Centralised Protocols for Estuaries: the Hunter River Valley Experience

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Abstract:

Estuaries are large geographic areas, containing many stakeholders and competing interests. Within an estuary, various studies are commonly undertaken to address multiple issues over varied spatial and temporal scales. This process often leads to each study starting anew with significant efforts spent on collating local data and reports, assessing quality control, redeveloping models, etc. As this process is repeated for each study, there is a significant loss of time and resources, a repetition of outcomes and a requirement to conduct robust peer reviews to verify approaches, data and verification procedures.

This research developed an estuary wide platform to streamline data and numerical modelling approaches for the entire Hunter River Estuary. The approach ensures future projects are undertaken using the best available information and techniques. Physical datasets and knowledge gaps were identified with prioritised data gathering programs outlined. All existing numerical models were reviewed and a series of modelling protocols established for future model developments. An estuary wide Steering Committee was also established to ensure that future projects follow the approach and established protocols.

The establishment of centralised modelling protocols, an ongoing estuary wide Steering Committee, electronic database and prioritised data gathering program provides significant long-term benefits to all future projects conducted across the estuary. This will ensure major projects and policy can be assessed efficiently using the best available scientific data for the Hunter River Estuary. The protocols and platform are encouraged for estuaries worldwide.

Introduction

The Hunter River and its estuary (Figure 1) are important to a wide range of stakeholders. The upper estuary, including the tidal pool, provides vital freshwater resources directly influenced by the upper catchments including regulated areas and large extraction industries. The mid-estuary contains internationally significant and recently restored tidal wetlands, whereas the lower estuary is home to large urban and industrial/port developments. The overall management of these assets, as well as a range of other stakeholder and environmental interests, requires an integrated approach based on scientific best practice.

Computer (or numerical) models are commonly used to help guide decision making. The models, based on real-world datasets, can be used to inform regional planning, guide scientific and environmental management, extrapolate existing data, help to understand the influences of development actions, and detail future scenarios. To date, a number of numerical models have been developed for the Hunter River estuary, using disparate datasets and various modelling techniques. Lacking a coordinated approach, the existing models have been developed in isolation resulting in piecemeal outcomes tailored to individual locations or problems.

To achieve a modelling standard necessary to guide accountable and informed decision making, an overarching coordinated approach has been proposed. The "Hunter Valley Hydrodynamic Platform and Model Project" has been developed to provide a whole of government physical processes model (or suite of models) for the Hunter River estuary. Once developed, the model(s) will inform various planning milestones including the 10-year review of the Hunter Regulated Water Sharing Plan, the Salinity Trading Scheme Regulation, the 5-year review of the Hunter Unregulated Water Sharing Plan (Williams River), the 10-year review of the Paterson River Water Sharing Plan and the Upper Hunter Water Sector Strategy Statement. Importantly, a comprehensive model based on the best available datasets, aligned with stakeholder requirements, that is scientifically robust, peer reviewed and flexible will provide, for the first time, a cost-effective and coordinated modelling approach to support planning, policy, the environment and industry.

A Scoping Study was undertaken to develop the protocols for the Hunter Valley Hydrodynamic Platform and Model Project. The Scoping Study objectives were to:

- Undertake a review of the existing data and models and identify any data gaps;
- Identify the modelling needs of the key stakeholders;
- Recommend the types of platform and model packages that could be used;
- Identify governance arrangements including custodianship and options for access and maintenance of the model; and,
- Provide recommendations on the future staging, timeframes and costs for the development of the model.

Following the Scoping Study future project stages have been proposed including Platform Development and Data Refinement (Stage 2), and Model Development and Ongoing Maintenance (Stage 3). This paper summarises the findings from the Scoping Study including methodology and recommendations. More detail can be found within Glamore et al. (2014).

It is important to note that this study was focused on the Hunter River estuary (Figure 1). This includes catchment inflows, estuary hydrodynamics and associated water quality modelling. This study does not include flooding processes, overbank inundation or detailed upland modelling of the upper (non-estuary) catchment.

While the findings present below are specific to the Hunter River estuary, the recommendations are largely applicable to estuaries worldwide. Preliminary discussions with estuary managers worldwide suggest that no other centralised modelling platforms exist globally and that this project represent world's best practice.

Figure 1: Hunter River Estuary and Tidal Limits

Modelling History

At the time of writing, reports pertaining to 12 different estuarine hydrodynamic and water quality models of the Hunter River estuary were available for review. These models range from one-dimensional (1D) empirical relationships to complex 3D bio-geochemical simulations. Similarly, the spatial and temporal resolution of the models has a broad range. The temporal domain ranges between 4 weeks and 76 years, although the spatial domain is generally constant from the ocean entrance to Oakhampton, Gostwyck and Seaham Weir.

For this study each model was identified by its:

- year of establishment;
- the organisation/person responsible for its development;
- derivation of boundaries conditions;
- areas of the estuary prioritised for model performance;
- if and how the models were calibrated and verified; and
- the nature of simulations run.

A detailed review of each model was undertaken for the study examining it's structure, relevance and limitations. A breakdown of the modelling review can be found in Glamore et al. (2014).

Stakeholder Engagement

As part of this study, various stakeholders in the Hunter River valley were contacted to determine their ongoing and future modelling and data requirements. To ensure that this process was inclusive and broad ranging, the engagement process initially focused on identifying estuarine issues that were important to stakeholders. This information was then distilled into relevant modelling needs and data gaps. A description of this process and relevant findings is detailed below.

The stakeholder list was generated in consultation with NSW OEH, City of Newcastle, the NSW Department of Premier and Cabinet, and NSW Office of Water. The final stakeholder list included representatives from public utilities, state and local government, local action groups, non-profit organisations and large corporations.

A stakeholder engagement workshop was held to outline the study aims, discuss relevant issues and detail outcomes. Over forty (40) organisations were contacted as stakeholders for this study. Following the workshop, attendees were asked to complete a questionnaire and provide any additional feedback on the project.

During the workshop attendees were asked to highlight:

- key relevant issues,
- available datasets,
- their modelling needs,
- barriers to modelling or data integration,
- benefits from the study,
- optimal governance and policy arrangements, and
- preferred outcomes.

The results from the engagement process have been used to guide knowledge gaps, determine barriers/benefits to moving forward and construct sustainable governance arrangements. A detailed flow chart (or mind map) was developed based on the stakeholder feedback to link the key management issues, information/data requirements and relevant processes that influence the Hunter River estuary. The outcomes from this process are detailed below.

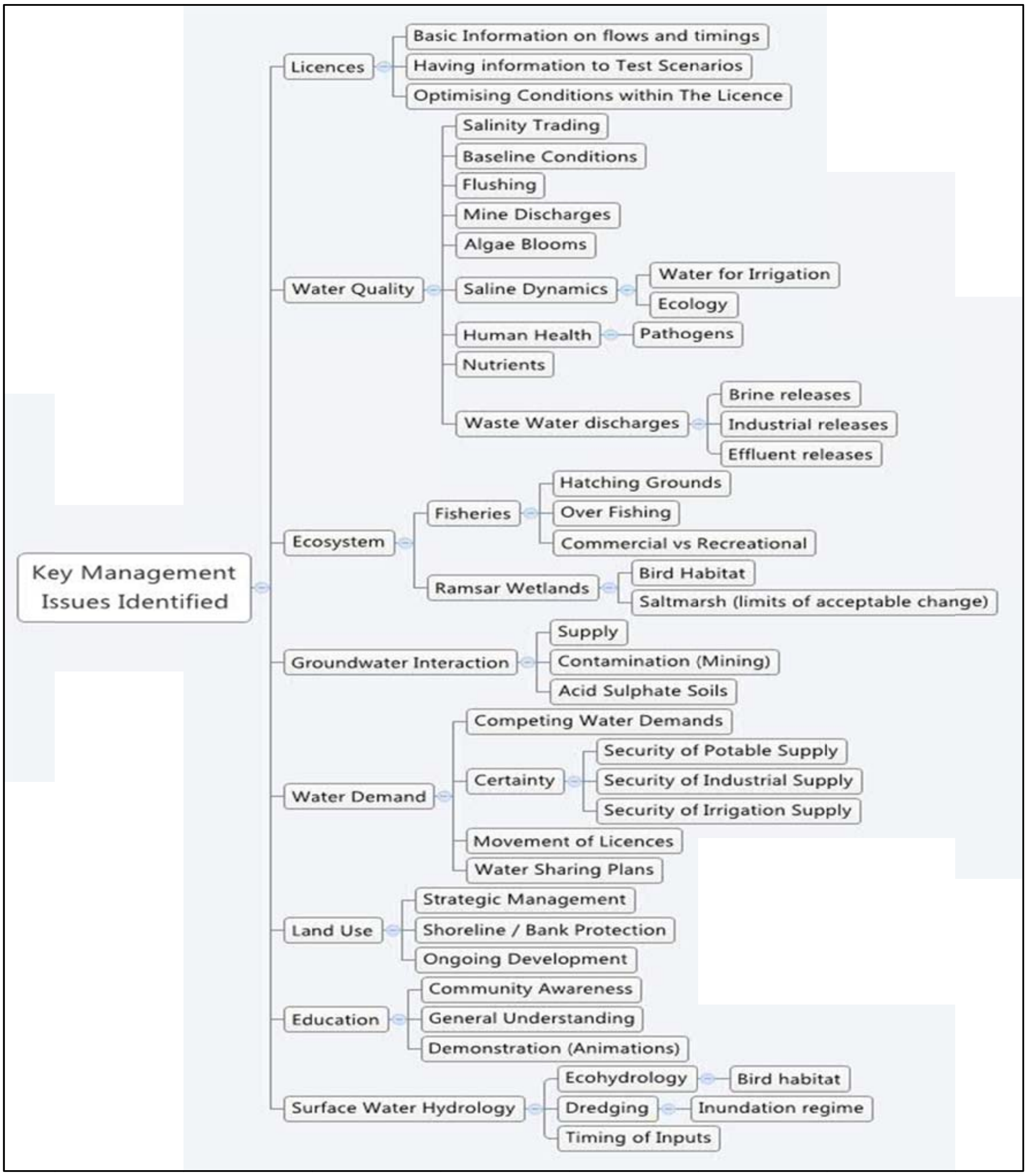

Figure 2. Key Management Issues Identified

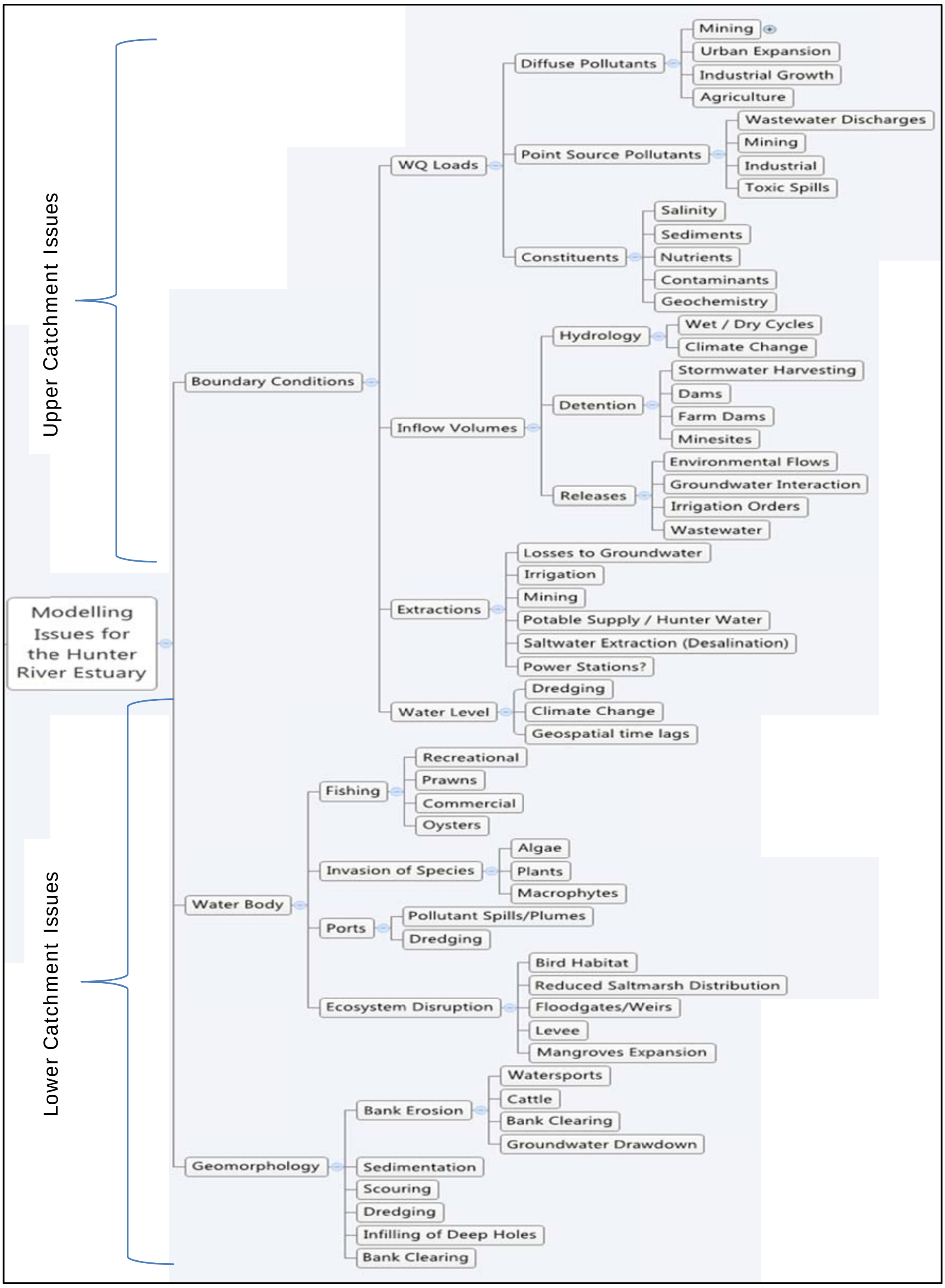

Figure 3. Modelling Issues for the Estuary

In addition to identifying key management and modelling issues (Figure 2 and 3), stakeholder discussions also focused on existing barriers to sharing information and datasets. This is particularly relevant as the existing data is owned by multiple stakeholders. Discussions indicated that many different groups have valuable data that would directly support a catchment and/or hydrodynamic model of the estuary

Any attempt to centralise this information requires an assessment of:

- where the data exists,
- the quality of the dataset,
- why the data was originally collected
- any legal liability or intellectual property issues, and
- data formatting and access (i.e. digitising hard copies).

Stakeholders identified a range of potential steps that would assist with data collation and sharing. These included (i) developing centralised plans for addressing missing data gaps, (ii) cataloguing previous studies and (iii) providing a centralised location for users to ask questions and discuss specific issues. Various stakeholders commented that the existing system of “calling around until you stumble across the right data source” is time consuming, inefficient and can promote the use of outdated data sources. However, one of the primary concerns with sharing data was the legal liability and intellectual property rights associated with the provision of previously collected data.

In summary, while stakeholders have identified a range of issues that could be directly addressed by a well-calibrated and approved numerical model and various data sources that could support the model, they have also highlighted that significant issues must be addressed within an overarching governance structure if a centralised approach is to be successful.

Benefits of Centralised Protocols

During the engagement process, stakeholders were asked to outline the potential benefits of a centralised calibrated/verified model and database. Benefits were largely grouped into three categories relating to (i) planning, (ii) scientific assessments and (iii) integration with other activities. It is worth emphasising that potential cost savings of a centralised database were noted by several stakeholders and are a major benefit of the proposed approach.

Other items mentioned by multiple stakeholders include:

- consistency (i.e. the ability to apply the model over multiple problems and get consistent answers),
- confidence (primarily with regulators in making assessments), and
- a regionally based approach (versus a series of local models that are not integrated).

An ancillary benefit of a coordinated data/model approach is improved catchment and estuarine governance. While the datasets and modelling alone do not provide a governance structure several stakeholders discussed that any group which was to be ‘in charge’ of the database or model(s) would invariably act as a single point of contact for information. Improved governance across the catchment is a major action as noted by NSW Department of Primary Industries (2013).

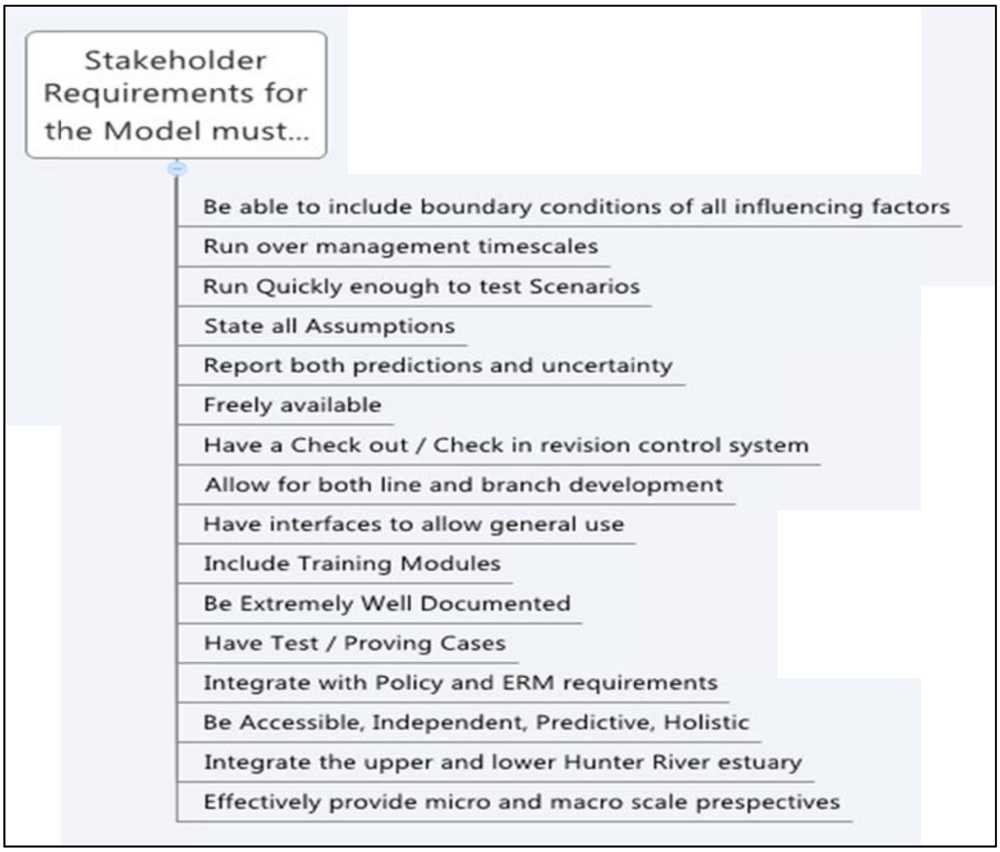

Figure 4. Stakeholder Requirements for any Proposed Modelling Platform

To assist in guiding stakeholder discussion, three governance arrangement models were identified as examples namely, (i) Open Access, (ii) Protocol Based, (iii) Sole Custodian. The open access approach is similar to Wikipedia where data is centralised onto a single server and the user community is responsible for quality assurance/control. In contrast, the Protocol Based approach establishes a series of criteria, tests and/or rules with which the users must comply (eg. Groundwater Modelling Guidelines). In the Sole Custodian model a single entity is in charge with all quality assurance, lending and data transfers the responsibility of the governing body (e.g. Bureau of Meteorology). While operational costs increase from the Open Access model to the Protocol Based model to the Sole Custodian model, the level of quality assurance is also likely to improve. To determine the preferred approach, stakeholders were asked to consider each model and outline their preferred governance outcome.

Amongst stakeholders there was limited desire for the Open Access governance model. The Protocol Based model was preferred by approximately 40% of stakeholders as it provides a means for ensuring quality control without limiting modelling approaches or software. The Protocol Based model was also preferred by several stakeholders due to the limited ongoing costs (in comparison to the Sole Custodian Model). In contrast the Sole Custodian model was desired by approximately 60% of stakeholders. The primary reason for preferring the Sole Custodian model was the high level of quality control, the long-term cost effectiveness, the ability to continuously update the data/model(s) and the ability to have explicit approval of a model/dataset by a regulator. The Hunter River Salinity Trading Scheme was highlighted by several users as an effective sole custodian approach model.

Several stakeholders highlighted that data sharing and model governance should have alternative governance approaches. Overall the preferred approach across stakeholders was a sole custodian model for the meta data sources ***and*** a protocol approach for the numerical model(s). The primary benefit of this combined approach is the cost savings associated with data sharing, while also allowing/promoting model development from various groups (to investigate various problems using different approaches). The protocol approach for the numerical model(s) would also decrease any perceived risk of unfair market practices. A publically available data portal approach with either annual membership fees or per use fees was mentioned by various stakeholders as suitable for this approach. Stakeholder requirements are detailed in Figure 4.

Despite the potential barriers, each of the stakeholders engaged in the study identified a number of important benefits and outcomes that could be achieved with the development of a centralised database or numerical model. Stakeholder feedback suggested that the overall preferred approach is a centralised database operated by a singular governance entity and a protocol based modelling approach. While a singular modelling approach was preferred by several stakeholders, there are major concerns amongst the stakeholders consulted associated with usability, model access, market practice, long-term governance and cost structure.

Issues and Risk Assessment

This study has been designed to assess the major barriers and benefits of a centralised multi-user numerical model of the Hunter River, focused on estuarine hydrodynamics (and excluding flooding). Several of the key concerns were outlined through the modelling review, data gap assessment and via stakeholder engagement. A summary of the key points is provided below in Table 1.

Table 1. Issues to Consider in Future Project Stages

Issue Topic	**Comment**
Existing Models	A review of existing models indicates that no one existing model has sufficient breadth to cover all identified issues. Stakeholders largely agree that a centralised publically available database with updated information should be developed to guide future model development.
Data Gaps	Major data gaps have been identified, most importantly catchment inflow rates/timing and upstream bathymetry. Recent spot checks of bathymetry data indicates significant change in the upper estuarine reaches and extensive geographic gaps. Newly obtained data should align with new calibration and verification periods. Significant scientific data is required to better understand linkages between ecology and hydrodynamic processes.
Identified Issues	A wide range of issues have been identified for possible inclusion within future models. The main issues, however, are tidal pool saline dynamics and implications of dredging on tidal dynamics. catchment land use change, waterborne pollution transport, and planning are the immediate drivers for future models.
Data Sharing	For historic datasets there are financial costs associated with collating datasets and providing public access. Legal liability and intellectual property rights issues must also be addressed. For all future data collection exercises, a range of data collection protocols must be developed and adhered to.

Quality Assurance/Control	A rigorous system of quality control must be applied to the data and model to ensure scientific credibility. A robust and transparent QA/QC protocol is required and must be supported by peer review from eminent non-biased professionals.
Initial Governance	Any governance arrangement must be transparent, robust, provide open access, be simple to use, easy to update, non-bias, comply with statutory requirements, be designed for the long-term and be self-sustaining.
Sustainable Governance	To ensure long term viability, any governance arrangement must be designed with sound funding mechanisms (preferably integrated into existing funded mechanisms) ensuring cost recovery. Any developed numerical model must also aim to minimise software legacy issues and be easily updated.
Statutory Alignment	Where relevant, the modelling must align with statutory acts and existing modelling requirements. Future use of the model under a statutory system (versus voluntary) will ensure consistency and regulatory agency buy-in.

With regards to statutory alignment, a multi-agency approach is recommended. Any singular modelling or data sharing approach is unlikely to be successful unless the models align with one or several act(s). A range of processes and relevant statutory acts that the model will need to comply with are summarised in Table 2.

Table 1: Statutory and Regulatory Alignment

Legislation or Processes	Comment
Water Sharing Plans	Final model should align with available approved IQQM catchment inflow models.
State Significant Development and State Significant Infrastructure	No formal enactment mechanism or ability to compel users to use data or models
Wastewater Discharge or extractive industries	Complies with relevant Environmental Protection Licence assessment and licence under the POEO Act.
Dredging	Compliance includes the Fisheries Management Act (1994) for Part 5 and Part 4 EP&A Act development proposals.
Estuary and Stormwater Management	Linked to Council's Part 4 Development assessment but lacking statutory act for enforcement.

Recommendations

Based on the information available the recommendations of the study include:

1. Undertake data gathering of high priority knowledge gaps.
2. Develop a centralised database with relevant datasets collated under a data sharing agreement with standardised quality assurance/control.
3. Upgrade catchment hydrology models to ensure valid upstream boundary conditions.
4. Use the best available data to develop a 1D/2D hydrodynamic model.
5. Develop a 3D version of the model for specific investigations in the lower estuary.
6. Outline modelling protocols to permit alternative model developments/configurations that comply with defined specifications.

The following section outlines the rationale behind the above recommendations. A summary is provided in Figure 5.

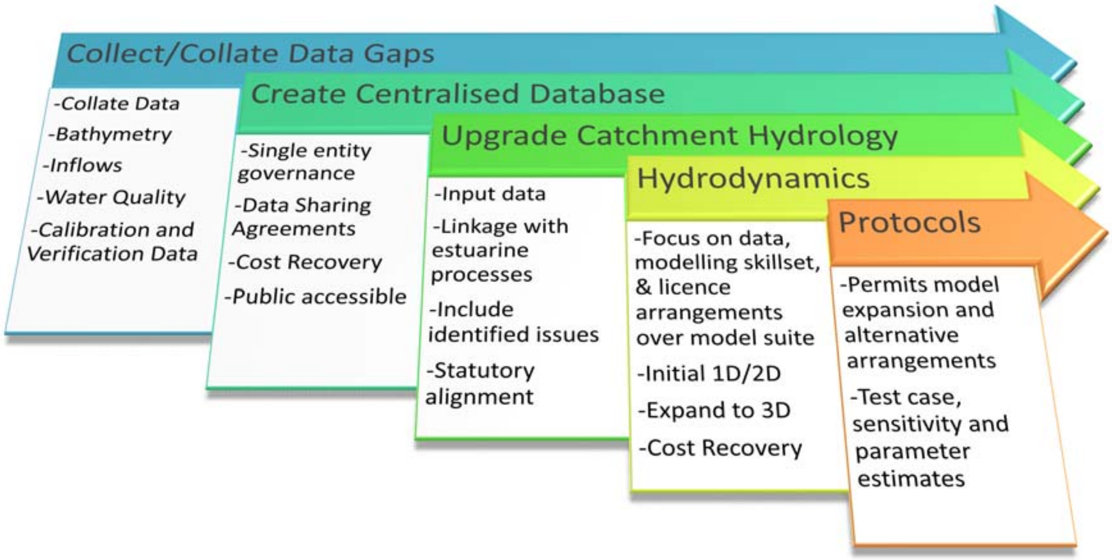

Figure 5: Summary Flowchart of Scoping Study Recommendations

Undertake data gather of high priority knowledge gaps.

Fundamentally, numerical models are developed to interpolate and extrapolate known datasets and test scenarios. The data gap analysis indicates that significant knowledge gaps exist in the available data. Collection of the recommended data would reduce model uncertainty, particularly in the upper estuary and in relation to the tidal pool dynamics. Targeted data collection exercises designed to align with the new datasets would also provide confidence in the calibration and verification process. Common Quality Assurance protocols should be followed for collection, analysis and reporting of the collected data.

Develop a centralised database with relevant datasets collated under a data sharing agreement with standardised quality assurance/control.

The existing available data should be collated within a centralised database or data warehouse. Each dataset should contain a meta-data file outlining the data collection procedure and quality assurance protocols. All efforts should be undertaken to ensure that the database is a comprehensive reflection of the available data. Where relevant, the database can act as a data portal to other ongoing collected datasets such as water levels and salinity data maintained by the Manly Hydraulics Laboratory or meteorological data maintained by the Bureau of Meteorology. Standardised data protocols are available to align datasets and apply quality assurance controls.

Collaboration and coordination between government agencies, universities, industry and related groups is required to optimise the data included in the database and share information amongst stakeholders. Data acquisition and sharing agreements between groups must be negotiated to ensure the data providers are not liable for the ongoing use of the data. Creative Commons licenses are recommended to communicate which rights to reserve and which rights to waive for the benefit of recipients or other creators.

Creative Commons Australia (http://creativecommons.org.au/) provides a range of free licences to share and reuse material legally. It is worth noting that AusGOAL, the Australian Governments Open Access and Licensing Framework, provides support and guidance to government and related sectors to facilitate open access to publically funded information (http://www.ausgoal.gov.au). AusGOAL supports the Australian Information Commissioners Open Access Principles and assists organisations in managing risks when publishing information and data. AusGOAL provides a licence suite that includes the Australian Creative Commons Version 3.0 licence, which could be directly applied to reduce uncertainty in data management and licencing for the proposed database. It is recommended that the database would be operated and maintained by a relevant government authority.

Upgrade catchment hydrology models to ensure valid upstream boundary conditions

The existing catchment models have several known operational concerns that limit the calibration and operation of any downstream hydrodynamic model. As a high priority task, the available catchment models should be collated and their capability assessed to produce accurate upstream boundary conditions. The review should take into account the issues identified by stakeholders pertaining to the upper catchment and available data and the timing requirements of hydrodynamic models.

The development of an upper catchment hydrology model calibrated for each catchment is a significant task requiring new datasets and extensive resources. As an interim measure the existing models can be expanded to include the regions where existing models finish and inflows for the hydrodynamic estuarine model commence. An alternative approach is to establish long term discharge locations at relevant estuarine or tidal pool inflow locations.

The development of any upper catchment hydrology model must aim to ensure that relevant statutory arrangements are considered. Where statutory arrangements are not applicable then a non-binding arrangement or memorandum of understanding between major stakeholders to use and develop the final catchment model is recommended.

Use the best available data to develop a 1D/2D hydrodynamic model of the entire estuary.

A range of hydrodynamic models have been previously developed for the Hunter River estuary. All of the existing models are constructed using information that does not accurately reflect the existing river bathymetry and require updating to current bathymetry and improved inflows. Concurrently, calibration and verification data is required to align flows, water levels and water quality data across the spatial domain with any new bathymetric or inflow data collected. This new information should be used to design (or upgrade) a hydrodynamic model of the Hunter River's estuary.

Based on the identified issues, a 1D/2D model of the river is recommended as a minimum. The 1D sections are applicable for areas upstream of Hexham Bridge with 2D (depth averaged) model refinement in the lower reaches of the model. A water quality dispersion model should be linked to the advection transport model.

The 1D-2D numerical model has several advantages over a more complex model. A 1D/2D model can quickly run over extended time periods effectively simulating historic

(50-100 years) time periods. This permits extended calibration periods over various environmental conditions. Computational efficiency also ensures that multiple scenarios can be tested. In combination, this will allow the model to be used for analysing the upper and mid estuary dynamics, including a conservative tracer (e.g. saline dynamics) for a range of uses (water sharing plans, environmental flow assessment, scenario testing of outfall discharges, ecosystem understanding, etc).

The developed model would need to be scientifically robust. The model would need to undergo extensive discharge and water level calibrations in the upper and lower sections of the estuary as well as comparison to velocity vectors in the 2D sections. Model verification is required from an alternative time period but should align with the updated bathymetry records. Model reports should be peer reviewed and the results of the peer review should be publically available. The calibration and verification process should ensure a range of tidal and flow conditions are tested to suit various environmental conditions.

Most numerical model packages commercially available are suitable to develop a 1D/2D model of the Hunter River. A review of commonly available modelling suites when undertaken for the study and indicated that several 1D/2D models are available that are technically suited to model the physical processes of the Hunter River's estuary and that no singular model or modelling package platform provides a standout significant advantage. For all commercially available modelling packages, key areas of consideration include ongoing model licence costs, training/education, availability of test cases, post processing file options, linkage with 3D packages, linkages with groundwater models, licence transferability, linkages with upstream catchment models, built-in versus customisable water quality modules and parameter estimation capabilities.

A sole government entity is the preferred governance arrangement. Model governance is best achieved when one entity is the primary manager. As such, a single governance approach with agreed sharing arrangements (as per the AusGOAL protocols) is recommended. It is envisaged that once the model is developed and associated check in/out and quality checks systems finalised, the ongoing costs associated with model management would be limited.

The recommended 1D/2D model will ensure the main issues identified can be adequately modelled in a scientifically defendable and numerically efficient method. A few identified issues, however, require a 3D approach in the lower estuary. This is particularly relevant in areas where tidal stratification or 3D currents are important such as in sediment transport studies or when modelling surface plumes (e.g. oil or ammonia spills, ballast water, etc).

To ensure that these processes are included, a 3D version of the hydrodynamic model is recommended. A 3D version should have sufficient vertical resolution to adequately represent the key processes. However, since a 3D model requires additional computing resources and may not be required for simulating many physical process, it is not recommended for the majority of modelling scenario testing. It is recommended that a 3D model is generated alongside the 1D/2D model and governed under the same arrangements/protocols. Importantly, the 3D model will require targeted 3D field data collection exercises to calibrate the model at various locations.

Outline modelling protocols to permit alternative model developments/configurations that comply with defined specifications.

The above recommendations will ensure that a state-of-the-art numerical model designed using current best practices will be developed for application over the wide majority of issues identified by stakeholders. The model would be made publically available (potentially via a cost recovery basis) and updated as additional data is gathered. All efforts should be undertaken to ensure that the model remains scientifically robust, peer reviewed and inclusive of all modern modelling techniques.

For various purposes, alternative hydrodynamic models may be created of the Hunter River and its estuary. Alternative models may be created to answer specific scientific questions or examine alternative spatial or temporal scales. Stakeholders or other consultants may perceive that a single model creates an unfair market practice or they may wish to create an alternative model to challenge legal outcomes or assumptions. In these circumstances, it is worthwhile to develop modelling protocols that permit alternative model configurations and comply with defined specifications.

Modelling protocols should be developed in conjunction with the outcomes from the newly developed 1D/2D/3D models. Standardised simulation tests indicating the acceptable level of uncertainty can be developed following the calibration and verification of the 1D/2D/3D models discussed previously. This is likely to include a range of test case scenarios, parameter estimates and sensitivity tests. The final protocols, including simulations for reference points and calibration and parameter variability, should be developed in conjunction with the reporting for the 1D/2D/3D modelling.

Proposed Governance Arrangement

A cost recovery scheme is recommended to ensure a cost neutral outcome. Initial grant funding would be required to establish the database, develop the model depository and finalise sharing terms and conditions. The cost recovery operation should be designed to ensure the long term carriage of the project and a business operation plan for the long term development, licencing and updating of the database and model should form part of any database/modelling request for tender.

Of particular importance to the project is ensuring that the created database and model are promoted by government agencies, industry, stakeholders and related bodies. While the need and benefits of the model have been outlined by the stakeholders, the model is unlikely to have any statutory powers. As such, a memorandum of understanding or non-binding agreement is recommended between key groups to ensure that the database and model will be the primary source of relevant information in the Hunter River's estuary. As this is fundamental to the success of the project, this agreement should be undertaken as a high priority task before any major investments are made towards database and modelling development.

A steering committee is recommended to oversee the database and model development and ensure the optimal conditions are created to ensure long-term maintenance. While it is recommended that the committee be chaired by staff from the NSW Office of Water, the committee should also include representatives from key stakeholders such as Hunter Water, NSW OEH, NSW Department of Premier and Cabinet, an industry representative (i.e. potentially NPC), a Council representative, and independent experts in estuarine data techniques and numerical modelling. The committee's primary function would be to provide oversight of the initial establishment of the database and models, ensure the long-term viability of the project, develop procurement strategies, approve development and operational budgets, and provide oversight/resolutions on any relevant disputes. The committee members would also provide regular reports back to their respective entities to ensure that partnering groups are informed and remained committed to the process.

Summary

The Hunter River and its estuary are important to a wide range of stakeholders in the region. To date, a number of numerical models have been developed for the Hunter River estuary, using disparate datasets and various modelling techniques. Lacking a coordinated approach, the existing models have been developed in isolation resulting in piecemeal outcomes tailored to individual locations or problems.

To achieve a modelling standard necessary to guide accountable and informed decision making, an overarching coordinated approach has been proposed. The "Hunter Valley Hydrodynamic Platform and Model Project" has been developed to provide a whole of government physical processes model (not including flood modelling) for the Hunter River estuary. A comprehensive model based on the best available datasets, aligned with stakeholder requirements, that is scientifically robust, peer reviewed and flexible will provide, for the first time, a costs-effective and coordinated modelling approach to support planning, policy, the environment and industry.

This paper outlines the methodology and findings from the first stage of the Hunter Valley Hydrodynamic Platform and Model Project's Scoping Study. Additional stages are currently ongoing.

References

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