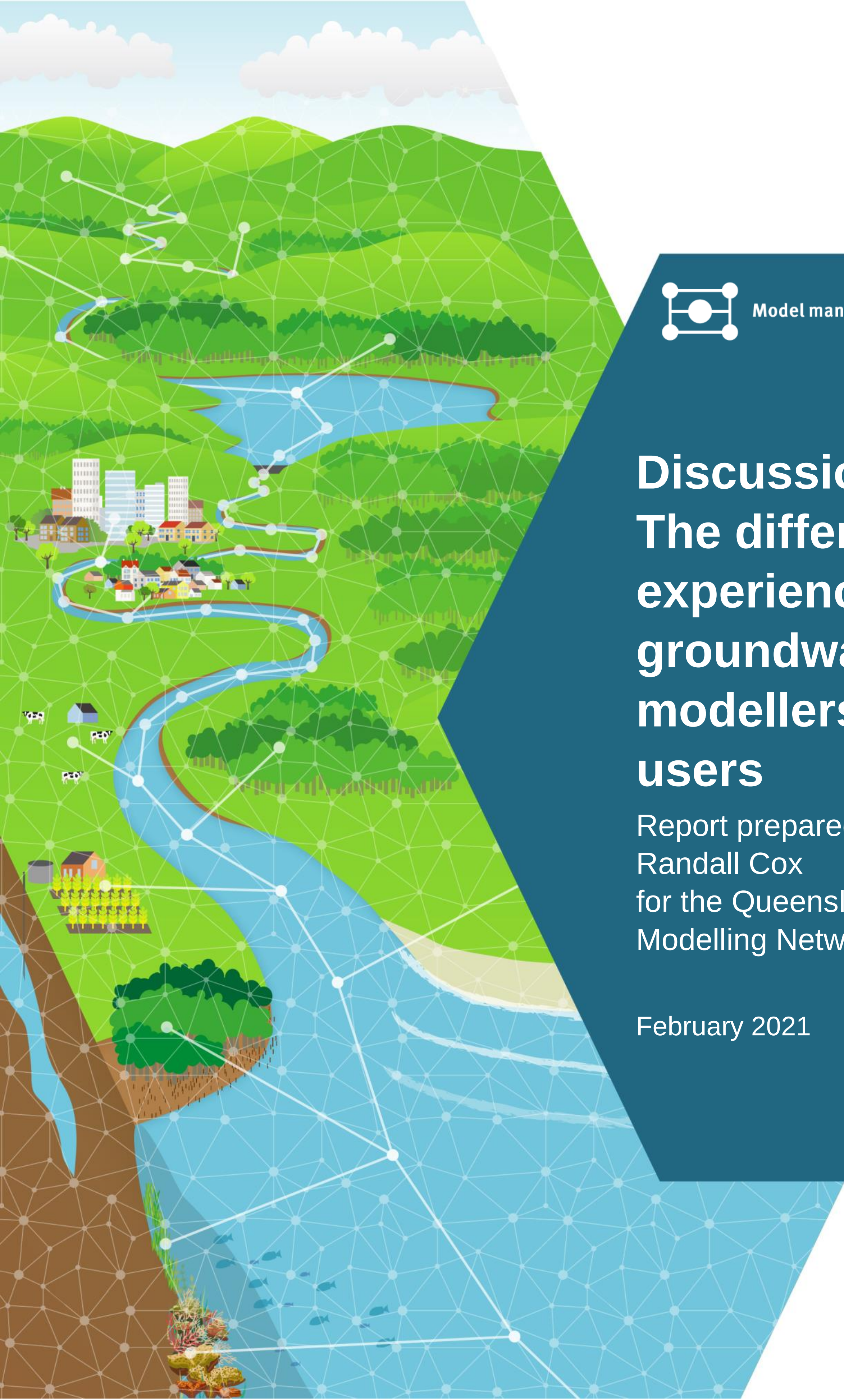
QUEENSLAND WATER MODELLING NETWORK



Model management

Discussion paper: The different experiences of groundwater modellers and end users

Report prepared by
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for the Queensland Water Modelling Network

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Queensland Government

The Queensland Water Modelling Network (QWMN) is an initiative of the Queensland Government that aims to improve the state's capacity to model its surface water and groundwater resources and their quality. The QWMN is led by the Department of Environment and Science with key links across industry, research and government.

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Executive Summary

This paper has been prepared for the Queensland Water Modelling Network (QWMN) with a view to increasing the use of groundwater models by prompting discussion about the interaction between groundwater modellers and the end users of the models.

The paper is based on one-on-one discussions with 21 senior modellers and end users. The discussions were semi-structured enabling the interviewees to raise issues from their own perspective based on a shared general framework. The method is not, therefore, a highly structured or detailed analysis of practitioner views, but the paper may provide a useful basis for further discussion in modelling and end user communities.

Outcomes are summarised as follows:

1. A lot of problems could be avoided if modellers and end users spent more time together at the beginning a modelling project, clearly identifying the management issue to be addressed and the potential to construct a groundwater model that would be useful in addressing the issue.

2. Modellers seek for end users to accept that there is uncertainty in groundwater modelling and a model can only be a decision support tool. End users point out that they need to make binary decisions and they therefore seek for modellers to see their perspective and make models as useful as possible.

3. It is becoming easier to make models more complex. This can result in models being more complex than they need to be, from a mathematical perspective. Models are also used by end users for educational purposes, however, and so need to be sufficiently complex to give stakeholders confidence that models adequately represent groundwater flow systems.

4. The need for engagement between end users and modelling teams is a recurring theme. The engagement needs to be early and ongoing, including peer review as a part of the process. Most of the difficulties between end users and modellers can be traced back to inadequate engagement.

5. Within some end user agencies, lack of groundwater skills and expertise is a major impediment to effective engagement with modelling teams. In those cases, external expert teams could be formed to support the end users in engagement activity.

6. The standard of reporting on modelling projects is highly variable. Poor reports are a problem for end users, both in understanding what has been done and for end user communication with stakeholders.

7. High-level modelling guidelines are supported but should not be misused as quasi-standards.

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Background

Purpose

This paper has been prepared for the Queensland Water Modelling Network (QWMN) with a view to increasing the impact of the use of groundwater models in informing policy, program, and regulatory domains, by prompting discussion about improving the interaction between groundwater modellers and the end users of the models. There are aspects of groundwater systems and of the different perspectives of modellers and of end users that cause difficulties in expectation and understandings, which can compromise outcomes. Although this paper explores those aspects, that focus should not detract from the fact that many modelling projects have been instrumental in positively supporting decision-making.

The QWMN Forum 2020[1] focussed on the 'water modelling pipeline' from research to model use, interpretation and communication. This paper links with matters explored at that Forum as it deals with some of the interfaces involved in movement along the water modelling pipeline.

The paper seeks to capture the views of a small number of experienced modellers and end users, to stimulate discussion. It does not reach detailed findings or make specific recommendations; rather, it seeks to narrow the focus to areas of more common concern and point to possible directions for improvement, for more detailed consideration by practitioners.

In this paper, the term 'end user' includes two subgroups:

- staff of regulatory agencies who consider applications for approval of development proposals; and
- managers who use model outputs to set water allocations and management rules and manage groundwater systems.

Where necessary the paper deals separately with those two groups of end users, while recognising there may also be other end users of groundwater models.

The term 'modeller' is the person who constructs a numerical groundwater model, although in places the term is used to cover all members of a modelling team that interfaces with an end user. As a result, a hydrogeologist may be a part of a modelling team while in another circumstance a hydrogeologist may be an end user using a model constructed by a specialist modeller for groundwater allocation management and communication purposes.

Method

The paper is based on one-on-one discussions that covered a range of perspectives. Preliminary discussions identified likely key areas of interest. Detailed interviews were carried out with 21 senior modellers and end users in the public and private sectors.

Interviews lasted about one hour. They were semi-structured discussions that enabled interviewees to raise issues from their own experience based on a shared general framework. From the interviews, common themes emerged. Individuals spoke frankly about successful and less successful projects that they have been involved in, on the basis that the discussion paper would not identify opinions about specific projects.

[1] https://watermodelling.org/resources/qwmn-forum-2020-presentations

The method used is not, therefore, a highly structured or detailed analysis of practitioner views; however, the paper may provide a useful basis for further discussion within the groundwater modelling and end user communities and may provide insights within the broader water modelling domain.

Use of groundwater models in decision-making

What is 'the question' that the model will explore?

Conceptually, a model is a thing that shows what another thing looks like or how it works, but a model cannot do everything. It is obvious that a clay model of a future car is good at showing what the car will look like but is no help in showing how the car will work. Similarly, a groundwater model cannot answer all the questions that arise in groundwater management.

There is a common theme among modellers and end users: that projects do not always commence with enough clarity about the management questions that proposed models are intended to explore. A water planner is likely to want a model for the purpose of testing options for management rules, and so there needs to be clarity about the potential scope of the management rules. A regulator considering a major development proposal will be seeking information about the long-term impacts of the development on receptors such as water supply bores and groundwater dependent ecosystems, and so there needs to be clarity about the receptors potentially at risk.

If there is opportunity for early discussion with the relevant stakeholders, it may become clear that a model is not needed at all. One experienced modeller operates on the following basis:

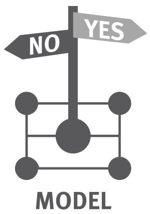
> *'There can only be confidence that "the question" to be explored by the model is understood and accepted as a workable basis for a modelling project if the underlying question, "exactly what scenarios will be run with the model?", has been explored.'*

End users bring another perspective to the issue; they seek early meaningful engagement with modellers to better understand what is realistically possible through modelling. One experienced end user said:

> *'It is difficult to engage modellers early in the process to discuss what is possible. We wind up getting model output only at a late stage of the decision-making window and discover far too late that the model can't do what we expected.'*

In summary, modellers seek early clarity on exactly what a proposed model will be used for, while end users seek early clarity on how groundwater modelling can be used in addressing a management issue. The underlying problem that leads to these differences in perspective relates to the timing and depth of engagement – a recurring theme in this paper.

Groundwater models are decision support tools



Much of the challenge with groundwater modelling arises from the fact that groundwater is a hidden resource. In comparison to other physical systems, including surface water flow systems, there is much more uncertainty. There is uncertainty about the hidden geological framework, as well as how water enters, moves through, and leaves the geologic framework. Reducing uncertainty through the acquisition of additional data is expensive and will never be completely adequate, so assumptions must be made.

Uncertainty, therefore, is a focus for all parties to a groundwater modelling project. Modellers act from a general position of seeking to specify and reduce uncertainty through the incorporation of additional relevant data and/or processes into a model. A model can help to understand the extent and sources of uncertainty and identify the future data acquisition and improvements in conceptual understanding that can best reduce it; however, output from a groundwater model will always be uncertain to an extent. As one modeller put it:

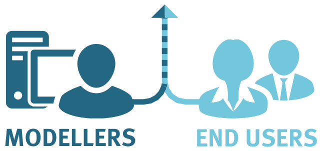
> *'Groundwater models are not "truth machines", they can only ever be "decision support tools".'*

End users recognise that an understanding of uncertainty is important in making informed decisions. End users, however, bring another perspective, pointing out that model output is a major input to the making of binary decisions, such as where to put a line on a map that separates areas where different sets of management rules will apply. End users therefore seek for modellers to view uncertainty from the perspective of the end user. For example, while it may be convenient, conservative and easily defendable for a modeller to accept a wide range of possible values for a hydraulic parameter, perhaps based on a simple literature search, the breadth of that range may lead to a wide band of uncertainty in model output. However, if the modeller was more sensitive to the management implications of the wide range of possible values adopted, a more complete search for relevant information might be carried out, leading to the adoption of a smaller range of values and a smaller uncertainty range in model output. The end user position could be summarised as:

> *'Groundwater models are not simply "mathematical exercises", they are "decision support tools" and must in fact support actual decision-making to the greatest extent possible.'*

Engagement issues

Early engagement results in better models



A consistent message from interviewees was that value is added by early engagement between the modelling teams and the end users. For projects that had poor outcomes, early engagement was usually missing or superficial.

Early engagement is important because of the wide range of skills and perspectives that need to be integrated in a modelling project. It provides opportunity to explore the prior knowledge and experience of the parties involved. Early engagement enables modellers to better understand the purpose and intended use of the model. If available, hydrogeologists with local expertise need to be involved from the beginning when the conceptual model of the groundwater flow system is being developed and relevant available data is being identified.

Interviewed modellers look for early engagement. They mentioned cases where there had been opportunity to visit the field at an early stage and discuss the conceptualisation with local knowledge experts and landholders. It was during those visits that they found the 'soft knowledge' about the 'hard data', which assisted them significantly. Some of the best insights came inadvertently, during informal conversations in the field and as relationships developed.

Continued engagement results in the best models

For projects that had the best outcomes, engagement was not only early but ongoing throughout the modelling project, continuing after formal project completion into review of the usefulness of model output and development of approaches to future model improvement. Continued engagement provides opportunity for progressive feedback, enabling adjustments to be made. When those with local hydrogeological knowledge start to see model outputs, they can point to constraints that need to be included. One example was given where initial model output implied that a reach of a watercourse would be a 'gaining reach', while local knowledge was that it was in fact a 'losing reach', information missed at the beginning of the project. This showed that the assumed water inputs, outputs and flow parameters could not collectively be correct, and some changes had to be made. When the model was modified to incorporate this constraint, model outputs changed, and the credibility of the model amongst local stakeholders improved.

Continued engagement over the length of a project also helps all parties to reach consistent understanding about how the model works, even if understandings are to different levels of detail. End users noted the need to be able to explain to stakeholders the assumptions, constraints, and output from a model, to a level of detail that meets the needs of stakeholders who over time develop better understanding and seek more detail.

Peer review during engagement

Over time, peer review has become accepted practice for groundwater modelling projects. Peer review initially was carried out at the end of a modelling project and was a review of the model itself. More recently, peer review has become a review of not just the final model, but the whole of the modelling process, as is called for in the Australian Groundwater Modelling Guidelines[2]. The approach involves presentation, discussion, and review comments, to be compiled at set points during a modelling project. This progressive approach improves transparency, exposes disagreements about assumptions and project directions at an early stage, allowing adjustments to be made and avoiding the need to go back to the beginning after arriving at what should be the end of a project. All interviewees strongly supported this approach.

Because groundwater modelling cannot be simply a matter of meeting formal standards, there is scope for individual peer reviewers to carry out peer review from different perspectives. Interviewees noted that early involvement of peer reviewers in a project provides opportunity to resolve issues arising from those differences.

Effective peer review of the whole process, starting with conceptualisation, requires a wide set of skills. To ensure reviewers have the range of skills and experience needed, it is tempting to consider some form of accreditation for peer reviewers; however, those interviewed considered that accreditation would be impractical because modelling is an agile science space, where proposed creative approaches need to be evaluated. As a result, interviewees considered that formalised accreditation would likely lead to difficulties in aligning accreditation to the state of play in modelling developments.

There was, however, support for the identification of high-level principles about the need for peer reviewers to have an appropriate breadth of skills and experience. Although the Australian Groundwater Modelling Guidelines do call for this, some suggested that there could be clearer recognition and endorsement of the peer review role.

Access to regulatory agencies

Engagement issues appear to be more problematic for modelling projects that support applications for approval of major development projects by regulatory agencies, than for projects that support water resource planning and management activity. The lack of engagement in the case of the development projects sometimes causes significant frustration for modellers at the decision-making stage. Modellers noted, for example:

> *'If a review comment by the regulator doesn't makes sense to me, I can't speak to the person who made the comment, to discuss it.'*

When issues arise at a late stage, regulators tend to seek external peer review to resolve disagreements; however, modellers contend that external reviewers brought in at the end of a project do not have enough time to become aware of the whole context of a project.

The staff of the regulatory agencies have their own perspective. They seek to have modellers who prepare reports in support of development applications also consider the wider regulatory context. Stakeholders will compare the approaches taken at comparable development sites and seek

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http://www.groundwater.com.au/media/W1siZiIsIjIwMTIvMTAvMTcvMjFfNDFfMzZfOTYwX0F1c3RyYWxpYW5fZ3JvdW5kd2F0ZXJfbW9kZWxsaW5nX2d1aWRlbGluZXMucGRmIl1d/Australian-groundwater-modelling-guidelines.pdf explanation of differences. Regulators aspire for modellers to consider this throughout a project. If there is no good reason to make different assumptions than were previously made at a comparable site, then the same assumptions should be used. If there is good reason to use different assumptions, then the reason should be explained. There needs to be transparency about the assumptions made and the data used to provide confidence that the assumptions and data are not selected to support a particular outcome.

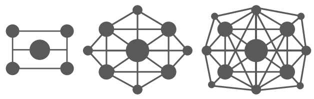
Complexity in models

Complexity is not always helpful in a mathematical sense

Modellers noted that it is becoming ever easier to build complexity into groundwater models. Where complexity is needed to best integrate conceptual understanding and available data to improve the usefulness of model output, the complexity is a good thing. Complexity is likely, however, to make the model slower to run, more difficult to calibrate, and harder to carry out uncertainty analysis. There is a view that modellers may be attracted to introducing complexity simply because it can be done and it makes the model appear impressive, without enough attention paid to how the added complexity improves the usefulness of output. The summary position could be expressed as:

'From a mathematical perspective, a model should be no more complex than it needs to be.'

Complexity may be helpful in a communications sense



End users point out that models sometimes need to include specific detail and produce specific outputs to meet statutory requirements, and they seek for modellers to recognise this reality. End users also point out that they use model output not only to support decision-making, but also for stakeholder communications. They point out that stakeholders see models as being the integration of knowledge about a groundwater flow system. Stakeholders gain confidence from knowing that some feature, such as a geologic fault, has been incorporated into the model. There are therefore circumstances where, while not adding value in terms of mathematical outcomes, model complexity is nonetheless useful in giving stakeholders confidence about the level to which the detail of the groundwater flow system is understood and taken into account. Clearly a balance is needed, but the value of a groundwater flow model and its underlying geologic and conceptual models as communication tools needs to be recognised. The end user position could be expressed as:

'From a communications perspective, a model should be as complex as it needs to be.'

Bespoke or commodity modelling

Mark Twain once said, 'I didn't have time to write you a short letter, so I wrote a long one instead'. The notion can well be channelled to characterise the choices that are made in the groundwater modelling space: a modelling project can be placed along a 'short letter – long letter' spectrum. At one end of the spectrum is what might be described as a 'bespoke' model (to adapt a term from the garment industry).

The advantage of bespoke models is that they are specifically designed to address specific management issues. Bespoke models are constructed in an enabling environment, with the following ideal characteristics:

- There is early and ongoing engagement between conceptualisers, modellers, peer reviewers and end users, who all understand the need for different skills that the other parties bring to the project.
- All available 'soft data' as well as 'hard data' is considered.
- The modeller is highly skilled and able to innovate and make changes or enhancements to the software, if needed.
- There are both time and financial resources to support the testing of creative approaches, some of which will prove useful and some will not, so failures along the way are expected.

While bespoke models can be expected to produce the most useful output for end users, the disadvantages are that they are expensive and likely to require highly skilled operators. There is also a risk that the development of new techniques can become an end in itself for the modeller and a distraction from the needs of the end user. This is a risk that can be minimised if there is sufficient engagement and feedback.

At the other end of the spectrum is what some interviewees described as a ‘commodity’ model. These models are likely to involve a modeller receiving data without significant contact with those who have local knowledge of the system, using standard modelling software and a standard workflow, with fast completion as a driving priority.

The advantage of commodity models is that they will be less expensive to construct and potentially may be able to be used by several operators in the end user environment if adequate operating guidelines are available. Such operational accessibility adds to the value of a model as a communications tool. The disadvantage of a commodity model is that it may not optimally address the question the model is intended to address and may fail to utilise all the soft and hard data available. A broad scale commodity model may however provide a useful framework that can be refined in focus areas at a later stage.

Senior modellers noted that groundwater modelling is a service provided by many providers of general engineering services, where standardised approaches are common. In those situations, there is likely to be a disposition towards the commodity model approach. However, groundwater modellers noted that because groundwater flow systems are highly complex and subject to great uncertainty, the counterbalancing need for a bespoke approach should be considered.

Improving end user skills and expertise

Many of the modellers and end users identified the need for improvement in end user understanding of groundwater systems and modelling if engagement between end users and modellers is to be effective. There are, however, differences between end users in agencies that assess applications for environmental approvals for major developments (‘regulatory agencies’), and end users in agencies that operate water allocation and management systems (‘water planning and management agencies’). The issues for the two groups are discussed separately in the following sections.

Skills and expertise in regulatory agencies

There is a perception among both modellers and staff of regulatory agencies that there is often a lack of relevant skills and expertise inside regulatory agencies. This is not easily addressed through recruitment and training, because regulatory agencies need to have capacity covering a wide range of disciplines well beyond groundwater modelling. It is unrealistic to expect that they will consistently retain skills in the range of areas involved in a groundwater modelling project, particularly as the skills are constantly evolving as science and techniques continue to develop.

Project outcomes will be limited if regulatory agencies do not have ongoing timely access to the skills and experience necessary to enable effective engagement with modellers. To address the issue, there is support among the interviewees for the following concept:

- A regulatory agency could establish a standing panel of technical experts with skills in the range of areas relevant to a modelling project. The panel would include local knowledge experts, hydrogeologists, ecologists, groundwater flow modellers and peer reviewers.
- For any individual development project, the regulatory agency could form a regulatory support team from the members of the standing panel.
- A representative of the regulatory agency and the regulatory support team would meet with the project proponent’s modelling team at the peer review stages, to work towards a common understanding.

Skills and expertise in water planning and management agencies

Water planning and management agencies have greater groundwater skills and experience than regulatory agencies because of the narrower focus of those agencies. They have some planning and management staff with significant groundwater knowledge and experience. These groundwater experts interface between groundwater modellers and other end users who have less groundwater experience. Both modellers and end users find this helpful.

One view given, however, was that while the involvement of the groundwater experts in this way is helpful, it can also result in the expert becoming a gatekeeper of knowledge, limiting improvements in the capacity of less experienced staff. It was suggested that the groundwater experts should see theirs as a communication role, helping modellers and end users understand each other and build relationships with each other, rather than as interpreters standing at an interface between modellers and end users.

Model reporting

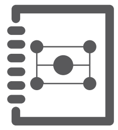
There is general agreement among those interviewed that the standard of model reporting varies enormously, ranging from excellent to awful. Sometimes, the details about the model are in an appendix to a project report, with little discoverable connection between the high-level modelling outcomes in the main report and the dense material about the model in the appendix. That makes it difficult for technically able end users to discover why particular approaches were taken and how data was used. Much time is then spent by end users going back to the modellers, seeking clarification. Those end users are an important audience because they play a key role in building trust between modelling teams and broader stakeholder groups.

There were mixed views among the interviewees on the usefulness of proformas for guiding the content of modelling reports. There was agreement that there is value in a proforma to the extent of a checklist on matters that should be covered, but also a general concurrence that the proforma should not be too prescriptive. Inexperienced end users may not initially be aware of the matters that need to be covered. Engagement with modellers at the beginning of a project could include the preparation of a checklist of the matters to be covered in the report – a checklist that could be reviewed as a project progressed.

The Australian Groundwater Modelling Guidelines identify the need for modelling reports to be written for a broad audience, however, inadequate model reports continue to be a pain point for end users.

Groundwater modelling guidelines

Content



There was a high level of support, among the modellers interviewed, for the existing guidelines for groundwater modelling. Most modellers considered that any guideline should be at a high level, be fit for purpose, avoid unnecessary bureaucracy and not be used as a quasi-standard to constrain good practice, as discussed in the following section on uncertainty analysis.

Uncertainty analysis

Uncertainty analysis in groundwater modelling is an emerging technique; the Guide to Uncertainty Analysis[3] (the 'Guide') seeks to assist in the implementation of the technique. The Guide states that it is not a textbook, instruction manual or formal guideline, but rather is intended to provide initial guidance on the value of and need for uncertainty analysis. In the experience of some modellers,

[3] http://www.iesc.environment.gov.au/publications/information-guidelines-explanatory-note-uncertainty-analysis

however, the Guide is tending to be used as a quasi-standard by some end users, which is leading to difficulties. Comments from modellers included:

> *'I was required to build a level 3 model and meet associated statistical performance measures. I could have built a model that better met the need, but it would not have met the specified performance measures. If I had built the better model, I could have reported other performance measures that were more relevant.'*

End users reported that modellers also use the Guide inappropriately sometimes, which can cause other difficulties. One end user comment was:

> *'They prepared a very crude model to which uncertainty analysis techniques had been applied almost as a 'get out of jail free' measure. The big uncertainty spreads disguised poor modelling as uncertainty.'*

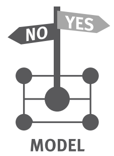
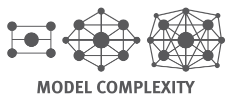
A recent webinar series[4], delivered by the Groundwater Decision Support Initiative within the National Centre for Groundwater Research and Training, has been directed at improving capacity to understand uncertainty in groundwater modelling. The webinars have been widely supported. Perhaps this is an approach that can improve end user understanding and reduce the misuse of guides that can lead to perverse outcomes.

National groundwater modelling guidelines

In 2012, the then National Water Commission prepared the Australian Groundwater Modelling Guidelines[5], which deal with matters mentioned in this paper, such as the need for model reporting to speak to a range of audiences, and for peer review to be multiskilled and integrated throughout the modelling process. Based on the interviews conducted for this discussion paper, there does seem to be a need for a process for progressive update of those guidelines.

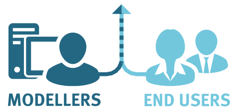
Conclusions

Conclusions from the project that could provide points for future discussion among modellers and end users with a view to increasing the use of groundwater models. Conclusions are as follows.

1. A lot of problems could be avoided if modellers and end users spent more time together at the beginning a modelling project, clearly identifying the management issue to be addressed and the potential to construct a groundwater model that would be useful in addressing the issue.	
2. Modellers seek for end users to accept that there is uncertainty in groundwater modelling and a model can only be a decision support tool. End users point out that they need to make binary decisions and they therefore seek for modellers to see their perspective and make models as useful as possible.	
3. It is becoming easier to make models more complex. This can result in models being more complex than they need to be, from a mathematical perspective. Models are also used by end users for educational purposes, however, and so need to be sufficiently complex to give stakeholders confidence that models adequately represent groundwater flow systems.	

[4] https://gmdsi.org/blog/seeking-common-ground-modellers-and-geologists/

[5] http://www.groundwater.com.au/media/W1siZiIsIjIwMTIvMTAvMTcvMjFfNDFfMzZfOTYwX0F1c3RyYWxpYW5fZ3JvdW5kd2F0ZXJfbW9kZWxsaW5nX2d1aWRlbGluZXMucGRmIl1d/Australian-groundwater-modelling-guidelines.pdf

4. The need for engagement between end users and modelling teams is a recurring theme. The engagement needs to be early and ongoing, including peer review as a part of the process. Most of the difficulties between end users and modellers can be traced back to inadequate engagement.	
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