Decision Support Systems as effective tools in water resources and flood management

Borge Storm

DHI

7th THAICID National Symposium, Bangkok

Water Management Challenges

Mitigating disasters:

- Floods
- Droughts
- Climate change
- Pollution
- Watershed degradation

Water Management Challenges

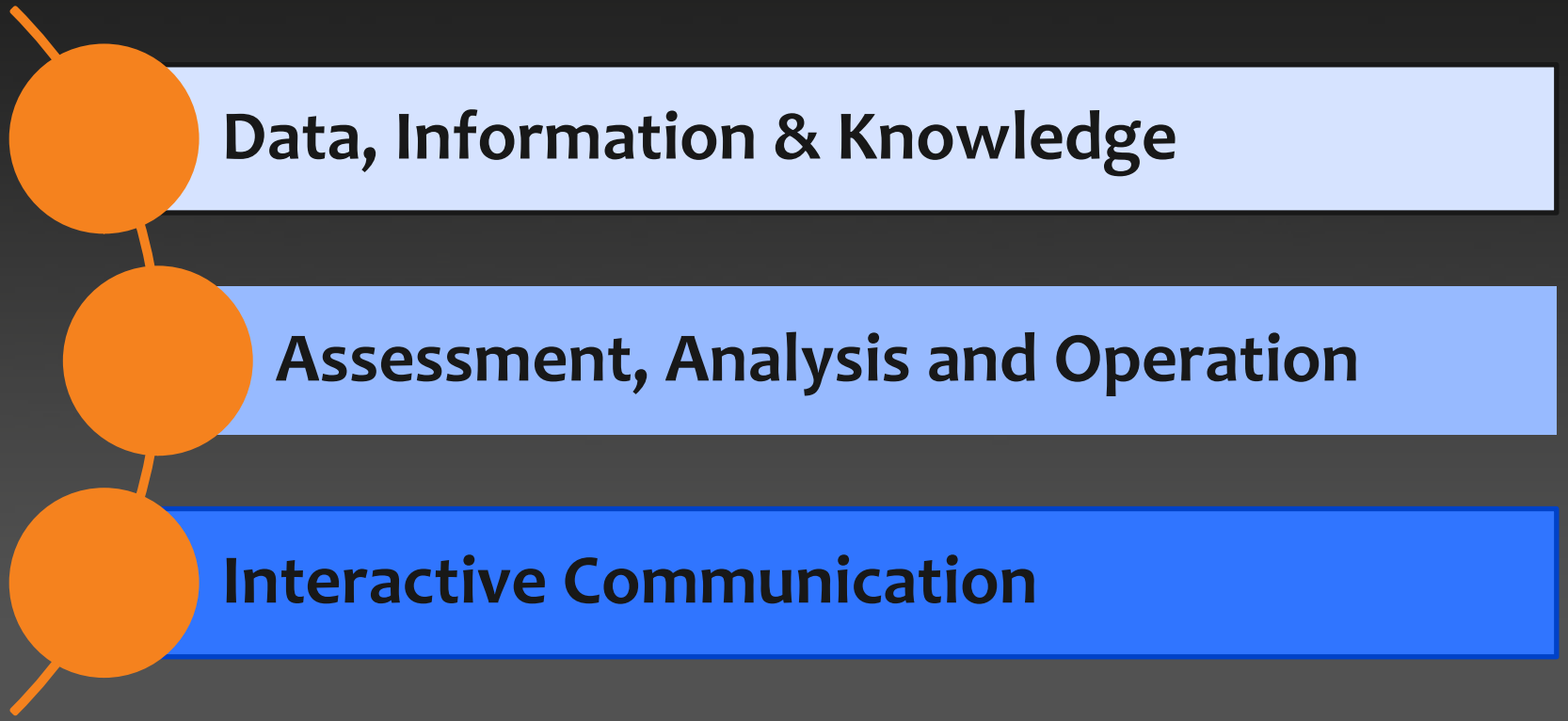
Securing water for:

- People
- Food
- Energy
- Environment
- Production

Why Decision Support Systems for water management?

- Provide an opportunity to embed IT and analytical tools more thoroughly in WR agencies' workflow;
- Provide a technical platform for collaboration internally and externally;
- The DSS concept suites well with undertaking multiple WRM responsibilities by WR agencies

Typical Technical Frameworks of DSSs



….based on a whole array of underlying tools

DHI DSS Solution Platform

Operations

Information & knowledge management

Optimization

Retrieving & storing data

Forecasting and early warning

Real-time

Core

Planning

Data analysis

CC adaptation

Water Allocation

Multi Criteria Analysis

Basin Plans

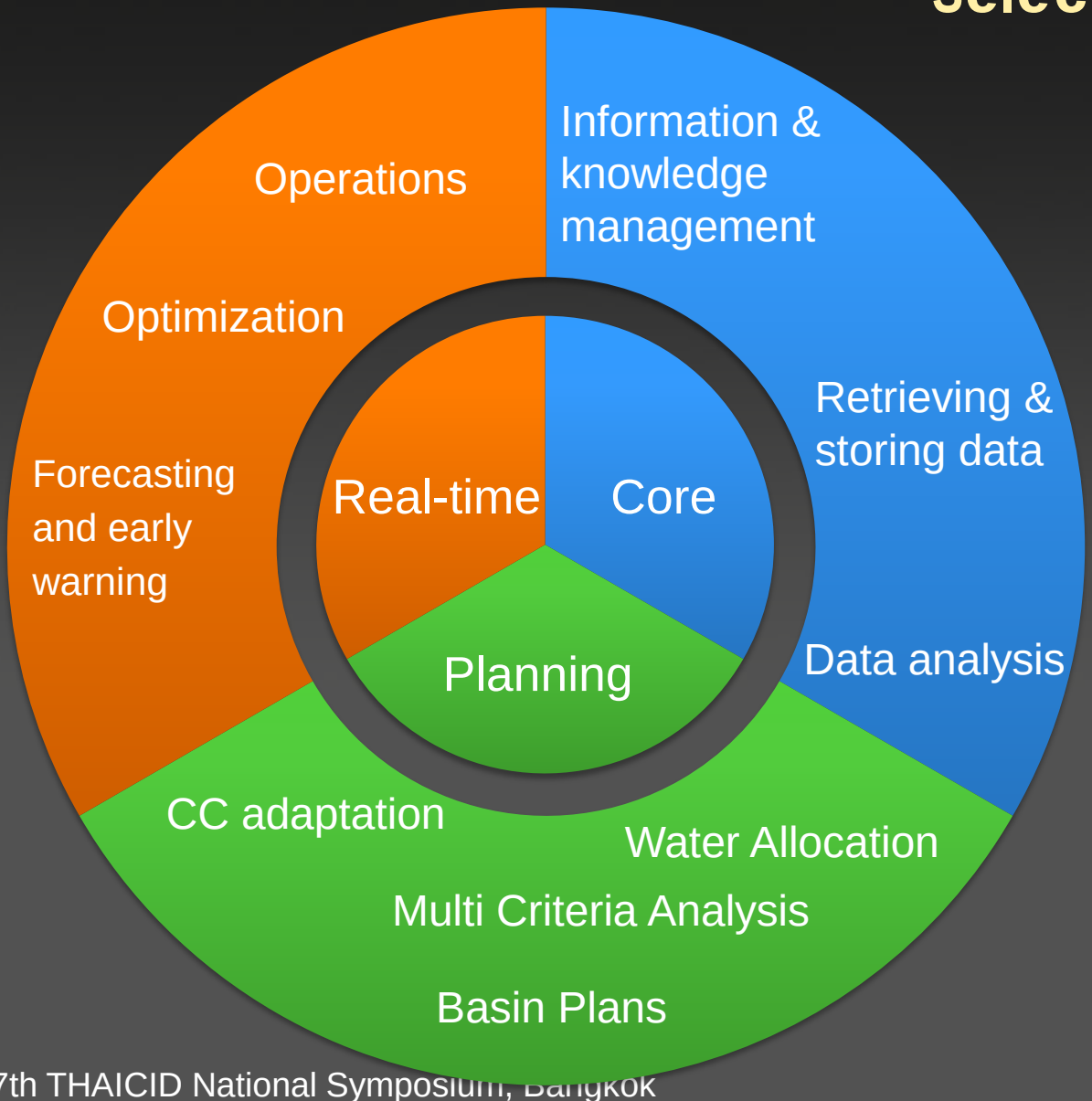
Bridges

Databases

Adapters

Models

DSS Solution Platform



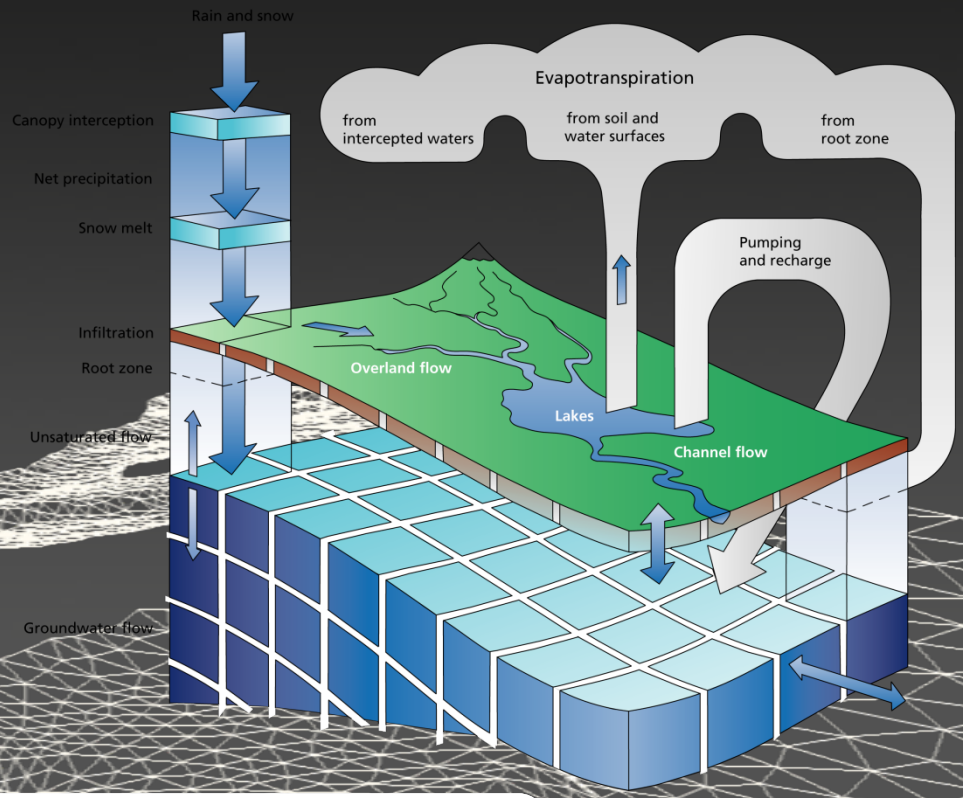
Selected key components

- User access
- WEB Publishing
- Time Series Management
- GIS
- Workflows
- Modelling/scripting
- Data Exchange

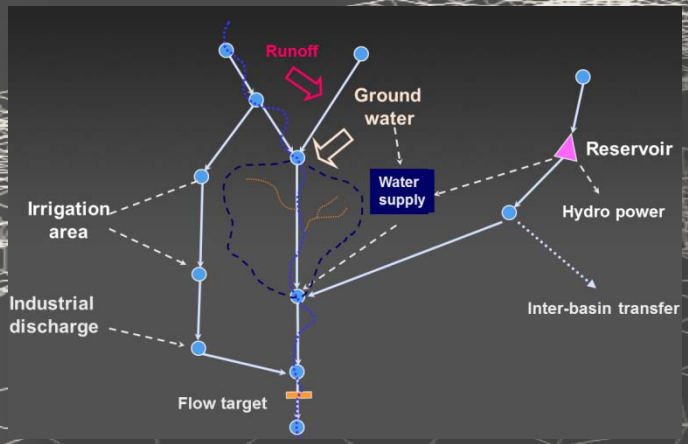
Open modelling environment

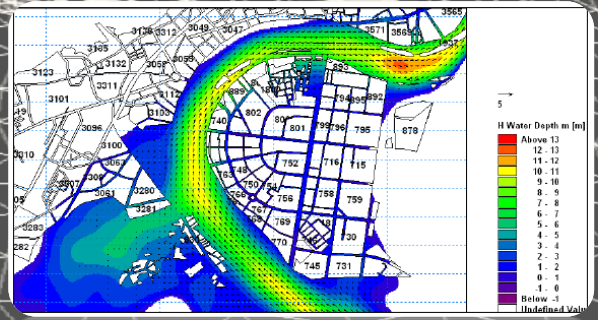
- Assessments
- Impact scenarios
- Planning scenarios
- Real-time forecasts
- On-line operations

Process oriented models



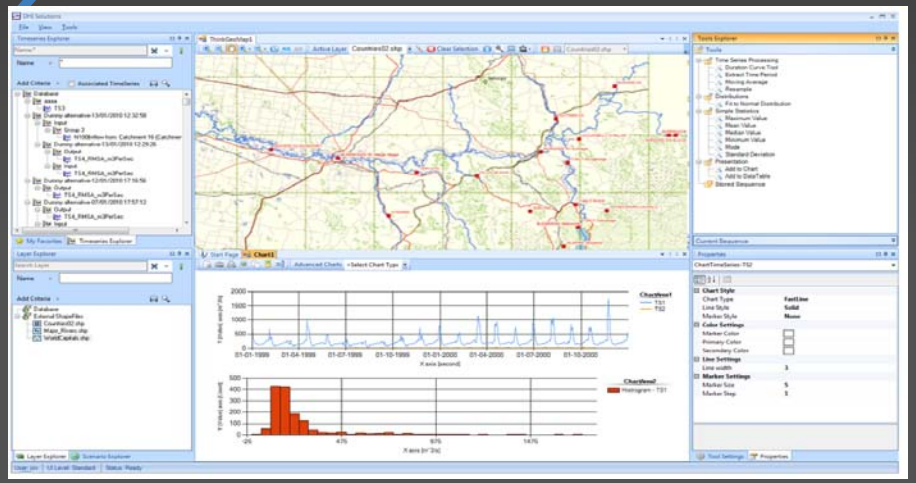
Planning oriented models





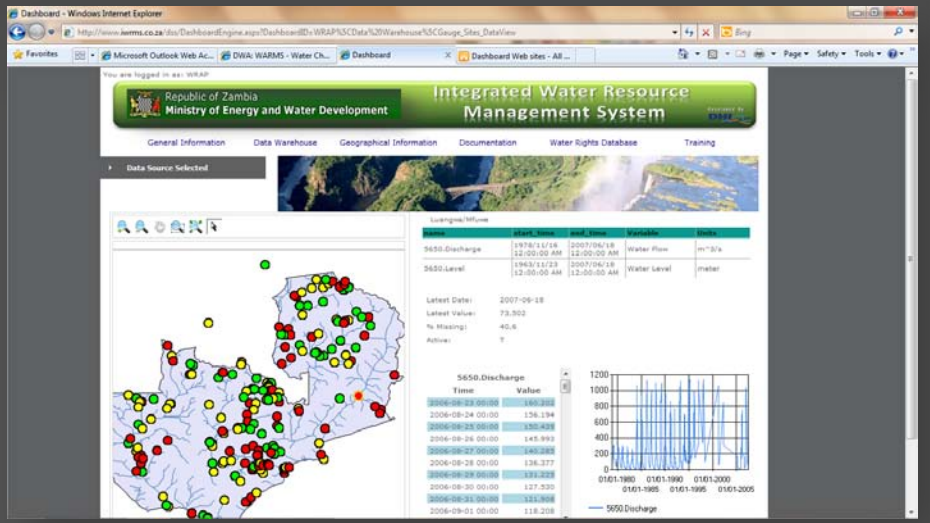
Customization

- Data / information
- Simulation / analysis
- Communication / dialogue



For technical staff

- Water authority's needs
- Configurable interfaces for technical, managerial and public levels
- Implementation and tailored training programs
- continued sustainable support framework



For public access

Real time Forecasting

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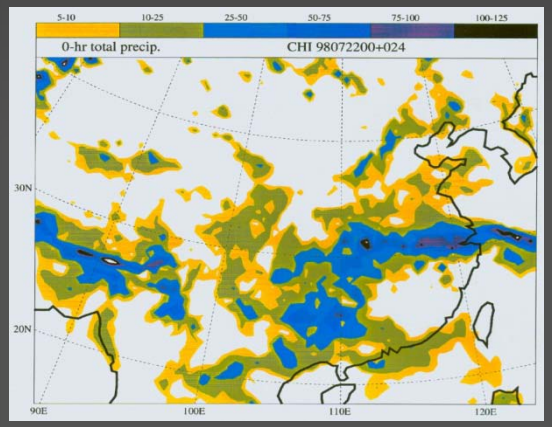
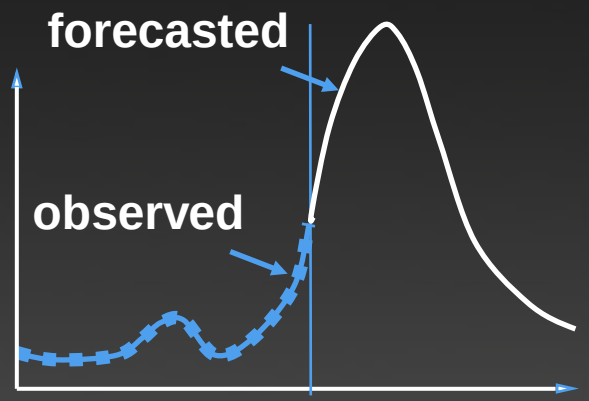
Real-time Flood Forecasting

Real-time
rainfall and flow



Meteorological
forecasts

Modelling &
Data assimilation



Forecasted hydrographs

Forecasted flood maps

(confluense of Sava and Krka, September 2010)

FLOOD FORECASTING SYSTEM FOR SAVA AND SOČA RIVERS, SLOVENIA

Acknowledgement :

REPUBLIKA SLOVENIJA
MINISTRSTVO ZA OKOLJE IN PROSTOR
AGENCIJA REPUBLIKE SLOVENIJE ZA OKOLJE
Vojkova 1b, 1000 Ljubljana

BOBER
BOLJŠE OPAZOVANJE ZA BOLJŠE EKOLOŠKE REŠITVE
BETTER OBSERVATION FOR BETTER ENVIRONMENTAL RESPONSE

Naložba v vašo prihodnost
OPERACIJO DELNO FINANCIRA EVROPSKA UNIJA
Kohezijski sklad

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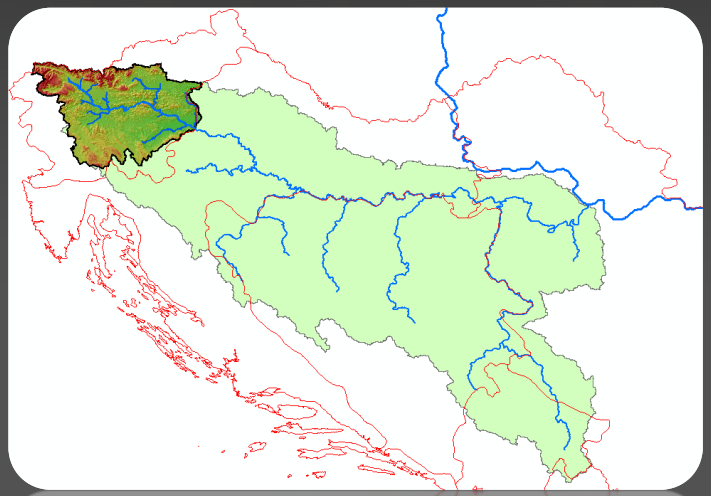
Operational Forecasting System

Information management system ➡ Status information available at hand

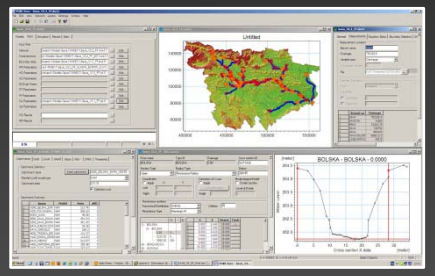
In-bank flood forecasting and warning system for Slovenian River basins ➡ Early forecasts and warnings disseminated through web and SMS

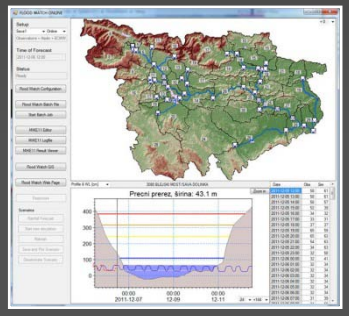


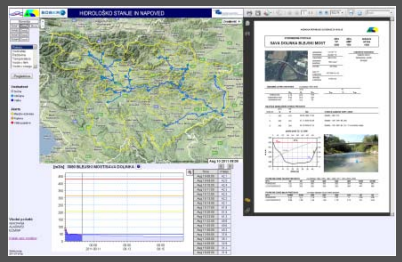
Sava River Basin:
11,000 km² in Slovenia

The Real-time DSS System

- Integration with Online Databases
  - Accessibilty of data
  - Telemetric data measured in the field
  - Weather forecast
  - Forecasting results
- Hydrological/Hydraulic models for Sava and Soca rivers
- A DSS Platform for ARSO for real time use
- Presentation of forecasts in an easy and userfrindly way

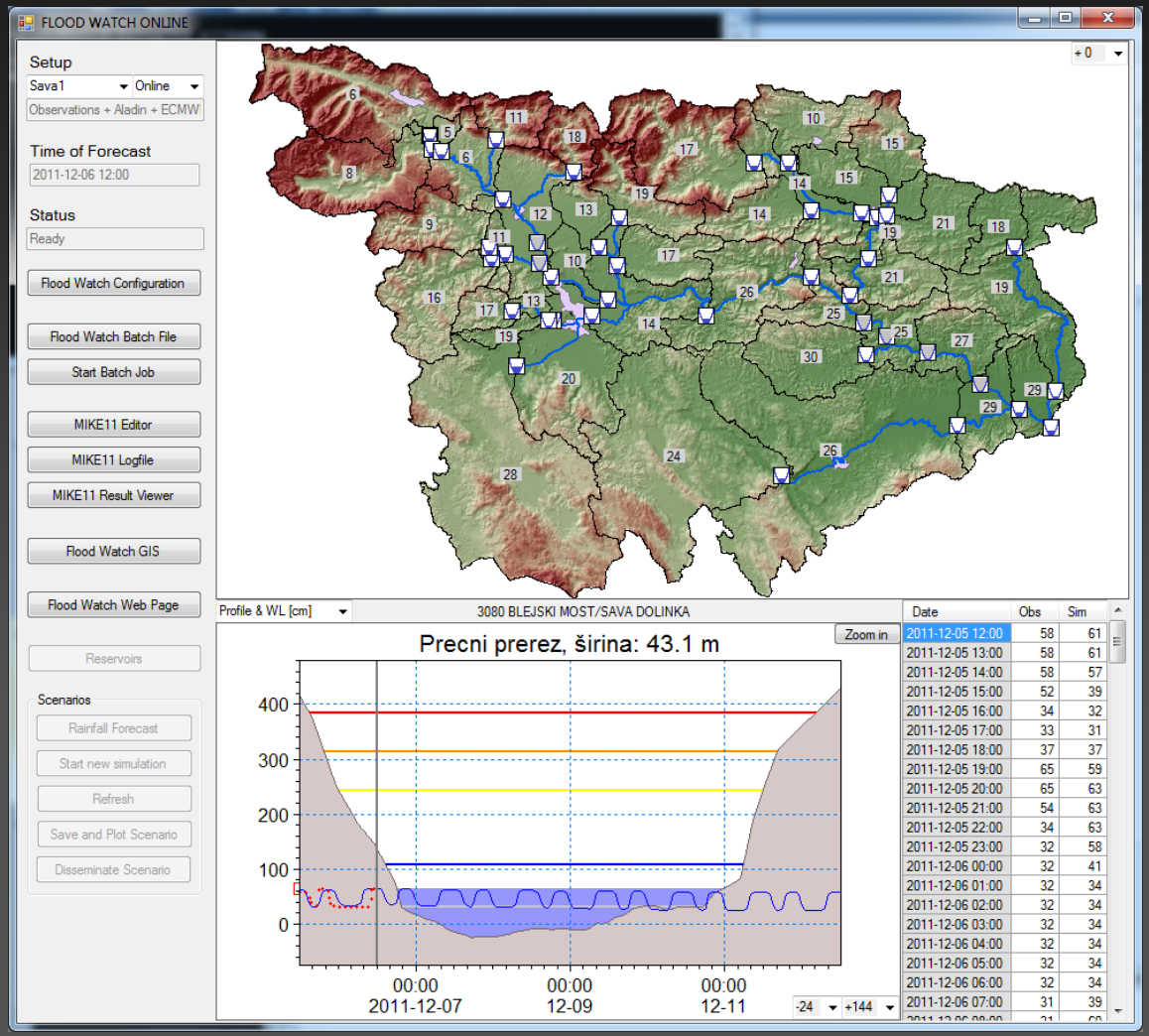






Customised requirements

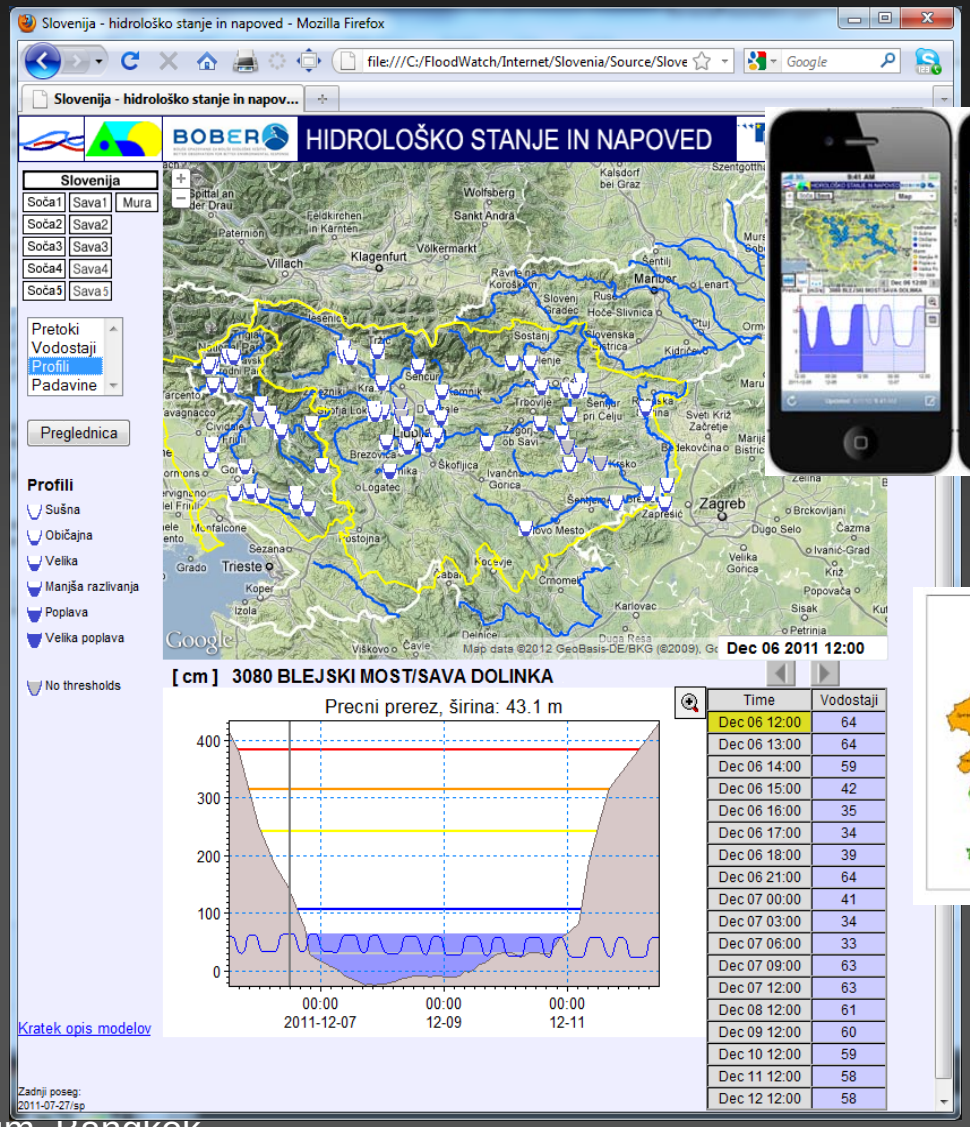
- Quick access to forecast
- Automatic / Offline Option
- Graphical and Tabular view of Water Level, Discharge, Profiles and Precipitation
- Detailed station information with online access to WEB camera
- Configuration Options
- Direct access to MIKE11
- Displays in Google Maps on the web
- Running alternative scenarios



Presentation of forecasts (on the web)

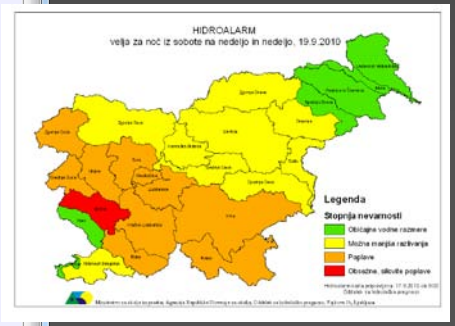
Forecasts and flood warnings:

- Forecasts for the following **6** days
- Forecasting of Flow and Water Levels at **74** locations
- New forecasts every hour - 24/7
- Forecast results from 5 different system setup



Quick access for specific users

Public Presentation



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Summary on Flood Forecasting System in Slovenia

- Now good understanding of flood modelling and forecasting;
- Consistent overview of the flood situation through measuring and modelling;
- Ability to act faster before and during floods;
- Improved communication and coordination.

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Flood Modelling

(a few comments)

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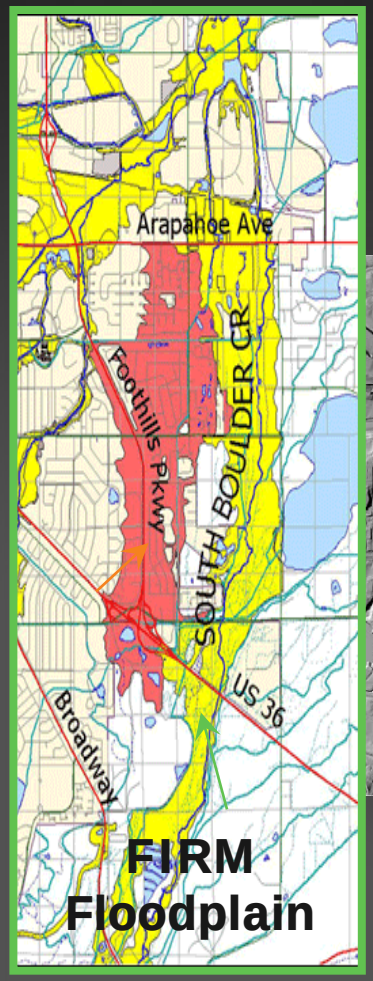
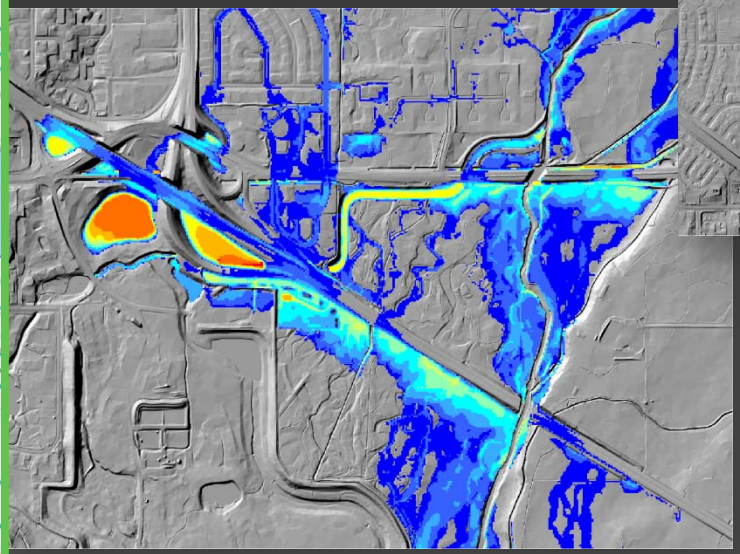
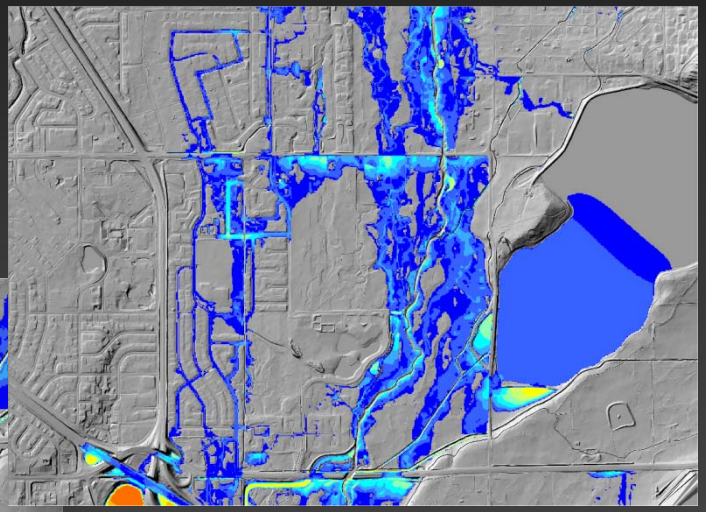
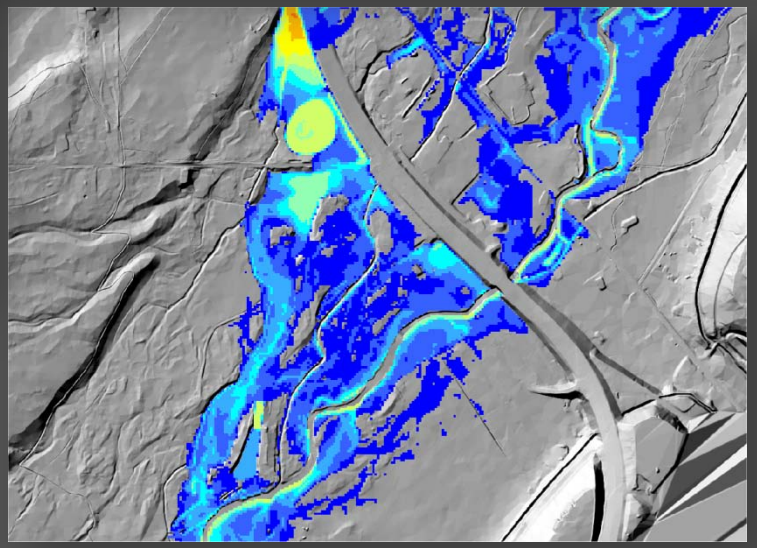
Modelling for flood mapping

South Boulder Creek, Colorado, USA





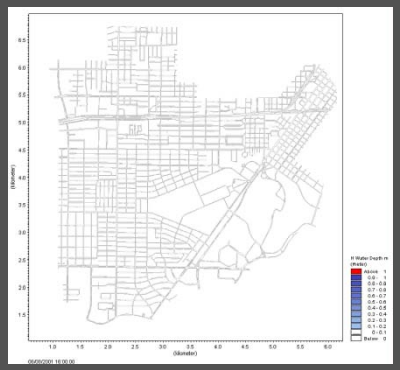




Modelling & detailed topographic information for accurate flood mapping

Harris Gully Watershed, Houston Texas, United States

Flooding behavior during Tropical Storm Allison



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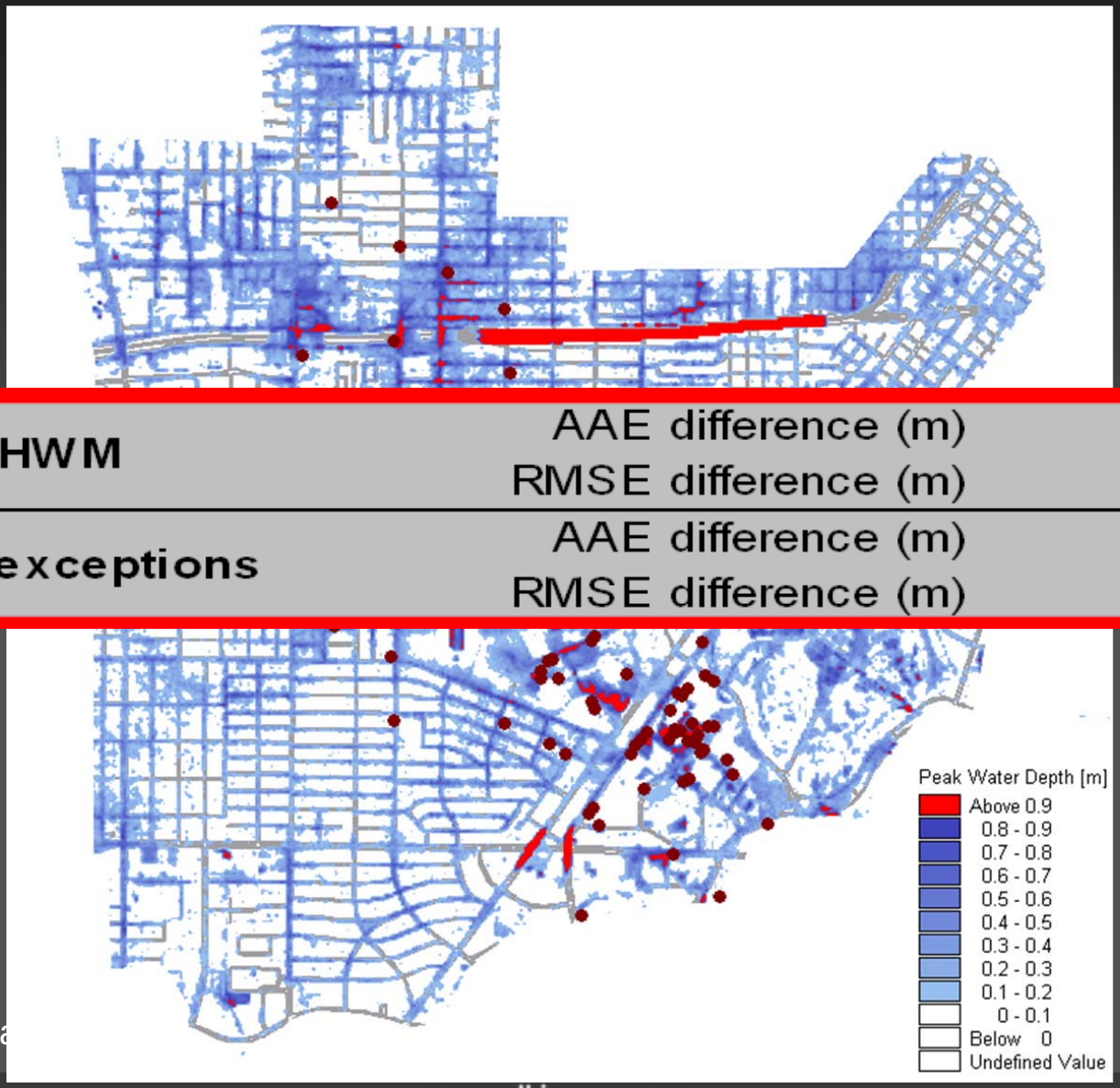
Tropical Storm Allison - Validation



All HWM	AAE difference (m)	**0.09**
	RMSE difference (m)	**0.12**
HWM - 9 exceptions	AAE difference (m)	**0.07**
	RMSE difference (m)	**0.09**

Real-time River Operation

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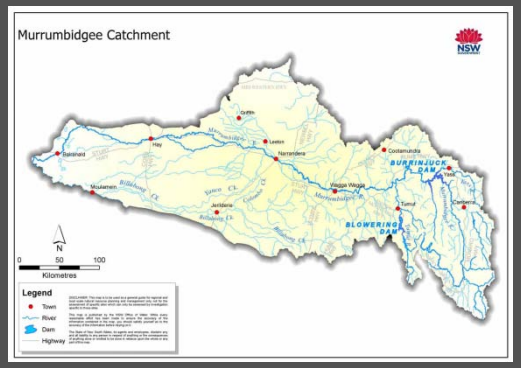
Computer Aided River Management (CARM)

Improving River Water Efficiency for the Murrumbidgee River, Australia



Acknowledgement:

State water
Taking care of it

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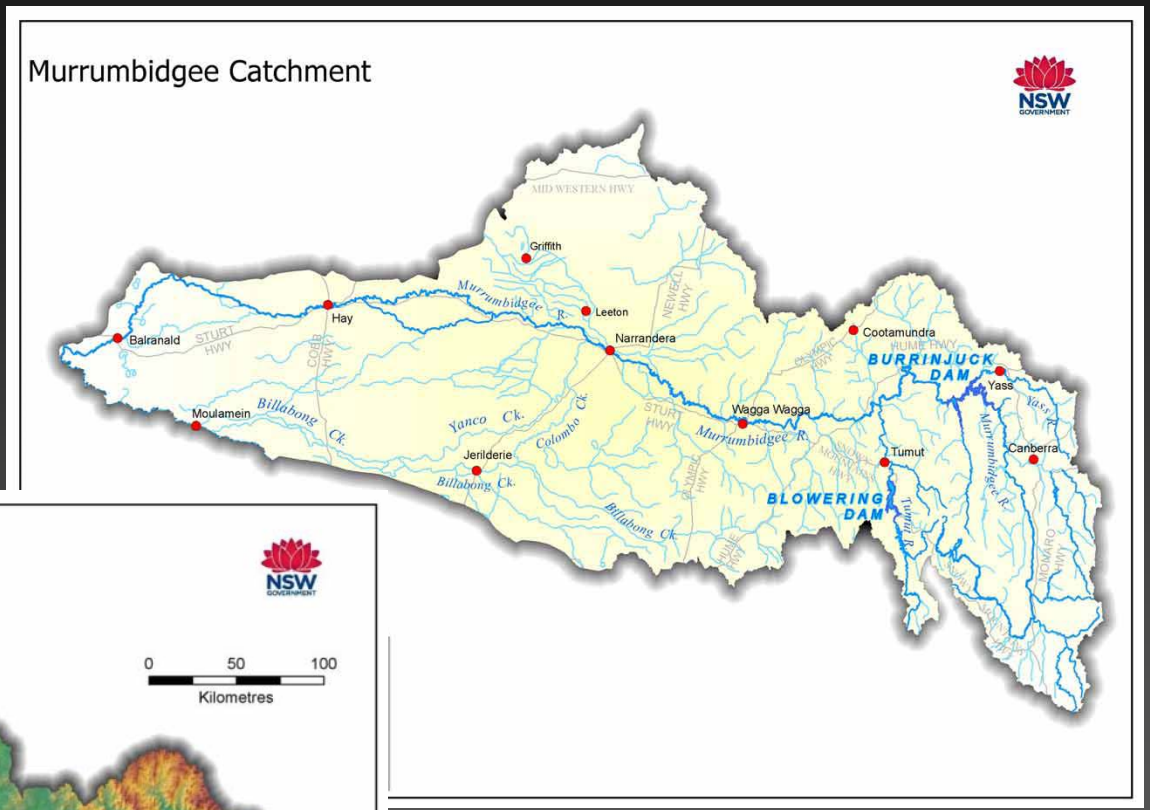
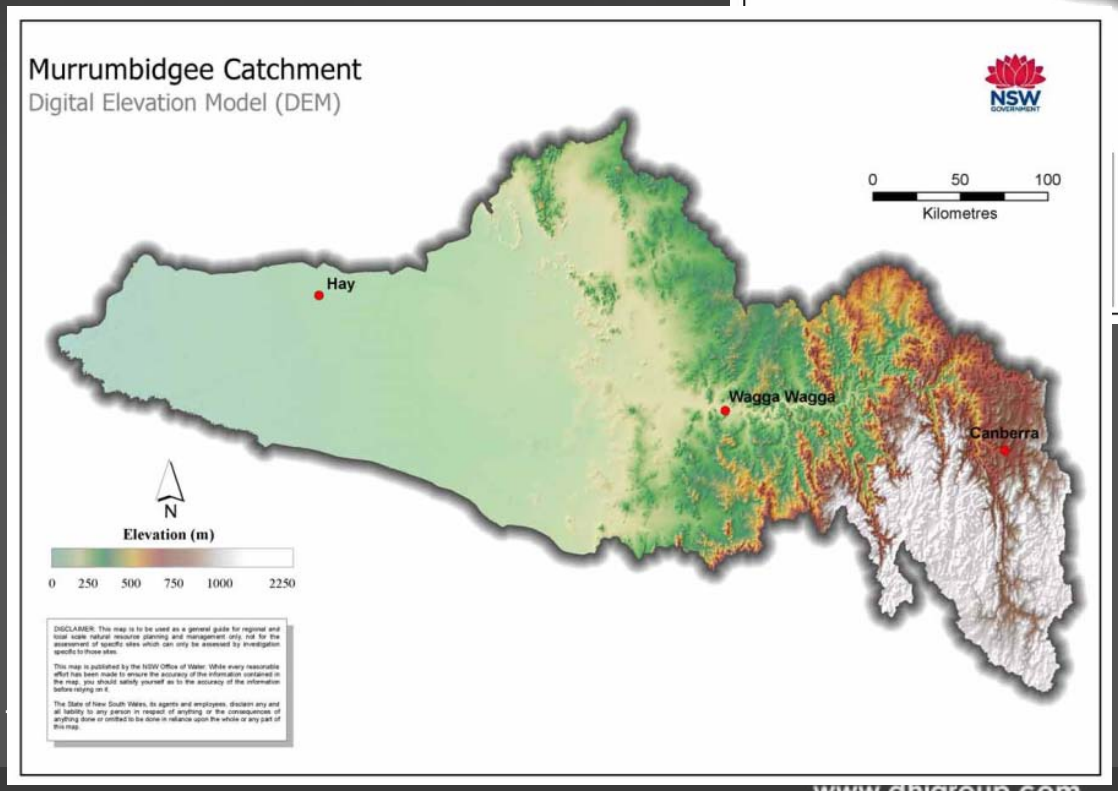
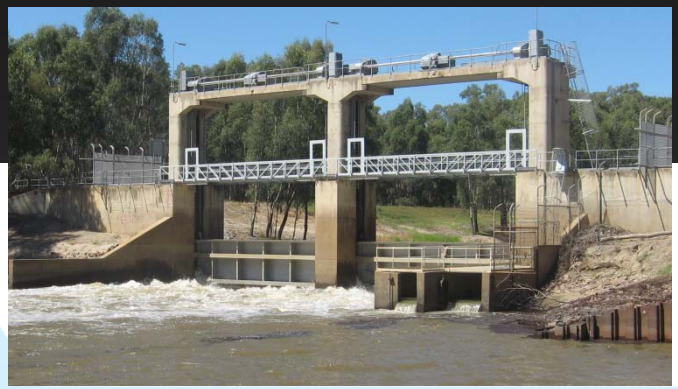
Murrumbidgee River Basin

Area: 84,000km^2
Length: 1600km
Pop: 520,000





Murrumbidgee Water Efficiency Project



System-wide telemetry-connected meters ensure certainty of water measurement

Protection of environmental flows

Improved measurement of irrigation offtakes

River gauge measurements in real time

Improved flow management and less evaporation

System-wide telemetry delivers real time data for better measurement and monitoring

Reduced transmission losses and improved flow for Yanco Creek

Improved flow management and less evaporation for Old Man Creek

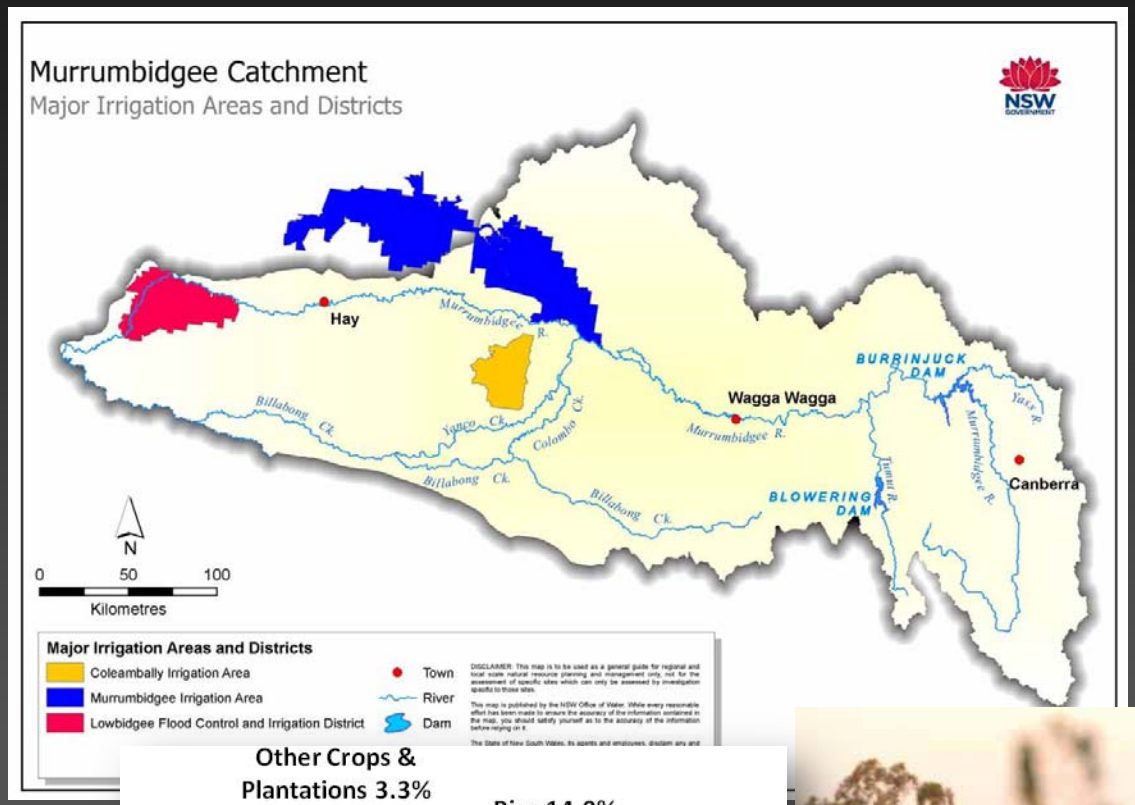
Modelling and forecasting of tributary inflows to better manage dam releases

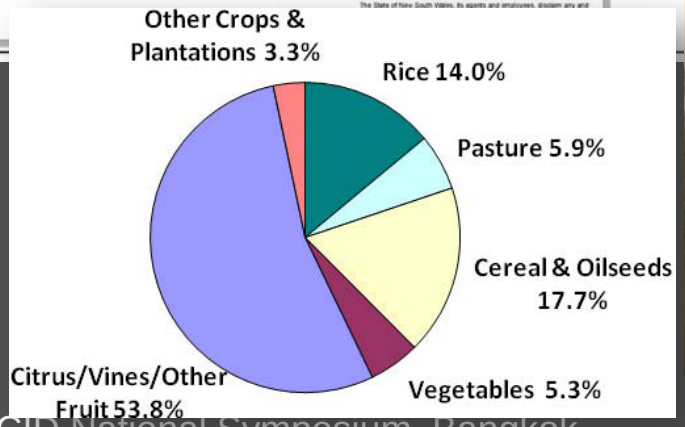
LEGEND

- Major towns
- Major weirs
- Water bodies
- Major dams
- Telemetry
- River system
- Irrigation system outfalls
- Water canals
- Project boundary
- Irrigation corporations

MIL–Murrumbidgee Irrigation Ltd and CICL– Coleambally Irrigation Co-Operative Ltd

Irrigation





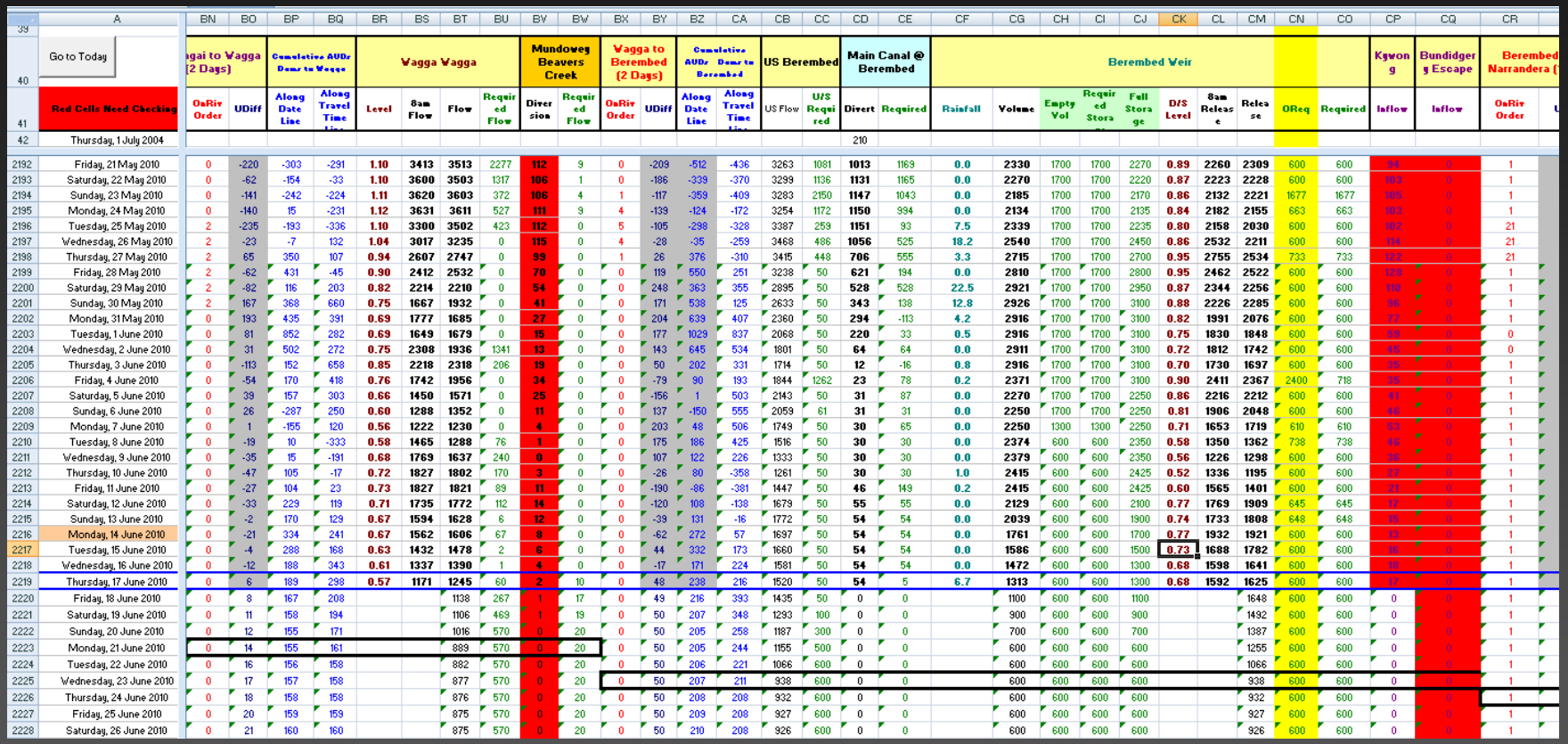
- Irrigation and environment are biggest water users
- Murrumbidgee and Coleambally use 50% and 20% of all irrigation water.

Current Challenges for River Operations

- Meeting water orders, while conserving available dam water, taking into account:
  - Water orders may change
  - Catchment inflow contributions
  - River conditions (variable travel times)
  - Potential losses and gains
  - Available storages and levels in weirs

- Constraints:
  - Manual, daily operation relies on judgement and experience
  - Limited ability to use real-time and forecast data (flows, rainfall, demands)
  - "Known unknowns" – tributary inflows, river seepage, evapotranspiration
  - Lack of real river hydraulics
  - Aging operations technology

Current River Operations



	A	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR
39																																
40	Go to Today		gai to Wagga (2 Days)		Cumulative AUDr Dsmr to Wagga	Wagga Wagga				Mundoweg Beavers Creek		Wagga to Berembed (2 Days)		Cumulative AUDr Dsmr to Berembed		US Berembed		Main Canal @ Berembed		Berembed Weir										Kywon g	Bundidger g Escape	Berembed Narrandera (
41	Red Cells Need Checking	OnRiv Order	UDiff	Along Date Line	Along Travel Time Line	Level	8am Flow	Flow	Required Flow	Diversion	Required Flow	OnRiv Order	UDiff	Along Date Line	Along Travel Time Line	US Flow	US Required	Divert	Required	Rainfall	Volume	Empty Vol	Required Storage	Full Storage	D/S Level	8am Release	Release	QReq	Required	Inflow	Inflow	OnRiv Order	U
42	Thursday, 1 July 2004																	210															
2192	Friday, 21 May 2010	0	-220	-303	-291	1.10	3413	3513	2277	112	9	0	-209	-512	-436	3263	1081	1013	1169	0.0	2330	1700	1700	2270	0.89	2260	2309	600	600	94	0	1	
2193	Saturday, 22 May 2010	0	-62	-154	-33	1.10	3600	3503	1317	106	1	0	-186	-339	-370	3299	1136	1131	1165	0.0	2270	1700	1700	2220	0.87	2223	2228	600	600	103	0	1	
2194	Sunday, 23 May 2010	0	-141	-242	-224	1.11	3620	3603	372	106	4	1	-117	-359	-409	3283	2150	1147	1043	0.0	2185	1700	1700	2170	0.86	2132	2221	1677	1677	105	0	1	
2195	Monday, 24 May 2010	0	-140	15	-231	1.12	3631	3611	527	111	9	4	-139	-124	-172	3254	1172	1150	994	0.0	2134	1700	1700	2135	0.84	2182	2155	663	663	103	0	1	
2196	Tuesday, 25 May 2010	2	-235	-193	-336	1.10	3300	3502	423	112	0	5	-105	-298	-328	3387	259	1151	93	7.5	2339	1700	1700	2235	0.80	2158	2030	600	600	102	0	21	
2197	Wednesday, 26 May 2010	2	-23	-7	132	1.04	3017	3235	0	115	0	4	-28	-35	-259	3468	486	1056	525	18.2	2540	1700	1700	2450	0.86	2532	2211	600	600	114	0	21	
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2199	Friday, 28 May 2010	2	-62	431	-45	0.90	2412	2532	0	70	0	0	119	550	251	3238	50	621	194	0.0	2810	1700	1700	2800	0.95	2462	2522	600	600	128	0	1	
2200	Saturday, 29 May 2010	2	-82	116	203	0.82	2214	2210	0	54	0	0	248	363	355	2895	50	528	528	22.5	2921	1700	1700	2950	0.87	2344	2256	600	600	110	0	1	
2201	Sunday, 30 May 2010	2	167	368	660	0.75	1667	1932	0	41	0	0	171	538	125	2633	50	343	138	12.8	2926	1700	1700	3100	0.88	2226	2285	600	600	96	0	1	
2202	Monday, 31 May 2010	0	193	435	391	0.69	1777	1685	0	27	0	0	204	639	407	2360	50	294	-113	4.2	2916	1700	1700	3100	0.82	1991	2076	600	600	77	0	1	
2203	Tuesday, 1 June 2010	0	81	852	282	0.69	1649	1679	0	15	0	0	177	1029	837	2068	50	220	33	0.5	2916	1700	1700	3100	0.75	1830	1848	600	600	59	0	0	
2204	Wednesday, 2 June 2010	0	31	502	272	0.75	2308	1936	1341	13	0	0	143	645	534	1801	50	64	64	0.0	2911	1700	1700	3100	0.72	1812	1742	600	600	45	0	0	
2205	Thursday, 3 June 2010	0	-113	152	658	0.85	2218	2318	206	19	0	0	50	202	331	1714	50	12	-16	0.8	2916	1700	1700	3100	0.70	1730	1697	600	600	35	0	1	
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2207	Saturday, 5 June 2010	0	39	157	303	0.66	1450	1571	0	25	0	0	-156	1	503	2143	50	31	87	0.0	2270	1700	1700	2250	0.86	2216	2212	600	600	41	0	1	
2208	Sunday, 6 June 2010	0	26	-287	250	0.60	1288	1352	0	11	0	0	137	-150	555	2059	61	31	31	0.0	2250	1700	1700	2250	0.81	1906	2048	600	600	46	0	1	
2209	Monday, 7 June 2010	0	1	-155	120	0.56	1222	1230	0	4	0	0	203	48	506	1749	50	30	65	0.0	2250	1300	1300	2250	0.71	1653	1719	610	610	53	0	1	
2210	Tuesday, 8 June 2010	0	-19	10	-333	0.58	1465	1288	76	1	0	0	175	186	425	1516	50	30	30	0.0	2374	600	600	2350	0.58	1350	1362	738	738	46	0	1	
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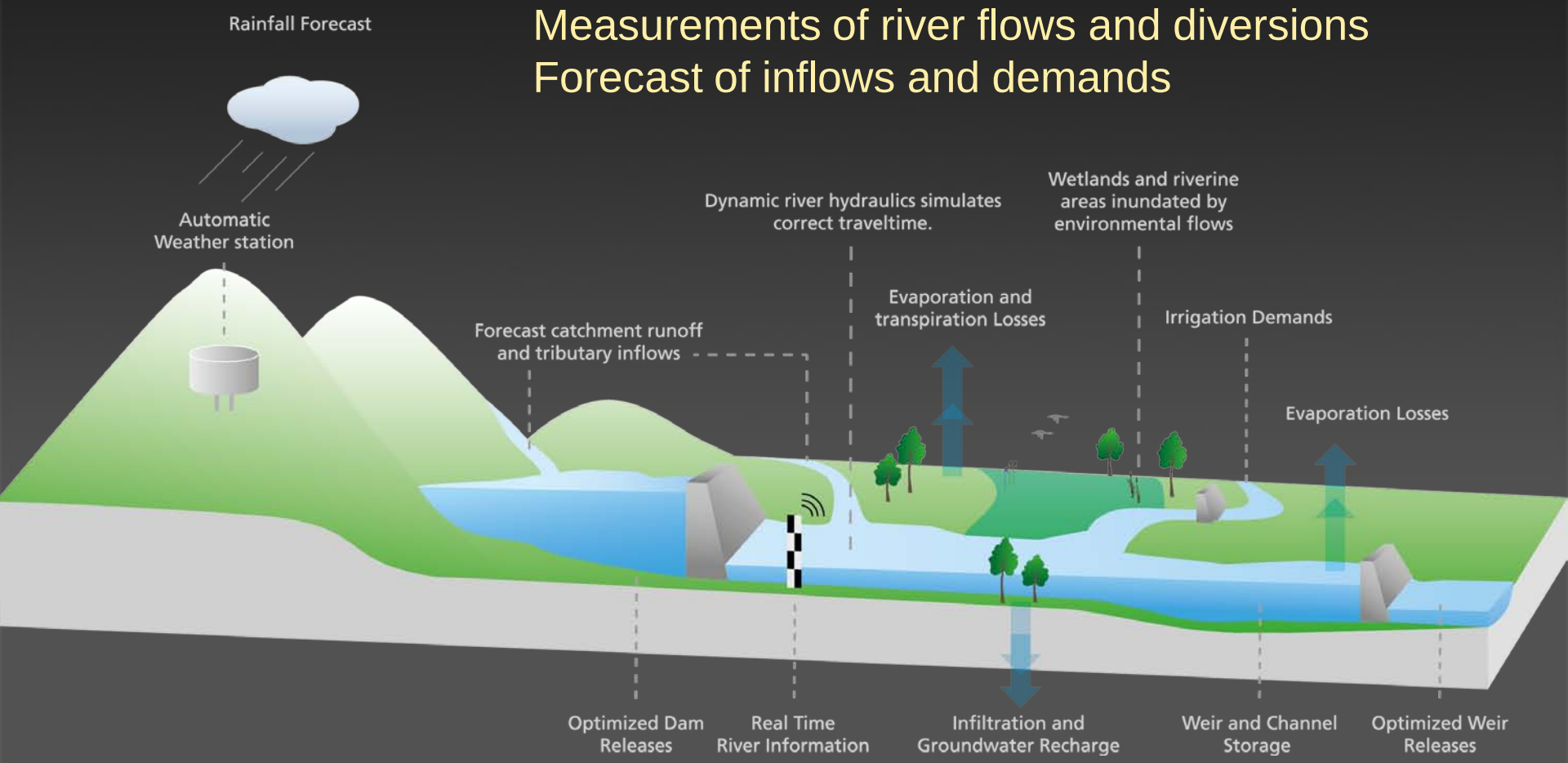
2214	Saturday, 12 June 2010	0	-33	229	119	0.71	1735	1772	112	14	0	0	-120	108	-138	1679	50	55	55	0.0	2129	600	600	2100	0.77	1769	1909	645	645	17	0	1	
2215	Sunday, 13 June 2010	0	-2	170	129	0.67	1594	1628	6	12	0	0	-39	131	-16	1772	50	54	54	0.0	2039	600	600	1900	0.74	1733	1808	648	648	35	0	1	
2216	Monday, 14 June 2010	0	-21	334	241	0.67	1562	1606	67	8	0	0	-62	272	57	1697	50	54	54	0.0	1761	600	600	1700	0.77	1932	1921	600	600	33	0	1	
2217	Tuesday, 15 June 2010	0	-4	288	168	0.63	1432	1478	2	6	0	0	44	332	173	1660	50	54	54	0.0	1586	600	600	1500	0.73	1688	1782	600	600	16	0	1	
2218	Wednesday, 16 June 2010	0	-12	188	343	0.61	1337	1390	1	4	0	0	-17	171	224	1581	50	54	54	0.0	1472	600	600	1300	0.68	1598	1641	600	600	18	0	1	
2219	Thursday, 17 June 2010	0	6	189	298	0.57	1171	1245	60	2	10	0	48	238	216	1520	50	54	5	6.7	1313	600	600	1300	0.68	1592	1625	600	600	17	0	1	
2220	Friday, 18 June 2010	0	8	167	208			1138	267	1	17	0	49	216	393	1435	50	0	0		1100	600	600	1100			1648	600	600	0	0	1	
2221	Saturday, 19 June 2010	0	11	158	194			1106	469	1	19	0	50	207	348	1293	100	0	0		900	600	600	900			1492	600	600	0	0	1	
2222	Sunday, 20 June 2010	0	12	155	171			1016	570	0	20	0	50	205	258	1187	300	0	0		700	600	600	700			1387	600	600	0	0	1	
2223	Monday, 21 June 2010	0	14	155	161			889	570	0	20	0	50	205	244	1155	500	0	0		600	600	600	600			1255	600	600	0	0	1	
2224	Tuesday, 22 June 2010	0	16	156	158			882	570	0	20	0	50	206	221	1066	600	0	0		600	600	600	600			1066	600	600	0	0	1	
2225	Wednesday, 23 June 2010	0	17	157	158			877	570	0	20	0	50	207	211	938	600	0	0		600	600	600	600			938	600	600	0	0	1	
2226	Thursday, 24 June 2010	0	18	158	158			876	570	0	20	0	50	208	208	932	600	0	0		600	600	600	600			932	600	600	0	0	1	
2227	Friday, 25 June 2010	0	20	159	159			875	570	0	20	0	50	209	208	927	600	0	0		600	600	600	600			927	600	600	0	0	1	
2228	Saturday, 26 June 2010	0	21	160	160			875	570	0	20	0	50	210	208	926	600	0	0		600	600	600	600			926	600	600	0	0	1	

- Manual operation
- Water orders aggregated upstream to dams
- Assumes water moves as parcels between gauges at fixed daily travel times
- Requires extensive operator experience

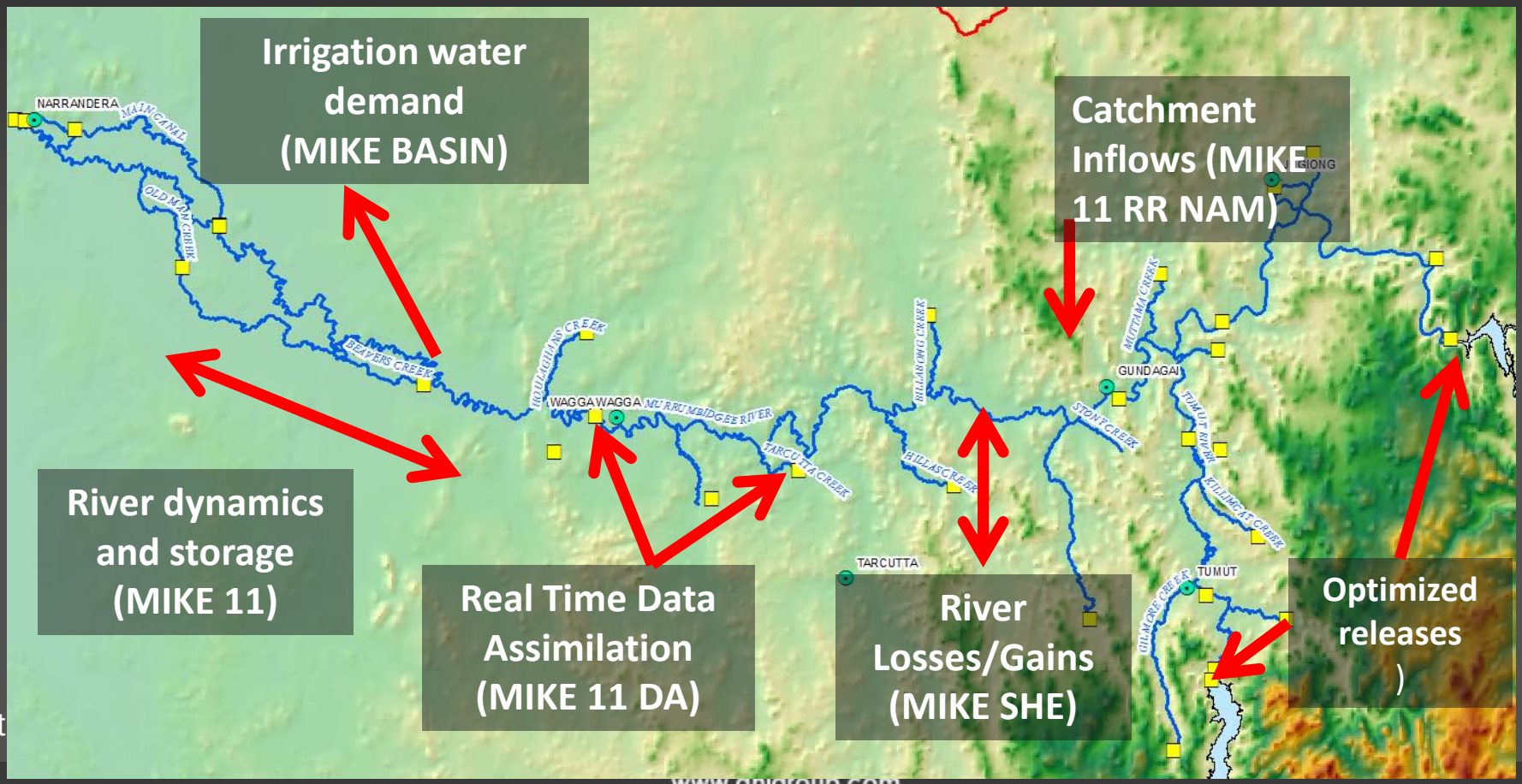
Computer Aided River Management

Knowledge of river behaviour
Measurements of river flows and diversions
Forecast of inflows and demands

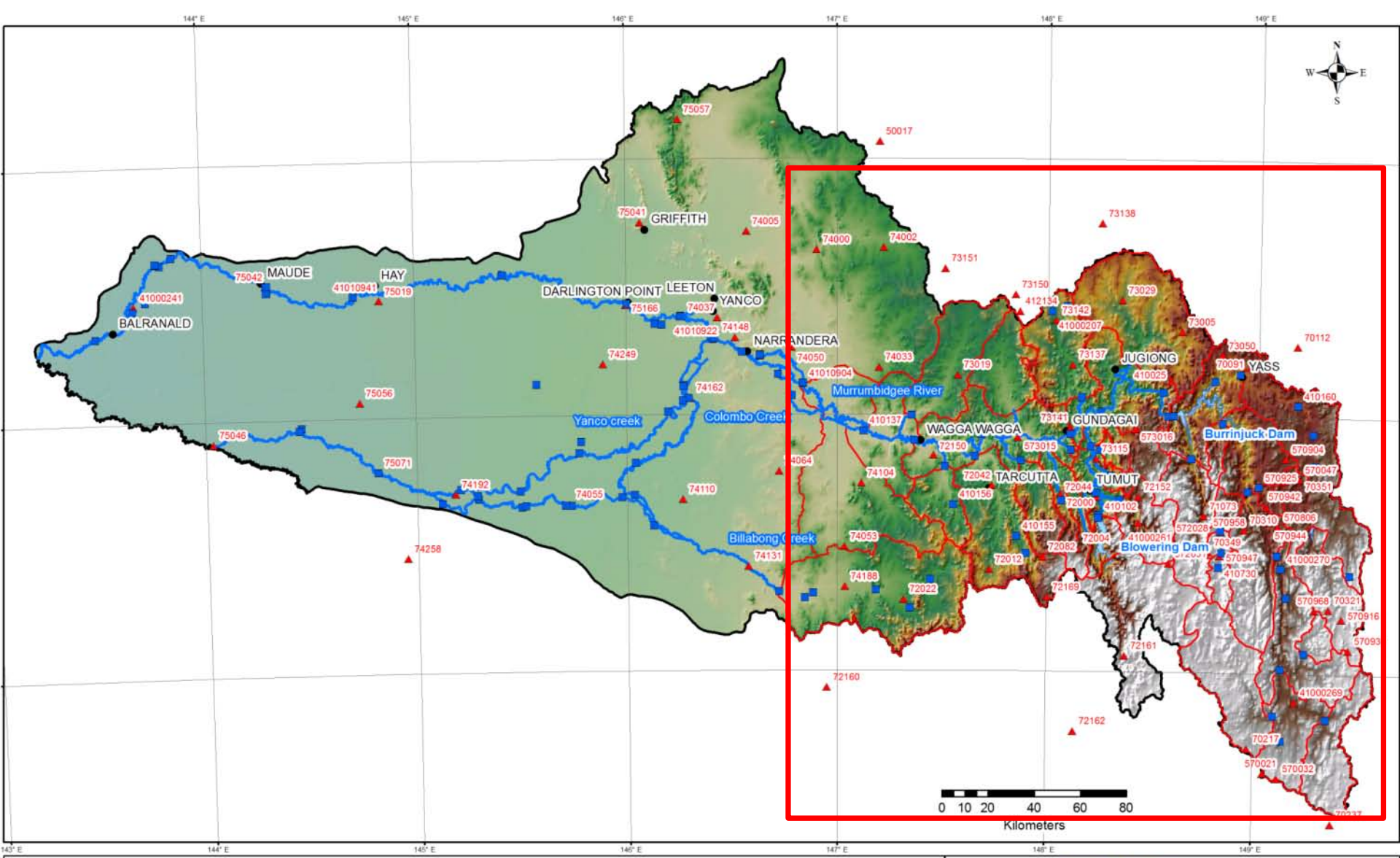


CARM Solution – Modelling Components

- River hydraulics and catchment hydrology simulation tools
- Real time information used to its maximum potential ("self correcting")
- Forecast of catchment inflows, river losses and gains
- Optimisation of dam and weir releases



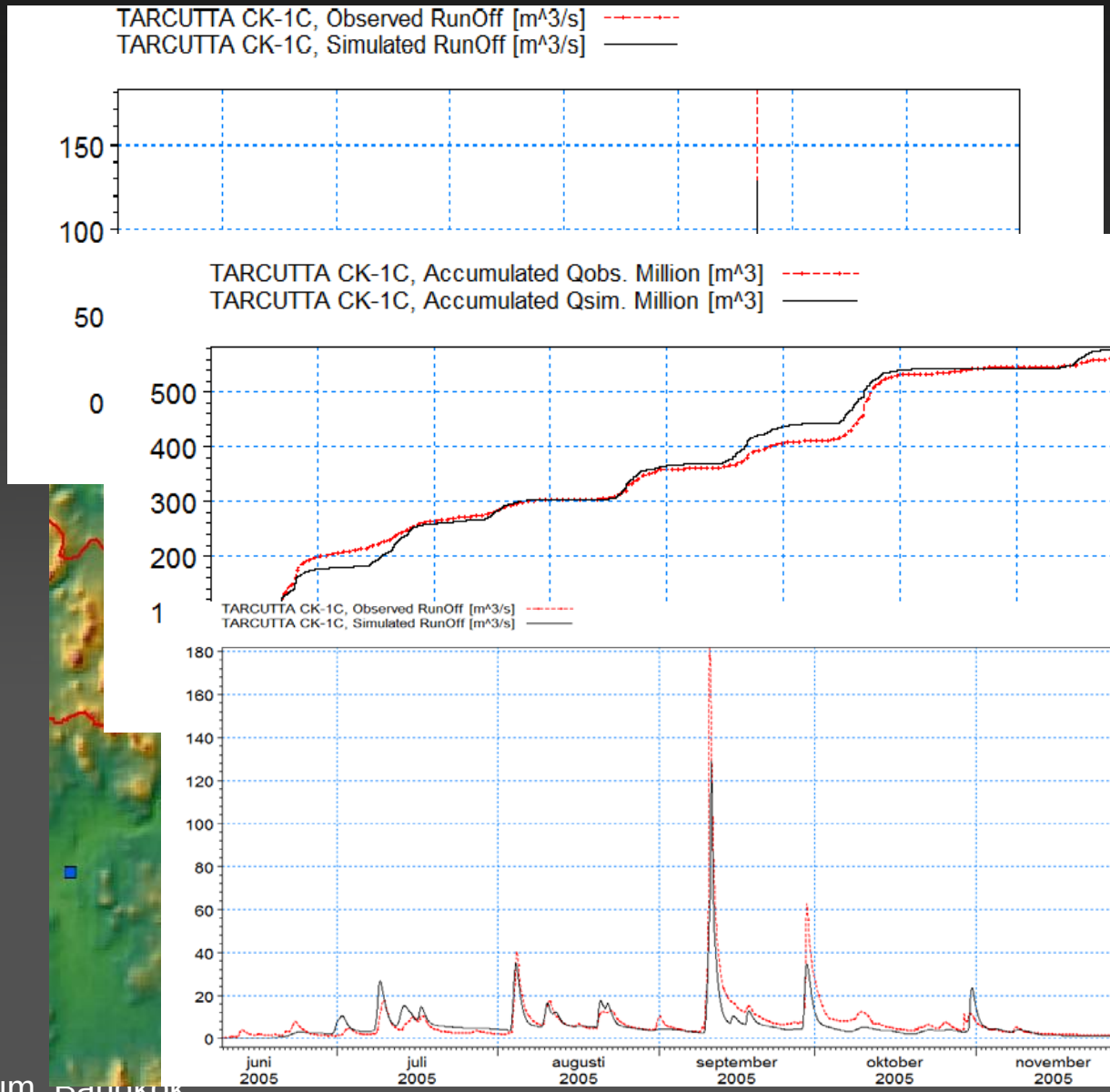
Tributary Inflow Models (inflows)



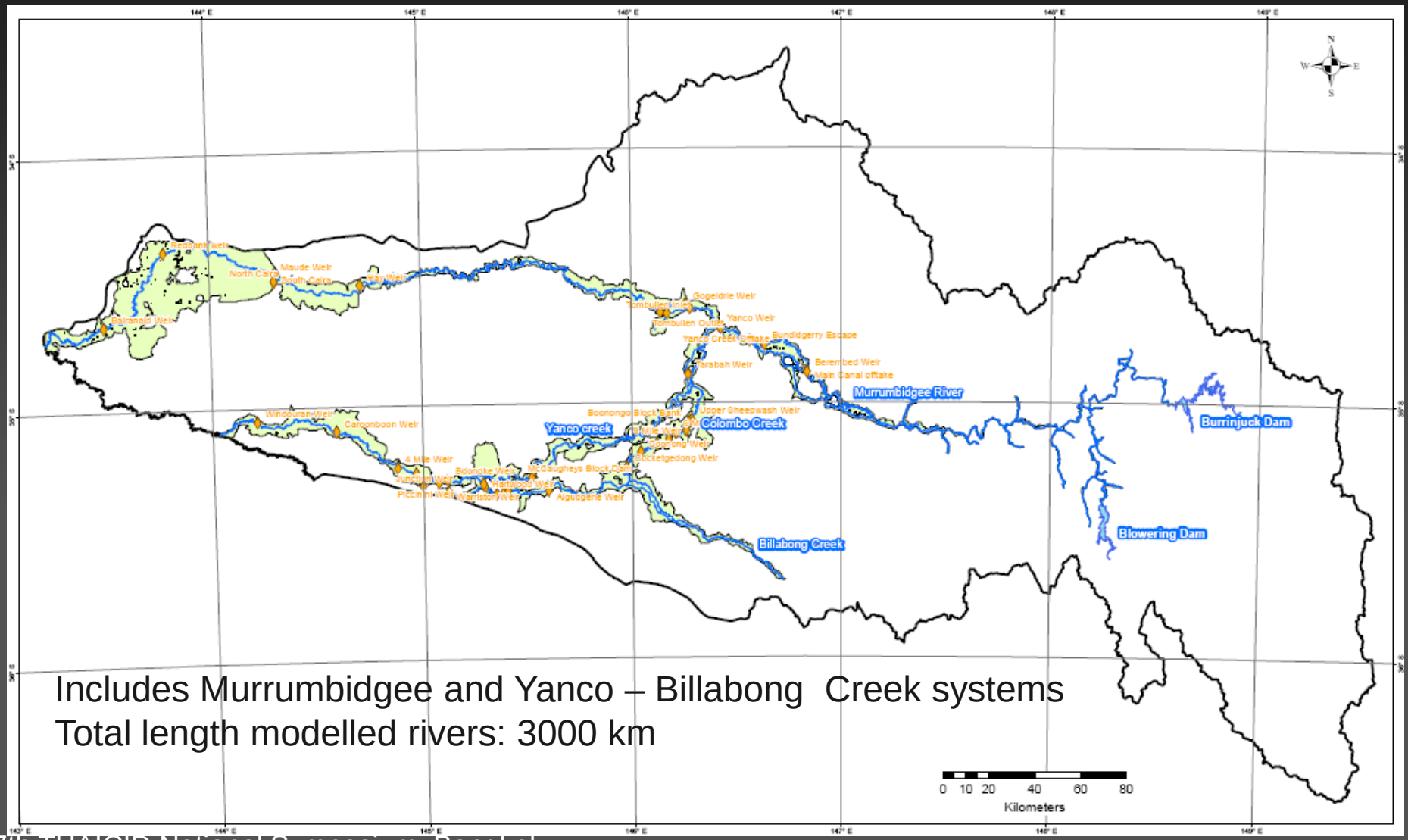
Tributary Inflow Model Results

- **Tarcutta Creek:**
- 1645km^2
- 200m-1000m elev.

- $R^{2=}0.74$.
- Vol err=3%



River Hydraulic Model – MIKE 11

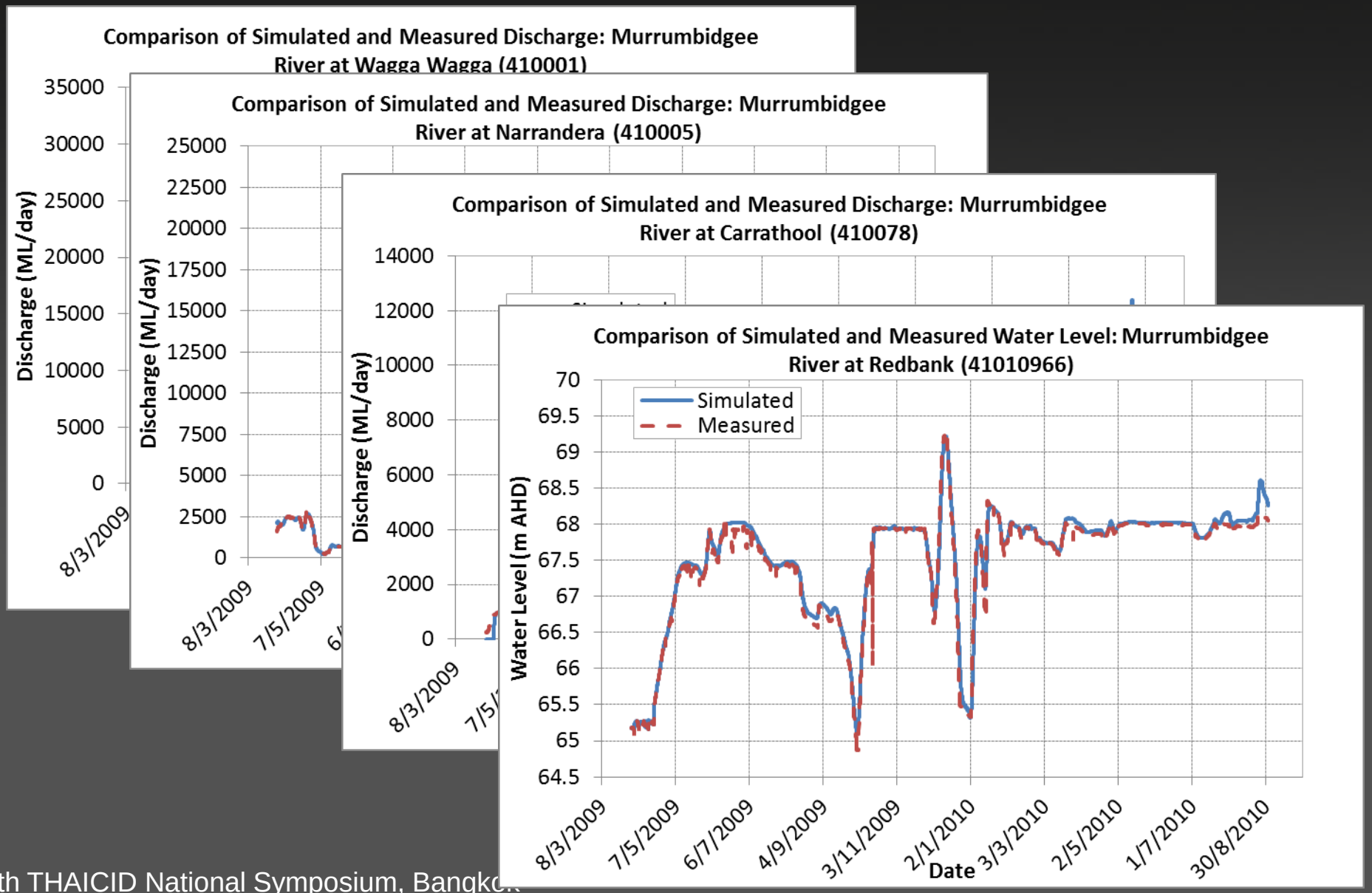


Includes Murrumbidgee and Yanco – Billabong Creek systems
Total length modelled rivers: 3000 km

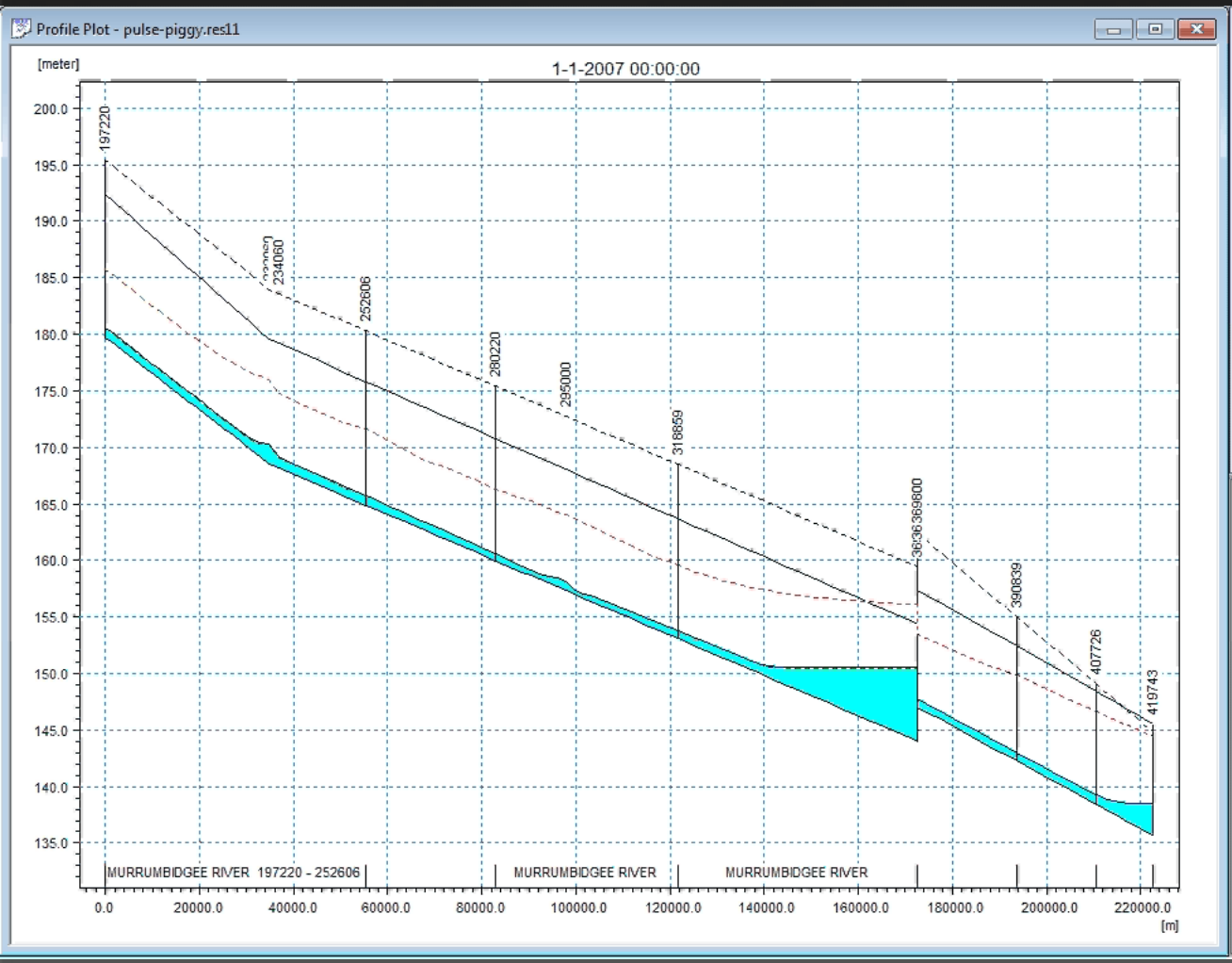
Weirs and Gates

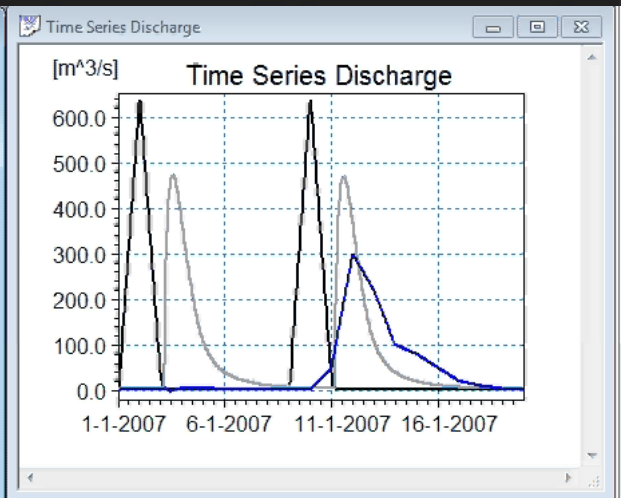
- Remotely controlled gates implemented as discharge structures – **setpoints** to be optimized
- Manually controlled structures – Spillers, Hartwood, Balranald – included as physical structures with gate levels pre-defined
- 25 fixed crest weirs included in Yanco-Billabong Creek System

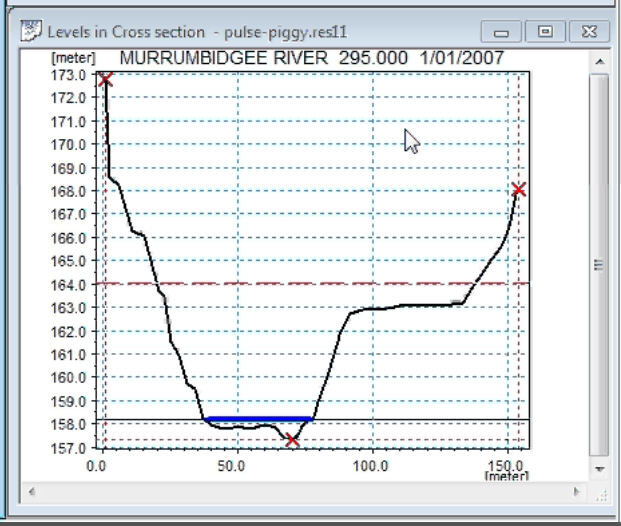
Calibration Results – Murrumbidgee River



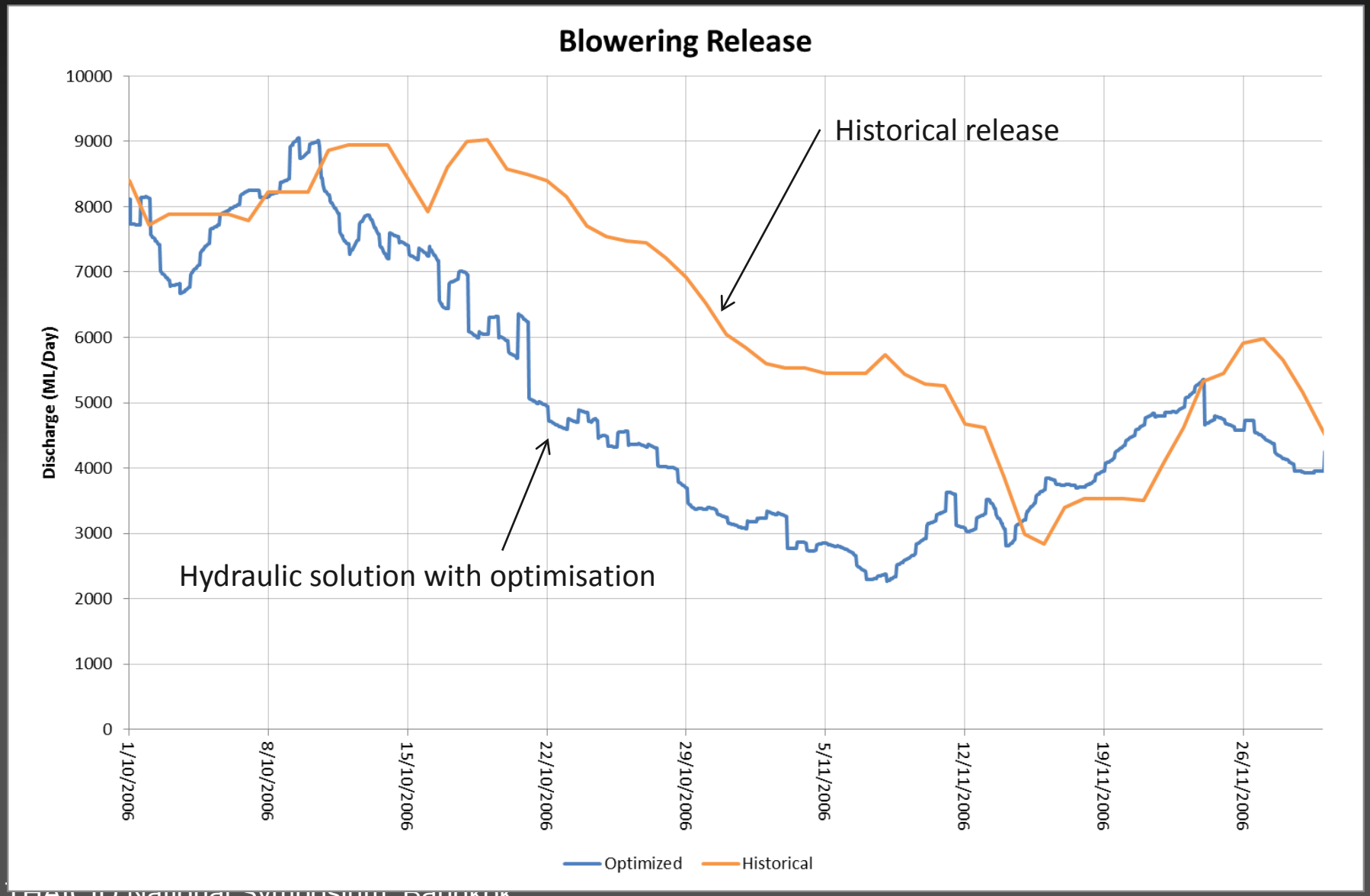
Routing of Flow - Demonstration



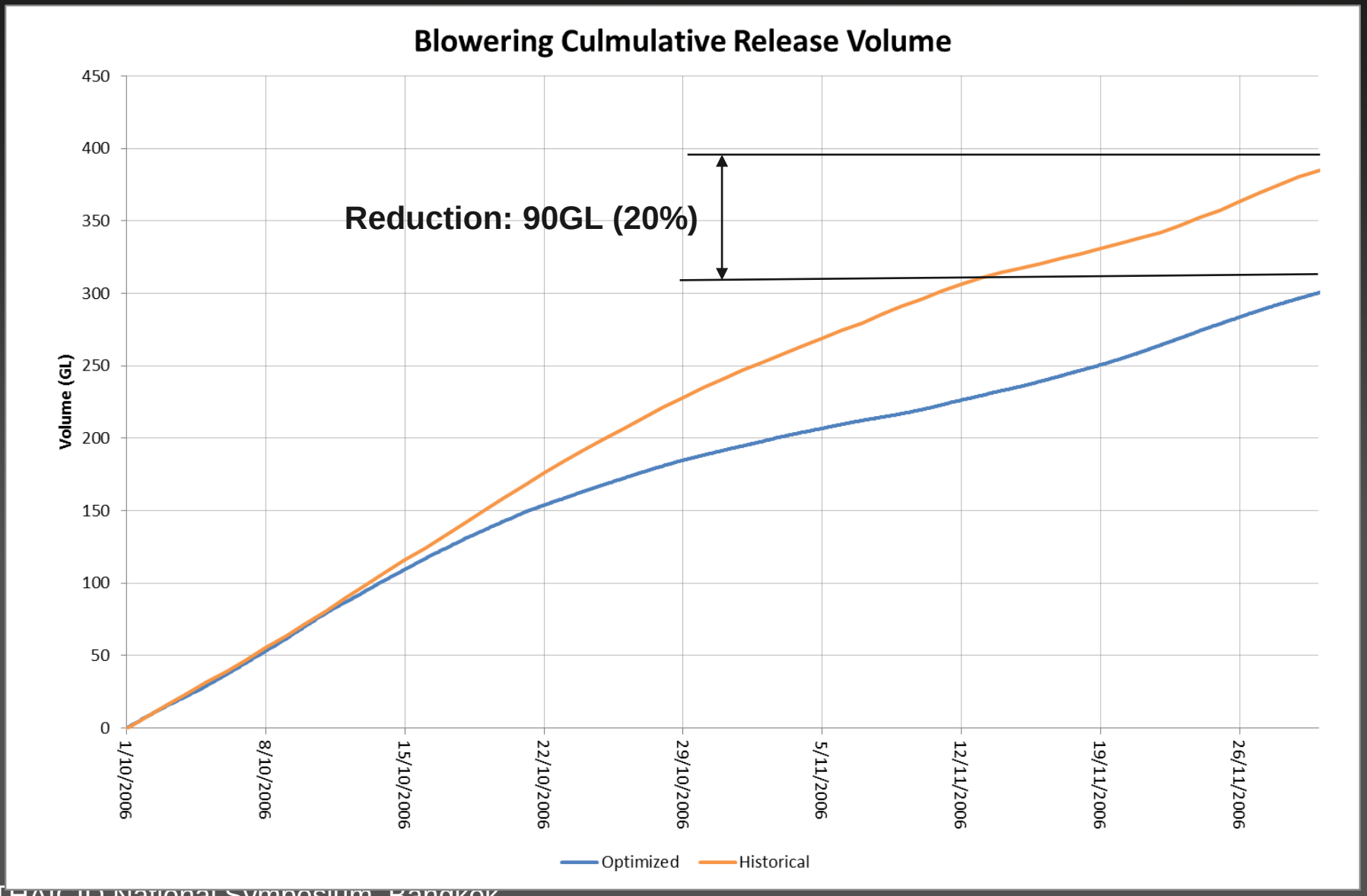




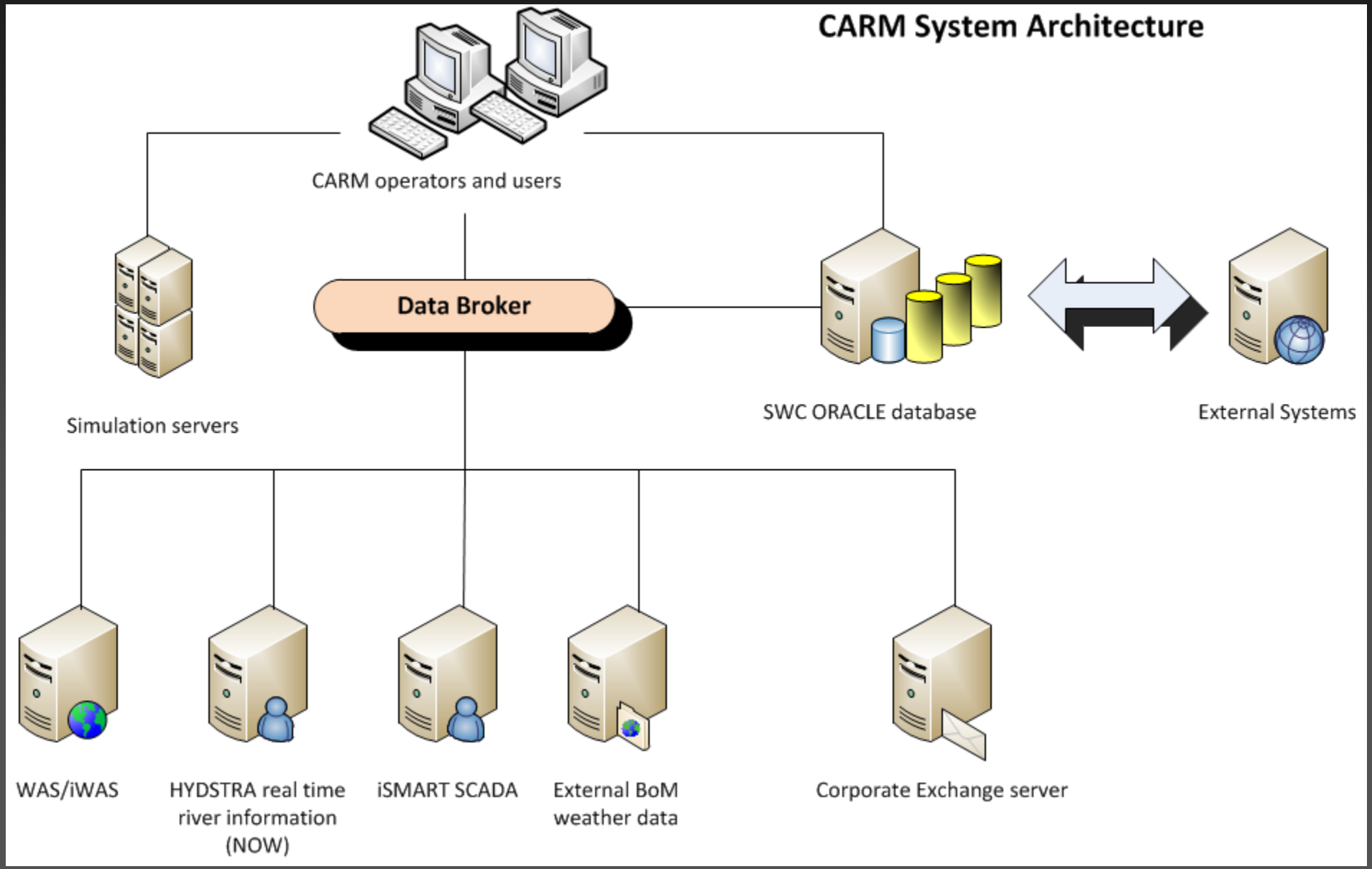
Dry Period: Release from Blowering



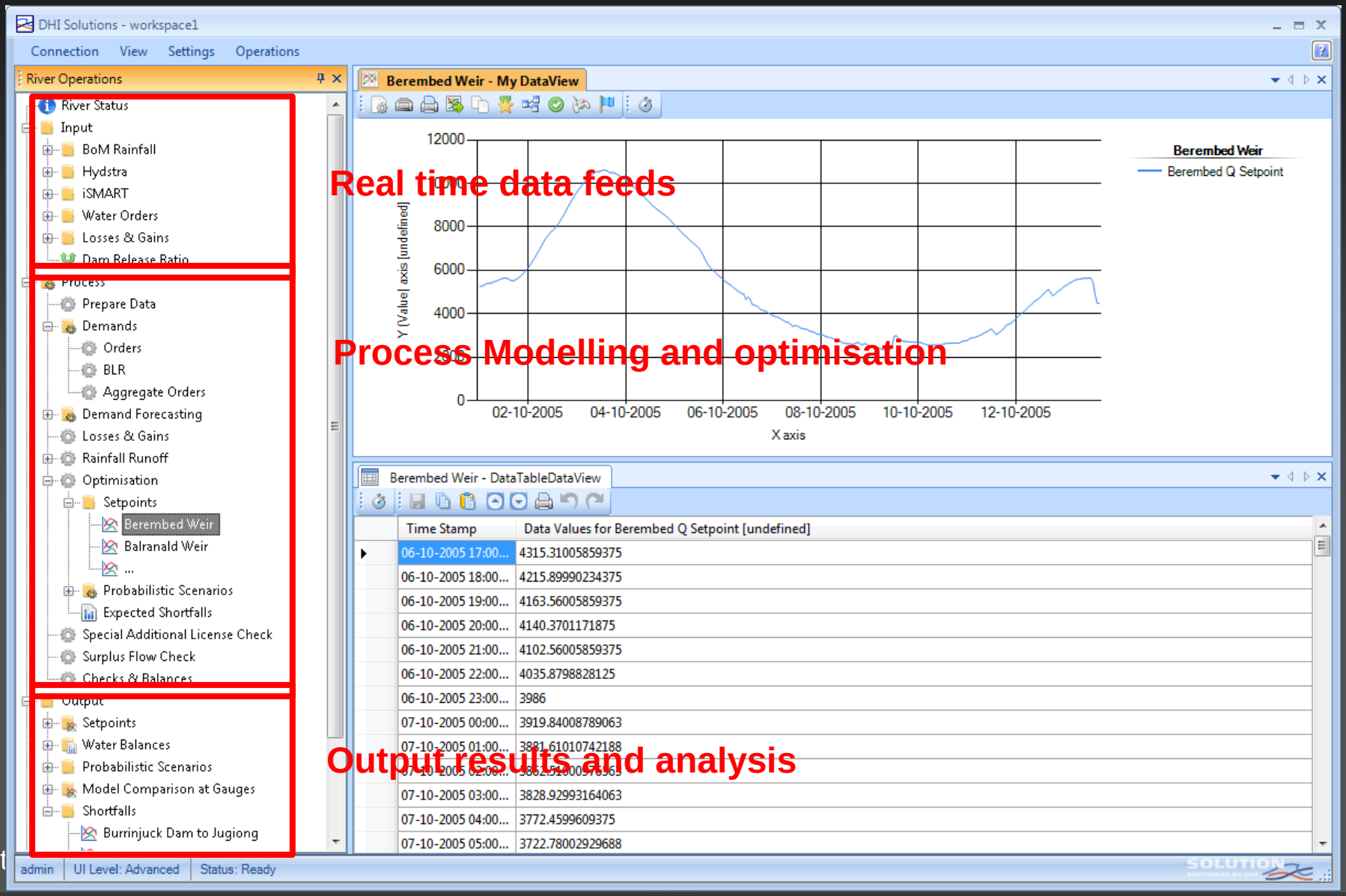
Dry Period: Release from Blowering



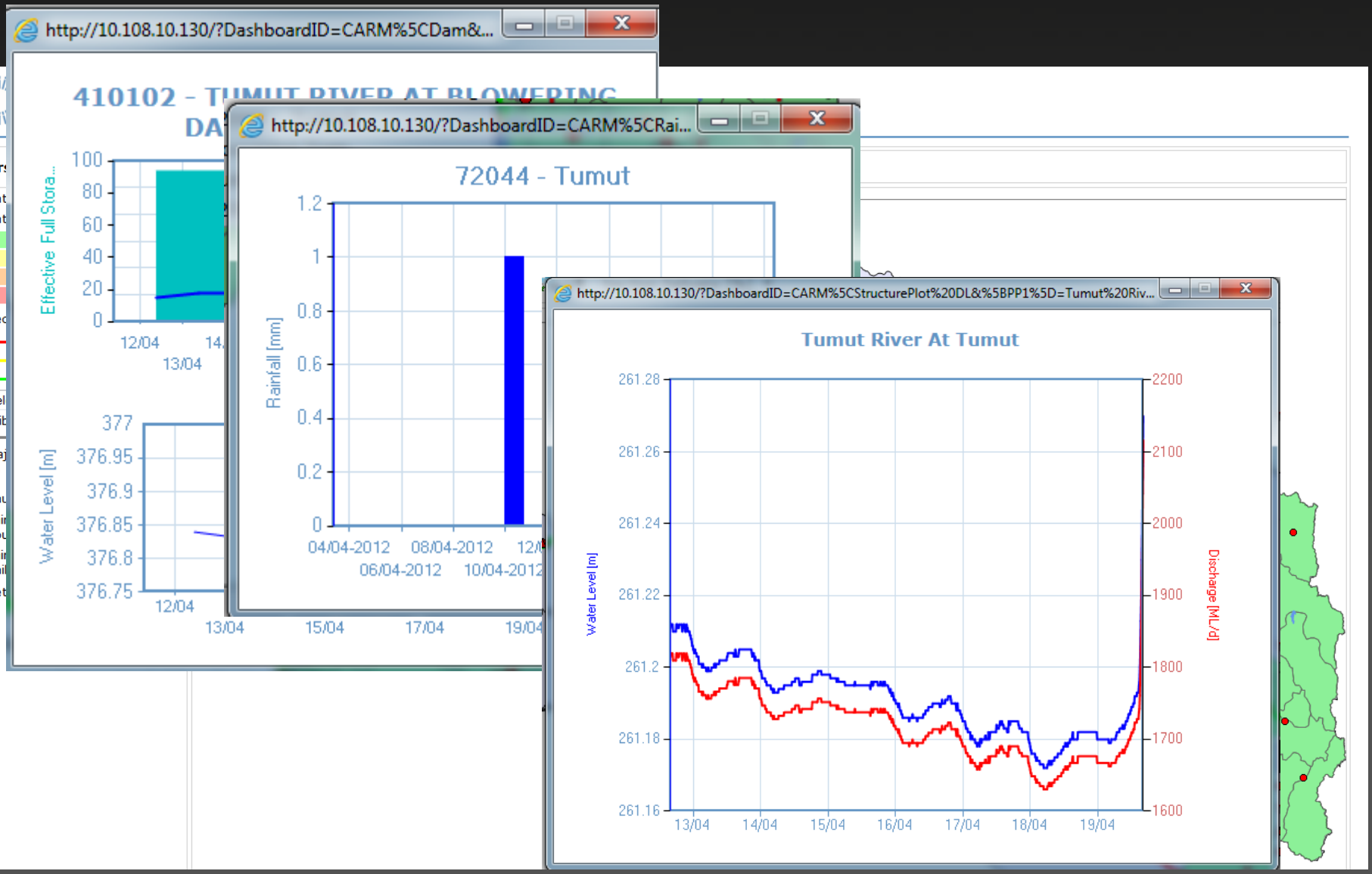
Integration with Existing Systems



River Operations Workflow



Web Dashboard – Hydrometric Display



Summary on Computer Aided River Management

- **Current operations are suboptimal**
  - Difficult to achieve more efficient operations with the older technology in the current system
- **Modern technology**
  - More precise hourly operations
  - Simulation and optimisation technology improves SWC's river operations
- **Precision water deliveries will**
  - Reduce operational surplus and improve reliability of deliveries
  - More water available for targeted environmental releases
  - Ensure accurate delivery of environmental flows

DSS Implementation at organisations

(a partnership between consultant and agency)

- **Based on the water authority's needs;**
- **Customization to serve technical, managerial & public levels;**
- **Acceptance & ownership;**
- **Training & capacity building;**
- **Creating sustainability.**

```
' Under the Tools menu,
Public Sub Macro1()

' any error will halt exe
On Error GoTo ErrorHandle

' declare variables
Dim engine As DHI_MikeBasin_Engine.engine
Dim theCatchment, theWaterUser, theReservoir, theRule As DHI_Mi
Dim iItemIndex, ctsDeficit, ctsRunoff, ctsUsedWater, ctsWaterLe
Dim dbName, description As String
Dim iSim, nSim As Integer
Dim startDate As Date

  ' Get input from Spreadsheet
  dbName = Sheets("MBDashBoard").Cells(4, 5).Value

  nSim = 10 ' The number of simulations
  iSim = 0  ' Simulation counter

  ' initialize calculations
  Set engine = New DHI_MikeBasin_Engine.engine
  engine.SimulationDescription = "DemoVB"
  engine.Silent = True ' Do not show progress info
```

So, where are we exactly on DSS?

- From single objective to multi-objective water management using one integrated technology serving many needs;
- Customised workflows for real time operations and off-line planning;
- Extensible and Scalable System can be extended to provide new system capabilities
- Modular and open architecture with International standards for model interoperability
- Simulation tools are separate from the system architecture

Thank you