Data requirements of water resources management

134901000-KM-09

6 November 2018

Background

- The learning will enable learners to demonstrate an understanding of:
  - Importance of data in water resources management (20%) - KM-09-KT01
  - Types, sources and availability of data (30%) - KM-09-KT02
  - Observed, raw and massaged data (25%) - KM-09-KT03
  - Real time data (25%) - KM-09-KT04

Importance of data in water resources management (themes)

- Long historical records with good spatial coverage in water resources management and planning.
- Up-to-date data in short term decision making from an operational management perspective.
- Historical data on which to base future projections for future planning and management of water resources.
- The need to prevent the loss of and closure of monitoring and measurement points over time.
- Managing water resources in data-scarce regions/catchments.

Internal Assessment Criteria:
Describe the importance and use of different lengths of records in decision making

Why is data important for Water Resource Management?

- Substantial public resources are employed in water resource infrastructure in support of socio-economic development and the environment.
- Data is essential for efficient management of water resource infrastructure and water provision systems.
- Need accurate water balances:
  - How much water is available or can be made available?
  - How much water is used and will be required in future?
- Need correct decisions of intervention implementation:
  - To early: Capital is unnecessary locked in.
  - To late: Water shortages occur, resulting in large economic losses, human suffering and deprived ecology.
  - To large flood estimates: Capital is unnecessary locked in.
  - To small flood estimates: Large economic losses and human suffering.

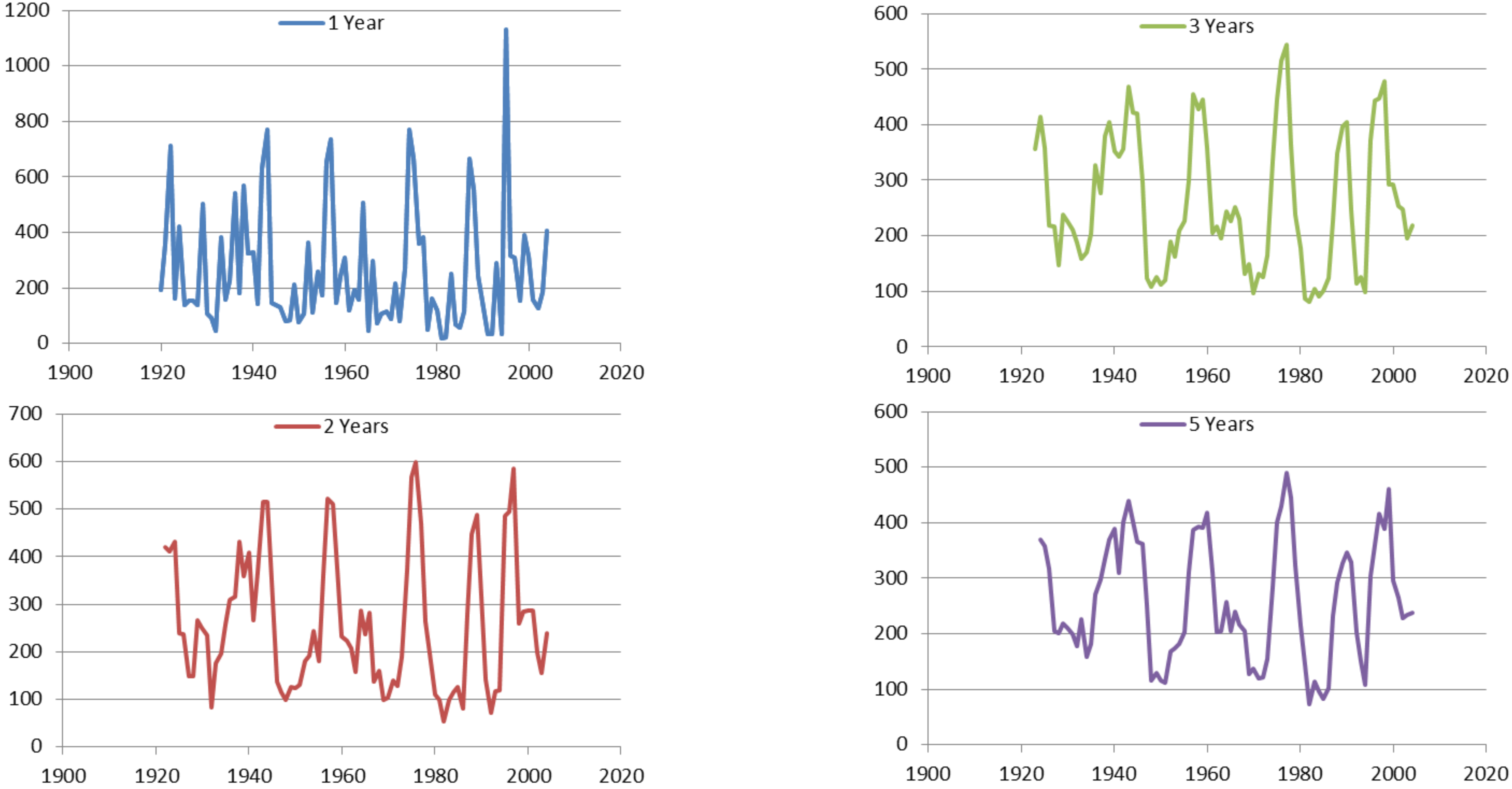
Importance of water

- "Water is one of the key and probably the most fundamental and indispensable of natural resources – fundamental to life, the environment, food production, hygiene, industry and power generation"
  - Quote from the introductory paragraph of the ***Hydrometry Module for Civil Learner Technicians***, Department of Water and Sanitation (formerly DWAF), dated 2000.
- **Compulsory reading, see TOC.**

Long historical records – Why?

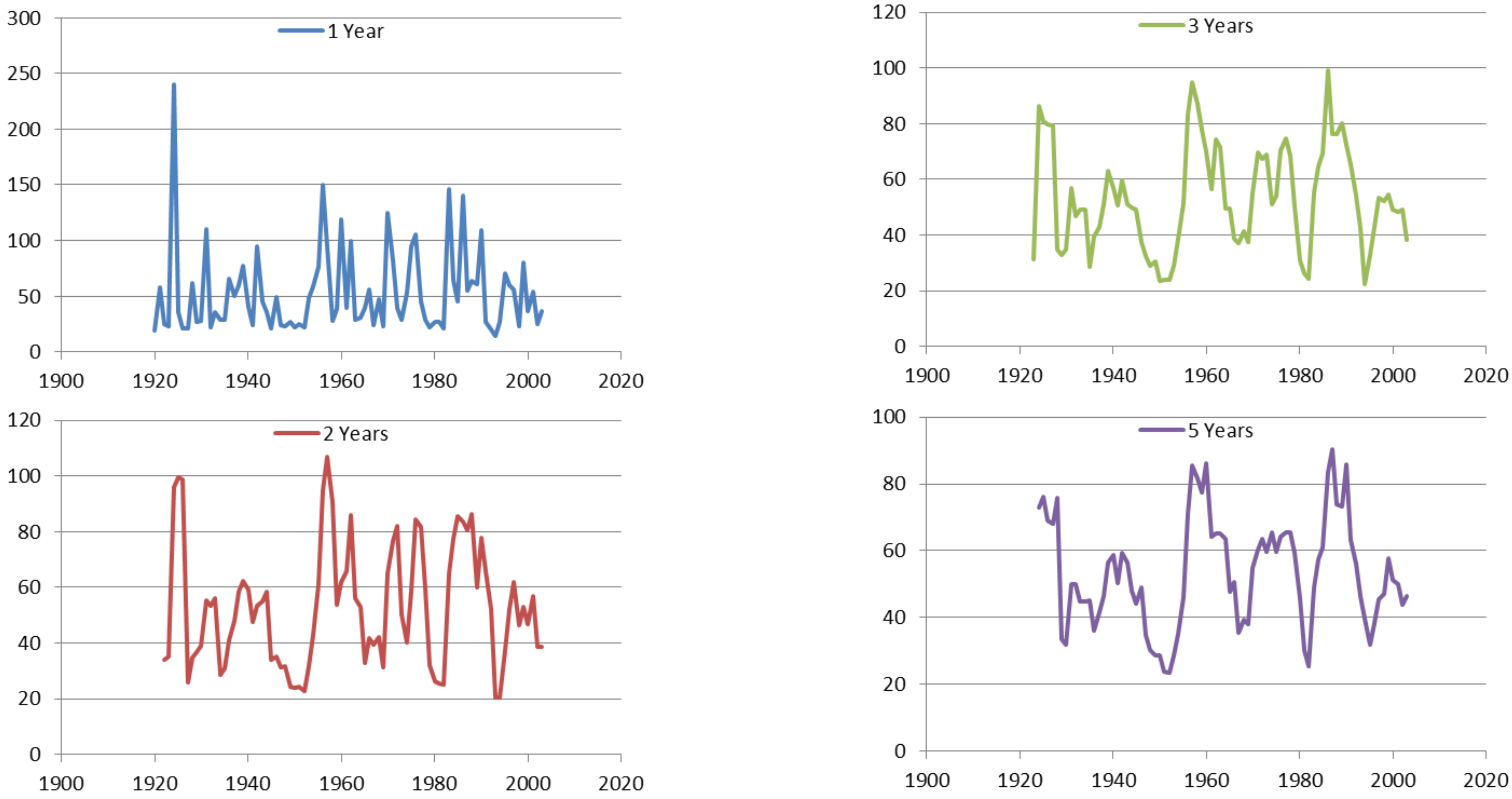
- Record to capture known knowledge of historical dry and wet periods – need to capture representative statistical characteristics:
  - Early 1930s were particularly dry in Southern Africa, has rainfall data to simulate runoff – therefore **record should start in 1920 or earlier**.
  - The end of the record period should be the previous water year.
  - Calibration of rainfall runoff model should benefits from the recent 10 years where more information is *usually* available (improvements due to “information age”).

A catchment upstream of Vaal Dam



Moving averages of annual total flows (1, 2, 3 and 5 years)

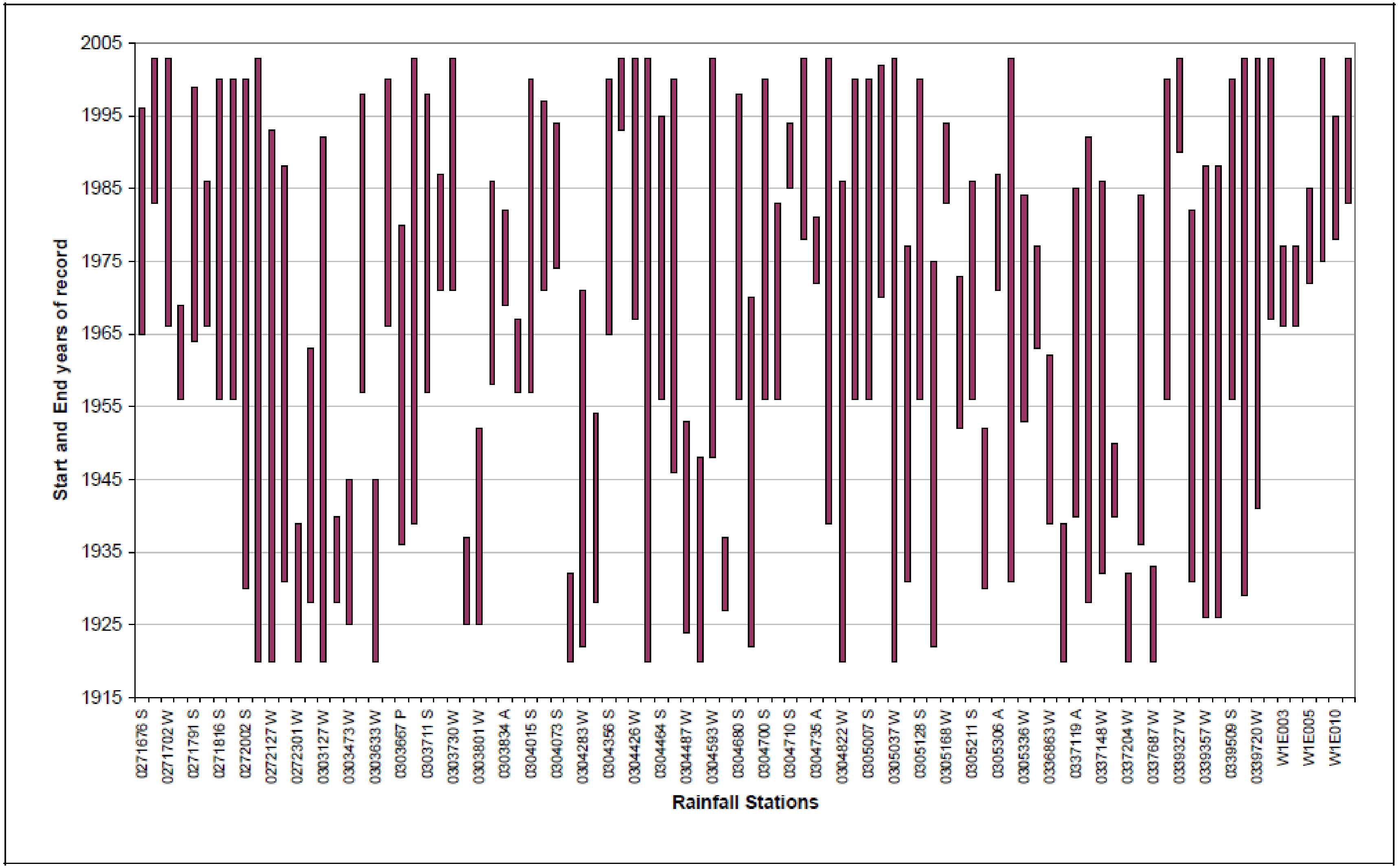
A catchment in Mhlathuze River System



Moving averages of annual total flows (1, 2, 3 and 5 years)

Mhlathuze River System Point Rainfall

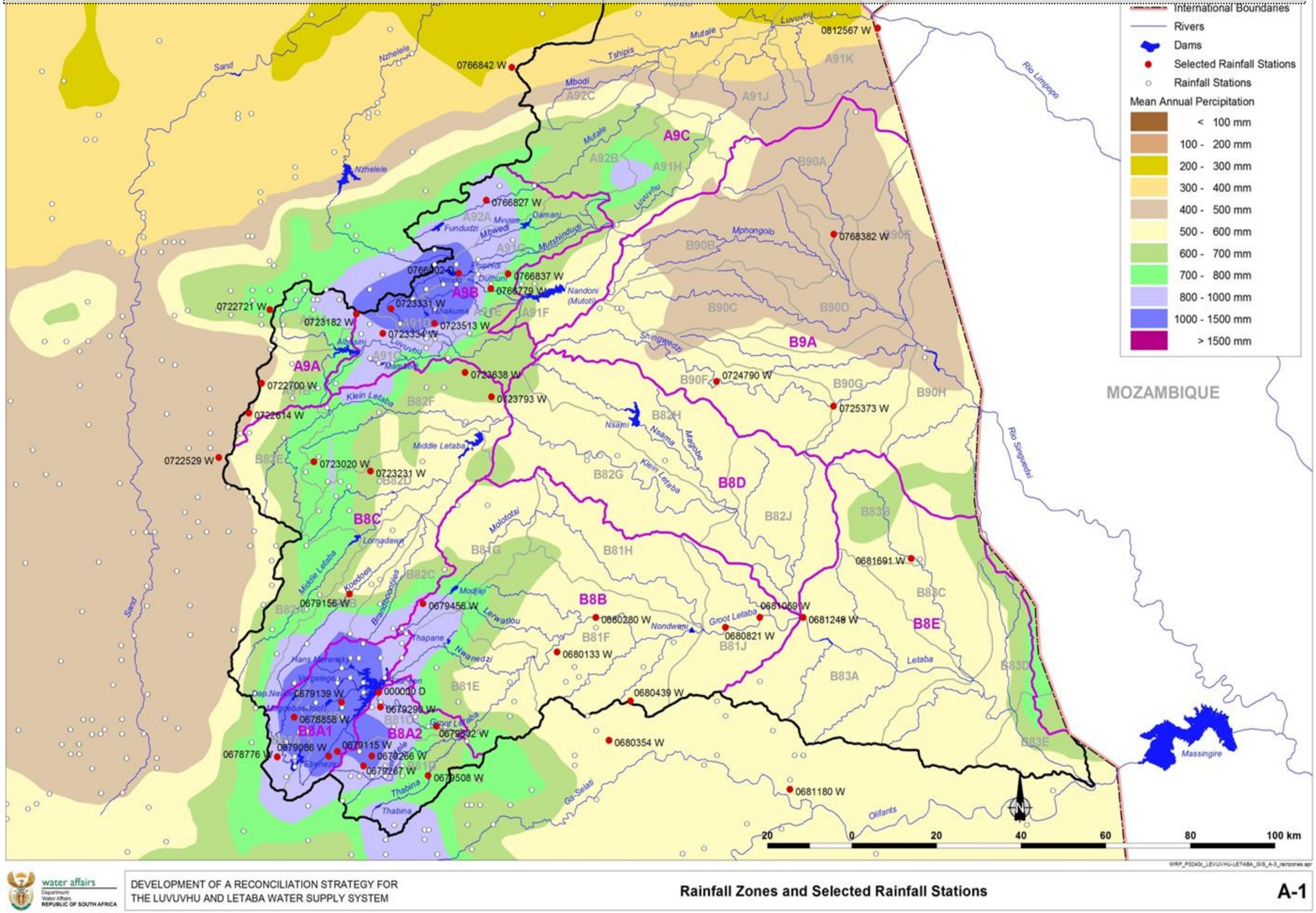
Figure 2-1 Duration and time span of rainfall records



Good spatial coverage – Why?

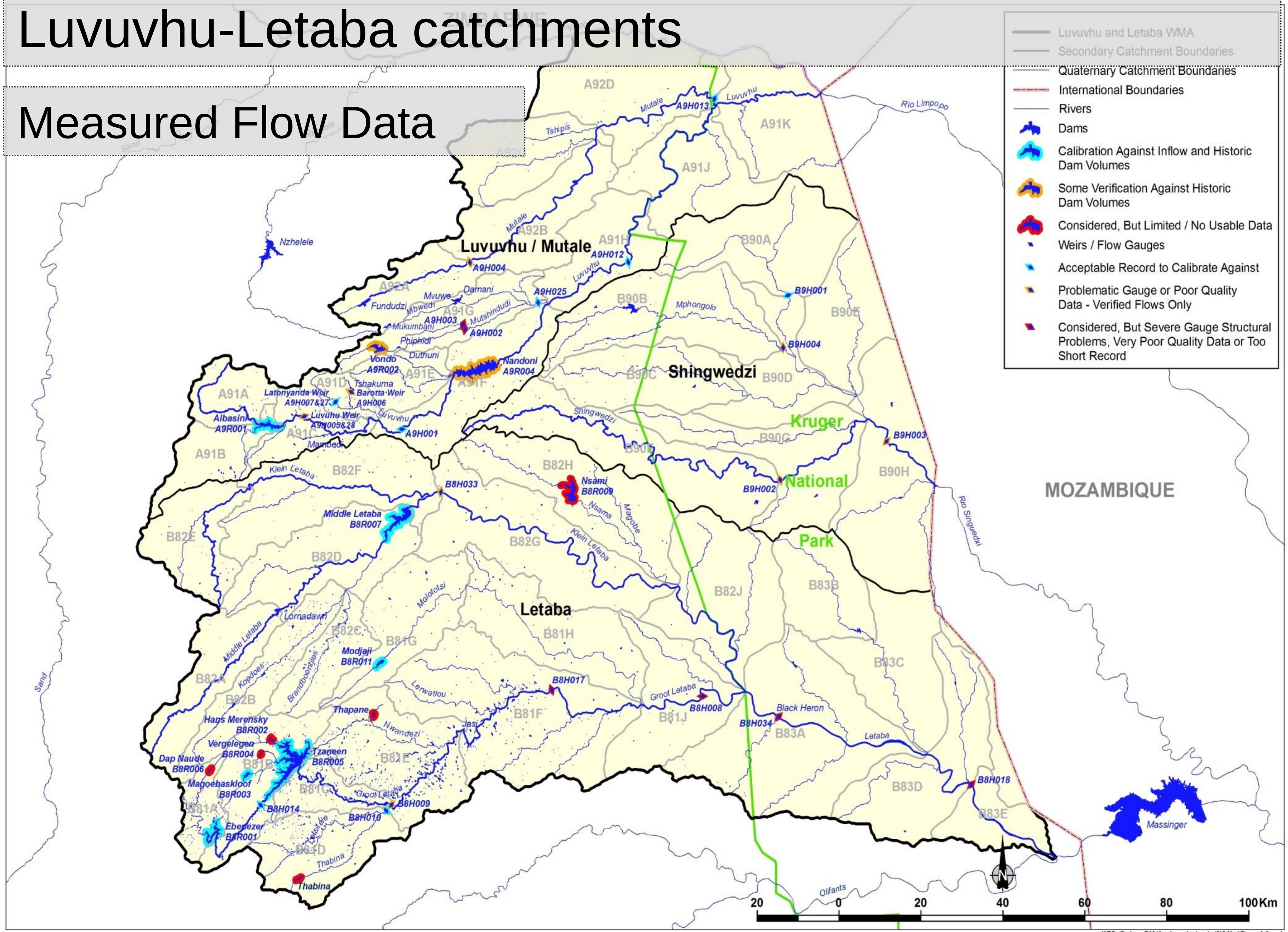
- Records should be relevant for catchments, account for spatial variance of rainfall, evaporation and runoff.
- In general, the density of point rainfall records should be higher in catchments where the rainfall gradient over the catchment area is high.
- There are no specific minimum density requirements, however, the uncertainly in the derived hydrology is inversely related to the number of observations points.
- It is acceptable to use some point rainfall records that are adjacent to the analysed catchment.

Example of point rainfall Luvuvhu-Letaba catchments



Luvuvhu-Letaba catchments

Measured Flow Data



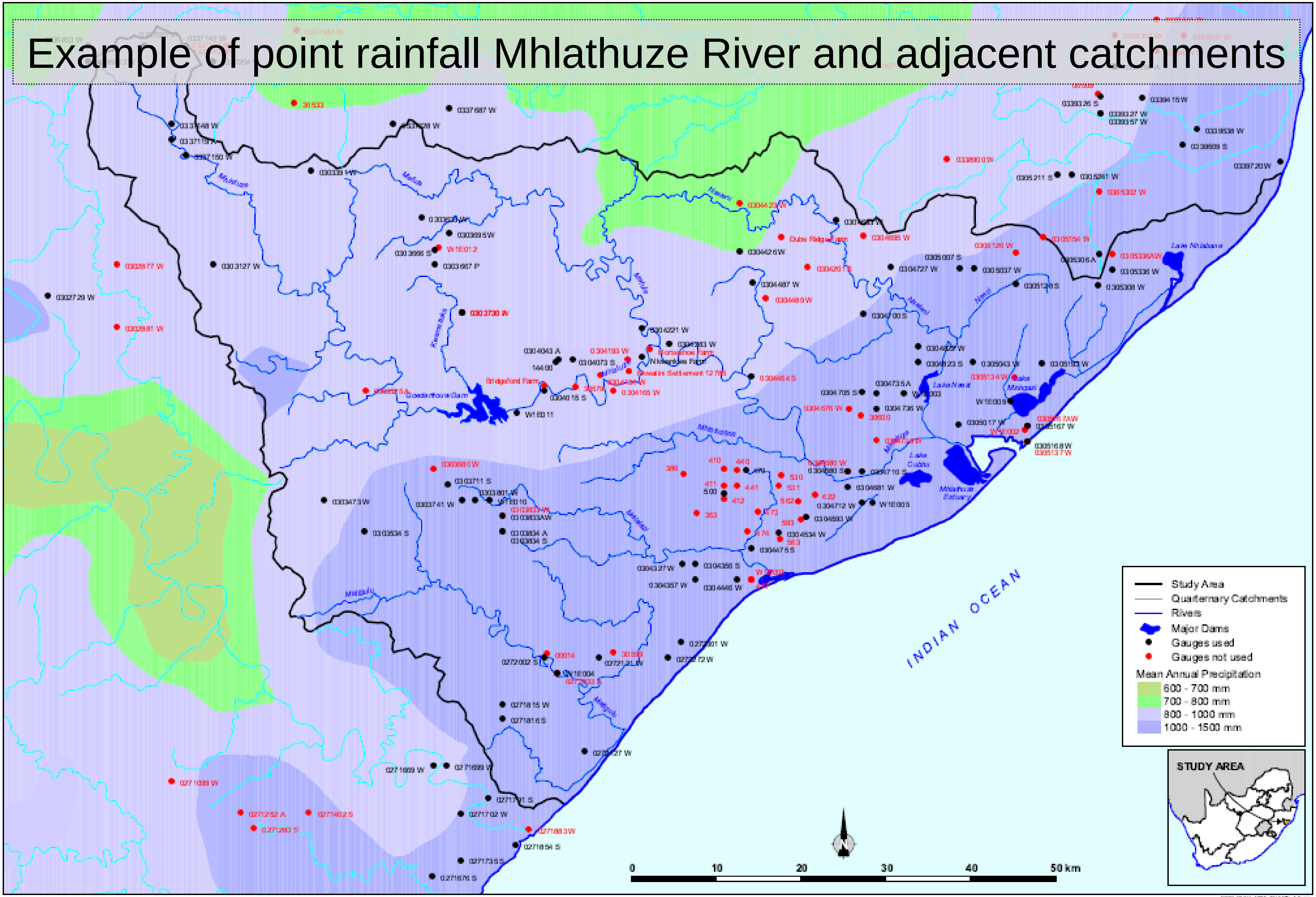
water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

DEVELOPMENT OF A RECONCILIATION STRAGEGY FOR
THE LUVUVHU AND LETABA WATER SUPPLY SYSTEM

Measured Flow Data Considered

Figure A-6

Example of point rainfall Mhlathuze River and adjacent catchments



water & forestry

WRP

WSM LESHIKA

MHLATHUZE WATER AVAILABILITY ASSESMENT STUDY

Rain gauges in and around the Mhlathuze / Amatikulu / Mlalazi River catchment

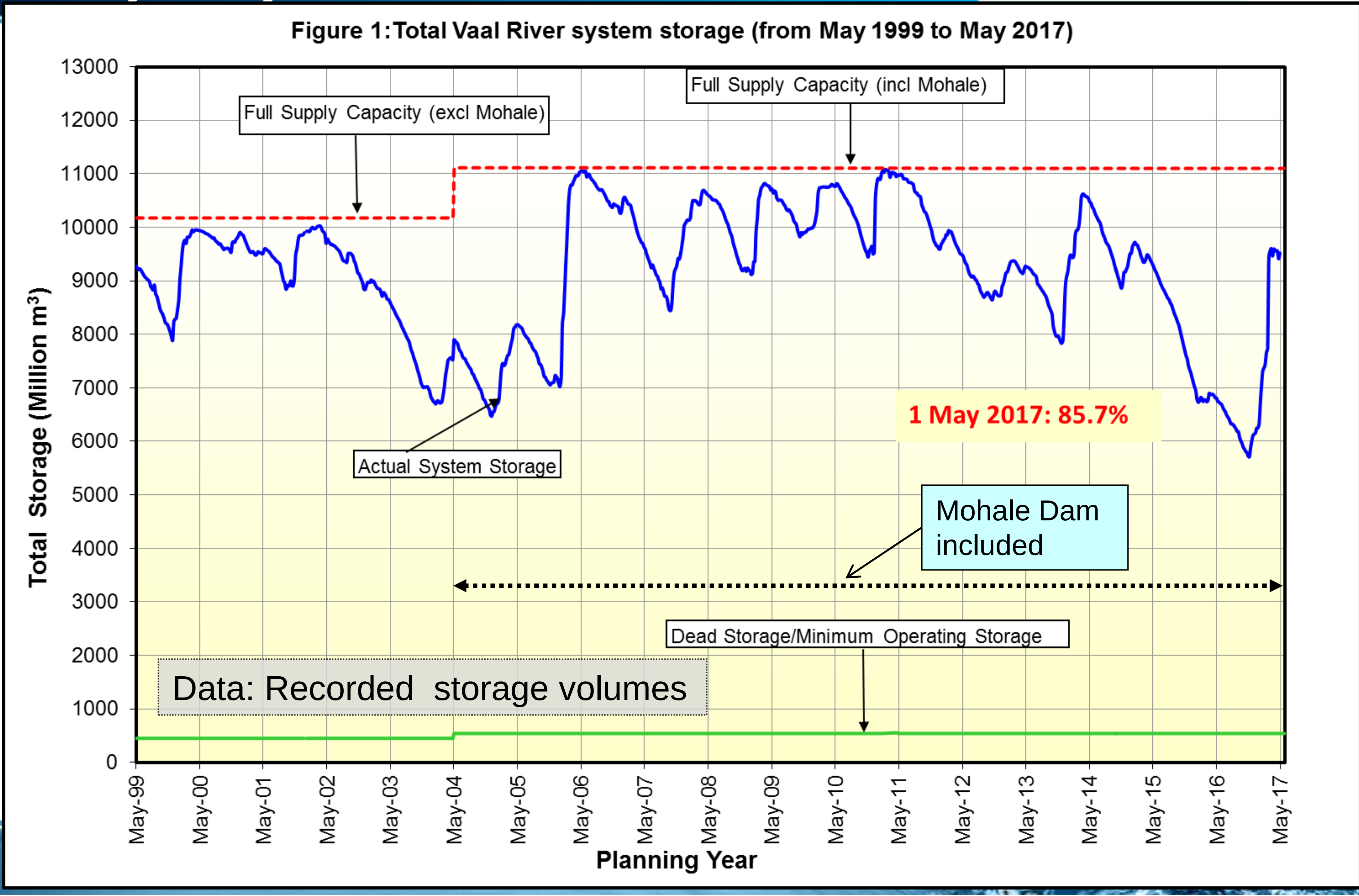
A-2

Data in short term decision making for operational management

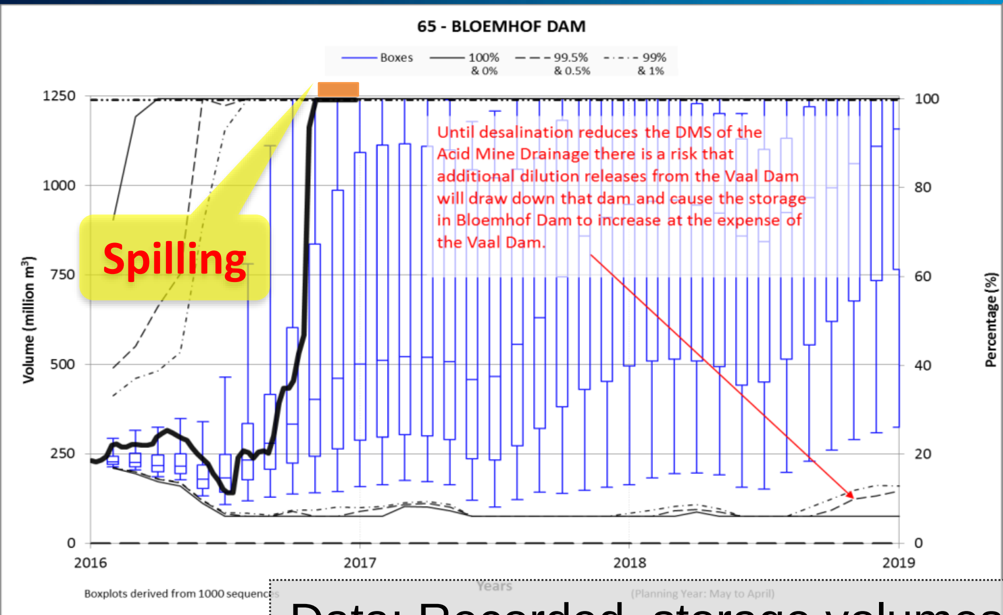
- Imperative for operation: Optimal efficiency in utilisation and distribution of water.
- How to achieve this?: Monitor key components of a water resource system to detect trends and anomalies.
- Data requirements for operational management:
  - Reservoir Storage, Rainfall, Flow: Releases, Transfers, Abstractions.
  - Water quality data
- Application of data: Compare actual system behaviour against the target operating regime.
- A benefit: Timeously implementation of corrective measures (early warning to trigger remedial measures).

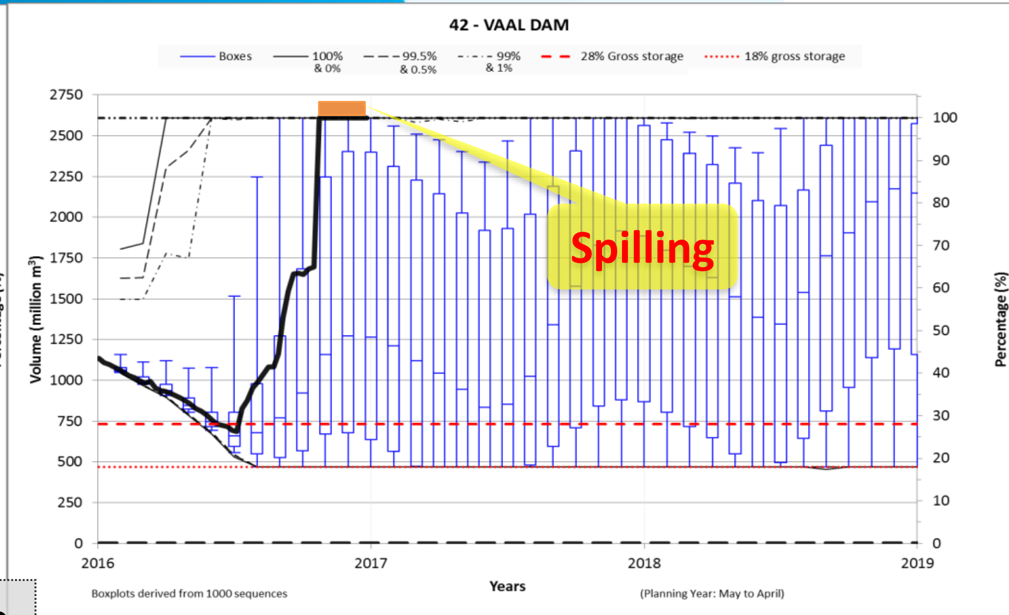
Guidelines for Water Supply Systems Operation and Management Plans During Normal and Drought Conditions (RSA C000/00/2305), October 2006

Monitoring Total System Storage Trajectory

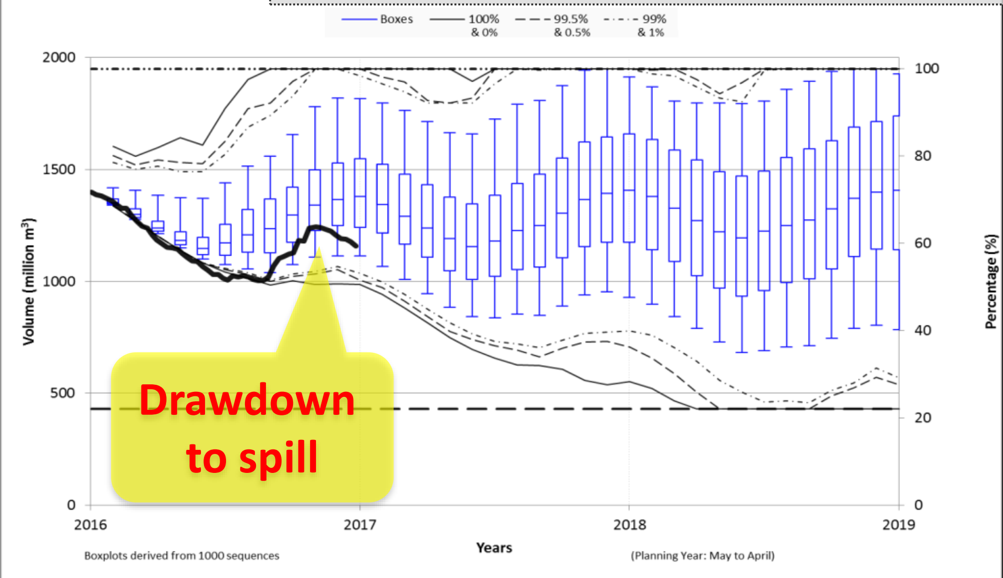


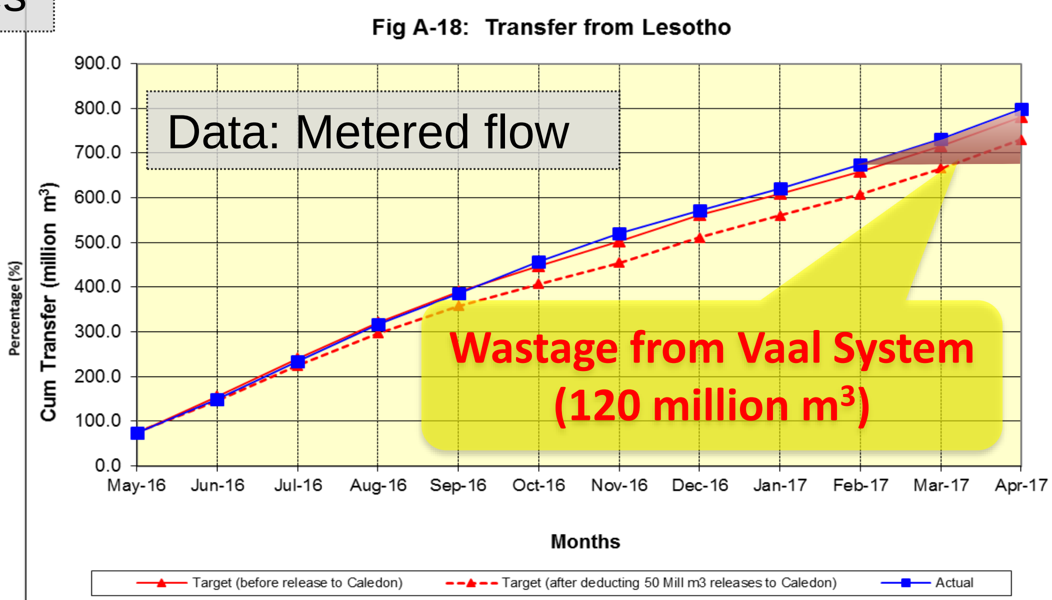
Tracking wastage from Vaal System



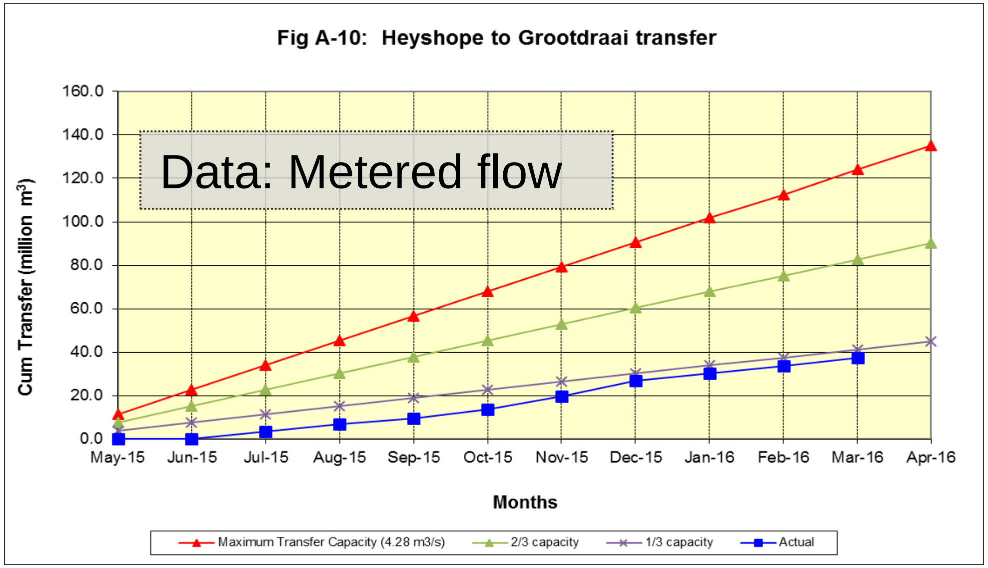


Data: Recorded storage volumes

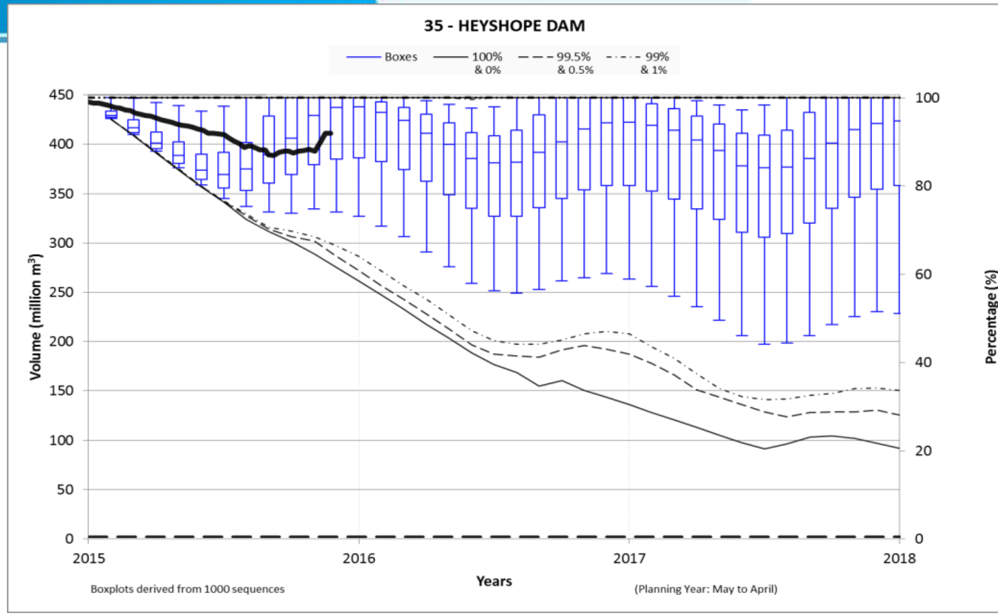


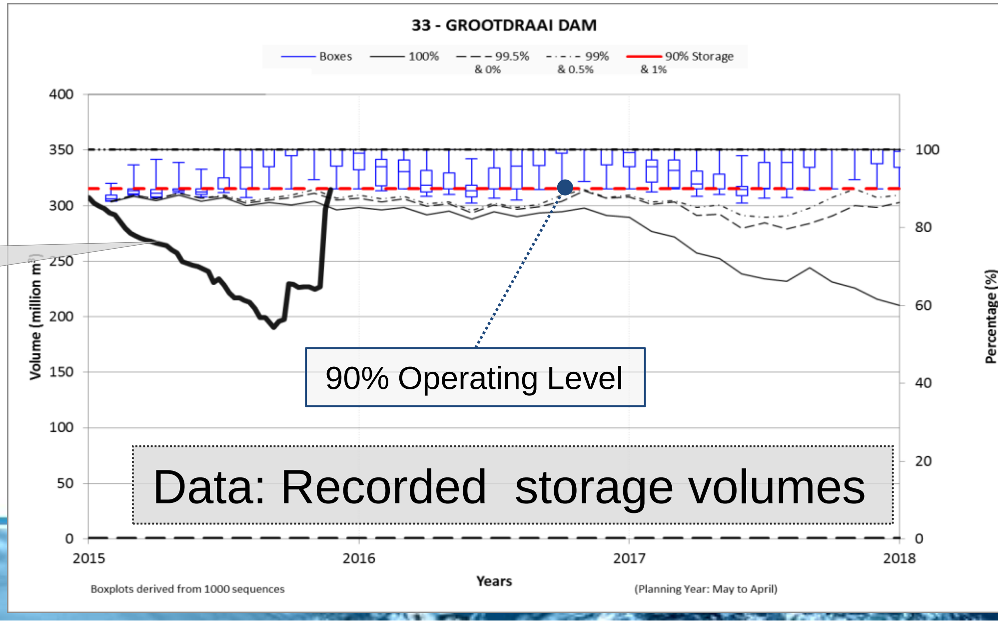


Data to monitor and identify anomalies

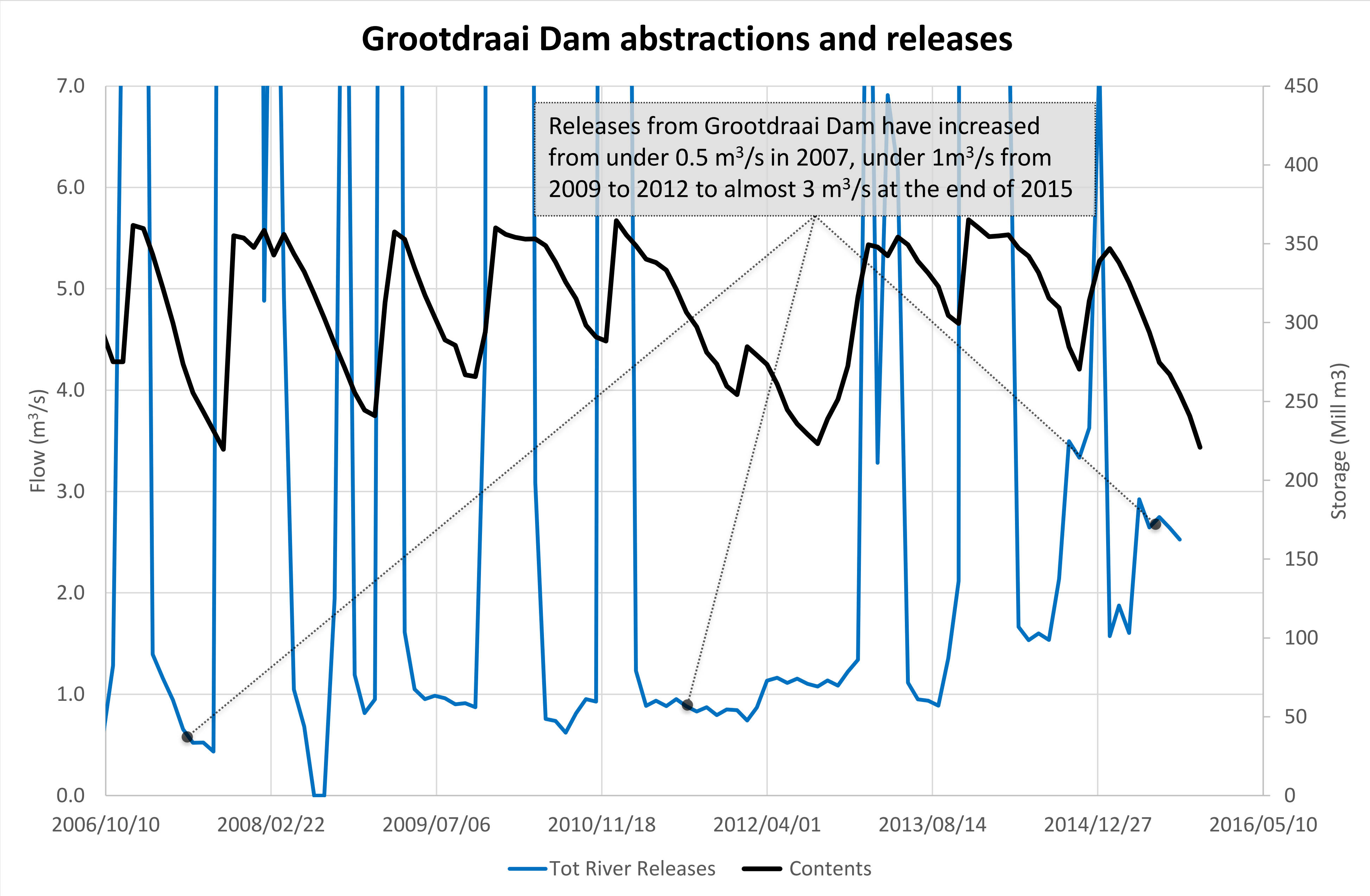


Anomaly:
Actual Storage significant lower than target levels.

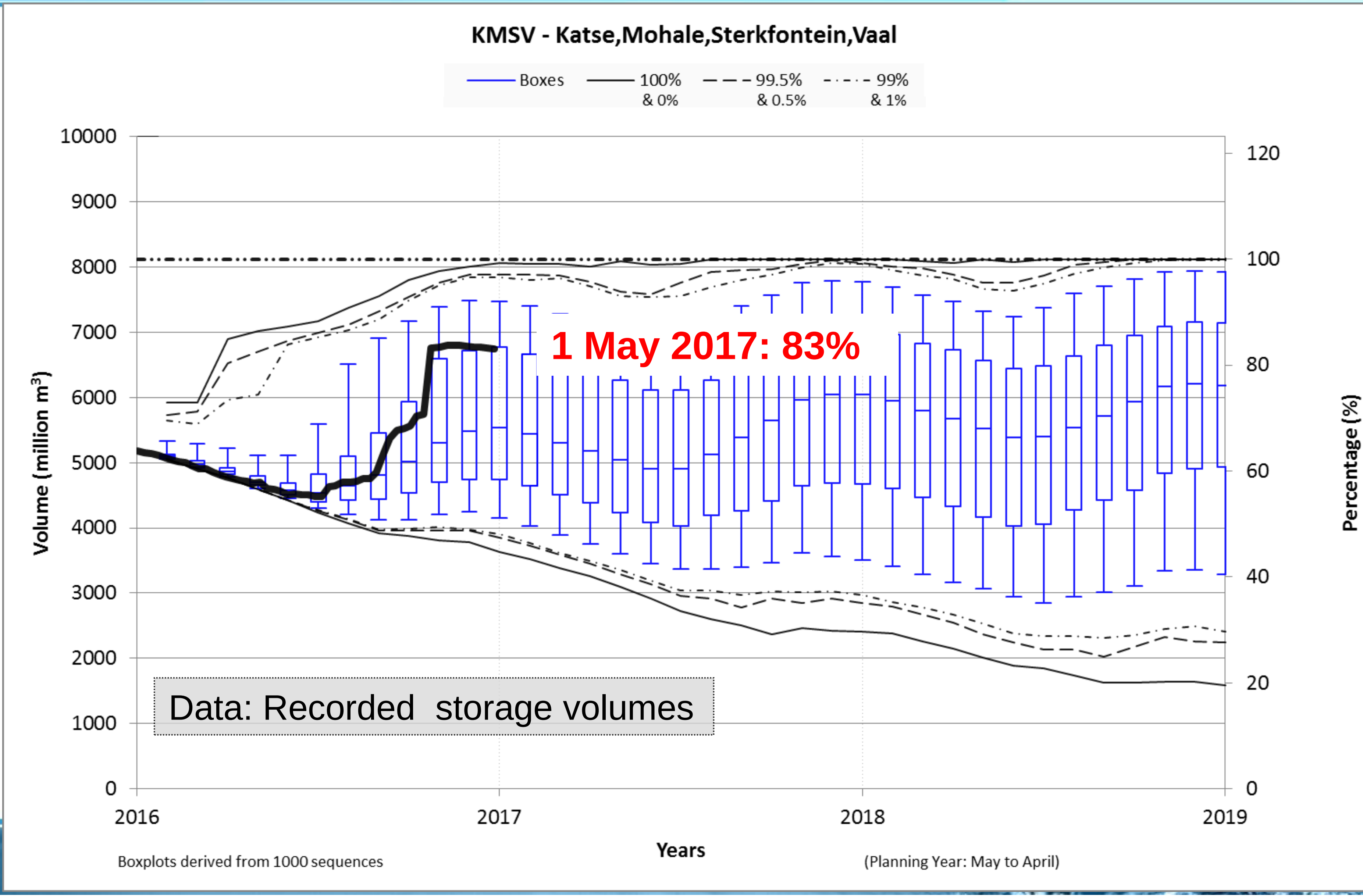




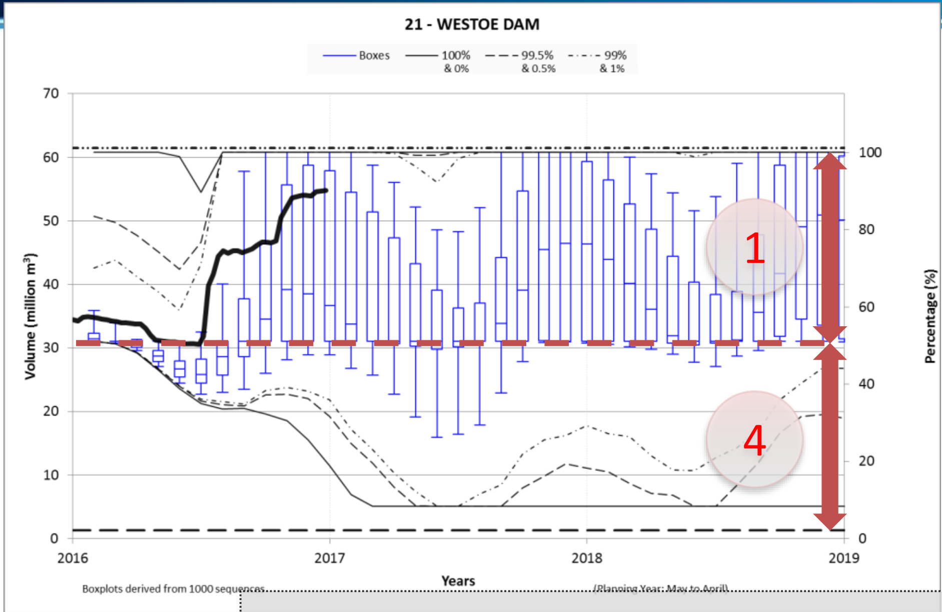
Data to investigate anomaly

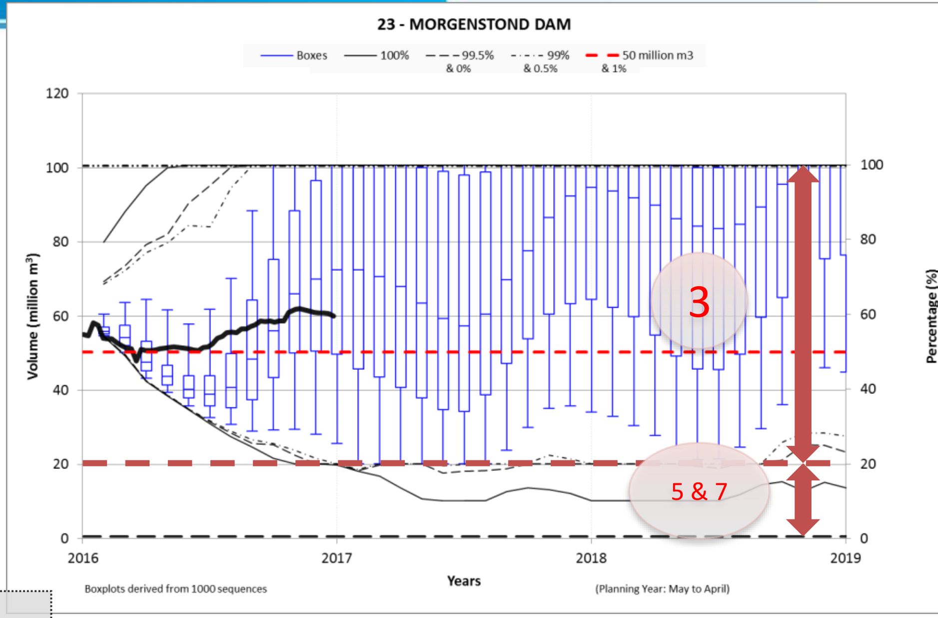


Katse, Mohale, Sterkfontein, Vaal

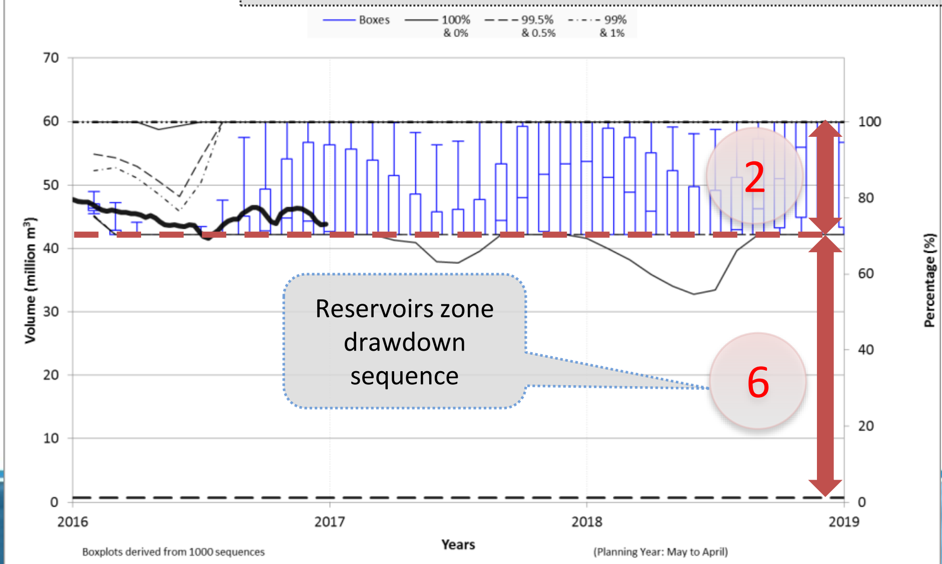


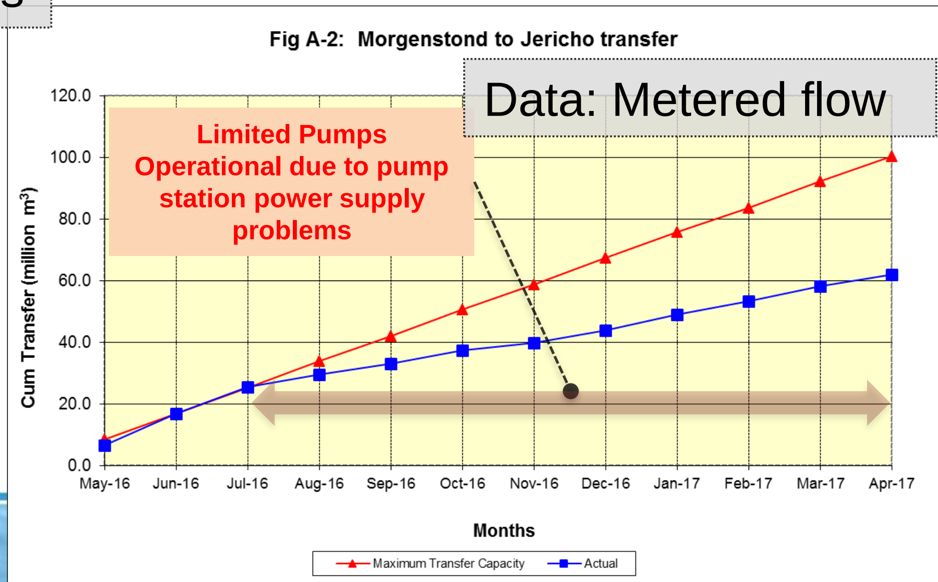
Monitoring transfers and adherence to operating rules: Usutu Sub-system





Data: Recorded storage volumes





Historical data as basis for future projections, planning and management of water resources

- Water use and return flows – in general.
- Land use:
  - Streamflow reduction: Forestations, Invasive Alien Plants.
  - Diffuse irrigations in catchments.
  - Ground water abstraction, reduction in river base flow. References: (a), (b)- Appendix F, page 209.
- Socio-economic development:
  - Historical population trends, migration and drivers.
  - Economic activities, trends and composition.

Data for Water Requirement and Return Flow Modelling: Urban

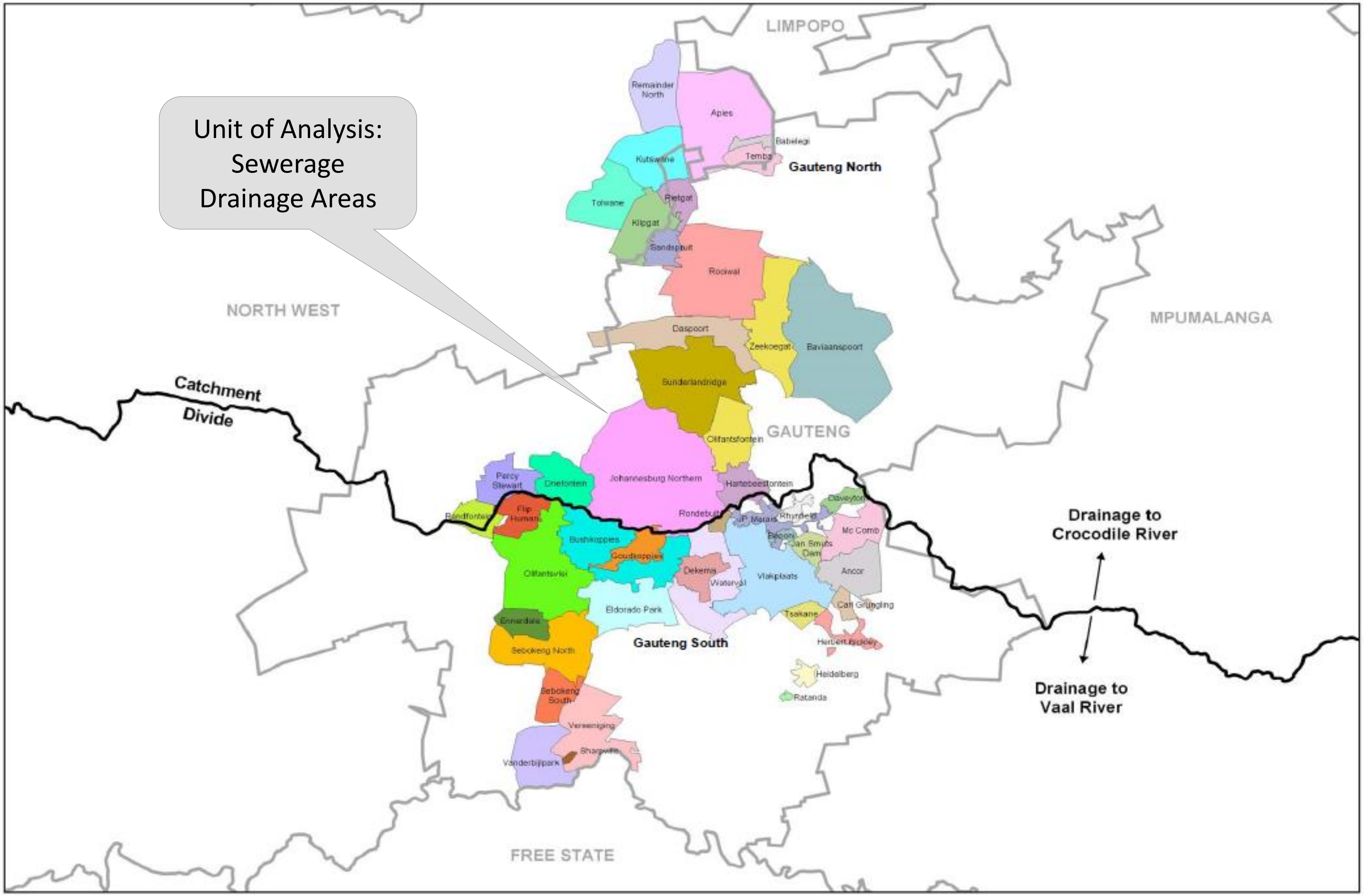
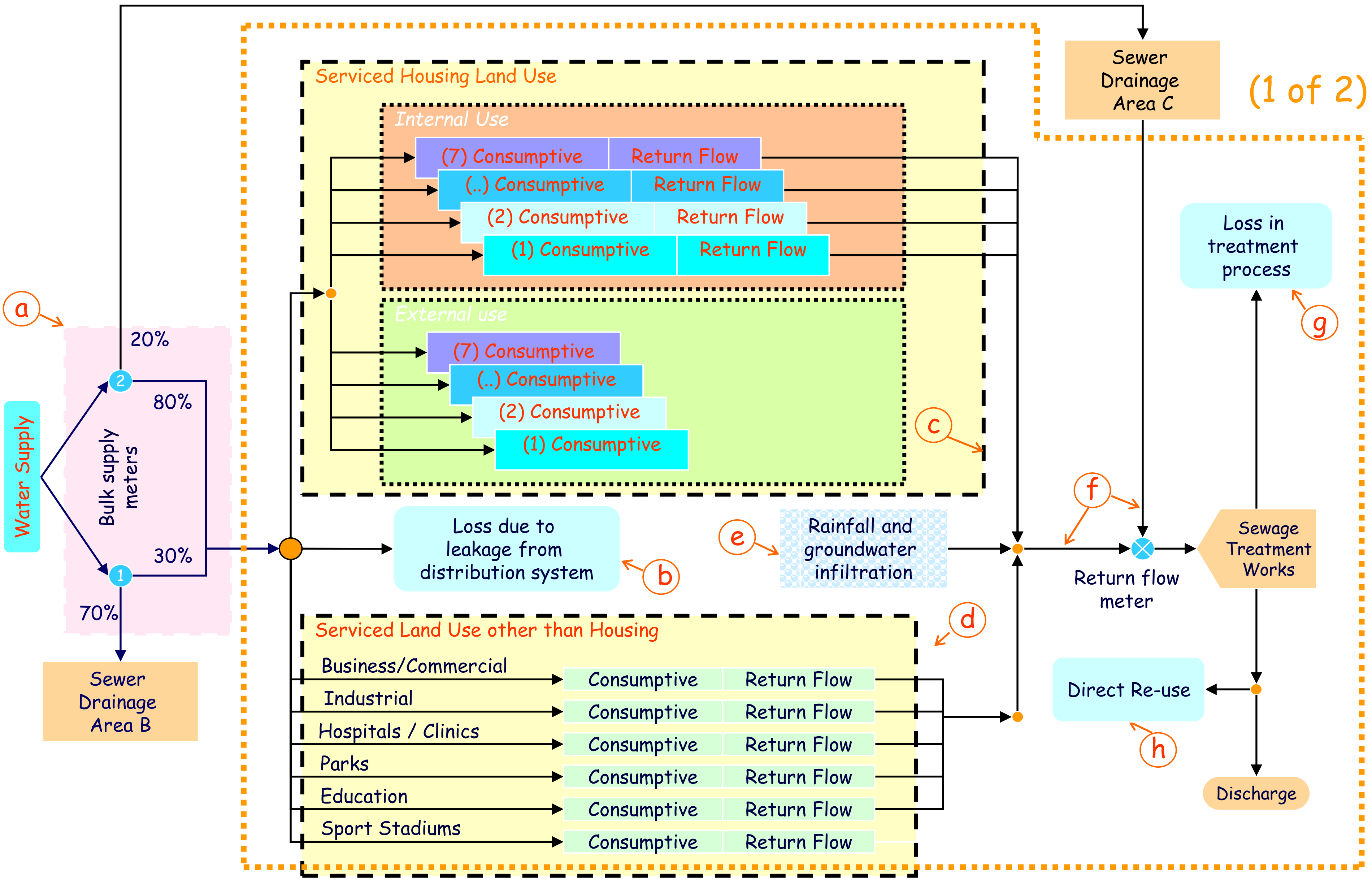


Figure 4-3: Location of the forty seven Sewage Drainage Areas

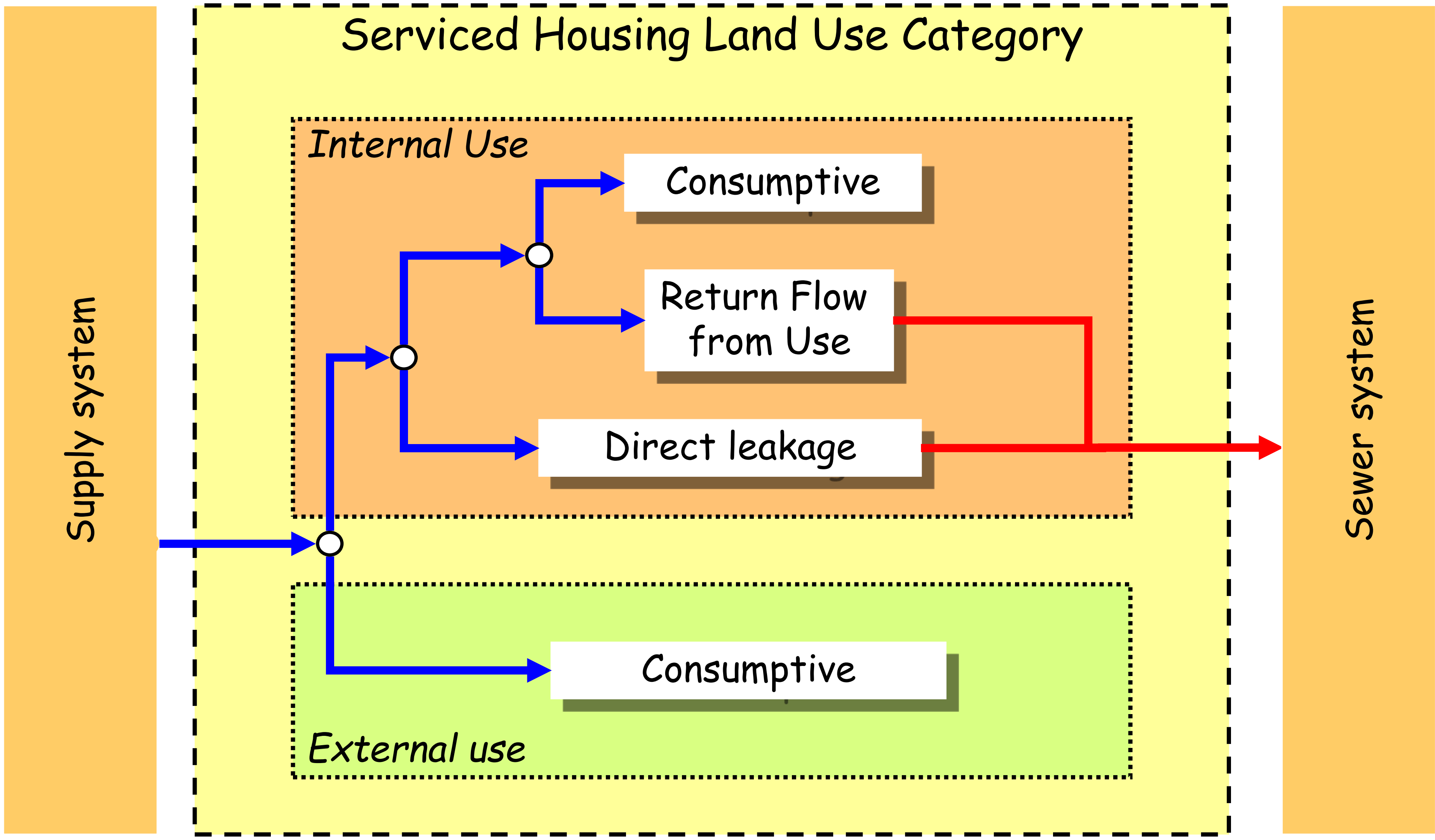
Urban water requirement and return flow modelling

- Method to develop scenarios for planning.
- Framework for establishing relationship between water requirement and return flow.
- Uses sewage drainage area as building block.
- Requires land use characteristics:
  - Seven housing types – see subsequent slide.
  - Other urban land use:
    - Business/Commercial
    - Industrial
    - Hospitals / Clinics
    - Parks
    - Education
    - Sport Stadiums

Conceptual model formulation for a sewerage drainage area



Housing Category Unit
Components and water balance



Data for Urban water requirement and return flow modelling

Housing Land Use

Population

Unit Consumption

Serviced housing category	Description
Category 1	Fully serviced houses on large erven (erven > 500 m^2)
Category 2	Fully serviced flats, townhouses or cluster homes
Category 3	Fully serviced houses on small erven (erven < 500 m^2)
Category 4	Small houses, RDP type houses and shanties with water connection, but no or minimal sewage service
Category 5	Informal houses serviced only by communal taps and no water borne sewage
Category 6	No service from any water distribution system
Category 7	Other/Miscellaneous (Includes hostels, military camps, etc.)

Infrastructure

Find more detail in user guide.

Drainage Area Report

1 Baviaanspoort

Population — Housing Categories

	1	2	3	4	5	6	7	TOTAL	
Number of stands:	3 500	500	46 496	16 500	0	0		66 996	T-C1
Number of people:							16 800		
People / Stand:	3	2.7	3.7	3.7	8	5.5	1		T-C2
Population (landuse)	10 500	1 350	172 035	61 050	0	0	16 800	261 735	Q-C1
% Population:	4.01	0.52	65.73	23.33	0.00	0.00	6.42	100.00	Q-C2+3
Normalised Population:	10 668	1 372	174 787	62 027	0	0	17 069	265 922	Q-C4

Water Requirements — Housing Categories

	1	2	3	4	5	6	7	TOTAL	
Per Capita (l/day):	420	420	215	117	12	5	117		T-D2
Total vol. (mcm/a):	1.64	0.21	13.73	2.65	0.00	0.00	0.73	18.95	Q-D1

Internal/external Housing Requirements

	1	2	3	4	5	6	7	TOTAL	
% Internal use:	70	85	85	0	0	0	85		T-D4
Int. vol. (mcm/a):	1.15	0.18	11.67	0.00	0.00	0.00	0.62	13.61	Q-D6
Ext. vol. (mcm/a):	0.49	0.03	2.06	2.65	0.00	0.00	0.11	5.34	Q-D6

Leakage from mains and connections

	1	2	3	4	5	6	7	TOTAL	
Pipe Lenth (m):	87 500	4 167	387 467	137 500	0	0	140 000		T-F
No of connections:	3 500	500	46 496	16 500	0	0	16 800		T-F

Loss / Length (l/day/m): 0.96   Loss / Connection (l/day/connect): 96   T-F

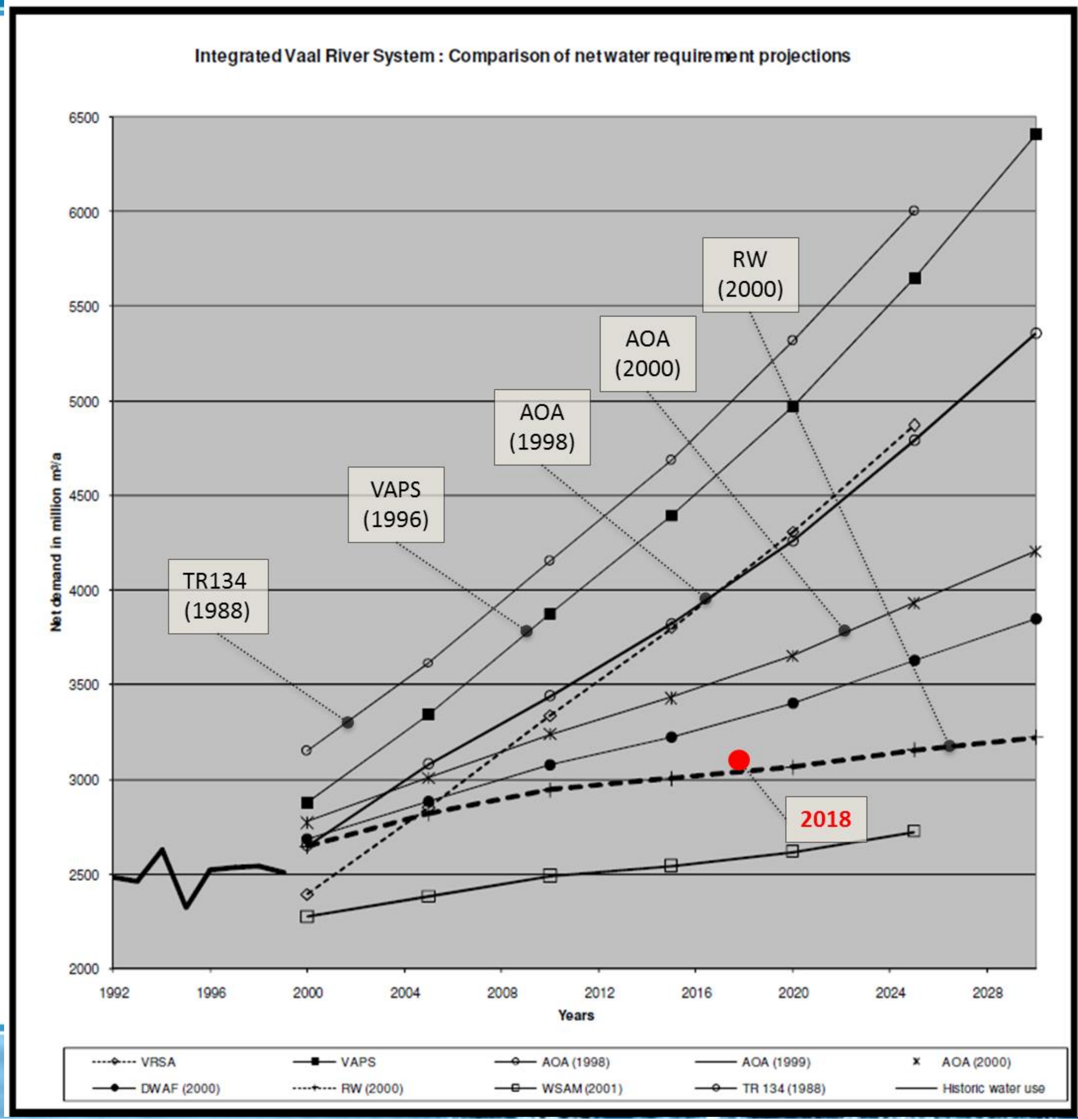
	1	2	3	4	5	6	7	TOTAL	
Distribution losses:	0.15	0.02	1.77	0.63	0.00	0.00	0.64	3.20	Q-F2

Notes: mcm = Million Cubic Metre

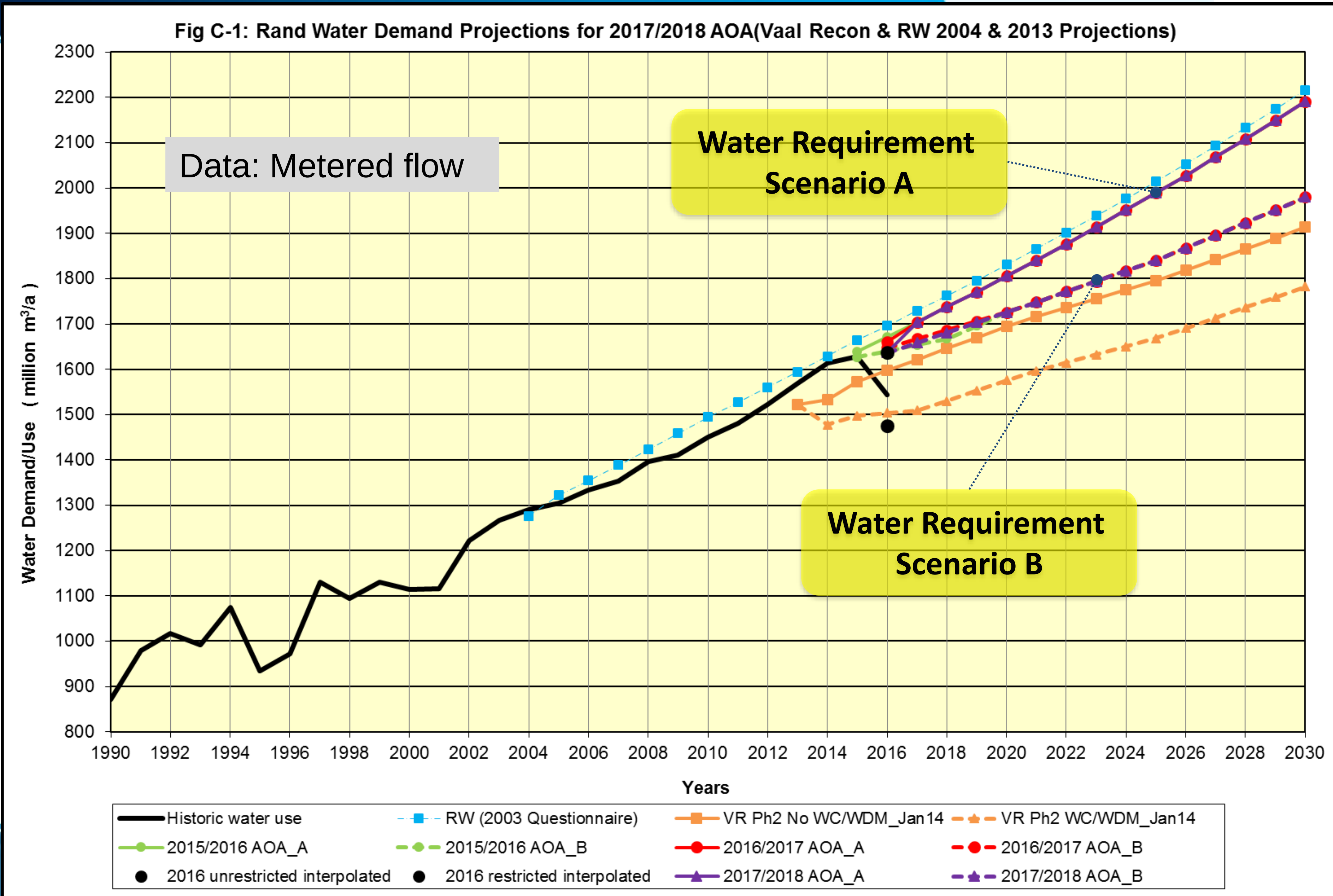
Water Requirements:
Monitor, understand, adjust.

Previous studies - 2007 assessment:

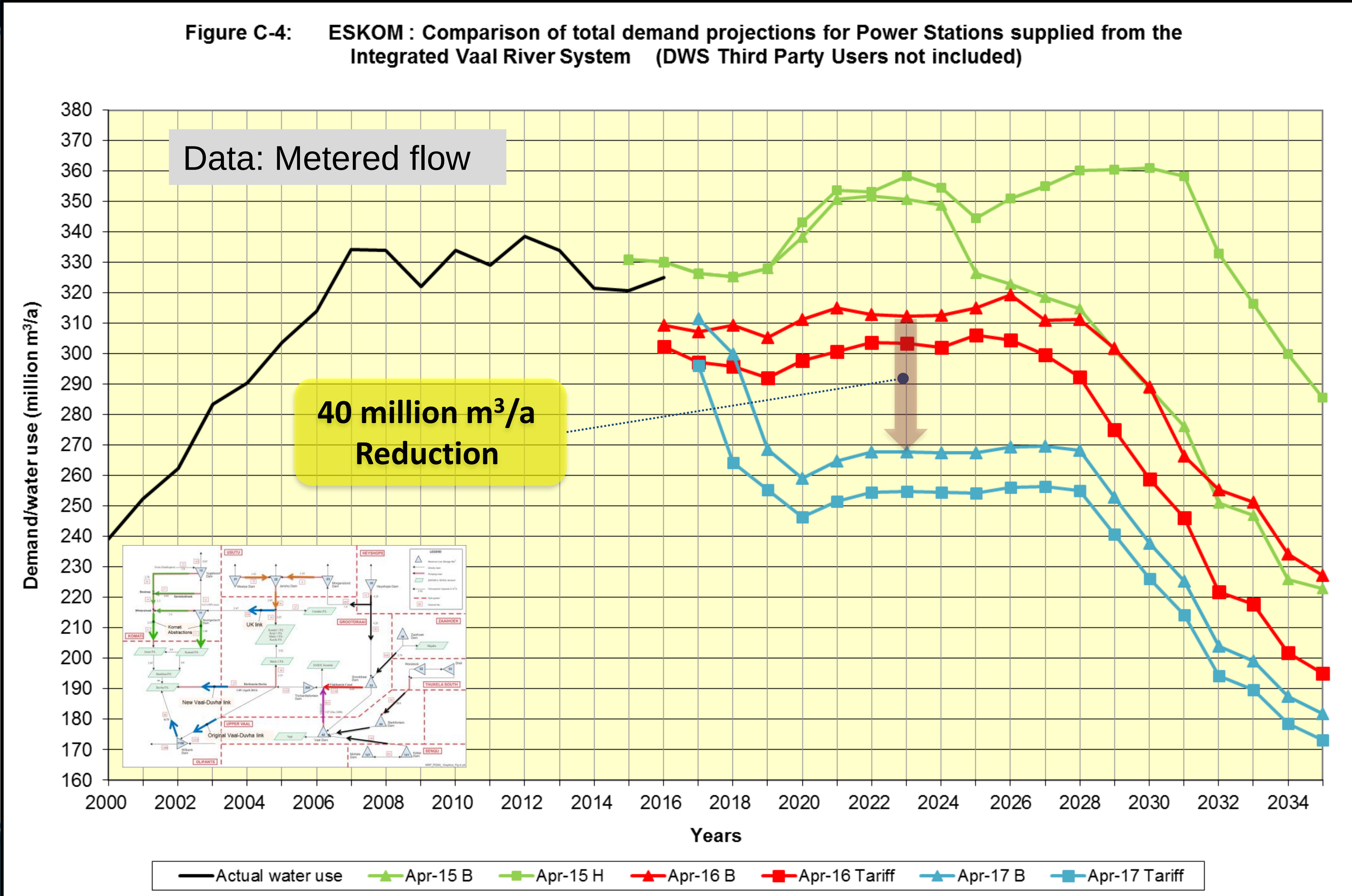
- Lesotho Highlands Water Project Treaty (1988)
- Technical Report TR 134, Water Demands in the Vaal River Supply Area forecast to Year 2025 (1988).
- Historic and Future Water Demands and Return Flows (BKS, 1988).
- Vaal Augmentation Planning Study: Future Water Demands and Return Flows (1994).
- DWAF Annual Updates (ongoing).
- National Water Resources Strategy (2004).



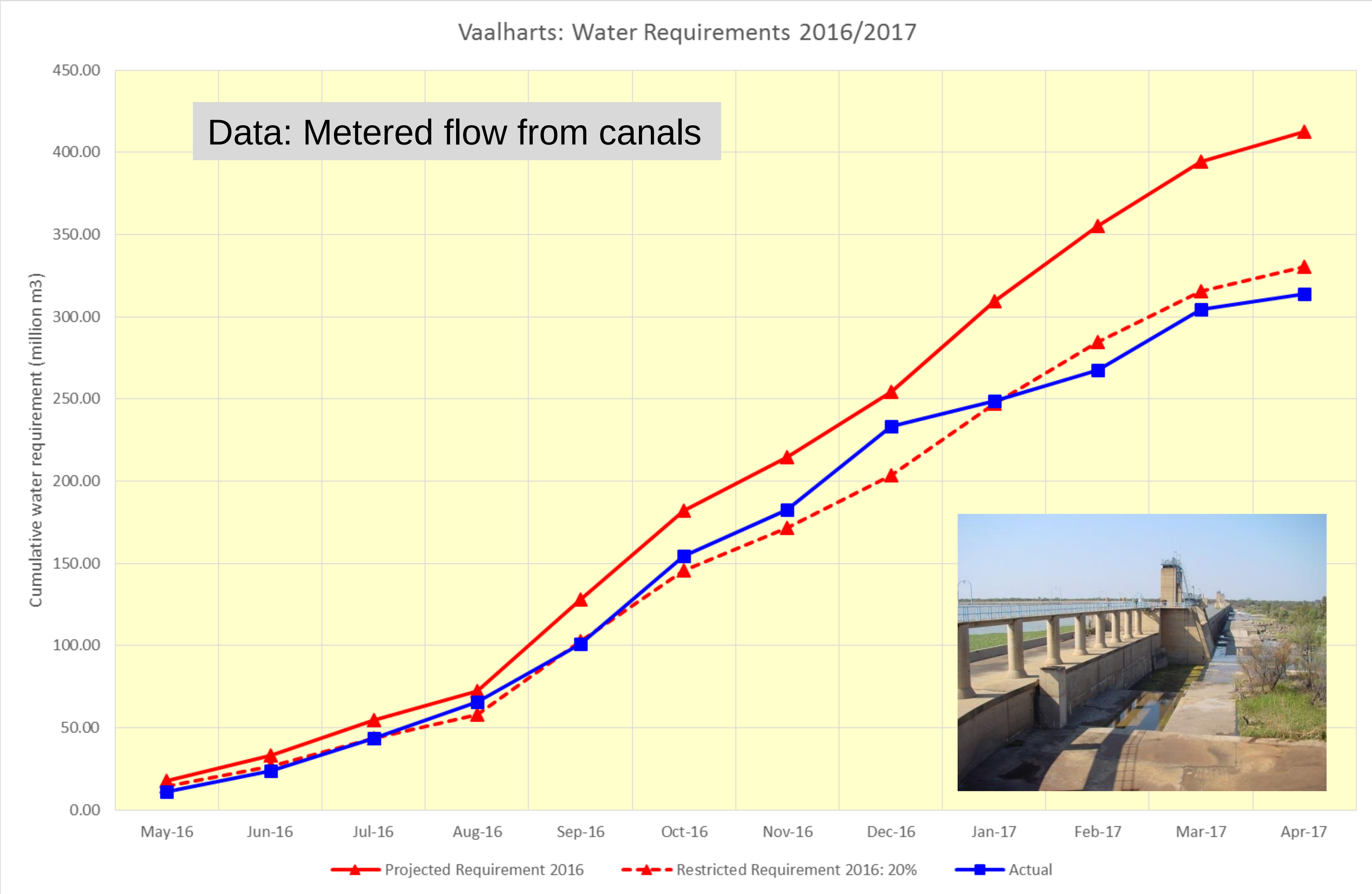
Rand Water Supply Area (2016 AOA)



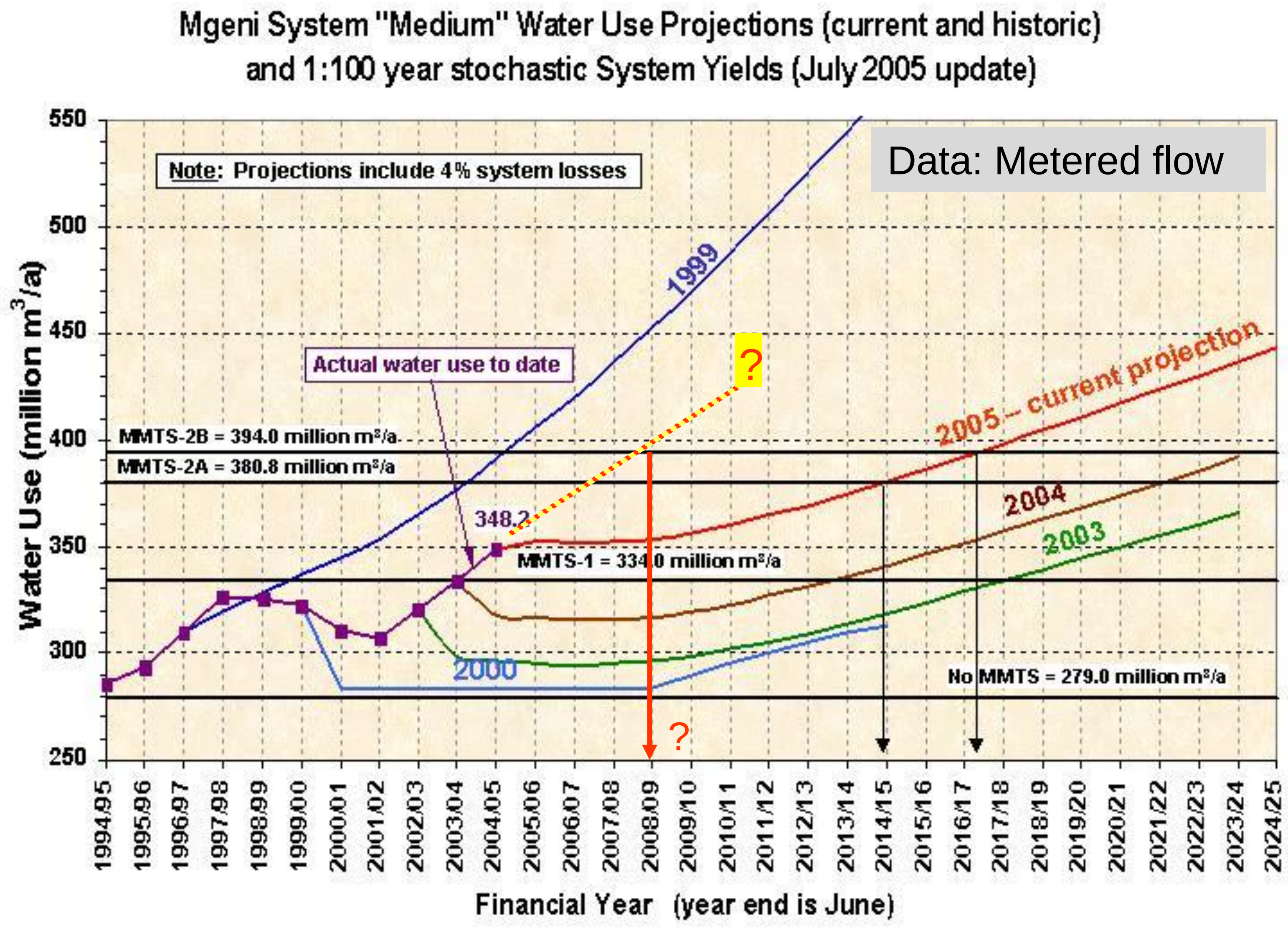
Eskom
(Total Integrated Vaal River System)



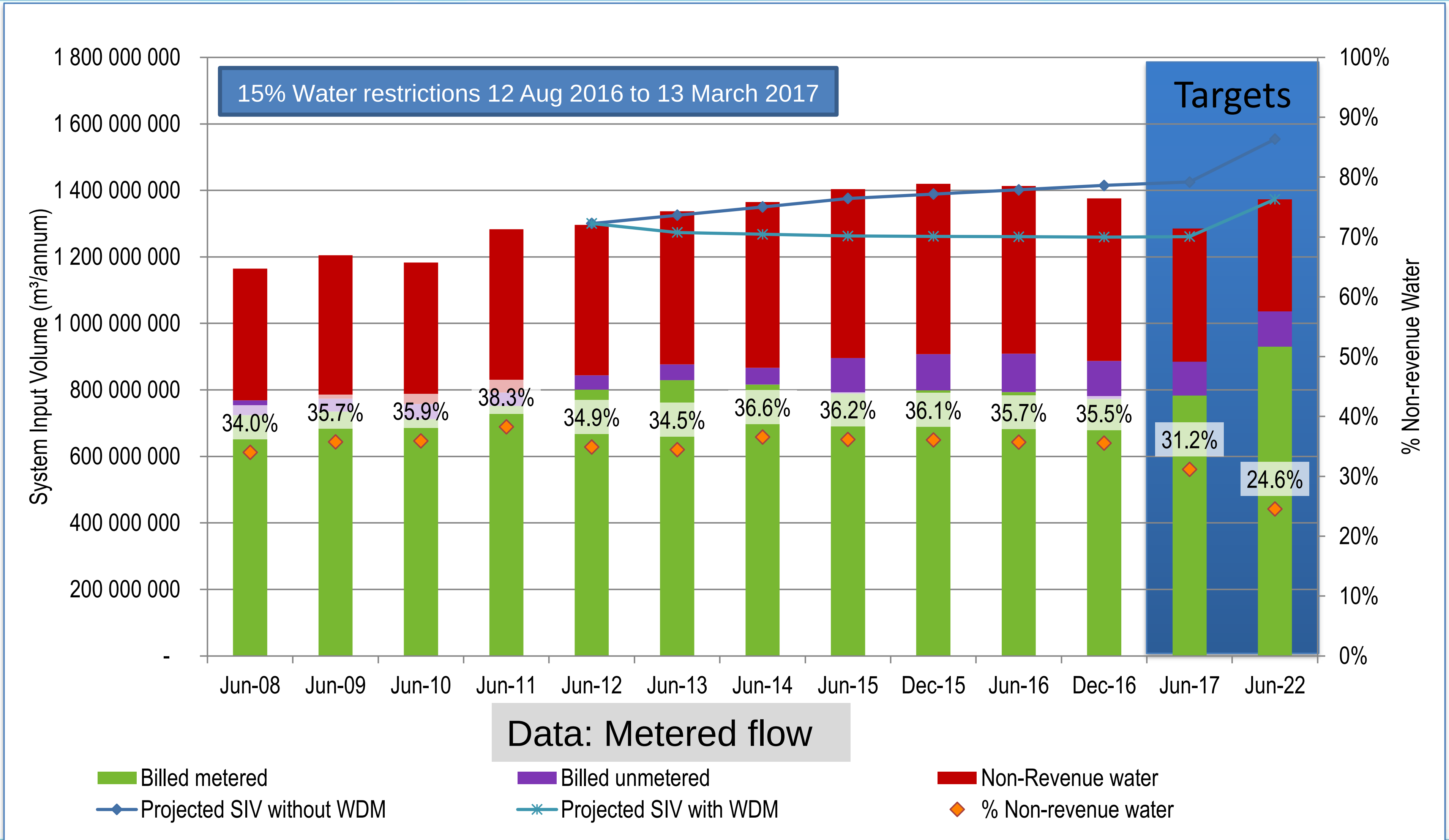
Vaalharts Irrigation Scheme Water Use monitoring



Comparison of water requirement scenarios & recorded data (Mgeni River System)



Monitoring Water Use Efficiency (Integrated Vaal River System)



Tracking Target Savings against Actual Savings

Data: Metered flow

Year ending	Projected SIV without WDM (X) kl/annum	Projected SIV with WDM (Z) kl/annum	Projected % savings (X – Z) / X * 100	Actual demand (Y) kl/annum	Actual % savings (X - Y) / X * 100
Jun-12	1 300 613 343	1 300 613 343	0.0%	1 296 073 215	0.3%
Jun-13	1 325 208 539	1 273 402 875	3.9%	1 337 536 245	-0.9%
Jun-14	1 350 262 570	1 268 011 188	6.1%	1 365 380 179	-1.1%
Jun-15	1 375 784 167	1 262 935 804	8.2%	1 403 523 126	-2.0%
Dec-15	1 388 841 060	1 261 797 859	9.1%	1 420 101 889	-2.3%
Jun-16	1 401 897 953	1 260 659 914	10.1%	1 413 031 287	-0.8%
Dec-16	1 414 954 845	1 259 521 968	11.0%	1 374 064 291	2.9%
Jun-17	1 424 217 581	1 261 854 997	11.4%		
Jun-22	1 554 334 603	1 373 114 426	11.7%		

Data from Water Services (DWS)

WATER IS LIFE, SANITATION IS DIGNITY

Network

Directorates

- Water Services
- Regulation
- Water Management
- Other
- List All

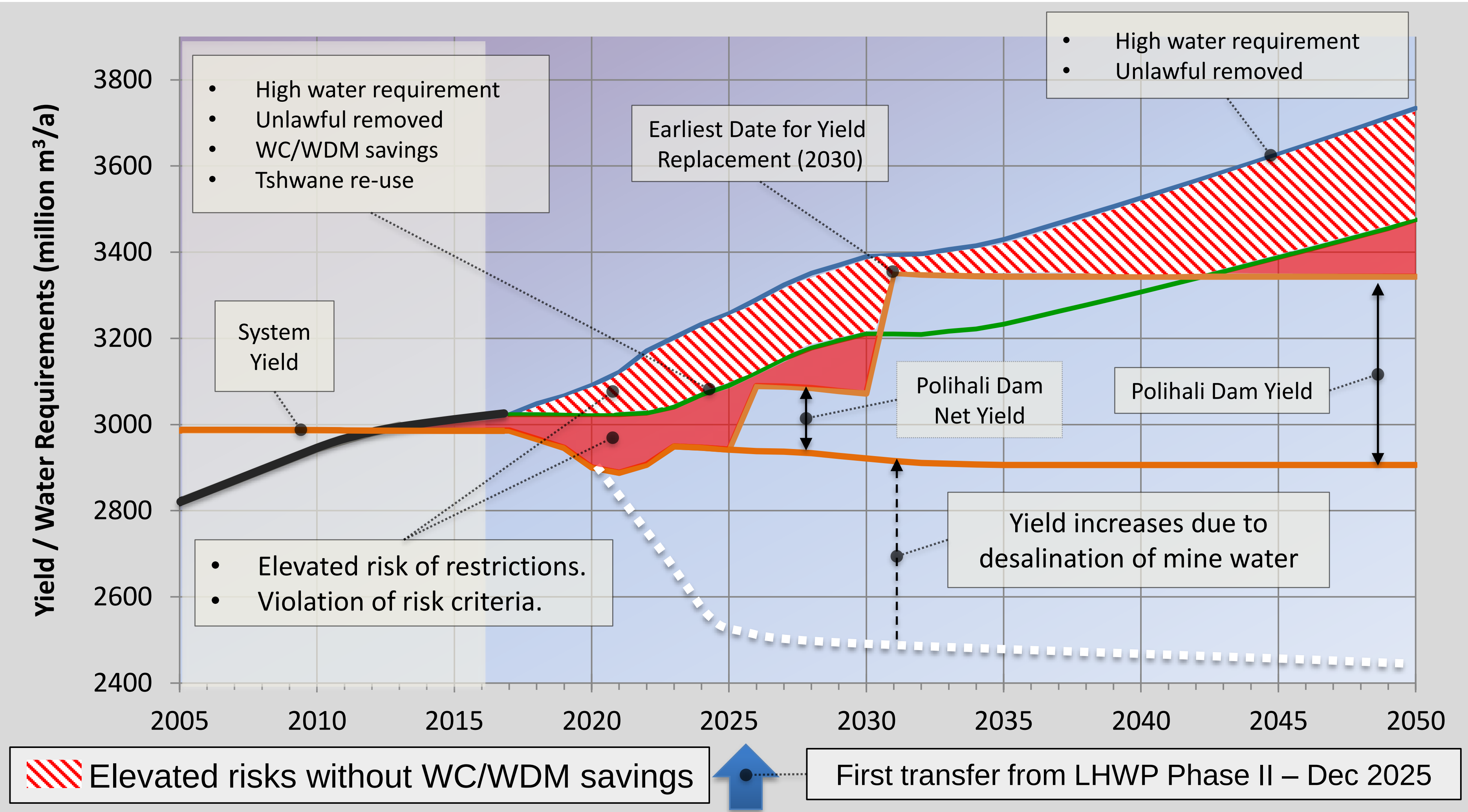
Water Services / Regulation Systems Menu

Logo	Acronym	System Name	ystem Description	Version	Platform
	WSKS	National Water Services Knowledge System	The National Water Services Knowledge System (WSKS), replaces the National Information System (NIS). This website contains data on a National, Provincial and WSA level regarding Demography, Basic Services Backlogs & Progress, Financial Perspectives, Projects and Free Basic Services.	1.1	ASP.NET 4
	WSDP	WSA WSDP Support Tool	The Water Services Development Planning Website displays WSDP Status, Contact Details and WSDP Checklist details on a Municipal level.	3.0	ASP.NET 4
green drop CERTIFICATION waste water service REGULATION	GDS	Green Drop Certification (GDS) Application	The Green Drop System (GDS) serves as a tool to facilitate the relationship between Regulation and Management of Wastewater Services, while also keeping relevant stakeholders informed on compliance trends of all registered systems. The system serves as information basis for the Green Drop Certification programme which is a global first for wastewater services incentive-based regulation.	2.1	ASP.NET 4
			The Integrated Regulatory Information System will initially serve as a tool to		

Data to compile historical and projected Water Balances

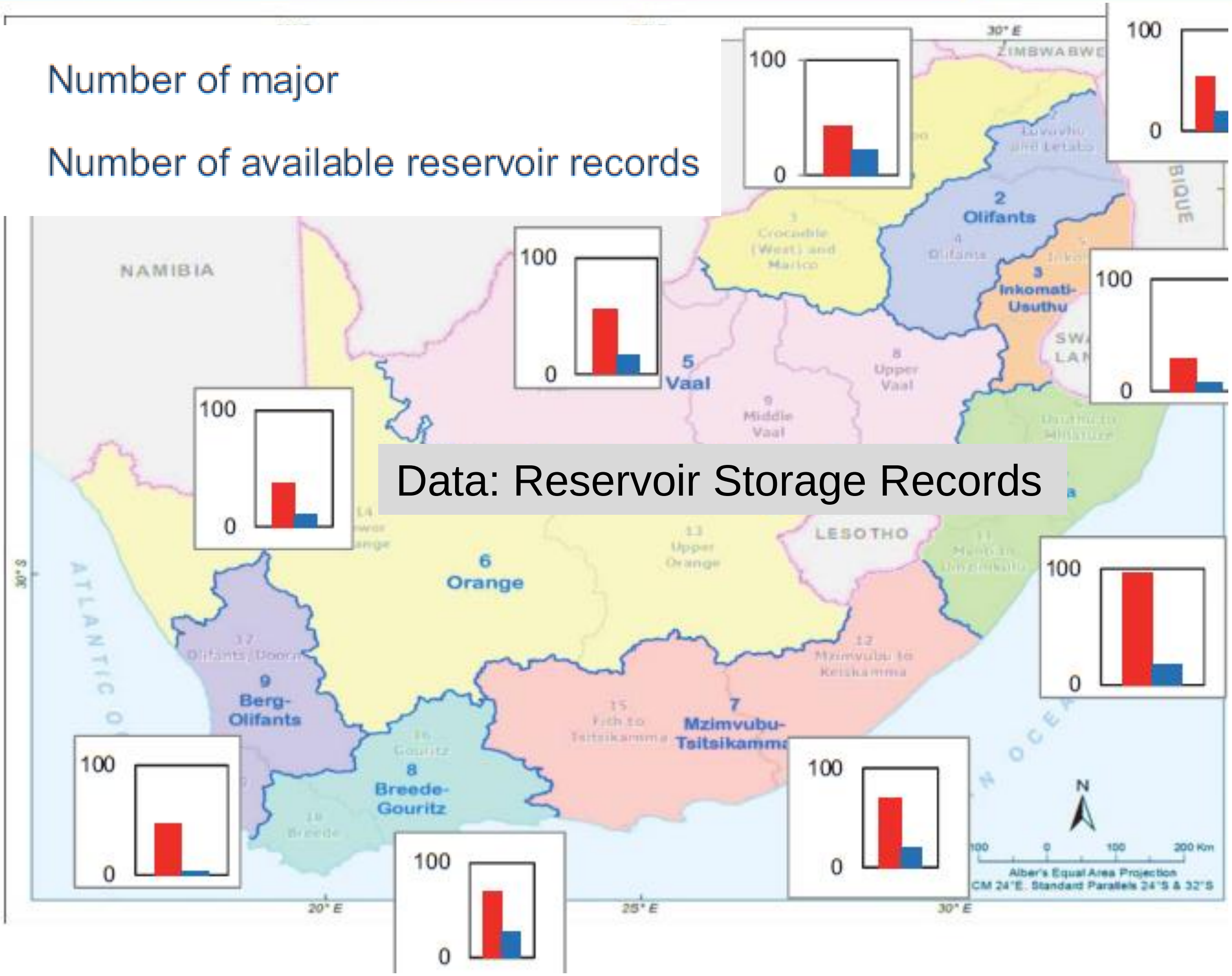
List the data types required to compile a water balance?

High with target WC/WDM	Desalination for urban use (from January 2022)	Unlawful removed	Re-use (Tshwane)



Diminishing measurement points over time > increasing uncertainly and risk

- Number of major
- Number of available reservoir records



Data: Reservoir Storage Records

Figure 7.1: Map showing major dams (greater than 1 million m³) and corresponding reservoir records

Diminishing measurement points over time > increasing uncertainly and risk

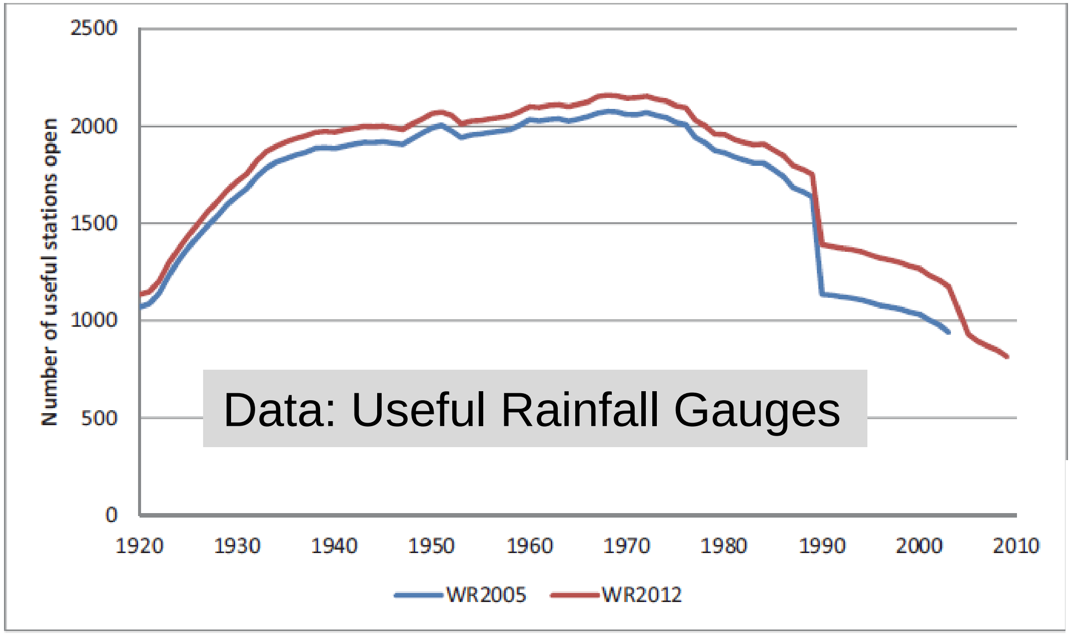


Figure 7.2: Number of useful rainfall stations open over time

Data: Observed Streamflow Gauges

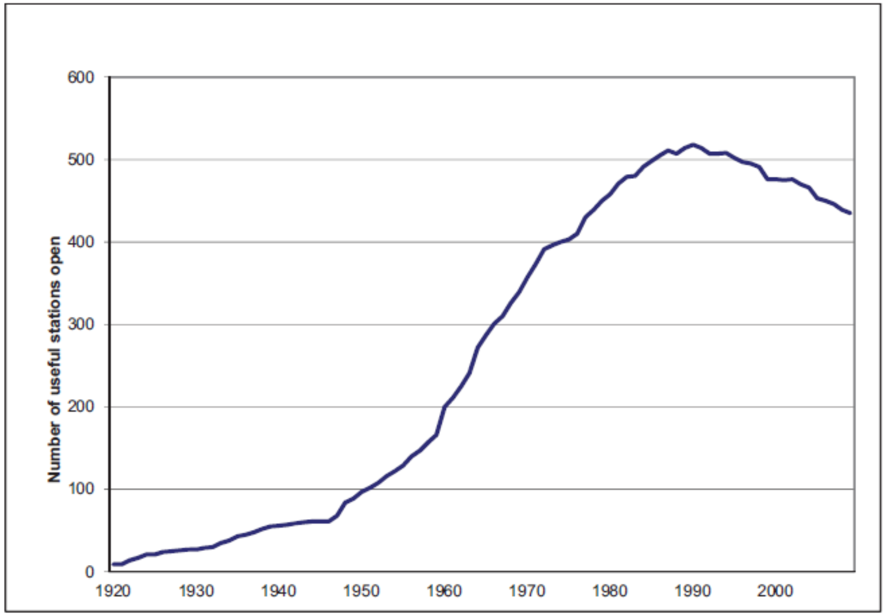


Figure 7.3: Number of useful observed streamflow stations open over time

Consequence of reduction in measuring points:

- Increased uncertainty in quantifying water availability and water use.
  - Results in, inaccurate water balance projections.
    - Causing, poor development and operational decisions due to inaccurate information .
      - Leading to social hardship, economic losses and inefficiencies.
- In short: Effective management depends on sufficient data.

Managing water resources in data-scarce regions/catchments.

- High uncertain hydrological data is available for all catchments in RSA - WRSM2012.
- When uncertain, adopt cautionary management decision making approaches, such as:
  - Don't allocation all available water resources – allow a buffer.
  - Implement measures to reduce uncertainty before large capital expenditure.
- In short: When uncertain take appropriate conservative and cautionary decisions.
- See documentation on: "Implementing uncertainty analysis in water resources assessment and planning"

Types, sources and availability of data (themes)

- Types of meteorological data required for water resources management such as rainfall, streamflow, evaporation and temperature .
- Non-meteorological data requirements such as groundwater, geomorphology, soils, water quality and population census data.
- Water use data such as registered water users and actual water abstraction information.
- Existing data repositories and data sources which house meteorological data.
- Existing Department of Water and Sanitation (DWS) and other internal data repository systems such as Water Authorisation Registration Management System (WARMS) and Hydstra.
- Dam storage data, approach to monitor and store dam storage level data and the need to continuously expand the existing dam monitoring network.
- Data interpretation, reporting and dissemination
- Global data sources relevant to South Africa such as gridded satellite rainfall data.

Internal Assessment Criteria:

- **Describe the types of data to be considered in managing water resources.**
- **List possible sources of non-meteorological available data.**
- **Describe the methods for interpreting, reporting and disseminating water related data.**

Types of meteorological data required for water resources management

- Primary data: Precipitation, streamflow, evaporation and temperature.
- Secondary: Wind intensity, radiation, crop evapotranspiration (ET_o).
- Evaporation Measuring Techniques:
  - Pan evaporation:
    - American tank or “A” Pan, Symons tank or “S” Pan.
  - Other methods: The Water Wheel July/August 2006

Existing data repositories and data sources which house meteorological data.

- Department of Water and Sanitation, Hydrology
- South Africa Weather Service
- Water Resource 2012
- Department of Agriculture
- SA Sugar Association
- Climate System Analysis Group University of Cape Town
- Grid based rainfall:

  Climatic Research Unit (CRU) University of East Anglia
- Other: National Oceanic and Atmospheric Administration U.S. : Africa

Research on using different rainfall data sources: (D.A. Hughes, A. Slaughter)

Non-meteorological data requirements.

- Water use and return flows:
  - Municipal, Water Service Providers, industries and Irrigation agriculture.
  - To estimate irrigation: Irrigated area, crop types, irrigation systems.
- Population history (census) and projections.
- Groundwater: Abstractions, borehole water levels.
- Water storage structures.
- Stream Flow Reduction Activities.
  - Forestry, Invasive Alien Plants.
- Water Quality Data

Existing data repositories and data sources or water use and return flow data

- Department of Water and Sanitation:
  - Water Authorization Registration Management System
  - Water Use Verification and Validation studies (DWS).
  - Hydrology
- Water Service Providers (Rand Water, Umgeni Water, ERWAT and many others).
- Catchment Management Agencies (such as IUCMA)
- Water User Associations (such as Vaalharts WUA**)**
- Municipalities, Local and District Municipalities.
- Water Resource 2012
- Department of Agriculture
- SA Sugar Association

Types of water use data

- Imported to distinguish between the types of data:
  - Measured or actual water use – metered records of flow data at a point in time or over a period (litres per day, million m^3/year, m^3/s)
  - Allocation – “allotted” or allowed volume of use.
  - Registered water use.
  - Estimated use – Irrigation is usually estimated from a range of other measured data (irrigation area, crops and crop factors, irrigation systems, rainfall, evaporation).

Non-meteorological data requirements such as groundwater, geomorphology, soils, water quality and population census data.

- Geomorphology – groundwater studies.
- Soils – runoff modelling and sedimentation studies.
- Water quality – determine fitness for use and to inform management strategies.
- Population – water use pattern and scenario planning.

Population data

- Population is primary driver of Urban water requirements and return flows.
- Historical population data, in combination with water use and return flow data, provide ratios:
  - Metric of efficiency, level of service: litres per capita per day.
  - Basis for projections (formulate future scenarios).
- Population projection scenarios is a key variable to derive future water requirement scenarios for water resource planning.

Water quality data.

- Water quality determines the fitness for use – important water resource management consideration.
- Guide and monitor waste management.
- Both surface and groundwater quality data is required.
- Water Quality constituents to measure: – relevant for the prevailing conditions in a catchment.
- Water Quality data required for modelling.
- Data needed to develop Water Quality Management Strategies.
- Ecological monitoring.

Water Quality Data Sources

- DWS: Resource Quality Information Services
- Water Service Providers: Providers (Rand Water, Umgeni Water, ERWAT and others).
- Catchment Management Agencies (such as IUCMA) Water User Associations (such as Vaalharts WUA)
- Municipalities, Local and District Municipalities.
- Large bulk water users.
- Research institutions.

Data interpretation, reporting and dissemination

- Interpretation relates to "converting" data into information, typically involving:
  - Graphing, listing data in tables, summary statistics, filtering and modelling.
  - When interpreting data always be on the lookout for anomalies and be critical. "It takes effort to avoid embarrassment".
- Data dissemination, in the information age, is through various electronic formats: text files structured or unstructured, spreadsheets, databases systems, web pages. {Data measured, collected and housed with public funds should be on the internet: DWS}

Observed, raw and patched data

- Types of data such as observed, raw and patched data.
- Equipment used to gather various types of data and the differences between electronic and manual data gathering methods.
- Data quality and credibility.
- The process of verifying unverified data including stage/discharge relationships and corrections.
- Determine and handle data outliers in historical data sets.
- Patching and infilling of missing/unreliable data sets, especially rainfall and streamflow data.

Internal Assessment Criteria:

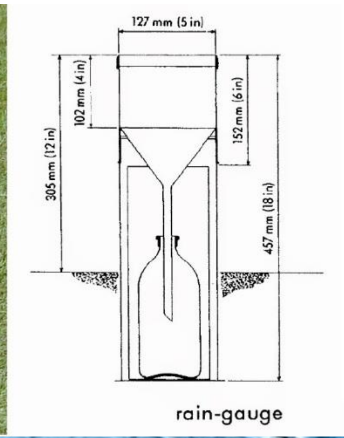
- **Differentiate between observed, raw and patched data.**
- **Describe the benefits and disbenefits of manual and electronic data sets.**
- **Describe the dangers of disseminating some raw data without first doing quality control of data.**

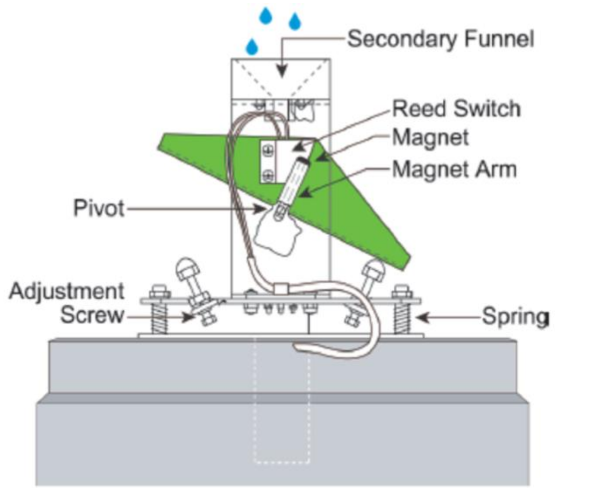
Observed or Raw data

- Water surface level: (River section, weirs, channels, dams).
- Flow meter readings: (Flow meters, channels).
- Rainfall: (daily measurements, automatic rain gauges - bucket tipping counts).
- Evaporation:
  - Pan water level measurements as well as rainfall.
  - Penman equation. Parameters: radiation, moistness, temperature and wind movement

Rainfall measurements

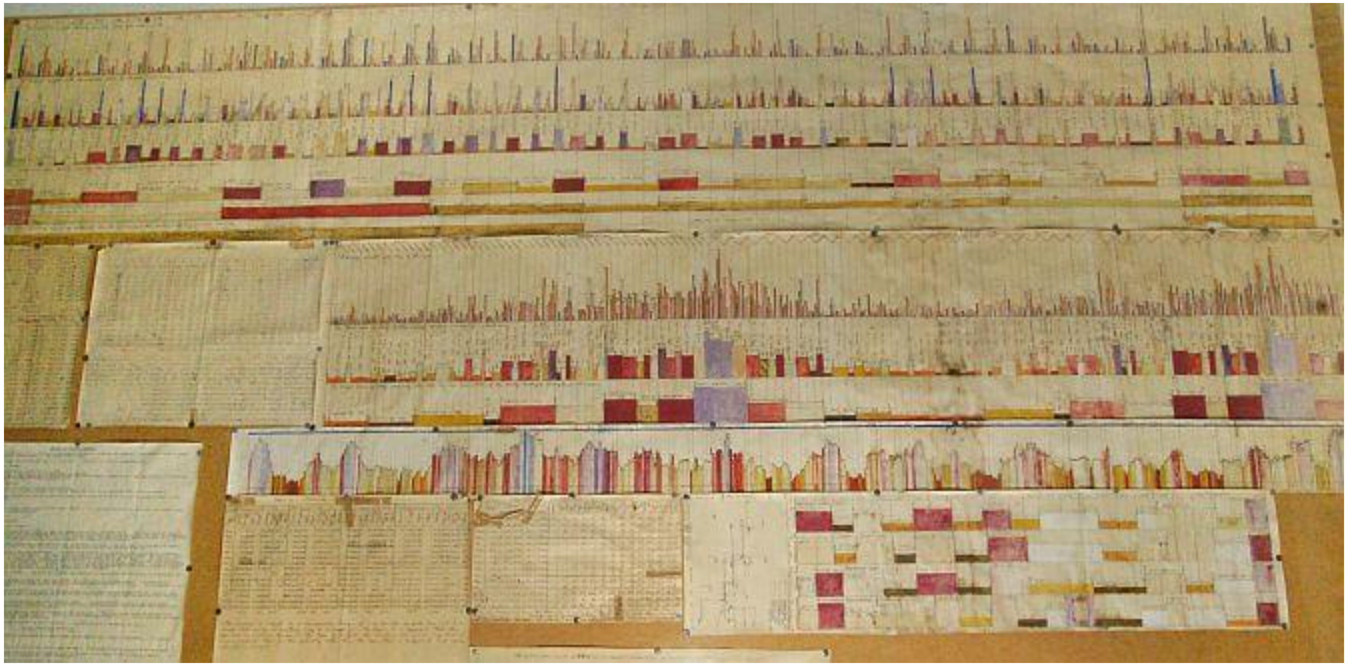
- Rain Gauges:
  - Weather Stations (standard 127 mm Ø rain gauge)
    - 4 parts: Catchment funnel, bucket, bucket holder, measuring glass.
  - Automatic rain gauges, various types:
    - Tipping bucket, weighing.



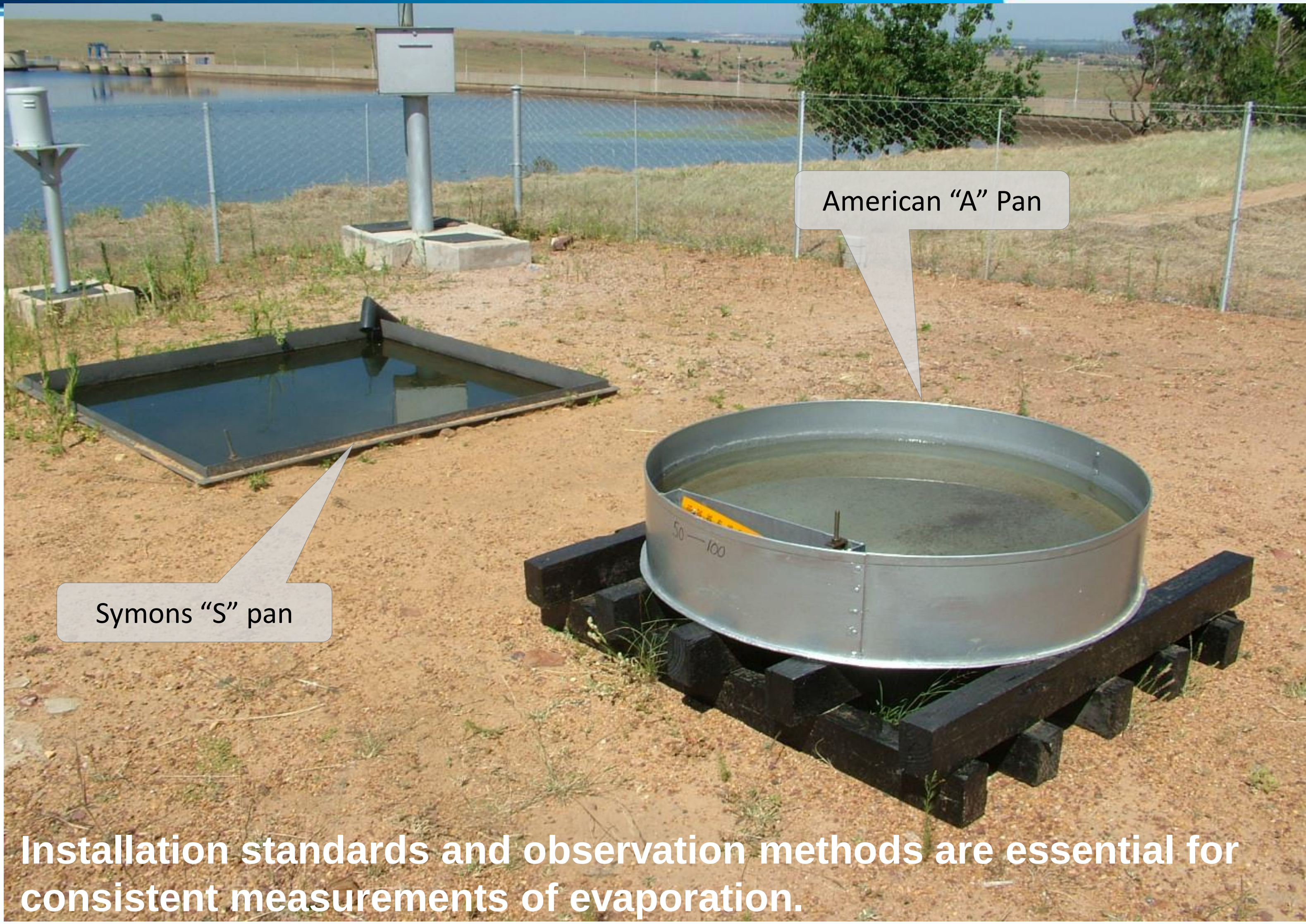


Example of rainfall measurement commitment.

- "Unperturbed by whatever came their way, except if it was a prolonged absence of rain, five generations of farmers diligently and keenly observed every drop of rain and meticulously jotted it down in the tome: "Wellwood Rain Records from 1874- ".

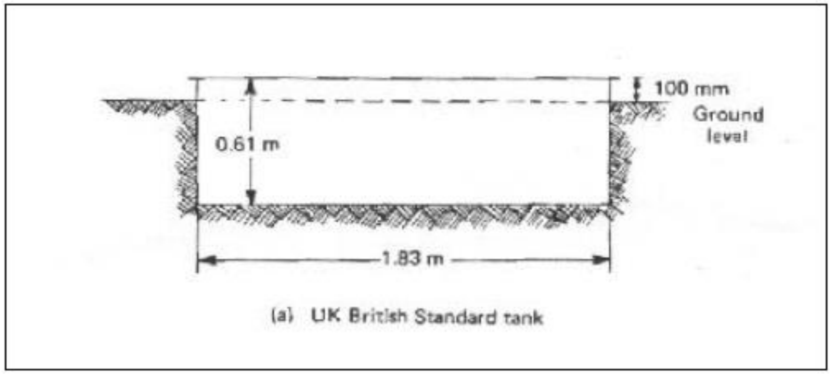


Pan evaporation measurement equipment examples:



Measuring detail on S Pan

Application of evaporation data in hydrological models



(a) UK British Standard tank

Monthly S-pan evaporation data

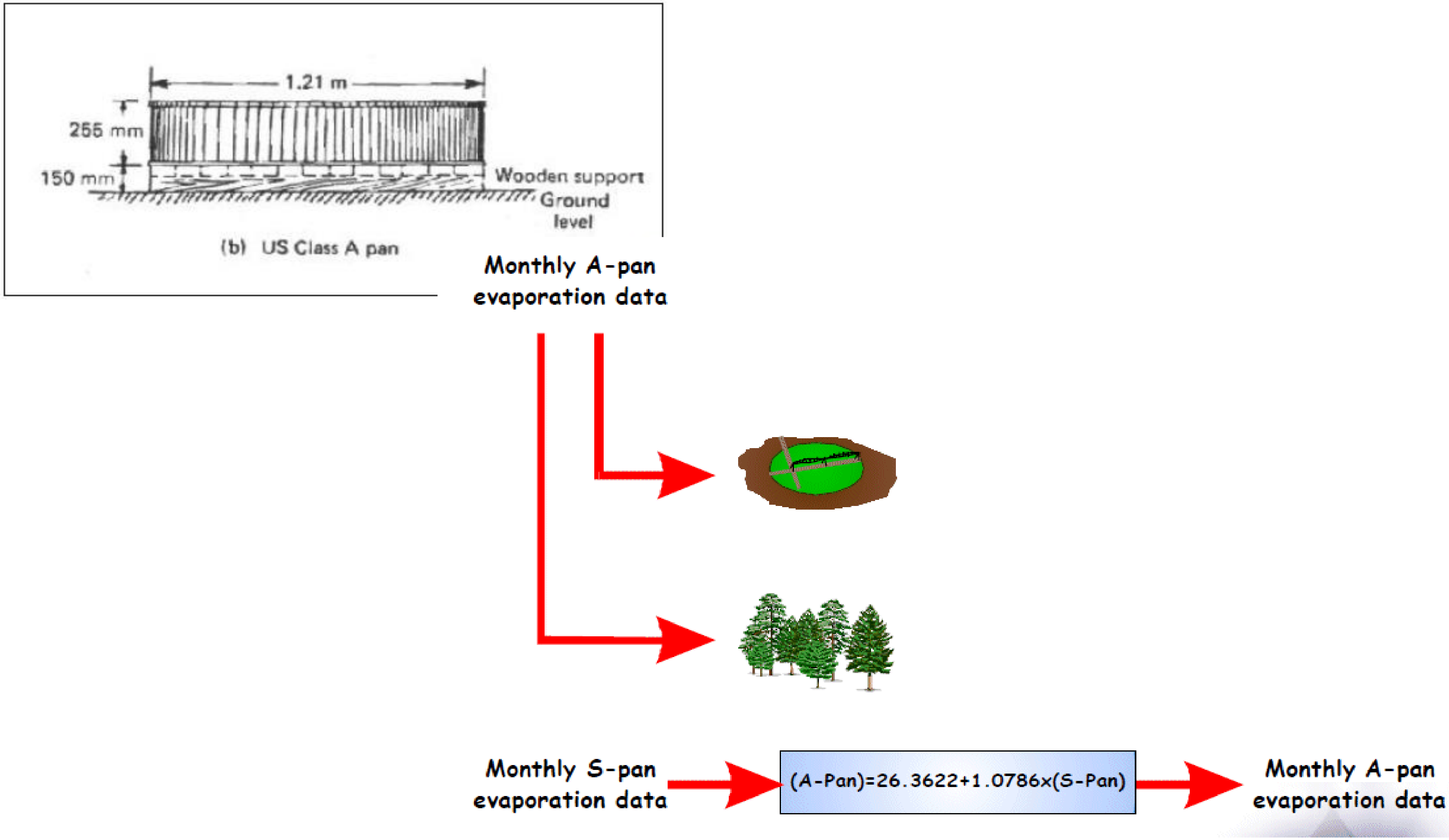
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.80

Catchment evapo-transpiration

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.81	0.82	0.83	0.84	0.88	0.88	0.88	0.87	0.85	0.83	0.81	0.81

Lake evaporation

Application of evaporation data in hydrological models



Factors influencing measurements of evaporation.

- Standards of installation and equipment required for consistent measurements.
- Diligently follow observation protocols:
  - Consistent reading of water level, correct filling of tanks, event notes to accompany numerical measurements and correct measurements key entries. See [1] for further details.

Flow measurements

- Streamflow gauging
- Reservoir balances
- Abstraction and release measurements

Gauge C2H001
Longest Flow Record

Download monthly data for gauge C2H001: What do you observe?

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

WATER IS LIFE, SANITATION IS DIGNITY

Home

Data retrieval: Data are continuously updated and reviewed. To limit server overheads and download time, limits per query are **7000** records (or **1** year of data) for primary data and **20** years of data for daily data. Do multiple queries to retrieve the full record.

Station C2H001 Mooi River @ Witrand C.Area 3595 km² Lat -26.64428 Long 27.09033 Site Type RIV

Photo

Quality Codes

Recorded data and information

Station Number-Type	Variable	Component	Start Date	End Date	Volume (Multiples of m³)	Flow (m³/s)	Primary Data
C2H001-RIV	100.00	Mooi @ Witrand	1904-07-31	2018-04-17	Monthly Volume	Daily Avg. Flow	Primary Data

☐ Date Volume Format (Non Matrix)

Rating Tables

DT No (GP Readings)	Date of application
6 (GP Readings)	1904-07-31

Data are continuously updated and reviewed.
The format of this file is as follows:
POS. 1-8 = Date of measurement CCYYMMDD
POS. 10-15 = Time of measurement HHMMSS
POS. 27-35 = Corrected level in m
POS. 37-40 = Quality code
POS. 52-60 = Corrected flow in cubic metres/sec
POS. 62-65 = Quality code
C2H001
Variable 100.00 Surface Water Level

DATE	TIME	COR.LEVEL	QUA	COR.FLOW	QU
19040731	**235900**	**0.341**	**5**	**1.545**	**5**
19040802	235900	0.341	5	1.545	5
19040803	000000	0.339	5	1.512	5
19040803	235900	0.339	5	1.512	5
19040804	000000	0.339	5	1.512	5
19040804	235900	0.339	5	1.512	5
19040805	000000	0.339	5	1.512	5
19040805	235900	0.339	5	1.512	5
19040806	000000	0.342	5	1.561	5
19040806	235900	0.342	5	1.561	5
19040807	000000	0.345	5	1.611	5
19040807	235900	0.345	5	1.611	5
19040808	000000	0.340	5	1.528	5
19040809	235900	0.340	5	1.528	5
19040810	000000	0.348	5	1.662	5
19040810	235900	0.348	5	1.662	5
19040811	000000	0.349	5	1.679	5
19040811	235900	0.349	5	1.679	5

Practical: What can be observed from the C2H001 flow data?

- 1.
- 2.
- 3.

Streamflow gauging

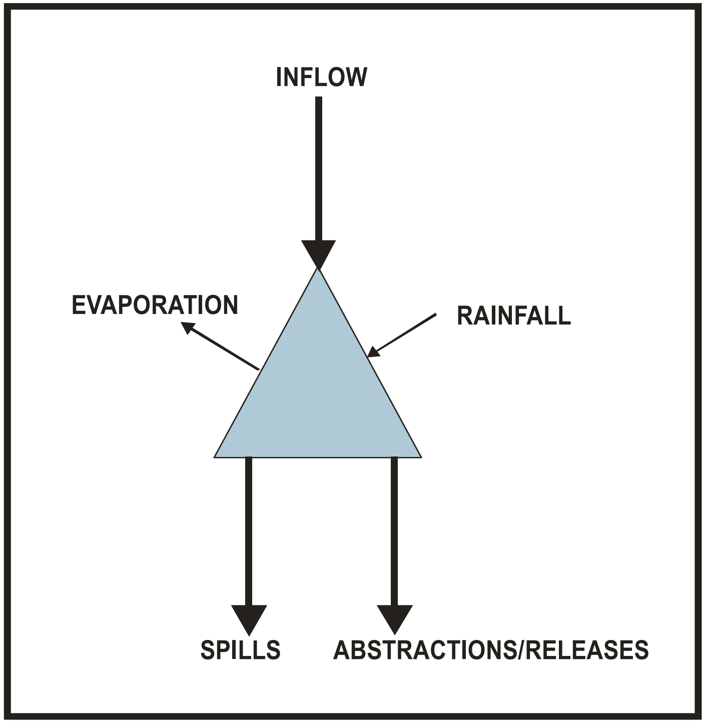
Structures:

- Broad crested weir.
- Sharp crested weir.
- Horizontal Crump.
- V-Crump.
- Parshall Flume.
- Ogee crest.
- Hydro flume
- Cippoletti & V-notch, Sluicing fume.

Reservoir Storage Data

Dam Balance Calculations
Inflow
= Change in Storage + Outflow
= (End storage – starting storage) +

actual evaporation + spills + actual use



Abstraction metering examples

Data Logging Examples

Status of monitoring network, DWS

REVIEW, EVALUATION AND OPTIMISATION OF THE SOUTH AFRICAN WATER RESOURCES MONITORING NETWORK

Implementation Strategy

Final
February 2017

Data quality and credibility

- Accurate and credible data depends on diligent implementation of the full chain of monitoring activities:
  - Installation of apparatus & structures.
  - Maintenance.
  - Data with explanatory metadata.
  - Traceable calculations.
  - Data and information repository management.
  - Verification activities to ensure relevance. [3]

Data verification (example)

- First step in hydrological studies should be to undertake an assessment to verify and screen all data sources.
- Example:

Ref No: P WMA19/000/00/0407

Department of Water Affairs and Forestry

Directorate: National Water Resource Planning

The Assessment of Water Availability in the Berg Catchment (WMA 19) by means of Water Resource Related Models

Report No. 3

The Assessment of Flow Gauging Stations

The process of verifying unverified data including stage/discharge relationships and corrections.

- Regular visual inspection & reporting of structure's status, recommend remedial measures.
- Calibration & re-calibration of flow gauging structures – stage/discharge relationship:
  - Periodically (consider siltation rate)
  - After flood damage and repair.
- Recalculation of dam balances when any component of balance equations is recalibrated or revised.
- Always maintain data history, even if it is superseded.

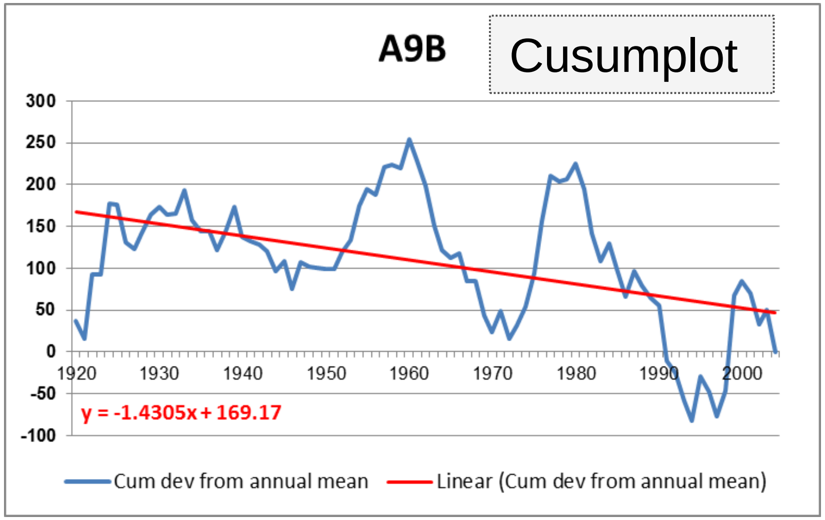
Rainfall Data Patching

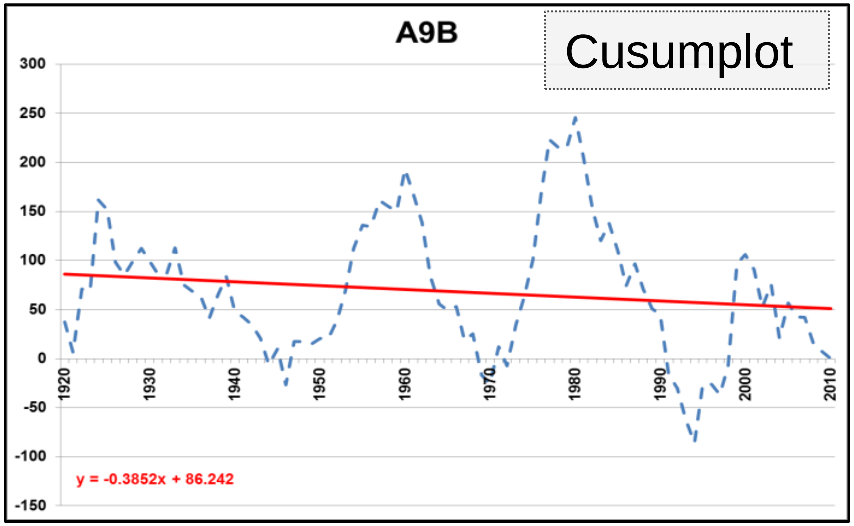
- **Step 1**: Obtain raw rainfall data from appropriate source (DWAF, Weather Bureau etc).
- **Step 2**: Convert to HRU format if required. (monthly data)
- **Step 3**: Create massplots and cusumplots using appropriate software (spreadsheet or Rain-IMS).
- **Step 4**: Tabulate the raw rainfall data for inspection and report.
- **Step 5**: Create a diagram showing record lengths.
- **Step 6**: A visual inspection of the tabulated rainfall files and the mass-plots should be undertaken to identify any clear-cut outliers and/or errors.
- **Step 7**: Undertake the initial cluster classification using CLASSR.
  - CLASSR will highlight numerous potential outliers and errors – user to select which needs replacing.
- **Step 8**: Infill missing data using the PATCHR software . Infilling and patching for all gauges in the group simultaneously.

Rainfall Data Patching

- **Step 9**: PATCHR creates a set of infilled and extended records. Trim the records to eliminate the extended portion, front and back.
- **Step 10**: Manually change the start and end year to reflect the actual period of record. **The MAP in the header line must then be re-calculated.**
- **Step 11**: The patched files should be tabulated and the mass-plots re-calculated Repeat of steps 3 and 4 for the patched/infilled records.
- **Step 12**: Calculate rainfall distribution files for sub-catchments using the patched rainfall files. This is the basic data to be used in the subsequent rainfall-runoff modelling.
- **Step 13**: Produce point rainfall for all reservoirs.

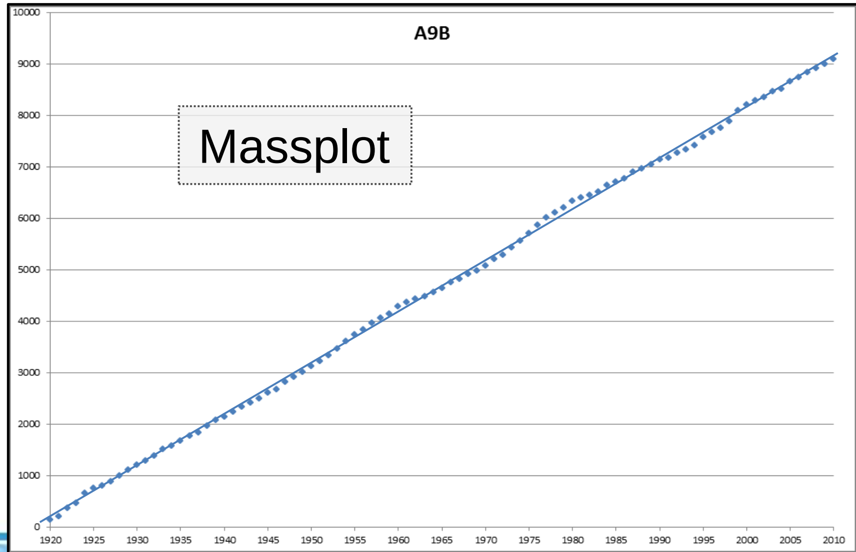
Example





Statistics:

- Stationarity.
- Slope – significance.
- Variance change.
- Split sample t-test: significance of change in mean.
- Depletion analysis.



Temporal coverage of rainfall data

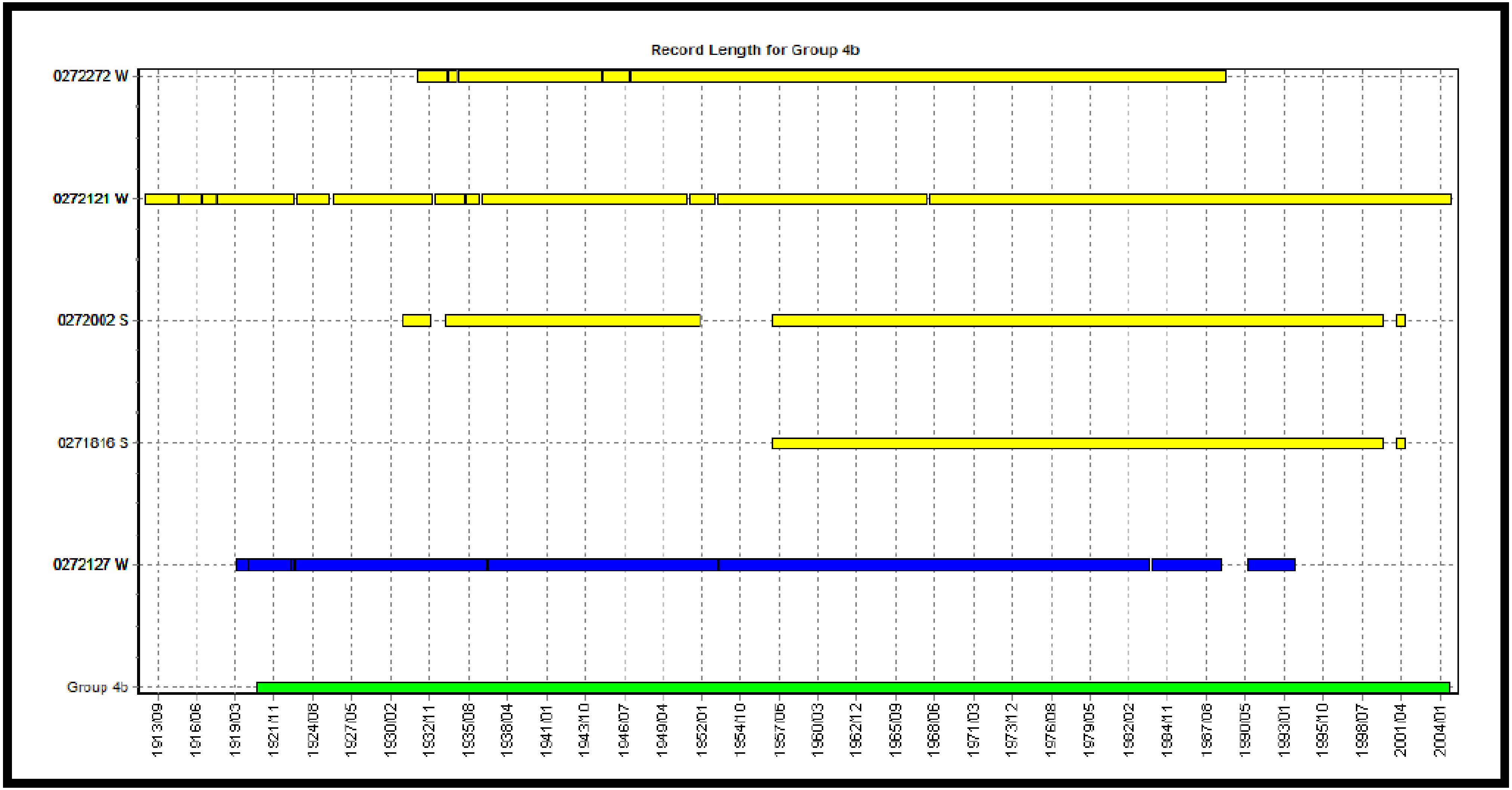
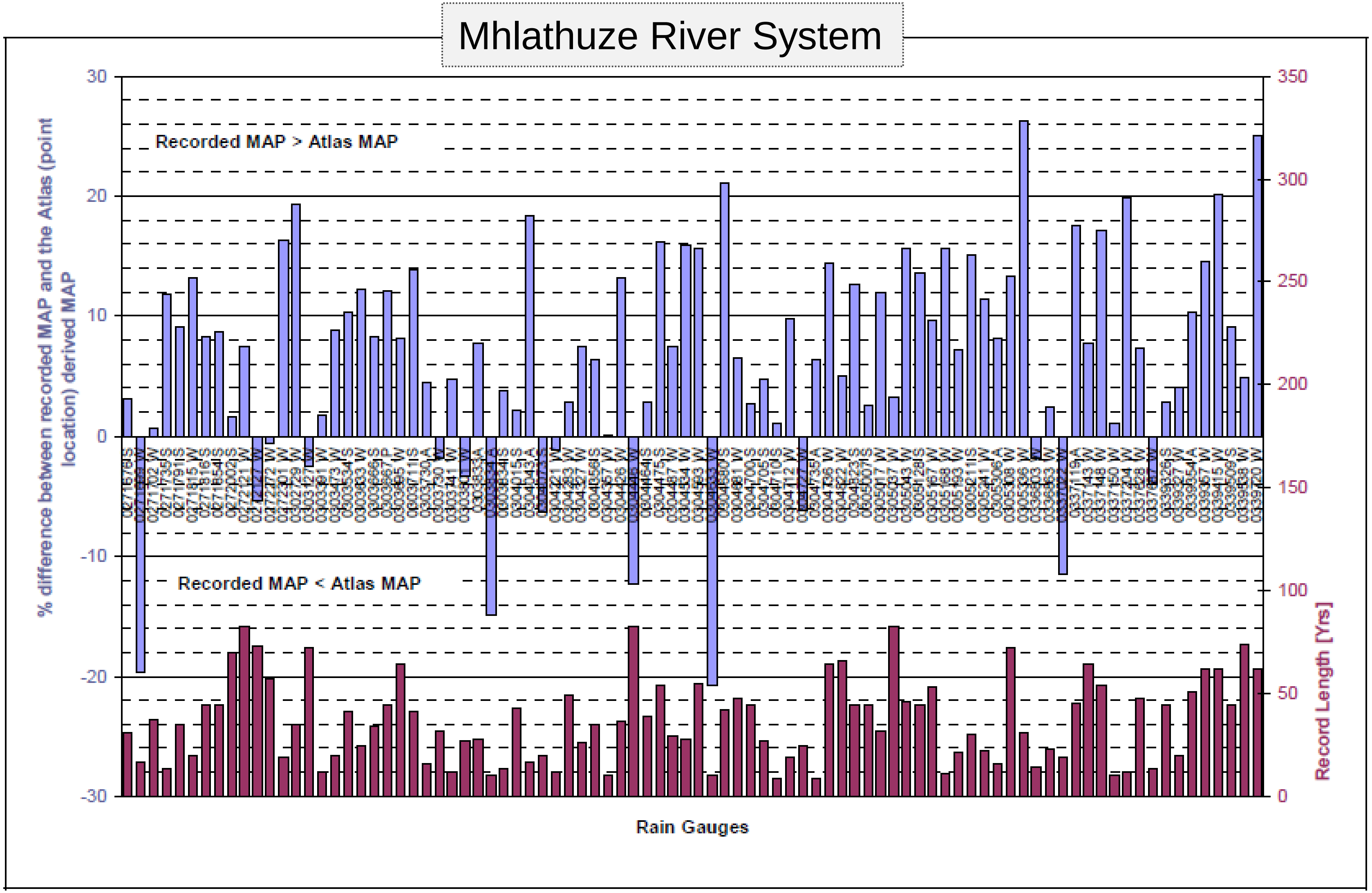


Figure 3-1: Example of bar chart showing overlapping years (Group 4B)

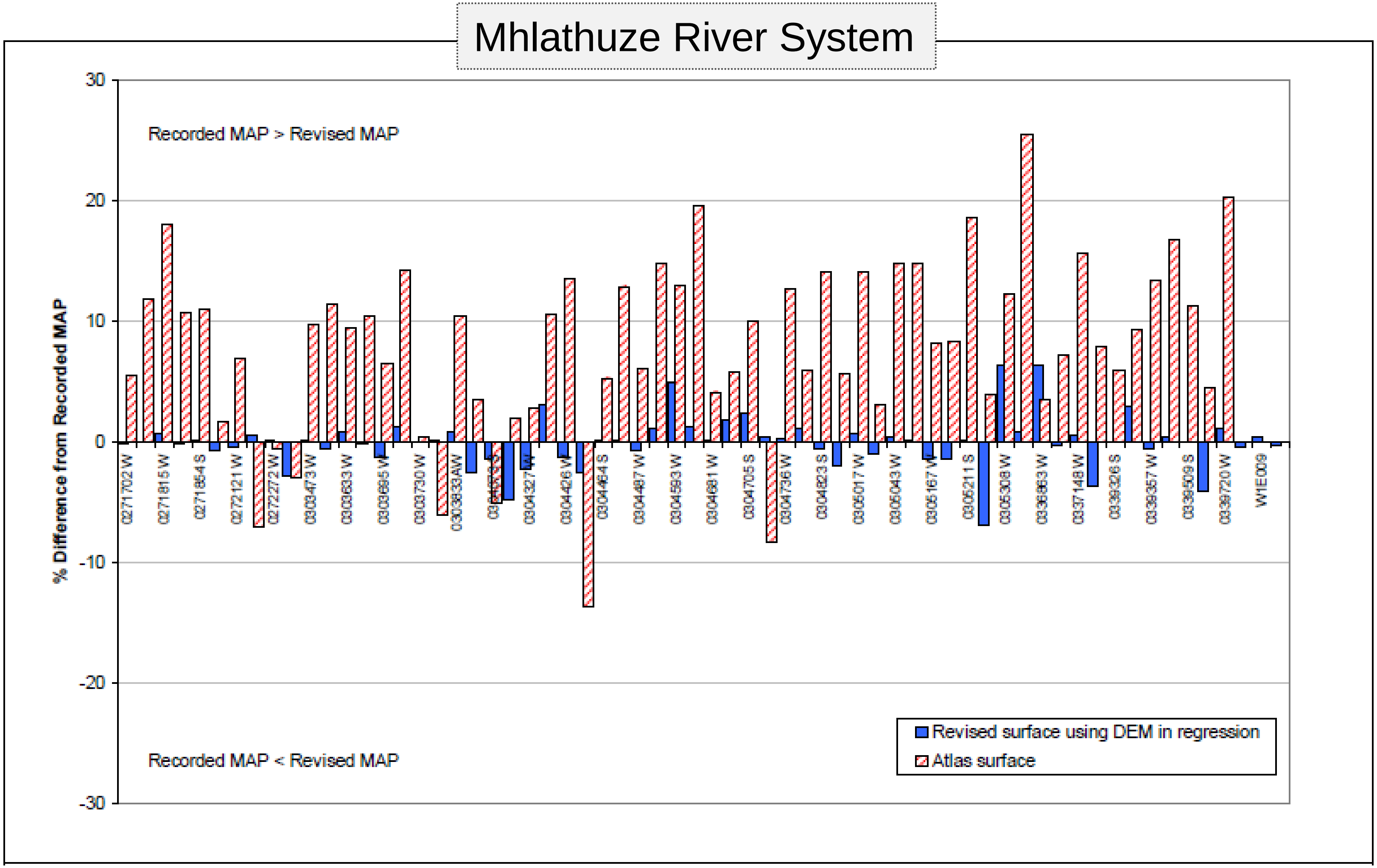
Evaluation of all data sources essential

Figure 1-1 Comparison of Atlas MAP and recorded MAP at rainfall stations



Revised rainfall grid

Figure 2-11 Comparison of modelled (DEM for regression) and recorded MAP at rainfall station locations



Screening of selected streamflow data

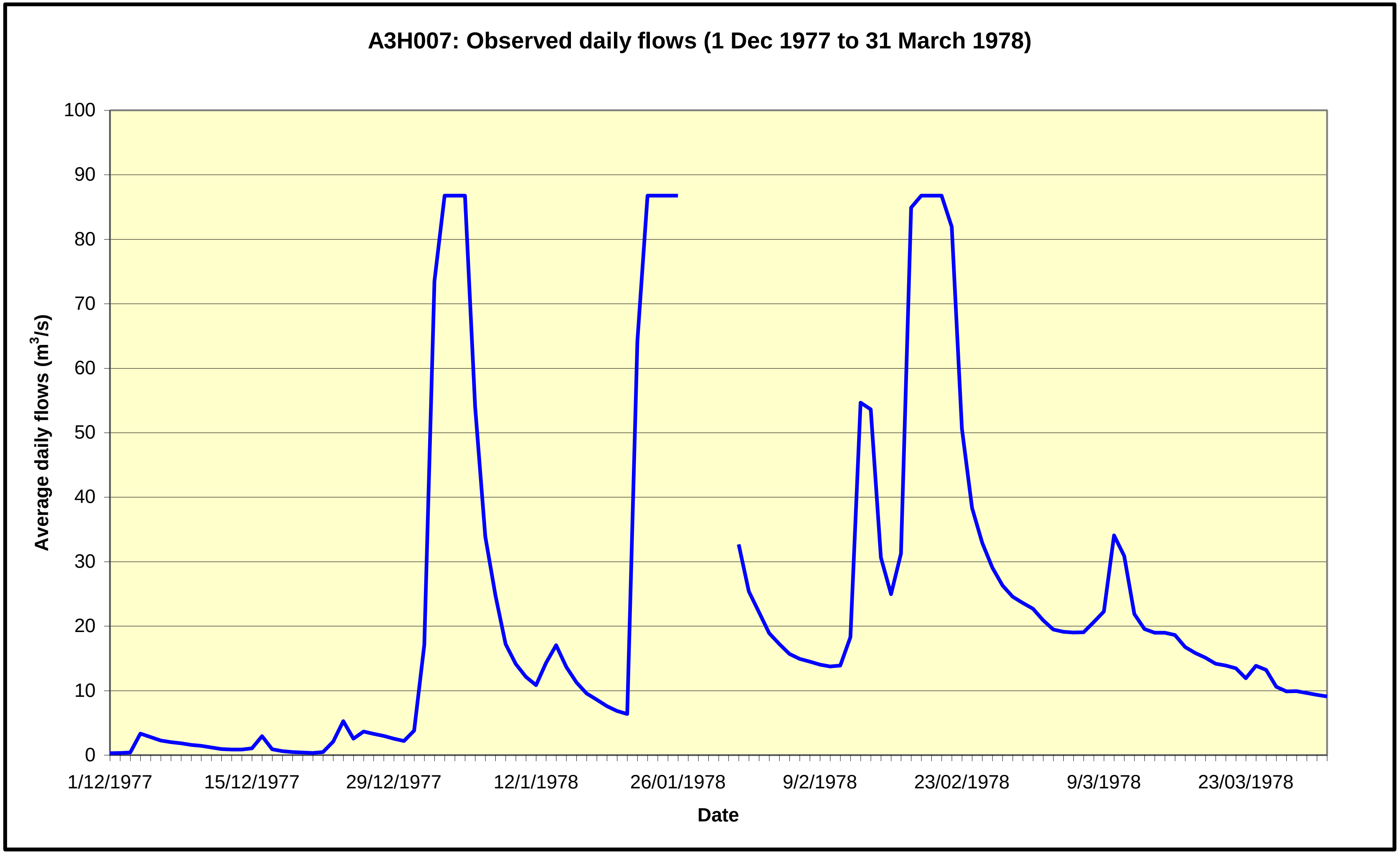
- **Obtain daily and monthly flow data for the selected streamflow gauges.**
- **From monthly flow data identify:**
  - months where measuring capacity of gauging structure was exceeded.
  - months with missing data (no data for entire month).
  - months with incomplete data (some days with missing data).
- **For months with incomplete data, use daily flow records to determine the number of days with missing data.**

Patching of streamflow data

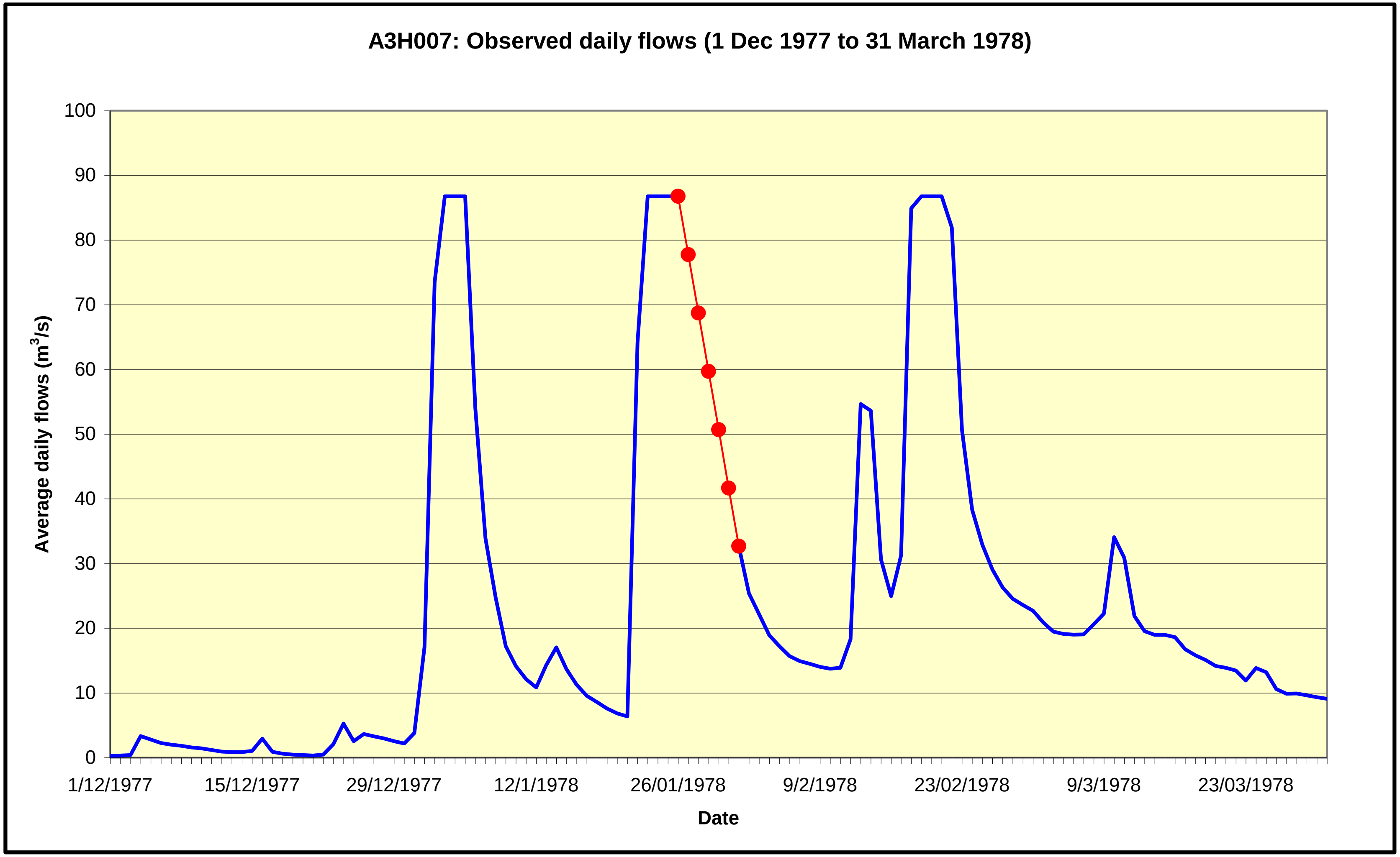
- **Incomplete months: for not more than 3-5 days with missing data use daily flows and interpolate if possible.**

- **For months with missing data and months where gauging limit was exceeded, infill /replace flow values as follows:**
  - Using the PATCHS program
  - Iterative simulation with rainfall-runoff model

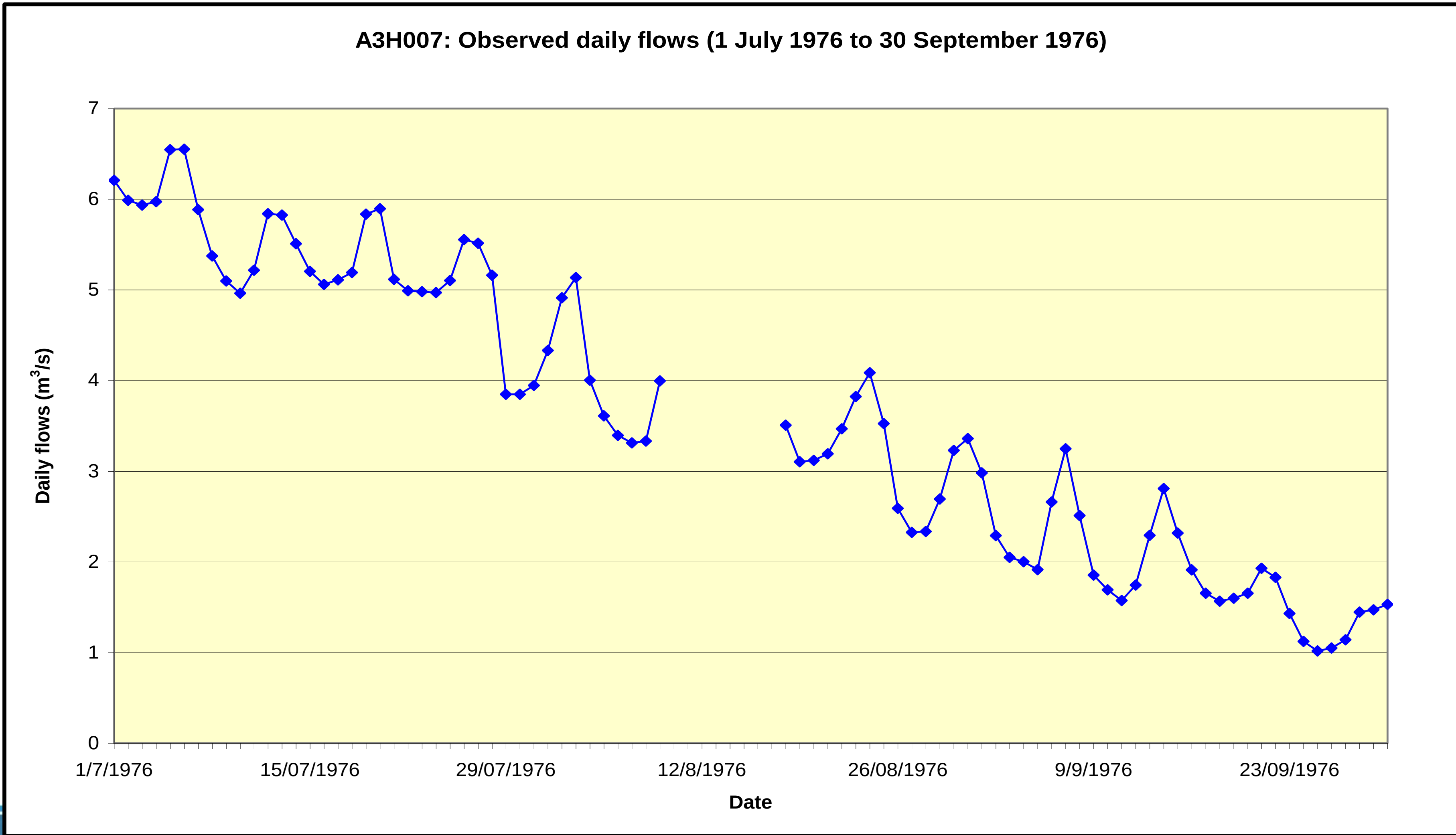
Infilling missing days (1 of 3)



Infilling missing days (2 of 3)



Infilling missing days (3 of 3)



Using PATCHS

- **Make use of other streamflow and rainfall data to patch target station.**
- **Control stations not required to have complete records**
- **Powerful statistical techniques: Cross-validation, EM algorithm and Kalman filter.**
- **Assist in identifying possible errors or outliers**
- **Example in Mhlatuze:**
  - Improved results with inclusion of streamflow as control station.
  - PATCHS consistently provided lower patched values than WRSM2000.

Iterative Patching with WRSM2000

- Run WRSM2000 model with regional parameter values.
- Replace missing/incomplete monthly data with simulated monthly values.
- Continue with calibration of WRSM2000 model and iterative replacement of missing/incomplete monthly data (proper booking important).
- Evaluate final patching of months with incomplete data by comparing against observed data.
- Be careful to “over fit” missing data.

Bookkeeping of patched values

A4H002.pt3			A4H002: WR90 Simulated Values		1st Calibration Results		A4H002.pt5 (2nd Patched observed)		
	Value	**Flag**	**Value**		**Values**		**Value**	**Patch**	**Comment**
Nov-48	6.18	+	9.54		8.28		8.28	*	Simulated value used
Feb-49	9.23	+	15.58		9.16		9.23	+	Observed Estimate Used
Nov-49	3.02	*	4.47		3.97		3.02	*	Estimated
Dec-50	4.96	+	0.02		0.47		4.96	+	Observed Estimate Used
May-51	6.79	*	12.42		5.32		6.79	*	Estimated
Sep-51	0	#	0.04		1.44		1.44	*	Simulated value used
Oct-51	0	#	0.71		1.42		1.42	*	Simulated value used
Nov-51	0	#	0.31		1.15		1.15	*	Simulated value used
Dec-51	0	#	0.05		0.8		0.8	*	Simulated value used
Jan-52	0	#	0.15		0.89		0.89	*	Simulated value used
Feb-52	0	#	2.62		2.16		2.16	*	Simulated value used
Mar-52	0.22	#	2.53		1.98		1.98	*	Simulated value used
Feb-53	15.1	+	123.41		88.92		88.92	*	Simulated value used
Mar-53	17.1	+	69.98		52.15		52.15	*	Simulated value used
Apr-53	16.5	+	20.92		15.68		16.5	+	Observed Estimate Used
Feb-54	13.8	+	14		9.16		13.8	+	Observed Estimate Used
Mar-54	12.4	+	7.36		5.53		12.4	+	Observed Estimate Used

Revision of data requirements: Focussing on data for hydrological analysis & presenting selected data examples

Data required for hydrological analysis

- Streamflow data
- Rainfall data
- Evaporation data
- Catchment Development Information – Land Use
- Water bodies
- Irrigation
- Streamflow Reduction Activities
- Afforestation
- Alien Invasive Plants

Sources of Data (hydrological analysis)

Description of data	Sources of information
Rainfall	RAINIMS, WR90 Study, WR2005 Study, SA Atlas of Climatology and Agrohydrology (WRC Study)
Evaporation	DWA Database, WR90 Study/ WR2012 Study, ACRU Database (University of KZN)
Streamflow	DWA Database
Land-use (including small dams)	Validation & Verification Study, WARMS, 1:50 000 maps
Reservoirs	DWA Database
Invasive Alien Plants	Working for Water, 1:50 000 maps
Water requirement and return flow projections	WARMS, Municipalities (WSDPs), All Towns Reconciliation Strategy Study

Land Use Data

- Alien invasive vegetation
- Water bodies
- Irrigation
- Point source abstractions and return flows

Water bodies

- Sources of Information:
  - Validation studies: small dams
  - DWA: large (major) reservoirs
- Small Dams (farm dams)
  - Satellite coverage for different development levels:
    - Area
    - Volume
  - Lumped individual dams into larger “dummy” dams
  - Added characteristics together.

Major Reservoirs

- Area-capacity relationships
- Dam balance record
- Weekly storage levels

Area-Capacity Relationship: Example

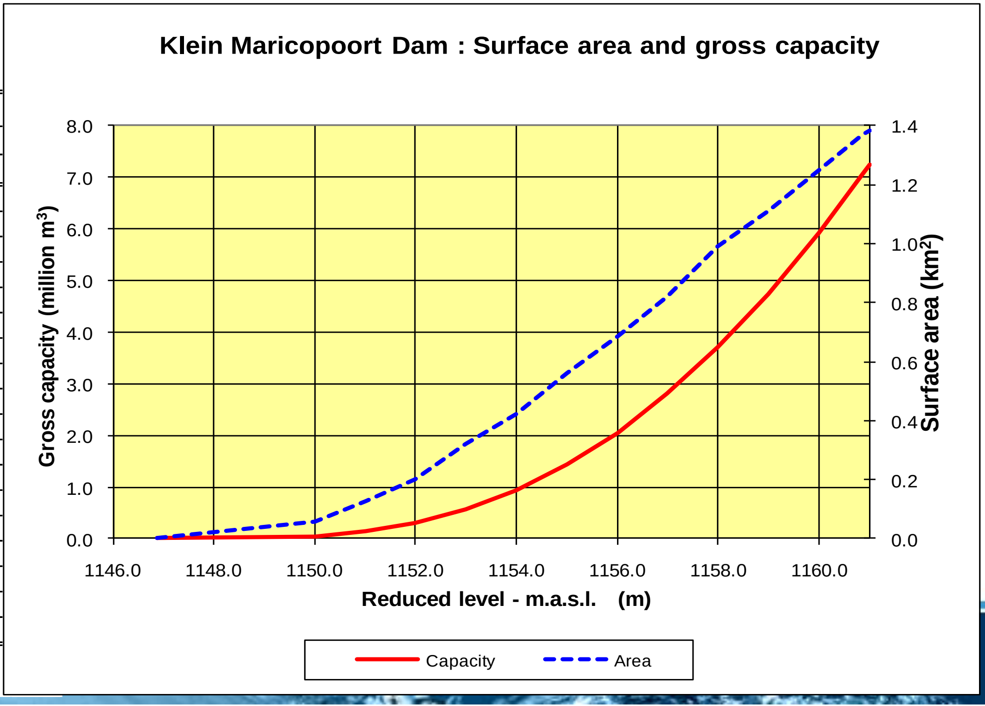
KLEIN MARICOPOORT DAM (A3R002) :
AREA-CAPACITY CHARACTERISTICS

Reservoir name :	**Klein Maricopoort Dam**
Gauge number :	**A3R002**
River :	**Klein Marico**
Catchment Area :	**1 191 km^2**
Construction date :	**1936 (Raised in 1965 by 4.3 m)**
Date of survey :	**October 1982**
Source of information :	**Department of Water Affairs and Forestry**
Utilisation :	**Provides water to the Klein Maricopoort Irrigation Scheme**
Owner :	**Department of Water Affairs and Forestry**

Full supply information :	
Reduced level :	**1160.87 m**
Gauge plate reading :	**14.01 m**
Gross supply volume :	**7.07 million m^3**
Net supply volume :	**7.07 million m^3**
Surface area :	**1.37 km^2**

Elevation m.a.s.l. (m)	Gross capacity (million m^3)	Gross capacity % FSC	Surface area (km^2)	Comments
1146.87	0.000	0.00	0.000	Bottom/Lowest outlet
1150.00	0.040	0.57	0.056	
1151.00	0.140	1.98	0.129	
1152.00	0.310	4.38	0.199	
1153.00	0.580	8.20	0.320	
1154.00	0.940	13.30	0.422	
1155.00	1.430	20.23	0.563	
1156.00	2.050	29.00	0.684	
1157.00	2.800	39.60	0.818	
1158.00	3.710	52.48	0.990	
1159.00	4.750	67.19	1.113	
1160.00	5.930	83.88	1.252	
1160.87	7.070	100.00	1.368	Full supply
1161.00	7.250	102.55	1.383	

Note : FSC = Full Supply Capacity
m.a.s.l. = metres above sea level



Dam Balance Example

a3r002dambalance.txt

A3R002 Klein Maricopoort Da

Dam Parameters at Full Supply

Date	Full Supply RL/Gauge (m)	Lowest Outlet RL/Gauge (m)	Gauge Zero RL/Gauge (m)	Surface Area (ha)	Net Capacity (Mil m**3)	Gross Capacity (Mil m**3)	Reason
1936-05-18	1156.610/ 9.760	1146.870/ 0.020	1146.850/ 0.000	80.63	3.20	3.31	Original
1966-02-01	1156.740/ 9.890	1146.870/ 0.020	1146.850/ 0.000	82.27	3.31	3.41	Temporary fsl
1966-09-20	1160.870/14.010	1146.870/ 0.010	1146.860/ 0.000	136.80	7.88	7.98	Raised
1976-10-01	1160.870/14.010	1146.870/ 0.010	1146.860/ 0.000	140.35	8.07	8.07	Basin survey
1982-10-01	1160.870/14.010	1146.870/ 0.010	1146.860/ 0.000	136.80	7.07	7.07	Basin survey

Date	Gauge Reading (m)	Contents (Ml)	Difference in Storage (Ml)	Uncont. Spill (Ml)	Total Outflow (Ml)	Irrigation (Ml)	Gross Evap (Ml)	Rain (Ml)	Calculated Streamflow (Ml)	Unaccountd Losses (Ml)
1936-10-01	7.641	1775	-460	0	578	529	79	21 &	176 &	0
1936-11-01	6.690	1316	1896	2146	2793	601	110 &	79 &	4721 &	0
1936-12-01	9.769	3212	-74	715	1275	512	137 &	51 &	1288 &	0
1937-01-01	9.676	3138	76	1850	2374	476	130 &	89 &	2491 &	0
1937-02-01	9.771	3213	-27	923	1306	339	90 &	54 &	1315 &	0
1937-03-01	9.737	3186	-165	0	360	312	107 &	47 &	254 &	0
1937-04-01	9.528	3021	-251	0	386	339	75 &	31 &	178 &	0
1937-05-01	9.193	2770	-561	0	622	573	62 &	0 &	122 &	0
1937-06-01	8.380	2209	-412	0	505	458	46 &	0 &	139 &	0
1937-07-01	7.682	1797	-331	0	480	432	36 &	0 &	185 &	0
1937-08-01	7.029	1466	-411	0	524	476	32 &	0 &	145 &	0
1937-09-01	6.029	1055	-402	0	561	514	45 &	2 &	202 &	0
1936/1937			-1122	5634	11763	5562	950 &	375 &	11217 &	0
1937-10-01	4.709	653	-373	0	564	516	37 &	4 &	224 &	0
1937-11-01	2.844	280	-203	0	412	366	25 &	4 &	230 &	0
1937-12-01	1.091	77	957	0	414	366	26 &	52 &	1345 &	0
1938-01-01	5.969	1034	461	0	307	258	64 &	30 &	802 &	0
1938-02-01	7.091	1495	390	0	159	116	63 &	34 &	578 &	0
1938-03-01	7.839	1884	-168	0	155	107	88 &	8 &	67 &	0
1938-04-01	7.531	1716	-201	0	269	222	55 &	44 &	79 &	0
1938-05-01	7.134	1515	-454	0	605	557	39 &	7 &	183 &	0
1938-06-01	6.046	1061	-45	0	83	36	26 &	0 &	63 &	0
1938-07-01	5.917	1016	-378	0	547	499	27 &	0 &	197 &	0
1938-08-01	4.649	638	-327	0	510	462	23 &	0 &	206 &	0
1938-09-01	3.048	311	-296	0	482	436	16 &	0 &	202 &	0
1937/1938			-638	0	4508	3940	489 &	183 &	4176 &	0

Irrigation data requirements

- Obtain information from Validation/other studies.
- Make use of satellite and aerial photos to delineate fields of WARMS data.
- Validate crops and irrigation systems.
- Schemes are normally excluded from studies (information available from scheme managers/operators).
- Information on crop requirements, return flows and application efficiency generated using SAPWAT.

Real-time data

- Management using real-time data.
- Water release decisions made with real-time data.
- Data monitoring points and compliance monitoring using real-time data
- Real time management systems including models used to assist with real-time systems operations.
- Various triggers and alarms required for management decisions.
- Monitoring and frequent calibration needs of real-time data instrumentation.

Internal Assessment Criteria:

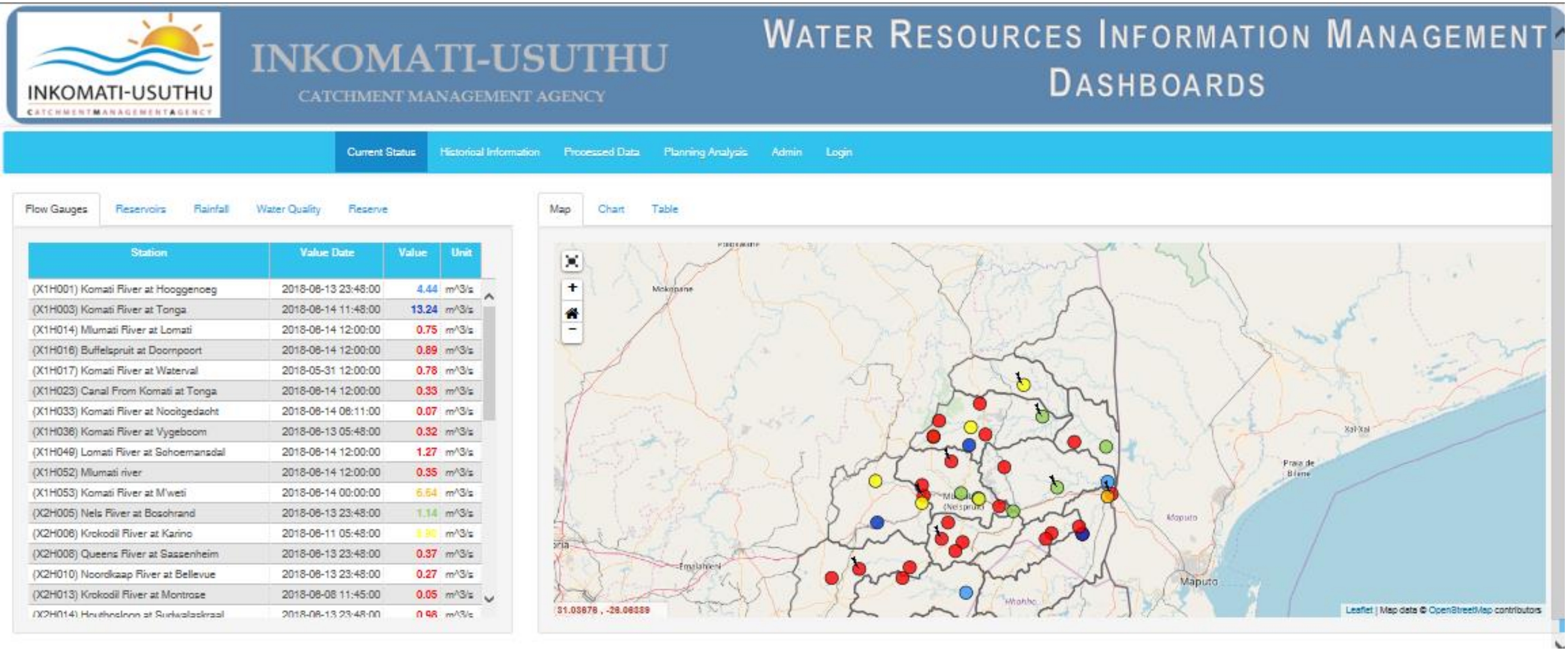
- **Describe the benefits of using real-time data in managing water resources.**
- **Describe an existing real-time data system and explain the need and importance of frequent calibration.**

Management using real-time data.

- Objective: Efficient & proportional distribution of available water over time and space.
- Minimising operating losses while supplying all legitimate water users at all times.
- Compliance monitoring of abstractions, releases and diversions.
- Real-time data applied to determine the status of the system at a given point in time – daily, hourly or more frequent.

Example of a real time management system

Data for management and monitoring



DWS hydrology – unverified data

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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Flow/Stage

Rainfall

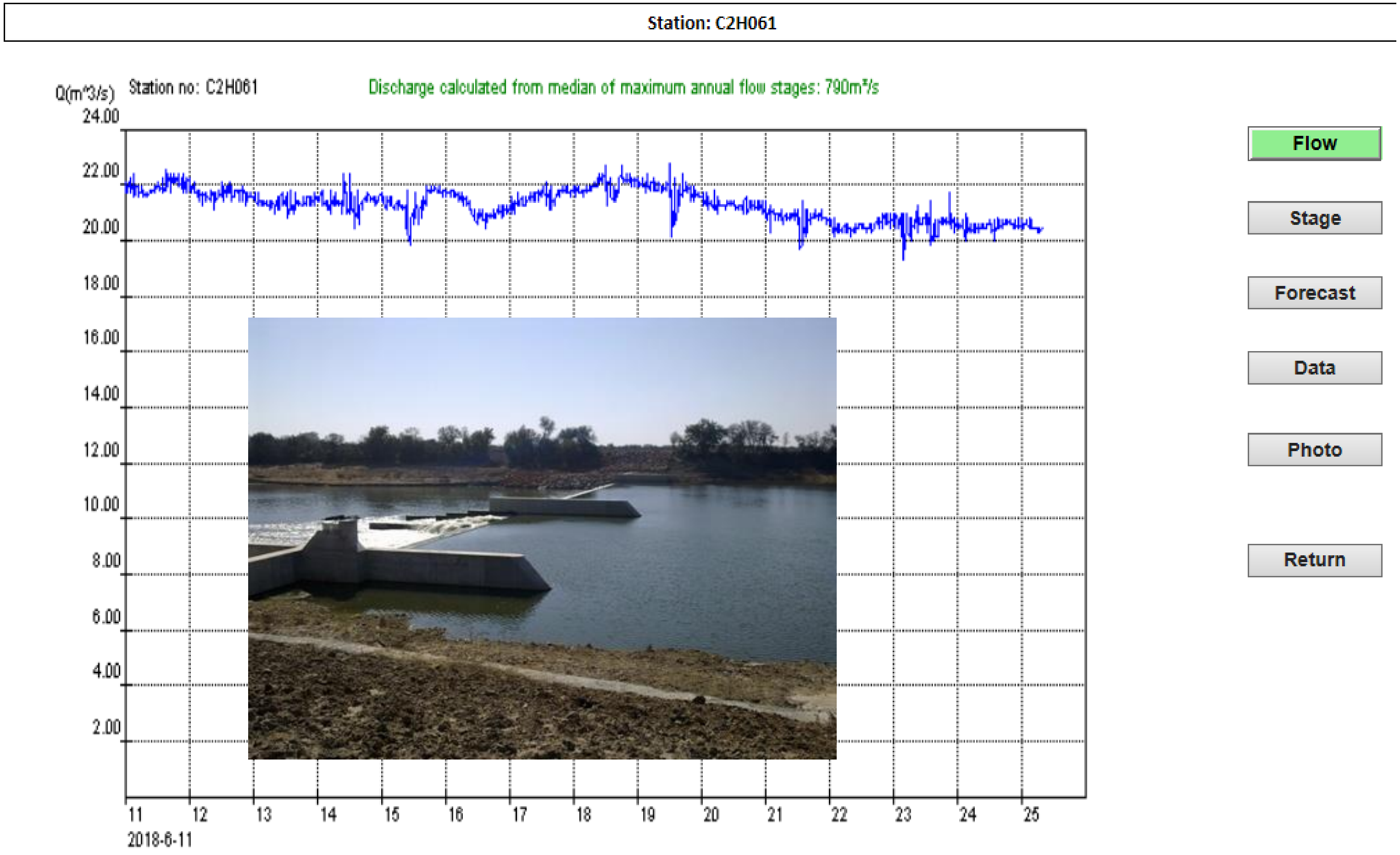
WMA1 Limpopo | WMA2 Olifants | WMA3 Inkomati-Usuthu | WMA4 Pongola-Mtamvuna | WMA5 Vaal Major | WMA6 Orange | WMA7 Mzimvubu-Tsitsikamma | WMA8 Breede-Gouritz | WMA9 Berg-Olifants

Stations in: 5. Vaal Major (Blue row indicates station is a dam)

Station	Place	Date/Time	Stage (m)	Flow/Cap.
C1H002	Klip at Sterkfontein	2018-06-25 11:00	0.397	1.73
C1H006	Blesbok at Rietvley	2018-06-25 11:00	0.114	0.11
C1H007	Vaal at Bloukop	2018-06-25 11:00	0.069	3.3
C1H008	Watervals at Elandslaagte	2018-06-25 11:00	0.485	0.19
C1H012	Vaal at Gladdedrift	2018-06-25 11:00	0.539	3.4
C1H019	Outflow from Grootdraai Dam	2018-06-25 11:00	0.335	1.04
C1H020	Sasol 2 Canal at Vlakfontein		no data	
C1L002	Vaal at Mooiplaats(Camden N2 Road Bridge		no data	
C1L003	Vaal at Welgelegen(Origin N17 Bridge)		no data	
C1L004	Vaal at Uitspanning(N211 Bridge to Amers		no data	
C1R001	Vaal at Vaal Dam	2018-06-25 11:00	22.548	100.35%
C1R002	Vaal at Grootdraai Dam	2018-06-25 11:00	26.261	91.91%
C2H005	Rietspruit at Kaalplaats	2018-06-25 10:00	0.004	0

Click on the image to see a larger version

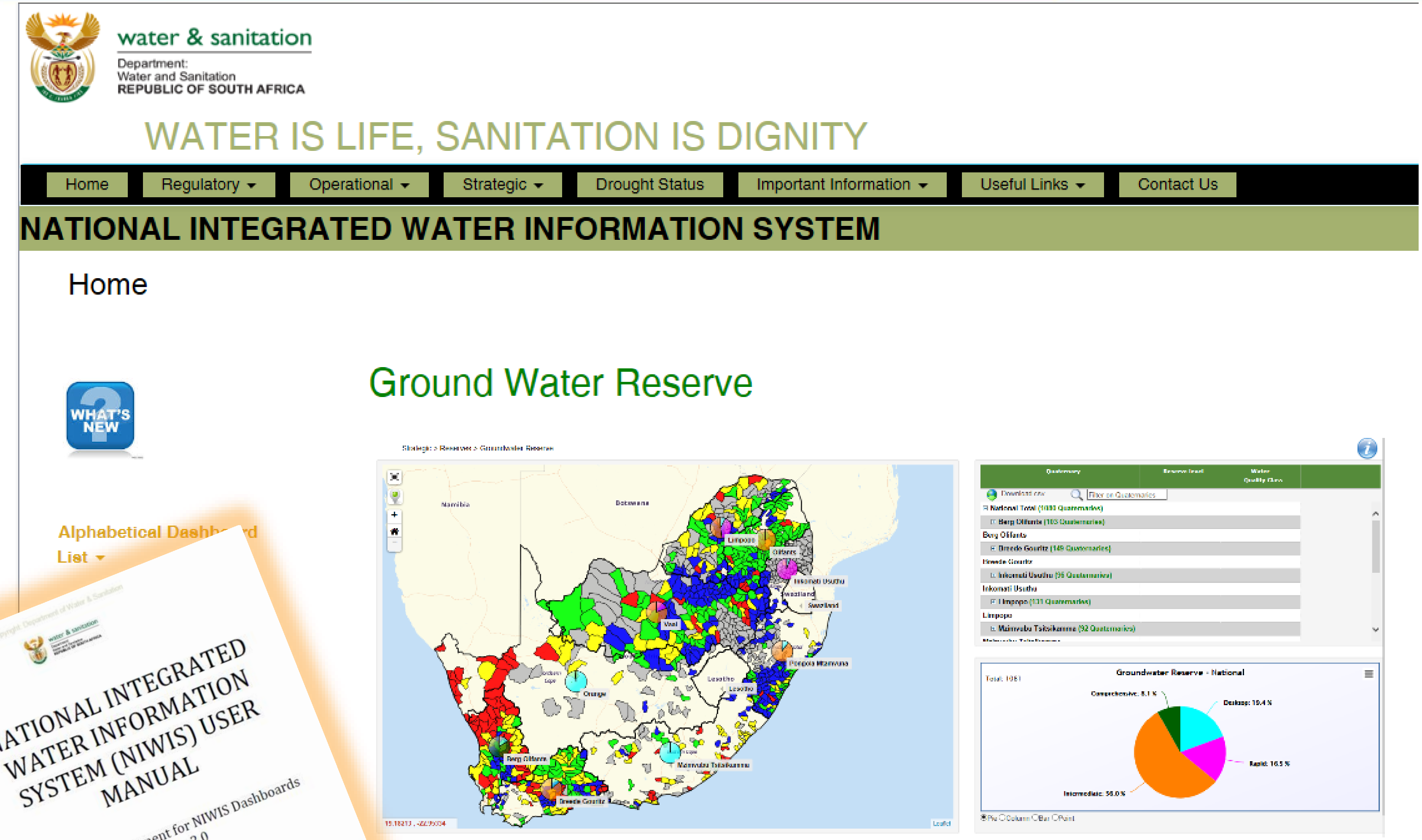
DWS web based data dissemination

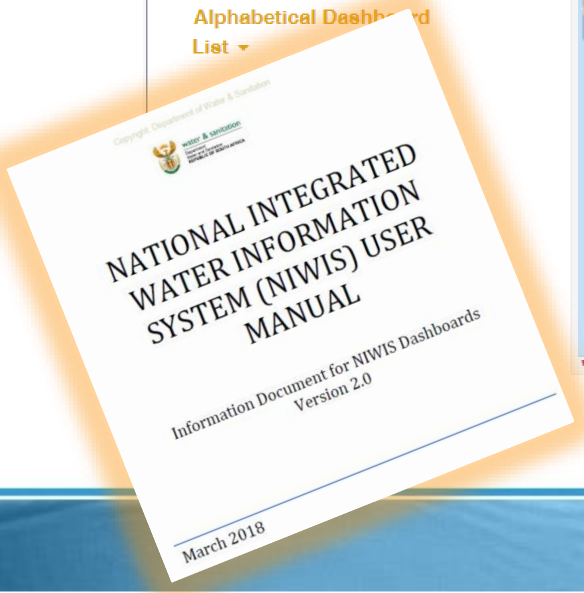


Date(YYYY-MM-DD)
Time(HH:MM)
ha(m)
Flow(m^3/s)
******

2018-06-11 00:00	0.375	22.094
2018-06-11 00:12	0.374	21.954
2018-06-11 00:24	0.373	21.815
2018-06-11 00:36	0.372	21.677
2018-06-11 00:48	0.374	21.954
2018-06-11 01:00	0.374	21.954
2018-06-11 01:12	0.374	21.954
2018-06-11 01:24	0.372	21.677
2018-06-11 01:36	0.374	21.954
2018-06-11 01:48	0.373	21.815
2018-06-11 02:00	0.376	22.234
2018-06-11 02:12	0.376	22.234
2018-06-11 02:24	0.372	21.677
2018-06-11 02:36	0.372	21.677
2018-06-11 02:48	0.373	21.815
2018-06-11 03:00	0.375	22.094
2018-06-11 03:12	0.373	21.815
2018-06-11 03:24	0.377	22.374
2018-06-11 03:36	0.373	21.815
2018-06-11 03:48	0.371	21.538
2018-06-11 04:00	0.372	21.677
2018-06-11 04:12	0.373	21.815
2018-06-11 04:24	0.374	21.954
2018-06-11 04:36	0.373	21.815
2018-06-11 04:48	0.374	21.954
2018-06-11 05:00	0.374	21.954
2018-06-11 05:12	0.373	21.815
2018-06-11 05:24	0.372	21.677

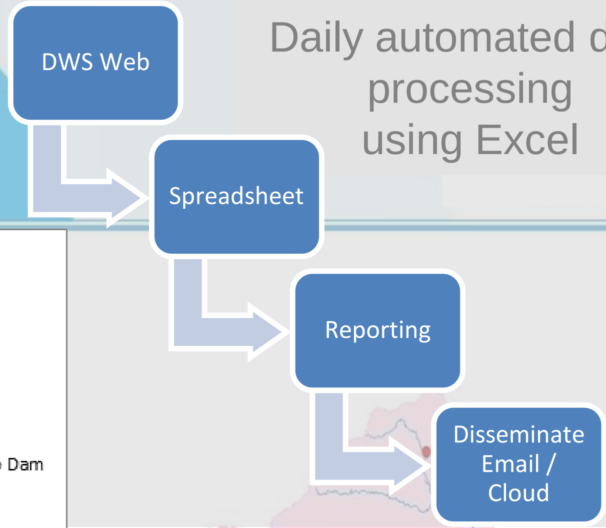
DWS: NATIONAL INTEGRATED WATER INFORMATION SYSTEM (NIWIS)

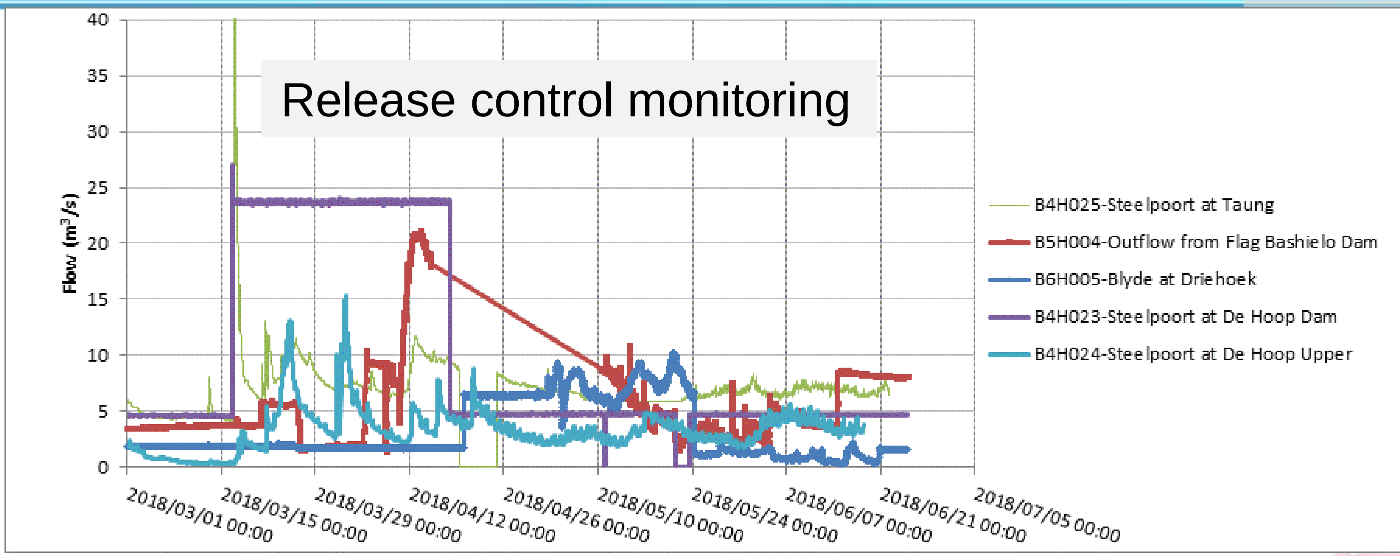


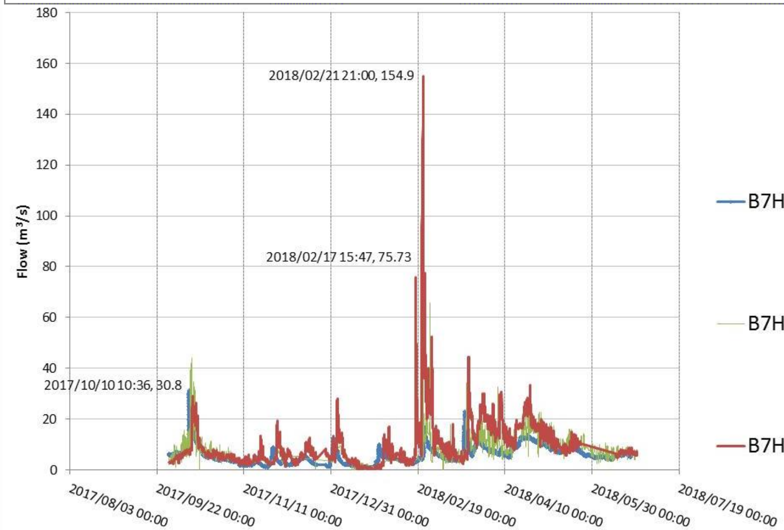


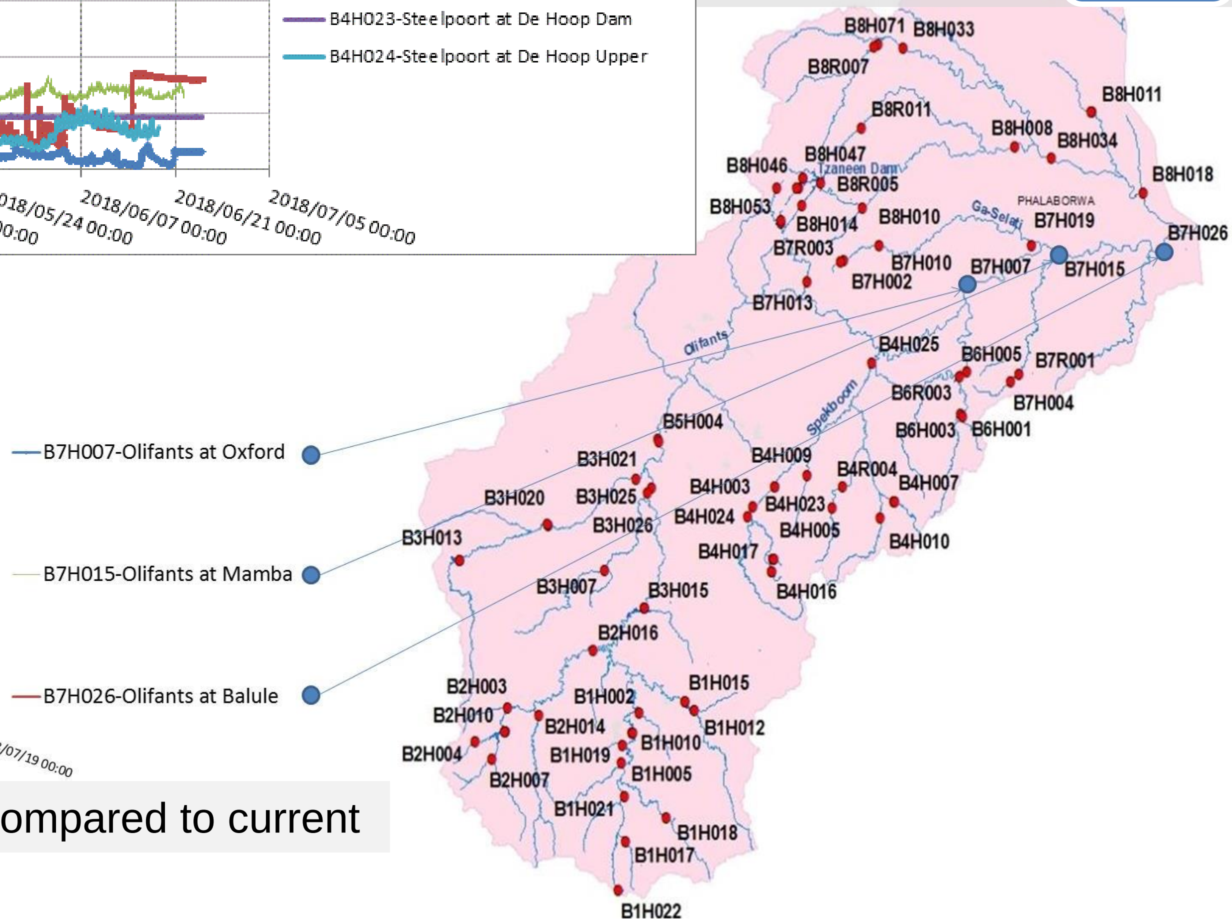
Data > information & automation

Daily automated data processing using Excel









Previous 8 months river flows compared to current

Giving affect to ecological protection

METHODS AND SOFTWARE FOR THE REAL-TIME IMPLEMENTATION OF THE ECOLOGICAL RESERVE – EXPLANATIONS AND USER MANUAL

Report to the
Water Research Commission

by

D A Hughes, S J L Mallory & D Louw

WRC Report No 1582/1/08
ISBN 978-1-77005-716-6

July 2008

Giving affect to ecological protection

Towards improving the assessment and implementation of the Reserve:

Real-time assessment and implementation of the Ecological Reserve

Final report

WRC project K8/881/2

March 2011

Sharon Pollard[1]
Stephen Mallory[2]
Edward Riddell[3]
Tendai Sawunyama[2]

1 Association for Water & Rural Development (AWARD)
2 Water for Africa (IWR Water Resources)
3 University of KwaZulu-Natal

DEVELOPING A REAL TIME HYDRAULIC MODEL AND A DECISION SUPPORT TOOL FOR THE OPERATION OF THE ORANGE RIVER

Kerry Fair

November 2002

In fulfilment of the requirements of a
Master of Science in Engineering
as set out by the University of Natal

Example of using real time data

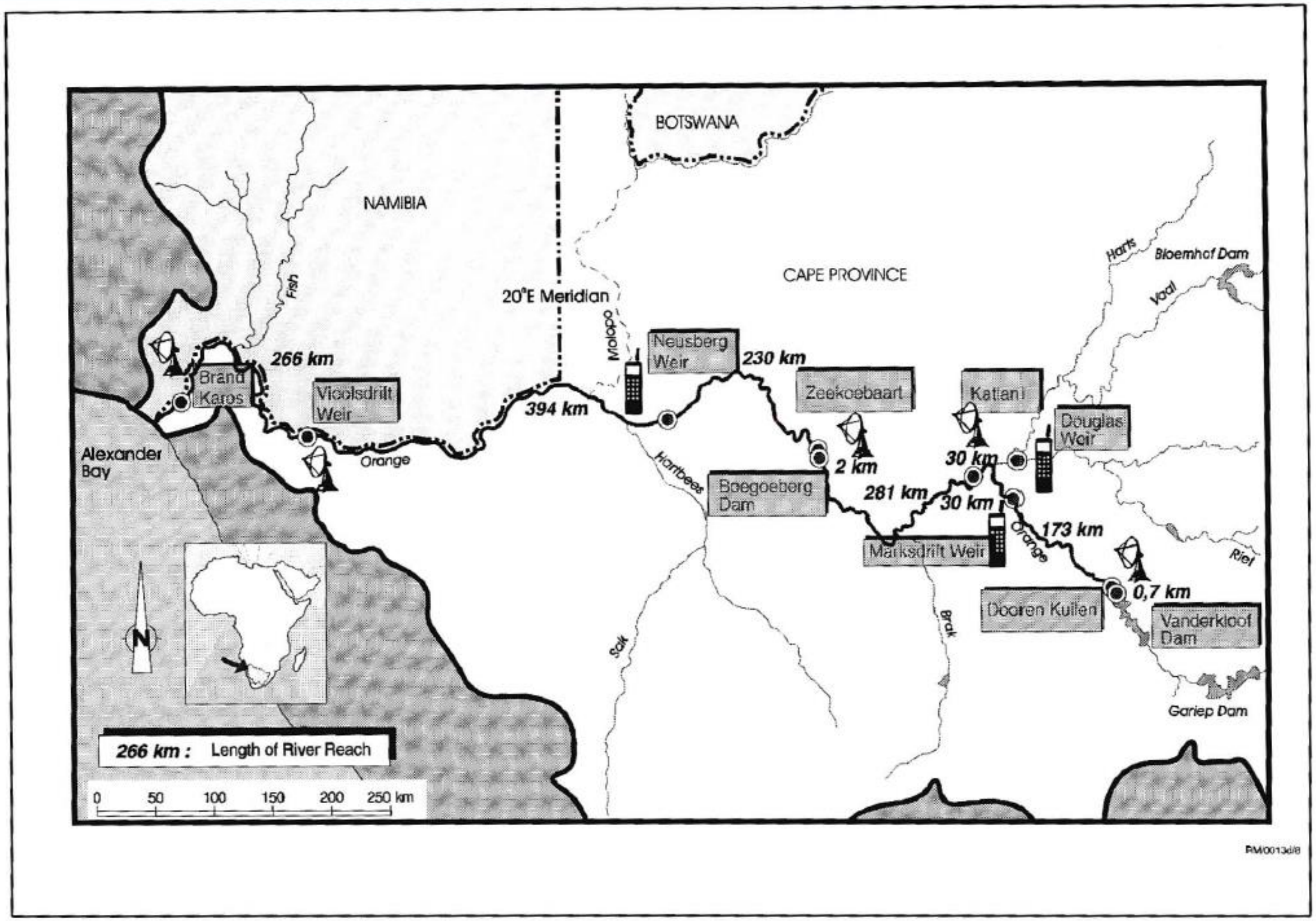
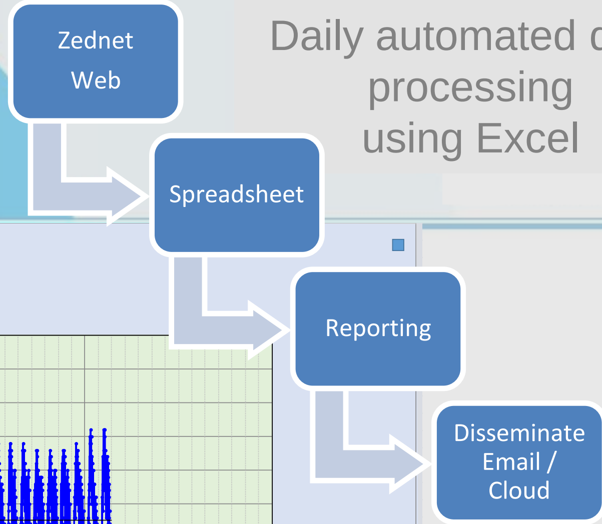


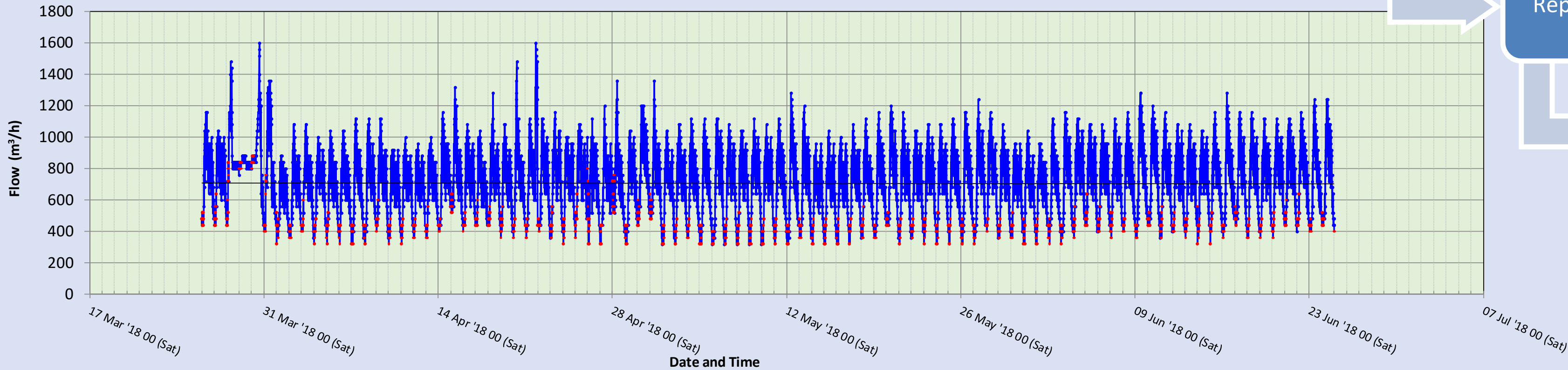
Figure 8.2: Position of real time gauging stations

Real Time Data and monitoring of Urban Systems

Daily automated data processing using Excel



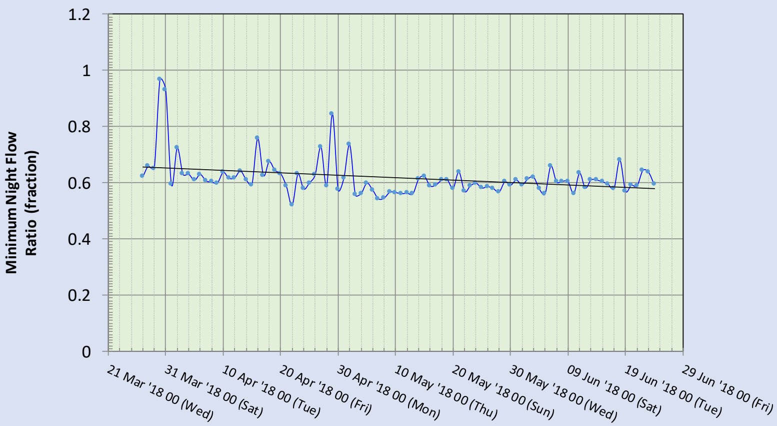
Reservoir Outflow



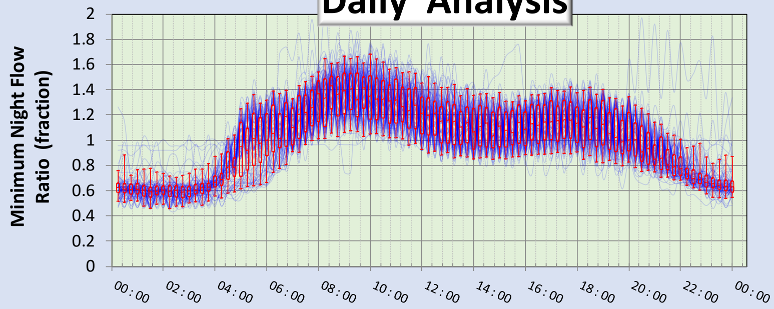
Units	Dialy Average	Daily Maximum	Daily Minimum	Min Night Flow (Average)	Minimum Night	Maximum
m3/h	325.27	481.96	63.08	181.05	0.00	624.00

Channel ID: 6097

Minimum Night Flow Trend Analysis



Daily Analysis



Alarm Design:

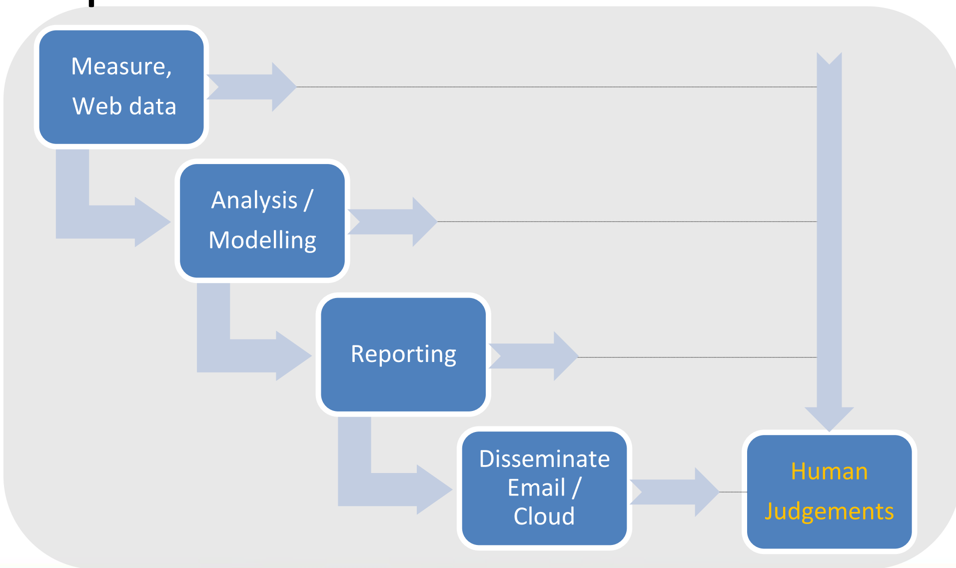
Night Flow Monitor Period: First Hour: 00:15 Last Hour: 04:00

Number of days analysed: 90

	Percentile:	Ratio thresholds:	Expected number of trigers:
Monitoring Ratios:	0.95	0.732	4.5
	0.75	0.630	22.5
	0.5	0.604	45
	0.25	0.581	67.5
	0.050	0.561	85.5

Summary of data for water resource management

- Tactical operational decisions, early warning for immediate remedial activities.
- Operations planning, drought management, water distribution control.
- Development decisions, informed by water balance projection status: water availability & water requirements.
- The future requires automation:
  - Software systems automates.
  - Humans make judgements.



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Thank You

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