Modelling and Decision Support for Integrated Climate Change Impact and Vulnerability Assessment

Tony Jakeman, Carmel Pollino & Serena Chen

iCAM, The Fenner School of Environment and Society
The Australian National University

The talk by parts

1. Scenarios for the Region and challenges
2. Adaptation, risk and vulnerability frameworks
   - essence of the frameworks for the Mekong
3. The role of modelling versus tools
   - different types of integrated modelling: strengths and weaknesses
4. The role of decision support systems
5. Some examples
6. Lessons and key messages

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Current Climate 'Change'

- Observed past & present trends in SE Asia
  - 0.1 to 0.3°C increase per decade (1951-2000)
  - Decline in number of rainy days (1961-1998)
  - Increase in hot days & warm nights (1961-1998)
  - Decrease in cold days & nights (1961-1998)
  - Increased occurrence of extreme rains (e.g. floods in Vietnam & Cambodia in 2000)
  - Droughts associated with ENSO years
- Glaciers in Tibetan Plateau (Mekong source) melting faster in recent years

(Cruz et al., 2007)

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Projected Climate Change

- By end of 21st Century:
- Max monthly flow (compared with 1961-1990 levels)
  - Increase 35-41 % in Basin
  - Increase 16-19% in Delta
- Min monthly flow
  - Decline by 17-24 % in Basin
  - Decline by 26-29 % in Delta
- Increased flooding risks during wet season
- Increased water shortage in dry season
- 40 cm sea level rise (conservative scenario)

(Cruz et al., 2007)

Examples of possible impacts of projected CC

Possible changes:

- Flooding
- Sea level rise
- Marine saline intrusion
- Glacial melt
- Heat stress
- Decreased flows in dry season
- Warmer sea surface temperature
- Increased frequency & intensity of tropical storms
- Changes to flow regime

(Cruz et al. 2007)

Examples of possible impacts of projected CC

- Impact on community
  - Flood residence of millions of people on coastal & riparian fringe
  - Damage to aquaculture industry & infrastructure
  - Loss of farm land
  - Climate-related diseases
  - Loss of income for those dependent on fisheries etc
  - Changes to crop yields
  - Drinking water supply
- Impact on natural resources
  - Water quality
  - Reduce recruitment of some species
  - Mangrove loss
  - Breeding & migration cycles/triggers of fish
  - Readjustments of floodplain veg
  - Weed species

(Penny 2006; Cruz et al. 2007)

Tonlé Sap - values

- **Largest freshwater lake in SE Asia**
- **Almost half Cambodia's pop benefit directly/indirectly from Lake's resources**
- **World's largest freshwater fishery**
- **Rich biodiversity**
  - Ecological hot spot – UNESCO biosphere
  - Floodplain – feeding, breeding, recruitment site
- **Fish migrations from lake → restock Mekong**
- **> 80% sediment received from Mekong stored in Lake & its floodplain**
- **Flow reversal**
  - Dry months – water flows out of Lake back into Mekong
  - Natural reservoir for Lower Mekong Basin
  - Flood protection
  - Assures dry season flow to Delta
  - Controls salinity intrusion

(Kummu et al., 2006)

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Tonlé Sap – current threats

- Overexploitation of fisheries & wildlife resources
- Deforestation
- Agricultural expansion
- Industrial & urban pollution
- Upstream dams
- Habitat fragmentation
- Introduction of non-native species
- Mining

(ADB, 2004)



Vietnamese Mekong Delta

- **Values**
  - 3.9 mill ha of Delta in Vietnam (of 6 mill ha total)
  - 14 mill people living in VMD
  - In 2000 – rice production 78 % land use
- **Threats**
  - 60 % soils – acid sulphate & saline soils
  - Upstream abstractions
  - 1.7 mill ha by salt water intrusion
  - ~ 1 mill ha affected by tidal flooding
  - Sept – Oct prone to large flooding
    - ~30% VMD flooded at depths of 0.5-4.0m
    - Inundation can last 2-6 months
  - Droughts
  - Deforestation - <10 % forest cover
  - Agricultural expansion

(Wassmann et al. 2004; Penny 2006)

Ongoing changes/threats in the Mekong

- **Increasing economic development**
  - increased demand for water & energy
  - hydropower, irrigated agriculture, industry, inter-catchment diversions
- **Overexploitation & degradation of land & water resources**
  - Overfishing
  - Deforestation
  - Pollution
  - Poor farming practices
- **Floods, droughts**
- **Population growth**

(MRC 2005; ADB 2004)

CC Challenges in the Mekong

- **Ongoing changes:**
  - Socio-economic change
  - Environmental change
  - Land use change
  - Technological advancement
- **Interactive effects of CC & other anthropogenic stressors**
- **Dependency of millions of people on natural resources**
- **Poverty – major barrier to developing capacity to cope & adapt**
- **Insufficient knowledge on:**
  - Impacts of CC
  - Responses of natural systems
- **Limited biophysical & socio-economic data**
- **Large natural climate variability**

(Cruz et al. 2007)

Part 2: A short list of frameworks

- IPCC Technical Guidelines
- ICLIPS (Potsdam)
- UKCIP (UK Climate Impacts Programme)
- UNDP-GEF Adaptation Policy Framework
- Risk assessment/management frameworks
  - generic – e.g. AS/NZS 4360 Risk Management,
  - for climate change – e.g. Jones 2001

IPCC Technical Guidelines

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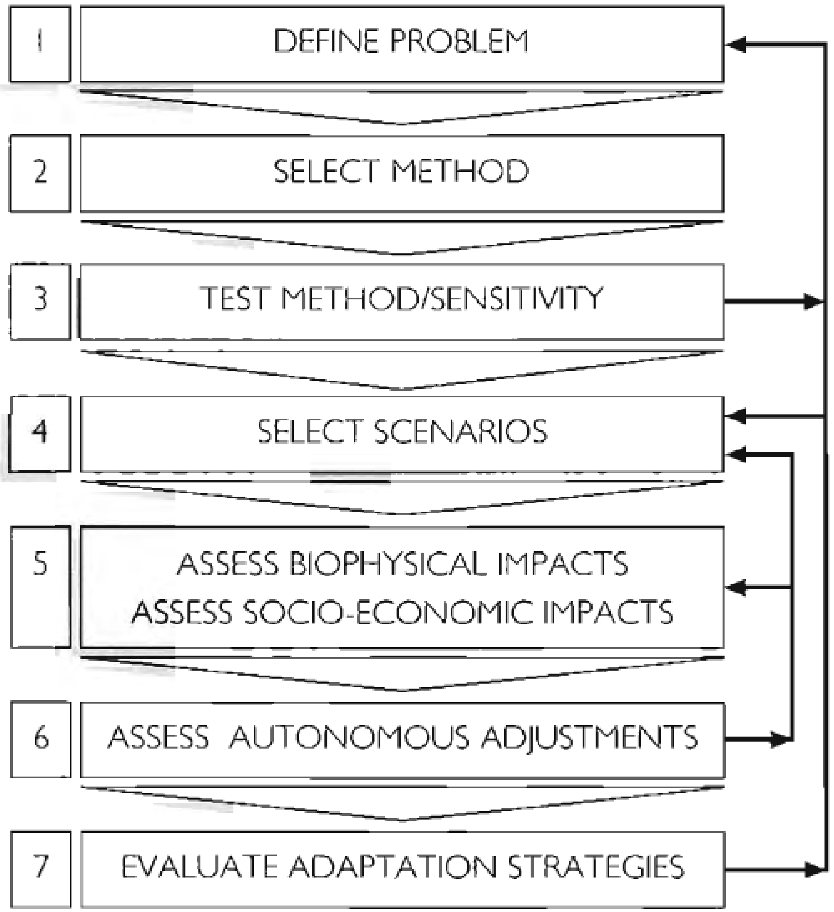
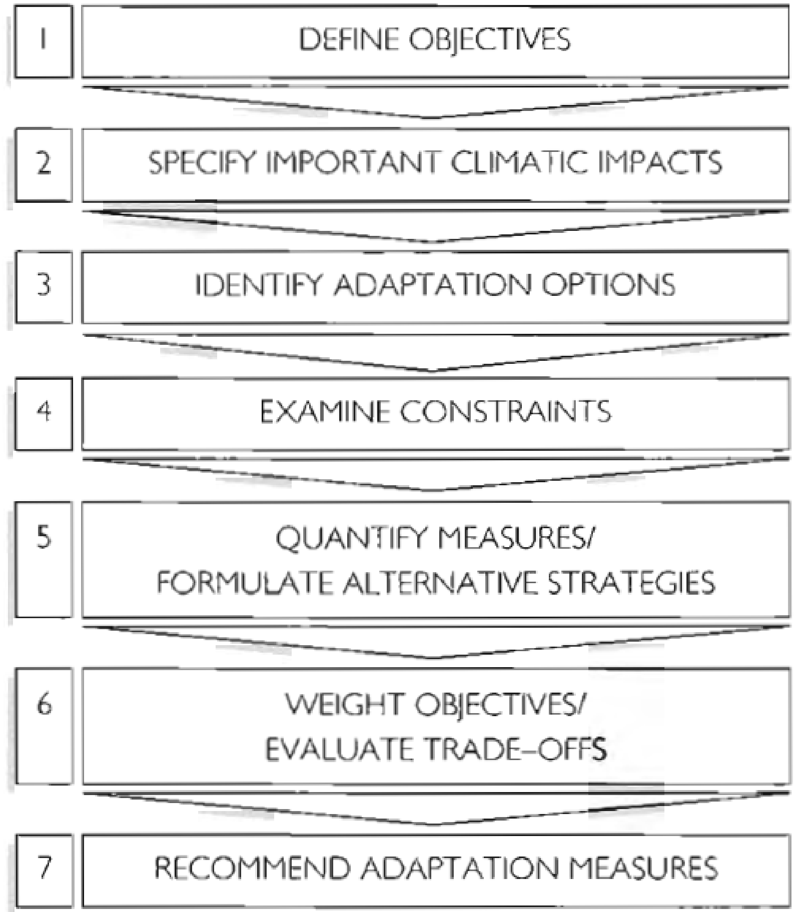
7-step Framework for Assessment

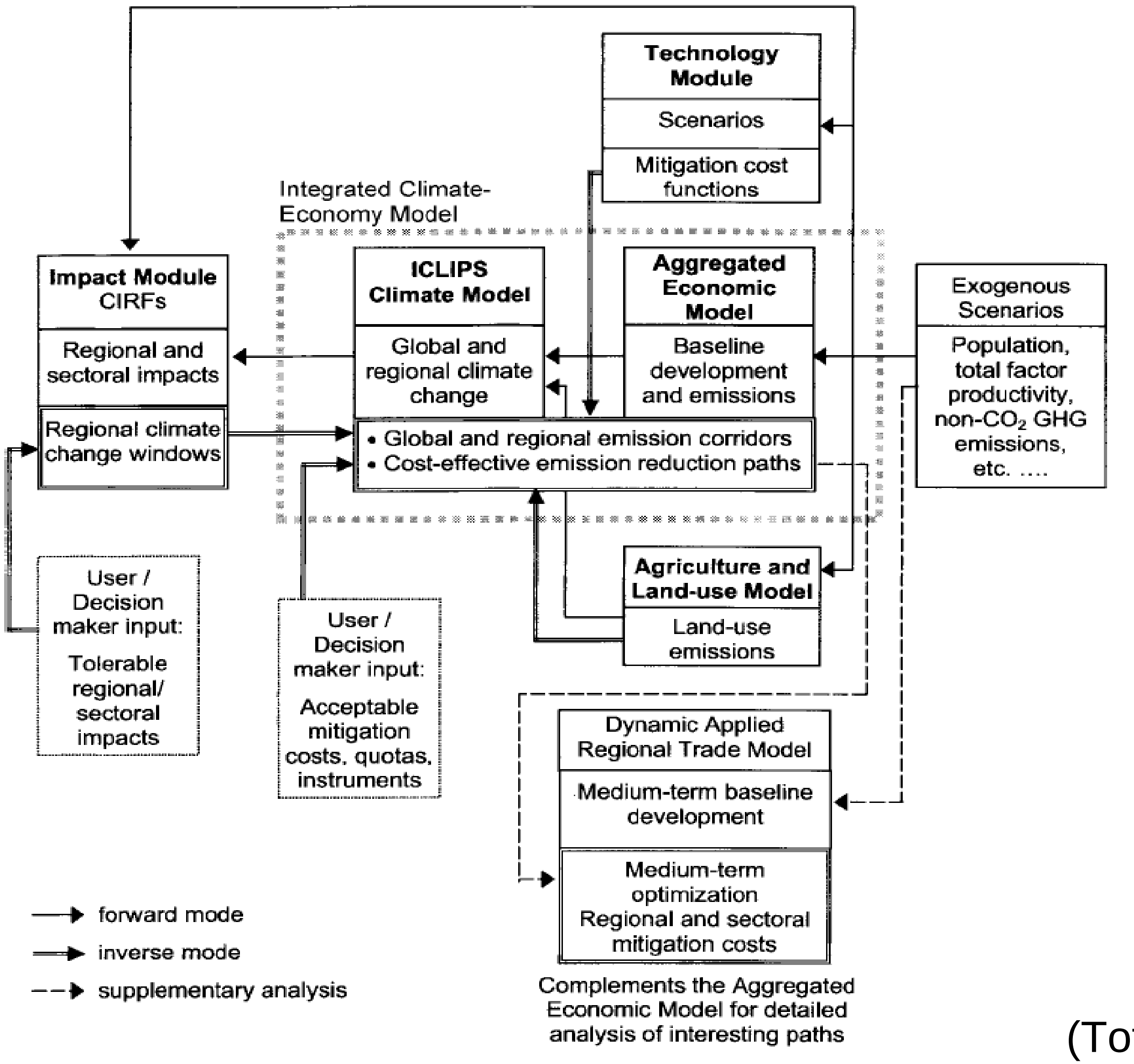


Evaluation of Adaptation Strategy



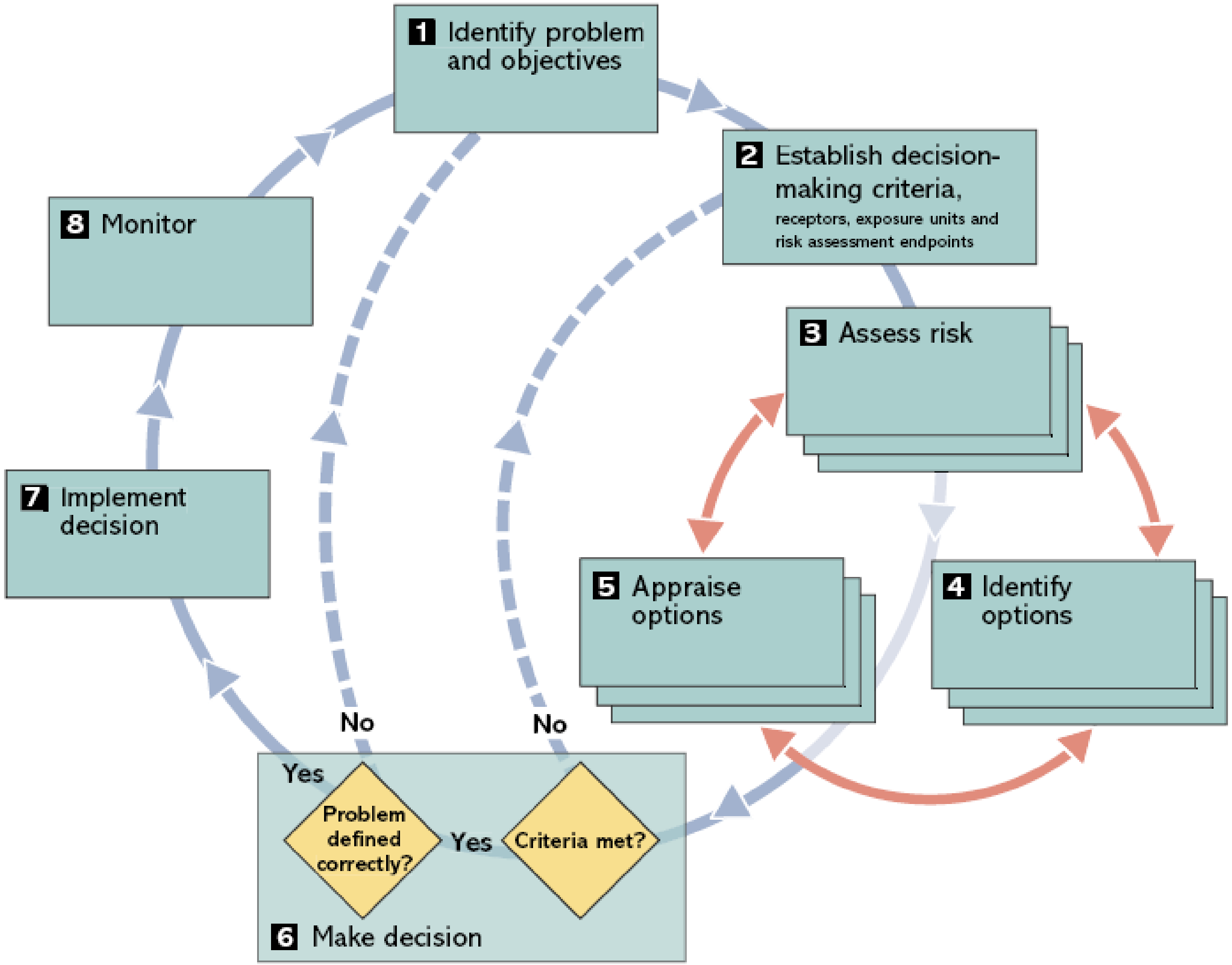
(Carter et al. 1994)

ICLIPS Integrated Assessment Framework



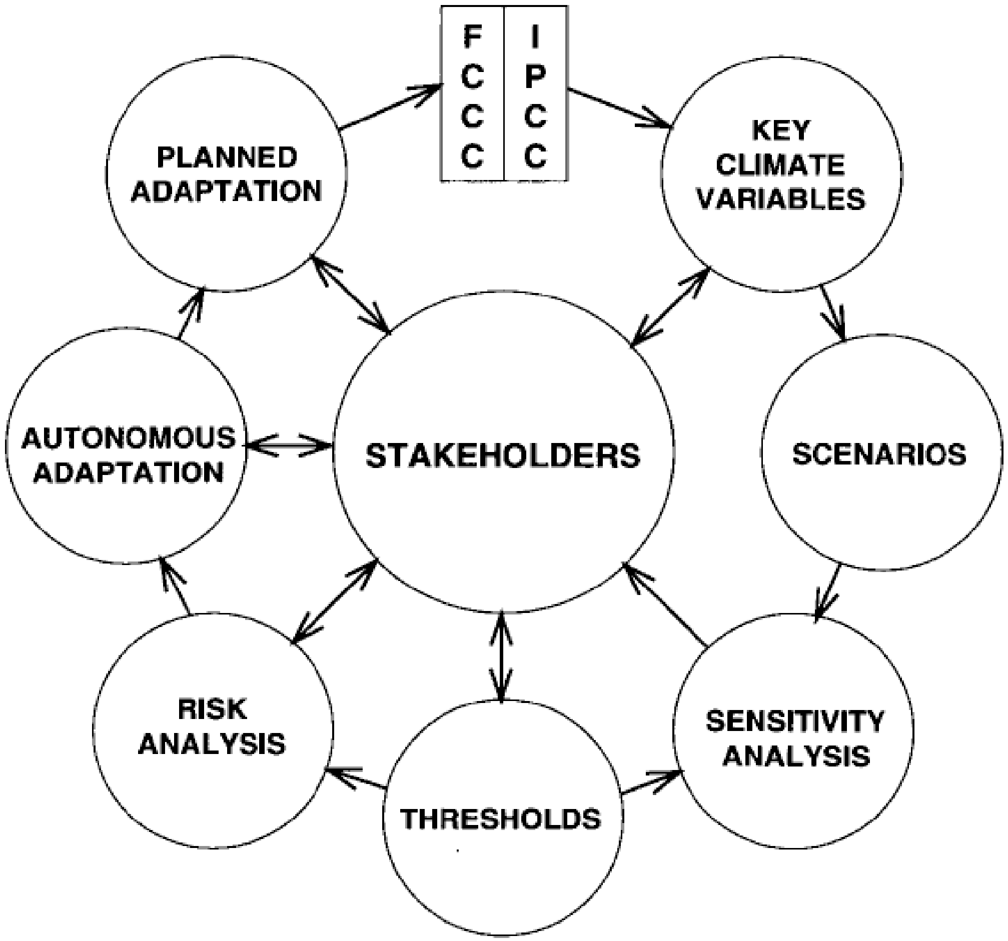
(Toth et al. 2003)

UKCIP Decision-Making Framework



(Willows & Connell, 2003)

Risk assessment/management framework



(Jones, 2001)

Climate Change Impact Assessment and Adaptation: some key components for the Mekong

- No single approach to assessing, planning & implementation
  - ✓ eg top-down and bottom-up risk and vulnerability identification
- An iterative, adaptive framework & ‘models’ to identify and integrate knowledge types, recognising, reducing and communicating uncertainty
  - ✓ integrate qualitative and quantitative information
- Build on current plans and strategies re sustainable development
  - ✓ utilise low regret options, non-climatic risk factors, current climate risks
- Active engagement & sustaining partnerships; implementation incentives; investment in projects and people
- Cost-effective, equitable, politically realistic options

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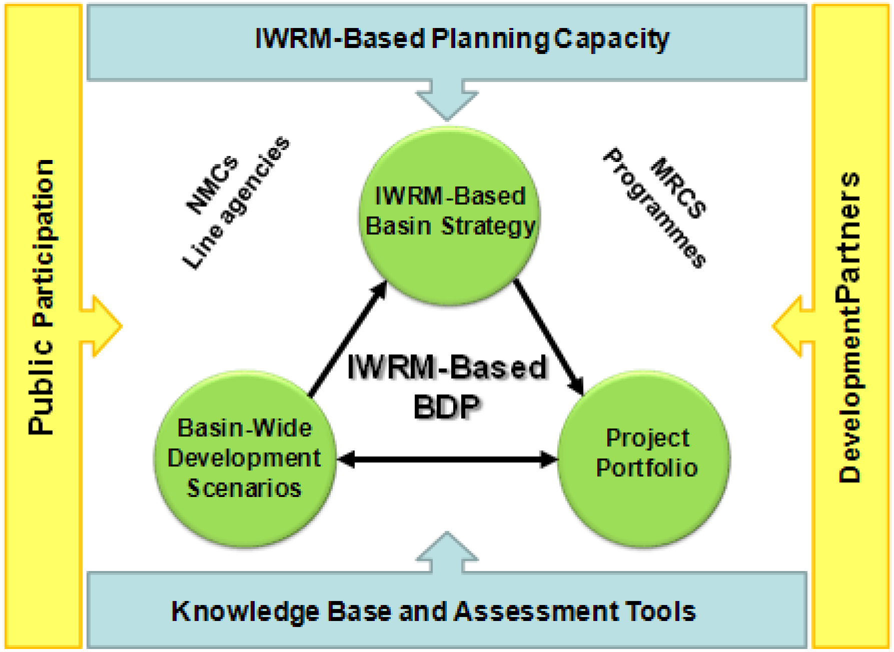
Climate Change in the Mekong

- Climate Adaptation Strategy: Building on existing processes in the Basin

  – IWRM: Basin Development Plan

    - *Development scenarios*
    - *An IWRM-based Basin Strategy*
    - *A project portfolio of structural (investment) projects and supporting non-structural projects*



www.mrcmekong.org

Slide 18

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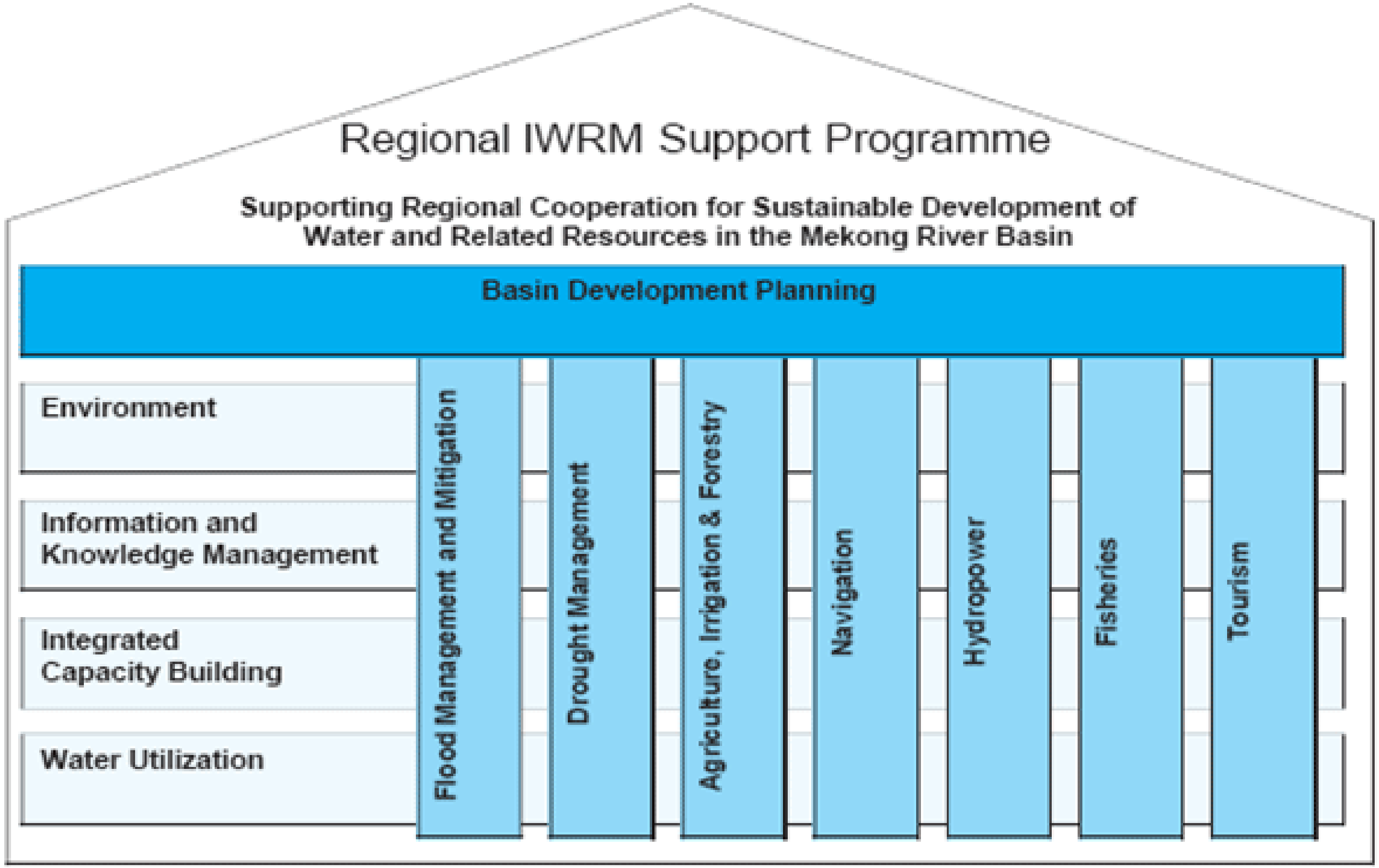
Scenarios to scenarios
glendinn, 11/25/2008

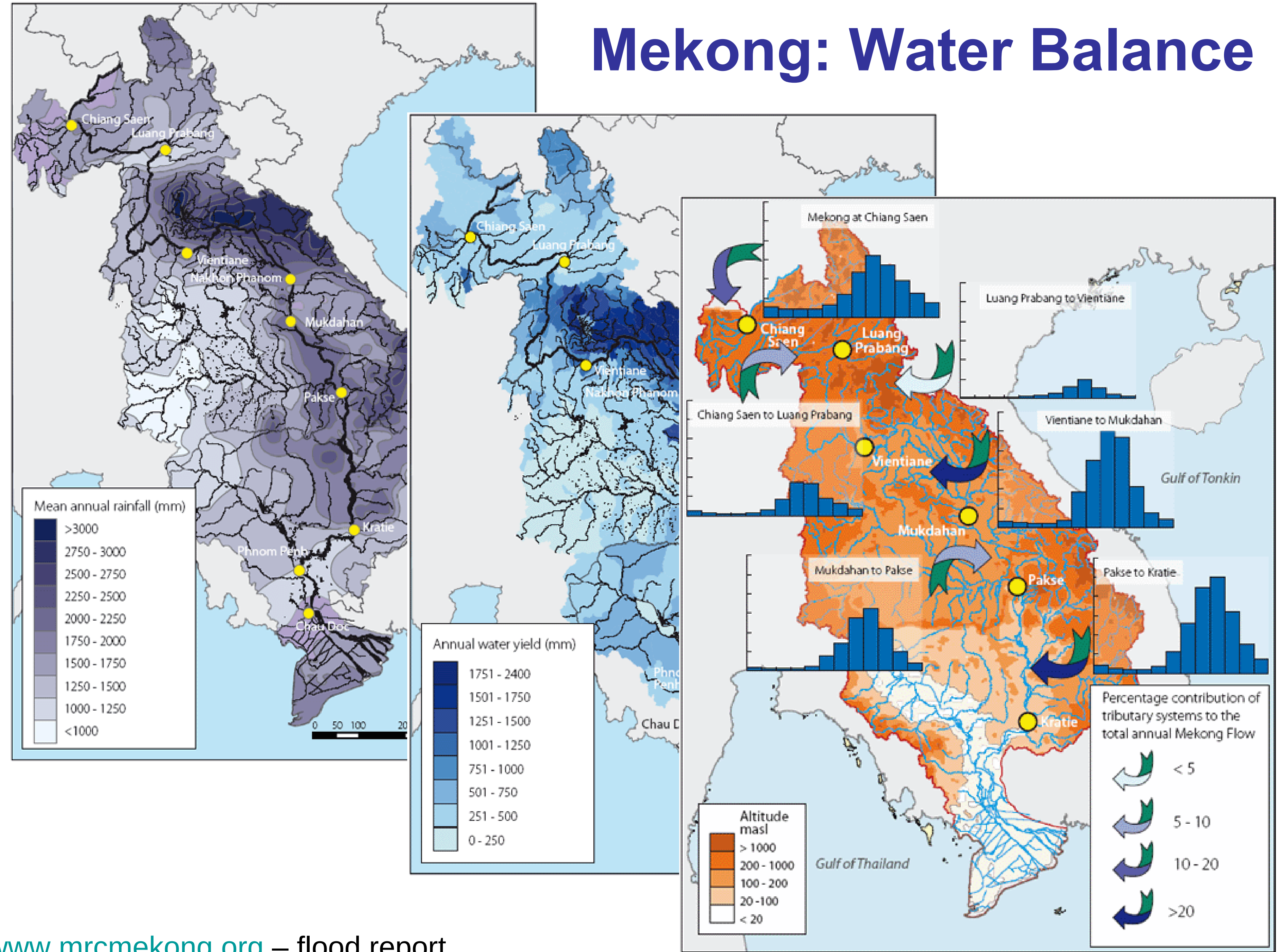
MRC: Basin Development Plan



Programmes supporting IWRM across the Lower Mekong Basin.

www,mrcmekong.org

Mekong: Water Balance



www.mrcmekong.org – flood report

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But what are the Adaptation options?

- Engineering options
- Traditional local strategies
- Social responses
  - resettlement
- Land use planning
  - zoning, development controls
- Economic instruments
  - subsidies, tax incentives
- Natural systems management
  - rehabilitation, enhancement
- Sector-specific adaptation practices eg in agriculture

(Carew-Reid, 2009)

What else does a robust climate change assessment entail?

- ‘State of the art’ models
  - Climate, hydrology, ecology, agriculture, human health, demography, social, economic…. and INTEGRATION of models
  - address uncertainties in: climate predictions; knowledge of and variability in system responses; and the coupling of different models



Part 3: Integrated Modelling (simplified)

Assumptions/

Alternatives

- Climate
- Shocks
- Demography
- Policy drivers
- Adaptation options
- External drivers

Environmental System

'Sustainability' indicators

- Economic
- Social
- Environmental

Assess tradeoffs to balance and compare alternatives

Integrated Modelling Approaches

The main types of integrated models with different strengths and weaknesses in particular situations:

- **Systems dynamics**
- **Bayesian networks**
- **Coupling complex models**
- **Agent-based models**
- **Hybrid expert systems**

Bayesian Networks

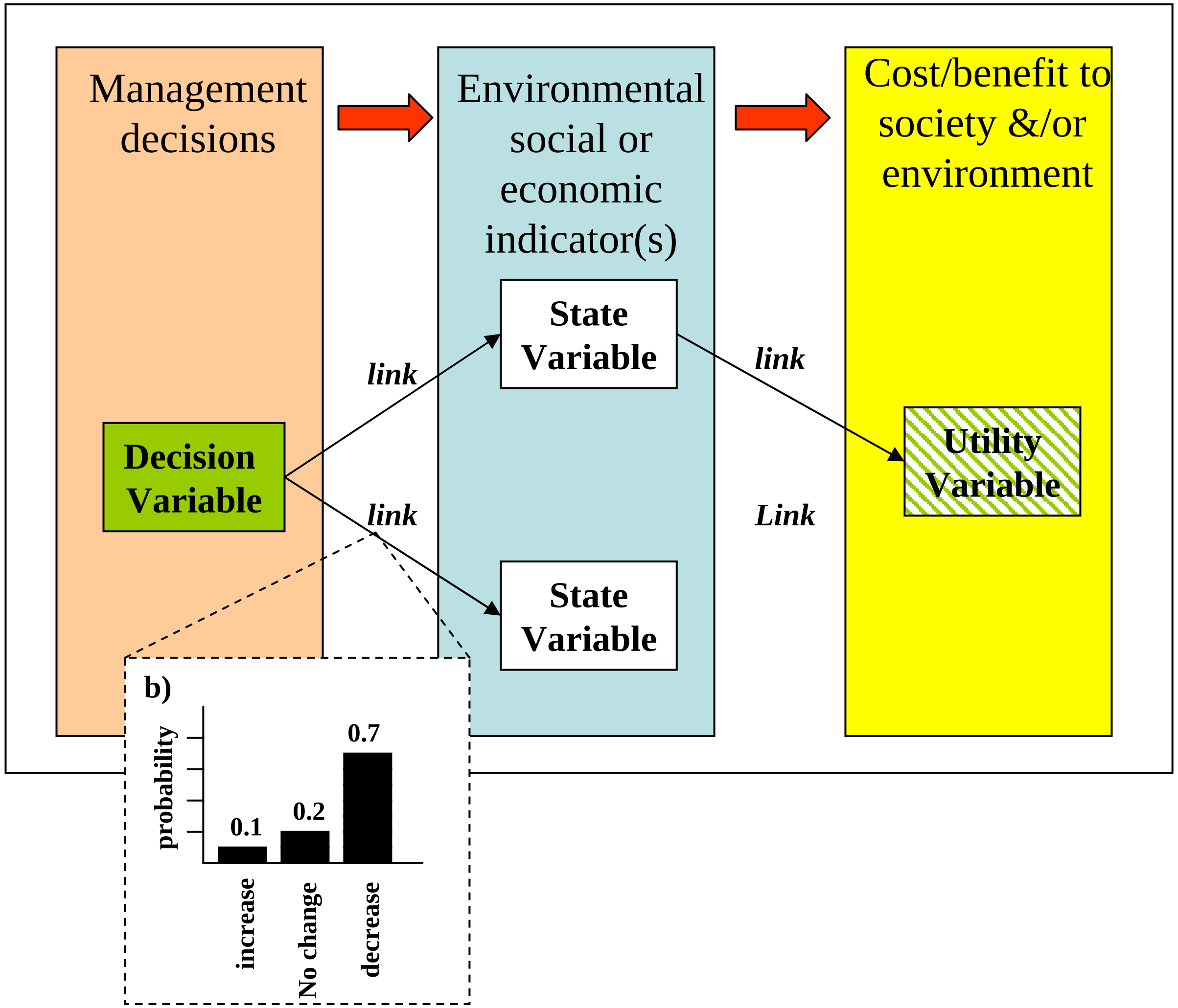
- **A fundamental adaptive modelling tool for decision-making and management where key considerations are:**
  - ✓ wide-scale issue and knowledge integration
  - ✓ knowledge is of varying quality and type
  - ✓ system knowledge and data can be updated

- **Uses conditional probabilities as a common basis to link cause and effect – ie to determine likelihood of different outcomes**

- **Conditional probabilities derived from:**
  - ➢ many (1000’s) of runs of component models
  - ➢ expert elicitation
  - ➢ stakeholder surveys
  - ➢ observed data – categoric and numeric

- **Excellent availability of technical/analytic tools**

Bayesian Decision Networks: linking nodes or variables



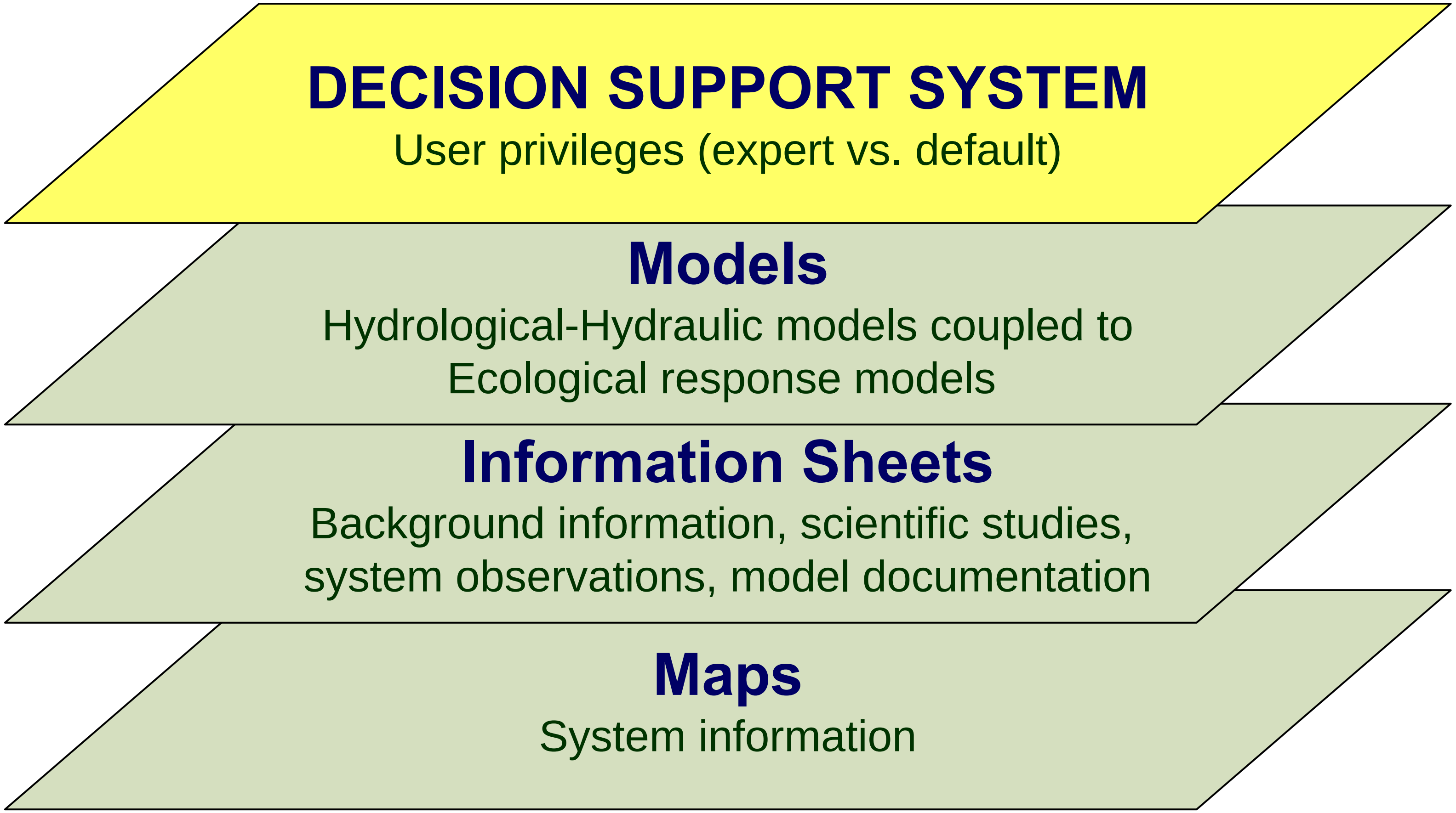
Step	Tasks involved	Tools
1. Identify objectives	•Identify issues, concerns •Build consensus on the problem(s) to be addressed	•Participatory methods
2. Problem framing	•Understanding the problem(s) •Define boundaries/scope	•Exploratory analysis •Visualisation tools (e.g. conceptual models, mind maps) •Participatory methods
3. Identify performance measures	•Identify criteria to be used to compare and evaluate alternatives •Gather value judgments	•Participatory methods
4. Identify alternatives	•Identify potential management options based on objectives	•Participatory methods •Scenario tools
5. Evaluate alternatives	•Evaluate each alternative based on how it is predicted to affect the performance measures •Explore tradeoffs •Narrow options	•Predictive/Simulation models (e.g. disciplinary tools) •Integrated models (e.g. Bayesian networks, coupled component models, system dynamics, hybrid expert systems) •Expert elicitation •Optimisation tools (e.g. heuristic search methods, optimisation models, pareto-optimal tradeoff curves) •Decision trees
6. Rank/select final alternative	•Compare and rank different outcomes •Select satisficing option	•Multi-criteria analysis •Cost-benefit analysis •Bayesian decision models •Participatory methods

Part 4: DSS

- **Modern Decision Support Systems**
  - Adaptive; suitable for investigating structured & semi-structured problems
  - Interactive and easy to understand
  - Quantitative & qualitative (hybrid), credible, good evidence-base for decision makers
  - Facilitate integration
  - Transparent and well-documented
- **DSSs can be used for engagement in**
  - Aligning tools with stakeholder & user needs
  - Investigating scenarios, priorities and strategies that are robust to uncertainties
  - Sharing likely outcomes of climate change scenarios
  - Identifying research needs to better understand climate change and its outcomes

Packaging it all up into a DSS

- Decision Support Systems for Climate Change
  - More than just a set of models



IBIS: Environmental flow DSS for NSW Wetlands

Building on the existing DSS?

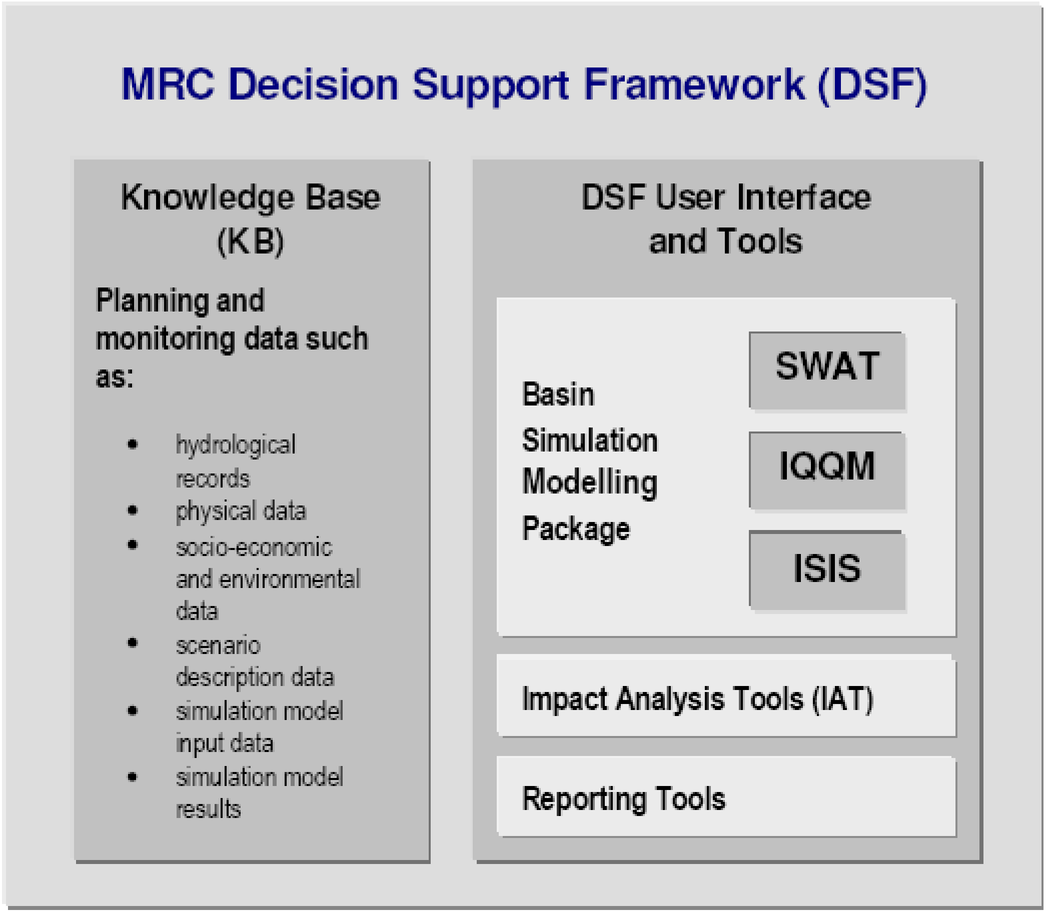
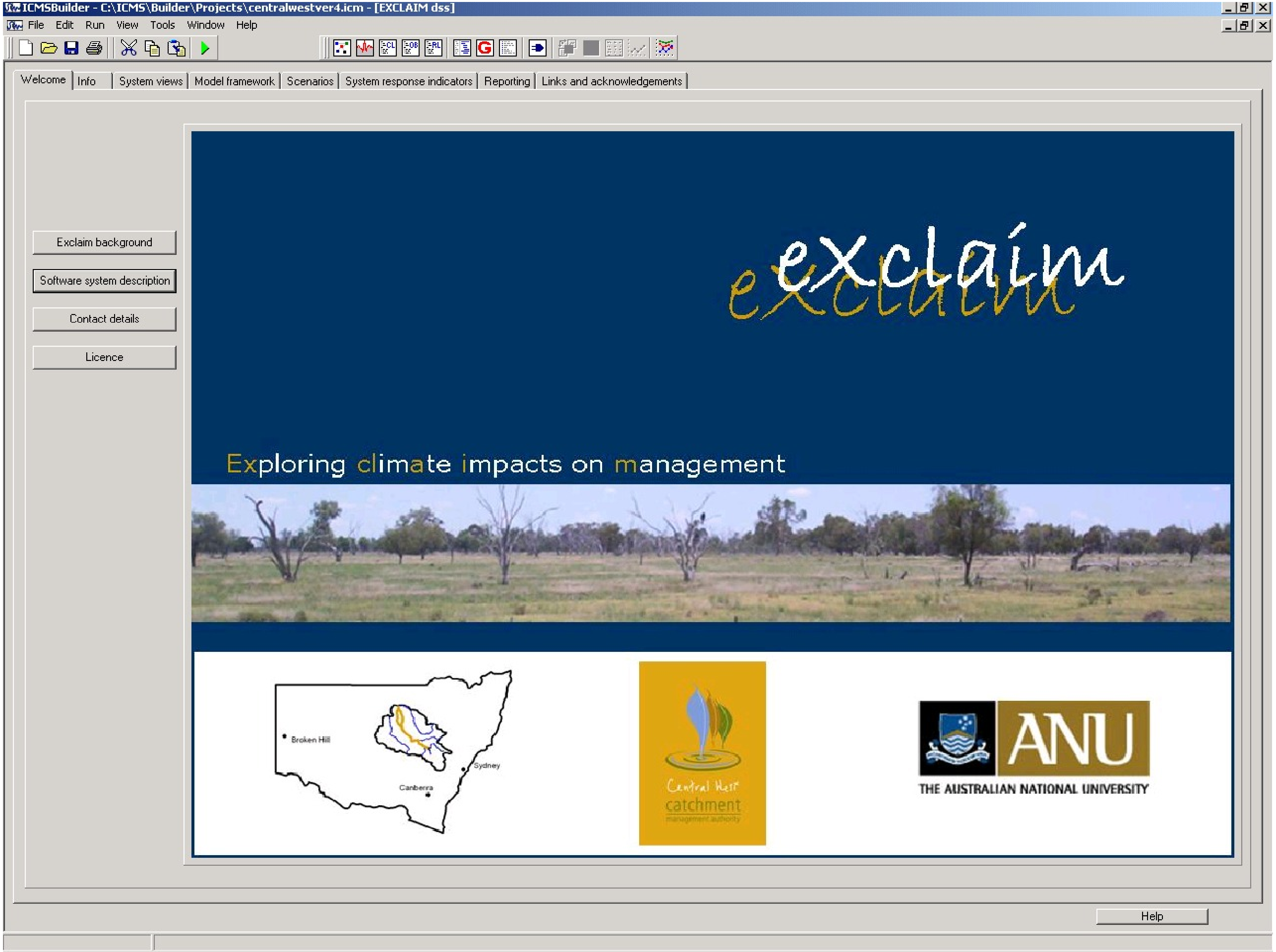


Figure 2-1. MRC Decision Support Framework

Part 5: Two examples of integrated modelling & DSS relevant to the Mekong

1. EXCLAIM: EXploring CLimAte Impacts on Management
   - Configuration of Bayesian Network models with hydrological time series inputs

2. IBIS: Wetland Decision Support Systems
   - Configuration of Bayesian Network, empirical and rule-based models integrated with hydrology and hydraulic models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Welcome
Info
System views
Model framework
Scenarios
System response indicators
Reporting
Links and acknowledgements
Exclaim background
Software system description
Contact details
Licence
exclaim
Exploring climate impacts on management
Broken Hill
Sydney
Canberra
Central West catchment management authority
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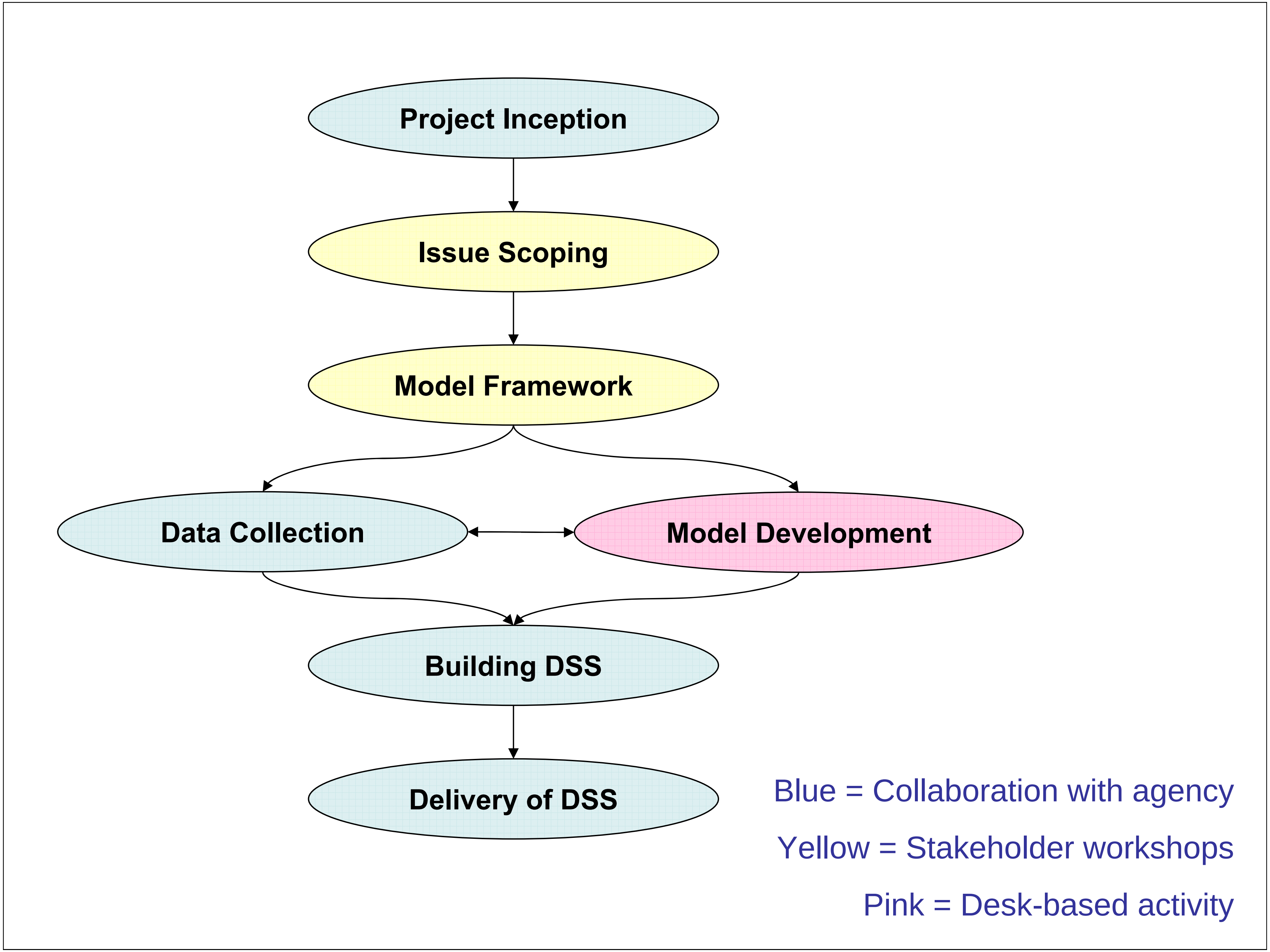
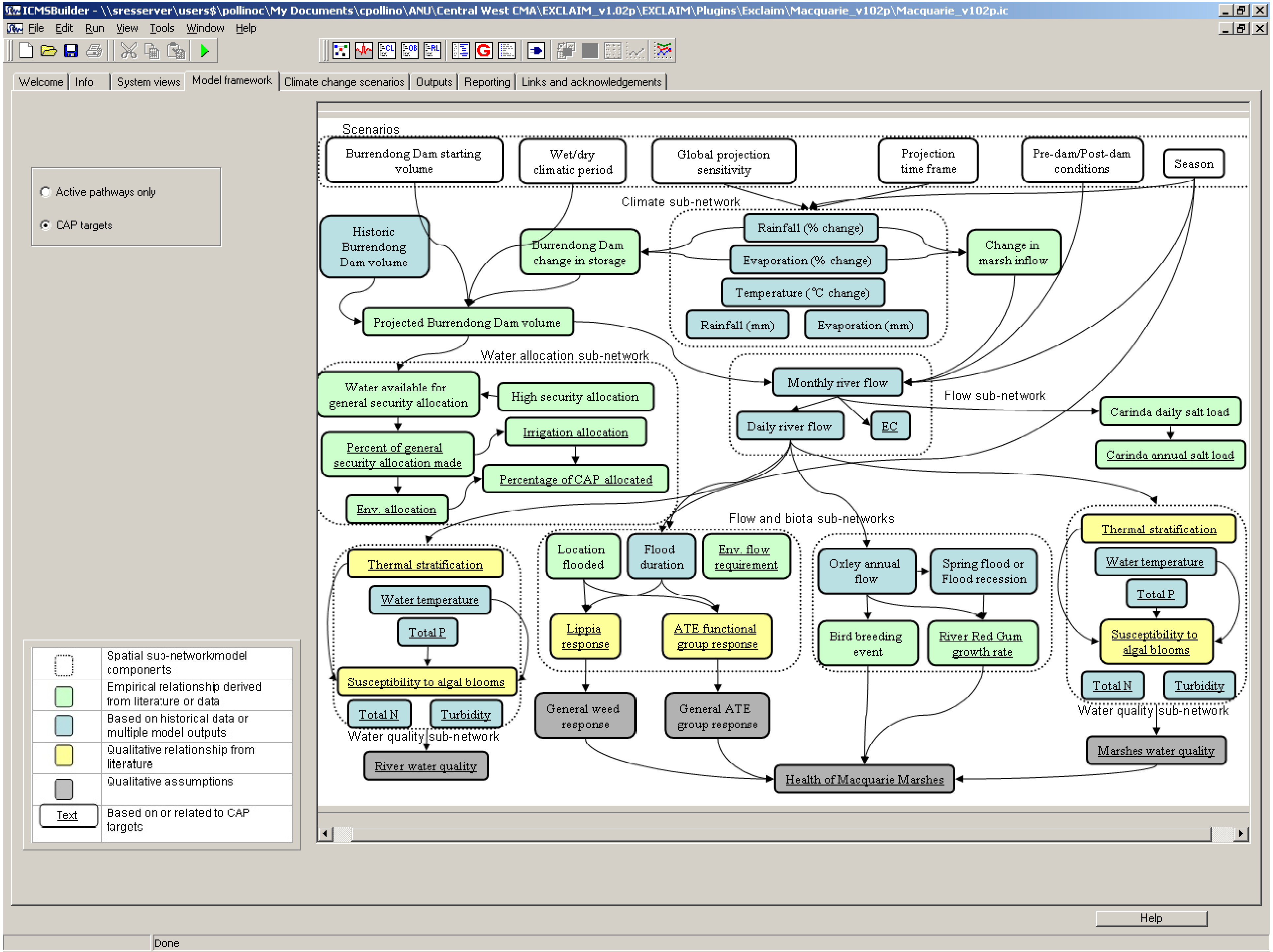
Help

Impacts of Climate Change on…

- Water flows
  - Irrigation and environmental needs
  - ‘High’ security requirements
- Water quality
  - Salinity
  - Nutrients
- River and wetland ‘health’
  - Ecological indicators
    - Algae, Vegetation, Birds, Fish


Project Inception
Issue Scoping
Model Framework
Data Collection
Model Development
Building DSS
Delivery of DSS
Blue = Collaboration with agency
Yellow = Stakeholder workshops
Pink = Desk-based activity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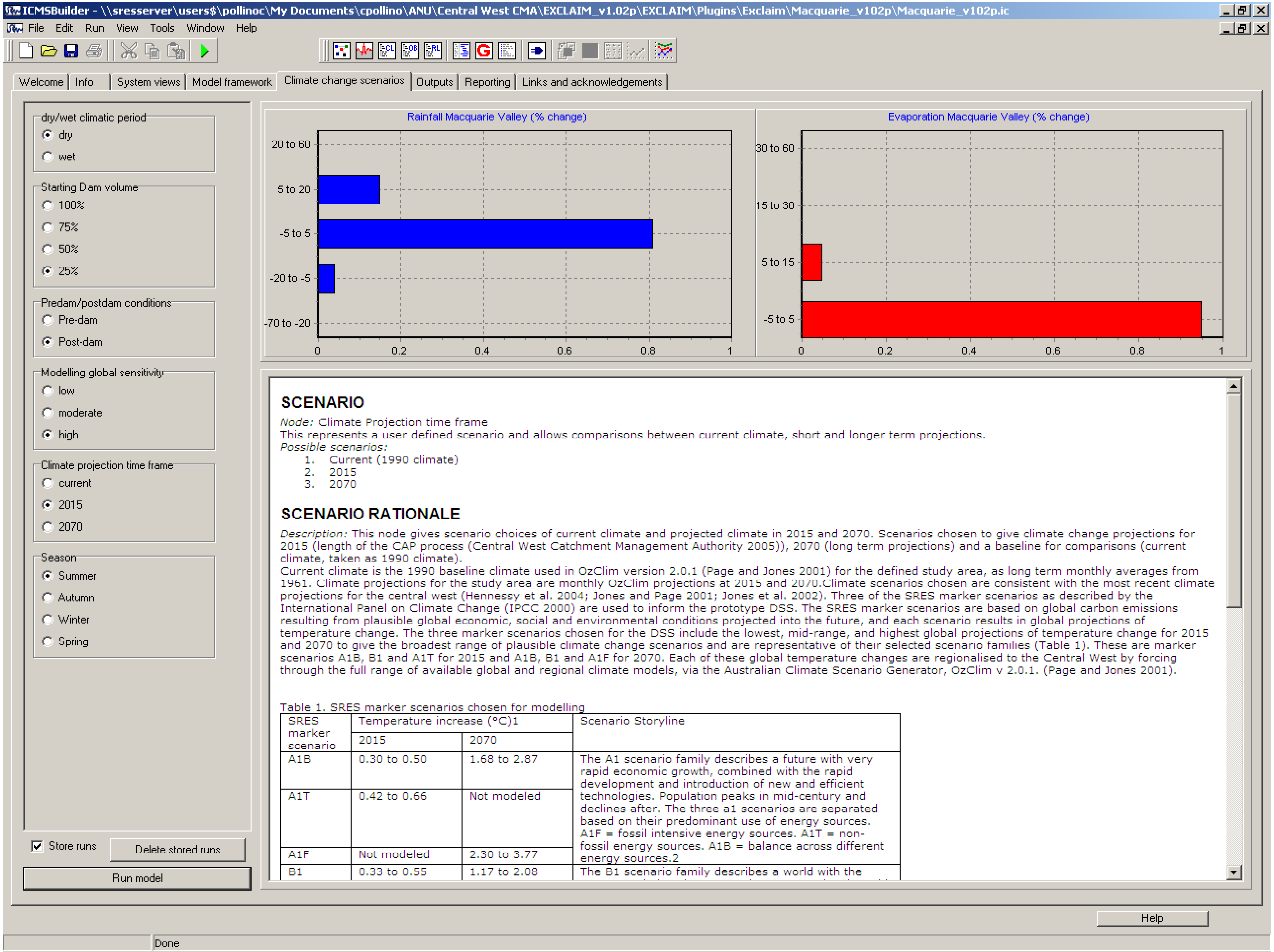
Welcome
Info
System views
Model framework
Climate change scenarios
Outputs
Reporting
Links and acknowledgements
Active pathways only
CAP targets
Scenarios
Burrendong Dam starting volume
Wet/dry climatic period
Global projection sensitivity
Projection time frame
Pre-dam/Post-dam conditions
Season
Climate sub-network
Historic Burrendong Dam volume
Burrendong Dam change in storage
Rainfall (% change)
Evaporation (% change)
Temperature (°C change)
Rainfall (mm)
Evaporation (mm)
Change in marsh inflow
Projected Burrendong Dam volume
Water allocation sub-network
Water available for general security allocation
High security allocation
Irrigation allocation
Percent of general security allocation made
Percentage of CAP allocated
Env. allocation
Monthly river flow
Flow sub-network
Daily river flow
EC
Carinda daily salt load
Carinda annual salt load
Flow and biota sub-networks
Thermal stratification
Water temperature
Total P
Susceptibility to algal blooms
Total N
Turbidity
Water quality sub-network
River water quality
Location flooded
Flood duration
Env. flow requirement
Lippia response
ATE functional group response
General weed response
General ATE group response
Oxley annual flow
Spring flood or Flood recession
Bird breeding event
River Red Gum growth rate
Health of Macquarie Marshes
Thermal stratification
Water temperature
Total P
Susceptibility to algal blooms
Total N
Turbidity
Water quality sub-network
Marshes water quality
Spatial sub-network/model components
Empirical relationship derived from literature or data
Based on historical data or multiple model outputs
Qualitative relationship from literature
Qualitative assumptions
Text
Based on or related to CAP targets
Help
Done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Welcome | Info | System views | Model framework | Climate change scenarios | Outputs | Reporting | Links and acknowledgements
dry/wet climatic period
dry
wet
Starting Dam volume
100%
75%
50%
25%
Predam/postdam conditions
Pre-dam
Post-dam
Modelling global sensitivity
low
moderate
high
Climate projection time frame
current
2015
2070
Season
Summer
Autumn
Winter
Spring
Store runs
Delete stored runs
Run model
Rainfall Macquarie Valley (% change)
20 to 60
5 to 20
-5 to 5
-20 to -5
-70 to -20
0
0.2
0.4
0.6
0.8
1
Evaporation Macquarie Valley (% change)
30 to 60
15 to 30
5 to 15
-5 to 5
0
0.2
0.4
0.6
0.8
1
SCENARIO
Node: Climate Projection time frame
This represents a user defined scenario and allows comparisons between current climate, short and longer term projections.
Possible scenarios:
1. Current (1990 climate)
2. 2015
3. 2070
SCENARIO RATIONALE
Description: This node gives scenario choices of current climate and projected climate in 2015 and 2070. Scenarios chosen to give climate change projections for 2015 (length of the CAP process (Central West Catchment Management Authority 2005)), 2070 (long term projections) and a baseline for comparisons (current climate, taken as 1990 climate).
Current climate is the 1990 baseline climate used in OzClim version 2.0.1 (Page and Jones 2001) for the defined study area, as long term monthly averages from 1961. Climate projections for the study area are monthly OzClim projections at 2015 and 2070.Climate scenarios chosen are consistent with the most recent climate projections for the central west (Hennessy et al. 2004; Jones and Page 2001; Jones et al. 2002). Three of the SRES marker scenarios as described by the International Panel on Climate Change (IPCC 2000) are used to inform the prototype DSS. The SRES marker scenarios are based on global carbon emissions resulting from plausible global economic, social and environmental conditions projected into the future, and each scenario results in global projections of temperature change. The three marker scenarios chosen for the DSS include the lowest, mid-range, and highest global projections of temperature change for 2015 and 2070 to give the broadest range of plausible climate change scenarios and are representative of their selected scenario families (Table 1). These are marker scenarios A1B, B1 and A1T for 2015 and A1B, B1 and A1F for 2070. Each of these global temperature changes are regionalised to the Central West by forcing through the full range of available global and regional climate models, via the Australian Climate Scenario Generator, OzClim v 2.0.1. (Page and Jones 2001).
Table 1. SRES marker scenarios chosen for modelling
SRES marker scenario
Temperature increase (°C)1
2015
2070
Scenario Storyline
A1B
0.30 to 0.50
1.68 to 2.87
The A1 scenario family describes a future with very rapid economic growth, combined with the rapid development and introduction of new and efficient technologies. Population peaks in mid-century and declines after. The three a1 scenarios are separated based on their predominant use of energy sources. A1F = fossil intensive energy sources. A1T = non-fossil energy sources. A1B = balance across different energy sources.2
A1T
0.42 to 0.66
Not modeled
A1F
Not modeled
2.30 to 3.77
B1
0.33 to 0.55
1.17 to 2.08
The B1 scenario family describes a world with the
Help
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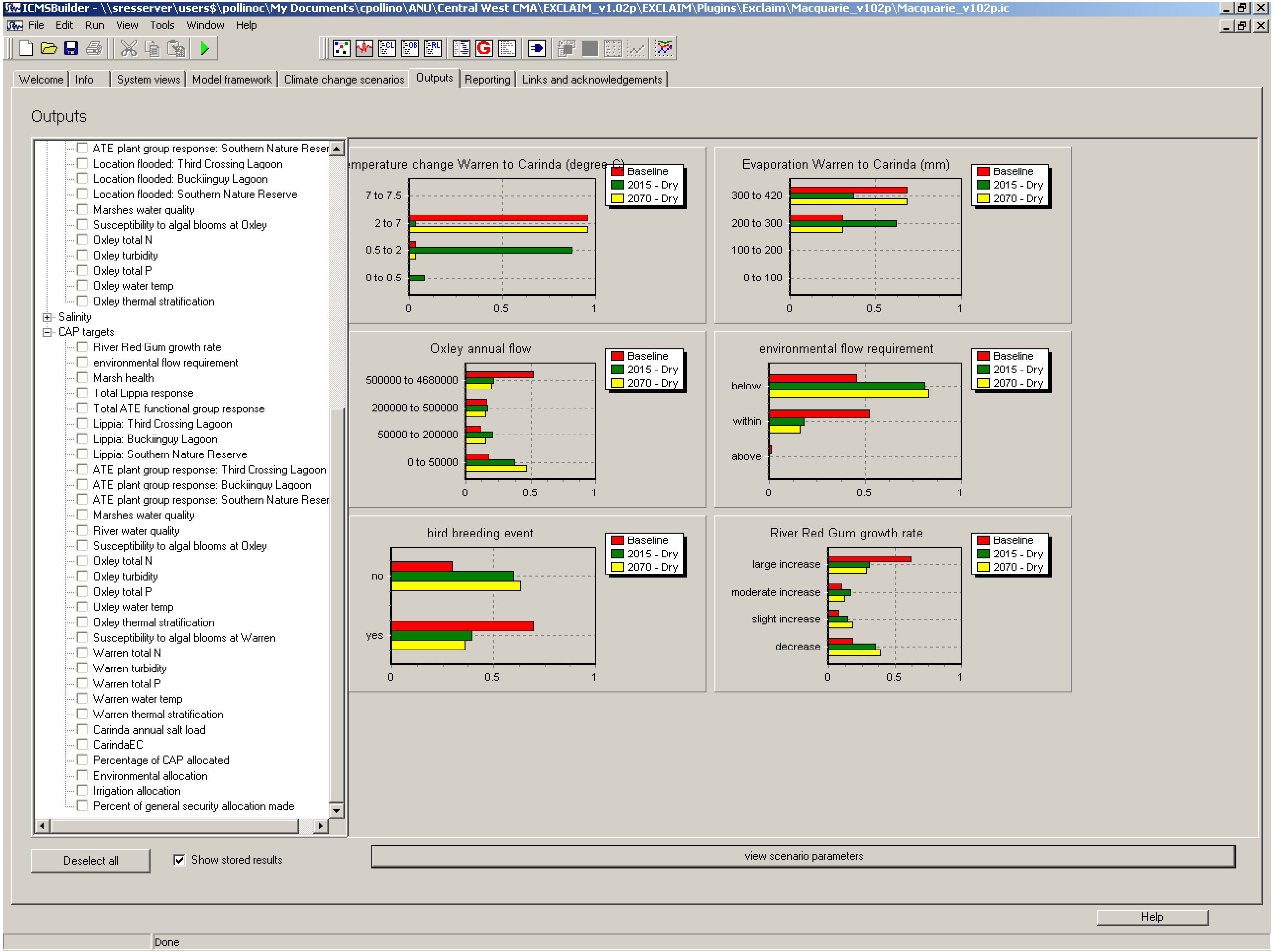
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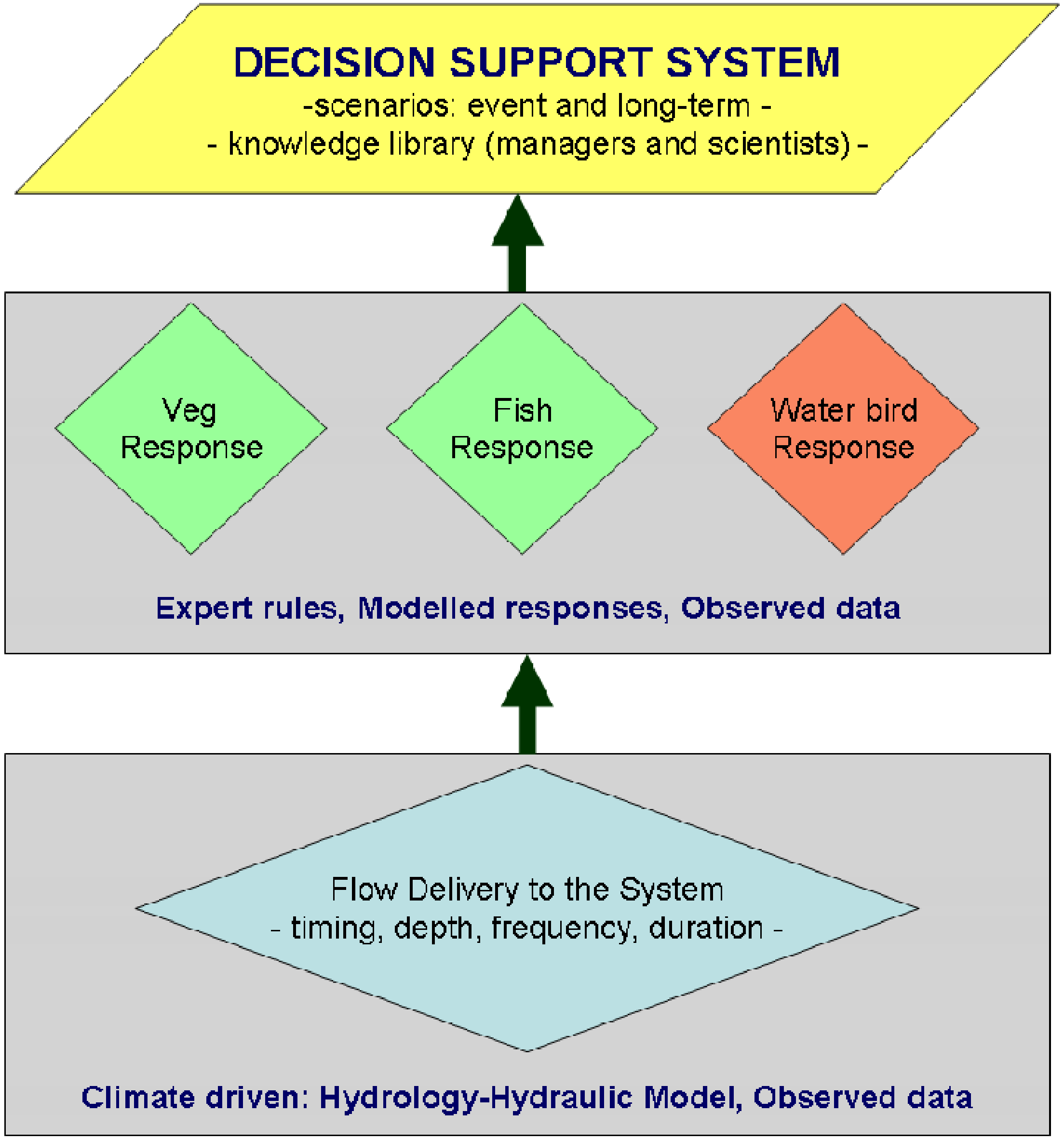
Climate change scenarios
Outputs
Reporting
Links and acknowledgements
Outputs
ATE plant group response: Southern Nature Reser
Location flooded: Third Crossing Lagoon
Location flooded: Buckiinguy Lagoon
Location flooded: Southern Nature Reserve
Marshes water quality
Susceptibility to algal blooms at Oxley
Oxley total N
Oxley turbidity
Oxley total P
Oxley water temp
Oxley thermal stratification
Salinity
CAP targets
River Red Gum growth rate
environmental flow requirement
Marsh health
Total Lippia response
Total ATE functional group response
Lippia: Third Crossing Lagoon
Lippia: Buckiinguy Lagoon
Lippia: Southern Nature Reserve
ATE plant group response: Third Crossing Lagoon
ATE plant group response: Buckiinguy Lagoon
ATE plant group response: Southern Nature Reser
Marshes water quality
River water quality
Susceptibility to algal blooms at Oxley
Oxley total N
Oxley turbidity
Oxley total P
Oxley water temp
Oxley thermal stratification
Susceptibility to algal blooms at Warren
Warren total N
Warren turbidity
Warren total P
Warren water temp
Warren thermal stratification
Carinda annual salt load
CarindaEC
Percentage of CAP allocated
Environmental allocation
Irrigation allocation
Percent of general security allocation made
mperature change Warren to Carinda (degree C)
7 to 7.5
2 to 7
0.5 to 2
0 to 0.5
0
0.5
1
Baseline
2015 - Dry
2070 - Dry
Evaporation Warren to Carinda (mm)
300 to 420
200 to 300
100 to 200
0 to 100
Oxley annual flow
500000 to 4680000
200000 to 500000
50000 to 200000
0 to 50000
environmental flow requirement
below
within
above
bird breeding event
no
yes
River Red Gum growth rate
large increase
moderate increase
slight increase
decrease
Deselect all
Show stored results
view scenario parameters
Help
Done

IBIS Component Models



- User-friendly interface overlies the models and provides access to supporting information, model documentation and model results
- Designed to support environmental flow decision-making (short and long term)

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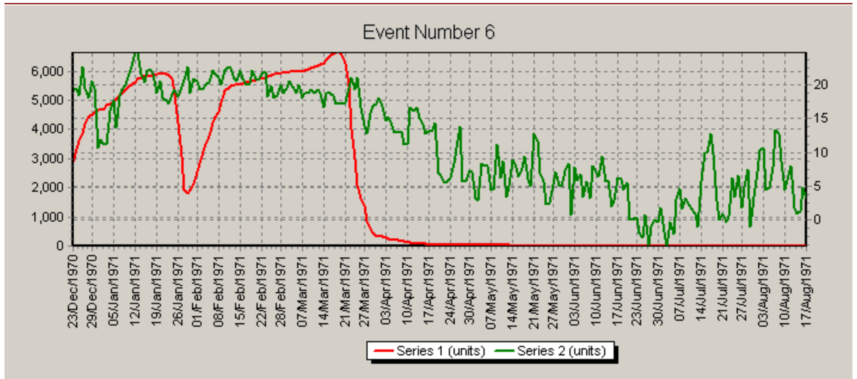
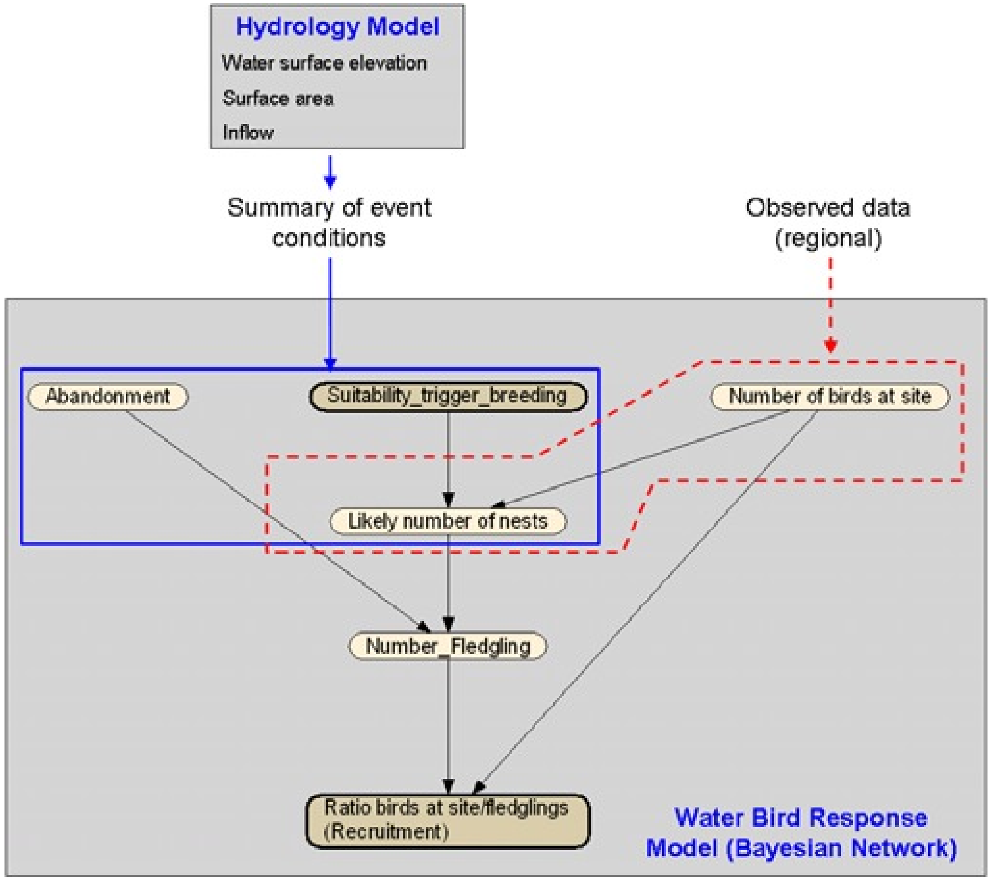
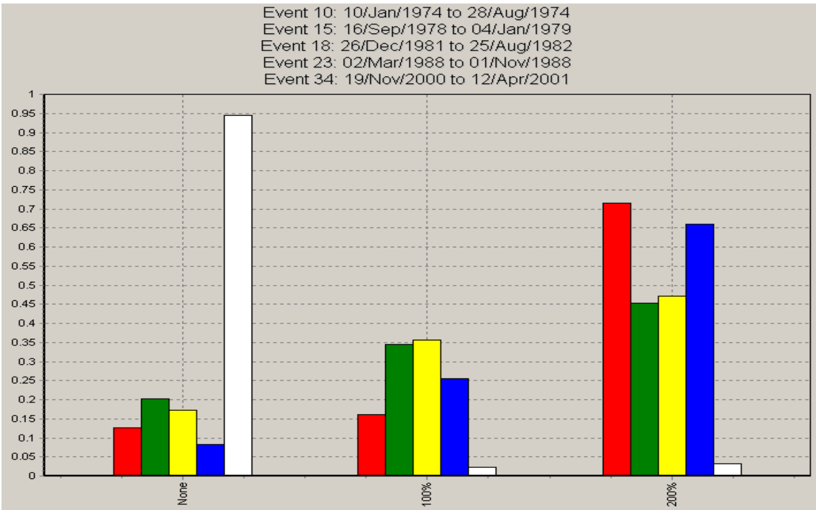
Integrated Model Structure

- Continuous daily hydrology model
- Characteristics of ‘event’ passed through discrete probabilistic response models
- *For each event*: the likely success of an outcome







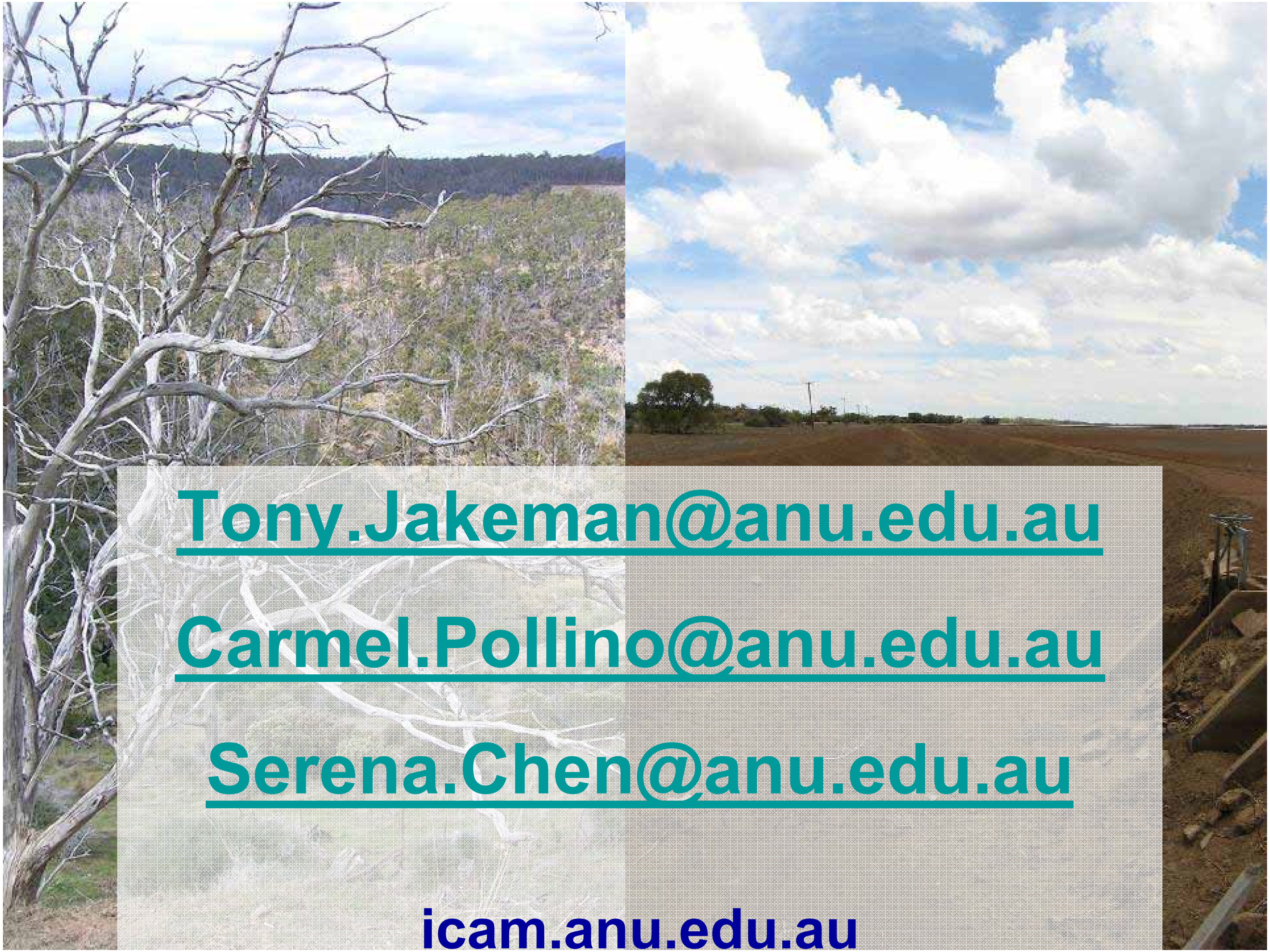
Part 6: Our Lessons

- Project process:
  - Builds relationships between institutions, researchers and stakeholders
  - Builds capacity, understanding, promotes systems thinking, leads to innovative ideas for change
- Participation needs to be flexible and a feature of the entire project cycle
  - Time, resources and effort are required to engage stakeholders
  - Goals of this need to be clearly defined
- 'Products' (DSS plus…) need to be adaptive, iterative and promote discovery of new knowledge

Key messages for Assessment

- Manage and communicate uncertainty - complexity, knowledge & data gaps; incorporate qualitative knowledge
- Utilise current programs and methods effectively
- Consider climatic and non-climatic risks jointly
- Prioritise options under resource constraints, balancing tradeoffs
- Look for robust solutions in the face of uncertainties
- Document, monitor and review: adaptive to incorporate new information
- Engage for transparency, accountability, legitimacy and adoption

Implies an adaptive but systematic process: explicit frameworks, eclectic modelling & decision support in a learning setting


Tony.Jakeman@anu.edu.au
Carmel.Pollino@anu.edu.au
Serena.Chen@anu.edu.au
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References

- Asian Development Bank, 2004. Tonle Sap Sustainable Livelihoods. Future Solutions Now – The Tonle Sap Initiative. December 2004. www.adb.org/Projects/Tonle_Sap/
- Carter, T.R., Parry, M.L., Harasawa, H., Nishioka, S., 1994. IPCC technical guidelines for assessing climate change impacts and adaptations. Part of the IPCC Special Report to the First Session of the Conference of the Parties to the UN Framework Convention on Climate Change, Department of Geography, University College London, London, UK.
- Cruz, R. V., H. Harasawa, M. Lal, S. Su, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li and N. Huu Ninh, 2007. Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, (Eds.) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson. Cambridge UK, Cambridge University Press: 469-506.
- Fussel, H.-M. and R. J. T. Klein, 2004. Conceptual frameworks of adaptation to climate change and their applicability to human health. PIK Report No. 91. Potsdam Institute for Climate Impact Research.
- IPCC, 2001. Mitigation – Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz, O. Davidson, R. Swart, and J. Pan (eds) Cambridge University Press, Cambridge, UK.
- Jones, R. N., 2001. An environmental risk assessment/management framework for climate change impact assessments. Natural Hazards 23: 197-230.
- Kummu, M., J. Sarkkula, J. Koponen and J. Nikula, 2006. Ecosystem management of the Tonle Sap Lake: an integrated modelling approach. International Journal of Water Resources Development 22: 497-519.
- Mekong River Commission, 2005. Overview of the Hydrology of the Mekong Basin. Mekong River Commission.
- Penny, D., 2006. The Holocene history and development of the Tonle Sap, Cambodia. Quaternary Science Reviews 25(3-4): 310-322.
- Prathumratana, L., S. Sthiannopkao and K. W. Kim, 2008. The relationship of climatic and hydrological parameters to surface water quality in the lower Mekong River. Environmental International 34(6): 860-866.
- Toth, F. L., T. Bruckner, H.-M. Fussel, M. Leimbach and G. Petschel-Held, 2003. Integrated assessment of long-term climate policies: Part 1- Model presentation. Climatic Change 56: 37-56.
- Wassmann, R., N. X. Hien, C. T. Hoanh and T. P. Tuong, 2004. Sea level rise affecting the Vietnamese Mekong Delta: water elevation in the flood season and implications for rice production. Climatic Change 66: 89-107.
- Willows, R.I. and Connell, R.K. (eds), 2003. Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.

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Climate Change problem involves..

- Geophysical, biological, socioeconomic systems
- Multiple decision makers (inc. other sectors)
- Countless stakeholders
- Web of constraints – barriers to adaptation
- Numerous competing objectives
- Uncertainties about future changes to climate variables & system responses
- Identifying priorities inc vulnerable ‘communities’ and assets
- Passive/existing and transformational changes -policy, institutional and practice

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Five preconditions to successful planned adaptation to CC

1. Availability of effective intervention measures
2. Availability of resources to implement these measures
3. Awareness of the problem
4. Information about these measures
5. Incentives for actually implementing these measures

(Fussel and Klein, 2004)

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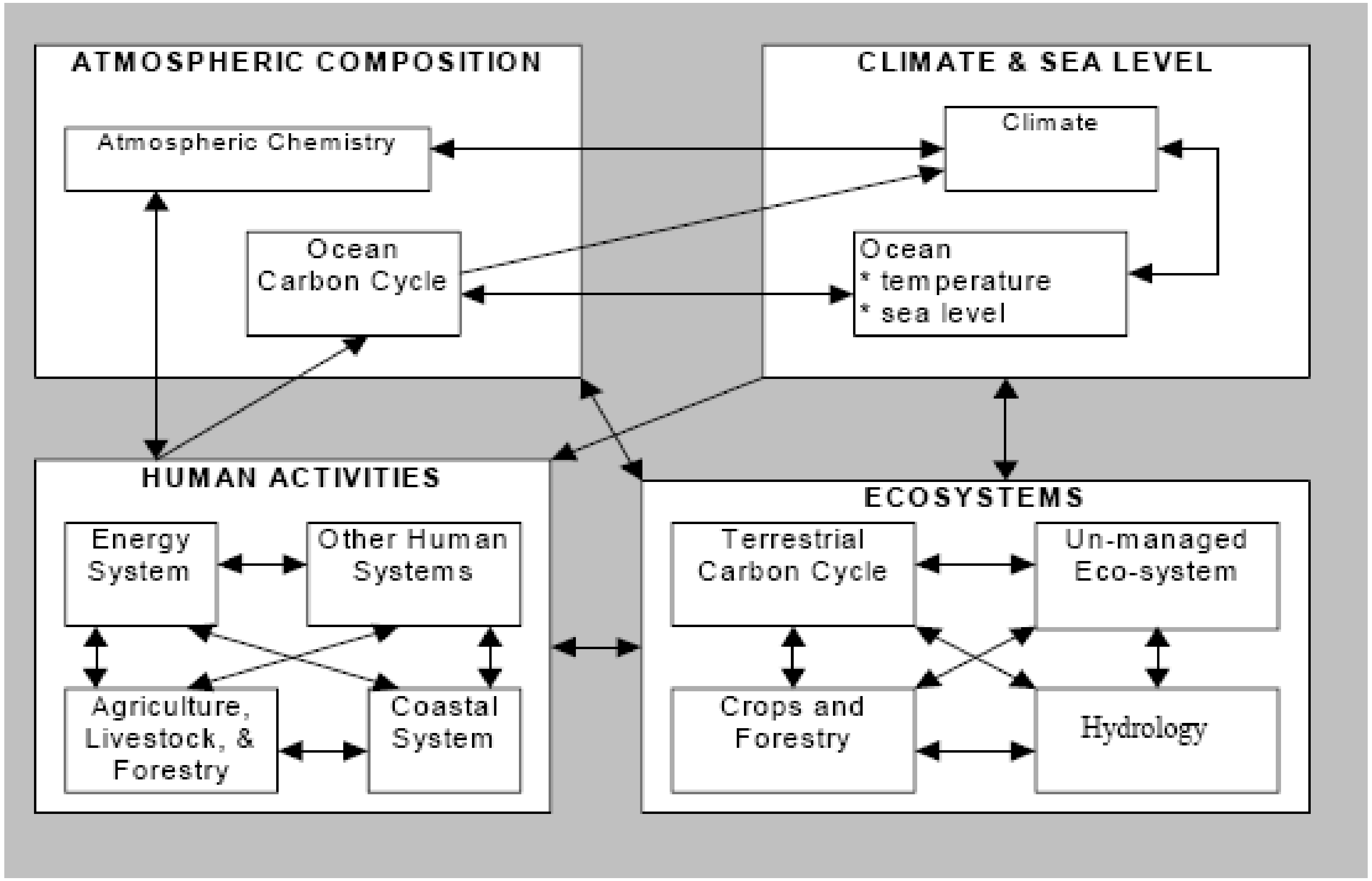
Integrated Assessment Models



Representation of a generalised IAM for climate change (IPCC 1996)