinery				
tractor	hour	2	2	
combine	hour	16.5	16.5	
Animal power	ID			
Sacks etc	ID			
Hired labour	person-day			
Family labour	person-day	0	4	
Agricultural outputs				
Maize	t	80	75	

2.3.2 Information taken from World Bank commodity forecasts has been used to provide worked examples of the approach.

Preliminary

Table 2: Economic price of crop as import substitute

Crop:	MAIZE			
Unit:	tonne			
(shadow price factors for handling and transport are weighted means according to tax/traded/non-traded proportions)				
			Currency X at 1986 prices	
Good	*Unit*	*Financial price*	*Shadow price factor*	*Economic price*
World price of maize in US$				
World Bank forecast for year xxxx				
US nr 2 maize fob US Gulf port	US$	116		
Quality adjustment factor, project/US nr 2	factor	1.04		
Adjusted price for project maize	US$	120.64		
Freight US Gulf port to Iraqi port	US$	53		
Insurance etc to Iraqi port	US$	8		
CIF price, imported maize, Iraqi port	US$	181.64		
Border equivalent price in local currency				
	exchange rates	2.53		2.91
CIF price, imported maize, Iraqi port	ID	459.55		528.57
Import and other taxes	ID	89.25	0.00	0.00
Port handling costs	ID	10.20	1.05	10.71
Transport, port to Baghdad market	ID	22.00	0.80	17.60
Deduct: project to Baghdad market	ID	-16.00	0.80	-12.80
Border equivalent farm gate price	ID	565.00		544.00

Preliminary

COMMODITY PRICE DATA

		Annual averages			Quarterly averages					Monthly averages		
		Jan-Dec	Jan-Dec	Jan-Oct	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Aug	Sep	Oct
Commodity	**Unit**	2003	2004	2005	2004	2004	2005	2005	2005	2005	2005	2005
Energy												
Coal, Australia	$/mt	27.84	54.70	51.34	60.42	55.65	53.04	52.94	50.17	50.88	47.00	44.94
Coal, US	$/mt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Crude oil, avg, spot	a/ $/bbl	28.90	37.73	52.92	40.52	42.68	46.24	50.79	59.98	61.89	61.69	58.19
Crude oil, Brent	a/ $/bbl	28.85	38.30	54.09	41.59	44.17	47.64	51.61	61.55	64.09	62.98	58.52
Crude oil, Dubai	a/ $/bbl	26.74	33.46	48.71	36.09	35.57	41.44	47.69	55.34	56.63	56.54	53.67
Crude oil, West Texas Int.	a/ $/bbl	31.11	41.44	55.96	43.89	48.31	49.65	53.06	63.05	64.96	65.54	62.36
Natural gas, Europe	$/mmbtu	3.91	4.28	6.10	4.34	4.93	5.49	5.89	6.52	6.56	6.58	7.28
Natural gas, US	$/mmbtu	5.49	5.89	8.37	5.49	6.36	6.42	6.94	10.04	9.63	12.88	13.52
Non Energy Commodities												
Agriculture												
Beverages												
Cocoa	b/ c/kg	175.1	155.0	155.1	161.2	159.9	164.7	154.5	149.1	148.1	150.5	145.7
Coffee, Arabica	b/ c/kg	141.5	177.4	256.8	168.3	202.1	266.8	278.6	233.4	238.5	219.3	231.6
Coffee, robusta	b/ c/kg	81.5	79.3	110.0	76.6	74.3	93.9	122.6	115.2	114.6	103.3	104.8
Tea, auctions (3), average	c/kg	151.7	168.6	164.5	176.4	176.7	159.9	166.0	166.8	165.3	165.9	167.3
Tea, Colombo auctions	b/ c/kg	154.1	178.1	183.2	177.9	201.4	193.5	176.5	176.2	175.6	188.5	194.0
Tea, Kokata auctions	b/ c/kg	146.5	172.2	162.7	193.2	179.8	136.9	179.1	175.3	170.7	156.8	153.4
Tea, Mombasa auctions	b/ c/kg	154.4	155.4	147.6	158.1	149.1	149.3	142.3	149.0	149.6	152.3	154.5
Food												
Fats and Oils												
Coconut oil	b/ $/mt	467.3	660.8	626.8	651.0	651.7	667.3	654.9	571.7	550.0	559.0	586.0
Copra	$/mt	299.9	450.0	420.9	444.3	448.3	447.8	446.4	380.7	371.0	346.0	384.0
Groundnut oil	b/ $/mt	1,243.2	1161.0	1081.9	1117.7	1130.3	1152.4	1101.3	1025.0	1023.0	1002.0	983.0
Palm oil	b/ $/mt	443.3	471.3	419.2	432.3	429.0	413.3	421.7	415.0	407.0	421.0	442.0
Palmkernel oil	b/ $/mt	458.8	648.1	631.9	629.0	653.0	662.3	655.6	582.3	558.0	577.0	618.0

http://siteresources.worldbank.org/INTPROSPECTS/Resources/Pnk_1105.pdf

	2004	2005	2006	2007	2010	2015
A. Energy (nominal)						
1. Energy index	164.9	236.0	244.8	227.3	174.8	153.0
2. Coal, Australia, $/mt	54.7	50.0	45.0	42.0	35.0	37.5
3. Crude oil, average, $/bbl	37.7	54.0	56.0	52.0	40.0	35.0
4. Natural gas, Europe, $/mmbtu	4.3	6.3	7.2	6.8	5.3	4.8
5. Natural gas, US, $/mmbtu	5.9	9.0	8.8	7.0	5.8	5.5
B. Non-energy commodities (nominal)						
1. Non-energy commodities index	107.5	120.9	116.8	109.1	99.5	104.1
C. Agriculture (nominal)						
1. Agriculture index	104.7	112.1	108.5	104.6	102.8	108.1
D. Beverages (nominal)						
1. Beverages index	94.0	118.3	115.2	111.2	99.7	106.0
2. Cocoa, c/kg	155.0	155.0	162.0	163.0	160.0	150.0
3. Coffee, arabica, c/kg	177.4	257.9	242.0	227.0	187.4	209.4
4. Coffee, robusta, c/kg	79.3	109.1	108.2	107.3	104.7	125.0
5. Tea, auctions(3) average, c/kg	168.6	166.0	166.0	165.0	165.0	170.0
E. Food (nominal)						
1. Food index	110.0	108.9	104.8	100.3	101.0	105.4
F. Grains (nominal)						
1. Grains index	100.2	102.8	99.6	95.2	94.5	99.7
2. Maize, $/mt	111.8	100.0	98.0	95.0	105.0	110.0
3. Rice, Thailand, 5%, $/mt	237.7	285.0	275.0	265.0	230.0	240.0
4. Sorghum, $/mt	109.8	97.0	94.0	92.0	100.0	108.0
5. Wheat, US, HRW, $/mt	156.9	150.0	145.0	135.0	145.0	155.0

World Bank commodity forecasts

3 CROP BUDGET

3.1 Financial

3.1.1 With the agronomic information and the farm size and type a start can be made to prepare crop budgets for each of the crops that are grown on a typical farm of this type. The first stage is to prepare the financial crop budget

Table 3a: Financial crop budget per hectare

Crop	Maize			
Farm type	Small holder irrigation		East Gharraf FS	
Situation	Present			
Prices	Financial			
Currency	Iraqi dinars at 1985 constant prices?			
Item	*Unit*	*Quantity*	*Price*	*Value*
Gross return				
Main product	t	5	80	400
By-product	t			0
Losses	t			0
			Gross return	400
Production costs				
Seed	kg	40	0.35	14
Fertilizer				
N	kg	200	0.06	12
P	kg	200	0.12	24
K	kg			0
Agro-chemicals	ID	34.4	1	34.4
Machinery				
tractor	hour	14.5	2	29
combine	hour	2.5	16.5	41.3
Animal power	ID			0
Sacks etc	ID			0
Hired labour	person-day			0
Family labour	person-day	18	0	0
			Total Costs	154.7
Net financial return	ID/hectare			245.3
Net return to family labour	ID/person-day			13.6

3.1.2 The analysis shown is for the PRESENT situation pre-project.

3.1.3 The future without- and future with- project budgets now need to be considered. For an individual crop there might be no difference but at the farm level improved water availability or better drainage (what ever the project is designed to improve) may lead to a change in the crops selected or to the use of improved varieties. Improved varieties often require more

Preliminary

inputs in order to achieve the best results (more fertilizer, more pesticides, etc).

3.2 Economic

3.2.1 The next step is to prepare the economic crop budget for each crop on the farm.

Table 5a: Economic crop budget per hectare

Crop	Maize			
Farm type	Small holder irrig?		East Gharraf FS	
Situation	Present			
Prices	Economic			
Currency	Iraqi dinars at 1985 constant prices?			
Item	*Unit*	*Quantity*	*Price*	*Value*
Gross return				
Main product	t	5	75	375
By-product	t			0
Losses	t			0
			Gross return	375
Production costs				
Seed	kg	40	0.35	14
Fertilizer				
N	kg	200	0.12	24
P	kg	200	0.24	48
K	kg			0
Agro-chemicals	ID	68.8	1	68.8
Machinery				
tractor	hour	14.5	2	29
combine	hour	2.5	16.5	41.3
Animal power	ID			0
Sacks etc	ID			0
Hired labour	person-day	0	0	0
Family labour	person-day	19.8	4	79.2
			Total Costs	304.3
Net economic return	ID/hectare			70.7

3.2.2 Note the cost of family labour is now included, and that the prices of some of the items are different to their values in the financial analysis – this is because the SPF for each of these items is not 1.0.

3.2.3 The analysis shown is for the PRESENT situation pre-project.

Preliminary

4 ARABLE FARM BUDGET

4.1.1 Once the analysis has been completed for every crop in the cropping pattern the whole annual farm budget can be prepared for both the financial and the economic case. The financial case is shown below for a fictitious farm and crops.

Table 4a: Financial arable farm budget

Farm type	Small holder irrigation				
Situation	Present				
Prices	Economic				
Currency	Iraqi dinars at 1985 constant prices?				
Crop	*Area for this crop*	*Net return, Iraqi dinars*		*Family labour*	
	ha	*per ha*	*per farm*	*per ha*	*per farm*
Maize	3	1392	4176	60	180
Cabbage	0.5	2270	1135	110	55
Tomatoes	0.5	2630	1315	125	62.5
Cowpeas	1	519	519	31	31
Totals	5		7145		328.5
Farm net return per hectare			1429		328.5
Farm net return per man-day of family labour					22

4.1.2 This applies to the present situation and needs to be repeated for the with-project situation.

Preliminary

5 LIVESTOCK ENTERPRISE BUDGET

5.1 Dairy Unit

5.1.1 Livestock enterprises are rather more complex to analyse than arable farms. In the case of a dairy unit there are a number of products and unlike the arable crop the livestock have a lifespan of several years so herd composition must be taken into account.

5.1.2 The table below is set out in the same format as the previous crop budgets and summarises the annual budget for a dairy enterprise. The prices are fictitious.

Table 5a: Economic dairy unit budget per 100 cows

Product	Milk			
Farm type	Dairy			
Situation	Present			
Prices	Economic			
Currency	Invented at 1985 constant prices?			
Item	*Unit*	*Quantity*	*Price*	*Value*
Gross return				
Main product	kg	304000	0.24	72960
By-product	t			
Old cows sold		13	255.42	3320.5
Bulls sold		35	316.08	11062.8
Heifers sold		22	306.5	6743
Manure (dry)	t	452	5	2260
Losses	t			0
			Gross return	96346.3
Production costs				
Feed				
Straw	t	252	5	1260
Green feed/silage	t	3949	1	3949
concentrates	t	320	150	48000
Vetinary	per head	330	6.79	2240.7
Machinery	per head	330	13.57	4478.1
Miscellaneous	17%			10372
Labour				
Hired labour				
Skilled	person-day	1	648	648
Unskilled/casual	person-day	20	216	4320
Family labour	person-day	0	0	0
			Total Costs	75267.8
Net economic return	ID/hectare			21078.5

5.1.3 Behind this table there are a number of preparatory calculations that are illustrated below.

Preliminary

Table X: Agronomic Information - Dairy Cattle

		Parametres	
Number of cows		100	
Calving rate		80%	
Calving interval (months)		15.0	
Calves born per year		80	
Young stock mortality		12%	* young stock mortality = 6% 0-1 years, 3% 1-2 years, 3% 2-3 years
Cow mortality		3%	
No. lactations per cow		5	
Milk	kg cow per lactation	3,800	
	kg cow per year	3,040	
Manure			
Casting age for cows (years)		8	

Herd Makeup and Feed Requirements

	Cows	Bullocks		Heifers		Calves	Herd
		2-3 yrs	1-2 yrs	2-3 yrs	1-2 yrs	0-1 yr	Total
Baseline							
Number of animals	100	37	38	37	38	80	330
Feeding: kg/head/day							
staw	2	5	2	2	2	1	
green feed/silage	50	40	25	40	25	12	
concentrate	5.0	3.0	2.0	2.0	1.5	0.8	
Feeding: total tons/year							
staw	73	68	28	27	28	29	252
green feed/silage	1,825	540	347	540	347	350	3,949
concentrate	182	41	28	27	21	22	320
Total feed requirement for herd (tons/year)							4,522

5.1.4 The economic information to build up the budget are summarised below.

Preliminary

Table X2: Basic Economic Parameters - Dairy Cattle

Value of livestock

	Cows	Bullocks		Heifers		Calves	
		2-3 yrs	1-2 yrs	2-3 yrs	1-2 yrs	0-1 yr	
value: soms/head	45,000	30,000	20,000	30,000	20,000	10,000	
Number of animals	100	37	38	37	38	80	330
total soms'000	4,500	1,110	760	1,110	760	800	9,040

Economic price of beef and milk as import substitute

World prices source information

Beef	import	Austral./New Zealand, frozen, boneless, cow forequart., cif US East Coast
Butter	import	New Zealand, export price, average 1996-9
SMP	import	skim milk powder, New Zealand, export price, average 1996-9

Milk and meat

		$/ton	
	Beef	Butter	SMP
green feed/silage	1729.18	1901.00	1818.00
quality adjustment	25%		
international freight etc.	300.00	300.00	150.00
Border price	2461.48	2201.00	1968.00
Local marketing	80.00	80.00	40.00
Value at wholesale	2541.48	2281.00	2008.00
Local processing etc.	-635.37		
Farm gate value	1906.11		

Conversion to fresh milk

Reconstitution of skim milk powder (SMP) and butter

100 tons fresh milk =	9 tons SMP + 3 tons butter	
= $/ton		249.15
less transport from farm		5.00
Farm gate value		244.15

Conversion - beef to live cattle

	Weight (kg)			$ per kg	$ per
	live	carcass	boneless		animal
bull - 2/3 years old	450.00	247.50	165.83	1.91	316.08
cow - 8/9 years old	400.00	200.00	134.00	1.91	255.42

Preliminary

6 EXAMPLE OF WITH- AND WITHOUT-PROJECT ANALYSIS

Preliminary

Appendix A Data Compilation Proforma

1. Crop data: variety, planting dates, harvest dates, operations and their timing
2. Overall cropping calendar
3. Local climate data

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Irrigation Water Requirements

GN 03

August 2006

GN 03 Rev 0

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This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note describes procedures for the calculation of crop water and irrigation diversion requirements in Iraq.

Preliminary

Report Issue and Revision Record

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P1	August 2006	Preliminary when Phase 1 curtailed

List of Contents

Page

Chapters and Appendices

1 Introduction 1

2 Requirements 2

2.1 Data Requirements 2

2.2 Software 3

2.3 Climate Data 3

2.4 Crop Coefficients 4

3 Irrigation Diversion Requirements 8

3.1 Introduction 8

3.2 Field Crops 8

3.3 Rice Crops 10

3.4 Total Irrigation Demand 11

4 Yield response to water 14

4.1 Yield Response to Water Quantity 14

4.2 Yield Response to Water Quality 14

List of Figures

Figure 2.1: Maize development stages 6
Figure 2.2: Maize crop data entry screen in CropWat 6
Figure 2.3: Prediction of irrigation and/or rainfall frequency 7
Figure 3.4: Calculation of Cotton Water Requirements in CropWat 9

Preliminary

1 INTRODUCTION

1.1.1 This note presents a step by step approach to the calculation of irrigation water requirements, from the estimation of crop coefficients to the calculation of irrigation diversion requirements. The methodology adopted is that of the Food and Agriculture Organisation (FAO) given in their series of Irrigation and Drainage Papers.

- Nr 24 'Crop water requirements', reprinted 1977
- Nr 25 'Effective rainfall', 1974
- Nr 29 'Water quality for agriculture', 1976
- Nr 33 'Yield response to water', 1979
- Nr 46 'CROPWAT A computer program for irrigation planning and management', 1992
- Nr 48 'The use of saline waters for crop production', 1993
- Nr 49 'CLIMWAT for CROPWAT', 1993
- Nr 56 'Crop evapotranspiration – Guidelines for computing crop water requirements', 1998

Preliminary

2 REQUIREMENTS

2.1 Data Requirements

2.1.1 Before starting the calculations it is necessary to assemble the following data:

- Location of the scheme for which the calculation is to be made
  - Rainfall characteristics at that location
  - Evaporation characteristics at that location
  - Soil characteristics at that location (to estimate seepage losses)
  - Zone in which the scheme is located (refer to Map 1)
  - Water quality
- Crops to be grown, including details of the seed variety
  - First and last planting date for the chosen variety
  - Length of growing season for the chosen variety or harvest dates
  - Area to be cultivated under each crop
  - Sensitivity of yield to water quantity and quality
- Farming operations for each crop
  - Land preparation: water required and when
  - Sowing: how many plantings, how many days apart, what proportion of the area to be sown at each planting
  - Irrigation frequency
  - Constraints and/or special measures
- Irrigation system operation
  - Characteristics of the irrigation system: traditional or modern
  - Gravity supply and/or pumping
  - Estimated irrigation efficiency: field and conveyance system efficiencies.

2.1.2 Appendix A contains proforma for the collection of the necessary agronomic data from the Ministry of Agriculture.

2.1.3 Information taken from the General Scheme Stage 2 reports has been used to provide worked examples of the approach.

Preliminary

2.2 Software

2.2.1 For most crops the procedure involves the use of the FAO program 'CropWat' and its associated database of climate data for key stations around the world. The CropWat 4 for Windows package, its user manual, and Climwat database can be downloaded directly from the FAO web site or from Claromentis. The Near East and North Africa Climwat database contains climate data for 20 stations in Iraq.

2.2.2 However, the CropWat package does not cover all crops that may be of interest in Iraq, in particular the Windows version does not cover rice. Therefore this note explains the calculation procedure for an example crop that is included in Cropwat and for rice which is not. A workbook for calculating the requirements has been developed which, for many crops, can then be compared to the Cropwat output.

2.2.3 The workbooks are called 'Rice Diversion Requirements rev0.xls' and 'Non-rice Diversion Requirements rev0.xls'.

2.3 Climate Data

2.3.1 The most important parameters are potential evaporation (Eo) and potential evapotranspiration (ETo) from plants, and rainfall.

2.3.2 Evaporation may be measured directly using an evaporation pan, but it is usually calculated from climatic parameters by one of a number of formulae such as the 'Penman-Montieth'. The latter uses temperature, humidity, sunshine, and wind data to compute ETo.

2.3.3 The Climwat database provides a first source of climate data for Iraq. The SWLRI project has also compiled data from the Ministry of Transport.

2.3.4 Either select the nearest station from the Climwat data set or from the SWLRI data set. It is better to put in data for temperature, humidity, sunshine and wind even if pan evaporation data is available so that ETo can be calculated by more than one method in CropWat.

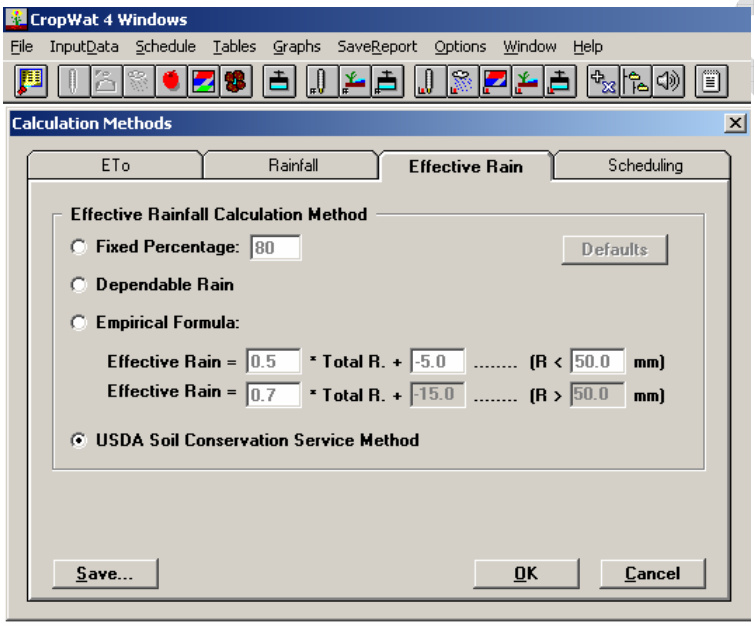
2.3.5 Refer to the CropWat manual for instructions on how to enter and save the data for the local station, and on how to calculate evaporation and evapotranspiration.

Preliminary

2.3.6 Rainfall data should be entered for the nearest local station in preference to Climwat data if at all possible. Rainfall can be quite spatially variable and therefore it is better to use local data – provided that it is considered reliable.

2.3.7 Refer to the CropWat manual for instructions on how to enter and save the data for the local station, and on how to calculate the 'effective rainfall'

2.3.8 Effective rainfall is that rain that falls during the growing season and can actually be used by the crops, hence saving on irrigation applications. It is always less than the total rainfall because some rainfall runs off to streams and drains and cannot be used by the crops. The CropWat program offers more than one method for estimating effective rainfall.



2.3.9 It is recommended that the USDA Soil conservation method is used with CropWat (the default) for manual calculation a fixed percentage may be more appropriate.

2.4 Crop Coefficients

2.4.1 Evapotranspiration losses from a field are the sum of crop transpiration (ETcrop) and evaporation from the soil surface. ETcrop is derived from ETo (potential evapotranspiration) using crop coefficients (kc).

2.4.2 The crop growing season of field and vegetable crops has been divided into four stages (FAO Paper 24). Crop coefficients (kc) for given stages of crop development and different climatic conditions are presented in Tables 1 and 2 of that publication; they are also available through the Cropwat software. The need to collect local data on growing season length and rate of crop development is highlighted.

2.4.3 The four stages in crop development are defined below.

1. Initial stage – germination and early growth when the soil surface is not, or is hardly covered by the crop (groundcover <10%)

2. Crop development stage – from the end of the initial stage to attainment of effective full groundcover. Start of the mid-season stage can be recognised in the field when the crop has attained 70-80% groundcover which, however, does not mean that the crop has reached its mature height. Effective full groundcover refers to cover when kc is approaching a maximum.

3. Mid-season stage – from attainment of effective full groundcover to time of start of maturing as indicted by discolouring of leaves (beans) or leaves falling off (cotton). For some crops this may extend to very near harvest (sugarbeets) unless irrigation is not applied at late season and a reduction in ETcrop is induced to increase yield and/or quality (sugarcane, cotton, some grains); normally well past the flowering stage of annual crops.

4. Late season stage – from end of mid-season stage until full maturing or harvest.

2.4.4 In FAO Paper 33 a more detailed description is provided of the growth stages of major crops, highlighting periods when full water supply is critical to high yields.

2.4.5 The steps needed to arrive at the kc values for the different growth stages are illustrated by an example of a maize crop to the grown on the Lower Khalis project as a summer season crop. The following extract from FAO Paper 33 gives the range of kc values for maize.

2.4.6 ‘Maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop. For maximum production a medium maturity grain crop requires between 500 and 800 mm of water depending on climate. To this, water losses during conveyance and application must be added. The crop factor (kc) relating water requirements to reference evapotranspiration is: initial stage 0.3 – 0.5 (15 to 20 days), the development stage 0.7 – 0.85 (30 to 45 days), the mid-season stage 1.05 – 1.2 (30 to 45 days), during the late season stage 0.8 – 0.9 (10 to 30 days), and harvest 0.55 – 0.6.’

Preliminary

Figure 2.1: Maize development stages

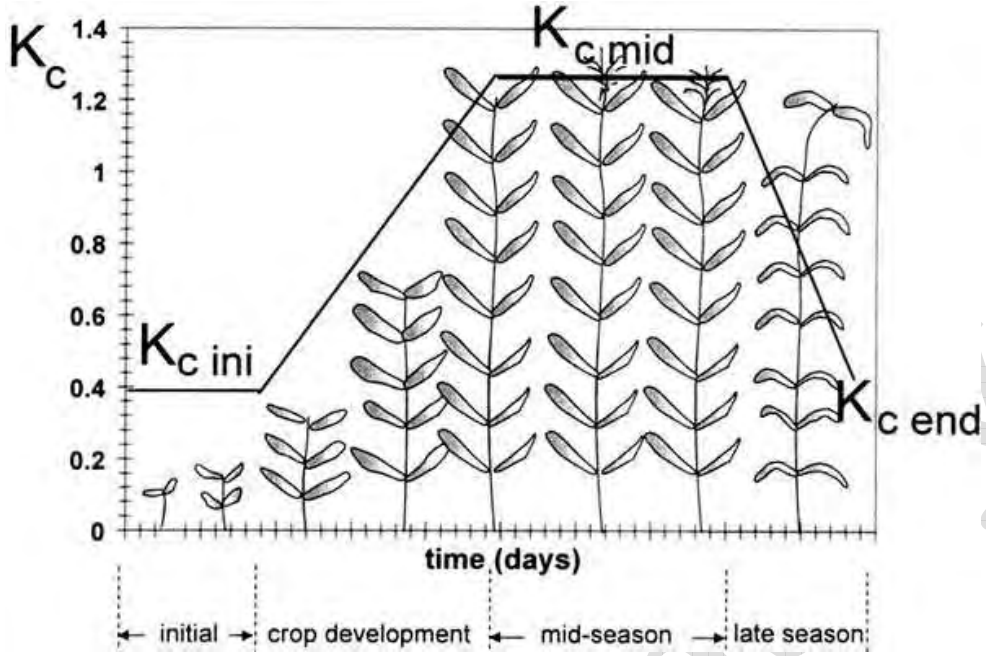
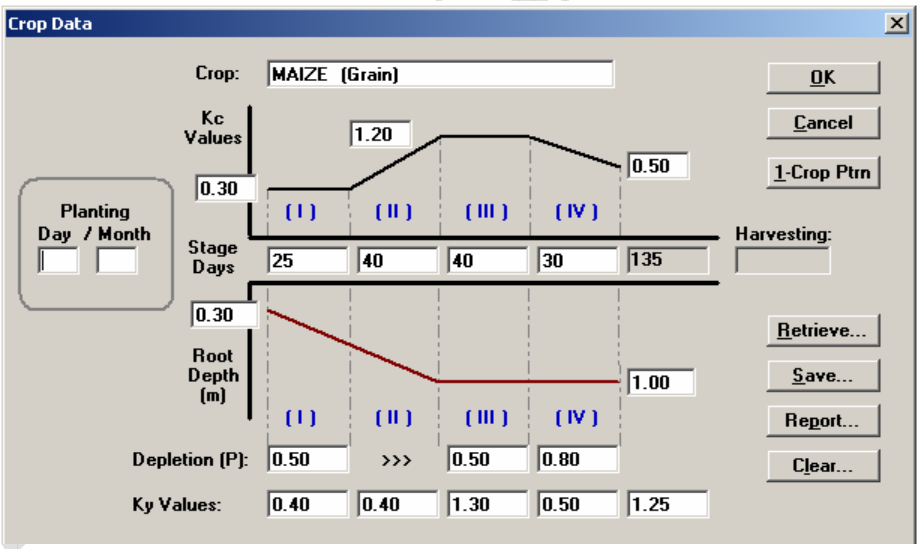


Figure 2.2: Maize crop data entry screen in CropWat



2.4.7 Where local information on the proposed crop variety does not match that provided as the standard in CropWat it is possible to edit the file and put in more appropriate lengths for each of the stages.

2.4.8 For maize on the Lower Khalis project:

1. Establish the planting date

2. Determine the total growing season and the length of each growth stage from local information

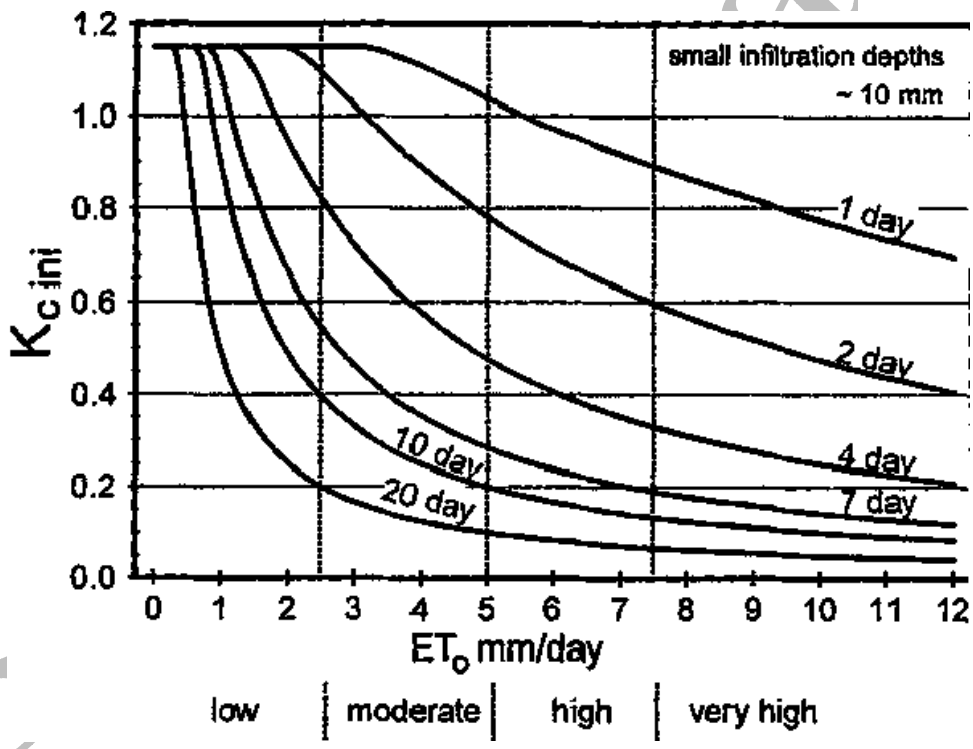
3. Initial stage: predict irrigation and/or rainfall frequency for predetermined ETo value select the initial kc value from the graph (Figure 2.3) below

4. Mid-season stage and late-season stage: for given climate (humidity and wind) select kc values from FAO publication tables

5. Join up the coefficients as shown in Figure 2.1 and Figure 2.2 above.

6. For each period being analysed (e.g. 15 day) obtain the kc value from the graph that you have drawn up.

Figure 2.3: Prediction of irrigation and/or rainfall frequency



3 IRRIGATION DIVERSION REQUIREMENTS

3.1 Introduction

3.1.1 Usually requirements are calculated for a series of planting dates to enable optimum planting dates to be selected. To reduce the peak water requirement and to spread the labour inputs it is usual to adopt staggered planting in three steps. The time interval selected will depend on the likely pattern of crop irrigations, 10 or 15 day intervals may be selected.

3.1.2 The calculation procedures for field crops and paddy rice crops are slightly different and hence are discussed separately, field crops first.

3.2 Field Crops

3.2.1 The calculations for field crops can be carried out within CropWat. The user manual gives detailed instructions. Here the method is summarised to demonstrate the main principles and to allow a comparison with the calculations for rice crops.

Land Preparation

3.2.2 The amount of water and period for land preparation must be determined from local information. Water may be required to leach accumulated salts from the soil or just as an aid to tillage depending on local conditions.

Consumptive Use

3.2.3 Actual evapotranspiration is calculated from the potential ETo and the kc value for each period

Percolation and Seepage

3.2.4 These rates depend on the soil type and the location of the groundwater table. The results of infiltration tests carried out in the study area in actual fields should be used where possible. It is usual to use standard figures and account for local factors through the field efficiency factor.

Preliminary

Effective Rainfall

3.2.5 Described in Section 2.3.7 above.

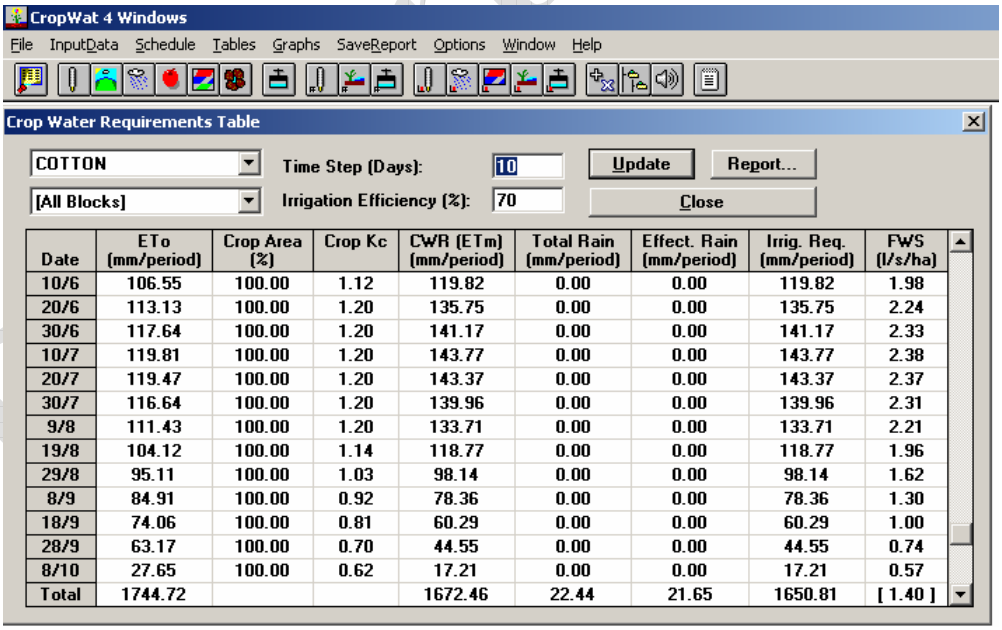
Irrigation Efficiency

3.2.6 Field losses can become large when applying relatively small amounts of water to dry-foot crops. Local information should be used where available. The General Scheme suggests farm plot values of between 0.7-0.75, and farm canal factors of around 0.9-0.95.

3.2.7 Further in order to allow for water losses from the canal system, from seepage, evaporation, gate leakage, etc an irrigation efficiency is estimated for the main canal and for secondary and tertiary canals. The efficiency factor should if possible be based on local information.

3.2.8 The factors are multiplied up so that farm plot and canal efficiencies together are 0.7*0.9 or 0.63. This factor is then multiplied by the canal system efficiency factor.

Figure 3.4: Calculation of Cotton Water Requirements in CropWat



Date	ETo (mm/period)	Crop Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Irrig. Req. (mm/period)	FWS (l/s/ha)
10/6	106.55	100.00	1.12	119.82	0.00	0.00	119.82	1.98
20/6	113.13	100.00	1.20	135.75	0.00	0.00	135.75	2.24
30/6	117.64	100.00	1.20	141.17	0.00	0.00	141.17	2.33
10/7	119.81	100.00	1.20	143.77	0.00	0.00	143.77	2.38
20/7	119.47	100.00	1.20	143.37	0.00	0.00	143.37	2.37
30/7	116.64	100.00	1.20	139.96	0.00	0.00	139.96	2.31
9/8	111.43	100.00	1.20	133.71	0.00	0.00	133.71	2.21
19/8	104.12	100.00	1.14	118.77	0.00	0.00	118.77	1.96
29/8	95.11	100.00	1.03	98.14	0.00	0.00	98.14	1.62
8/9	84.91	100.00	0.92	78.36	0.00	0.00	78.36	1.30
18/9	74.06	100.00	0.81	60.29	0.00	0.00	60.29	1.00
28/9	63.17	100.00	0.70	44.55	0.00	0.00	44.55	0.74
8/10	27.65	100.00	0.62	17.21	0.00	0.00	17.21	0.57
Total	1744.72			1672.46	22.44	21.65	1650.81	[1.40]

3.3 Rice Crops

Land Preparation and Nursery

3.3.1 A period for land preparation must be determined from local information. The nursery requirement is normally for 20-25 days. The period allowed for land preparation usually includes the nursery period.

3.3.2 The major water requirement at the start of the land preparation is to saturate the soil and establish a water layer, whereas towards the end of the period topping up to overcome evaporation and seepage losses is the predominant requirement.

Consumptive Use

3.3.3 Actual evapotranspiration is calculated from the potential ETo and the kc value for each period

Percolation and Seepage

3.3.4 Such seepage losses as occur are normally reused in adjacent fields so no special allowance for seepage needs to be made.

3.3.5 The results of infiltration tests carried out in the study area in actual wet paddy fields should be used where possible. In general infiltration rates on land classified as suitable for rice are 1-4 mm/day

Effective Rainfall

3.3.6 Described in Section 2.3.7 above

Water layer replacement

3.3.7 In order to apply fertiliser and carry out weeding operations it is usual to draw down the water level in the paddy fields. The water layer must then be replaced. The amount and timing for water layer replacement application(s) should be based on local practices.

Preliminary

Irrigation Efficiency

3.3.8 In order to allow for water losses from the canal system, from seepage, evaporation, gate leakage, etc an irrigation efficiency is estimated for the main canal and for secondary and tertiary canals. The efficiency factor should if possible be based on local information.

3.4 Total Irrigation Demand

3.4.1 The total monthly (or other interval) demand at the head of the system depends on the selected cropping pattern and cropping intensity. Unit diversion requirements for the crops involved are multiplied by the proposed area and summed to give the total demand in million cubic metres for comparison with river flows or reservoir releases.

3.4.2 It should be noted that this is the theoretical demand for supply to the crop from the head of the system and does not take account of operational water requirements for other purposes that are met from the irrigation network – in Iraq the flow in irrigation canals may be determined by the needs for downstream users (environment, local water supply), to maintain levels, or to pass flood waters.

3.4.3 Sample output from the Non-rice Diversion Requirements.xls and Rice Diversion Requirements.xls workbooks follows.

Preliminary

Crop Water and Diversion Requirements for: **Maize (grain), variety ?, Iraq, Central Zone**

Period (0.5 month)	Crop Coefficient	Evapotrans-piration mm/d	Land Preparation mm/d	Consumptive Use mm/d	Percolation mm/d	Water Layer Replacement mm/d	Total mm/d	Effective Rain mm/d	Net Water Requirement mm/d	Crop Water Requirement l/s/ha	Field Requirement l/s/ha	Diversion Requirement l/s/ha
February 1	0.00	2.5	2.00	0.00	0		2.00	0.80	1.20	0.14	0.20	0.31
February 2	0.00	2.5	2.00	0.00	0		2.00	0.80	1.20	0.14	0.20	0.31
March 1	0.58	3.9		2.28	0		2.28	0.86	1.42	0.16	0.23	0.36
March 2	0.58	3.9		2.28	0		2.28	0.86	1.42	0.16	0.23	0.36
April 1	0.82	5.4		4.40	0		4.40	0.71	3.69	0.43	0.61	0.94
April 2	0.82	5.4		4.40	0		4.40	0.71	3.69	0.43	0.61	0.94
May 1	1.08	7.5		8.13	0		8.13	0.26	7.87	0.91	1.30	2.00
May 2	1.08	7.5		8.13	0	0.67	8.80	0.26	8.53	0.99	1.41	2.17
June 1	0.80	10.8		8.62	0	0.67	9.29	0.00	9.29	1.07	1.54	2.36
June 2	0.80	10.8		8.62	0		8.62	0.00	8.62	1.00	1.43	2.19
July 1	0.00	11.8		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
July 2	0.00	11.8		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
August 1	0.00	11.1		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
August 2	0.00	11.1		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
September 1	0.00	7.9		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
September 2	0.00	7.9		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	5.0		0.00	0		0.00	0.10	0.00	0.00	0.00	0.00
October 2	0.00	5.0		0.00	0		0.00	0.10	0.00	0.00	0.00	0.00
Total (mm)				703			783	82	704		1006	1547
Peak requirement (l/s/ha)												2.36

Factors and allowances	
LP (mm)	60
Nr of periods for LP	2
WLR (mm)	20
Nr of periods for WLR	2
Field Efficiency	70%
Conveyance Efficiency	65%
Percolation (mm/d)	0
Growing season (days)	120
Calculation period (days)	15

Notes:

Zones as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Crop coefficients for this crop in this zone as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Evapotranspiration rates as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Effective rainfall as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?
Field efficiency as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Conveyance efficiency (canal system) as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Land preparation requirement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Water layer replacement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?
Percolation rates from ? Assuming soil type ?

Preliminary

Crop Water and Diversion Requirements for: **Paddy rice, variety Basian, Iraq, Central Zone**

Period (0.5 month)	Crop Coefficient	Evapotrans-piration mm/d	Land Preparation mm/d	Consumptive Use mm/d	Percolation mm/d	Water Layer Replacement mm/d	Total mm/d	Effective Rain mm/d	Net Water Requirement mm/d	Crop Water Requirement l/s/ha	Field Requirement l/s/ha	Diversion Requirement l/s/ha
April 1	0.00	5.4	8.33	0.00	4		12.33	0.71	11.63	1.35	1.35	2.07
April 2	0.00	5.4	8.33	0.00	4		12.33	0.71	11.63	1.35	1.35	2.07
May 1	1.10	7.5		8.28	4	2.67	14.95	0.26	14.68	1.70	1.70	2.61
May 2	1.10	7.5		8.28	4	2.67	14.95	0.26	14.68	1.70	1.70	2.61
June 1	1.20	10.8		12.92	4	2.67	19.59	0.00	19.59	2.27	2.27	3.49
June 2	1.20	10.8		12.92	4	2.67	19.59	0.00	19.59	2.27	2.27	3.49
July 1	1.25	11.8		14.79	4	2.67	21.46	0.00	21.46	2.48	2.48	3.82
July 2	1.25	11.8		14.79	4	2.67	21.46	0.00	21.46	2.48	2.48	3.82
August 1	1.05	11.1		11.69	4	2.67	18.36	0.00	18.36	2.12	2.12	3.27
August 2	1.05	11.1		11.69	4	2.67	18.36	0.00	18.36	2.12	2.12	3.27
September 1	0.65	7.9		5.12	4		9.12	0.00	9.12	1.06	1.06	1.62
September 2	0.00	7.9		0.00	4		0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	5.0		0.00	4		0.00	0.10	0.00	0.00	0.00	0.00
October 2	0.00	5.0		0.00	4		0.00	0.10	0.00	0.00	0.00	0.00
Total (mm)				1507			2737	32	2708		2708	4166
Peak requirement (l/s/ha)												3.82

Factors and allowances	
LP (mm)	250
Nr of periods for LP	2
WLR (mm)	320
Nr of periods for WLR	8
Field Efficiency	100%
Conveyance Efficiency	65%
Percolation (mm/d)	4
Growing season (days)	120
Calculation period (days)	15

Notes:

Zones as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Crop coefficients for this crop in this zone as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Evapotranspiration rates as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Effective rainfall as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?
Field efficiency as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Conveyance efficiency (canal system) as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Land preparation requirement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982
Water layer replacement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?
Percolation rates from ? Assuming soil type ?

Preliminary

4 YIELD RESPONSE TO WATER

4.1 Yield Response to Water Quantity

4.2 Yield Response to Water Quality

Preliminary

Appendix A Data Compilation Proforma

1. Crop data: variety, planting dates, harvest dates, operations and their timing
2. Overall cropping calendar
3. Local climate data

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Technical Report Series

Groundwater

TR 06

August 2006

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This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of technical reports published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The technical report presents key challenges and issues facing Iraq related to groundwater.

Report Issue and Revision Record

Rev	Date	Description
P1	August 2006	Preliminary when Phase 1 curtailed

Preliminary

List of Contents

Page

Chapters and Appendices

1 Introduction 1

2 Key Challenges Facing Groundwater in Iraq 2

3 previous studies 4

4 Hydrogeological Provinces 5

4.2 Nubio-Arabian Province 5

4.3 Taurus Zagros Province 6

4.4 Principal aquifers 6

5 Potential for Groundwater Exploitation 7

5.1 Introduction 7

5.2 Western and Southern Deserts 9

5.3 Jezira Hydrogeologic Region 9

5.4 The Aquifer Systems of Alluvial Fans, Mandali-Badra-Tib Region 9

5.5 The Foothill Aquifer System 9

5.6 Mesopotamian Plain 10

5.7 Taurus-Zagros Belt 10

6 Existing Groundwater use 11

7 Institutional Arrangements and Groundwater 12

List of Figures

List of Tables

Table 1: Groundwater Potential and Provinces of Iraq (information from [Jassim and Goff 2006] and [UN, 1982]. 4

Preliminary

Preliminary

1 Introduction

1.1.1 There are a number of key references relating to groundwater in Iraq. While being methodical and substantial in the material, the Russian report from 1980s is somewhat outdated and in need of a revision. A more recent work was reported by FAO especially in the NE Iraq. A recently published 'Geology of Iraq', a joint effort edited by Jassim and Goff, brought a more recent description of groundwater in Iraq. There is however a need for a document summarising the resource status and listing the key references accessible to both technical users and water managers who are not necessarily groundwater specialists.

1.1.2 This technical note is therefore intended to provide a summary of the historical and current information available on groundwater in Iraq that would enable non-specialists to quickly develop an understanding of groundwater in Iraq. It should also identify the key places to obtain further information.

Preliminary

2 Key Challenges Facing Groundwater in Iraq

2.1.1 The concepts of integrated water resources management are underpinned by the axiom that the separation of groundwater and surface water is an artificial, although often useful, separation. Thus the hydrogeology and groundwater resource development potential can be examined in terms of its interaction with surface water in the relation to irrigation and drainage, potable water supply and sustaining the requirements of the natural environment.

2.1.2 The present total area irrigated in Iraq by surface waters covers only about 25% of Iraq. The river and irrigation systems are critically important sources of potable water in areas where groundwater is unavailable at a quality or in quantities that can support human activity. Groundwater has therefore has the potential to play an important role in the development and in sustaining the environment of the remaining 75% of the country.

2.1.3 Over the course of the project the following key challenges and issues facing Iraq relating to groundwater were highlighted:

- The use of groundwater varies considerably across Iraq, with some regions being solely dependent on groundwater, where as others are predominantly supplied by surface water.
- It appears that groundwater is being used increasingly as a water resource in preference to surface water.
- Unsustainable groundwater abstraction rates have resulted in significant falls in the water level in some areas. As a result many wells have gone dry, or have had to be deepened.
- There are also challenges from groundwater quality, both in terms of salinity, and other types of pollution.

From UN report, 1982:

2.1.4 Generally the cost of groundwater (per m^3) is relatively high owing to the depth of wells and the cost of maintenance. It is emphasised that a large number of new drilled wells are dry or are characterised by a small yield. Many of these wells become dry after a period of time. The water is often highly mineralised and has to be treated before use

2.1.5 The problem of desalination of groundwater has not been dealt with, but it should be possible to solve in 10-15 years time. Solving the problem would be of particular significance in respect to the vast region of Mesopotamia. We note that no real progress has been made in dealing with this issue.

Preliminary

From [Jassim and Goff, 2006]:

2.1.6 In the Mesopotamian Plain most surface water is used for irrigation. Seepage of water from canals or during irrigation raises groundwater levels which can cause soil salinisation when the so-called "critical depth" to groundwater level is reached. During hot seasons water rises to the root zone or surface by capillary action. Evaporation then leads to salt accumulation in the soil. During the rainy season the salt is leached and transported downward by percolating water towards deep groundwater bodies where the salinity continuously increases. To prevent soil salinisation, groundwater levels must be lowered below the "critical depth" by drainage.

2.1.7 We note that more modern strategies tend to focus on water availability and salinity in the root zone and the potential contribution of sub-irrigation with the intention of avoiding the capital cost and increased irrigation demands associated with over-draining. A further consideration is whether a drainage outlet or a salt sink is available and whether ultimately salt is retained within the irrigated area or exported. Exports into the irrigation system, whether by artificial drainage or by regeneration of river flows can promote upstream versus downstream conflicts amongst water users as well as being ecologically unsustainable.

Preliminary

3 PREVIOUS STUDIES

3.1.1 The hydrogeology of Iraq has been documented through a series of major investigations carried out in the past and this report draws heavily on them since no original fieldwork has been carried out. The major investigations and publications (in chronological order) are:

- Parsons, R.M. 1955. *Groundwater Resources of Iraq.* The Ralph M Parsons Company.
- USSR 1982. *General Scheme of Water Resources and Land Development in Iraq.* Volume 1, Book2, Geological and Hydrogeological Conditions. Produced through collaboration between the Ministry of Irrigation in Iraq, and the USSR.
- UN 1982. *Groundwater in the Eastern Mediterranean and Western Asia.* Natural Resources/Water Series No. 9. United Nation Publications.
- FAO, 2004. *Hydrogeology of Northern Iraq.* FAO publications, Rome. We have also looked at data collected in relation to the FAO programme for well-drilling undertaken between 2000 and 2003.
- Jassim A.Z. and Goff, J.C., 2006. *Geology of Iraq*. Dolin Publishers, Prague.

Preliminary

4 HYDROGEOLOGICAL PROVINCES

4.1.1 Iraq belongs to two major hydro-geological provinces, the Nubi-Arabian Provinces and the Taurus Zagros Province [Jassim and Goff, 2006].

4.2 Nubio-Arabian Province

4.2.1 This is made up of the Nubio-Arabian platform comprising of crystalline ("hard") rocks and an unfolded/gently folded sedimentary cover.

4.2.2 Regional groundwater flow occurs in the extensive Mesopotamian aquifer mega system. Intensive groundwater flow occurs in the upper part of the mega system, especially in its SW and NE flanks where several basin-wide aquifer systems or sub-systems with relatively independent groundwater flow occur. The discharge zone of the whole mega system is in the Mesopotamian Zone.

4.2.3 The Mesopotamian Aquifer Mega system of the Nubio-Arabian Groundwater Province consists of five hydrogeologic sub units:

1. The Aquifer System of the Western and the Southern Desert (south-western artesian basin)

2. The Jezira Hydrogeologic Region

3. The Aquifer system of the Mesopotamian Plain, including the Baquba-Tikrit region. The Fatha (Lower Fars) formation outcrops in the Tigris valley in the north or in the Jezira area between the Euphrates and the Tharthar.

4. The Aquifer systems of alluvial fans, Mandali-Badra-Tib Region. The alluvial fans occur along the foot of the mountains along the Iraqi-Iran frontier in southern Iraq. They comprise gravely and sandy sediments deposited by braided rivers. Most of them are hydraulically connected to the Mesopotamian Plain system, except for the series of fans of Mandal-Badra_tib which are hydraulically separated from the plain by low permeability sheet run-off deposits. The lower distal parts of these aquifer systems lie within Iraq, while the proximal higher parts mostly lie within Iran. Groundwater replenishment originates from river-influent seepage where river courses run across elevated outcrops of alluvial fan deposits. In other areas groundwater bodies are fed mostly by precipitation. Groundwater flows regionally from elevated areas of coalescing alluvial fans to the SW or S. Groundwater discharge occurs in the distal portions of the alluvial fans by springs, by the drainage effect of rivers and by evaporation and transpiration

Preliminary

5. The Aquifer System of the foothills, including Erbil-Kirkuk artesian basin. The Aquifer system of the Foothill zone covers a vast NW-SE trending area of approximately 37000 km2. To the east and in central Iraq the area extends up to the border with Iran. In N and NE Iraq it forms a boundary with the high folded zone. The hydraulic parameters vary due to variations in lithology and aquifer thickness. Regional groundwater flow prevails in the Foothill aquifer system, mostly with well-defined regional discharge zone along the main left-bank tributaries of the Tigris River, e.g., the Lesser Zab and Diyala. In addition to the hydraulic boundaries along river courses, structural geological elements (anticlines, faults) often form regionally important hydrogeological boundaries. There are a number of aquifer sub-systems.

4.3 Taurus Zagros Province

4.3.1 A mountain province including a group of Zagros and Taurian Artesian basins. Is located in intensively folded and thrusted rocks, It contains small aquifer systems in hard rocks, clastics and karstified carbonates mostly with local, confined, relatively shallow groundwater flow. However, some of these aquifers act as an external recharge zone in the Mesopotamian Aquifer Megasystem, especially through deep-seated, regional groundwater flow.

4.3.2 Groundwater flow: The occurrence of crystalline rocks and frequent lithological changes result in spatially limited aquifer systems. Therefore no significant regional groundwater flow. Extremely high heterogeneity and anisotropy of karst aquifers that result in uneven regional distribution of karst springs and large differences in the productivity of water wells.

4.3.3 Groundwater recharge is solely due to percolation from precipitation. Discharge takes place in the form of springs in lows and also along the contacting with less permeable rocks [USSR ,1982].

4.4 Principal aquifers

4.4.1 Lithological and structural geological conditions determine the spatial distribution and extent of hydrogeological bodies (aquifers, aquitards) and their hydrogeological environment.

4.4.2 In Iraq fourteen main aquifers/aquifer groups, identified by their relationship to geological formations, can be defined. The surface and near-surface distribution of these aquifers within Iraq is shown in Figure 1.

Preliminary

5 POTENTIAL FOR GROUNDWATER EXPLOITATION

5.1 Introduction

5.1.1 Table 1 outlines the key properties of the hydrogeological provinces and sub units of Iraq.

5.1.2 Figure 2 shows the depth of the water table from the surface.

5.1.3 Figure 3 shows the groundwater salinity of shallow groundwaters.

Preliminary

Table 1: Groundwater Potential and Provinces of Iraq (information from [Jassim and Goff 2006] and [UN, 1982].

	Sub-Hydro-geological Region	Groundwater Depth	Salinity	Aquifer	Depth of Wells (m)	Specific Yield (l/s/m)	Transmissivity (m^2/day)
Major Hydrogeological Region Nubio-Arabian Province	Western and Southern Desert	Depth increases westwards from 10m along the Euphrates to >250m near the Saudi border.		Dibdiba (Miocene-Pliocene)	70-100		
				Limestone(Eocene-Paleocene)	(50-100)-(200-300)	2-5	300-500
				Sandstone(Cretaceous and Older)	150-300	0.02-0.06	300-500
	Jezira Hydrogeologic Region	Generally 10-20m in the central part of the Abu Rassain High, 5m in the main discharge area of the Tharthar lake and less than 1m near salt playas.	Usually 3-5 g/l, but in the discharge area near the salt lakes, the salinity increases to 20g/l.	Lower Fars (Miocene)	20-50		
				Upper Fars (Miocene)	20-50		
	Alluvial fans Mandali-Badra-Tib Region	Greater than 35m in the upper parts of the fans.	Relatively low salinity. The salinity is 1-7g/l increasing from NW to SE		Sand-gravel fan deposits	1-5	Variable (1000-2000 m^2/day where great aquifer thickness. Can be less than 40m^2/day.
	Foothills Aquifer System	Depth to groundwater often varies significantly over short distances due to variable topography. Generally 20-30m	Freshwater, of <1g/l salinity, dominates the eastern part of the Foothill Zone. Irrigation water, of < 3 g/l, exits in other parts. Within the foothill aquifer system, from north to south, the salinity increases from <0.5 g/l to 6 g/l	Bakhtiari (Pliocene and Pleistocene)	10-40	7-20	1,000
				Fars (Miocene and Eocene)	5-20	0.1-0.3	70-80
	Mesopotamian Plain, including the Baquba-Tikrit	Very Shallow (<1m) in the area south of Kut. 1-5m between Kut and Baghdad.	Salinity increases in the central, topographically lower, plain. It is greatest in the southeast.	Quaternary	1-5		
Taurus-Zagros Belt			Dominated by freshwater of <1g/l salinity.	Limestone (Cretaceous)	20		
				Clastic (Cretaceous)	3-5	1-1.5	
				Alluvium			

Preliminary

5.2 Western and Southern Deserts

5.3 Jezira Hydrogeologic Region

5.3.1 The discharge of wells within this zone is generally very low, and many wells have been abandoned. However, near the Tigris and the Tharthar valley there is a possibility of better well yields (up to 30 l/s). [Jassim and Goff 2006].

5.3.2 Despite the relatively high salinity of groundwater (3-5g/l), in most of the region the groundwater has been used for irrigation and watering livestock. This is outside international guidelines but it seems that local sheep breeds can tolerate water with a salinity of up to 12g/l. At depths greater than 25m the salinity increases sharply from 3g/l to over 30g/l. Wells should not be drilled into this saline zone. [Jassim and Goff 2006]

5.4 The Aquifer Systems of Alluvial Fans, Mandali-Badra-Tib Region

5.4.1 The alluvial fans have a high importance for groundwater supply. Hydrogeologically, the fans are complicated aquifers due to their stratification, variable lithology and uneven recharge. Aquifers occur close to the mountain range where the fan deposits are coarsest. The highest transmissivities (1000-2000 m^2/day) occur where the aquifer thickness is highest. More typically the transmissivity is between 300-500 m^2/day, for example in the Mandali area and in the Badra-Zurbatiya area. [Jassim and Goff 2006]

5.4.2 Detailed investigations showed that safe yield assessments of 370 l/s in the Mandali alluvial fan and 256 l/s in the Badra-Zurbatiya fans [Jassim and Goff 2006]. In the foothill area to the southeast, where precipitation is much lover, safe yield estimates may be lower.

5.5 The Foothill Aquifer System

5.5.1 The foothill aquifer system is the most promising hydrogeological unit for regional scale groundwater development in Iraq. The aquifers have an estimated sustainable discharge of between 10 and 40 m^3/s, at depths of 5-50m [FAO Aquastat info on Iraq]. In the north and northeast, groundwater recharge is 2-5 l/s km^2 [Jassim and Goff 2006]. However, pumping in “close-to-river” zones, where induced groundwater resources are formed, can increase the recharge.

5.5.2 Groundwater quality in many areas is adequate for water supply as potable and irrigation water. However, quality is not so good in the south and west, and in places groundwater development is impossible for this reason. Even in areas where groundwater quality is acceptable, excessive pumping can cause intrusion from below during the decline in water head. Thus knowledge of vertical changes in groundwater quality is important where heavy pumping is planned.

Preliminary

5.5.3 The other issue with groundwater development arises because of the high transmissivity. The high transmissivity means that excessive groundwater drawdown could easily occur. Knowledge of the rate of groundwater recharge is therefore of vital importance for future groundwater development assessment.

5.6 Mesopotamian Plain

5.6.1 Upper parts: are favourable for exploitation – well discharge and transmissivity are reported to be high in many areas. The upper aquitard occurring beneath most of the plain protects the lower groundwater body from pollution

5.6.2 Lower Parts: too saline for use. However, in some "close to river zones" influent seepage from rivers or irrigation canals occurs during pumping. However salt-water encroachment from adjacent and deep-seated aquifers into the pumped groundwater body may take place.

5.6.3 Storage of groundwater, compared to surface water storage in artificial reservoirs allows between water quality protection and prevents evaporation losses

5.6.4 Artificial recharge can also improve groundwater quality – under suitable natural conditions, following sufficient pumping, fresh water may extend beyond the close-to-river zone. [Jassim and Goff 2006].

5.6.5 The aquifers on the right bank of the Euphrates River are found at depths of up to 300m, and have an estimated discharge of 13m3/s. Salinity varies between 0.3 and 0.5mg/l [FAO Aquastat info on Iraq].

5.7 Taurus-Zagros Belt

5.7.1 The potential for groundwater extraction is erratic due to the heterogeneity of the karst aquifers. Thus large groundwater withdrawals are often limited to small sites at high-yield karst springs.

5.7.2 However, some of the large cities at the boundary with the adjacent Foothill aquifer system are supplied from wells drilled into the Pila Spi aquifer. There are also important alluvial aquifers along large rivers.

5.7.3 Recently an ambitious FAO project was carried out in the Taurus-Zagros Province and extensive parts of the Foothill aquifer system. By March 2003 about 500 water wells were drilled, capable for pumping 3000 l/s for irrigation and livestock breeding purposes.

Preliminary

6 EXISTING GROUNDWATER USE

From UN report, 1982:

- In around 1950 only a modest number of wells had been drilled in the northern, western and central parts of Iraq. In 1953 – 1957, on the basis of the data which were then available, and at the request of the government, the Ralf Parsons Engineering Company prepared an over-all description of the hydrogeological conditions in Iraq.
- Between 1960 and 1980 more than 2,500 wells were drilled by different government organisations and foreign firms. The majority of the wells were suitable for exploitation. The number of hand-dug wells may be several times greater than that of drilled wells.
- Although surface water is the main source of water supply in Iraq , groundwater is an essential source of supply in the desert areas (which cover about 58% of the country) and some parts of Jezireh and the foothills. Groundwater represents the most important factor for the development of areas in the western desert in the future
-

Information obtained through discussions with the Iraqi visitors to Cambridge and from Dr Sadik, of the Groundwater Studies Centre, Baghdad:

- Groundwater use in Iraq is small in proportion to surface water, but is more important in rural areas. It may be the only practical source of water in large areas of the country.
- There is a perception that groundwater is currently used mainly in the northern governorates including Erbil and Sulaymaniyah.
- Groundwater is also used where surface water is not readily available e.g. in Najaf, Anbar and Muthanna governorates.
- There are wells located in other governorates.
- There is no recent estimate of groundwater use for drinking. Older estimates (2000) mentioned an annual use of about 2×10^9 m^3 of which we assume a proportion is returned to the rivers or to groundwater and the remainder is lost by evapotranspiration.
- Both deep (up to 150m depth) and shallow hand-dug wells are used.
- There are a high proportion of private wells (records can be prepared upon request to the general directorate of well drilling).
- There is no sign that groundwater exploitation has been increased in the majority of Iraq. However, the representative from the Ministry of Agriculture and Water Resources in Erbil suggested during the Study Visit that there had been a considerable expansion in groundwater use in parts of Kurdistan as the technology became available and the need for self sufficiency increased and other economic opportunities decreased with the political upheavals following the first Gulf War.
- Groundwater is used for both agriculture and drinking water.
- Wells pump only a few hours a day. Estimates place maximum pumping hours to 16 but on average 8 hours or less a day. Pumping from shallow wells could be as much and as long as deep wells. Normally flow rates for shallow wells do not exceed 15 l/s. Deep wells could reach up to 25-30 l/s. An average shallow well will discharge 5-6 l/s and in areas shallow wells don't produce more than 3-5 m^3/hr. There are no abstraction records maintained. Irrigation area per well varies between 1 to 10 hectares.

Preliminary

7 INSTITUTIONAL ARRANGEMENTS AND GROUNDWATER

National, Governorate, Province, District, Ministries, private/informal sectors.

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Technical Report Series

Hydraulic and Water Quality Modelling

TR 03

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This document is one of a series of technical reports published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The technical report presents hydraulic and water quality modelling which is intended to evaluate the likely effects in Iraq of possible changes in the stream flows arriving from upstream countries.

Preliminary

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Rev	Date	Description
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List of Contents

Page

1 Introduction 1
1.1 Background 1
1.2 The Modelling Approach 2
1.3 Capacity Building 2
2 Conceptual Model for Salinity 4
2.1 Conceptual Model for Nodes and Reaches 4
2.2 Reservoirs 6
2.3 Lag Coefficients for River Networks 6
3 Modelling Approach for Test Reaches for Salinity Analysis 8
3.1 Introduction 8
3.2 Data Available 9
3.3 Model Development for Tharthar Reservoir 10
3.4 Model Development for Tigris River 12
3.5 Lag Coefficients 14
4 Water Quality Parameters 15

List of Figures

Figure 3.1: Model Region - Tharthar Reservoir 8
Figure 3.2: Model Region – River Tigris 9
Figure 3.3: Model Network for Test Reach at Tharthar Reservoir 11
Figure 3.4: Model Network for Test Reach on Tigris River 12
Figure 3.5: HYDRO-1D Screenshot showing Inflow data for the Tigris Test Model 13
Figure 3.6: Example of Longitudinal Profile Plot of Salinity Concentration in the Test Model 13
Figure 4.1: Water Quality Parameters Available for Simulation in HYDRO-1D 15

List of Tables

Table 3.1: Availability of Water Quality Data Series for River Gauging Stations 10
Table 3.2: Table of Lag Coefficients from Test Model of the River Tigris 14

Preliminary

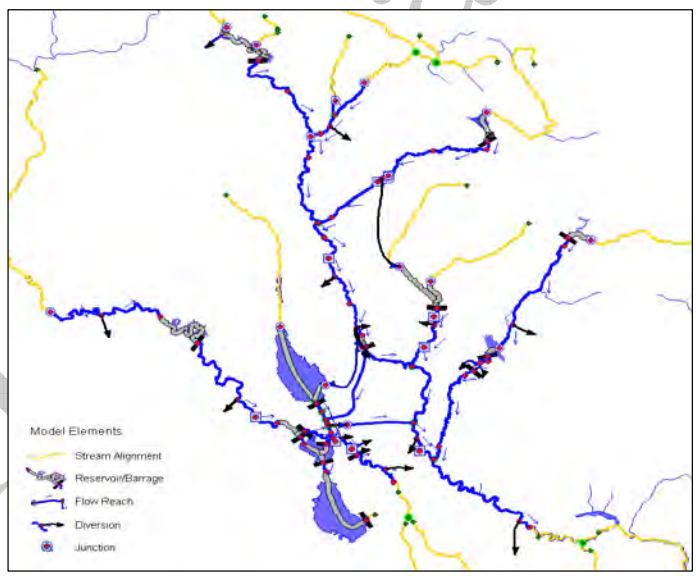
Preliminary

1 INTRODUCTION

1.1 Background

1.1.1 More than seventy percent of the water resources available to Iraq originate from outside its borders, and upstream utilization is progressing in the riparian countries, particularly in Turkey in the upper basin of the Tigris-Euphrates.

1.1.2 The SWLRI component for hydrologic analysis and water management system modelling of the Tigris and Euphrates basins in Iraq is tied to the reservoir simulation model development work conducted by the HEC in collaboration with Ministry of Water Resources (MoWR) staff. As part of the Iraq Marshland Restoration Program, a USAID-sponsored program from the Fall 2003 through Winter 2005, a Water Management System Model (WMSM) was established capturing the watershed characteristics and the functions of major water control and conveyance projects, including key points along the system for delivering water to the Marshes. Detailed operating criteria comprising reservoir rule curves, water supply objectives, and flood control targets were incorporated in the Tigris-Euphrates WMSM. Figure 1 illustrates part of the complex existing system for water control in Iraq as built into the WMSM.



1.1.3 The model is intended to evaluate the likely effects in Iraq of possible changes in the streamflows arriving from upstream countries in the future.

1.1.4 Water quality is already a significant issue in the lower reaches of the rivers, and more so in the drains, and will become more serious when upstream countries use even more of the water in the two major rivers. Some potential interventions will need to be justified largely on their impact on water quality (e.g. flushing Lake Tharthar or damming the Greater Zab), and that may require quantification of the effects with a model. In order to provide a tool to model movement and changes in 'conservative' water quality parameters including salt, and the ‘non-conservative’ and mutually interacting ones such as oxygen content / BOD and the agricultural nutrients that come with irrigation return flows, a water quality extension to the WMSM was being

Preliminary

developed in collaboration with HEC. This extension would have enabled water quality simulations to be run as part of the WMSM. This model together with test models developed in another one-dimensional modelling package is described in more detail in the following sections.

1.2 The Modelling Approach

1.2.1 As part of the collaborative study with HEC, Mott MacDonald has developed water quality models for sample reaches of Tigris and Euphrates Rivers. The purpose of these models was to establish appropriate model coefficients to simulate the salinity level along the Tigris and Euphrates Rivers using the HEC-ResSim model.

1.2.2 The HEC-ResSim model has already been developed to simulate the flows along the Tigris and Euphrates Rivers systems. The flow routing procedure in this model is based on the 'Coefficient Method' as described in the HEC-5 software user's manual (HEC-5 was the precursor to the more recent ResSim modelling package). This method is based on simulating the downstream flow in a river reach by using predefined weighting factors for upstream inflows at various time lags. The weighting factors are defined to predict the discharges by conserving the mass within a river reach.

1.2.3 In order to obtain the salinity level at the downstream location of a river reach the same procedure of 'Coefficient Method' has been used. This procedure allows compatibility with the flow routing model and conserves the mass of both flows and salt in the river reaches and nodal locations.

1.2.4 HEC has already developed the scripts to simulate the salinity level for river reaches and the ResSim model can be used to study any water allocation and distribution scenarios. This is the subject of a separate report published by HEC. The weighting factors can be defined using the results from the hydraulic and salinity simulation models applied to sample reaches of Rivers Tigris and Euphrates.

1.2.5 During the study period Mott MacDonald has been continuously liaison with HEC to modelling strategies and to develop the salinity modules within HEC-ResSim. This involved arranging regular conference calls and visits by Mott MacDonald staff to the head office of HEC in California. This collaboration was important to ensure that the water quality modelling could be integrated with the water resource modelling in ResSim as efficiently as possible.

1.3 Capacity Building

1.3.1 In order to apply the HYDRO-1D model and to gain a good understanding of the modelling procedures Mott MacDonald have undertaken a training programme in their office in Cambridge, UK for the specialist staff from the

Preliminary

Ministry of Water Resources in Iraq. These trainees received a copy of the model and the model user manual at the conclusion of the training.

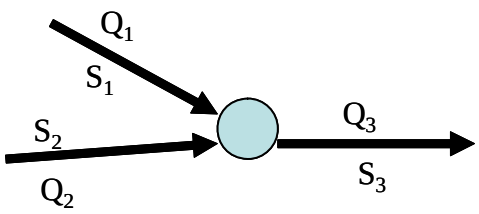
Preliminary

2 CONCEPTUAL MODEL FOR SALINITY

2.1 Conceptual Model for Nodes and Reaches

2.1.1 The methodology used to develop the HEC-ResSim model to simulate the water quality determinands are outlined in the diagrams and equations below. The model conserves the mass at nodes (river confluences, diversion points, etc) and along channel reaches. The particular case of reservoirs is considered in Section 2.2.

2.1.2 Case 1 - Continuity Equation (Nodes)



Mass Balance at Nodes

$Q_3 = Q_1 + Q_2$

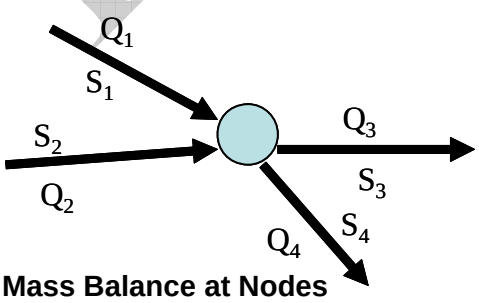
Salt Balance

$S_3 = (Q_1S_1 + Q_2S_2)/Q_3$

Where:

Q_1, Q_2	=	nodal inflows
S_1, S_2	=	salinity corresponding to inflows Q_1 and Q_2 respectively
Q_3	=	outflow
S_3	=	salinity of outflow Q_3

2.1.3 Case 2 - Continuity Equation (Nodes)



Mass Balance at Nodes

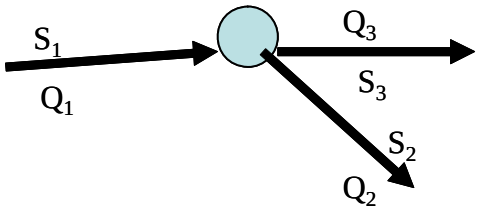
$Q_3 + Q_4 = Q_1 + Q_2$

Preliminary

Salt Balance

$S_3 = S_4 = (Q_1S_1 + Q_2S_2)/(Q_1+Q_2)$

2.1.4 Case 3 - Continuity Equation (Nodes)



Mass Balance at Nodes

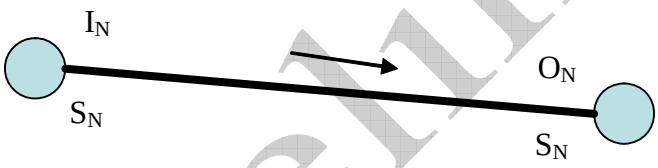
$Q_3 + Q_2 = Q_1$

Salt Balance

$S_3 = S_2 = S_1$

Continuity Equation along a Channel Reach

HEC-ResSim simulates the downstream flow in a channel reach based on a weighted combination of inflows from various time lags at the upstream end of a reach:



$O_N = C_1I_N + C_2I_{N-1} + C_3I_{N-2} + \ldots\ldots\ldots\ldots\ldots\ldots$

Where:

O_N	=	ordinate of outflow hydrograph at time n
I_N, I_{N-1}, etc.	=	ordinates of inflow hydrograph at times n, n-1, etc.
C_1, C_2, etc	=	routing coefficients, as coefficients of inflow

Salt Balance

$S_{ON} = (C_1I_NS_{IN} + C_2I_{N-1}S_{IN-1} + C_3I_{N-21}S_{IN-3} + \ldots\ldots)/O_N$

Where:

S_{ON} = salinity level at time N at the downstream end of a reach

S_{IN}, S_{IN-1}, etc = salinity level at time N, N-1 etc. at the upstream end of a reach

Preliminary

2.2 Reservoirs

2.2.1 HEC-ResSim simulates the outflows from a reservoir as a time series of discharges based on operating rules. The water balance equation is given by:

Rate of change of storage = Inflow – outflow – losses

2.2.2 Estimating the salinity of outflow from a reservoir is a complex procedure. Although the hydraulic and salinity model network has been developed for the Tharthar Reservoir and the model has been tested, the data available is too sparse to derive the model coefficients for this reservoir. Further monitoring of discharges entering the reservoir and releases from the reservoir with their salinity concentration is essential to maximise the benefit of the Tharthar Reservoir model. The data used for the test model and the possible modelling procedure for reservoir simulations are discussed further in Section 3.

2.3 Lag Coefficients for River Networks

2.3.1 The lag coefficients for the flow routing component and the solute transport process in a river system depend on several factors as summarised below.

- Selected duration of time step for the model runs;
- Distance between nodal points (sub-divided reach length of the river);
- Discharge and hydraulic parameters of the river system.

2.3.2 There is a distinct difference between the lag coefficients associated with flows and the transport of contaminants in a river system. The lag coefficients associated with flows are related to the celerity of the flood wave, whereas for the transport of contaminants they are related to the velocity of the fluid particles and the dispersion characteristics. If we simplify the dynamic equation to the diffusive wave the flow equation can be represented by:

$$\frac{\partial Q}{\partial t} + c\frac{\partial Q}{\partial x} - D\frac{\partial^2 Q}{\partial x^2} = 0$$

2.3.3 In the above equation *c* is the celerity of the flood wave which is higher than the velocity of flow. The above equation is valid for the transport of pollutant in a river system and in this case the celerity in the advection equation is replaced by average velocity of the fluid particle and the discharge is replaced by the concentration of contaminant. Salinity is a conservative parameter. For a non conservative determinant an additional term is

Preliminary

introduced in the above equation to incorporate the degradation rate of the contaminant. This means that the lag coefficients for non-conservative determinants will be different to those for conservative determinants.

Preliminary

3 MODELLING APPROACH FOR TEST REACHES FOR SALINITY ANALYSIS

3.1 Introduction

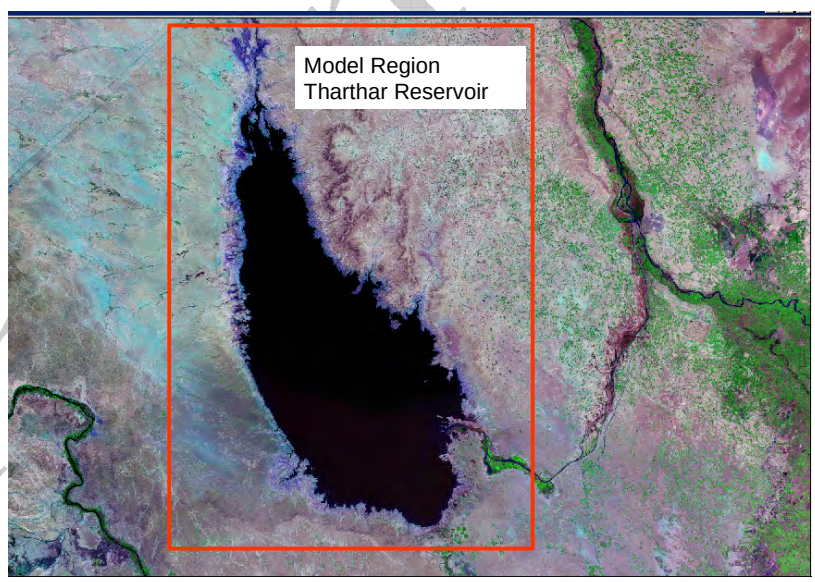
3.1.1 The sample hydraulic and salinity models have been developed using Mott MacDonald's in-house software HYDRO-1D for the following regions:

- Tigris River in the vicinity of Baghdad City;
- Tharthar Reservoir.

3.1.2 Of the above sample studies the former has been used to assess the weighting factors for channel reaches while the latter has been developed to estimate the weighting factors for reservoirs and lakes. The models have been tested using the existing data with estimated values. In order to achieve the maximum benefits of both models future monitoring of flows and salinity concentrations are very important.

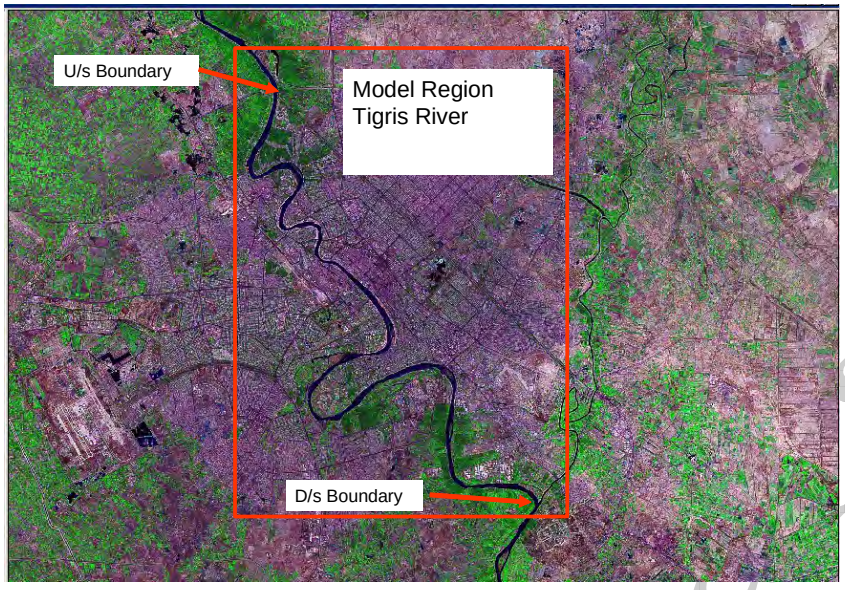
3.1.3 The sample regions are shown in the following figures.

Figure 3.1: Model Region - Tharthar Reservoir



Preliminary

Figure 3.2: Model Region – River Tigris



3.2 Data Available

Topographic Information

3.2.1 To build a one-dimensional hydraulic model of river reaches and lakes it is necessary to have cross section data or bathymetric survey data. At the start of development of the test bed models no cross section data was available so it was necessary to develop the required data from other sources of information.

Flow Data

3.2.2 Flow data sets have been prepared by HEC for inflows to the ResSim model and flows at intermediate points, such as the inflow to Tharthar reservoir from the Tigris, can be extracted after a model run.

Water Quality Data

3.2.3 Hand-written water quality record sheets were received for various gauging sites on the Tigris and the Euphrates. The periods of data covered in the records are shown in the following table. The timestep for the data collection varied between gauging stations and also through each record between monthly data and as frequent as daily data for some periods of record although there are extensive periods of missing data. The lengths of the data sets shown below are for the salinity or conductivity data records although further data series are present at most sites for other water quality parameters.

Preliminary

3.2.4 Perhaps most significantly, although most of the record sheets where referenced to particular gauging sites along the watercourses there is no indication of a location for each of the sites. A grid reference for each gauging station would be very useful for any future work. This would enable the precise location of the observed readings to be used including for example whether the…

Table 3.1: Availability of Water Quality Data Series for River Gauging Stations

River	Location	Period of Record
Tigris	Srai Baghdad	1971-2000
	Amara	1977-2002
	Baghdad	1979-1990
	Mosul	1971-2001
	Samarra Barrage	1974-2001
Shat al Arab	Al Qurna	1971-1990
Euphrates	Al Hindiah Dams	1971-1998
	Al Ramady Dams	1971-2001
	Al Samawah	1973-2002
	Di Qar	1978-2002

3.2.5 Twenty-three other record sheets were available but the gauging locations were not marked clearly on the sheets.

3.2.6 Monthly salinity observed data was used from the records for Baghdad for the test channel reach model. The model was run for 1990 using this available data.

3.3 Model Development for Tharthar Reservoir

3.3.1 Tharthar Reservoir was selected to assess the salinity distribution within for a test reservoir using the HYDRO-1D model. The Tharthar Reservoir is a key component of the water control infrastructure in Iraq and was originally designed to be a natural sink for flood waters from the Tigris. The reservoir is now connected by various drainage channels to both the Tigris and the Euphrates although increased salinity largely due to high evaporation rates is known to be a problem. Inflow from the catchments at the northern end of the reservoir is minimal in comparison to the Tigris drainage channels entering the reservoir at the southern end near the outlet works and the dam. Due to the layout of the inflow and outflow points there is only likely to be active exchange of water in the southern part of the lake. To fully model the system, a three-dimensional model of the reservoir could be developed although this would require detailed bathymetric, hydraulic and water quality survey data. However, in this case, given the approaches adopted for the modelling of the rest of the river network, a one-dimensional model is a valid approximation of the reservoir system.

3.3.2 The model allows for longitudinal variation of salinity level with area averaged salinity across any cross-section. The model covers a length of 60

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Technical Report Series

Municipal Water Supplies

TR 04

August 2006

TR 04 Rev 0

This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of technical reports published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The technical report relates to the provision of water for household, industrial, commercial, institutional and other uses within the towns and villages of Iraq.

Preliminary

Report Issue and Revision Record

Rev	Date	Description
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List of Contents

Page

1 Introduction 1
1.1 Purpose of Document 1
1.2 Format of Document 1
2 Review of Available Data 2
2.1 Population 2
2.2 Existing Municipal Water Supplies 2
2.2.1 Data from the Ministry of Municipalities and Public Works 2
2.2.2 Mini Master Plans 3
2.2.3 New Eden Project 5
2.2.4 Information from the Reconstruction Project in Southern Iraq 6
2.2.5 Analysis of Data 6
2.3 Industrial Water Supplies 8
2.4 Existing Wastewater Collection and Treatment Facilities 8
3 The Demand for Municipal Water and Wastewater Services 10
3.1 Current Levels of Consumption 10
3.2 Current Planning Criteria 10
3.3 Demand Management and its Potential Impacts 11
3.4 Demand Forecasting 12
3.4.1 Approach 12
3.4.2 Per Capita Demands 12
3.4.3 Preliminary Demand Forecasts 13
4 Water Balances 16
5 Investment Planning 19

List of Figures

Figure 4-1: Preliminary Water Balance for Thi Qar Governorate 17
Figure 4-2: Preliminary Water Balance for Erbil Governorate 18

List of Tables

Table 2-1: Planning Criteria for Basrah Demand Forecast 4
Table 2-2: Suggested Long Term Planning Criteria 6
Table 2-3: Summary of Data on Existing Water Supplies 7
Table 2-4: Sewage Treatment Plants in Four Southern Governorates 9
Table 3-1: Provisional Forecasts of Per Capita Demands 13
Table 3-2: Average Daily Water Demands - Preliminary Forecasts for Each Governorate 14
Table 3-3: Peak Daily Water Demands - Preliminary Forecasts for Each Governorate 15

Preliminary

Preliminary

1 Introduction

1.1 Purpose of Document

1.1.1 This document relates to the provision of water for household, industrial, commercial, institutional and other uses within the towns and villages of Iraq. It generally considers potable water supplies, i.e. those treated to a level to make them suitable for human consumption, although only a very small percentage of such water is actually consumed. Consideration is also given to non potable water used for industrial purposes and the non potable piped water supply system in Baghdad, which provides water primarily for garden watering.

1.1.2 In the context of the current project, the studies on potable water supplies are largely limited to assessing the demand for water and establishing abstractions from and returns to the natural water environment.

1.2 Format of Document

1.2.1 The document is structured as follows:

Section 2 Review of data availability

Section 3 Water supply and demand in Iraq

Section 4 Water balances

Section 5 Investment planning *(Not completed)*

Preliminary

2 Review of Available Data

2.1 Population

2.1.1 We have population and housing data from the Ministry of Planning which includes the following:

- Total population for years 1957,1965 and 1970 to 2004
- Population broken down into total urban and total rural for each governorate for 1997 and 2004
- Numbers of housing units and households broken down into urban and rural for 1997
- Numbers of housing units and households for each governorate for 1997.

2.1.2 Historic data indicates a past growth rate of about 3% per annum. Growth appears to have been fairly uniform. This rate of growth is used by the Ministry of Municipalities and Public Works to project future populations. The mini Master Plan for Basrah indicates that the Ministry of Planning projects future populations at a growth rate of 2.25% per annum to 2010 and 2.0% per annum thereafter.

2.2 Existing Municipal Water Supplies

Data from the Ministry of Municipalities and Public Works

2.2.1 The Ministry of Municipalities and Public Works (MMPW) has provided a list of water treatment plants, wells and compact units for 15 governorates. There is no data for the three Kurdish governorates of Dahuk, Erbil and Sulaymaniyah. Data for each facility include location given by coordinates, planned output, actual output and numbers of people served.

2.2.2 We understand that the list is probably far from complete, although it is believed to be the most comprehensive list available. There is a reasonable correlation between the number of water treatment plants in the list and those recorded in specific plans for individual governorates, but the number of compact units (CUs) varies widely. We understand that CUs are put in by various organisations without any real coordination or record keeping

2.2.3 A weakness of the MMPW list is that it does not indicate which town(s) each treatment plant serves, nor the source of water for each works. There are coordinates for the location of each works, but these are unreliable, and in any case the treatment plant does not necessarily serve the area in which it is located, or the source of raw water may be far from the works.

Preliminary

2.2.4 Analysis of per capita consumption (pcc) from data for outputs and people served in the MMPW list shows a very wide range with many anomalous figures, e.g.

- For water treatment plants, the calculated pcc varies from 24 to over 10,000 litres per person per day (lpcd)
- The variation is even more extreme for CUs
- In 8 governorates (over half for which data are supplied) the average pcc is 333 lpcd for all works. The governorates with this figure throughout are Al Anbar, Baghdad, Basrah, Diyala, Maysan, Muthanna, Qadisiyah and Salah al Din. We assume that 333 is a target figure for supply and population served is calculated from measured/estimated works output or actual output is calculated backwards from population served.

Mini Master Plans

2.2.5 Water supply mini master plans have been or are being prepared for the governorates of Basrah, Erbil and Sulaymaniyah and copies have been provided. A wastewater plan has been prepared for Karbala and copy of that has also been provided. Further plans are due to be completed for water supplies to, Najaf, Diwania and Kirkuk.

2.2.6 Despite their name, these plans appear quite comprehensive, although their coverage varies. That for Basrah covers the whole governorate with the focus on the municipality of Basrah, whilst those for Erbil and Sulaymaniyah cover the governorate except for the main towns of Erbil of Sulaymaniyah. The wastewater mini master plan for Karbala is only for the main town.

2.2.7 A very brief outline of the planning criteria used and water requirements for each plan is given below.

(i) Basrah

2.2.8 The basic demand criteria used for Basrah were as shown below.

Preliminary

Table 2-1: Planning Criteria for Basrah Demand Forecast

Location	Level of Service Factors (l/c/d)				
	Domestic	Commercial	Industrial	UfW	Total
Basrah	300	30	30	72	432
Towns with industry	200	30	30	52	312
Towns without industry	200	30		46	276
Rural	200			40	240

2.2.9 There is no indication whether these figures are average or peak daily demands. It is assumed that they are peak figures as they are used to establish capacity requirements.

2.2.10 The population of the governorate is projected to rise from 1,761,000 in 2003 to 3,375,000 in 2025, using a growth rate of 3% per annum in line with that used by MMPW. Applying the above figures for per capita water demands to the projected population gives a present total peak daily water demand of about 650,000 m^3/d rising to 1,167,400 m^3/d by 2025.

2.2.11 The mini master plan examined seven options for meeting this demand and recommended a combination of conventional treatment of water from the River Tigris at Al Quorna and desalination of water from the Shat al Arab in Basrah. It is proposed that normally 40% of the water will come from Al Qorna and 60% from the Shat al Arab. The different supplies will be blended to give a potable supply meeting Iraqi and WHO guidelines.

(ii) Erbil

2.2.12 The population of Erbil is expected to grow from its current level of about 1,600,000 to 2,900,000 by 2025. This is a growth rate of 3% per annum. The urban centres, outside the city of Erbil itself, have a present population of about 250,000 and this is projected to rise to 437,520 by 2025.

2.2.13 The overall per capita demand for people in the district centres is taken to be between 360 and 390 l/d and applying these figures to the population forecast gives a total demand rising to 160,216 m^3/d by 2025. The total demand from sub-district centres is forecast to be 52,861 m^3/d by 2025. No water demand figures are given

Preliminary

for rural areas, although it is noted that about 28% of the total population of the governorate are classified as rural.

2.2.14 Proposals for development of water supplies generally anticipate increases in abstractions from existing local sources, which are a mixture of springs, rivers and groundwater.

(iii) Sulaymaniyah

2.2.15 The population of Sulaymaniyah is expected to grow from its current level of about 1,800,000 to 3,300,000 by 2025. This is a growth rate of 3% per annum. The urban centres, outside the city of Sulaymaniyah itself, have a present population of about 257,000 and this is projected to rise to 464,171 by 2025.

2.2.16 The overall per capita demand for people in the district centres is taken to be 360 l/d and applying this figure to the population forecast gives a total demand rising to 167,101 m^3/d by 2025. The total demand from sub-district centres is forecast to be 521,972 m^3/d by 2025. No water demand figures are given for rural areas, although it is noted that about 20% of the total population of the governorate are classified as rural.

2.2.17 Proposals for development of water supplies generally anticipate various new surface water and groundwater sources. Sources will generally be local to the communities supplied.

New Eden Project

2.2.18 The reports provide data on existing systems and estimates for the development of water and sanitations systems. Although costs are given, there are no projections of water demand or lists of schemes in the main report.

2.2.19 The criteria for water demand assessment are given in the report as follows:

Governorate headquarters	450 lpcd
District capitals	360 lpcd
Rural communities	250 lpcd

2.2.20 These are similar to those used in the mini master plans and were agreed with MMPW. They are assumed to overall peak day demands, including an allowance for unaccounted for water (UfW).

Preliminary

Information from the Reconstruction Project in Southern Iraq

2.2.21 As part of its work on the reconstruction project in Southern Iraq, Mott MacDonald has worked on water sanitation projects in Basrah, Thi Qar, Al Muthanna and Maysan governorates. As part of this work, outline plans were prepared for the development of water and sanitation systems in these four governorates in 2004.

2.2.22 The figures in the table below were used as an initial guideline for assessing water requirements and the adequacy of existing systems.

Table 2-2: Suggested Long Term Planning Criteria

Item	Per capita water demand (l/day)	
	Urban areas with developed internal plumbing systems	Rural areas with limited internal plumbing systems
Household demand	160	120
Non-household demand (industry, commerce, institutions, etc.)	40	20
Total consumption	200	140
Unaccounted for water	67	47
Total water requirement (average day)	267	187
Total water requirement (peak summer day)	335	237

2.2.23 The figures in the above table assume unaccounted for water is 25% of water production, which is a reasonable, but certainly not demanding target. The average per capita household consumption assumes a reasonably careful use of water and is based the normal requirements for household use. The figures used are also similar to figures which Mott MacDonald has recently used for a master plan for Oman. The summer peak assumes a 40% increase in average household demand, reflecting the extremes in temperature, and a 10% increase in non-household demand.

Analysis of Data

2.2.24 The following table summarises the data in the MMPW lists for 15 governorates and provides comparisons with data from other sources.

Preliminary

Table 2-3: Summary of Data on Existing Water Supplies

Governorate	Actual capacity from MMPW list (m3/d)				Population 2004	Capacity per person (l/d)	Capacities from other sources (m3/d)		
	WTP	Well	CU	Total			New Eden	Mini MP	MM 2004
Al Anbar	326,561		96,240	422,801	1,328,776	318			
Babil	71,760		26,256	98,016	1,493,718	66			
Baghdad	235,591		113,460	349,051	6,554,126	407			
Baghdad municipality	2,208,000		113,000	2,321,000					
Basrah	476,206		371,540	847,746	1,797,821	472	850,000	555,600	n/a
Diyala	308,465		65,050	373,515	1,418,455	263			
Karbala	215,270		30,720	245,990	787,072	313			
Al Tamim (Kirkuk)	383,140	7,000	30,840	420,980	854,470	493			
Maysan	56,314		89,640	145,954	762,872	191	271,656		197,000
Al Muthanna	83,138		16,920	100,058	554,994	180			86,000
Najaf	257,300		21,140	278,440	978,400	285			
Ninawah	603,217	22,059	62,068	687,344	2,554,270	269			
Qadisiyah	210,352		39,185	249,537	911,641	274			
Salah al Din	228,930		54,060	282,990	1,119,369	253			
Thi Qar	108,340		116,832	225,172	1,472,405	153	308,000		129,000
Wasit	174,300		52,794	227,094	971,280	234			
Total	5,946,884	29,059	1,299,745	7,275,688	23,559,669	309			

Notes:

1 Population data from Ministry of Planning figures

2 New Eden: new Eden Master plan for Integrated Water resources Management in the Marshlands Area, April 2006

3 Mini MP: Drinking Water Supply Mini Master Plan, CH2M Hill/Parsons, 2005.

4 MM 2004: Data from Mott Macdonald's outline plans for the four southern provinces, 2004.

Preliminary

2.2.25 Although only limited comparisons between different data sources are available, it is clear that there are wide differences in several places where such comparisons are possible. The New Eden Project generally gives significantly higher figures than he MMPW list, whilst the Basrah Mini Master Plan and the Mott MacDonald data from 2004 appear generally to give low figures.

2.2.26 In some cases, the differences may be due to the coverage of the reports e.g. Mott MacDonald's work was focussed only the main towns. Another possible source of error is the number of operating hours assumed each day. The data in the New Project reports is given in m^3/hour, and the figures in the table above assume 24 hours per day operation and make no allowance for outages. We understand, however, that some works operate only in daylight hours.

2.2.27 The data from the MMPW list indicates that average per capita supply capacity is just over 300 lpcd, but varies widely between governorates from a low of 66 lpcd in Babil to a high of 472 in Basrah. The figures suggest that the overall supply capacity in many governorates should be adequate to maintain at least a good basic level of service to most of the population. However, reports suggest that this is rarely the case due to a variety of reasons including inequitable distribution of water, high levels of leakage, frequent loss of supply due to loss of power and reduced operating hours due to security problems.

2.2.28 About 18% of the total capacity is from compact units (CUs). These are prefabricated steel plants with a limited lifespan, perhaps only 10 years. The New Eden Project reports record the condition and performance of the works and many CUs are classified as 'poor' in both respects. It is likely that a major programme of replacement of these plants with more robust conventional plants will be required in the coming years.

2.3 Industrial Water Supplies

2.3.1 A limited amount of information has been received from the Ministry of Industry and Materials. Tabulated data collected describes each industrial water user, the source of the water, the volume used, the volume discharged and a description of the discharge location. There are 107 records, but not all have complete information. Unfortunately the list does not indicate what units are used for measurement of abstractions and discharges, nor the location of the industry, although a separate list gives longitude and latitude references for a few companies. There are several major water consumers with private supplies in the chemical, petroleum, iron & steel, sugar refining and cement industries.

2.4 Existing Wastewater Collection and Treatment Facilities

2.4.1 Data on wastewater systems is only available from other reports. In general, piped sewerage schemes serve district headquarters but are limited in extent and wastewater treatment plants serve only parts of the major towns and often perform

Preliminary

poorly if at all. Many houses have septic tanks but these are often badly maintained and rarely emptied, and much wastewater is discharged to open drains. The situation on sewage treatment in the four southern provinces has been complied from reports on the New Eden Project and from the work of Mott MacDonald in 2004. The situation is summarised in the table below.

Table 2-4: Sewage Treatment Plants in Four Southern Governorates

Governorate/town	Capacity (PE)	Remarks
Basrah		
- Hamdan WWTP, Basrah city	400,000	Poor condition, partial treatment only
- Khur al Zubair	100,000	Not working
Thi Qar		
- Nasariyah	85,000	Not working
- Ali Askan Al Sinaie	10,000	Acceptable
Maysan		
- Amarah	150,000	Acceptable
Al Muthanna		
- Samawah	n/a	Two works dedicated to residential complexes only

2.4.2 We understand the situation in the four southern provinces is not atypical and clearly the collection treatment and disposal of wastewater in an environmentally acceptable way will require massive investment.

Preliminary

3 The Demand for Municipal Water and Wastewater Services

3.1 Current Levels of Consumption

3.1.1 There are few details of water of current water consumption by individuals or households beyond the gross output figures divided by estimates of the population served. As noted above, the calculation of per capita demand from the MMPW list of treatment plants and population served gives widely varying and anomalous results. It provides at best an overall value of the volume of water put into supply per person in the service area. It can not be broken down into water used by different categories of consumer (households, industry, commerce, institutions, etc) and unaccounted for water, which may again be sub-divided into leakage, meter error, legitimate unmetered use and illegal consumption.

3.1.2 Despite the lack of information on water consumption, there are indications that it may be high relative to levels in Europe and other countries where there is an emphasis on conservation of water. For example, in Amarah city the estimated output of the treatment plants, allowing for the normal maximum operating hours, is about 120,000 m^3/d. The population is about 400,000, so the supply amounts to 300 lpcd. This would certainly provide a reasonable level of service is leakage is kept to an acceptable level, there are no exceptionally large non-household demands and the water is equitably distributed. Even in the remaining districts and sub-districts the supply amounts to over 200 lpcd.

3.2 Current Planning Criteria

3.2.1 The key planning criteria adopted by MMPW to assess demand is apparently the figure for household consumption of 300 lpcd for supplies to major cities. To this is added an allowance for non-household use and UfW, as in Table 2-1 for Basrah, to give a gross figure of 432 lpcd for Basrah city. The overall per capita demand figures of 360 to 390 lpcd used for Erbil and Sulaymaniyah district centres, and the figures of 450 lpcd and 360 lpcd used for governorate and district headquarters in the New Eden Project all appear to be broadly consistent with the figure for Basrah. In the Basrah Mini Master Plan, a household consumption of 200 lpcd was used for district towns, giving an overall of 276 to 312 lpcd.

3.2.2 Neither the mini master plans nor the New Eden Project include any allowance for seasonal variations in demand. Because the above figures are used to determine the capacity of water treatment plants required, we assume that they are peak daily demands.

3.2.3 The Basrah figures include an allowance for UfW of only 20% of demand (17% of water production). This is an optimistic assumption and a level that will be difficult to achieve with replacement of much the existing water distribution network.

Preliminary

3.2.4 The build up of the demand forecast for the four southern governorates by Mott MacDonald in 2004 started with lower basic household per capita demands, from a gross average per capita demand figure was calculated and then increased to provide a peak summer demand. The overall demand figure of 335 lpcd for urban areas is broadly similar to the gross figures for district towns in the Basrah Mini Master Plan, but rather less than figures used elsewhere. The MM 2004 demand estimate also uses a figure of 25% of water production for UfW.

3.3 Demand Management and its Potential Impacts

3.3.1 In formulating any demand forecast, it is essential to consider what policy is to be adopted with regard to restraining the growth of demand though various mechanisms. Demand management is important because it ensures an efficient allocation of resources. This is very important where water resources are scarce and there is competition for available supplies, but even where water is abundant, demand management minimises the investments needed in treatment and distribution to meet the demand for potable water thereby freeing financial resources for other priority projects.

3.3.2 The various means of restraining demand are described in the Guidance Note – Demand Management. They may be broadly divided into the following:

3.3.3 Short term measures to cope with droughts or other supply failures:

- Restrictions on use
- Appeals to the public to conserve water.

3.3.4 Long term

- Tariff increases and tariff structures
- Building restrictions
- Education programmes
- Reducing UfW.

3.3.5 We would not expect short term measures to deal with droughts to have a wide relevance in Iraq, although there will undoubtedly be occasions when the unexpected loss of a major treatment plant or other key installation will cause a critical loss of supply for an appreciable period.

3.3.6 The main focus here will be on the long term control of water demand by eliminating wasteful use. The key to demand management is setting an appropriate tariff as without this the message that water is valuable and needs to be conserved will not be readily received.

3.3.7 The impact of demand management varies widely depending on social factors and peoples attitudes to water use. The introduction of metering of individual consumers

Preliminary

and increasing tariffs to the levels needed for full cost recovery can have dramatic impacts where wages are low. It is expected that the imposition of a strict demand management policy, including setting tariffs to recover the full cost of supplies, would have a substantial impact on demand in Iraq.

3.4 Demand Forecasting

Approach

3.4.1 The approach to demand forecasting is given in the Guidance Note – Forecasting Demands for Municipal and Rural Water Supplies. The guidance note presents a simple procedure based on breaking the demand down into the following components:

- Household consumption, including consumption for both in the house and outside for car washing, yard cleaning and garden watering.
- General non-household consumption (Institutions, commercial premises, small and medium industries)
- Major industries with large water demands
- Unaccounted for water (UfW), which includes physical losses from the distribution system, legitimate unmeasured use, illegal consumption and meter error.

3.4.2 The system could be made more sophisticated as more data become available, but at present demand forecasting is likely to be limited by data availability and any forecasts must be regarded as indicative projections that will need to be updated in the future. In fact there is always an element of uncertainty in demand forecasting and the growth in demand always needs to be monitored carefully and forecasts reviewed and improved as necessary.

3.4.3 The Guidance Note also includes assessments of wastewater returns.

Per Capita Demands

3.4.4 Per capita demands have been assessed assuming that a programme of demand management is implemented. The derivation of the figures used is described in the Guidance Note. Household demand, non-household demand and Unaccounted for Water have all been expressed in litres per capita per day (lpcd).

3.4.5 The figures are summarised in the table below.

3.4.6 It is emphasised that these are broad assessments of a reasonable level of demand and need to be re-assessed for individual schemes. They provide a reasonable basis for a preliminary assessment of demands and the investments that will be needed in water supply and wastewater systems.

Preliminary

Table 3-1: Provisional Forecasts of Per Capita Demands

Baghdad		
Category	Average daily demand (lpcd)	Peak daily demand (lpcd)
Households	160	200
Non-households (See Note 1)	80	88
UfW	80	80
Total	320	368
Other towns		
Category	Average daily demand (lpcd)	Peak daily demand (lpcd)
Households	160	200
Non-households (See Note 1)	40	44
UfW	67	67
Total	267	311
Rural communities with piped distribution		
Category	Average daily demand (lpcd)	Peak daily demand (lpcd)
Households	120	150
Non-households (See Note 1)	12	13
UfW	44	44
Total	176	207

Note: 1. Specific large industries and residential institutions to be added separately to the overall allowance

Preliminary

Preliminary Demand Forecasts

3.4.7 Preliminary overall estimates of water demand throughout Iraq are presented Tables 3.2 (average daily demand) and 3.3 (Peak daily demand).

3.4.8 These are based on 3% p.a. increase in population and the overall gross per capita demands above.

Table 3-2: Average Daily Water Demands - Preliminary Forecasts for Each Governorate

Governorate	Average Water Demand (m3/d)														
	2005			2010			2015			2020			2025		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Nineveh	429,104	180,183	609,287	497,449	208,882	706,331	576,680	242,151	818,831	668,530	280,719	949,249	775,009	325,431	1,100,440
Al-Tameem	163,446	47,158	210,605	189,479	54,669	244,149	219,658	63,377	283,035	254,644	73,471	328,115	295,202	85,173	380,376
Diala	162,376	150,103	312,479	188,238	174,011	362,249	218,219	201,727	419,946	252,976	233,856	486,832	293,268	271,104	564,372
Al-Anbar	189,943	115,675	305,617	220,195	134,099	354,294	255,267	155,457	410,724	295,924	180,218	476,142	343,057	208,922	551,979
Baghdad	1,895,679	145,509	2,041,187	2,197,611	168,684	2,366,296	2,547,634	195,551	2,743,185	2,953,406	226,698	3,180,104	3,423,807	262,805	3,686,612
Babylon	194,014	142,892	336,906	224,915	165,651	390,566	260,739	192,035	452,773	302,268	222,621	524,888	350,411	258,078	608,489
Kerbela	141,023	49,721	190,745	163,485	57,641	221,125	189,523	66,821	256,345	219,710	77,464	297,174	254,704	89,802	344,506
Wasit	140,146	83,693	223,839	162,468	97,023	259,491	188,345	112,476	300,821	218,343	130,390	348,734	253,120	151,158	404,278
Salah Al-Deen	139,486	110,974	250,459	161,702	128,649	290,351	187,457	149,139	336,596	217,314	172,893	390,207	251,927	200,431	452,357
Al-Najaf	185,636	54,997	240,634	215,203	63,757	278,960	249,480	73,912	323,392	289,216	85,684	374,899	335,280	99,331	434,611
Al-Qadisiya	130,967	78,932	209,899	151,826	91,504	243,330	176,008	106,078	282,087	204,042	122,974	327,016	236,540	142,560	379,101
Al-Muthanna	67,528	56,096	123,625	78,284	65,031	143,315	90,752	75,389	166,141	105,207	87,396	192,603	121,963	101,316	223,280
Thi-Qar	236,158	111,248	347,406	273,772	128,967	402,739	317,377	149,508	466,884	367,926	173,321	541,247	426,528	200,926	627,454
Maysan	136,837	48,094	184,931	158,632	55,754	214,386	183,898	64,634	248,532	213,188	74,928	288,116	247,143	86,862	334,006
Basrah	389,231	69,337	458,568	451,225	80,381	531,606	523,094	93,183	616,277	606,409	108,025	714,434	702,994	125,231	828,225
Duhouk	95,596	22,593	118,189	110,822	26,191	137,013	128,473	30,363	158,836	148,935	35,199	184,134	172,656	40,805	213,462
Arbil	292,380	59,629	352,009	338,948	69,126	408,075	392,934	80,136	473,070	455,518	92,900	548,418	528,071	107,696	635,767
Sulaimaniya	332,857	91,590	424,447	385,872	106,178	492,050	447,332	123,089	570,421	518,580	142,694	661,274	601,177	165,422	766,598
Total	5,322,406	1,618,424	6,940,830	6,170,128	1,876,197	8,046,325	7,152,869	2,175,026	9,327,896	8,292,136	2,521,452	10,813,588	9,612,858	2,923,054	12,535,912

Preliminary

Table 3-3: Peak Daily Water Demands - Preliminary Forecasts for Each Governorate

Governorate	Peak Day Water Demand (m3/d)														
	2005			2010			2015			2020			2025		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Nineveh	499,818	211,920	711,737	579,426	245,673	825,099	671,713	284,803	956,516	778,700	330,164	1,108,864	902,726	382,751	1,285,477
Al-Tameem	190,381	55,465	245,846	220,704	64,299	285,003	255,857	74,540	330,397	296,608	86,412	383,020	343,850	100,175	444,025
Diala	189,134	176,542	365,676	219,258	204,661	423,919	254,180	237,258	491,438	294,665	275,047	569,712	341,597	318,855	660,452
Al-Anbar	221,244	136,050	357,293	256,482	157,719	414,201	297,333	182,839	480,173	344,691	211,961	556,652	399,591	245,721	645,312
Baghdad	2,180,031	171,138	2,351,169	2,527,253	198,396	2,725,649	2,929,779	229,995	3,159,774	3,396,417	266,627	3,663,044	3,937,378	309,094	4,246,472
Babylon	225,986	168,060	394,047	261,980	194,828	456,808	303,707	225,859	529,566	352,079	261,832	613,912	408,157	303,535	711,692
Kerbela	164,263	58,479	222,742	190,426	67,793	258,219	220,756	78,591	299,347	255,916	91,108	347,025	296,677	105,620	402,297
Wasit	163,241	98,434	261,675	189,242	114,112	303,353	219,383	132,287	351,670	254,325	153,357	407,682	294,832	177,783	472,615
Salah Al-Deen	162,472	130,520	292,992	188,350	151,309	339,658	218,349	175,408	393,757	253,126	203,346	456,472	293,443	235,734	529,176
Al-Najaf	216,228	64,684	280,912	250,668	74,987	325,655	290,593	86,930	377,523	336,876	100,776	437,652	390,532	116,827	507,359
Al-Qadisiya	152,549	92,835	245,384	176,846	107,621	284,468	205,013	124,763	329,776	237,667	144,634	382,301	275,521	167,670	443,191
Al-Muthanna	78,656	65,977	144,633	91,184	76,485	167,670	105,708	88,668	194,375	122,544	102,790	225,334	142,062	119,162	261,224
Thi-Qar	275,075	130,843	405,918	318,888	151,683	470,570	369,678	175,842	545,520	428,558	203,849	632,407	496,817	236,316	733,133
Maysan	159,387	56,565	215,952	184,773	65,574	250,347	214,203	76,018	290,221	248,320	88,126	336,446	287,871	102,162	390,033
Basrah	453,374	81,550	534,924	525,585	94,539	620,124	609,297	109,596	718,893	706,342	127,052	833,394	818,844	147,288	966,132
Duhouk	111,349	26,572	137,922	129,084	30,805	159,889	149,644	35,711	185,355	173,479	41,399	214,877	201,109	47,993	249,102
Arbil	340,562	70,132	410,694	394,805	81,302	476,107	457,687	94,251	551,938	530,585	109,263	639,848	615,094	126,665	741,759
Sulaimaniya	387,710	107,722	495,432	449,462	124,880	574,342	521,050	144,770	665,819	604,039	167,828	771,867	700,247	194,558	894,805
Total	6,171,462	1,903,487	8,074,950	7,154,416	2,206,663	9,361,080	8,293,929	2,558,128	10,852,057	9,614,937	2,965,571	12,580,508	11,146,347	3,437,910	14,584,257

Preliminary

4 Water Balances

4.1.1 An assessment of water demands and the methods of disposal of wastewater enables a water balance for the potable and industrial water supplies for each district to be prepared. This water balance will show transfers from one part of the river system to another and also movements between surface water and groundwater. An example for Thi Qar governorate is given in Figure 4-1.

4.1.2 In the diagram for Thi Qar, water for the towns is known to come mostly from the major rivers. Assumptions have had to be made about the sources of water for rural areas, in particular the volume taken from groundwater and from canals.

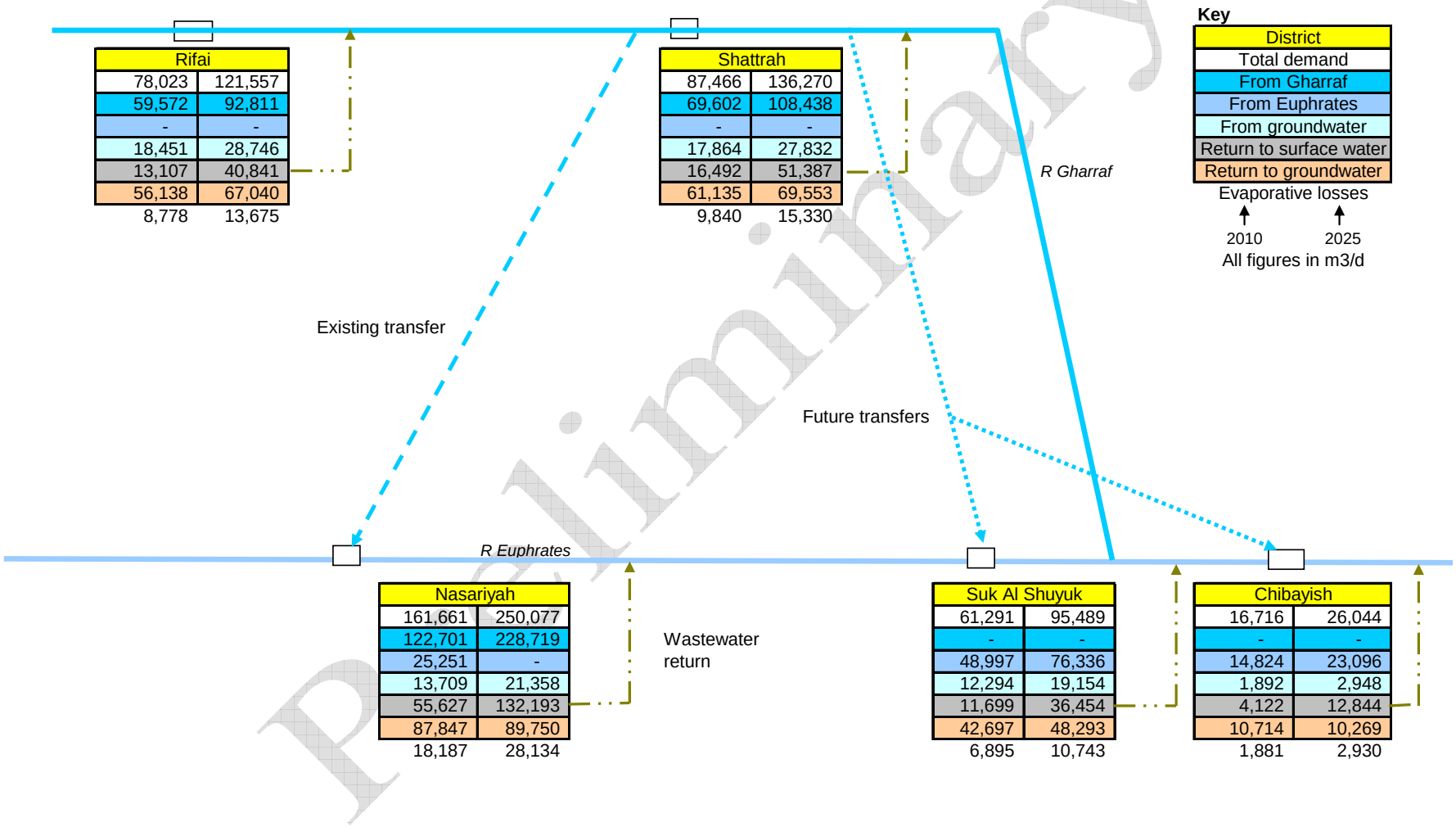
4.1.3 Water for Nasariyah is transferred from the Gharaff River, which has relatively good quality water, but the wastewater is returned to the Euphrates or to groundwater from septic tank soakaways. Assumptions have been made about the number of people and institutions disposing of wastewater either to the sewerage system, open drains or septic tanks with soakaways. The sewerage system and the open drains are assumed to deliver wastewater to the river.

4.1.4 For other towns, it is assumed that more water will be transferred from the Gharaff River in the future, but wastewater will be returned after treatment to the River Euphrates.

4.1.5 A similar diagram for Erbil Governorate is given in Figure 4-2. Data on the water demands and wastewater generation for Erbil city were not available and are omitted from the diagram.

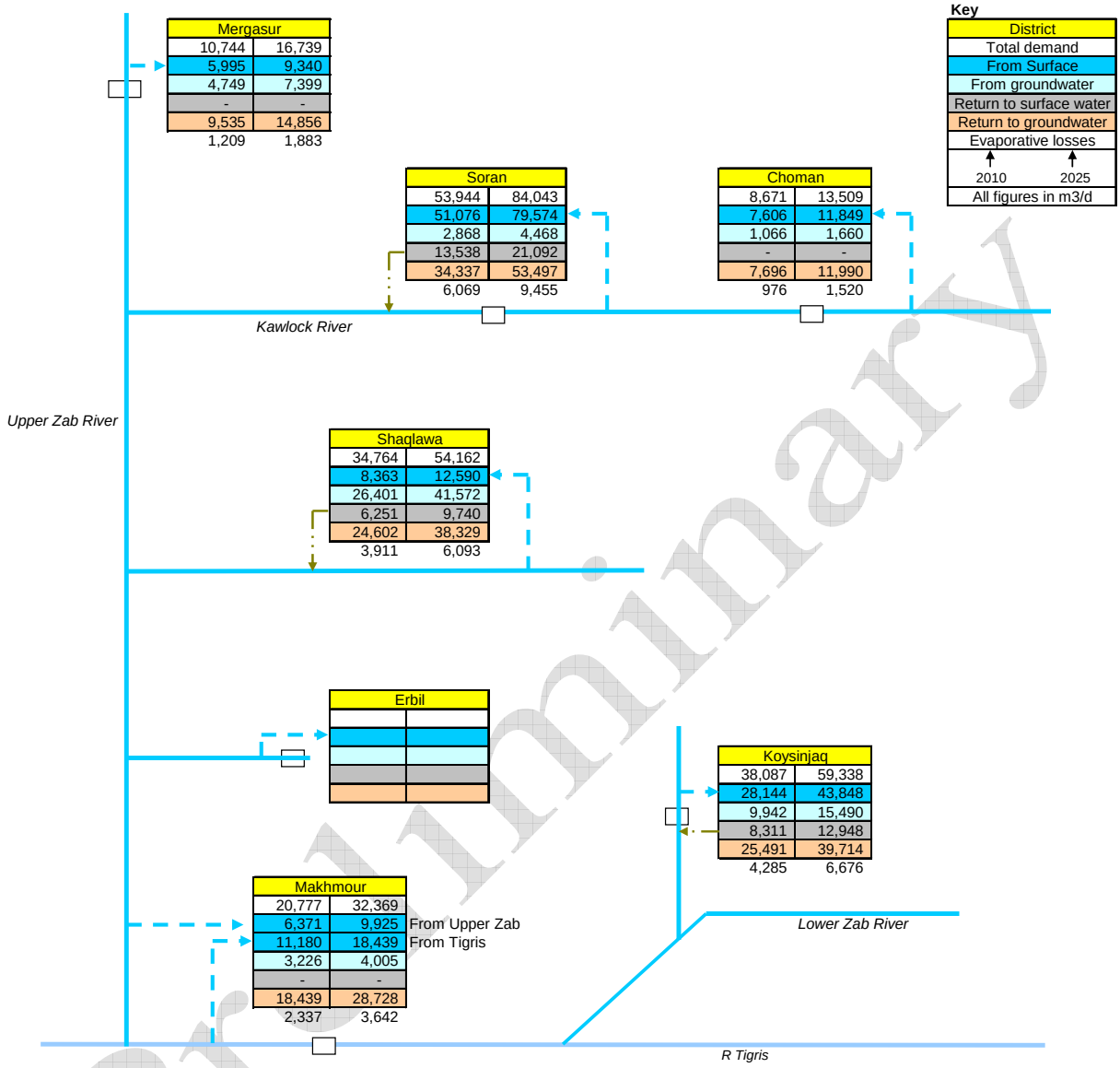
Preliminary

Figure 4-1: Preliminary Water Balance for Thi Qar Governorate



Preliminary

Figure 4-2: Preliminary Water Balance for Erbil Governorate



Preliminary

5 Investment Planning

5.1.1 The provision of an investment plan for potable water supplies is beyond the scope of this study. However, it is intended in this section to provide an overall view on the following:

- The capacity of water sources and water treatment works required in comparison with existing works. This would include conventional works and compact units.
- The additional resource capacity required to 2025, with indications of probable source (surface water, groundwater, seawater desalination).
- New treatment capacity, including replacement of compact units.
- Indicative extent of new distribution networks and numbers of additional consumer connections.
- The requirements for leakage control.
- Indicative extent of new sewerage systems and numbers of additional consumer connections.

5.1.2 The extent of works required will be determined on the basis of the demand forecasts in Section 3 above.

5.1.3 An outline of the approach to determining the investments needed was to be included in a brief guidance note.

5.1.4 This section and the associated Guidance Note have not been written.

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Forecasting Demand for Municipal and Rural Water Supplies and Wastewater Services

GN 06

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GN 06 Rev 0

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This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note presents guidelines for forecasting the demand for municipal and rural potable water supplies, and also for wastewater services.

Preliminary

Report Issue and Revision Record

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List of Contents

Page

1 Introduction 1

2 Components of Demand 2

3 Forecasting Demand 3

3.1 Household Consumption 3

3.2 Non-household Consumption 5

3.3 Unaccounted for Water 6

3.4 Summary of Provisional Estimates of Per Capita Demand 7

4 Wastewater Flows 9

4.1 Options for Wastewater Treatment and Disposal 9

4.2 Estimation of Sewage Flows 10

5 Example of Demand Calculation 13

List of Figures

Figure 4-1 : Wastewater Treatment and Disposal Options..... 10

List of Tables

Table 3-1 : Provisional Forecasts of Per Capita Demands 8
Table 4-1 : Preliminary Calculation of Per Capita Wastewater Flows..... 11
Table 5-1 : Example of Forecast of Water Demand and Wastewater Generation..... 14

Preliminary

Preliminary

1 INTRODUCTION

1.1.1 The Guidance Note presents guidelines for forecasting the demand for municipal and rural potable water supplies, and also for wastewater services. A realistic demand forecast is the essential first step in planning investments in water and wastewater facilities. Demand forecasts may be required over any time period for specific purposes but are usually required for 20 to 30 years for strategic planning purposes.

1.1.2 The present approach to demand forecasting in Iraq at present is very basic. Sometimes it appears to be little more than applying a single overall per capita demand figure combined with a rough estimate of future population. To some extent, further sophistication of the demand forecasting methodology is restricted by the availability of data, but there are some improvements that can be made now and a more complex approach will encourage planners to think in more detail about demand and also collect better data to improve assessments in the future.

1.1.3 **In this note, the approach to forecasting demand is described for each component, essentially household consumption, non-household consumption and unaccounted for water (UfW). The forecast needs to calculate the average daily demand over the year and also the peak seasonal daily demand**.

1.1.4 The average daily demand is used for assessment of revenues from water sales and the costs of production. It is also an important figure in the assessment of water resources, especially where groundwater sources are used as aquifers will generally provide adequate storage to meet seasonal peaks.

1.1.5 The peak daily demand figure is the basis for sizing abstraction, treatment and water transmission works.

1.1.6 The approach to demand forecasting presented here, and particularly any indicative levels for consumption for the various components of demand, assume the implementation of a Demand Management Policy, incorporating the actions described in the related Guidance Note – Demand Management for Municipal Water Supplies.

Preliminary

2 COMPONENTS OF DEMAND

2.1.1 Demand forecasts are usually built up by the following components:

- Household consumption
- Non-household consumption, which may be subdivided broadly as follows if data on different categories of consumer are readily available from the billing system:
  - Industry
  - Commerce (Offices, shops, etc.)
  - Institutions (Government bodies, schools, hospitals and religious institutions, etc.)
- Unaccounted for water, which may be subdivided as follows:
  - Physical losses from leakage in the distribution system and the service pipe to the customers' property.
  - Unregistered consumption through illegal connections and bypasses to consumer meters.
  - Connections that are not recorded and billed due to deficiencies in the water authority's billing system.
  - Under registration by consumer meters.
  - Legitimate unbilled consumption for fire fighting, mains flushing, etc.

2.1.2 The components and sub-components may be varied depending on the classification used in the billing system and may include special items related to a particular place.

Preliminary

3 FORECASTING DEMAND

3.1 Household Consumption

General Approach

3.1.1 Household demand is normally estimated as population served multiplied by per capita demand. Population forecasts may be based on Government official forecasts, but these may have to be extrapolated up to the water services planning horizon, which is often 20 or 25 years in the future.

3.1.2 Per capita demand may be estimated in several ways:

- From recent consumption data, extrapolating from past trends.
- An assessment from data from similar countries and regions. Data from different regions could be used to assess demands from different social groups, and under different demand management policies.
- A build up from analysis of the micro component data (drinking, cooking, bathing, clothes washing, toilet flushing, etc.). This can lead to different demands for different types of housing, sizes of households, etc. It requires detailed metering, logging and analysis of the data to determine useful factors that can be built into a regional demand forecast.

3.1.3 Per capita demand could also differentiate between metered and unmetered customers.

3.1.4 The immediate problem for Iraq is likely to the availability of reliable data on which to base an assessment of the current unrestrained consumption for different categories of customers. Only a minority of households have supplies through a working meter and the measurement of water entering the distribution system is also generally unreliable or non-existent. Under these circumstances, a basic approach is required at this stage, which may be developed further at a later date when more data become available.

Existing Consumption

3.1.5 Existing consumption is often constrained by supply and much of the data available on water consumption and population is clearly unreliable. The list of treatment works from the Ministry of Municipalities and Public Works gives actual outputs and population served, but the calculation of the per capita demand gives widely varying and, in many cases, clearly anomalous figures.

3.1.6 In areas with substantial capacity, per capita demand appears high. For example, the Basrah Mini Master Plan lists treatment plants in the governorate with a total

Preliminary

design capacity of 695,000 m^3/d for a total population of about 1.8 million. Therefore the capacity is equivalent to over 380 lpcd. it is impossible to say what proportion of this is household consumption because losses are unknown and probably high. However, it is a large overall figure, especially because it includes all the rural population.

3.1.7 The MMPW uses a figure of 450 lpcd for the overall demand in major cities. Other plans use high figures for household demand e.g. the Basrah Mini Master Plan uses 300 lpcd in Basrah and 200 lpcd elsewhere, including rural areas. For Basrah city, the per capita household demand translates into an overall figure of 432 lpcd including UfW equivalent to 20% of consumption. Other plans use similar figures for overall demand e.g. The New Eden Project uses 450 lpcd for governorate capitals and 360 lpcd for district capitals, and the mini master plans for Erbil and Sulamaniyah also use 360 lpcd for district capitals.

3.1.8 The mini master plans, the New Eden Project and MMPW all use a single figure for demand. There is no reference to seasonal variations and no data on such variations, although we would expect demand to be substantially higher in the hot summer months.

Future Demands

3.1.9 We believe that the **there should be an active demand management policy in Iraq** as outlined in the Guidance Note – Demand Management for Municipal Water Supplies. This should include raising tariffs to recover as much as possible of the total cost of supplying water, within the limits of people's affordability. We believe this will constrain winter demands to the levels in Europe and Muscat (See Guidance Note on Demand Management), whilst there may be an increase in the hot summer months. On this basis, we would expect the demand in winter to be about 130 to 140 lpcd, increasing in the summer by, say, 25 lpcd to allow for extra washing and bathing. In addition, in the main towns it is necessary to allow for the use of air coolers in the summer. From discussions with Iraqi visitors, we understand that water consumption by air coolers amounts to between 25 and 50 lpcd and 90% of homes in Baghdad would use them. From this we assume that the household consumption in the main towns may be estimated as follows:

- Winter consumption, 6 months at 135 lpcd
- Summer consumption, 6 months at 160 lpcd (excluding air coolers)
- Additional use for air coolers, 4 months at 40 lpcd.

3.1.10 This gives an average annual consumption of about 160 lpcd, with a summer peak of 200 lpcd.

3.1.11 For rural areas we would expect there to be less internal plumbing in the houses and much less use of air coolers in the summer. We believe that it would be reasonable to assume:

- Winter consumption, 6 months at 100 lpcd

Preliminary

- Summer consumption, 6 months at 125 lpcd (excluding air coolers)
- Additional use for air coolers, 4 months at 20 lpcd.

3.1.12 This gives an average annual consumption of about 120 lpcd, with a summer peak of 150 lpcd.

3.1.13 Clearly these are preliminary estimates based mainly on international experience and hearsay evidence. However, we believe that they are reasonable figures to be used as a starting point. **They may be viewed as preliminary figures, which should be refined by those responsible for planning water supply systems in Iraq as more data on actual consumption is collected**.

3.1.14 One aspect that is not included in the above is garden watering. We understand that in Baghdad there is a separate non-potable water supply network that distributes untreated water, primarily for garden watering. In general, the use of potable water for irrigation of any form is to be discouraged, although some garden watering is to be expected, and can be a very efficient means of irrigation as it will usually provide only the water required and often be used for high valuable vegetable crops. In Baghdad the garden watering network should be considered separately. Elsewhere, it may be necessary to add in an allowance for garden watering for part of the year. This will increase the peak demands.

3.2 Non-household Consumption

3.2.1 Non-household consumption can only be assessed from billing records for metered supplies. Unfortunately, only a minority of connections presently appear to be metered. Data from Baghdad municipality indicates that only 21% of industrial and commercial connections are metered and no connections to government offices and institutions are metered. For medium sized non-industrial towns, non-household consumption might be taken as about 25% of household consumption as a first estimate. For small towns and villages, non-household demand is usually low, unless there is a single major industrial or institutional water user based there and which is disproportionate in size to the resident population. In Baghdad non-households account for about 35% of the total number of connections, many of which would be expected to have a much higher consumption than the average household. This would suggest that non-household demand is at least 50% of household demand in Baghdad. However, the figures may be misleading. Firstly, there is an average of about 16 persons per household connection, suggesting that some connections serve several households, presumably single connections to a block of flats. There are many government connections, which suggests that some may be to government housing, that is they are in effect household connections although categorised as non-household. The demand from any connections to residential buildings should be included in the calculation for household demand.

3.2.2 A further complication is the presence of major residential institutions such as military camps and hostels for students, etc. If the people living in these institutions are included in the census, there is a danger of double counting them – both as household demand and non-household. If they are in the census population, and

Preliminary

therefore included in the population for the purpose of estimating household water demands, they should be excluded from projections of non-household demand.

3.2.3 Major industries will often have their own separate private water supply, but any large water users that take water from the public supply, say using more than 0.5% of the total water supply, should be included separately and in addition to any overall allowance for non-household consumption.

3.2.4 As a first estimate of non-household demand we propose that it should be taken as a percentage of household demand, but varied according to the type of town and with special allowances for major industries and large residential institutions, where people are not included in the population for the purposes of estimating household demand. Preliminary proposals for estimating non-household demand are:

Baghdad	50% of household demand plus identified major consumers
Other towns	25% of household demand plus identified major consumers
Rural areas	10% of household demand plus identified major consumers

3.2.5 There is an urgent need to reassess non-household demand and this requires metering of all non-household connections. There should also be clarity on the rules concerning the gathering of census data, in particular whether people in residential institutions are included.

3.2.6 Peak seasonal demand factors are usually less for non-household than household supplies. Where there is no data to allow an assessment of peak factors in a particular town, it is suggested that the peak summer demand be taken as 110% of the average demand.

3.3 Unaccounted for Water

3.3.1 Unaccounted for water (UfW) is the difference between the volume of water put into the distribution system and that which is charged for. UfW comprises:

3.3.2 Physical losses from leakage in the distribution system and the pipework taking the supply into the customer's house.

- Commercial losses, which comprise:
  - Unregistered consumption through illegal connections and bypasses to consumer meters
  - Connections that are not recorded and billed due to deficiencies in the water authorities billing system
  - Under registration by consumer meters
  - Legitimate unbilled consumption for fire fighting, mains flushing, etc.

Preliminary

3.3.3 Further details of UfW and how to control it are given in the Guidance Note – Demand Management for Municipal Water Supplies.

3.3.4 Existing levels of unaccounted for water are unknown because of the lack production meters and consumer meters. It is believed that losses are large because much of the distribution pipe is in poor condition and in many places has been damaged in recent conflicts.

3.3.5 A priority, wherever the security situation allows, should be the control of leakage from the system and reduction of UfW. An appropriate target figure for UfW is 25% of water distributed. This is not a demanding target, and could be set lower in the future.

3.3.6 The first requirement will be the installation of production meters on all treatment plants and metering of all non-household consumers. Household consumers should also be metered as soon as is practicable. This will allow an assessment of the overall level of UfW. This will be followed by the establishment of District Meter Areas (DMAs), monitoring of night flows, leak detection and repair programmes and other actions necessary to minimise UfW.

3.3.7 In the absence of any reliable data, it is proposed that UfW should be provisionally assessed at 40% of production at present reducing to 25% by say 2015.

3.3.8 Whilst the measurement of UfW as a percentage of water production is still the commonest form of presenting the figure, it is generally not considered the best means of comparing rates. Water companies are now tending to present UfW in terms of litres per connection per day or cubic metres per kilometre of distribution main per day. A standard measured in these terms reflects the fact that most leakage occurs at consumer connections and on the customer's supply pipe, and then from joints in the distribution pipework. It is recommended that water authorities in Iraq adopt such standards when data is available. A suitable target figure would be 150 litres per connection per day or 12 m^3 per kilometre of distribution main per day.

3.4 Summary of Provisional Estimates of Per Capita Demand

3.4.1 Provisional proposals for per capita demands to be used in developing future demand forecasts are presented in the table below.

Preliminary

Table 3-1 : Provisional Forecasts of Per Capita Demands

Baghdad

Category	Average daily demand (lpcd)	Peak daily demand (lpcd)
Households	160	200
Non-households (See Note 1)	80	88
UfW	80	80
Total	320	368

Other towns

Category	Average daily demand (lpcd)	Peak daily demand (lpcd)
Households	160	200
Non-households (See Note 1)	40	44
UfW	67	67
Total	267	311

Rural communities with piped distribution

Category	Average daily demand (lpcd)	Peak daily demand (lpcd)
Households	120	150
Non-households (See Note 1)	12	13
UfW	44	44
Total	176	207

Note: 1. Specific large industries and residential institutions to be added separately to the overall allowance

3.4.2 No allowance is made for changes in per capita consumption over time. It is expected to reduce towards the levels in the above table as demand management measures, including customer metering and tariff increases, are implemented.

3.4.3 **These are only provisional figures and it is important that each water service provider develops its own demand forecast based on actual data, which will require the installation of new meters on many treatment works and extension of consumer metering**

Preliminary

4 WASTEWATER FLOWS

4.1 Options for Wastewater Treatment and Disposal

4.1.1 Wastewater is normally either delivered to the public sewer or treated on site. For households without a connection to the sewer, wastewater is likely to be discharged to a septic tank and the overflow passes to a soakaway and thence to the groundwater table. In some areas the overflow may be delivered to surface drains, although since the overflow still has considerable oxygen demand this is not an environmentally satisfactory solution and may lead to unpleasant odours and transmission of disease. In Iraq at the present time it is clear that much wastewater is discharged to open drains, with a consequential impact on the environment. Septic tanks, provided they are well designed, should operate for a few years before the sludge builds up to a point where it needs to be removed. Industries and large institutions may have their own treatment plants and discharge treated wastewater to the river.

4.1.2 In assessing wastewater flows, it is first of all necessary to understand the treatment and disposal options available and assess:

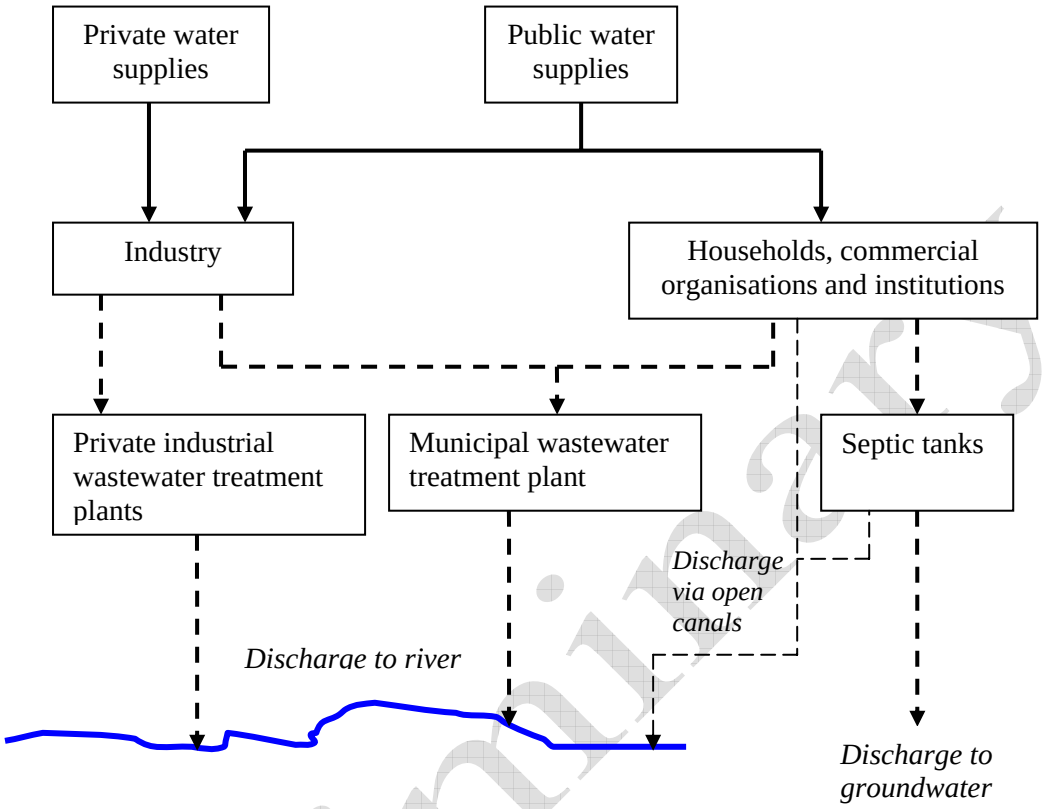
- The number of household, commercial and institutional customers discharging wastewater to the sewerage system
- The number of household, commercial and institutional customers discharging wastewater to septic tanks
- Industries with connections to the public water supply which also discharge their wastewater to the public sewers
- Industries with connections to the public water supply which treat and discharge their wastewater to the environment
- Industries with private water supplies but which discharge their wastewater to the public sewers.

4.1.3 The above options for wastewater treatment and disposal are shown diagrammatically in Figure 4-1.

4.1.4 Septic tanks offer the most economic method of treatment and disposal of wastewater for small towns and villages where the density of population is reasonably low, the water table is more than five metres below the surface and the underlying strata is permeable. In much of Iraq the water table is high and the long term aim is likely to be the installation of piped sewerage systems in most towns. However, at present very few towns have an extensive sewer network, and even fewer have an adequately sized fully operational sewage treatment plant.

Preliminary

Figure 4-1 : Wastewater Treatment and Disposal Options



4.2 Estimation of Sewage Flows

Household Wastewater

4.2.1 Sewage flows are estimated as a percentage of water consumption. The wastewater discharged to sewers or septic tanks from households is usually about 80% to 90% of water supplied, the remainder being lost to evaporation from house cleaning, yard cleaning, plant watering, etc. In calculating wastewater generation in Iraq, it will be necessary to exclude the water consumption by air coolers and any major garden watering from overall water use as these may be substantial volumes of water supplied which are not returned to the sewer.

4.2.2 A preliminary assessment of the wastewater volumes likely to be generated in urban and rural areas is presented in Table 4-1. In the table the returns to wastewater are assumed to be 90% of water supplied in winter and 85% in summer, allowing for small scale garden and house plant watering and generally higher evaporative losses. The table includes the water used for air coolers, but no large scale garden watering, which would not contribute to wastewater flows.

Preliminary

4.2.3 Household wastewater generation is estimated to be an average of 129 lpcd in urban areas and 116 lpcd in rural areas. Peak flows are estimated to be 136 lpcd in urban areas and 123 lpcd in rural areas. As with water demands, these figures are preliminary estimates and need to be reviewed when better data is available.

Table 4-1 : Preliminary Calculation of Per Capita Wastewater Flows

Location/consumption category	Average demand lpcd	Waste-water %	Waste-water lpcd
Urban areas			
Household use winter (6 months)	135	90%	122
Household use summer	160	85%	136
Air coolers (4 months)	40	0%	-
Average water use/wastewater return	161	80%	129
Rural Areas			
Household use winter (6 months)	120	90%	108
Household use summer	145	85%	123
Air coolers (4 months)	20	0%	-
Average water use/wastewater return	139	83%	116

Non- household Wastewater Flows

4.2.4 Non-household wastewater flows will be about 90% of water supplied for commercial and institutional customers. Industrial wastewater will depend on the nature of the industry and large firms must be considered individually. The volume discharged to public sewers and the environment will depend on whether it treats all or part of its own wastewater. In calculating the requirements for sewerage and sewage treatment, it is also necessary to allow for industries that have their own water supply, but return wastewater to the public sewers.

Calculation of Wastewater Flows to Treatment Plants

4.2.5 The sewage flows to wastewater treatment plants in urban areas will be calculated as follows:

Average daily flow $= (P \times N_p \times 129)/1000 + C \times Nc + I_a$

Peak summer flow $= (P \times N_p \times 136)/1000 + C \times 1.1 \times Nc + I_p$

Where the flows are in m^3/d and:

P = Total population

N_p = Percentage of total population connected to the sewer network

C = Average consumption by commercial, institutional and small industrial customers in m^3/d

N_c = Percentage of commercial, institutional and small industrial customers connected to the sewer network in m^3/d

I_a = Average discharge from major industries in m^3/d

I_a = Peak summer discharges from major industries in m^3/d

Preliminary

4.2.6 In addition to the above sewage flows it will be necessary to add:

- Infiltration to sewers from the groundwater. In areas where the groundwater table is high infiltration is often substantial, especially if sewers are old and/or in poor condition. In these circumstances infiltration may be as much as 50% of the total flow in the sewers. The volume of infiltration can only be determined by measurement of flows.
- Stormwater flows. Even where there are separate foul sewers and stormwater drains some rain water will enter the foul sewers from roof drainage, via open manholes, etc. This can only be determined by measurement of flows in the field.

4.2.7 Whilst infiltration and stormwater flows are very important factors in the design of the sewer system and treatment plants, from the point of water resources they only have a small localised impact on run off to rivers and the transfers between groundwater and surface water.

Preliminary

5 EXAMPLE OF DEMAND CALCULATION

5.1.1 An example of a calculation of water demands and volumes of wastewater generated is presented in the table below. This is only included as an example and will need to be modified for actual data and adapted to different locations. The table has been developed using the criteria presented above. An overall figure of 85% of water consumption has been used to estimate returns to sewers.

Preliminary

Table 5-1 : Example of Forecast of Water Demand and Wastewater Generation

District: Nasariyah

		Year				
		2005	2010	2015	2020	2025
Population (See Note 1)						
Urban	Nr	423,897	491,413	569,683	660,418	765,606
Rural	Nr	134,378	155,781	180,593	209,356	242,701
Population served as % total						
Urban	%	90%	100%	100%	100%	100%
Rural	%	0%	100%	100%	100%	100%
Average per capita water demands						
Urban	(lpcd)	160	160	160	160	160
Rural	(lpcd)	120	120	120	120	120
Unaccounted for water	%	40%	25%	25%	25%	25%
Average daily water demand						
Urban households	m3/d	61,041	78,626	91,149	105,667	122,497
Rural households	m3/d	-	18,694	21,671	25,123	29,124
Non-household (Note 2)	m3/d	12,860	20,372	23,999	28,204	33,078
Major industry	m3/d	2,400	2,400	2,400	2,400	2,400
UfW	m3/d	50,868	40,031	46,407	53,798	62,366
Total average day	**m3/d**	**127,169**	**160,123**	**185,626**	**215,191**	**249,466**
Peak daily water demand						
Urban households	m3/d	76,302	98,283	113,937	132,084	153,121
Rural households	m3/d	-	25,704	29,798	34,544	40,046
Non-household (Note 2)	m3/d	14,146	22,409	26,399	31,024	36,386
Major industry	m3/d	2,400	2,400	2,400	2,400	2,400
UfW	m3/d	50,868	40,031	46,407	53,798	62,366
Total average day	**m3/d**	**143,716**	**188,827**	**218,940**	**253,850**	**294,319**
Flows to WWTP						
Population connected						
Urban	%	25%	35%	50%	75%	100%
Rural	%	0%	0%	0%	0%	0%
Non households connection						
Urban	%	25%	50%	80%	100%	100%
Rural	%	0%	0%	0%	0%	0%
Average sewage flow to WWTP						
Urban households	m3/d	12,971	23,391	38,738	67,363	104,122
Rural households	m3/d	-	-	-	-	-
Urban non-household	m3/d	2,733	7,334	13,863	20,414	23,991
Rural non-households	m3/d	-	-	-	-	-
Industry	m3/d	2,040	2,040	2,040	2,040	2,040
Total sewage flow	**m3/d**	**17,744**	**32,765**	**54,642**	**89,817**	**130,153**
Infiltration	m3/d	Determine from field measurements				
Total average DWF	**m3/d**	**= sewage flow + infiltration**				

1 Population assumes growth rate of 3% per annum

2 Non-household demand assumed to be 25% of household in urban areas, 15% in rural areas

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Demand Management for Municipal Supplies

GN 07

August 2006

GN 07 Rev 0

This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note presents guidelines for managing the demand for municipal and rural potable water supplies.

Preliminary

Report Issue and Revision Record

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Contents

1 Introduction 1

2 Methods of Managing Demand 2

2.1 Tariff Increases 2

2.2 Building Regulations and Restrictions on Water Using Devices in the Home 3

2.3 Education and Public Campaigns 3

2.4 Restrictions on Use 4

2.5 Reducing Unaccounted for Water 4

3 Potential Impacts of Demand Management 6

3.1 International Experience 6

3.2 Likely Impacts in Iraq 7

Appendix A Approach to NRW Control A-1

List of Figures

Figure 3-1 : Household Water Consumption in Selected Locations 6
Figure A-1 : Diagrammatic Representation of UFW and NRW A-2
Figure A-2 : Pressure Management – Leakage Index A-5

List of Tables

Table A-1 : Indicative Costs of DMAs and Leak Detection Teams..... A-8

Preliminary

Preliminary

1 INTRODUCTION

1.1.1 The Guidance Note presents guidelines for managing the demand for municipal and rural potable water supplies. Although it may be seen merely as an attempt to persuade people to use less water, the wider aims of demand management are to:

- Prevent wasteful use of water, limiting consumption and hence minimising investments needs;
- Ensure an equitable distribution of potable water supplies to all customers;
- Ensure water supply systems are sustainable, providing customers with the level of service they want at a price they can afford while covering the total costs of providing water.
- Ensure an efficient and equitable distribution of available water resources between municipal water supplies, industry, agriculture and the environment.

1.1.2 This Guidance Note focuses on long term demand management, to limit the growth of demand in the long term in order to minimise investment. It can, however, also be applied to overcome short term problems caused by droughts or loss of supply capacity.

Preliminary

2 METHODS OF MANAGING DEMAND

2.1 Tariff Increases

2.1.1 Raising the marginal tariffs to the level of the marginal cost of supply is the theoretical level required to achieve efficiency in the allocation of resources. There is considerable evidence from around the world that heavily subsidised water supplies lead to excessive and wasteful consumption by those who have access to water and shortages for people at high points or at the end of the distribution network, as investment in new resources fails to keep up with demand. Metering consumers, charging by the amount of water consumed and setting tariffs to meet the full cost of the supply is a key component of any demand management programme. Any significant subsidy sends the consumer a message that water has a low intrinsic value and wastage of water is not important. The charges for water should as far as possible cover the full cost of the service provided, which makes the system sustainable since the water company will be able to expand its system to meet rising demand from its own revenues. The full cost includes:

- Operating and maintenance costs, including personnel, energy, chemicals, spare parts, consumables and all other overhead costs;
- Depreciation of existing assets;
- The cost of financing investments in new works.

2.1.2 It has to be accepted that in many countries, especially low income countries, it is difficult for everybody to pay the full of the service. One method of ensuring that poorer people can receive an affordable basic level of service is to structure the tariff in a way that allows those households using low volumes of water to pay the lowest cost. This is achieved by the following means:

- Metering supplies so that customers pay according to the volume of water that they consume.
- Having a low fixed element of the charge. There is usually a fixed monthly charge, not related to the volume of water consumed, to cover the water company's fixed costs. It may be desirable to reduce this and put more on the variable charge, which minimises bills for low water users.
- Different tariffs for different categories of consumer. By charging them higher tariffs, industrial, commercial and institutional customers can subsidise household customers.
- A progressive tariff with a low rate for the first 10 m^3 per month (or whatever quantity may be deemed appropriate in specific circumstances) and a much higher tariff for consumption above this figure. Poorer customers can limit their consumption to levels that meet basic needs and pay less per unit volume of water than richer households which use well over the 10 m^3 per month limit for the lowest tariff band.
- In rural areas where people may have limited internal plumbing in their houses and want only a yard tap, neighbouring households can be encouraged to share a connection, which reduces the connection charges and fixed charges for each household.

Preliminary

2.2 Building Regulations and Restrictions on Water Using Devices in the Home

2.2.1 Most water is used in the home for:

- Toilet flushing
- Bathing and showers
- Clothes washing
- Dish washing

2.2.2 Water consumption for all the above uses may be reduced by regulating the design, manufacture, installation and marketing of water using devices.

2.2.3 **Toilet flushing** is one of the largest single uses of water in the home. Old cisterns contain 9.0 litres of water, whereas a modern well designed toilet operates with 6.0 litres. Building regulations may be easily changed to require the use of 6.0 litre cisterns in all new houses or whenever cisterns are replaced. Further saving may be effected by requiring dual flush toilets to be installed. These have a small flush to remove liquid and a larger flush for solids. The full effect of such regulations is of course only felt over time as more new houses are built and more people have their bathrooms and toilets refurbished. However, this is an effective and economic means of reducing water consumption.

2.2.4 A more rapid impact can be gained by inserting solid objects in existing large toilet cisterns to reduce the volume of water. Such objects are best specially made as if any objects that interfere with the flushing mechanism are inserted they may prevent closure of the valves, which causes leaks and hence the devices are counterproductive.

2.2.5 For **washing machines and dishwashers**, it is also possible to limit water consumption by imposing standards on water use. This is already done in some countries and manufacturers of washing machines and dish washers are responding by designing new environmentally friendly low water using machines.

2.3 Education and Public Campaigns

2.3.1 Education and publicity are two key components of a demand management policy. Education is often conducted with school children, who are effective at taking the message of the importance of saving water home to their parents. However, it is also important to explain to adults why it is necessary to save water, how they can contribute to savings and how using water carefully can help reduce their water and wastewater bills. This is effective when combined with increases in tariffs and the imposition of new tariff structures.

2.3.2 Education campaigns can cover:

Preliminary

- The importance of not wasting water, including replacing washers on leaking taps, not leaving taps running, not washing up under running taps, etc.;
- Advice on purchasing water saving washing machines, dishwashers, toilets, etc.
- Advice on plants with a low water consumption for the garden.
- The implications of excessive water use for the environment and levels of service that can be provided to all customers.

2.3.3 Campaigns can be effective in restricting use in a severe drought. Experience in some areas which can suffer from droughts, e.g. mid-western USA and Australia has shown people respond well to appeals to save water provided they are kept well informed of the situation and appreciate the need to conserve water. However, such appeals must be used for limited periods (a few months at most) and water companies must be open and honest with their customers.

2.3.4 Persuading people to invest in devices for the home that use less water will have a long term beneficial effect. The tariff is also an important influence here as if people are paying the full cost of water, they will be more likely to recoup the cost of their investments in water saving devices from reductions in their water bills.

2.4 Restrictions on Use

2.4.1 This is generally applicable to drought periods and restrictions stay in force for a few months. Common restrictions may include:

- Banning the use of hosepipes to water the garden and other outside activities
- Closing down car washes
- Restricting watering of parks, sports fields, etc.

2.4.2 All these actions are short term measures to overcome shortages created by extreme droughts or major unanticipated failure in the supply system.

2.5 Reducing Unaccounted for Water

2.5.1 All the above measures are aimed at reducing water consumption by the customer. It is also important the water service provider takes action to minimise the loss of water from his own distribution system and other water that is not charged for. The term non-revenue water (NRW) is now preferred to unaccounted for water (UfW) and is the difference between the volume of water put into the distribution system and that which is charged for. NRW comprises:

2.5.2 Physical losses from leakage in the distribution system and the consumer connection pipework up to the meter or property boundary, including the supply pipe from the property boundary to the meter, where it is installed inside the house.

Preliminary

2.5.3 Commercial losses, which comprise:

- Unregistered consumption through illegal connections and bypasses to consumer meters;
- Connections that are not recorded and billed due to deficiencies in the water authorities billing system;
- Under registration by consumer meters;
- Legitimate unbilled consumption for fire fighting, mains flushing, etc.

2.5.4 Taking action to minimise UfW directly reduces the demand through the reduction in leakage and indirectly by ensuring that all customers are properly billed and charged for water used, which discourages wasteful use.

2.5.5 Further details of how to control UfW are given in Appendix A.

Preliminary

3 POTENTIAL IMPACTS OF DEMAND MANAGEMENT

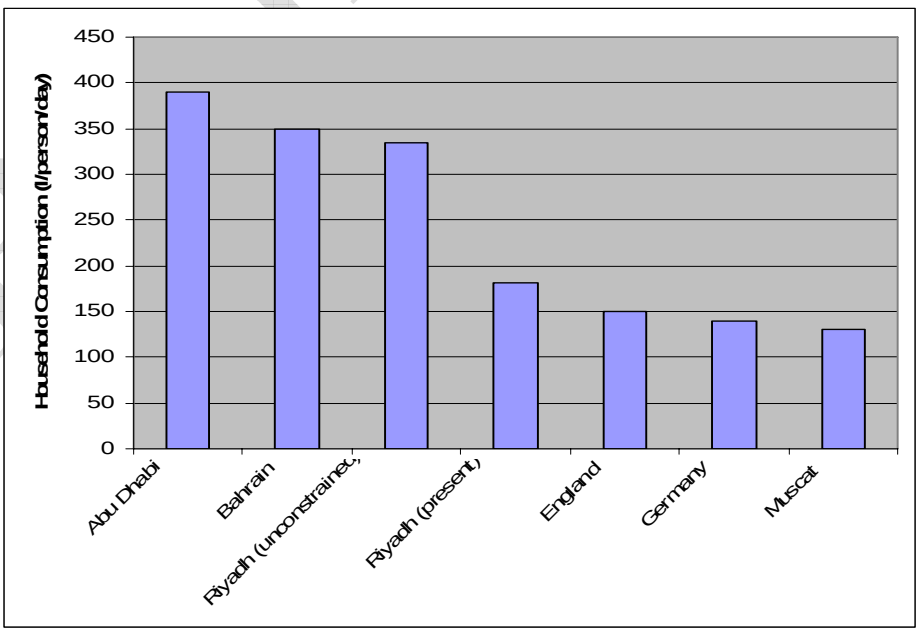
3.1 International Experience

3.1.1 The impacts of demand management measures will vary according to the particular circumstances in the country, or even the district, where they are applied. They will depend on the income levels of customers, local customs, attitudes to conservation and present water consumption practices.

3.1.2 There is little doubt that the tariff is a key element of demand management. Figure 3-1 below shows a comparison of per capita consumption levels in various countries in the Middle East and Europe.

3.1.3 The demand is very high in Abu Dhabi and Bahrain, which are characterised by a hot arid climate (similar to Oman) and low tariffs. In the early 1990s, the consumption in Riyadh was similarly high, but has reduced dramatically in recent years due to supply constraints. Demand in England and Germany, which are characterised by a temperate climate and tariffs meeting the full cost of supply, consumption is much lower. In Muscat, where tariffs cover over 50% of the supply costs, the present consumption is actually less than that in England and Germany, and less than half of that in the neighbouring countries, where tariffs are much lower. This is an indicator of the possible magnitude of reductions in demand that might be expected in the Middle East from metering of supplies and increased tariffs combined with other demand management measures.

Figure 3-1 : Household Water Consumption in Selected Locations



3.1.4 The impacts of more widespread metering and higher tariffs in Eastern Europe have also had a dramatic impact on water consumption, which has fallen by over 50% where individual flats have been metered and tariffs raised to cover some new investment costs as well as operating and maintenance expenses.

3.1.5 In England, on the other hand, the introduction of metering for household supplies has had a relatively small impact on demand. Prior to 1990, very few household customers in UK were metered. Trials were introduced to assess the impact of metering in the early 1990s. The outcome of these trials indicated that there would be an immediate fall in demand of about 20% on the introduction of metering and charging for water by volume. However, over a period of about year there was also a recovery in the level of demand, so the long term savings appear to be about 10%.

3.2 Likely Impacts in Iraq

3.2.1 It is very difficult to assess the impact of demand management in Iraq, but given the apparently high present levels of consumption, where it is not constrained by supply, we would anticipate that it would be significant. We believe that if an intensive demand management programme accompanied by full metering of household supplies and increases in tariffs can be implemented, then winter demands should be brought down to the levels currently seen in Europe and Oman.

3.2.2 The demand in summer will be increased due the extreme heat experienced in any areas. Apart from the increase in water used for washing and bathing in the summer, an important factor in Iraq is the use of air coolers, which consume a significant volume of water.

3.2.3 The likely impacts of demand management are reflected in the guidance note on demand forecasting.

Preliminary

Preliminary

Appendix A Approach to NRW Control

A.1 Terminology and Definition of Non Revenue Water

The term 'non revenue water' (NRW) is now generally preferred to 'unaccounted for water' (UFW) to describe that water which is put into the distribution system but not delivered to registered consumers paying for a supply. NRW comprises:

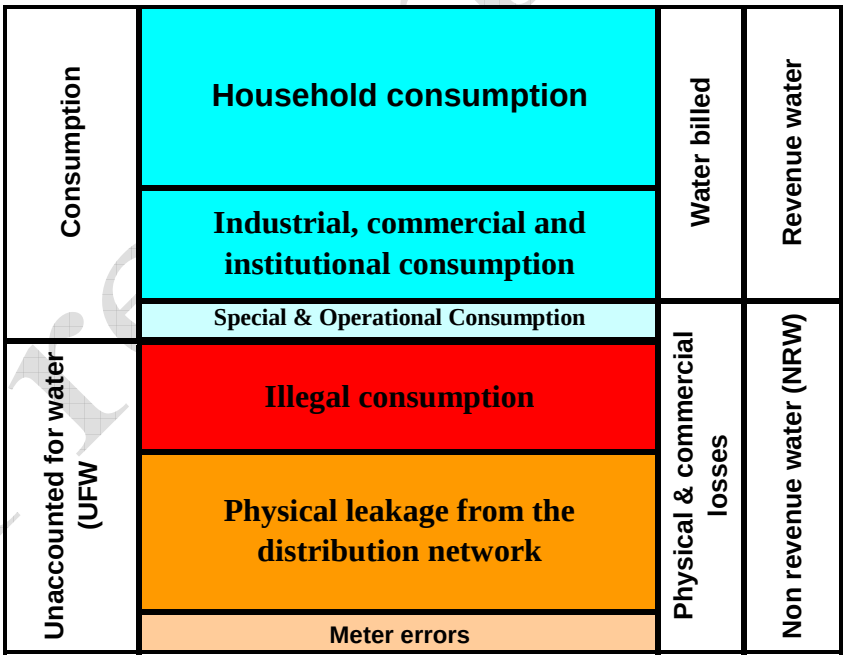
- Physical losses from leakage in the distribution system and consumer connection pipework up to the meter, or property boundary.

Commercial losses, which comprise:

- Unregistered consumption through illegal connections and bypasses to consumer meters;
- Connections that are not recorded and billed due to deficiencies in the water authorities billing system;
- Under registration by consumer meters;
- Legitimate unbilled consumption for fire fighting, mains flushing, etc.

It should be noted that 'water accounted for' normally includes authorised water consumed but not billed, such as that for fire fighting, whilst 'revenue water' only includes water actually billed. The definition of NRW and UFW is presented diagrammatically in the figure below.

Figure A-1 : Diagrammatic Representation of UFW and NRW



UFW is slightly less than NRW. Legitimate unrecorded use is usually a very small component of NRW, so the difference is not significant. NRW sometimes includes allowance for unpaid bills, but in this report we have considered this separately under the heading of collection efficiency.

A.2 Identifying the Components of NRW

As noted above, legitimate unbilled consumption is normally very small and may be ignored.

Meter Under-registration

Under-registration of meters should also be small, at least while meters are typically not more than five years old and provided the water put into supply is of potable quality. The under registration may be expected to increase as the meters age and it will be important to have a programme for checking and replacement or repair of meters when errors reach uneconomic levels, i.e. when the cost of meter repair or replacement is exceeded by the loss of revenue from under recording of consumption.

The accuracy of meters also depends on the class of meter used. Class A meters have the lowest accuracy and Class D meters are the most accurate. It is recommended that Class B or C meters are used. The savings obtained from using Class A meters are usually rapidly offset by losses in revenue, whilst the extra cost of Class D meters is less likely to be justified by gains in revenue. Furthermore, Class D meters are more susceptible to clogging by any particles in the water and therefore likely to need more frequent replacement. This will be an important consideration in Iraq until water treatment facilities and water quality control are enhanced.

Physical leakage

In residential areas, physical leakage may be estimated by measurement of minimum night flows. The minimum flow is usually determined by measurements between 2.00 a.m. and 4.00 a.m. Leakage is then estimated as the minimum flow during this period less an allowance for legitimate use, which in the absence of actual data may be taken as 2.0 l/hour/connection in a residential area. If the area into which flow is measured contains any industrial connections or other non-household customers that may use significant volumes of water over night, these must be allowed for separately.

Illegal consumption

Once physical leakage has been estimated, illegal consumption may be calculated as NRW less physical losses less an allowance for consumer meter under registration.

Preliminary

A.3 Measurement of Flows

The key to identifying the different components of NRW is the ability to measure night flows accurately. Mechanical meters without a low flow bypass will not measure low flows accurately. Therefore, to measure minimum night flows, it is recommended that full-bore electromagnetic flow meters are used. These meters have the flow range capable of measuring peak flows and minimum night flows required for determination of leakage levels. The full-bore flow sensor is installed in the main without the need for a chamber, with the measuring display unit housed in an above ground cabinet. The flow meters can be mains powered or battery powered using lithium batteries, which have a life of around three years.

A.4 Reducing Illegal Consumption

Reducing illegal consumption depends on a combination of good billing records, which can be related to mapping of the system, and inspections of properties where there appear to be inconsistencies between the billed water consumption and the facilities in the building. It can be further influenced by relations between the service provider and the customer, and the policy on dealing with non-payment of bills. The following actions may be considered to address the problem of water theft and assist in its reduction.

- Establish a Commercial Losses Section: This section would have a continual programme of checking the status of every connection, but focusing on inactive connections, to identify instances of water theft. NRW and its reduction must be a priority for all water operating organisations and we believe the formation of a Commercial Losses Section with dedicated staff is essential in areas where illegal consumption is a serious problem to allow the required focus and attention to be given to this important task.
- Public Awareness Programme: A public awareness programme should be initiated informing the public that water theft will, without exception, result in action being taken against the offender. An amnesty period should be allowed for current offenders to stop taking water or register their connection. The programme should send the key message that theft of water is an anti-social activity which has an adverse impact on registered customers by keeping the tariffs higher than they would be otherwise. The programme should inform customers of the penalties for theft of water.
- Avoiding Disconnections: Customers should be disconnected as a last resort as this encourages theft of water. There are various ways of minimising the number of disconnections, including not allowing arrears to accumulate to the point at which they are unmanageable, extending repayment terms for arrears and reviewing debt collection procedures to improve revenue collection performance. This might involve the use of debt collection agencies or court action to collect arrears rather than disconnecting the customer.
- Prosecution: If all other actions to attempt to persuade a defaulting customer to come to an arrangement to pay his outstanding bills fail but, he should be prosecuted and a court order obtained to recover debts by distraint on his property. When necessary, prosecution should be implemented impartially against any customer, whatever his status and should be free from political interference.

Preliminary

A.5 Reducing Physical Leakage

A.5.1 General

There are various ways of reducing leakage. The decision on whether and how these should be implemented will depend on the relative costs of the measures and the potential benefits to be obtained. The intensity of leakage control activities should be increased until the marginal cost of leakage control exceeds the marginal value of water saved. The means of reducing system leakage are broadly the following:

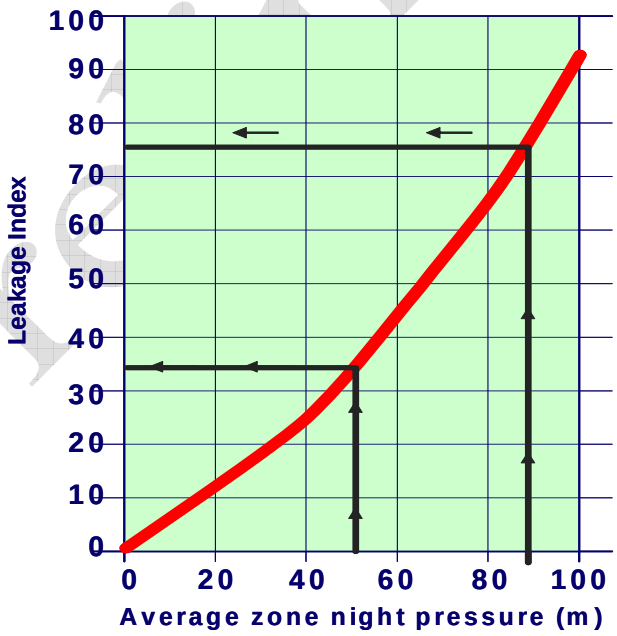
- Pressure management.
- District metering, followed by active leak detection and repair.
- Replacement of old pipework that is in poor condition.

These are likely to be in order of increasing cost, so pressure management, where appropriate will offer the greatest benefit cost ratio. Large scale replacement of distribution pipes will be an expensive solution, and only adopted where large sections of pipe are in poor structural condition or badly laid resulting in a high rate of leak repairs.

A.5.2 Pressure Management

Research undertaken by the UK water industry has determined the impact of pressure on leakage levels and this is presented below.

Figure A-2 : Pressure Management – Leakage Index



Preliminary

From Figure A-2, it can be seen that a knowledge of existing and proposed night pressures allows the leakage index to be determined from which the impact on leakage level from a reduction in system pressure can be calculated. The figure indicates that reducing the average zone night pressure from 90 m to 50 m would reduce leakage to 44% (=35/75) of its present value. The actual impact will vary from system to system, but where night time pressures are high, reducing the pressure could provide a substantial reduction in leakage at a low cost. This is most likely to be applicable to the mountainous districts on Northern Iraq.

A.5.3 District Metering

District metering requires the installation of flow meters at strategic points in the distribution system, each meter recording flows into and, where appropriate, out of a discrete district that has a defined and permanent boundary. Such a district is called a District Meter Area (DMA).

The DMA design process comprises:

- Preliminary design
- Detailed site survey and data collection
- Network modelling.

A DMA normally contains about 1,000 to 3,500 customer connections.

Surveys of the distribution system should be undertaken to confirm the location and nature of the mains and valves within the DMAs as a prerequisite to constructing the DMA network models. It is essential to ensure that adequate supplies are maintained to all customers in the DMA once it has been established. This can be confirmed by network analysis and field measurement.

Data loggers may be used to capture flow and pressure data recorded by insertion flowmeters and pressure transducers deployed at key points on the system. In conjunction with demand data determined from meter records, the flow and pressure data allow construction of network models for each DMA. Comparison of the model's simulated pressures and actual field pressures assist in identifying anomalies such as shut valves (when they should be open), cross connections (where none recorded) or dead ends, as well as variances in expected flow regimes. Network modelling also identifies pressures that need to be maintained at critical points to ensure adequate levels of service to all consumers.

If the model indicates deficiencies in the level of service the appropriate works, such as installation of a cross-connection or a new augmentation main, can be designed and implemented.

Appropriate valves for use as boundary valves and step valves are also identified from the models and, where appropriate, locations for new valves identified.

The process for establishing the DMA is as follows.

Proving of DMA boundary valves: The boundary valves need to be checked to confirm that they are drop tight.

Preliminary

Isolation test: The DMA is isolated from the adjoining system by closing the boundary valves and the district meter valve. DMA pressures should fall to zero thus indicating that the DMA is hydraulically separate from the adjoining system.

District meter installation: The district meters should be full-bore electromagnetic flow meters, which have the flow range capable of measuring peak flows and minimum night flows required for determination of leakage levels. The full-bore flow sensor is installed in the main, without the need for a chamber, with the measuring display unit housed in an above ground cabinet. The flow meters can be mains powered or battery powered using lithium batteries with a life of around three years.

Proving of step valves: Step valves allow sections of the DMA to be progressively shutdown. By measuring the effect of progressive shut downs on flow through the district meter, the sections exhibiting the highest leakage can be identified, thus allowing the leak detection effort to be directed to best effect.

After establishing the DMA, the minimum night flow is measured and the net night flow (the minimum night flow less an allowance for legitimate use) is determined to give an estimate of physical leakage. Where leakage is above the target level, a programme of leak detection and repair is undertaken to bring it down below the target level. The night flows are then monitored and when the leakage level rises again, a further programme of leak detection and repair is undertaken. The process continues indefinitely.

Research suggests that up to 65% leakage reduction can be achieved through district metering compared with a passive leakage control policy. However, in practice the reduction achieved will depend on a variety of factors including:

- The existing level of leakage in the distribution system.
- The pressures in the system.
- The type of pipe in the system. It is more difficult to detect leaks on non-metallic mains than on metallic mains.

The costs of establishing DMAs will depend on the need for new boundary valves and pipework to reconfigure systems and ensure service levels are maintained. Indicative costs for the materials and equipment for 12 DMAs and one leak detection team, which would cover the 12 DMAs are given below.

Preliminary

Table A-1 : Indicative Costs of DMAs and Leak Detection Teams

Item	Cost (US$)
Establish 12 DMAs - Design of DMA - Install meters, incl. isolating valves & above ground flow recorders - Install boundary valves and additional pipework	 25,000 180,000 Depends on requirements
Equipping leak detection team: - Leak detection equipment for one team - Purchase of vehicle	 40,000 30,000

A.5.4 Mains Replacement

Mains replacement is a last resort to reduce leakage and should always be targeted at pipe which is in a poor structural condition or where the number of leak repairs is such that it is more economic to replace large sections of pipework. Pipe replacement may be the preferred option in the following cases:

- Where leaks occur on GI service pipes, the full service pipe from the main to the water meter should be replaced as the whole length of pipe is likely to be severely corroded and in poor condition. The ferrule connection to the main should also be replaced if the existing connection is suspect. For plastic service pipes, the burst section only may be replaced by inserting a new piece of pipe if this is considered more economic than complete replacement. This may be the case where there is a very long service connection.
- Where frequent leaks occur on the barrels of pipes, this indicates a poor structural condition and it is likely that pipe of a particularly material or in a particular area should be replaced.

The pipe to be replaced should be carefully targeted and clearly this requires good information on the condition of the pipe and the nature of repairs being made. This in turn requires good records to be kept by the water authority.

A.5.5 Supply Pipe Replacement

Where water resources are heavily used and the shortage of resources is one of the main drivers for controlling leakage, companies will also need to address losses from the supply pipe, which is the pipe from the boundary valve or meter to the inside of the property. Whilst this pipe is normally the consumer's responsibility, many water companies offer to repair or replace it free of charge as it is often a major source of leakage to reduce demand and the need for investment in new sources of supply.

Preliminary

Preliminary

Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Hydropower Spreadsheet

GN 08

August 2006

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This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of occasional guidance notes published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The guidance note examines the hydropower potential in Iraq.

Preliminary

Report Issue and Revision Record

Rev	Date	Description
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List of Contents

Page

1 Introduction 1

1.1 Scheme Summary Sheet 1

1.2 Scenario Sheet 2

1.3 Recommended Usage 3

List of Tables

Table 1.1: Hydropower Potential in Iraq-Euphrates River Basin 4
Table 1.2: Hydropower Potential in Iraq-Tigris River Basin 5
Table 1.3: Hydropower Potential in Iraq-Lesser Zab River Basin 6
Table 1.4: Hydropower Potential in Iraq-Greater Zab River Basin 7
Table 1.5: Hydropower Potential in Iraq-Khabur River Basin 8
Table 1.6: Hydropower Potential in Iraq-Diyala River Basin 9
Table 1.7: Hydropower Potential in Iraq-Adhaim River Basin 10
Table 1.8: Existing Hydropower Developments in Iraq 11
Table 1.9: Forecast Hydropower Energy and Power Requirements and Possible Scenarios 12

Preliminary

1 INTRODUCTION

1.1 Scheme Summary Sheet

Assumptions

1.1.1 The installed capacity, annual energy generation, annual hours of generation, static head values and expected capital costs have been obtained for the 7 existing and 68 potential hydropower stations in Iraq (Tables 1.1-1.8 present draft spreadsheets). These figures were obtained from a spreadsheet provided by the Ministry of Energy in Iraq. This data is assumed to be current and accurate; however there is limited information available regarding the assumptions used to create these estimates. It is uncertain when the cost estimates were developed and these could have changed substantially. It is assumed however that for cost comparison purposes this data is sufficient. The assumed operating rules are also unclear and may be driven by demand for irrigation flows. The level of consideration for the interaction of these issues is unclear and could have a substantial impact on costs and benefits associated with the hydropower schemes. With these issues in mind, the data from the table has been used to give an indication of some of the possible scenarios for hydropower development in Iraq from now until 2030. As the accuracy of the input data is improved, the scenarios can be updated and more accurate conclusions can be reached.

1.1.2 Using the installed capacity and static head with assumptions for turbine and generator efficiency and headlosses in the system, the flow required to produce this power was calculated. Using the number of hours of annual generation, the total yearly flow has been calculated. The annual energy generation and the number of hours of annual generation appear to assume that the station is only operated at rated capacity which is unlikely to be the case at all times, particularly if the flow is controlled by irrigation requirements as is currently the case for most hydropower schemes in Iraq.

1.1.3 The expected construction period has been estimated based on the installed capacity and Mott MacDonald's past experience for the purposes of planning when the various schemes could potentially be commissioned. Bekhme Power Station, which is expected to be the first plant commissioned, is already partially constructed and as such the estimated construction period is that required to finish the construction. Staff from the Ministry of Water Resources indicated that this station is hoped to be commissioned by 2010. If this is unachievable it is expected the scheme would be included in the 2015 scenario.

Recommended Usage

1.1.4 The scheme summary sheet should be used to get an impression of the potential for hydropower development in Iraq as well as approximate power and energy production that could be obtained at different sites and the water required to

Preliminary

produce this. The spreadsheet should be updated with more accurate data as it becomes available, for example as pre-feasibility and feasibility studies of these potential schemes are carried out.

1.1.5 The installed capacity, annual energy production and annual water requirements given in the scheme summary sheet, will be the main inputs for the optimisation model that has been developed. The scheme summary spreadsheet can also be used to understand some issues which may influence the construction programme of the potential schemes. This includes the scheme location, comparison between unit costs as well as approximate expected construction period.

1.2 Scenario Sheet

Assumptions

1.2.1 The scenario sheet (see Table 1.9) is based on the following key data and assumptions:

- The existing power and energy demand in Iraq;
- The rate of growth of power and energy demand in Iraq;
- The percentage of the total energy production which is currently being achieved by hydropower; and
- The expected change in this percentage from now to 2030.

1.2.2 This data has been sourced from spreadsheets developed by the ministry of energy containing 2005 data.

Data used

1.2.3 From the previously discussed spreadsheet containing summary information for the potential schemes, the following key data has been used to select the schemes which form each of the 5 year scenarios:

- Annual energy generation;
- Rated power output;
- Unit cost;
- Location; and
- Construction period.

Limitations and assumptions of data used

- Rated power output not as important for determining the number of new schemes required as annual energy generation was unit cost only comparative

Preliminary

- Location - north vs south
- Construction period not really used to choose schemes just to make sure is viable, particularly for 2010 case.

Development of Scenarios

1.2.4 Include how scenarios developed- how much energy needed? How much of that might come from hydropower? Which stations might be able to meet this demand? Stations selected based on size (bigger usually better), unit cost, location (balance between north & south)

Limitations

1.2.5 Problems with this are that if multi purpose schemes, as most in Iraq are, the decision on which dams to build may be based more on where the irrigation water is needed rather than the financials of the hydropower project. For a multi purpose scheme the project financials should also include the costs and benefits of the irrigation component which has not been included in the cost estimates used here.

1.3 Recommended Usage

1.3.1 How should future scenarios be developed?

1.3.2 What info needs replacing?

Preliminary

Table 1.1: Hydropower Potential in Iraq-Euphrates River Basin

Hydropower Potential in Iraq- Euphrates River Basin

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Euphrates River Basin	Rawa	Euphrates	330	*2354*	830	*676*	*21316*	18	2515	*29%*	165	135	1000	*7*	165	500	*5*
Euphrates River Basin	Al-Baghdadi	Euphrates	400	*1511*	1250	*539*	*16996*	34	3125	*36%*	102.5	500	800	*2*	220	550	*5.5*
Euphrates River Basin	Hit-1	Euphrates	50	*1284*	215	*630*	*19879*	5	4300	*49%*	68.5	68	40	*1*	55	1100	*3.5*
Euphrates River Basin	Hit-2	Euphrates	65	*1325*	280	*652*	*20558*	6	4310	*49%*	68.5	10	50	*5*	54	830	*4*

Notes:
1. Values in italics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

Source:
1. Some data for the existing schemes was taken from a table provided by the Iraq Ministry of Water Staff "Design Capacity for Hydropower in Iraq" (Provided at meeting in Cambridge)
2. Key data for existing and potential schemes was taken from a table provided by the Iraq Ministry of Energy "Basic Parameters of Hydropower Schemes in Iraq with a Capacity Over 10 MW" (Obtained from the Extranet)

Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.2: Hydropower Potential in Iraq-Tigris River Basin

Hydropower Potential in Iraq- Tigris River Basin

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Tigris River Basin	Nineveh-1	Tigris	300	*1427*	900	*489*	*15410*	27	3000	*34%*	244	43	350	*8*	120	450	*5*
Tigris River Basin	Nineveh-2	Tigris	20	*642*	90	*330*	*10402*	4	4500	*51%*	217	7	20	*3*	24		*3*
Tigris River Basin	Khamam	Tigris	240	*1401*	720	*480*	*15130*	22	3000	*34%*	212	25	110	*4*	170	710	*5*
Tigris River Basin	Nimrud	Tigris	80	*1141*	230	*375*	*11814*	9	2875	*33%*	199	5	20	*4*			*4.5*
Tigris River Basin	Qaiyara	Tigris	420	*2345*	1380	*879*	*27732*	23	3285	*38%*	190	38	150	*4*	220	524	*5.5*
Tigris River Basin	Qaiyara Diversion	Tigris	400	*2233*	1230	*784*	*24723*	23	3075	*35%*	190	15	70	*5*			*5.5*
Tigris River Basin	Assur	Tigris	415	*2221*	1350	*824*	*25980*	24	3250	*37%*	167	27	100	*4*	270	650	*5.5*
Tigris River Basin	Assur Diversion	Tigris	400	*2140*	1220	*855*	*26967*	24	3500	*40%*	167	15	50	*3*			*5.5*
Tigris River Basin	Abassi	Tigris	200	*2568*	610	*894*	*28200*	10	3050	*35%*	143	20	80	*4*	130	650	*5*
Tigris River Basin	Makhul	Tigris	500	*3058*	1480	*1033*	*32581*	21	2960	*34%*	133	65	58	*1*	260	520	*5.5*
Tigris River Basin	Tikrit	Tigris	600	*2266*	1990	*858*	*27044*	34	3315	*38%*	112	50	235	*5*	420	700	*6*
Tigris River Basin	Tikrit-1	Tigris	300	*2568*	870	*850*	*26813*	15	2900	*33%*	112	13	65	*5*			*5*
Tigris River Basin	Tikrit-2	Tigris	280	*1892*	930	*717*	*22619*	19	3320	*38%*	97	17	85	*5*			*5*
Tigris River Basin	Daur	Tigris	170	*2183*	570	*835*	*26328*	10	3350	*38%*	78	20	90	*5*	120	706	*5*
Tigris River Basin	Samarra-1	Tigris	56	*599*	200	*244*	*7702*	*12*	3570	*41%*	68	*70*	*110*	*2*	20	360	*4*
Tigris River Basin	Samarra-2	Tigris	300	*2752*	1070	*1121*	*35366*	14	3570	*41%*	56	18	35	*2*	115	383	*5*
Tigris River Basin	Samarra-3	Tigris	80	*1468*	370	*674*	*21266*	7	4025	*46%*	42	15	70	*5*	85	1062	*4.5*
Tigris River Basin	Badush-1	Tigris	154	*1163*	497	*429*	*13514*	17	3227	*37%*	244	15	30	*220*	88	708	*5*
Tigris River Basin	Badush-2	Tigris	38	*610*	219	*401*	*12655*	8	5763	*66%*	227	15	8	*31*	48		*3.5*

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

Source:
1. Some data for the existing schemes was taken from a table provided by the Iraq Ministry of Water Staff "Design Capacity for Hydropower in Iraq" (Provided at meeting in Cambridge)
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Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.3: Hydropower Potential in Iraq-Lesser Zab River Basin

Hydropower Potential in Iraq- Lesser Zab River Basin

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Lesser Zab River Basin	Osam	Kala Cholan	32	*34*	79	*10*	*305*	120	2470	28%	1200	16	230	*14*	19	762	*3.5*
Lesser Zab River Basin	Surba	Kala Cholan	24	*51*	71	*17*	*547*	60	2960	34%	1080	1	80	*80*	17	412	*3*
Lesser Zab River Basin	Nurabab	Kala Cholan	30	*70*	78	*21*	*656*	55	2600	30%	1020	4	70	*18*	20	250	*3.5*
Lesser Zab River Basin	Awa	Kala Cholan	65	*76*	163	*22*	*694*	110	2540	29%	965	3	40	*13*	40	432	*4*
Lesser Zab River Basin	Kili	Kala Cholan	80	*137*	207	*40*	*1253*	75	2540	29%	855	24	650	*27*	62	487	*4.5*
Lesser Zab River Basin	Mawat	Kala Cholan	120	*154*	260	*40*	*1270*	100	2290	26%	780	4	50	*12.5*	50	1000	*5*
Lesser Zab River Basin	Khazina	Kala Cholan	35	*150*	90	*43*	*1370*	30	2540	29%	680	1	10	*10*	24	900	*3.5*
Lesser Zab River Basin	Qala-Diza-1	Kala Cholan	300	*550*	700	*146*	*4616*	70	2330	*27%*	620	5	127	*25*	86	1074	*5*
Lesser Zab River Basin	Qala-Diza-2	Kala Cholan	165	*543*	500	*188*	*5926*	39	3030	*35%*	550	20	355	*18*	110	765	*5*
Lesser Zab River Basin	Taq-taq	Kala Cholan	400	*685*	980	*192*	*6041*	75	2450	*28%*	415	80	2400	*30*	210	940	*5.5*
Lesser Zab River Basin	Altun Kupri	Kala Cholan	300	*494*	1200	*226*	*7112*	78	4000	*46%*	340				190	773	*5*

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

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Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.4: Hydropower Potential in Iraq-Greater Zab River Basin

Hydropower Potential in Iraq- Greater Zab River Basin

Region	Hydro/Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Greater Zab River Basin	Bekhme	Greater Zab	1500	#DIV/0!	4800	#DIV/0!	#DIV/0!		3200	37%	587	200	14000	70	1144	762	4
Greater Zab River Basin	Amadiya	Greater Zab	900	#DIV/0!	1780	#DIV/0!	#DIV/0!		1980	23%	860	19	900	47	371	412	6.5
Greater Zab River Basin	Rashawa	Greater Zab	550	#DIV/0!	980	#DIV/0!	#DIV/0!		1780	20%	710	3	72	24	137	250	6
Greater Zab River Basin	Bawn	Greater Zab	220	#DIV/0!	620	#DIV/0!	#DIV/0!		2820	32%	635	4	73	18	95	432	5
Greater Zab River Basin	Mandawa	Greater Zab	480	#DIV/0!	2240	#DIV/0!	#DIV/0!		4665	53%	394	80	2200	28	234	487	5.5
Greater Zab River Basin	Halwan	Greater Zab	200	#DIV/0!	1020	#DIV/0!	#DIV/0!		5100	58%	317			#DIV/0!	200	1000	5
Greater Zab River Basin	Eski Kelek with Ifraz weir	Makhmur Main Canal	100	#DIV/0!	408	#DIV/0!	#DIV/0!		4080	47%	278.5			#DIV/0!	90	900	4.5
Greater Zab River Basin	Nahola	Shamdenan	140	#DIV/0!	280	#DIV/0!	#DIV/0!		2000	23%	860	7	350	50	120	857	5
Greater Zab River Basin	Taili with Murak Hydros	Shamdenan/ W. Balka	300	#DIV/0!	606	#DIV/0!	#DIV/0!		2020	23%	718	11	520	47	185	617	5.5
Greater Zab River Basin	Shushan	Barazgir	25	#DIV/0!	65	#DIV/0!	#DIV/0!		2600	30%	900	1	5	5	14	560	3
Greater Zab River Basin	Shush	Barazgir	15	#DIV/0!	38	#DIV/0!	#DIV/0!		2535	29%	800		1	#DIV/0!	9	600	2
Greater Zab River Basin	Kulla	Barazgir	18	#DIV/0!	46	#DIV/0!	#DIV/0!		2555	29%	740		12	#DIV/0!	24	1333	2.5
Greater Zab River Basin	Khomari with Haji Bak Hydros	Barazgir	65	#DIV/0!	130	#DIV/0!	#DIV/0!		2000	23%	685	23	585	25	64	985	4
Greater Zab River Basin	Silem	Rawanduz	30	#DIV/0!	56	#DIV/0!	#DIV/0!		1865	21%	935	3	117	39	66	2200	3.5
Greater Zab River Basin	Omarawa	Rawanduz	18	#DIV/0!	34	#DIV/0!	#DIV/0!		1890	22%	820	1	6	6	15	833	2.5
Greater Zab River Basin	Bairus	Rawanduz	53	#DIV/0!	109	#DIV/0!	#DIV/0!		2055	23%	755	4	130	33	130	2450	4
Greater Zab River Basin	Jindian	Rawanduz	18	#DIV/0!	42	#DIV/0!	#DIV/0!		2335	27%	625	1	1	1	10	555	2.5
Greater Zab River Basin	Nila	Balikian	30	#DIV/0!	55	#DIV/0!	#DIV/0!		1835	21%	800	8	183	23	54	1800	3.5
Greater Zab River Basin	Shiwan	Balikian	15	#DIV/0!	30	#DIV/0!	#DIV/0!		2000	23%	722	1	5	5	11	733	2.5
Greater Zab River Basin	Dirana	Balikian	21	#DIV/0!	44	#DIV/0!	#DIV/0!		2095	24%	685		5	#DIV/0!	16	762	3
Greater Zab River Basin	Kholarash	Balikian	20	#DIV/0!	47	#DIV/0!	#DIV/0!		2350	27%	635		1	#DIV/0!	10	500	3
Greater Zab River Basin	Bakurman with Khalikan Dam	Khazir	70	#DIV/0!	80	#DIV/0!	#DIV/0!		1145	13%	574.5	20	490	25	67	957	4.5
Greater Zab River Basin	Lower Bakurman	Khazir	27	*87*	30	*11*	*346*	40	1110	*13%*	470	1	10	*10*	29	1074	*3.5*
Greater Zab River Basin	Safiya	Greater Zab	170	*1092*	510	*374*	*11789*	20	3000	*34%*	248	9	60	*7*	130	765	*5*
Greater Zab River Basin	Quwair- 1	Greater Zab	85	*910*	290	*354*	*11166*	12	3410	*39%*	228	8	40	*5*	80	940	*4.5*
Greater Zab River Basin	Quwair- 2	Greater Zab	85	*910*	290	*353*	*11134*	12	3400	*39%*	216	12	50	*4*	80	940	*4.5*
Greater Zab River Basin	Quwair- 3	Greater Zab	110	*1009*	370	*387*	*12205*	14	3360	*38%*	204	13	70	*5*	85	773	*4.5*

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

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Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.5: Hydropower Potential in Iraq-Khabur River Basin

Hydropower Potential in Iraq- Khabur River Basin

No static head values!!

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Khabur River Basin	Besar	Khabur	50	#DIV/0!	180	#DIV/0!	#DIV/0!		3600	*41%*	925	3	82	*27*	60	1200	*4*
Khabur River Basin	Riwan	Khabur	130	#DIV/0!	275	#DIV/0!	#DIV/0!		2115	*24%*	820	20	817	*41*	102	785	*5*
Khabur River Basin	Basi	Khabur	70	#DIV/0!	174	#DIV/0!	#DIV/0!		2485	*28%*	703	3	45	*15*	410	586	*4*
Khabur River Basin	Kufaki	Khabur	70	#DIV/0!	156	#DIV/0!	#DIV/0!		2230	*25%*	640	5	14	*3*	43	614	*4*
Khabur River Basin	Dalal	Khabur	110	#DIV/0!	245	#DIV/0!	#DIV/0!		2230	*25%*	590	16	385	*24*	79	718	*4.5*
Khabur River Basin	Dola	Khabur	120	#DIV/0!	265	#DIV/0!	#DIV/0!		2210	*25%*	518	4	40	*10*	67	558	*4.5*
Khabur River Basin	Zakho	Khabur	100	#DIV/0!	230	#DIV/0!	#DIV/0!		2300	*26%*	450	2	12	*6*	60	600	*4.5*
Khabur River Basin	Bajuka	Khabur	150	#DIV/0!	370	#DIV/0!	#DIV/0!		2465	*28%*	395	5	25	*5*	70	467	*4.5*

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

Source:
1. Some data for the existing schemes was taken from a table provided by the Iraq Ministry of Water Staff "Design Capacity for Hydropower in Iraq" (Provided at meeting in Cambridge)
2. Key data for existing and potential schemes was taken from a table provided by the Iraq Ministry of Energy "Basic Parameters of Hydropower Schemes in Iraq with a Capacity Over 10 MW" (Obtained from the Extranet)

Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.6: Hydropower Potential in Iraq-Diyala River Basin

Hydropower Potential in Iraq- Diyala River Basin

No static head values!!

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Diyala River Basin	Tongar	Diyala	155	#DIV/0!	450	#DIV/0!	#DIV/0!		2905	*33%*	380	8	110	*14*	100	645	*4.5*
Diyala River Basin	Bebas	Diyala	110	#DIV/0!	370	#DIV/0!	#DIV/0!		3365	*38%*	335	31	440	*14*	110	1000	*4.5*
Diyala River Basin	Bawanur	Diyala	175	#DIV/0!	550	#DIV/0!	#DIV/0!		3145	*36%*	302	11	170	*15*	150	857	*5*
Diyala River Basin	Sankar	Diyala	110	#DIV/0!	350	#DIV/0!	#DIV/0!		3180	*36%*	250	8	30	*4*	70	636	*4.5*
Diyala River Basin	Kalar	Diyala	105	#DIV/0!	320	#DIV/0!	#DIV/0!		3050	*35%*	215			#DIV/0!	80	762	*4.5*
Diyala River Basin	Qara Teppe	Diyala	245	#DIV/0!	730	#DIV/0!	#DIV/0!		2980	*34%*	181			#DIV/0!	160	653	*5*
Diyala River Basin	Qara Teppe-1	Diyala	105	#DIV/0!	310	#DIV/0!	#DIV/0!		2950	*34%*	181			#DIV/0!	100	952	*4.5*
Diyala River Basin	Qara Teppe-2	Diyala	140	#DIV/0!	420	#DIV/0!	#DIV/0!		3000	*34%*	148			#DIV/0!	60	428	*4.5*

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

Source:
1. Some data for the existing schemes was taken from a table provided by the Iraq Ministry of Water Staff "Design Capacity for Hydropower in Iraq" (Provided at meeting in Cambridge)
2. Key data for existing and potential schemes was taken from a table provided by the Iraq Ministry of Energy "Basic Parameters of Hydropower Schemes in Iraq with a Capacity Over 10 MW" (Obtained from the Extranet)

Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.7: Hydropower Potential in Iraq-Adhaim River Basin

Hydropower Potential in Iraq- Adhaim River Basin

No static head values!!

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)	Expected Construction Period
Adhaim River Basin	Damir Kapu	Adhaim	40	*#DIV/0!*	200	*#DIV/0!*	*#DIV/0!*		5000	*57%*	135	105	1400	*13*	67	1675	*3.5*

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.
5. These calculations assume the station is operated at rated capacity only. In reality this is unlikely.

Source:
1. Some data for the existing schemes was taken from a table provided by the Iraq Ministry of Water Staff "Design Capacity for Hydropower in Iraq" (Provided at meeting in Cambridge)
2. Key data for existing and potential schemes was taken from a table provided by the Iraq Ministry of Energy "Basic Parameters of Hydropower Schemes in Iraq with a Capacity Over 10 MW" (Obtained from the Extranet)

Assumptions:
1. For the potentail schemes the flow has been calculated using the power equation with an assumed 10% headloss, 90% turbine efficiency and 98% generator efficiency.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.8: Existing Hydropower Developments in Iraq

Existing hydropower developments in Iraq

Region	Hydro/ Dam Name	River	Installed Capacity (MW)	Rated Discharge (m^3/s)	Annual Energy Generation (GWh/yr)	Average Annual Flow (m^3/s)	Total Yearly Flow (mill m^3/yr)	Static Head (m)	No of Machines	No. Hours Operation / Year	Capacity Factor	NMOL (m)	Reservoir Water Area (km^2)	Reservoir Full Storage Capacity (mill m^3)	Average Depth (m)	Capex (mill ID)	Unit Cost (ID/kW)
Euphrates River Basin	Haditha	Haditha	660	1980	1680	*578*	*18212*	44.5	6	2555	*29%*	147	500	8200	*16*	350	500
Tigris River Basin	Mosul-1	Tigris	750	1140	2420	*420*	*13235*	73.5	4	3225	*37%*	330	380	11110	*29*	400	494
Tigris River Basin	Mosul-2	Tigris	60	*808*	346	*531*	*16761*	11	*2*	5765	*66%*	256.5	4	21	*5*		
Tigris River Basin	Sammara Barrage	Tigris	80	1170	510	*811*	*25567*	12	3	6070	*69%*	68	70	110	*2*		
Lesser Zab River Basin	Dokan	Lesser Zab	400	550	1130	*178*	*5603*	96	5	2830	*32%*	511	270	6850	*25*		
Diyala Basin	Derbendekan	Diyala	166	240	610	*70*	*2195*		3	2540	*29%*	485	110	3000	*27*		
Diyala Basin	Hemrin	Diyala	50	200	250	*114*	*3600*		2	5000	*57%*	104	350	2600	*7*		
	Hindyqa Barrage		5						1			31.9					

So Haditha uses approximately 1980 m^3/s for approximately 3 months of the year, presumably during the wet season, and has a total yearly flow of 18,212 mill m^3

Notes:
1. Values in itallics were calculated or assumed values (not provided in tables from Iraq)
2. Currently have no static head figures for greyed out schemes so can't calculate flows.
3. ID= Iraqi Dollars
4. The static head will change as the stations are operated as the water level in the reservoir changes. This has not been accounted for here.

Source:
1. Some data for the existing schemes was taken from a table provided by the Iraq Ministry of Water Staff "Design Capacity for Hydropower in Iraq" (Provided at meeting in Cambridge)
2. Key data for existing and potential schemes was taken from a table provided by the Iraq Ministry of Energy "Basic Parameters of Hydropower Schemes in Iraq with a Capacity Over 10 MW" (Obtained from the Extranet)

Assumptions:
1. Where flow not available, assume 10% headloss, 0.85 turbine efficiency and 0.9 generator efficiency for power calc.
2. Construction periods taken from graph in James Arthur's hydropower presentation.

Preliminary

Table 1.9: Forecast Hydropower Energy and Power Requirements and Possible Scenarios

Forecast Hydropower Energy and Power Requirements and Possible Scenarios

	Additional Energy Demand (GWh)	% of Total Energy Demand which could be met by Hydropower	Additional Hydropower Energy Demand (GWh)	Potential Schemes to be Constructed	Energy (GWh/yr)
2005 - 2010	22,444	20%	**4,489**	Bekhme	4,800
2010 - 2015	31,479	18%	**5,666**	Samarra-1	200
				Samarra-2	1,070
				Nineveh-1	900
				Nineveh-2	90
				Rawa	830
				Qaiyara	1,380
				Qaiyara Diversion	1,230
2015 - 2020	44,152	16%	**7,064**	Makhul	1,480
				Al-Baghdadi	1,250
				Assur	1,350
				Assur Diversion	1,220
				Altun Kupri	1,200
				Kili	207
2020 - 2025	61,925	14%	**8,669**	Abassi	610
				Tikrit	1,990
				Tikrit-1	870
				Tikrit-2	930
				Daur	570
				Badush-1	497
				Badush-2	219
				Khamam	720
				Nimrud	230
				Safiya	510
				Quwair- 1	290
				Quwair- 2	290
				Taq-taq	980
2025 - 2030	86,853	12%	**10,422**	Qala-Diza-1	700
				Qala-Diza-2	500
				Quwair- 3	370
				Amadiya	1,780
				Rashawa	980
				Bawn	620
				Mandawa	2,240
				Halwan	1,020
				Taili with Murak Hydr	606
				Tongar	450
				Qara Teppe	730
				Qara Teppe-2	420

	Additional Power Demand (MW)	% of Total Power Demand which could be met by Hydropower	Additional Hydropower Power Demand (MW)	Potential Schemes	Power (MW)
2005 - 2010	3,061	20%	**612**	Bekhme	1,500
2010 - 2015	4,293	18%	**773**	Samarra-1	56
				Samarra-2	300
				Nineveh-1	300
				Nineveh-2	20
				Rawa	330
				Qaiyara	420
				Qaiyara Divers	400
2015 - 2020	6,021	16%	**963**	Makhul	500
				Al-Baghdadi	400
				Assur	415
				Assur Diversio	400
				Altun Kupri	300
				Kili	80
2020 - 2025	8,444	14%	**1,182**	Abassi	200
				Tikrit	600
				Tikrit-1	300
				Tikrit-2	280
				Daur	170
				Badush-1	154
				Badush-2	38
				Khamam	240
				Nimrud	80
				Safiya	170
				Quwair- 1	85
				Quwair- 2	85
				Taq-taq	400
2025 - 2030	11,843	12%	**1,421**	Qala-Diza-1	300
				Qala-Diza-2	165
				Quwair- 3	110
				Amadiya	900
				Rashawa	550
				Bawn	220
				Mandawa	480
				Halwan	200
				Taili with Mura	300
				Tongar	155
				Qara Teppe	245
				Qara Teppe-2	140

Notes:
Annual energy production is factor determining plants to be implemented, not installed capacity

Preliminary