Uncertainty Analysis Methodologies Workshop
September 19, 2015,
Québec City, Canada

Uncertainties in water system models : Breaking down the water discipline silos

An overview of the discussions and outcomes of the 2015 Watermatex Uncertainty workshop

Evangelia Belia

Primodal
Earth Essential Technologies

Peter Vanrolleghem

UNIVERSITÉ LAVAL

Tony Jakeman

Australian National University

DOUT
Design and operations uncertainty task group

Motivation for DOUT

Why? Facilitate full advantage of simulators and uncertainty analysis – for more (social) cost-effective solutions

How? Communicate state-of-art (academia to practice), show advantages, identify uncertainty sources

- How are uncertainty and risk currently dealt with?
- Terms and definitions
- List sources of uncertainty for typical project phases and contract delivery mechanisms
- Existing uncertainty-related methods
- What about other application fields?
- Present examples

Uncertainty in Wastewater Treatment Design and Operation: *Addressing Current Practices and Future Directions*

Scientific and Technical Report No. 21

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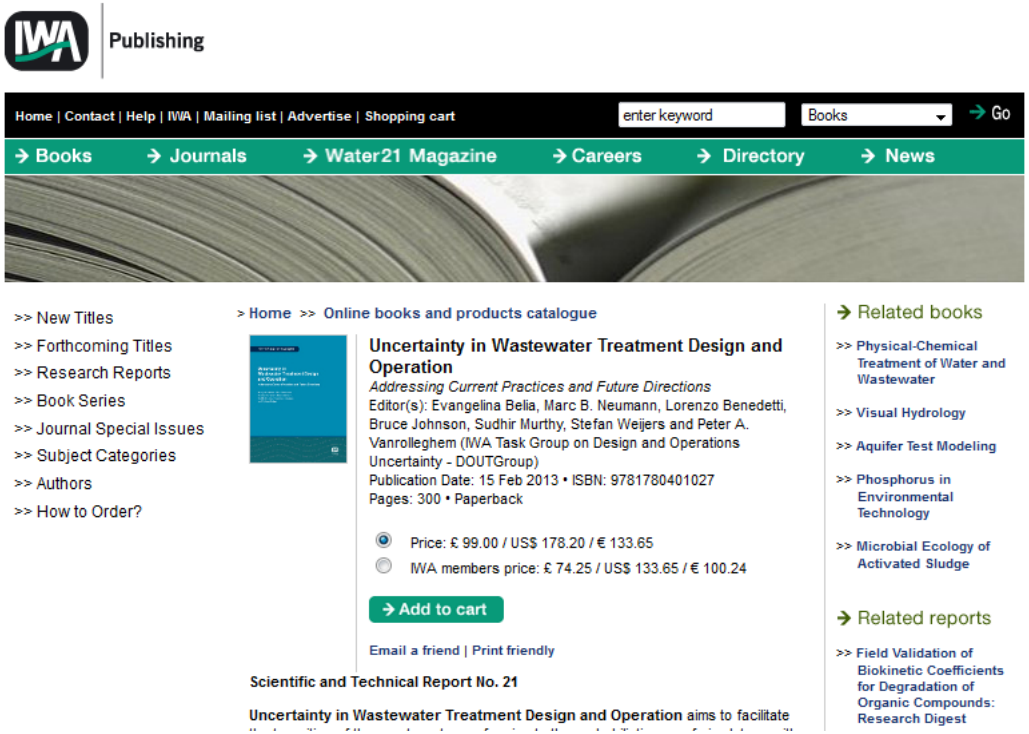
Key Outputs



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Uncertainty in Wastewater Treatment Design and Operation

Addressing Current Practices and Future Directions

Editor(s): Evangelina Belia, Marc B. Neumann, Lorenzo Benedetti, Bruce Johnson, Sudhir Murthy, Stefan Weijers and Peter A. Vanrolleghem (IWA Task Group on Design and Operations Uncertainty - DOUTGroup)

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Scientific and Technical Report No. 21

Uncertainty in Wastewater Treatment Design and Operation aims to facilitate

→ Related books

>> Physical-Chemical Treatment of Water and Wastewater
>> Visual Hydrology
>> Aquifer Test Modeling
>> Phosphorus in Environmental Technology
>> Microbial Ecology of Activated Sludge

→ Related reports

>> Field Validation of Biokinetic Coefficients for Degradation of Organic Compounds: Research Digest

ISSUE PAPER

UNCERTAINTY EVALUATIONS IN MODEL-BASED WWTP DESIGN FOR HIGH LEVEL NUTRIENT REMOVAL

LITERATURE REVIEW AND RESEARCH NEEDS

Evangelina Belia, Primodal Inc.
Bruce Johnson, CH2M HILL

Lorenzo Benedetti, Waterways Srl.
Charles B. Bott, HRSD
Cristina Martin, Université Laval
Sudhir Murthy, DCWATER
Marc B. Neumann, Université Laval
Leiv Rieger, EnviroSim Ass. Ltd & inCTRL Inc.
Stefan Weijers, Waterschap De Dommel
Peter A. Vanrolleghem, Université Laval

2013

Water Environment Research Foundation

DOUT

Workshop

Uncertainties in water system models :
Breaking down the water discipline silos

Accounting for Uncertainties in Models for Water Infrastructure Systems: A Cross-Sectoral Review

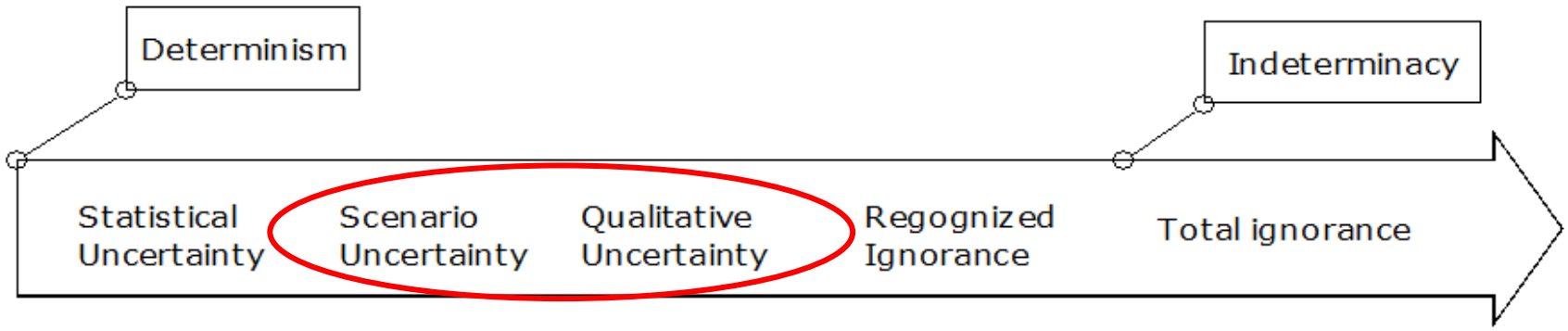
Peter Vanrolleghem, Université Laval, Canada

Not the first one…

- Workshop on Uncertainty in Water System Models

DOUT

Agreement


Determinism
Indeterminacy
Statistical Uncertainty
Scenario Uncertainty
Qualitative Uncertainty
Regognized Ignorance
Total ignorance

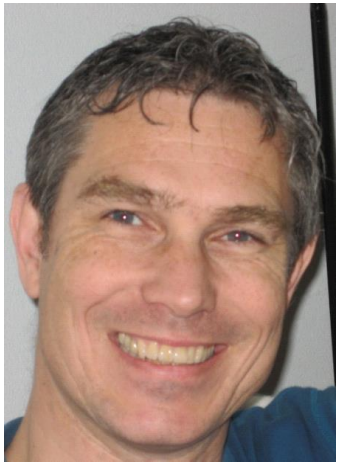
Need for sharing developments

- Major methodological developments take place in hydrology
- Transferable/desired in other water fields

- Many uncertainty-related methods around!
- Too many?
- Meta-guidance by van der Keur et al. (2010) (a guidance on available guidances!) to navigate through the wealth of tools

IWA Design and Operational Uncertainty Task Group (DOUT)

Stefan Weijers, Waterschap De Dommel, The Netherlands



Different angles/perspectives

- Systems analysis framework - **statisticians**
  - sampling error, measurement error, parameter uncertainty, model structure, numerical
- Modelling project phases **- modellers**
  - Project definition – data collection – model building – calibration/validation – simulation
- Infrastucture project phases - **engineers**
  - Plan – Preliminary design – Detailed design – Construction- Commissioning – Operation
- Contracting/delivery mechanisms - **stakeholders**
  - design-bid-build vs. design-build-own-operate-transfer

Contract delivery mechanisms

P: Private Company
U: Utility
M: Municipality
R: Regulator

indices 0,1&2 in P:
different companies

in bold:
the phases covered by
the actual contract

Delivery mechanism / Project Phase	Design-Bid-Build (DBB)	Design-Build-Operate (DBO)
Regulatory	R	R
Planning	P0, U, M, R	P0, M, R
Preliminary Design	P1, U	**P1**
Detailed Design	P1, U	**P1**
Construction	**P2**	**P1**
Commissioning	P1/P2	**P1**
Operation	U	**P1**

Stakeholders responsible for taking decisions within the project phases for two contract delivery mechanisms

Who takes which risk? Increasing need to make more explicit !

Identifiability methods as a first step in uncertainty analysis

Tony Jakeman, The Australian National University, Canberra

Tony's Sound Bytes

- The underwhelming modelling practice
- Modellers stubbornly prefer their familiar paradigm, The model 'landscape' investigated too infrequently
- Scant discussion of model assumptions, strengths and weaknesses; very little frank reporting of uncertainties
- Underutilised tools at our disposal
- Insufficient stress-testing of the models (validation)

Identifiability

- Extent to which parameter values can be captured from the observational data and prior knowledge (*practical identifiability*)
- Often a model structure is over-parameterised, sometimes unnecessarily so, regardless of noise in data (*structural identifiability*)
- Lack of information content in the data may impede identification; lack of persistent excitation by inputs

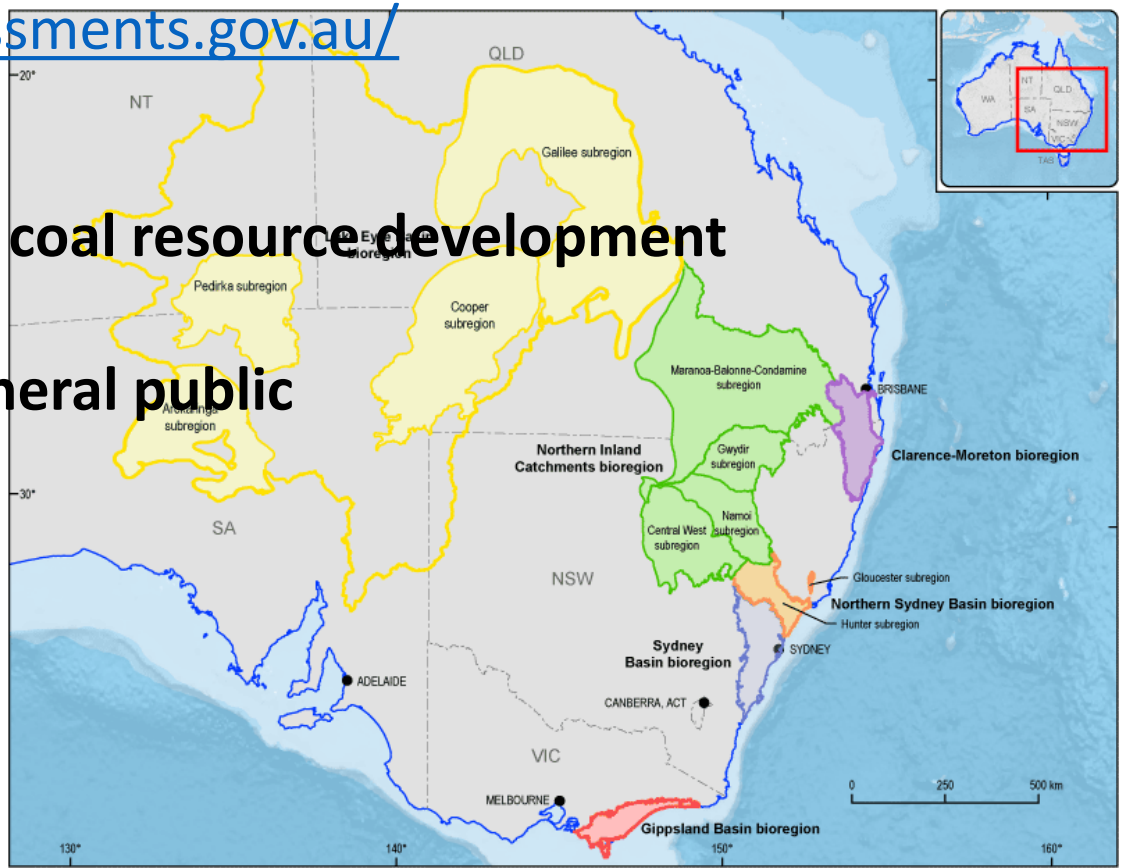
Generic, robust model -and data-independent uncertainty quantification

Luk Peeters, CSIRO Land & Water, Australia

Bioregional Assessments

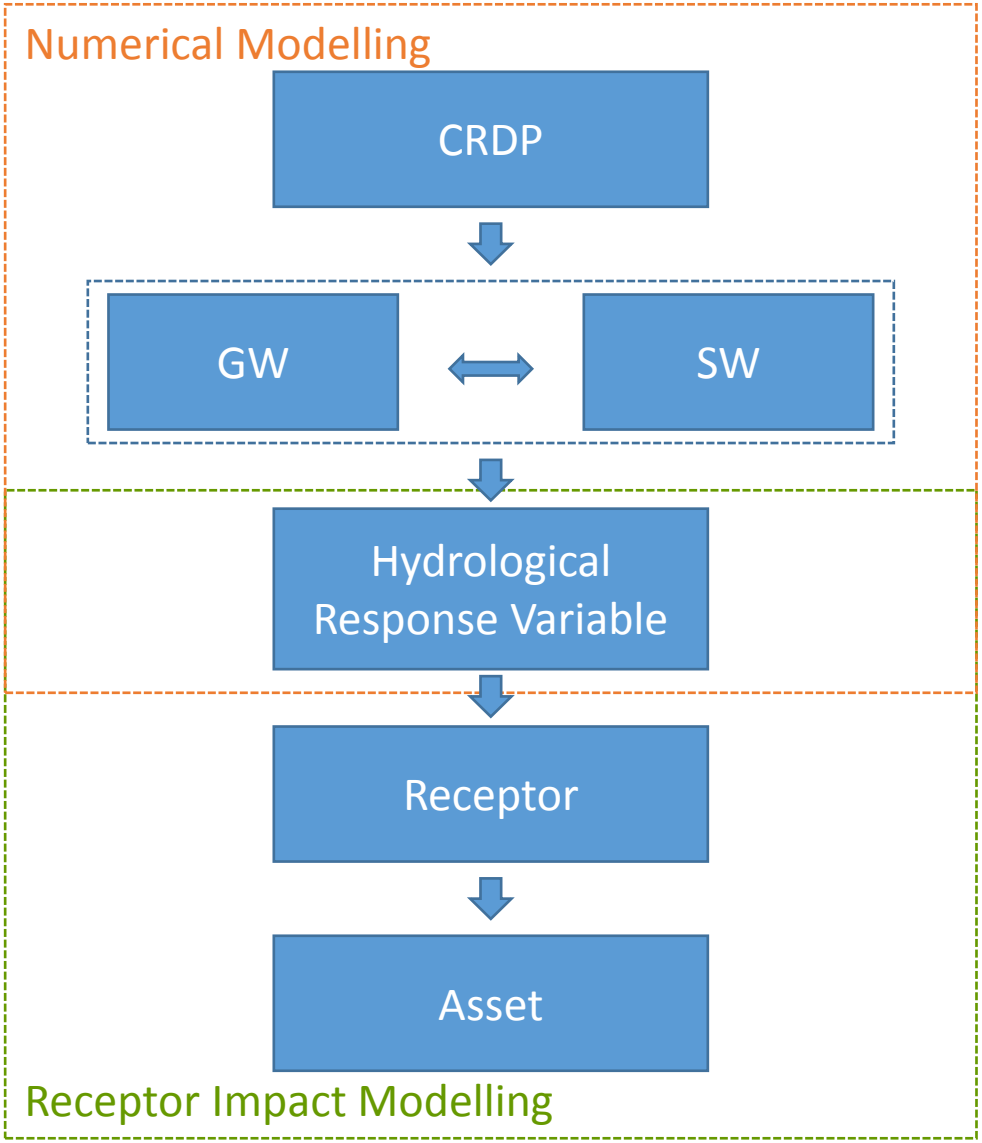
http://www.bioregionalassessments.gov.au/

- **risk analysis of impact of coal resource development on water related assets**
- **advise government & general public**



Bioregional Assessments

1. Define
   a) stress
   b) prediction
2. Establish model
3. Figure out what matters
   a) qualitative
   b) quantitative
4. Priors
   a) experts
   b) soft/hard data
   c) constrain by state obs
5. PDF of prediction

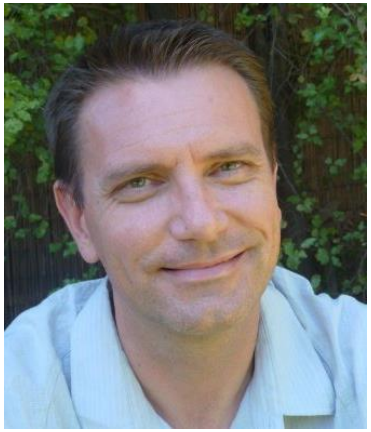


Conclusions

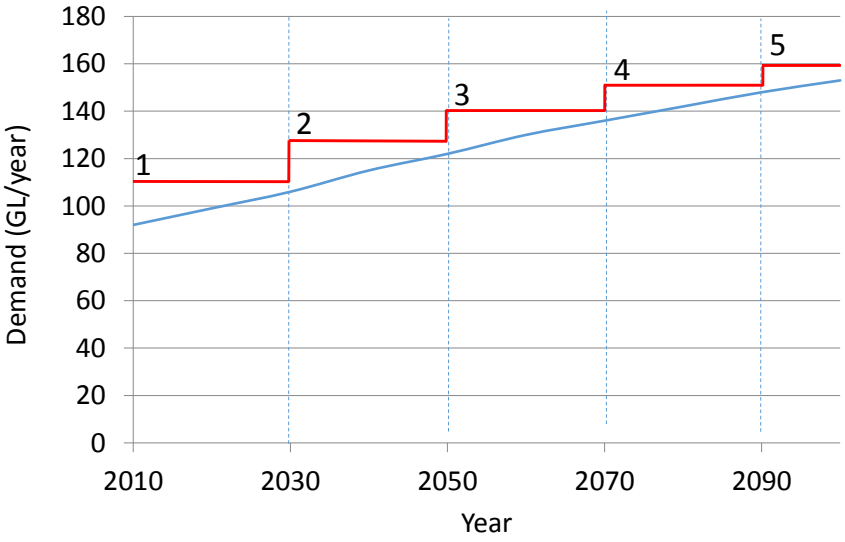
- Focus on stress & prediction rather than model & data
- Sensitivity analysis - qualitative
  - Set of scenarios
  - Explicitise hypotheses underlying the scenarios
- Qualitative analysis discussion starter for public review
- Starting point for receptor impact modelling

Optimal Water Infrastructure Planning Under Deep Uncertainty: Balancing Robustness, Flexibility and Adaptability

Holger Maier, University of Adelaide, Australia



The Planning Problem

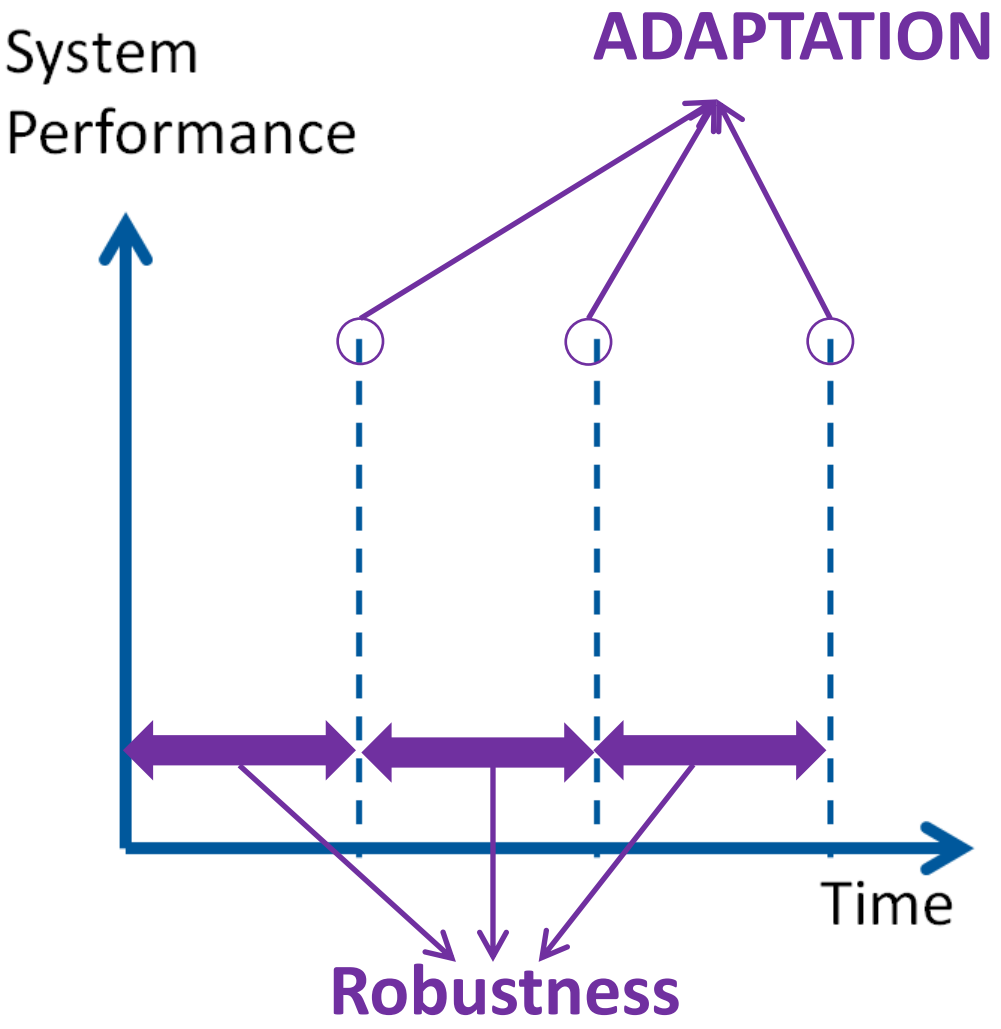


Long-term water infrastructure planning is complicated by:

- Global (deep) uncertainty
- Longevity of infrastructure
- Long project lead times

The planning dilemma

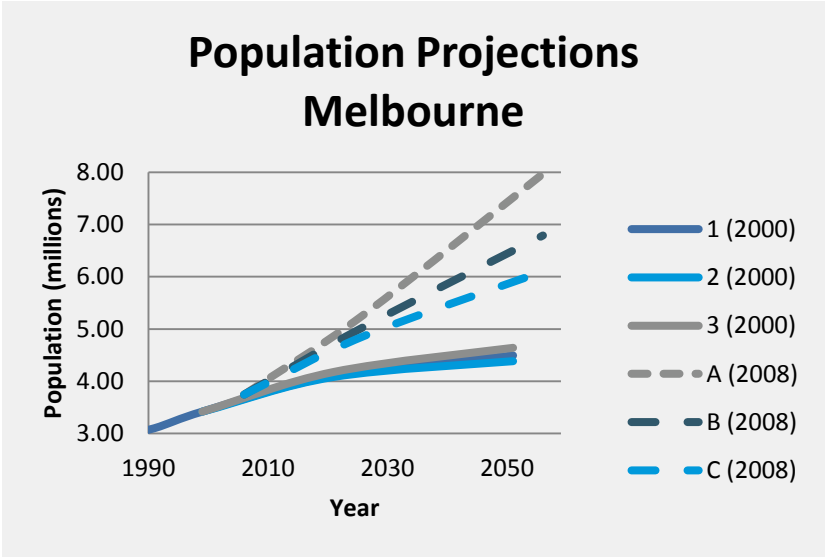
Solution: Robust adaptation



Socio-technical modelling tools to examine urban water management strategies under deeply uncertain future scenarios

Christian Urich, Monash University, Australia

Deep uncertainty - Using scenarios to support strategic planning



Predictive — Probable: What will happen?

Explorative — Possible: What might happen?

Normative — Preferred: How to reach a vision?

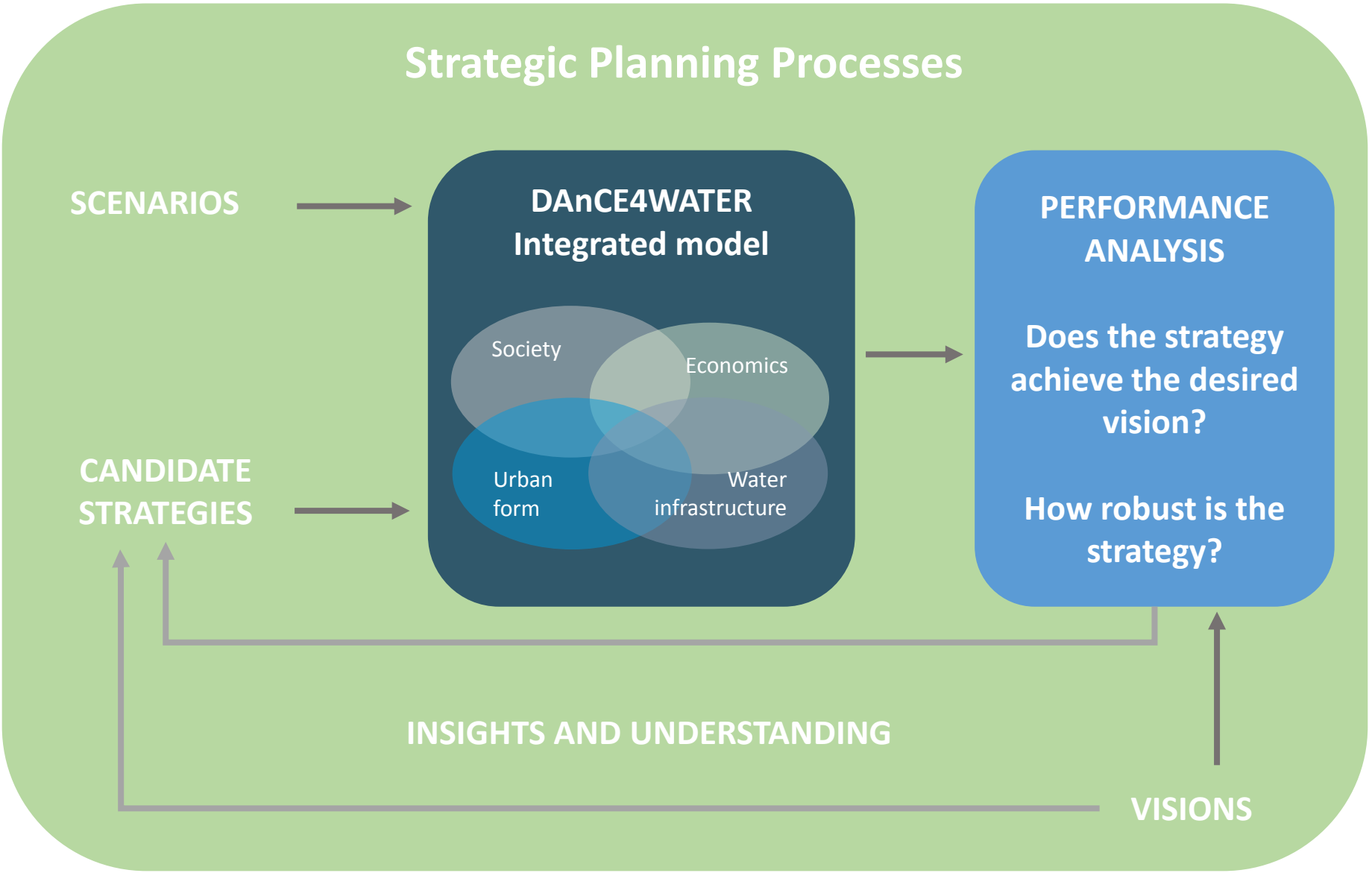
Backcasting from a future vision

Water Sensitive City

Current System

Ferguson et al. (2012) Melbourne transition scenarios

DAnCE4Water as exploratory modelling tool



Overall discussion

- Uncertainty is always implicitly considered
- Uncertainty is now talked about explicitly, so
  - People need/want to communicate about it
  - People need/want to be educated about it
  - People want transparency about it
- Trust in model-based decisions relies on success on the above

Overall discussion (cont'd)

- Within consulting companies,
  uncertainty is typically dealt with by the risk analysts
- Engineers are typically not in contact with risk people
  (closed because of corporate risk)

Overall discussion (cont'd)

- Early involvement of stakeholders in model-based decision making is essential, to
  - Make the model-based approach acceptable
  - Make the model choice transparent
  - Help define the expected uncertainties

- Multicriteria analysis leads to subjective weighting
- The decision-making must thus involve the stakeholders to make that weighting transparent
- This must be prepared at the project definition phase and must involve uncertainty aspects

Steps to accelerated adoption

Method development

- PDF selection
- Incorporate expert knowledge
- Correlation
- Incorporating human error & equipment failures
- Accounting for temporal and spatial variability (3-D space vs. simulation space)
- Meaningful composition of heterogeneous components (different sources, large variety of interaction mechanisms, different levels of abstraction)
- Generating additional key process indicators such as process stability

Concept communication

- Variability vs. uncertainty
- Moving from single parameter values to distributions
- Communicating key concepts - PONC
- Scenario development
- Visualization
- Psychology and preferential engineering

Method adoption

- Incorporating existing design concepts e.g. “max month”
- Linking SF in guidelines to sources of uncertainty
- Developing MOP for methods
- Case studies
- Post project audits
- Collaboration: engineer-modeler-statistician
- Software tools

Workshop

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