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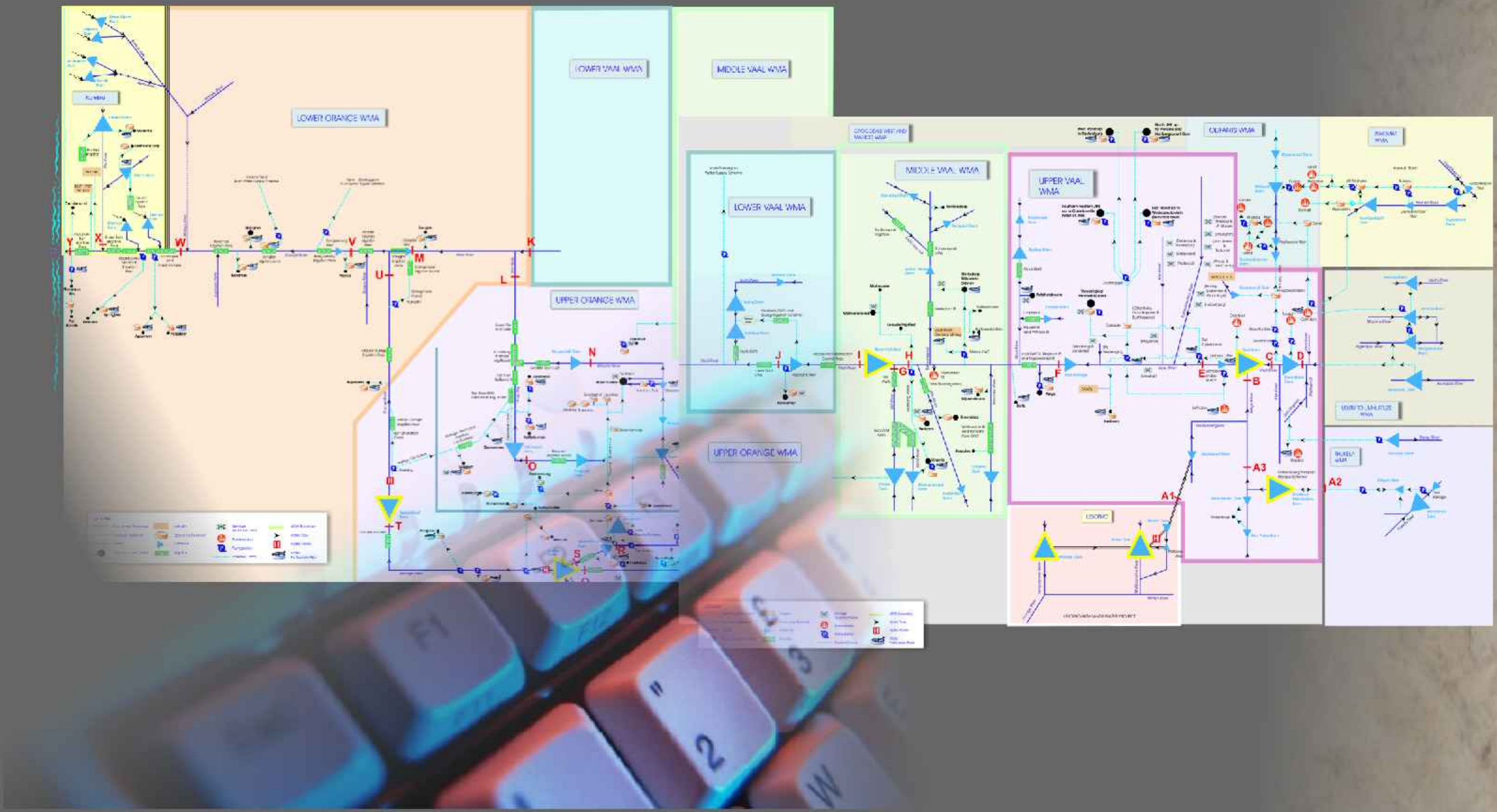
SUPPORT TO PHASE 2 OF THE ORASECOM BASIN-WIDE INTEGRATED WATER RESOURCES MANAGEMENT PLAN
Work Package 1:
Water Resources Modelling of the Orange-Senqu Basin

Capacity Building and Setting Up the Models in Each Country; Process of Continuous Review



February 2011

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Prepared by

in association with

SUPPORT TO PHASE 2 OF THE ORASECOM BASIN-WIDE INTEGRATED WATER RESOURCES MANAGEMENT PLAN

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Water Resources Modelling of the Orange-Senqu Basin

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Study Name	**Support to Phase 2 of the ORASECOM Basin-wide Integrated Water resources Management Plan**
Report Title:	***Capacity Building and Setting up the Models in each Country; Process of Continuous Review***
Submitted by:	WRP Consulting Engineers in association with Golder Associates, DMM, PIK, RAMBOLL and WCE

REPORTS, WPS AND OTHER DELIVERABLES SUBMITTED	**TYPE**	**No.**
Overall Study		
Inception Report	Report	004/2010
Overall Project Executive Summary	Report	013/2011
Work Package 1: WATER RESOURCES MODELLING OF THE ORANGE-SENQU BASIN		
Strengths and Weaknesses of Existing Models	WP	005/2010
Setting up and Testing of the Final Extended and Expanded Models; Changes in Catchment Yields and Review of Water Balance	Report & WP	001/2011
Modelling software and datasets	Software	None
Capacity Building and Setting up the Models in each Country; Process of Continuous Review	***WP***	***003/2011***
Work Package 2: EXTENSION AND EXPANSION OF HYDROLOGY OF ORANGE-SENQU BASIN		
Improvements to Gauging Network and Review of Existing Data Acquisition Systems	WP	005/2011
Extension of Hydrological Records	Report	006/2011
Hydrological Database	Database	None
Work Package 3: INTEGRATED WATER RESOURCES QUALITY MANAGEMENT PLAN		
Development of Water Quality Monitoring programme and Data Management Framework	Report	007/2011
Development of Specifications for the Water Quality Model	WP	006/2010
Work Package 4: CLIMATE CHANGE IN THE ORANGE-SENQU RIVER BASIN		
Downscaling Methodology and Ongoing Climate Modelling Initiatives	WP	007/2010
GCC Downscaling for the Orange-Senqu River Basin	Report	008/2011
Projection of impacts and Guidelines on Climate Change Adaptation Strategies	WP	009/2011
Work Package 5: ASSESSMENT OF ENVIORNMENTAL FLOW REQUIREMENTS		
Literature survey and Gap Analysis	WP	008/2010
Delineation of Management Resource Units	WP	009/2010
Desktop EcoClassification Assessment	Report	016/2010
Goods and Services Report	WP	010/2010
Environmental Flow Requirements	Report	010/2011
Work Package 6: WATER CONSERVATION AND WATER DEMAND IN THE IRRIGATION SECTOR		
The Promotion of WC WDM in the Irrigation Sector	Report	011/2011
Irrigation GIS Database, Interactive Database and Irrigation Scenario Tools	WP	012/2011
Irrigation GIS Database and Interactive Classification Tool	Software	None
Irrigation Scenario Generation Tool	Software	None

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1 INTRODUCTION

1.1 General Context

The Orange - Senqu River originates in the highlands of Lesotho some 3 300m above mean sea level, and it runs for over 2300km to its mouth on the Atlantic Ocean. The river system is one of the largest river basins in southern Africa with a total catchment area of more than 850,000km^2 and includes the whole of Lesotho as well as portions of Botswana, Namibia and South Africa. The natural mean annual runoff at the mouth is estimated to be in the order of 11 500 million m^3, but this has been significantly reduced by extensive water utilization for domestic, industrial and agricultural purposes to such an extent that the current flow reaching the river mouth is now in the order of half the natural flow. The basin is shown in **Figure 1-1.** The Orange-Senqu system is regulated by more than thirty one major dams and is a highly complex and integrated water resource systems with numerous large inter and intra basin transfers.

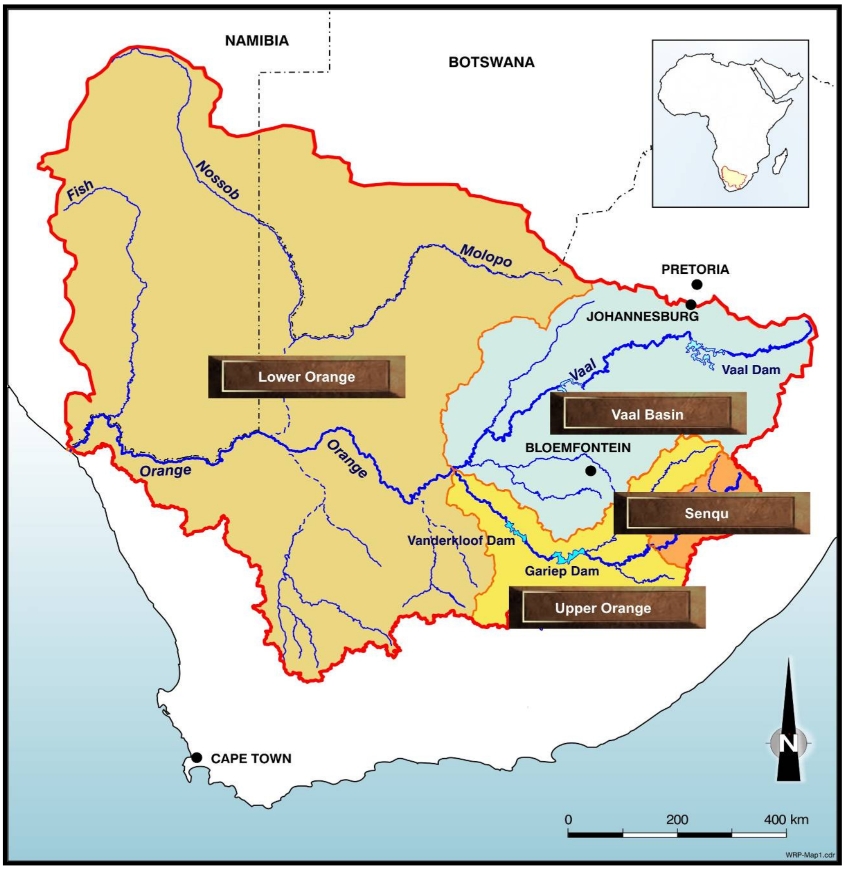

Figure 1-1: Orange – Senqu River Basin

1.2 Management and Environmental Context

1.2.1 General

Management issues, including environmental protection, conservation and sustainable development have to deal with problems relating to, both, water quantity and quality, potential conflicts between users, pollution sources from industry, mining, agriculture, watershed management practices and the need to protect ecologically fragile areas. The riparian countries have for some time recognized that a basin-wide integrated approach has to be applied in order to find sustainable solutions to these problems and that this approach must be anchored through strong political will. The development of this strong political will is one of the key initiatives of SADC, in particular the Revised Protocol on Shared

Watercourses and the establishment of the Orange-Senqu River Basin Commission (ORASECOM). These initiatives are intended to facilitate the implementation of the complicated principles of equitable and beneficial uses of a shared watercourse system. It is accepted by all countries that the management of water resources should be carried out on a basin-wide scale with the full participation of all affected parties within the river basin.

Water supply in terms both of quantity and quality for basic human needs is being outstripped by the demands within and outside of the basin. Meeting the water supply needs of rapidly growing towns and cities at the same time having sufficient water of an acceptable quality to meet existing and proposed irrigation and other demands (including environmental) further downstream is a challenge for planners and decision makers and stakeholders in the Orange-Senqu river basin.

1.2.2 ORASECOM

Southern Africa has fifteen trans-boundary watercourse systems including the Orange–Senqu system. The Southern African Development Community (SADC) has adopted the principle of basin–wide management of the water resources for sustainable and integrated water resources development. In this regard, the region recognizes the United Nations Convention on the Law of Non-navigational Uses of International Watercourses, and has adopted the “Revised Protocol on Shared Watercourse Systems in the SADC Region”. Under this Revised Protocol, a further positive step has been the initiatives towards the establishment of river basin commissions in order to enhance the objectives of integrated water resources development and management in the region, while also strengthening the bilateral and multilateral arrangements that have been in existence for some time. The Orange–Senqu River Basin Commission (ORASECOM) which was established on 3 November, 2000 in Windhoek, Namibia. is a legal entity in its own right.

The highest body of the ORASECOM is the Council consisting of three permanent members, including one leader, for each delegation from the four riparian states. Support from advisors and ad hoc working groups can be established by the council. The main task of the Council is to “serve as technical advisor to the Parties on matters relating to the development, utilization and conservation of the water resources in the River System”, but the council can also perform such other functions pertaining to the development and utilization of water resources as the partiers may agree.

1.3 Context of the Study and this Working Paper

1.3.1 GIZ Support to SADC and ORASECOM

The overall goal of the GIZ-supported ‘Transboundary Water Management in SADC’ programme is to strengthen the human, institutional, and organisational capacities for sustainable management of shared water resources in accordance with SADC’s Regional Strategic Action Plan (RSAP). The programme, which GIZ implements on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), and in delegated cooperation with the UK Department for International Development (DFID) and the Australian Agency for International Development (AusAID), consists of the following components:

- Capacity development of the SADC Water Division
- Capacity development of the river basin organisations (RBO) and
- Capacity development of local water governance and transboundary infrastructure.

The activities of this Consultancy, “Support to Phase II of the ORASECOM Basin-wide Integrated Water Resources Management Plan”, being undertaken by WRP (Pty) Ltd and Associates, contributes to Component 2 above. The work of Phase 2 comprises six work packages as briefly outlined in **Section 1.3.2.2** below

1.3.2 Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

1.3.2.1 Objectives of the Overall Consultancy

The main objectives of this consultancy are to enlarge and improve the existing models for the Orange-Senqu Basin, so that they incorporate all of the essential components in the four Basin States and are accepted by each Basin State. These models must be capable of being used to meet the current and likely future information needs of ORASECOM. These needs will likely encompass additional options to achieve water security in each Basin State – including changing configurations for water supply and storage infrastructure - and ensure that ORASECOM is able to demonstrate that its operations are aligned with the principles embodied in the SADC Water Protocol.

1.3.2.2 The Six Work Packages

In order to contribute to the realisation of the above-mentioned objectives, the project includes six work packages as outlined in **Table 1-1**. The first of these work packages is central to Phase 2 of the IWRM Plan and will also be at the core of the final plan to be developed in Phase 3. In work package 1 the WRYM water resources simulation model is being updated and expanded to cover the entire basin.

Table 1-1 Summary of Work Package Objectives and Main Activities

Work Package	Main Objectives	Main Activities
WP 1: Development of Integrated Orange-Senqu River Basin Model	To enlarge and improve existing models so that they incorporate all essential components in all four States and are accepted by each State	• Extension and expansion of existing models • Capacity building for experts and decision-makers • Review of water balance and yields • Design/initiation of continuous review process
WP 2: Updating and Extension of Orange-Senqu Hydrology	Updating of hydrological data, hands-on capacity building in each basin state for generation of reliable hydrological data including the evaluation of national databases,	• Assessment of Required Improvements to the Existing Gauging Networks. • Capacity Development • Extension of Naturalized Flow Data • Review of Existing Data Acquisition Systems, proposals on basin-wide data acquisition and display system.
WP 3: Preparation and development of integrated water resources quality management plan	Build on Phase 1 initial assessment to propose water quality management plan, based on monitoring of agreed water quality variables at selected key points	• Establishment of protocols, institutional requirements for a water quality monitoring programme, data management and reporting. • Development of specifications for a water quality model that interfaces with the systems models. • Capacity building to operate the water quality monitoring system and implement the water quality management plan.
WP 4: Assessment of global climate change	Several objectives leading to assessment of adaptation needs	• Identification of all possible sources of reliable climate data and Global Climate Model downscaling for the Orange-Senqu Basin • Scenario assessment of impacts on soil erosion, evapotranspiration, soil erosion, and livelihoods • Identification of water management adaptation requirements with respect to observed and/or expected impacts on water resources • Assessment of major vulnerabilities and identification of measures for enhancing adaptive capacities
WP 5: Assessment of Environmental Requirements	Several objectives leading to management and monitoring system responsive to environmental flow allocations	• A scoping level assessment of ecological and socio-cultural condition and importance • Delineation into Management Resource Units and selection of EFR sites. • One biophysical survey to collate the relevant data at each EFR site and two measurements at low and high flows for calibration. • Assessment of the Present Ecological State and other scenarios • Assessment of flow requirements, Goods and Services, and monitoring aspects.
WP 6: Water Demand management in irrigation sector	To arrive at recommendations on best management practices in irrigation sector and enhanced productive use of water	• Establish a standard methodology for collecting data on irrigation water applied to crops, water use by crops and crop yields; • Document best management practices for irrigation in the basin and finalise representative, best-practice demonstration sites through stakeholder consultation • Consider and assess various instruments that support water conservation/water demand management.

The other work packages are both self-standing and intended to provide inputs to an improved and more complete water resources simulation model for the whole basin. The model will be enhanced by a more complete hydrology (WP2), better and more complete water quality information (WP3), allowance for climate change impacts and adaptation (WP4), inclusion of environmental flow requirements at key points (WP5) and modelling of scenarios with improved water demand management in the key irrigation sector (WP6).

1.3.3 Background to Work Package 1 and this Working Paper

1.3.3.1 Work Package Objectives

The main objectives for this Work Package are to enlarge and improve the existing models to cover the total Orange River Basin and to capacitate representatives of each of the basin states to set up and use the models effectively.

1.3.3.2 Work Package Activities

- Assessment of the strengths and weaknesses of the existing models
- Extension and expansion of the existing models
- Provision of a clear assessment of any anticipated changes in the yield of each catchment, in a probabilistic manner
- Review the water balance for the Basin, (recording both the demand and supply components);
- Design and initiation of a suitable technical process for a continuous review (at least annually) of the water balance to identify and pre-empt potential future problems;
- Assist representatives from each of the four Basin States to set up the models in each country and ensure that ORASECOM staff in each basin state are able to use the models effectively

1.3.3.3 This Working Paper

This working paper provides feedback on the capacity building process and the setting up of the models in each of the countries. It also outlines the proposed continuous review process.

2 CAPACITY BUILDING PROVIDED

2.1 Introduction

At the time of the Inception Phase it was proposed to capacitate the basin state representatives/experts who would be responsible for the running of the WRYM and WRPM water resources models. The courses were to be presented at a hands-on technical level and the participants would be the people who are actually going to operate the models. Allowance was made to train two representatives from each country

During the course of the project, however, it became clear that it was critically important to ORASECOM that senior-decision makers also be exposed to the models and capacitated. They should be able to understand the principles of how the models work, what input information they need. In addition the training should highlight what results can be generated and how they can can be interpreted and used for both strategic planning and operational planning.

WRP offered to develop and present a customized decision-makers course over two days, in addition to the original week-long expert-level courses. Unfortunately many of the decision-makers were unable to attend the two-day decision-maker course with the result that an additional compressed one-day version was also presented which was well attended.

Expert level training took place in WRP's offices for participants from Lesotho, Botswana and South Africa. Due to the fact that no delegates from Namibia were able to attend the initial week-long course held in South Africa, an additional week-long course was also presented to Namiibian participants in Windhoek.

2.2 Expert Level Capacity Building

2.2.1 Introduction

Two courses were presented:

- Pretoria, 22 – 26 November 2010 attended by Botswana, Lesotho, South Africa and ORASECOM
- Windhoek, 14 – 17 February 2011 attended by Namibia and ORASECOM

Details of those who attended the courses are provided in the attendance register which is included in **Appendix A1**.

2.2.2 Course Contents

The following modules were presented:

- Module 1: The Integrated Orange-Vaal River System
- Module 2: Introduction to Water resources Modeling
- Module 3: Stochastic Streamflow and Yield
- Module 4: Defining a System Network

- Module 5: Defining System Operating Rules
- Module 6: Introduction to the Water Resources Integrated Management System (WRIMS)
- Module 7: Creating a new System Network
- Module 8: Application of the WRIMS
    - Case Study 1: Caledon-Modder System
    - Case Study 2: Polihali Dam
    - Case Study 3: Neckertal Dam

All modules included hands-on practical training sessions. In total, the course included 10 practical exercises covering the following areas:

- Using a basic reservoir model
- Interpreting yield-reliability curves
- Interpreting penalties
- Defining the system network
- Determining historical firm yield
- Determining system operating rules
- Evaluating development options
- Generating yield reliability curve
- Polihali Dam
- Neckertal Dam

The course programme is included in Appendix A1. The course presentations in “handout” format are provided in Appendix A2.

2.2.3 Manuals

Detailed manuals in electronic form (CD) were prepared prior to the training courses and provided to each of the participants. These manuals are also included on the work package CD and from the project website under Work Package 1.

2.2.4 Feedback from Participants

Feedback from the participants was very positive with the usefulness of the courses rated as either 4 or 5 out of 5 by all participants. The feedback forms are included in **Appendix A1**.

Comments and suggestions included the following:

- Course should be longer to include more practical examples
- More of these course will be very useful to include more water managers and decision-makers
- The software is a little complicated and further training would be useful

The need to carry out this type of capacity-building on a regular basis was strongly expressed. Clearly this is essential if each of the basin states is to maintain capacity and

ORASECOM should continue to play a leading role in ensuring that these capacity building courses continue at least annually.

2.3 Decision-maker Level Capacity Building

2.3.1 Introduction

Two courses were presented:

- Pretoria, 29 – 30 November 2010 attended by Botswana, Lesotho, South Africa and ORASECOM
- Pretoria, 25 January attended by Botswana, Lesotho, South Africa and ORASECOM

Namibia was unfortunately not able to send participants to either of the decision-maker courses. Details of those who attended the courses are provided in the attendance register which is included in **Appendix B1**.

2.3.2 Course Contents

The following modules were presented:

- Module 1: The Integrated Orange-Vaal River System
- Module 2: Overview of Water Resource Management
- Module 3: Water Resource Assessment
- Module 4: Water Resource Allocations
- Module 5: Management of Water Resources Systems
- Module 6: Intervention Planning

All modules included group discussion sessions.

The course programme is included in Appendix B1. The course presentations in “handout” format are provided in **Appendix B2.**

2.3.3 Feedback from Participants

Feedback from the participants was very positive with the usefulness of the courses rated as either 4 or 5 out of 5 by all participants. The feedback forms are included in **Appendix A1**.

Comments and suggestions from the two day course included the following:

- More such courses should be arranged in the future
- A high level course should be offered to Permanent Secretaries/Director Generals who are closer to Ministers who ultimately make decisions
- More of these training courses including more senior decision-makers would be good
- More time could be spent on economic (socio-economic) considerations

From the one day course, comments and suggestions included the following:

- Interesting but more time needed
- Overall, very good workshop, may need to programme more frequent training at this level
- Excellent course
- Too much information in a short time, 1.5 days would be better
- The model is highly needed, essential for proper management of Orange-Senqu River basin. It must be endorsed by the four member states as a universal tool for decision-making
- This made the task of designing institutional and governance arrangements easier

The need to carry out this type of capacity-building on a regular basis was expressed as well as the need to bring in even more senior decision-makers

Clearly this is essential if each of the basin states is to maintain capacity and ORASECOM should continue to play a leading role in ensuring that these capacity building courses continue at least annually.

3 SETTING UP OF THE MODELS IN EACH COUNTRY

3.1 Expert Level Capacity Building purposes

The training courses on the Water Resource models included hands-on technical level components. For this purpose it is required to use one or the other water supply system to be defined in the models and analysed as part of the capacity building programme. The Orange River System was selected for this purpose, as all the basin states are familiar with this subsystem or at least with some parts of the sub-system. This sub-system is also part of the final complete Orange-Senqu-Vaal Integrated system model to be delivered to each basin state as a final product from this study.

The most up-to-date data sets for the Orange River sub-system were therefore installed as part of the WRIMS on several PC's or laptop's as required by the different basin states. The software installed as part of the capacity building courses included:

- The latest IMS version of the WRYM
- The WRYM data sets for the whole Orange River System (This includes the Senqu, Upper Orange, complete Riet-Modder, the Lower Orange as well as the Fish in Namibia) The total demand that need to be supplied to the Eastern Cape is imposed on the Orange system as one of the major demand centres. The Eastern Cape sub-system is, however, not modelled in detail as part of this setup. This was the latest WRYM data set updated as part of this study. It was not the final product from this study at the time as some changes still need to be included.
- Only the practical on the Caledon-Modder sub-system included the IMS Visio lay-out at the time.

The Procedure Manual for the Water Resource Models was provided in electronic format to all the attendees at the two courses.

3.2 Final extended and improved WRYM and WRPM data sets

The final water resource models will be installed on MPU's, one per basin state. The software will include:

- The latest IMS version of the WRYM
- The WRYM data sets for the Orange/Senqu/Vaal integrated system will include two main sub-systems:
  - The Vaal River System comprising the whole Vaal Basin but also including the Tugela transfer.
  - The Orange-Senqu System similar to the one installed as part of the training, covering the rest of the Orange-Senqu basin not included in the Vaal River system.
- The complete set of updated natural flow data (hydrology data) for the entire Orange-Senqu basin.

- The final WRYM data sets for both the Vaal and the Orange will include the IMS Visio lay-outs
- The WRPM setup for the complete Orange-Senqu basin will be an integrated system including the total combined Integrated Vaal with the Orange-Senqu system. This means that all the existing sub-systems used to support the Vaal will also be part of this system.
- The latest WRPM Fortran executable as the IMS version of the WRPM is not yet fully operational. This development (inclusion of WRPM in IMS) is being carried out under a separate DWA (RSA) project and is currently in the testing phase of the WRPM IMS, which might only be completed towards the end of 2011.
- For the WRPM data sets the appropriate schematics will be provided in hard copy and in electronic format

The final hydrology and WRYM data sets will, on request, be imported into the already installed WRIMS available on the basin state's PC's and Laptops used during the capacity building courses.

The Procedure Manual for the Water Resource Models will be provided in hard copy and in electronic format to each of the basin states.

3.3 Future updates

The data sets for the WRYM and in particular for the WRPM are continuously improved and updated over time. The WRPM data sets are used on an annual basis for operating analysis carried out for the Integrated Vaal, the Orange River Project (Gariep & Vanderkloof), and the BloemWater sub-system. The most important demands, return flows and infrastructure changes for these sub-systems within the overall Orange-Senqu-Vaal integrated system is therefore updated on an annual basis.

Updates will most probably in future also be made to these models by all the basin states. It will therefore be of utmost importance that all these updates be shared by the basin states and that a fully updated master set be available to all basin states. This most up to date and complete WRYM and WRPM sets for the Orange-Senqu basin should be available from a central office, which is accessible to all basin states**. It is proposed that ORASECOM should be the custodian of the Orange-Senqu Basin models to allow easy access and control over basin wide updates to the models.**

Development on the IMS (WRYM and WRPM) is an ongoing process which is carried out by DWA RSA. Updates of the WRIMS (model without data files) can be obtained free of charge from DWA RSA and should form part of the annual update of the Orange-Senqu basin Models.

4 PROCESS OF CONTINUOUS REVIEW

4.1 Introduction

The WRYM and WRPM models (WRIMS) have been used by the Department of Water Affairs in South Africa for many years now for modelling of the Orange-Senqu and other systems in South Africa. During Phase 2 of the project, experts and decision-makers in the other three basin states were trained on the use of these models in order that they would be more able to discuss basin-wide water resources planning and management issues on an equal footing. This is just the first step towards a process of continuous review jointly involving all four basin states.

If the momentum gained during Phase 2 is maintained, it is essential that a regular review process be put in place and that ORASECOM Secretariat plays a leading role in the coordination of this review, as well as participating in it at the expert level.

During steering committee meetings this issue has been discussed and there is general agreement that the review process is an annual one.

It is proposed that the review includes three components

- Capacity review and needs assessment
- Verification and reviews of updates
- Joint review of water resources in the basin

4.2 Capacity Review and Needs Assessment

As already indicated, the courses presented during phase 2 were only a start. There may be a need to present more advanced training course as well as to repeat the introductory courses for new experts and decision-makers. Every effort should be made to ensure that an acceptable level of capacity is maintained on a continuous basis. For this reason it is proposed that each country submits its training needs to the secretariat early in the year so that training courses can be arranged for immediately prior to the basin water resources review process proposed under **Section 4.3**. In this way the basin water resources review can proceed immediately following this training. DWA (RSA) arranges similar training courses from time to time which can also be utilised for this purpose.

4.2.1 Verification and reviews of Updates

As already indicated in **Section 3**, the data sets for the WRYM and in particular for the WRPM are continuously improved and updated over time. This includes modifications to infrastructure and demands which are already being made by DWA South Africa on a regular basis. As the other basin states get more involved in the process and start to use the model they will also be making changes and modifications in their respective parts of the basin. It will therefore be of utmost importance that all these updates be shared by the basin states and that a fully updated master set be available to all basin states. This most up to date and complete WRYM and WRPM sets for the Orange-Senqu basin should be available from a central office, which is accessible to all basin states. It is proposed that ORASECOM should be the custodian of the Orange-Senqu Basin models to allow easy access and control over basin wide updates to the models. Verification of the updating could be carried out as part of the continuous review process.

Development on the IMS (WRYM and WRPM) is an ongoing process which is carried out by DWA RSA. Updates of the WRIMS (model without data files) can be obtained free of charge from DWA RSA and should form part of the annual update of the Orange-Senqu basin Models

4.3 Basin Water Resources Review

The WRPM will be used to evaluate and update the water balance of the Orange River Basin and the various sub-systems within the basin on an annual basis. Currently this process already includes the Integrated Vaal River system, the Orange River Project and the Bloemwater (Caledon Modder) sub-system. The analysis for these sub-systems are carried out in May each year, as most of the summer runoff had by then entered the storage dams. It is therefore proposed that the basin review process should follow after the changes and updates for the May analysis were completed, which should be early in June each year. The ORASECOM Secretariat should be involved in this process. The necessary model runs should be performed and the results made available prior to the convening of a Review Session. This could take place in any one of the basin States but should be organised by the ORASECOM Secretariat.

Results from the WRPM that will be used as part of this process will typically include the following for the selected major and important water supply systems:

- Storage projections of the major and important storage dams.
- Demand and supply projections
- Possibility of curtailments now and in future by using curtailment plots.
- Flows at key points in the system.
- The time when intervention options is required to maintain the supply to users at the required assurance.
- Evaluation of proposals coming from the member states

4.4 Proposed Process

All these aspects will be presented to and discussed with the basin states representatives during a typically two to three day meeting. The meeting should be attended by both experts and decision-makers from each of the basin states, the ORASECOM Secretariat and the experts contracted to do the model runs prior to the review meeting.

The objective of the review process should be for all states to have a clear understanding of the water resource status for the year ahead, and of the management and operational options that are likely to be considered

5 APPENDICES

Appendix A: Capacity Building for Experts

Appendix A1: Course Programmes, Attendance and Feedback

Appendix A2: Course Material

Appendix B: Capacity Building for Decision-makers

Appendix B1: Course Programmes, Attendance and Feedback

Appendix B2: Course Material

APPENDIX A1:

Workshop Programmes, Attendance Registers and Feedback Forms

Workshop Programmes

ORASECOM Water Resource Modelling Training Course

22 – 26 November 2010

Schedule		Training module
Start time	Duration	
		Day 1
08:30	00:15	**Welcome**
		Module 1: The Integrated Vaal River System
08:45	00:30	1. Description of the Study Area
09:15	00:30	2. Description of the operating rules
09:45	00:15	Tea break
		Module 2: Introduction to Water Resource Modelling
10:00	00:30	1. The Water Resources Planning Processs
10:30	00:30	2. Modelling Water Resources Systems
11:00	00:30	3. Basic modelling principles
11:30	00:30	4. Definition of terms
12:00	00:30	5. Practical 1: Using a basic reservoir model
12:30	00:45	Lunch break
		Module 3: Stochastic Streamflow and Yield
13:15	00:15	1. Background
13:30	00:15	2. Streamflow generation
13:45	00:15	3. Stochastic yield analysis
14:00	00:15	4. Practical 2:Interpreting yield-reliability curves
		Module 4: Defining a system network
14:15	00:15	1. Creating a representative network model
14:30	00:15	2. Basic building blocks
14:45	00:15	3. General data requirements
15:00	00:15	Tea break
		Module 5: Defining System Operating Rules
15:15	00:15	1. Background
15:30	00:30	2. Using "penalties" to define operating rules
16:00	00:30	3. Practical 3: Interpreting penalties
16:30		Close
		Day 2
08:30	00:15	**Welcome: Review of Day 1**
		Module 6: The Integrated Orange Vaal River System (Orange focus)
08:45	01:00	1. Description of the Study Area
09:45	00:20	2. Improvements extensions - ORASECOM Study
10:05	00:25	3. Description of Operating Rules Part 1
10:30	00:15	Tea break
		Module 6: The IOVRS (Orange focus) Continue
10:45	00:25	4. Description of Operating Rules Part 2
11:10	00:45	5. Hydrology used in current models
11:55	00:30	6. System Demands
12:25	00:45	Lunch break
		Module 6: The IOVRS (Orange focus) Continue
13:10	00:30	7. Water resouce Infrastructure
13:40	00:45	8.Annual Opperating Analysis
14:25	00:25	9 Future updates
14:50	00:15	Tea break
15:05	00:15	Discussion
15:20	00:05	Close
	Note:	**Modules 7 to 11 part of the Vaal Training group presentations on hydrology**

Day 3

08:30	00:15	**Welcome: Review of Day 2**
		Module 12: Introduction to the WRIMS
08:45	00:60	Introduction & Background to the WRYM
09:45	00:30	Setting up a study & the hydrology directory
10:15	00:15	Tea break
10:30	02:00	Navigating the user interface: model inputs
12:30	00:45	Lunch break
13:15	00:30	Network diagram
13:45	00:30	Running the model (historics)
14:15	00:45	Viewing results (historics)
15:00	00:15	Tea break
15:15	00:30	Running the model (stochastics)
15:45	00:30	Viewing and Interpreting results (stochastics)
16:15		Close

Day 4

08:30	00:15	**Welcome: Review of Day 3**
		Module 13: Introduction to the WRPM
08:45	00:15	1. Role of the WRPM
09:00	00:15	2. Model Structure
09:15	00:15	3. Modelling approach
09:30	00:15	4. Overview of model results
09:45	00:30	**Module 14: Interpretation of WRPM Results**
10:15	00:15	Tea break
		Module 15: Water Resource Allocation Procedure
10:30	00:15	1. Water User Criteria
10:45	00:30	2. Short-term yield reliability curves
11:15	00:45	3. Allocation and curtailment
12:00	00:30	4. Practical 4: Water resource allocation
12:30	00:45	Lunch break
13:15	00:30	**Module 16: Water Quality Modelling**
		Module 17: Configuration of the WRPM
13:45	00:15	1. General input data requirements
14:00	00:30	2. Overview of WRPM input data files
14:30	00:15	2. Overview of WRPM input data files
14:45	00:15	**Module 18 : Additional Control Features**
15:00	00:15	Tea break
15:15	00:30	**Module 19 : WRPM Plot Programmes**
15:45	00:30	**Module 20 : Basic Applications of the WRPM**
16:15		Close

Day 5

08:30	00:15	**Welcome: Review of Day 4**
		Module 21: Application of the WRIMS
		Case Study 1: Caledon Modder Sub-system
08:45	00:30	1. Background
09:15	01:00	2. Determining historic firm Yield
10:15	00:15	Tea break
		Case Study 1: Caledon Modder Sub-system Continue
10:30	00:30	3. Evaluating system operating rules
11:00	01:00	4. Evaluating development options
12:00	00:30	5. Generating yield reliability curve
12:30	00:45	Lunch break
		Case Study 2: Polihali Dam
13:15	00:20	1. Background
13:35	01:00	2. Practical
14:35	00:15	Tea break
		Module 22: Creating a new system network
14:50	00:30	1. Background
15:20	01:00	2. Practical
16:20		Close

ORASECOM Water Resource Modelling Training Course
Namibia

14 – 17 February 2011

Schedule		Training module
Start time	Duration	
		Day 1
10:00	00:15	**Welcome**
10:15	00:15	**Introduction**
		Module 1: The Integrated Orange/Senqu-Vaal River System
10:30	01:00	1. Description of the Study area
11:30	00:15	2. Improvements extensions - ORASECOM Study
11:45	01:00	3. Description of operating rules
12:45	00:15	4. Group discussion
13:00	00:45	Lunch break
		Module 2: Introduction to Water Resource Modelling
13:45	00:30	1. The water resources planning processs
14:15	00:30	2. Modelling water resources systems
14:45	00:30	3. Basic modelling principles
15:15	00:15	Tea break
15:30	00:30	4. Definition of terms
16:00	00:30	5. Practical 1: Using a basic reservoir model
16:30	00:15	6. Group discussion
16:45		Close
		Day 2
08:30	00:15	**Welcome: Review of Day 1**
		Module 3: Stochastic Streamflow and Yield
08:45	00:15	1. Background
09:00	00:15	2. Streamflow generation
09:15	00:15	3. Stochastic yield analysis
09:30	00:15	4. Practical 2: Interpreting yield-reliability curves
09:45	00:15	Tea break
		Module 4: Defining a System Network
10:00	00:15	1. Creating a representative network model
10:15	00:15	2. Basic building blocks
10:30	00:15	3. General data requirements
		Module 5: Defining System Operating Rules
10:45	00:15	1. Background
11:00	00:30	2. Using "penalties" to define operating rules
11:30	00:30	3. Practical 3: Interpreting penalties
12:00	00:45	Lunch break
		Module 6: Introduction to the WRIMS
12:45	00:60	1. Introduction and background to the WRYM
13:45	00:30	2. Setting up a study and hydrology directory
14:15	00:15	Tea break
14:30	02:00	3. Navigating the user interface: model inputs
16:30	00:30	4. Network diagram
17:00		Close

Day 3

08:30	00:15	**Welcome: Review of Day 2**
		Module 6: (cont.)
08:45	00:30	5. Running the model (historical)
09:15	00:45	6. Viewing results (historical)
10:00	00:15	Tea break
10:15	00:30	7. Running the model (stochastic)
10:45	00:30	8. Viewing and interpreting results (stochastic)
		Module 7: Creating a New System Network
11:15	00:30	1. Background
11:45	01:00	2. Practical 4: Defining the system network
		Module 8: Introduction to the WRPM
12:45	00:15	1. Role of the WRPM
13:00	00:15	2. Model structure
13:15	00:45	Lunch break
14:00	00:15	3. Modelling approach
14:15	00:15	4. Overview of model results
14:30	00:15	5. Group discussion
		Module 9: Application of the WRIMS
		Case Study 1: Caledon-Modder Sub-system
14:45	00:30	1. Background
15:15	00:15	Tea break
15:30	01:00	2. Practical 5: Determining historical firm yield
16:30	00:30	3. Practical 6: Evaluating system operating rules
17:00		Close

Day 4

08:30	00:15	**Welcome: Review of Day 3**
		Module 9: (cont.)
		Case Study 1: Caledon Modder Sub-system (cont.)
08:45	01:00	4. Practical 7: Evaluating development options
09:45	00:30	5. Practical 8: Generating yield reliability curve
10:15	00:15	Tea break
		Case Study 2: Polihali Dam
10:30	00:20	1. Background
10:50	01:00	2. Practical 9: Polihali Dam
		Case Study 3: Neckartal Dam
11:50	00:15	1. Background
12:05	00:45	2. Practical 10: Neckartal Dam
12:50	00:15	Group discussion
13:05	00:45	Lunch break
13:50		Close

Attendance Registers

Attendance Register

Course:	Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan Training on Water Resources Yield Model - Orange		
Presenters:	Manie Maré & Gerald de Jager		
Venue:	Namibia	**Date:**	14-17 February 2011

Present

Name	Position	Organization	Telephone	Cell phone	E-mail
Unandapo Lazarus	Assistant Hydrologist	MAWF	061 208 7026	+264 81 28 00070	penta4liz@gmail.com
GUIDO VAN LANGENHOVE	HEAD. HYDROLOGY	MAWF	061 2087257	081 1244180	guidovanlongenhove@yahoo.fr
RAPULE Pule	WATER RESOURCES SPECIALIST	ORASECOM	+27126430934	+27822304669	rapule.pule@gmail.com
Pauline Mufeti	Hydrologist-chief	Mawf	061-208 7191	+264 812500094	mufetip@mawf.gov.na pmufeti@yahoo.com
WALTO METZLER	HYDROLOGIST - SNR	MAWF - HYDROLOGY	061-2087253	081-6881391	metzlerw@mawf.gov.na metzlerw@yahoo.com

Last updated:

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Attendance Register

Course:	Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan Training on Water Resources Yield Model - Orange Mr. [illegible] – Decision Maker!
Presenters:	Pieter van Rooyen, Manie Maré, Susan ~~Swart, Caryn Seago, Bennie Haasbroek~~ Ronnie McKenzie
Venue:	WRP(Pty) Ltd, Pretoria Office
Date:	22-26 November 2010 22.[illegible]

Present

Name	Position	Organization	Telephone	Cell phone	E-mail
LESHORORO 'NENA	HYDROLOGIST	DWA - LESOTHO	+266 22317991	+26658444483	nena@dwa.gov.ls
Molefi Pule	HYDROLOGIST	DWA - LESOTHO	+266 22325983	+266 63283682	molefi.pule@yahoo.com

Feedback Forms

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange

14 - 17 February 2011
Namibia

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): GUIDO VAN LANGENHOVE

Course: WRYM

Date: 17/02/2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	[✓ 2]	3	4	5
Food Quality	1	[✓ 2]	3	4	5
Event speakers					
• Manie Maré	1	2	3	[✓ 4]	5
• Gerald de Jager	1	2	3	4	[✓ 5]
Quality of information	1	2	3	[✓ 4]	5
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	[✓ 4]	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

SHOULD BE LONGER TO INCLUDE MORE PRACTICALS

A Miya
Group Company

Thank you for your feedback

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange

14 - 17 February 2011
Namibia

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): WALTO C. METZLER

Course: WRYM

Date: 14 – 17 FEBRUARY 2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Manie Maré	1	2	3	4	[✓ 5]
• Gerald de Jager	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	[✓ 4]	5
Meeting your needs	1	2	3	[✓ 4]	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

Looking forward to update and work on Neckartal and Lower Orange Hydrology.

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Thank you for your feedback

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange

14 - 17 February 2011
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Australian Government Aid Program

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): ______________________

Course: ORASECOM WATER RESOURCE MODELLING

Date: 14-17 FEBRUARY 2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	[✓ 3]	4	5
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Manie Maré	1	2	3	[✓ 4]	5
• Gerald de Jager	1	2	3	[✓ 4]	5
Quality of information	1	2	3	[✓ 4]	5
Usefulness	1	2	3	[✓ 4]	5
Meeting your needs	1	2	3	[✓ 4]	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

MORE OF THESE WILL BE VERY USEFUL TO INCLUDE MORE WATER MANAGERS & DECISION MAKERS

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Thank you for your feedback

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Training on Water Resources Yield Model -Orange

14 - 17 February 2011
Namibia

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): Unandapo Lazarus

Course: Water Resources yield Model - Orange

Date: 14 - 17 february 2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	5	1	2	3	4	5
Food Quality	5	1	2	3	4	5
Event speakers						
• Manie Maré	5	1	2	3	4	[✓ 5]
• Gerald de Jager	5	1	2	3	4	5
Quality of information	5	1	2	3	4	5
Usefulness	4	1	2	3	4	5
Meeting your needs	3	1	2	3	4	5
Overall quality of the workshop	4	1	2	3	4	5

Any comments or suggestions:

The software its alittle complicated but thats only maybe due to the fact that all this is new to me

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Thank you for your feedback

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Training on Water Resources Yield Model -Orange

14 - 17 February 2011
Namibia

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): ____________________

Course: WRYM

Date: 17 February 2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue Good	1	2	3	[✓ 4]	5
Food Quality Good	1	2	3	[✓ 4]	5
Event speakers					
• Manie Maré	1	2	3	4	[✓ 5]
• Gerald de Jager	1	2	3	[✓ 4]	5
Quality of information	1	2	[✓ 3]	4	5
Usefulness	1	2	3	[✓ 4]	5
Meeting your needs	1	2	[✓ 3]	4	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

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Thank you for your feedback

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APPENDIX A2:

Course Presentations

Training and Technology Transfer Workshop

14 & 17 February 2011

Welcome and introduction

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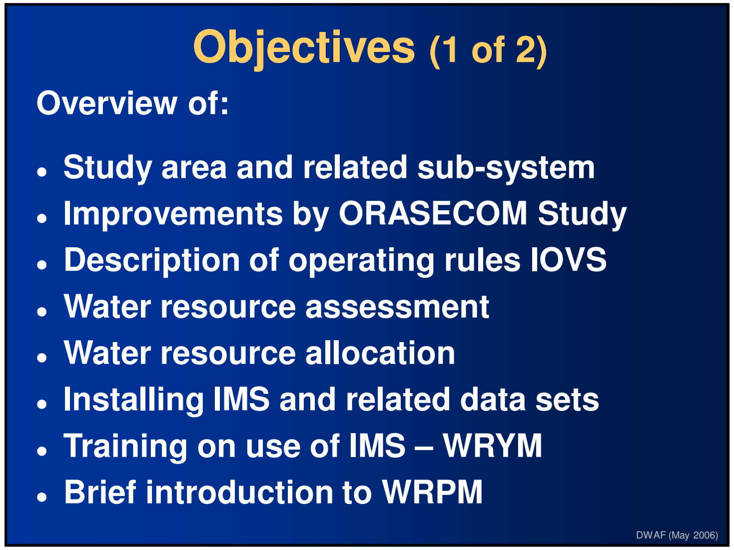
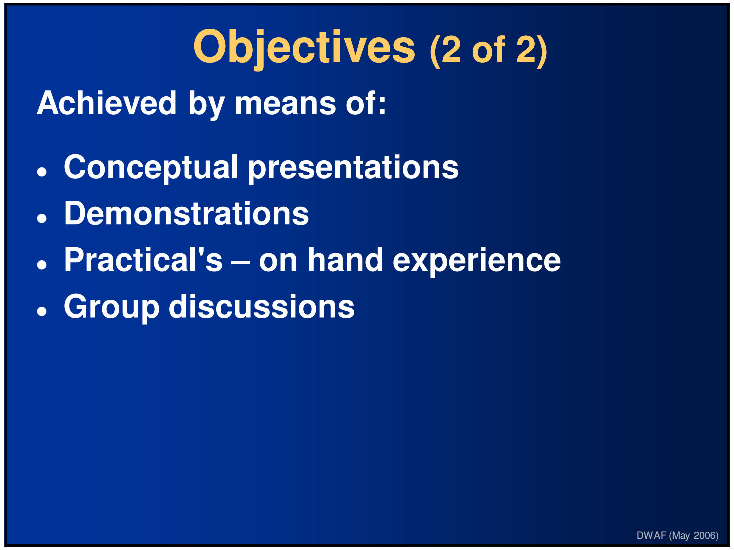


Objectives (1 of 2)

Overview of:

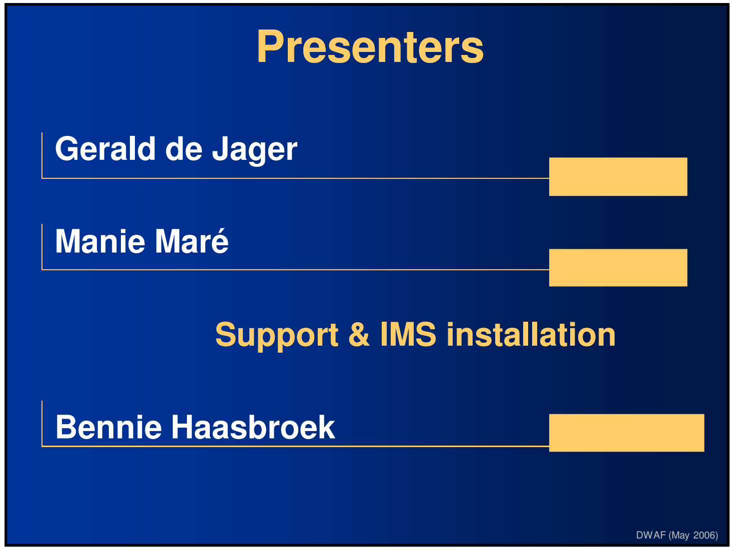
- Study area and related sub-system
- Improvements by ORASECOM Study
- Description of operating rules IOVS
- Water resource assessment
- Water resource allocation
- Installing IMS and related data sets
- Training on use of IMS – WRYM
- Brief introduction to WRPM



Objectives (2 of 2)

Achieved by means of:

- Conceptual presentations
- Demonstrations
- Practical's – on hand experience
- Group discussions



Presenters

Gerald de Jager

Manie Maré

Support & IMS installation

Bennie Haasbroek

Training and Technology
Transfer Workshop

14 & 17 February 2011

End of module

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan &
Vaal River System Annual Operating Analysis 2010-2012

14 - 17 February 2011

Water Resource Simulation Model Development, Verification & Application

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Introduction (1 of 2)

- Development Suite of WRSM mid 1980's
  - Water Resource Development planning
  - Water Resource Operations planning
- Models & related analytical techniques were instrumental in making
  - Optimal decisions large capital projects
  - Maximising benefits through system operational analyses

Introduction (2 of 2)

- Scientific foundation analysis techniques embedded in models
  - Reviewed by external specialists National & International
  - Tested and evaluated in various water resource studies subjected to external reviewers
  - Several technical papers – local & international symposia and technical publications

Description Modelling System

- Consists of suit of analytical tools
  - Hydrological data preparation software, rainfall runoff simulation model, water quality modules and stochastic time series generation procedures
  - WRYM to determine long and short-term yield characteristics of water resource
  - WRPM the main decision support system

WRYM & WRPM (1 of 2)

- Consists of four main modules
  - Main simulation engine – network solver
    a) defines system as network of reservoirs, rivers conveyance infrastructure abstractions
    b) Implementing operating rules by means of data entries
  - Rigorous stochastic streamflow generation module
  - Drought curtailment algorithm (WRPM only)
  - Water Quality module (WRPM only)

WRYM & WRPM (2 of 2)

- Integrating various interdependent Water Resource management aspects
  - Inter-basin transfer rules for major conveyances Eastern sub-system, Thukela-Vaal, LHWP etc.
  - Increasing water requirements & return flows multiple users throughout IOVS system
  - Hydro-power requirements & related operating rules taking into account other users & envirmt
  - Commissioning characteristics new infrastruct Filling of Polihali Dam and effect on the sub-sequent risk of supply from Vaal and Orange

Verification Analysis Techniques and Modelling System (1 of 2)

- Pegram (1983) Providing an overview of the stochastic hydrology methodology
- DWAF (1986) Report presenting details of the multisite stochastic model – Vaal River System
- McKenzie & Allan (1990) Illustrates the application of the risk based analysis methods – Vaal System
- Pegram & McKenzie (1991) Paper describing the "Synthetic streamflow generation in VRS study"
- O'Connet et al.(1991) Paper on "Multisite synthetic streamflow modelling in a semi arid region

Verification Analysis Techniques and Modelling System (2 of 2)

- Van Niekerk & Basson (1993) Paper describing the application of probabilistic based management
- Basson et al. (1994) Book on "Probabilistic management of Water Resources and Hydropower Systems"
- DWAF (2008) Procedural Manual for the Water Resources Simulation Model (WRSM)
- DWAF (1999) Main Report of the Orange River Development Project Replanning Study reviewed by a panel of specialists

Application History of Model in Vaal & Orange River System (1 of 3)

- IVRS WRPM in use since 1989 providing WR decision support info for development & operational planning by RSA DWA
- WRPM configured for Orange River System in 1993 as part of Orange River System Analysis study
- Over past 2 decades models were refined & updated to represent physical system as realistically as possible
- In 2004 the Orange System Model & the IVRS Model was combined into one large integrated system

Application History of Model in Vaal & Orange River System (2 of 3)

- IVRS WRPM in use since 1989 providing WR decision support info for development & operational planning by RSA DWA
- WRPM configured for Orange River System in 1993 as part of Orange River System Analysis study
- Over past 2 decades models were refined & updated to represent physical system as realistically as possible
- In 2004 the Orange System Model & the IVRS Model was combined into one large integrated system

Application History of Model in Vaal & Orange River System (3 of 3)

- DWA 2009 Water for Growth Development Framework – Based on comprehensive investigations of all major WR systems in SA. - Water availability & supply info were determined by simulation models
- Phase II of ORASECOM WR Management Plan study .
    - Models will be updated extended & refined
    - Training provided for operators & decision makers in basin states
    - Copies of final updated model provided to all basin states

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan &
Vaal River System Annual Operating Analysis 2010-2012

End

ORASECOM
Water Resources Training
MODULE 1a

14 -17 February 2011

VAAL & ORANGE/SENQU RIVER BASIN

STUDY AREA DESCRIPTION

-

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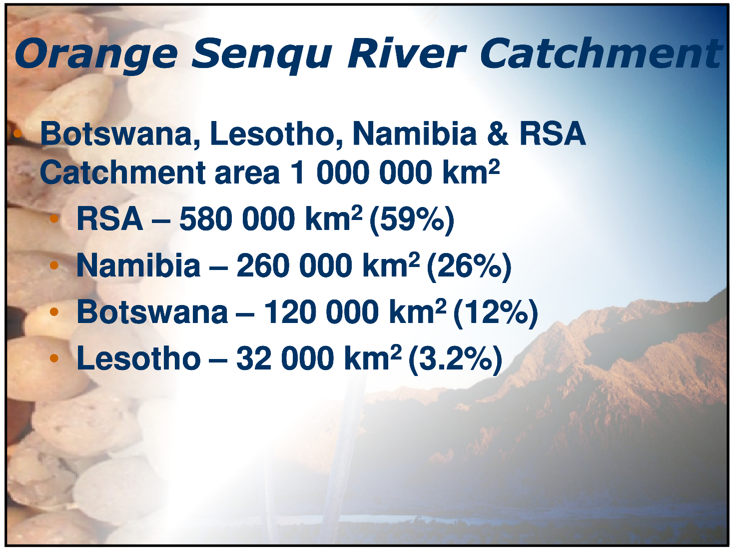
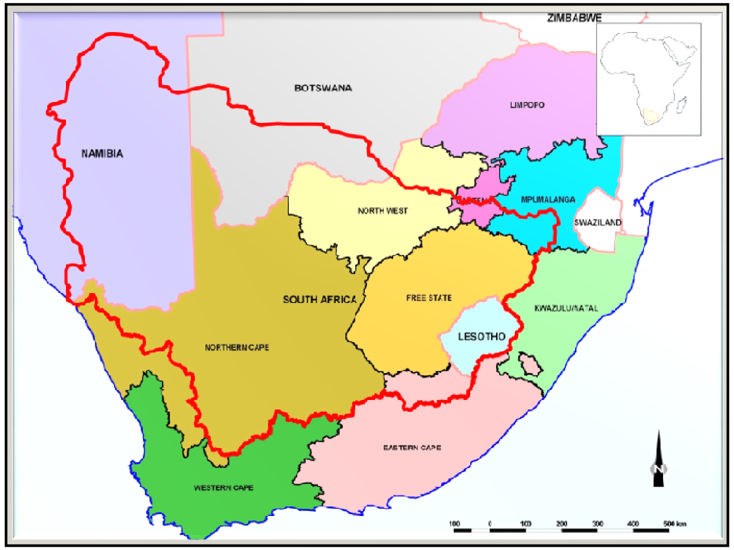
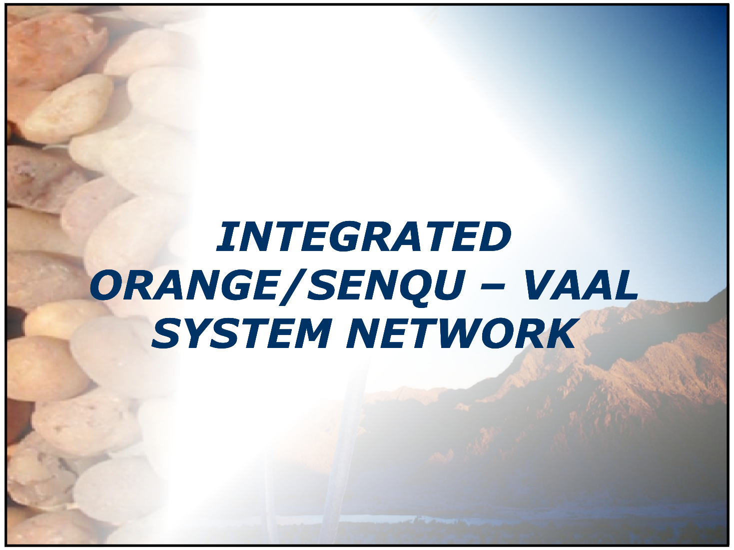


Orange Senqu River Catchment

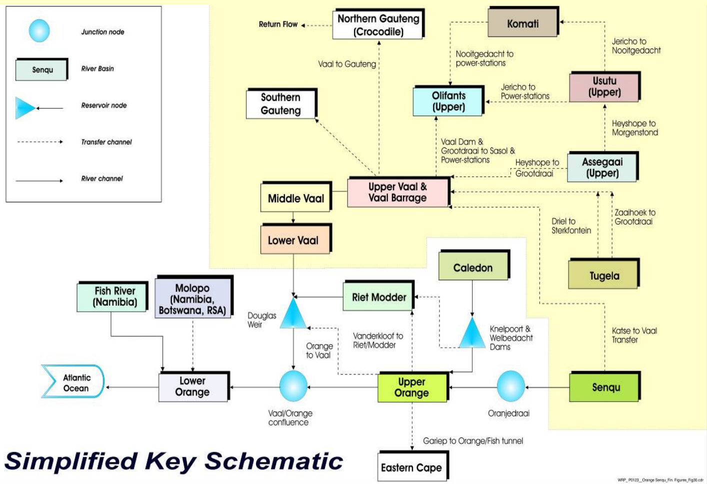
- Botswana, Lesotho, Namibia & RSA Catchment area 1 000 000 km^2
  - RSA – 580 000 km^2 (59%)
  - Namibia – 260 000 km^2 (26%)
  - Botswana – 120 000 km^2 (12%)
  - Lesotho – 32 000 km^2 (3.2%)



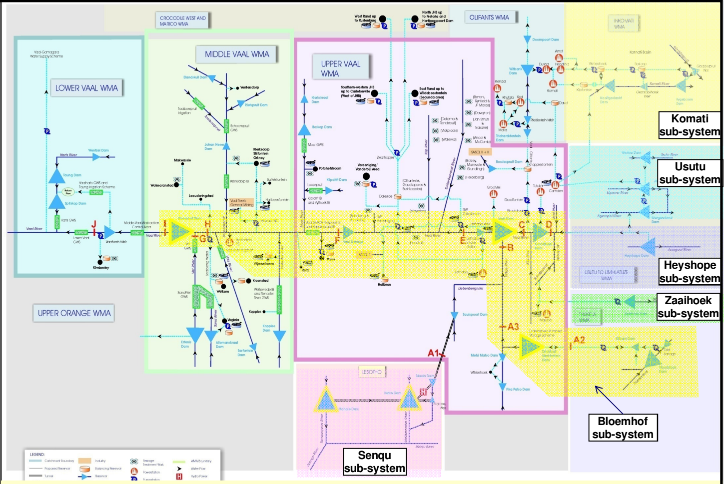


INTEGRATED ORANGE/SENQU – VAAL SYSTEM NETWORK

Integrated Orange /Vaal system



Simplified Key Schematic



Integrated Vaal system

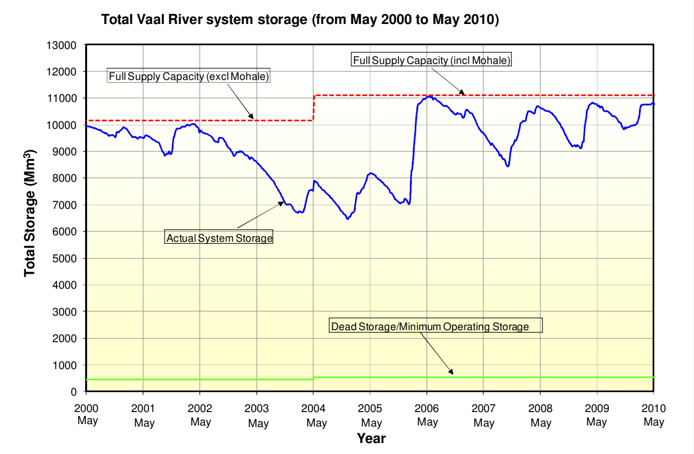
IVRS Major Reservoirs

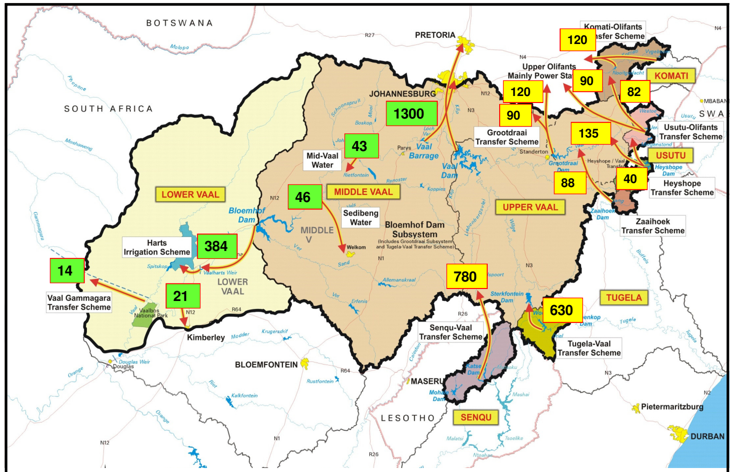
Catchment	Dam Name	Gross Area (km²)	Natural MAR (&) (million m³/a)	FSC ($) (million m³)	FSC as % of Total System Storage
Komati	Nooitgedacht	1 588	66	78	0.7
	Vygeboom	3 132	194	83	0.8
Usutu	Morgenstond	548	56	101	0.9
	Westoe	533	44	61	0.5
	Jericho	219	24	60	0.5
Assegaai	Heyshope	1 120	129	453	4.1
Buffalo	Zaaihoek	622	100	185	1.7
Thukela	Woodstock	1 171	433	373	3.4
Vaal	Grootdraai	7 995	458	350	3.2
	Sterkfontein	195	18	2 617	23.6
	Vaal	38 638	1 977	2 610	23.5
	Bloemhof	108 125	3 315	1 240	11.2
Senqu	Katse	1 867	552	1 950	17.6
	Mohale	938	305	947	8.5
Total :				11 109	100.0

Note: (&) : MAR = Mean Annual Runoff

($) : FSC = Full Supply Capacity

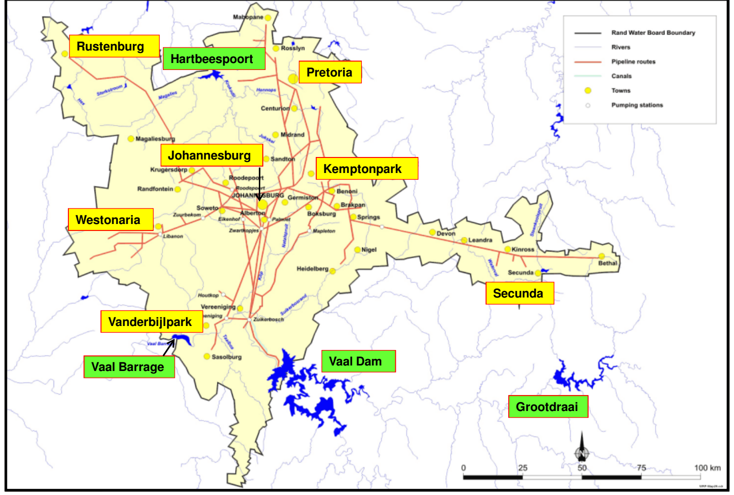
Total System Storage Trajectory





Integrated VaaL System Transfers 2007/08 (million m³/a)

Rand Water Supply Area



IVRS Demand Projection

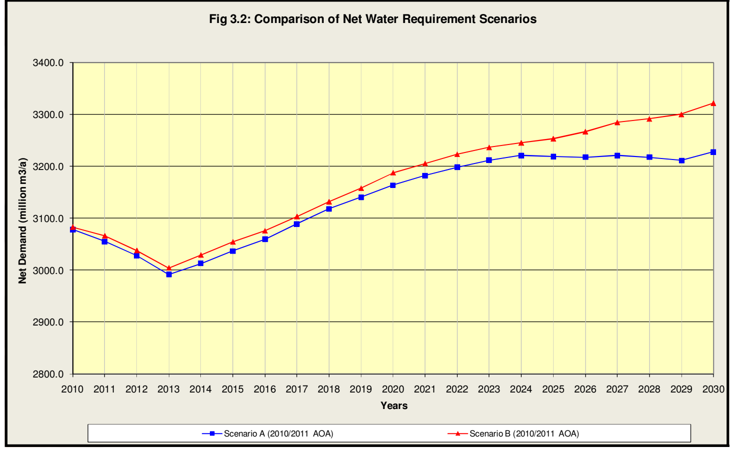
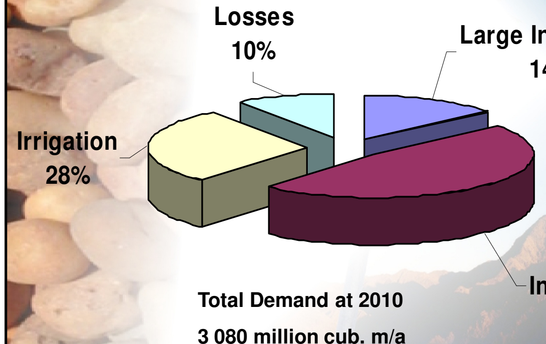


Fig 3.2: Comparison of Net Water Requirement Scenarios

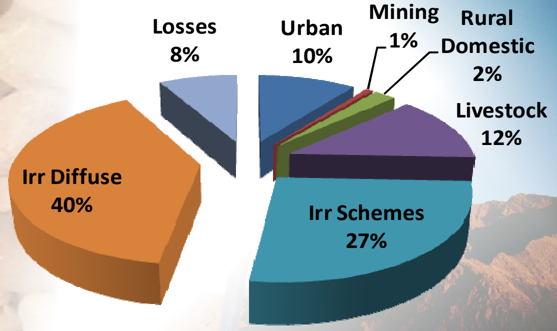
IVRS Demand Distribution



Total Demand at 2010

3 080 million cub. m/a

Vaal Small sub-systems Demand distribution



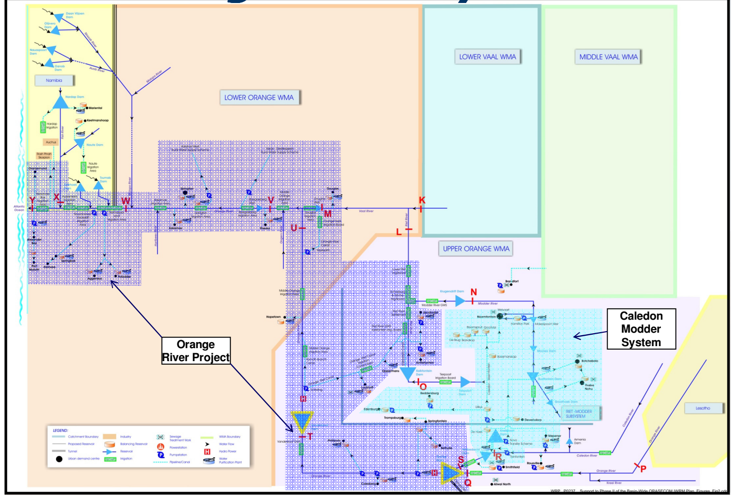
Vaal Small Sub-systems
2010 demand 880 million m^3/a

Vaal River Confluence and Vaal Douglas


© R.McKenzie

ORANGE RIVER SYSTEM NETWORK

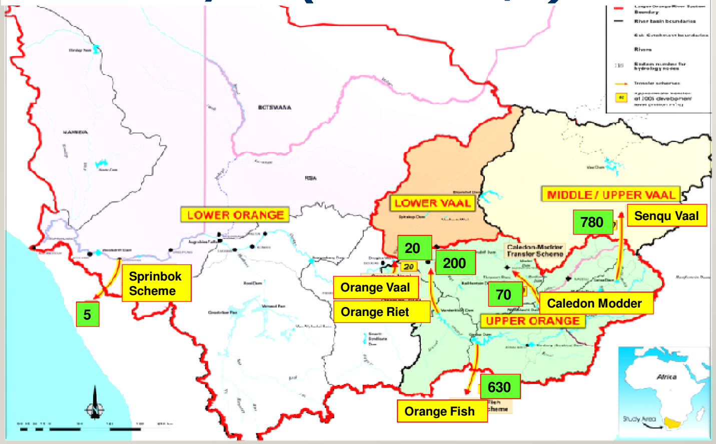
Orange River System



Orange River System

- Orange River System sub-divided into 3 main sub-systems and several small sub-systems:
  - 1 Lesotho Highlands (Katse & Mohale)
  - 2 Caledon Modder (Welbedacht, Knellpoort, Rustfontein, Mockes & Groothoek dams)
  - 3 Orange River Project (Gariep & Vanderkloof dams)

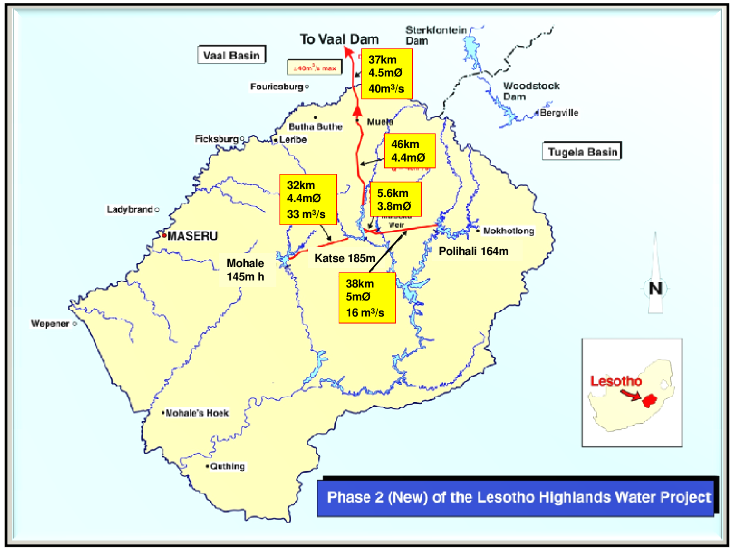
Orange System Transfers 2005/06 (million m³/a)



Lesotho Highlands Water Project

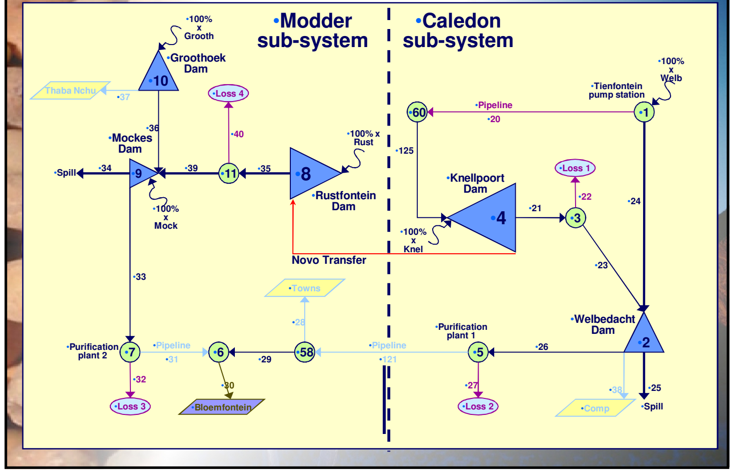
LHWP Tunnel

Photo DWAF

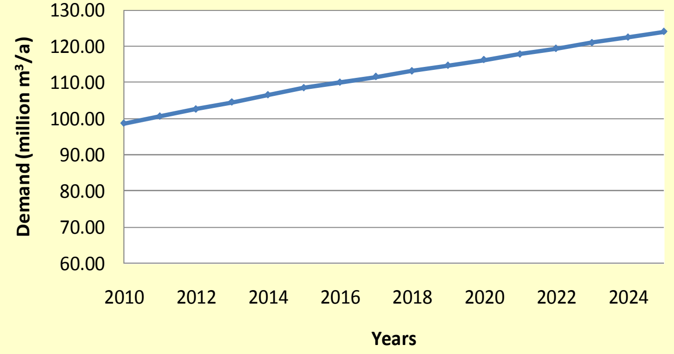


Phase 2 (New) of the Lesotho Highlands Water Project

Caledon Modder sub-system



BloemWater Demand Projection



Orange River Project (1 of 4)

Orange River Project (ORP):

Total system yield ± 3 300 mcm/a

Current surplus ± 100 mcm/a

- + Gariep Dam storage cap 5 340 mcm
- + Vanderkloof Dam storage cap 3 190 mcm
  - Combined storage 8 530 mcm

Orange River Project (2 of 4)

- Main demands upstream of Vaal confluence
  - Hydro-power generation at both dams 2200 mcm/a Gariep – 2100 mcm/a Vdklf
  - Orange Fish Transfer Scheme 650 mcm/a
  - Vanderkloof Canals Scheme 330 mcm/a
  - Orange Vaal Transfer Scheme 140 mcm/a
  - Abstractions directly from river:
    - Irr & Towns

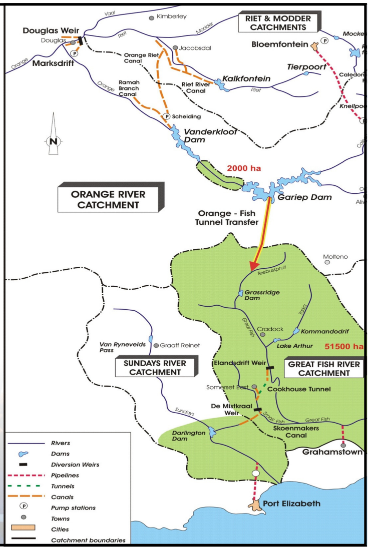
Orange River Project (3 of 4)

- Main Rural/Urban demands Lower Orange
  - Karos-Geelkoppen Rural WS Scheme
  - Kalahari-West Rural WS Scheme
  - Pelladrift WS Scheme
  - Springbok Regional WS Scheme
  - Urban, Industrial & Mining – Prieska, Upington, Alexander Bay, Oranjemund, Rosh Pinah, Noord Oewer, etc.

Orange River Project (4 of 4)

- Main irrigation Schemes Lower Orange
  - Boegoeberg Scheme
  - Upington Scheme
  - Kakamas Scheme
  - Onseepkans
  - Vioolsdrift
  - Noordoewer & Aussenkehr
  - Irrigation abstractions directly from river

ORS Eastern Cape Demand Centres



Orange Fish Tunnel

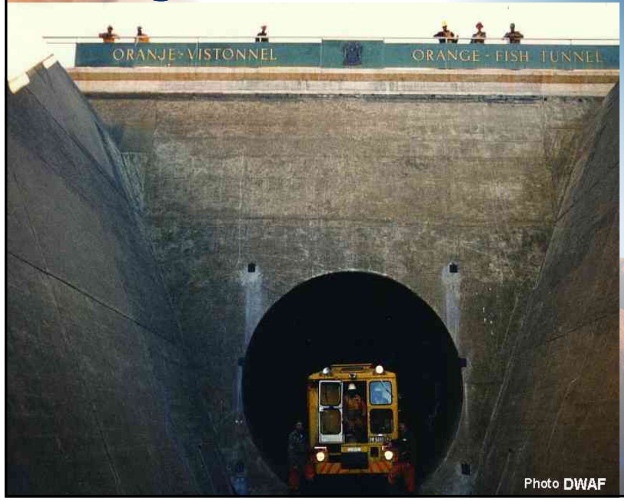
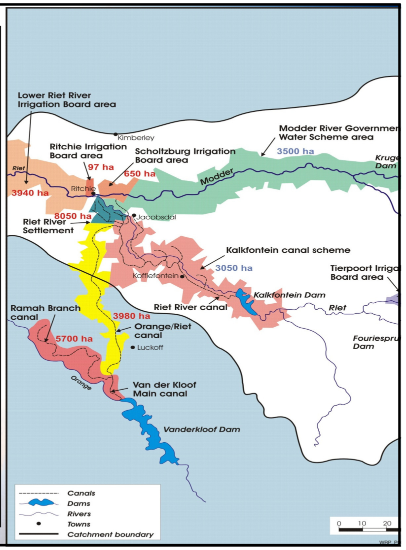
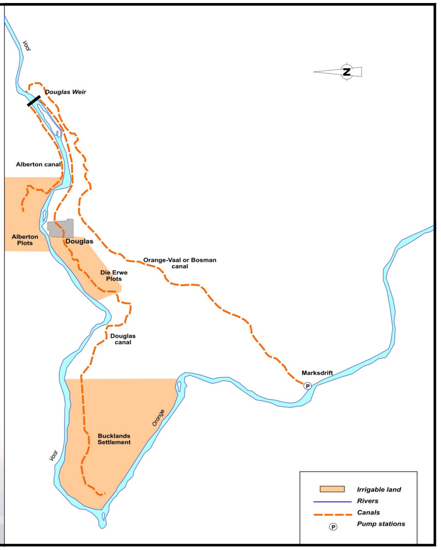


Photo DWAF

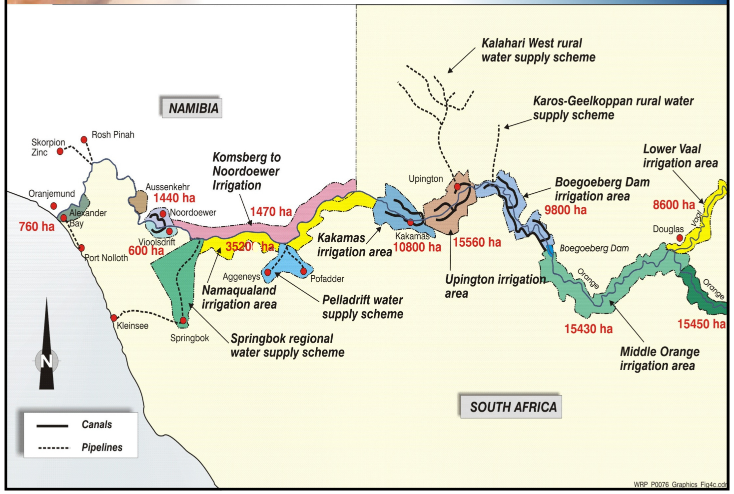
ORS Riet-Modder Demand Centres

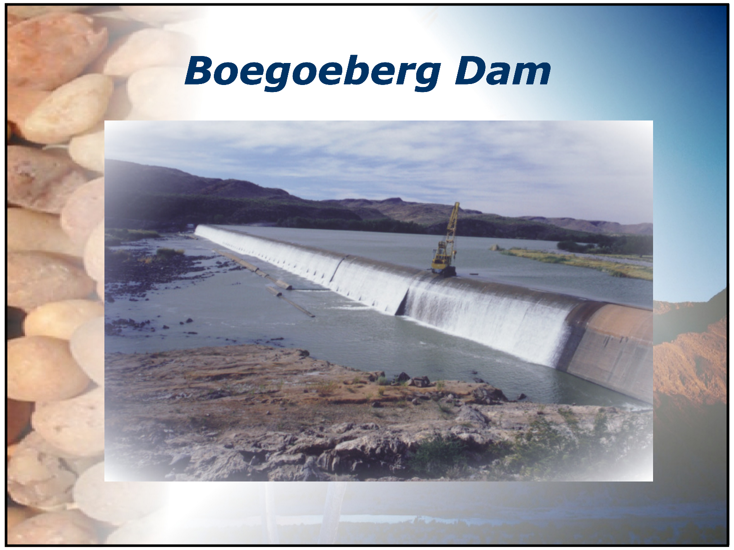


Orange Vaal Transfer Scheme

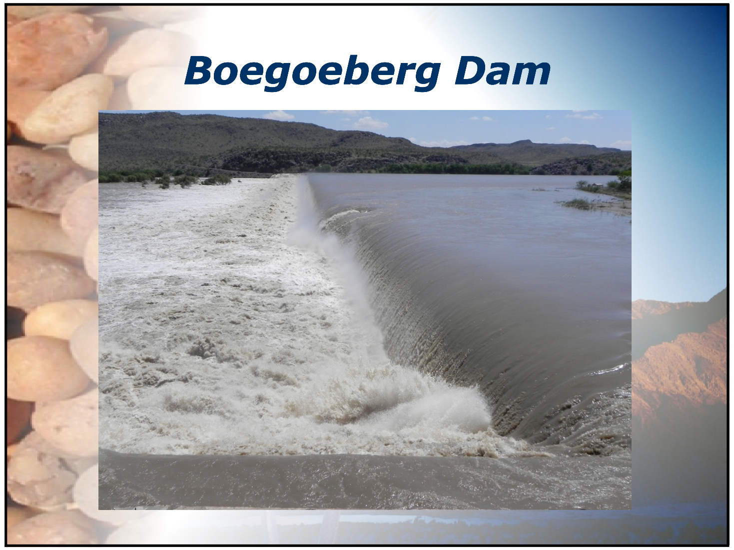


Lower Orange Demand Centres





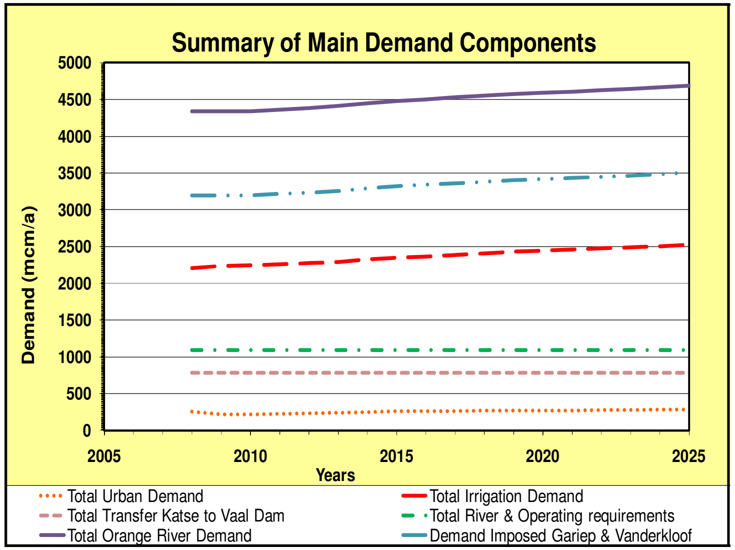
Boegoeberg Dam



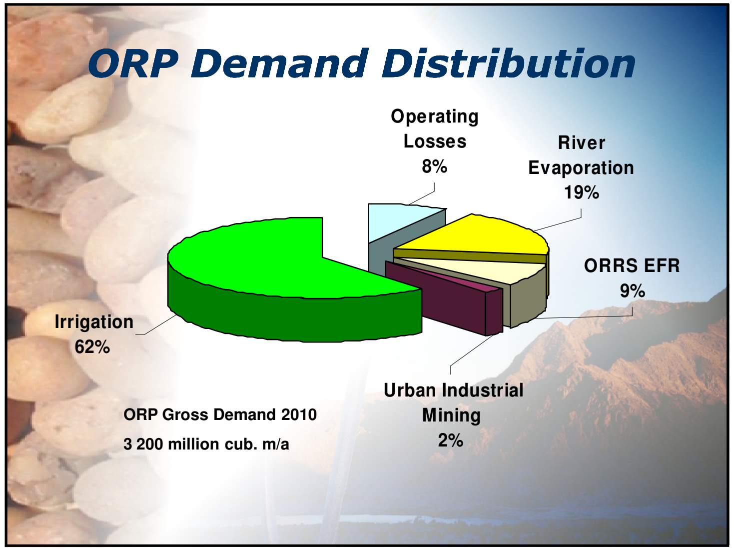
Boegoeberg Dam

Augrabies Falls

© R.McKenzie



Summary of Main Demand Components

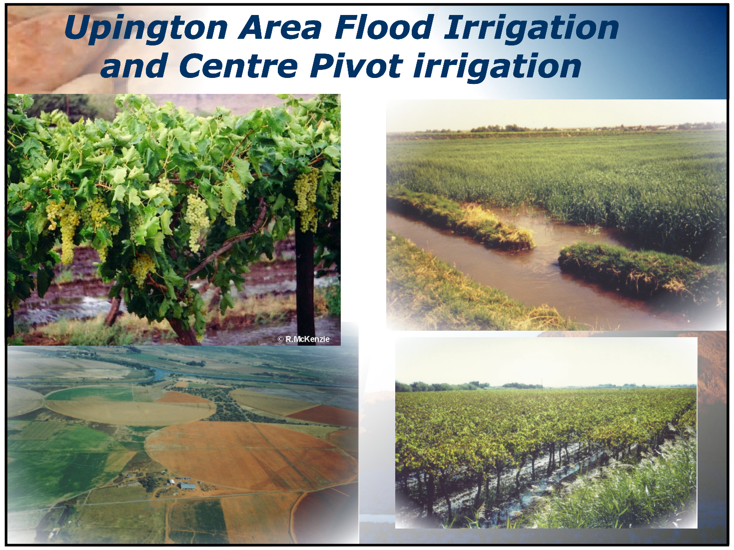


ORP Demand Distribution

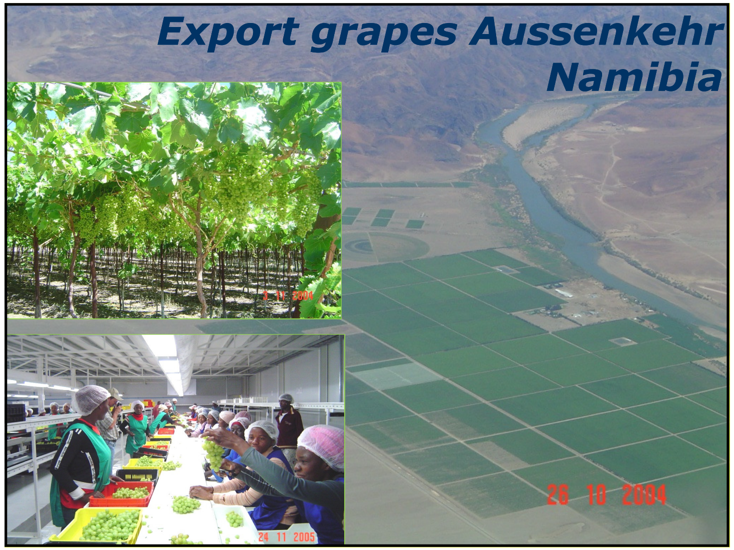
ORP Gross Demand 2010

3 200 million cub. m/a

Richtersveld Riparian Vegetation

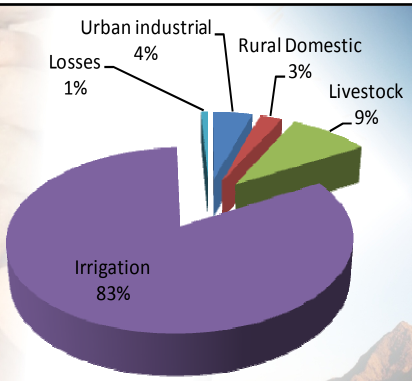


Upington Area Flood Irrigation and Centre Pivot irrigation



Export grapes Aussenkehr Namibia

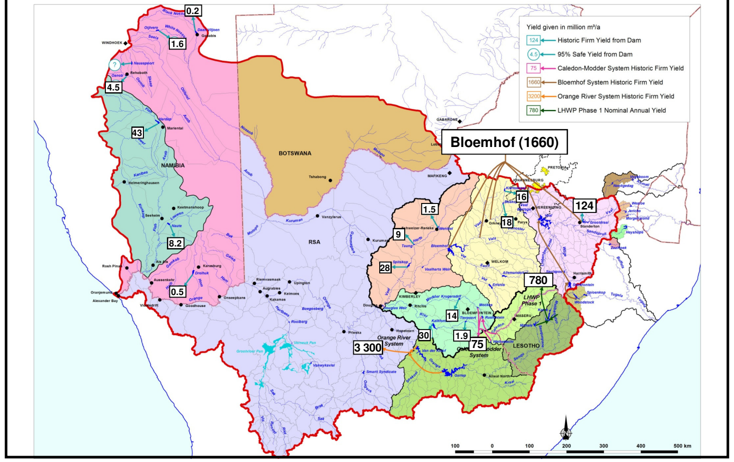
Orange River Mouth and Alluvial Diamond Mines



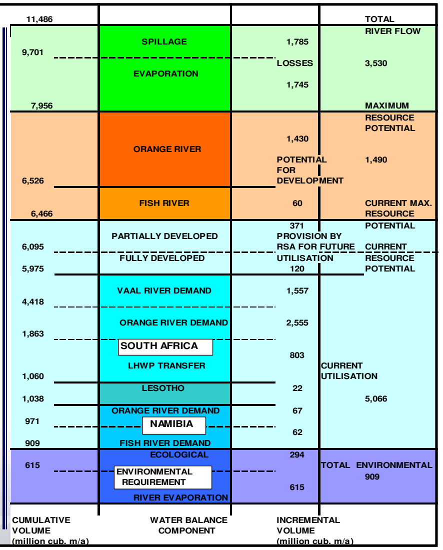
Orange Small sub-systems Demand distribution

2010 490 million m^3/a

YIELD SUB-SYSTEMS (mcm/a)



Preliminary ORS Water balance



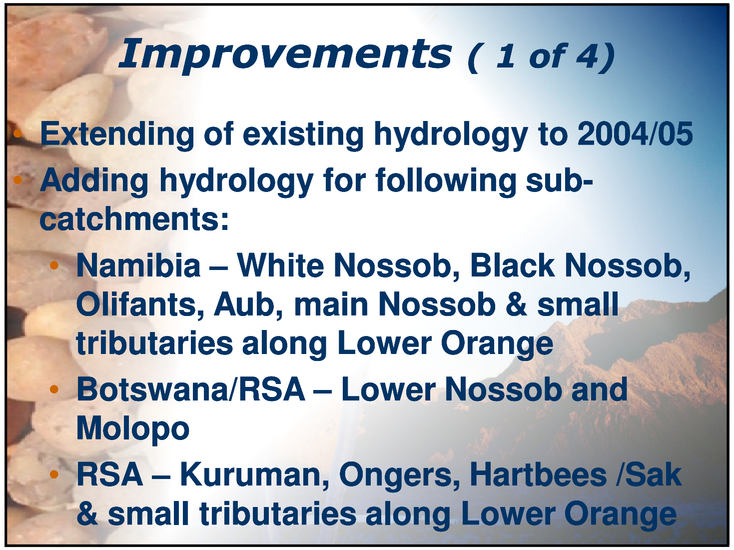
Thank You

ORASECOM
Water Resources Training
MODULE 1b

14-17 February 2011

ORANGE/SENQU RIVER BASIN
IMPROVEMENTS ADDED

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program
wrp A Miya Group Company



Improvements (1 of 4)

- Extending of existing hydrology to 2004/05
- Adding hydrology for following sub-catchments:
  - Namibia – White Nossob, Black Nossob, Olifants, Aub, main Nossob & small tributaries along Lower Orange
  - Botswana/RSA – Lower Nossob and Molopo
  - RSA – Kuruman, Ongers, Hartbees /Sak & small tributaries along Lower Orange

Improvements (2 of 4)

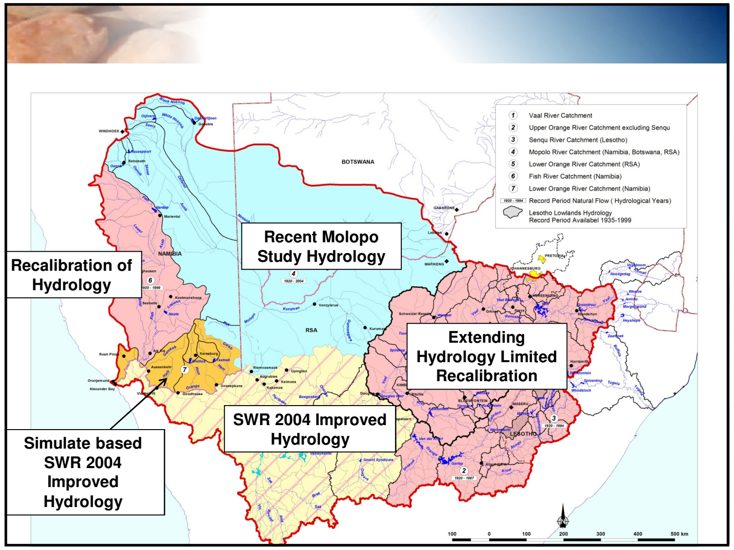
- Re-calibration of hydrology – Caledon, Upper Orange, Fish River Namibia
- Adding hydrology for following sub-catchments:
- Inclusion of Lesotho Lowlands Identified Schemes – Hlotse, Hololo, Makhaleng & Metolong Dam
- Updated hydrology for Usutu & Komati sub-systems – Obtained from two separate studies

Improvements (3 of 4)

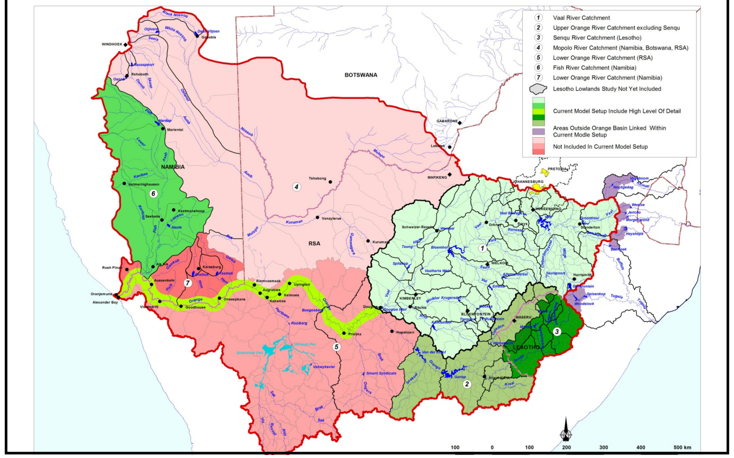
- Molopo sub-system details:
  - RSA – Lotlamoreng, Modimolo & Disaneng dams also Kuruman, Molopo eye & others
  - Namibia – Otjivero, Daan Viljoen, Tilda Viljoen, Nauaspoort & Oanob dams
- Ongers sub-system – Smartt Syndicate Dam
- Sak Hartbees sub-system – Rooiberg, Modderpoort & Vanwyksvlei dams
- Lower Orange Namibia - Dreihuk

Improvements (4 of 4)

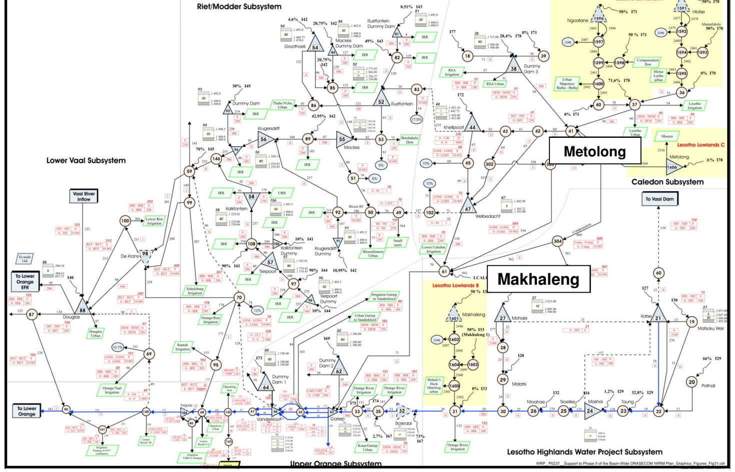
- Demand & demand projections:
  - Latest from Annual operating analysis IVRS & Orange System
  - Towns – All town study projections
  - Updated irrigation data from ORASECOM Irrigation task



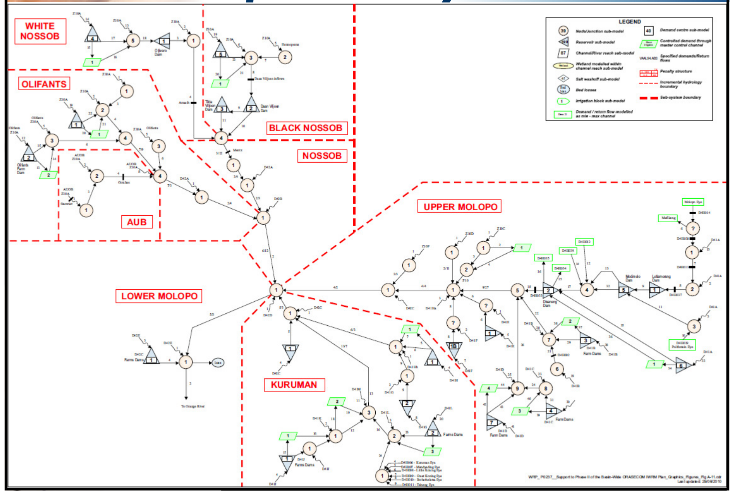
Area covered by WRYM/WRPM



Upper Orange Lesotho



Molopo sub-system



Thank You

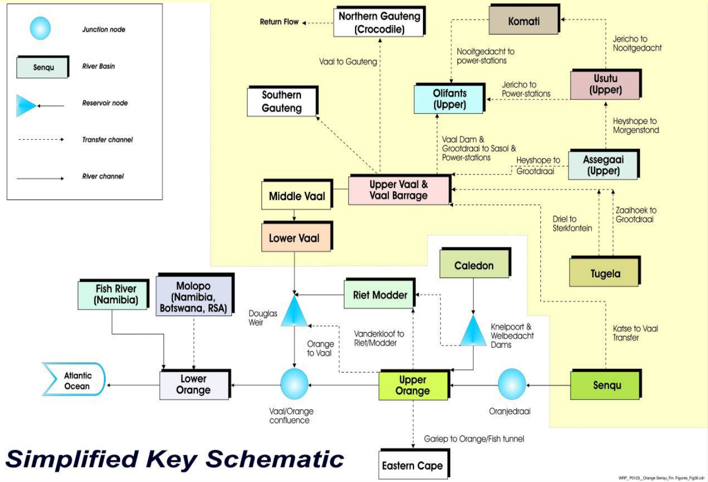
ORASECOM
Water Resources Training
MODULE 1c

14 -17 February 2011

VAAL & ORANGE/SENQU RIVER BASIN
OPERATING RULES

Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program
wrp A Miya Group Company

Integrated Orange /Vaal system

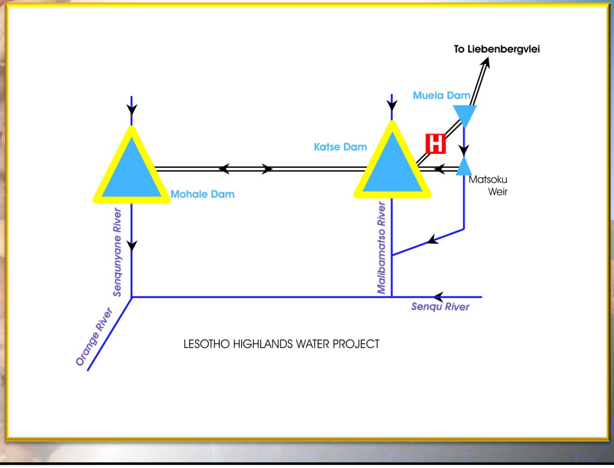


Simplified Key Schematic

Orange River System

- Orange River System sub-divided into 3 main sub-systems and several small sub-systems:
  - 1 Lesotho Highlands (Katse & Mohale)
  - 2 Caledon Modder (Welbedacht, Knellpoort, Rustfontein, Mockes & Groothoek dams)
  - 3 Orange River Project (Gariep & Vanderkloof dams)

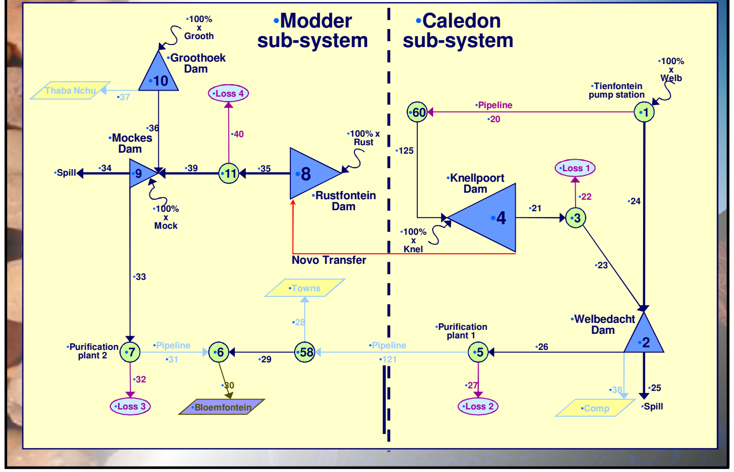
Lesotho Highlands Water Project



LHWP Operating Rules

- Releases to RSA based on agreed schedule phased in over time. Reached the maximum transfer volume 2009 – 780 mcm/a
- No releases to support downstream dams
- IFR releases from Mohale and Katse

Caledon Modder sub-system

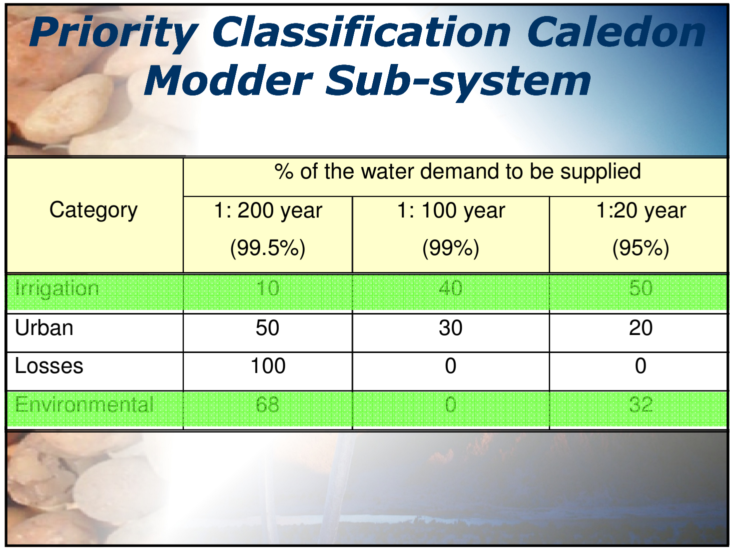


Caledon Modder Operating Principals (1 of 2)

- Maintain Assurance of Supply
  - Primary objective of the operation of CMS is to maintain the assurance of supply to users
- Restriction of Demands
  - The operation of the CMS is based on the principle that demands are restricted during severe drought

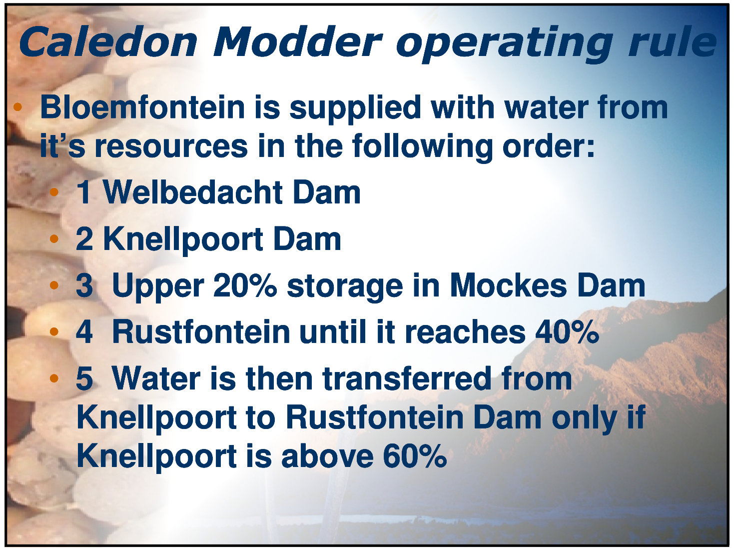
Caledon Modder Operating Principals (2 of 2)

- Restriction of Demands
  - Objective is to reduce supply to less essential use to protect the assurance of supply for more essential use
  - The basis on which restrictions are implemented is defined by means of a user priority classification definition



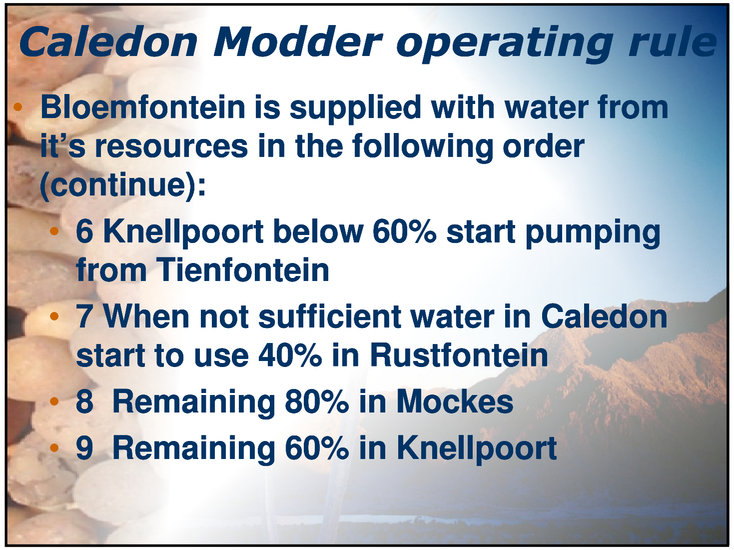
Priority Classification Caledon Modder Sub-system

Category	% of the water demand to be supplied		
	1: 200 year (99.5%)	1: 100 year (99%)	1:20 year (95%)
Irrigation	10	40	50
Urban	50	30	20
Losses	100	0	0
Environmental	68	0	32



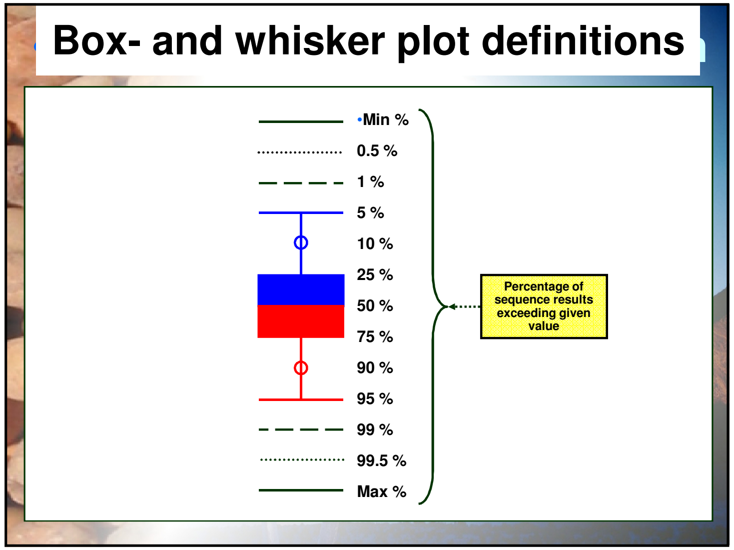
Caledon Modder operating rule

- Bloemfontein is supplied with water from it's resources in the following order:
  - 1 Welbedacht Dam
  - 2 Knellpoort Dam
  - 3 Upper 20% storage in Mockes Dam
  - 4 Rustfontein until it reaches 40%
  - 5 Water is then transferred from Knellpoort to Rustfontein Dam only if Knellpoort is above 60%

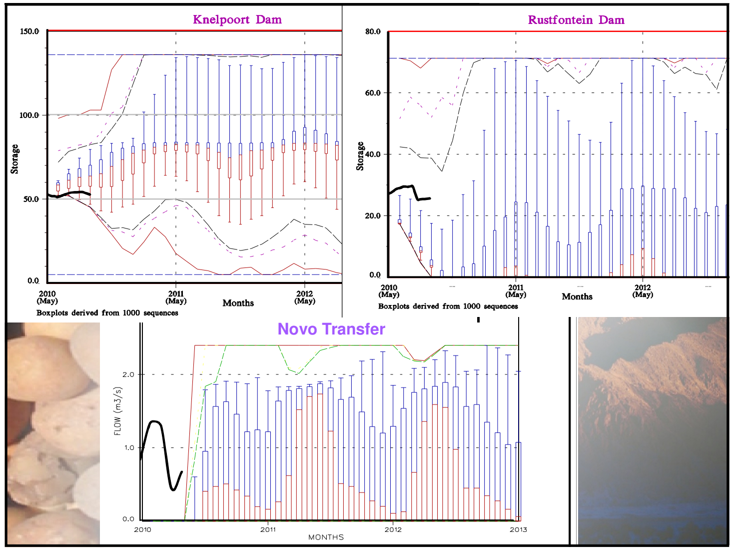


Caledon Modder operating rule

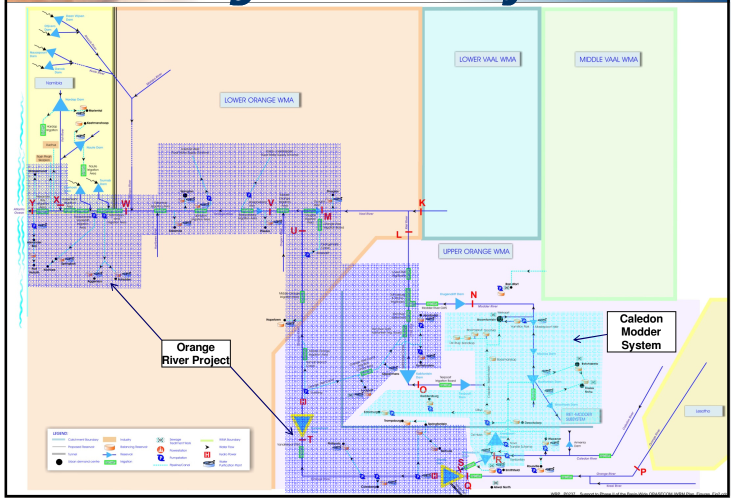
- Bloemfontein is supplied with water from it's resources in the following order (continue):
  - 6 Knellpoort below 60% start pumping from Tienfontein
  - 7 When not sufficient water in Caledon start to use 40% in Rustfontein
  - 8 Remaining 80% in Mockes
  - 9 Remaining 60% in Knellpoort



Box- and whisker plot definitions



Orange River Project



ORP Operating Principals (1 of 2)

- Maintain Assurance of Supply
  - Primary objective of the operation of ORP is to maintain the assurance of supply to users
- Hydro Power Operating Rules
  - Secondary objective is to implement rules that will maximize the hydro-power benefit without jeopardizing the assurance of supply to the users.

ORP Operating Principals (2 of 2)

- Restriction of Demands
  - The operation of the Orange River Project (Gariep and Vanderkloof dams) is based on the principle that demands are restricted during severe drought
    - Objective is to reduce supply to less essential use to protect the assurance of supply for more essential use
    - The basis on which restrictions are implemented is defined by means of a user priority classification definition

Priority Classification ORP Sub-system *(% basis)*

Category	% of the water demand to be supplied		
	1: 200 year (99.5%)	1: 100 year (99%)	1:20 year (95%)
Irrigation	10	40	50
Urban	50	30	20
Losses	100	0	0
Environmental	68	0	32

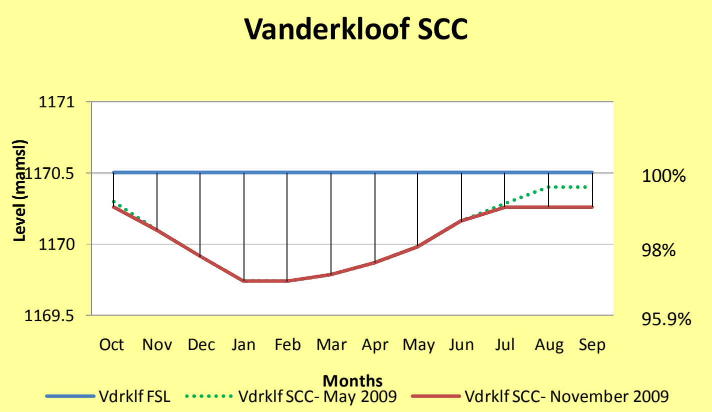
ORP Operating Rules

- Larger Orange River System
  - Storage dams upstream Gariep & Vanderkloof not used to support Gariep & Vanderkloof dams
  - Only releases for
    + Environment
    + Compensation to users
    + Spills

ORP Operating Rules

- Vanderkloof Dam
  - Releases into canal outlet on right bank
  - Releases into the river also used to generate HP
  - River releases according to downstream demand pattern
  - Additional releases if surplus allocated for HP
  - Additional releases for HP if water level above storage control curves

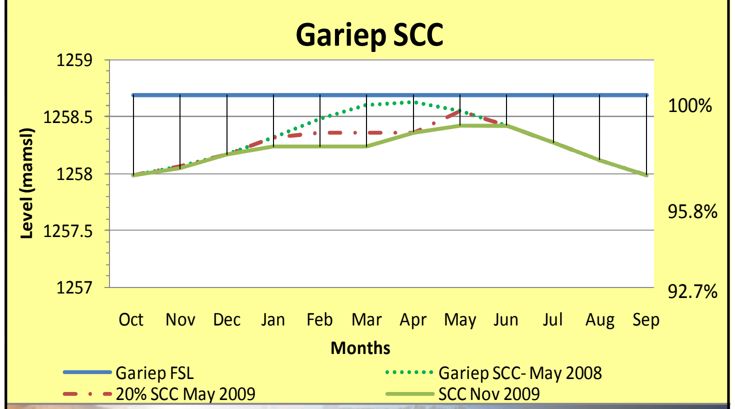
Vanderkloof Storage Control Curve



ORP Operating Rules

- Gariep Dam
  - Releases through Orange/Fish tunnel based on Operational model
  - Releases into the river also used to generate HP
  - River releases according to inverse of the downstream demand pattern
  - Additional releases if surplus allocated for HP
  - Additional releases for HP if water level above storage control curves

Gariep Storage Control Curve



Orange and Vaal System Link

- Orange and Vaal River systems are operated separately
- The only links are:

The transfers from the Senqu to the Vaal

- These transfers is fixed and independent of the water supply situation in the Orange d/s of the LHWP or in the IVRS

Spills from the Vaal to the Orange

- Operating rule of IVRS minimizes spills from the Vaal into the Orange. Spills from the Vaal do however enter the Orange during periods of high runoff and as result of operating losses and irrigation return flows in the Lower Vaal.

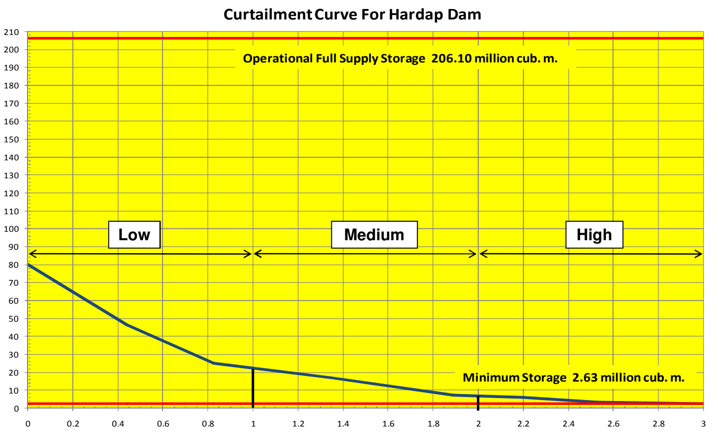
Small Orange sub-systems

- Kalkfontein, Krugersdrift, Tierpoort, Groothoek, Rooipoort, Smartt Syndicate, Naute, Hardap,etc
- These dams use an in-house rule in practice
- In current WRPM – Supply demand until dam failure occur then supply whatever is available
- Proper scientific operating rules to be developed
- Hardap in Namibia – operating rule was developed

Priority Classification Hardap Dam Sub-system (% basis)

User Category	Priority Classification & Assurance of Supply		
	Low 80% 1 in 5 year	Medium 90% 1 in 10 year	High 95% 1 in 20 year
Urban/industrial	0%	0%	100%
Irrigation	83%	17%	0%
Losses	50%	0%	50%

HARDAP Curtailment Curve

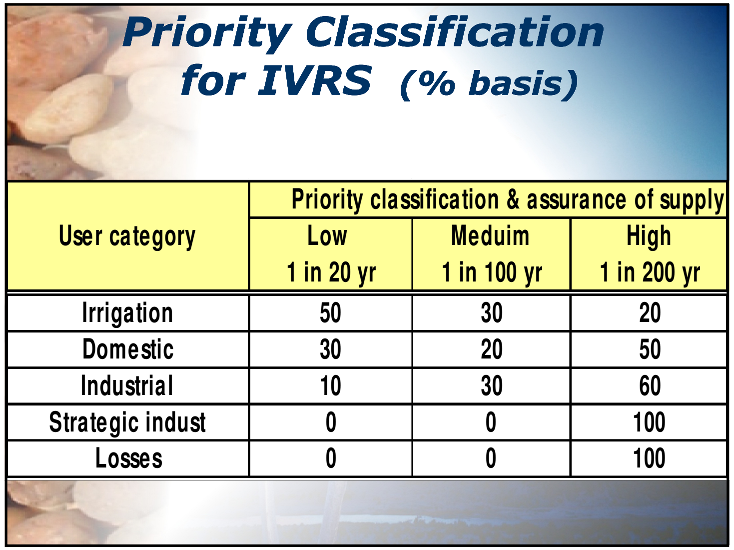


Integrated Vaal River System Principals (1 of 2)

- <u>General Operating Principle</u>
  - Must be operated as an integrated system irrespective of who owns or operate each component of the system
- <u>Maintain Assurance of Supply</u>
  - **Primary objective of the operation of IVRS is to maintain the assurance of supply to users**
- <u>Cost Saving Operating Rules</u>
  - Secondary objective to implement cost saving operating rules during wet hydrological conditions when dams are full.

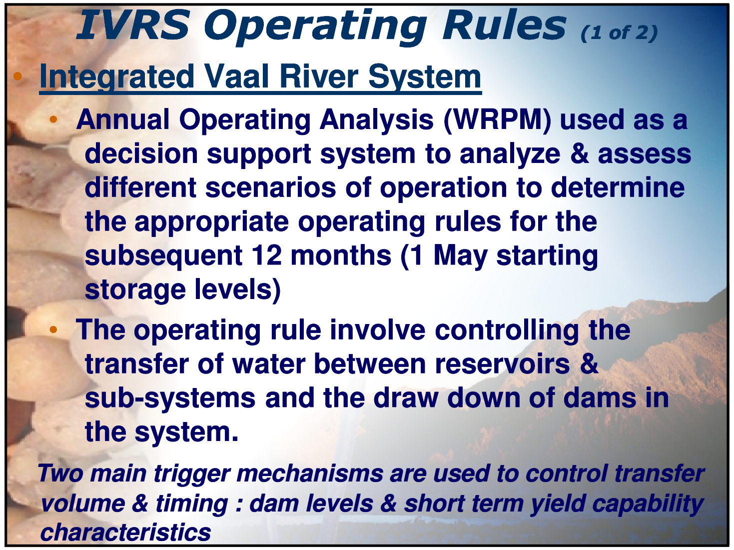
Integrated Vaal River System Principals (1 of 2)

- **Restriction of Demands**
  - **The operation of the IVRS is based on the principle that demands are restricted during severe drought events.**
    - **Objective is to reduce supply to less essential use to protect the assurance of supply for more essential use.**
    - **The basis on which restrictions are implemented is defined by means of a user priority classification definition.**



Priority Classification for IVRS (% basis)

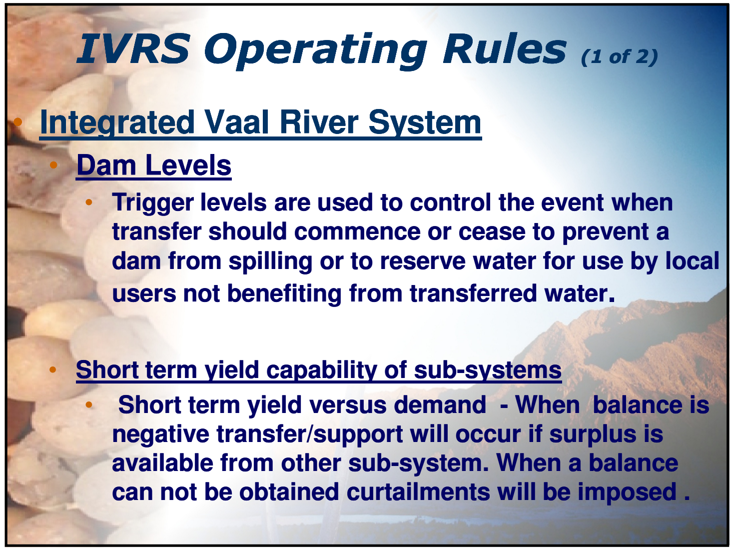
User category	Priority classification & assurance of supply		
	Low 1 in 20 yr	Meduim 1 in 100 yr	High 1 in 200 yr
Irrigation	50	30	20
Domestic	30	20	50
Industrial	10	30	60
Strategic indust	0	0	100
Losses	0	0	100



IVRS Operating Rules (1 of 2)

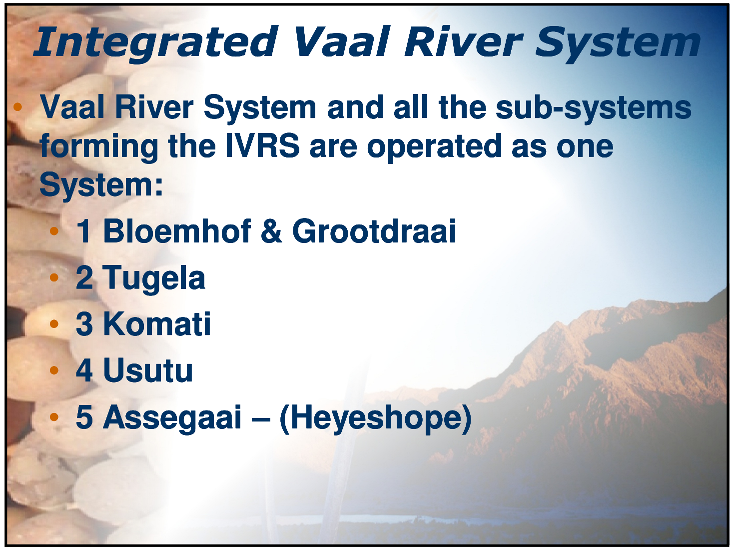
- Integrated Vaal River System
  - Annual Operating Analysis (WRPM) used as a decision support system to analyze & assess different scenarios of operation to determine the appropriate operating rules for the subsequent 12 months (1 May starting storage levels)
  - The operating rule involve controlling the transfer of water between reservoirs & sub-systems and the draw down of dams in the system.

Two main trigger mechanisms are used to control transfer volume & timing : dam levels & short term yield capability characteristics



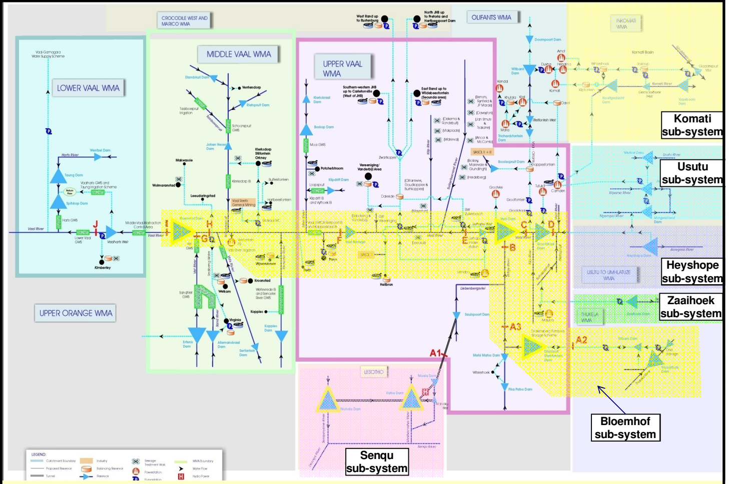
IVRS Operating Rules (1 of 2)

- Integrated Vaal River System
  - Dam Levels
    - Trigger levels are used to control the event when transfer should commence or cease to prevent a dam from spilling or to reserve water for use by local users not benefiting from transferred water.
  - Short term yield capability of sub-systems
    - Short term yield versus demand - When balance is negative transfer/support will occur if surplus is available from other sub-system. When a balance can not be obtained curtailments will be imposed .



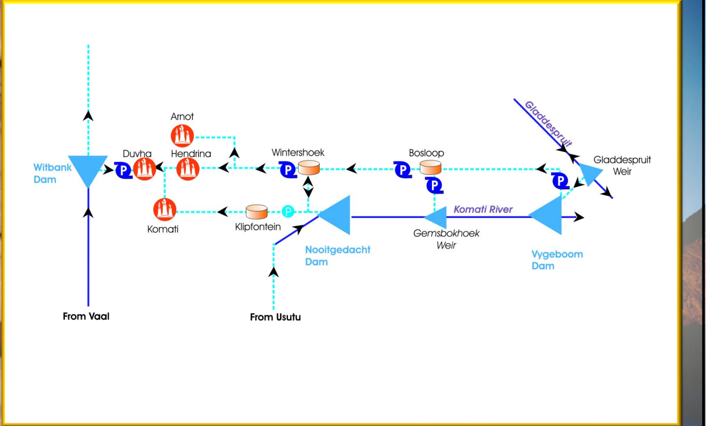
Integrated Vaal River System

- Vaal River System and all the sub-systems forming the IVRS are operated as one System:
  - 1 Bloemhof & Grootdraai
  - 2 Tugela
  - 3 Komati
  - 4 Usutu
  - 5 Assegaai – (Heyeshope)

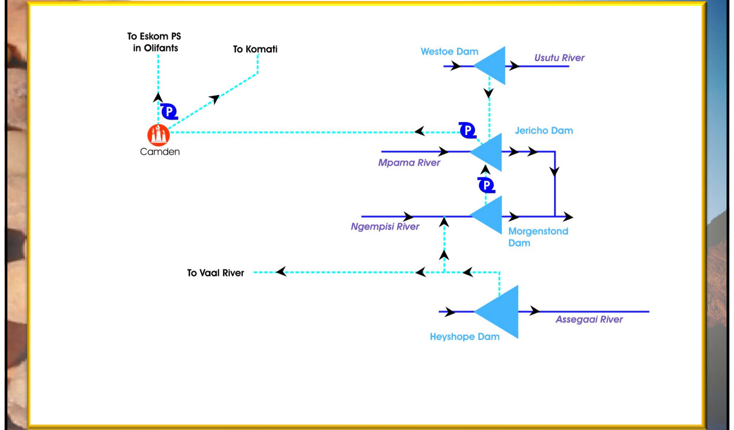


Integrated Vaal system

Komati sub-system



Usutu & Heyshope sub-systems



Usutu sub-system

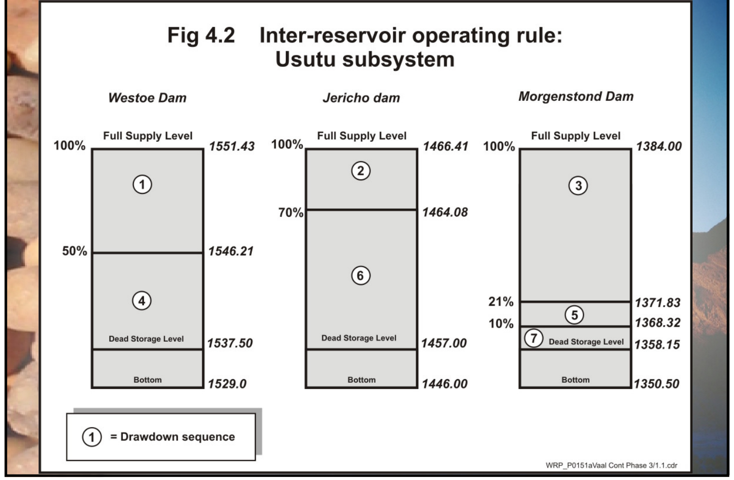
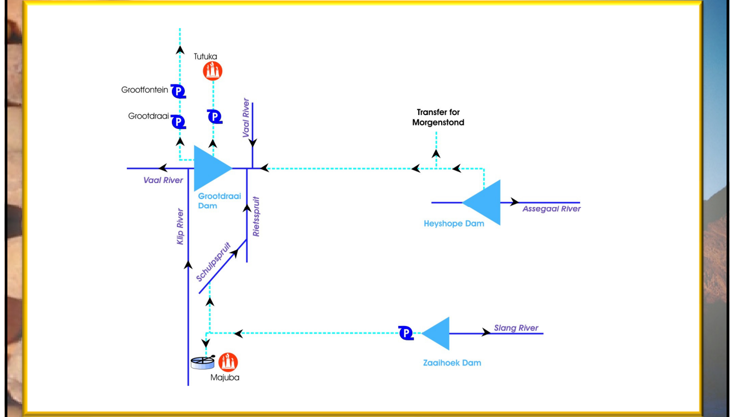


Fig 4.2 Inter-reservoir operating rule: Usutu subsystem

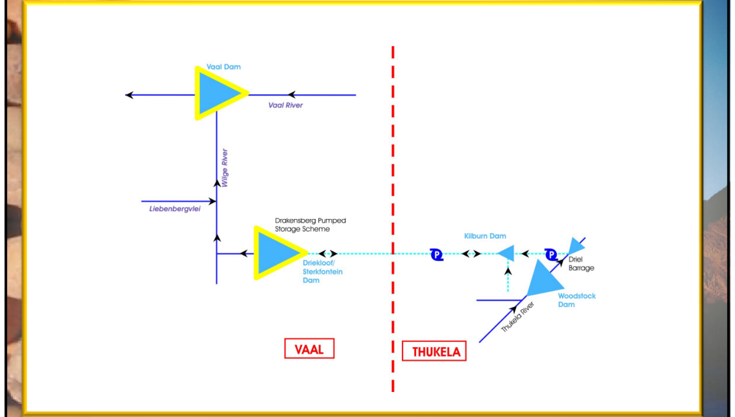
① = Drawdown sequence

WRP_P0151aVaal Cont Phase 3/1.1.cdr

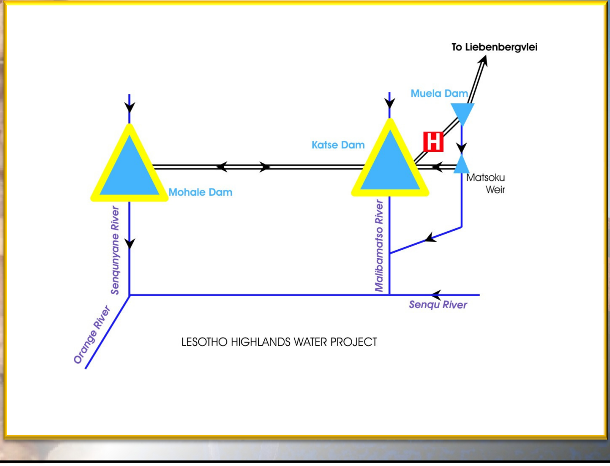
Heyshope & Zaaihoek sub-systems



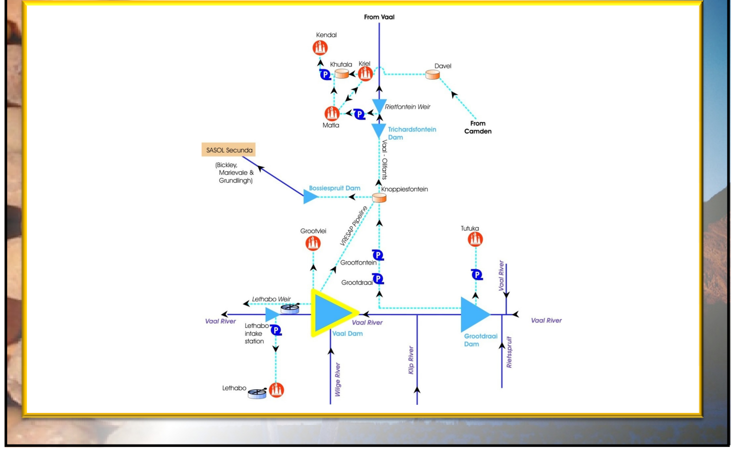
Thukela Vaal Transfer Scheme (Woodstock & Sterkfontein Dams)

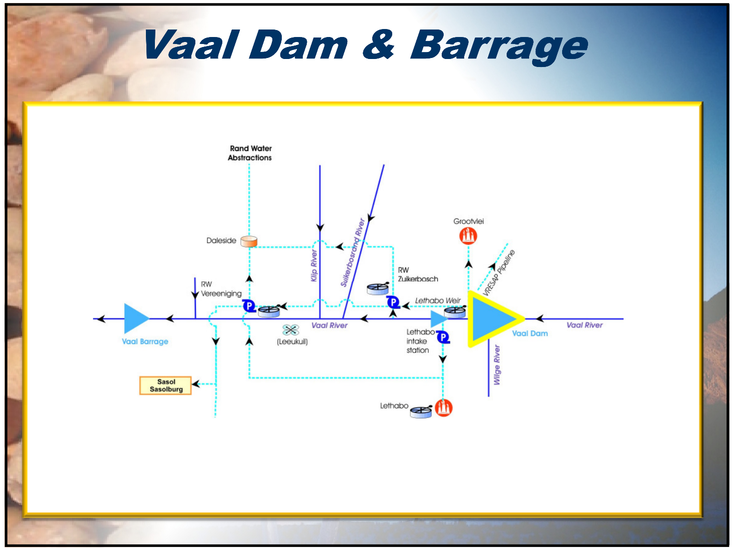


Lesotho Highlands Water Project

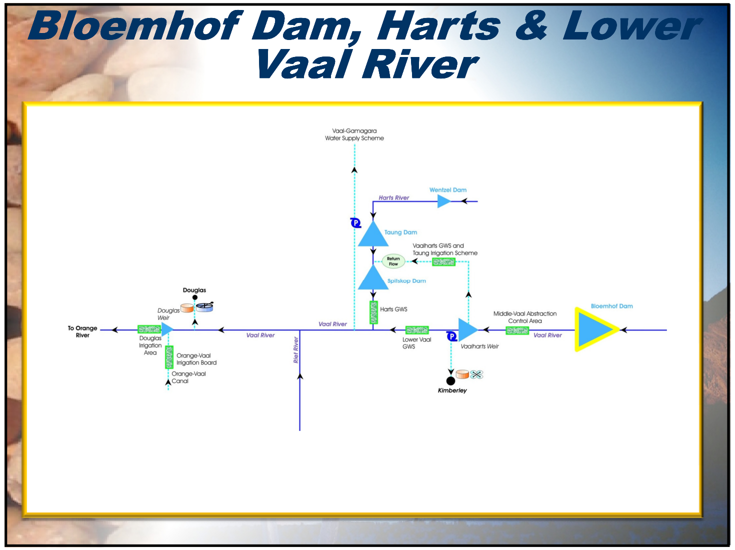


Grootdraai VRESAP Transfers





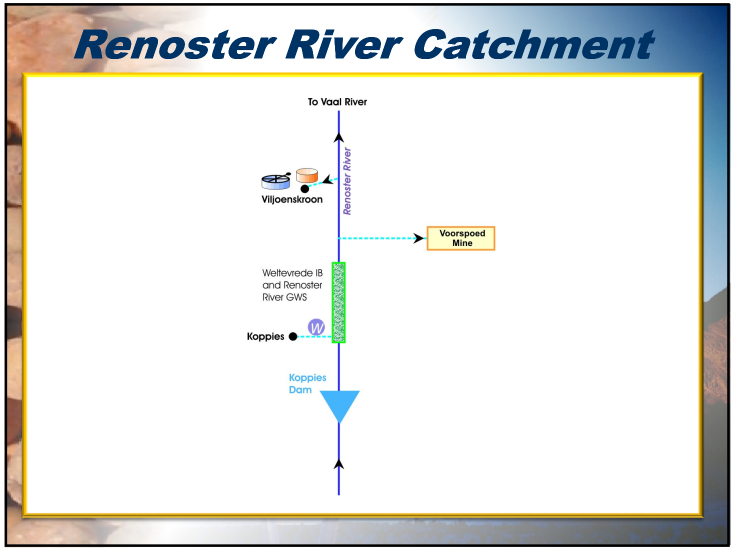
Vaal Dam & Barrage



Bloemhof Dam, Harts & Lower Vaal River

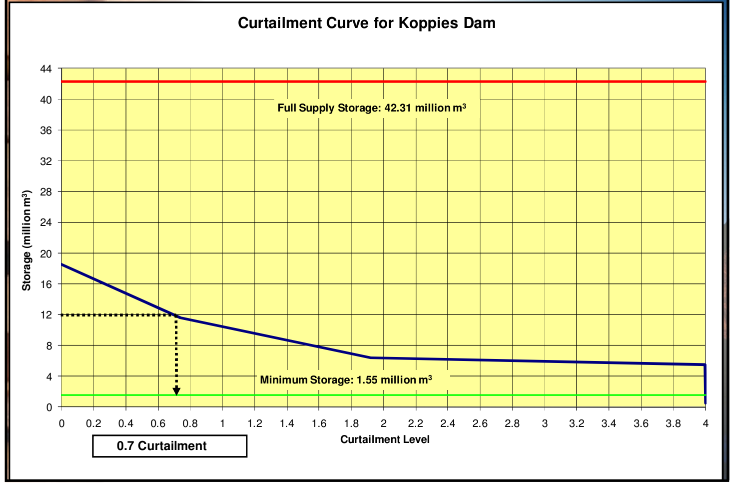
Small Vaal sub-systems

- Mooi River, Renoster, Schoonspruit, Sand-Vet sub-systems, etc.
- Operating rules were developed for :
  - Mooi River, Rhenoster & Sand-Vet
- Schoonspruit sub-system and other small dams use in-house operating rules
  - In current WRPM – Supply demand until dam failure occur then supply what is available



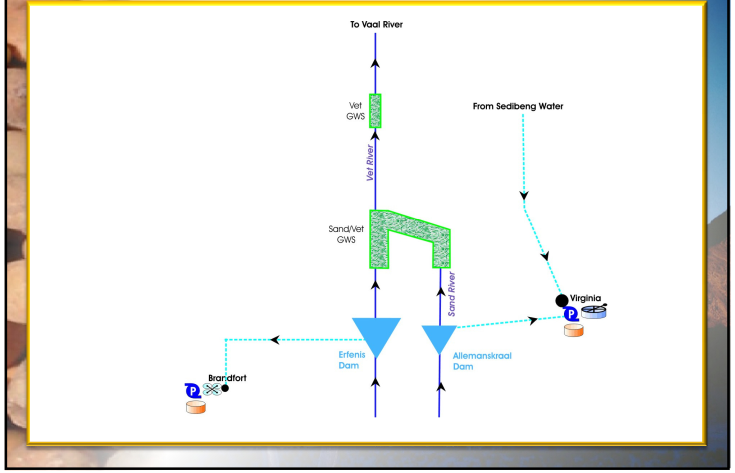
Renoster River Catchment

Renoster River Catchment

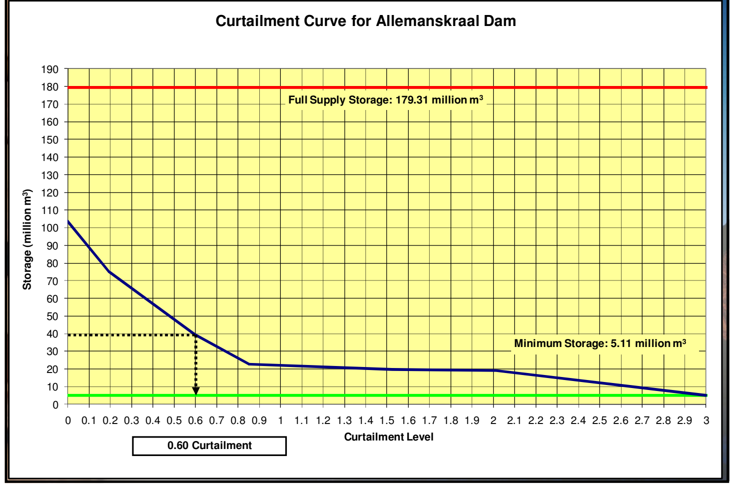


Curtailment Curve for Koppies Dam

Sand-Vet River Catchment

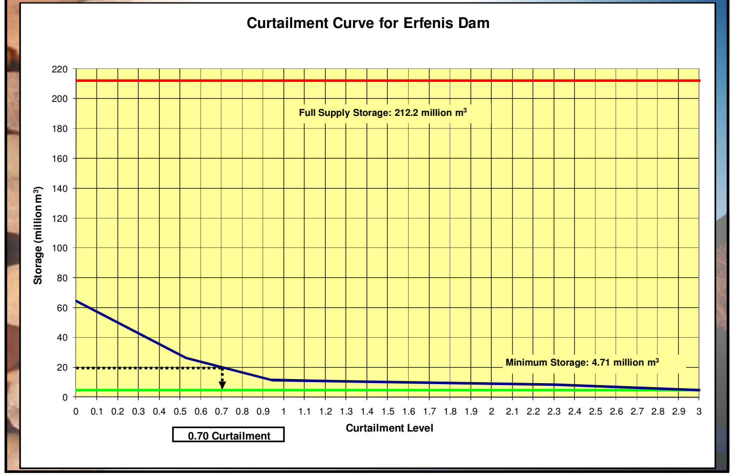


Allemanskraal operating rule



Curtailment Curve for Allemanskraal Dam

Erfenis operating rule



Curtailment Curve for Erfenis Dam

Thank You

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 - 17 February 2011)

Module 2:
Introduction to Water Resource Modelling

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program

wrp A Mija Group Company

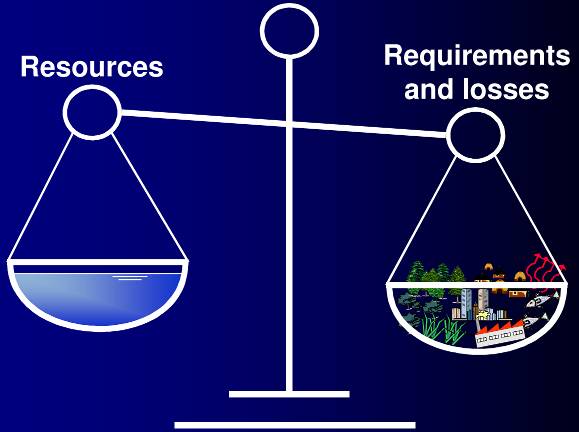
Contents

1. The water resources planning process
2. Modelling water resource systems
3. Basic modelling principles
4. Definition of terms
5. Practical 1: Using a basic reservoir model

1. The water resources planning process

Typical water resource system

Balance



Primary objective

Ensuring the supply of water resources to support changing water requirements:

- Over planning horizon
- In sustainable and cost-effective way

Achieved through:

- Assessment
- Intervention scheduling
- Management
- Monitoring

Assessment

- Resource capability
- Resource assurance
- Water requirements
- User criteria
- Water quality

Intervention scheduling

- Conservation
  - Demand management
  - Recycling
  - Resource reallocation
  - Adjustment of user criteria
  - Catchment management
- Resource development
  - Reservoirs
  - Transfer schemes
  - Other

Management

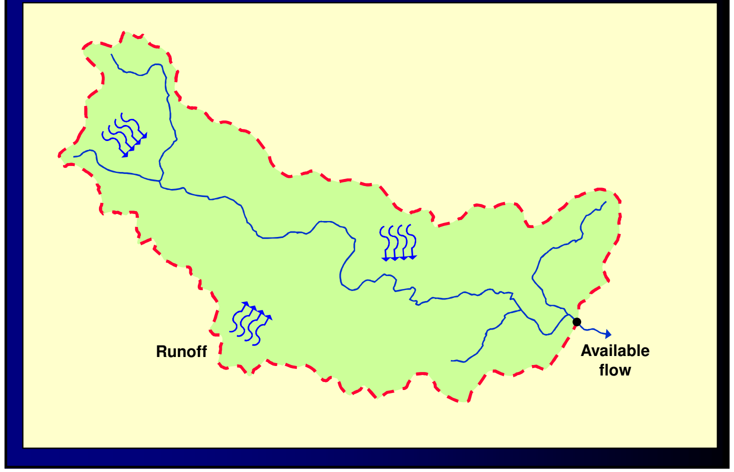
- Resource operation
  - Reservoirs
  - Supply priorities
  - Transfers
  - Blending / dilution
- Operational cost savings
- System maintenance

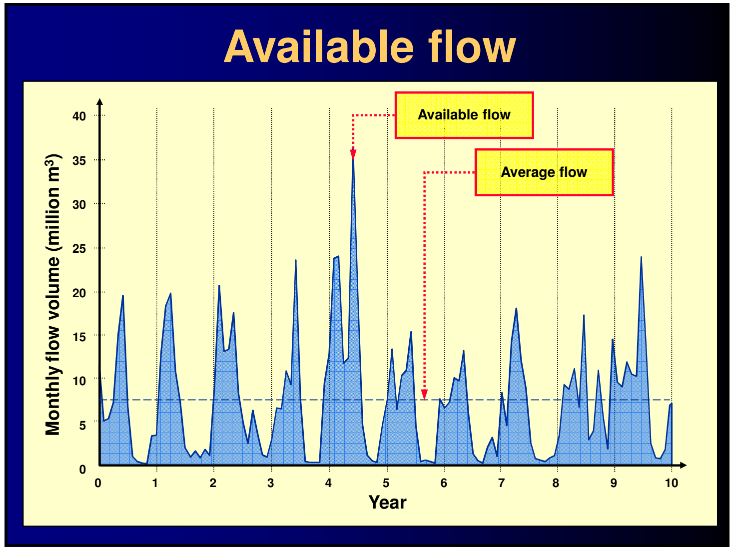
Monitoring

- System behaviour
- Water requirements
- Impact initiatives / interventions
- Water quality objectives

2. Modelling water resource systems

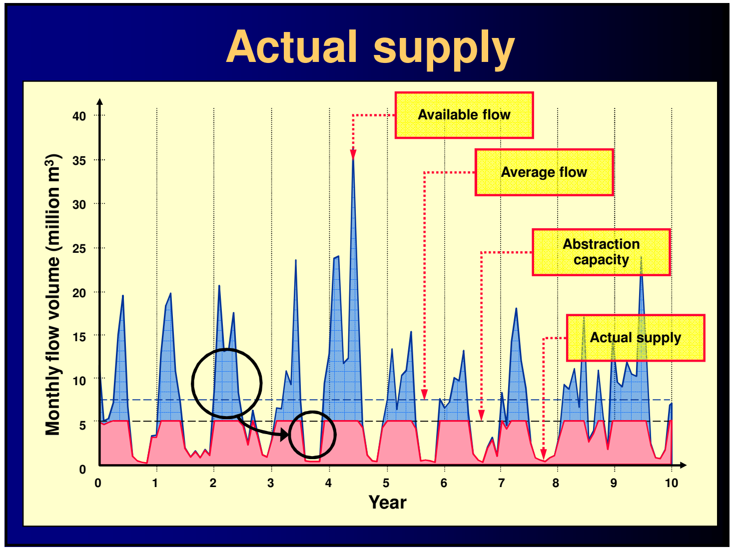
Undeveloped catchment



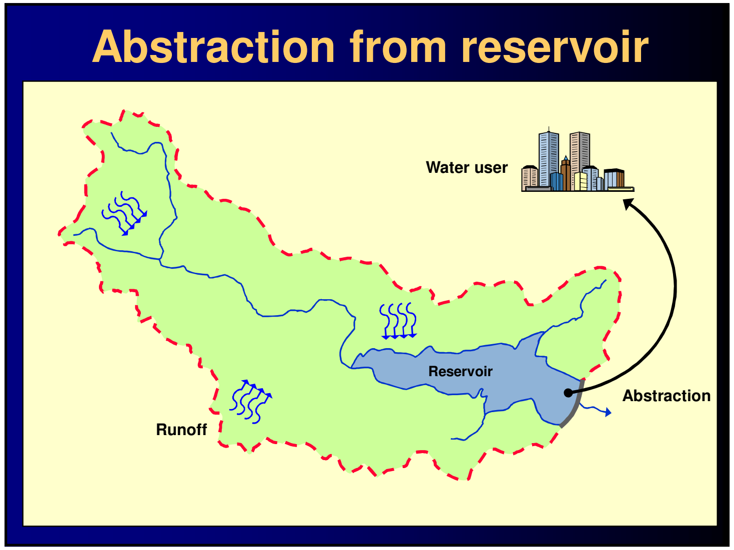


Available flow

Abstraction from river



Actual supply



Abstraction from reservoir

Definition of a “model”

> *“… a simplified mathematical description of a system or process, used to assist calculations and predictions…”*

– Oxford English Dictionary

Benefits of modelling

- Representation of real world
- Prediction of actual behaviour
- Testing environment for resource and cost impact of:
  - Human activities
  - Interventions
  - Management options
- Allows “mistakes” prior to actual implementation

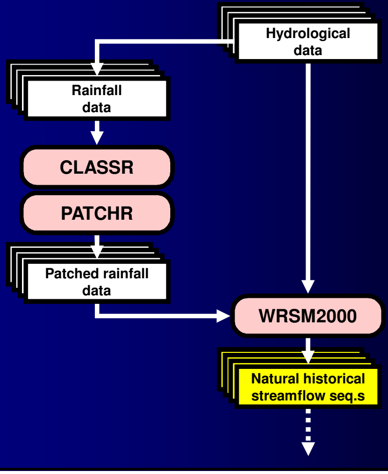
Limitations of modelling

- Inherently a simplification
- Assumption-dependent
- Data-dependent
- Selection of appropriate model
- Standardisation of modelling approach
- Specialist software:
  - Expert configuration and interpretation
  - Extensive checking and testing
  - Long turn-around time
  - (Typically) small user groups

Example models and utilities

- Data pre-processors (various)
- Data patching utilities (PATCHR, PATCHS)
- Rainfall-runoff models (WRSM2000)
- Stochastic streamflow models (STOMSA)
- Yield analysis models (WRYM)
- Planning analysis models (WRPM)
- Water quality models (WQS)
- Information management systems (IMSs)

Hydrological analysis



Hydrological data

Rainfall data

CLASSR

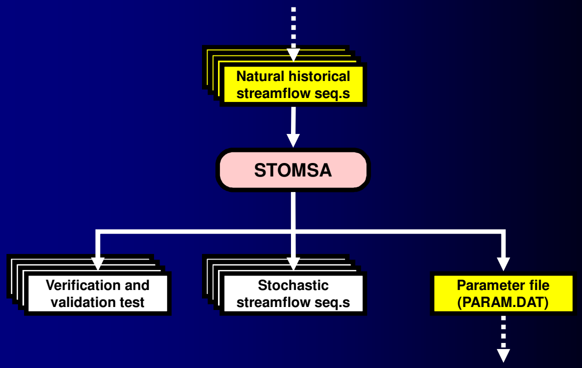
PATCHR

Patched rainfall data

WRSM2000

Natural historical streamflow seq.s

Stochastic streamflow generation



Natural historical streamflow seq.s

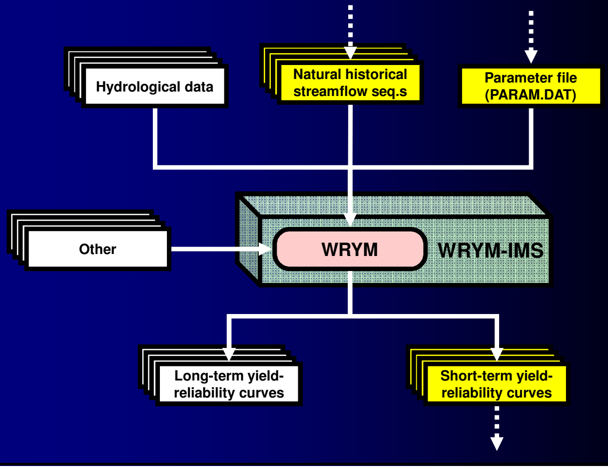
STOMSA

Verification and validation test

Stochastic streamflow seq.s

Parameter file (PARAM.DAT)

Sub-system yield analysis



Hydrological data

Natural historical streamflow seq.s

Parameter file (PARAM.DAT)

Other

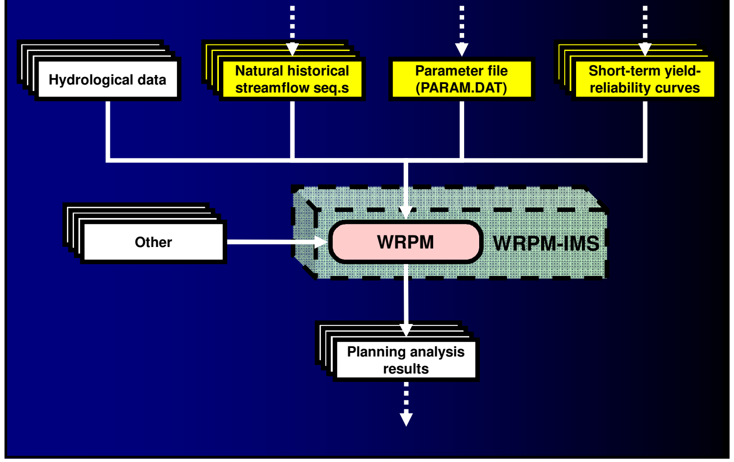
WRYM

WRYM-IMS

Long-term yield-reliability curves

Short-term yield-reliability curves

System planning analysis



Hydrological data

Natural historical streamflow seq.s

Parameter file (PARAM.DAT)

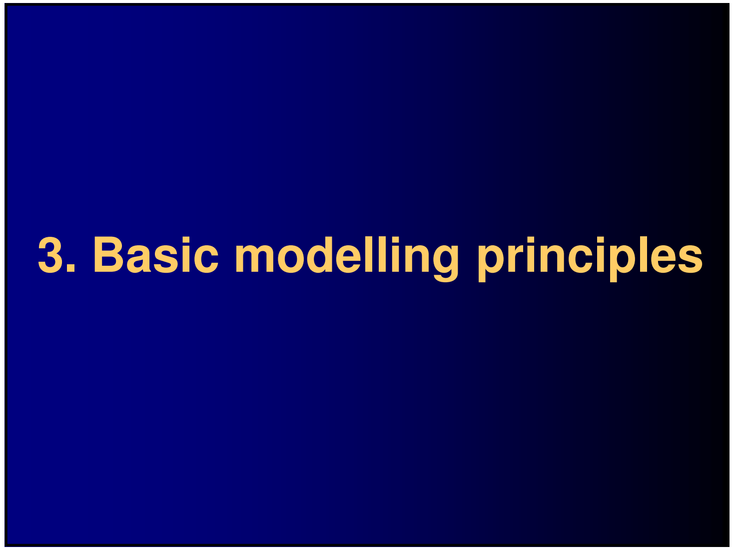
Short-term yield-reliability curves

Other

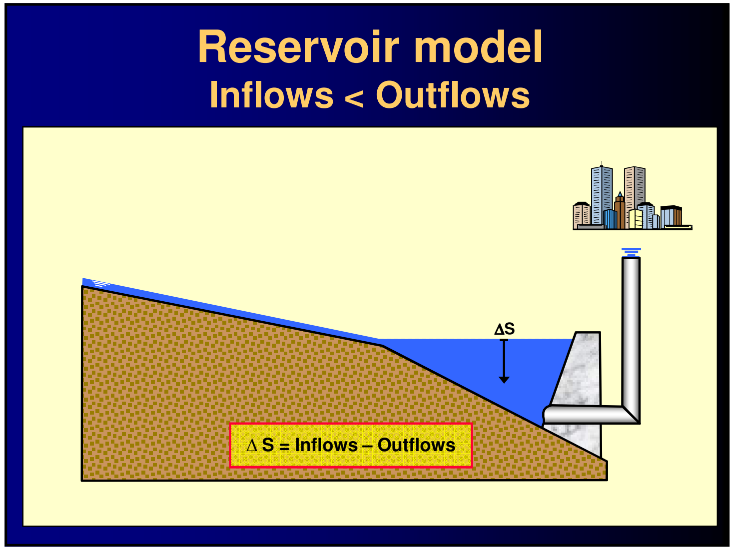
WRPM

WRPM-IMS

Planning analysis results

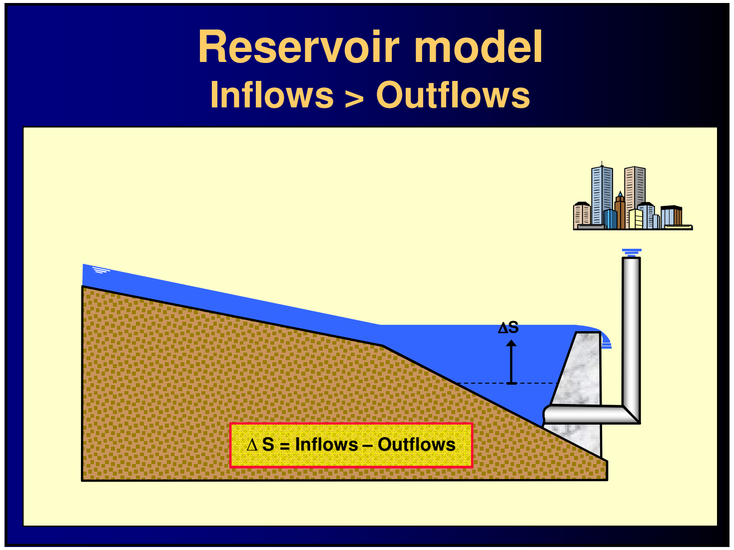


3. Basic modelling principles



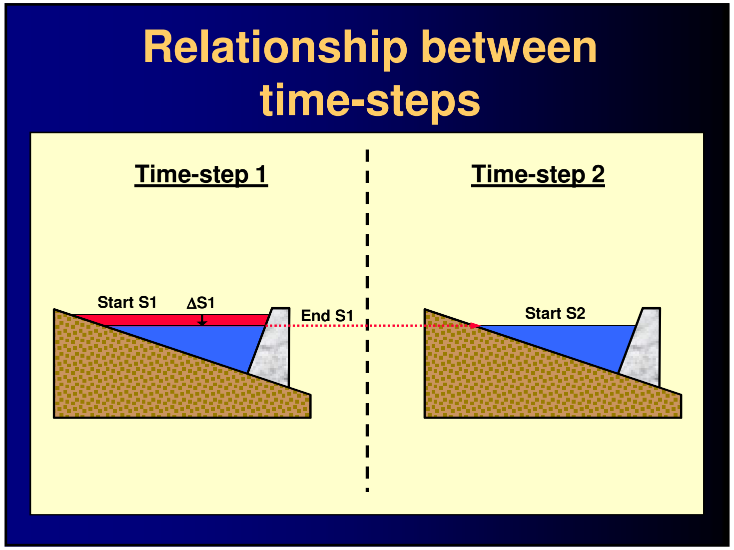
Reservoir model

Inflows < Outflows



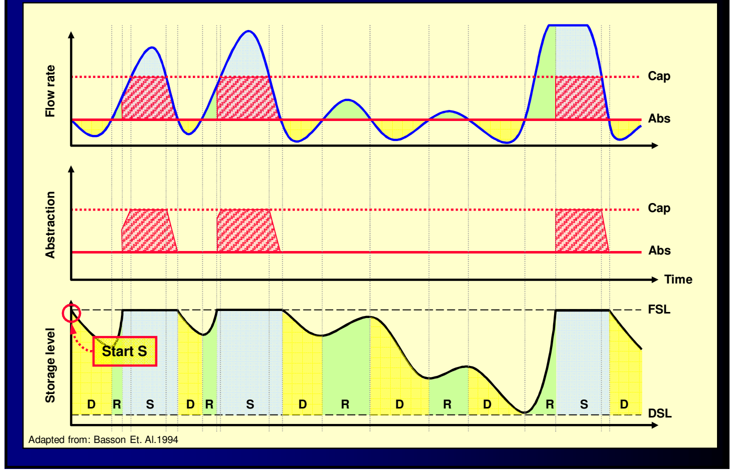
Reservoir model

Inflows > Outflows



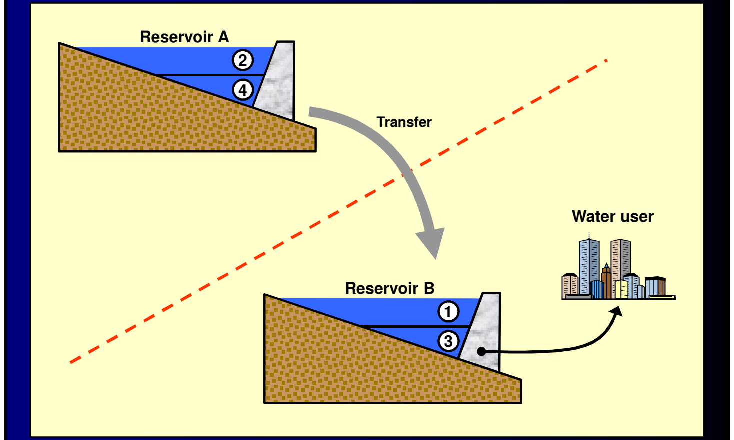
Relationship between time-steps

Simulation



Adapted from: Basson Et. Al.1994

Analysing scenarios (1 of 2)



Analysing scenarios (2 of 2)

Variables	Scenarios					
	1 (Base)		2		3	
	(A)	(B)	(A)	(B)	(A)	(B)
Operation:	2 4	1 3	2	1 3	2	1 3
Capacity:	150	300	150	300	200	300
Demand:	10.0		10.0		10.0	
Result:	?		?		?	

The modelling process

- Define objectives
- Identify main physical features
- Define system network
- Select system operating rules
- Undertake scenario analysis
- Evaluate results
- (Repeat process)
- Implement decision

4. Definition of terms

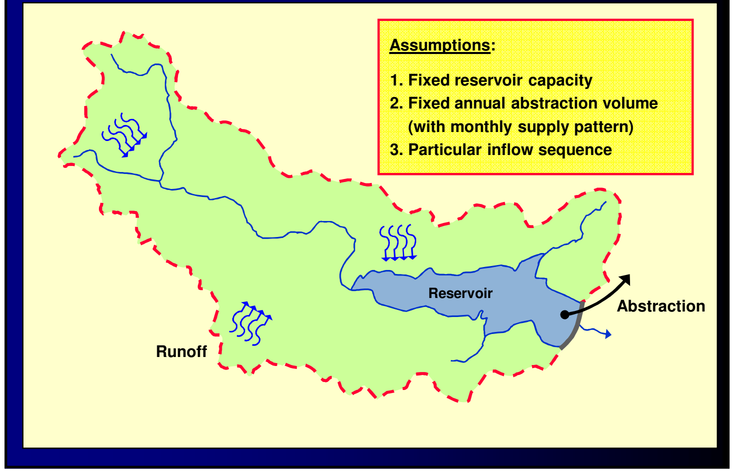
Commonly used terms

- “Firm yield”
- “Secondary yield”
- “Total yield”
- “Historical yield”
- “1:100 year yield”
- “Yield with 95 % assurance”

Yield terms

- Target draft
- Reservoir failure and recovery
- Critical period
- Yield
- Base yield
- Firm yield
- Secondary yield

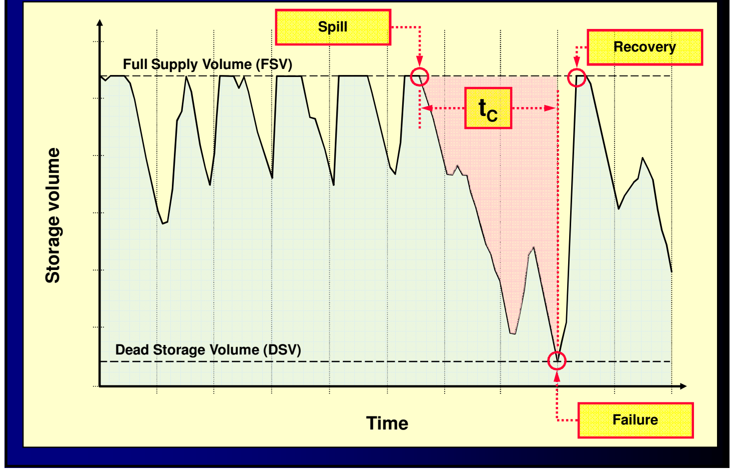
Water resource system



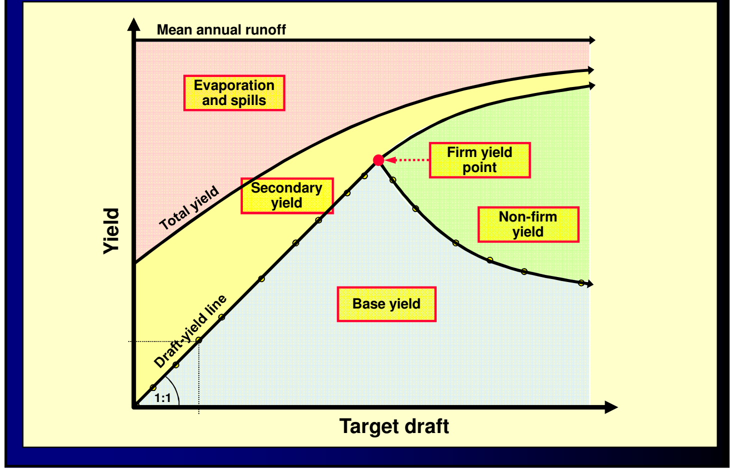
Assumptions:

1. Fixed reservoir capacity
2. Fixed annual abstraction volume (with monthly supply pattern)
3. Particular inflow sequence

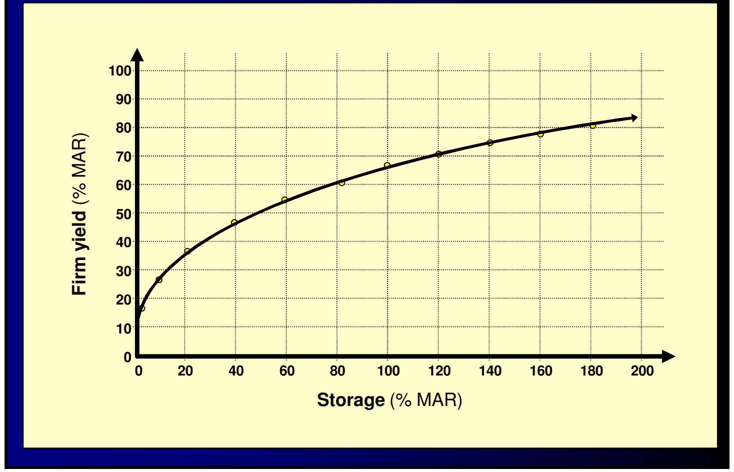
Reservoir trajectory



Target draft vs. yield diagram



Storage and firm yield



5. Practical 1: Using a basic reservoir model

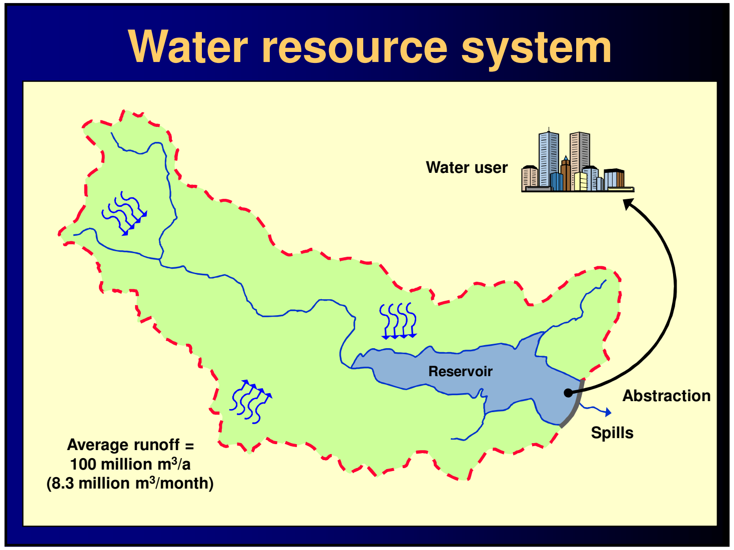
Purpose and methodology

Purpose:

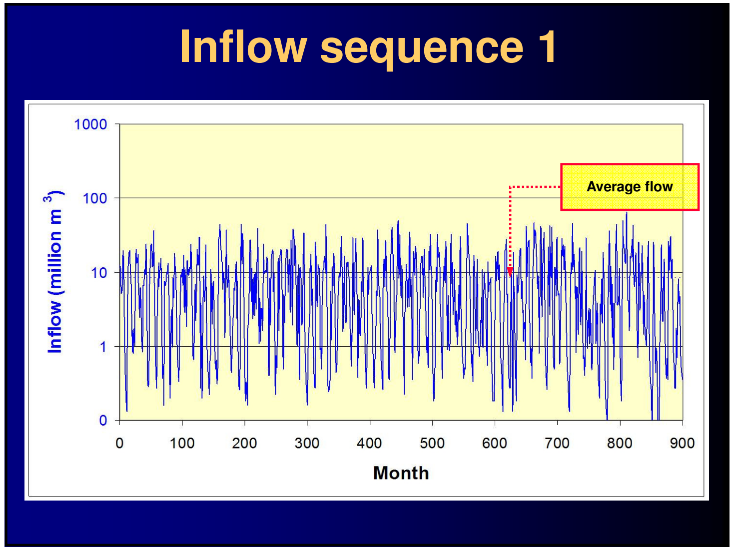
- Explore use of basic reservoir model

Methodology:

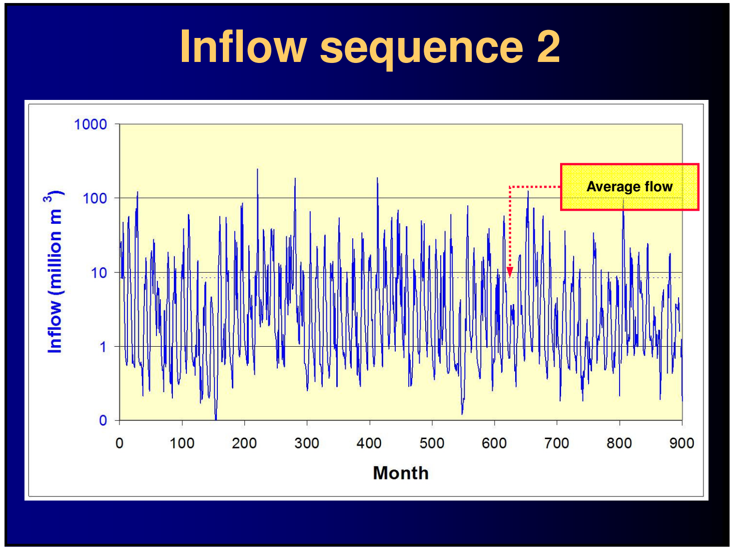
- Use spreadsheet model provided in [c:\Wrym\Basic Reservoir Model*.*]
- Analyse system for 3 inflow sequences
- Complete table with analysis results
- Interpret results



Water resource system

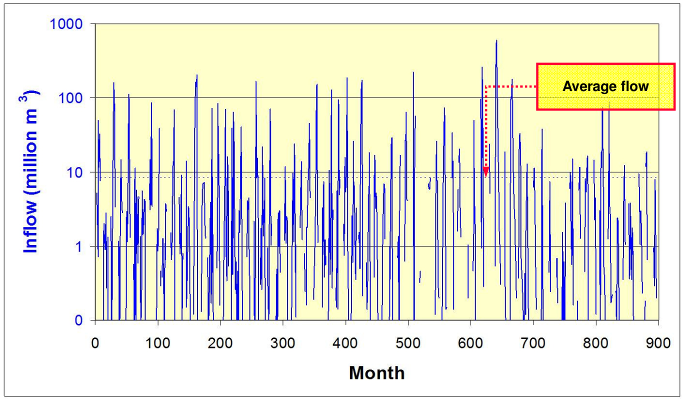


Inflow sequence 1



Inflow sequence 2

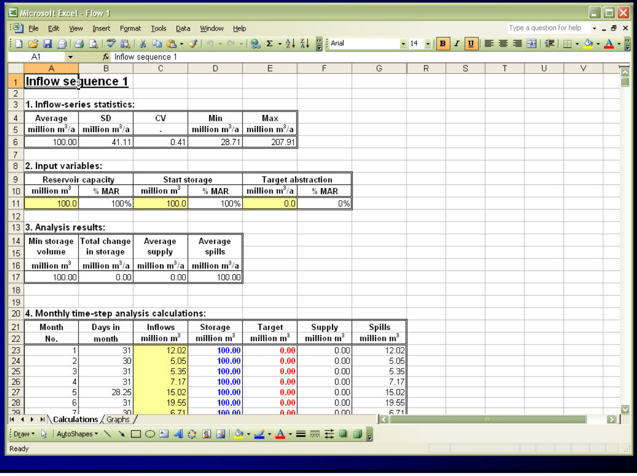
Inflow sequence 3



Statistics for 3 inflow sequences

Sequence	Average (million m^3/a)	SD (million m^3/a)	CV	Min (million m^3/a)	Max (million m^3/a)
1	100.00	41.11	0.41	28.71	207.91
2	100.00	78.22	0.78	10.91	350.75
3	100.00	156.34	1.56	1.30	1 023.87

Spreadsheet model



A1: Inflow sequence 1

Inflow sequence 1

1. Inflow-series statistics:

Average million m^3/a	SD million m^3/a	CV -	Min million m^3/a	Max million m^3/a
100.00	41.11	0.41	28.71	207.91

2. Input variables:

Reservoir capacity		Start storage		Target abstraction	
million m^3	% MAR	million m^3	% MAR	million m^3/a	% MAR
100.0	100%	100.0	100%	0.0	0%

3. Analysis results:

Min storage volume million m^3	Total change in storage million m^3/a	Average supply million m^3/a	Average spills million m^3/a
100.00	0.00	0.00	100.00

4. Monthly time-step analysis calculations:

Month No.	Days in month	Inflows million m^3	Storage million m^3	Target million m^3	Supply million m^3	Spills million m^3
1	31	12.02	100.00	0.00	0.00	12.02
2	30	5.05	100.00	0.00	0.00	5.05
3	31	5.35	100.00	0.00	0.00	5.35
4	31	7.17	100.00	0.00	0.00	7.17
5	28.25	15.02	100.00	0.00	0.00	15.02
6	31	19.55	100.00	0.00	0.00	19.55
7	30	6.71	100.00	0.00	0.00	6.71

Questions

1. What is the firm yield of the system for a reservoir capacity of 100 million m^3? (start the reservoir full)
2. What is the length of the critical period?
3. Start the reservoir empty and re-determine the firm yield. What do you observe?
4. Is there a change in the critical period?
5. What is the minimum reservoir capacity required for a firm yield of 60 million m^3/a? (start the reservoir at 60 million m^3)

Table to be completed

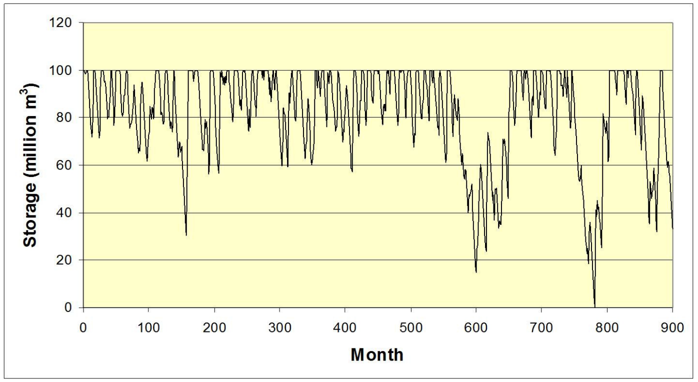
Question	Results for indicated flow sequence		
	1	2	3
1	million m^3/a	million m^3/a	million m^3/a
2	years	years	years
3	million m^3/a	million m^3/a	million m^3/a
4			
5	million m^3	million m^3	million m^3

Results

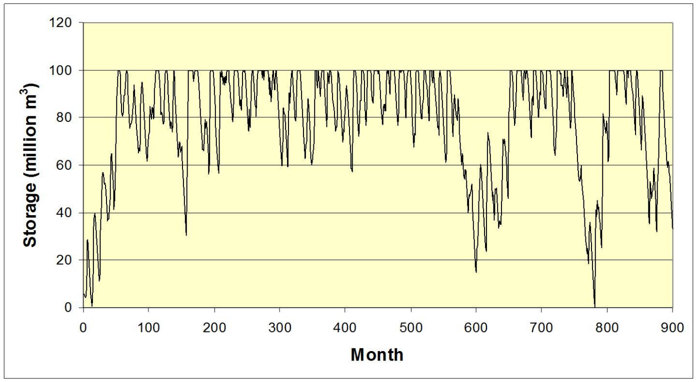
Completed table

Question	Results for indicated flow sequence		
	1	2	3
1	72.6 million m^3/a	49.2 million m^3/a	30.5 million m^3/a
2	3.0 years	3.7 years	6.6 years
3	72.6 million m^3/a	49.2 million m^3/a	0.0 million m^3/a
	No change.	No change.	Dropped to zero.
4	No change.	No change.	Yes, moved to start.
5	63.2 million m^3	174.7 million m^3	524.7 million m^3

Storage trajectory sequence 1, starting full



Storage trajectory sequence 1, starting empty



Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 – 17 February 2011

End

gtz

Commissioned by:

Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid

Australian Government
Aid Program

wrp

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 – 17 February 2011

Module 3: Stochastic Streamflow and Yield

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with: UKaid from the Department for International Development Australian Government Aid Program

wrp A Miya Group Company

Contents

1. Background
2. Streamflow generation
3. Stochastic yield analysis
4. Practical 2: Interpreting yield-reliability curves

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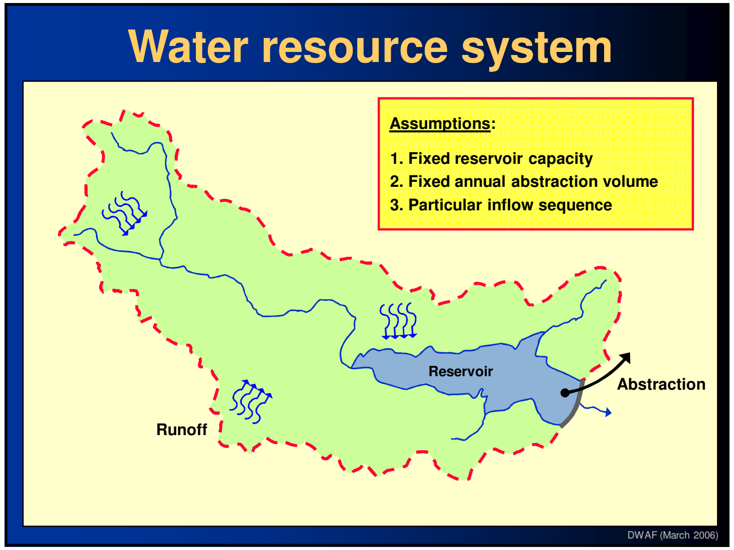
1. Background

Why bother?

Historical yield analysis at Midmar Dam

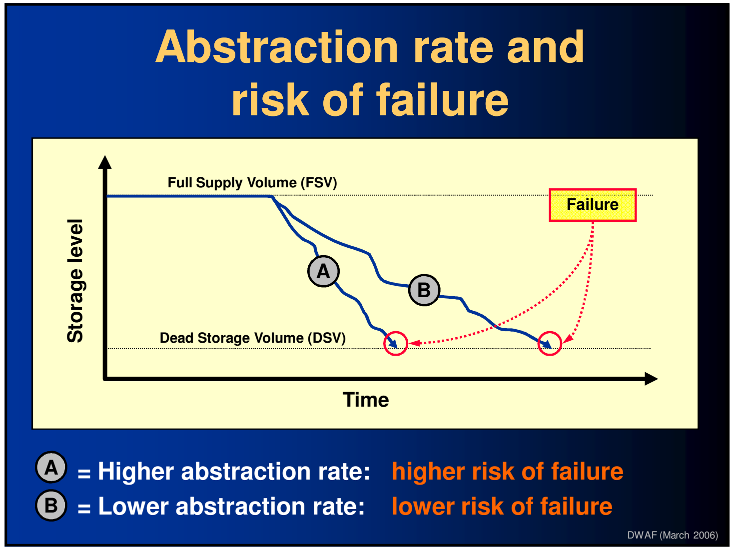
Period of analysis (hydrological years)	Number of years	Firm yield (million m^3/a)
1930 – 1934	5	81
1930 – 1939	10	69
1930 – 1949	20	69
1930 – 1969	40	69
1930 – 1989	60	36



Water resource system

Assumptions:

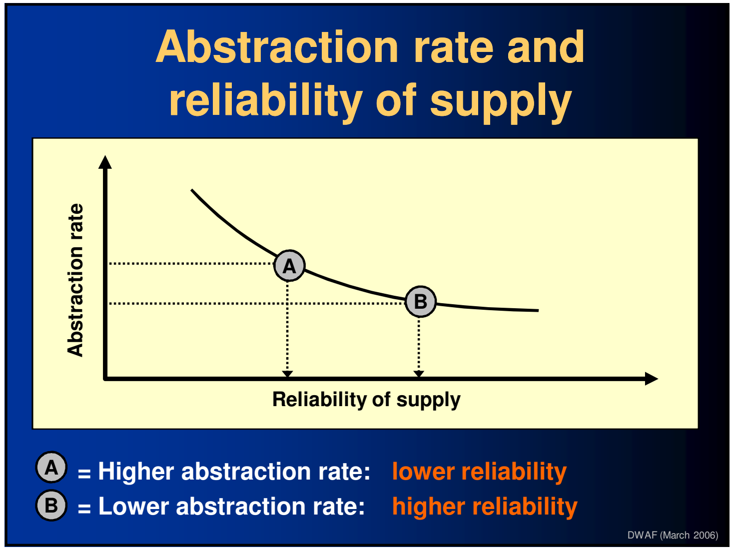
1. Fixed reservoir capacity
2. Fixed annual abstraction volume
3. Particular inflow sequence



Abstraction rate and risk of failure

Ⓐ = Higher abstraction rate: higher risk of failure

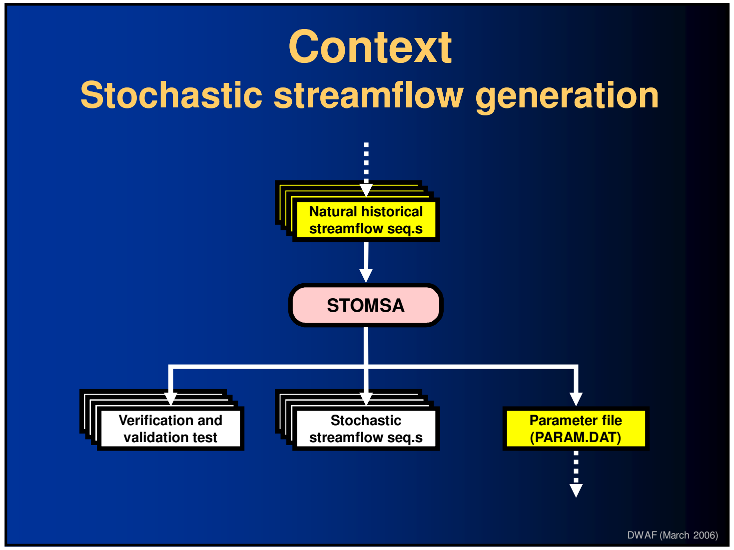
Ⓑ = Lower abstraction rate: lower risk of failure



Abstraction rate and reliability of supply

Ⓐ = Higher abstraction rate: lower reliability

Ⓑ = Lower abstraction rate: higher reliability



Context

Stochastic streamflow generation

Natural historical streamflow seq.s

STOMSA

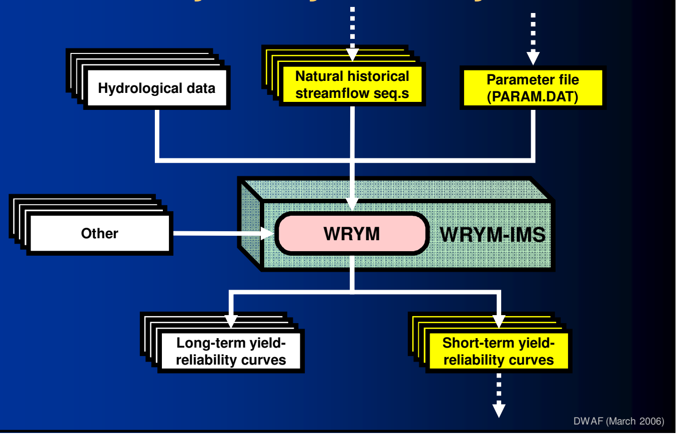
Verification and validation test

Stochastic streamflow seq.s

Parameter file (PARAM.DAT)

Context

Sub-system yield analysis



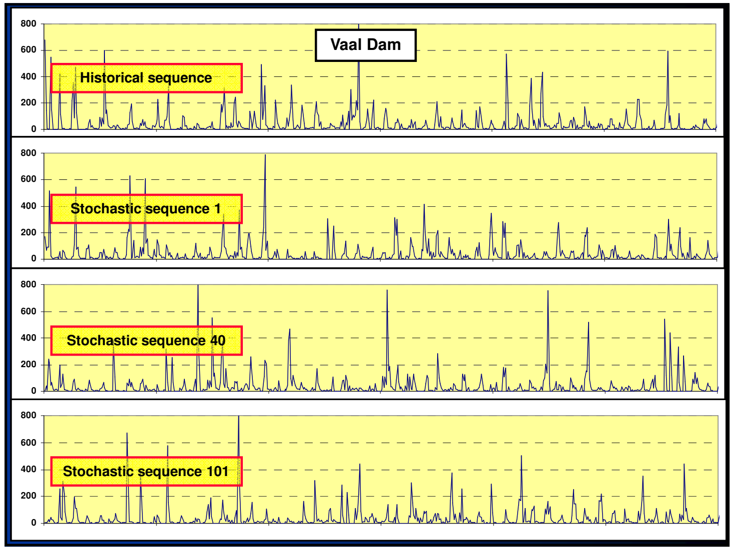
---

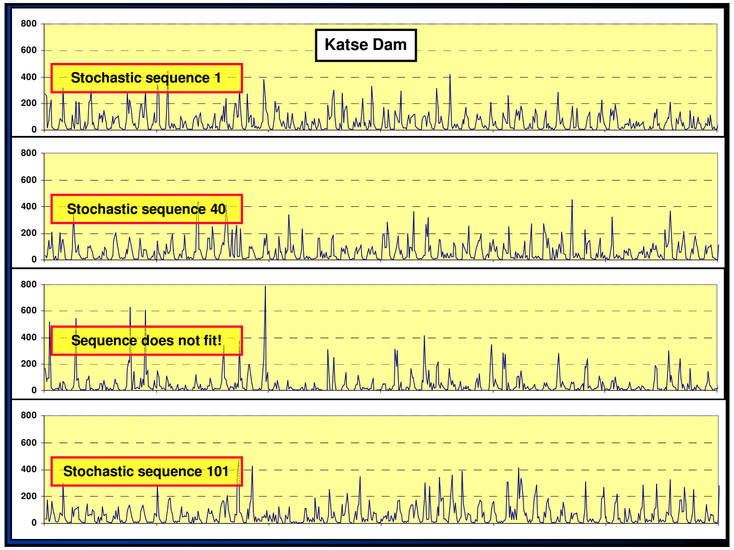
2. Streamflow generation

Stochastic streamflow sequence

- Streamflow sequences generated synthetically
- Sequence did not actually occur
- Based on characteristics of historical streamflows
- Generated by means of statistical (or stochastic) distributions

---



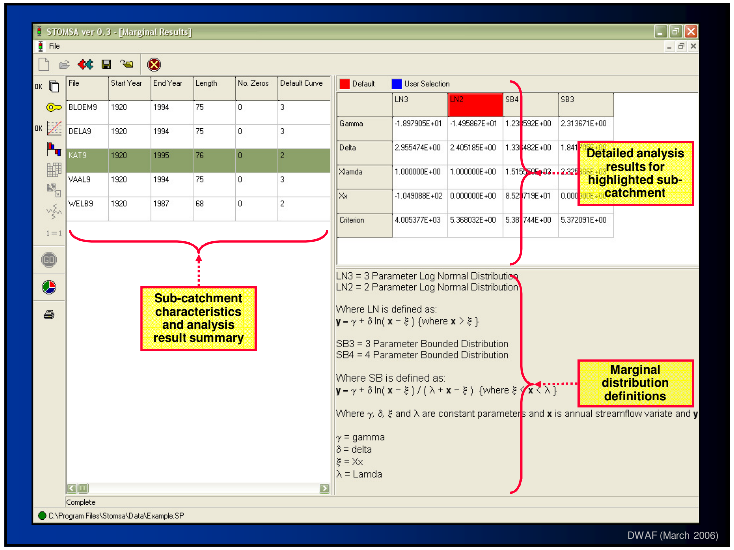


Streamflow generation process

- Select statistical distribution models based on historical streamflow sequence:
  - *Marginal distribution*
  - *Serial correlation*
  - *Cross-correlation*
- Generate streamflow sequences
- Undertake verification and validation tests
- **Stochastic Streamflow Model (STOMSA)**

Marginal distribution

- Relationship between total annual flows
- Represented as flows plotted against probability of exceedance
- 4 marginal distribution models:
  - 2-parameter Log-normal (LN2)
  - 3-parameter Log-normal (LN3)
  - 3-parameter Bounded (SB3)
  - 4-parameter Bounded (SB4)
- Result: <u>normalised</u> annual flows



File	Start Year	End Year	Length	No. Zeros	Default Curve
BLOEM9	1920	1994	75	0	3
DELA9	1920	1994	75	0	3
KAT9	1920	1995	76	0	2
VAAL9	1920	1994	75	0	3
WELB9	1920	1987	68	0	2

	LN3	LN2	SB4	SB3
Gamma	-1.897905E+01	-1.495867E+01	1.23[illegible]592E+00	2.313671E+00
Delta	2.955474E+00	2.405185E+00	1.33[illegible]482E+00	1.841705E+00
Xlamda	1.000000E+00	1.000000E+00	1.5155[illegible]E+03	2.325386E+03
Xx	-1.049088E+02	0.000000E+00	8.52[illegible]719E+01	0.000000E+00
Criterion	4.005377E+03	5.368032E+00	5.38[illegible]744E+00	5.372091E+00

LN3 = 3 Parameter Log Normal Distribution
LN2 = 2 Parameter Log Normal Distribution

Where LN is defined as:
$\mathbf{y} = \gamma + \delta \ln(\mathbf{x} - \xi) \{\text{where } \mathbf{x} > \xi \}$

SB3 = 3 Parameter Bounded Distribution
SB4 = 4 Parameter Bounded Distribution

Where SB is defined as:
$\mathbf{y} = \gamma + \delta \ln(\mathbf{x} - \xi) / (\lambda + \mathbf{x} - \xi) \ \{\text{where } \xi < \mathbf{x} < \lambda \}$

Where γ, δ, ξ and λ are constant parameters and **x** is annual streamflow variate and **y**

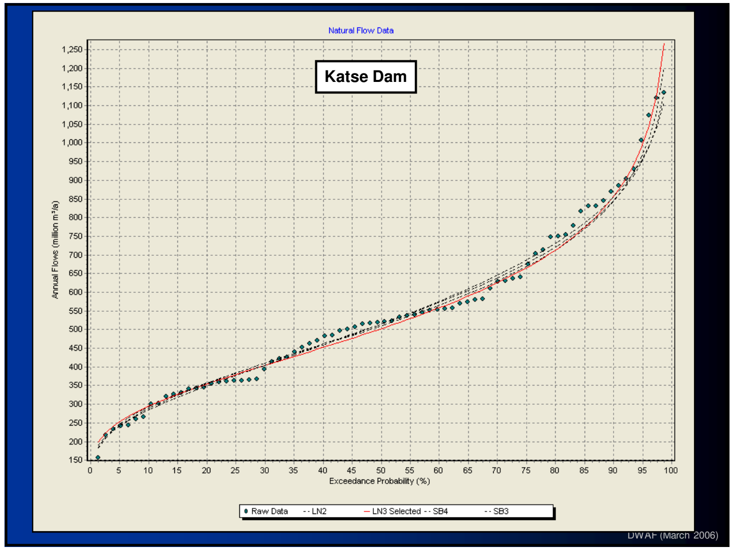
γ = gamma
δ = delta
ξ = Xx
λ = Lamda

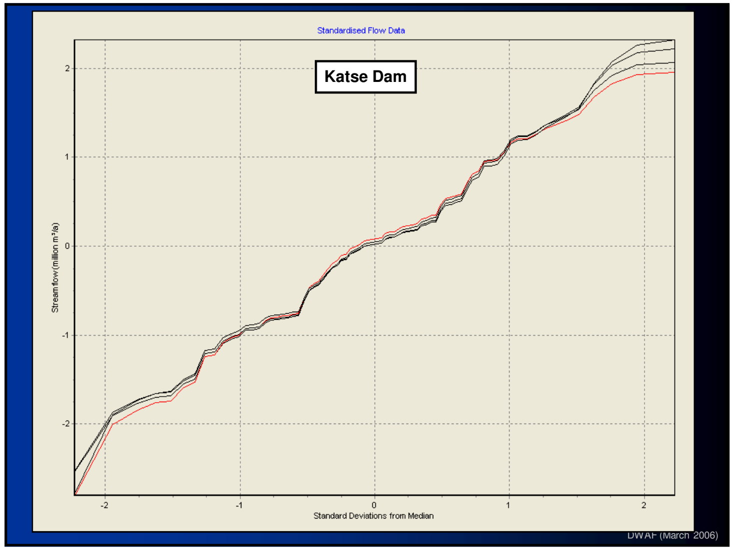
Complete
C:\Program Files\Stomsa\Data\Example.SP

Sub-catchment characteristics and analysis result summary

Detailed analysis results for highlighted sub-catchment

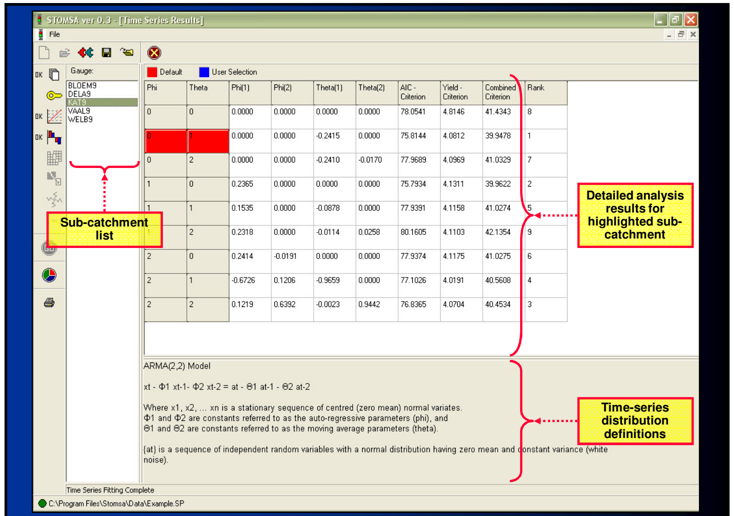
Marginal distribution definitions





Serial correlation

- Relationship between normalised annual flows
- Represented with *correlogram*
- 9 time-series distribution models:
  - ARMA (0,0); ARMA (0,1) ARMA (0,2)
  - ARMA (1,0); ARMA (1,1) ARMA (1,2)
  - ARMA (2,0); ARMA (2,1) ARMA (2,2)
- Result: normalised <u>residual</u> annual flows



Phi	Theta	Phi(1)	Phi(2)	Theta(1)	Theta(2)	AIC - Criterion	Yield - Criterion	Combined Criterion	Rank
0	0	0.0000	0.0000	0.0000	0.0000	78.0541	4.8146	41.4343	8
0	1	0.0000	0.0000	-0.2415	0.0000	75.8144	4.0812	39.9478	1
0	2	0.0000	0.0000	-0.2410	-0.0170	77.9689	4.0969	41.0329	7
1	0	0.2365	0.0000	0.0000	0.0000	75.7934	4.1311	39.9622	2
1	1	0.1535	0.0000	-0.0878	0.0000	77.9391	4.1158	41.0274	5
1	2	0.2318	0.0000	-0.0114	0.0258	80.1605	4.1103	42.1354	9
2	0	0.2414	-0.0191	0.0000	0.0000	77.9374	4.1175	41.0275	6
2	1	-0.6726	0.1206	-0.9659	0.0000	77.1026	4.0191	40.5608	4
2	2	0.1219	0.6392	-0.0023	0.9442	76.8365	4.0704	40.4534	3

ARMA(2,2) Model

xt - Φ1 xt-1- Φ2 xt-2 = at - Θ1 at-1 - Θ2 at-2

Where x1, x2, ... xn is a stationary sequence of centred (zero mean) normal variates.
Φ1 and Φ2 are constants referred to as the auto-regressive parameters (phi), and
Θ1 and Θ2 are constants referred to as the moving average parameters (theta).

{at} is a sequence of independent random variables with a normal distribution having zero mean and constant variance (white noise).

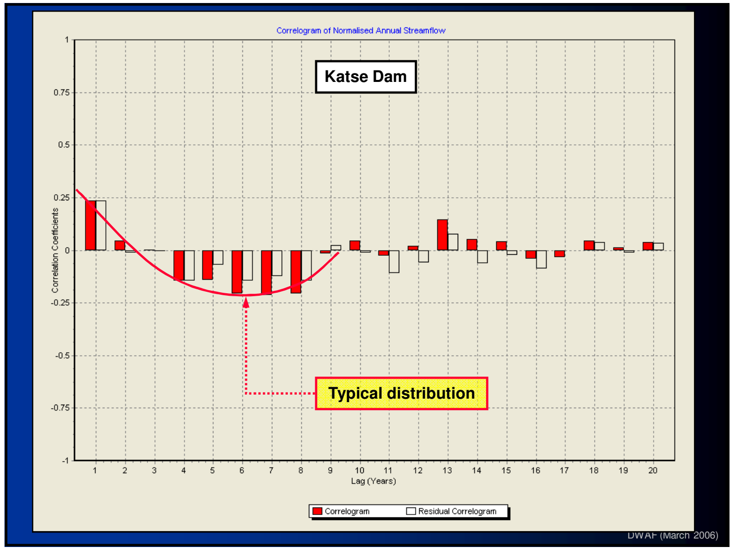
Time Series Fitting Complete

C:\Program Files\Stomsa\Data\Example.SP

Sub-catchment list

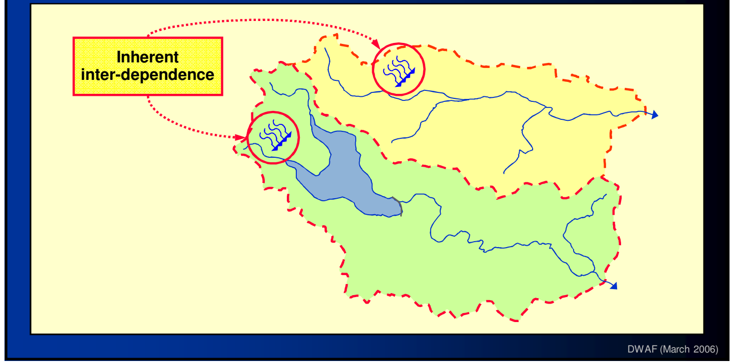
Detailed analysis results for highlighted sub-catchment

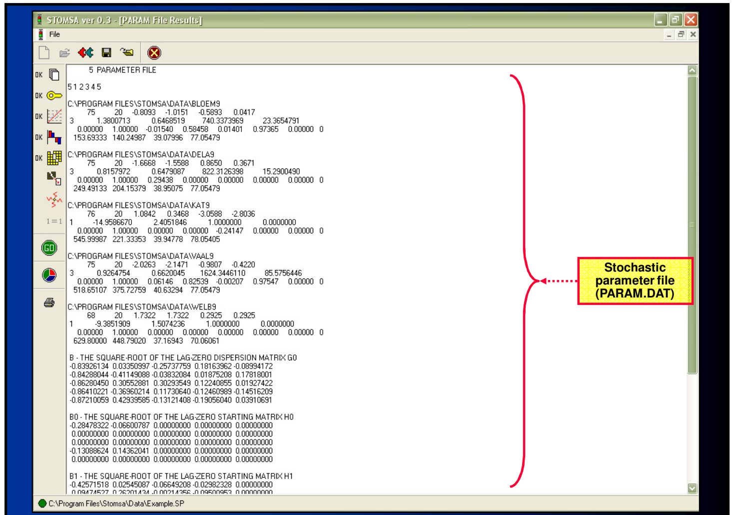
Time-series distribution definitions



Cross-correlation

- Flows from different catchments
- Result: parameter file (PARAM.DAT)





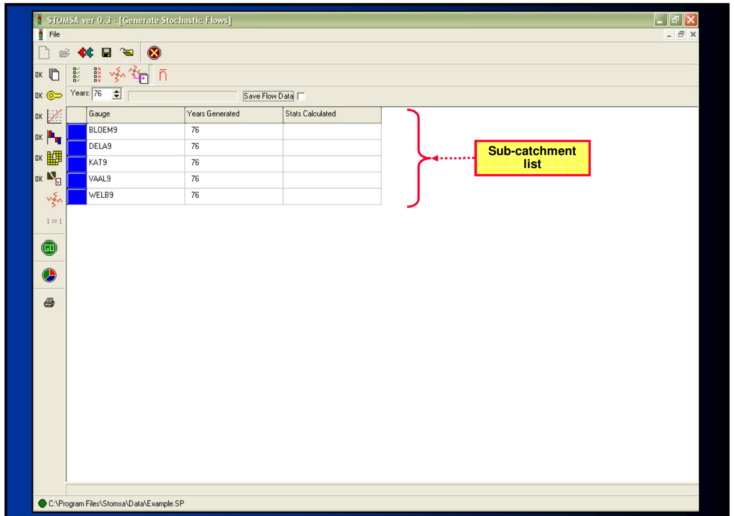
```
      5  PARAMETER FILE

5 1 2 3 4 5

C:\PROGRAM FILES\STOMSA\DATA\BLOEM9
      75        20    -0.8093    -1.0151    -0.5893     0.0417
 3         1.3800713        0.6468519        740.3373969        23.3654791
   0.00000    1.00000   -0.01540    0.58458    0.01401    0.97365    0.00000   0
  153.69333  140.24987   39.07996   77.05479

C:\PROGRAM FILES\STOMSA\DATA\DELA9
      75        20    -1.6668    -1.5588     0.8650     0.3671
 3         0.8157972        0.6479087        822.3126398        15.2900490
   0.00000    1.00000    0.29438    0.00000    0.00000    0.00000    0.00000   0
  249.49133  204.15379   38.95075   77.05479

C:\PROGRAM FILES\STOMSA\DATA\KAT9
      76        20     1.0842     0.3468    -3.0588    -2.8036
 1        -14.9586670        2.4051846        1.0000000        0.0000000
   0.00000    1.00000    0.00000    0.00000   -0.24147    0.00000    0.00000   0
  545.99987  221.33353   39.94778   78.05405

C:\PROGRAM FILES\STOMSA\DATA\VAAL9
      75        20    -2.0263    -2.1471    -0.9807    -0.4220
 3         0.9264754        0.6620045        1624.3446110        85.5756446
   0.00000    1.00000    0.06146    0.82539   -0.00207    0.97547    0.00000   0
  518.65107  375.72759   40.63294   77.05479

C:\PROGRAM FILES\STOMSA\DATA\WELB9
      68        20     1.7322     1.7322     0.2925     0.2925
 1        -9.3851909        1.5074236        1.0000000        0.0000000
   0.00000    1.00000    0.00000    0.00000    0.00000    0.00000    0.00000   0
  629.80000  448.79020   37.16943   70.06061

 B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
 -0.83926134  0.03350997 -0.25737759  0.18163962 -0.08994172
 -0.84288044 -0.41149088 -0.03832084  0.01875208  0.17818001
 -0.86280450  0.30552881  0.30293549  0.12240855  0.01927422
 -0.86410221 -0.36960214  0.11730640 -0.12460989 -0.14516209
 -0.87210059  0.42939585 -0.13121408 -0.19056040  0.03910691

 B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
 -0.28478322 -0.06600787  0.00000000  0.00000000  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 -0.13088624  0.14362041  0.00000000  0.00000000  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000

 B1 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H1
 -0.42571518  0.02545087 -0.06649208 -0.02982328  0.00000000
  0.09474527  0.26201434 -0.00214356 -0.09500953  0.00000000
```

C:\Program Files\Stomsa\Data\Example.SP

Generation of flow sequences

- Generate random numbers
- Apply selected statistical distribution models:
  - *Cross-correlation*
  - *Serial correlation*
  - *Marginal distribution*
- Disaggregate annual into monthly flow values

Reverse order



Years: 76

Save Flow Data ☐

	Gauge	Years Generated	Stats Calculated
🟦	BLOEM9	76	
🟦	DELA9	76	
🟦	KAT9	76	
🟦	VAAL9	76	
🟦	WELB9	76	

Sub-catchment list

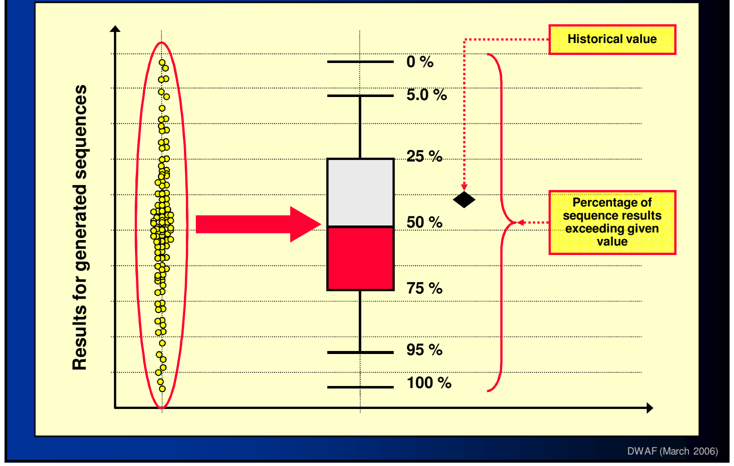
C:\Program Files\Stomsa\Data\Example.SP

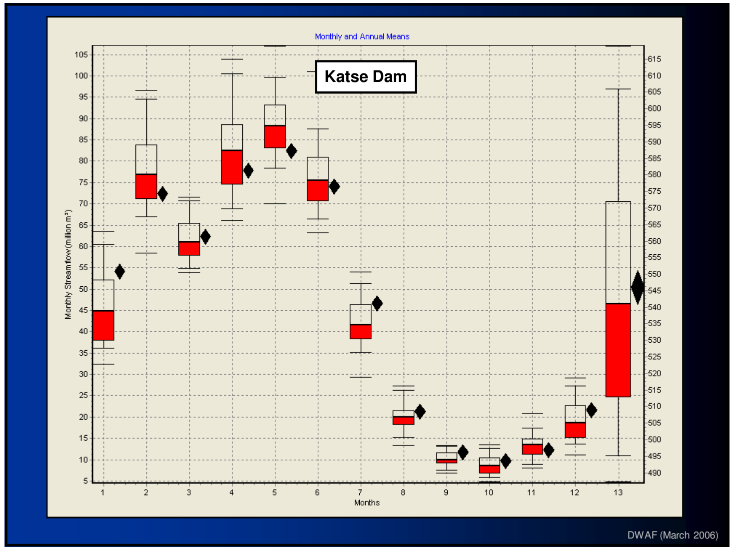
Verification and validation tests

- *Verification*: statistics used in generation
- *Validation*: reservoir storage tests

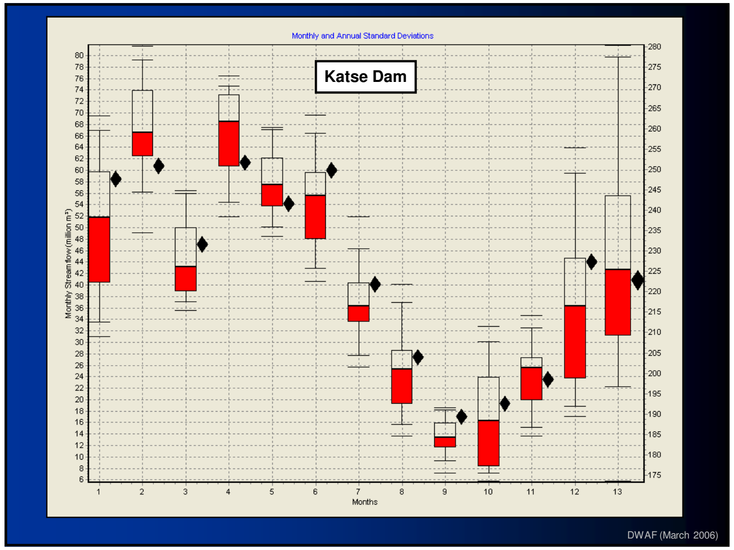
- Generate stochastic sequences
- Calculate particular characteristic for each sequence
- Plot resulting statistical distribution and compare to historical value
- Acceptable if between 25 & 75 percentiles

Plotting statistical distribution

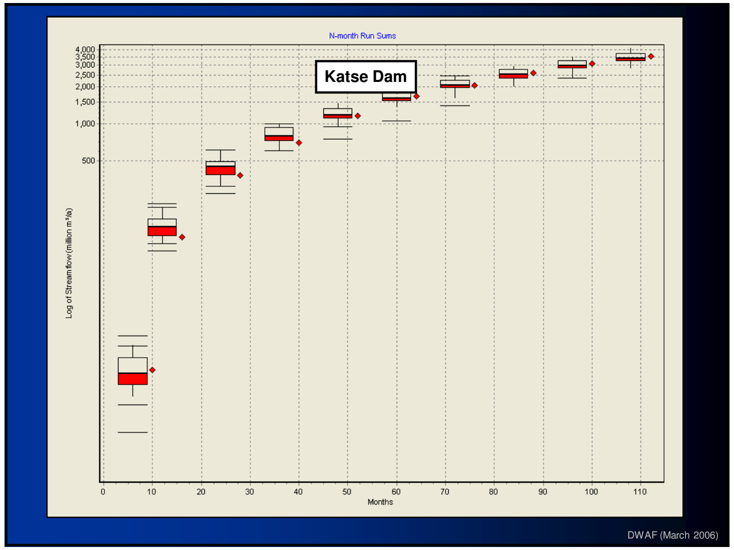




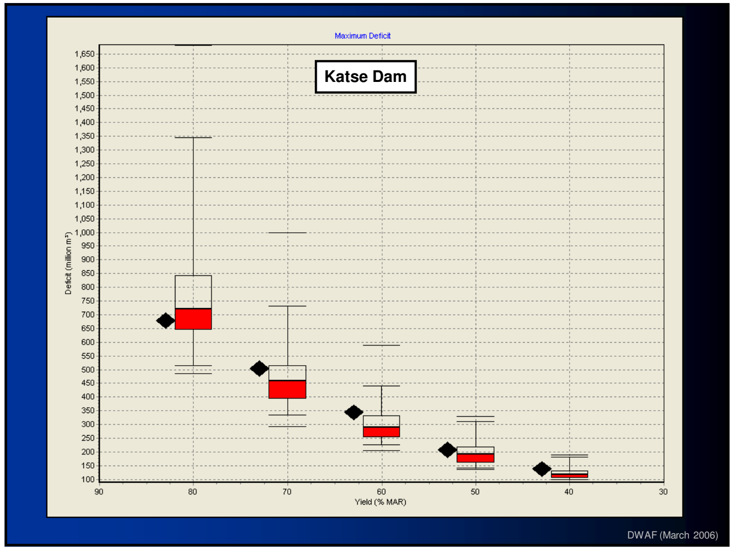
DWAF (March 2006)



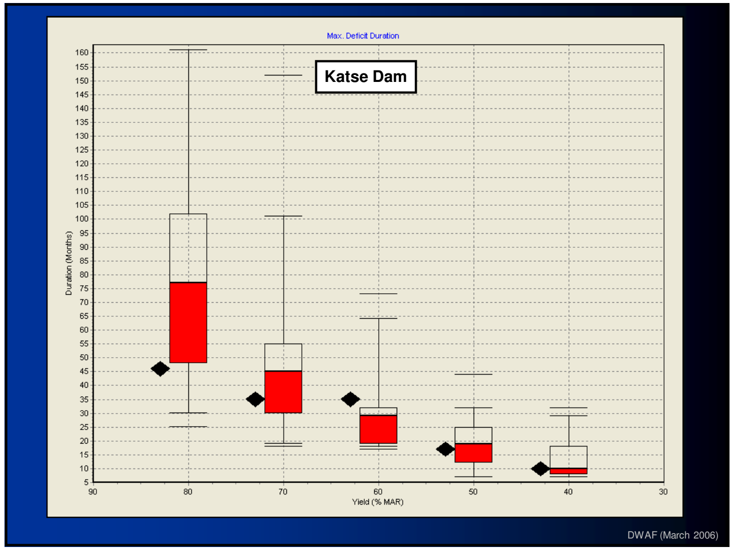
DWAF (March 2006)

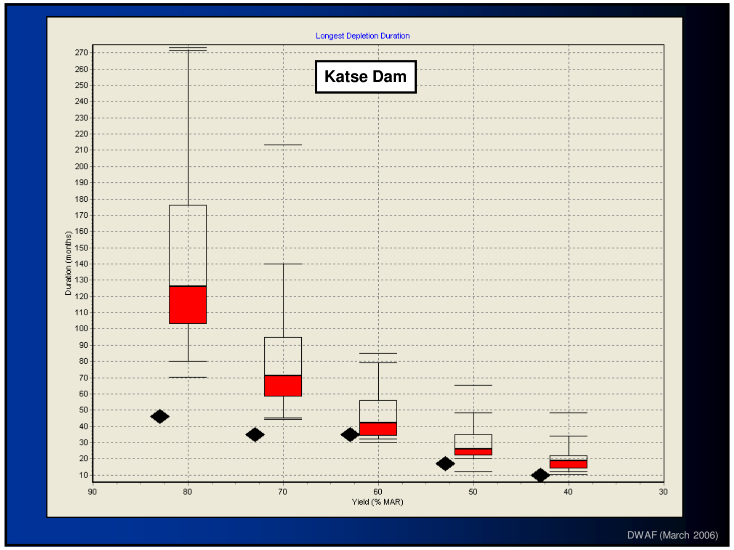


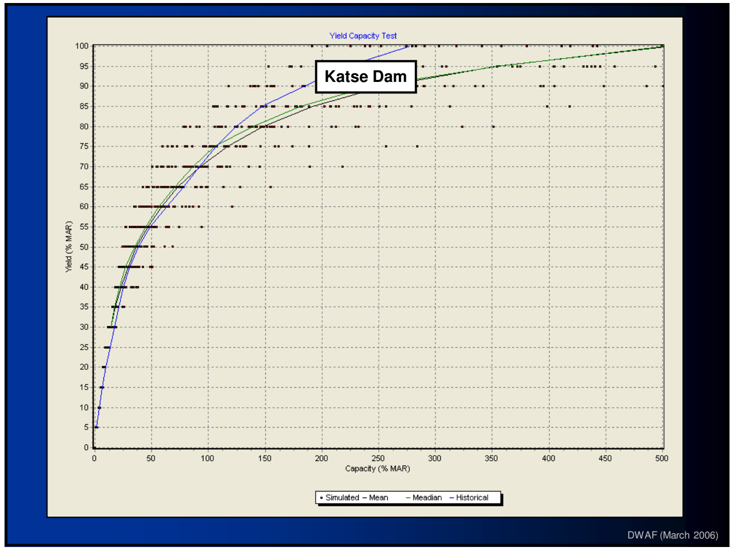
DWAF (March 2006)



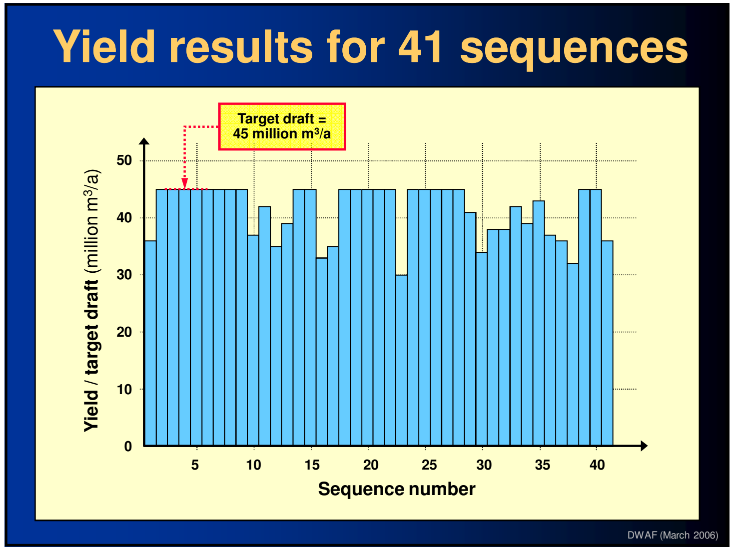
DWAF (March 2006)



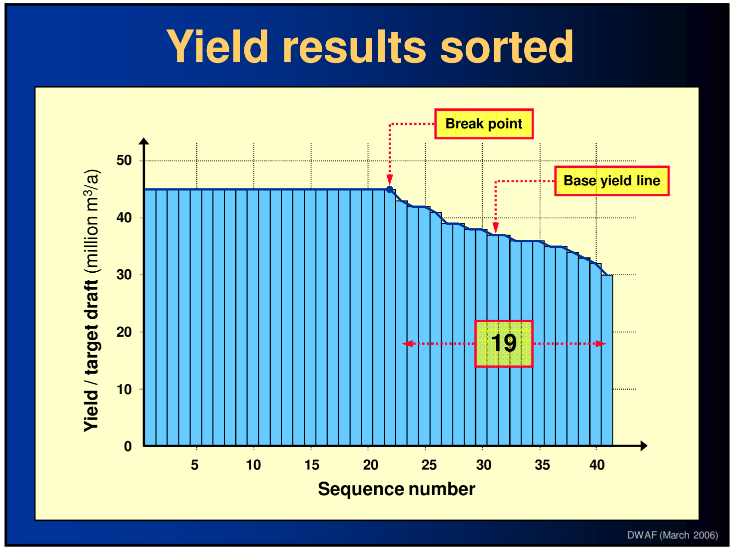




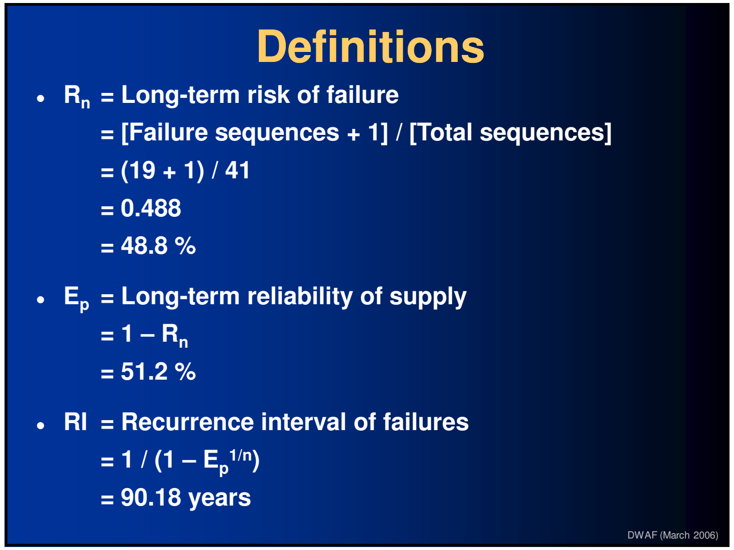
3. Stochastic yield analysis



Yield results for 41 sequences

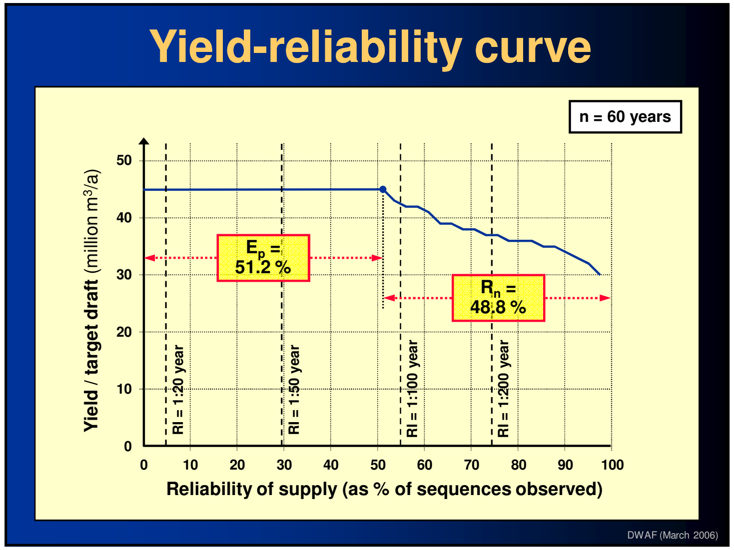


Yield results sorted



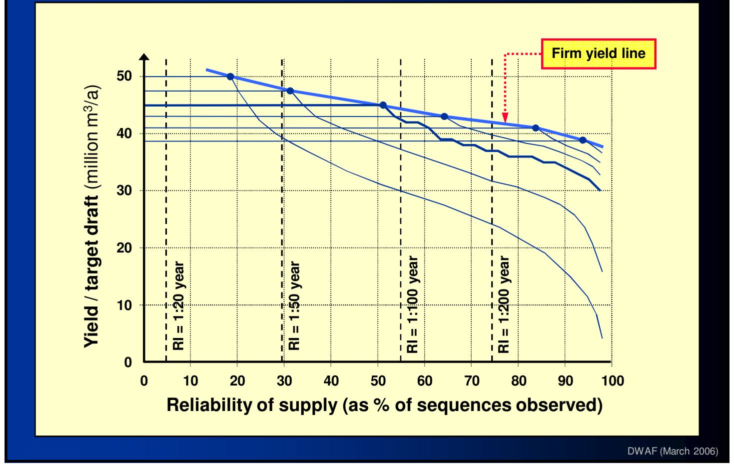
Definitions

- R_n = Long-term risk of failure
  = [Failure sequences + 1] / [Total sequences]
  = (19 + 1) / 41
  = 0.488
  = 48.8 %
- E_p = Long-term reliability of supply
  = $1 - R_n$
  = 51.2 %
- RI = Recurrence interval of failures
  = $1 / (1 - E_p^{1/n})$
  = 90.18 years

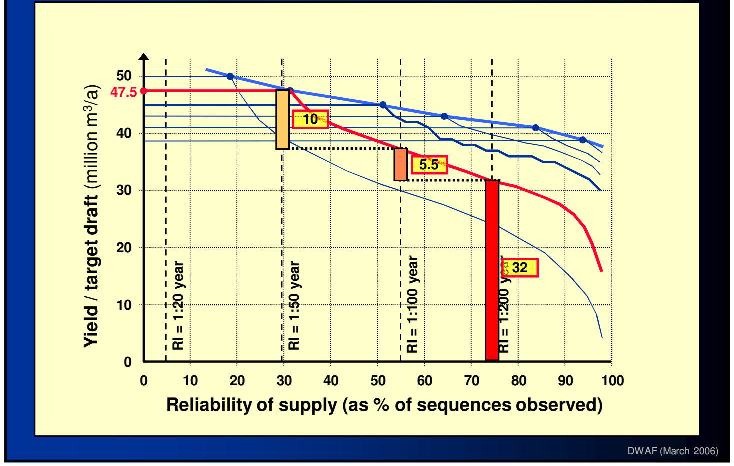


Yield-reliability curve

Family of yield-reliability curves



Available resource



4. Practical 2: Interpreting yield-reliability curves

Purpose and methodology

Purpose:

- Explore interpretation of yield-reliability curve

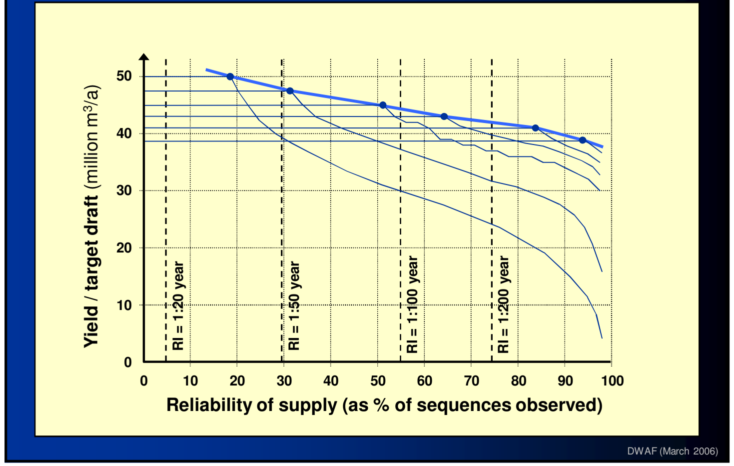
Methodology:

- Allocate prescribed water requirements at various assurance categories
- Interpret results

Water requirements

Water user	Assurance category (RI)	Requirement (million m^3/a)
Domestic	1:200 years	15
Environmental	1:100 years	10
Industrial	1:50 years	10
Irrigation	1:20 years	15
Total:		50

Figure to be completed

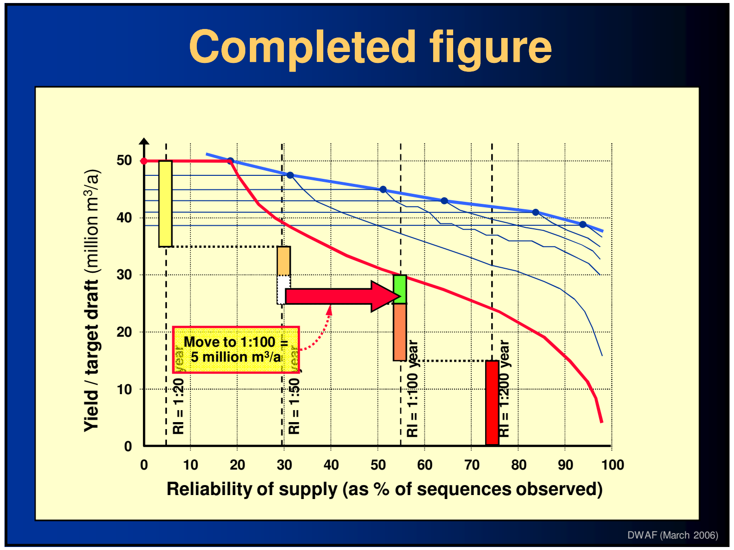


Interpretation

- How does the base yield line of the imposed target draft compare to the requirement in each assurances category?
- What does the above observation imply?
- How much of the industrial requirement (RI = 1:50) can actually be supplied at RI = 1:100?

  Show this amount on the figure.

Results



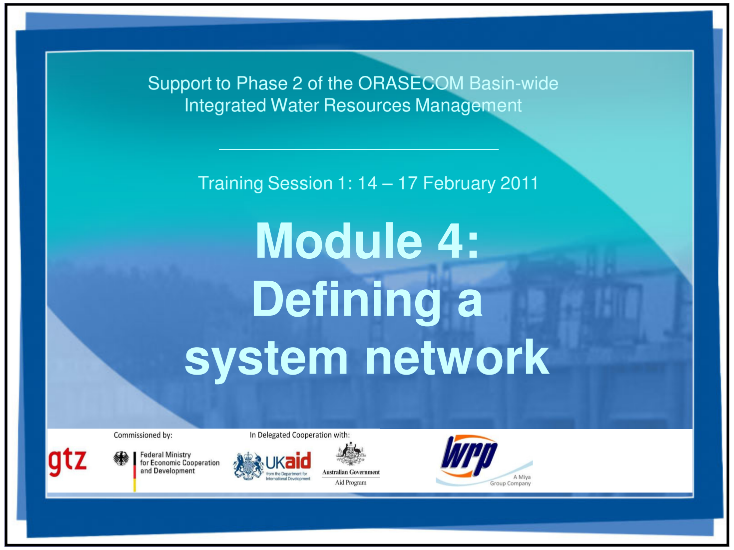
Completed figure

DWAF (March 2006)

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 – 17 February 2011

End



Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management

Training Session 1: 14 – 17 February 2011

Module 4: Defining a system network

Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program

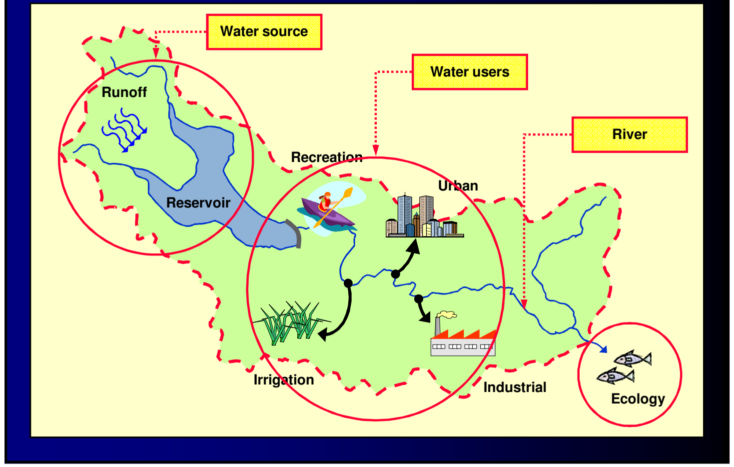
wrp
A Miya Group Company

Contents of module

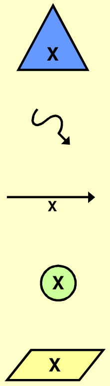
1. Creating a representative network model
2. Basic building blocks
3. General data requirements

1. Creating a representative network model

Identify main physical features



Representative model symbols



= Reservoir

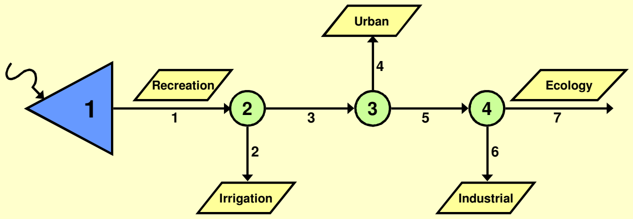
= Runoff

= Flow route (with sink ▸)

= Junction node

= Water user

Resulting network model



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2. Basic building blocks

Channels (1 of 2)

- Conduits that convey water in a water resource system network
- Used for defining physical features, incl.:
  - System target draft
  - River reaches
  - Flow constraints
  - Monthly time-series requirements
  - Losses

Channels (2 of 2)

Physical system features (cont.):

- Diversion infrastructure efficiencies
- Ecological requirements (IFRs)
- Pumping stations
- Minimum flow specifications
- Irrigation areas
- Inflows from other systems
- Flow control structures
- Hydropower plants

Channel types (1 of 3)

- Model allows for 12 types of channels
- Each used for modelling particular system feature:
- Master control (yield) channel

  Impose target draft to determine system yield
- General flow channel

  Flow in open river with no capacity constraint

Channel types (2 of 3)

- Multi-purpose min-max channel

  Versatile channel type, e.g. abstractions routes (with monthly distribution) and channels with physical flow constraints
- Specified demand channel

  Abstraction routes (monthly time-series)
- Loss channel

  System losses due to evaporation or seepage

Channel types (3 of 3)

- Diversion channel

  Efficiency of diversion structures for utilising river flow
- IFR channel

  Water releases for ecological requirements
- Other channels:

  Hydropower, pumping, minimum flow, irrigation and specified inflow

Nodes

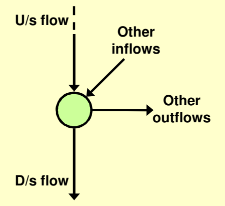
Join channels according to physical layout of system:

- Combining flow from tributary catchments
- Points from which flow can be abstracted or diverted
- Splitting conveyance routes to simulate differing physical constraints

---

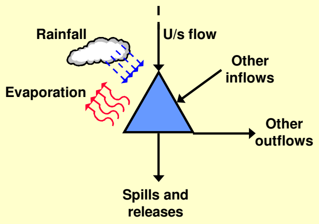
Nodes without storage

- Serve as junctions only
- No additional characteristic definitions required



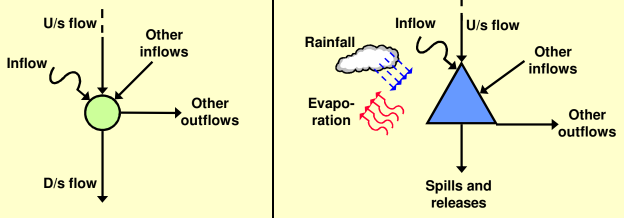
Nodes with storage

- Used to model reservoirs
- Range of physical and operational characteristics required

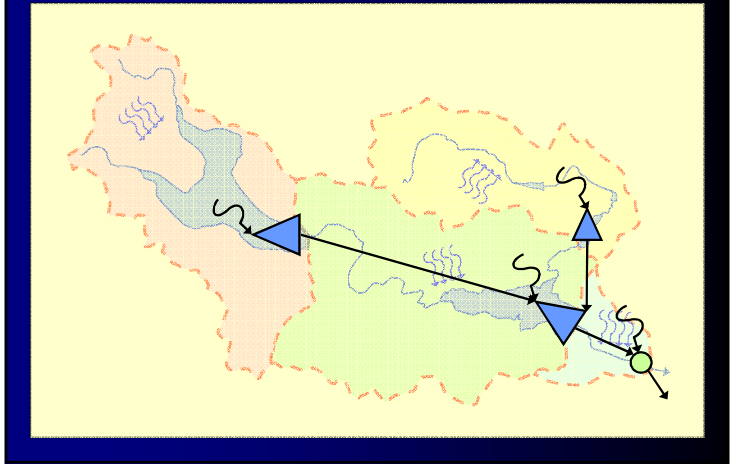


Nodes with “inflows” (1 of 3)

- “Inflows” represent net runoff from incremental sub-catchments
- Both nodes with and without storage

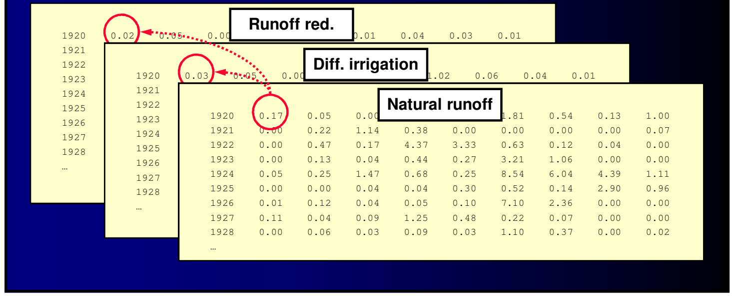


Nodes with “inflows” (2 of 3)



Nodes with “inflows” (3 of 3)

- Net runoff = natural runoff, minus diffuse irrigation and runoff reductions
- Incorporated as monthly time-series:



1920	0.17	0.05	0.00			1.81	0.54	0.13	1.00
1921	0.00	0.22	1.14	0.38	0.00	0.00	0.00	0.00	0.07
1922	0.00	0.47	0.17	4.37	3.33	0.63	0.12	0.04	0.00
1923	0.00	0.13	0.04	0.44	0.27	3.21	1.06	0.00	0.00
1924	0.05	0.25	1.47	0.68	0.25	8.54	6.04	4.39	1.11
1925	0.00	0.00	0.04	0.04	0.30	0.52	0.14	2.90	0.96
1926	0.01	0.12	0.04	0.05	0.10	7.10	2.36	0.00	0.00
1927	0.11	0.04	0.09	1.25	0.48	0.22	0.07	0.00	0.00
1928	0.00	0.06	0.03	0.09	0.03	1.10	0.37	0.00	0.02
…									

---

3. General data requirements

Overview

- Study definition
- Run configuration
- Result output configuration
- System network definition
- Catchment hydrology data

Study definition

- Study name, description, etc.
- Sub-area name, description, etc.
- Scenario name, description, etc
- Version of WRYM to be applied
- WRYM data file name prefix
- Location of WRYM input data files
- Location of WRYM result output files
- Location of stochastic parameter file

Run configuration

- General run description
- Description of months (names and number of days)
- Selection of run type (historical or stochastic)
- Stochastic run options
- Automatic determination of firm yields

Result output configuration

- WRYM result output file options:
  - Create data file (Y/N)
  - Level of output detail
- Channel flow data output options
- Reservoir data output options:
  - Month-end storage volumes
  - Month-end storage elevations
  - Net runoff, rainfall and evaporation

System network definition

- Reservoirs
  - Properties (name, status, etc.)
  - Physical characteristics
  - Zone and rule curve elevations
  - Start storage level
  - Associated incremental sub-catchment
- Flow routes
- System layout/connectivity
- Operational aspects

Catchment hydrology data

- Time-series data for incremental sub-catchments:
  - Natural runoff
  - Streamflow reductions (forestry, etc.)
  - Diffuse irrigation
  - Point rainfall
- Evaporation (12 monthly values)
- Parameters for generating stochastic streamflow data

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14– 17 February 2011

End

Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program
WRP A M Group Comp
water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 – 17 February 2011

Module 5: Defining system operating rules

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program

wrp A Miya Group Company

Contents

1. Background
2. Using “penalties” to define operating rules
3. Practical 2: Interpreting penalties

---

1. Background

General

- Operation of system must be controlled
- Generally based on:
  - Practical experience
  - Specialist analysis
- Overall objectives:
  - Optimise utilisation of water resource (capability, assurance, sustainability, quality)
  - Minimise cost of operation

Typical aspects

- Prioritisation of supply to water users
- Prioritisation of use of water sources
- Conditions under which inter-reservoir and inter-basin support occurs
- Minimisation of spillage
- Blending options
- Flood management

Selection process

- Define objectives
- Select initial set of operating rules
- Implement initial selection in model
- Undertake analysis and interpret results
- Evaluate achievement of objectives
- Reselect operating rules
- Repeat selection process

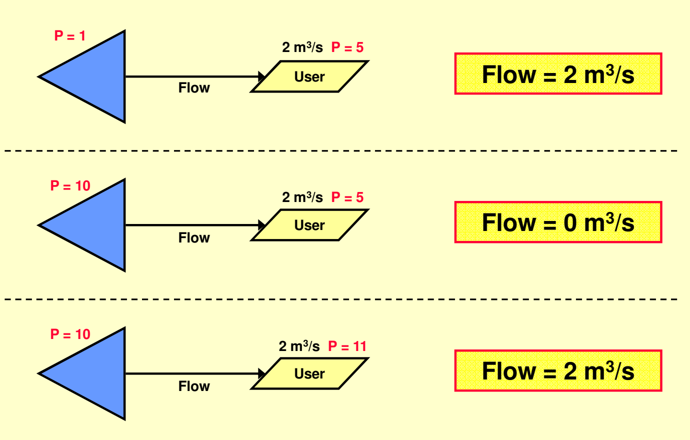
---

2. Using "penalties" to define operating rules

Penalties

- Tool for implementing selected operating rules in model
- Dimensionless value assigned by analyst to system components:
  - Channels: for every unit of flow
  - Reservoirs: for every unit of water in storage
- Interpreted by comparing relative size
- Basis of model flow-routing solution

Penalty selection (1 of 3)

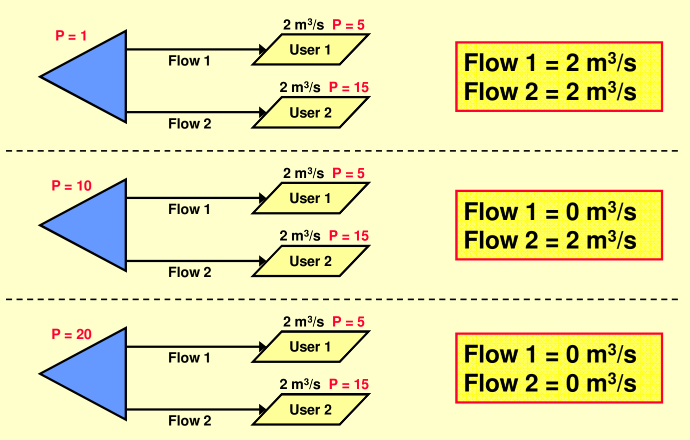


Flow = 2 m^3/s

Flow = 0 m^3/s

Flow = 2 m^3/s

Penalty selection (2 of 3)

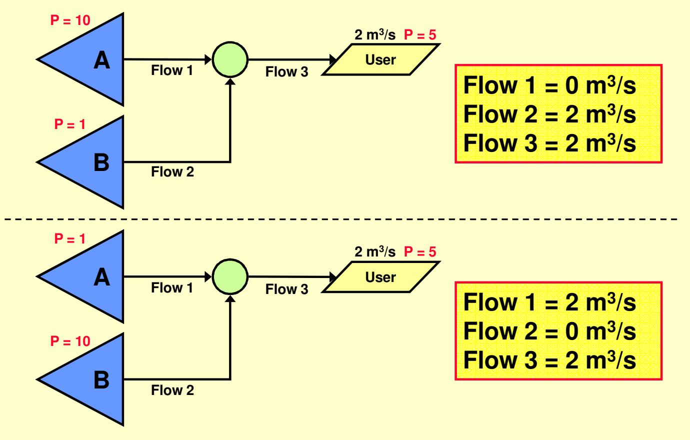


Flow 1 = 2 m^3/s
Flow 2 = 2 m^3/s

Flow 1 = 0 m^3/s
Flow 2 = 2 m^3/s

Flow 1 = 0 m^3/s
Flow 2 = 0 m^3/s

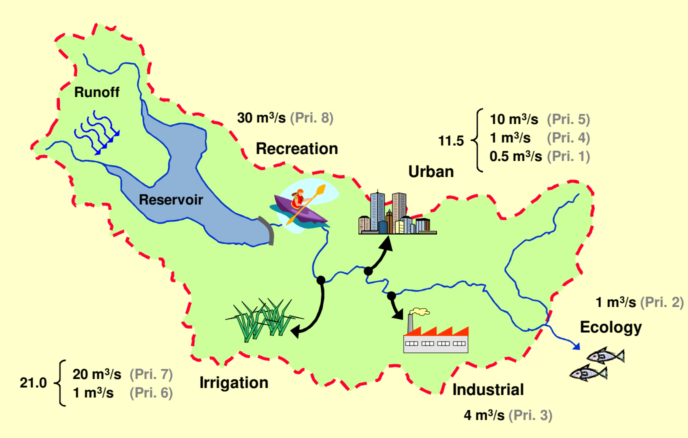
Penalty selection (3 of 3)



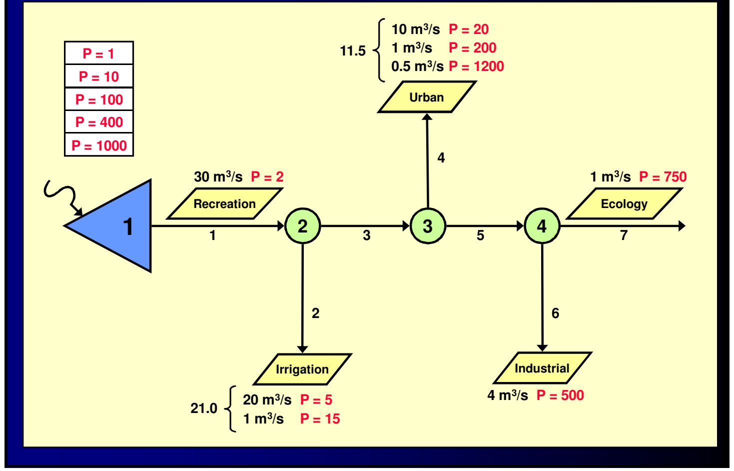
Flow 1 = 0 m^3/s
Flow 2 = 2 m^3/s
Flow 3 = 2 m^3/s

Flow 1 = 2 m^3/s
Flow 2 = 0 m^3/s
Flow 3 = 2 m^3/s

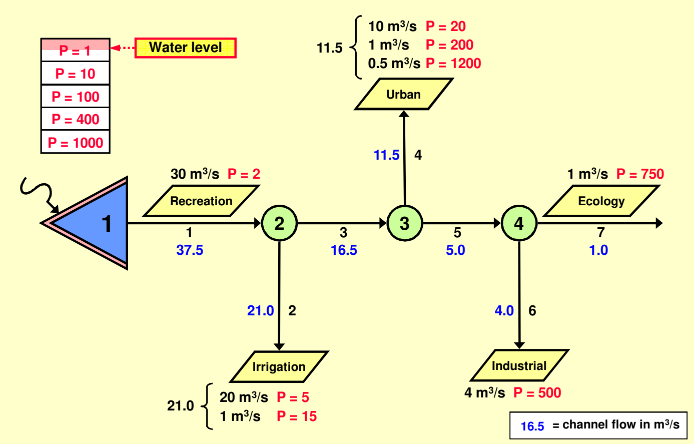
Water resource system



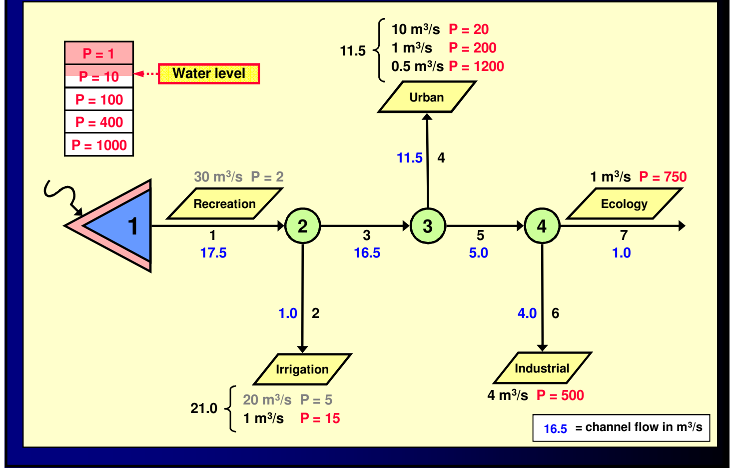
Network model with penalties



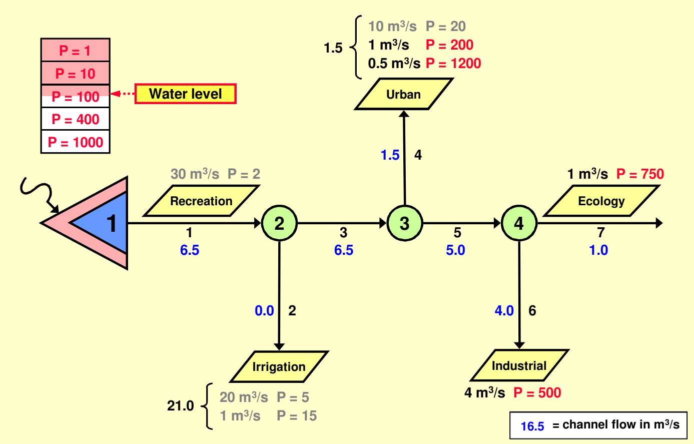
Case 1: Reservoir in Zone 1



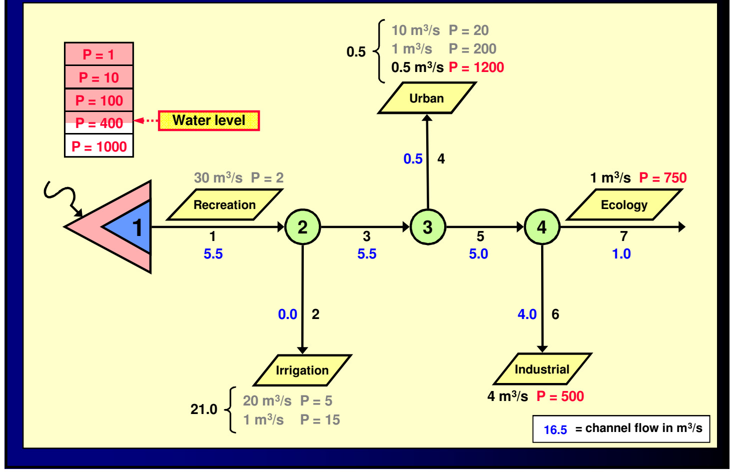
Case 2: Reservoir in Zone 10



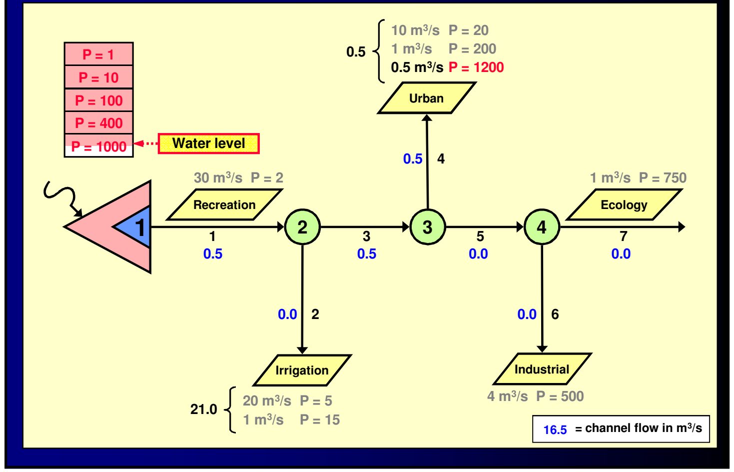
Case 3: Reservoir in Zone 100



Case 4: Reservoir in Zone 400



Case 5: Reservoir in Zone 1000

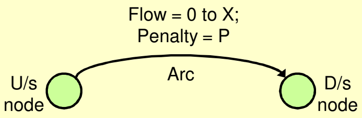


Modelling channel penalties

- Basic building blocks: “arcs”
- Allow particular flows under specific circumstances
- For each arc, 3 data values defined:
  - Lower flow limit
  - Upper flow limit
  - Penalty (“dis-benefit” of every unit of flow)
- Up to 5 arcs, generally only 1 or 2

1-arc channel

Configuration



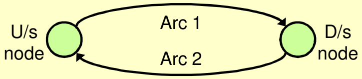
Standard notation

0 to X	P

2-arc channel (1 of 2)

Configuration

Flow = X to Y (usually Y = X);
Penalty = 0 (usually)

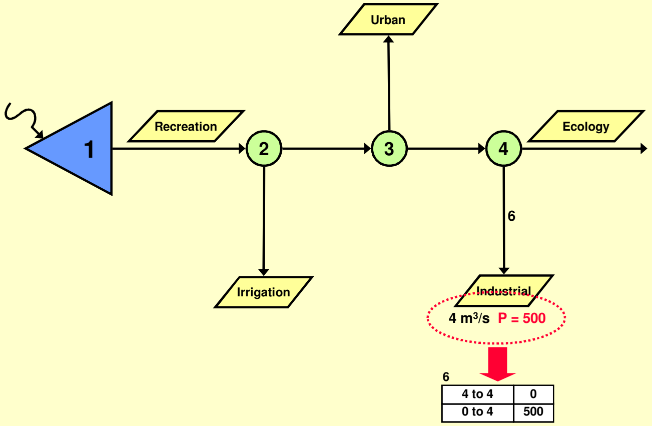


Flow = 0 to X;
Penalty = P

Standard notation

X to Y	0
0 to X	P

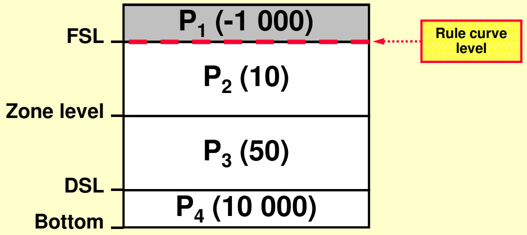
2-arc channel (2 of 2)



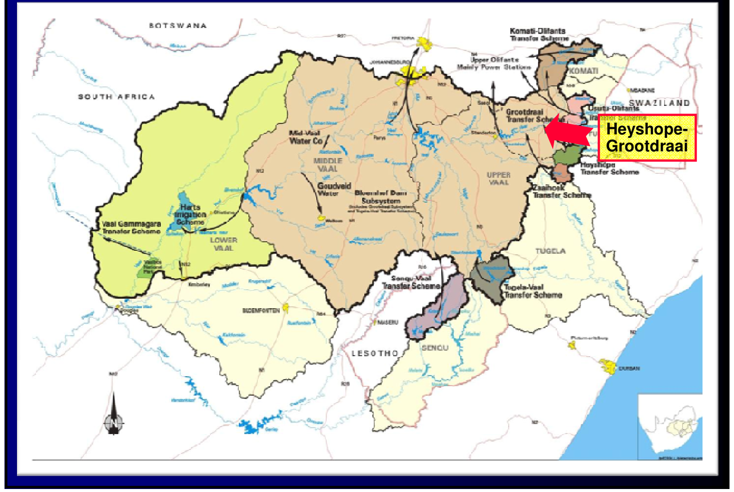
Modelling reservoir penalties

- Defined in terms of "storage zones" and "rule curve level"
- For each zone, 2 data values defined:
  - Elevation of lower zone boundary
  - Zone penalty
- Penalty relation to rule curve:
  - Above: "dis-benefit" of water in storage
  - Below: "benefit" of water in storage

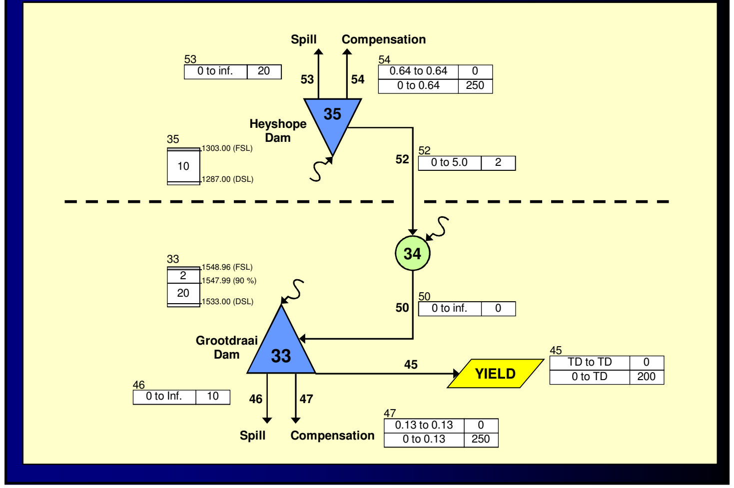
Standard reservoir notation



Example: Heyshope-Grootdraai transfer (1 of 2)



Example: Heyshope-Grootdraai transfer (2 of 2)



3. Practical 3: Interpreting penalties

Purpose and methodology

Purpose:

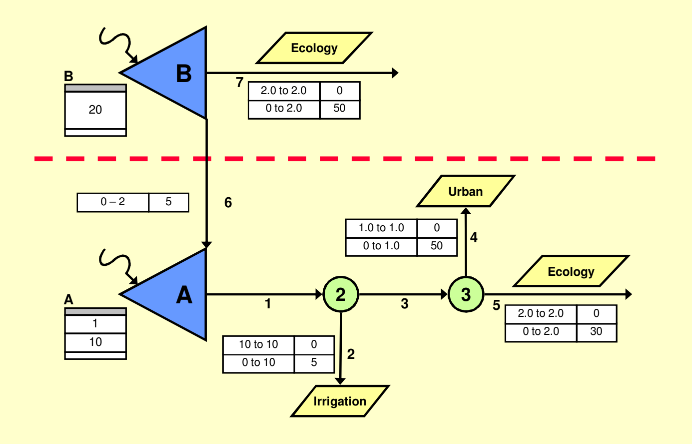
- Explore use of penalties to model operating rules
- Investigate behaviour of system under various situations

Methodology:

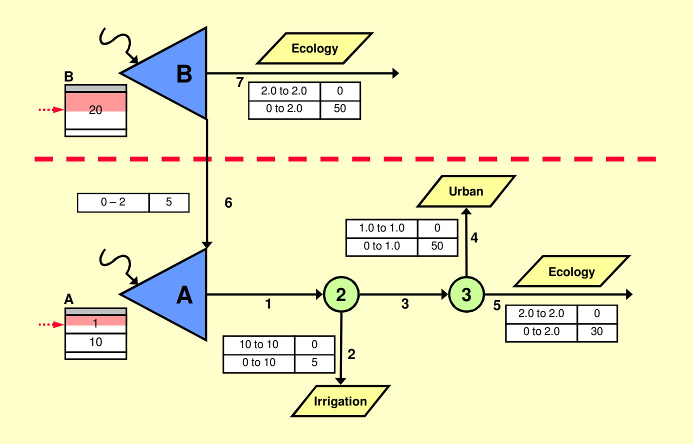
- Analyse system for 3 cases
- Complete table with results

Physical system

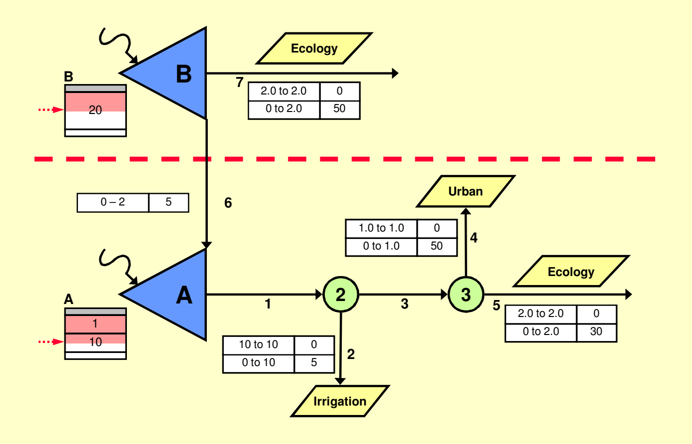
Network model with penalties

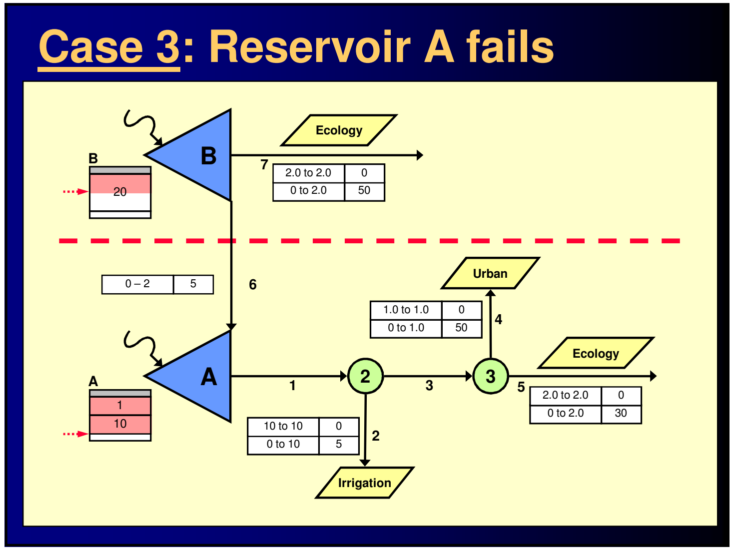


Case 1: Reservoir A in Zone 1



Case 2: Reservoir A in Zone 10





Case 3: Reservoir A fails

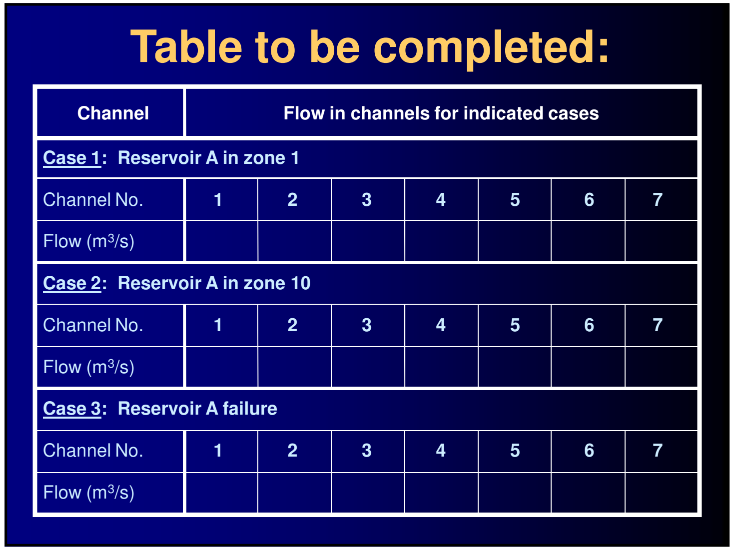
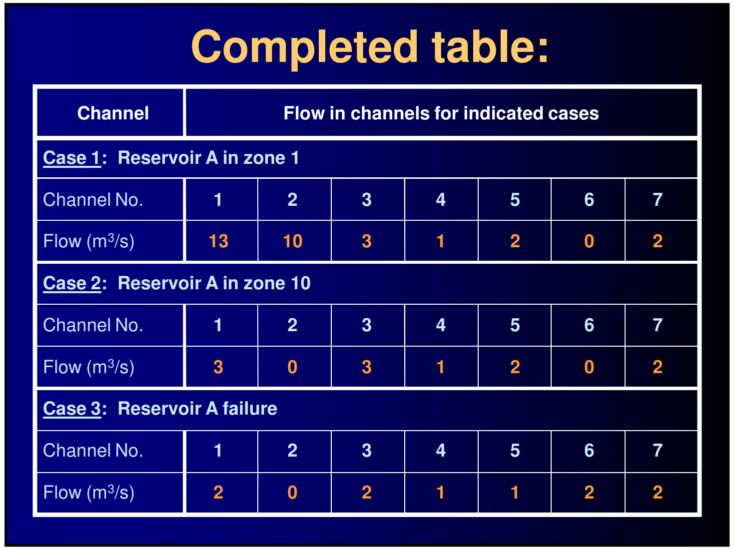


Table to be completed:

Channel	Flow in channels for indicated cases						
Case 1: Reservoir A in zone 1							
Channel No.	1	2	3	4	5	6	7
Flow (m^3/s)							
Case 2: Reservoir A in zone 10							
Channel No.	1	2	3	4	5	6	7
Flow (m^3/s)							
Case 3: Reservoir A failure							
Channel No.	1	2	3	4	5	6	7
Flow (m^3/s)							

Results



Completed table:

Channel	Flow in channels for indicated cases						
Case 1: Reservoir A in zone 1							
Channel No.	1	2	3	4	5	6	7
Flow (m^3/s)	13	10	3	1	2	0	2
Case 2: Reservoir A in zone 10							
Channel No.	1	2	3	4	5	6	7
Flow (m^3/s)	3	0	3	1	2	0	2
Case 3: Reservoir A failure							
Channel No.	1	2	3	4	5	6	7
Flow (m^3/s)	2	0	2	1	1	2	2

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 – 17 February 2011

End

Commissioned by:

gtz

Federal Ministry
for Economic Cooperation
and Development

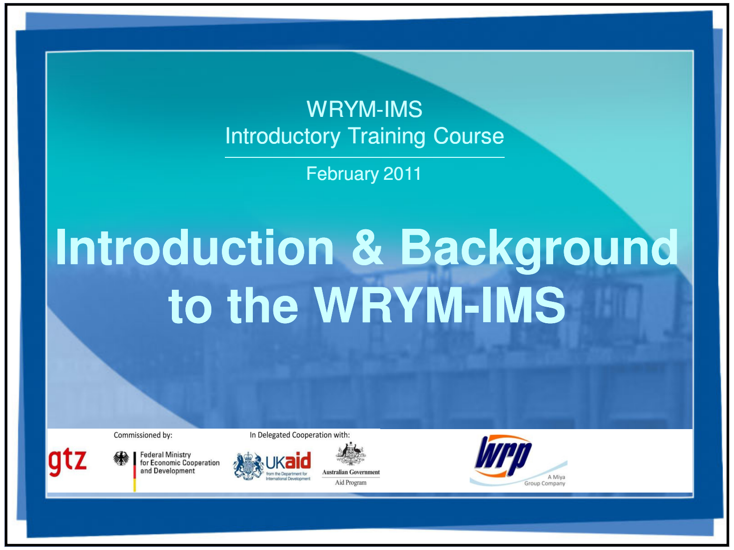
In Delegated Cooperation with:

UKaid
from the Department for
International Development

Australian Government
Aid Program

wrp

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA



WRYM-IMS
Introductory Training Course
February 2011

Introduction & Background to the WRYM-IMS

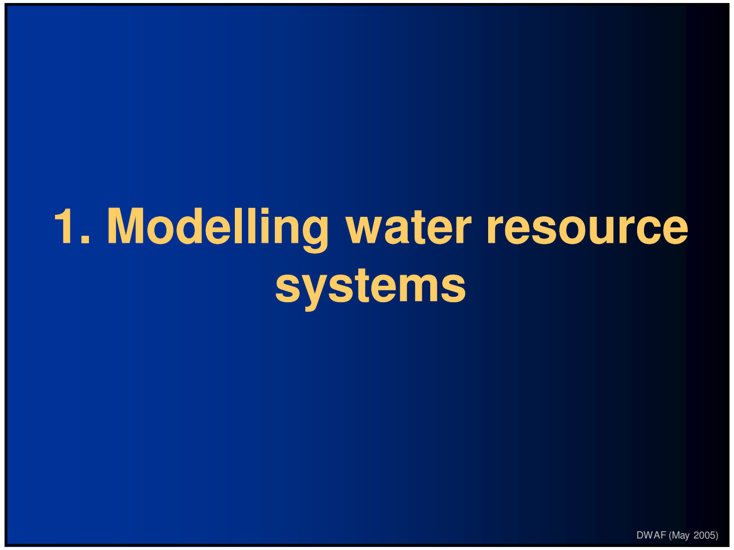
Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:
UKaid
Australian Government Aid Program

wrp
A Miya Group Company

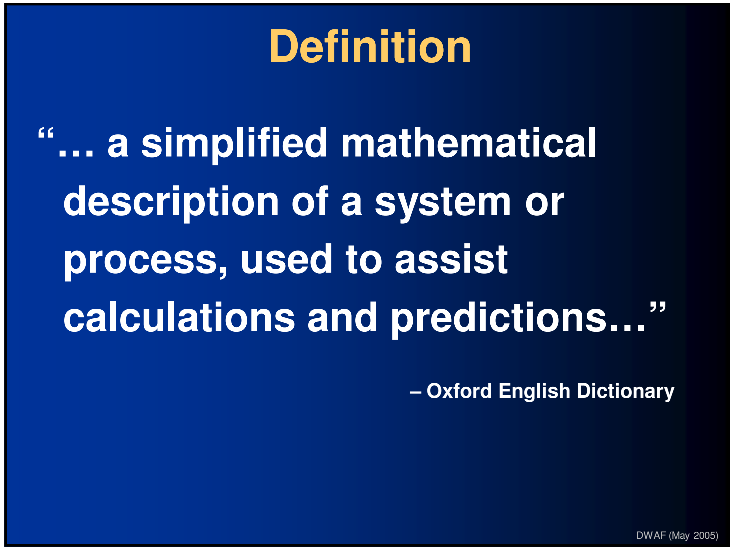
Introduction & background of trainees

DWAF (May 2005)



1. Modelling water resource systems

DWAF (May 2005)

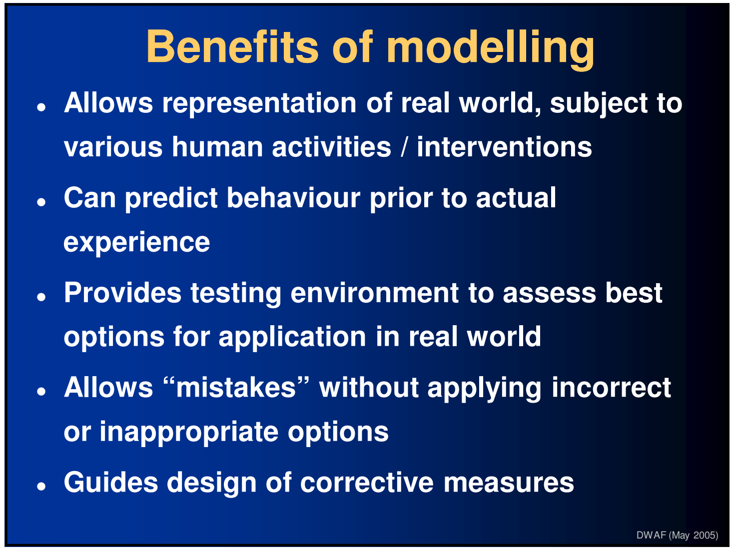


Definition

"… a simplified mathematical description of a system or process, used to assist calculations and predictions…"

– Oxford English Dictionary

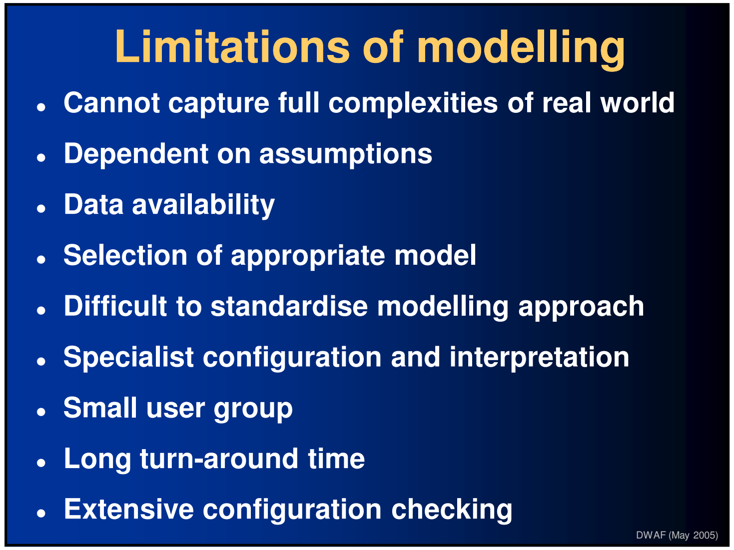
DWAF (May 2005)



Benefits of modelling

- Allows representation of real world, subject to various human activities / interventions
- Can predict behaviour prior to actual experience
- Provides testing environment to assess best options for application in real world
- Allows “mistakes” without applying incorrect or inappropriate options
- Guides design of corrective measures

DWAF (May 2005)



Limitations of modelling

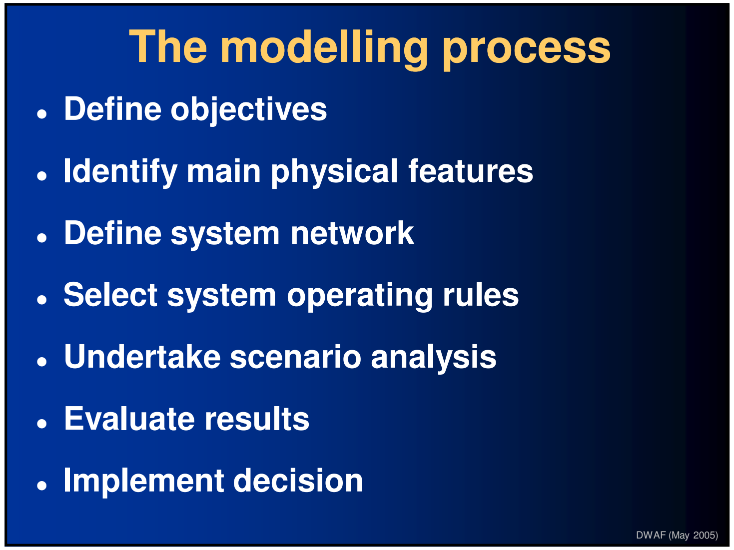
- Cannot capture full complexities of real world
- Dependent on assumptions
- Data availability
- Selection of appropriate model
- Difficult to standardise modelling approach
- Specialist configuration and interpretation
- Small user group
- Long turn-around time
- Extensive configuration checking

DWAF (May 2005)

Purpose

- Assessment
  - Resource capability
  - Resource assurance
  - Water quality
- Impact of interventions
  - Conservation
  - Resource development
- Impact of management options
  - Resource operation
  - System maintenance
- Monitoring of observed behaviour

DWAF (May 2005)



The modelling process

- Define objectives
- Identify main physical features
- Define system network
- Select system operating rules
- Undertake scenario analysis
- Evaluate results
- Implement decision

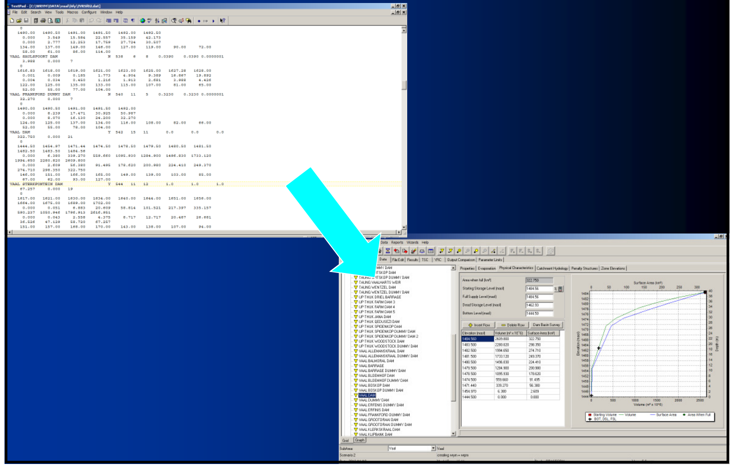
DWAF (May 2005)

2. Background

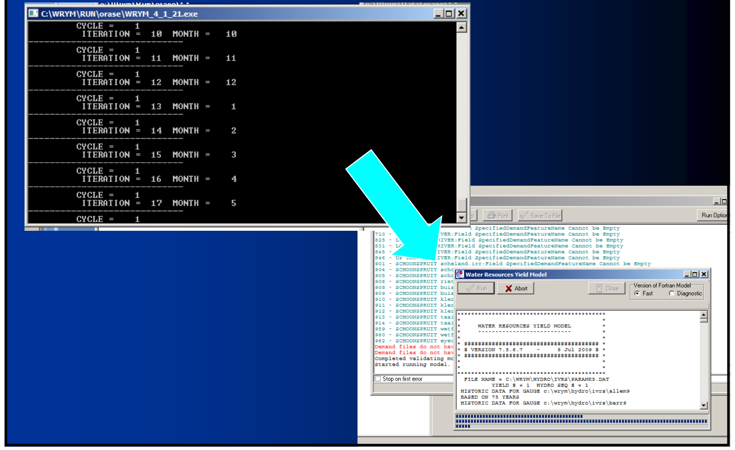
History of WRYM

- ***Water Resources Yield Model*** **(WRYM) development commenced in mid-1980s**
- **Network simulation model to analyse complex water resource systems**
- **Based on *Acres Reservoir Simulation Program* (ARSP) (from Canada)**
- **Progressive development**
- **Custodian: D: IWRP**

Past to Present (data files)



Past to Present (model simulation)



C:\WRYM\RUN\orase\WRYM_4_1_21.exe

```
          CYCLE =     1
           ITERATION =   10  MONTH =   10
--------------------------------
          CYCLE =     1
           ITERATION =   11  MONTH =   11
--------------------------------
          CYCLE =     1
           ITERATION =   12  MONTH =   12
--------------------------------
          CYCLE =     1
           ITERATION =   13  MONTH =    1
--------------------------------
          CYCLE =     1
           ITERATION =   14  MONTH =    2
--------------------------------
          CYCLE =     1
           ITERATION =   15  MONTH =    3
--------------------------------
          CYCLE =     1
           ITERATION =   16  MONTH =    4
--------------------------------
          CYCLE =     1
           ITERATION =   17  MONTH =    5
--------------------------------
          CYCLE =     1
```

```
                 SpecifiedDemandFeatureName Cannot be Empty
710 -           VER:Field SpecifiedDemandFeatureName Cannot be Empty
825 - L         RIVER:Field SpecifiedDemandFeatureName Cannot be Empty
831 - LC        RIVER:Field SpecifiedDemandFeatureName Cannot be Empty
845 -           IVER:Field SpecifiedDemandFeatureName Cannot be Empty
846 - UP        IVER:Field SpecifiedDemandFeatureName Cannot be Empty
901 - SCHOONSPRUIT scheland.irr:Field SpecifiedDemandFeatureName Cannot be Empty
904 - SCHOONSPRUIT scho
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Demand files do not hav
Demand files do not hav
Completed validating mo
Started running model.
```
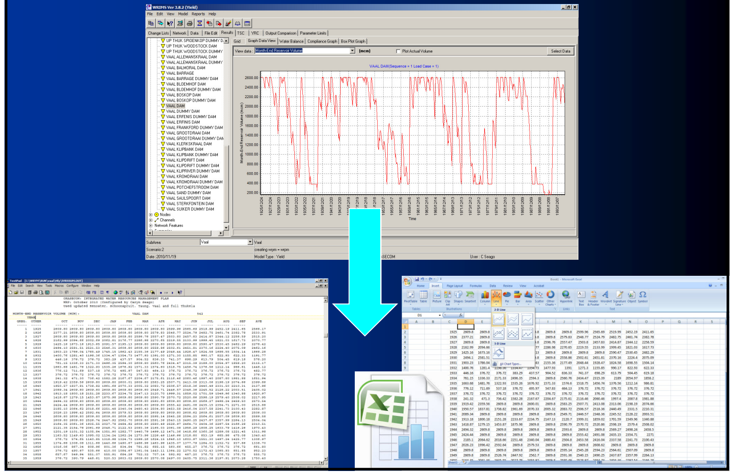

☐ Stop on first error

Water Resources Yield Model

Version of Fortran Model: ● Fast ○ Diagnostic

```
*******************************************
*                                         *
*     WATER RESOURCES YIELD MODEL         *
*     ---------------------------         *
*                                         *
* ####################################### *
* # VERSION 7.5.6.7    -      8 Jul 2009 # *
* ####################################### *
*                                         *
*                                         *
*******************************************
  FILE NAME = C:\WRYM\HYDRO\IVRS\PARAMK5.DAT
          YIELD # = 1  HYDRO SEQ # = 1
 HISTORIC DATA FOR GAUGE c:\wrym\hydro\ivrs\allem9
 BASED ON 75 YEARS
 HISTORIC DATA FOR GAUGE c:\wrym\hydro\ivrs\barr9
```

Past to Present (viewing results)



Importance of WRYM

- Used extensively in detailed studies for over 20 years
- Basis for important decisions with significant financial implications
- Theoretical basis accepted and trusted
- Results independently verified
- Widely considered as a leading water resource management tool

---

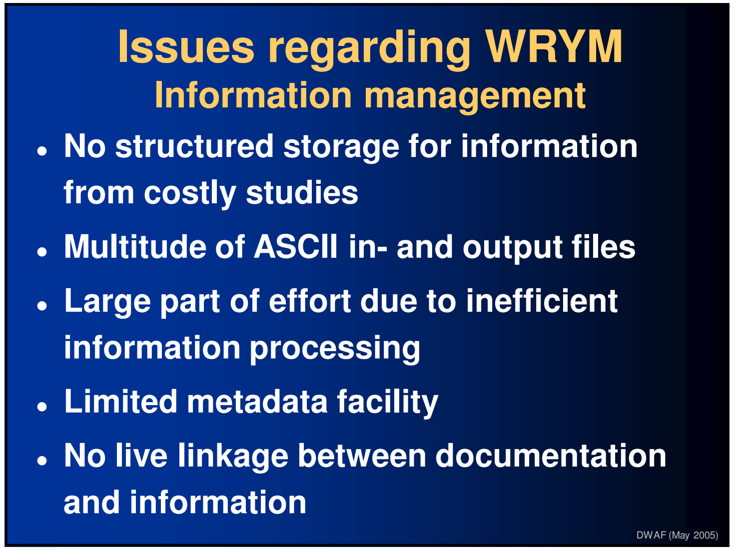
Application of WRYM

Water resource system simulation for:

- Resource assessment
- Impact of interventions
- Impact of management and operational options
- Basis for monitoring observed system behaviour

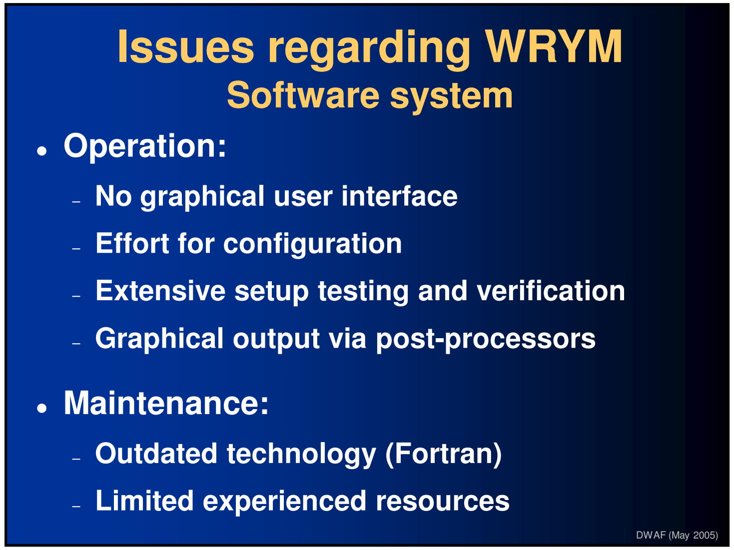
Strengths of WRYM

- Flexible system configuration
- Complex systems
- Multiple reservoirs, water users
- Variety of physical system features
- Flexible operating rule definitions
- Rigorous stochastic flow generation
- Software forward and backward compatible



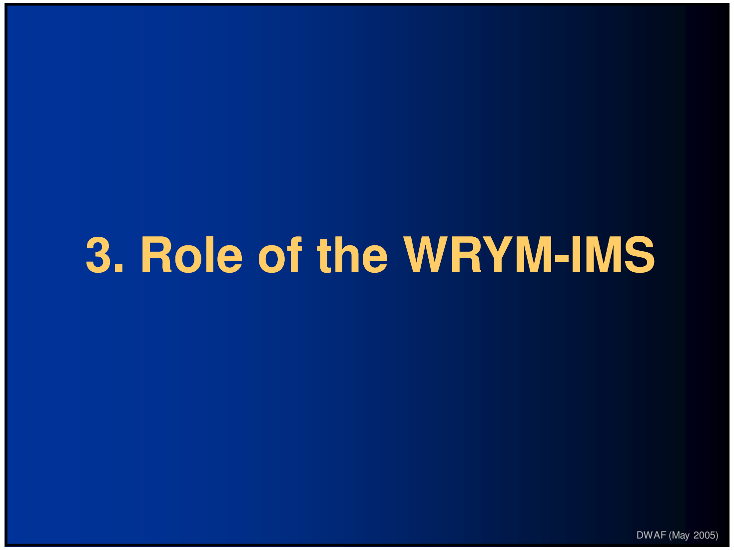
Issues regarding WRYM
Information management

- No structured storage for information from costly studies
- Multitude of ASCII in- and output files
- Large part of effort due to inefficient information processing
- Limited metadata facility
- No live linkage between documentation and information

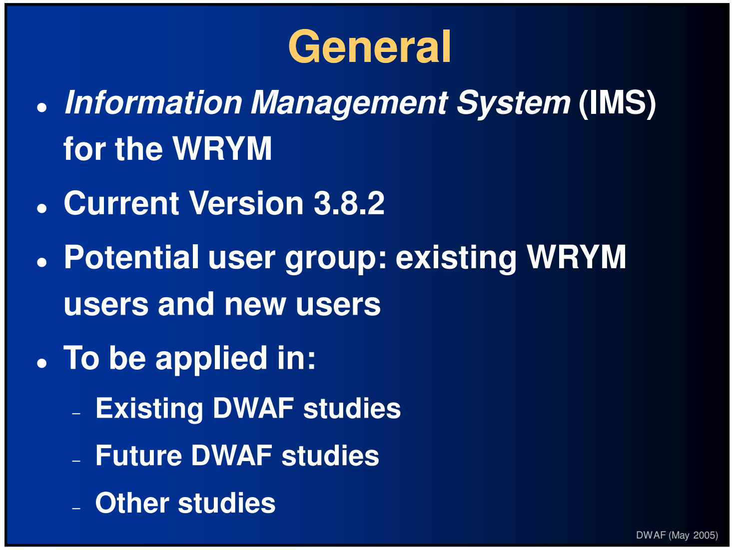


Issues regarding WRYM
Software system

- Operation:
  - No graphical user interface
  - Effort for configuration
  - Extensive setup testing and verification
  - Graphical output via post-processors
- Maintenance:
  - Outdated technology (Fortran)
  - Limited experienced resources



3. Role of the WRYM-IMS



General

- *Information Management System* (IMS) for the WRYM
- Current Version 3.8.2
- Potential user group: existing WRYM users and new users
- To be applied in:
  - Existing DWAF studies
  - Future DWAF studies
  - Other studies

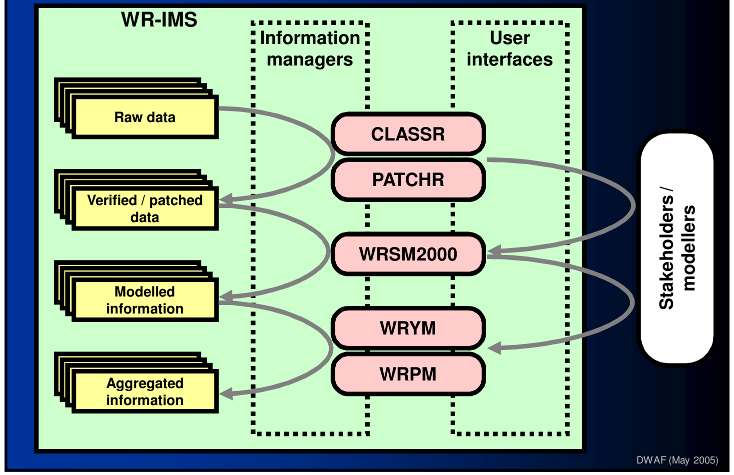
Components

- Information management
- User interface
- Water resource system simulation (WRYM)

Information management

- Database for structured storage, retrieval and sharing of information
- Import existing WRYM data files
- Validate WRYM input data
- Create new WRYM input data files
- Capture additional metadata
- Link to study reports, documentation
- Manage studies and scenarios

Information management design



User interface

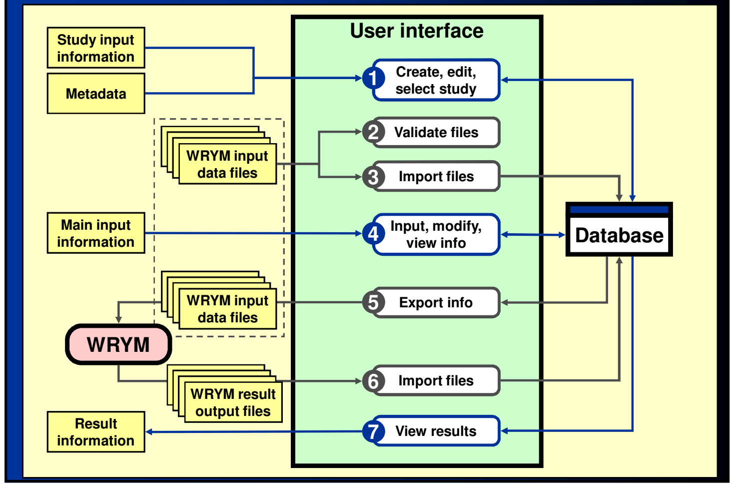
Windows dialogs to:

- Interact with database
- Input, modify and view information
- Initiate and display results of data validation
- Initiate WRYM model run
- View results (data grid, graph)
- Export results for documentation

System simulation (WRYM)

- WRYM model run, based on definition of:
  - System network definition
  - System operating rules
  - Specific scenario
  - Run control options
  - Result output options
- Data input files exported from IMS
- Result output files imported to IMS

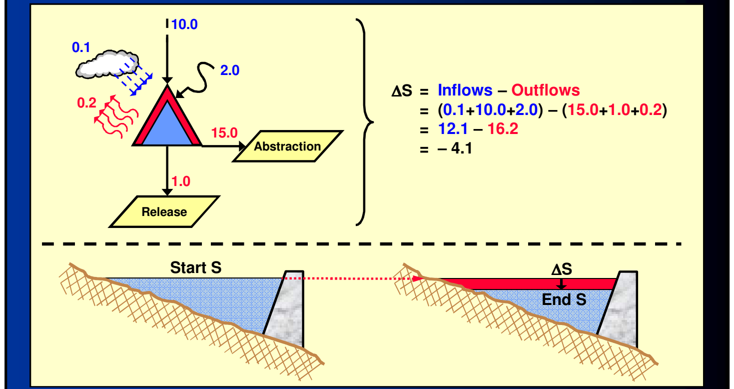
Linkage between components



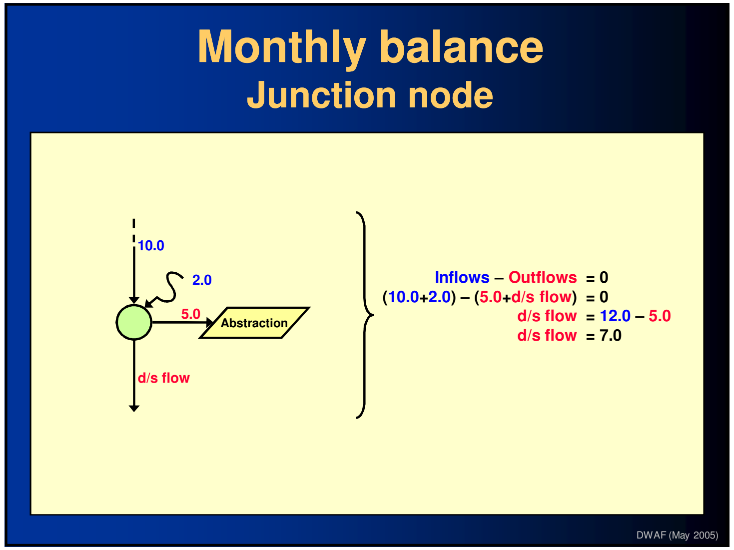
4. Modelling approach

Monthly balance

Reservoir node



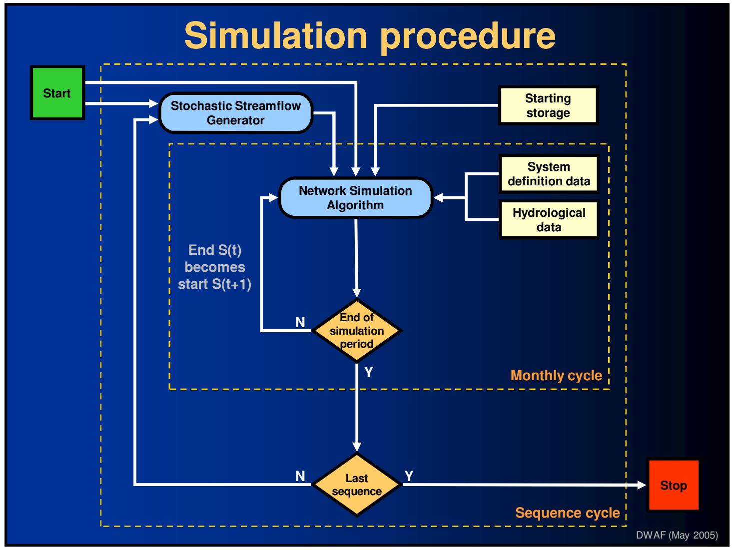
$$\Delta S = \text{Inflows} - \text{Outflows}$$
$$= (0.1+10.0+2.0) - (15.0+1.0+0.2)$$
$$= 12.1 - 16.2$$
$$= -4.1$$



Monthly balance
Junction node

Inflows – Outflows = 0
(10.0+2.0) – (5.0+d/s flow) = 0
d/s flow = 12.0 – 5.0
d/s flow = 7.0

DWAF (May 2005)



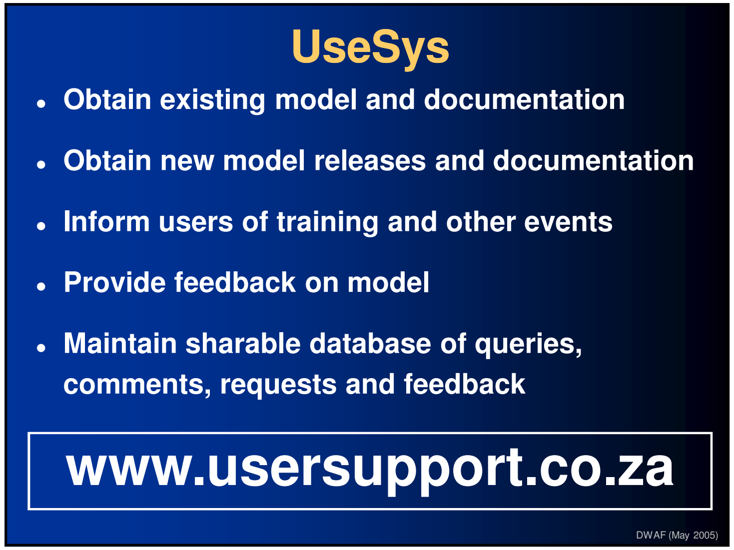
Simulation procedure

Start
Stochastic Streamflow Generator
Starting storage
System definition data
Hydrological data
Network Simulation Algorithm
End S(t) becomes start S(t+1)
N
End of simulation period
Y
Monthly cycle
N
Last sequence
Y
Stop
Sequence cycle

DWAF (May 2005)

5. System development and user support

DWAF (May 2005)



UseSys

- Obtain existing model and documentation
- Obtain new model releases and documentation
- Inform users of training and other events
- Provide feedback on model
- Maintain sharable database of queries, comments, requests and feedback

www.usersupport.co.za

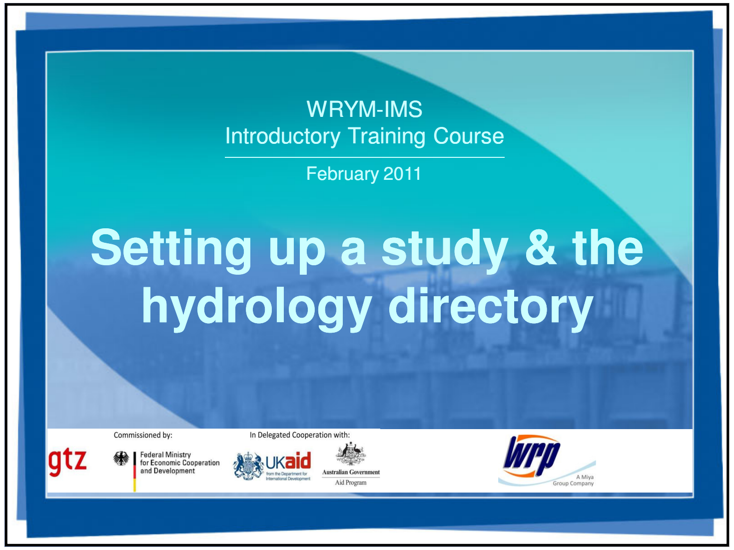
DWAF (May 2005)

Help desk

- Obtain help on using the model
- Obtain information on new model releases, documentation and training
- Provide feedback on model, documentation and training

+2712 336 7090

DWAF (May 2005)



WRYM-IMS
Introductory Training Course

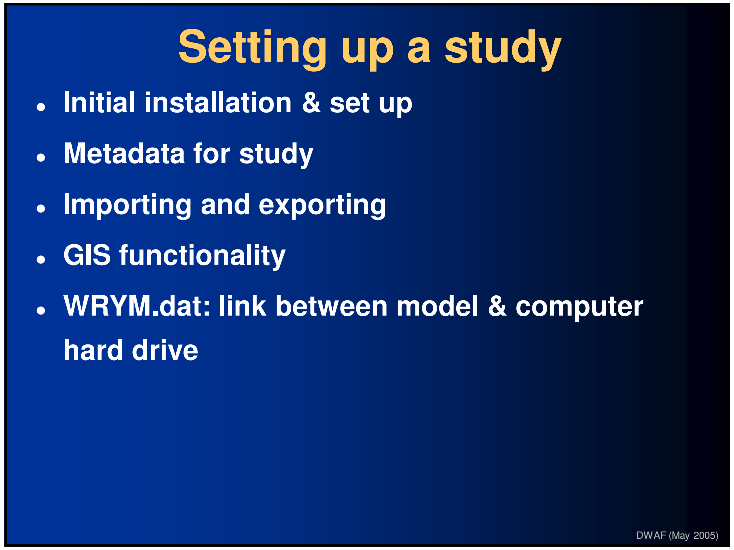
February 2011

Setting up a study & the hydrology directory

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program

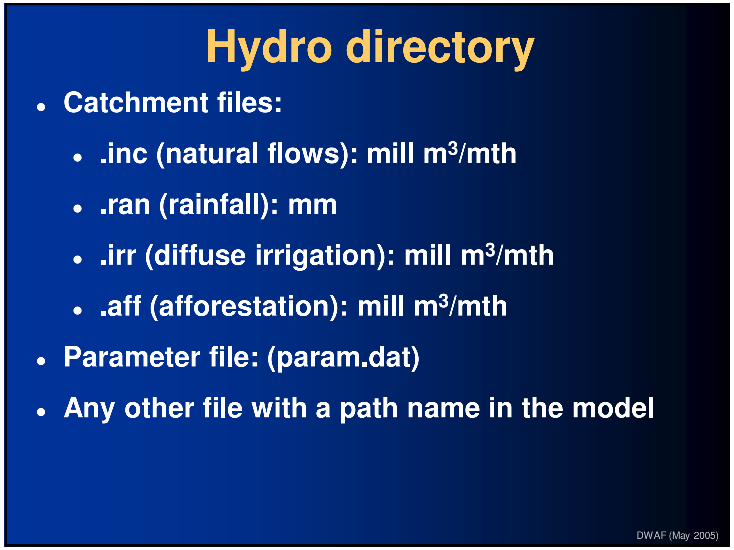
wrp A Miya Group Company



Setting up a study

- Initial installation & set up
- Metadata for study
- Importing and exporting
- GIS functionality
- WRYM.dat: link between model & computer hard drive

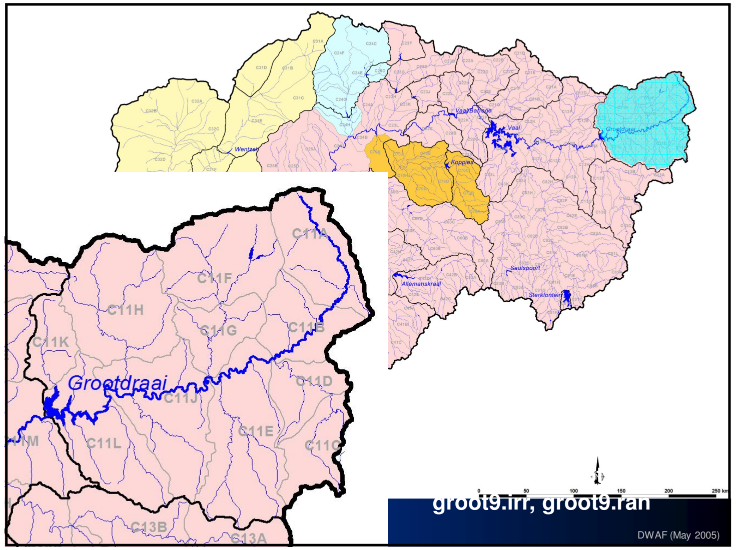
DWAF (May 2005)



Hydro directory

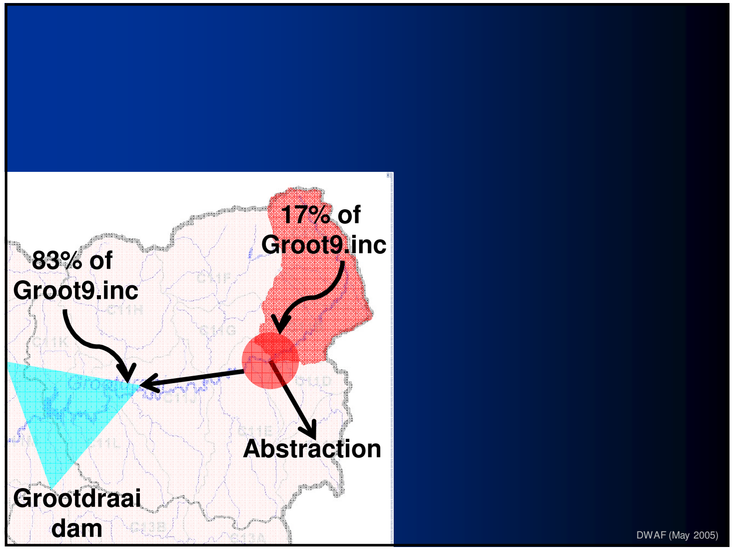
- Catchment files:
  - .inc (natural flows): mill m³/mth
  - .ran (rainfall): mm
  - .irr (diffuse irrigation): mill m³/mth
  - .aff (afforestation): mill m³/mth
- Parameter file: (param.dat)
- Any other file with a path name in the model

DWAF (May 2005)



groot9.irr, groot9.ran

DWAF (May 2005)



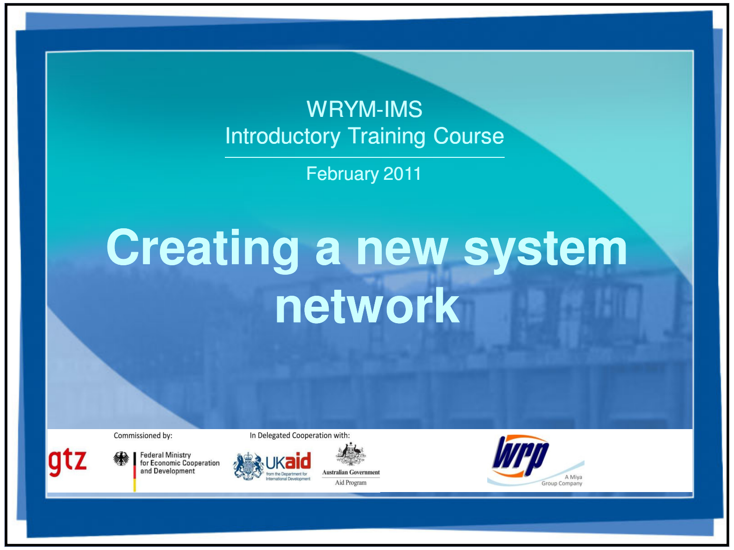
17% of Groot9.inc

83% of Groot9.inc

Abstraction

Grootdraai dam

DWAF (May 2005)



WRYM-IMS
Introductory Training Course

February 2011

Creating a new system network

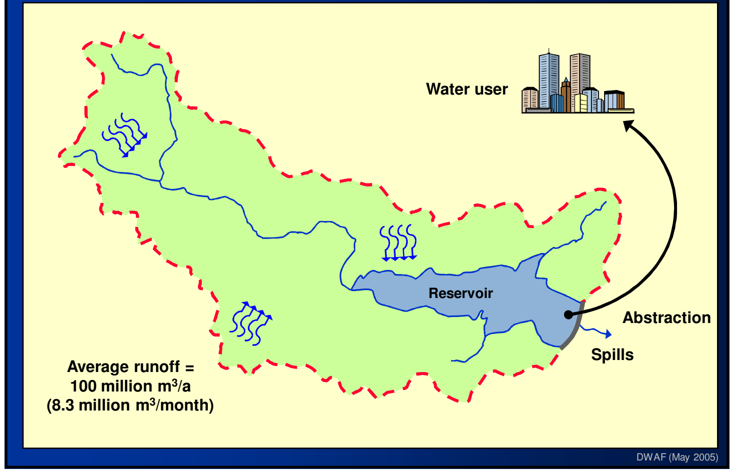
Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program

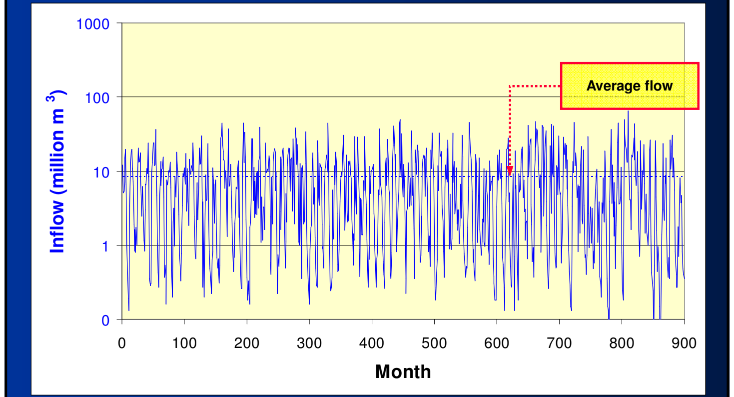
wrp A Miya Group Company

Background

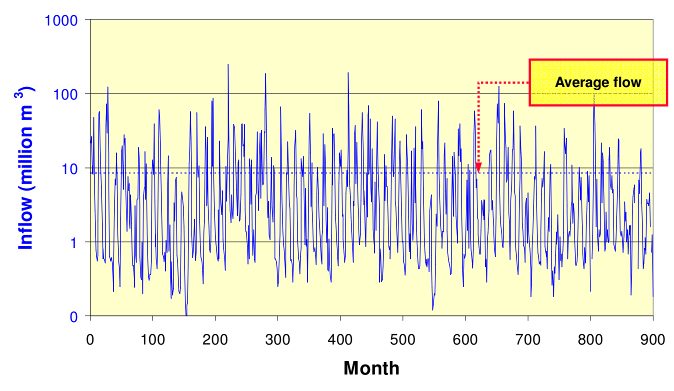
Case study



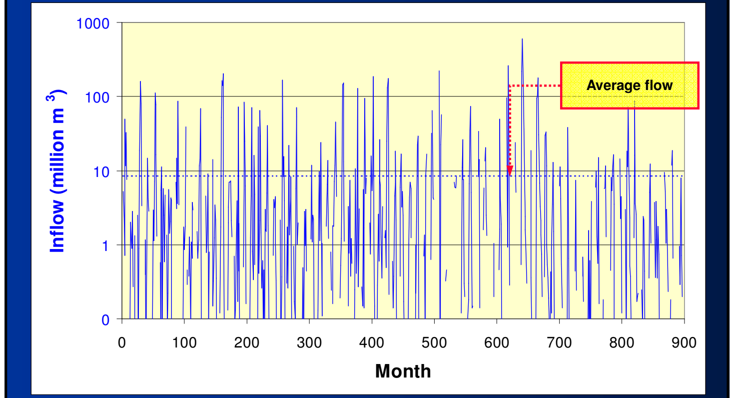
Inflow sequence 1



Inflow sequence 2



Inflow sequence 3



Statistics for 3 inflow sequences

Sequence	Average (million m^3/a)	SD (million m^3/a)	CV	Min (million m^3/a)	Max (million m^3/a)
1	100.00	41.11	0.41	28.71	207.91
2	100.00	78.22	0.78	10.91	350.75
3	100.00	156.34	1.56	1.30	1 023.87

Creating a new study

Purpose and methodology

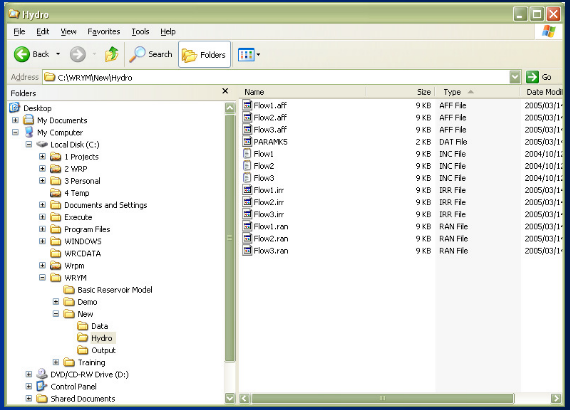
Purpose:

- Create a new study in the WRYM-IMS to be used for subsequent practicals

Methodology:

- Use hydrological data files provided in directory [c:\Wrym\New\Hydro*.*]
- Create new sub-area and new scenario
- Create new WRYM.DAT-file for the study
- Open new study
- Define analysis period: start 1920, 75 years
- Set model output to appropriate level of detail

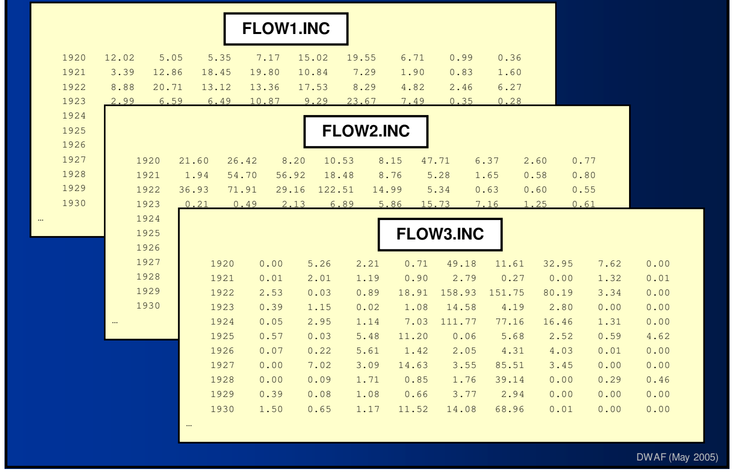
Hydrological data files



Desktop
- My Documents
- My Computer
  - Local Disk (C:)
    - 1 Projects
    - 2 WRP
    - 3 Personal
    - 4 Temp
    - Documents and Settings
    - Execute
    - Program Files
    - WINDOWS
    - WRCDATA
    - Wrpm
    - WRYM
      - Basic Reservoir Model
      - Demo
      - New
        - Data
        - Hydro
        - Output
      - Training
  - DVD/CD-RW Drive (D:)
  - Control Panel
  - Shared Documents

Name	Size	Type	Date Modi
Flow1.aff	9 KB	AFF File	2005/03/1
Flow2.aff	9 KB	AFF File	2005/03/1
Flow3.aff	9 KB	AFF File	2005/03/1
PARAMK5	2 KB	DAT File	2005/03/1
Flow1	9 KB	INC File	2004/10/1
Flow2	9 KB	INC File	2004/10/1
Flow3	9 KB	INC File	2004/10/1
Flow1.irr	9 KB	IRR File	2005/03/1
Flow2.irr	9 KB	IRR File	2005/03/1
Flow3.irr	9 KB	IRR File	2005/03/1
Flow1.ran	9 KB	RAN File	2005/03/1
Flow2.ran	9 KB	RAN File	2005/03/1
Flow3.ran	9 KB	RAN File	2005/03/1

Incremental natural runoff files



FLOW1.INC

```
1920   12.02    5.05    5.35    7.17   15.02   19.55    6.71    0.99    0.36
1921    3.39   12.86   18.45   19.80   10.84    7.29    1.90    0.83    1.60
1922    8.88   20.71   13.12   13.36   17.53    8.29    4.82    2.46    6.27
1923    2.99    6.59    6.49   10.87    9.29   23.67    7.49    0.35    0.28
1924
1925
1926
1927
1928
1929
1930
…
```

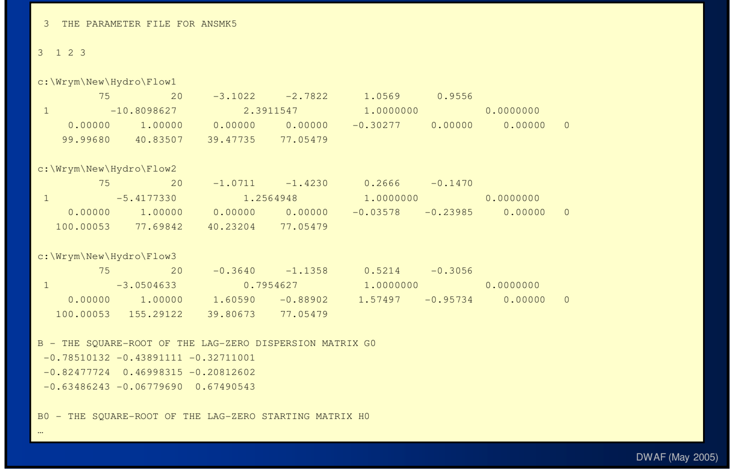
FLOW2.INC

```
1920   21.60   26.42    8.20   10.53    8.15   47.71    6.37    2.60    0.77
1921    1.94   54.70   56.92   18.48    8.76    5.28    1.65    0.58    0.80
1922   36.93   71.91   29.16  122.51   14.99    5.34    0.63    0.60    0.55
1923    0.21    0.49    2.13    6.89    5.86   15.73    7.16    1.25    0.61
1924
1925
1926
1927
1928
1929
1930
…
```

FLOW3.INC

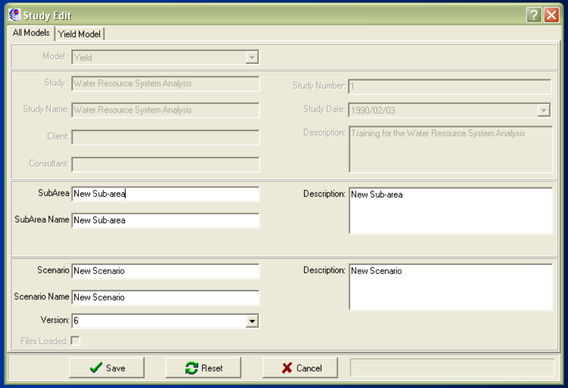
```
1920    0.00    5.26    2.21    0.71   49.18   11.61   32.95    7.62    0.00
1921    0.01    2.01    1.19    0.90    2.79    0.27    0.00    1.32    0.01
1922    2.53    0.03    0.89   18.91  158.93  151.75   80.19    3.34    0.00
1923    0.39    1.15    0.02    1.08   14.58    4.19    2.80    0.00    0.00
1924    0.05    2.95    1.14    7.03  111.77   77.16   16.46    1.31    0.00
1925    0.57    0.03    5.48   11.20    0.06    5.68    2.52    0.59    4.62
1926    0.07    0.22    5.61    1.42    2.05    4.31    4.03    0.01    0.00
1927    0.00    7.02    3.09   14.63    3.55   85.51    3.45    0.00    0.00
1928    0.00    0.09    1.71    0.85    1.76   39.14    0.00    0.29    0.46
1929    0.39    0.08    1.08    0.66    3.77    2.94    0.00    0.00    0.00
1930    1.50    0.65    1.17   11.52   14.08   68.96    0.01    0.00    0.00
…
```

PARAM.DAT-file



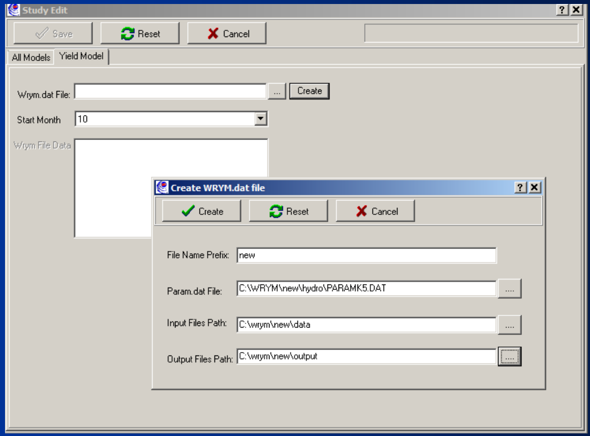
```
 3  THE PARAMETER FILE FOR ANSMK5

3  1 2 3

c:\Wrym\New\Hydro\Flow1
         75          20     -3.1022     -2.7822      1.0569      0.9556
 1          -10.8098627           2.3911547           1.0000000           0.0000000
    0.00000     1.00000     0.00000     0.00000    -0.30277     0.00000     0.00000   0
   99.99680    40.83507    39.47735    77.05479

c:\Wrym\New\Hydro\Flow2
         75          20     -1.0711     -1.4230      0.2666     -0.1470
 1           -5.4177330           1.2564948           1.0000000           0.0000000
    0.00000     1.00000     0.00000     0.00000    -0.03578    -0.23985     0.00000   0
  100.00053    77.69842    40.23204    77.05479

c:\Wrym\New\Hydro\Flow3
         75          20     -0.3640     -1.1358      0.5214     -0.3056
 1           -3.0504633           0.7954627           1.0000000           0.0000000
    0.00000     1.00000     1.60590    -0.88902     1.57497    -0.95734     0.00000   0
  100.00053   155.29122    39.80673    77.05479

B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
 -0.78510132 -0.43891111 -0.32711001
 -0.82477724  0.46998315 -0.20812602
 -0.63486243 -0.06779690  0.67490543

B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
…
```

Study Edit-dialog



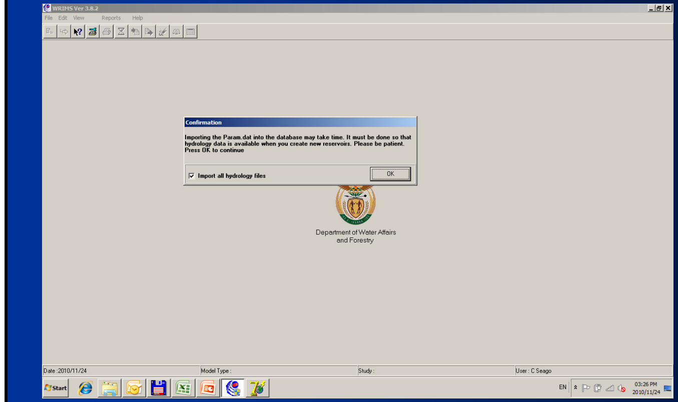
Model : Yield
Study : Water Resource System Analysis
Study Number: 1
Study Name: Water Resource System Analysis
Study Date: 1990/02/03
Client:
Description: Training for the Water Resource System Analysis
Consultant:
SubArea New Sub-area
Description: New Sub-area
SubArea Name New Sub-area
Scenario New Scenario
Description: New Scenario
Scenario Name New Scenario
Version: 6
Files Loaded: ☐

Create WRYM.dat file-dialog



Wrym.dat File:
Start Month 10
Wrym File Data
File Name Prefix: new
Param.dat File: C:\WRYM\new\hydro\PARAMK5.DAT
Input Files Path: C:\wrym\new\data
Output Files Path: C:\wrym\new\output

Validation Window-dialog

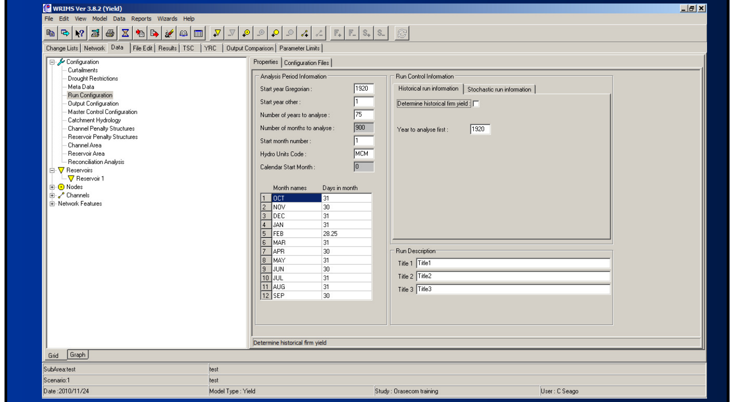


Importing the Param.dat into the database may take time. It must be done so that hydrology data is available when you create new reservoirs. Please be patient. Press OK to continue

☑ Import all hydrology files

Date :2010/11/24 Model Type : Study : User : C Seago

Run Configuration-dialog



Start year Gregorian : 1920
Start year other : 1
Number of years to analyse : 75
Number of months to analyse : 900
Start month number : 1
Hydro Units Code : MCM
Calendar Start Month : 0

	Month names	Days in month
1	OCT	31
2	NOV	30
3	DEC	31
4	JAN	31
5	FEB	28.25
6	MAR	31
7	APR	30
8	MAY	31
9	JUN	30
10	JUL	31
11	AUG	31
12	SEP	30

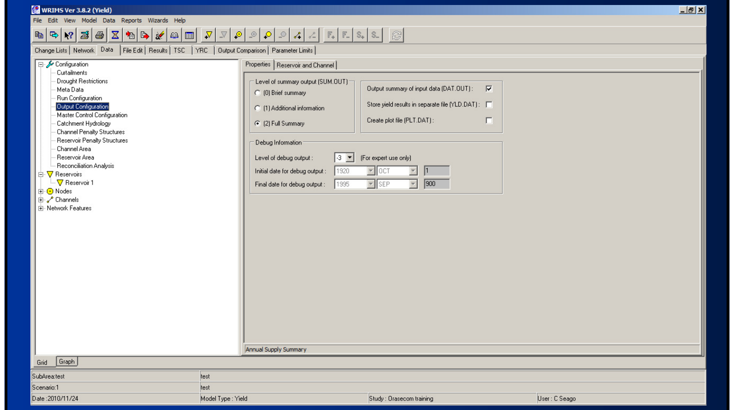
Determine historical firm yield : ☐
Year to analyse first : 1920

Title 1 Title1
Title 2 Title2
Title 3 Title3

Determine historical firm yield

SubArea:test test
Scenario:1 test
Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

Output Configuration-dialog



Level of summary output (SUM.OUT)

○ (0) Brief summary

○ (1) Additional information

● (2) Full Summary

Output summary of input data (DAT.OUT) : ☑

Store yield results in separate file (YLD.DAT) : ☐

Create plot file (PLT.DAT) : ☐

Debug Information

Level of debug output : -3 (For expert use only)

Initial date for debug output : 1920 OCT 1

Final date for debug output : 1995 SEP 900

SubArea:test test

Scenario:1 test

Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

---

Defining the system network

Purpose and methodology

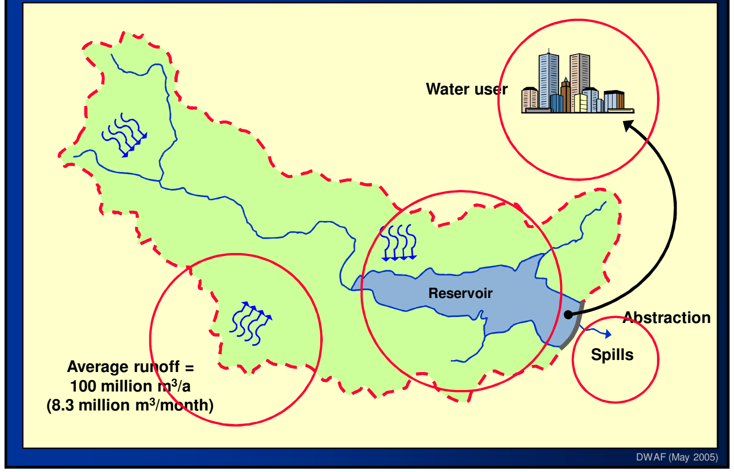
Purpose:

- Define the system network, identical to that for basic spreadsheet model (Practical 1)

Methodology:

- Identify main physical features
- Create representative network model
- Select system operating rules
- Set up using basic building blocks
- Run model
- Create system network diagram

Main physical features



Basic assumptions

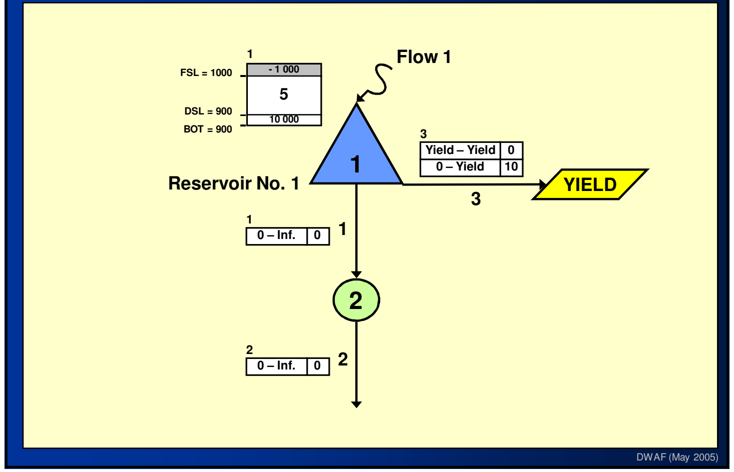
Configuration identical to Practical 1:

- Use inflow sequence 1
- Set target draft = 100 million m^3/a
- No dead storage zone in reservoir
- Supply to master control (yield) channel when reservoir above DSL
- Spillage when reservoir above FSL
- No evaporation losses from reservoir surface
- No rainfall on reservoir surface
- Reservoir characteristics as follows:

Reservoir characteristics

Elevation (m, masl)	Volume (million m^3)	Surface area (km^2)
FSL = 1000	100	10.0
980	80	8.0
960	60	6.0
940	40	4.0
920	20	2.0
DSL = 900	0	0.0

System network model

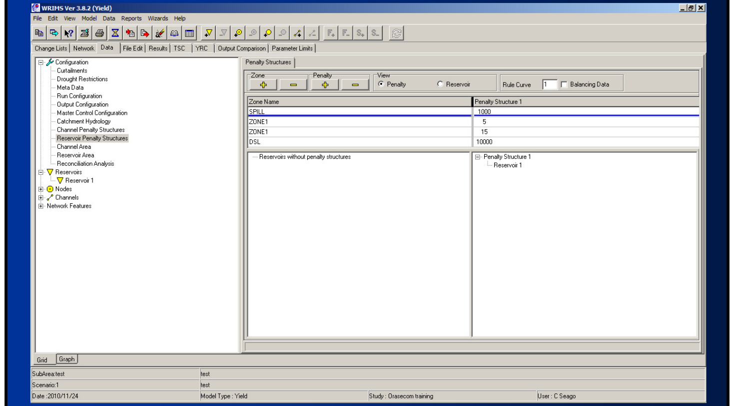


Basic building blocks

Set up using basic building blocks:

- Define reservoir penalty structures
- Define channel penalty structures
- Create reservoirs
- Define catchment hydrologies
- Create nodes
- Create channels
- Define functional system features

Reservoir Penalty-dialog



● Penalty ○ Reservoir

Rule Curve 1 ☐ Balancing Data

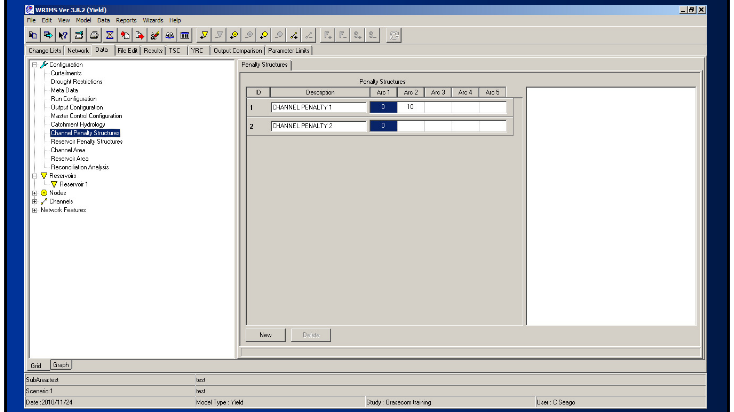
Zone Name	Penalty Structure 1
SPILL	1000
ZONE1	5
ZONE1	15
DSL	10000

Reservoirs without penalty structures

Penalty Structure 1
Reservoir 1

SubArea:test test
Scenario:1 test
Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

Channel Penalty-dialog

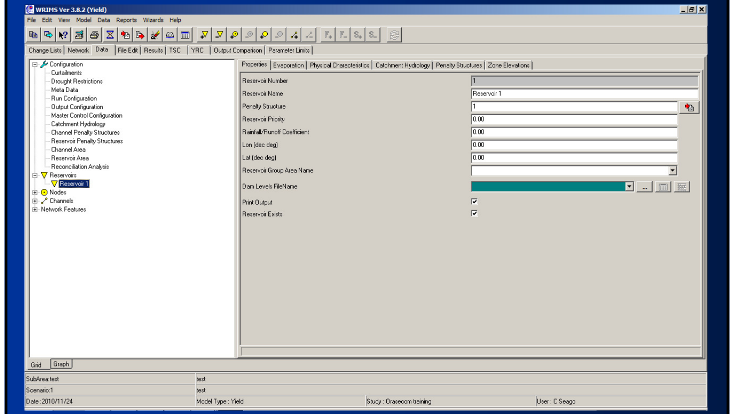


Penalty Structures

ID	Description	Arc 1	Arc 2	Arc 3	Arc 4	Arc 5
1	CHANNEL PENALTY 1	0	10			
2	CHANNEL PENALTY 2	0				

SubArea:test test
Scenario:1 test
Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

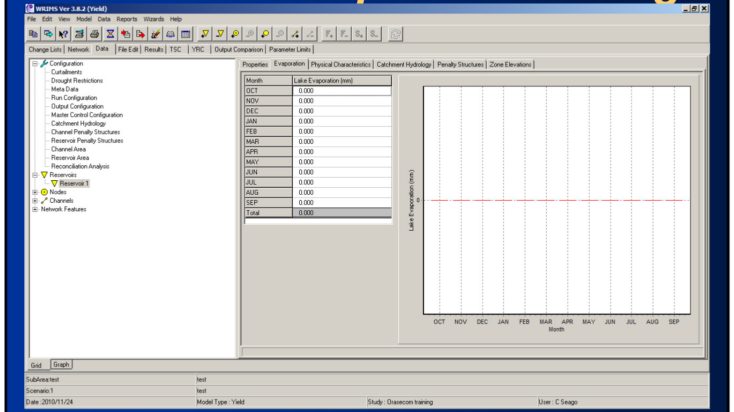
Reservoir Properties-dialog



Reservoir Number 1
Reservoir Name Reservoir 1
Penalty Structure 1
Reservoir Priority 0.00
Rainfall/Runoff Coefficient 0.00
Lon (dec deg) 0.00
Lat (dec deg) 0.00
Reservoir Group Area Name
Dam Levels FileName
Print Output ☑
Reservoir Exists ☑

SubArea:test test
Scenario:1 test
Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

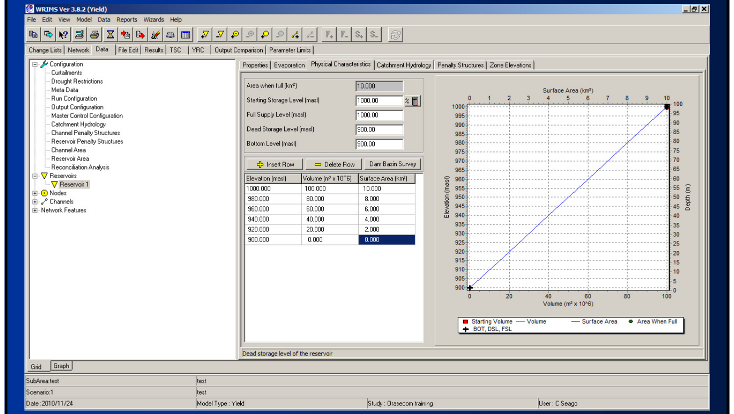
Reservoir Evaporation-dialog



Month	Lake Evaporation (mm)
OCT	0.000
NOV	0.000
DEC	0.000
JAN	0.000
FEB	0.000
MAR	0.000
APR	0.000
MAY	0.000
JUN	0.000
JUL	0.000
AUG	0.000
SEP	0.000
Total	0.000

SubArea:test test
Scenario:1 test
Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

Reservoir Characteristics-dialog



Area when full (km²) 10.000

Starting Storage Level (masl) 1000.00

Full Supply Level (masl) 1000.00

Dead Storage Level (masl) 900.00

Bottom Level (masl) 900.00

Elevation (masl)	Volume (m³ x 10^6)	Surface Area (km²)
1000.000	100.000	10.000
980.000	80.000	8.000
960.000	60.000	6.000
940.000	40.000	4.000
920.000	20.000	2.000
900.000	0.000	0.000

Dead storage level of the reservoir

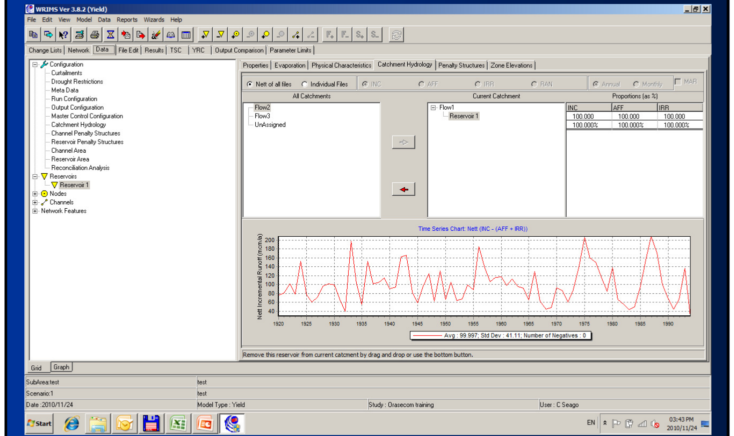
SubArea:test test

Scenario:1 test

Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

DWAF (May 2005)

Catchment Hydrology-dialog



● Nett of all files ○ Individual Files ● INC ○ AFF ○ IRR ○ RAN ● Annual ○ Monthly ☐ MAR

Proportions (as %)

INC	AFF	IRR
100.000	100.000	100.000
100.000%	100.000%	100.000%

Avg : 99.997; Std Dev : 41.11; Number of Negatives : 0

Remove this reservoir from current catchment by drag and drop or use the bottom button.

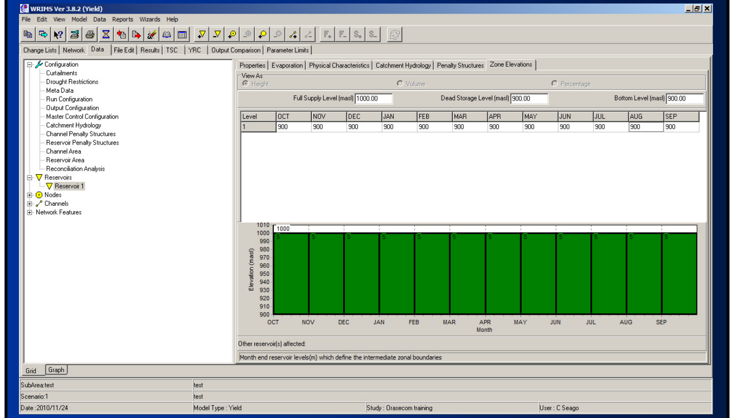
SubArea:test test

Scenario:1 test

Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

DWAF (May 2005)

Zone Elevations-dialog



View As ● Height ○ Volume ○ Percentage

Full Supply Level (masl) 1000.00 Dead Storage Level (masl) 900.00 Bottom Level (masl) 900.00

Level	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	900	900	900	900	900	900	900	900	900	900	900	900

Other reservoir(s) affected:

Month end reservoir levels(m) which define the intermediate zonal boundaries

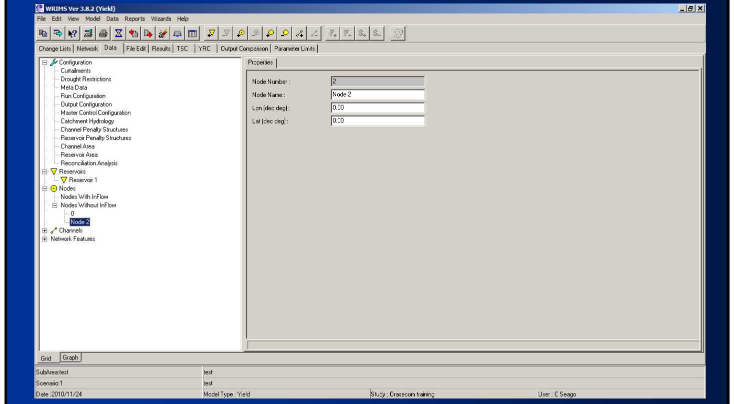
SubArea:test test

Scenario:1 test

Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

DWAF (May 2005)

Nodes Without Inflow-dialog



Node Number : 2

Node Name : Node 2

Lon (dec deg) : 0.00

Lat (dec deg) : 0.00

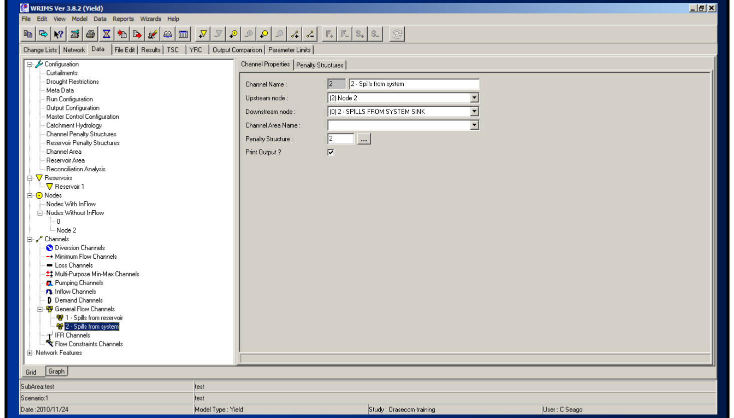
SubArea:test test

Scenario:1 test

Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

DWAF (May 2005)

Channel Properties-dialog

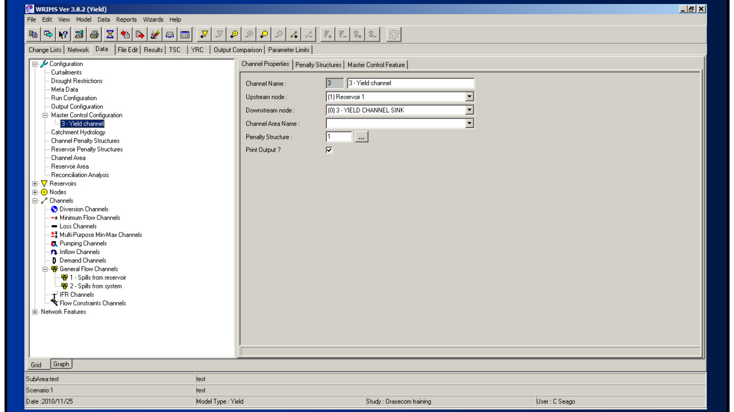


Channel Name : 2 | 2 - Spills from system
Upstream node : (2) Node 2
Downstream node : (0) 2 - SPILLS FROM SYSTEM SINK
Channel Area Name :
Penalty Structure : 2
Print Output ? ☑

SubArea:test test
Scenario:1 test
Date :2010/11/24 Model Type : Yield Study : Orasecom training User : C Seago

---

Master Control Properties-dialog

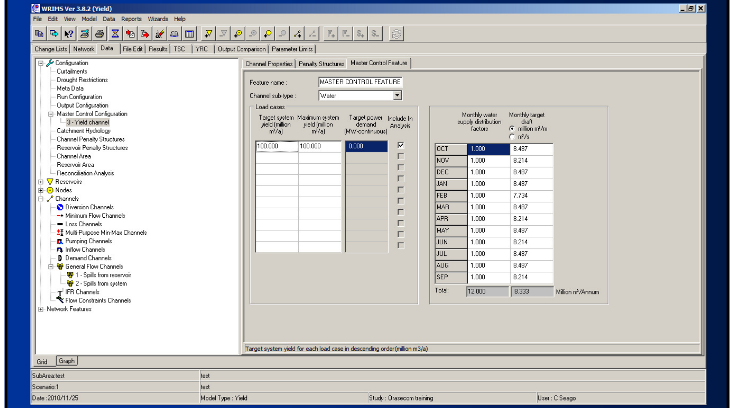


Channel Name : 3 | 3 - Yield channel
Upstream node : (1) Reservoir 1
Downstream node : (0) 3 - YIELD CHANNEL SINK
Channel Area Name :
Penalty Structure : 1
Print Output ? ☑

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Orasecom training User : C Seago

---

Master Control Feature-dialog



Feature name : MASTER CONTROL FEATURE
Channel sub-type : Water

Load cases

Target system yield (million m³/a)	Maximum system yield (million m³/a)	Target power demand (MW-continuous)	Include In Analysis
100.000	100.000	0.000	☑
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐

Monthly target draft: ● million m³/m ○ m³/s

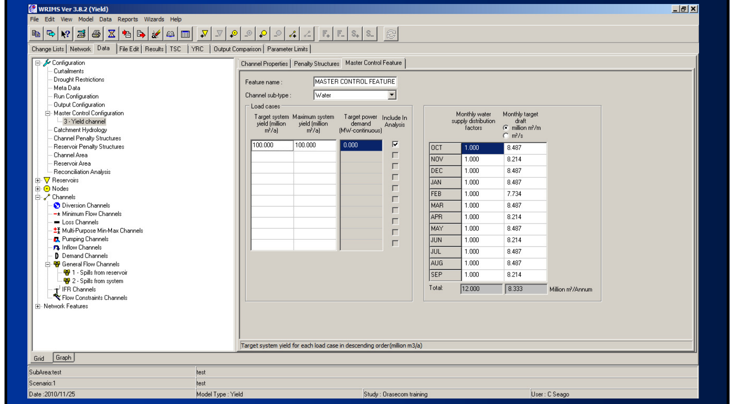
	Monthly water supply distribution factors	Monthly target draft
OCT	1.000	8.487
NOV	1.000	8.214
DEC	1.000	8.487
JAN	1.000	8.487
FEB	1.000	7.734
MAR	1.000	8.487
APR	1.000	8.214
MAY	1.000	8.487
JUN	1.000	8.214
JUL	1.000	8.487
AUG	1.000	8.487
SEP	1.000	8.214
Total:	12.000	8.333 Million m³/Annum

Target system yield for each load case in descending order(million m3/a)

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Orasecom training User : C Seago

---

Run Model-dialog



Feature name : MASTER CONTROL FEATURE
Channel sub-type : Water

Load cases

Target system yield (million m³/a)	Maximum system yield (million m³/a)	Target power demand (MW-continuous)	Include In Analysis
100.000	100.000	0.000	☑
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐

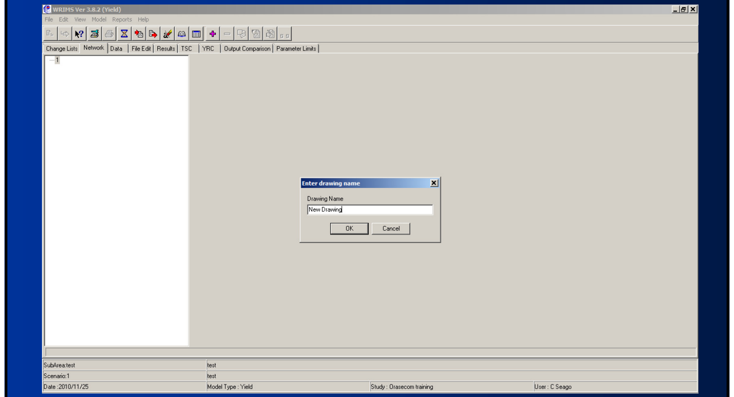
Monthly target draft: ● million m³/m ○ m³/s

	Monthly water supply distribution factors	Monthly target draft
OCT	1.000	8.487
NOV	1.000	8.214
DEC	1.000	8.487
JAN	1.000	8.487
FEB	1.000	7.734
MAR	1.000	8.487
APR	1.000	8.214
MAY	1.000	8.487
JUN	1.000	8.214
JUL	1.000	8.487
AUG	1.000	8.487
SEP	1.000	8.214
Total:	12.000	8.333 Million m³/Annum

Target system yield for each load case in descending order(million m3/a)

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Orasecom training User : C Seago

Drawing Properties-dialogs



Enter drawing name

Drawing Name: New Drawing

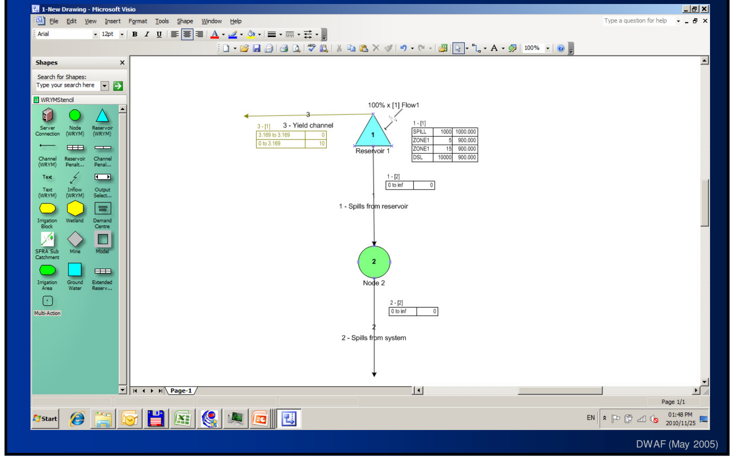
SubArea:test | test

Scenario:1 | test

Date :2010/11/25 | Model Type : Yield | Study : Orasecom training | User : C Seago

---

Create drawing



3.169 to 3.169	0
0 to 3.169	10

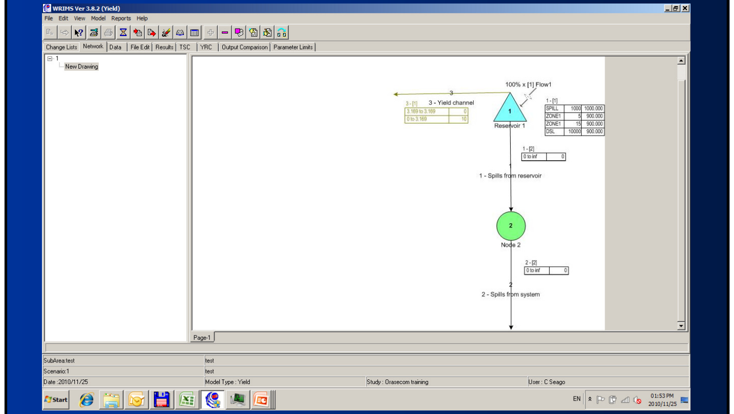
SPILL	1000	1000.000
ZONE1	5	900.000
ZONE1	15	900.000
DSL	10000	900.000

0 to inf	0

0 to inf	0

Results

Network-tab sheet



SubArea:test | test

Scenario:1 | test

Date :2010/11/25 | Model Type : Yield | Study : Orasecom training | User : C Seago

Verifying and testing the system network definition

Background

Standard procedure followed after each system configuration change:

- Document nature and purpose
- Implement
- Verify system network integrity
- Test system operational behaviour
- Make corrections, if necessary
- Repeat procedure

Documentation

Ensures specific configuration can be recalled, verified, reviewed, duplicated:

- Assigned number and name
- Description and purpose
- Configuration upon which it is based
- Nature of modification
- Model parameters edited
- Summary of run results

Verify network integrity

Check that basic input data and network definition provided by user are correct:

- Typical data input errors
- Sub-catchment hydrology data
- Physical system characteristics
- System network connectivity

Verify network integrity

Typical data input errors

- Data entry outside format structure
- Tabs and other invalid characters
- Incorrect number of input elements
- Inconsistencies in number of inputs
- Duplication of element numbers
- Incorrect data file directory references

Verify network integrity

Sub-catchment hydrology data

- Compare:
  - Simulated inflows to each node
  - Net runoff from associated sub-catchment (*.INC – *.IRR – *.AFF)
- Based on historical model run:
  - Particular month
  - Average over analysis period
- Based on stochastic model run average

Verify network integrity

Physical system characteristics

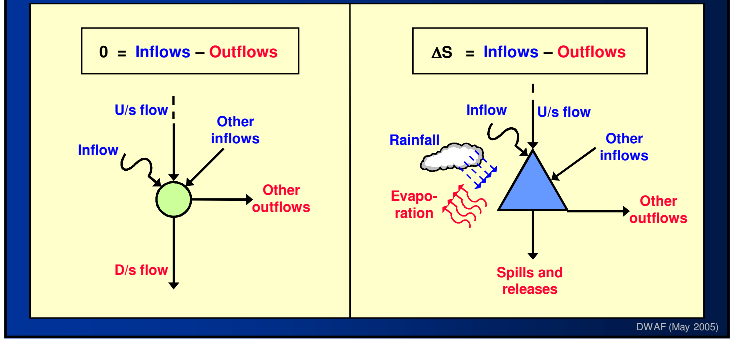
Compare model run results with known characteristics of system elements:

- Reservoir characteristics, e.g. FSL, DSL and bottom level
- Reservoir water levels
- Maximum capacity of transfers
- Hydraulic constraints of channels

Verify network integrity

System network connectivity

Undertake simple mass balance calculation at each node:



Test operational behaviour

Ensure system behaviour does reflect intended operating rules:

- Observe simulated model results
- Check behaviour of system elements:
  - When reservoirs are full
  - When reservoirs are empty
  - During drawdown events
  - Supply priorities
  - Inter-reservoir transfers

Purpose and methodology of practical

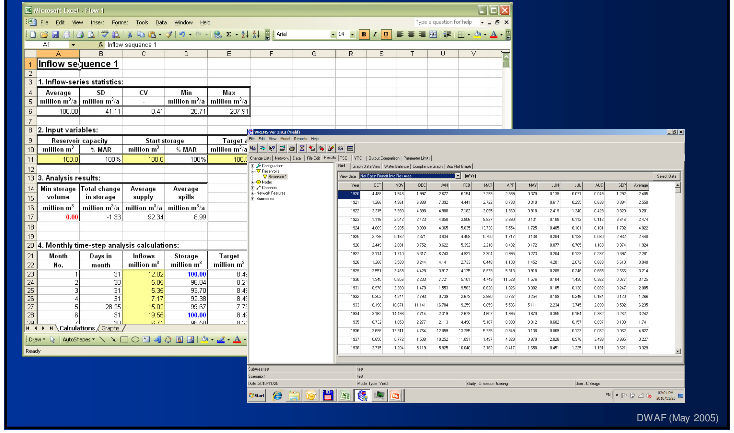
Purpose:

- Verify and test the system network as defined in Practical 10

Methodology:

- Verify system network integrity:
  - Sub-catchment hydrology data
  - Physical system characteristics
  - System network connectivity
- Test system operational behaviour

Verify network integrity
Sub-catchment hydrology data



Inflow sequence 1

1. Inflow-series statistics:

Average million m³/a	SD million m³/a	CV -	Min million m³/a	Max million m³/a
100.00	41.11	0.41	28.71	207.91

2. Input variables:

Reservoir capacity million m³	Reservoir capacity % MAR	Start storage million m³	Start storage % MAR	Target a million m³/a
100.0	100%	100.0	100%	100.0

3. Analysis results:

Min storage volume million m³	Total change in storage million m³/a	Average supply million m³/a	Average spills million m³/a
0.00	-1.33	92.34	8.99

4. Monthly time-step analysis calculations:

Month No.	Days in month	Inflows million m³	Storage million m³	Target million m³
1	31	12.02	100.00	8.4
2	30	5.05	96.84	8.2
3	31	5.35	93.70	8.4
4	31	7.17	92.38	8.4
5	28.25	15.02	99.67	7.7
6	31	19.55	100.00	8.4
7	30	6.71	98.50	8.2

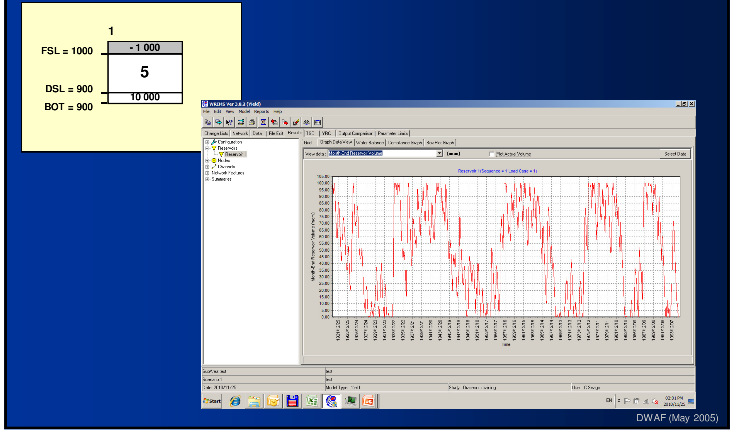
View data : Net Basin Runoff Into Res Area (m³/s)

Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Average
1920	4.488	1.948	1.997	2.677	6.154	7.299	2.589	0.370	0.139	0.071	0.049	1.292	2.405
1921	1.266	4.961	6.888	7.392	4.441	2.722	0.733	0.310	0.617	0.295	0.638	0.394	2.550
1922	3.315	7.990	4.898	4.988	7.182	3.095	1.860	0.918	2.419	1.340	0.429	0.320	3.201
1923	1.116	2.542	2.423	4.058	3.806	8.837	2.890	0.131	0.108	0.112	0.112	3.646	2.474
1924	4.809	9.205	8.998	4.365	5.035	13.736	7.554	1.725	0.405	0.161	0.101	1.782	4.822
1925	2.796	5.162	2.371	3.834	4.458	5.750	1.717	0.138	0.204	0.138	0.060	2.932	2.448
1926	2.449	2.801	3.752	3.622	5.392	2.218	0.482	0.172	0.077	0.765	1.169	0.374	1.924
1927	3.114	1.740	5.317	6.743	4.921	3.304	0.995	0.273	0.204	0.123	0.287	0.397	2.281
1928	1.266	3.580	3.244	4.141	2.733	6.448	1.103	1.452	4.201	2.072	0.683	5.610	3.040
1929	3.551	3.465	4.428	3.917	4.175	8.979	5.313	0.918	0.289	0.246	0.665	2.666	3.214
1930	1.945	0.856	2.233	7.721	5.101	4.749	11.528	1.576	0.104	1.430	0.362	0.077	3.125
1931	0.978	3.380	1.478	1.553	9.583	6.620	1.026	0.302	0.185	0.138	0.082	0.247	2.085
1932	0.302	4.244	2.793	0.739	2.679	2.860	0.737	0.254	0.189	0.246	0.164	0.120	1.266
1933	0.198	10.671	11.141	16.704	9.259	6.859	5.586	5.111	2.234	3.745	2.890	0.502	6.235
1934	3.162	14.498	7.714	2.319	2.679	4.607	1.995	0.870	0.355	0.164	0.362	0.262	3.242
1935	0.732	1.053	2.277	2.113	4.490	5.167	0.899	3.312	0.602	0.157	0.097	0.100	1.741
1936	3.696	17.311	4.764	12.059	13.795	5.735	0.849	0.138	0.069	0.123	0.082	0.062	4.827
1937	0.650	0.772	1.538	10.252	11.091	1.497	4.329	0.870	2.828	0.978	3.498	0.995	3.227
1938	3.715	1.204	5.119	5.925	16.040	3.162	0.417	1.658	0.451	1.225	1.191	0.621	3.329

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Orasecom training User : C Seago

---

Verify network integrity
Physical system characteristics

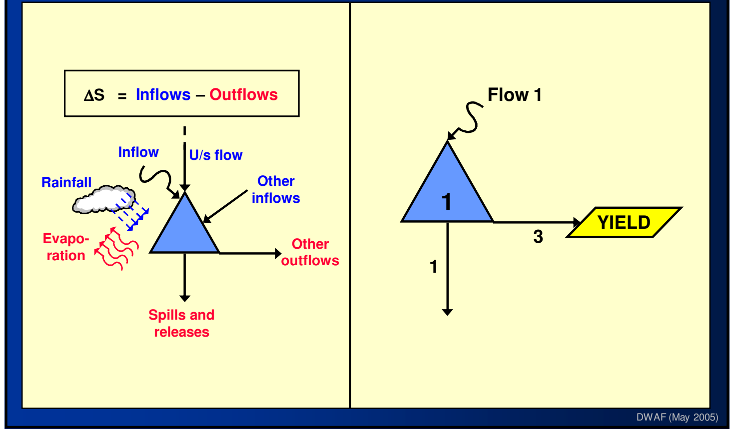


View data : Month-End Reservoir Volume (mcm) ☐ Plot Actual Volume

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Orasecom training User : C Seago

Verify network integrity

System network connectivity (1 of 3)



ΔS = Inflows – Outflows

Verify network integrity

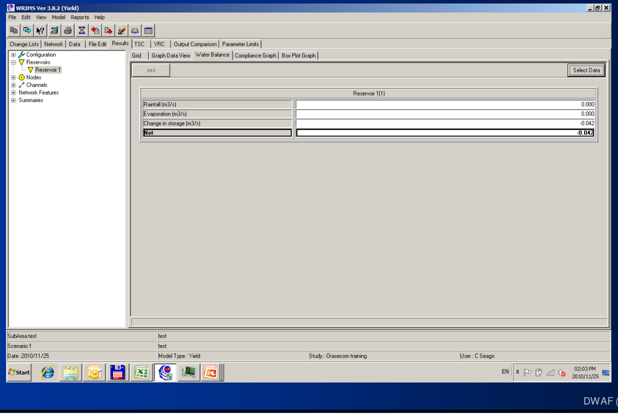
System network connectivity (2 of 3)

Table to be completed:

Description	**Result**	
	m^3/s	**million m^3/a**
Inflows:		
Runoff		
Outflows:		
Yield channel		
Spill channel		
Balance (= Inflows – Outflows)		
Δ**S** (as simulated)		

Verify network integrity

System network connectivity (3 of 3)



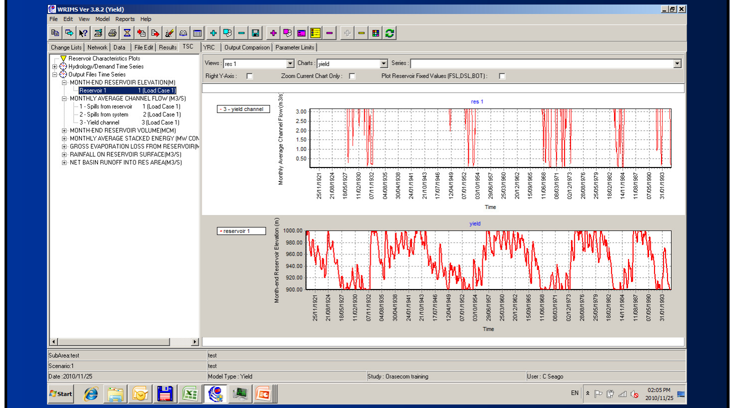
Reservoir 1(1)

Rainfall (m3/s)	0.000
Evaporation (m3/s)	0.000
Change in storage (m3/s)	-0.042
Net	**-0.042**

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Diasecom training User : C Seago

---

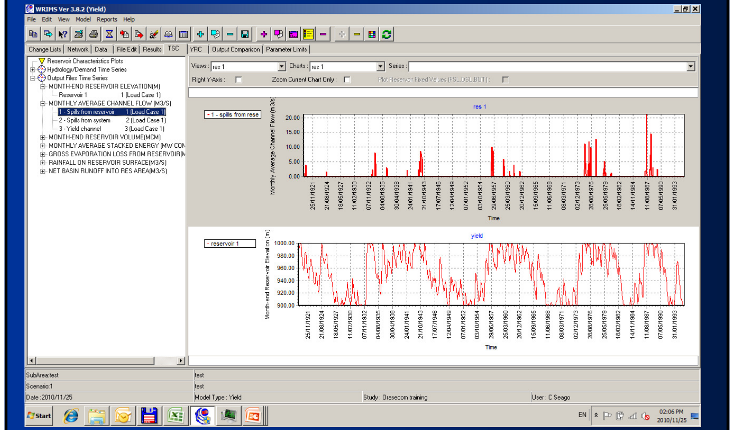
Test operational behaviour (1 of 2)



Views : res 1 Charts : yield Series :

SubArea:test test
Scenario:1 test
Date :2010/11/25 Model Type : Yield Study : Diasecom training User : C Seago

Test operational behaviour (2 of 2)



SubArea:test
test

Scenario:1
test

Date :2010/11/25
Model Type : Yield
Study : Orasecom training
User : C Seago

Results

Completed table

Description	Result	
	m^3/s	million m^3/a
Inflows:		
Runoff	3.169	100.00
Outflows:		
Yield channel	2.926	92.34
Spill channel	0.285	8.99
Balance (= Inflows – Outflows)	**-0.042**	**-1.33**
∆**S** (as simulated)	**-0.042**	**-1.33**

Question: determine the historic firm yield of the reservoir?

WRYM-IMS
Introductory Training Course

February 2011

End of module

the dwaf

wrp

ISIFUNDI
CONSULTANTS

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan

Training Session 1: 14 - 17 February 2011)

Module 8:
Introduction to the WRPM

Commissioned by:

Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid

Australian Government
Aid Program

A Miya
Group Company

Contents

1. Role of the WRPM
2. Model structure
3. Overview of model results

---

1. Role of the WRPM

Intervention planning

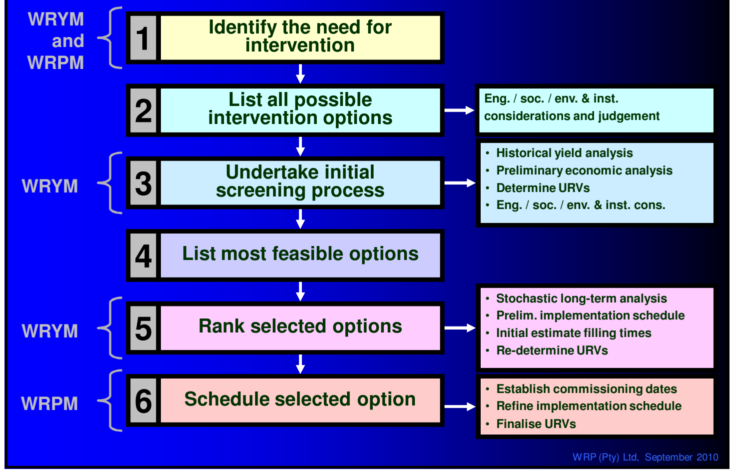
To determine, over a planning horizon:

- Need for intervention
- Timing of intervention
- Implementation schedules
- Filling times

Within context of:

- Growing water requirements
- User criteria of acceptable risks
- Salinity-related system constraints

The process of intervention planning



WRYM and WRPM
1 **Identify the need for intervention**

2 **List all possible intervention options**
- Eng. / soc. / env. & inst. considerations and judgement

WRYM
3 **Undertake initial screening process**
- Historical yield analysis
- Preliminary economic analysis
- Determine URVs
- Eng. / soc. / env. & inst. cons.

4 **List most feasible options**

WRYM
5 **Rank selected options**
- Stochastic long-term analysis
- Prelim. implementation schedule
- Initial estimate filling times
- Re-determine URVs

WRPM
6 **Schedule selected option**
- Establish commissioning dates
- Refine implementation schedule
- Finalise URVs

Operations planning (1 of 2)

To determine operating rules for:

- Reservoirs
- Inter-reservoir support
- Inter-sub-system transfer
- Salinity (TDS) blending
- Management of dual users (e.g. hydropower and irrigation)
- Minimising operational costs (projected probabilistic cost analyses)

Operations planning (2 of 2)

To determine :

- If and when curtailment are required
- The severity of required curtailments
- Volumes that need to be transferred for inter-sub-system support
- Short-term surplus available in the system
- To identify short comings in the Management/Operating of the system
- To assist with various operational related decisions

Capabilities

- Variety of physical system features
- Flexible configuration (not hard coded)
- Complex systems, multiple reservoirs
- Multiple users and assurance levels
- Flexible operating rule definitions
- Dynamic changes over time
- Rigorous stochastic flow generation
- Software forward compatible

Limitations

- High level of experience
- Effort for configuration and maintenance
- Extensive testing and verification
- Graphical output via post-processors
- No automatic optimisation (scenarios)
- No antecedent flow conditions
- Few specialists for maintenance

2. Model structure

Model structure (1 of 2)

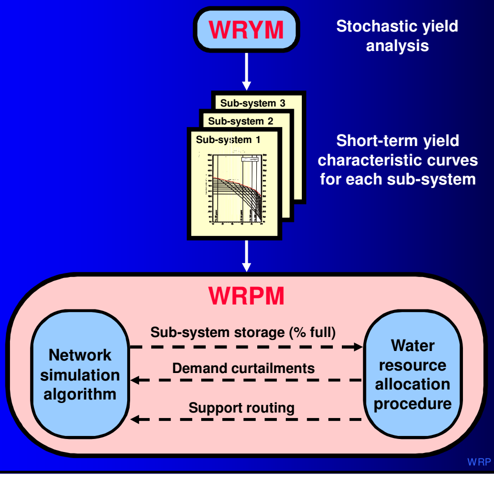
4 basic components:

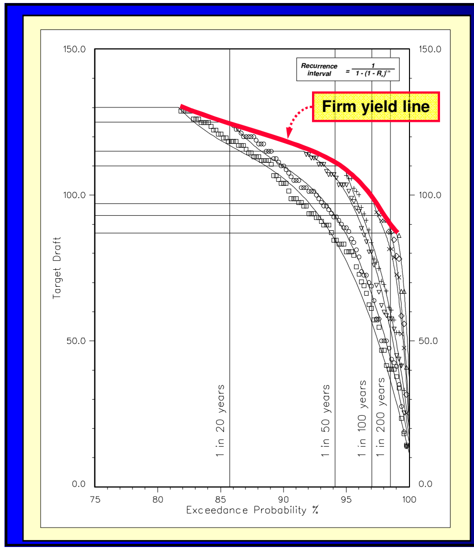
- Network simulation algorithm
- Stochastic streamflow generator
- Water resource allocation procedure
- Salinity modeling procedures

WRYM

WRPM

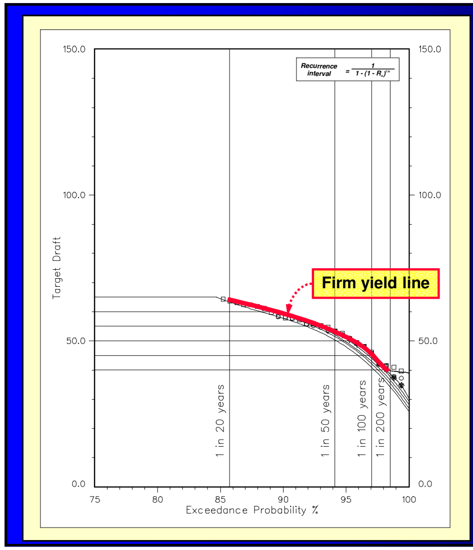
Model structure (2 of 2)





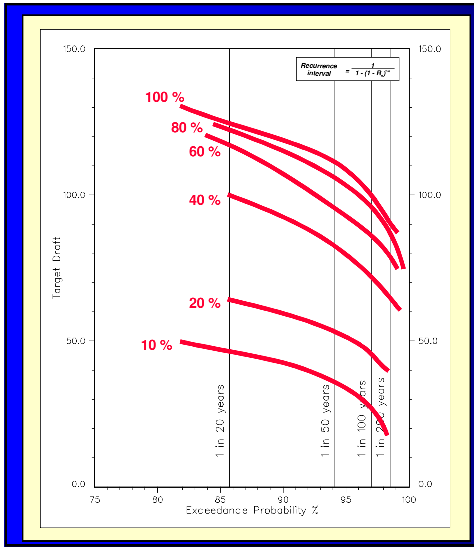
Impact of starting storage

Start at 100 % of live FSV



Impact of starting storage

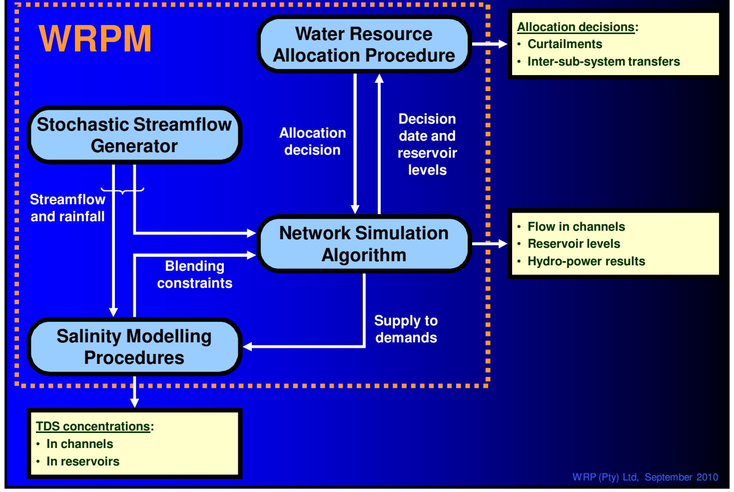
Start at 20 % of live FSV



Impact of starting storage

Family of firm yield lines

Linkages between components



WRPM

Water Resource Allocation Procedure

Stochastic Streamflow Generator

Network Simulation Algorithm

Salinity Modelling Procedures

Allocation decision

Decision date and reservoir levels

Streamflow and rainfall

Blending constraints

Supply to demands

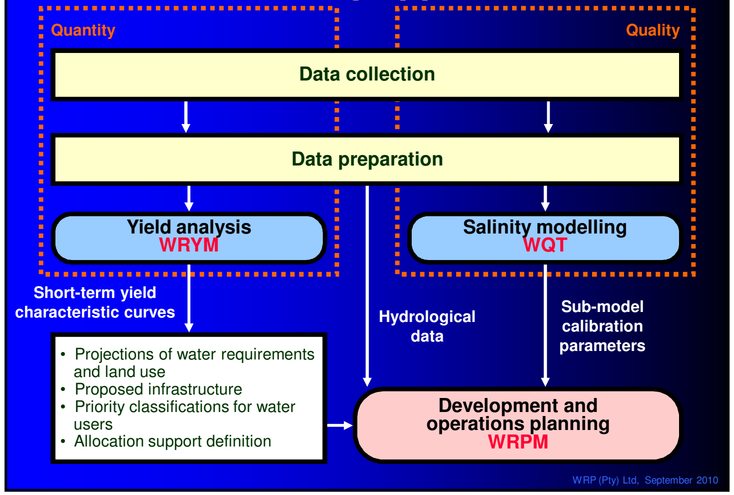
Allocation decisions:
- Curtailments
- Inter-sub-system transfers

- Flow in channels
- Reservoir levels
- Hydro-power results

TDS concentrations:
- In channels
- In reservoirs

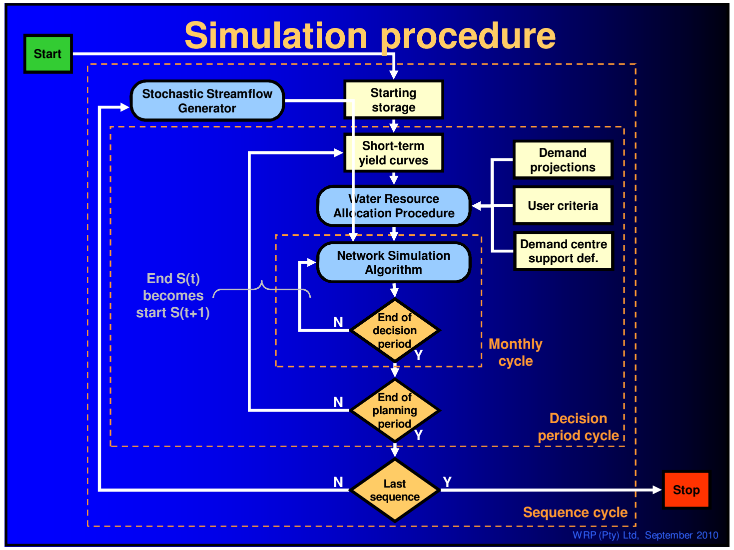
4. Modelling approach

Modelling approach



- Projections of water requirements and land use
- Proposed infrastructure
- Priority classifications for water users
- Allocation support definition

Simulation procedure



3. Overview of model results

Main model results (1 of 2)

Projection plots of:

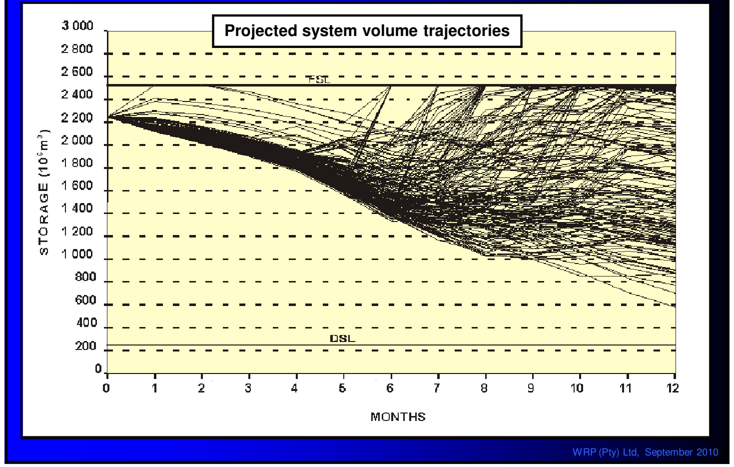
- Monthly / annual reservoir volumes
  (also with historically observed trajectory)
- Monthly / annual system volumes
- Annual total demand vs. supply
- Annual curtailment levels

Main model results (2 of 2)

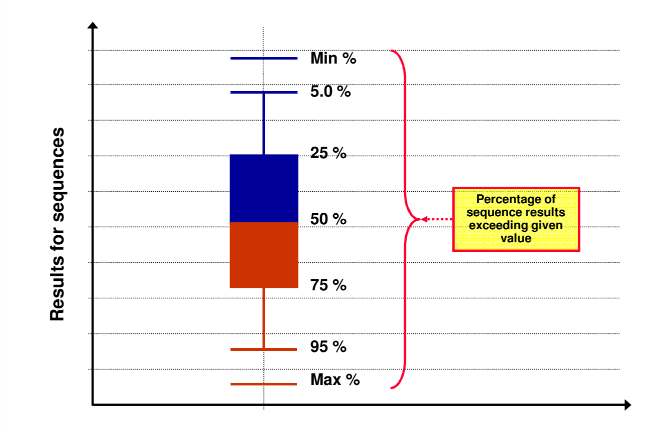
Projection plots of:

- Monthly / annual avg. channel flows
- Monthly / annual avg. TDS concentrations
  (channels and reservoirs)
- Hydropower:
  - Energy
  - Power

Result presentation (1 of 7)

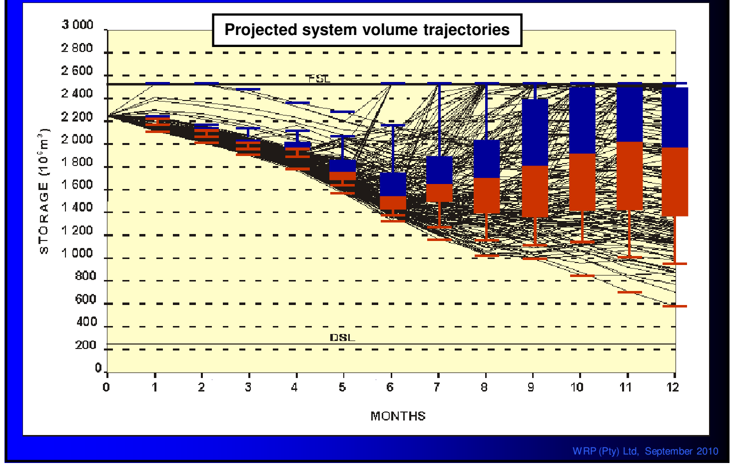


Result presentation (2 of 7)

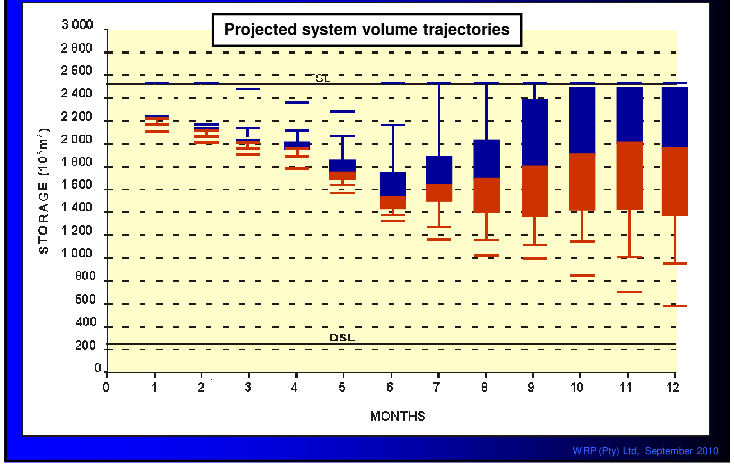


Percentage of sequence results exceeding given value

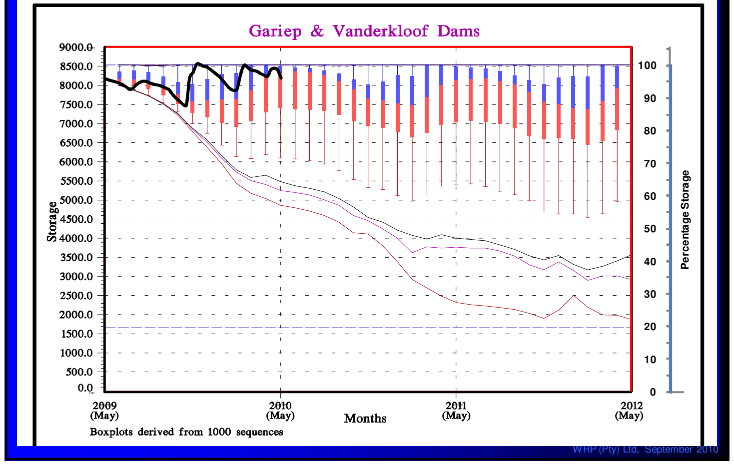
Result presentation (3 of 7)



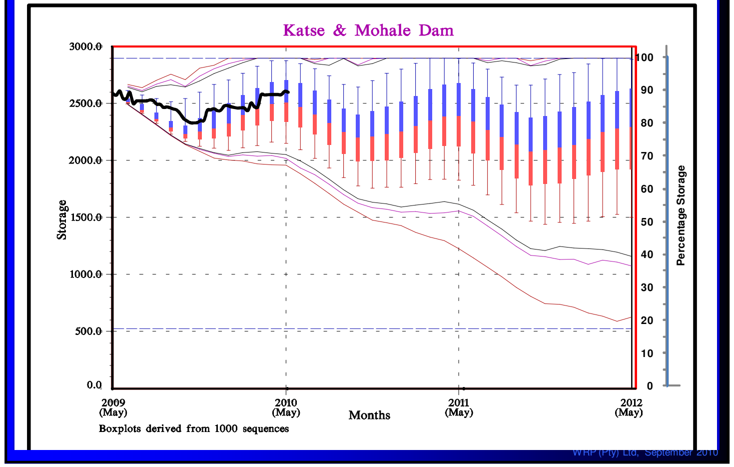
Result presentation (4 of 7)



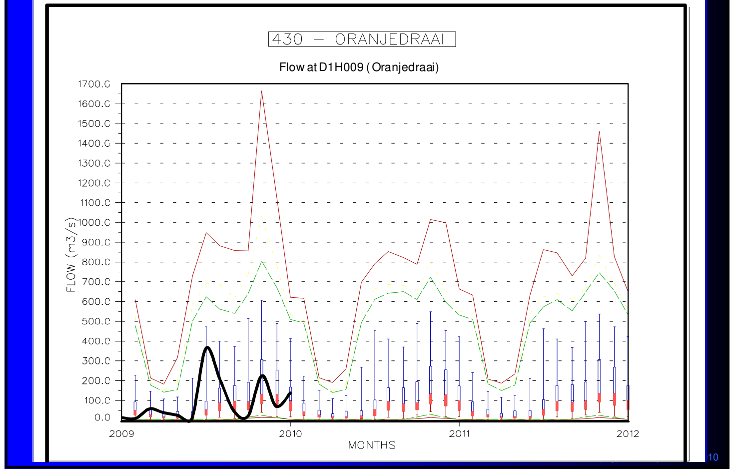
Result presentation (5 of 7)



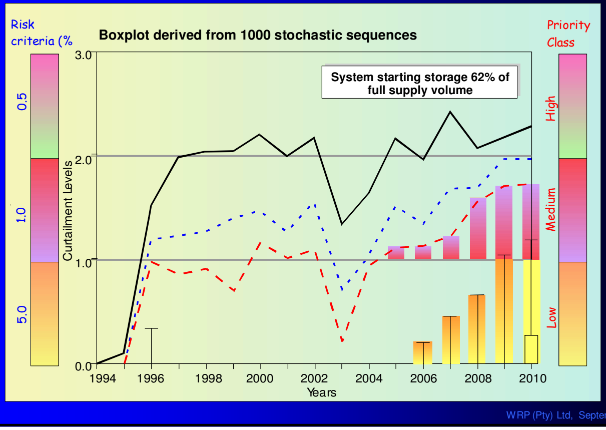
Result presentation (6 of 7)



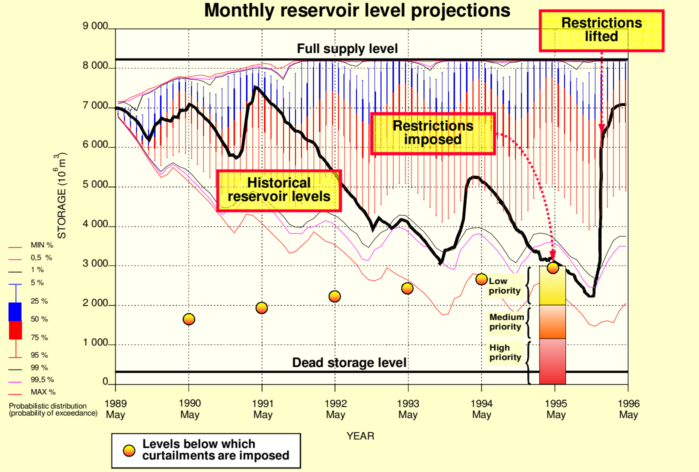
Result presentation (7 of 7)



Projected curtailment levels
Scenario 1 (Start at 62 %)



Total Vaal River System
Monthly reservoir level projections



Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management

Training Session 1: 14 – 17 February 2011

End

Commissioned by:

gtz

Federal Ministry for Economic Cooperation and Development

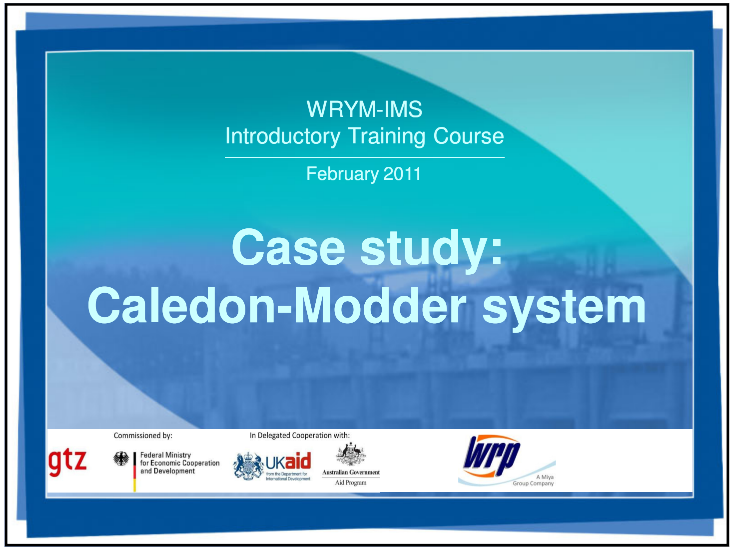
In Delegated Cooperation with:

UKaid from the Department for International Development

Australian Government Aid Program

wrp A M Group Comp

water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA



WRYM-IMS
Introductory Training Course

February 2011

Case study: Caledon-Modder system

Commissioned by:

In Delegated Cooperation with:

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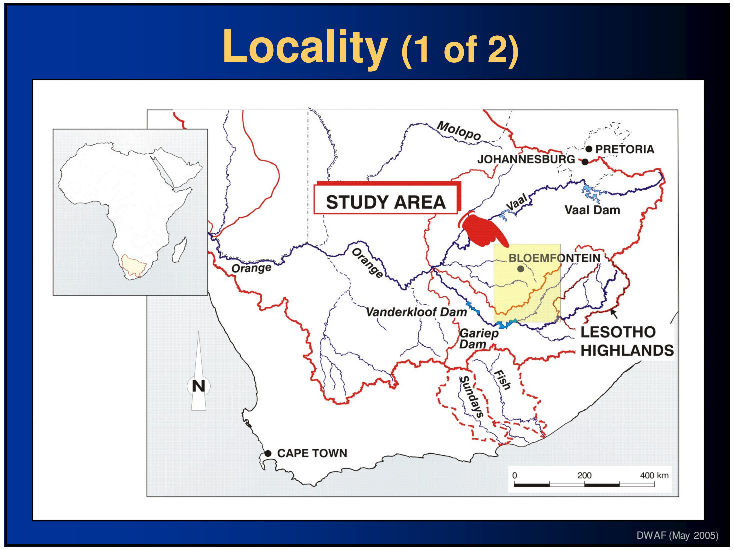
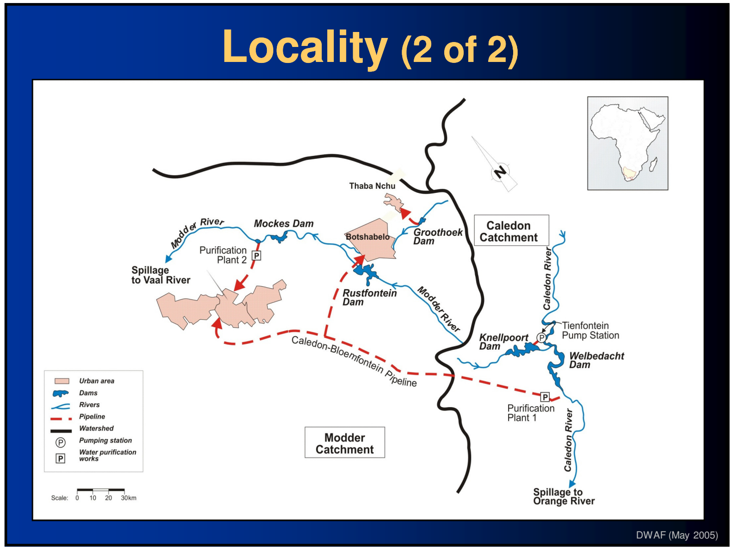
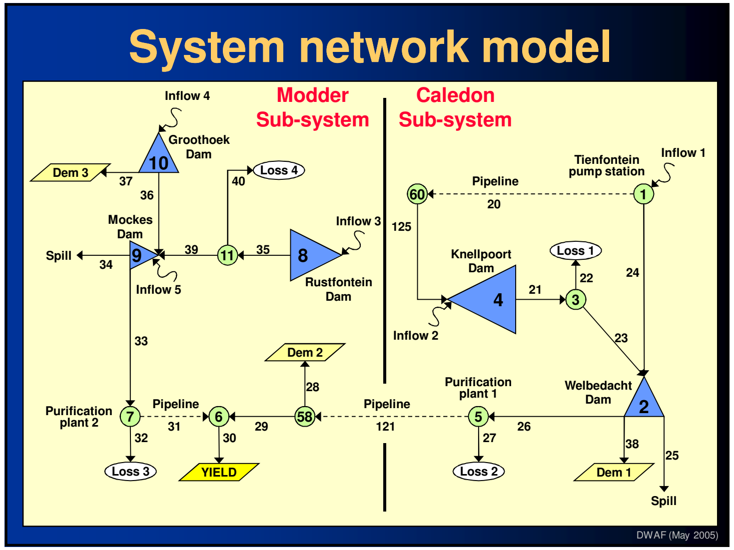
1. Background

Locality (1 of 2)

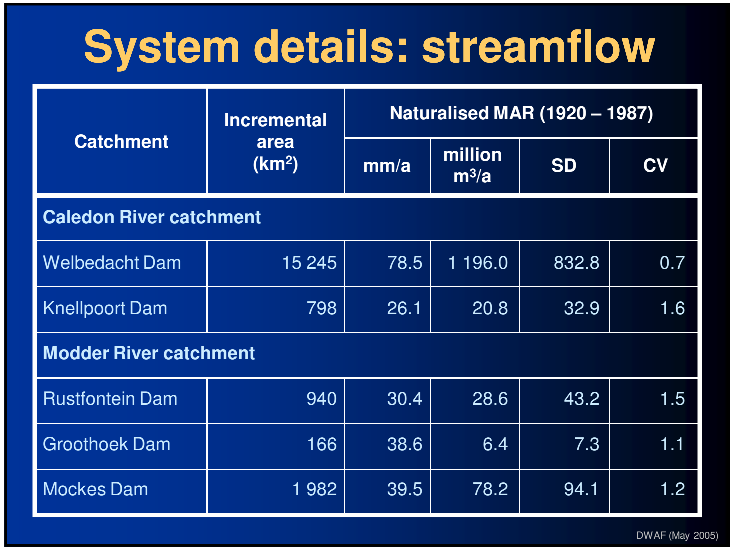


Locality (2 of 2)



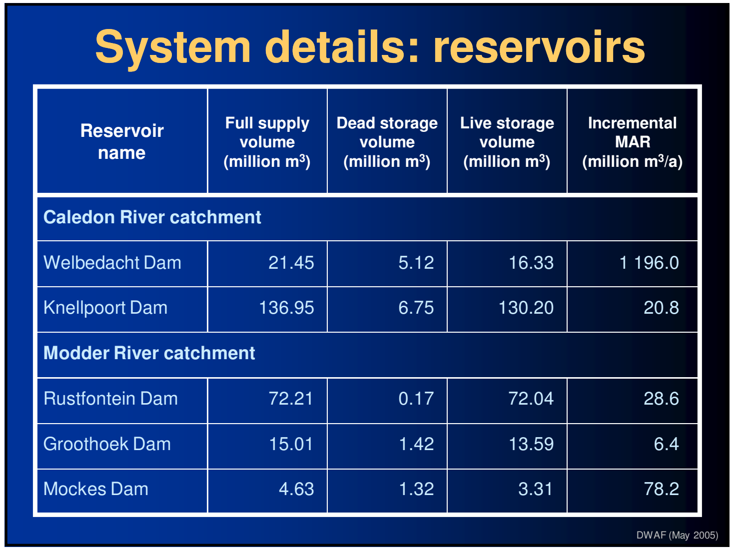


System network model



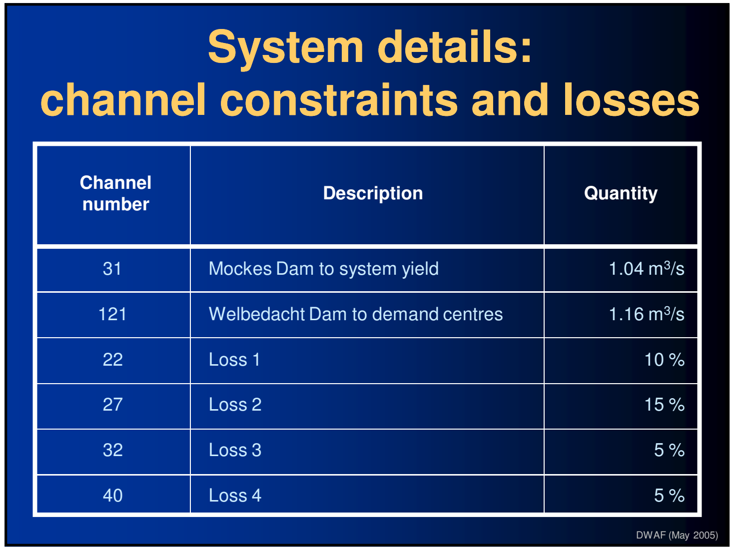
System details: streamflow

Catchment	Incremental area (km^2)	Naturalised MAR (1920 – 1987)			
		mm/a	million m^3/a	SD	CV
Caledon River catchment					
Welbedacht Dam	15 245	78.5	1 196.0	832.8	0.7
Knellpoort Dam	798	26.1	20.8	32.9	1.6
Modder River catchment					
Rustfontein Dam	940	30.4	28.6	43.2	1.5
Groothoek Dam	166	38.6	6.4	7.3	1.1
Mockes Dam	1 982	39.5	78.2	94.1	1.2



System details: reservoirs

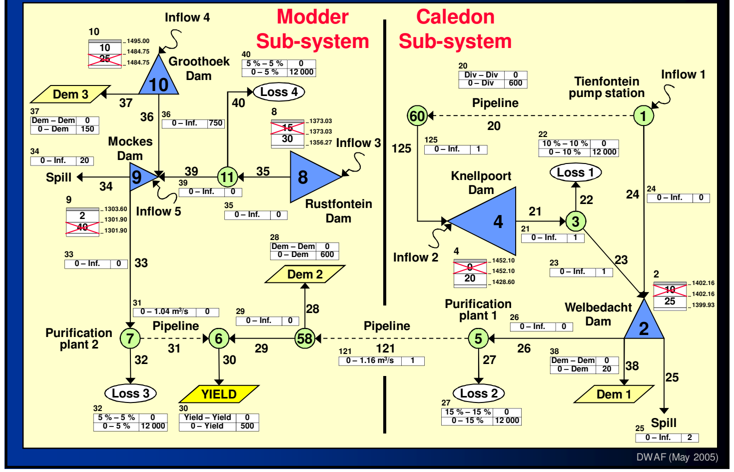
Reservoir name	Full supply volume (million m^3)	Dead storage volume (million m^3)	Live storage volume (million m^3)	Incremental MAR (million m^3/a)
Caledon River catchment				
Welbedacht Dam	21.45	5.12	16.33	1 196.0
Knellpoort Dam	136.95	6.75	130.20	20.8
Modder River catchment				
Rustfontein Dam	72.21	0.17	72.04	28.6
Groothoek Dam	15.01	1.42	13.59	6.4
Mockes Dam	4.63	1.32	3.31	78.2



System details: channel constraints and losses

Channel number	Description	Quantity
31	Mockes Dam to system yield	1.04 m^3/s
121	Welbedacht Dam to demand centres	1.16 m^3/s
22	Loss 1	10 %
27	Loss 2	15 %
32	Loss 3	5 %
40	Loss 4	5 %

System network with penalties



Operational details

- Mockes Dam used first for system yield
- Welbedacht kept full by releases from Knellpoort
- No releases from Groothoek
- Welbedacht used before Rustfontein
- Demand channel 28 takes priority over main system yield (channel 30)
- Demand channel 38 low priority – only supplied if Welbedacht spills
- Spill channel 34 penalty causes change in supply priority to Modder system (Rustfontein) when spilling

---

2. Practical: Determining historical firm yield

Purpose and methodology

Purpose:

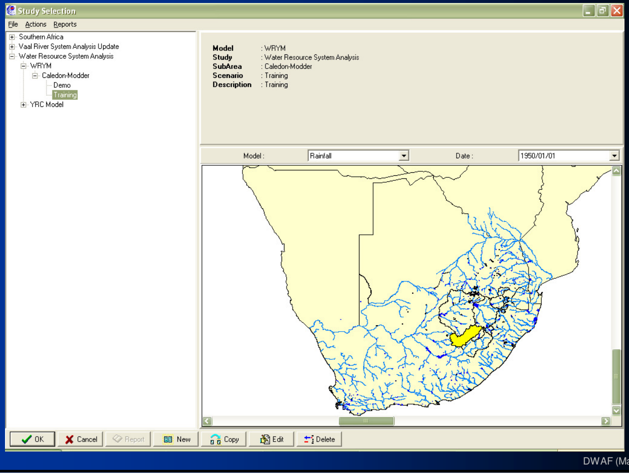
- Develop draft-yield line
- Determine historical firm yield

Methodology:

- Select WRYM-IMS study as defined under [Caledon-Modder]; [Training]
- Analyse a range of target drafts and document yield results in table
- Draw *Draft* vs. *Yield*-line

Draft vs. *Yield*-line

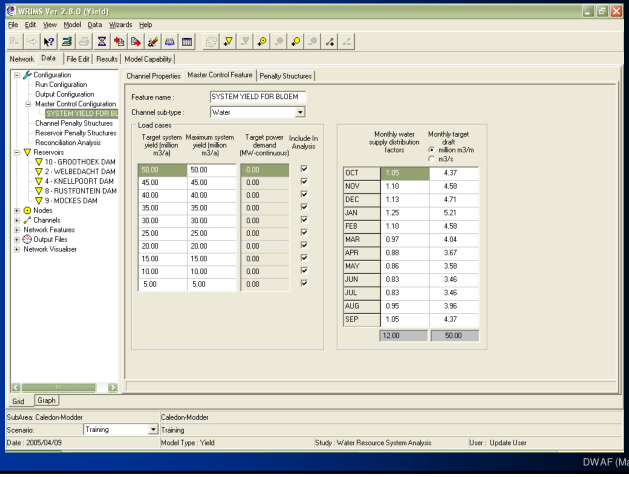
Study Selection-dialog



Model : WRYM
Study : Water Resource System Analysis
SubArea : Caledon-Modder
Scenario : Training
Description : Training

Model : Rainfall
Date : 1950/01/01

Master Control Feature-dialog



Feature name : SYSTEM YIELD FOR BLOEM
Channel sub-type : Water

Load cases

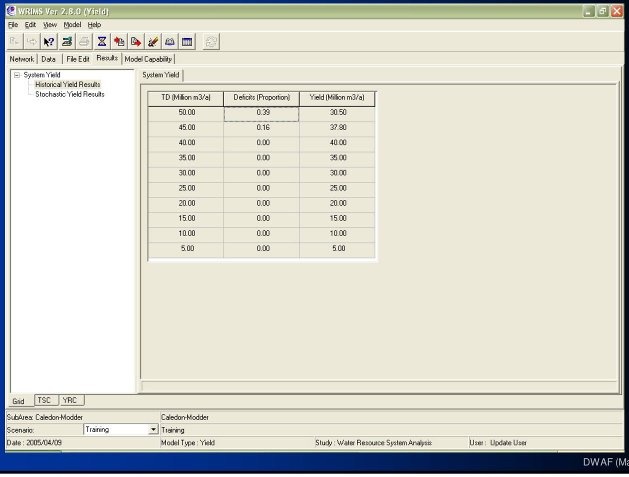
Target system yield (million m3/a)	Maximum system yield (million m3/a)	Target power demand (MW-continuous)	Include In Analysis
50.00	50.00	0.00	☑
45.00	45.00	0.00	☑
40.00	40.00	0.00	☑
35.00	35.00	0.00	☑
30.00	30.00	0.00	☑
25.00	25.00	0.00	☑
20.00	20.00	0.00	☑
15.00	15.00	0.00	☑
10.00	10.00	0.00	☑
5.00	5.00	0.00	☑

	Monthly water supply distribution factors	Monthly target draft ● million m3/m ○ m3/s
OCT	1.05	4.37
NOV	1.10	4.58
DEC	1.13	4.71
JAN	1.25	5.21
FEB	1.10	4.58
MAR	0.97	4.04
APR	0.88	3.67
MAY	0.86	3.58
JUN	0.83	3.46
JUL	0.83	3.46
AUG	0.95	3.96
SEP	1.05	4.37
	12.00	50.00

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/04/09 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

---

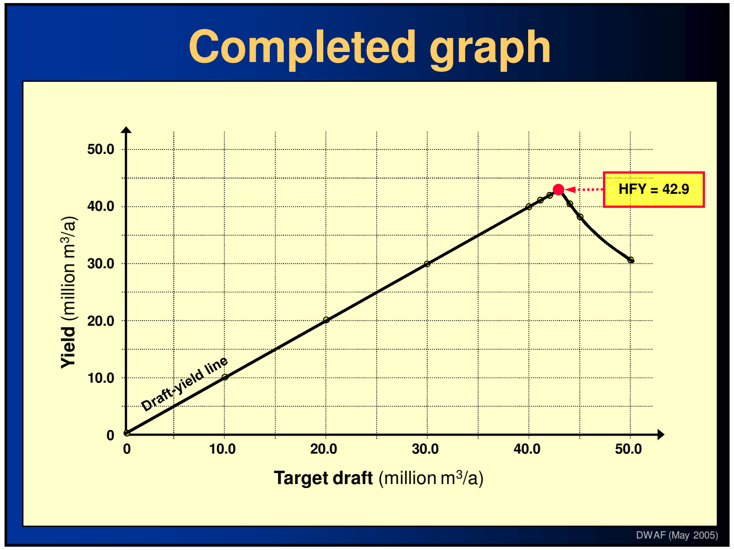
Yield Results-dialog



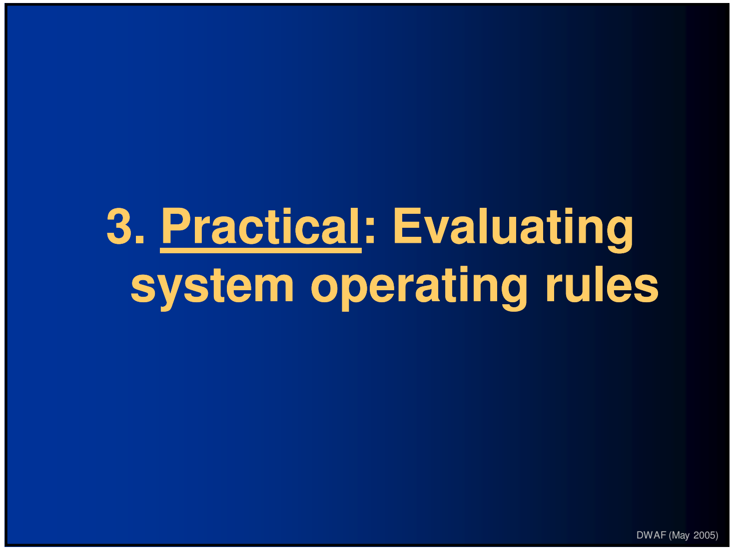
TD (Million m3/a)	Deficits (Proportion)	Yield (Million m3/a)
50.00	0.39	30.50
45.00	0.16	37.80
40.00	0.00	40.00
35.00	0.00	35.00
30.00	0.00	30.00
25.00	0.00	25.00
20.00	0.00	20.00
15.00	0.00	15.00
10.00	0.00	10.00
5.00	0.00	5.00

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/04/09 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

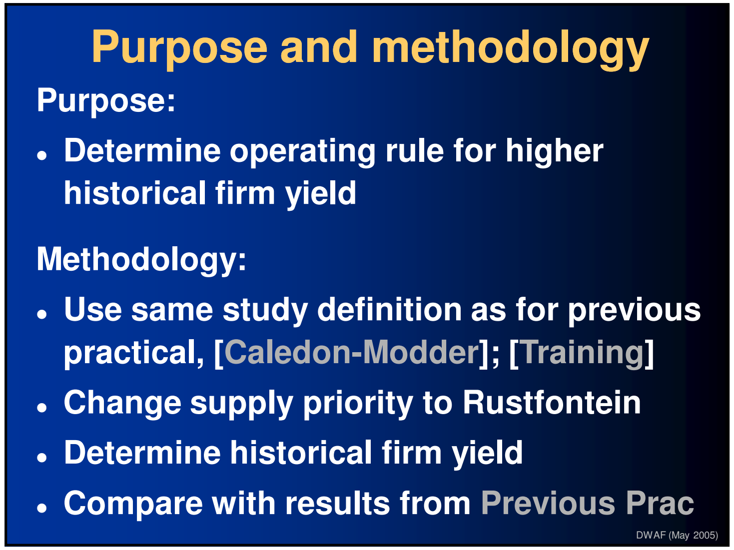
Results



Completed graph



3. Practical: Evaluating system operating rules



Purpose and methodology

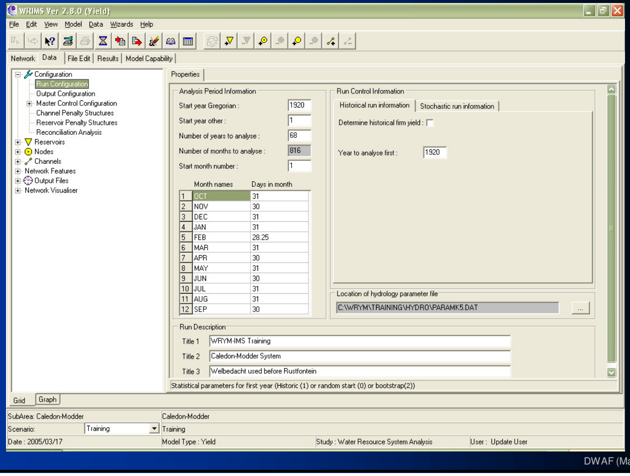
Purpose:

- Determine operating rule for higher historical firm yield

Methodology:

- Use same study definition as for previous practical, [Caledon-Modder]; [Training]
- Change supply priority to Rustfontein
- Determine historical firm yield
- Compare with results from Previous Prac

Run Configuration-dialog



Analysis Period Information

Start year Gregorian : 1920

Start year other : 1

Number of years to analyse : 68

Number of months to analyse : 816

Start month number : 1

	Month names	Days in month
1	OCT	31
2	NOV	30
3	DEC	31
4	JAN	31
5	FEB	28.25
6	MAR	31
7	APR	30
8	MAY	31
9	JUN	30
10	JUL	31
11	AUG	31
12	SEP	30

Run Control Information

Historical run information | Stochastic run information

Determine historical firm yield : ☐

Year to analyse first : 1920

Location of hydrology parameter file

C:\WRYM\TRAINING\HYDRO\PARAMK5.DAT

Run Description

Title 1 WRYM-IMS Training

Title 2 Caledon-Modder System

Title 3 Welbedacht used before Rustfontein

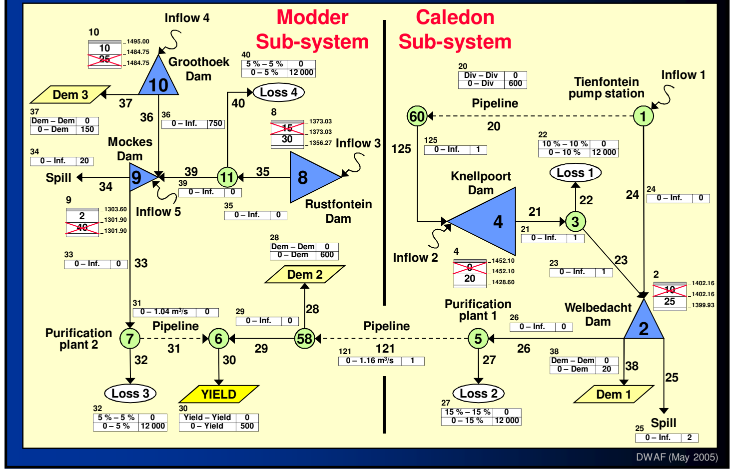
Statistical parameters for first year (Historic (1) or random start (0) or bootstrap(2))

SubArea: Caledon-Modder | Caledon-Modder

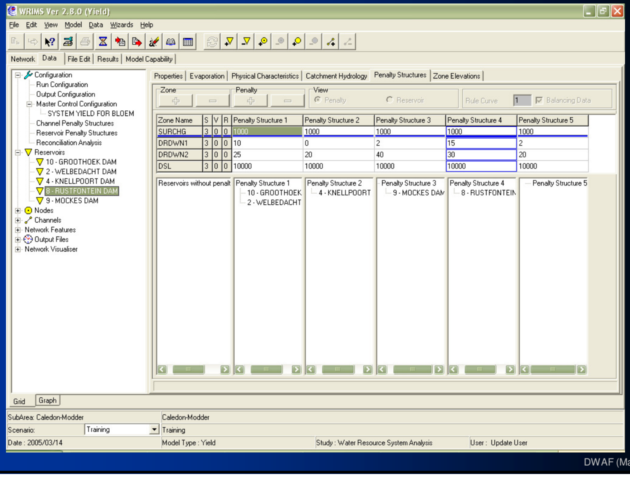
Scenario: Training | Training

Date : 2005/03/17 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

System network with penalties



Penalty Structures-dialog



View: ● Penalty ○ Reservoir

Rule Curve 1 ☑ Balancing Data

Zone Name	S	V	R	Penalty Structure 1	Penalty Structure 2	Penalty Structure 3	Penalty Structure 4	Penalty Structure 5
SURCHG	3	0	0	1000	1000	1000	1000	1000
DRDWN1	3	0	0	10	0	2	15	2
DRDWN2	3	0	0	25	20	40	30	20
DSL	3	0	0	10000	10000	10000	10000	10000

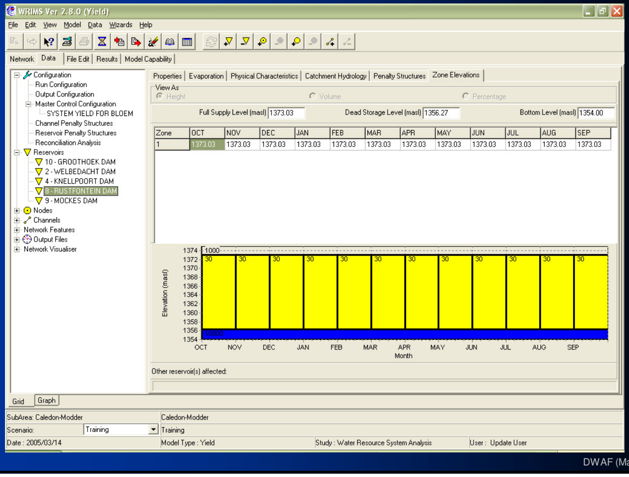
Reservoirs without penalt	Penalty Structure 1	Penalty Structure 2	Penalty Structure 3	Penalty Structure 4	Penalty Structure 5
	10 - GROOTHOEK 2 - WELBEDACHT	4 - KNELLPOORT	9 - MOCKES DAM	8 - RUSTFONTEIN	

SubArea: Caledon-Modder | Caledon-Modder

Scenario: Training | Training

Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Zone Elevations-dialog



View As: ● Height ○ Volume ○ Percentage

Full Supply Level (masl) 1373.03

Dead Storage Level (masl) 1356.27

Bottom Level (masl) 1354.00

Zone	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03

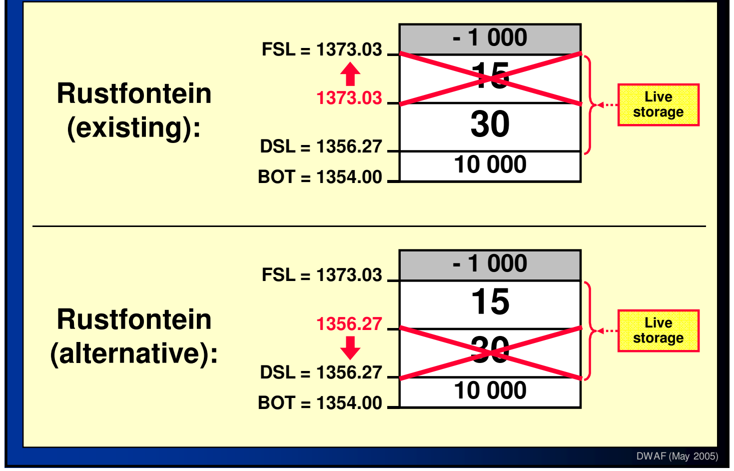
Other reservoir(s) affected:

SubArea: Caledon-Modder | Caledon-Modder

Scenario: Training | Training

Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Changing zone elevations



Rustfontein (existing):

FSL = 1373.03

1373.03

DSL = 1356.27

BOT = 1354.00

- 1 000

~~15~~

30

10 000

Live storage

Rustfontein (alternative):

FSL = 1373.03

1356.27

DSL = 1356.27

BOT = 1354.00

- 1 000

15

~~30~~

10 000

Live storage

Interpretation

- For the operating rule *Welbedacht used before Rustfontein*, what is the historical firm yield?
- For the operating rule *Rustfontein used before Welbedacht*, what is the historical firm yield?
- Which operating rule results in a higher historical firm yield?

Results

---

4. Practical: Evaluating development options

Purpose

Practical divided into two parts:

- Part 1:

  Evaluate possible development options to increase historical firm yield

- Part 2:

  Determine preferred operating rule for selected development option

---

Part 1: Methodology

- Use same study definition as for previous practical, [Caledon-Modder]; [Training]
- Define single target draft, equal to system historical firm yield (= 32.6 million m^3/a)
- Execute model and import results
- Create chart to view simulated reservoir volume results (use *Normalised*-view)
- Focus on Welbedacht, Knellpoort and Rustfontein

Observations

- Welbedacht Dam:

  Maintained at FSL for entire analysis

- Knellpoort Dam:

  Under-utilised

- Rustfontein Dam:

  Used extensively and emptied in the 1933 hydrological year

Possible development options

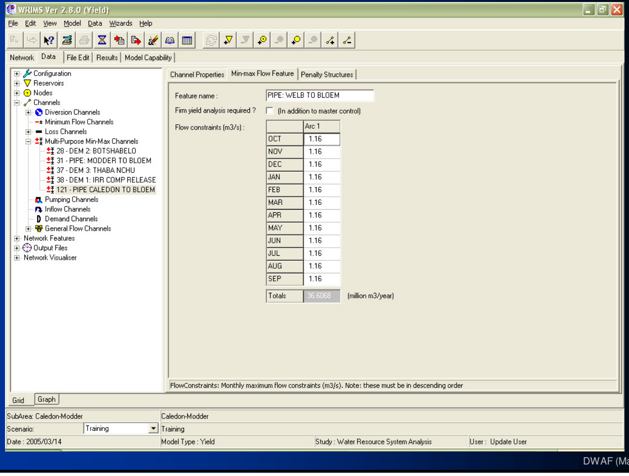
- Raise Rustfontein Dam
- Raise Knellpoort Dam
- Increase capacity of Tienfontein pumping station (channel 20)
- Increase capacity of transfer from Mockes Dam (channel 31)
- Increase capacity of transfer from Welbedacht (channel 121)

Part 2: Methodology

- Use same study definition as for previous practical, [Caledon-Modder]; [Training]
- Analyse system with range of capacities for channel 121
- Use functionality to determine historical firm yield automatically
- Document results in table and draw *Channel Capacity* vs. *Yield*-line
- Repeat with system configured for both operating rule options

---

Min-max Flow Feature-dialog



Feature name : PIPE: WELB TO BLOEM

Firm yield analysis required ? ☐ (In addition to master control)

Flow constraints (m3/s) :

	Arc 1
OCT	1.16
NOV	1.16
DEC	1.16
JAN	1.16
FEB	1.16
MAR	1.16
APR	1.16
MAY	1.16
JUN	1.16
JUL	1.16
AUG	1.16
SEP	1.16
Totals	36.6068

(million m3/year)

FlowConstraints: Monthly maximum flow constraints (m3/s). Note: these must be in descending order

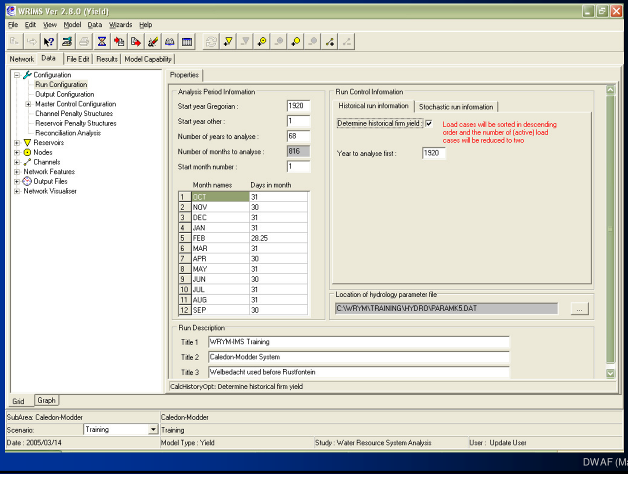
SubArea: Caledon-Modder Caledon-Modder

Scenario: Training Training

Date : 2005/03/14 Model Type : Yield Study : Water Resource System Analysis User : Update User

---

Run Configuration-dialog



Analysis Period Information

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Start year other : 1

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Number of months to analyse : 816

Start month number : 1

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2	NOV	30
3	DEC	31
4	JAN	31
5	FEB	28.25
6	MAR	31
7	APR	30
8	MAY	31
9	JUN	30
10	JUL	31
11	AUG	31
12	SEP	30

Run Control Information

Determine historical firm yield : ☑ Load cases will be sorted in descending order and the number of (active) load cases will be reduced to two

Year to analyse first : 1920

Location of hydrology parameter file

C:\WRYM\TRAINING\HYDRO\PARAMK5.DAT

Run Description

Title 1 WRYM-IMS Training

Title 2 Caledon-Modder System

Title 3 Welbedacht used before Rustfontein

CalcHistoryOpt: Determine historical firm yield

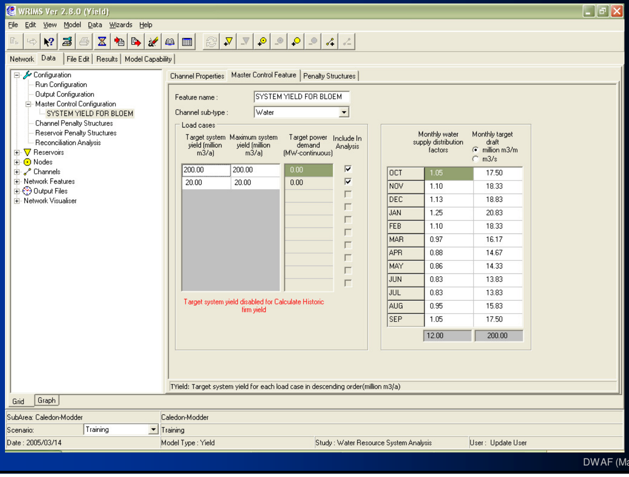
SubArea: Caledon-Modder Caledon-Modder

Scenario: Training Training

Date : 2005/03/14 Model Type : Yield Study : Water Resource System Analysis User : Update User

---

Master Control Feature-dialog



Feature name : SYSTEM YIELD FOR BLOEM

Channel sub-type : Water

Load cases

Target system yield (million m3/a)	Maximum system yield (million m3/a)	Target power demand (MW-continuous)	Include In Analysis
200.00	200.00	0.00	☑
20.00	20.00	0.00	☑
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐

Target system yield disabled for Calculate Historic firm yield

Monthly target draft: ● million m3/m ○ m3/s

	Monthly water supply distribution factors	Monthly target draft
OCT	1.05	17.50
NOV	1.10	18.33
DEC	1.13	18.83
JAN	1.25	20.83
FEB	1.10	18.33
MAR	0.97	16.17
APR	0.88	14.67
MAY	0.86	14.33
JUN	0.83	13.83
JUL	0.83	13.83
AUG	0.95	15.83
SEP	1.05	17.50
	12.00	200.00

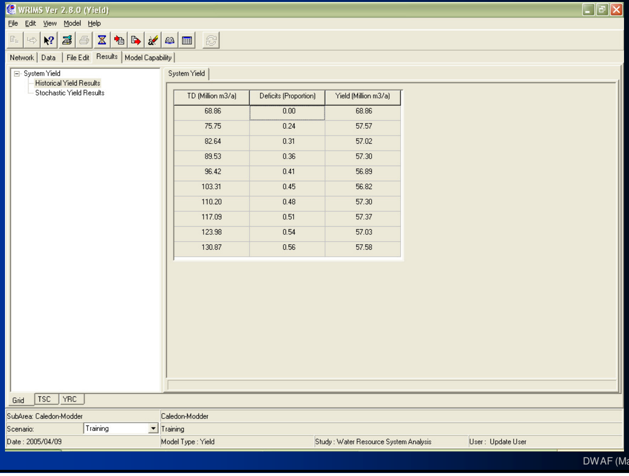
TYield: Target system yield for each load case in descending order(million m3/a)

SubArea: Caledon-Modder Caledon-Modder

Scenario: Training Training

Date : 2005/03/14 Model Type : Yield Study : Water Resource System Analysis User : Update User

Yield Results-dialog



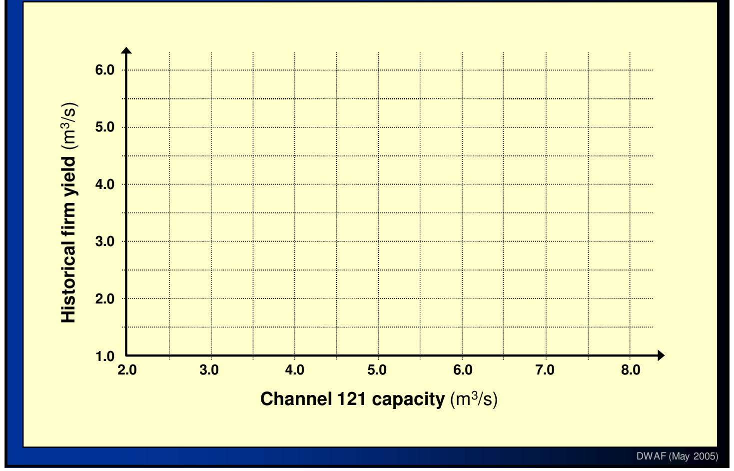
TD (Million m3/a)	Deficits (Proportion)	Yield (Million m3/a)
68.86	0.00	68.86
75.75	0.24	57.57
82.64	0.31	57.02
89.53	0.36	57.30
96.42	0.41	56.89
103.31	0.45	56.82
110.20	0.48	57.30
117.09	0.51	57.37
123.98	0.54	57.03
130.87	0.56	57.58

SubArea: Caledon-Modder
Caledon-Modder
Scenario: Training
Training
Date : 2005/04/09
Model Type : Yield
Study : Water Resource System Analysis
User : Update User

Table to be completed

Description	Channel 121 capacity and corresponding yield results						
Welbedacht used before Rustfontein							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):							
Historical firm yield (m^3/s)							
Rustfontein used before Welbedacht							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):							
Historical firm yield (m^3/s)							

Graph to be completed



Interpretation

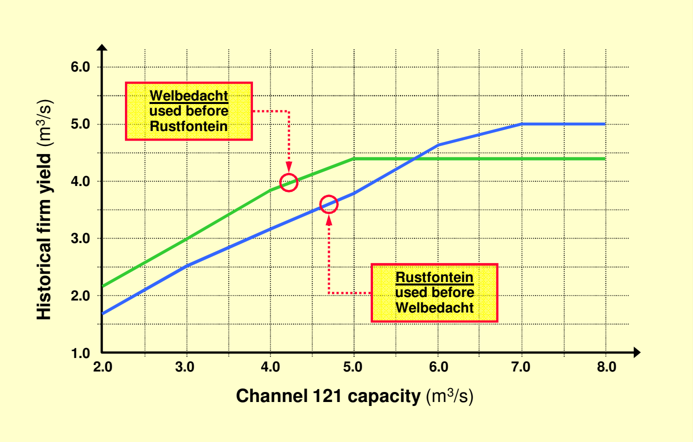
- For *Welbedacht used before Rustfontein*, what is the yield with a Channel 121 capacity of 7.0 m^3/s?
- For *Rustfontein used before Welbedacht*, what is the yield with a Channel 121 capacity of 7.0 m^3/s?
- Which operating rule results in a higher yield with a Channel 121 capacity of 7.0 m^3/s?
- How does this compare with results obtained from previous practicals, where the Channel 121 capacity was 1.16 m^3/s?
- What general lesson can be learned from the above observation?

Results

Completed table

Description	Channel 121 capacity and corresponding yield results						
Welbedacht used before Rustfontein (as for Practical 4)							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):	68.9	94.9	120.2	140.2	138.5	138.5	138.5
Historical firm yield (m^3/s)	2.2	3.0	3.8	4.4	4.4	4.4	4.4
Rustfontein used before Welbedacht (as for Practical 5)							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):	53.0	80.1	99.5	119.1	144.5	157.1	157.1
Historical firm yield (m^3/s)	1.7	2.5	3.2	3.8	4.6	5.0	5.0

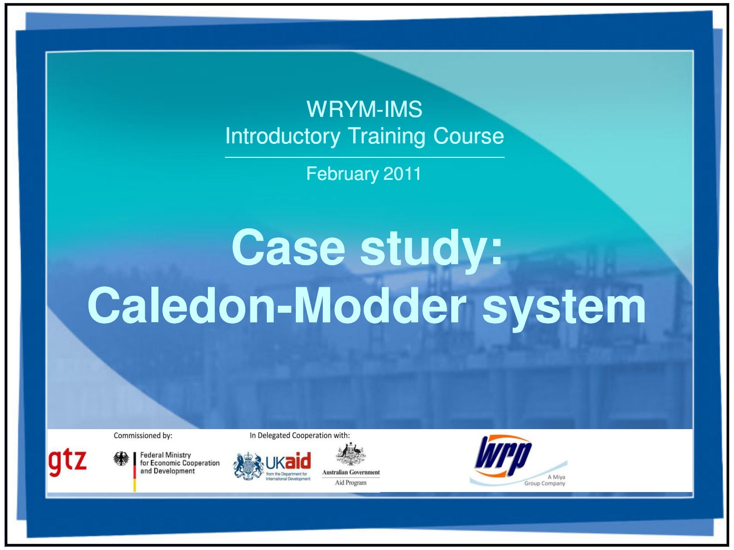
Completed graph



WRYM-IMS
Introductory Training Course

February 2011

End of module



WRYM-IMS
Introductory Training Course

February 2011

Case study: Caledon-Modder system

Commissioned by:

gtz

Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:

UKaid from the Department for International Development

Australian Government Aid Program

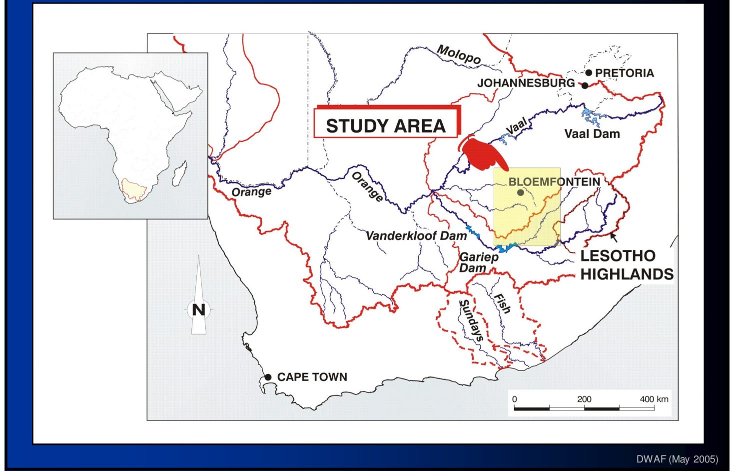
wrp A Miya Group Company

---

1. Background

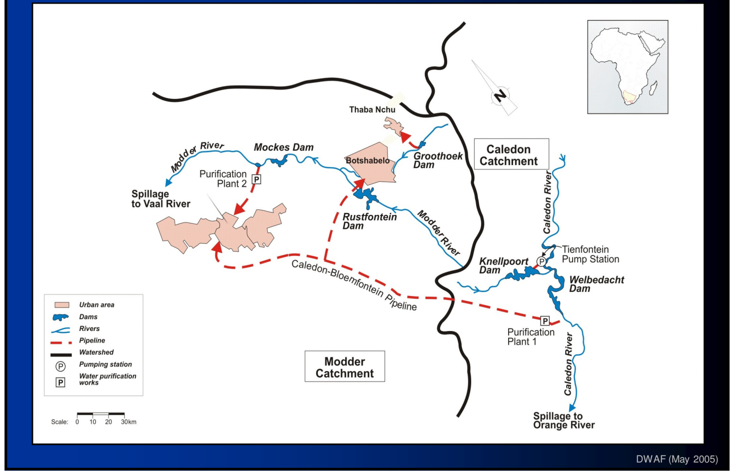
DWAF (May 2005)

Locality (1 of 2)

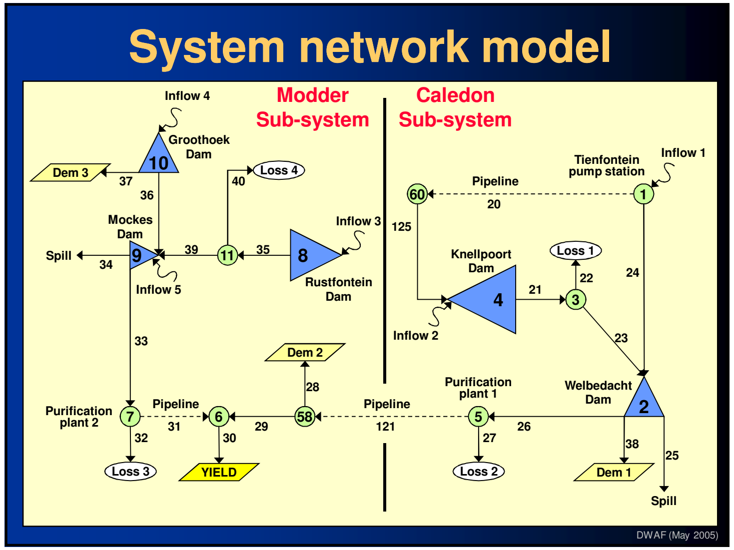


DWAF (May 2005)

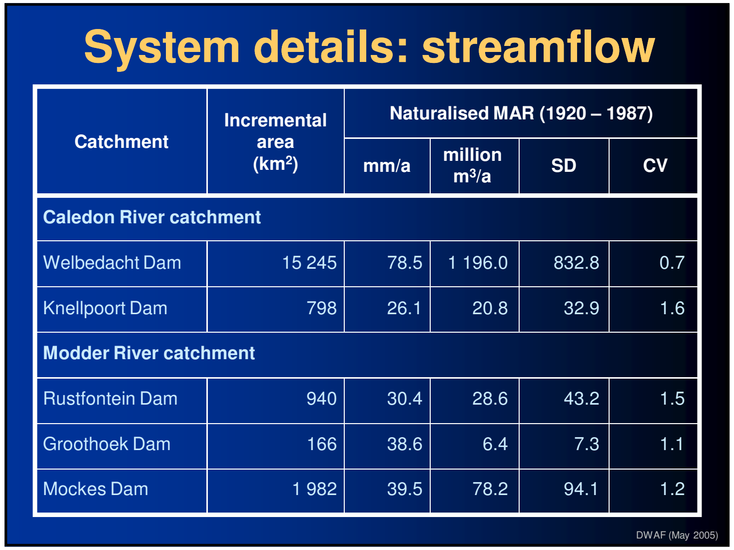
Locality (2 of 2)



DWAF (May 2005)

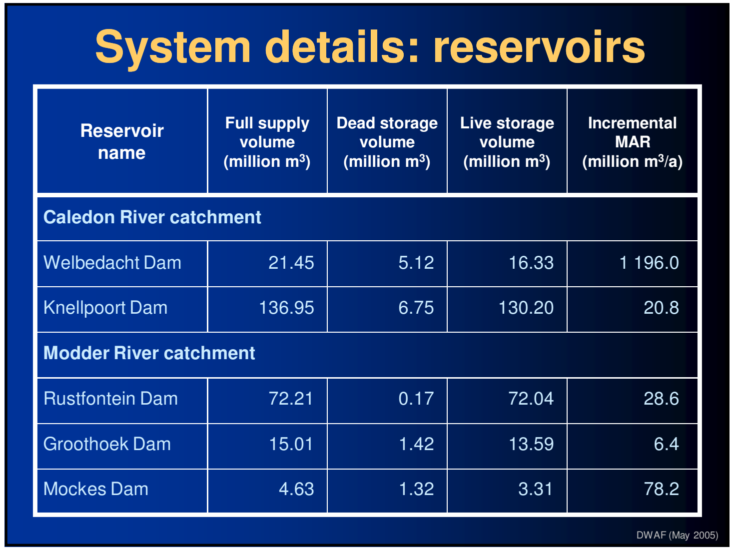


System network model



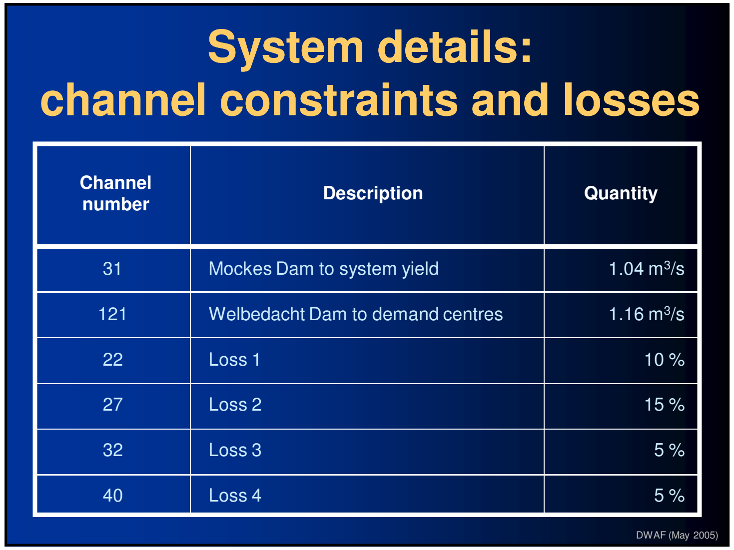
System details: streamflow

Catchment	Incremental area (km²)	Naturalised MAR (1920 – 1987)			
		mm/a	million m³/a	SD	CV
Caledon River catchment					
Welbedacht Dam	15 245	78.5	1 196.0	832.8	0.7
Knellpoort Dam	798	26.1	20.8	32.9	1.6
Modder River catchment					
Rustfontein Dam	940	30.4	28.6	43.2	1.5
Groothoek Dam	166	38.6	6.4	7.3	1.1
Mockes Dam	1 982	39.5	78.2	94.1	1.2



System details: reservoirs

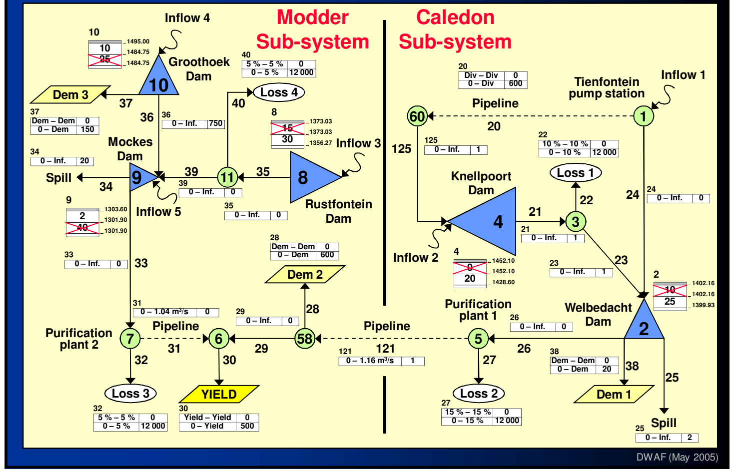
Reservoir name	Full supply volume (million m³)	Dead storage volume (million m³)	Live storage volume (million m³)	Incremental MAR (million m³/a)
Caledon River catchment				
Welbedacht Dam	21.45	5.12	16.33	1 196.0
Knellpoort Dam	136.95	6.75	130.20	20.8
Modder River catchment				
Rustfontein Dam	72.21	0.17	72.04	28.6
Groothoek Dam	15.01	1.42	13.59	6.4
Mockes Dam	4.63	1.32	3.31	78.2



System details: channel constraints and losses

Channel number	Description	Quantity
31	Mockes Dam to system yield	1.04 m³/s
121	Welbedacht Dam to demand centres	1.16 m³/s
22	Loss 1	10 %
27	Loss 2	15 %
32	Loss 3	5 %
40	Loss 4	5 %

System network with penalties



Operational details

- Mockes Dam used first for system yield
- Welbedacht kept full by releases from Knellpoort
- No releases from Groothoek
- Welbedacht used before Rustfontein
- Demand channel 28 takes priority over main system yield (channel 30)
- Demand channel 38 low priority – only supplied if Welbedacht spills
- Spill channel 34 penalty causes change in supply priority to Modder system (Rustfontein) when spilling

---

2. Practical: Determining historical firm yield

Purpose and methodology

Purpose:

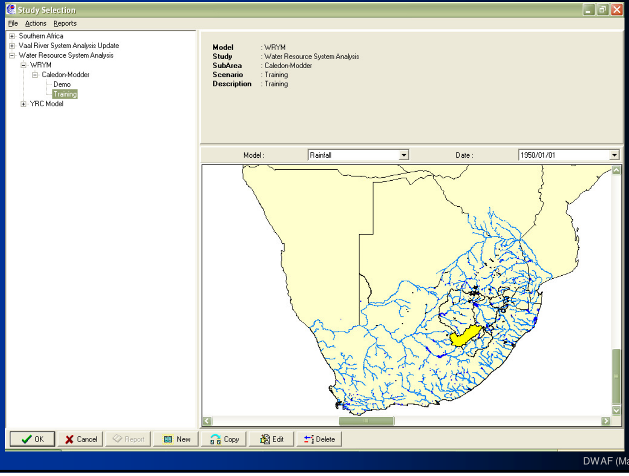
- Develop draft-yield line
- Determine historical firm yield

Methodology:

- Select WRYM-IMS study as defined under [Caledon-Modder]; [Training]
- Analyse a range of target drafts and document yield results in table
- Draw *Draft* vs. *Yield*-line

Draft vs. *Yield*-line

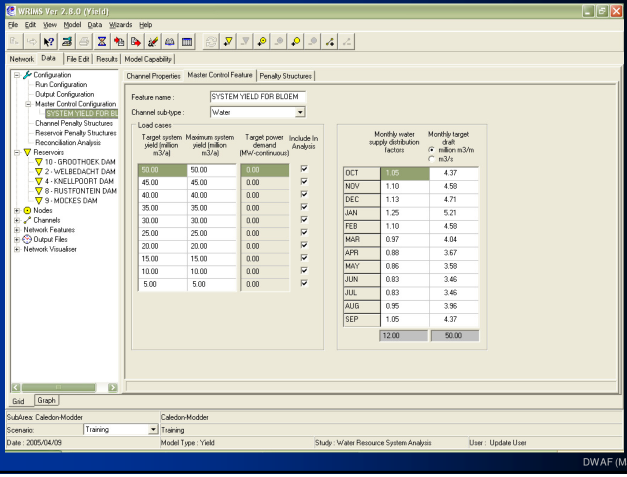
Study Selection-dialog



Model : WRYM
Study : Water Resource System Analysis
SubArea : Caledon-Modder
Scenario : Training
Description : Training

Model : Rainfall
Date : 1950/01/01

Master Control Feature-dialog



Feature name : SYSTEM YIELD FOR BLOEM
Channel sub-type : Water

Load cases

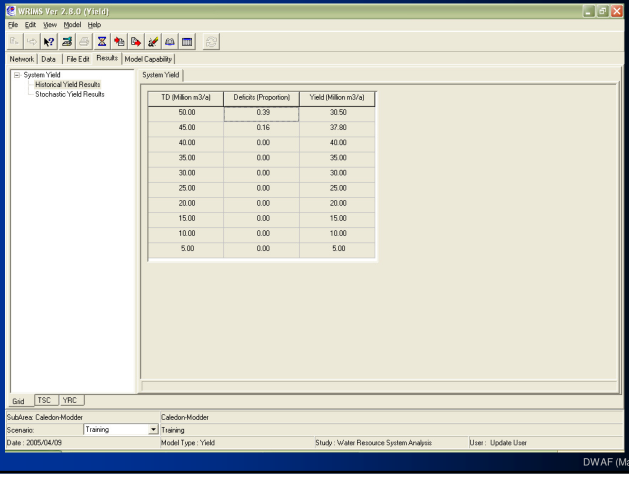
Target system yield (million m3/a)	Maximum system yield (million m3/a)	Target power demand (MW-continuous)	Include In Analysis
50.00	50.00	0.00	☑
45.00	45.00	0.00	☑
40.00	40.00	0.00	☑
35.00	35.00	0.00	☑
30.00	30.00	0.00	☑
25.00	25.00	0.00	☑
20.00	20.00	0.00	☑
15.00	15.00	0.00	☑
10.00	10.00	0.00	☑
5.00	5.00	0.00	☑

Monthly target draft: ● million m3/m ○ m3/s

	Monthly water supply distribution factors	Monthly target draft
OCT	1.05	4.37
NOV	1.10	4.58
DEC	1.13	4.71
JAN	1.25	5.21
FEB	1.10	4.58
MAR	0.97	4.04
APR	0.88	3.67
MAY	0.86	3.58
JUN	0.83	3.46
JUL	0.83	3.46
AUG	0.95	3.96
SEP	1.05	4.37
	12.00	50.00

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/04/09 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Yield Results-dialog

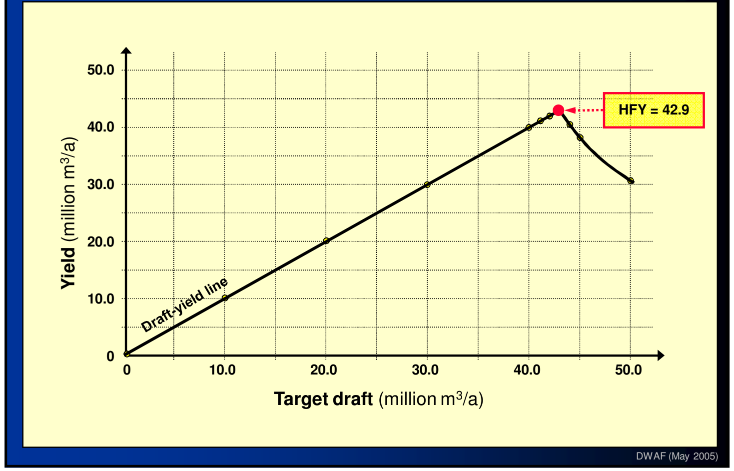


TD (Million m3/a)	Deficits (Proportion)	Yield (Million m3/a)
50.00	0.39	30.50
45.00	0.16	37.80
40.00	0.00	40.00
35.00	0.00	35.00
30.00	0.00	30.00
25.00	0.00	25.00
20.00	0.00	20.00
15.00	0.00	15.00
10.00	0.00	10.00
5.00	0.00	5.00

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/04/09 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Results

Completed graph



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3. Practical: Evaluating system operating rules

Purpose and methodology

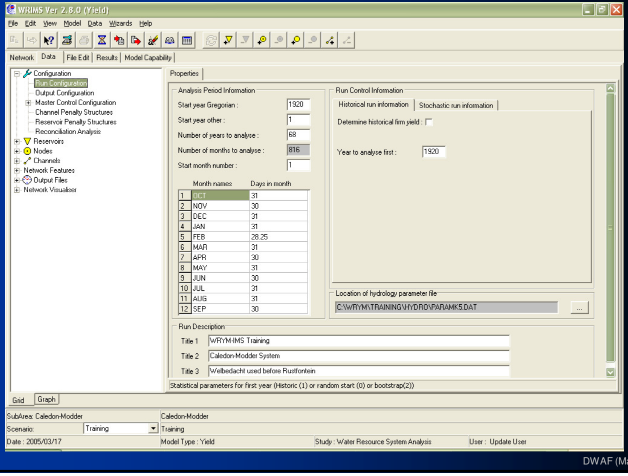
Purpose:

- Determine operating rule for higher historical firm yield

Methodology:

- Use same study definition as for previous practical, [Caledon-Modder]; [Training]
- Change supply priority to Rustfontein
- Determine historical firm yield
- Compare with results from Previous Prac

Run Configuration-dialog



Analysis Period Information

Start year Gregorian : 1920

Start year other : 1

Number of years to analyse : 68

Number of months to analyse : 816

Start month number : 1

	Month names	Days in month
1	OCT	31
2	NOV	30
3	DEC	31
4	JAN	31
5	FEB	28.25
6	MAR	31
7	APR	30
8	MAY	31
9	JUN	30
10	JUL	31
11	AUG	31
12	SEP	30

Run Control Information

Historical run information | Stochastic run information

Determine historical firm yield : ☐

Year to analyse first : 1920

Location of hydrology parameter file

C:\WRYM\TRAINING\HYDRO\PARAMK5.DAT

Run Description

Title 1 WRYM-IMS Training

Title 2 Caledon-Modder System

Title 3 Welbedacht used before Rustfontein

Statistical parameters for first year (Historic (1) or random start (0) or bootstrap(2))

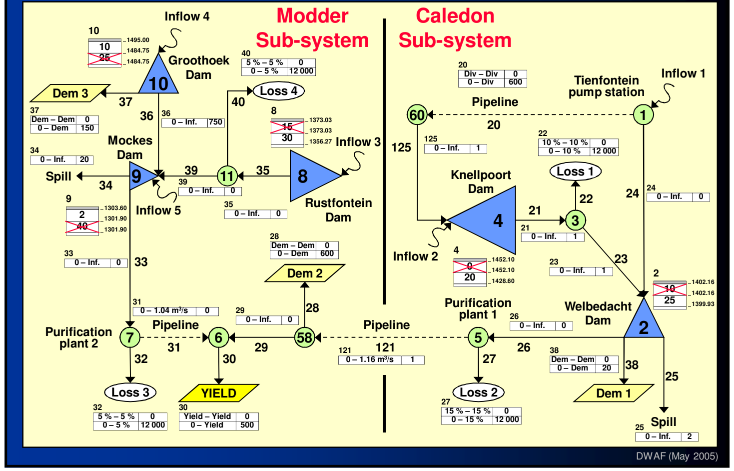
SubArea: Caledon-Modder | Caledon-Modder

Scenario: Training | Training

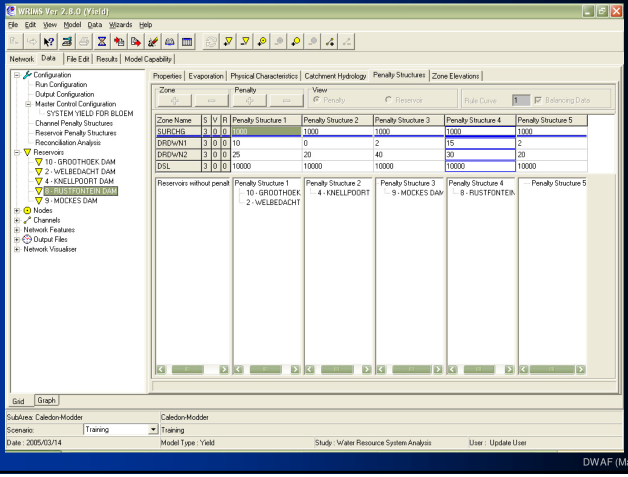
Date : 2005/03/17 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

---

System network with penalties



Penalty Structures-dialog



View: ● Penalty ○ Reservoir

Rule Curve 1 ☑ Balancing Data

Zone Name	S	V	R	Penalty Structure 1	Penalty Structure 2	Penalty Structure 3	Penalty Structure 4	Penalty Structure 5
SURCHG	3	0	0	1000	1000	1000	1000	1000
DRDWN1	3	0	0	10	0	2	15	2
DRDWN2	3	0	0	25	20	40	30	20
DSL	3	0	0	10000	10000	10000	10000	10000

Reservoirs without penalt	Penalty Structure 1	Penalty Structure 2	Penalty Structure 3	Penalty Structure 4	Penalty Structure 5
	10 - GROOTHOEK 2 - WELBEDACHT	4 - KNELLPOORT	9 - MOCKES DAM	8 - RUSTFONTEIN	

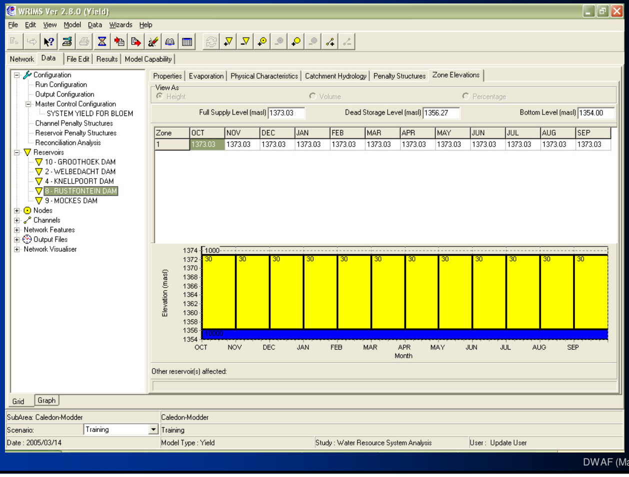
SubArea: Caledon-Modder | Caledon-Modder

Scenario: Training | Training

Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

---

Zone Elevations-dialog



View As: ● Height ○ Volume ○ Percentage

Full Supply Level (masl) 1373.03

Dead Storage Level (masl) 1356.27

Bottom Level (masl) 1354.00

Zone	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03	1373.03

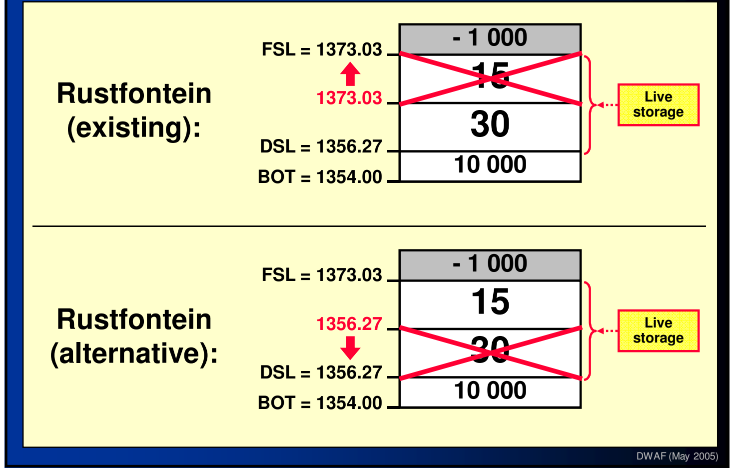
Other reservoir(s) affected:

SubArea: Caledon-Modder | Caledon-Modder

Scenario: Training | Training

Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Changing zone elevations



Rustfontein (existing):

FSL = 1373.03
1373.03
DSL = 1356.27
BOT = 1354.00

- 1 000
~~15~~
30
10 000

Live storage

Rustfontein (alternative):

FSL = 1373.03
1356.27
DSL = 1356.27
BOT = 1354.00

- 1 000
15
~~30~~
10 000

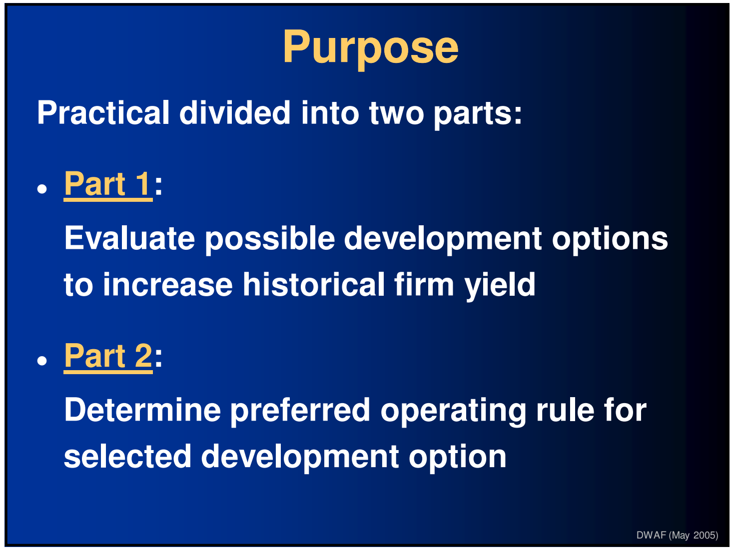
Live storage

Interpretation

- For the operating rule *Welbedacht used before Rustfontein*, what is the historical firm yield?
- For the operating rule *Rustfontein used before Welbedacht*, what is the historical firm yield?
- Which operating rule results in a higher historical firm yield?

Results

4. Practical: Evaluating development options



Purpose

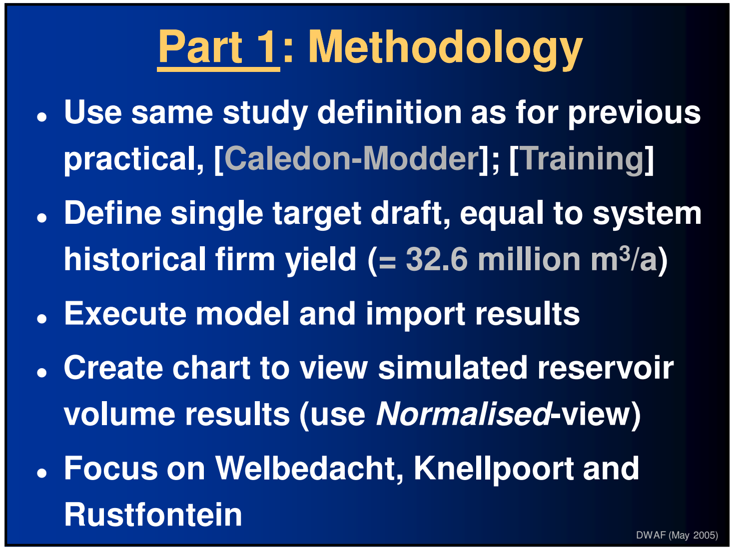
Practical divided into two parts:

- Part 1:

  Evaluate possible development options to increase historical firm yield

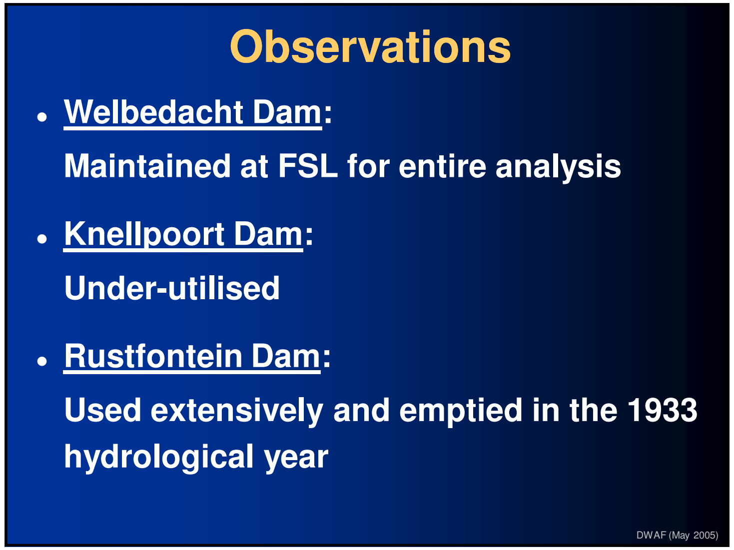
- Part 2:

  Determine preferred operating rule for selected development option



Part 1: Methodology

- Use same study definition as for previous practical, [Caledon-Modder]; [Training]
- Define single target draft, equal to system historical firm yield (= 32.6 million m^3/a)
- Execute model and import results
- Create chart to view simulated reservoir volume results (use *Normalised*-view)
- Focus on Welbedacht, Knellpoort and Rustfontein



Observations

- Welbedacht Dam:

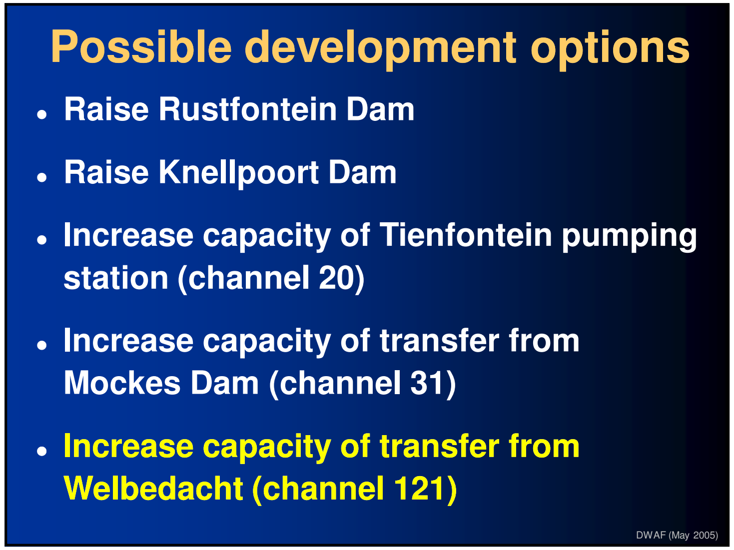
  Maintained at FSL for entire analysis

- Knellpoort Dam:

  Under-utilised

- Rustfontein Dam:

  Used extensively and emptied in the 1933 hydrological year



Possible development options

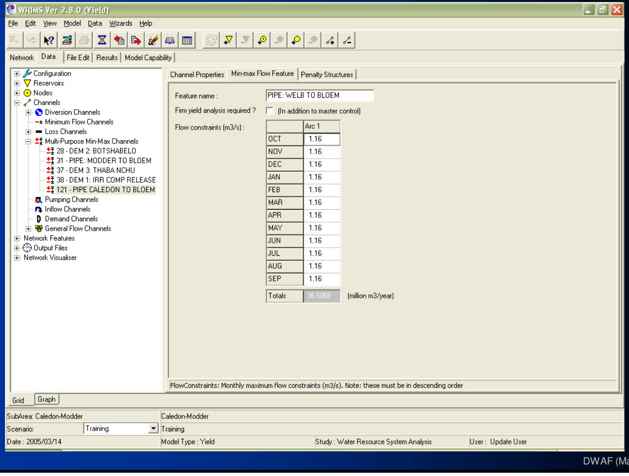
- Raise Rustfontein Dam
- Raise Knellpoort Dam
- Increase capacity of Tienfontein pumping station (channel 20)
- Increase capacity of transfer from Mockes Dam (channel 31)
- Increase capacity of transfer from Welbedacht (channel 121)

Part 2: Methodology

- Use same study definition as for previous practical, [Caledon-Modder]; [Training]
- Analyse system with range of capacities for channel 121
- Use functionality to determine historical firm yield automatically
- Document results in table and draw *Channel Capacity* vs. *Yield*-line
- Repeat with system configured for both operating rule options

---

Min-max Flow Feature-dialog



Feature name : PIPE: WELB TO BLOEM

Firm yield analysis required ? ☐ (In addition to master control)

Flow constraints (m3/s) :

	Arc 1
OCT	1.16
NOV	1.16
DEC	1.16
JAN	1.16
FEB	1.16
MAR	1.16
APR	1.16
MAY	1.16
JUN	1.16
JUL	1.16
AUG	1.16
SEP	1.16
Totals	36.6068

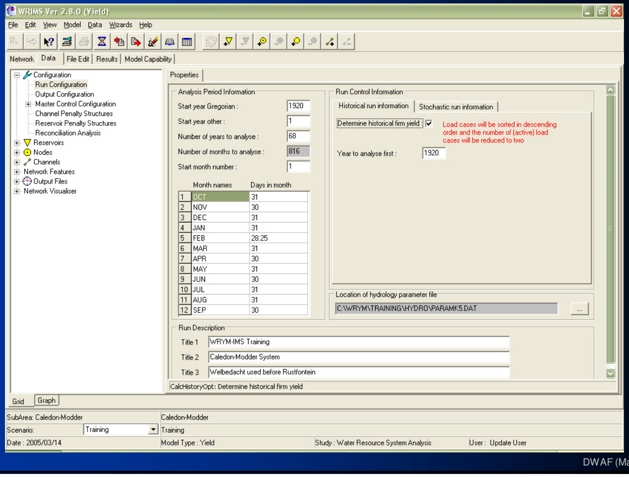
(million m3/year)

FlowConstraints: Monthly maximum flow constraints (m3/s). Note: these must be in descending order

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

---

Run Configuration-dialog



Analysis Period Information

Start year Gregorian : 1920
Start year other : 1
Number of years to analyse : 68
Number of months to analyse : 816
Start month number : 1

	Month names	Days in month
1	OCT	31
2	NOV	30
3	DEC	31
4	JAN	31
5	FEB	28.25
6	MAR	31
7	APR	30
8	MAY	31
9	JUN	30
10	JUL	31
11	AUG	31
12	SEP	30

Run Control Information

Historical run information | Stochastic run information

Determine historical firm yield : ☑

Load cases will be sorted in descending order and the number of (active) load cases will be reduced to two

Year to analyse first : 1920

Location of hydrology parameter file

C:\WRYM\TRAINING\HYDRO\PARAMK5.DAT

Run Description

Title 1 WRYM-IMS Training
Title 2 Caledon-Modder System
Title 3 Welbedacht used before Rustfontein

CalcHistoryOpt: Determine historical firm yield

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

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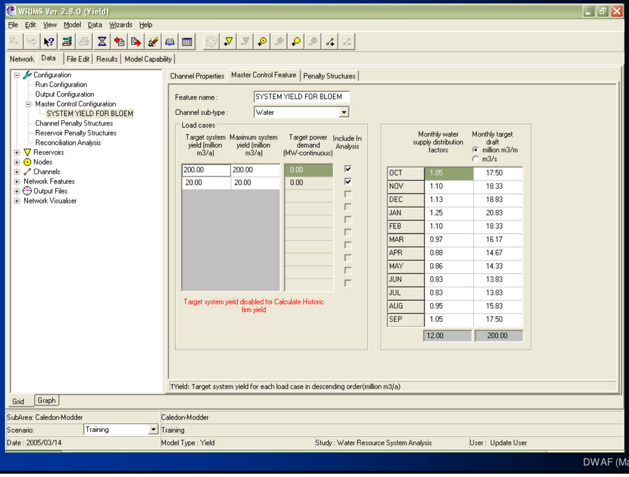
Master Control Feature-dialog



Feature name : SYSTEM YIELD FOR BLOEM

Channel sub-type : Water

Load cases

Target system yield (million m3/a)	Maximum system yield (million m3/a)	Target power demand (MW-continuous)	Include In Analysis
200.00	200.00	0.00	☑
20.00	20.00	0.00	☑
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐

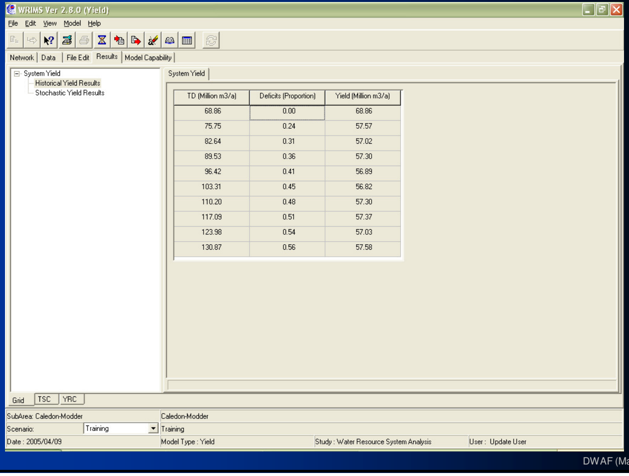
Target system yield disabled for Calculate Historic firm yield

	Monthly water supply distribution factors	Monthly target draft ● million m3/m ○ m3/s
OCT	1.05	17.50
NOV	1.10	18.33
DEC	1.13	18.83
JAN	1.25	20.83
FEB	1.10	18.33
MAR	0.97	16.17
APR	0.88	14.67
MAY	0.86	14.33
JUN	0.83	13.83
JUL	0.83	13.83
AUG	0.95	15.83
SEP	1.05	17.50
	12.00	200.00

TYield: Target system yield for each load case in descending order(million m3/a)

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/03/14 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Yield Results-dialog



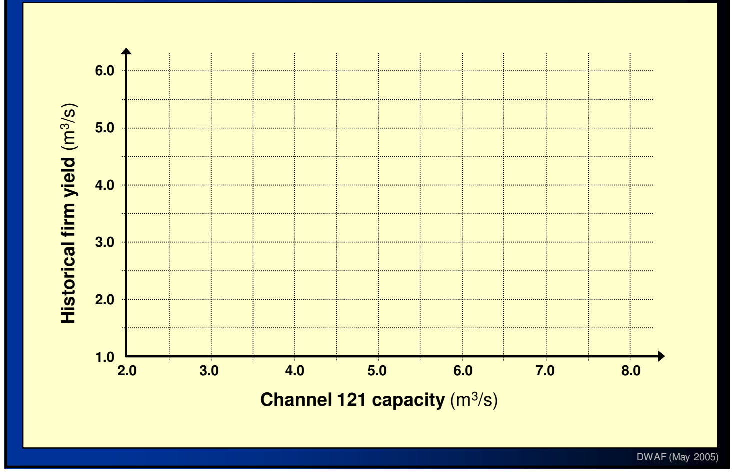
TD (Million m3/a)	Deficits (Proportion)	Yield (Million m3/a)
68.86	0.00	68.86
75.75	0.24	57.57
82.64	0.31	57.02
89.53	0.36	57.30
96.42	0.41	56.89
103.31	0.45	56.82
110.20	0.48	57.30
117.09	0.51	57.37
123.98	0.54	57.03
130.87	0.56	57.58

SubArea: Caledon-Modder | Caledon-Modder
Scenario: Training | Training
Date : 2005/04/09 | Model Type : Yield | Study : Water Resource System Analysis | User : Update User

Table to be completed

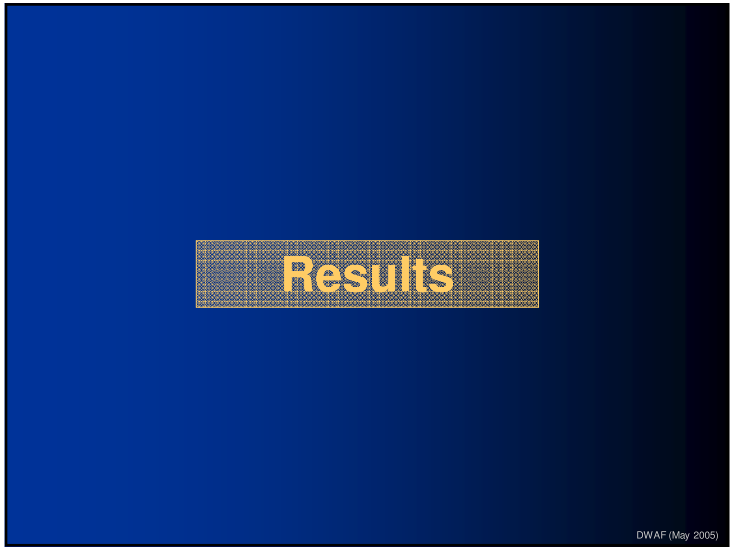
Description	Channel 121 capacity and corresponding yield results						
<u>Welbedacht</u> used before Rustfontein							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):							
Historical firm yield (m^3/s)							
<u>Rustfontein</u> used before Welbedacht							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):							
Historical firm yield (m^3/s)							

Graph to be completed

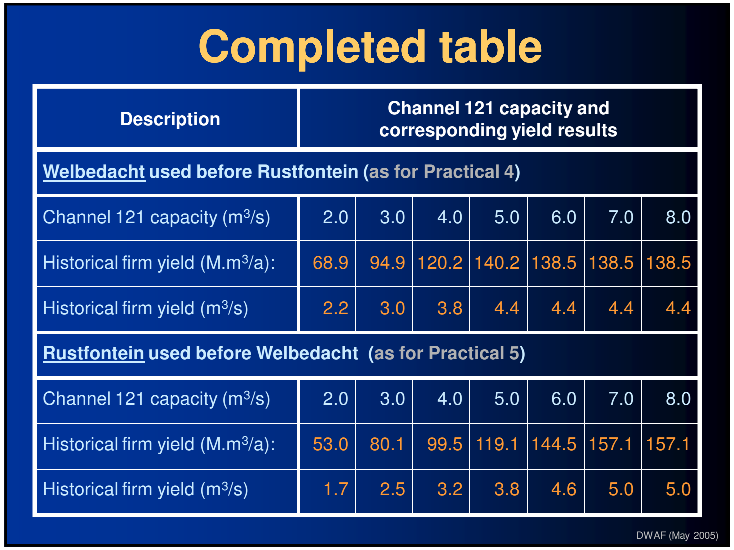


Interpretation

- For *Welbedacht used before Rustfontein*, what is the yield with a Channel 121 capacity of 7.0 m^3/s?
- For *Rustfontein used before Welbedacht*, what is the yield with a Channel 121 capacity of 7.0 m^3/s?
- Which operating rule results in a higher yield with a Channel 121 capacity of 7.0 m^3/s?
- How does this compare with results obtained from previous practicals, where the Channel 121 capacity was 1.16 m^3/s?
- What general lesson can be learned from the above observation?

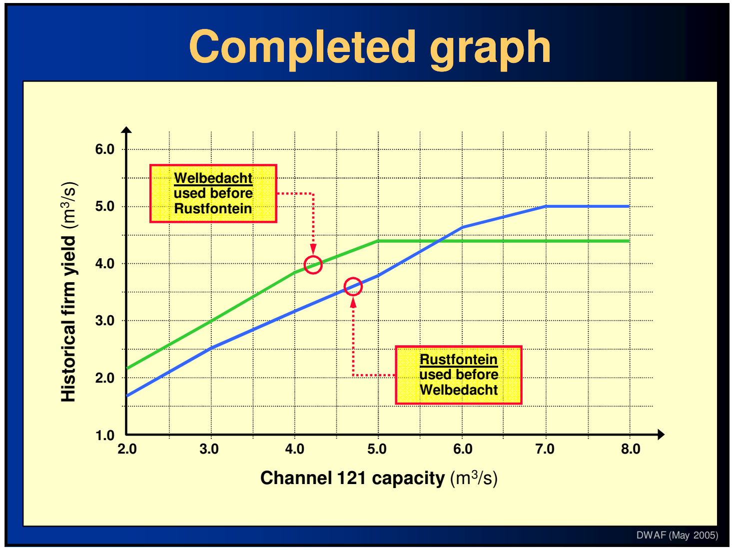


Results



Completed table

Description	Channel 121 capacity and corresponding yield results						
Welbedacht used before Rustfontein (as for Practical 4)							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):	68.9	94.9	120.2	140.2	138.5	138.5	138.5
Historical firm yield (m^3/s)	2.2	3.0	3.8	4.4	4.4	4.4	4.4
Rustfontein used before Welbedacht (as for Practical 5)							
Channel 121 capacity (m^3/s)	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Historical firm yield ($M.m^3/a$):	53.0	80.1	99.5	119.1	144.5	157.1	157.1
Historical firm yield (m^3/s)	1.7	2.5	3.2	3.8	4.6	5.0	5.0



Completed graph

WRYM-IMS
Introductory Training Course

February 2011

End of module

WRYM-IMS
Introductory Training Course

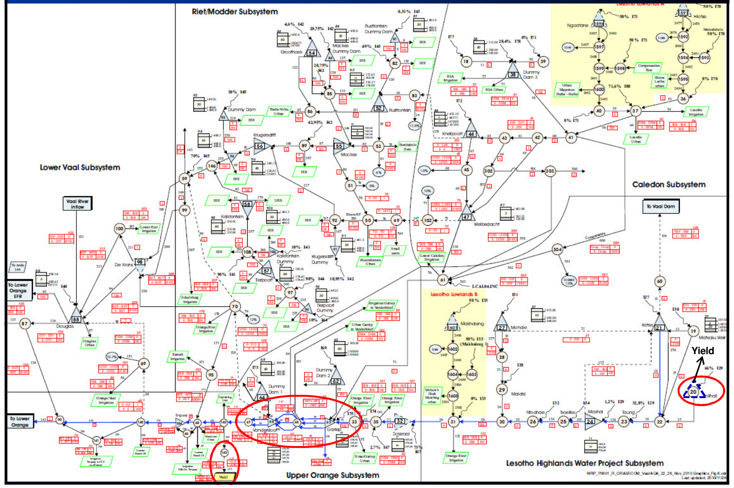
February 2011

Case study:
Orange River system
Polihali Dam

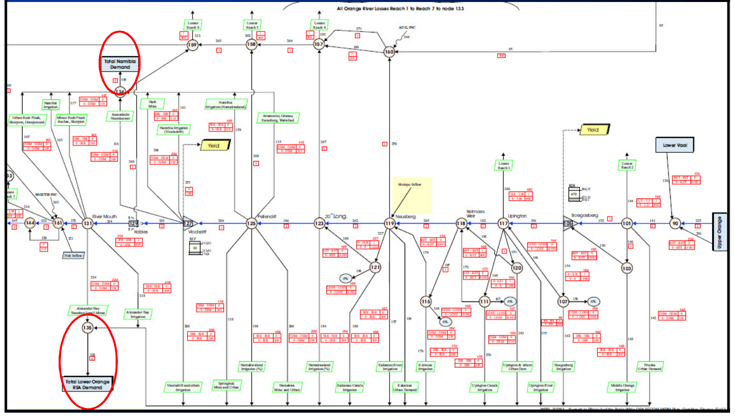
Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program
wrp
A Miya Group Company

Phase 2 (New) of the Lesotho Highlands Water Project

Upper Orange Senqu System



Lower Orange Senqu System



A: Current system

- Determine surplus yield in Orange River Project with all downstream demands in place:
- What is the average flow through channels 169 & 228: (the lower Orange demands):
- What is the annual evaporation loss from Gariep Dam:

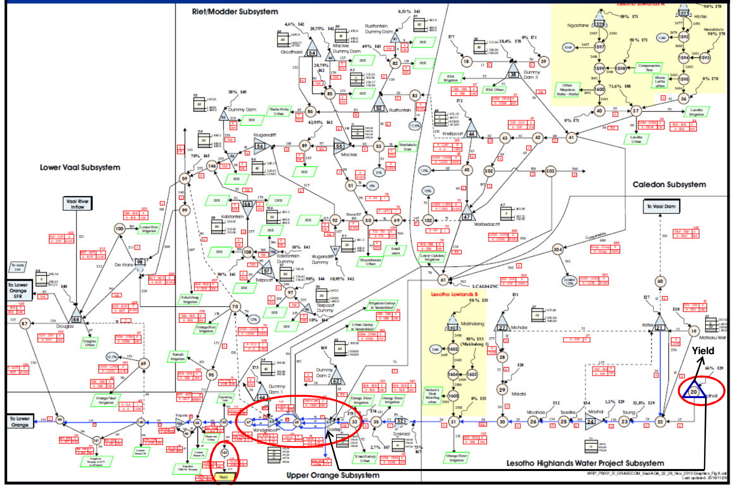
B: Inclusion of Polihali Dam

- Turn Polihali dam on
- Move yield channel to Polihali Dam
- Add channel onto node 143 and abstract HFY obtained in scenario A (37 mill m3/a = 1.172 m3/s) from node 143
- Determine Polihali HFY:
- What is the average flow through channels 169 & 228: (the lower Orange demands)
- What is the average VDK release, channel 47:

C: Polihali Dam supports Gariep

- Add support channel from Polihali to Gariep (node 63): general flow channel, with penalty = 50
- Change the yield channel's penalty from 155 to 90
- Determine Polihali surplus yield:
- What is the drop in yield as a result of Polihali's support
- What is the average support required
- What is the average flow through channels 169 & 228: (the lower Orange demands)
- What is the annual evaporation loss from Gariep Dam
- What is the saving in evaporation at Gariep as a result of Polihali Dam

Upper Orange Senqu System



2. Results

A: Current system

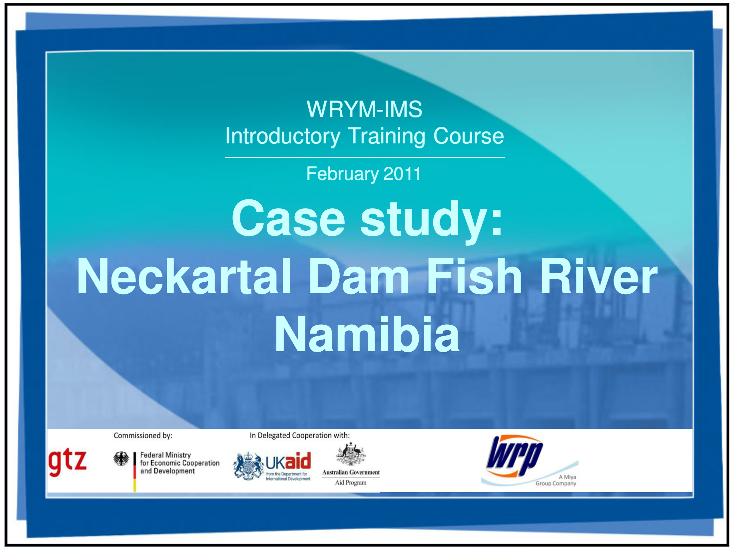
- Determine surplus yield in Orange River Project with all downstream demands in place: 37 Mm3/a
- What is the average flow through channels 169 & 228: (the lower Orange demands): 2.118 cumec, 22.278 cumec
- What is the annual evaporation loss from Gariep Dam: 16.949 cumec

B: Inclusion of Polihali Dam

- Turn Polihali dam on
- Move yield channel to Polihali Dam
- Add channel onto node 143 and abstract HFY obtained in scenario A (37 mill m3/a = 1.172 m3/s) from node 143
- Determine Polihali HFY: 409 Mm3/a
- What is the average flow through channels 169 & 228: (the lower Orange demands) 2.096 cumec, 21.993 cumec
- What is the average VDK release, channel 47: 103.756 cumec

C: Polihali Dam supports Gariep

- Add support channel from Polihali to Gariep (node 63): general flow channel, with penalty = 50
- Change the yield channel's penalty from 155 to 90
- Determine Polihali surplus yield: 393 Mm3/a
- What is the drop in yield as a result of Polihali's support 409 – 393 = 16 Mm3/a
- What is the average support required 3.147 cumec
- What is the average flow through channels 169 & 228: (the lower Orange demands) 2.118 cumec, 22.278 cumec
- What is the annual evaporation loss from Gariep Dam 15.410 cumec
- What is the saving in evaporation at Gariep as a result of Polihali Dam 16.949 – 15.410 = 1.539 cumec



WRYM-IMS
Introductory Training Course

February 2011

Case study:
Neckartal Dam Fish River Namibia

Commissioned by:

gtz

Federal Ministry for Economic Cooperation and Development

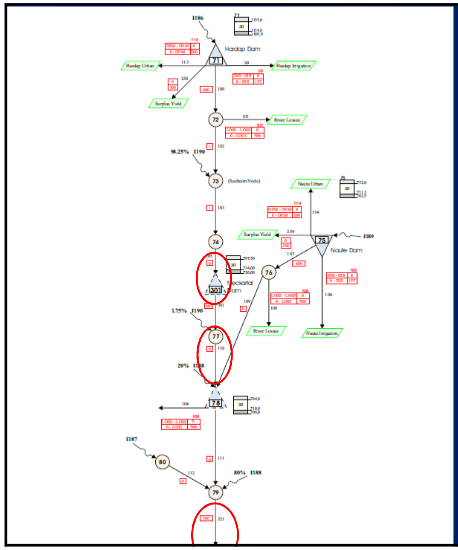
In Delegated Cooperation with:

UKaid from the Department for International Development

Australian Government Aid Program

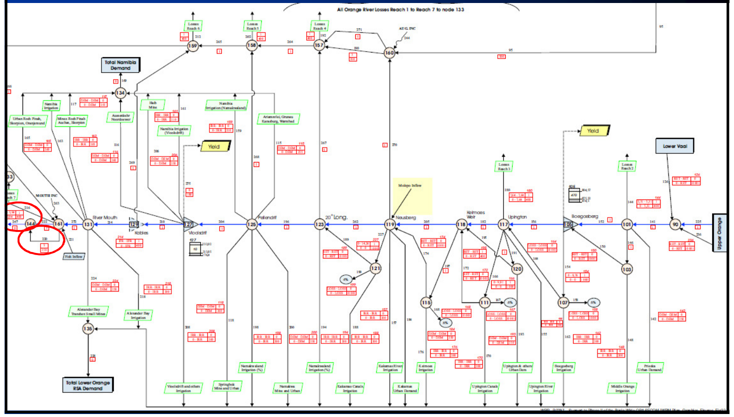
wrp A Miya Group Company

Namibia Fish River

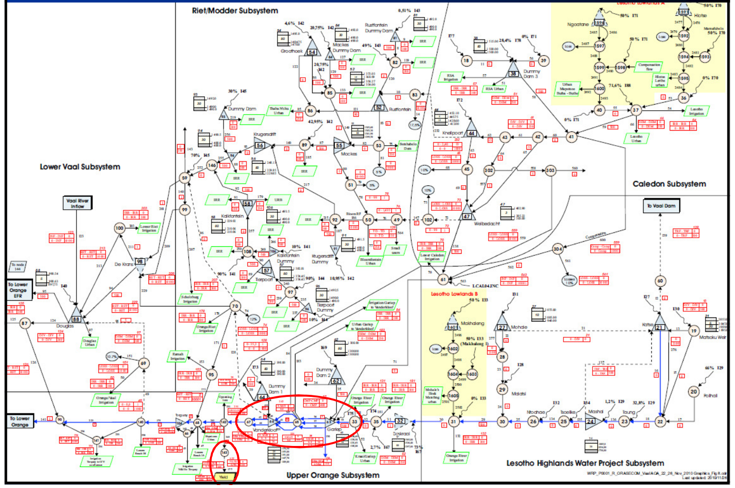


DWAF (May 2005)

Lower Orange Senqu System



Upper Orange Senqu System



A: Current system

- Check surplus yield in Orange River Project with all downstream demands in place. Should be the same as for Polihali case study current system
- What is the average flow just down stream Neckartal Dam site (channel 110)
- What is contribution from the Fish to the Orange (Channel 221)
- What is the total flow at the Orange River mouth and check EWR (channel 247 & 220)

B: Inclusion of Neckartal

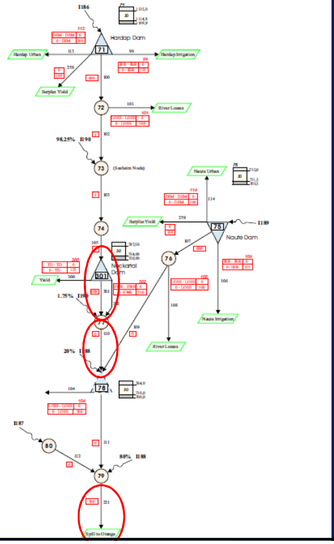
- Turn Neckartal dam on
- Move yield channel to Neckartal Dam
- Determine Neckartal Dam HFY
- What is the average flow just down stream Neckartal Dam site (channel 110)
- What is contribution from the Fish to the Orange (Channel 221)
- What is the total flow at the Orange River mouth and check EWR (channel 247 & 220)

B-2: Neckartal / Vanderkloof

- Move yield channel to Vanderkloof Dam (Node 143)
- Impose Neckartal Yield as demand on the dam (use min max channel 300)
- Determine surplus yield available at Vanderkloof (ORP surplus)
- What is the total flow at the Orange River mouth and check EWR (channel 247 & 220)

C: Include EWR for Neckartal

- Use data set as for scenario B:
- Include EWR channel 302 from node 301 to 77 (min max channel two arc penalty 0 – 550)
- Include EWR’s using IFR pre-prosessor
- Determine the yield at Neckartal Dam with EWR in place. What is the reduction in yield
- What is the average flow just down stream Neckartal Dam site and EWR (channel 110 & 302)
- What is contribution from the Fish to the Orange (Channel 221)
- What is the total flow at the Orange River mouth and check EWR (channel 247 & 220)



Namibia Fish River

C-2: Neckartal EWR/ Vanderkloof

- Move yield channel to Vanderkloof Dam
- Impose Neckartal Yield as demand on the dam (use min max channel 300)
- Determine surplus yield available at Vanderkloof (ORP surplus)
- What is the total flow at the Orange River mouth and check EWR (channel 247 & 220)

---

2. Results

Results

Scenario description	ORP surplus	Neckartal	Flow d/s Neckartal		Fish Outflow		Flow at OR Mouth		
	Yield (chan 177) mcm/a	Yield (chan 177) mcm/a	EWR (chan 302) mcm/a	Total (chan 110) mcm/a	(Chan 221) mcm/a	cm/s	EWR (Chan 220) mcm/a	Total (Chan 247) mcm/a	cm/s
Base Scenario									
Neckartal no EWR									
Neckartal & EWR									

Results

Scenario description	ORP surplus Yield (chan 177)	Neckartal Yield (chan 177)	Flow d/s Neckartal		Fish Outflow (Chan 221)		Flow at OR Mouth		
			EWR (chan 302)	Total (chan 110)			EWR (Chan 220)	Total (Chan 247)	
	mcm/a	mcm/a	mcm/a	mcm/a	mcm/a	cm/s	mcm/a	mcm/a	cm/s
Base Scenario	37	0	0	376	441	13.969	1051	4185	132.629
Neckartal no EWR	21	91	0	215	302	9.566	1051	4081	129.330
Neckartal & EWR	23	73	35	233	306	9.696	1051	4085	129.457

APPENDIX B1:

Workshop Programmes, Attendance Registers and Feedback Forms

Workshop Programmes

ORASECOM Water Resource Modelling Training Course For Decision Makers

29 – 30 November 2010

Schedule		Training module
Start time	**Duration**	
		Day 1
10:00	00:15	**Welcome**
10:15	00:30	**Introduction**
		Module 1: The Integrated Orange Vaal River System
10:45	01:00	1. Description of the Study Area
11:45	00:15	2. Improvements extensions - ORASECOM Study
12:00	01:00	3. Description of Operating Rules
13:00	00:15	4. Group discussion
13:15	00:45	Lunch break
		Module 2: Overview of Water Resource Management
14:00	00:30	1. Overview of Water Resource Management
		Module 3: Water Resource Assessment
14:30	00:25	1. Modelling Water Resources Systems
14:55	00:25	2. Basic modelling principles
15:20	00:15	Tea break
15:35	00:15	3. Definition of terms
15:50	00:30	4. Stochastic yield analysis
16:20	00:15	5. Group discussion
16:35		Closure
		Day 2
08:30	00:15	**Welcome: Review of Day 1**
		Module 4: Water Resource Allocation
08:45	00:10	1. Water Use Criteria
08:55	00:40	2. Short-term Yield reliability
09:35	00:30	3. Curtailing Water Users
10:05	00:15	Tea break
10:20	00:20	4. Assessing availability for licensing
10:40	00:15	5. Group discussion
		Module 5: Management of Water Resource Systems
10:55	00:45	1. Defining System Operating Rules
11:40	00:30	2. Practical concicderations
12:10	00:15	3. Group discussion
12:25	00:45	Lunch break
		Module 6: Intervention Planning
13:10	00:15	1. Introduction
13:25	00:20	2. Water requirement scenarios
13:45	00:30	3. Undertaking detailed phasing analysis
14:15	00:15	Tea break
14:30	00:45	4. Reconciliation Strategies
15:15	00:15	5. Group discussion
15:15		Close

ORASECOM Water Resource Modelling Training Course For Decision Makers

25-janv-11

Schedule		Training module
Start time	**Duration**	
		Day 1
08:15	00:15	**Welcome**
08:30	00:15	**Introduction**
		Module 1: The Integrated Orange Vaal River System
08:45	01:00	1. Description of the Study Area
09:45	00:15	2. Improvements extensions - ORASECOM Study
10:00	00:10	Tea break
		Module 2: Overview of Water Resource Management
10:10	00:30	1. Overview of Water Resource Management
		Module 3: Water Resource Assessment
10:40	00:25	1. Modelling Water Resources Systems
11:05	00:25	2. Basic modelling principles
11:30	00:15	3. Definition of terms
11:45	00:25	4. Stochastic yield analysis
12:10	00:30	Lunch break
		Module 4: Water Resource Allocation
12:40	00:10	1. Water Use Criteria
12:50	00:30	2. Short-term Yield reliability
13:20	00:15	3. Curtailing Water Users
13:35	00:15	4. Assessing availability for licensing
		Module 5: Management of Water Resource Systems
13:50	00:35	1. Defining System Operating Rules
14:25	00:30	2. Practical concicerations
14:55	00:15	3. Description of Existing Operating Rules
15:10	00:10	Tea break
		Module 6: Intervention Planning
15:20	00:15	1. Introduction
15:35	00:20	2. Water requirement scenarios
15:55	00:20	3. Undertaking detailed phasing analysis
16:15	00:45	4. Reconciliation Strategies
17:00		Closure

Attendance Registers

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development

In Delegated Coope with: UKaid Australian Government Aid Program

wrp A Miya Group Company

Attendance Register

Course:	Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan Training on Water Resources Modelling –Decision Makers		
Presenters:	Pieter van Rooyen, Manie Maré & Ronnie Mckenzie		
Venue:	WRP(Pty) Ltd, Pretoria Office	**Date:**	29-30 November 2010

Present

Name	Position	Organization	Telephone	Cell phone	E-mail
OBED GOZA	ENGINEER	DEPT OF WATER AFFAIRS	012 3368096	0739359546	obgoza@yahoo.com
THATO SETLOBOKO		WATER AFFAIRS BOTSWANA	+267 3607383	+267 71490378	tssetloboko@gov.
LESHOBORO NENA	HYDROLOGIST	DWA-LESOTHO	+266 22317991	+266 58444483	nena@dwa.gov.ls
Peter van Niekerk	WR Expert	DWA - RSA	+27 12 336 8762	+27 82 807 4981	niekerP@dwa.gov.za
LAWRENCE RAMOSOEU	PRINCIPAL ENGINEER	WATER COMMISSION-LES	+26659095377	+26659095377	ramosoeu kolobere @yahoo.com
RAPULE PULE	WATER RESOURCES SPECIALIST	WATER RESOURCES SPECIALIST	+27722304669	+27722304669	pulerz@dwa.gov.za
TENDAYI MAKOMBE	WATER RESOURCE ENGINEER	DWA : RSA	+2712 336 8503	+27(83)662 1414	makombet@dwa.gov.za
LENKA THAMAE	Executive Secretary	ORASECOM Secretariat	2772 376 8888	"	Lenka.thamae @gmail.com

Attendance Register

Course:	Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan Training on Water Resources Simulation Models -Orange For Decision Makers (1 Day Training)
Presenters:	Ronnie McKenzie, Pieter van Rooyen & Manie Maré
Venue:	WRP(Pty) Ltd, Pretoria Office
Date:	25 January 2011

Present

Name	Position	Organization	Telephone	Cell phone	E-mail
LERATO BAPELA	Scientific Manager	Dept of Water Affairs (South Africa)	+2712 336 8324	+82 902 8161	bapelal@dwa.gov.za
GAVIN QUIBELL	EU PROJECT TEAM LEADER	ORASECOM SECRETARIAT	082 5834504		gavinquibell@yahoo.co.uk
Khomoatsana Tau	Deputy Principal Secretary	LESOTHO	+266 22323698		khomoatsana@yahoo.c
Othusitse Katai	Coordinator IWU	Botswana	+267 3656667	+267 72324956	okatai@gov.bw
E. LESOMA	COMMISSIONER	LESOTHO	+266-22320127		Lwsip.lesoma@yahoo.com
F. Malachamela	Director LLWSU	LESOTHO	+266 2232 7413		Malachamela@yahoo.co
R. Pule	WATER RESOURCES SPECIALIST	ORASECOM SECRETARIAT	+27126430934/8	+27722304669	rapule.pule@gmail.com
Christoph Mor	Project Manager	UNDP	— " —	083/457 9239	christophmo@undp
LENKA THAMAE	Ex. Sec.	ORASECOM Secretariat	27126430934	0723768888	lenka.thamae@gmail.com

Feedback Forms

ORASECOM

Commissioned by:

gtz
Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid
Australian Government
Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): Kalai

Course: AS ABOVE (TRAINING)

Date: 25 - 01 - 2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue ~~314 on Clark~~	1	2	3	[✓ 4]	5
Food Quality	1	2	[✓ 3]	4	5
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

Interesting, but needed more time to
fully cover the material

wrp
A Miya Group Company

Thank you for your feedback

Please return this form today or fax to +27 12 346-9956

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Federal Ministry for Economic Cooperation and Development

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Australian Government Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): Leka

Course: Simulation models - for Decision makers.

Date: 25/1/2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

- Hotel should be encouraged to include more variety for lunch.

- Overall very good workshop - may need to programme more frequent training at Decision makers level.

A Miya Group Company

Thank you for your feedback

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Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): Christoph Mor

Course:

Date:

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality	1	2	3	4	[✓ 5]
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

This was all excellent - many thanks, and congratulations!

wrp
A Miya Group Company

Thank you for your feedback

Please return this form today or fax to +27 12 346-9956

WRP_A0001_Admin_ Course Feedback Forms_Graphic 39.cdr

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Australian Government Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): ______

Course: Water Resourcces Simulation Models

Date: 25/01/2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

Too much information in a short time
1½ days would have been fine

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A Miya Group Company

Thank you for your feedback

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

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Federal Ministry for Economic Cooperation and Development

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Australian Government Aid Program

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): ____________________

Course: ____________________

Date: ____________________

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	[✓ 4]	5
• Manie Maré	1	2	3	[✓ 4]	5
• Ronnie Mckenzie	1	2	3	[✓ 4]	5
Quality of information	1	2	3	[✓ 4]	5
Usefulness	1	2	3	[✓ 4]	5
Meeting your needs	1	2	3	[✓ 4]	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

____

____

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A Miya Group Company

Thank you for your feedback

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
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UKaid from the Department for International Development
Australian Government Aid Program

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): EMMANUEL M. LESOMA

Course: ORASECOM WATER RESOURCE MODELLING TRAINING COURSE FOR DECISION MAKING

Date: 25TH JANUARY, 2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality	1	2	3	4	[✓ 5]
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

THE MODEL IS HIGHLY NEEDED, ESSENTIAL FOR PROPER MANAGEMENT OF ORANGE-SENQU RIVER BASIN IT MUST BE ENDORSED BY FOUR(4) MEMBER STATES AS UNIVERSAL TOOL FOR DECISION MAKING

wrp
A Miya Group Company

Thank you for your feedback

Please return this form today or fax to +27 12 346-9956

ORASECOM

Commissioned by:

gtz

Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid

Australian Government
Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): TAU

Course: Water R. Modeling (ORASECOM)

Date: 25/01/11

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5	limite acce at R
Food Quality	1	2	[✓ 3]	4	5	No choice
Event speakers						
• Pieter van Rooyen	1	2	3	[✓ 4]	5	
• Manie Maré	1	2	3	[✓ 4]	5	
• Ronnie Mckenzie	1	2	3	4	[✓ 5]	
Quality of information	1	2	3	[✓ 4]	5	
Usefulness	1	2	3	4	[✓ 5]	
Meeting your needs	1	2	3	[✓ 4]	5	
Overall quality of the workshop	1	2	3	[✓ 4]	5	

Any comments or suggestions:

Too much info in short period affect absorptive capacity. All participants were leaving for Lesotho immediately thereafter. This would have been held in Lesotho

A Miya Group Company

Thank you for your feedback

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Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with:
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Australian Government Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Simulation Models -Orange For Decision Makers

25 January 2011
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): GAVIN QUIBELL

Course: WATER RESOURCE MODELLING / DECISION MAKE

Date: 25/01/2011

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5
Food Quality	1	2	[✓ 3]	4	5
Event speakers					
• Pieter van Rooyen	1	2	3	[✓ 4]	5
• Manie Maré	1	2	3	[✓ 4]	5
• Ronnie Mckenzie	1	2	3	[✓ 4]	5
Quality of information	1	2	3	4	5
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

THIS HAS MADE THE TASK OF DESIGNING INSTITUTIONAL + GOVERNANCE ARRANGEMENTS EASIER. PITY NAMIBIA WAS NOT HERE!

wrp
A Miya Group Company

Thank you for your feedback

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from the Department for International Development

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): Obed Goza

Course: Yield model for decision maker

Date: 29–30 Nov 2010

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	[✓ 4]	5
• Manie Maré	1	2	3	[✓ 4]	5
• Ronnie Mckenzie	1	2	3	[✓ 4]	5
Quality of information	1	2	3	[✓ 4]	5
Usefulness	1	2	3	[✓ 4]	5
Meeting your needs	1	2	3	[✓ 4]	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

Arrange more such in future

wrp
A Miya
Group Company

Thank you for your feedback

Please return this form today or fax to +27 12 346-9956

ORANGE-SENQU RIVER COMMISSION
ORASECOM
Established 2000

Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): SETLOBOKO, THATO SETH

Course: TRAINING ON WRYM FOR DECISION MAKERS

Date: 29th AND 30th NOVEMBER 2010

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality	1	2	3	4	[✓ 5]
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	[✓ 4]	5
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

MAYBE OFFER THE COURSE TO PS's
AND DG WHO ARE MORE CLOSER TO
MINISTERS. WHO ULTIMATELY MAKE DECISION.

wrp
A Miya Group Company

Thank you for your feedback

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ORASECOM

Commissioned by:

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Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid from the Department for International Development
Australian Government
Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): ____________________

Course: WRYM & WRPM

Date: 30/11/10

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue WRP OFFICES	1	2	3	4	5
Food Quality	1	2	[✓ 3]	4	5
Event speakers					
• Pieter van Rooyen	1	2	3	[✓ 4]	5
• Manie Maré	1	2	3	[✓ 4]	5
• Ronnie Mckenzie	1	2	3	[✓ 4]	5
Quality of information	1	2	3	[✓ 4]	5
Usefulness	1	2	3	[✓ 4]	5
Meeting your needs	1	2	3	[✓ 4]	5
Overall quality of the workshop	1	2	3	[✓ 4]	5

Any comments or suggestions:

MORE OF THESE TRAINING COURSES
including FOR MORE SENIOR DECISION
MAKERS ~~AR~~ WOULD BE GOOD.

wrp
A Miya Group Company

Thank you for your feedback

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gtz

Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid
from the Department for International Development

Australian Government
Aid Program

Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): TENDAYI MAROMBE

Course: WRYM - ORANGE - FOR DECISION MAKERS

Date: 29-30 November 2010

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

MORE TIME ON ECONOMIC CONSIDERATIONS (SOCIO-ECONOMIC) decisions are done in integrated fashion.

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Thank you for your feedback

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): __________

Course: WATER RESOURCES YIELD MODEL – ORANGE FOR DECISION MAKERS

Date: 30/11/10

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality	1	2	3	4	[✓ 5]
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	[✓ 4]	[✓ 5]
Overall quality of the workshop	1	2	3	[✓ 4]	[✓ 5]

Any comments or suggestions:

wrp
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Thank you for your feedback

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ORASECOM
ORANGE-SENQU RIVER COMMISSION

Commissioned by:

gtz
Federal Ministry for Economic Cooperation and Development

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): K L RAmoseu

Course:

Date: 29 - 30 November

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	[✓ 4]	5
Food Quality	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	[✓ 4]	5
• Manie Maré	1	2	3	[✓ 4]	5
• Ronnie Mckenzie	1	2	3	[✓ 4]	5
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

wrp
A Miya Group Company

Thank you for your feedback

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Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

Training on Water Resources Yield Model -Orange For Decision Makers

29 - 30 November 2010
Pretoria

Commissioned by:
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Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program

Feedback Form

Thank you for attending the workshop. Your feedback is important to us and will assist in the planning of future events. Please take the time to complete this form.

Name (optional): Lenka Thamae

Course: WR Yield Model for Decision Makers

Date: 2010/11/30

Rate the following on a scale of 1 (poor) to 5 (excellent):

Venue	1	2	3	4	[✓ 5]
Food Quality Could use Braai on one of the days.	1	2	3	[✓ 4]	5
Event speakers					
• Pieter van Rooyen	1	2	3	4	[✓ 5]
• Manie Maré	1	2	3	4	[✓ 5]
• Ronnie Mckenzie	1	2	3	4	[✓ 5]
Quality of information	1	2	3	4	[✓ 5]
Usefulness	1	2	3	4	[✓ 5]
Meeting your needs	1	2	3	4	[✓ 5]
Overall quality of the workshop	1	2	3	4	[✓ 5]

Any comments or suggestions:

wrp
A Miya Group Company

Thank you for your feedback

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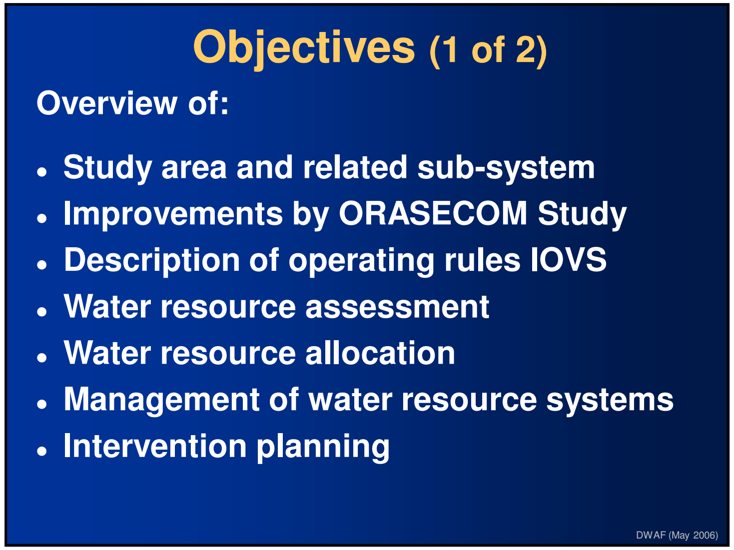
APPENDIX B2:

Course Presentations

Training and Technology Transfer Workshop

29 & 30 November 2010

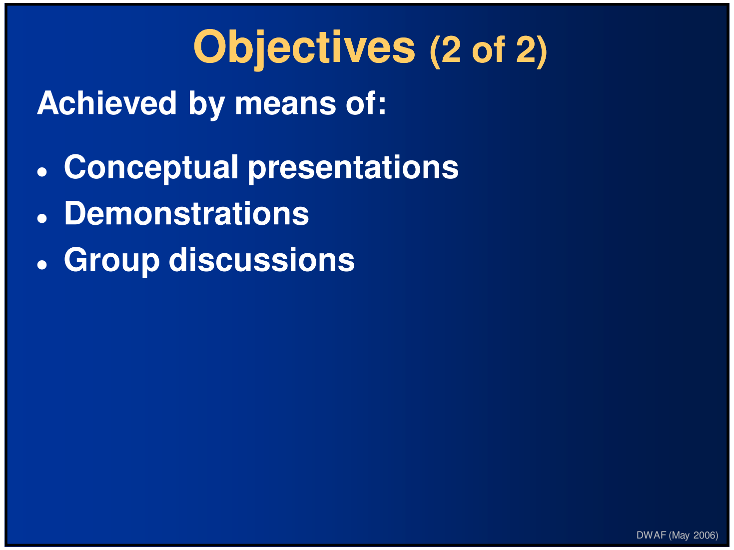
Welcome and introduction



Objectives (1 of 2)

Overview of:

- Study area and related sub-system
- Improvements by ORASECOM Study
- Description of operating rules IOVS
- Water resource assessment
- Water resource allocation
- Management of water resource systems
- Intervention planning



Objectives (2 of 2)

Achieved by means of:

- Conceptual presentations
- Demonstrations
- Group discussions

10:00	**Welcome and introduction**
	Module 1: Introduction to IOVS
10:45	1. Description of study area & related sub-systems
11:45	2. Improvement s by ORASECOM Study
12:00	3. Description of Operating Rules
13:00	4 Group discussion
13:15	**> Lunch break**
	Module 2: Overview of water resource management
14:00	1. Overview of water resource management
	Module 3: Water resource assessment
14:30	1. Modelling water resource systems
14:55	2. Basic modelling principles
15:20	**> Tea break**
15:35	3. Definition of Terms
15:50	4. Stochastic Yield Analysis
16:20	5. Group discussion
16:35	**> Close**

	Module 4:
08:45	1. Water user criteria
08:55	2. Short-term yield reliability
09:35	3. Curtailing water users
10:05	**> Tea break**
10:20	4. Assessing availability for licensing
10:40	5. Group discussion
	Module 5: Management of water resource systems
10:55	1. Defining system operating rules
11:40	2. Practical considerations
12:10	3. Group discussion
12:25	**> Lunch break**
	Module 6: Intervention planning
13:10	1. Introduction
13:25	2. Water requirement scenarios
13:45	3. Undertaking detailed phasing analyses
14:15	**> Tea break**
14:30	4. Reconciliation Strategies
15:15	5. Group discussion
15:30	**Close**

Presenters

Ronnie McKenzie (WRP)

Manie Maré (WRP)

Pieter van Rooyen (WRP)

Training and Technology Transfer Workshop

29 & 30 November 2010

End of module

Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan &
Vaal River System Annual Operating Analysis 2010-2012

Module 5: Defining system operating rules

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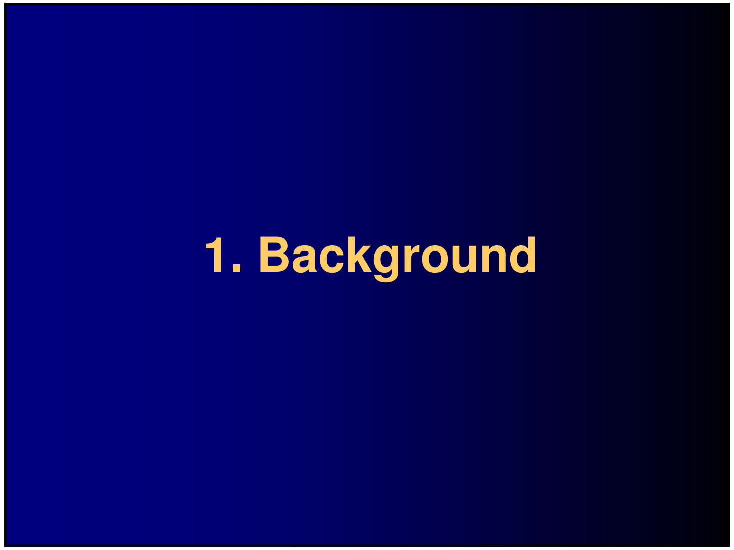
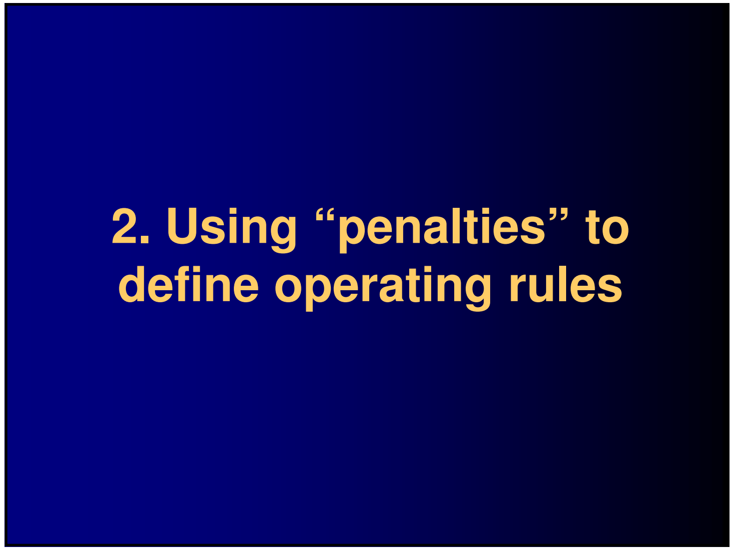
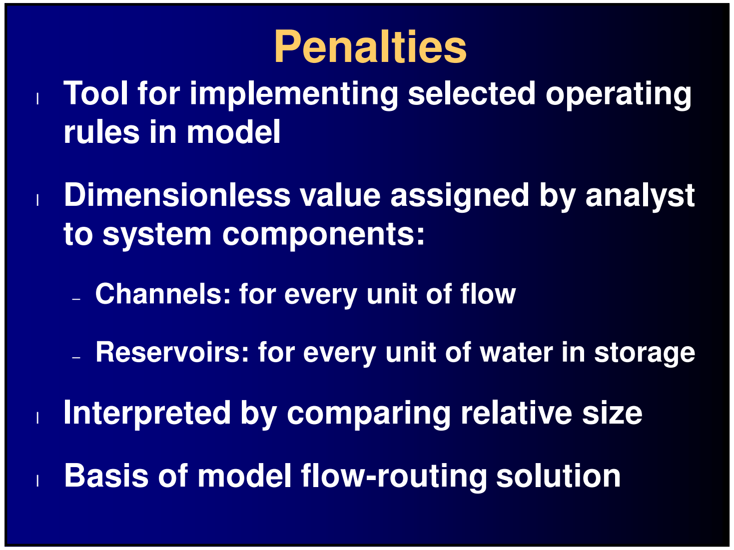
UKaid from the Department for International Development
Australian Government Aid Program
wrp
water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA



1. Background



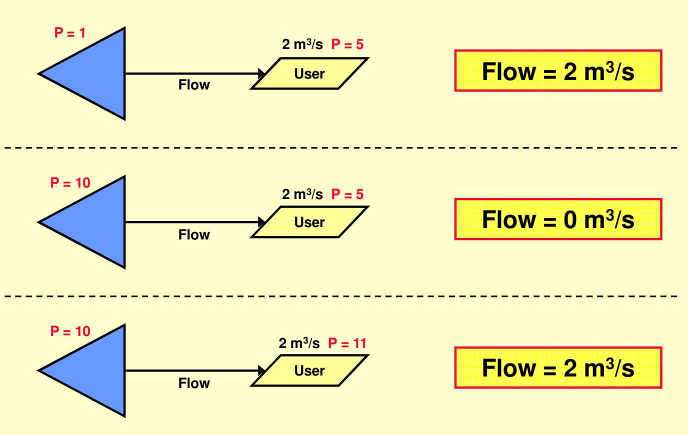
2. Using "penalties" to define operating rules



Penalties

- Tool for implementing selected operating rules in model
- Dimensionless value assigned by analyst to system components:
  - Channels: for every unit of flow
  - Reservoirs: for every unit of water in storage
- Interpreted by comparing relative size
- Basis of model flow-routing solution

Penalty selection (1 of 3)



P = 1
Flow
2 m^3/s P = 5
User

Flow = 2 m^3/s

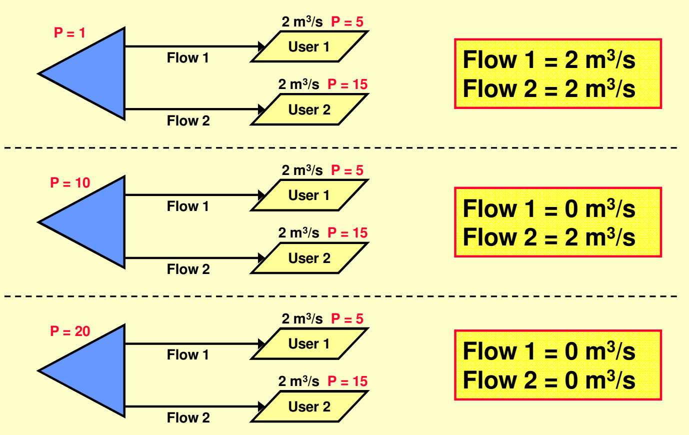
P = 10
Flow
2 m^3/s P = 5
User

Flow = 0 m^3/s

P = 10
Flow
2 m^3/s P = 11
User

Flow = 2 m^3/s

Penalty selection (2 of 3)



P = 1
Flow 1
2 m^3/s P = 5
User 1
Flow 2
2 m^3/s P = 15
User 2

Flow 1 = 2 m^3/s
Flow 2 = 2 m^3/s

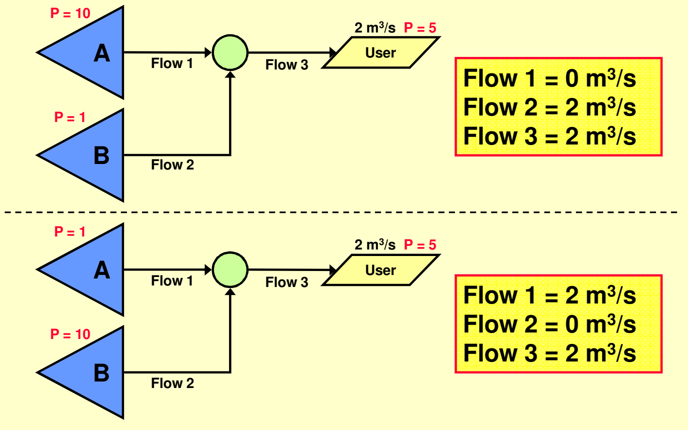
P = 10
Flow 1
2 m^3/s P = 5
User 1
Flow 2
2 m^3/s P = 15
User 2

Flow 1 = 0 m^3/s
Flow 2 = 2 m^3/s

P = 20
Flow 1
2 m^3/s P = 5
User 1
Flow 2
2 m^3/s P = 15
User 2

Flow 1 = 0 m^3/s
Flow 2 = 0 m^3/s

Penalty selection (3 of 3)



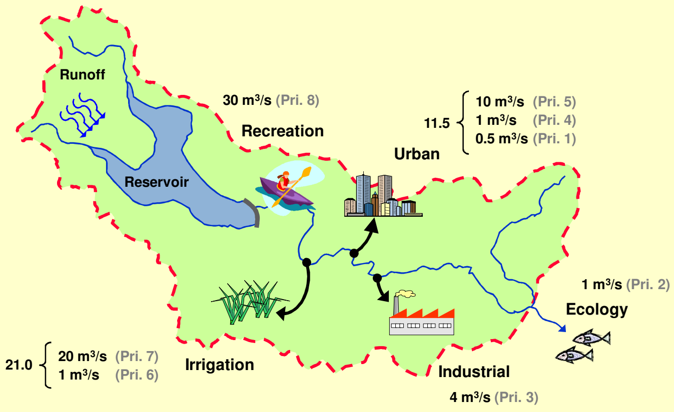
P = 10
A
Flow 1
Flow 3
2 m^3/s P = 5
User
P = 1
B
Flow 2

Flow 1 = 0 m^3/s
Flow 2 = 2 m^3/s
Flow 3 = 2 m^3/s

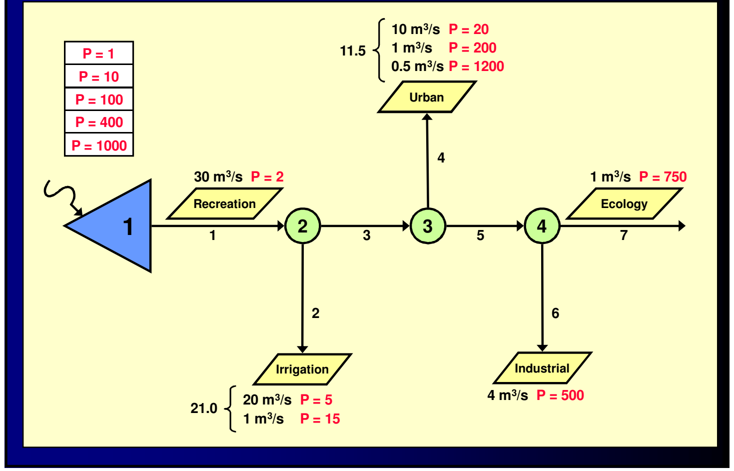
P = 1
A
Flow 1
Flow 3
2 m^3/s P = 5
User
P = 10
B
Flow 2

Flow 1 = 2 m^3/s
Flow 2 = 0 m^3/s
Flow 3 = 2 m^3/s

Water resource system



Network model with penalties



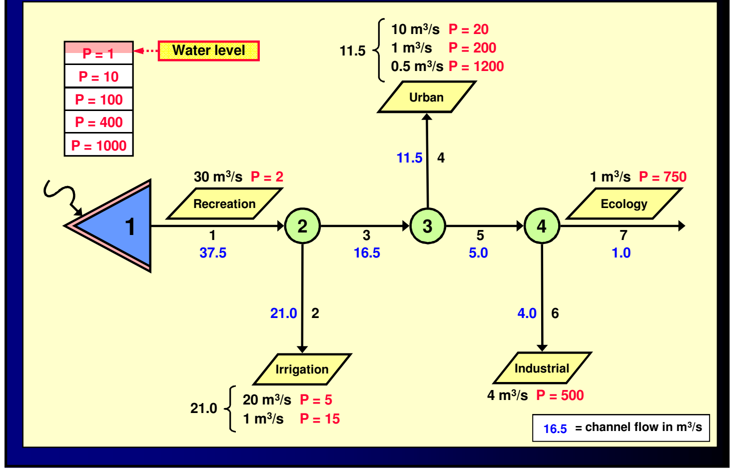
P = 1
P = 10
P = 100
P = 400
P = 1000

11.5 { 10 m^3/s P = 20
1 m^3/s P = 200
0.5 m^3/s P = 1200 }

Urban
4
30 m^3/s P = 2
Recreation
1 m^3/s P = 750
Ecology
1
2
3
4
1
3
5
7
2
6
Irrigation
Industrial
4 m^3/s P = 500

21.0 { 20 m^3/s P = 5
1 m^3/s P = 15 }

Case 1: Reservoir in Zone 1



P = 1
P = 10
P = 100
P = 400
P = 1000
Water level

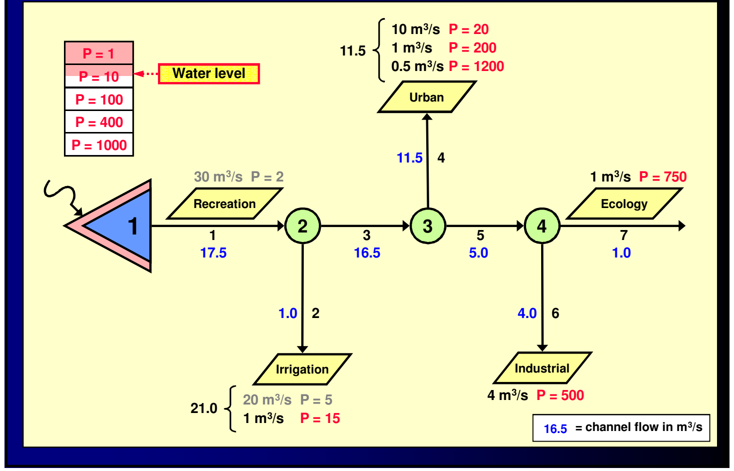
11.5 { 10 m^3/s P = 20
1 m^3/s P = 200
0.5 m^3/s P = 1200 }

Urban
11.5 4
30 m^3/s P = 2
Recreation
1 m^3/s P = 750
Ecology
1
2
3
4
1 37.5
3 16.5
5 5.0
7 1.0
21.0 2
4.0 6
Irrigation
Industrial
4 m^3/s P = 500

21.0 { 20 m^3/s P = 5
1 m^3/s P = 15 }

16.5 = channel flow in m^3/s

Case 2: Reservoir in Zone 10



P = 1
P = 10
P = 100
P = 400
P = 1000
Water level

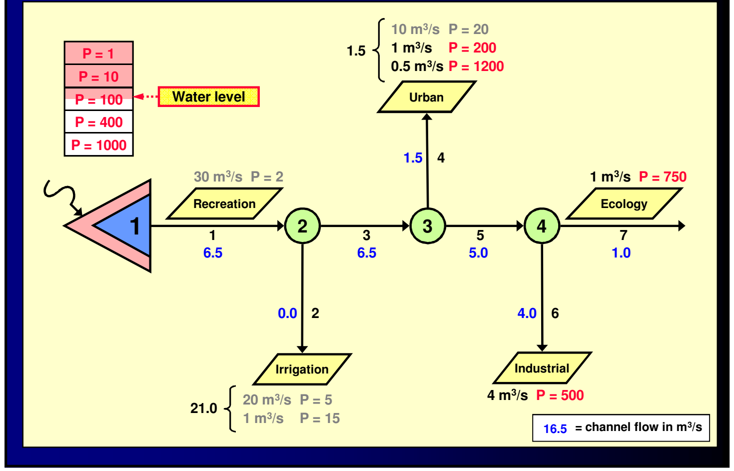
11.5 { 10 m^3/s P = 20
1 m^3/s P = 200
0.5 m^3/s P = 1200 }

Urban
11.5 4
30 m^3/s P = 2
Recreation
1 m^3/s P = 750
Ecology
1
2
3
4
1 17.5
3 16.5
5 5.0
7 1.0
1.0 2
4.0 6
Irrigation
Industrial
4 m^3/s P = 500

21.0 { 20 m^3/s P = 5
1 m^3/s P = 15 }

16.5 = channel flow in m^3/s

Case 3: Reservoir in Zone 100



P = 1
P = 10
P = 100
P = 400
P = 1000
Water level

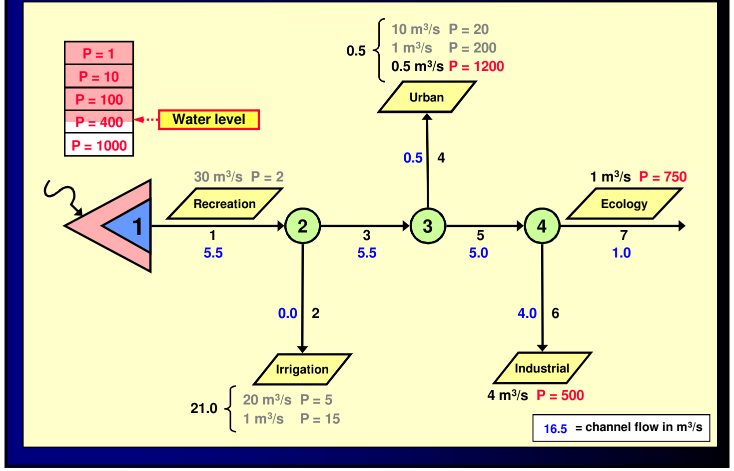
1.5 { 10 m^3/s P = 20
1 m^3/s P = 200
0.5 m^3/s P = 1200 }

Urban
1.5 4
30 m^3/s P = 2
Recreation
1 m^3/s P = 750
Ecology
1
2
3
4
1 6.5
3 6.5
5 5.0
7 1.0
0.0 2
4.0 6
Irrigation
Industrial
4 m^3/s P = 500

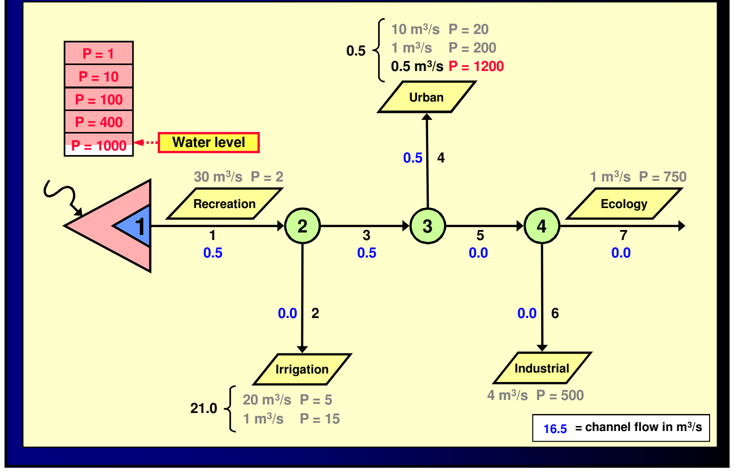
21.0 { 20 m^3/s P = 5
1 m^3/s P = 15 }

16.5 = channel flow in m^3/s

Case 4: Reservoir in Zone 400



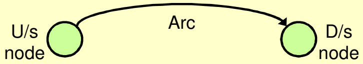
Case 5: Reservoir in Zone 1000



1-arc channel

Configuration

Flow = 0 to X;
Penalty = P



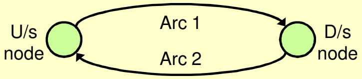
Standard notation

0 to X	P

2-arc channel (1 of 2)

Configuration

Flow = X to Y (usually Y = X);
Penalty = 0 (usually)

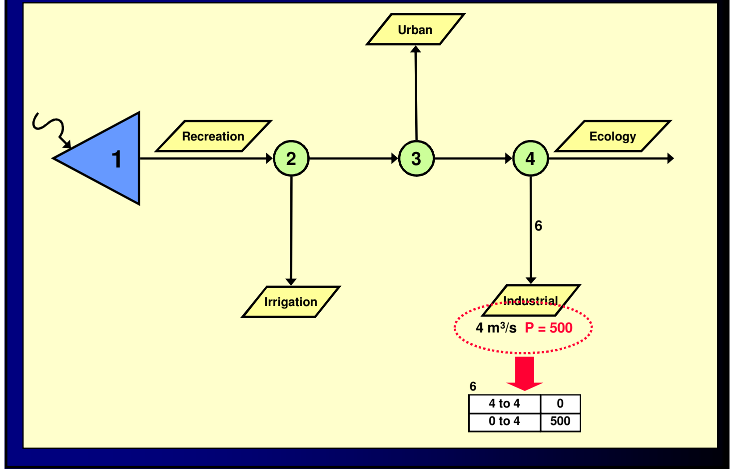


Flow = 0 to X;
Penalty = P

Standard notation

X to Y	0
0 to X	P

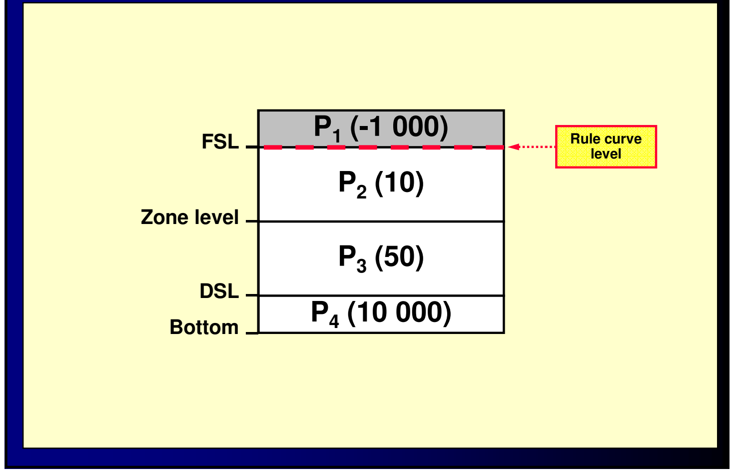
2-arc channel (2 of 2)



Modelling reservoir penalties

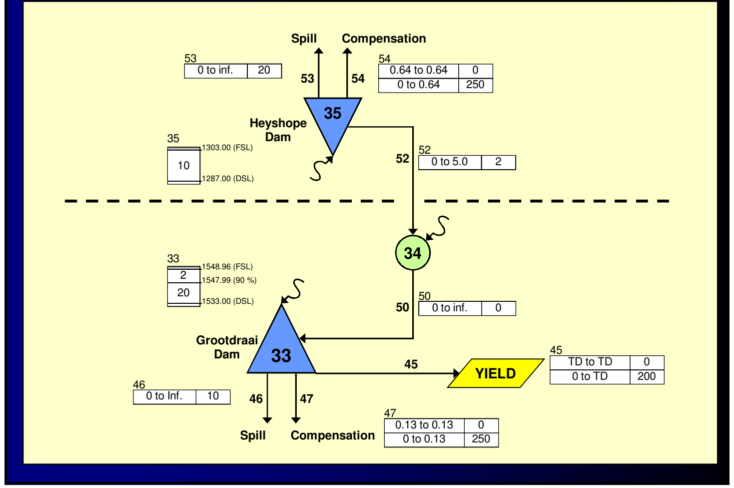
- Defined in terms of “storage zones” and “rule curve level”
- For each zone, 2 data values defined:
  - Elevation of lower zone boundary
  - Zone penalty
- Penalty relation to rule curve:
  - Above: “dis-benefit” of water in storage
  - Below: “benefit” of water in storage

Standard reservoir notation



Example: Heyshope-Grootdraai transfer (1 of 2)

Example: Heyshope-Grootdraai transfer (2 of 2)



Support to Phase 2 of the ORASECOM Basin-wide
Integrated Water Resources Management Plan &
Vaal River System Annual Operating Analysis 2010-2012

End

Commissioned by:
In Delegated Cooperation with:
gtz
Federal Ministry for Economic Cooperation and Development
UKaid from the Department for International Development
Australian Government Aid Program
wrp
water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

ORASECOM Water Resources Training MODULE 1a

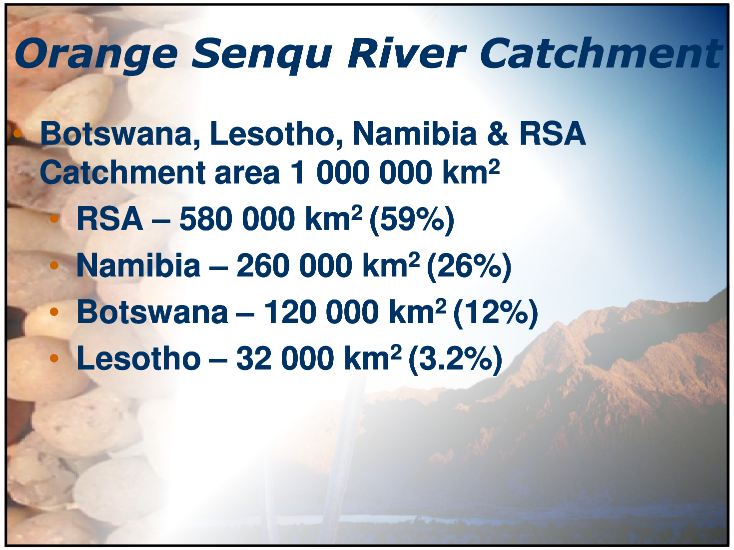
29 -30 November 2010

VAAL & ORANGE/SENQU RIVER BASIN

STUDY AREA DESCRIPTION

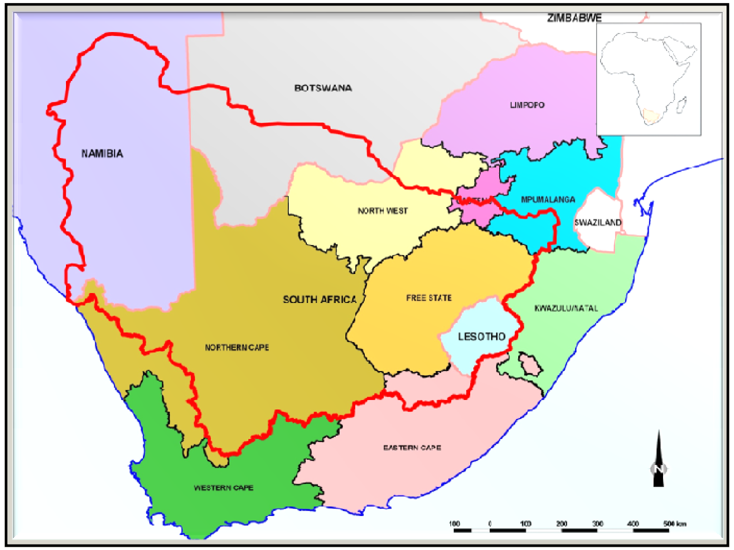
-

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with: UKaid from the Department for International Development Australian Government Aid Program
wrp A Miya Group Company



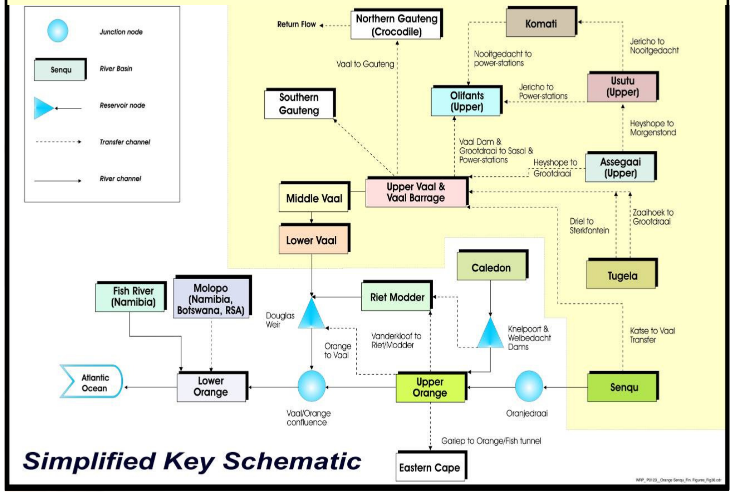
Orange Senqu River Catchment

- Botswana, Lesotho, Namibia & RSA Catchment area 1 000 000 km^2
  - RSA – 580 000 km^2 (59%)
  - Namibia – 260 000 km^2 (26%)
  - Botswana – 120 000 km^2 (12%)
  - Lesotho – 32 000 km^2 (3.2%)



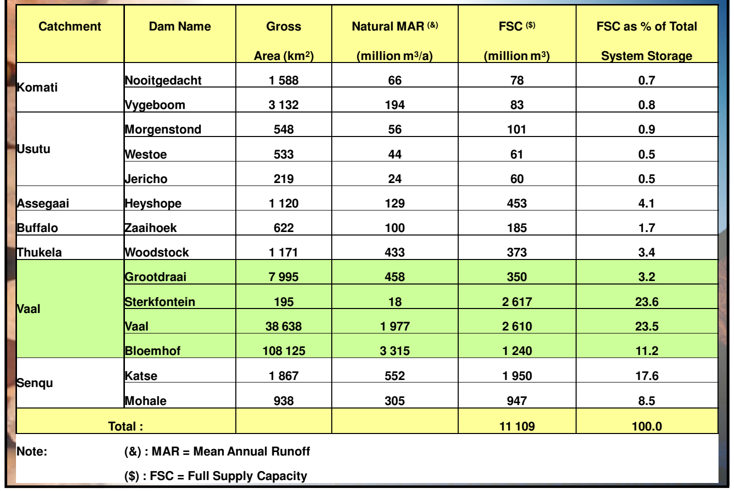
INTEGRATED ORANGE – VAAL SYSTEM NETWORK

Integrated Orange /Vaal system



Simplified Key Schematic

IVRS Major Reservoirs

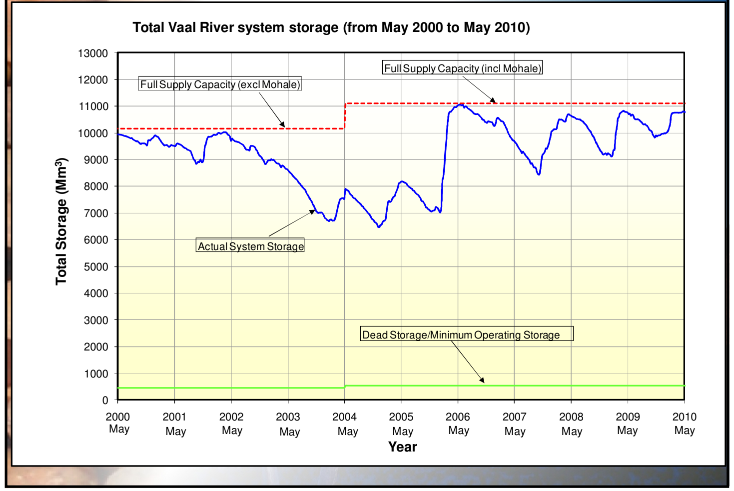


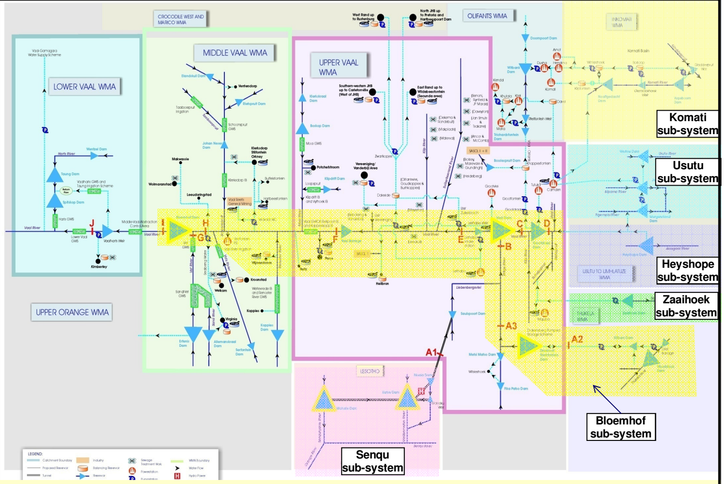
Catchment	Dam Name	Gross Area (km²)	Natural MAR (&) (million m³/a)	FSC ($) (million m³)	FSC as % of Total System Storage
Komati	Nooitgedacht	1 588	66	78	0.7
	Vygeboom	3 132	194	83	0.8
Usutu	Morgenstond	548	56	101	0.9
	Westoe	533	44	61	0.5
	Jericho	219	24	60	0.5
Assegaai	Heyshope	1 120	129	453	4.1
Buffalo	Zaaihoek	622	100	185	1.7
Thukela	Woodstock	1 171	433	373	3.4
Vaal	Grootdraai	7 995	458	350	3.2
	Sterkfontein	195	18	2 617	23.6
	Vaal	38 638	1 977	2 610	23.5
	Bloemhof	108 125	3 315	1 240	11.2
Senqu	Katse	1 867	552	1 950	17.6
	Mohale	938	305	947	8.5
Total :				11 109	100.0

Note: (&) : MAR = Mean Annual Runoff

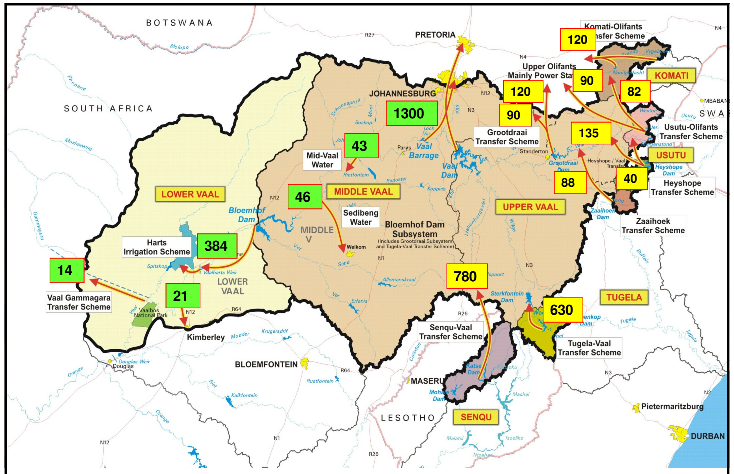
($) : FSC = Full Supply Capacity

Total System Storage Trajectory



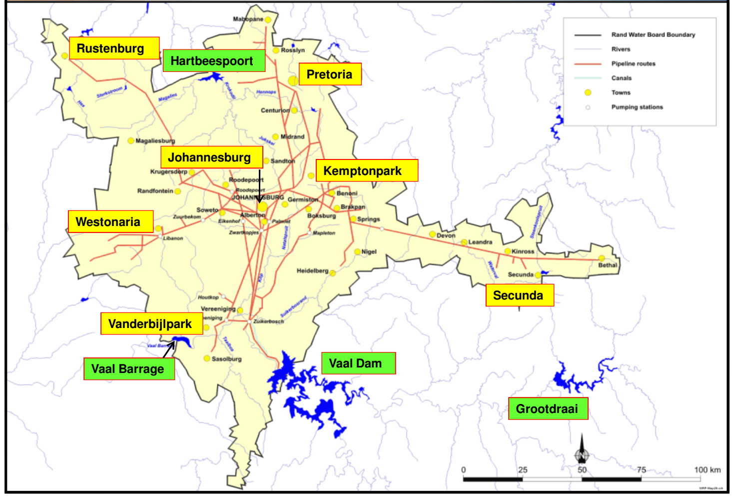


Integrated Vaal system



Integrated VaaL System Transfers 2007/08 (million m³/a)

Rand Water Supply Area



IVRS Demand Projection

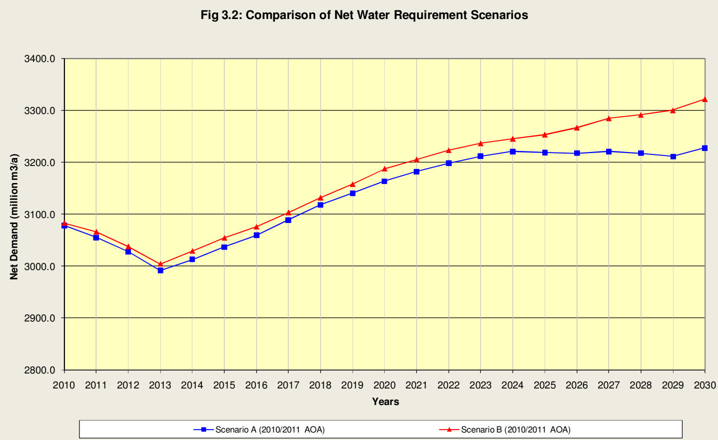
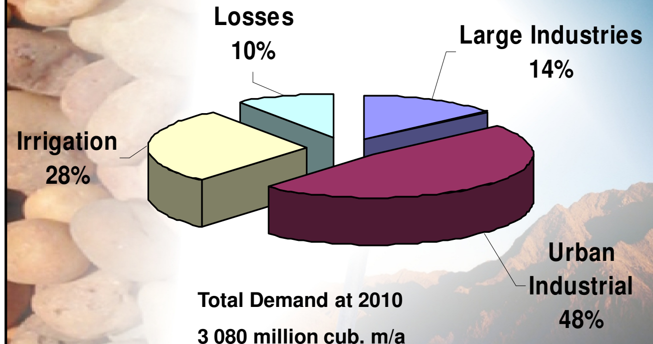


Fig 3.2: Comparison of Net Water Requirement Scenarios

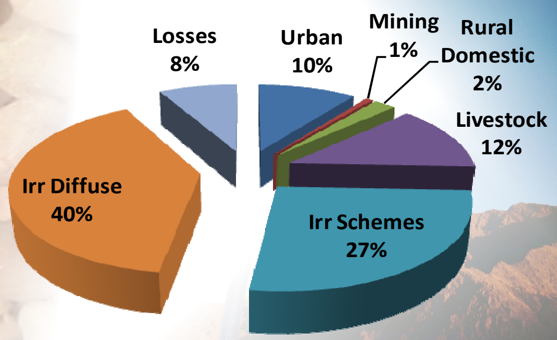
IVRS Demand Distribution



Total Demand at 2010

3 080 million cub. m/a

Vaal Small sub-systems Demand distribution

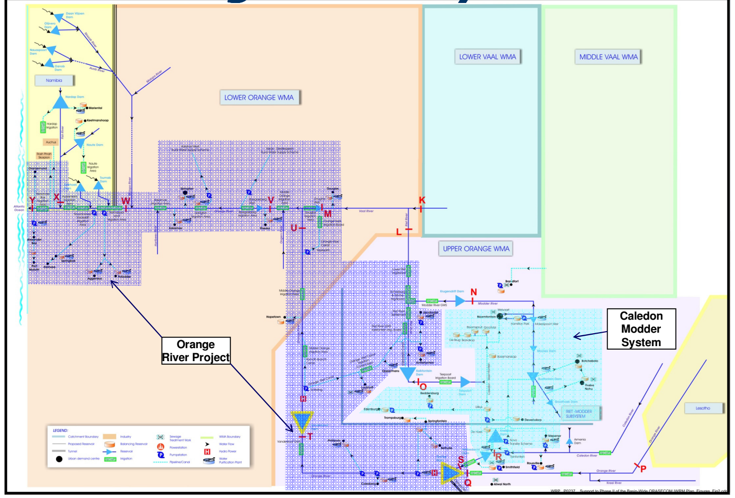


Vaal Small Sub-systems
2010 demand 880 million m^3/a

Vaal River Confluence and Vaal Douglas

ORANGE RIVER SYSTEM NETWORK

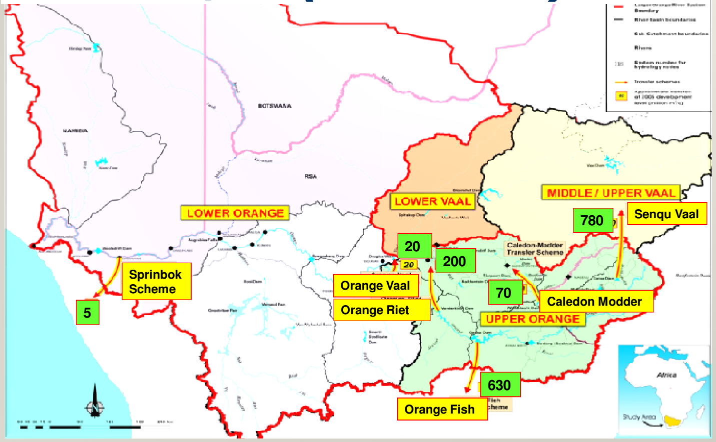
Orange River System



Orange River System

- Orange River System sub-divided into 3 main sub-systems and several small sub-systems:
  - 1 Lesotho Highlands (Katse & Mohale)
  - 2 Caledon Modder (Welbedacht, Knellpoort, Rustfontein, Mockes & Groothoek dams)
  - 3 Orange River Project (Gariep & Vanderkloof dams)

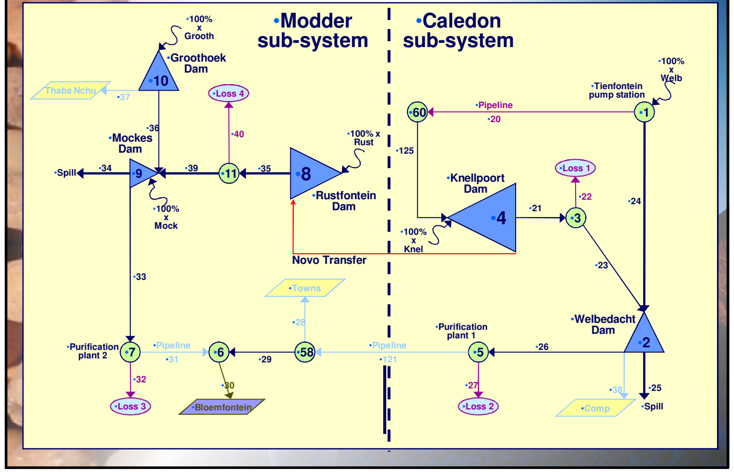
Orange System Transfers 2005/06 (million m³/a)



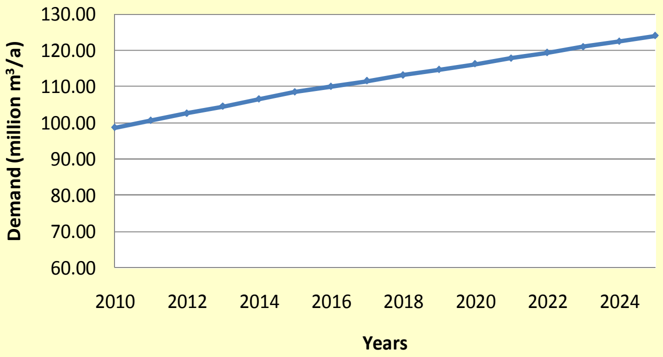
Lesotho Highlands Water Project

Phase 2 (New) of the Lesotho Highlands Water Project

Caledon Modder sub-system



BloemWater Demand Projection



Orange River Project (1 of 4)

Orange River Project (ORP):

Total system yield ± 3 300 mcm/a

Current surplus ± 100 mcm/a

- + Gariep Dam storage cap 5 340 mcm
- + Vanderkloof Dam storage cap 3 190 mcm
  - Combined storage 8 530 mcm

Orange River Project (2 of 4)

- Main demands upstream of Vaal confluence
  - Hydro-power generation at both dams 2200 mcm/a Gariep – 2100 mcm/a Vdklf
  - Orange Fish Transfer Scheme 650 mcm/a
  - Vanderkloof Canals Scheme 330 mcm/a
  - Orange Vaal Transfer Scheme 140 mcm/a
  - Abstractions directly from river:
    - Irr & Towns

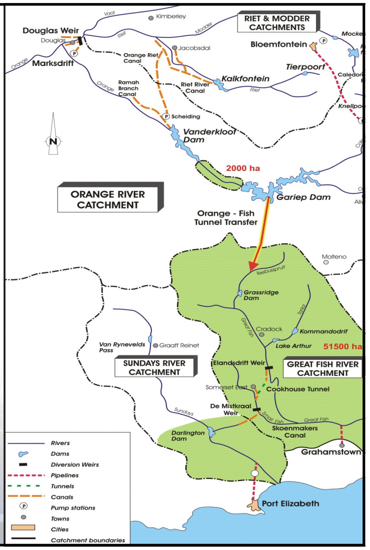
Orange River Project (3 of 4)

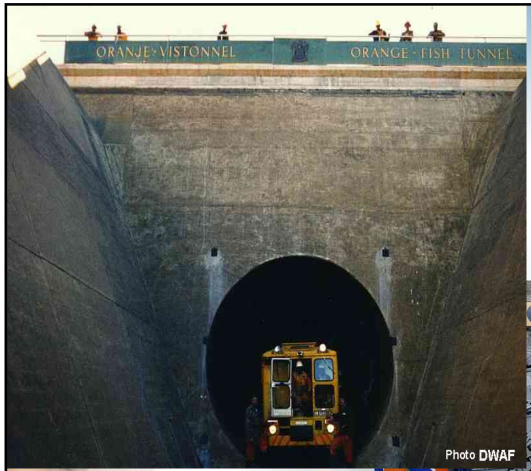
- Main Rural/Urban demands Lower Orange
  - Karos-Geelkoppen Rural WS Scheme
  - Kalahari-West Rural WS Scheme
  - Pelladrift WS Scheme
  - Springbok Regional WS Scheme
  - Urban, Industrial & Mining – Prieska, Upington, Alexander Bay, Oranjemund, Rosh Pinah, Noord Oewer, etc.

Orange River Project (4 of 4)

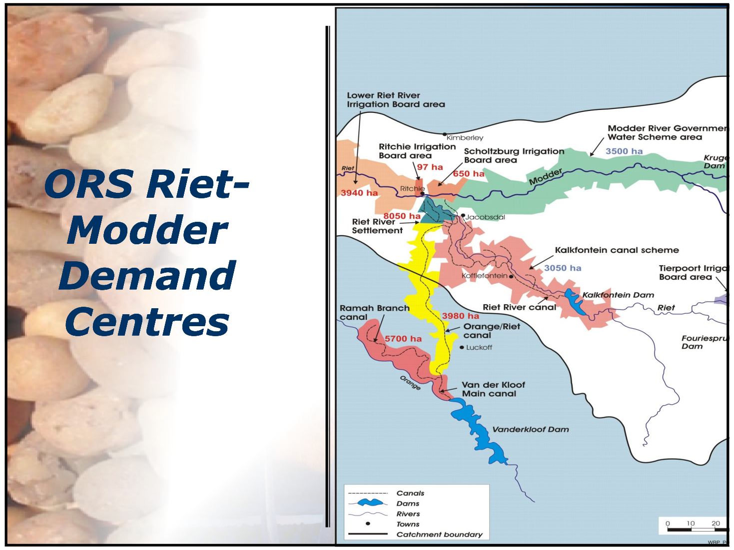
- Main irrigation Schemes Lower Orange
  - Boegoeberg Scheme
  - Upington Scheme
  - Kakamas Scheme
  - Onseepkans
  - Vioolsdrift
  - Noordoewer & Aussenkehr
  - Irrigation abstractions directly from river

ORS Eastern Cape Demand Centres

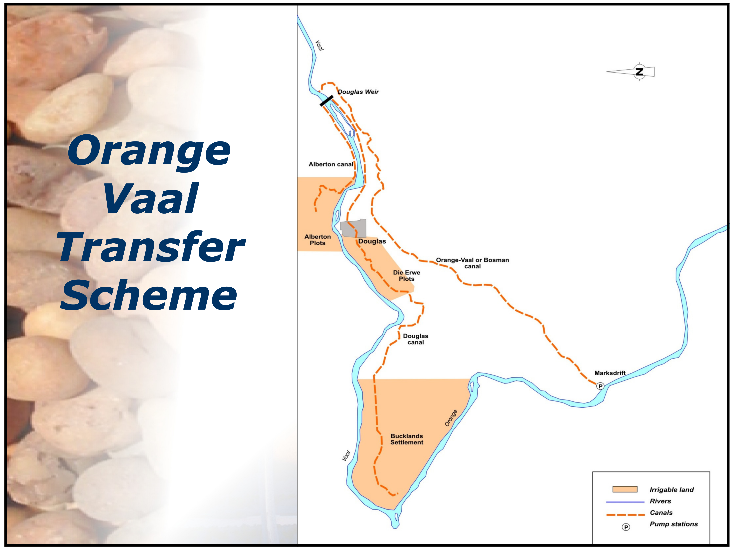




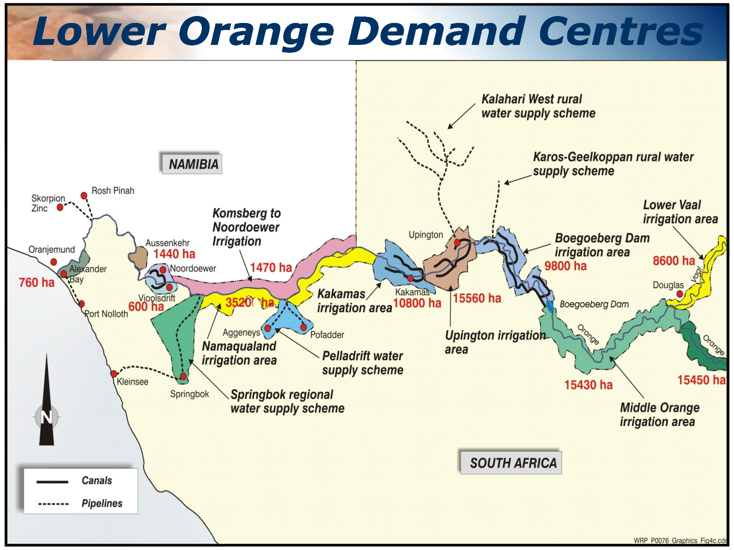
Orange Fish Tunnel



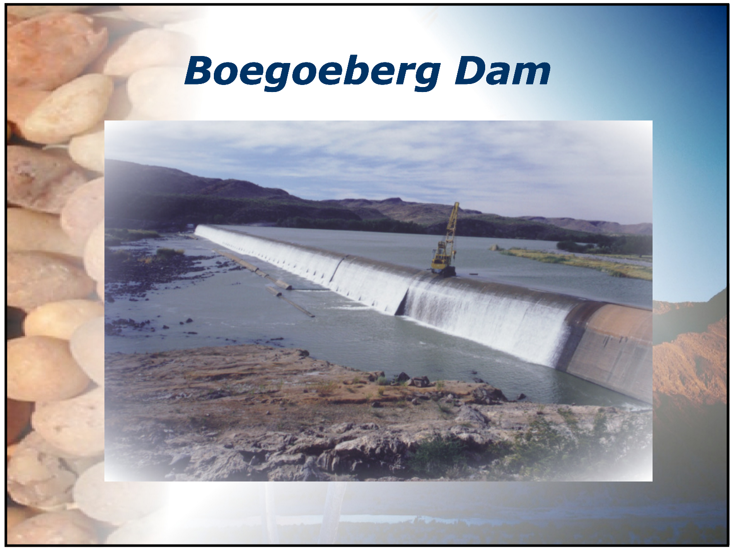
ORS Riet-Modder Demand Centres



Orange Vaal Transfer Scheme

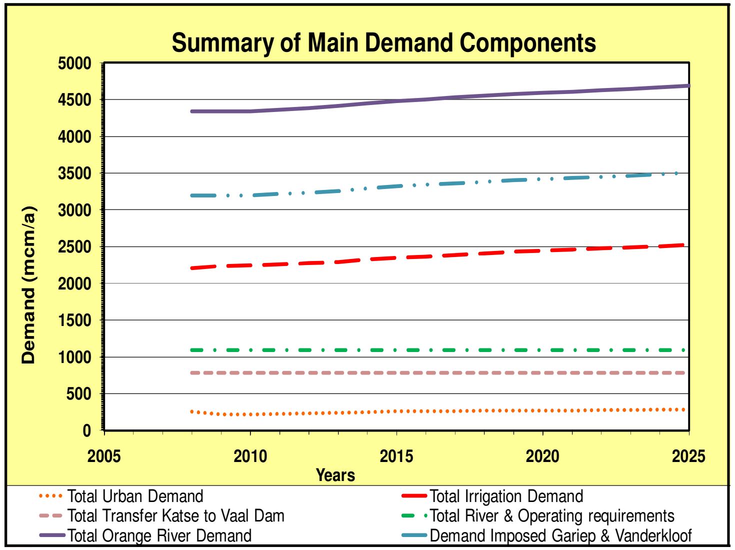


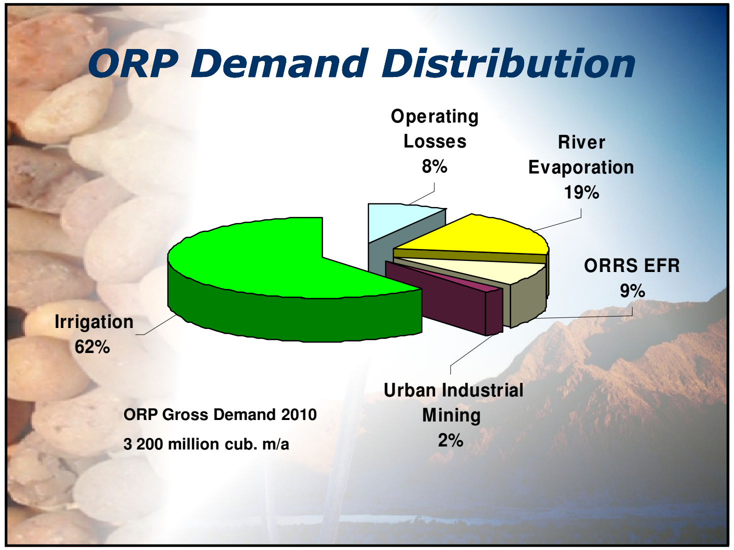
Lower Orange Demand Centres



Boegoeberg Dam

Augrabies Falls



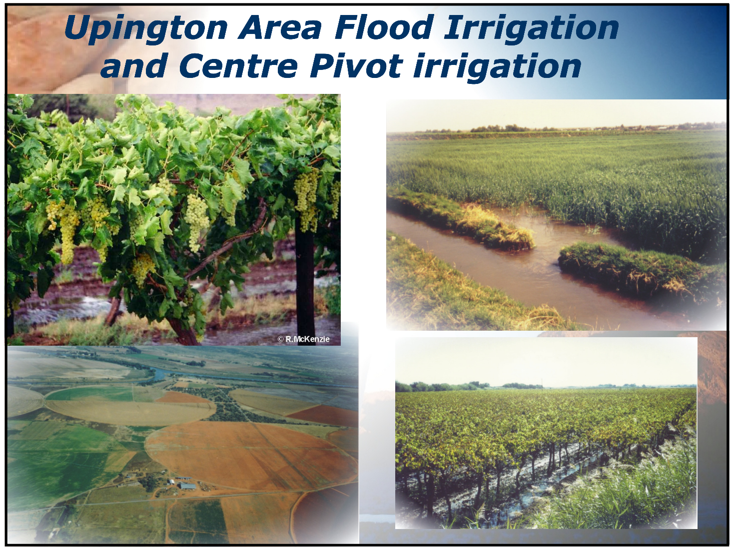


ORP Demand Distribution

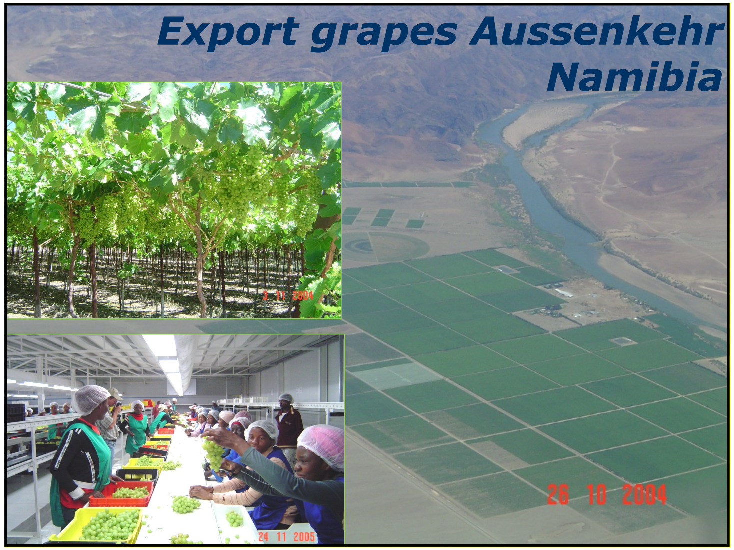
ORP Gross Demand 2010

3 200 million cub. m/a

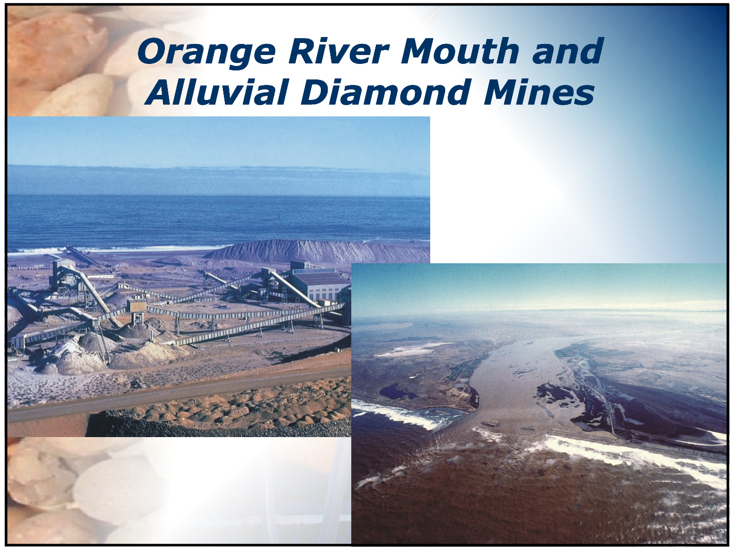
Richtersveld Riparian Vegetation



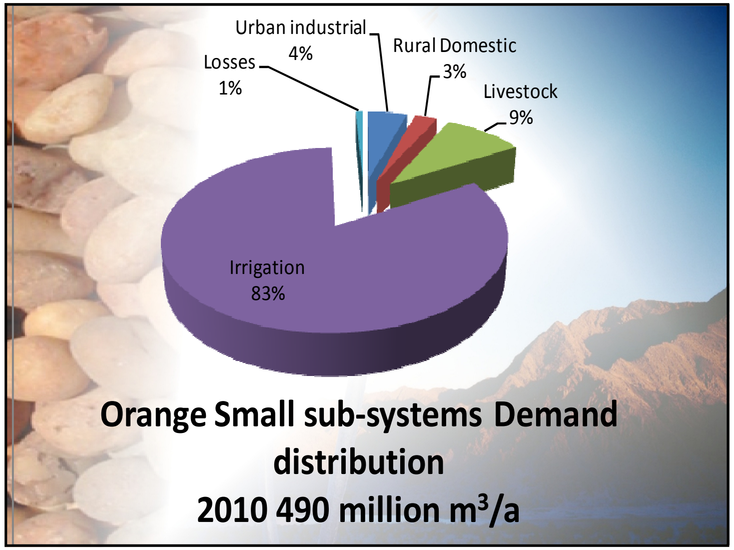
Upington Area Flood Irrigation and Centre Pivot irrigation



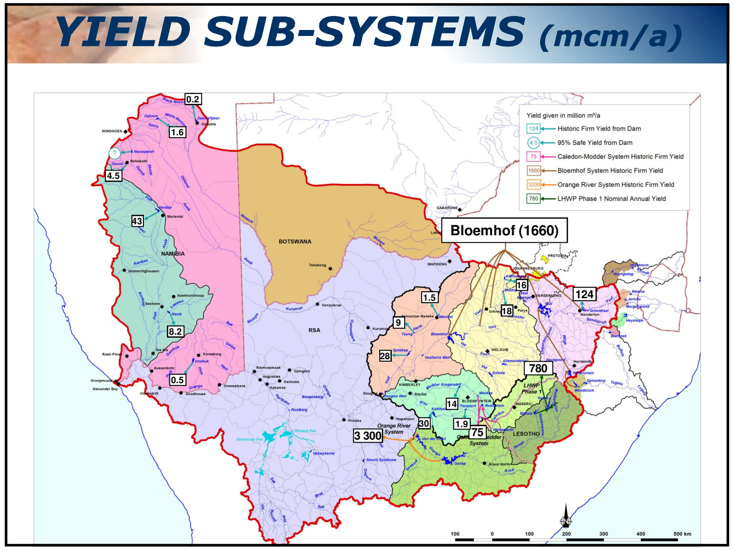
Export grapes Aussenkehr Namibia



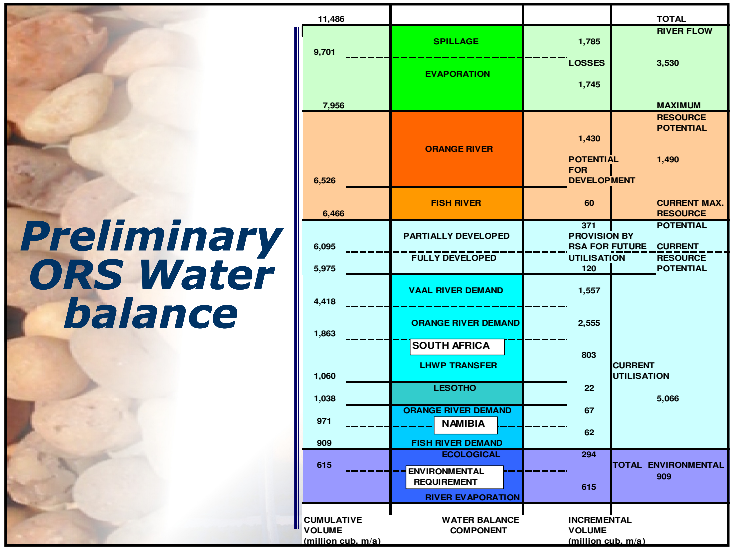
Orange River Mouth and Alluvial Diamond Mines



Orange Small sub-systems Demand distribution
2010 490 million m^3/a



YIELD SUB-SYSTEMS (mcm/a)



Preliminary ORS Water balance

Thank You

ORASECOM
Water Resources Training
MODULE 1b

29 -30 November 2010

ORANGE/SENQU RIVER BASIN
IMPROVEMENTS ADDED

Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program
wrp A Miya Group Company

Improvements (1 of 4)

- Extending of existing hydrology to 2004/05
- Adding hydrology for following sub-catchments:
  - Namibia – White Nossob, Black Nossob, Olifants, Aub, main Nossob & small tributaries along Lower Orange
  - Botswana/RSA – Lower Nossob and Molopo
  - RSA – Kuruman, Ongers, Hartbees /Sak & small tributaries along Lower Orange

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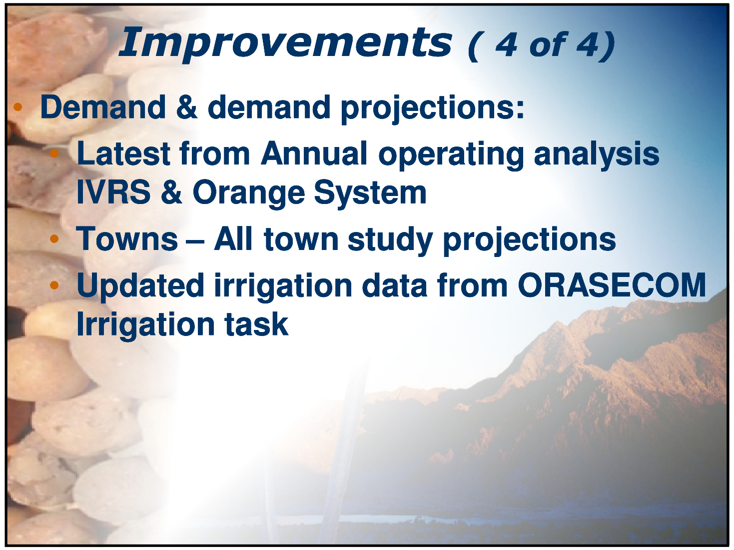
Improvements (2 of 4)

- Re-calibration of hydrology – Caledon, Upper Orange, Fish River Namibia
- Adding hydrology for following sub-catchments:
- Inclusion of Lesotho Lowlands Identified Schemes – Hlotse, Hololo, Makhaleng & Metolong Dam
- Updated hydrology for Usutu & Komati sub-systems – Obtained from two separate studies

---

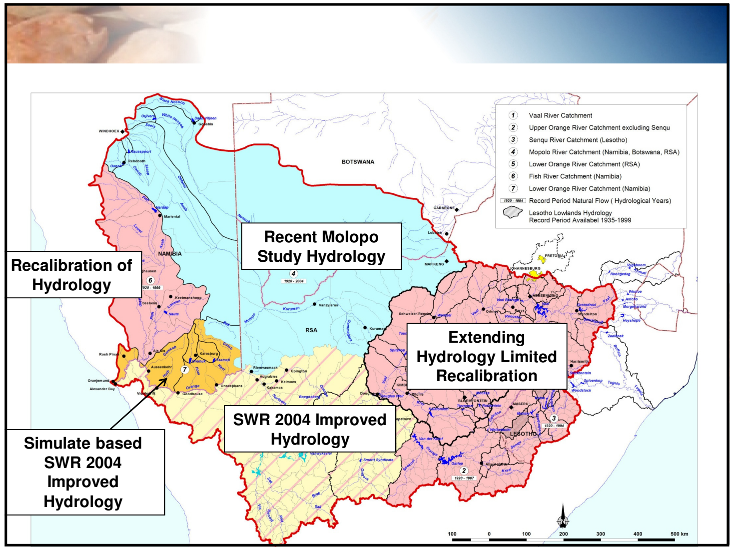
Improvements (3 of 4)

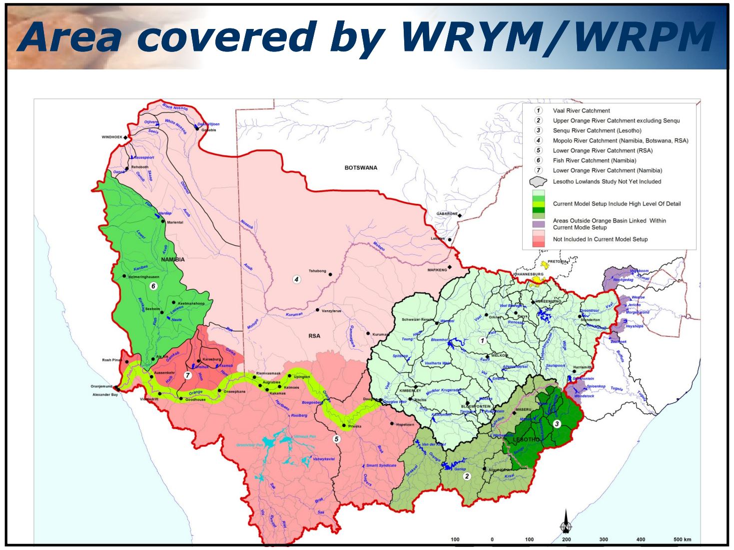
- Molopo sub-system details:
  - RSA – Lotlamoreng, Modimolo & Disaneng dams also Kuruman, Molopo eye & others
  - Namibia – Otjivero, Daan Viljoen, Tilda Viljoen, Nauaspoort & Oanob dams
- Ongers sub-system – Smartt Syndicate Dam
- Sak Hartbees sub-system – Rooiberg, Modderpoort & Vanwyksvlei dams
- Lower Orange Namibia - Dreihuk



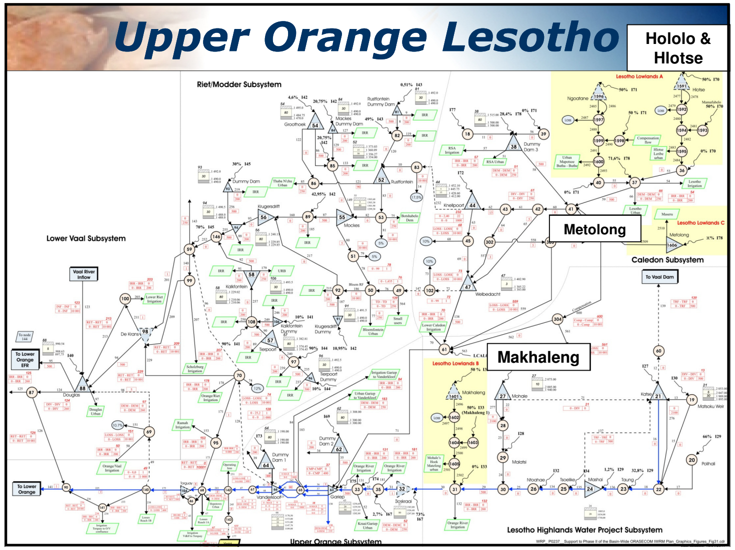
Improvements (4 of 4)

- Demand & demand projections:
  - Latest from Annual operating analysis IVRS & Orange System
  - Towns – All town study projections
  - Updated irrigation data from ORASECOM Irrigation task



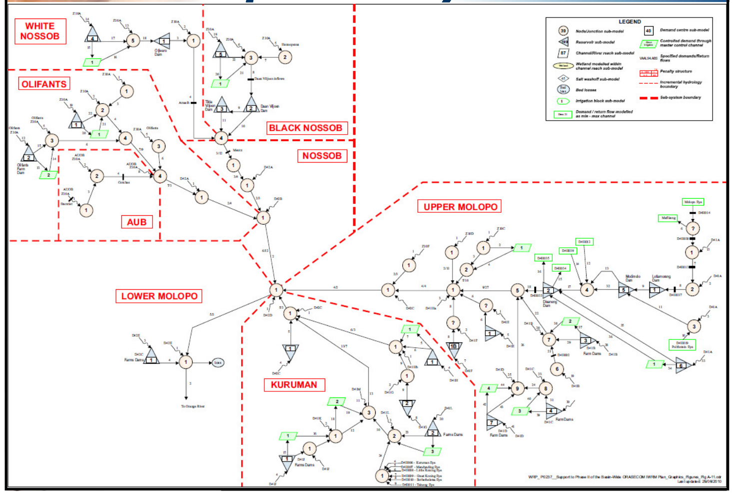


Area covered by WRYM/WRPM



Upper Orange Lesotho

Molopo sub-system



Thank You

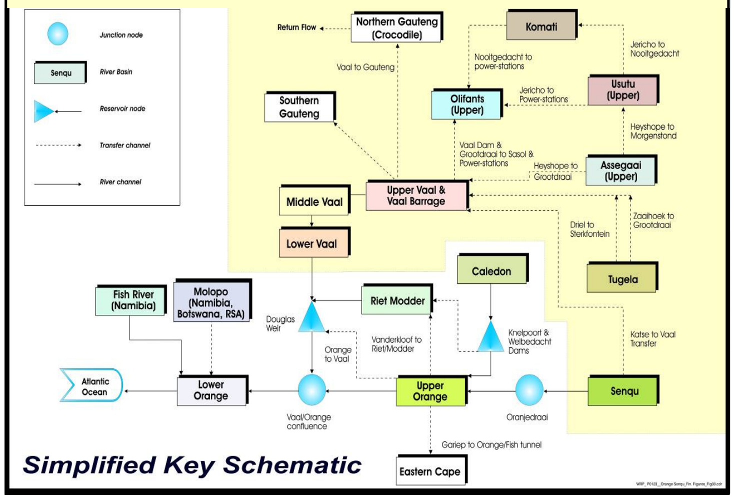
ORASECOM
Water Resources Training
MODULE 1c

29 -30 November 2010

VAAL & ORANGE/SENQU RIVER BASIN
OPERATING RULES

Commissioned by: gtz Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program
wrp A Miya Group Company

Integrated Orange /Vaal system

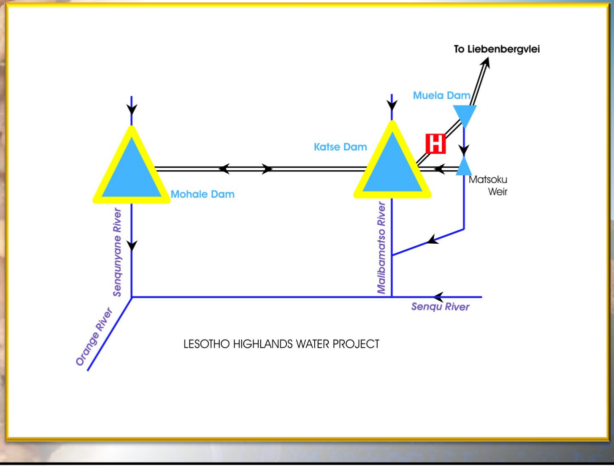


Simplified Key Schematic

Orange River System

- Orange River System sub-divided into 3 main sub-systems and several small sub-systems:
  - 1 Lesotho Highlands (Katse & Mohale)
  - 2 Caledon Modder (Welbedacht, Knellpoort, Rustfontein, Mockes & Groothoek dams)
  - 3 Orange River Project (Gariep & Vanderkloof dams)

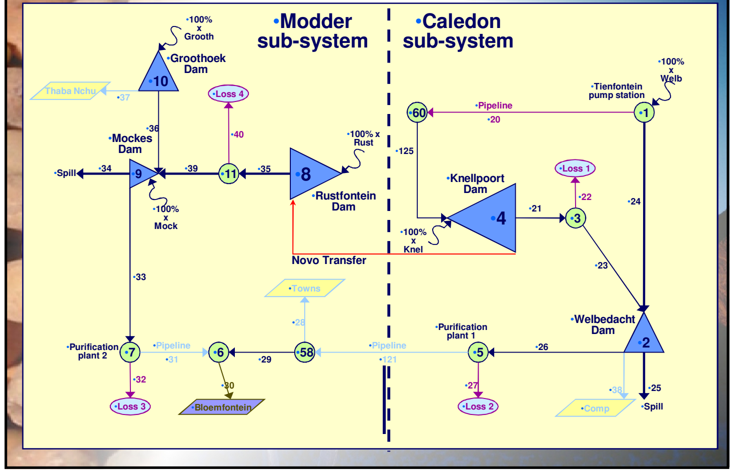
Lesotho Highlands Water Project



LHWP Operating Rules

- Releases to RSA based on agreed schedule phased in over time. Reached the maximum transfer volume 2009 – 780 mcm/a
- No releases to support downstream dams
- IFR releases from Mohale and Katse

Caledon Modder sub-system



Caledon Modder Operating Principals (1 of 2)

- Maintain Assurance of Supply
  - Primary objective of the operation of CMS is to maintain the assurance of supply to users
- Restriction of Demands
  - The operation of the CMS is based on the principle that demands are restricted during severe drought

Caledon Modder Operating Principals (2 of 2)

- Restriction of Demands
  - Objective is to reduce supply to less essential use to protect the assurance of supply for more essential use
  - The basis on which restrictions are implemented is defined by means of a user priority classification definition

Priority Classification Caledon Modder Sub-system

Category	% of the water demand to be supplied		
	1: 200 year (99.5%)	1: 100 year (99%)	1:20 year (95%)
Irrigation	10	40	50
Urban	50	30	20
Losses	100	0	0
Environmental	68	0	32

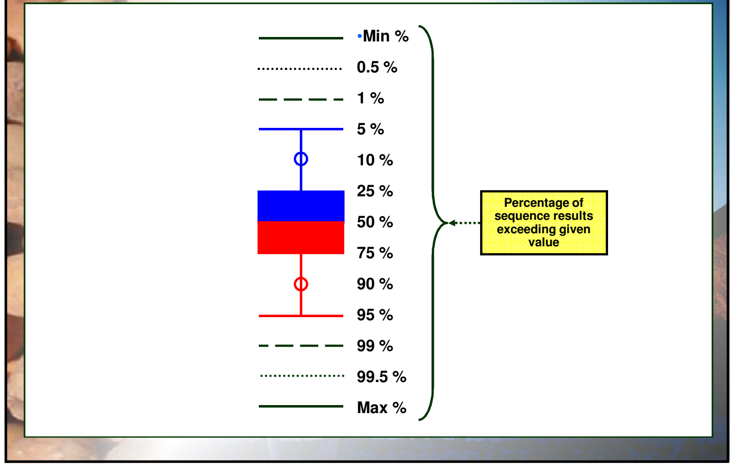
Caledon Modder operating rule

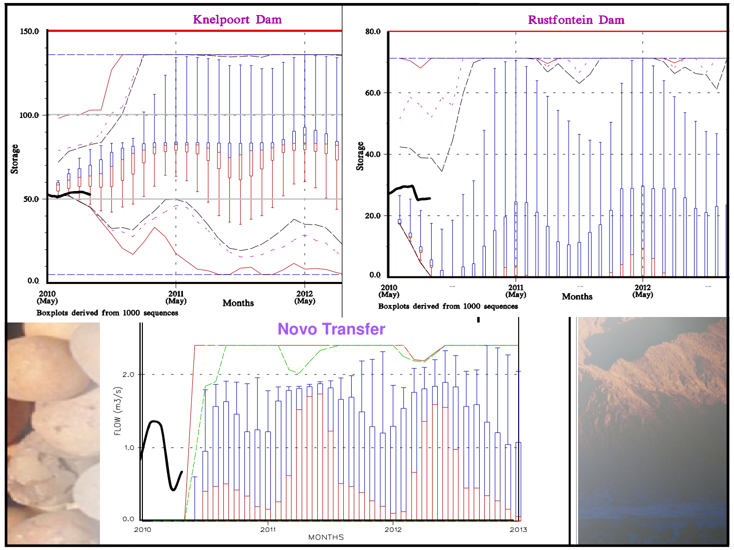
- Bloemfontein is supplied with water from it's resources in the following order:
  - 1 Welbedacht Dam
  - 2 Knellpoort Dam
  - 3 Upper 20% storage in Mockes Dam
  - 4 Rustfontein until it reaches 40%
  - 5 Water is then transferred from Knellpoort to Rustfontein Dam only if Knellpoort is above 60%

Caledon Modder operating rule

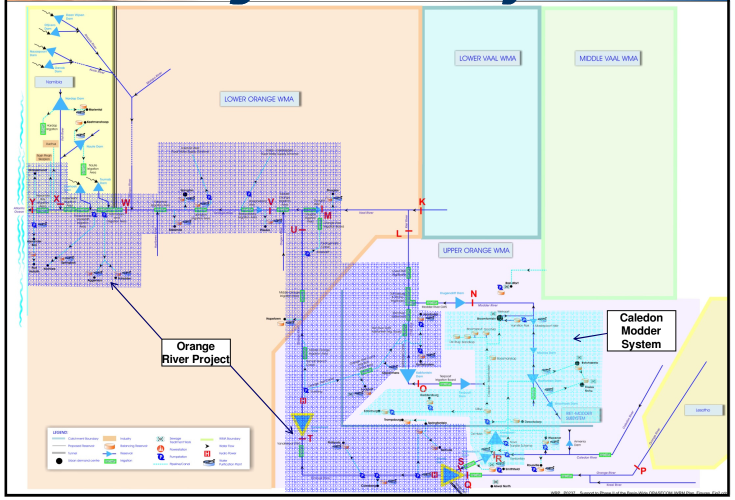
- Bloemfontein is supplied with water from it's resources in the following order (continue):
  - 6 Knellpoort below 60% start pumping from Tienfontein
  - 7 When not sufficient water in Caledon start to use 40% in Rustfontein
  - 8 Remaining 80% in Mockes
  - 9 Remaining 60% in Knellpoort

Box- and whisker plot definitions





Orange River Project



ORP Operating Principals *(1 of 2)*

- Maintain Assurance of Supply
  - Primary objective of the operation of ORP is to maintain the assurance of supply to users
- Hydro Power Operating Rules
  - Secondary objective is to implement rules that will maximize the hydro-power benefit without jeopardizing the assurance of supply to the users.

ORP Operating Principals *(2 of 2)*

- Restriction of Demands
  - The operation of the Orange River Project (Gariep and Vanderkloof dams) is based on the principle that demands are restricted during severe drought
    - Objective is to reduce supply to less essential use to protect the assurance of supply for more essential use
    - The basis on which restrictions are implemented is defined by means of a user priority classification definition

Priority Classification ORP Sub-system *(% basis)*

Category	% of the water demand to be supplied		
	1: 200 year (99.5%)	1: 100 year (99%)	1:20 year (95%)
Irrigation	10	40	50
Urban	50	30	20
Losses	100	0	0
Environmental	68	0	32

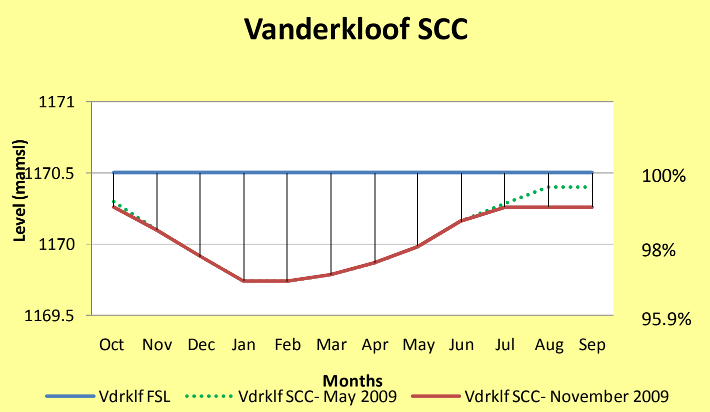
ORP Operating Rules

- Larger Orange River System
  - Storage dams upstream Gariep & Vanderkloof not used to support Gariep & Vanderkloof dams
  - Only releases for
    + Environment
    + Compensation to users
    + Spills

ORP Operating Rules

- Vanderkloof Dam
  - Releases into canal outlet on right bank
  - Releases into the river also used to generate HP
  - River releases according to downstream demand pattern
  - Additional releases if surplus allocated for HP
  - Additional releases for HP if water level above storage control curves

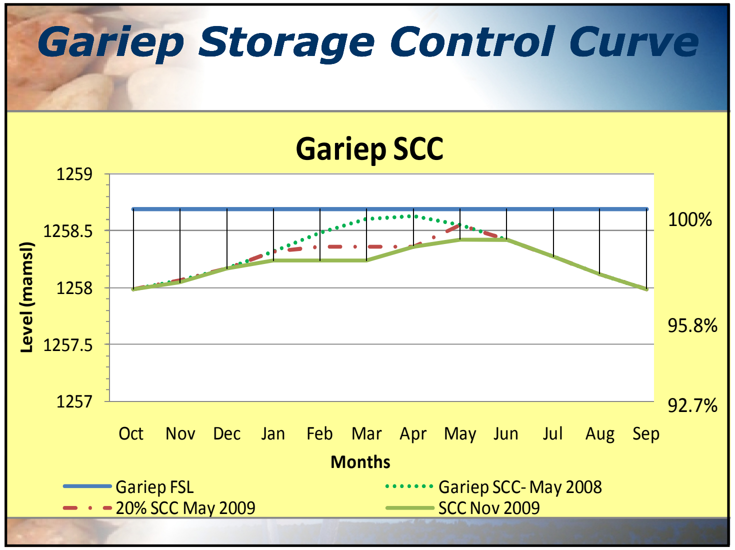
Vanderkloof Storage Control Curve



ORP Operating Rules

- Gariep Dam
  - Releases through Orange/Fish tunnel based on Operational model
  - Releases into the river also used to generate HP
  - River releases according to inverse of the downstream demand pattern
  - Additional releases if surplus allocated for HP
  - Additional releases for HP if water level above storage control curves

Gariep Storage Control Curve



Orange and Vaal System Link

- Orange and Vaal River systems are operated separately
- The only links are:

  The transfers from the Senqu to the Vaal
  - These transfers is fixed and independent of the water supply situation in the Orange d/s of the LHWP or in the IVRS

  Spills from the Vaal to the Orange
  - Operating rule of IVRS minimizes spills from the Vaal into the Orange. Spills from the Vaal do however enter the Orange during periods of high runoff and as result of operating losses and irrigation return flows in the Lower Vaal.

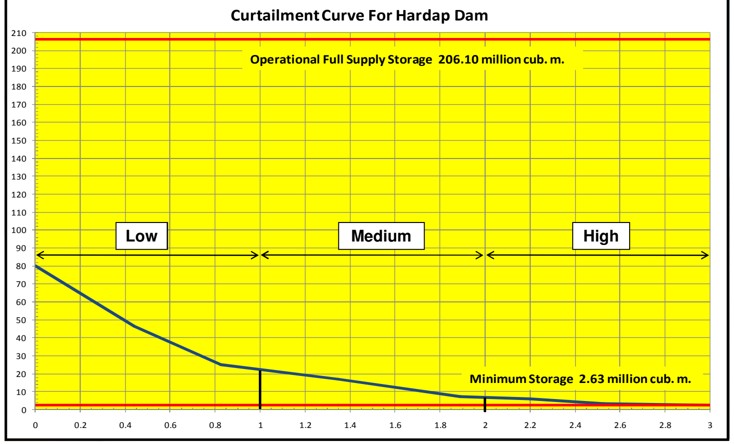
Small Orange sub-systems

- Kalkfontein, Krugersdrift, Tierpoort, Groothoek, Rooipoort, Smartt Syndicate, Naute, Hardap,etc
- These dams use an in-house rule in practice
- In current WRPM – Supply demand until dam failure occur then supply whatever is available
- Proper scientific operating rules to be developed
- Hardap in Namibia – operating rule was developed

Priority Classification Hardap Dam Sub-system *(% basis)*

User Category	Priority Classification & Assurance of Supply		
	Low 80% 1 in 5 year	Medium 90% 1 in 10 year	High 95% 1 in 20 year
Urban/industrial	0%	0%	100%
Irrigation	83%	17%	0%
Losses	50%	0%	50%%

HARDAP Curtailment Curve

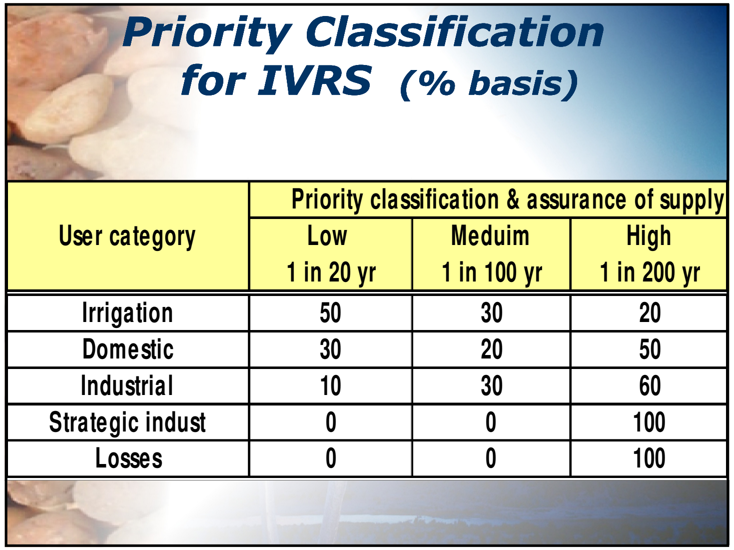


Integrated Vaal River System Principals *(1 of 2)*

- General Operating Principle
  - Must be operated as an integrated system irrespective of who owns or operate each component of the system
- Maintain Assurance of Supply
  - **Primary objective of the operation of IVRS is to maintain the assurance of supply to users**
- Cost Saving Operating Rules
  - Secondary objective to implement cost saving operating rules during wet hydrological conditions when dams are full.

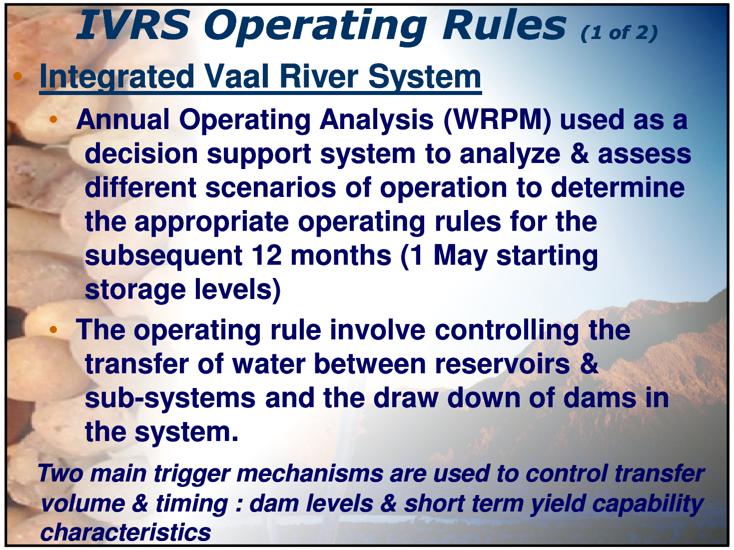
Integrated Vaal River System Principals *(1 of 2)*

- Restriction of Demands
  - **The operation of the IVRS is based on the principle that demands are restricted during severe drought events.**
    - **Objective is to reduce supply to less essential use to protect the assurance of supply for more essential use.**
    - **The basis on which restrictions are implemented is defined by means of a user priority classification definition.**



Priority Classification for IVRS (% basis)

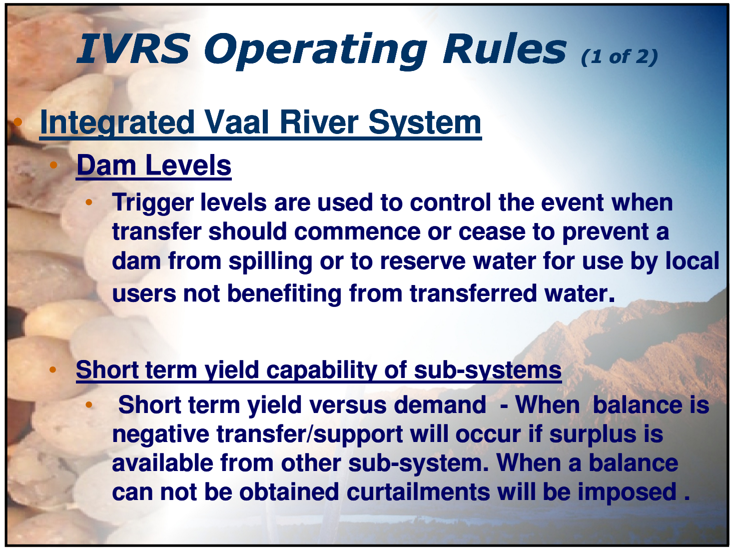
User category	Priority classification & assurance of supply		
	Low 1 in 20 yr	Meduim 1 in 100 yr	High 1 in 200 yr
Irrigation	50	30	20
Domestic	30	20	50
Industrial	10	30	60
Strategic indust	0	0	100
Losses	0	0	100



IVRS Operating Rules *(1 of 2)*

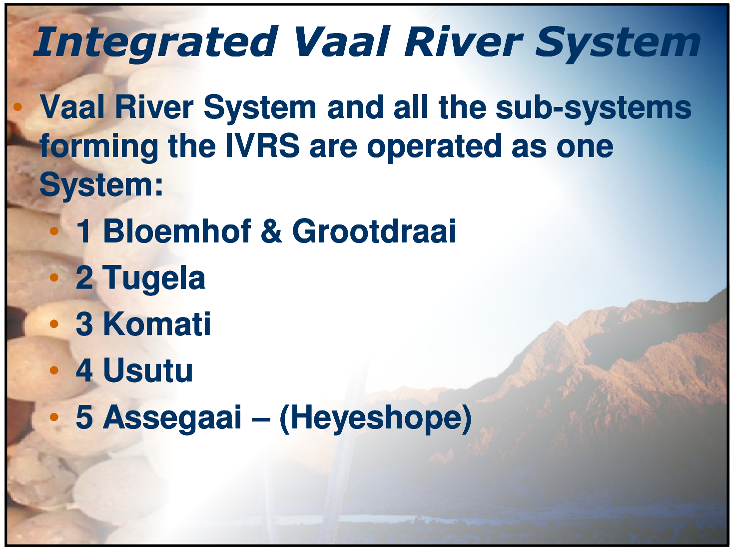
- <u>Integrated Vaal River System</u>
  - Annual Operating Analysis (WRPM) used as a decision support system to analyze & assess different scenarios of operation to determine the appropriate operating rules for the subsequent 12 months (1 May starting storage levels)
  - The operating rule involve controlling the transfer of water between reservoirs & sub-systems and the draw down of dams in the system.

Two main trigger mechanisms are used to control transfer volume & timing : dam levels & short term yield capability characteristics



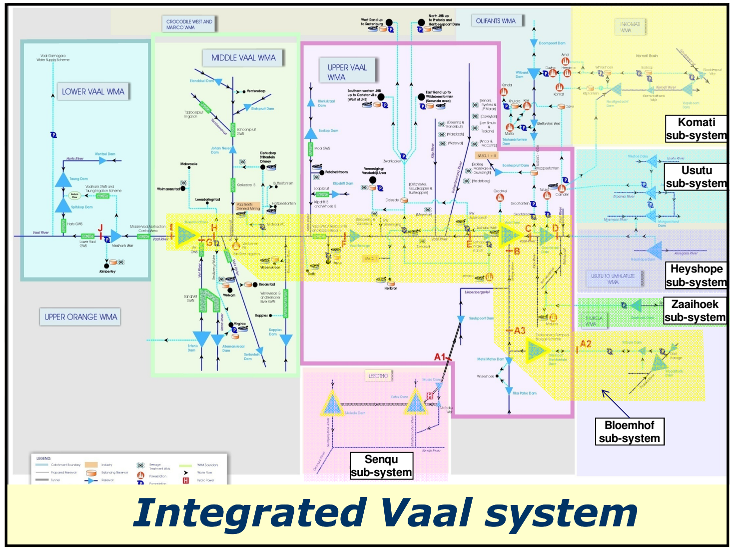
IVRS Operating Rules *(1 of 2)*

- <u>Integrated Vaal River System</u>
  - <u>Dam Levels</u>
    - Trigger levels are used to control the event when transfer should commence or cease to prevent a dam from spilling or to reserve water for use by local users not benefiting from transferred water.
  - <u>Short term yield capability of sub-systems</u>
    - Short term yield versus demand - When balance is negative transfer/support will occur if surplus is available from other sub-system. When a balance can not be obtained curtailments will be imposed .

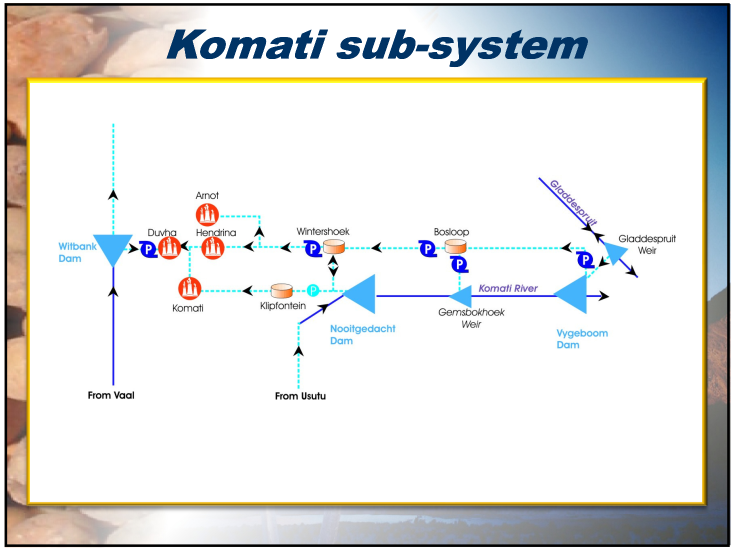


Integrated Vaal River System

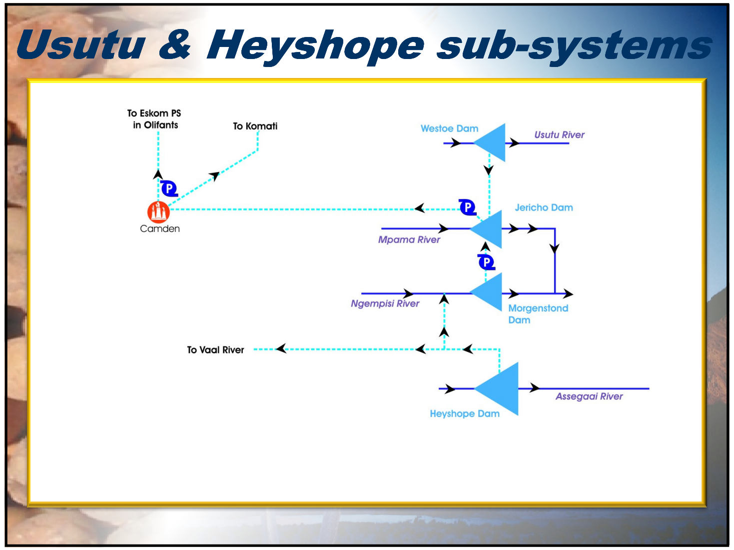
- Vaal River System and all the sub-systems forming the IVRS are operated as one System:
  - 1 Bloemhof & Grootdraai
  - 2 Tugela
  - 3 Komati
  - 4 Usutu
  - 5 Assegaai – (Heyeshope)



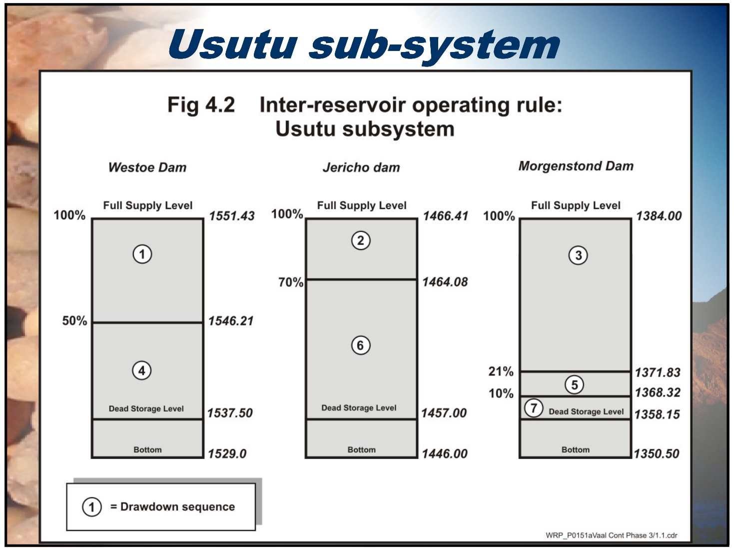
Integrated Vaal system



Komati sub-system

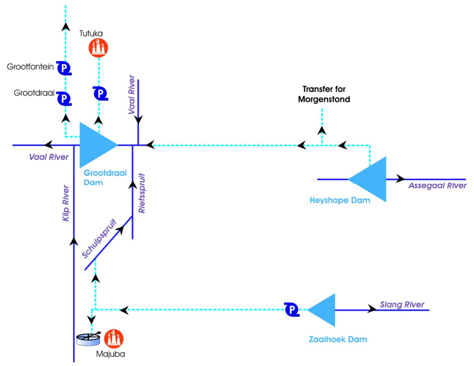


Usutu & Heyshope sub-systems

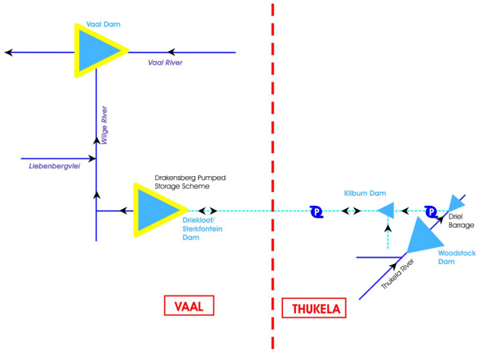


Usutu sub-system

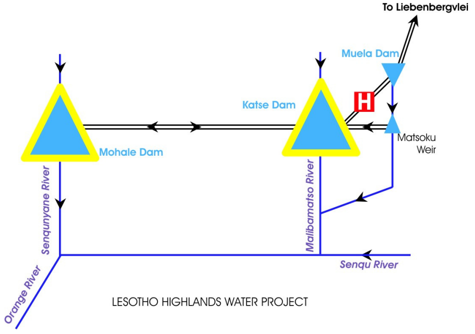
Heyshope & Zaaihoek sub-systems



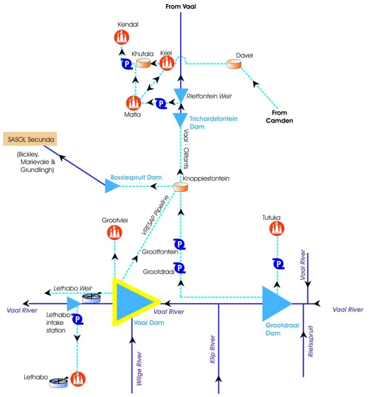
Thukela Vaal Transfer Scheme (Woodstock & Sterkfontein Dams)

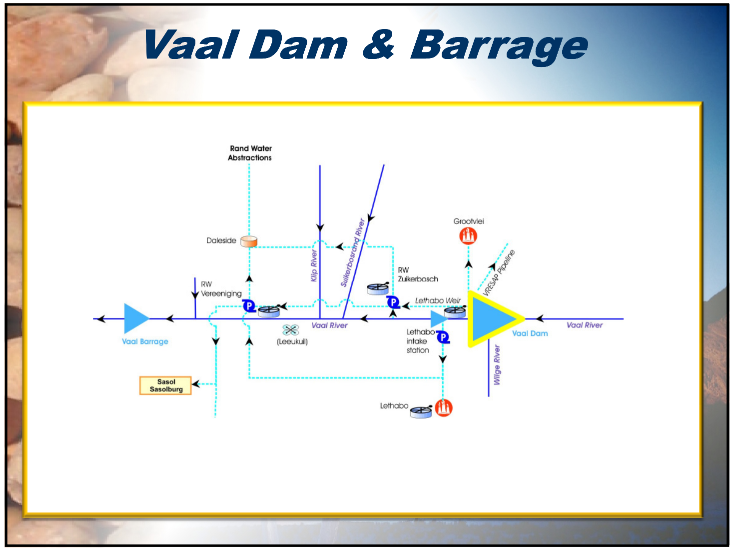


Lesotho Highlands Water Project

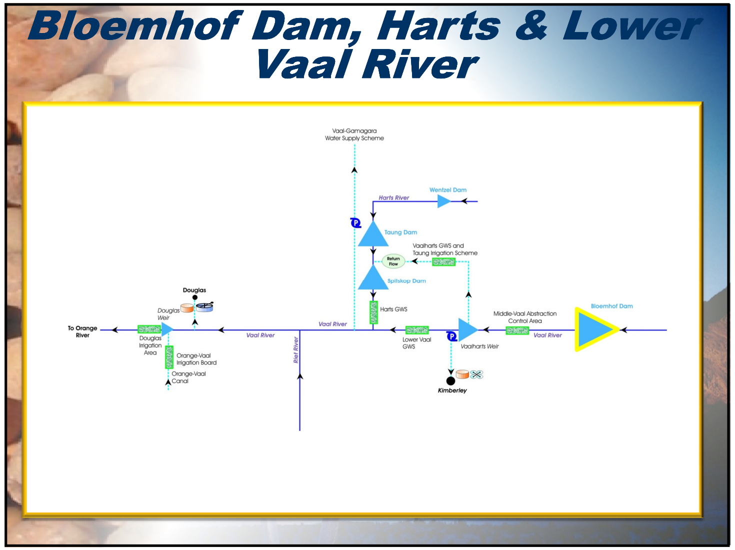


Grootdraai VRESAP Transfers





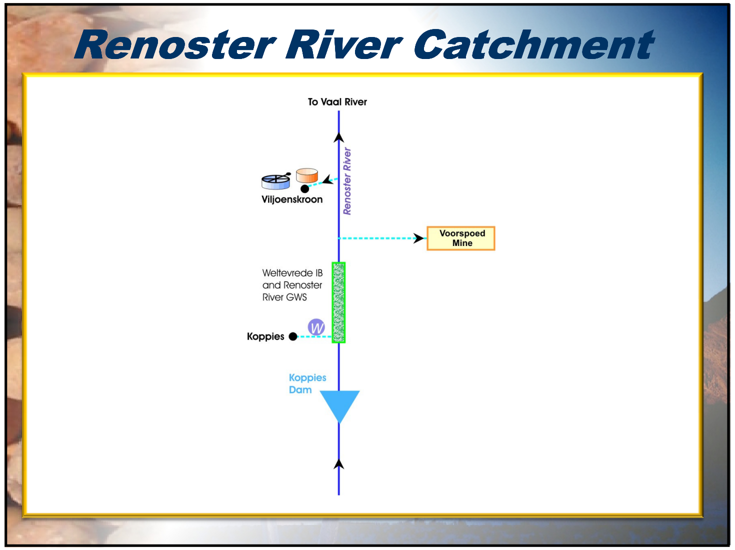
Vaal Dam & Barrage



Bloemhof Dam, Harts & Lower Vaal River

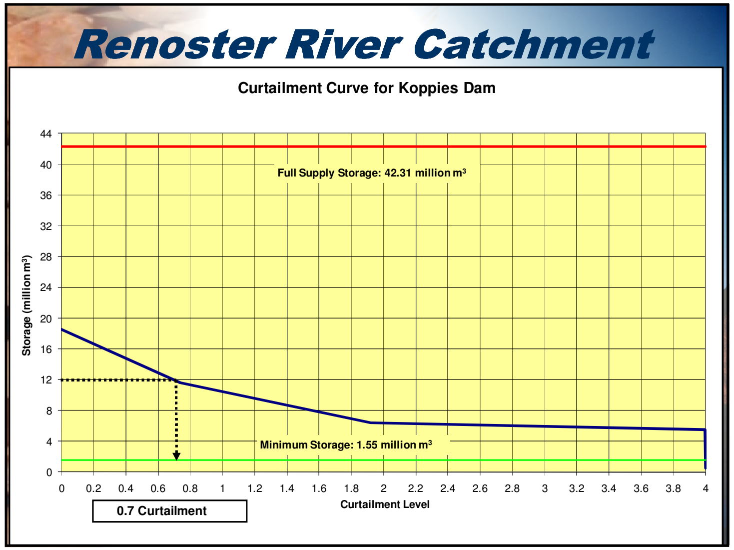
Small Vaal sub-systems

- Mooi River, Renoster, Schoonspruit, Sand-Vet sub-systems, etc.
- Operating rules were developed for :
  - Mooi River, Rhenoster & Sand-Vet
- Schoonspruit sub-system and other small dams use in-house operating rules
  - In current WRPM – Supply demand until dam failure occur then supply what is available

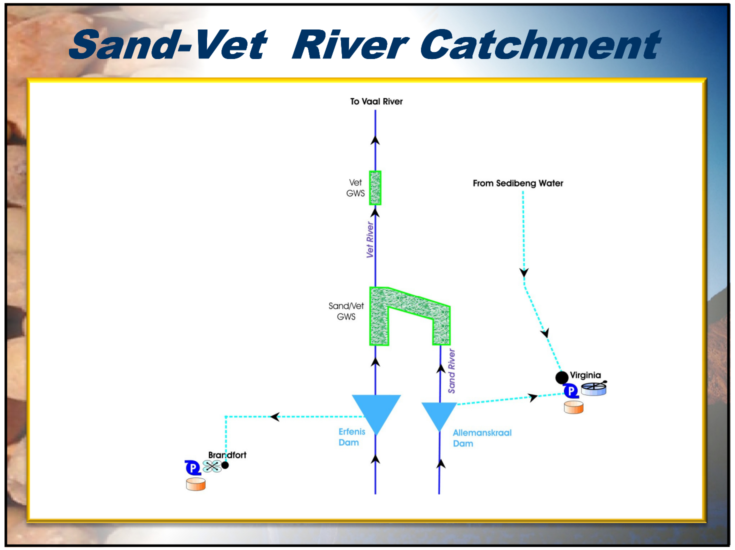


Renoster River Catchment

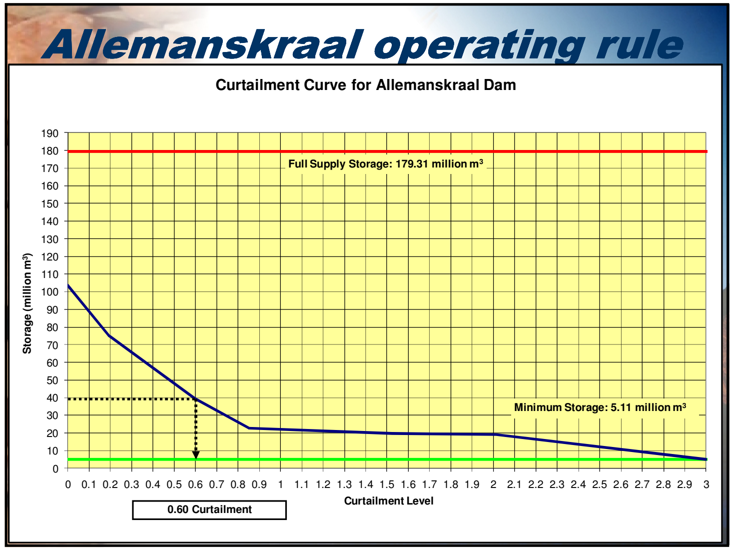
Renoster River Catchment



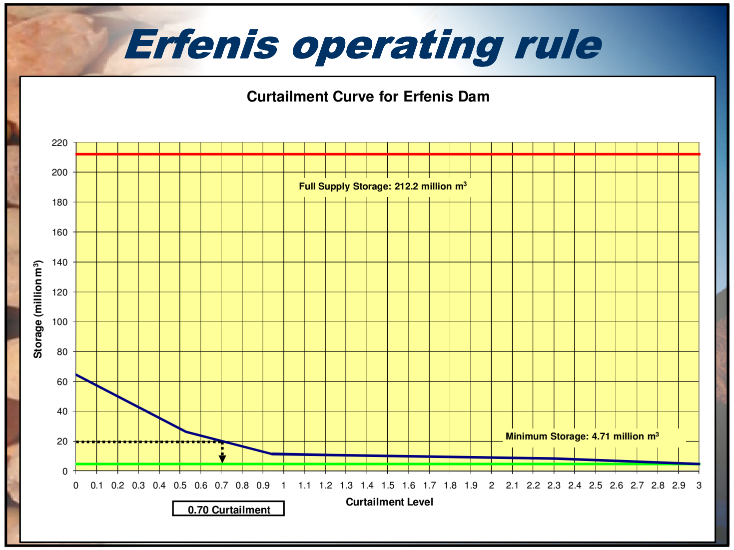
Sand-Vet River Catchment



Allemanskraal operating rule



Erfenis operating rule



Thank You

Training and Technology
Transfer Workshop

29 & 30 November 2010

Module 2: Overview of water resource management

Commissioned by:

gtz

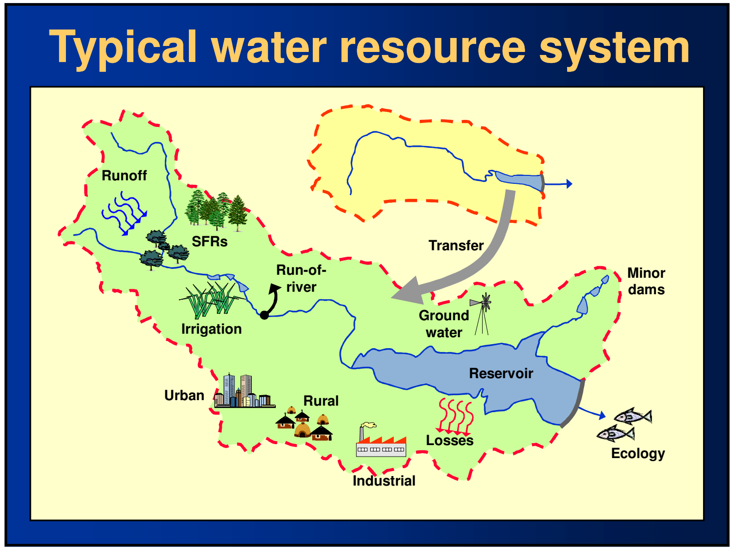
Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

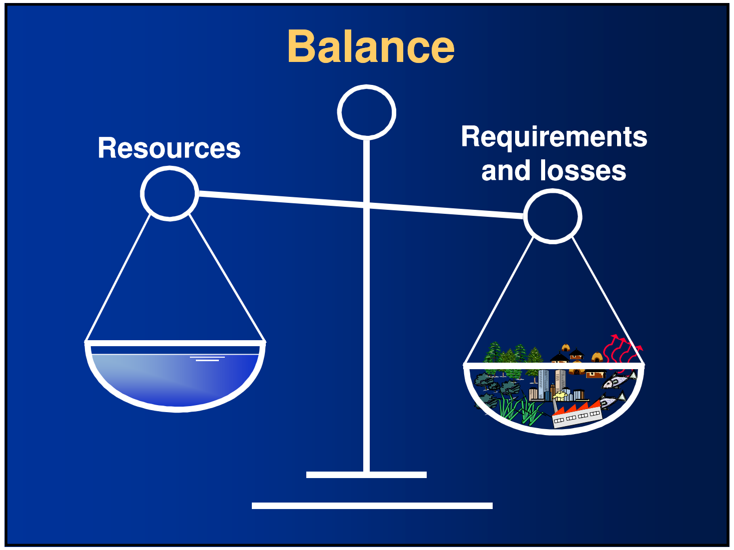
UKaid
from the Department for
International Development

Australian Government
Aid Program

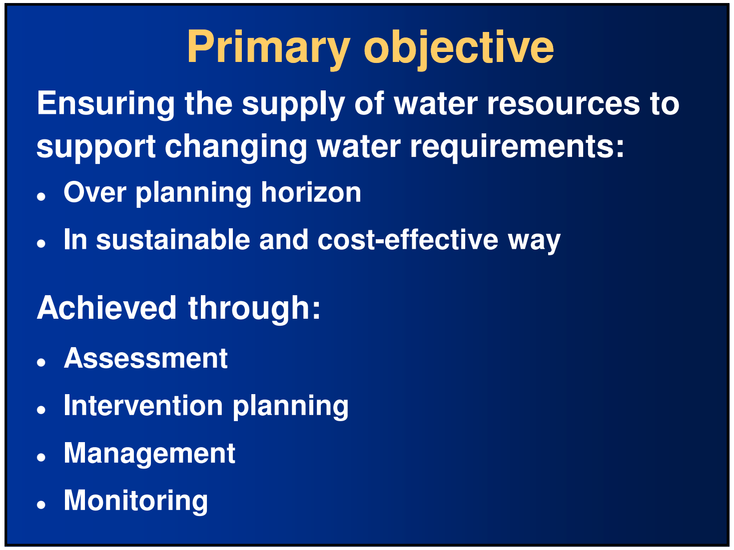
wrp
A Miya
Group Company



Typical water resource system



Balance



Primary objective

Ensuring the supply of water resources to support changing water requirements:

- Over planning horizon
- In sustainable and cost-effective way

Achieved through:

- Assessment
- Intervention planning
- Management
- Monitoring

Assessment

- Resource capability
- Resource assurance
- Water quality
- Water requirements
- User criteria

Intervention planning

- Conservation
  - Demand management
  - Recycling
  - Resource reallocation
  - Adjustment of user criteria
  - Catchment management
- Resource development
  - Reservoirs
  - Transfer schemes
- Revision of allocations (Licensing)
- Water Quality Management Measures

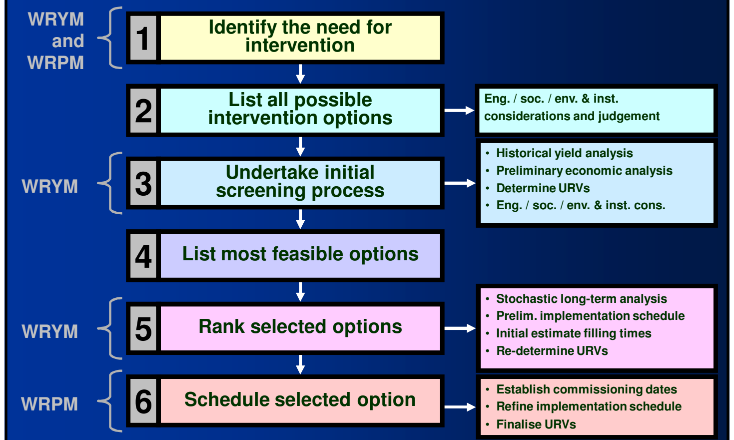
Management

- Resource operation
  - Reservoirs
  - Supply priorities
  - Transfers
  - Blending / dilution
  - Implementation of Ecological Water Requirements
- Operational cost savings
- System maintenance

Monitoring

- System behaviour
- Water requirements
- Impact initiatives / interventions
- Water quality objectives
- EWR supply

The water resource planning process



WRYM and WRPM

1 Identify the need for intervention

2 List all possible intervention options

Eng. / soc. / env. & inst. considerations and judgement

WRYM

3 Undertake initial screening process

- Historical yield analysis
- Preliminary economic analysis
- Determine URVs
- Eng. / soc. / env. & inst. cons.

4 List most feasible options

WRYM

5 Rank selected options

- Stochastic long-term analysis
- Prelim. implementation schedule
- Initial estimate filling times
- Re-determine URVs

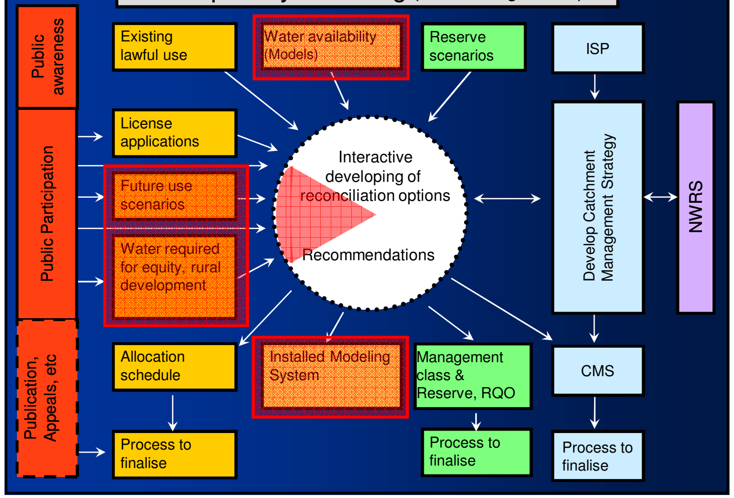
WRPM

6 Schedule selected option

- Establish commissioning dates
- Refine implementation schedule
- Finalise URVs

Water Availability Assessment
for
Water Allocation (Licensing)

Compulsory Licensing (Formalising IWRM)



Public awareness

Public Participation

Publication, Appeals, etc

Existing lawful use

Water availability (Models)

Reserve scenarios

ISP

License applications

Future use scenarios

Water required for equity, rural development

Interactive developing of reconciliation options

Recommendations

Develop Catchment Management Strategy

NWRS

Allocation schedule

Installed Modeling System

Management class & Reserve, RQO

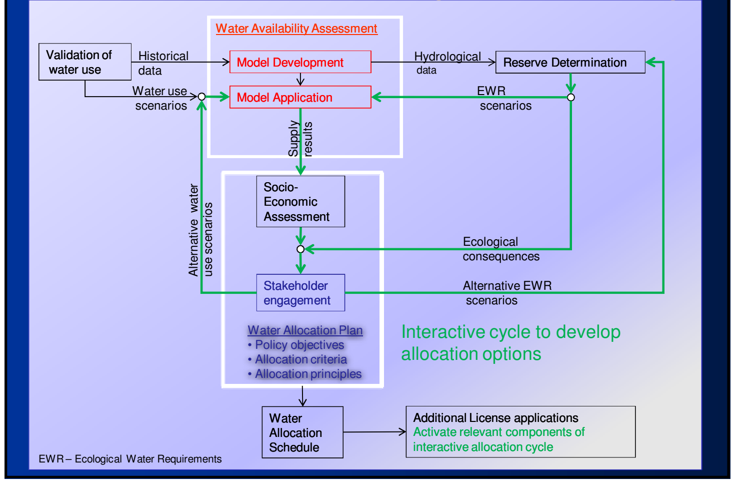
CMS

Process to finalise

Process to finalise

Process to finalise

Allocation Planning (Licensing)



Water Availability Assessment

Validation of water use

Historical data

Model Development

Hydrological data

Reserve Determination

Water use scenarios

Model Application

EWR scenarios

Supply results

Alternative water use scenarios

Socio-Economic Assessment

Ecological consequences

Stakeholder engagement

Alternative EWR scenarios

Water Allocation Plan
- Policy objectives
- Allocation criteria
- Allocation principles

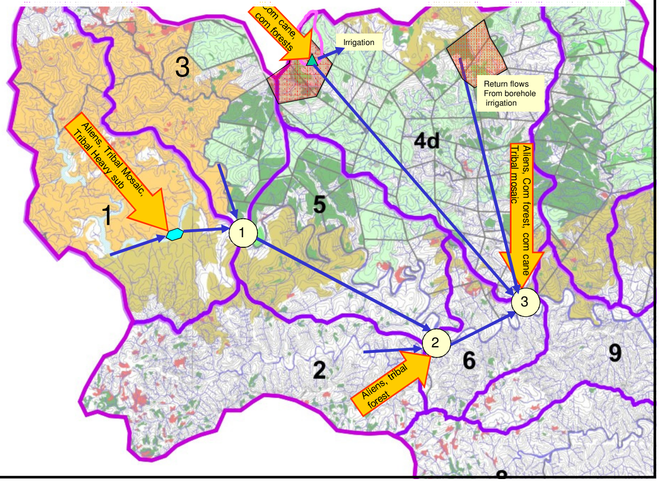
Interactive cycle to develop allocation options

Water Allocation Schedule

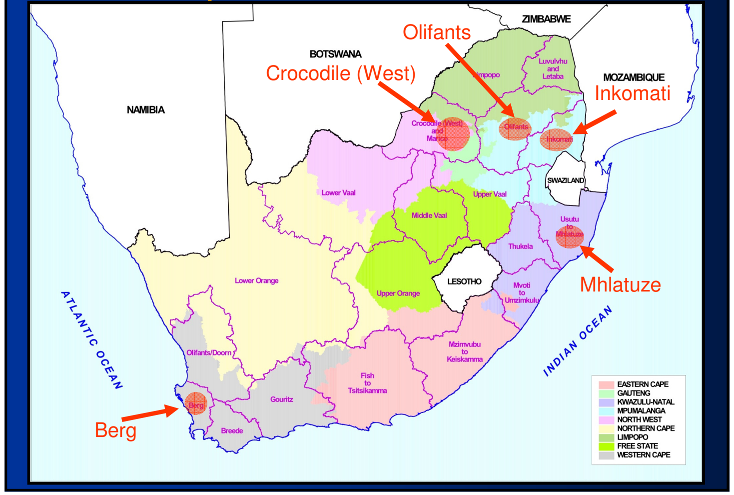
Additional License applications
Activate relevant components of interactive allocation cycle

EWR – Ecological Water Requirements

Higher Resolution Model



Completed WAA Studies



Training and Technology
Transfer Workshop

5 & 6 May 2006

End of module

Training and Technology
Transfer Workshop

29 & 30 November 2010

Module 3: Water resource assessment

Commissioned by:
gtz
Federal Ministry for Economic Cooperation and Development
In Delegated Cooperation with:
UKaid from the Department for International Development
Australian Government Aid Program
wrp A Miya Group Company

Contents

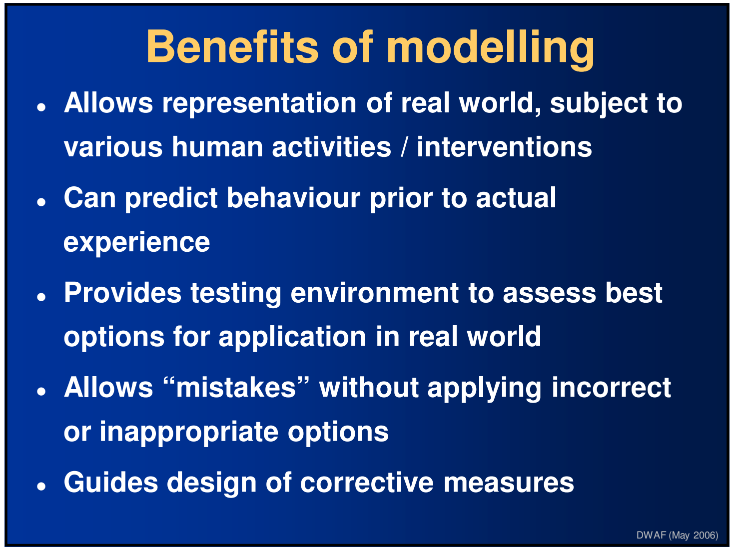
1. Modelling water resource systems
2. Basic modelling principles
3. Definition of terms
4. Stochastic yield analysis
5. Group discussion

1. Modelling water resource systems

Definition

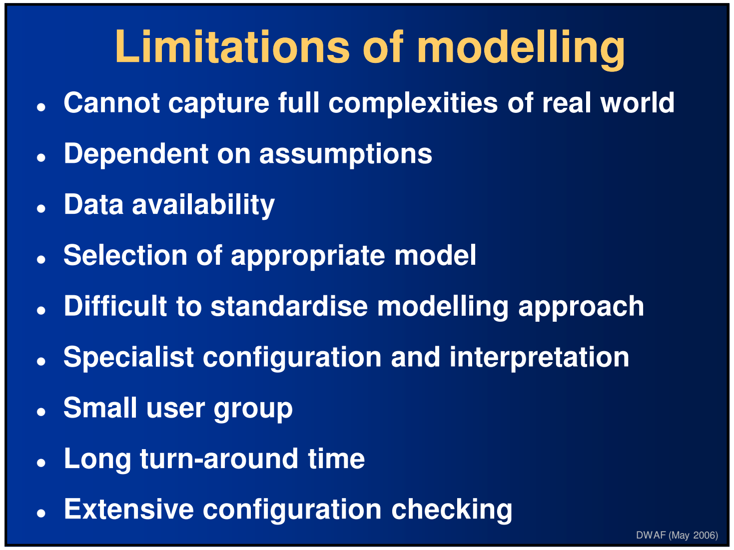
"… a simplified mathematical description of a system or process, used to assist calculations and predictions…"

– Oxford English Dictionary



Benefits of modelling

- Allows representation of real world, subject to various human activities / interventions
- Can predict behaviour prior to actual experience
- Provides testing environment to assess best options for application in real world
- Allows “mistakes” without applying incorrect or inappropriate options
- Guides design of corrective measures

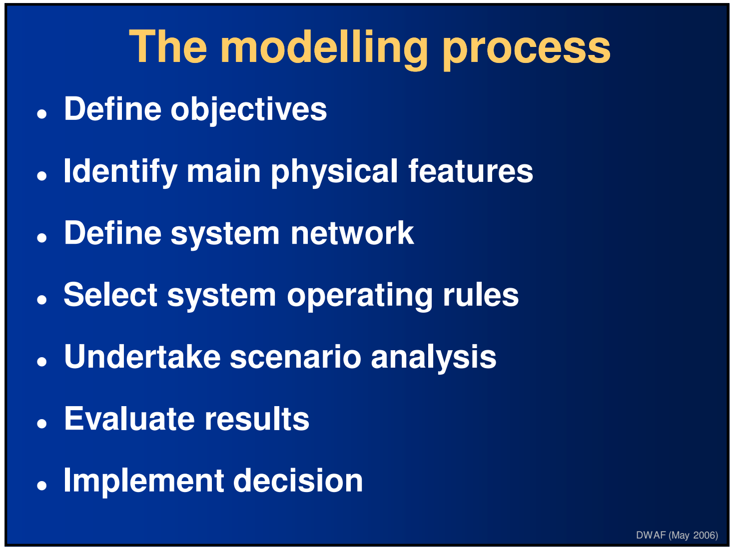


Limitations of modelling

- Cannot capture full complexities of real world
- Dependent on assumptions
- Data availability
- Selection of appropriate model
- Difficult to standardise modelling approach
- Specialist configuration and interpretation
- Small user group
- Long turn-around time
- Extensive configuration checking

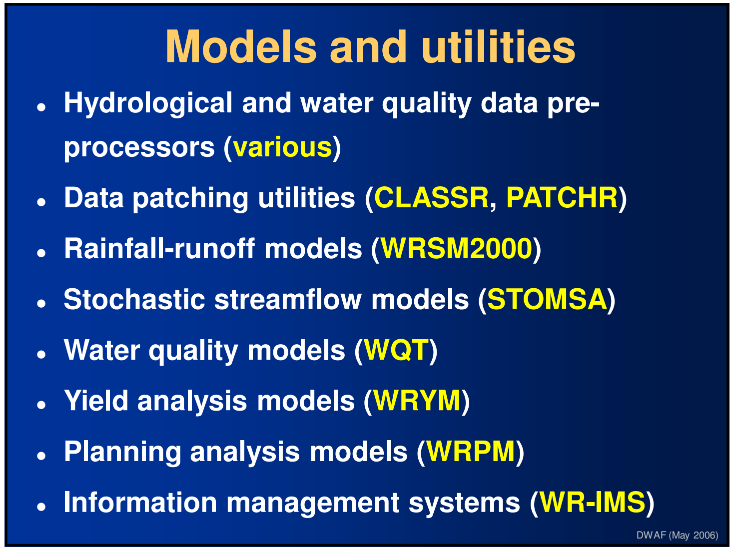
Purpose

- Assessment
  - Resource capability
  - Resource assurance
  - Water quality
- Impact of interventions
  - Conservation
  - Resource development
- Impact of management options
  - Resource operation
  - System maintenance
- Monitoring of observed behaviour



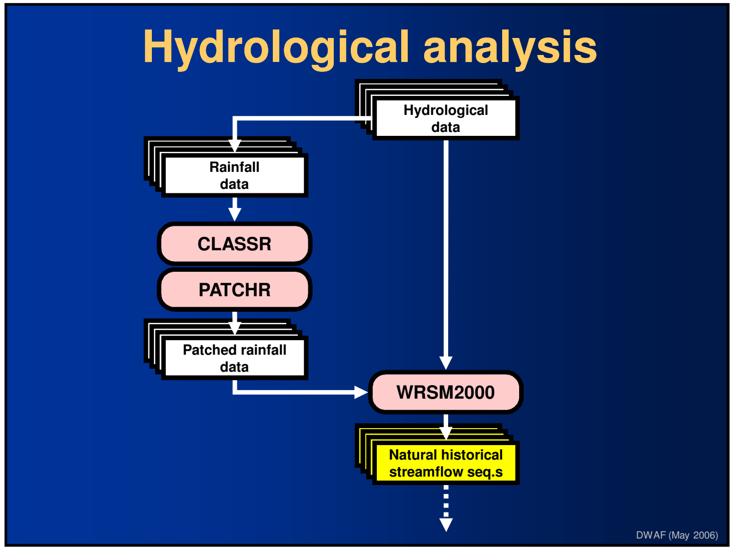
The modelling process

- Define objectives
- Identify main physical features
- Define system network
- Select system operating rules
- Undertake scenario analysis
- Evaluate results
- Implement decision



Models and utilities

- Hydrological and water quality data pre-processors (various)
- Data patching utilities (CLASSR, PATCHR)
- Rainfall-runoff models (WRSM2000)
- Stochastic streamflow models (STOMSA)
- Water quality models (WQT)
- Yield analysis models (WRYM)
- Planning analysis models (WRPM)
- Information management systems (WR-IMS)



Hydrological analysis

Hydrological data

Rainfall data

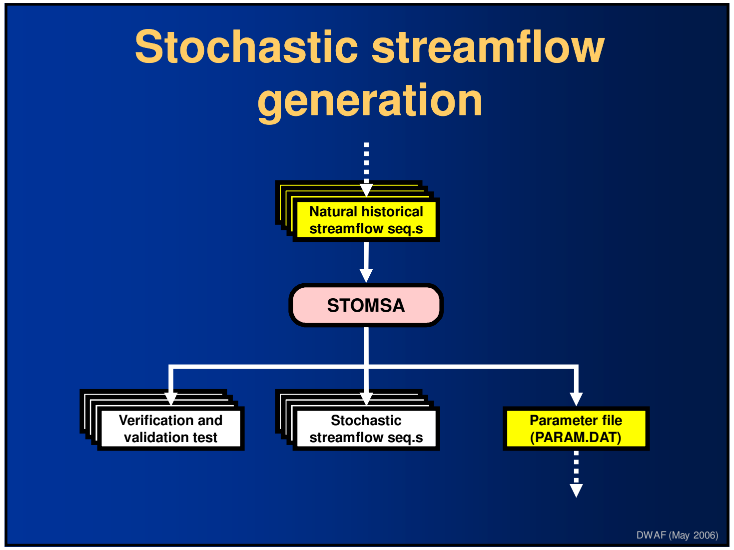
CLASSR

PATCHR

Patched rainfall data

WRSM2000

Natural historical streamflow seq.s



Stochastic streamflow generation

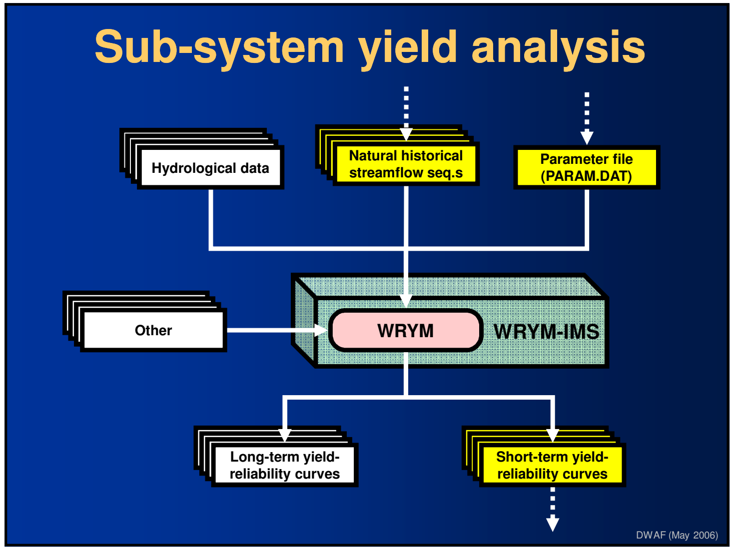
Natural historical streamflow seq.s

STOMSA

Verification and validation test

Stochastic streamflow seq.s

Parameter file (PARAM.DAT)



Sub-system yield analysis

Hydrological data

Natural historical streamflow seq.s

Parameter file (PARAM.DAT)

Other

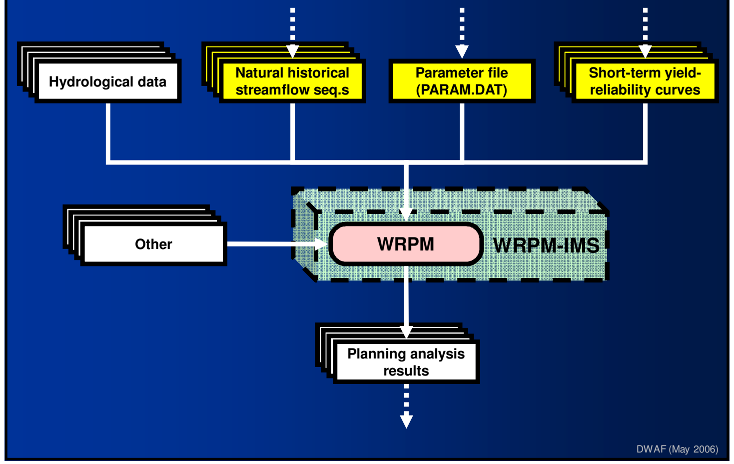
WRYM

WRYM-IMS

Long-term yield-reliability curves

Short-term yield-reliability curves

System planning analysis



Hydrological data

Natural historical streamflow seq.s

Parameter file (PARAM.DAT)

Short-term yield-reliability curves

Other

WRPM

WRPM-IMS

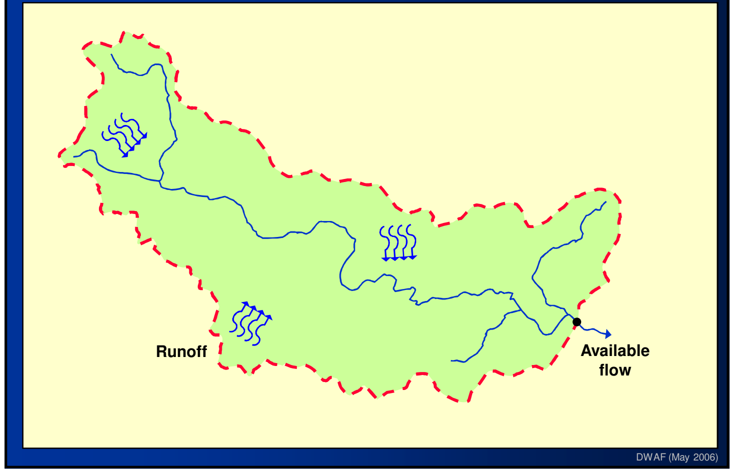
Planning analysis results

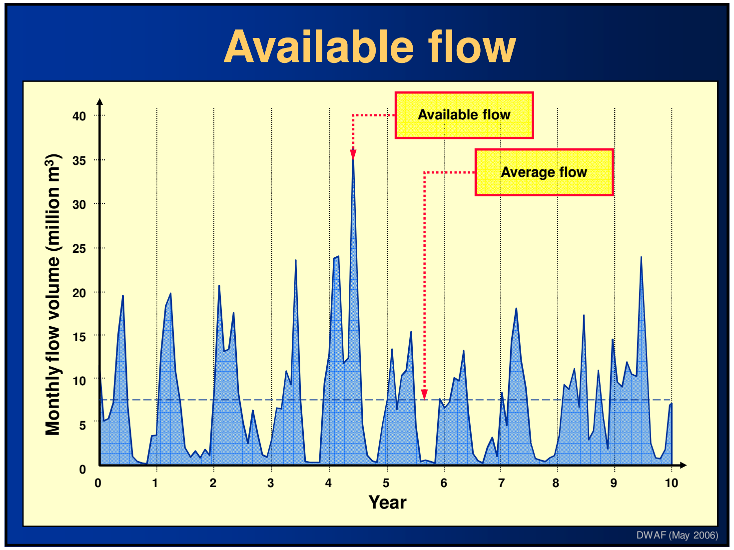
Other aspects

- Information management systems:
  - Population data
  - Economic data
  - Hydro-meteorological data
- Research – improved modelling / management methodologies

2. Basic modelling principles

Undeveloped catchment



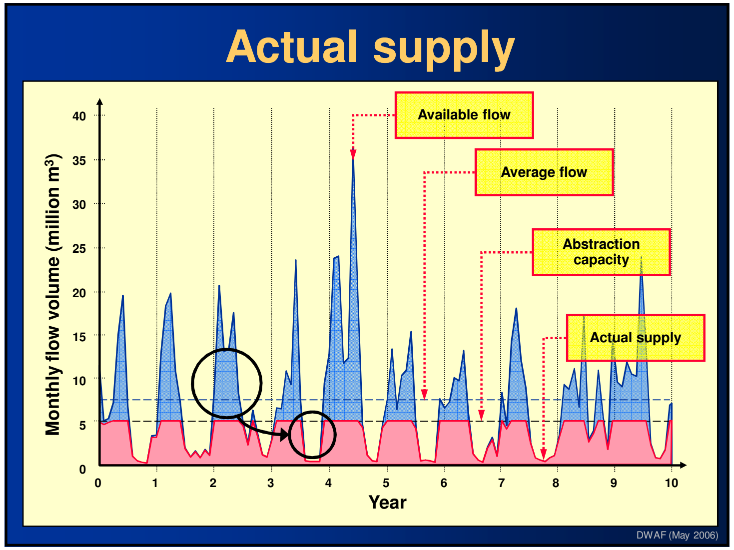


Available flow

DWAF (May 2006)

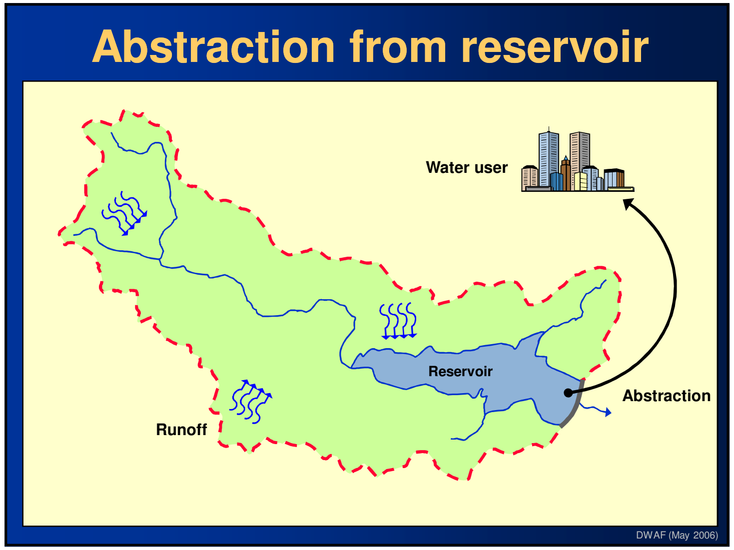
Abstraction from river

DWAF (May 2006)



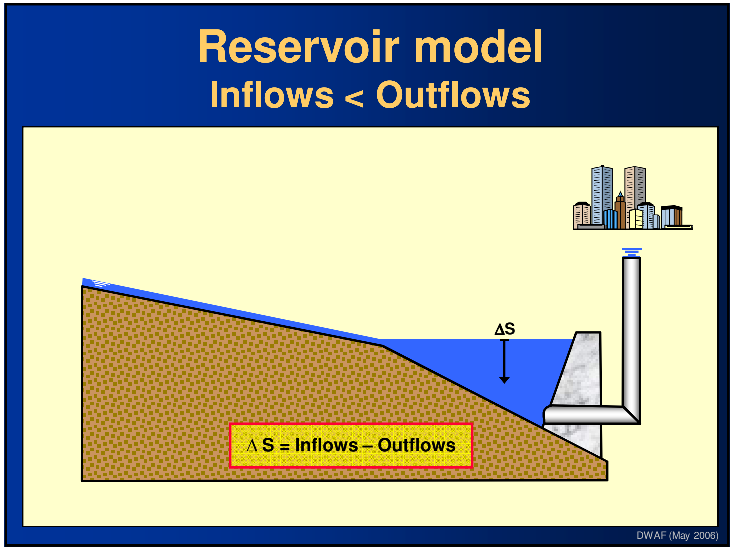
Actual supply

DWAF (May 2006)



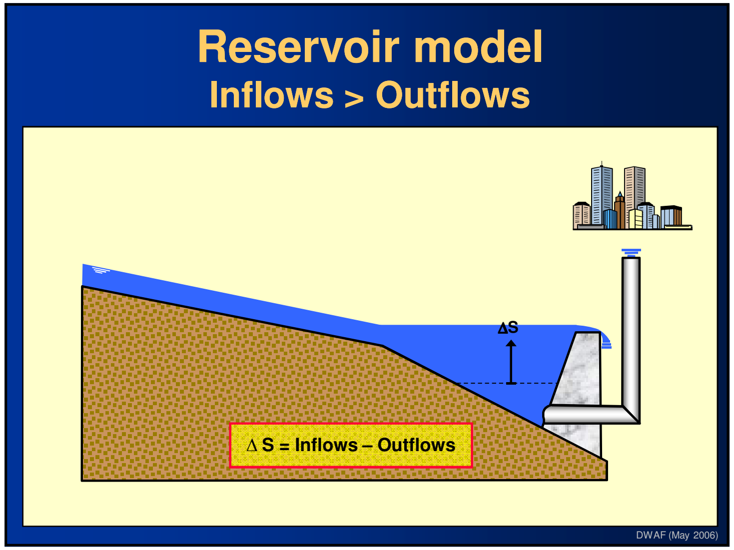
Abstraction from reservoir

DWAF (May 2006)



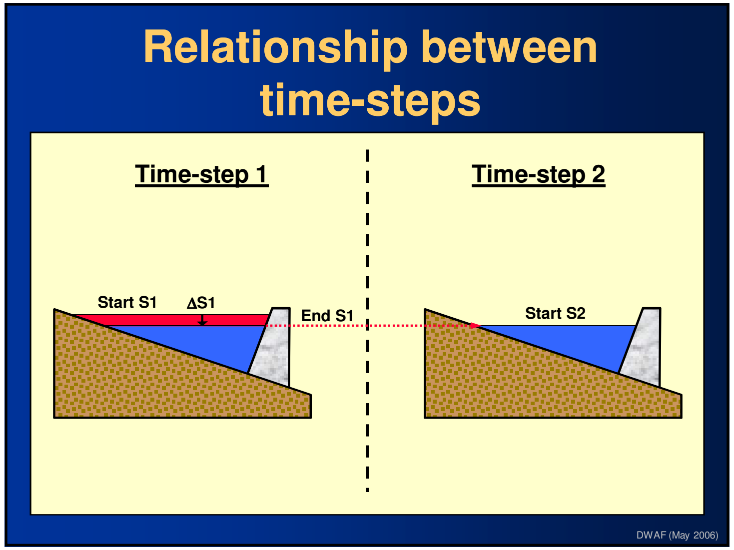
Reservoir model
Inflows < Outflows

Δ S = Inflows – Outflows

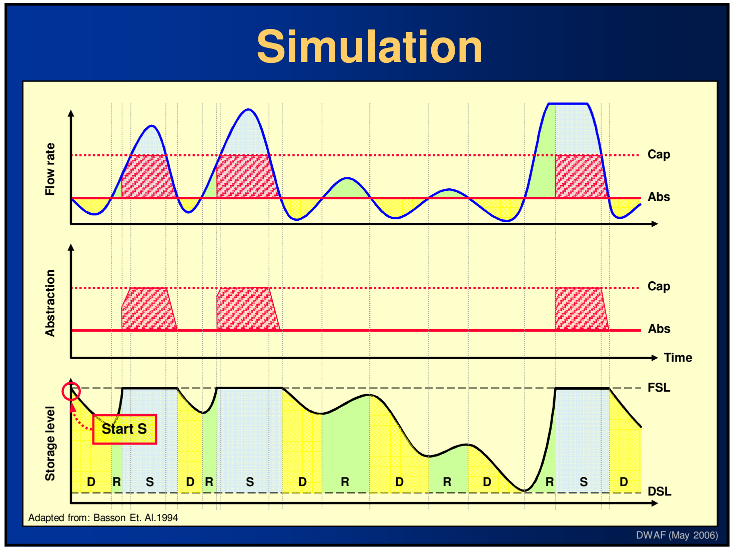


Reservoir model
Inflows > Outflows

Δ S = Inflows – Outflows



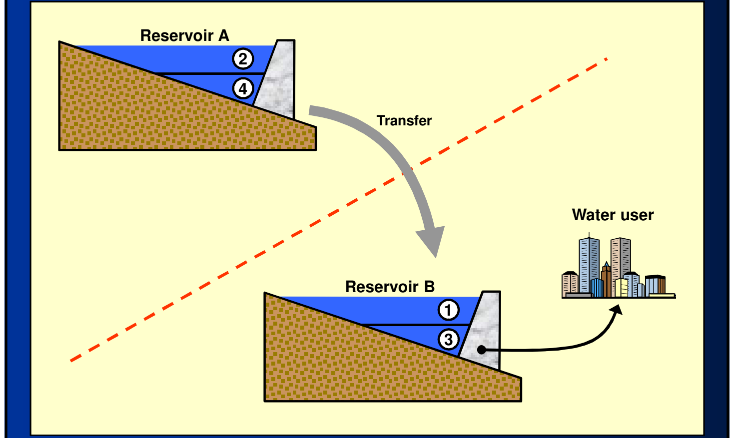
Relationship between time-steps



Simulation

Adapted from: Basson Et. Al.1994

Analysing scenarios (1 of 2)



Analysing scenarios (2 of 2)

Variables	Scenarios					
	1 (Base)		2		3	
	(A)	(B)	(A)	(B)	(A)	(B)
Operation:	2 4	1 3	2	1 3	2 4	1 3
Capacity:	150	300	150	300	200	300
Demand:	10.0		10.0		10.0	
Result:	?		?		?	

Groundwater modelling

- Groundwater-surface water interaction
- Model developed by K Sami (DWAF, October 2004)
- Currently being incorporated into WRSM2000 rainfall-runoff model and WRYM
- Review in progress

3. Definition of terms

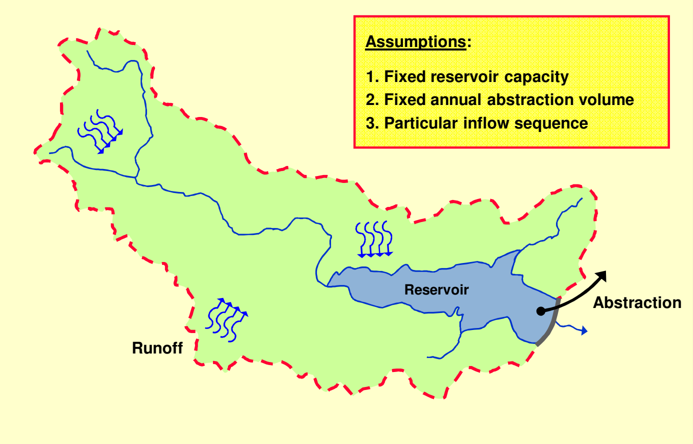
Commonly used terms

- “Firm yield”
- “Secondary yield”
- “Total yield”
- “Historical yield”
- “1:100 year yield”
- “Yield with 95 % assurance”

Yield terms

- Target draft
- Reservoir failure and recovery
- Critical period
- Yield
- Base yield
- Firm yield
- Secondary yield

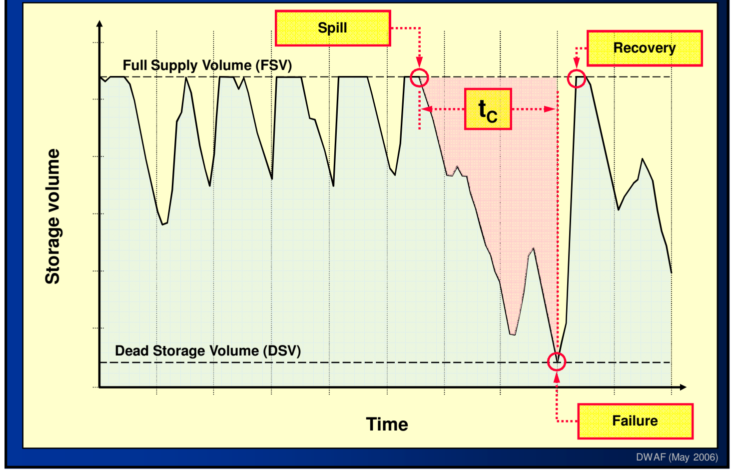
Water resource system

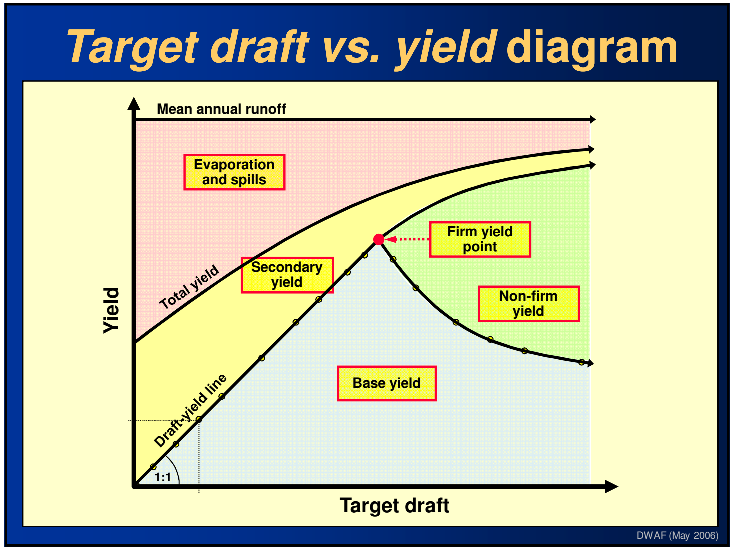


<u>Assumptions</u>:

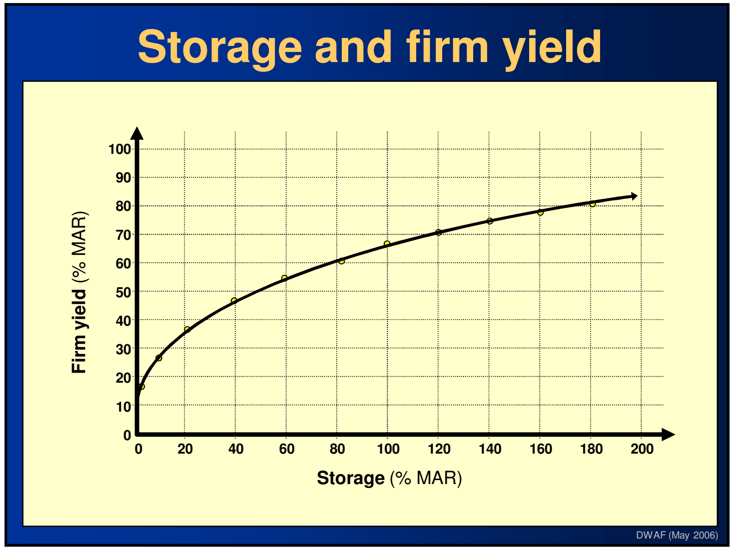
1. Fixed reservoir capacity
2. Fixed annual abstraction volume
3. Particular inflow sequence

Reservoir trajectory



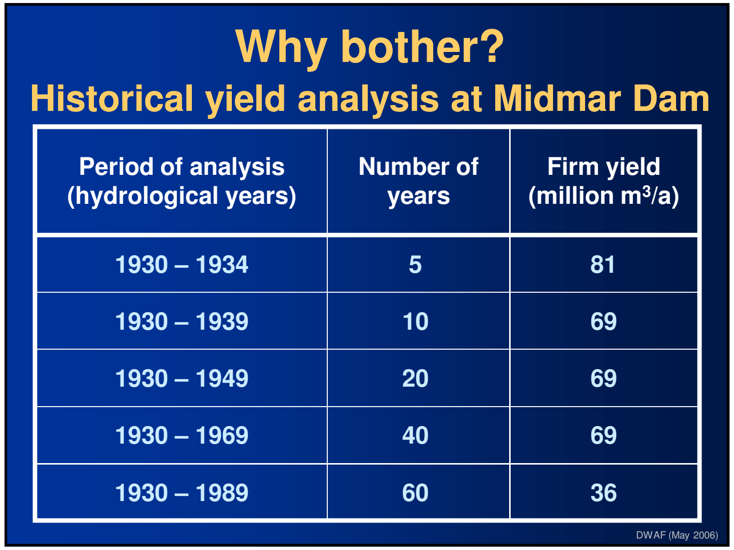


Target draft vs. yield diagram



Storage and firm yield

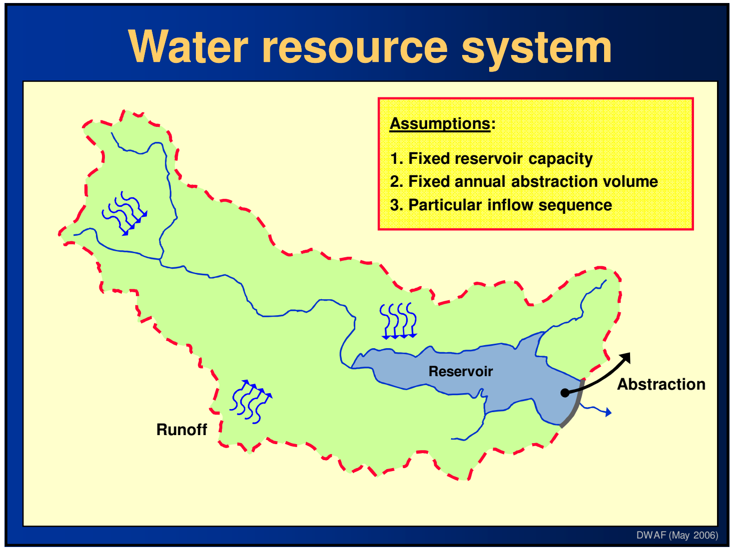
4. Stochastic yield analysis



Why bother?

Historical yield analysis at Midmar Dam

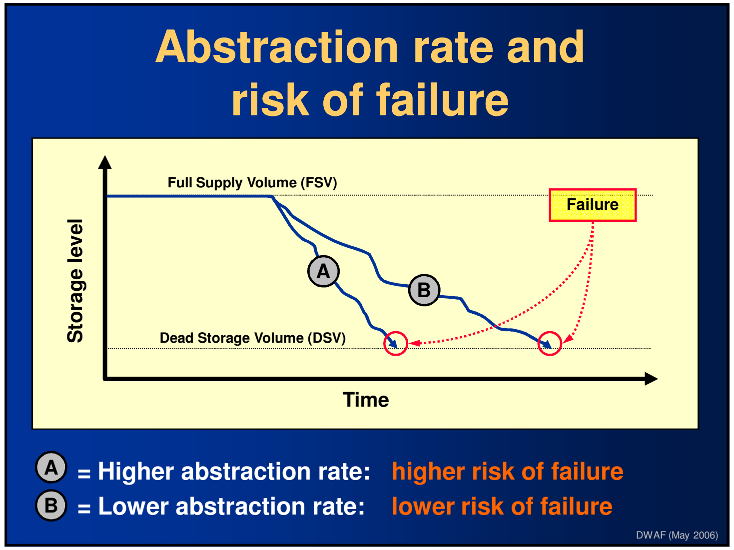
Period of analysis (hydrological years)	Number of years	Firm yield (million m^3/a)
1930 – 1934	5	81
1930 – 1939	10	69
1930 – 1949	20	69
1930 – 1969	40	69
1930 – 1989	60	36



Water resource system

Assumptions:

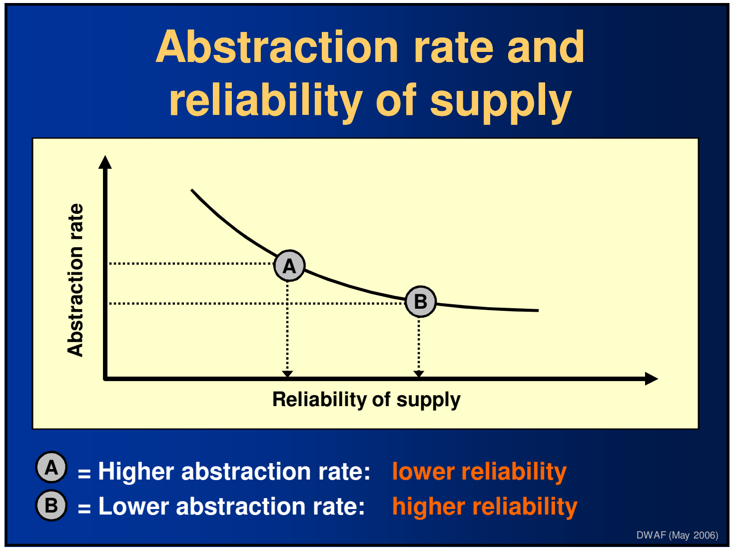
1. Fixed reservoir capacity
2. Fixed annual abstraction volume
3. Particular inflow sequence



Abstraction rate and risk of failure

Ⓐ = Higher abstraction rate: higher risk of failure

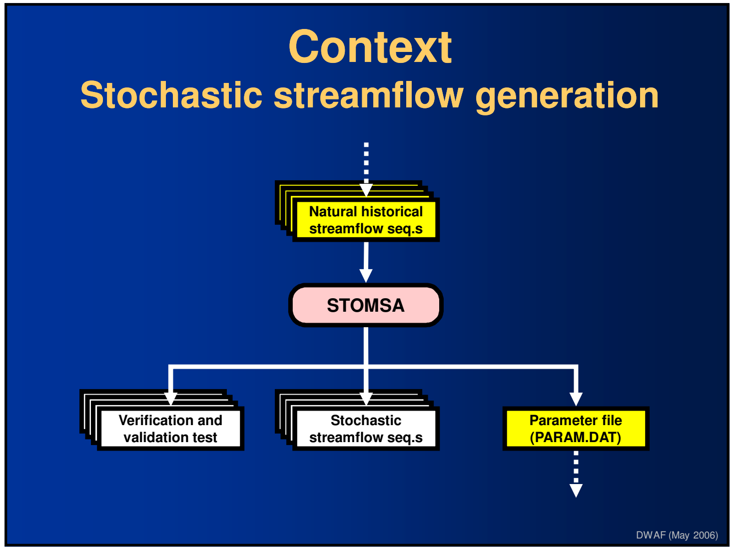
Ⓑ = Lower abstraction rate: lower risk of failure



Abstraction rate and reliability of supply

Ⓐ = Higher abstraction rate: lower reliability

Ⓑ = Lower abstraction rate: higher reliability



Context

Stochastic streamflow generation

Natural historical streamflow seq.s

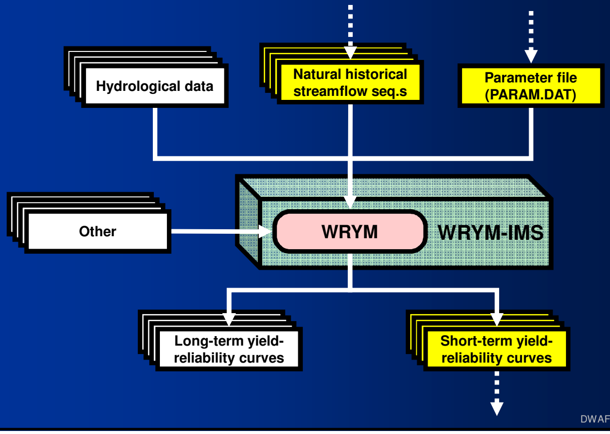
STOMSA

Verification and validation test

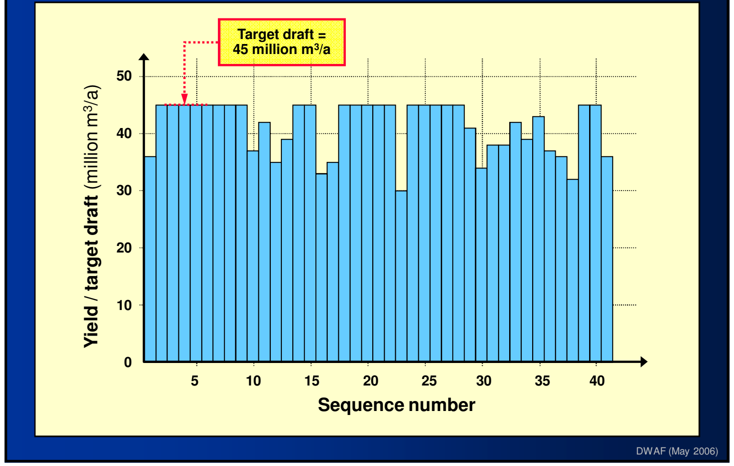
Stochastic streamflow seq.s

Parameter file (PARAM.DAT)

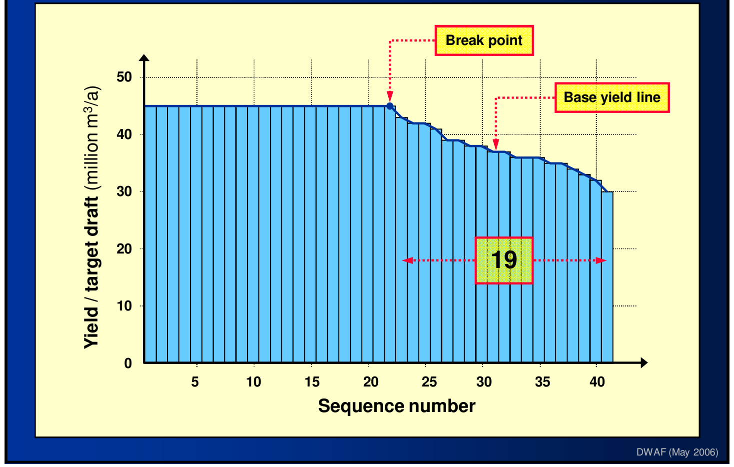
Context
Sub-system yield analysis



Yield results for 41 sequences



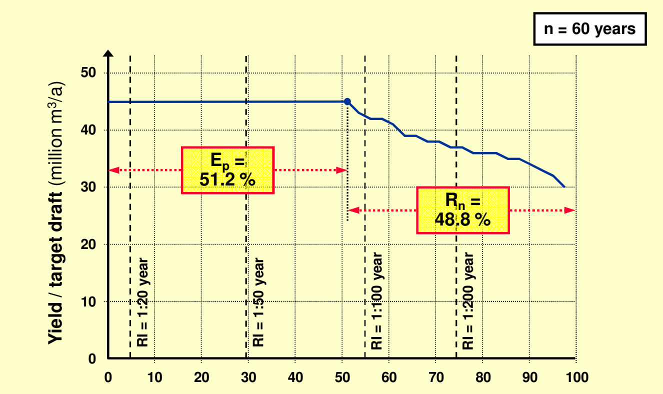
Yield results sorted



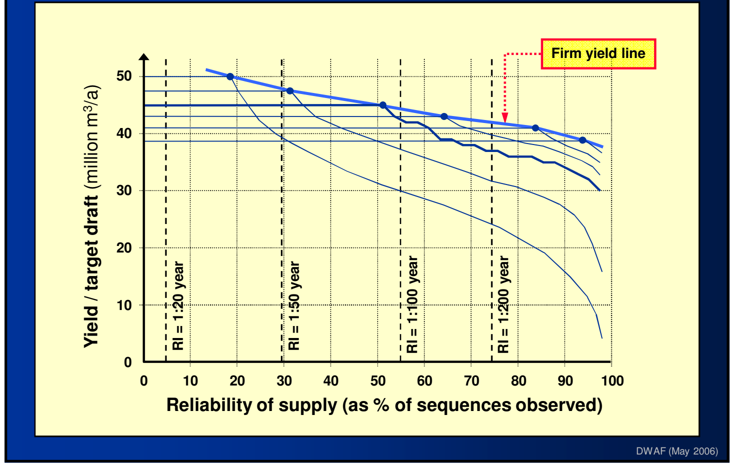
Definitions

- R_n = Long-term risk of failure
  = [Failure sequences + 1] / [Total sequences]
  = (19 + 1) / 41
  = 0.488
  = 48.8 %
- E_p = Long-term reliability of supply
  = $1 - R_n$
  = 51.2 %
- RI = Recurrence interval of failures
  = $1 / (1 - E_p^{1/n})$
  = 90.18 years

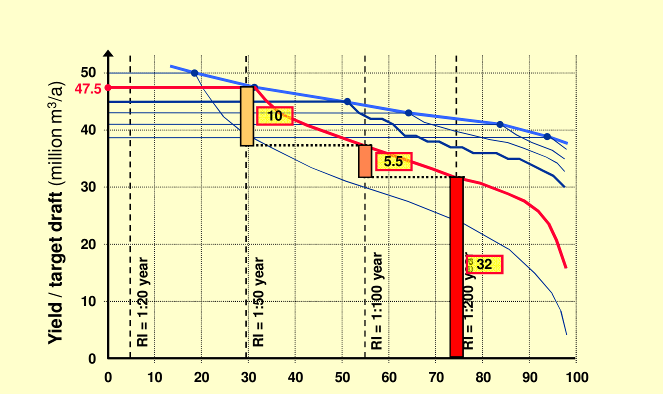
Yield-reliability curve



Family of yield-reliability curves



Available resource



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5. Group discussion

Training and Technology
Transfer Workshop

5 & 6 May 2006

End of module

Training and Technology Transfer Workshop

29 & 30 November 2010

Module 4: Water resource allocation

Commissioned by: gtz, Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with: UKaid from the Department for International Development, Australian Government Aid Program

WRP A Miya Group Company

Contents

1. Water user criteria
2. Yield reliability
3. Curtailing water users
4. Assessing availability for licensing
5. Group discussion

---

1. Water user criteria

Water user criteria

Example: Mgeni River system

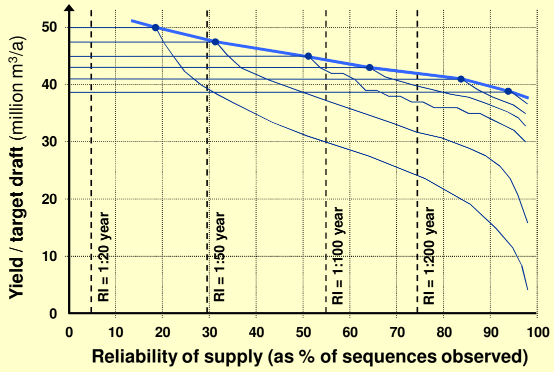
Description of water requirement components	Percentage of total requirement	Percentage allocated to indicated priority class			
		1:200 years (0.5 %)	1:100 years (1.0 %)	1:50 years (2.0 %)	1:20 years (5.0 %)
Losses	24.5	100	-	-	-
Wet industry	16.3	70	10	10	10
Dry industry	12.2	70	15	5	10
Domestic	47.0	40	20	20	20
Total	**100.0**	**63**	**13**	**12**	**12**
Priority class:		**H**	**MH**	**ML**	**L**

2. Yield reliability

Water requirements and user criteria

Water user	Assurance category (RI)	Requirement (million m^3/a)
Domestic	1:200 years	15
Environmental	1:100 years	10
Industrial	1:50 years	10
Irrigation	1:20 years	15
Total:		50

Yield-reliability curve

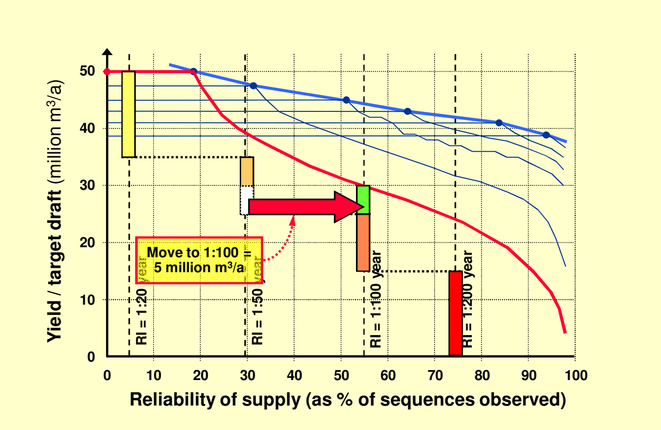


Interpretation

- How does the base yield line of the imposed target draft compare to the requirement in each assurances category?
- What does the above observation imply?
- How much of the industrial requirement (RI = 1:50) can actually be supplied at RI = 1:100?

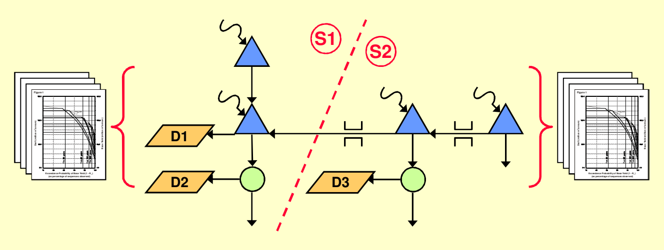
  Show this amount on the figure.

Completed figure



Short-term yield reliability

- Represent yield-reliability characteristics over short term (up to 5 years)
- Individual set for each defined subsystem



Dependent on:

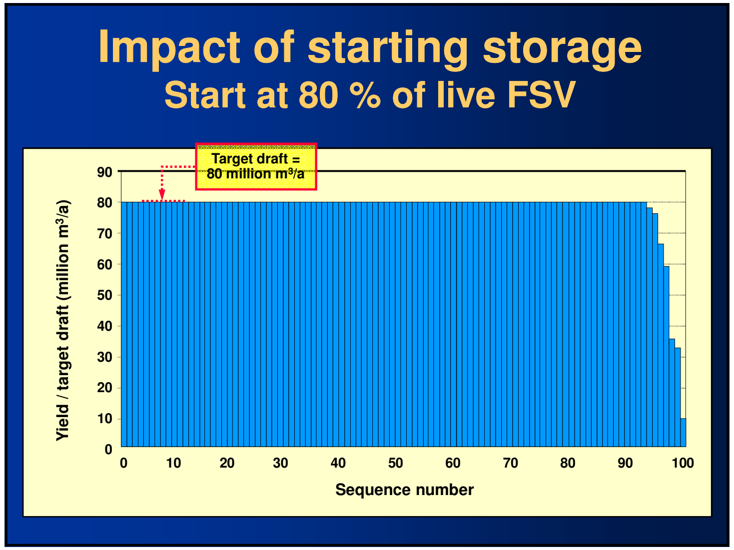
- Hydrology
- Physical characteristics of system
- Operating rule
- Uncontrolled water requirements (e.g. afforestation and diffuse irrigation)

<u>Note</u>: If any of the above changes, curves must be updated!

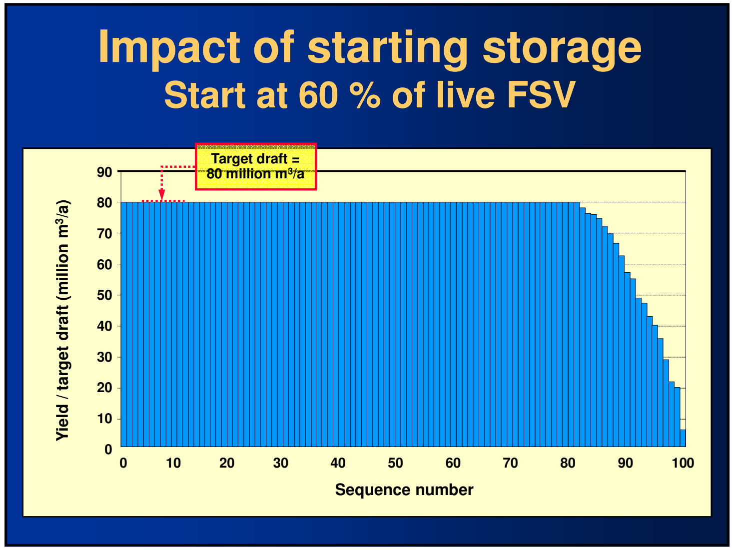
Independent of:

- Controlled water requirements
- Selected priority classification
- Inter-subsystem support definition

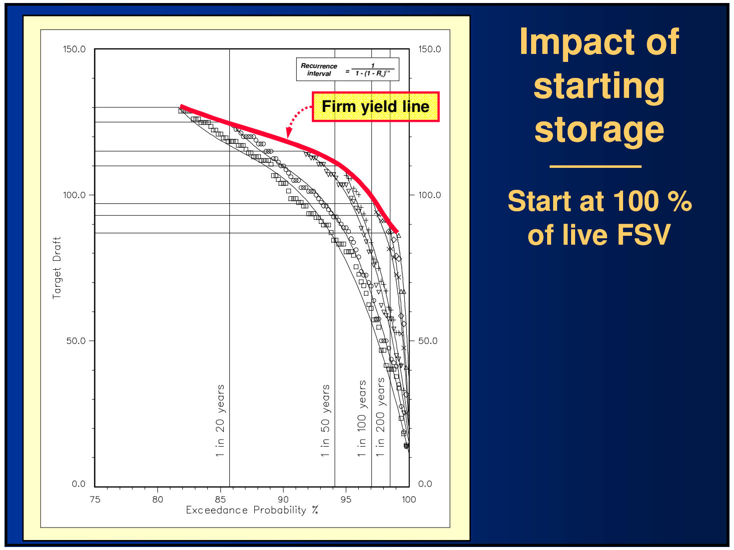
<u>Note</u>: Curves need not be updated for a change in any of the above



Impact of starting storage
Start at 80 % of live FSV

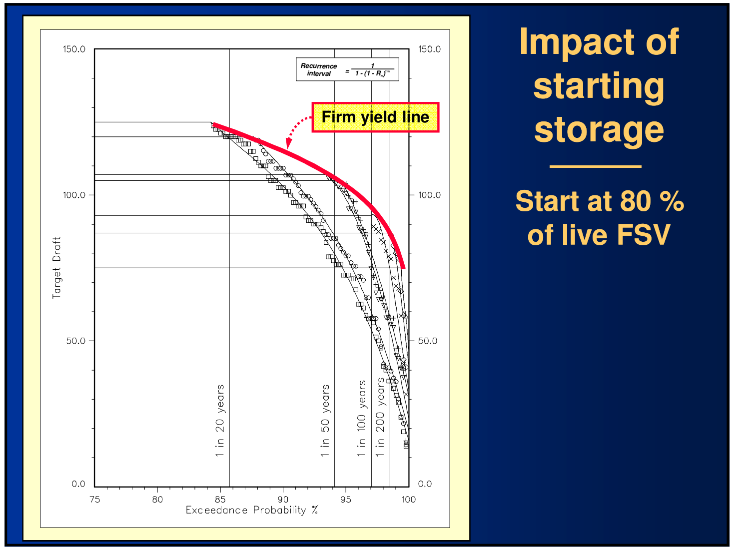


Impact of starting storage
Start at 60 % of live FSV



Impact of starting storage

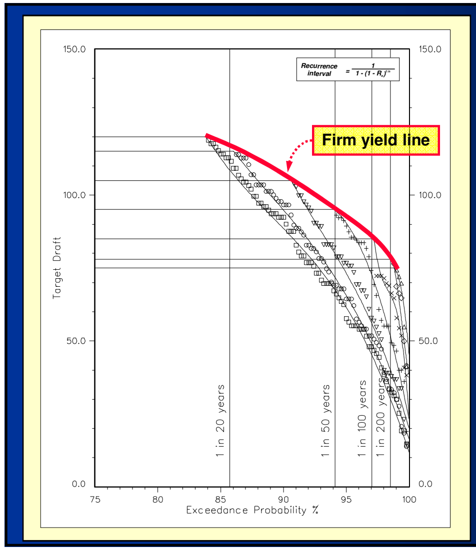
Start at 100 % of live FSV



Impact of starting storage

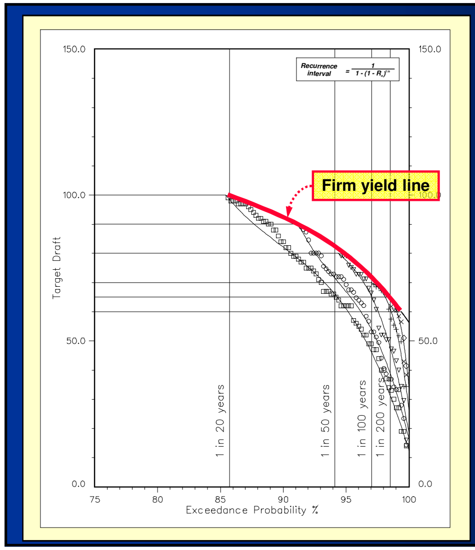
Start at 80 % of live FSV

Impact of starting storage



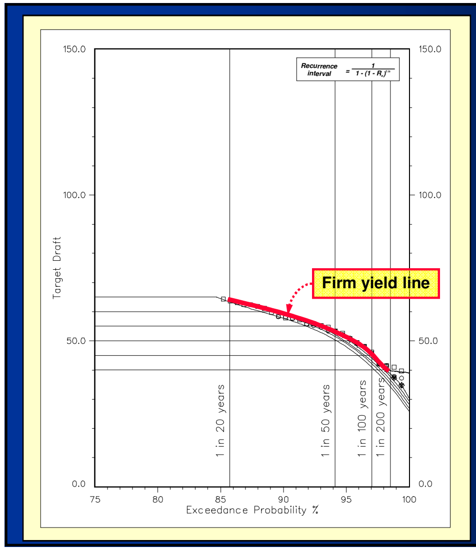
Start at 60 % of live FSV

Impact of starting storage



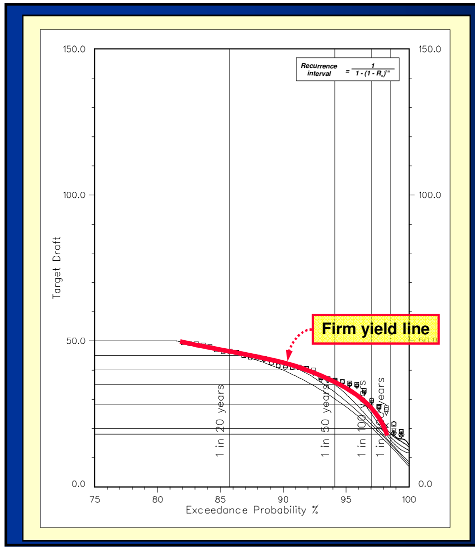
Start at 40 % of live FSV

Impact of starting storage



Start at 20 % of live FSV

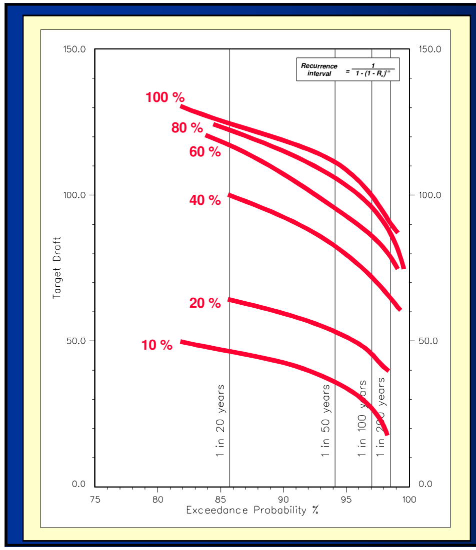
Impact of starting storage



Start at 10 % of live FSV

Impact of starting storage

Family of firm yield lines



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3. Curtailing water users

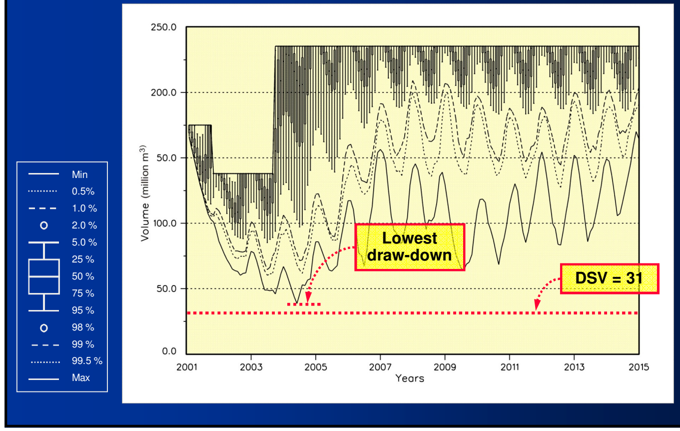
Basic principles

- Water users can be curtailed
- Based on allowable risk of non-supply
- Objective to avoid failure (zero storage volume in reservoirs)
- Water users prioritised into classes
  - Balanced allocation within a single class
  - Curtailments in low priority class first, to protect higher classes
- Curtailment is an operating rule and should always be tested and checked

---

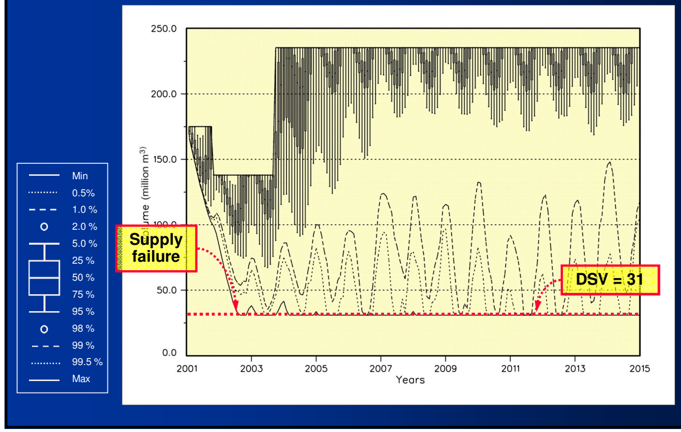
Curtailment vs. failure

Midmar Dam (with curtailments)



Curtailment vs. failure

Midmar Dam (without curtailments)



Example: Allocation decision

(1 of 3)

Demand distribution

Demand	Million m^3/a	Distribution into classes (million m^3/a)		
		Low	Medium	High
Irrigation	50	25	15	10
Domestic	70	14	21	35
Total	120	39	36	45

Example: Allocation decision

(2 of 3)

Curtailed demands (Case 1)

Demand	Million m^3/a	Distribution of curtailed demand into classes (million m^3/a)		
		Low	Medium	High
Total allocated	90	9	36	45
Prop. supplied	75 %	23 %	100 %	100 %
Allocation to individual users				
Irrigation	30.8	5.8	15	10
Domestic	59.3	3.3	21	35

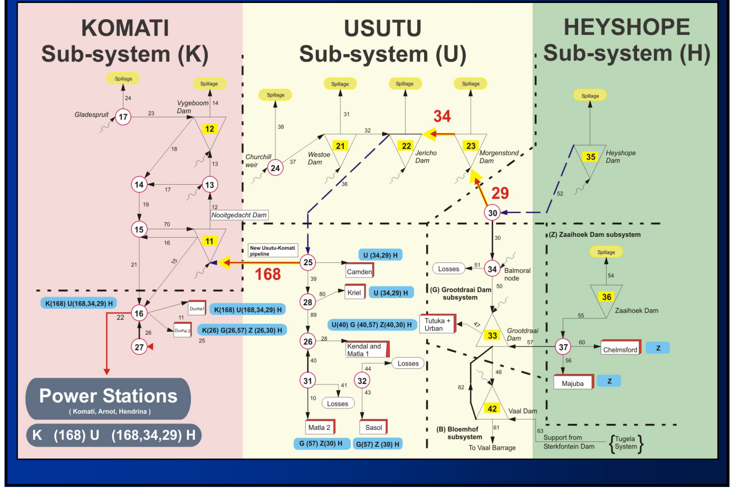
Example: Allocation decision

(3 of 3)

Curtailed demands (Case 2)

Demand	Million m^3/a	Distribution of curtailed demand into classes (million m^3/a)		
		Low	Medium	High
Total allocated	60	0	15	45
Prop. supplied	50 %	0 %	42 %	100 %
Allocation to individual users				
Irrigation	16.3	0	6.3	10
Domestic	43.7	0	8.7	35

Example: user support definition



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5. Demonstration 1: Water resource allocation

Purpose and methodology

Purpose:

- Apply user priority classification table and short-term yield curves
- Undertake allocation calculations

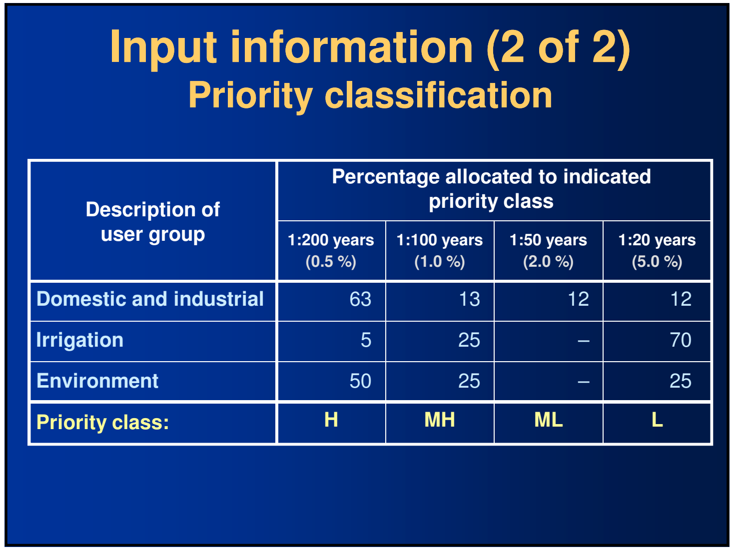
Methodology:

- Midmar Dam sub-system (dam not raised)
- Storage at 80 % of live FSV
- 2002 demands (*2001 Planning Analysis*)

Input information (1 of 2)

Water requirements

User description	User group	Demand (million m^3/a)
Pietermaritzburg and Edendale	Dom. and industrial	40.51
Pipes 57, 61 and others	Dom. and industrial	29.34
Albert Falls irrigation	Irrigation	2.95
Midmar compensation releases	Environment	28.40
TOTAL		101.20



Input information (2 of 2)

Priority classification

Description of user group	Percentage allocated to indicated priority class			
	1:200 years (0.5 %)	1:100 years (1.0 %)	1:50 years (2.0 %)	1:20 years (5.0 %)
Domestic and industrial	63	13	12	12
Irrigation	5	25	–	70
Environment	50	25	–	25
Priority class:	H	MH	ML	L

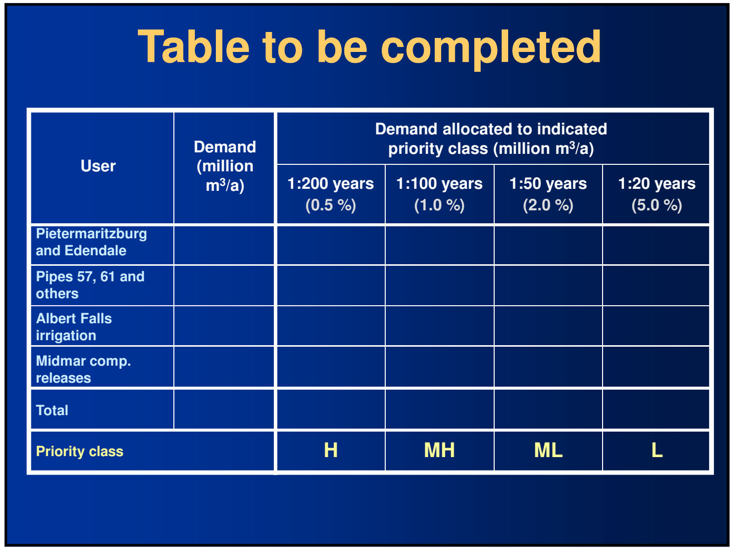


Table to be completed

User	Demand (million m^3/a)	Demand allocated to indicated priority class (million m^3/a)			
		1:200 years (0.5 %)	1:100 years (1.0 %)	1:50 years (2.0 %)	1:20 years (5.0 %)
Pietermaritzburg and Edendale					
Pipes 57, 61 and others					
Albert Falls irrigation					
Midmar comp. releases					
Total					
Priority class		H	MH	ML	L

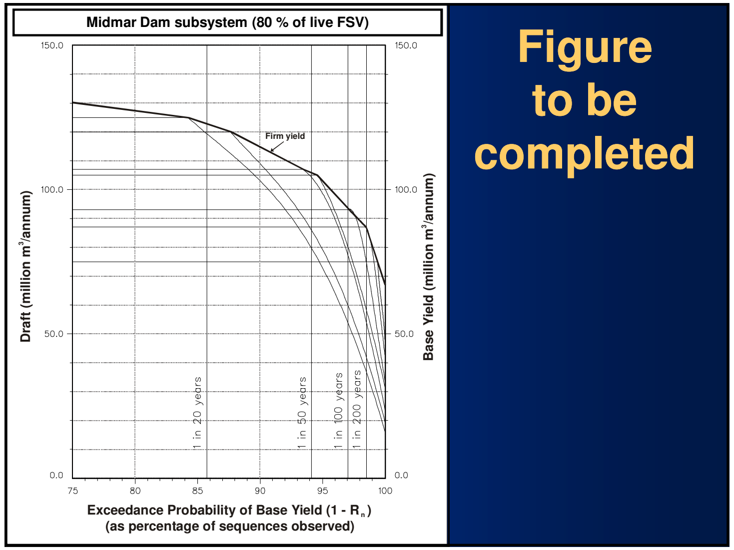
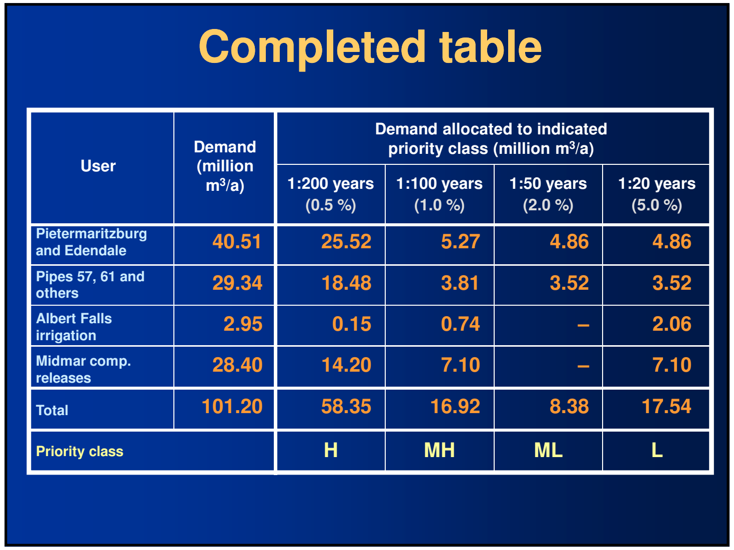
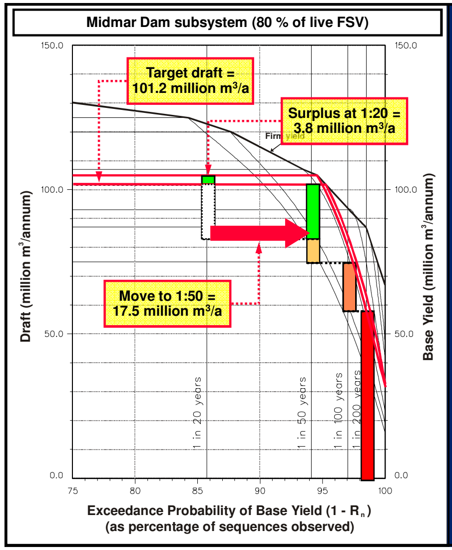


Figure to be completed



Completed table

User	Demand (million m^3/a)	Demand allocated to indicated priority class (million m^3/a)			
		1:200 years (0.5 %)	1:100 years (1.0 %)	1:50 years (2.0 %)	1:20 years (5.0 %)
Pietermaritzburg and Edendale	40.51	25.52	5.27	4.86	4.86
Pipes 57, 61 and others	29.34	18.48	3.81	3.52	3.52
Albert Falls irrigation	2.95	0.15	0.74	–	2.06
Midmar comp. releases	28.40	14.20	7.10	–	7.10
Total	101.20	58.35	16.92	8.38	17.54
Priority class		H	MH	ML	L



Completed figure

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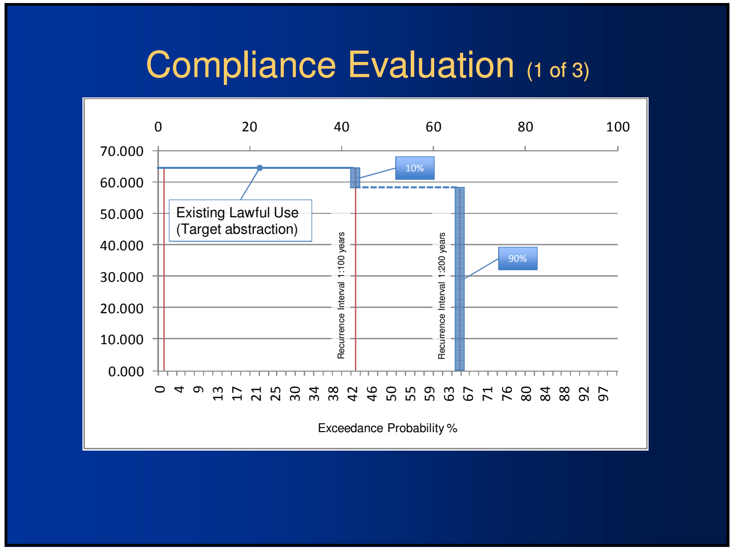
4. Assessing availability for licensing

Method

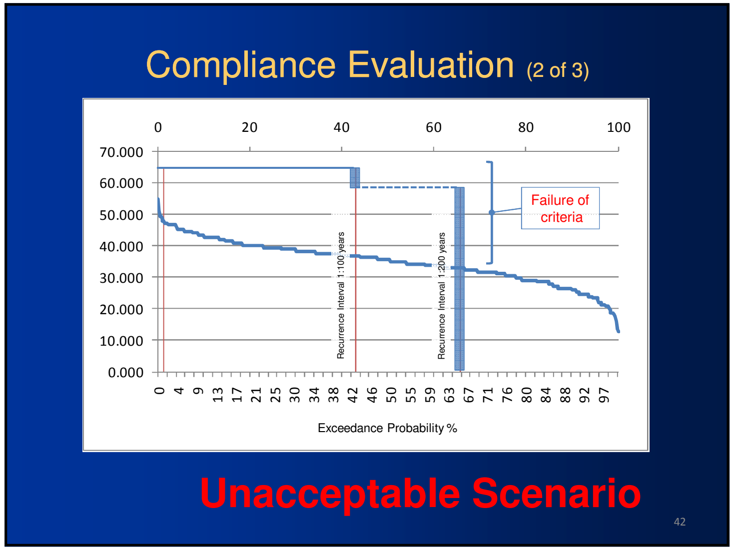
- Using risk (reliability) as indicator
- Assess multi abstractions
- Apply user reliability criteria

Assurance of Supply Criteria

Water use sector	**Percent of the water use that must be supplied at the indicated recurrence interval or risk of failure (%)**				
	1 in 200 years	**1 in 100 years**	**1 in 50 years**	**1 in 20 years**	**1 in 4 years**
	0.5%	**1%**	**2%**	**5%**	**25%**
Irrigation			50%		50%
Urban	30%	30%		30%	10%
Industrial 1 (1)	70%	20%		10%	
Industrial 2	90%	10%			

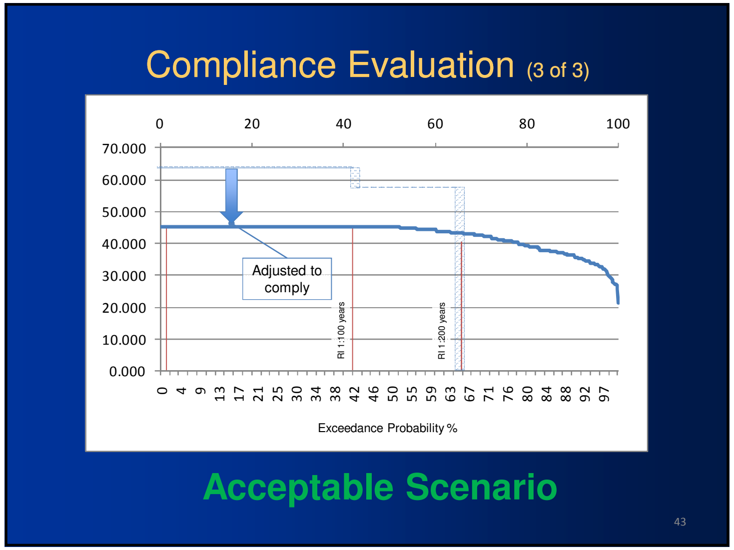


Compliance Evaluation (1 of 3)



Compliance Evaluation (2 of 3)

Unacceptable Scenario



Compliance Evaluation (3 of 3)

Acceptable Scenario

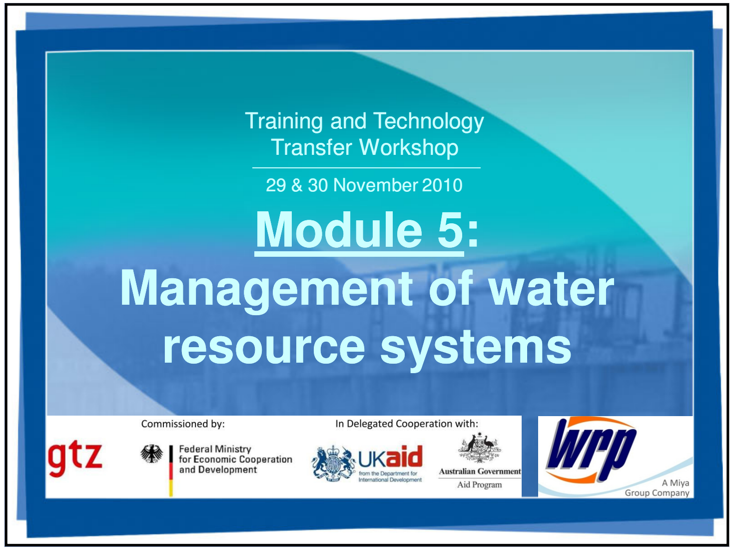
Example Application

6. Group discussion

Training and Technology Transfer Workshop

5 & 6 May 2006

End of module



Training and Technology Transfer Workshop

29 & 30 November 2010

Module 5:
Management of water resource systems

Commissioned by:

gtz

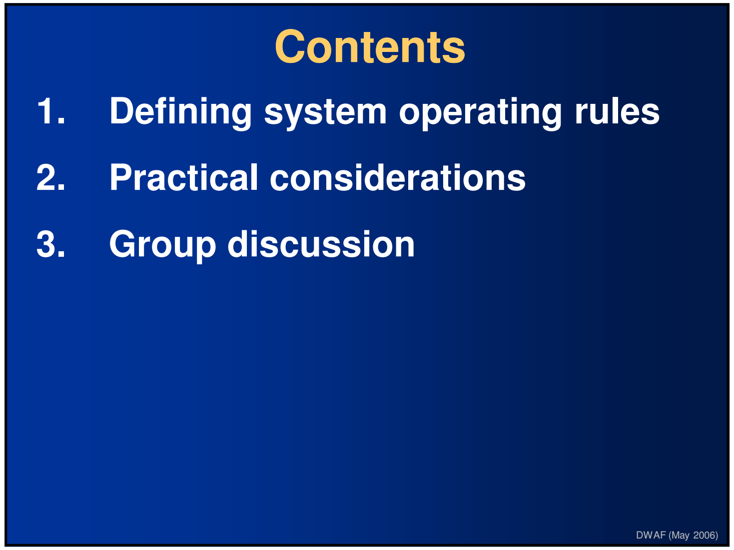
Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with:

UKaid from the Department for International Development

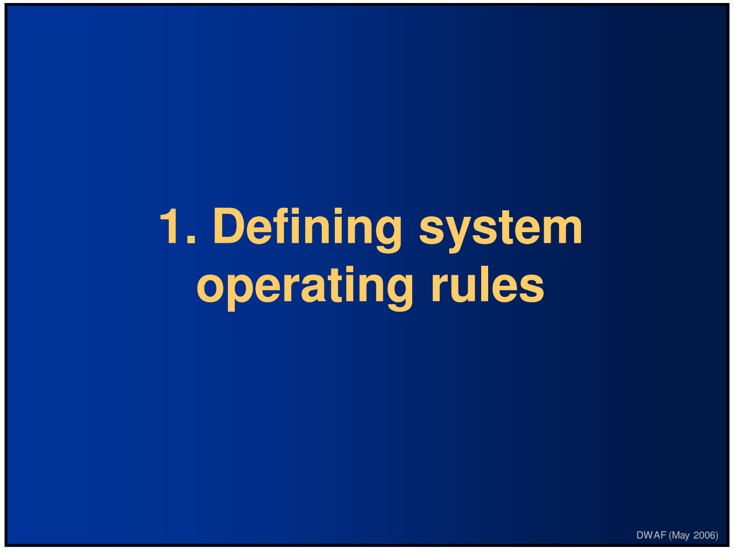
Australian Government Aid Program

wrp A Miya Group Company

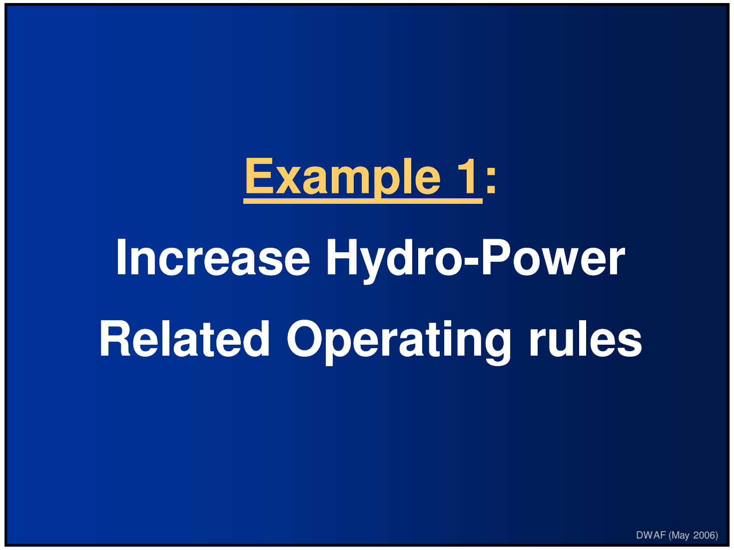


Contents

1. Defining system operating rules
2. Practical considerations
3. Group discussion



1. Defining system operating rules



Example 1:

Increase Hydro-Power Related Operating rules

Background (1 of 2)

- **Purpose**:
  To implement rules that will maximize the hydro-power benefit at Gariep & Vanderkloof dams without jeopardizing the assurance of supply to the users.

- **Decision criteria**:
  Should not have negative impact on long-term and short-term reliability of supply

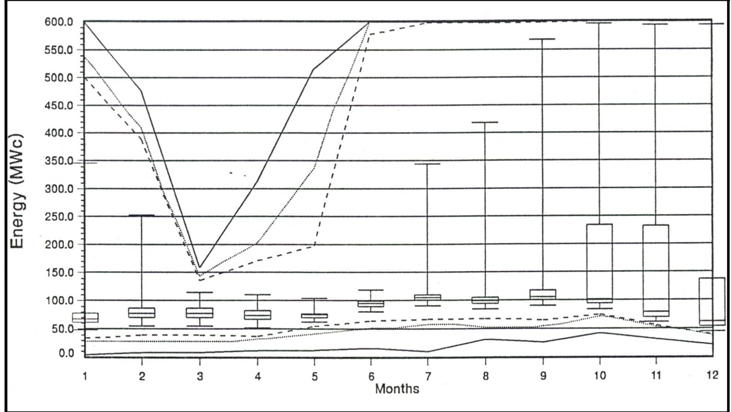
- **Example**:
  - Orange River system – Orange River Project
  - *Annual Operating Analyses* (2008/09)

Background (2 of 2)

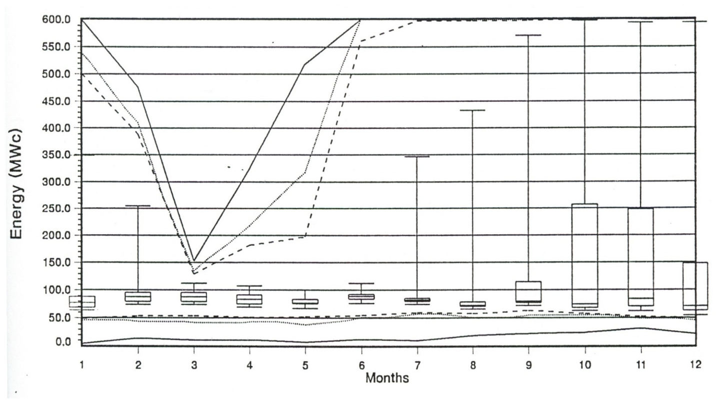
- **Options investigated**:
  - Reduce non-generating spillage at both dams
  - Improve monthly distribution pattern of generated energy
  - Utilise short-term surplus in the system to generate Hydro Power

- **Methods implemented**:
  - Introduce storage control curves (SCC)
  - Use mirror image of Vanderkloof release pattern and impose on Gariep releases
  - Use annual operating analysis (WRPM) to determine short-term surplus or deficit in system.

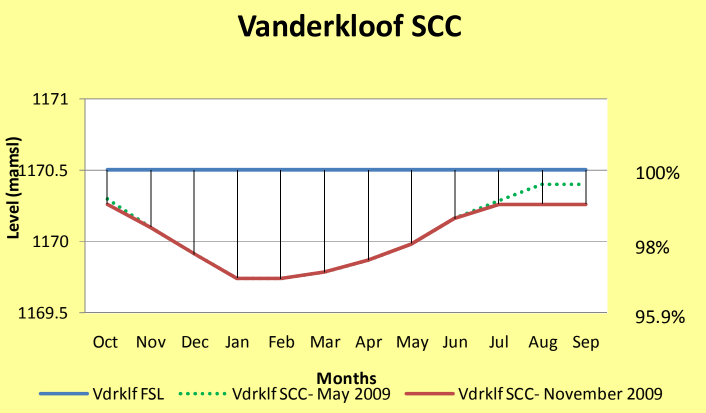
Energy generated with existing distribution patterns



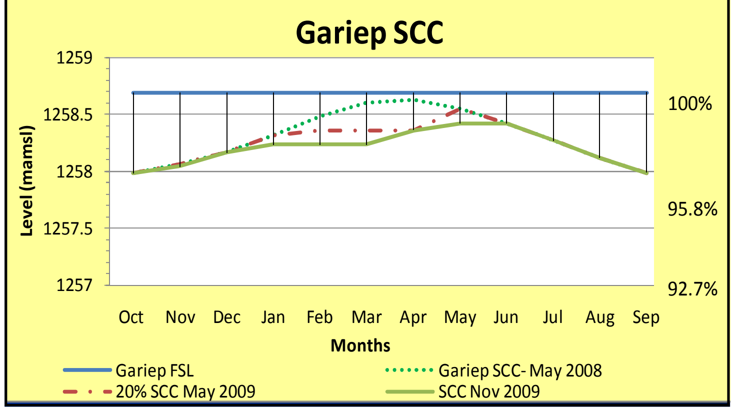
Energy generated with mirror image of release pattern



Vanderkloof Storage Control Curve (SCC)



Gariep Storage Control Curve (SCC)



Short-term surplus ORP

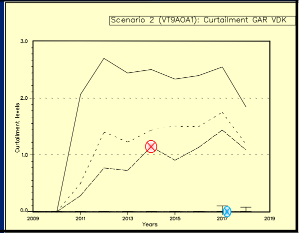
- <u>Use Long-term stochastic analysis</u>

  1000 sequences of 15 years each constant development level

Surplus Volume (million m^3)	Risk of curtailments for different curtailment levels.		
	Level 1 (5%)	Level 2 (1%)	Level 3 (0.5%)
140	2.03	0.95	0.19

- <u>Use Short-term projection</u>

  Curtailment criteria violated first time by 2014



<u>Example 2</u>:

Appropriate blending rule

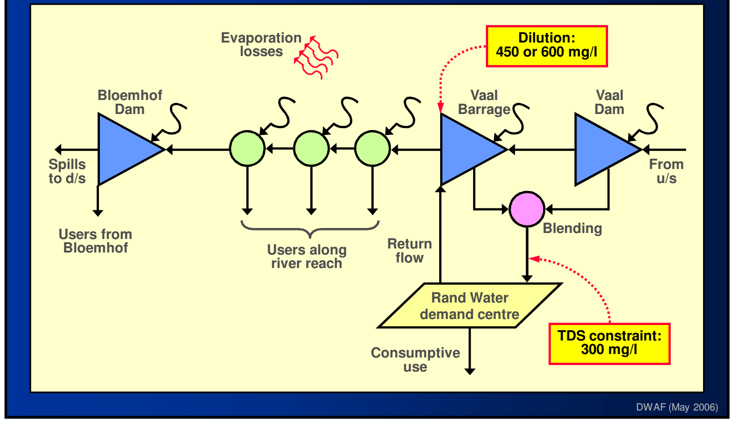
DWAF (May 2006)

Background (1 of 3)

- **Purpose**:
  Test the possibility of deviating from the long-term blending rule for the purpose of improving, over the short-term, the quality of supplied water.
- **Decision criteria**:
  Should not have negative impact on long-term reliability of supply
- **Example**:
  - Integrated Vaal River system
  - *Annual Operating Analyses* (2000/01)

Background (2 of 3)

- **System configuration**:

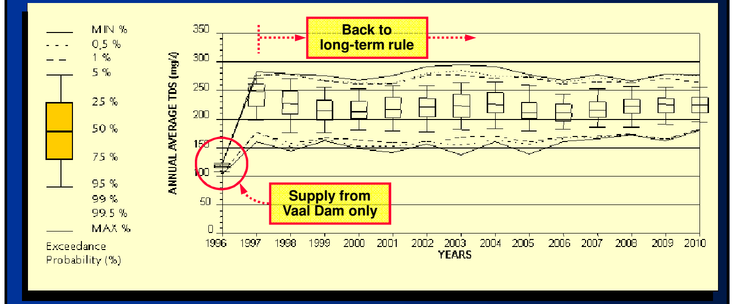


Background (3 of 3)

- **Methodology**:
  Analyse various scenarios and compare the relative projected TDS concentrations:
  - Scenario 1: Long-term rule
    - Rand Water supplied from Vaal Barrage as priority
    - Blend with Vaal Dam water to not exceed 300 mg/l
  - Scenario 2: Revised rule
    - First 12 months: 600 mg/l dilution in Vaal Barrage and Rand Water supplied from Vaal Dam only
    - After 12 months revert back to long-term rule

Annual average TDS

Rand water supply
(Scenario 2)

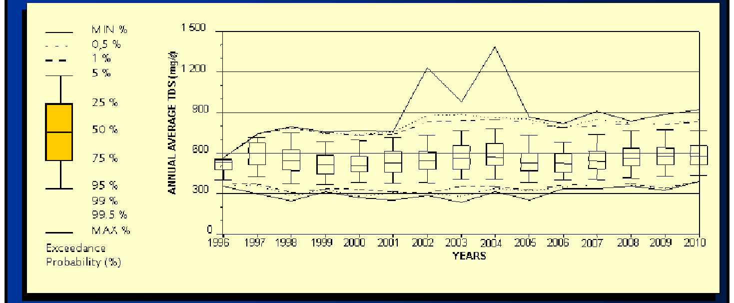


Back to long-term rule

Supply from Vaal Dam only

Annual average TDS

Users downstream of Vaal Barrage (Scenario 2)



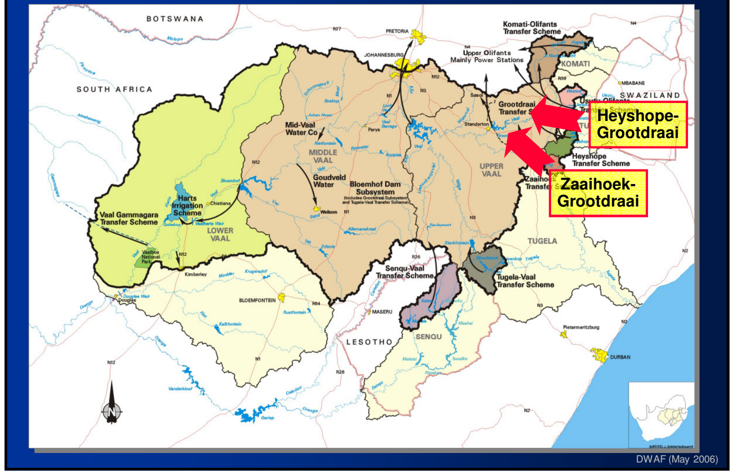
Example 3:

Saving of operational costs

Background (1 of 4)

- **Purpose**:
  Test the possibility of deviating from the long-term operating rule for the purpose of reducing operating costs. Note:
  - Can only be applied during periods of high system storage
  - Decision is based on current system information
- **Decision criteria**:
  Should not have negative impact on long-term reliability of supply
- **Example**:
  - Integrated Vaal River system
  - *Annual Operating Analyses* (2000/01)

Background (2 of 4)



Background (3 of 4)

- **Methodology:**

  Analyse 2 scenarios and compare the relative projected pumping costs:

  - Scenario 1: Long-term rule
    - Transfer until Grootdraai above 90 % of live FSV
  - Scenario 2: Revised rule
    - From May 2000 for 12 months
    - Transfer only until Grootdraai above 75 % of live FSV
    - After 12 months revert back to long-term rule

Background (4 of 4)

- **Methodology (cont.):**

  A cost calculation is undertaken as follows:

  - Run 2 scenarios as previously described
  - Undertake 1 000 sequences
  - Multiply unit cost of transfer with transferred volumes, for a single sequence for both scenarios
  - Calculate difference in cost between two scenarios, for that sequence
  - Repeat for both transfer links and add results, for that sequence
  - Repeat for all sequences and derive probability distribution, for both transfer links and for total

---

Actual projected savings

Revised compared with long-term rule (Over 5-year period)

Description of transfer	Saving at indicated exceedance probability (%)[1] (X R1 million)										
	99.5	99	98	95	75	50	25	5	2	1	0.5
Heyshope to Grootdraai	0.6	0.8	1.0	1.7	4.1	5.4	6.9	10.4	11.5	12.5	13.7
Zaaihoek to Grootdraai	(0.5)	(0.4)	(0.1)	0.1	1.0	1.8	2.6	3.8	4.2	4.5	5.3
Total[2]	0.9	1.2	1.8	2.8	5.7	7.3	9.1	13.1	14.7	15.8	17.4

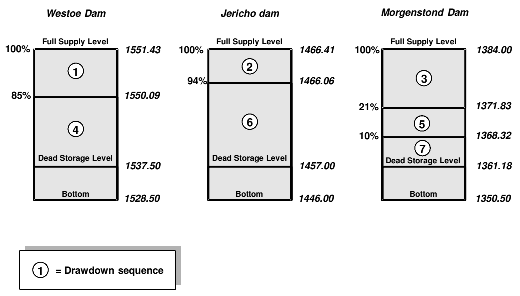
Notes: (1) Values in brackets indicate a cost increase.
(2) Not the sum of columns.

Example 4:

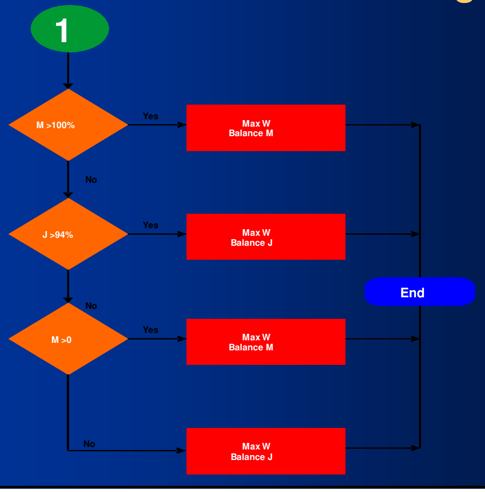
Operational decision flow diagram

Usutu draw-down sequence

Fig 2.1 Inter-reservoir operating rule:
Usutu subsystem



Operational flow decision diagram



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2. Practical considerations

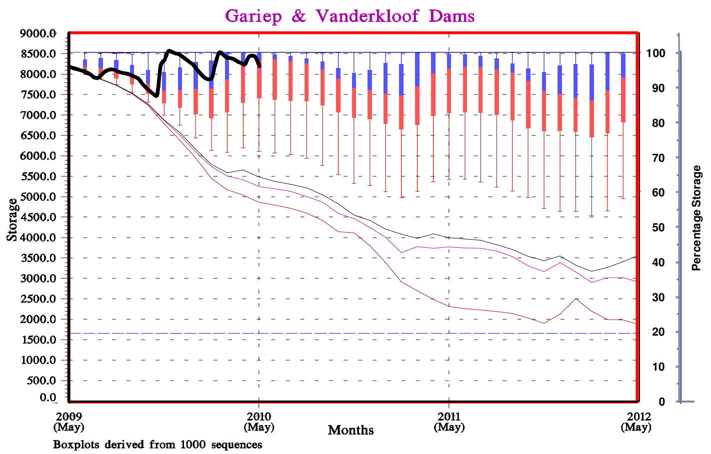
Example 1:

Monitoring system operation

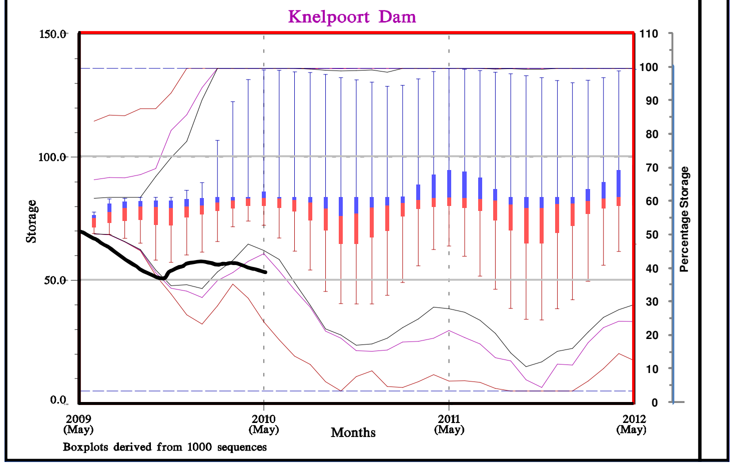
General aspects

- Compare simulated and actual recorded behavior of system variables
- Reservoir trajectories
- Transfer volumes
- Water requirements

Gariep & Vanderkloof Dams



Knellpoort Dam



Example 2:

Monitoring transfer volumes

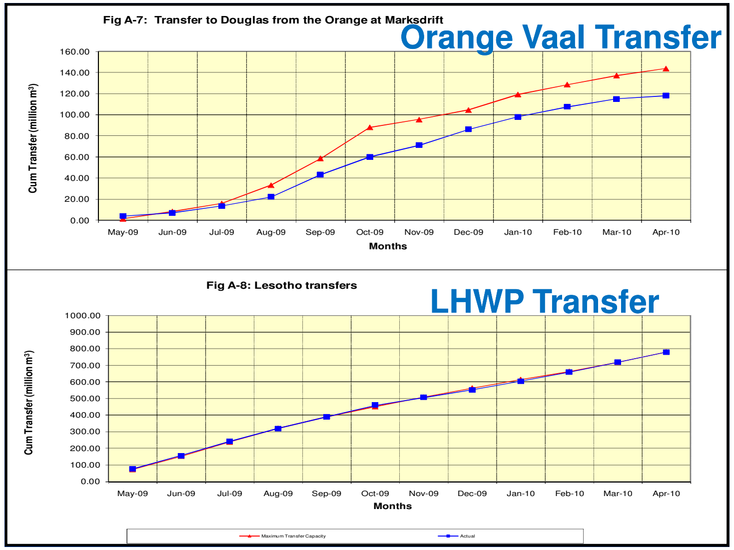
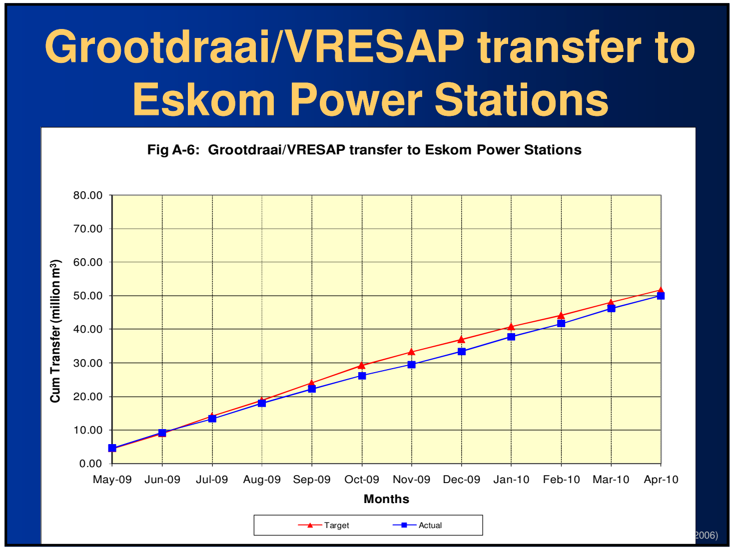


Fig A-7: Transfer to Douglas from the Orange at Marksdrift

Orange Vaal Transfer

Fig A-8: Lesotho transfers

LHWP Transfer

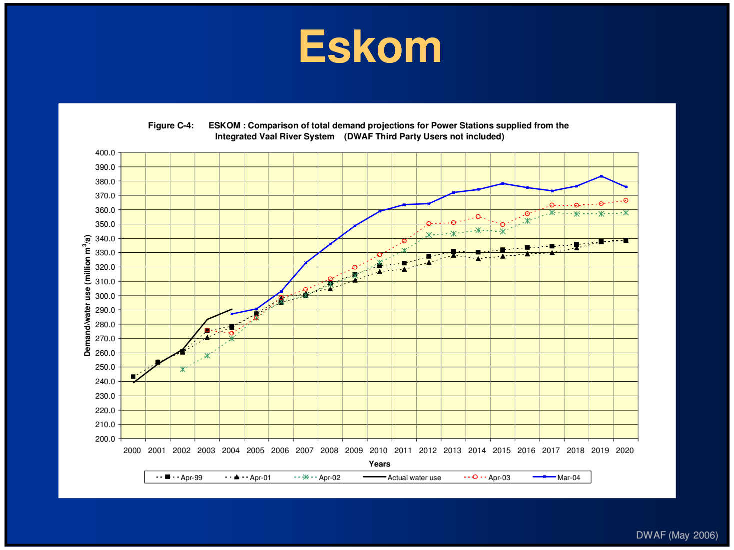


Grootdraai/VRESAP transfer to Eskom Power Stations

Fig A-6: Grootdraai/VRESAP transfer to Eskom Power Stations

Example 3:

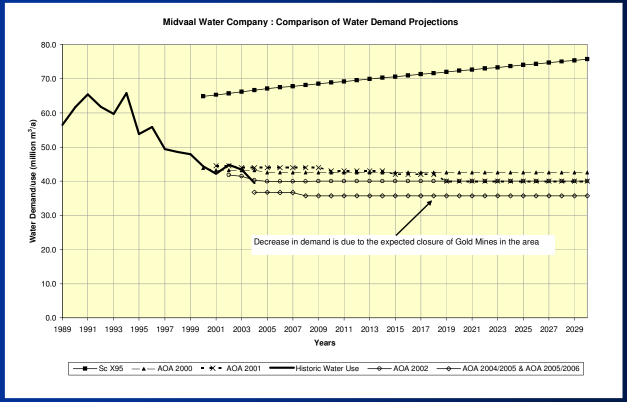
Monitoring water requirements



Eskom

Figure C-4: ESKOM : Comparison of total demand projections for Power Stations supplied from the Integrated Vaal River System (DWAF Third Party Users not included)

Midvaal

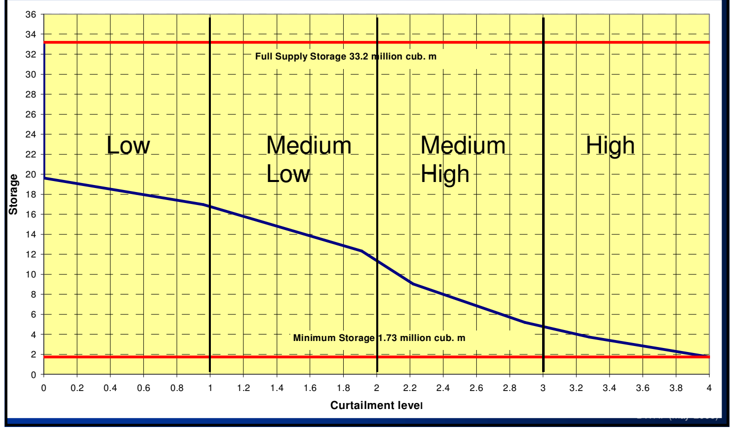


Example 4:

Simplified curtailment graphs

Simplified curtailment graph

(Luvhuvhu, Vondo/Tshakuma system)



Example 6:

Curtailment Planning

Background

- **Purpose**:

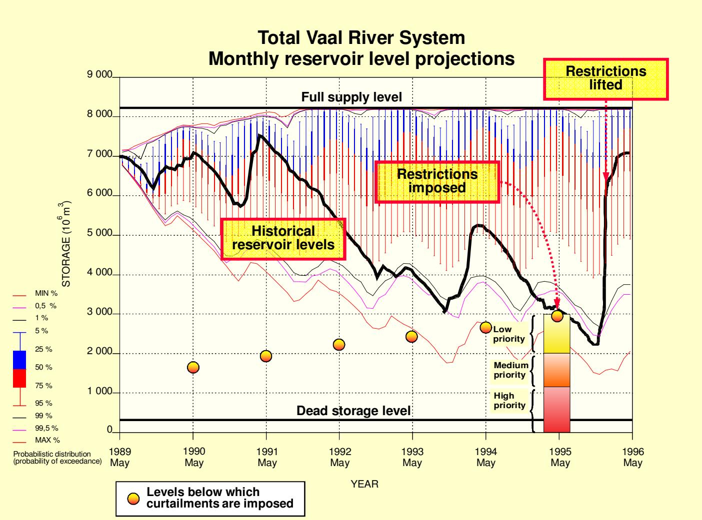
  Identify circumstances in a system warranting the implementation, as well as the lifting of restrictions

- **Example**:
  - Integrated Vaal River system
  - 1993 to 1995

- **Methodology**:

  Monitor the behaviour of a system by plotting, on the graph of projected system volumes, the actual system volume trajectory

---



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3. Group discussion

Training and Technology Transfer Workshop

29 & 30 November 2010

End of module

Training and Technology
Transfer Workshop

29 & 30 November 2010

Module 6:
Intervention planning

Commissioned by:

gtz

Federal Ministry
for Economic Cooperation
and Development

In Delegated Cooperation with:

UKaid
from the Department for International Development

Australian Government
Aid Program

wrp

A Miya
Group Company

Contents

1. Introduction
2. Water requirement scenarios
3. Undertaking detailed phasing analyses
4. Group discussion

---

1. Introduction

General

To determine, over a planning horizon:

- Need for intervention
- Timing of intervention
- Implementation schedules
- Filling times

Within context of:

- Growing water requirements
- User criteria of acceptable risks
- Salinity-related system constraints

Aspects of intervention planning

- Augmentation planning
- WC&DM
- Water quality
- Ecological Reserve
- Water Quality Management Measures

WC&DM

- Engineering
- Institutional responsibilities and objectives (local government)
- Political buy-in
- Financing
- Social influence
- Stakeholder engagement
- Tariffs

Augmentation planning

- Engineering aspects:
  - Design
  - Economics
- Social and environmental impacts of intervention
- Institutional arrangements (central government)
- Financial considerations
- Stakeholder engagement

Water quality

- Water should be fit for use
- Managed by setting Water Quality Objectives
- Integrated management essential
- Management Measures
  - Operational – blending/dilution
  - Waste Discharge Charge System
  - Treatment (discharge or abstraction)

2. Water requirement scenarios

General

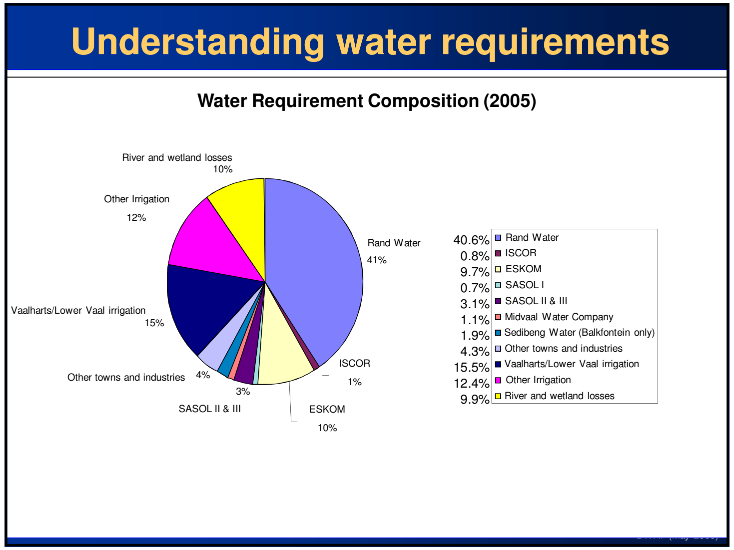
- Need future projections for twenty year planning period – long lead time of large schemes, 10 to 15 years
- Municipalities usually only provide short term projections
- Therefore DWAF studies determine scenarios
- Have to understand the relationship between water requirements and return flow
- Need to know where in a system the return flows will become available

Drivers of water requirements

- Population growth and migration – demographic assessment
- Economic growth
- Changes in economic activities (industrial vs. service)
- Service level changes
- Water Conservation and Water Demand Management
- Technology (irrigation systems)
- Water tariff
- Legislation and government policies

Example 1:

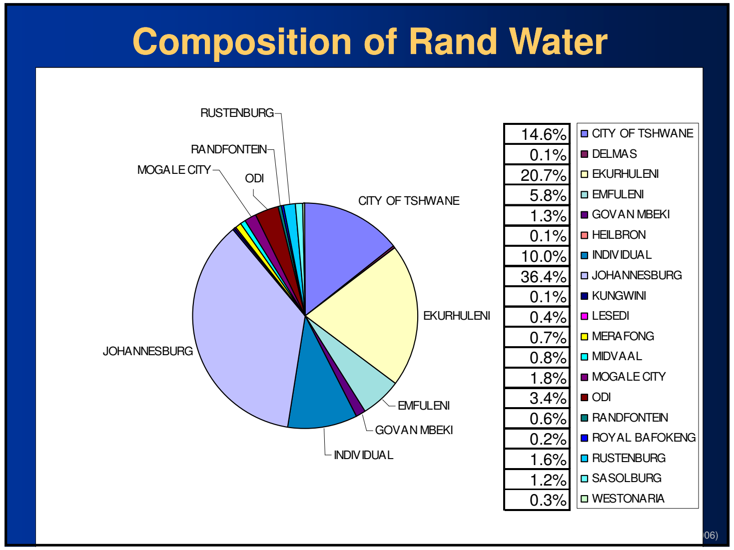
Vaal River system



Understanding water requirements

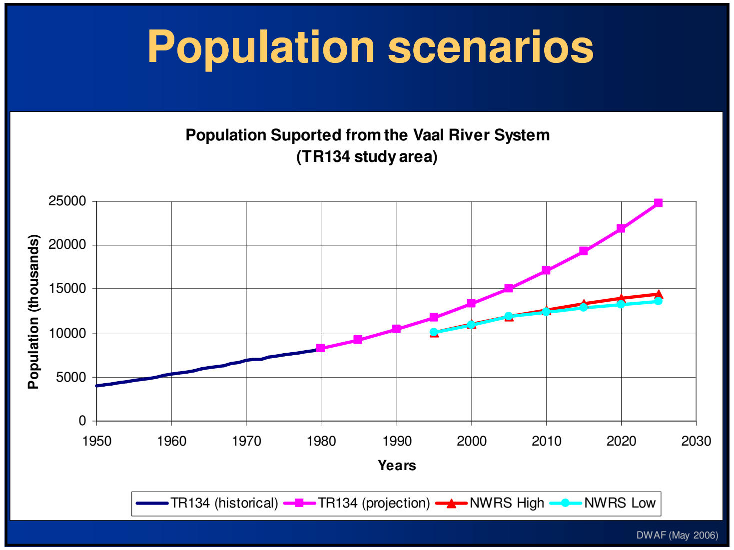
Water Requirement Composition (2005)

40.6%	■ Rand Water
0.8%	■ ISCOR
9.7%	■ ESKOM
0.7%	■ SASOL I
3.1%	■ SASOL II & III
1.1%	■ Midvaal Water Company
1.9%	■ Sedibeng Water (Balkfontein only)
4.3%	■ Other towns and industries
15.5%	■ Vaalharts/Lower Vaal irrigation
12.4%	■ Other Irrigation
9.9%	■ River and wetland losses



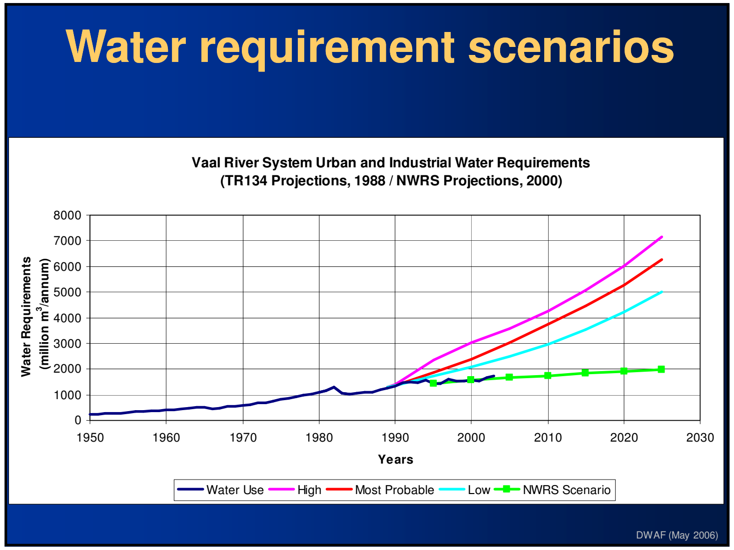
Composition of Rand Water

14.6%	■ CITY OF TSHWANE
0.1%	■ DELMAS
20.7%	■ EKURHULENI
5.8%	■ EMFULENI
1.3%	■ GOVAN MBEKI
0.1%	■ HEILBRON
10.0%	■ INDIVIDUAL
36.4%	■ JOHANNESBURG
0.1%	■ KUNGWINI
0.4%	■ LESEDI
0.7%	■ MERAFONG
0.8%	■ MIDVAAL
1.8%	■ MOGALE CITY
3.4%	■ ODI
0.6%	■ RANDFONTEIN
0.2%	■ ROYAL BAFOKENG
1.6%	■ RUSTENBURG
1.2%	■ SASOLBURG
0.3%	■ WESTONARIA



Population scenarios

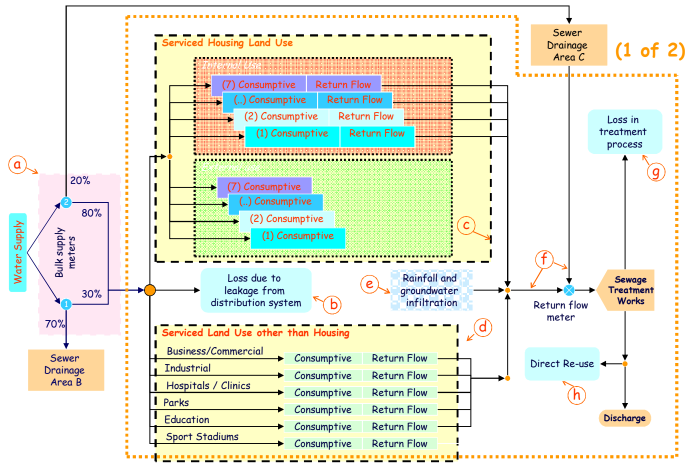
Population Suported from the Vaal River System (TR134 study area)



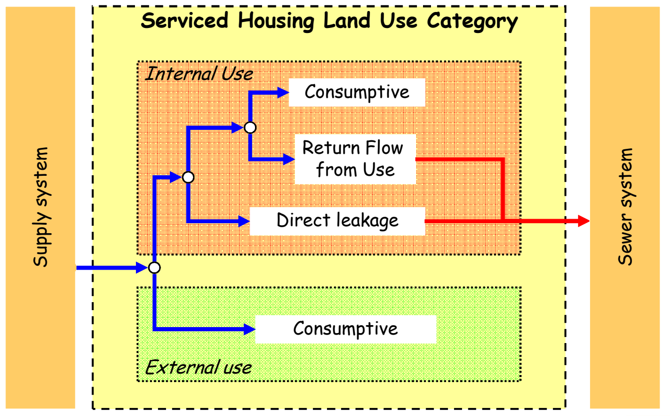
Water requirement scenarios

Vaal River System Urban and Industrial Water Requirements (TR134 Projections, 1988 / NWRS Projections, 2000)

Conceptual model (1 of 2)



Conceptual model (2 of 2)



3. Undertaking detailed phasing analyses

WRPM capabilities

- Variety of physical system features
- Flexible configuration (not hard coded)
- Complex systems, multiple reservoirs
- Multiple users and assurance levels
- Flexible operating rule definitions
- Dynamic changes over time
- Rigorous stochastic flow generation
- Software forward compatible

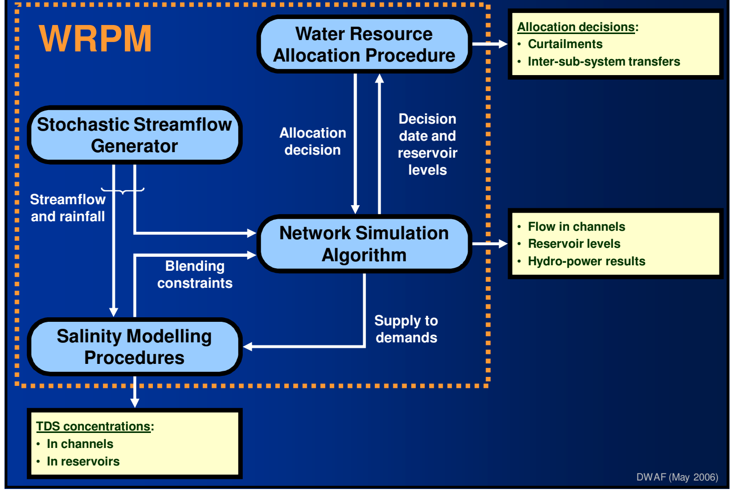
WRP limitations

- High level of experience
- Effort for configuration and maintenance
- Extensive testing and verification
- Graphical output via post-processors
- No automatic optimisation (scenarios)
- No antecedent flow conditions
- Few specialists for maintenance

Basic components of the WRPM

- Network simulation algorithm
- Stochastic streamflow generator
- Water resource allocation procedure
- Salinity modelling procedures

Linkages between WRPM components



WRPM

Water Resource Allocation Procedure

<u>Allocation decisions</u>:
- Curtailments
- Inter-sub-system transfers

Stochastic Streamflow Generator

Allocation decision

Decision date and reservoir levels

Streamflow and rainfall

Network Simulation Algorithm

- Flow in channels
- Reservoir levels
- Hydro-power results

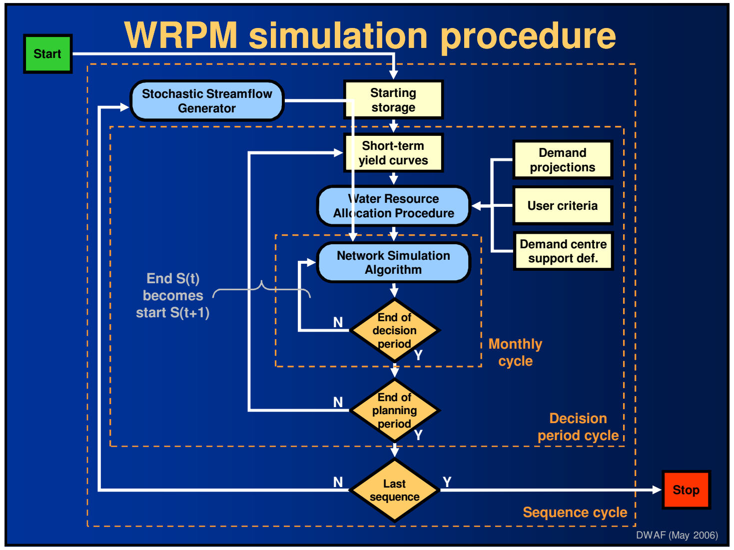
Blending constraints

Supply to demands

Salinity Modelling Procedures

<u>TDS concentrations</u>:
- In channels
- In reservoirs

WRPM simulation procedure



Start

Stochastic Streamflow Generator

Starting storage

Short-term yield curves

Demand projections

Water Resource Allocation Procedure

User criteria

Demand centre support def.

Network Simulation Algorithm

End S(t) becomes start S(t+1)

N

End of decision period

Y

Monthly cycle

N

End of planning period

Y

Decision period cycle

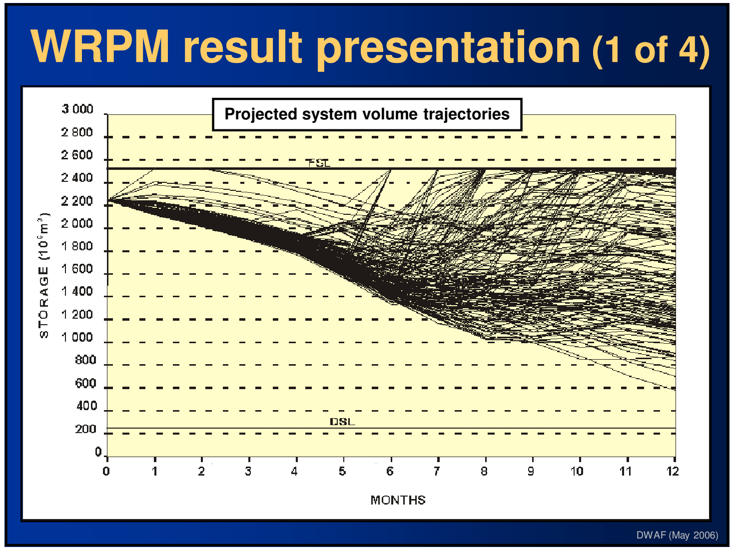
N

Last sequence

Y

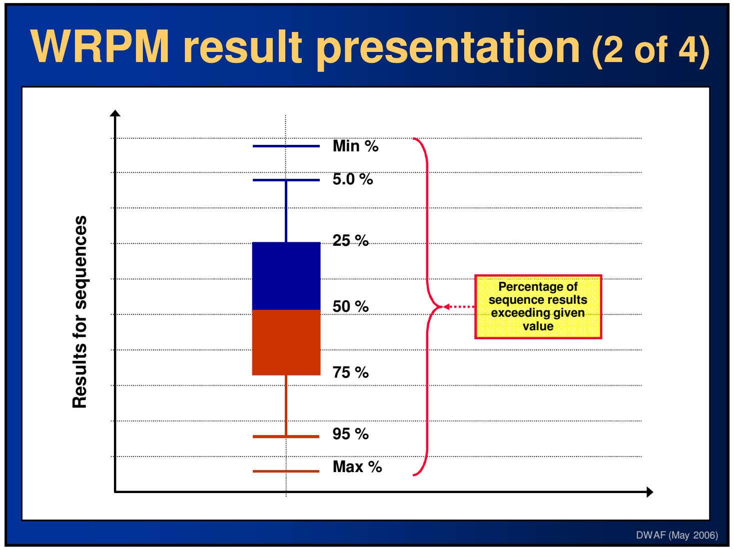
Stop

Sequence cycle



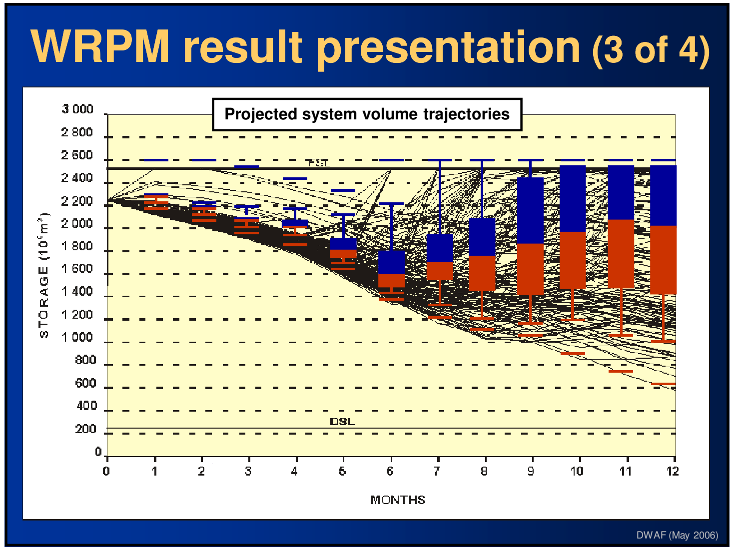
WRPM result presentation (1 of 4)

DWAF (May 2006)



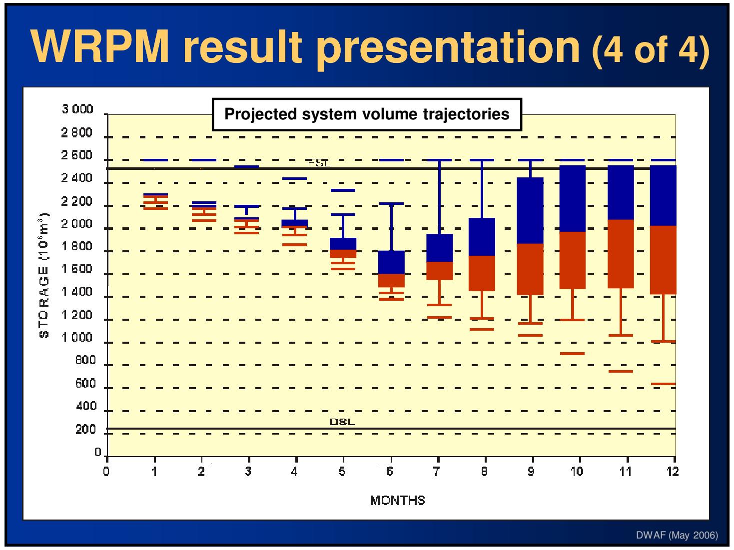
WRPM result presentation (2 of 4)

DWAF (May 2006)



WRPM result presentation (3 of 4)

DWAF (May 2006)



WRPM result presentation (4 of 4)

DWAF (May 2006)

Main WRPM results (1 of 2)

Projection plots of:

- Monthly / annual reservoir volumes
  (also with historically observed trajectory)
- Monthly / annual system volumes
- Annual total demand vs. supply
- Annual curtailment levels

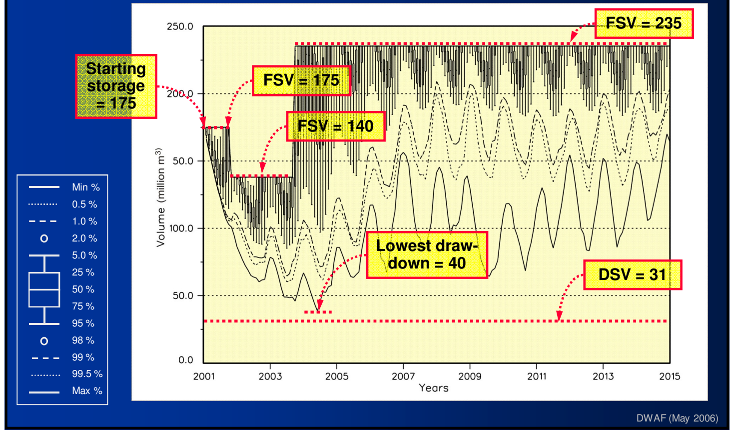
Main WRPM results (2 of 2)

Projection plots of:

- Monthly / annual avg. channel flows
- Monthly / annual avg. TDS concentrations
  (channels and reservoirs)
- Hydropower:
  - Energy
  - Power

Monthly reservoir volumes

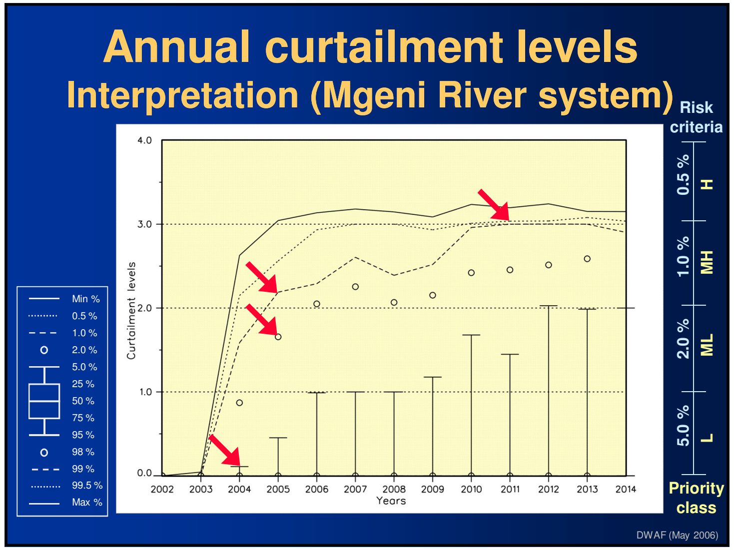
Example: Midmar Dam



Monthly reservoir volumes

Interpretation

- Volume at full supply level:
  - Current = ± 175 mill m^3
  - Lowered = ± 140 mill m^3
  - Raised = ± 235 mill m^3
- Vol. at dead storage level = ± 31 mill m^3
- Starting storage vol. = ± 175 mill m^3
- Lowest draw-down vol. = ± 40 mill m^3
- What is the minimum live storage at the 99.5 % exceedance probability?

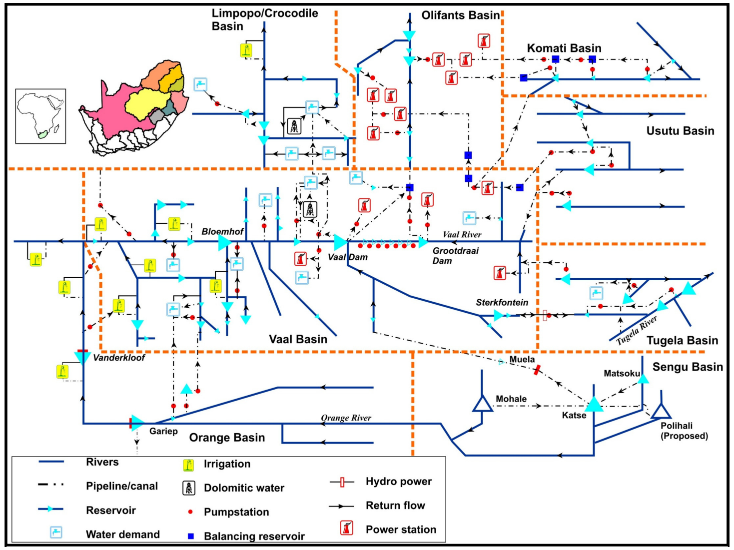


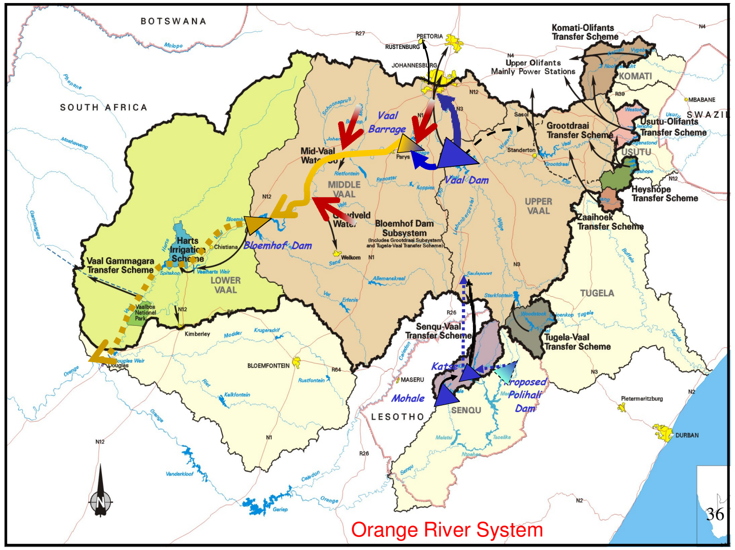
Annual curtailment levels
Interpretation (Mgeni River system)

DWAF (May 2006)

Vaal River System Reconciliation Strategy

DWAF (May 2006)



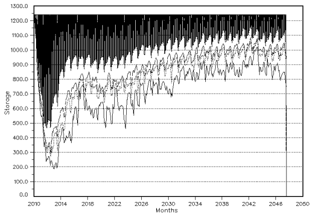


Orange River System

Scenarios

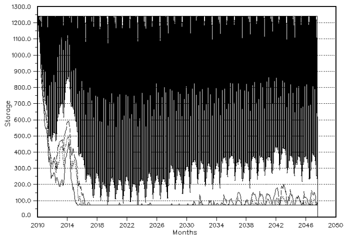
No.	Water Requirements and Return Flows	Mine water Management	Unlawful Water Use	LHWP Phase 2
1	High without further WC/WDM	Neutralisation and discharge into Vaal	Not reduced	Delivery 2020
2	High with target WC/WDM	Neutralisation and discharge into Vaal	Removed by 2013	Delivery 2020
3	High with target WC/WDM	Desalination and used	Removed by 2013	Not implemented
4	High with target WC/WDM	Desalination for urban use	Removed by 2013	Delivery 2020

Results – Bloemhof Dam



Scenarios 1 and 2
(AMD neutralised)

Scenarios 3 and 4
(AMD potable)



Results – TDS Concentrations

Point	Scenario		RWQO
	1	4	
Klip	1022	596	600
Suikerbosrand	1084	651	650
Barrage	730	569	600
Midvaal offtake	636	622	600
Sedibeng offtake	688	648	600
Bloemhof Dam	775	602	750
Vaal Harts Weir	800	629	750

TDS Concentrations in mg/L
95 th Percentile concentrations determined from 101 sequences

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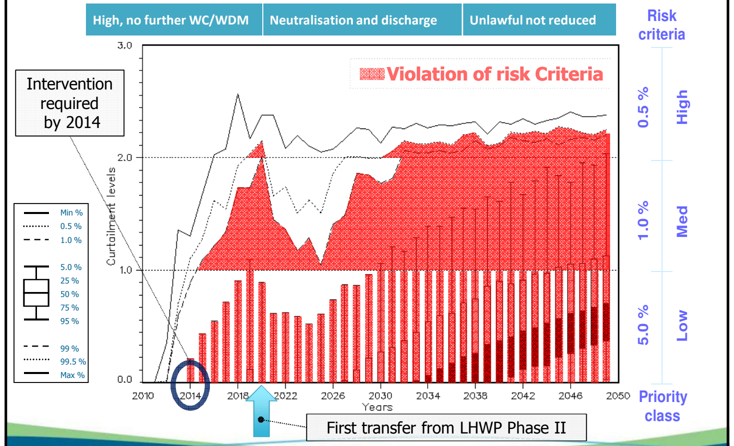
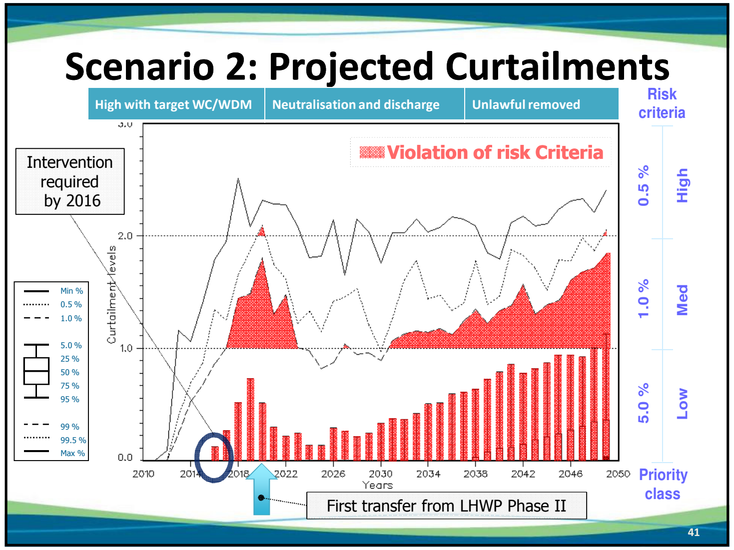
Scenario 1: Projected Curtailments

High, no further WC/WDM	Neutralisation and discharge	Unlawful not reduced



Intervention required by 2014

First transfer from LHWP Phase II



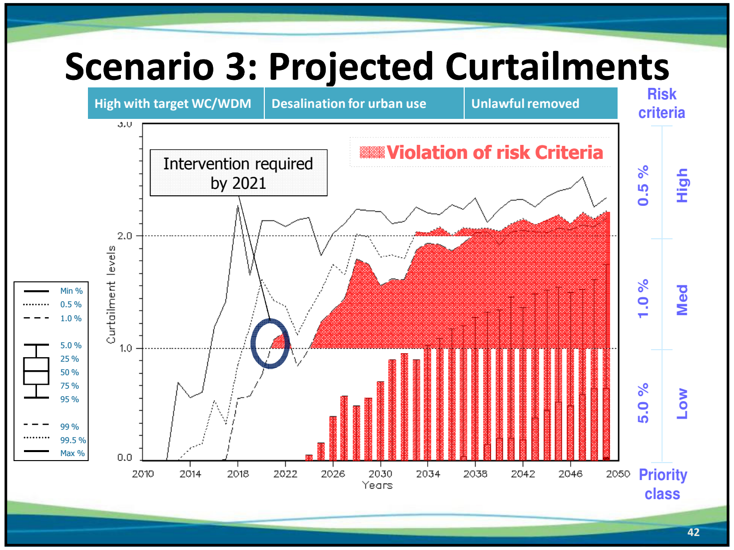
Scenario 2: Projected Curtailments

High with target WC/WDM | Neutralisation and discharge | Unlawful removed

▨ Violation of risk Criteria

Intervention required by 2016

First transfer from LHWP Phase II

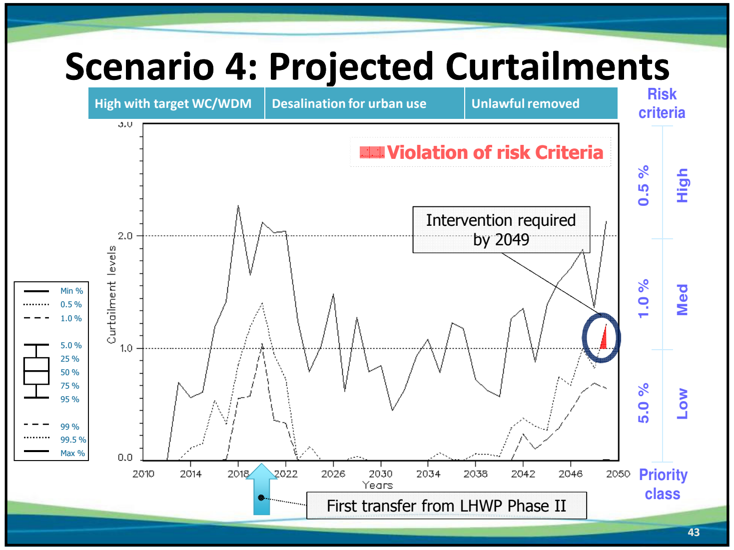


Scenario 3: Projected Curtailments

High with target WC/WDM | Desalination for urban use | Unlawful removed

▨ Violation of risk Criteria

Intervention required by 2021



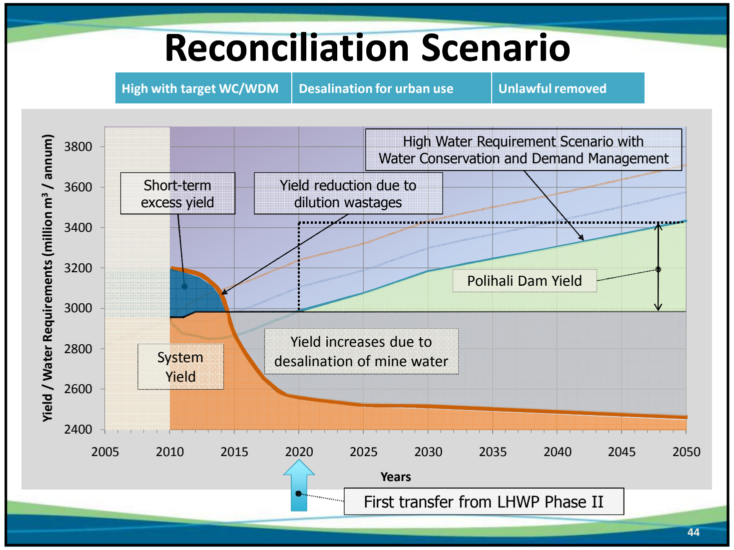
Scenario 4: Projected Curtailments

High with target WC/WDM | Desalination for urban use | Unlawful removed

▨ Violation of risk Criteria

Intervention required by 2049

First transfer from LHWP Phase II



Reconciliation Scenario

High with target WC/WDM | Desalination for urban use | Unlawful removed

High Water Requirement Scenario with Water Conservation and Demand Management

Short-term excess yield

Yield reduction due to dilution wastages

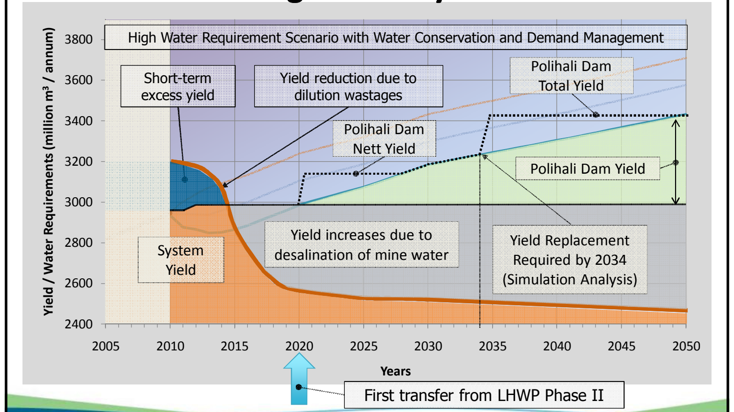
Polihali Dam Yield

Yield increases due to desalination of mine water

System Yield

First transfer from LHWP Phase II

Scheduling of Yield Replacement in the Orange River System



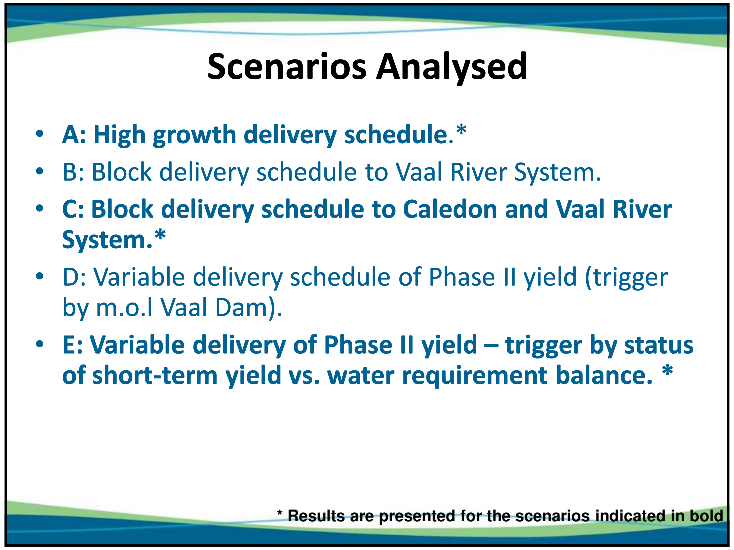
Planning of LHWP Phase 1

Operating Objectives

- Key objectives of operating the IVRS is to first use downstream dams before releases are made from upstream dams.
- This has the following advantages:
  - Maximises the capturing of runoff and reduces spills.
  - Operate Bloemhof and Vaal dams as low as possible to reduce evaporation losses.
  - Basin characteristics and evaporation rate in the upper dams are more favourable to the lower reservoirs.
- The alternative delivery and transfer operating rules evaluate the implication of the above objectives through risk analysis of the Integrated Vaal River System.

Scenario Assumptions

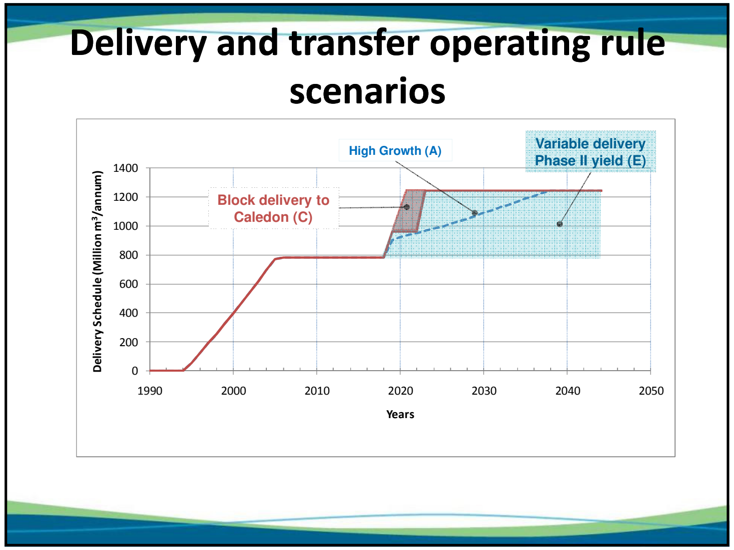
- Water requirements and return flow scenario used:
  - Conservative high planning scenario which requires more water from the LHWP compared to the “Scenario D” of the LHWP Feasibility Study.
- LHWP Phase II components:
  - Based on information from the System Analysis Report of the LHWP Feasibility Study second stage (**LHWC, 2008)**



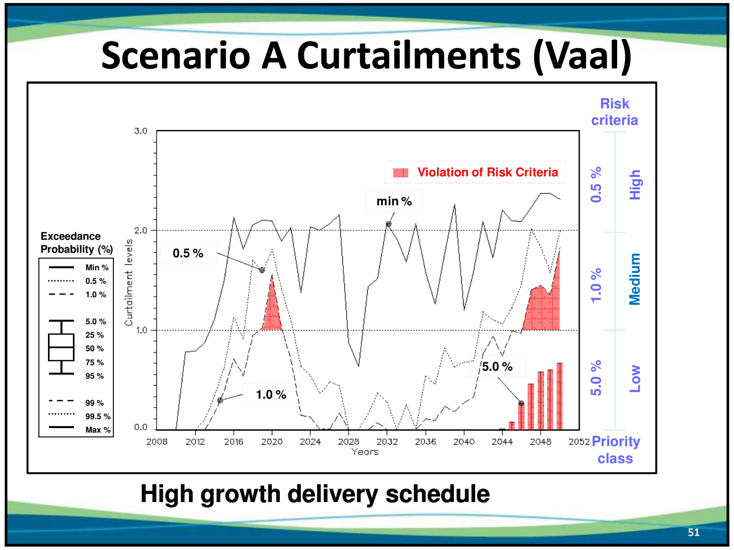
Scenarios Analysed

- **A: High growth delivery schedule.***
- B: Block delivery schedule to Vaal River System.
- **C: Block delivery schedule to Caledon and Vaal River System.***
- D: Variable delivery schedule of Phase II yield (trigger by m.o.l Vaal Dam).
- **E: Variable delivery of Phase II yield – trigger by status of short-term yield vs. water requirement balance. ***

*** Results are presented for the scenarios indicated in bold**

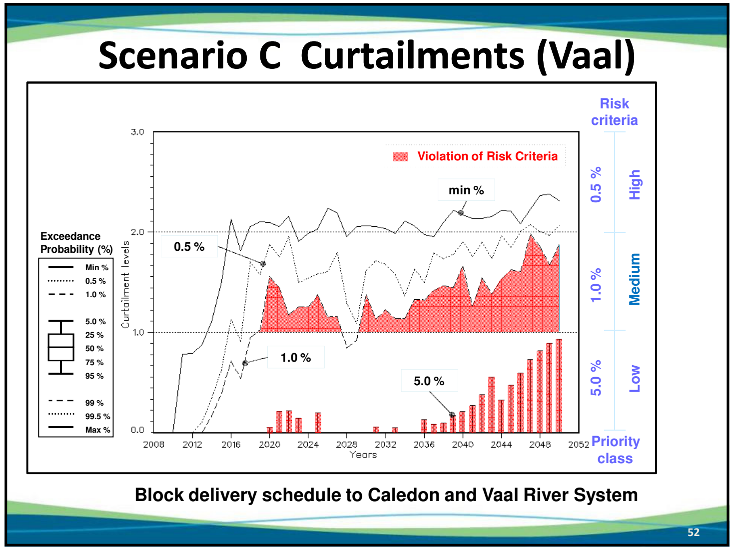


Delivery and transfer operating rule scenarios



Scenario A Curtailments (Vaal)

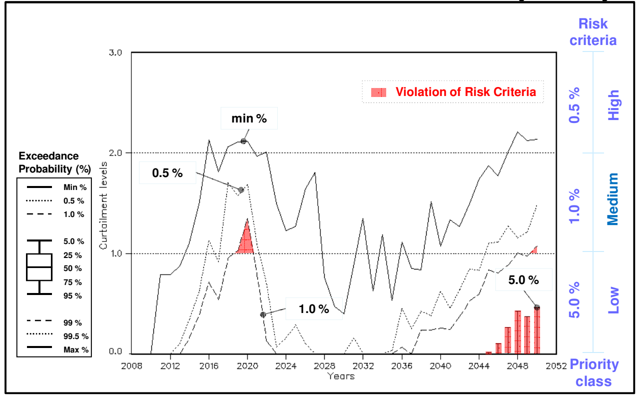
High growth delivery schedule



Scenario C Curtailments (Vaal)

Block delivery schedule to Caledon and Vaal River System

Scenario E Curtailments (Vaal)



Variable delivery of Phase II yield – trigger by status of short-term yield vs. water requirement balance

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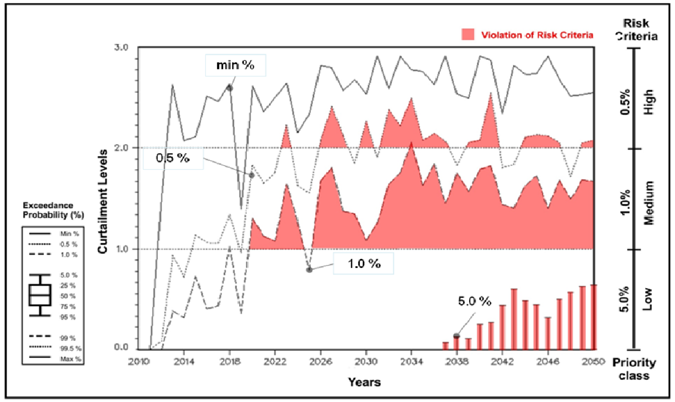
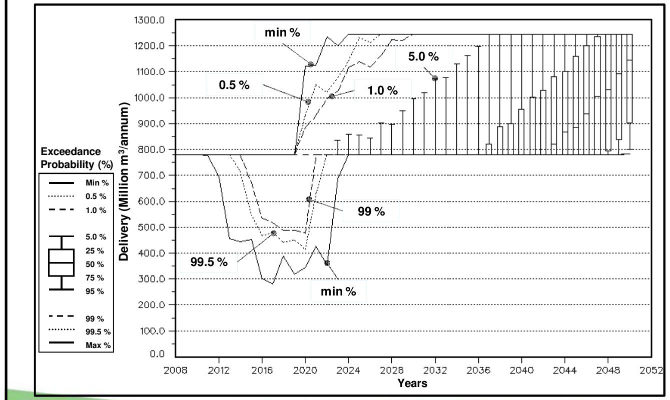
Scenario E Curtailments (Orange)

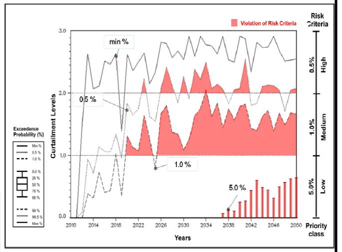


Scenario E Delivery



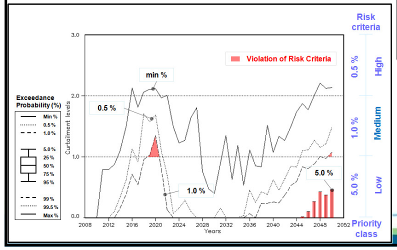
Integrated Analysis (Vaal & Orange)

Scenario E Curtailments



Orange River System

Vaal River System



Summary

- The risk of water restrictions are significantly higher for the block delivery option compared to the other transfer scenarios presented.
- The block delivery rule results in almost continuous violations of the risk criteria over the analysis period.
- The date to augment after Phase II is significantly delayed for all the delivery scenarios compared to the block delivery option.
- Shared utilisation of LHWP provides flexibility and optimisation in management of Orange River Basin water resources.

4. Group discussion

Training and Technology
Transfer Workshop

5 & 6 May 2006

End of module

ORASECOM