

Multiple tools and techniques for water resources management

Modern Tools and Techniques for Water Resources Assessment and Management

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16 September 2014

Overview

CSIRO: Who we are

IWRM

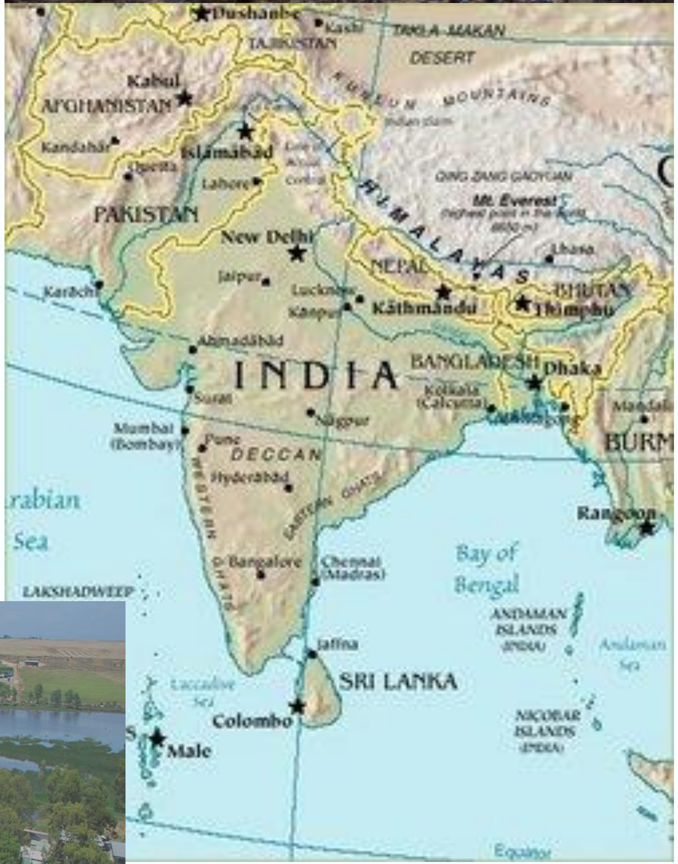
Nexus webs

Modelling framework

Model choice

Water resource management technology

Best practice modelling



CSIRO: Who we are

People	**6000**
Locations	**58**
Flagships	**9**
Budget	**$1B+**

Top 1% of global research institutions in 14 of 22 research fields

Top 0.1% in 4 research fields

We provide scientific responses and solutions to major national and global challenges

CSIRO: What it brings to Water Resource Management

- Significant depth and breadth of skills/expertise
- An understanding of complex multi-disciplinary systems
- Framework for integrating science
- A focus on impact in the science that we do



CSIRO supporting water resource management in South Asia

- Brahmani – Baitarni: development of a planning model to support water resource management across three states.
- Koshi Basin: development of a water balance model to support hydro-power, flood and sediment management.

- Indus Basin: development of a planning model to support management of transboundary flows and within country water resource sharing.
- Bangladesh: supporting development of groundwater resource plans

Integrated Water Resource Management

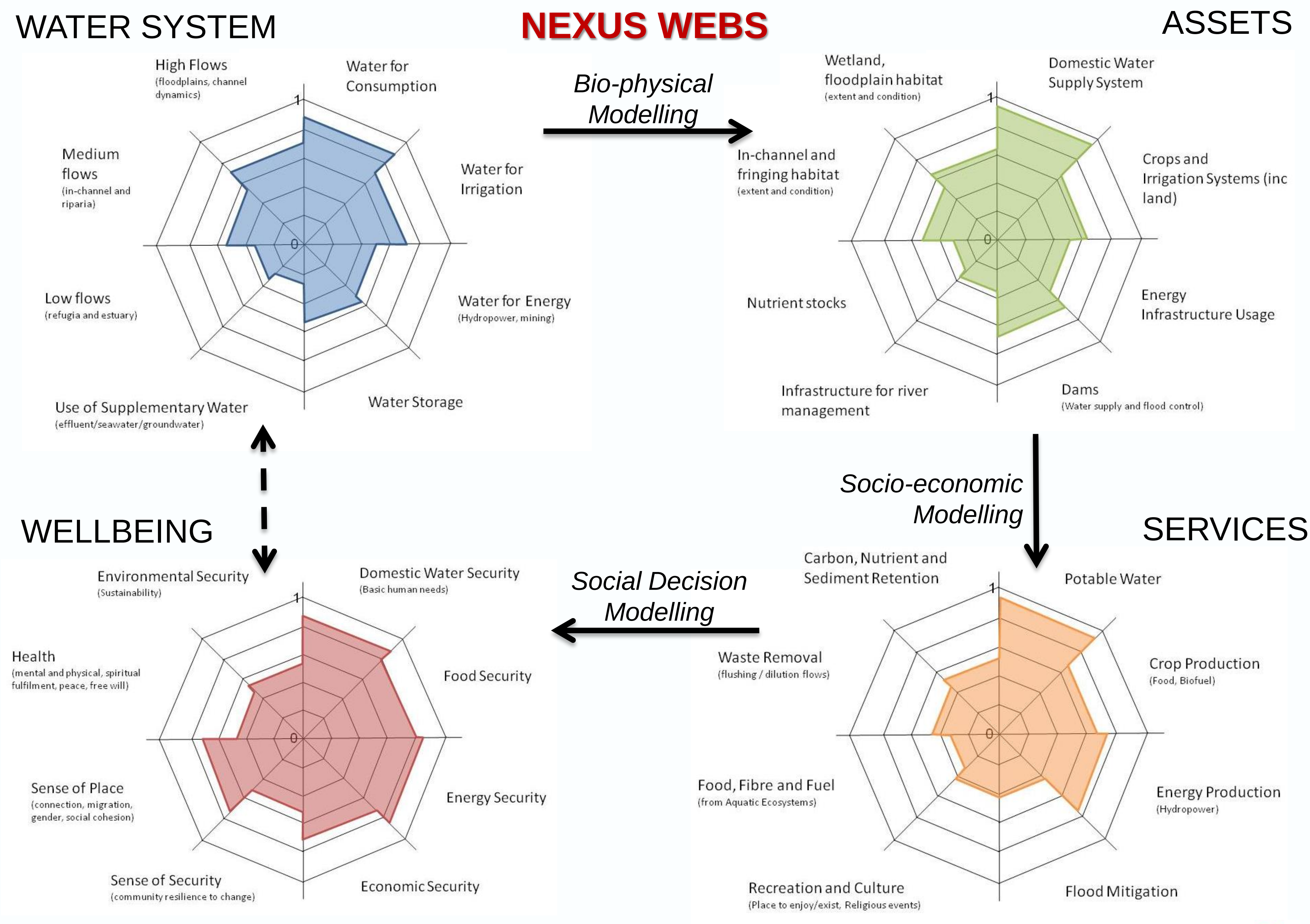
"Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." GWP-TAC, 2000[i]

[i] GWP–TAC (2000). Integrated water resources management. Stockholm, Sweden, Global Water Partnership, Technical Advisory Committee Paper No. 4.

Water-Assets-Services-Wellbeing
Sharing a finite and changing resource for people

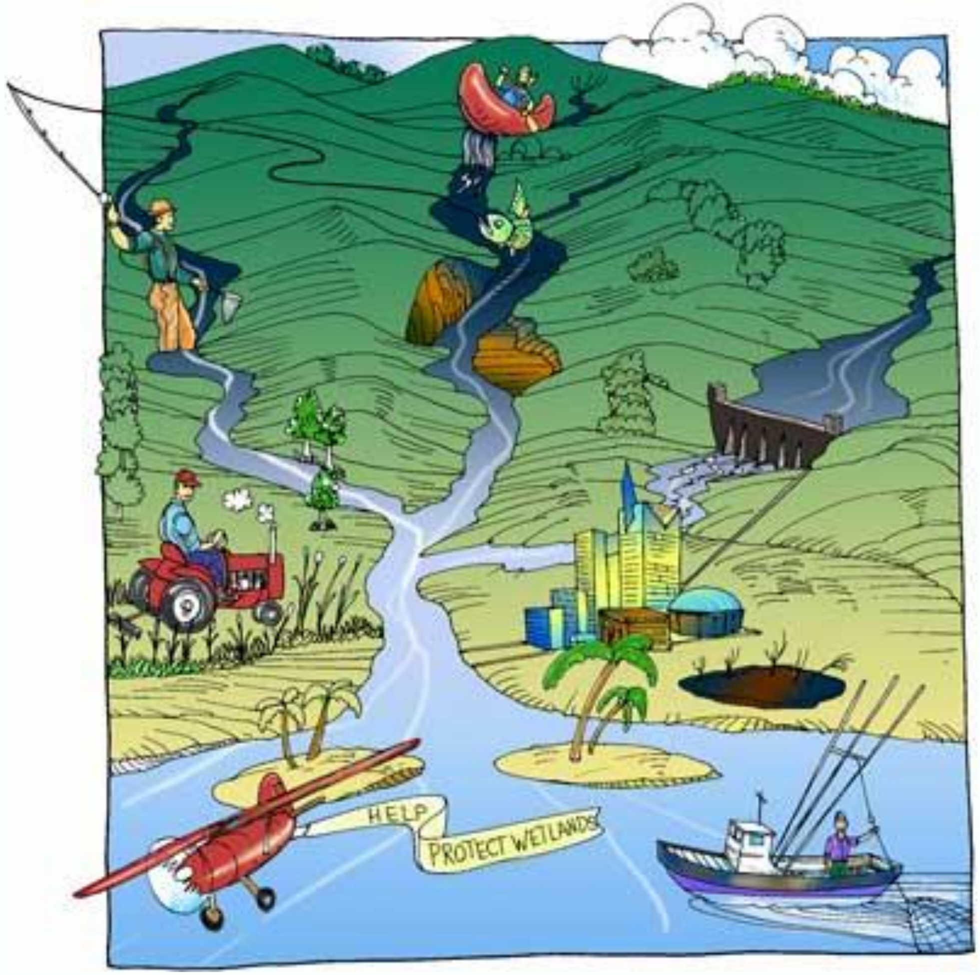
- Water System
  - **Water balance** (domestic, irrigation, storage, end-of-system flows) ~Σ1
  - **Dynamics** (hydropower flows, low flows, medium flows, flood flows)
  - **Additional** (groundwater, desalinisation)
- Assets
  - **Infrastructure** (water supply, irrigation, hydropower, dams)
  - **Natural assets** (estuary, wetlands, floodplains)
- Services
  - **Products from infrastructure** (food, energy, mitigation)
  - **Ecosystem system services** (food, nutrient cycling, recreation)
- Wellbeing
  - **Economic** (water/food/energy security, economic security)
  - **Social** (social security, social cohesion, health)
  - **Environmental** (environmental security/sustainability)

NEXUS WEBS

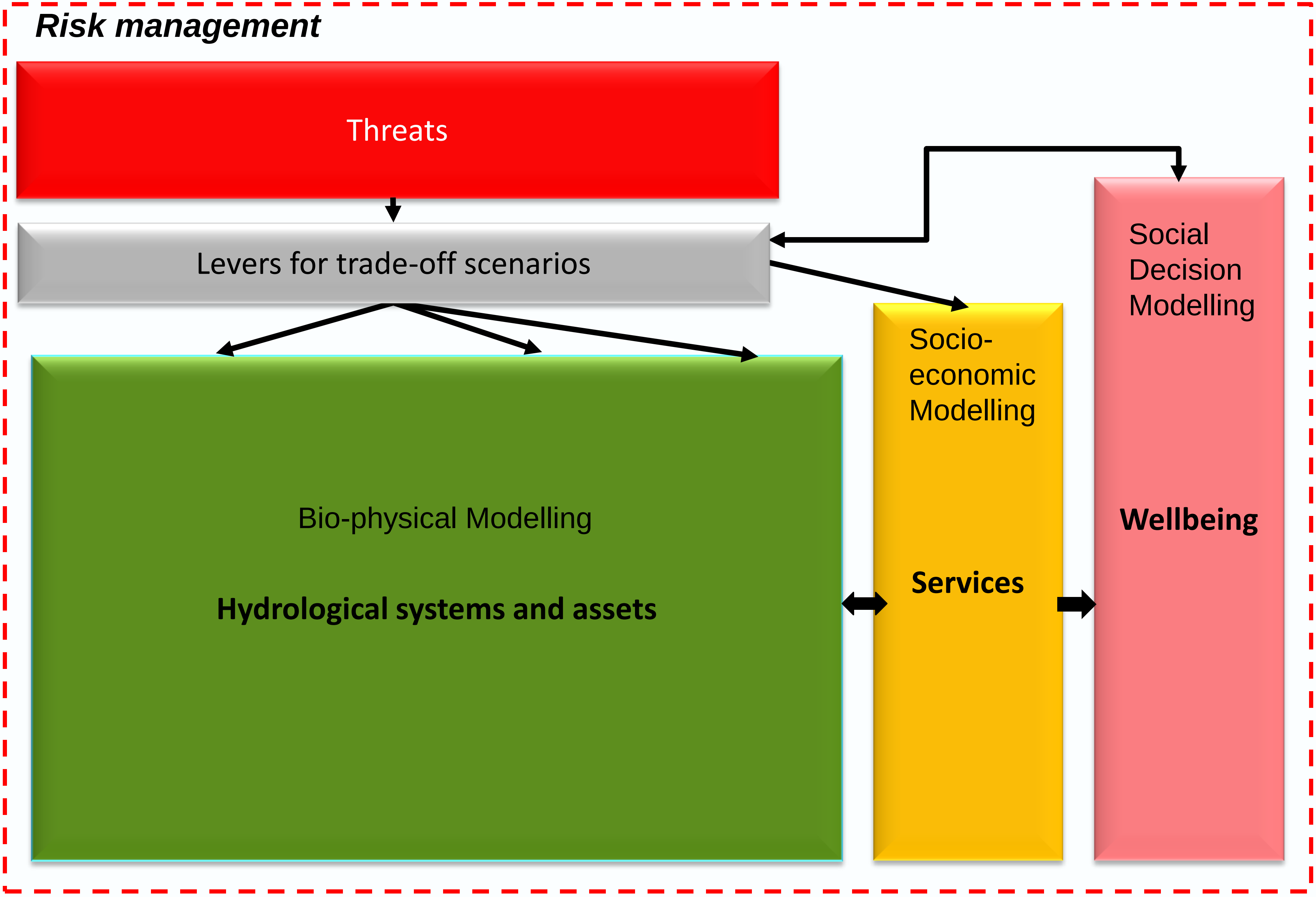

WATER SYSTEM
ASSETS
WELLBEING
SERVICES
Bio-physical Modelling
Socio-economic Modelling
Social Decision Modelling
High Flows
(floodplains, channel dynamics)
Water for Consumption
Water for Irrigation
Water for Energy
(Hydropower, mining)
Water Storage
Use of Supplementary Water
(effluent/seawater/groundwater)
Low flows
(refugia and estuary)
Medium flows
(in-channel and riparia)
Wetland, floodplain habitat
(extent and condition)
Domestic Water Supply System
Crops and Irrigation Systems (inc land)
Energy Infrastructure Usage
Dams
(Water supply and flood control)
Infrastructure for river management
Nutrient stocks
In-channel and fringing habitat
(extent and condition)
Carbon, Nutrient and Sediment Retention
Potable Water
Crop Production
(Food, Biofuel)
Energy Production
(Hydropower)
Flood Mitigation
Recreation and Culture
(Place to enjoy/exist, Religious events)
Food, Fibre and Fuel
(from Aquatic Ecosystems)
Waste Removal
(flushing / dilution flows)
Environmental Security
(Sustainability)
Domestic Water Security
(Basic human needs)
Food Security
Energy Security
Economic Security
Sense of Security
(community resilience to change)
Sense of Place
(connection, migration, gender, social cohesion)
Health
(mental and physical, spiritual fulfilment, peace, free will)
1
0

Conceptual Model Design

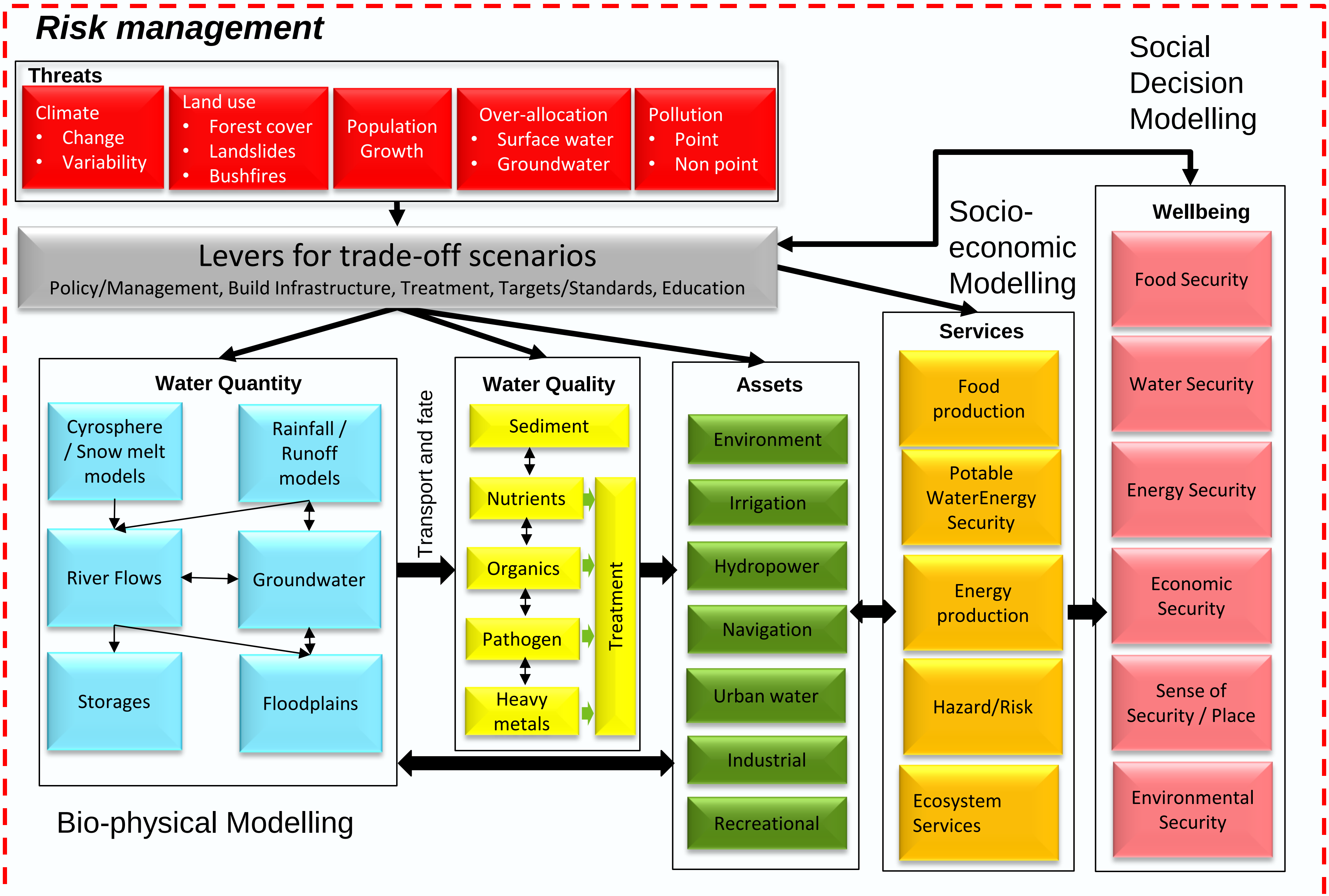
- Climate
- Rainfall/Snow/Ice
- Surface/groundwater
- Water quality
- River systems modelling
- Biophysical modelling
  - Ecosystems
- Socio-economic modelling
  - Potable water
  - Hydropower
  - Agriculture
  - Ecosystem services
  - Social benefits



Integrating Conceptual Framework



Integrating Conceptual Framework

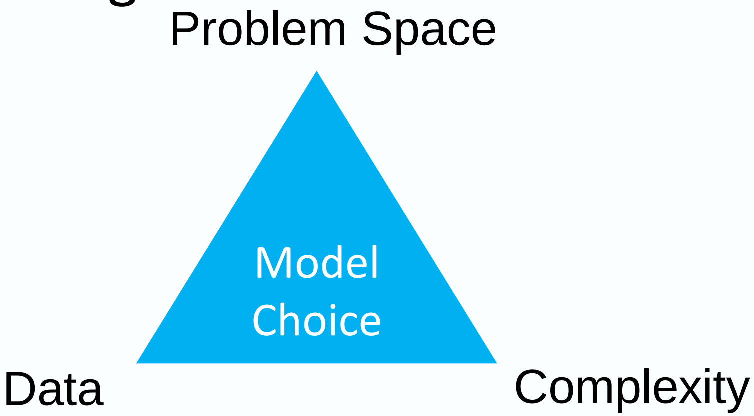


Model choice

There are lots of different models available (too many acronyms to remember) and in many cases the underlying algorithms are similar

There is no one model that can do everything

Model choice is a trade-off



Parsimony: Choose the simplest model that best answers the question

Take into consideration uncertainty. Is the model telling us something useful or is it noise?

Model choice Questions

Problem Space (What are the issues to be considered?)

Planning (scale, sectors, sharing rules, WQ)

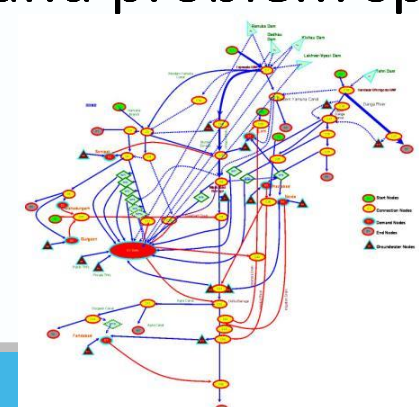
Operations (dams, structures, hydro, irrigation, environment, culture, WQ)

Forecasts (scale, lead time, extent, floods, allocations)

Data (What is needed and available?)

- Global/Local, Observed/Inferred, Historic/Realtime
- What is the uncertainty in the data?

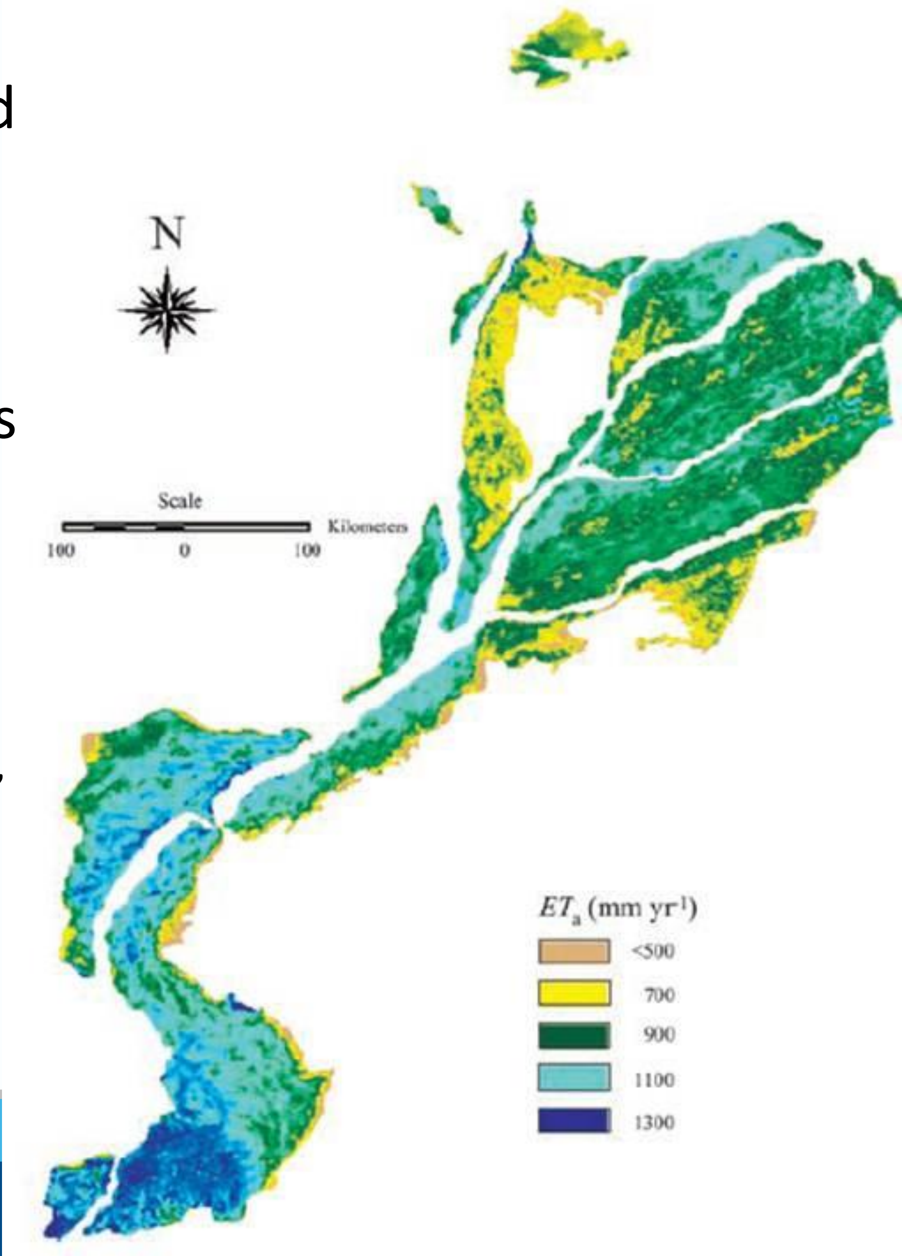
Complexity (What is justified given data and problem space?)



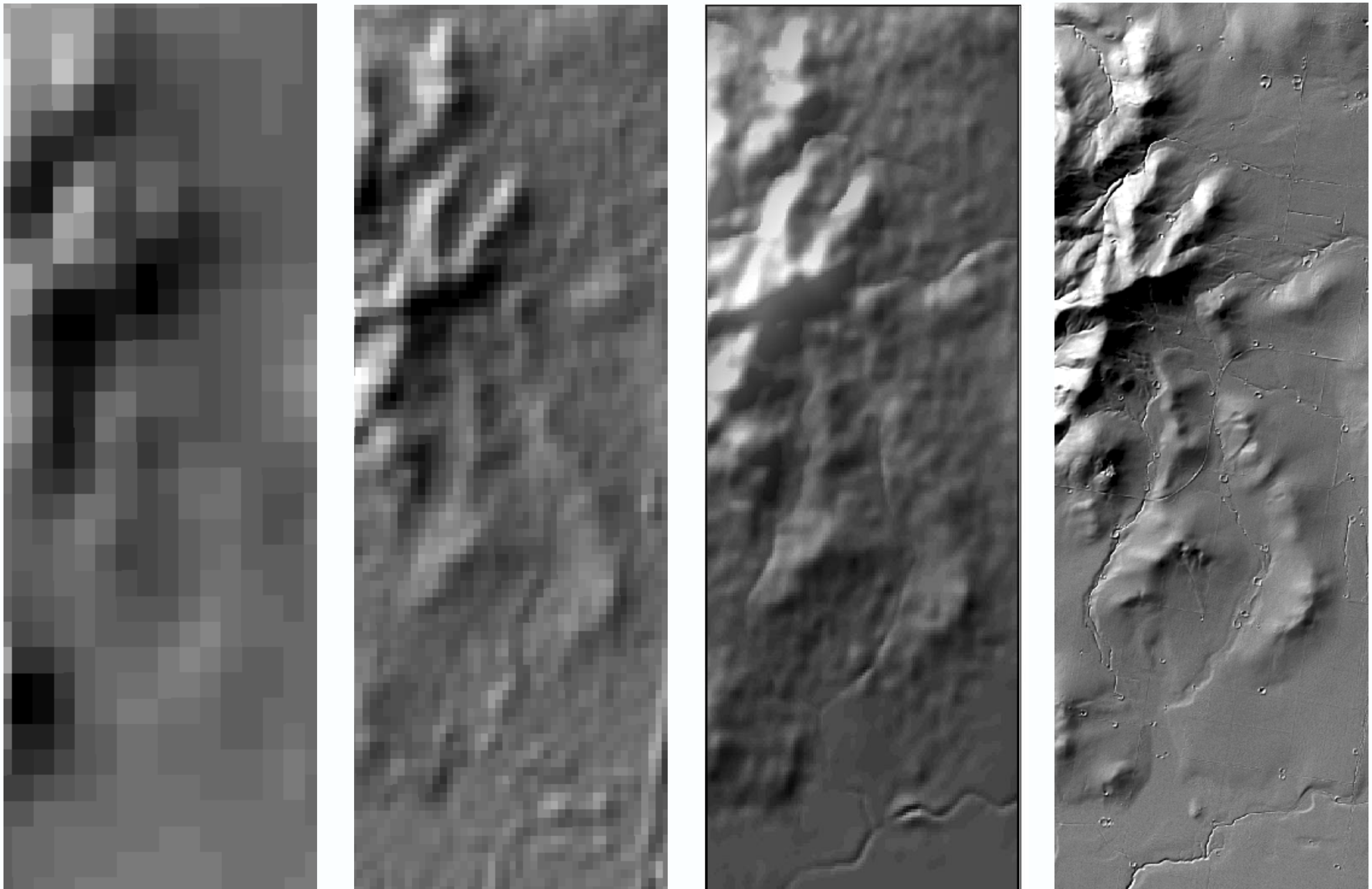
- Spatial and temporal scale
- Process description
- Run times
- Number or parameters

Water Resource Management Technology

- Remote sensing (LIDAR, DEM, ET and Land use)
- Climate surfaces, GCMs and downscaling
- Water Resource Information Systems
- Flood forecasting systems
- Flexible hydrological modelling frameworks
- Workflow tools (integrating hydrological, environmental and economic models)
- Modelling uncertainty and risk
- Technology in the cloud and web

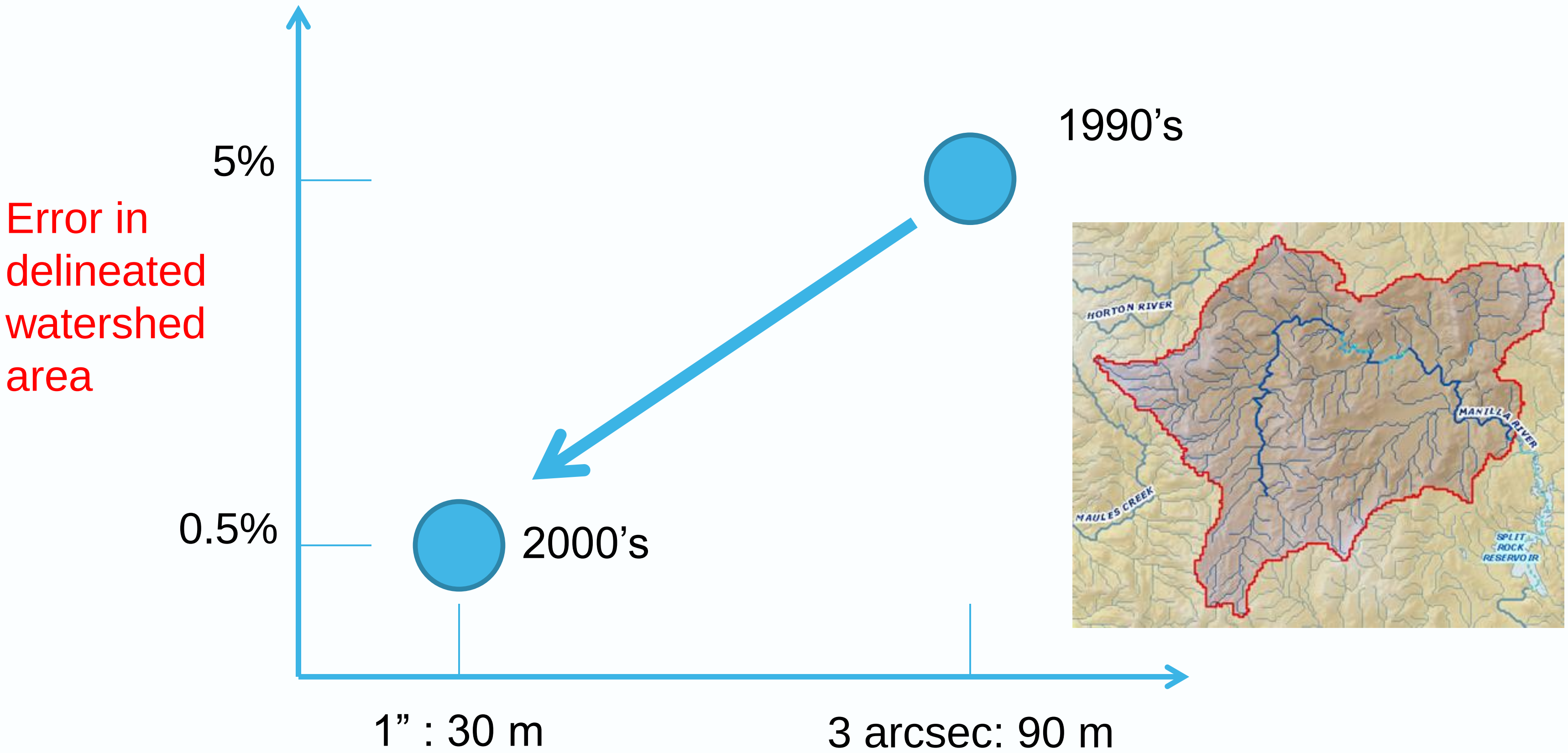


The spectrum of DEM products



9 second | SRTM 3 second | DEM-H 1 second | Lidar 5 m

Catchment delineation



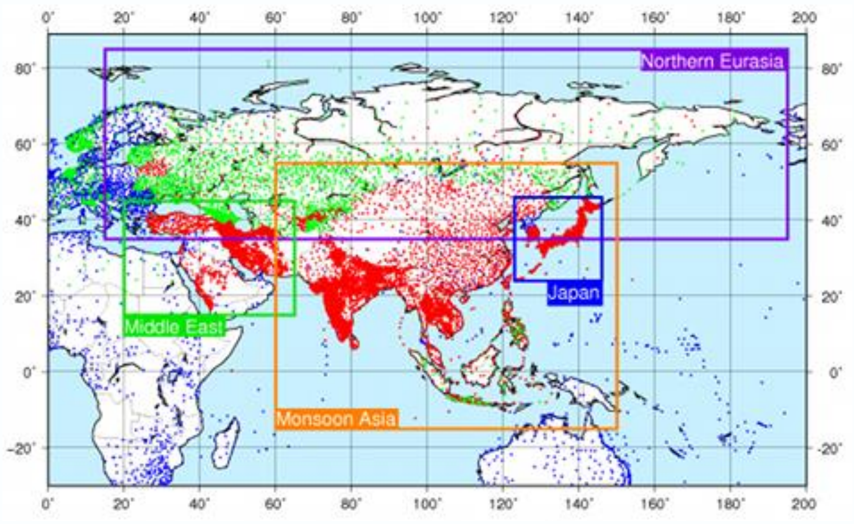
From: Maidment (2011)

DEM Cell Size

Climate data for South Asia

Climate variables

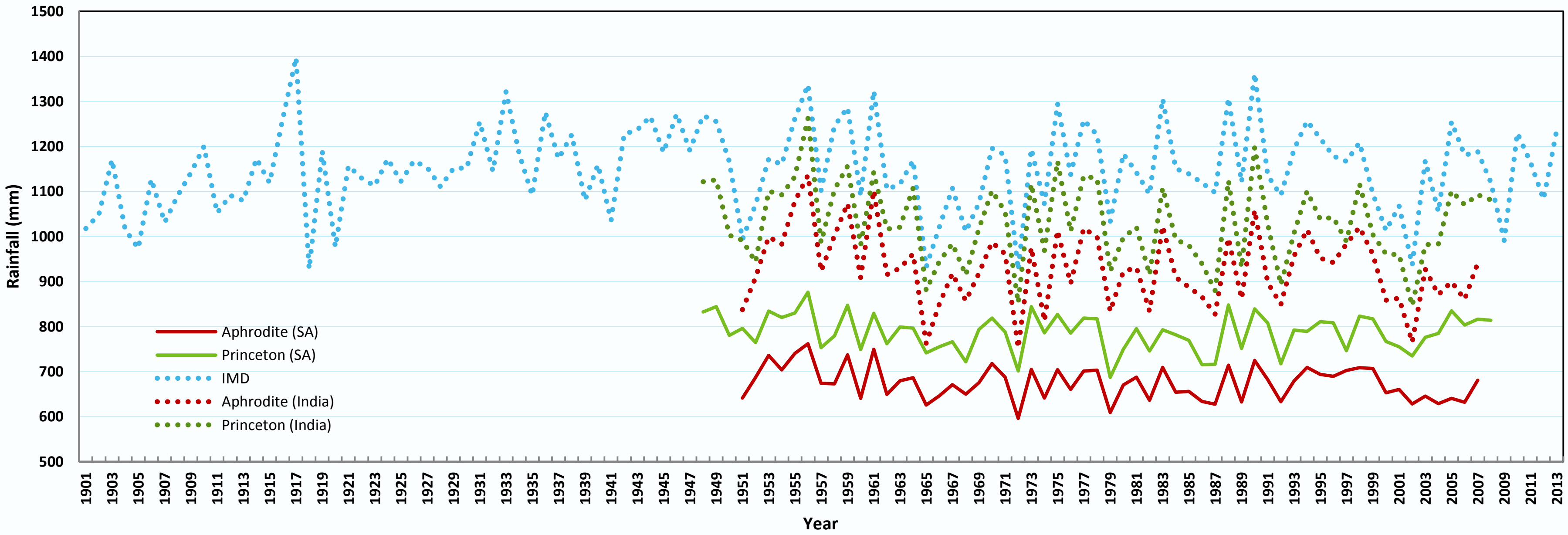
- Precipitation (rainfall, snow)
- Temperature
- Potential evaporation
- Humidity
- Solar radiation
- Wind speed/run

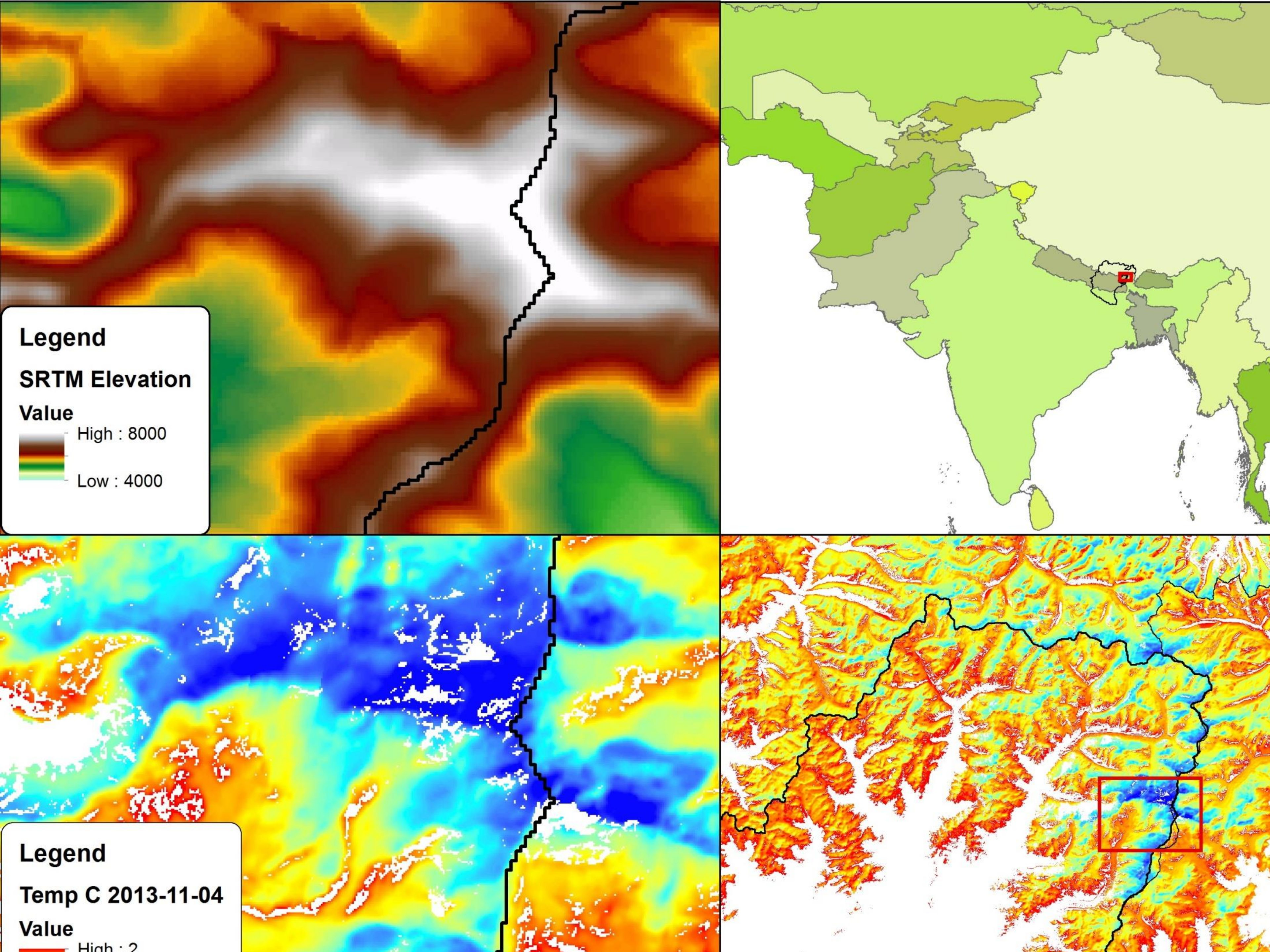


Data sources

- Local climate stations and local data products
- Aphrodite Asian precipitation data base
  - 0.25° gridded daily rainfall data for Monsoon Asia
  - 1951–2007
  - http://www.chikyu.ac.jp/precip/products/index.html
- IMD Indian precipitation data base
  - 0.25° gridded daily rainfall data for India
  - 1901–2010
  - http://www.imd.gov.in/doc/nccraindata.pdf
- Princeton global reanalyses climate data base
  - 0.5° gridded daily climate data
  - 1948–2008
  - http://hydrology.princeton.edu/data.pgf.php

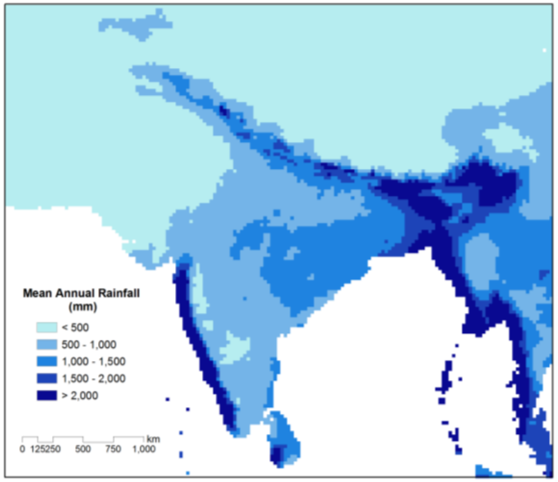
Comparison of annual precipitation series




Legend
SRTM Elevation
Value
High : 8000
Low : 4000
Legend
Temp C 2013-11-04
Value

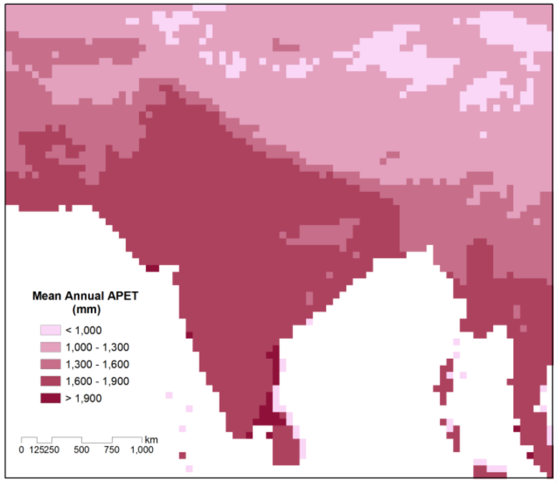
Precipitation, APET and runoff across South Asia

Mean annual
PRECIPITATION



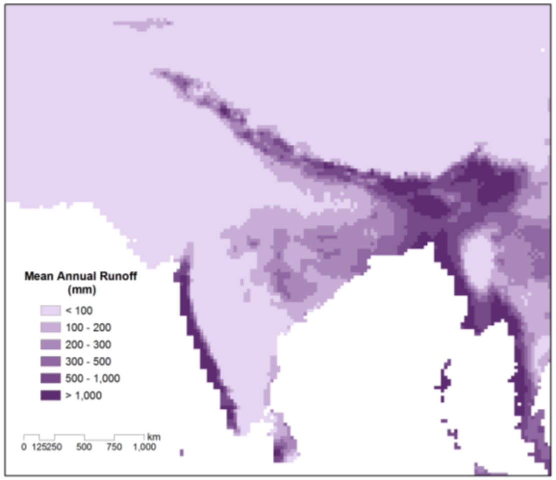
From Aphrodite database

Mean annual
AREAL POTENTIAL
EVAPORATRANSPIRATION



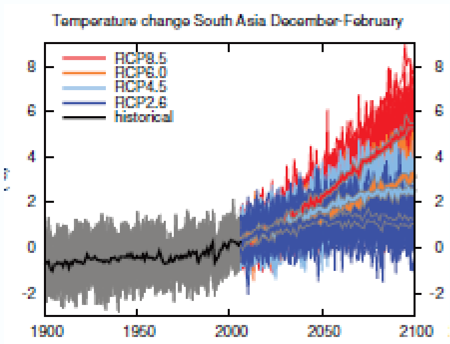
Estimated from Princeton climate data using Morton's E_w formulation

Mean annual
RUNOFF

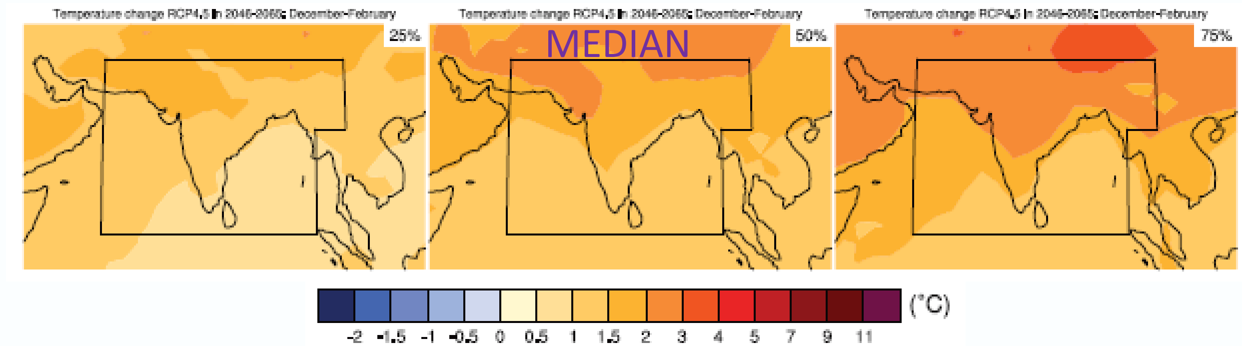


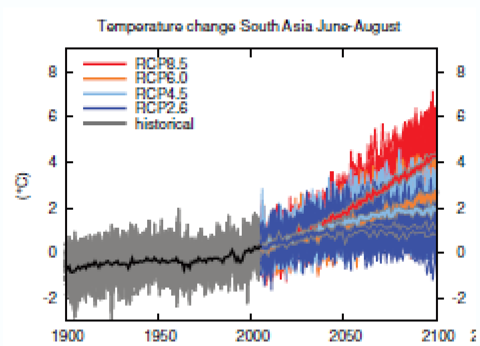
Estimated using Budyko relationship

IPCC AR5 future temperature projections for South Asia

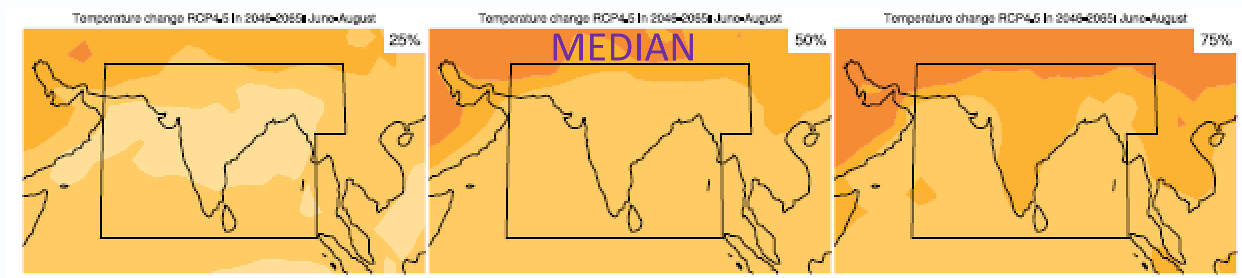


2046–2065 Dec–Feb temperature relative to 1986–2005 [RCP4.5]





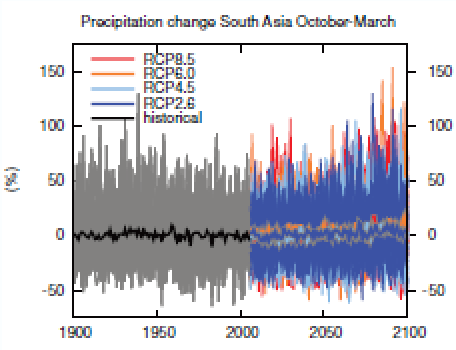
2046–2065 Jun–Aug temperature relative to 1986–2005 [RCP4.5]



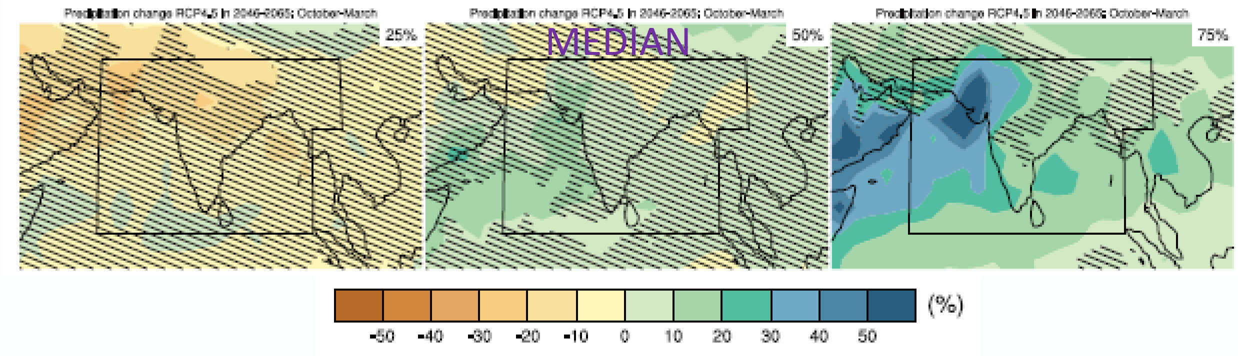
From IPCC AR5 “Atlas of global and regional climate projections”, http://www.climatechange2013.org/report/full-report/

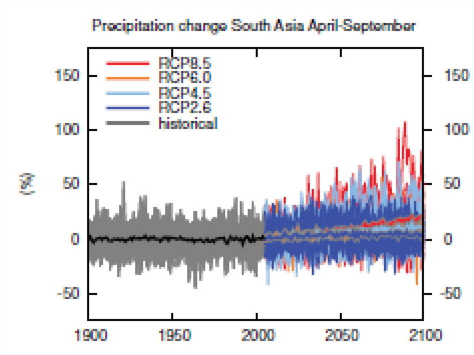
CMIP5 data portal, http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html

IPCC AR5 future precipitation projections for South Asia

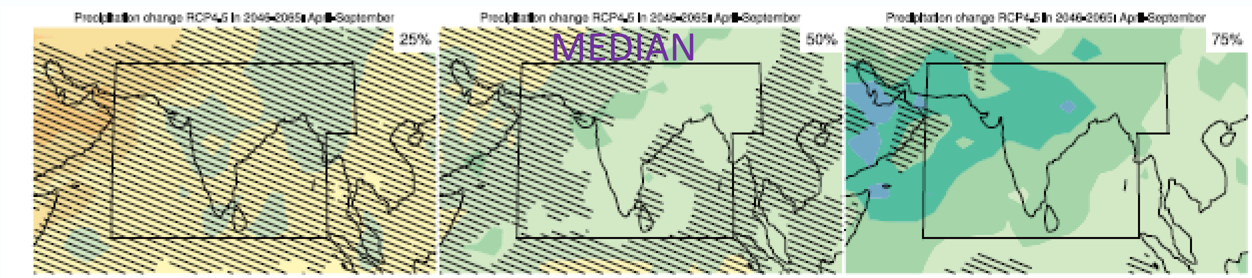


2046–2065 Oct–Mar precipitation relative to 1986–2005 [RCP4.5]





2046–2065 Apr–Sep precipitation relative to 1986–2005 [RCP4.5]



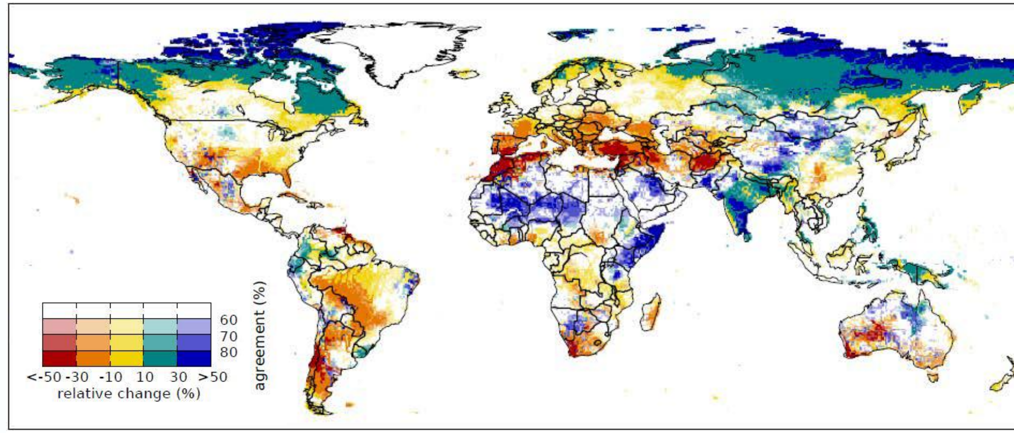
From IPCC AR5 "Atlas of global and regional climate projections", http://www.climatechange2013.org/report/full-report/

CMIP5 data portal, http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html

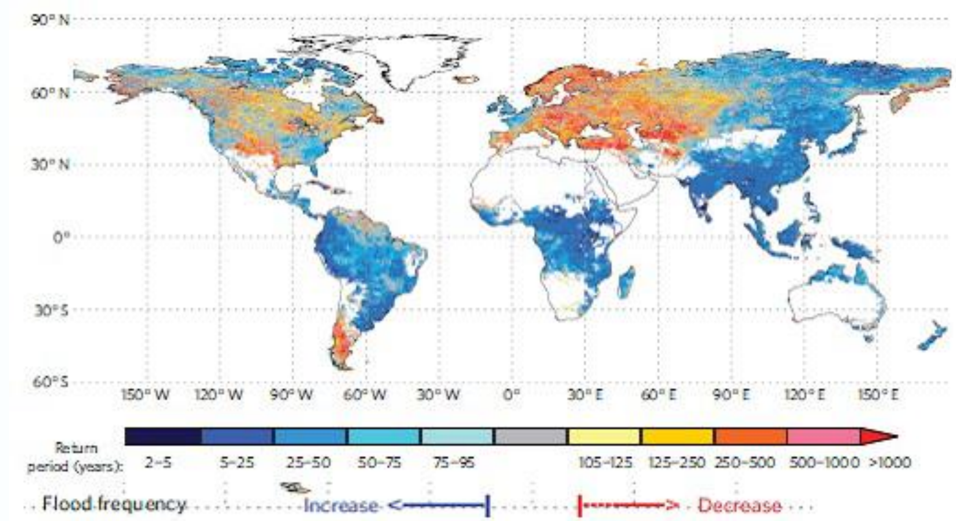
Climate change impact on water

- Changed water availability
- Enhanced variability and reduced water security:
  - longer droughts
  - more precipitation falling as rain rather than snow
  - retreat of glaciers
  - increased seasonality of flow
- Enhanced flood risk

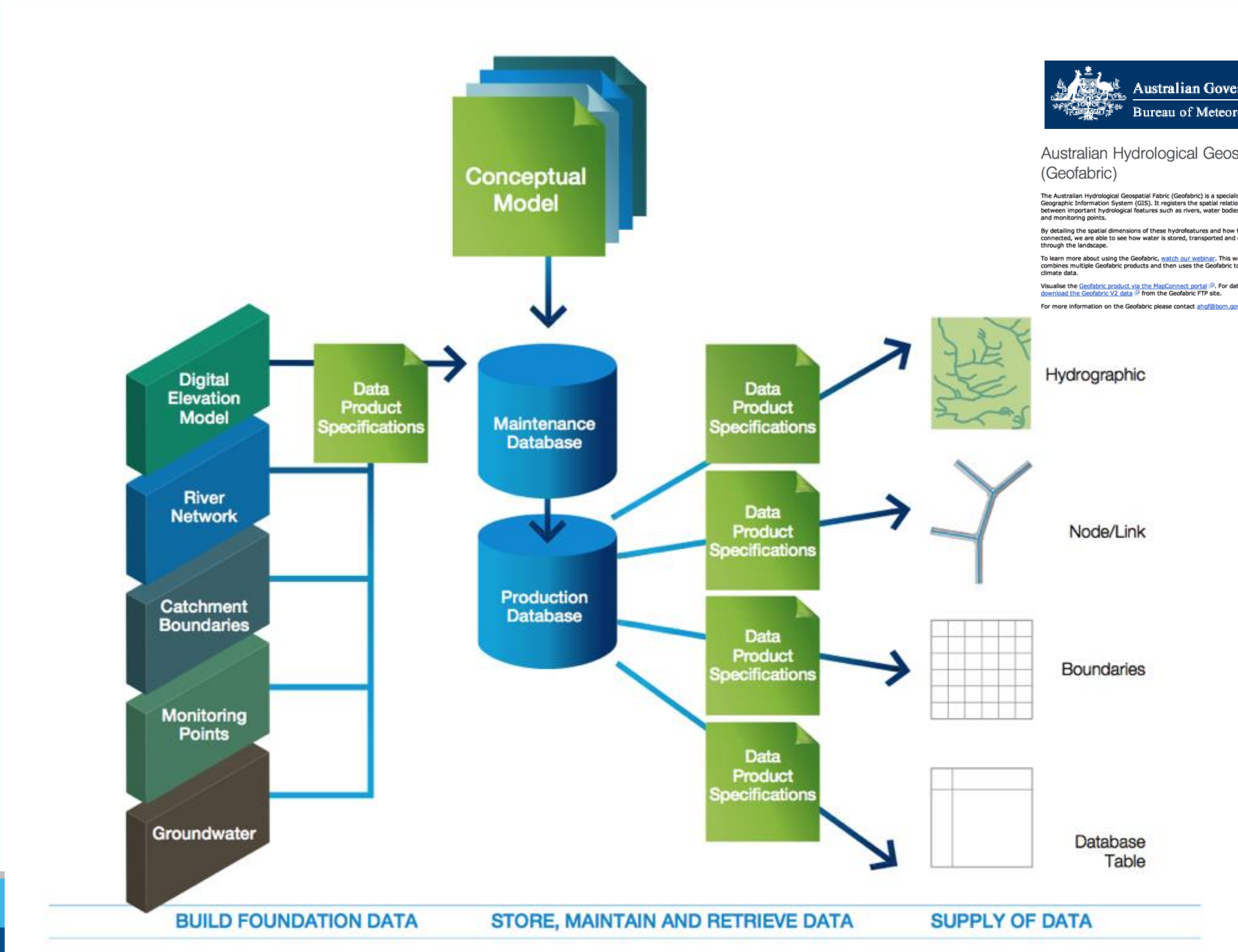
Change in mean annual runoff for 2°C warming



2080 flood frequency for 20th century 100-year flood



Water Resource Information Systems: Geofabric



Australian Government
Bureau of Meteorology

Australian Hydrological Geospatial Fabric (Geofabric)

The Australian Hydrological Geospatial Fabric (Geofabric) is a specialised Geographic Information System (GIS). It registers the spatial relationships between important hydrological features such as rivers, water bodies, aquifers and monitoring points.

By detailing the spatial dimensions of these hydrofeatures and how they are connected, we are able to see how water is stored, transported and used through the landscape.

To learn more about using the Geofabric, watch our webinar. This webinar combines multiple Geofabric products and then uses the Geofabric to analyse climate data.

Visualise the Geofabric product via the MapConnect portal. For data only, download the Geofabric V2 data from the Geofabric FTP site.

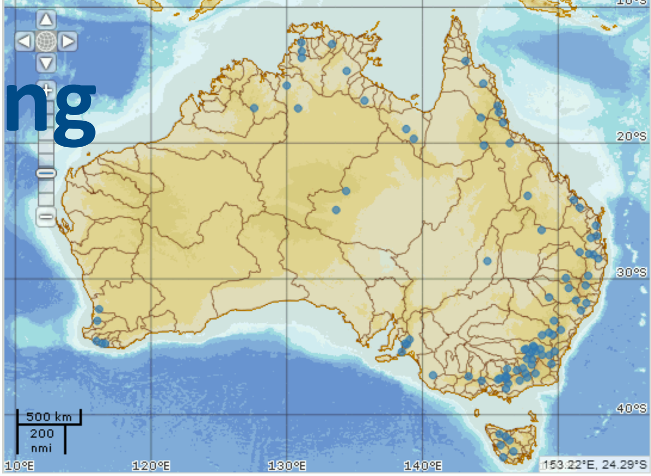
For more information on the Geofabric please contact ahgf@bom.gov.au

Geofabric

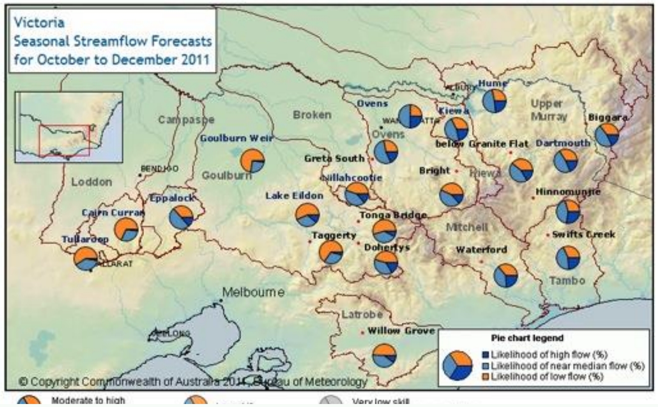
- About Geofabric
- Downloads
- Documentation
- Drainage Divisions and River Regions
- Glossary
- Partnerships
- User feedback

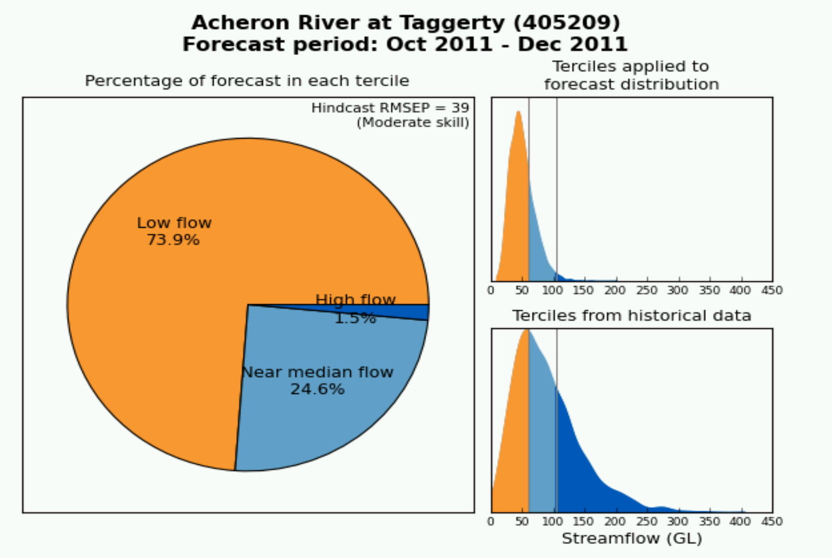
CSIRO

Seasonal streamflow forecasting



- 3 month probabilistic outlook of unregulated total streamflow volumes
- Ensemble forecasts at 74 sites in 32 river basins
- Uses CSIRO developed statistical model (BJP)
- Further testing on sites in all states and territories
- Extend to 200 sites by the mid 2015
- www.bom.gov.au/water/ssf





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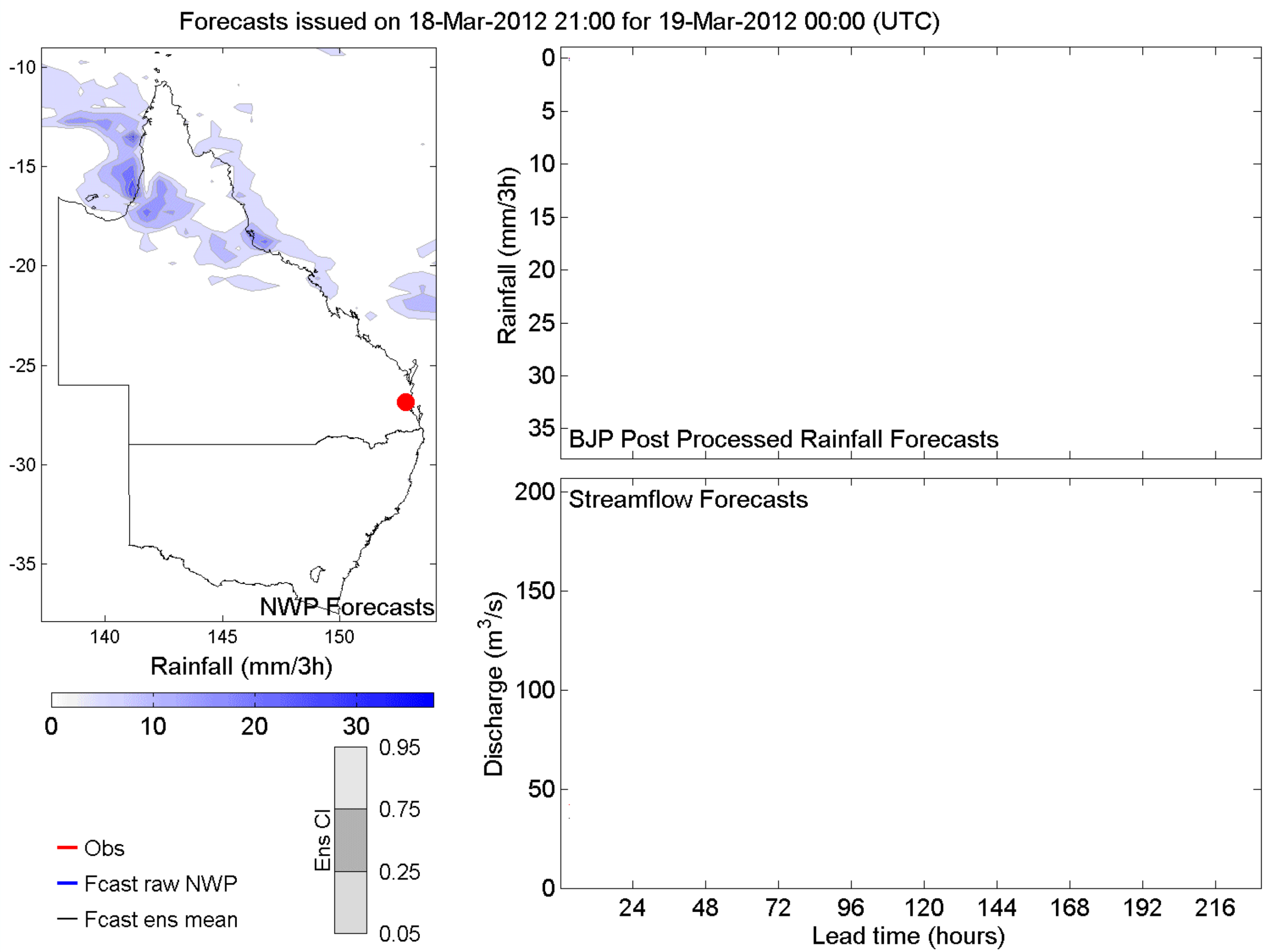
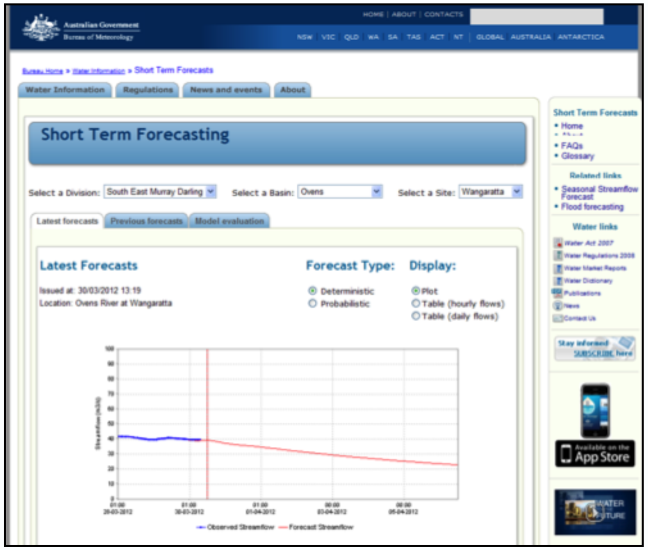
Flood & short-term forecasting

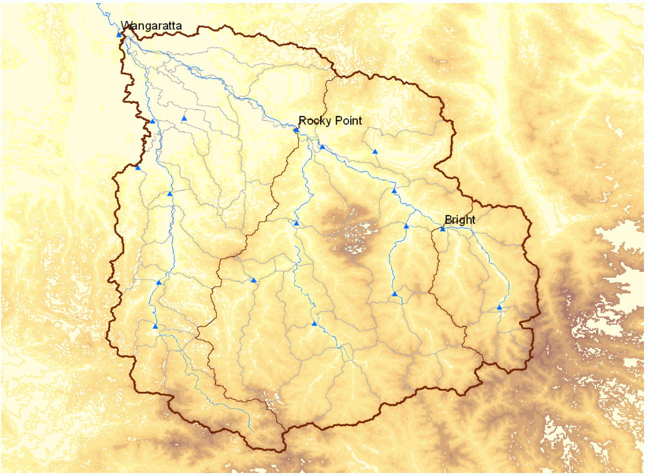


Ensemble forecast of a flood event in the Stanley River

Short term streamflow forecasting

- Flow forecasts up to 10 days ahead
- Unregulated inflows to regulated systems
- Includes rainfall forecasts
- R&D conducted through CSIRO
- Ovens River pilot for registered users





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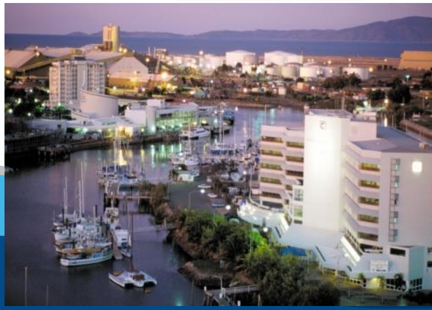
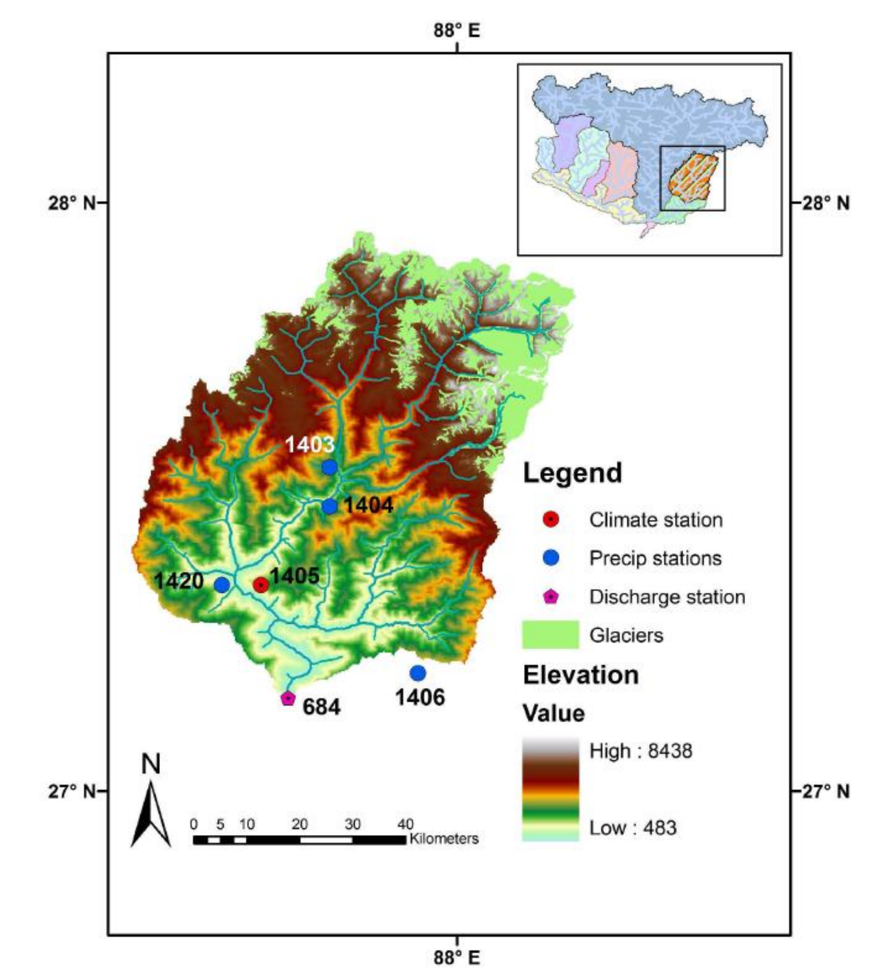
CSIRO

Flexible hydrological modelling frameworks



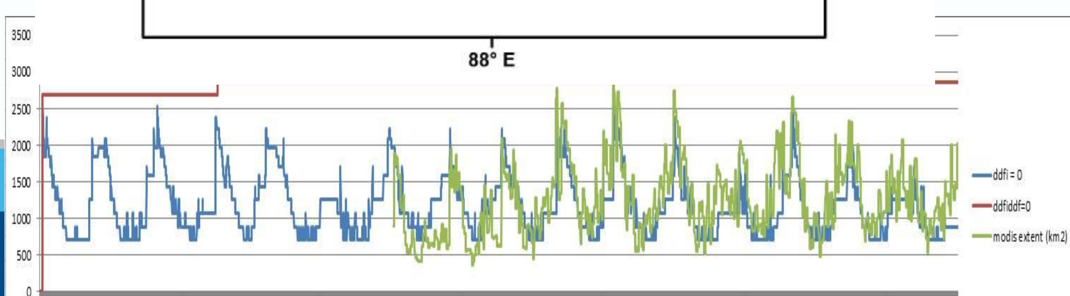
Tamor daily rainfall runoff model

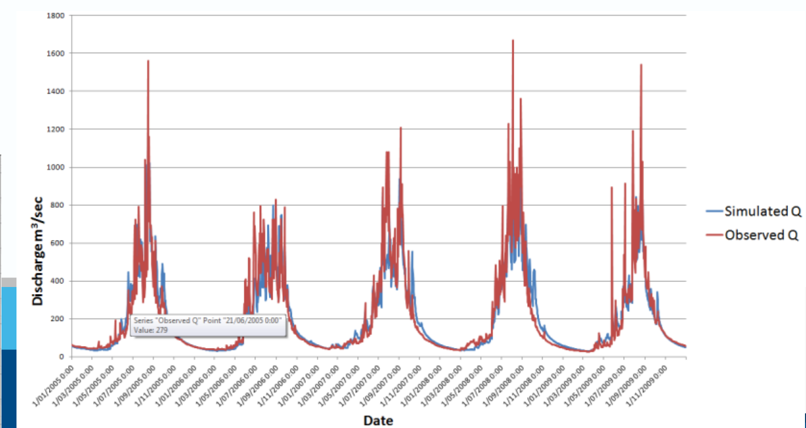


- Area: 4058 km^2
- Elevation: 422 – 8505 m
- Glacier area: 13%

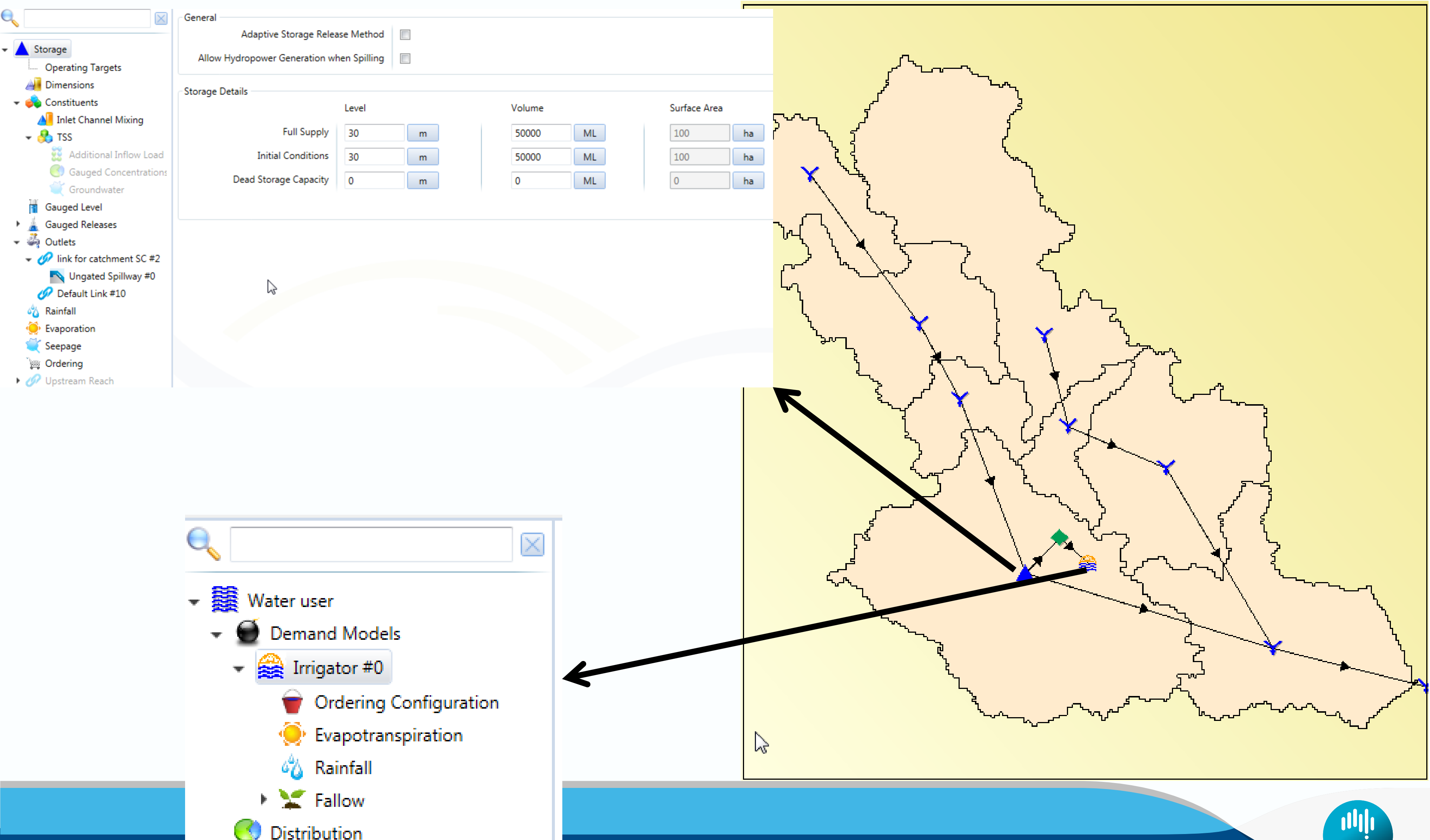
Rainfall runoff model

- GR4J+snow+glacier
- 7 parameters
- 44 HRUs
- Bias 2% NSE 0.87



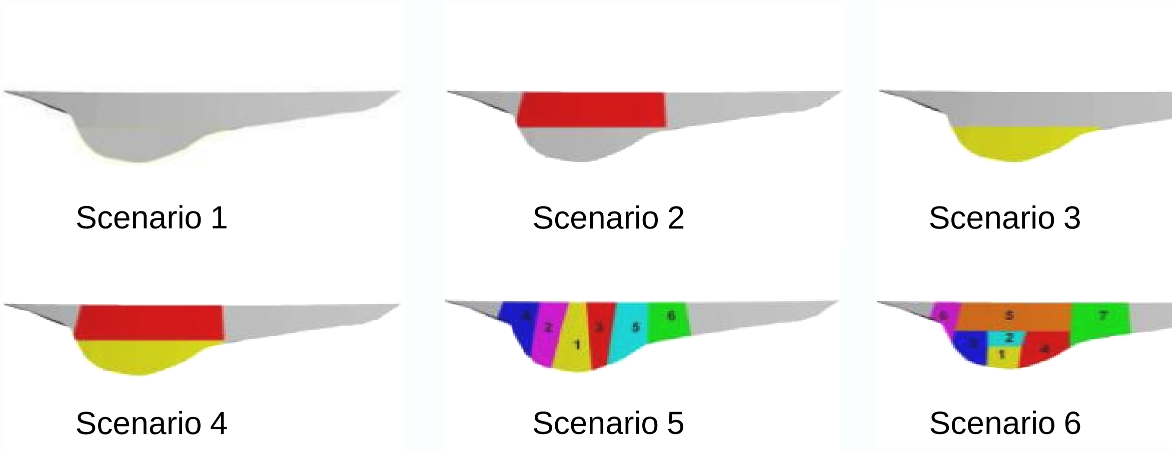


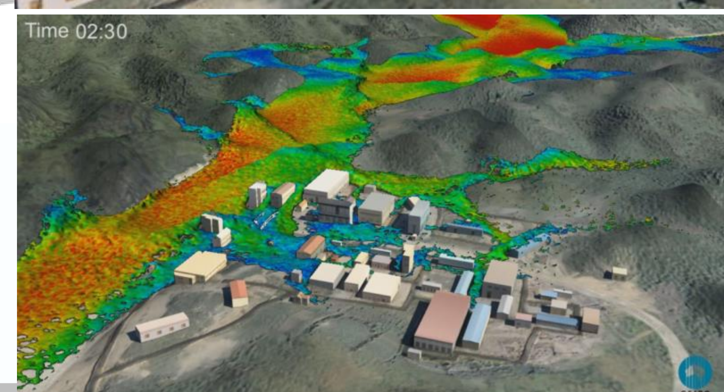
Brahmani-Baitarani river model



Dam break modelling

- CSIRO 2 and 3d hydrodynamic models
- Geheyan Dam in China
- Different dam break scenarios

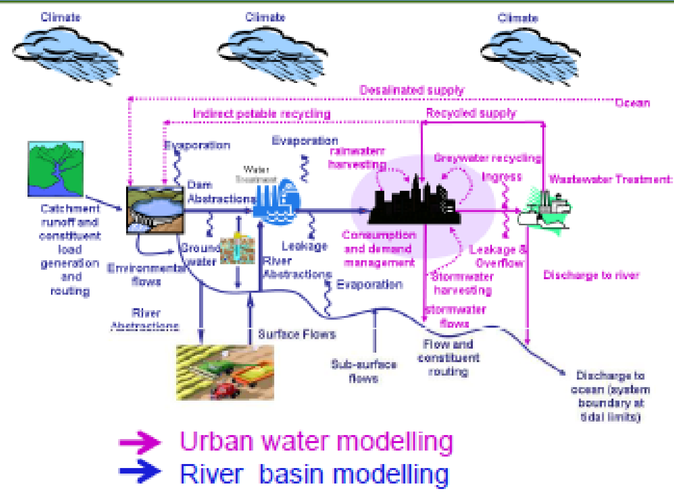




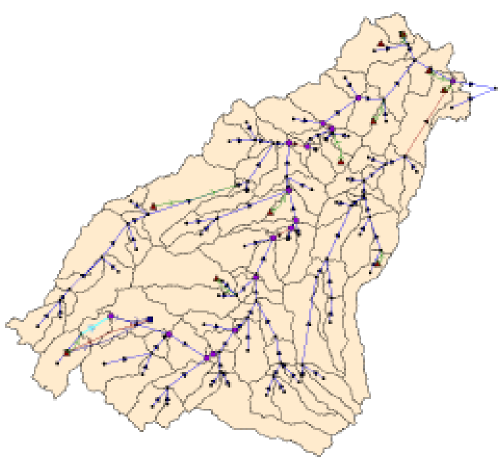
Urban water management

Simulation of urban water systems from supply catchments to receiving waters, as a sub-set of a river basin

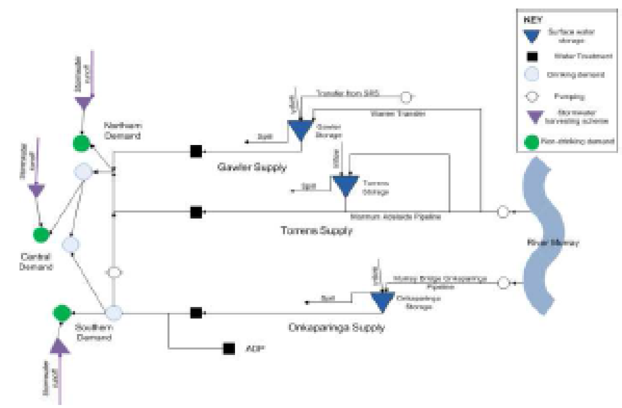
Water quality: Total nitrogen discharge to Moreton Bay for different water management options



Coupling with multi-objective optimisation/MCA to identify optimal mix of sources in Adelaide



eWater Source



Key paper: Moglia M, Perez P, Burn S (2010) Modelling an Urban Water System on the Edge of Chaos, Environmental Modelling and Software 25(12), pp.1528-2538

CSIRO

Irrigation modelling

Farm scale bio-physical models (e.g. APSIM) consider:

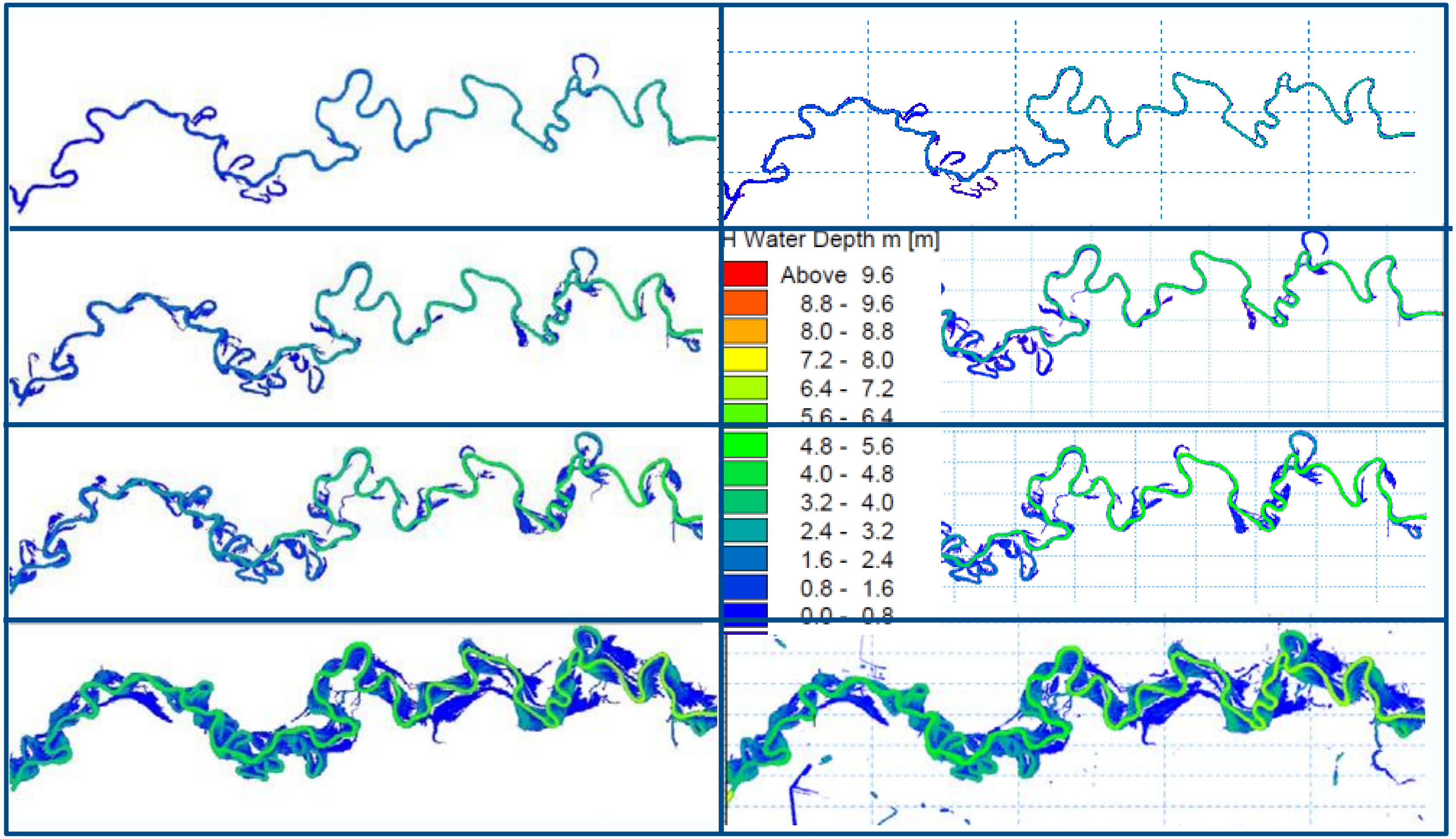
- Physical properties of different crops over growing period
- Soil type
- Water and heat stress
- Irrigation efficiency
- Fertiliser application
- Yield and production

Regional scale crop models (e.g. Source) consider:

- Supply storages both regional and local
- Water access rules
- Multiple water sources (surface and groundwater)
- Distribution and return systems (irrigation districts)
- FAO 56 crop factors to drive current use and future demands
- Losses (channel, escapes, deep percolation)
- Crude yield and production estimates

Floodplain modelling hydrologic vs 2d hydrodynamic

a) Simulated inundation by LiDAR based approach   b) Simulated inundation by 2D HD model

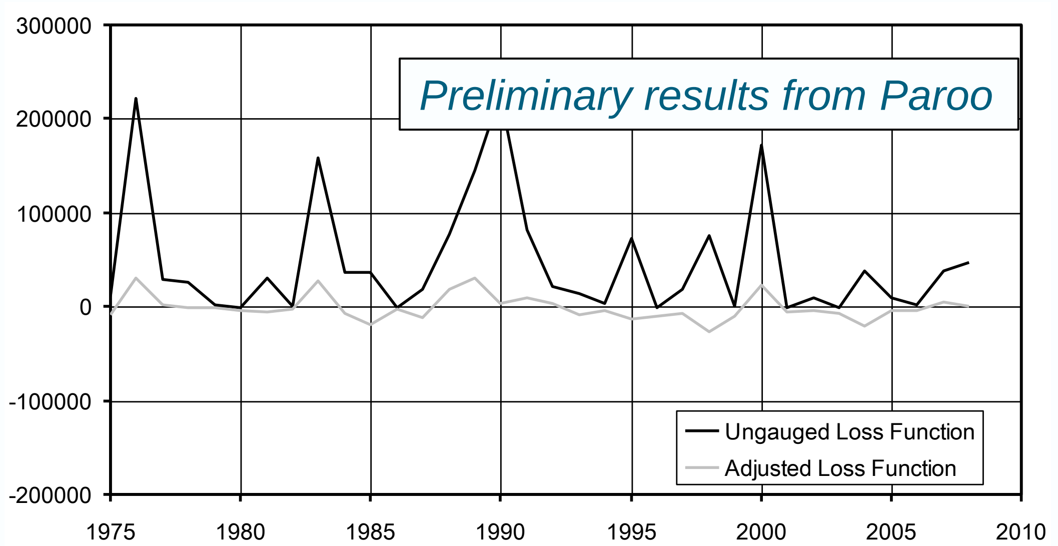


22 month event   55 day event

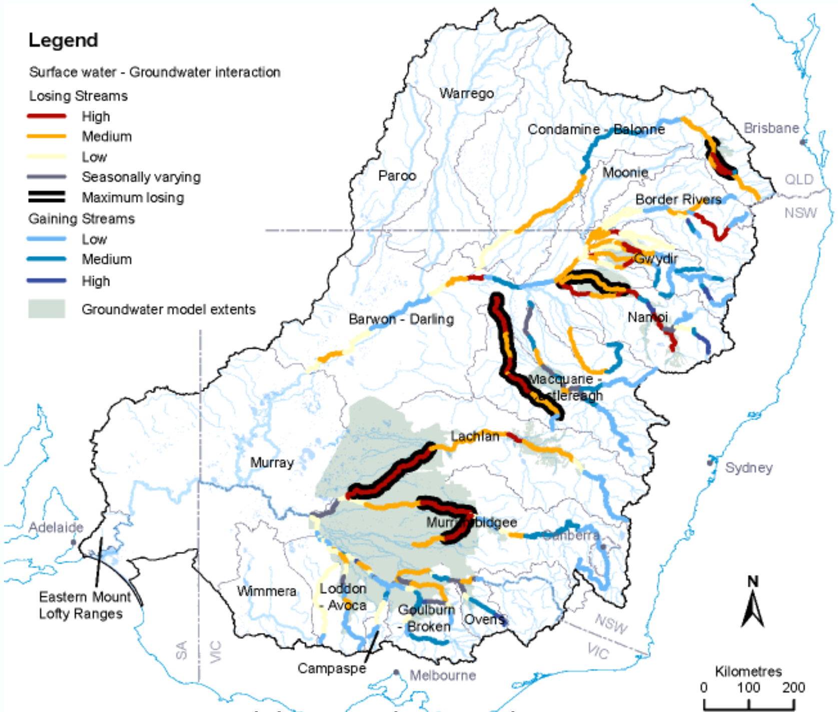
10 minute run time   10 day run time

SW-GW interaction

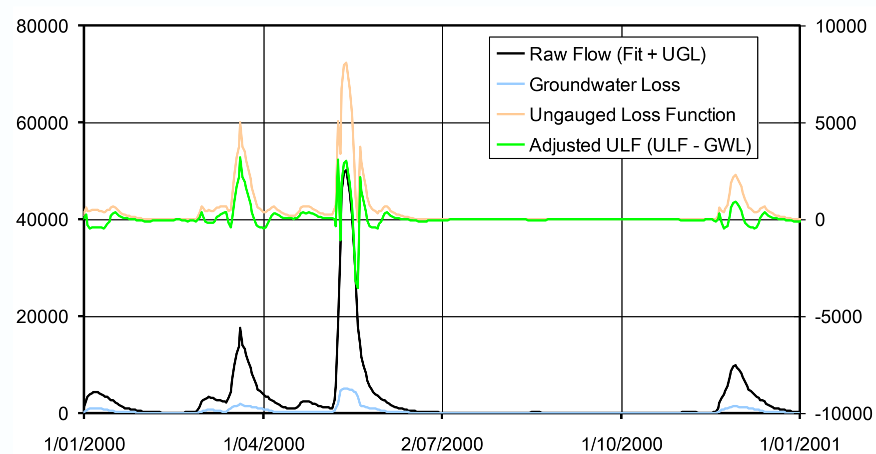
- Establishing relationships in losing and gaining streams
- Validating the relationships
- Integrating with the river system model



Revised annualised Ungauged Losses and Adjusted Losses (ML): Willara to Wanaaring. (Positive values are losses, negative values are gains)

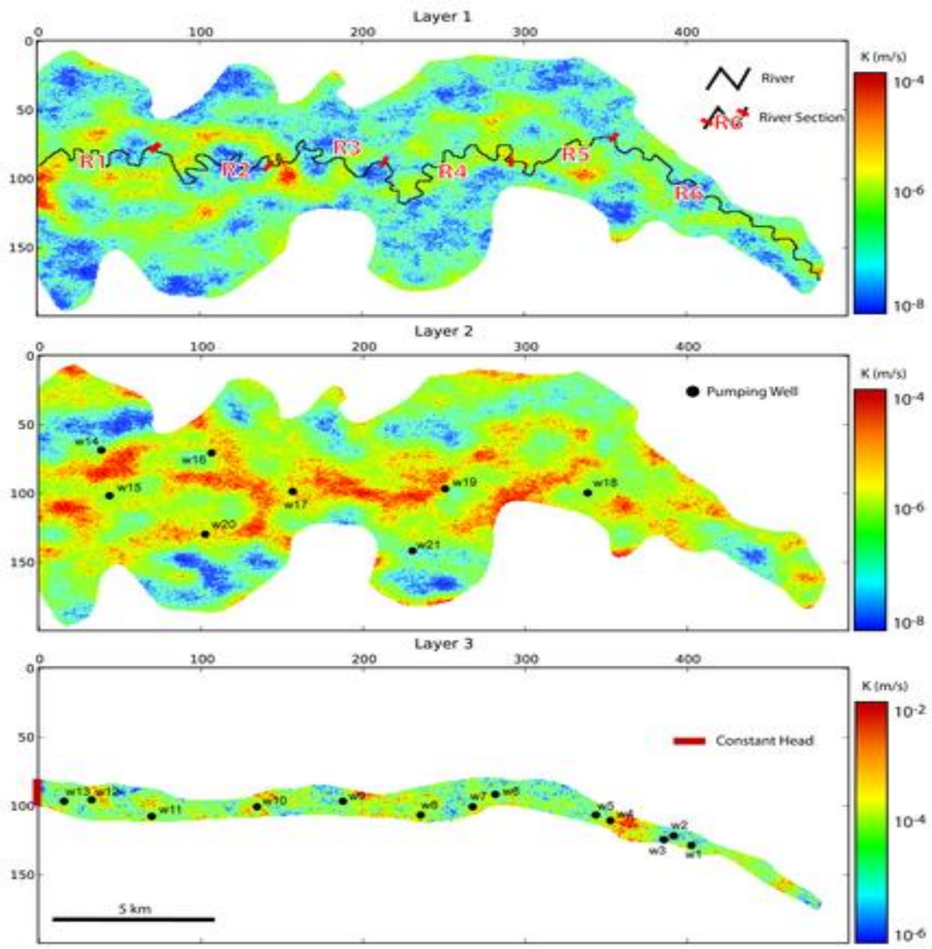


SW-GW connectivity map (MDBSY)



Revised daily flow components for the year 2000 (ML/d), Willara to Wanaaring. River flow and GW loss are on left-axis, loss/gain functions on the right-axis.

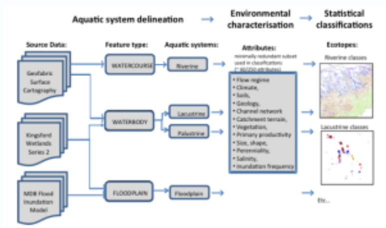
Physically based groundwater models



Ecological Systems: Environmental Flow Modelling

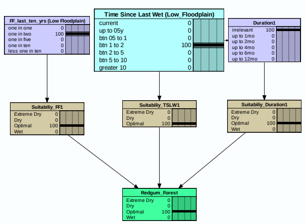
Understanding Ecosystem Complexity

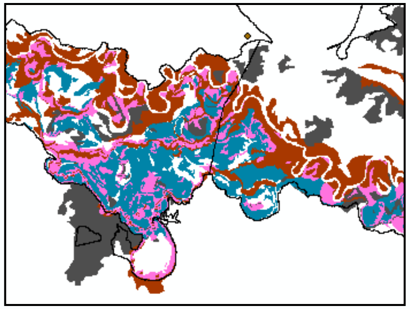
- Species, habitats and refugia



Predicting Ecological Outcomes

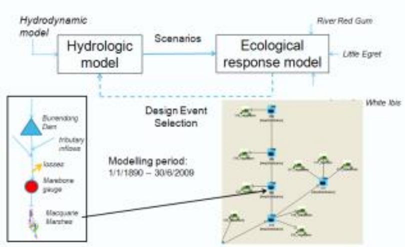
- Ecological Response Models
- Driver-Pressure-Stressor-Impact-Response

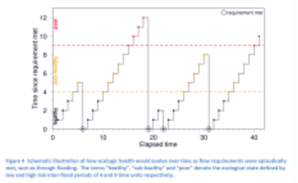




Integration: Models & Assessment

- Scenario-based tools
- Optimisation-based tools





Environmental Flows: Why? What?

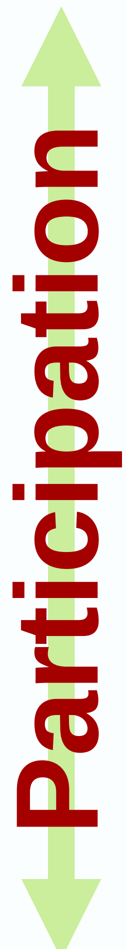
Impacts of….? Vulnerability of ecosystems to….?

- River Regulation?
- Climate Change?
- Hydropower?
- Land cover change?

What to consider in Basin planning?

- *Ecosystem Services*
  - Water Quality
  - Ecosystem function
  - Fish for food
  - Tourism / Recreation
  - Habitat
  - Cultural values
- *Conservation*
  - System assets
  - Biodiversity
  - Threatened species, Ramsar sites

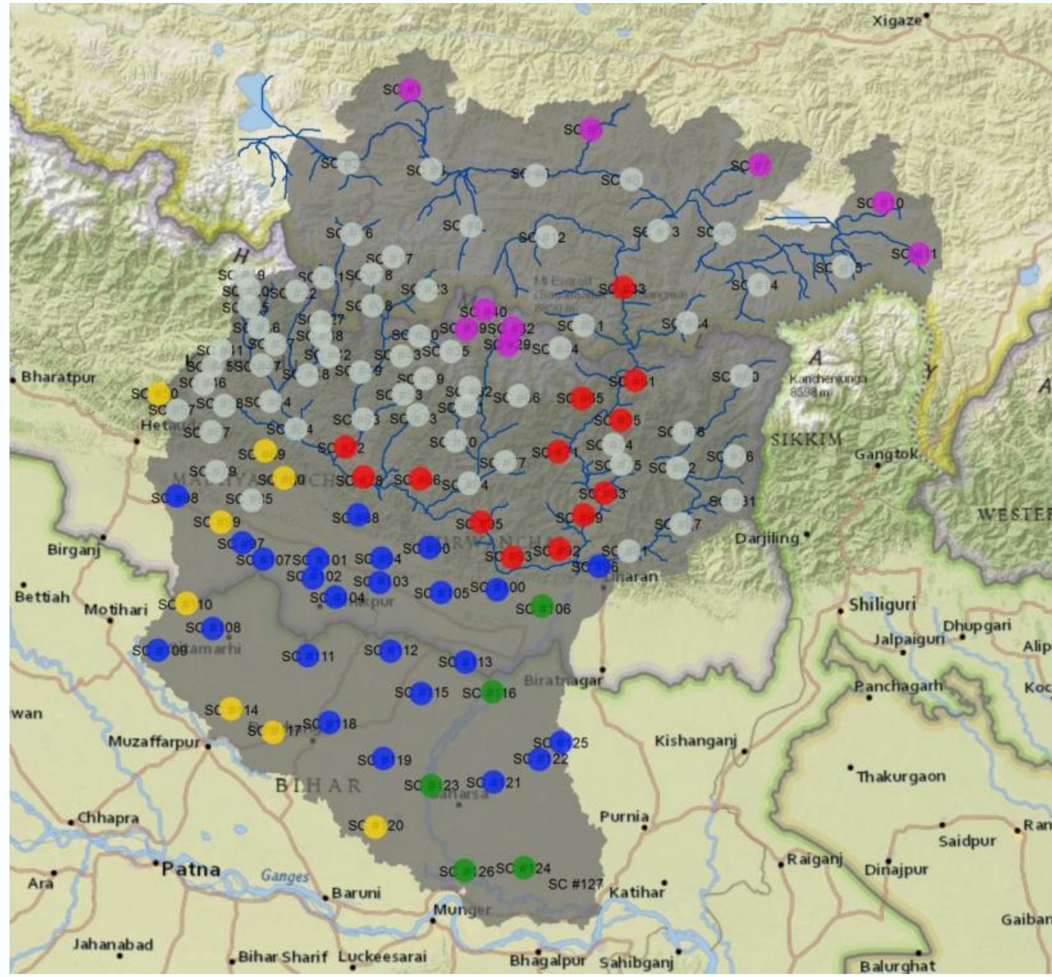
Predicting Ecological Outcomes: Models that are 'Fit for Purpose'

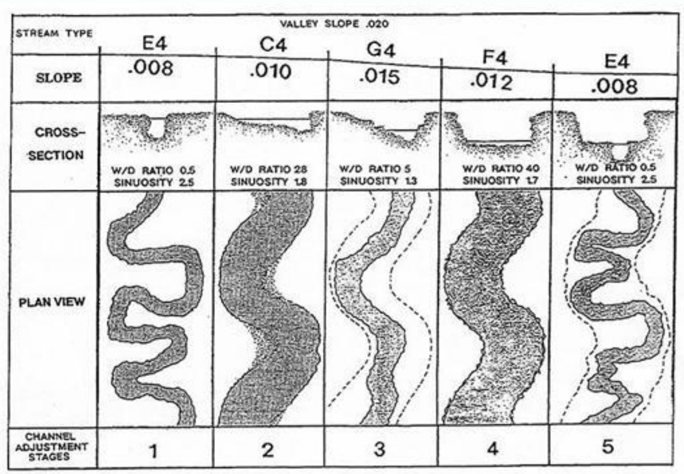


No Data, High uncertainty	Conceptual, Hydrologic Alteration
Some Data, Some Knowledge	Expert system, Habitat models, Uncertainty analysis
Lots of Data, Good Knowledge	Population dynamics, Function dynamics
Data complete, System well defined	Dynamic ecosystem models

Prioritisation of Effort: A Data Poor Basin

- Defining Ecosystem Classes:
  - Which classes are predicted to change hydrologically (dam development, climate change?)
  - What are the essential services, functions and assets by class?
  - Classes for extrapolation
  - Assessment: Uniqueness, Vulnerability to change





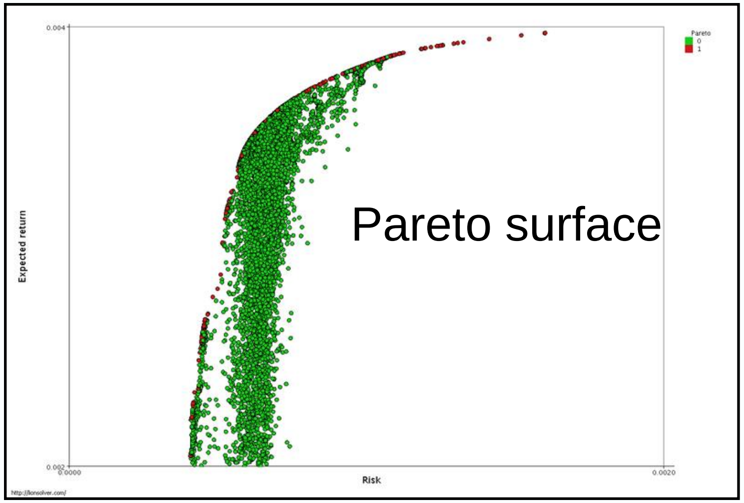
Economic modelling

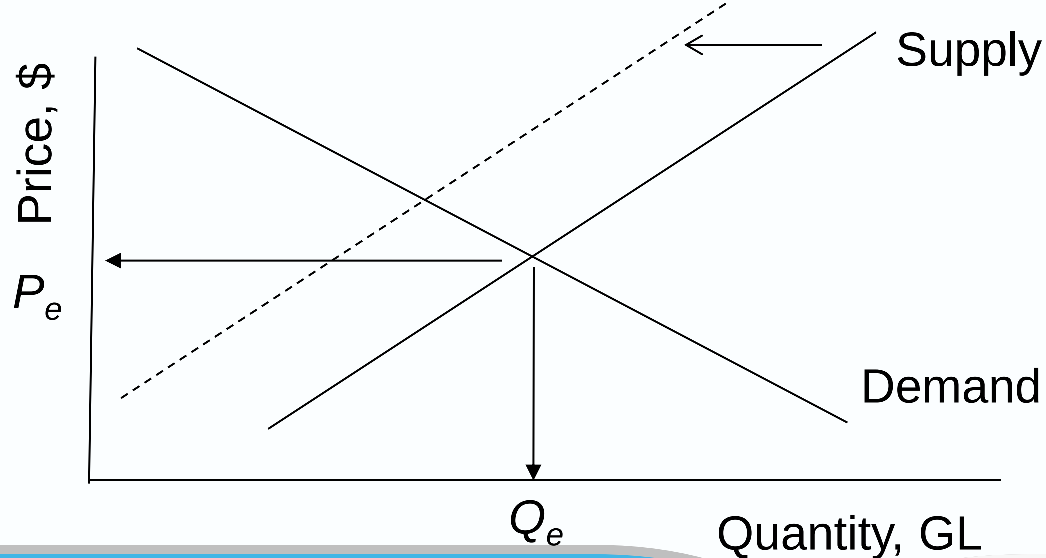
Local scale (farm, hydro station)

Regional scale (irrigation districts, countercyclical trade)

National scale (computable general equilibrium)

Trans-boundary scale (trade between countries)





Workflows to integrate and run models

Many different workflow tools are available

Allow different models, data sources and outputs to be connected together in a windows based interface.

Can connect different scale models

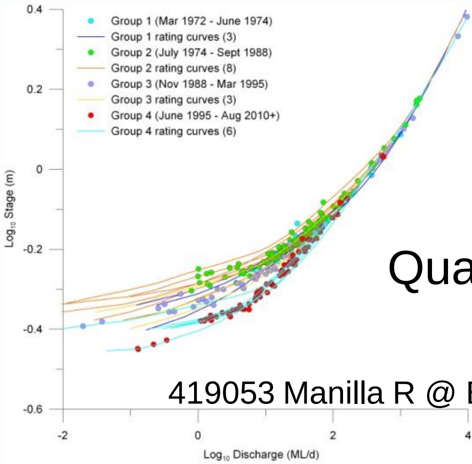
Can link hydrologic, environmental and economic models.

Can use HPC to run things many times on lots of computers.

Provides provenance so that you can reproduce results

Uncertainty and risk assessment

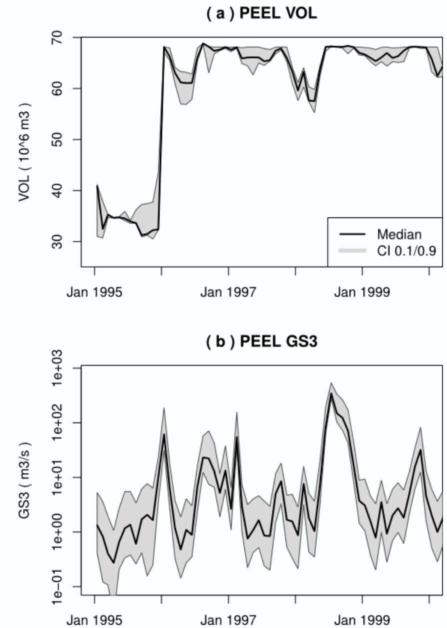
Quantifying rating uncertainty



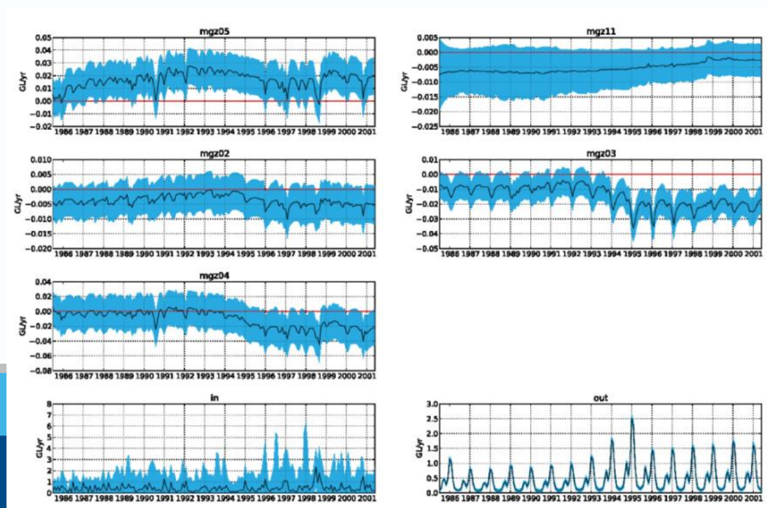
419053 Manilla R @ Black Springs

Quantifying rainfall uncertainty

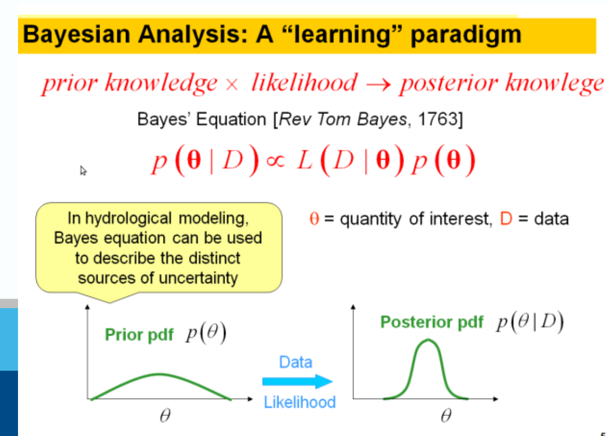
Quantifying river model uncertainty



Quantifying groundwater model uncertainty



BATEA Uncertainty analysis

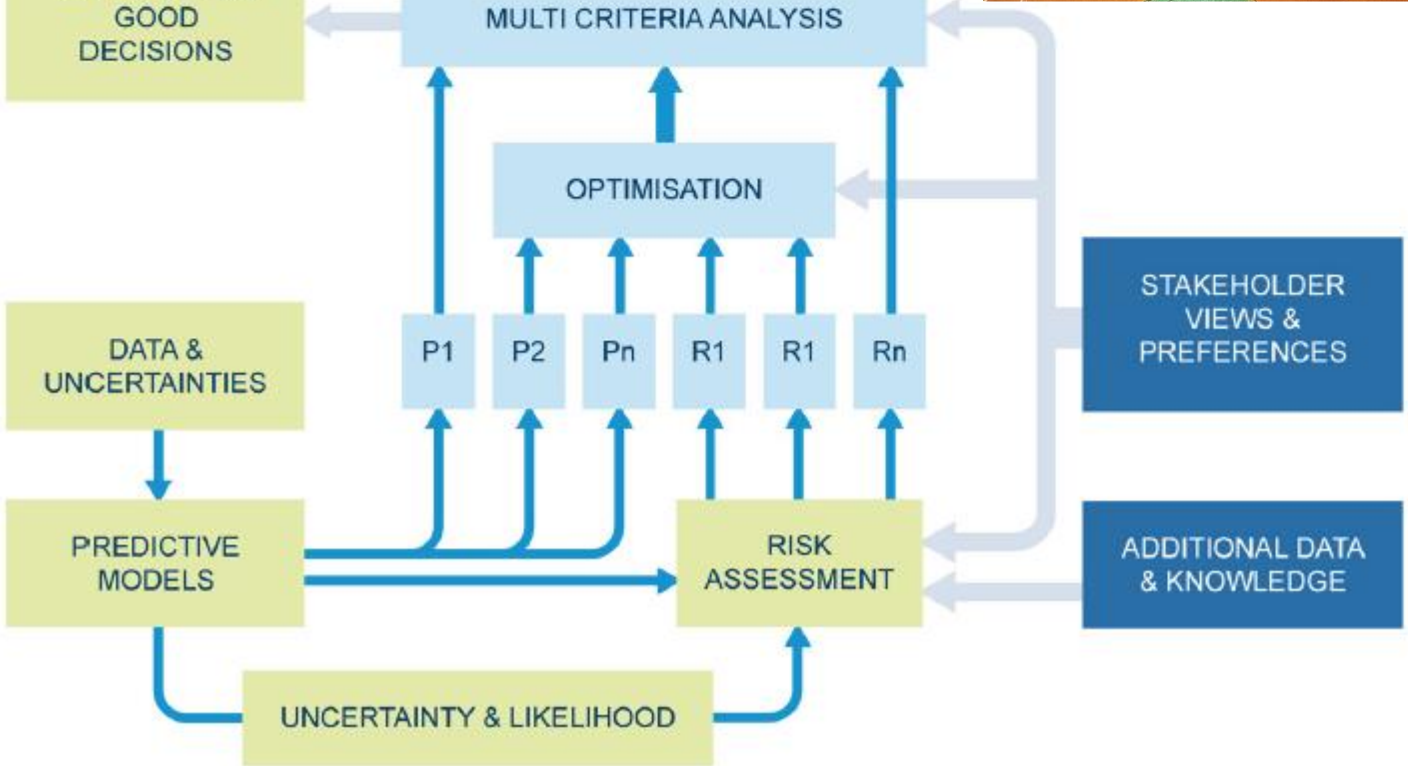


Decision Support

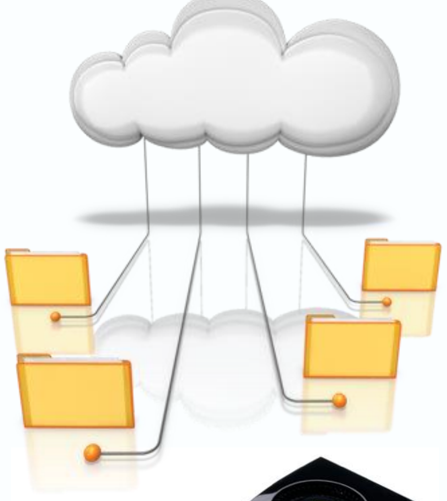
KEY:

P = Performance

R = Risk



Emerging Technologies

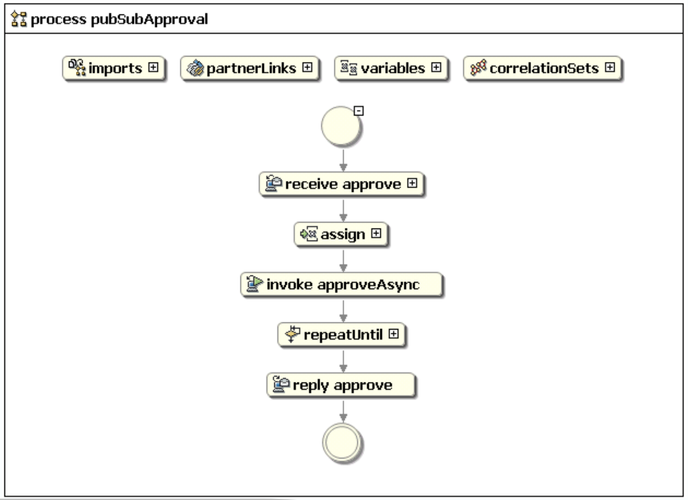


The cloud

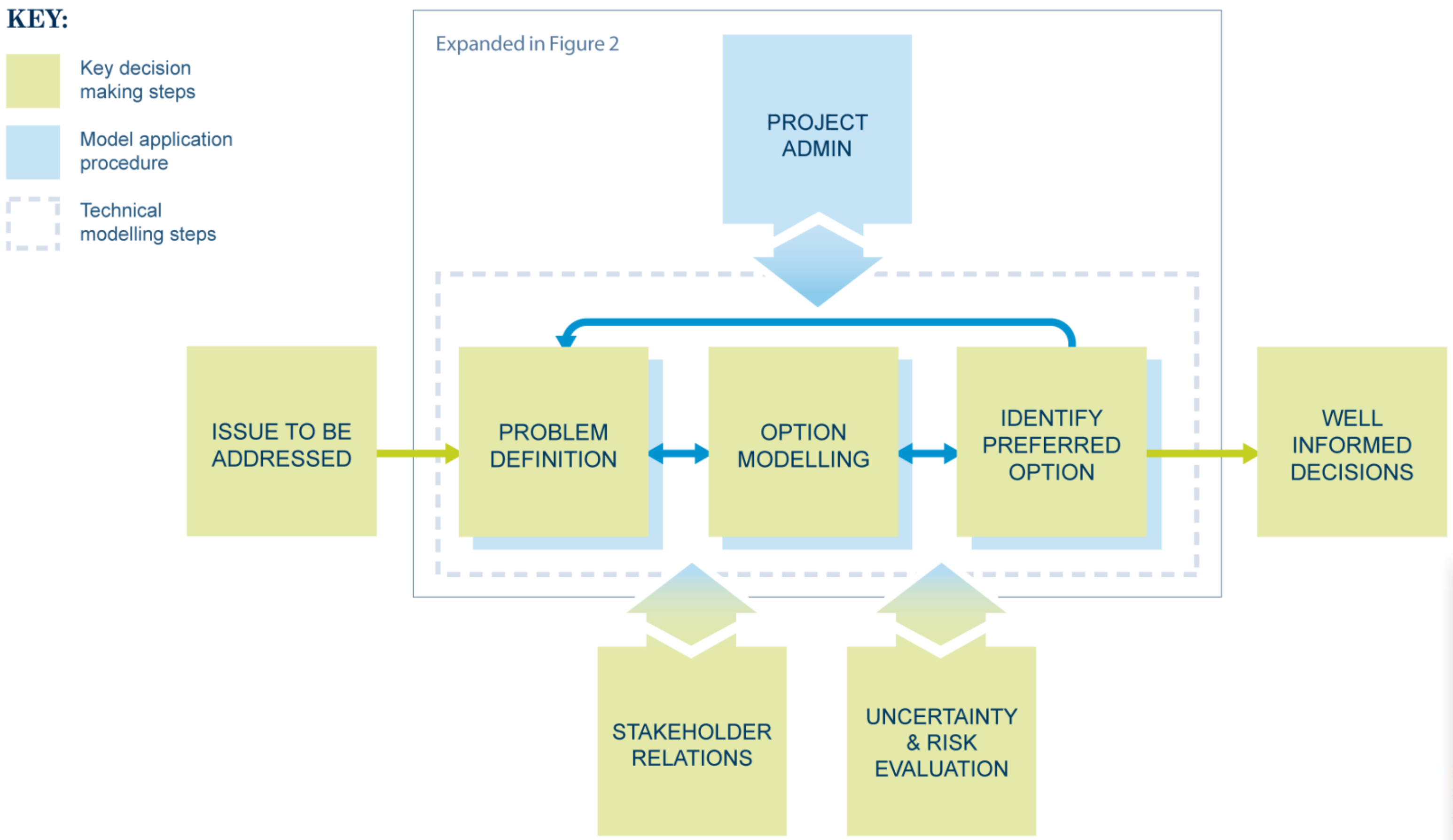
- Running models as a service
- Running workflows as a service

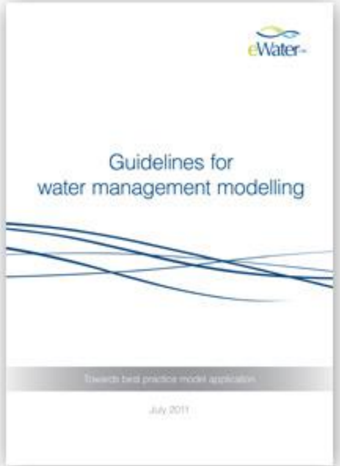
Semantic web, linked open data

- Common data formats (e.g. WaterML2.0)
- Linking models to data and parameters via the web
- Making results publicly available in a standard form



Best practice modelling framework





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Thank you