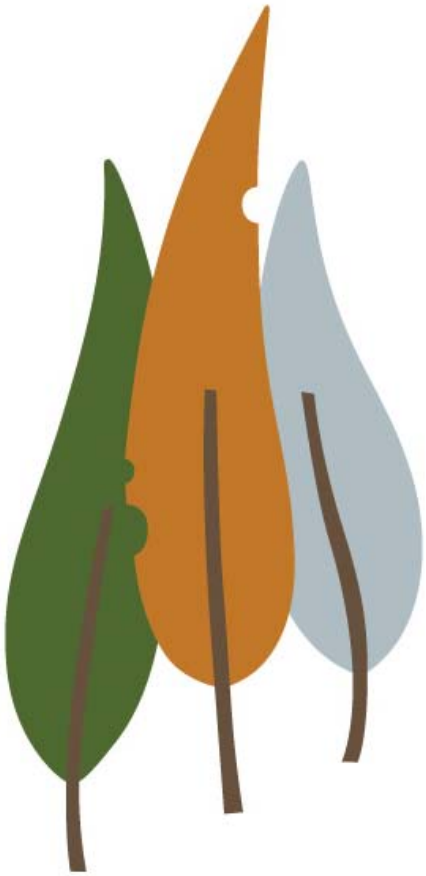
Trees in the landscape

Technical Report 220

Guide to participatory modelling

Caroline Sinclair

CRC for Forestry
Researching sustainable forest landscapes



Technical Report 220

Guide to participatory modelling

C Sinclair[1,2]

Public report

[1] Cooperative Research Centre for Forestry
[2] University of Tasmania

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COOPERATIVE RESEARCH CENTRE FOR FORESTRY
College Road, Sandy Bay, Tasmania
Private Bag 12, Hobart, Tasmania 7001 Australia

www.crcforestry.com.au

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Executive summary

Participatory modelling (PM) is one form of community engagement that can be used to engage stakeholders with forestry issues and with forest management. This report synthesises the findings about PM from a trial in Australian forestry in 2009 (Leys 2010; Leys and Vanclay 2010; Leys and Vanclay 2011) and an extensive literature review, adding to the community engagement resources already available in the *Handbook for operational community engagement within Australian plantation forest management* (Dare, Schirmer *et al.* 2011).

In a PM process, stakeholders with diverse perspectives work together with a facilitator to examine an issue or a system of interest. They create a shared understanding of the issue or system from their interactions with each other and from the model outputs. In practice, this may involve several meetings of a group of stakeholders (generally between 12 and 30 individuals) to develop and refine models. Important outcomes of PM include enhanced democratic participation, better quality stakeholder engagement, more acceptable and efficient management solutions and reduced conflict over resources.

Participatory modelling has only become popular in the last decade, but there are successful examples in both developed and developing contexts. Participatory modelling may be more appropriate than other forms of community engagement where contextual factors (such as system complexity or data scarcity) invite a complex and involved approach, and where sufficient willingness and resources exist to put it into practice. Situations in Australian forest management and beyond that could benefit from PM include:

- negotiating major industry reform (such as the 2011 Tasmanian 'Peace Deal'[1] and consequent priorities for the Inter-governmental Agreement (IGA) funding)
- gaining effective community input to forest management strategic plans
- reviewing planning processes for industry development proposals
- developing integrated plans for large-scale forest management activities (such as harvest and haulage of large quantities of woodchips in the Green Triangle region on the border of Victoria and South Australia)
- working through discrete issues raised during strategic planning processes, such as to workshop alternatives and model how they might work, or to work through large-scale changes (such as the incorporation of river red gum forests into conservation reserves in New South Wales and Victoria in 2010[2])
- facilitating reviews of forest policy (such as local government policies about plantation establishment; pest management protocols).

The design of a PM process, including the form of stakeholder involvement and the type of model used, can vary significantly. This report provides a key resource for those considering using PM in Australian forestry (and beyond). International experience provides a wealth of knowledge which informs the tips and techniques contained in this report, enabling

[1] The Tasmanian Forests Intergovernmental Agreement (see http://www.environment.gov.au/land/forests/tasmanian-forests-agreement.html)

[2] For further information see http://www.riverredgums.nsw.gov.au/

practitioners to maximise the effectiveness of the process and the chances of effectively engaging stakeholders.

Some key considerations for practitioners include:

- **Participatory modelling versus community engagement:** Participatory modelling is most advantageous in complex issues which already require a high level of engagement, or where models are already useful. Otherwise, simpler forms of community engagement may be more cost effective and time efficient.
- **Principles of participation:** Inclusion, transparency and openness are important principles in effectively engaging stakeholders in participatory processes and should be incorporated into the design.
- **Trust and neutrality of process and facilitator:** A key feature of PM is its ability to bring people together to discuss issues more comprehensively through the relatively neutral framework of creating a model together, and it is therefore important that the process, modellers and facilitators are trusted or are perceived as neutral in the situation.
- **Managing balance between stakeholder and expert knowledge:** It may not always be desirable for stakeholders' knowledge to replace expert knowledge and the potential for this to occur needs to be evaluated. Stakeholders work most effectively if they have clarity about the extent that their participation will affect the process.
- **Using modelling to support engagement:** Modelling may or may not be a key feature of the process. Participatory modelling can fulfil many different objectives. In some cases, participatory objectives such as stakeholder engagement and social learning may be just as important as producing an accurate model. In a few cases, the accuracy of the model may be *less* important than whether stakeholders managed to resolve their differences.

Introduction

Community engagement is widely used to incorporate a range of perspectives and address a range of concerns when making decisions about managing resources (Lynam, Jong *et al.* 2007). Using various forms of community engagement has been shown to be a successful strategy within Australian plantation forest management (Dare, Schirmer *et al.* 2011). One form of engagement trialled in Australian plantation forestry is participatory modelling (PM) (see Leys 2010; Leys and Vanclay 2010; Leys and Vanclay 2011). Participatory modelling is an innovative method for engaging stakeholders in resource management and planning processes. Participatory modelling has some unique features that set it apart from other forms of engagement; namely, the deliberate collective participation of a wide range of stakeholders with an intention to model (and create greater understanding of) an issue of interest (e.g. game control alternatives; weed and pest control regimes).

The modelling process integral to PM is thought to lead to better management and planning solutions as well as to greatly improve relationships with stakeholders (Voinov and Bousquet 2010). Participatory modelling effectively supports dialogue and problem-solving because it can provide a framework that is seen as neutral and is accepted by all stakeholders[3] as indicated by Voinov and Bousquet (2010) in their recent review:

> *As with other participatory methods, we are trying to build more equity and confidence in a heterogeneous group of people by providing a framework to share knowledge, cultural and traditional principles, access to power and status, ability to communicate and interact.* (2010, p. 1273)

As an example, the process conducted by CRC for Forestry researchers in 2009 that trialled PM in Australian forestry resulted in some positive outcomes, including more moderate views among all participating stakeholders and evidence of collective (social) learning (Leys 2010; Leys and Vanclay 2010; Leys and Vanclay 2011).

Participatory modelling has become popular in many contexts, and has been especially supportive for management decisions involving complex systems[4] (Voinov and Bousquet 2010). In natural resource management (NRM), system complexity arises both from biophysical systems, such as landscape or ecological complexity, as well as from social complexity, such as the diverse needs and views of stakeholders. Participatory modelling is common in water management in Europe and the USA and became popular when the focus of water management shifted from traditional 'water quality management' to 'watershed management':

> *Whereas traditional water quality management [in the US] focused on issuing permits to point sources of pollution such as industries and waste water treatment plants, watershed management involves decisions about land uses, farming practices, and allocation of costs and benefits among all users of water resources. Such decisions are simultaneously more complex, more uncertain, and of greater interest to the general public.* (Korfmacher 2001, p. 162)

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[3] There are some situations where this may not be the case, as will be discussed in the section 'Guidelines for how to conduct a participatory modeling process'.

[4] PM is not always directly linked to a decision-making process; however, informing decision-making is often an important aim.

Participatory modelling has also been applied successfully across a range of other concerns and disciplines:

- *Public engagement:* Participatory modelling is an alternative to other (non-modelling) forms of public engagement which might otherwise be less structured and more 'informal' (Newig, Gaube *et al.* 2008).
- *Problem-solving and decision-making in governance:* Participatory modelling provides an alternative to 'traditional modelling' where decision-makers traditionally rely on expert analyses (Daniell 2008). Participatory modelling broadens the knowledge base for decisions by including non-expert knowledge. Participatory modelling has also been applied to decision-making in combination with other approaches such as multi-criteria decision analysis (Mendoza and Martins 2006) and adaptive management (Pahl-Wostl 2007).
- *Participatory action research (PAR)*[5]*:* Participatory modelling has extended the range of methods available in community development by extending PAR, which is popular in developing contexts (e.g. Mutimukuru-Maravanyika, Prabhu *et al.* 2008; Vanclay, Prabhu *et al.* 2006).
- *Social learning:* Participatory modelling supports 'social learning' (i.e. learning from others and learning as a group) because it involves an iterative approach that builds trust while systematically creating collective knowledge. Another key feature of participatory modelling that supports social learning is the focus on the process and not just the outcomes (Leys and Vanclay 2011; Pahl-Wostl, Sendzimir *et al.* 2007).
- *Integrated assessments:* Participatory modelling has contributed to integrated assessments—an approach to landscape assessment that integrates different scientific approaches (see for example Hare, Letcher *et al.* 2003 and Lotze-Campen 2008).

Given the level of interest in PM internationally, it is timely that PM has recently been applied in Australian forestry. The PM process conducted in 2009 by Andrea Leys and Jerry Vanclay (CRC for Forestry researchers) demonstrated how PM might be applied in Australian forestry. This project involved multiple stages and incorporated a social learning process (Leys and Vanclay 2011). Initially public meetings were held in key towns. At these meetings, community members were invited to express their interest in forming an advisory committee. This advisory committee was established with 12 community representatives (including forest industry members) who met monthly over the course of a year, developing greater understanding of the impacts of plantation forestry. Leys and Vanclay (2011) noted that the project was successful in the sense that stakeholders' views of local plantation forestry were more moderate after participation in the process, and that all stakeholders learnt from each other during the process.

Encouraged by the positive outcomes of that trial, this report synthesises available information on PM to provide a resource for anyone considering applying this innovative engagement strategy in Australian forestry. This report therefore adds to the previously published *Handbook for operational community engagement within Australian plantation forest management* (Dare, Schirmer *et al.* 2011) which provides a resource for conducting community engagement in Australian forestry. The resources in this report were developed by drawing insights from a review of PM literature, integrating previous reviews of PM literature

[5] PAR is a community engagement technique commonly used in developing countries in Asia and Africa.

and guidelines (Bots and van Daalen 2008; Daniell 2008; Hare 2011; Korfmacher 2001; Renger, Kolfschoten *et al.* 2008; Voinov and Bousquet 2010) and drawing on insights from studies undertaken within the CRC for Forestry's 'Communities' project. This report synthesises all of this information to describe the origins and uses of PM, with particular focus on past and future applications within the Australian forest industry.

While this report focuses on the Australian forest industry, it is also applicable for those working across a range of resource management disciplines, including:

- general resource management and policy
- natural resource management (NRM) and catchment management authorities
- local government
- infrastructure development
- extractive industries (e.g. mining and gas exploration).

What is participatory modelling (PM) and why is it important?

What is participatory modelling (PM)?

> *Participatory modelling describes a diverse range of modelling activities whose common element is that they involve stakeholders in one or more stages of the modelling process, from data collection through to model construction and use.* (Hare 2011, p. 386)

Participatory modelling approaches have proliferated as part of the broader trend of increased public participation in environmental and natural resource management (Reed 2008). The changing context for resource management has driven the need to change related policy and governance processes, which includes the push for greater participation in governance processes (Daniell 2008). This changing context has driven the adoption of PM for several reasons. Firstly, members of the public expect greater involvement in decisions that may impact them directly and that influence the future of resource availability. There is also a greater amount of information available about biophysical systems and how they function, yet information from different areas of knowledge needs to be combined to give a fuller picture. There is also greater recognition of the uncertainty of available information which necessitates the coordination of stakeholders with different understandings of potential risks including those subject to the risks.

Participatory modelling has no single accepted definition; rather, a range of complementary definitions have been proposed (e.g. Daniell 2008; Ferrand 1997 cited in Daniell 2008; Pahl-Wostl, Sendzimir *et al.* 2007; Renger, Kolfschoten *et al.* 2008; Vanclay 2003; Voinov and Gaddis 2008). For the purposes of this report, participatory modelling is defined as follows:

Participatory modelling is using modelling processes to explicitly collect and incorporate key stakeholder perspectives in order to develop shared understandings and identify mutually acceptable outcomes.

'Participation', 'stakeholders' and 'modelling' are fully described later in this section.

It is important to recognise that PM does not refer to a single or distinct method; instead, the term describes a range of approaches. Common characteristics across these approaches include:

- the object of inquiry is viewed as a system (van den Belt 2009)
- some form of stakeholder involvement is included (van den Belt 2009)
- a model is produced (that may or may not meet modelling standards) (van den Belt 2009)
- the process seeks to reconcile multiple and differing perspectives
- the process involves knowledge creation (i.e. problem analysis and/or shared learning).[6]

[6] In addition, the process may or may not support decision-making.

Key approaches to participatory modelling

A key distinction between different approaches to PM is whether the process is model-focused or participation-focused:

Model-focused: A model-focused process often arises when a complex model of the system of interest already exists (or is desired). In this case, developing, building and testing the model will often form the focus of the process, and public participation is invited only for specific, pre-defined tasks such as refining and testing the model (e.g. Bots and van Daalen 2008; Daniell 2008; Gaddis, Falk *et al.* 2010; Renger, Kolfschoten *et al.* 2008).

Participation-focused: A participation-focused process occurs when stakeholders are engaged primarily to provide an opportunity for democratic participation, to build social networks or to build capacity (this is the form most likely to be used within the Australian forest industry). In these situations, models may be used when (and if) they will support these outcomes (Newig, Gaube *et al.* 2008; Pahl-Wostl, Sendzimir *et al.* 2007; Voinov and Bousquet 2010). In these situations, there is often greater scope for public input, for example inviting all stakeholders to define the problem and how it should be approached rather than only inviting stakeholder input after the problem and approach have been defined by experts. It is important to note that PM is not always directly linked to a decision-making process; however, informing decision-making is often an important aim.

Alternative terms are often used to describe different forms of PM (see Voinov and Bousquet 2010, Daniell 2008 and Renger, Kolfschoten *et al.* 2008). As Voinov and Bousquet (2010) note, a number of terms have been coined by different groups to distinguish their own brand of participatory modelling. Terms commonly used when discussing PM are briefly described in Box 1 (following).

Why 'participatory'?

Participation in environmental management has become widespread in recent years (Newig and Fritsch 2009; Newig, Gaube *et al.* 2008; Reed 2008). A range of reasons for increased participation have been identified, including (Korfmacher 2001; Yearly, Cinderby *et al.* 2003):

- participatory resource management is seen to be democratic by providing opportunities for stakeholders (or citizens) to participate in decisions
- stakeholders' knowledge contributes to better problem-solving
- solutions that are 'owned' by stakeholders are more successful and more durable.

Box 1: Participatory modelling and associated approaches: origins

Participatory modelling

(Leys and Vanclay 2010; Leys and Vanclay 2011; Sandker, Campbell *et al.* 2010; Vanclay, Prabhu *et al.* 2006; Vanclay, Sinclair *et al.* 2003; Voinov and Gaddis 2008)

'Participatory modelling' is a general term used by a variety of researchers working in different contexts, with some influenced by the field of PAR. For example Voinov and Gaddis (2008) working in the USA; Vanclay, Prabhu *et al.* (2006), Mutimukuru-Maravanyika, Prabhu *et al.* (2008) and Sandker, Campbell *et al.* (2010) in Asia and Africa; and Leys and Vanclay (2010; 2011) in Australian forestry.

Other terms for participatory modelling

Terms coined by different groups to distinguish their own brand of participatory modelling are outlined below (Voinov and Bousquet 2010).

Shared vision planning (Lund and Palmer 1997; Palmer and Keyes 1993)

'Shared vision planning' (SVP) emerged from the US Army Corps of Engineers (ACE), and has been applied primarily to planning and regulatory issues in water management (Lund and Palmer 1997; Voinov and Bousquet 2010). Most publications relating to SVP and its applications are ACE reports with very few peer-reviewed papers.

Mediated modelling (van den Belt 2004; van den Belt 2009)

Van den Belt (2004) developed 'mediated modelling' (MM) (Voinov and Bousquet 2010). MM, as described by Voinov and Bousquet (2010), translates individual viewpoints into common language and links them into a coherent whole. This process requires intensive participation and a high level of commitment. Van den Belt notes that modelling that is mediated, cooperative and collaborative focuses on group learning rather than the content of the model. Mediated modelling draws on 'system dynamics' (see Box 2).

Group model building (Andersen, Richardson et al. 1997; Vennix 1996)

'Group model building' (GMB) originated in the Netherlands and was further developed in the USA (Andersen, Richardson *et al.* 1997). GMB uses tools of system dynamics such as causal loop diagrams. A key feature is that the modeller/facilitator supports participants to build a conceptual model.

Companion modelling (Barreteau, Antona et al. 2003; Bousquet, Barreteau et al. 1999; D'Aquino, Page et al. 2003)

'Companion modelling' or 'ComMod' is another distinct approach developed by French researchers. A point of difference of this approach is that the key modelling method used is not system dynamics but 'agent-based modelling' (ABM) using role-playing games. There are many examples of applications of ComMod, including several in the special issue on modelling with stakeholders in the journal *Environmental Modelling & Software* (Voinov and Bousquet 2010).

Participatory simulation

'Participatory simulation' originated from the system dynamics group at MIT in America in the early 1960s (Voinov and Bousquet 2010) and has been advanced by others (e.g. Meadows 1986 who created a game called 'Fish Banks' – a fishery optimisation computer game). Modifications to gaming applications allowed for games to be played over the internet, creating the ability for multiple users to contribute to simulation and allowing better recording of interactions. While some participation is possible in this form of modelling, the settings and the rules of the games are not modified by stakeholders (Voinov and Bousquet 2010).

In current conditions, the information required to make management decisions is increasingly complex and the deliberate inclusion of stakeholders increases the legitimacy of decisions.[7] Consequently, stakeholder participation is generally increasing because the complex problems often surrounding environmental management require flexible and transparent engagement approaches that can embrace a diversity of perspectives (Reed 2008).

In addition, participatory processes can support more meaningful assessment of the risks associated with resource management activities. Inclusive decision-making processes, or knowledge development processes, can encourage the development of trust while also empowering citizens (Treffny and Beilin 2011). An increasing number of competing interests in natural resources also leads to greater decision-making complexity. In the face of multiple interests, risk assessment requires judgments which cannot be responsibly made by one person or organisation. As Korfmacher notes of water management in the USA:

> *In the past, water quality modelling has been generally viewed as a technical activity, appropriately carried out by technical experts in environmental agencies. However, managers are increasingly coming to agree that 'watershed management, although dependent on science and engineering, is fundamentally social in nature' (Rhoads and others 1999, p. 298).* (Korfmacher 2001, p. 161)

Importantly, the vast body of work on participation has identified some themes for PM, such as how much participation is appropriate and what can help or hinder effective participation. In particular, experience has shown that it is counterproductive to claim that a process offers greater inclusion and participation than it can realistically offer. Different levels of participation have been described, including the seminal work of Arnstein (1969) with the original 'ladder of citizen participation' and the IAP2's 'spectrum of public participation' (International Association of Public Participation 2007) (see Figure 1). Hierarchies such as these typically describe the breadth of participation, from no participation (e.g. receiving information only) to power-sharing between community and decision-makers, or in some cases where decision-making is devolved entirely to the community. Therefore, understanding and providing transparency about the type of participation being invited and the potential for influence on decisions or outcomes is critical to managing stakeholder expectations and optimising stakeholder contributions (Johnson 2009).

Participatory modelling, as a more collaborative form of stakeholder involvement, would usually engage people at the higher end of the spectrum. Some of the typical activities in which PM engages stakeholders include the following as listed by Voinov and Bousquet:

> *Stakeholders can be engaged in the form of knowledge provision, model selection and development, data collection and integration, scenario development, interpretation of results, and development of policy alternatives.* (2010, p. 1274)

Although many believe that stakeholders may participate in some or all of these activities (Voinov and Bousquet 2010), some researchers (such as Daniell 2008) maintain that PM only truly occurs when stakeholders are involved in the full range of modelling activities, including the early stage of defining the problem as well as later stages such as constructing the model.

[7] For further information on this topic, Funtowicz and Ravetz (who developed the concept of 'post-normal science') discuss the reversal of the relationship between facts and values. That is, while previously 'hard facts' tended to override 'soft values', in current management conditions 'hard value commitments' need to be made based on 'soft facts' (Kloprogge and Sluijs 2006). The term 'soft facts' refers to the increasing complexity and uncertainty of management parameters that were once more straightforward or certain.

Increasing level of public impact

	Inform	Consult	Involve	Collaborate	Empower
Public participation goal:	To provide the public with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions	To obtain public feedback on analysis, alternatives and/or decisions	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered	To partner with the public in each aspect of the decision, including the development of alternatives and the identification of the preferred solution	To place final decision-making in the hands of the public
Promise to the public:	We will keep you informed	We will keep you informed, listen to and acknowledge concerns and provide feedback on how public input influenced the decision	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible	We will implement what you decide
Example Tools:	Fact sheets Websites Open houses	Public comment Focus groups Surveys Public meetings	Workshops Deliberative polling	Citizen advisory committees Consensus-building Participatory decision-making	Citizen juries Ballots Delegated decisions

Figure 1: IAP2 Spectrum of public participation

Why 'stakeholders'?

The term 'stakeholders' (and less often 'participants') is used in PM rather than 'citizens', 'community' or 'general public'. 'Stakeholders' differ from the 'general public' in that they have specific concerns about the issue or topic of the project because they may be directly impacted or because their interests may be affected by decisions, or because they have the capacity to influence the process (Reed, Graves *et al.* 2009). The term is inclusive of all who have an interest in the problem or issues that are the subject (or object) of the modelling process.

Stakeholders are a subset of the broader community who, due to their specific interest in the issues, are invited into the PM process. Drawing on Dietz, Ostrom *et al.* (2003), stakeholders can be defined as including representatives from three social groupings:

- 'scientists' (or experts)
- 'officials' (or decision-makers at different levels of government, or environmental managers)
- 'other interested parties' (e.g. private organisations or individuals with an interest in the issue) (Daniell 2008; Voinov and Bousquet 2010).

Figure 2 highlights the three stakeholder categories defined by Dietz, Ostrom *et al.* (2003).

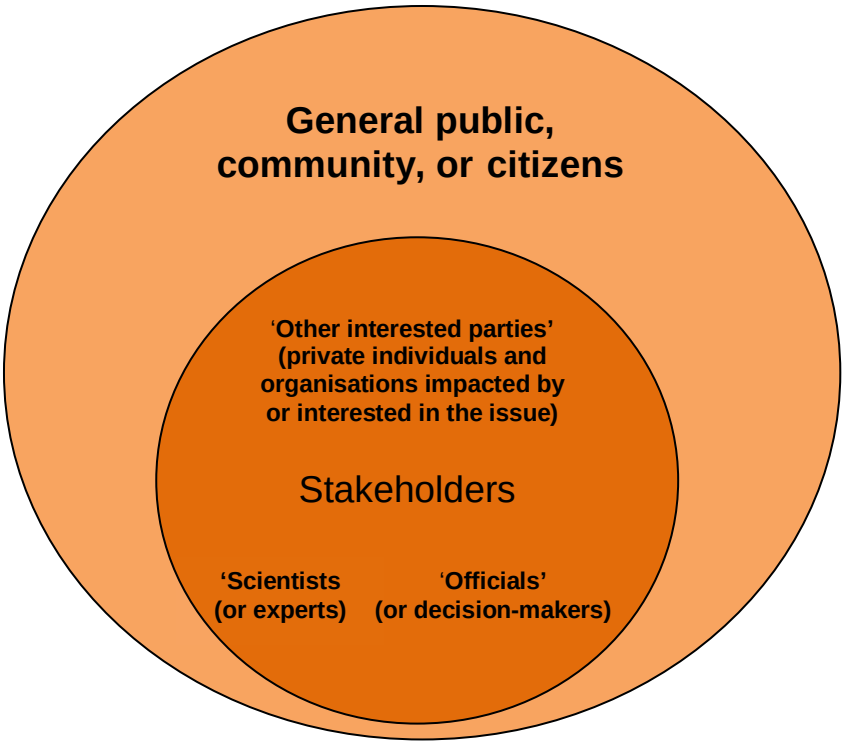

Figure 2: Stakeholder groups within a participatory modelling process

Why 'modelling'?

What is a model and why are models useful?

The models used in PM processes can be of many types but, generally speaking, they most often represent a system by linking together the key elements, their functions and interacting dynamics. Models in PM are not usually representative in a realistic sense (e.g. 'drawn to scale'), but capture the essential elements of a system through graphic or pictorial representations.

Models are useful because they simplify reality and therefore also make it possible to 'zoom in' on the most relevant aspects of a system. These qualities make models efficient for answering questions about the real world (Bots and van Daalen 2008). However, experts in PM caution against overlooking the simplicity of models:

> *It is inappropriate to think of models as anything but crude—yet in many cases absolutely essential—abstract representations of complex interrelationships among system components.* (Costanza and Ruth 1998, p. 184)

Fortunately, sophisticated computer modelling programs have been specifically modified to enable a wider range of people to use them more easily (Renger, Kolfschoten *et al.* 2008). The advantage of using these programs for problem-solving in participatory modelling is the relative ease of manipulation (or simulation) of different aspects of the system to test different situations and solutions (Costanza and Ruth 1998).

Despite the many technical aspects of modelling, Korfmacher (2001) cautions that since modelling inherently involves making assumptions and judgment calls, it is therefore 'a value-laden part of the political process'. Given the value-driven nature of modelling, guidelines for public involvement in public decision-making are equally applicable to participatory modelling (see, for example, the *Handbook for operational community engagement* as developed by Dare, Schirmer *et al.* 2011).

How does participatory modelling address limitations in expert-led modelling?

Most modelling efforts consist of a core of experts who create a model and a group for whom the model is designed (termed 'users'). In traditional modelling processes, separation between these two groups often results in confusion and difficulties as described below:

> *While [users] are often interviewed ... they often lack the skills to actively participate in the modelling effort. ... their problems, solutions and ideas are difficult to communicate to the analyst. ... Further, analysts and entrepreneurs might have mental models, visions of a solution or system design, but might lack the adequate means of articulating these in terms familiar to all stakeholders involved (Hill and Levenhagen, 1995). ...* (Renger, Kolfschoten *et al.* 2008, p. 249)

Participatory modelling therefore offers an advantage in that the two 'groups', modellers and users, work together to construct, refine and test the model. As Renger, Kolfschoten *et al.* conclude:

> *...it would be useful if all the stakeholders can be actively engaged in the construction and modification of such models.* (2008, p. 249)

How is modelling used in participatory modelling?

The type of model, the modelling theory used and the role that models play in the process can be as varied as the level and type of stakeholder involvement. Models for PM can be simple, but one of the key advantages of PM is to use complex models to create understanding beyond the individual's usual capacity for reasoning and problem-solving.

Participatory modelling generally uses two types of models: simulation models and conceptual models:

- *simulation models* involve a 'computational model of a system which allows the user to simulate system behaviour' (Hare 2011)
- *conceptual models* qualitatively describe a system from stakeholder perceptions.

Simulation is an important technique used in PM. Using computational, realistic models (rather than the qualitative, abstract models used for conceptual modelling), simulation provides the opportunity to speed up time or expand geographic coverage so that outcomes which might be distant in time and space can be brought into the present decision-making situation. However, as Voinov and Bousquet note, not all PM uses simulation:

> *There are many tools, which can help in the formalisation of knowledge. People can collectively draw maps, diagrams, logical frameworks, databases, etc. There are methods that focus on mental models, trying to elicit and present the ways different stakeholders see the problem (Becu et al., 2003; Mendoza and Prabhu, 2006; Giordano et al., 2007; Lynam et al., 2007). Sometimes the mental models are further integrated into simulation models, sometimes not.* (2010, p. 1270)

Refer to Box 2 (following) for further description of different modelling approaches used in PM.

The scope of the model will differ depending on the objectives. Bots and van Daalen (2008) identify different 'sub-types' based on the following:

- *purely biophysical system ('physical')*—models of this kind can represent the structure and dynamics of physical, biological or ecological aspects of the resource, but do not take into account dynamics of individual or social behaviour
- *individual actors and their actions ('individual')*—models of this kind can represent how individual actors influence the physical system, but do not take into account interaction between actors
- *interactions between individuals as with multi-agent systems ('social')*—models of this kind can represent the structure and dynamics of the social space (including institutions and policy) but do not take into account how this affects the physical aspects of the natural resource
- *combinations of two or all of these (the combination of all three being labelled 'socio-physical system model')*—models of this kind can represent a complete NRM system, including the physical mechanisms of the natural resource, the actors involved, and the social mechanisms that codetermine individuals' behaviour.

Box 2: Modelling approaches used for participatory modelling

System dynamics uses dynamic simulation models to understand system behaviour. System dynamics provides insights into how systems change over time (dynamically) (Beall and Zeoli 2008). Some of the basic dynamic patterns of systems (e.g. 'growth') can be incorporated into the models. Elements of systems are captured by defining stocks (entities in the system) and flows (the dynamic connections between stocks). In PM, the aim is usually to create visual simulations of different (management) scenarios (Andersen and Richardson 1997) rather than to predict the future (Barnaud, Promburom *et al.* 2007).

Agent-based modelling (ABM) has completely different origins to system dynamics. Janssen and Ostrom (2006) note that agent-based modelling emerged out of 'games' focusing on interactions between 'agents'. Agents model an actor (i.e. individual, group, organisation or cultural object), and ABM models interactions between agents according to simple rules to assess the probability of different outcomes. An example is the well-known 'prisoner's dilemma' where an example of a 'rule' was cooperation, while another was to give 'tit for tat' (Janssen and Ostrom 2006). For companion modelling (see Box 1), computerised models, labelled multi-agent systems, are created based on empirical observations of the real-life system. Stakeholders are then invited into a role-playing game (RPG) where participants act out the current 'rules in use' (i.e. rules used by real-world stakeholders). This stage is often very revealing, showing the flaws in the system (e.g. Barnaud, Paassen *et al.* 2010). This step also tests whether the model has captured all the relevant agents and the nature of their communication (Barnaud, Paassen *et al.* 2010; Barnaud, Promburom *et al.* 2007; Barreteau, Antona *et al.* 2003; Bousquet, Barreteau *et al.* 1999). Stakeholders can then create scenarios using rules of their choice. For example, Bousquet, Barreteau *et al.* (1999) modelled water usage of a particular Indonesian village to three different scenarios—that water was used in accordance with the religious calendar; that water was used at the same time by all; and that water was used in a haphazard manner. The first scenario was found to be agriculturally optimal.

Conceptual modelling is modelling that *qualitatively* explains a system 'on the basis of preconceived notions of how the system works' (Mulligan and Wainwright, 2004, p. 14). 'This might include paper- or computer-based representations of a system's ontological model (i.e. key system components and their structural relationships). A common representation is a directed graph in which components are visualized by nodes and relationships by directed arrows between nodes (e.g. causal diagrams or influence diagrams)' (Hare 2011, p. 389). This differs from simulation modelling which would use computation or quantitative description rather than qualitative description.

Other kinds of modelling approaches used in PM include **Bayesian networks** (Voinov and Bousquet 2010), **fuzzy cognitive mapping** (Voinov and Bousquet 2010), **geographic information systems** (**GIS)** (Cinderby, Snell *et al.* 2008) and **mental models** (Doyle and Ford 1998).

In addition, models can be central to the PM process or play only a minor part (Bots and van Daalen 2008). Where models have historically informed decisions, complex scientific models will usually already be available. However, complex models are often difficult to understand and their outputs do not necessarily match stakeholders' experience of the issue. In these situations, stakeholders can participate by refining the model and/or verifying the outputs of the model.

However, in situations in which there is no predetermined model, a group might decide to rely less on models or use simpler models. Nancarrow (2005) and Newig and Fritsch (2009) recommend careful consideration of whether and what type of model should be used, suggesting that the entire PM process should be reviewed to establish the value of a model in particular circumstances. In particular, social learning processes have taken an approach in which modelling is optional. Simpler models may generate and compare alternatives (e.g. alternative game control measures to control browsing in eucalypt plantations; alternative haulage routes; alternative harvesting schedules where consideration needs to be given to weather, contractor availability, etc.). In these cases, the focus is on working through an issue, and modelling is brought in if and when it is useful.

Depending on the type of model and approach to modelling, stakeholders may participate in building the model, or may only contribute to its construction. Bots and van Daalen (2008) describe five roles that stakeholders can play in the construction and use of a model: to inform model construction, make modelling decisions, provide inputs for model use, use the computer model, and act in gaming simulation.

When PM uses complex models, modelling expertise is needed. Most often, expert modellers are involved in these processes; although, for some PM processes, the ideal is for stakeholders to take responsibility for as much of the model construction as possible. Despite the availability of software that simplifies modelling, it has not always been easy for stakeholders to develop the model, and stakeholders in many PM processes continue to rely heavily on expert modellers (Leys and Vanclay 2010). Depending on the context of the process, a complex scientific model may already be available with which modellers can assist stakeholders to engage, or modellers may build a model during the process of engagement. In some cases (reported in Renger, Kolfschoten *et al.* 2008) stakeholders receive training in modelling so that they can participate more fully in the modelling process.

Finally, PM emphasises different outcomes than those expected from more traditional uses of models (see section on 'Common objectives and functions of PM processes', p. 25). Modelling outcomes may also be very different depending on the goals of the process. Generally in PM a model that supports decision-making or creates greater understanding of an issue will be more important than a scientifically accurate model. However, some authors such as Daniell (2008) do emphasise the importance of scientific accuracy as well.

Models have been traditionally used in a way that Daniell (2008) (drawing on Landry, Banville *et al.* 1996) describes as 'instrumental use'; that is, models were thought simply to provide accurate information for decision-making. As Landry, Banville *et al.* (1996) note, however, using a model always has other outcomes which tend to be less noticeable. These outcomes usually occur as a by-product of process design rather than as part of an explicit plan. However, if a process designer is aware of these potential outcomes, they can be managed and turned into a positive outcome for the process. Therefore they are subsidiary 'uses' of models (in addition to the instrumental use).

In PM, these less obvious (or more subtle) uses of models have greater importance because the objectives of PM usually extend beyond simply providing decision-makers with information.[8] The first of the less obvious outcomes (or potential uses) is credibility (or potential loss of credibility)—this is termed 'symbolic' use of models (Daniell 2008). A model designer may wish to use a modelling process to enhance credibility. To do this, it is critical to understand that credibility results from both inclusion and transparency (Daniell 2008). Stakeholders must be included in deciding on the assumptions used for modelling to increase credibility. Similarly, transparency is created when there is openness about assumptions (i.e. stakeholders are made aware of model assumptions). The alternative (to be avoided because it excludes stakeholders) is 'black-boxing' the model's assumptions, so they become invisible. The second subtle outcome, identified by Landry, Banville *et al.* 1996 and which Daniell (2008) considers is important to PM, is that choosing some model assumptions has the side-effect of determining which knowledge, information or values are considered important to the model. This is called 'underground use' because model assumptions can be selected to intentionally exclude certain stakeholders from the outset. However, if a model designer wants to ensure that model assumptions create the conditions for including a diversity of knowledge and values, they can invite a diverse range of key stakeholders to participate in choosing model assumptions. In this way the modelling process can be used to intentionally broaden the scope of the model and enhances the model's wider value (Daniell 2008).

[8] Providing decision-makers with information can be an important objective for PM, particularly when, as is often the case, the process does not have a direct role in actually making a decision.

What are the key differences among participatory modelling approaches?

Several attempts have been made to categorise the differences among PM approaches. Figure 3 highlights some of the key differences in PM approaches which typically range from simple processes to more complex and inclusive processes:

Increasing complexity of process →						
Timing of PM intervention (in the timeline of the core issue)	Early			Mid		Late
Role of models in the process	Central (model focused)					Minor (method/tool only)
System scope	Physical system			Individual actors		Social system
Degree of stakeholder involvement	Minor					Major
Degree of diversity among stakeholders	Low					High
Purpose of model	Clarify arguments and values	Research and analyse	Design and recommend	Provide strategic advice	Mediate	Democratise
Type of data	Quantitative					Qualitative
Complexity of model (number of parameters)	Low					High
Length of project	Short-term					Ongoing
Participatory methods	Interviews	Cognitive mapping	Contribute data	Mediated use	Group model building	Direct use
Skill of organising team	Modelling skills			Facilitation skills		Knowledge acquisition skills
Form of participatory modelling	Front or back end* participation			Front and back end* participation		Co-construction participatory modelling

** Front end participation is involvement in setting up the model; back end participation is involvement in reviewing the model. Front and back end participation involve stakeholders stepping out of the process in the middle phases, with advantages described by Hare (2011).* (References: Beall and Ford 2007; Bots and van Daalen 2008; Daniell 2008; Hare 2011)

Figure 3: Differences in participatory modelling approaches

There has been no systematic identification of forms of PM in academic literature based on the variables identified in Figure 3; however, we can identify forms of PM processes based on their key outcomes:

- *Social learning approaches*—emphasis is on interactions and learning among stakeholders; modelling will be used to the extent that it supports this and may not be used at all.
- *Actor behaviour modelling*—emphasis is on how stakeholders interact, and what behaviours are displayed as they role-play the system in action. This helps to elicit and resolve key tensions between stakeholders. Modelling is an active process.
- *Inclusive modelling*—emphasis is on involving stakeholders in contributing to and maybe even developing a model. The focus is on producing a reasonably accurate scientific model to contribute to information for decisions, as well as engaging stakeholders.

Each of these modelling approaches has defined objectives and outcomes and requires different inputs in terms of time, stakeholder participation and facilitator skill. Like other forms of community engagement (see Dare, Schirmer *et al.* 2011), it is important when using PM as a form of participation to be explicit about the type of modelling to be implemented, the potential outcomes, and the limitations of the approach.

Who usually initiates a participatory modelling process?

An important consideration in whether and how to undertake a PM process is who would actually initiate the process given that many parties and many different interests are potentially involved. Voinov and Bousquet (2010) note that in their experience PM is usually initiated by managers or researchers from a governmental agency or university. Voinov and Bousquet (2010) identify the following initiation processes:

- Initiation is by managers or researchers from a government agency or university who seek to engage other stakeholders as quickly as possible.
- Initial interactions occur between scientists and government representatives.
- Initial interactions occur between scientists and interested parties (members of the public).
- All stakeholders work together from the beginning.

Benefits and limitations of participatory modelling

While PM has some key advantages over other forms of engagement, it will not necessarily be suited to every engagement situation. Key benefits and limitations of PM are described in Table 1. Benefits include developing greater understanding of resource management, achieving greater acceptance of decision-making outcomes, or developing better solutions by engaging stakeholders to collectively investigate a system. The key limitations of PM include difficulty in fully realising the benefits of PM (which are often intangible), as well as the often high resource requirements including the significant time commitment and the high associated costs.

Table 1: Benefits and limitations of participatory modelling

Benefits	Limitations
Achieve better understanding of public values in relation to the issue under investigation	Time consuming (and therefore costly) to involve public
Identify solutions that have a better chance of providing overall benefit	Public might not have knowledge required to interact with models
Gain greater support for outcomes (i.e. solutions, decisions, models)	Model might not be trusted and therefore any results/outcomes will lose support
Improve ability to respond to change through enhancing social capacity, adaptability, flexibility and resilience	A public view which may not be accurate or appropriate may override expert wisdom, and therefore be 'overlegitimised'
Overcome limitations in human capacity to process complex information	Models can easily become too complex
Reduce risks of unintended consequences	Risks are difficult to assess
Put adaptive learning and management into practice	Potential 'delegitimisation' of traditional governance processes if trust in experts decreases as a result of stakeholder participation in PM
Impose a 'healthy empirical discipline on the conversation' (Andersen and Richardson 1997)	Some modelling expertise may be required and it may be difficult and/or costly to access these skills
Provide a neutral platform by providing structure to problem-solving	Difficult to be neutral and additionally difficult to be perceived as neutral
Enable participants with multiple (and even conflicting) perspectives to learn from each other (rather than playing adversarial roles) and build constructive relationships	Conflict may increase (rather than decrease) through interactions
Address 'real' problems by including stakeholders in problem identification	
Generate greater creativity and innovation	
Achieve greater individual and social learning	
Develop richer and more realistic action plans	
Implementation of solutions (or adoption of management plans) may be more successful and less costly	

(References: Andersen and Richardson 1997; Andersson, Jonsson *et al.* 2010; Barnaud, Paassen *et al.* 2010; Costanza and Ruth 1998; Daniell 2008; Dougill, Fraser *et al.* 2006; Korfmacher 2001; Leys and Vanclay 2010; Pahl-Wostl 2007; Voinov and Bousquet 2010)

Principles of participatory modelling

Principles of PM are very similar to those relevant for participatory approaches more generally. The following set of principles has been developed based on the principles and guidelines proposed by Voinov and Bousquet (2010) and Korfmacher (2001). The principles capture important features *in general* of PM approaches and do not represent strict guidelines, as the application will depend on contextual factors including the process aims, the scope and the social setting. These principles do not prescribe actions but provide a basis for good practice.

Transparency

Transparency is a key principle in PM processes to manage expectations, build trust and gain legitimacy. Transparency is important to maintain in both a scientific sense, meaning openness about methods and models, and also in a social sense, using a collaborative and open approach with integrity (Korfmacher 2001; Voinov and Bousquet 2010).

Openness (to different ideas or knowledge and to alternative methods)

Learning from other stakeholders and from the process is a key feature of PM. This involves stakeholders, facilitators and organisers being open to the learning that emerges from the process and from others in the process (as opposed to maintaining a particular position). The process also requires openness from the facilitator and the group to adapt the process, allowing the inquiry to 'go in circles and branch out' (Voinov and Bousquet 2010, p. 1273). Openness also involves being willing to accept a level of uncertainty, particularly because certainty may not be possible. Assessing PM also calls for openness to different measures of success such as group validation and verification (Voinov and Bousquet 2010).

Democratic inclusiveness/representation

Participatory modelling processes are often a substitute for other processes of public representation. It is therefore important that they are at least as democratic as the system they replace, and are hopefully more so. In this sense it is important to ensure that involvement is appropriately representative (Korfmacher 2001). Beyond simply inviting the appropriate stakeholders into the process, it is important to monitor the social and group dynamics, being mindful of special interests and the effect of power and hierarchies (Voinov and Bousquet 2010). In other words, inclusiveness requires a good understanding of any potential power imbalances and resulting marginalised voices, bringing these forward into the process, and, at a minimum, making the effect of any exclusions explicit.

Process focused

The objectives of PM stretch beyond simply extracting information from a model. Important objectives such as participation, inclusion and learning are best achieved by focusing on creating the conditions for them during the process rather than focusing purely on the outcomes (Voinov and Bousquet 2010). Designing and monitoring the process with all objectives in mind helps to ensure that it can deliver what stakeholders need.

Effectiveness

Stakeholders will want to know that their participation will be effective. An important aspect of this is to inform participants about the effect that their participation will have for decisions. Designing stakeholder involvement to maximise effectiveness signals appreciation of stakeholder participation and gains trust and commitment. While at times it may be necessary for expert knowledge to prevail over non-expert knowledge, being clear at the outset about when this might occur allows all participants to understand when and how they will have an effect on the outcomes (Korfmacher 2001).

Commitment to continuation

Solutions to management of environmental systems will never be final and will need ongoing revision. Participatory modelling processes therefore need to commit to continuous evolution, even after achieving certain milestones (Voinov and Bousquet 2010). Additionally, involving stakeholders in ongoing participation has been shown to provide the best opportunity for them to provide input to decision-making (Griffin 1999; Korfmacher 2001).

Participatory modelling in practice

When and where has participatory modelling been used?

Participatory modelling has been applied in a range of contexts and is popular in both developing contexts (generally the southern hemisphere, or 'global South' with the exception of Australasia) and developed contexts (generally the northern hemisphere or 'global North'). One of the generically successful applications of PM in developed contexts has been in multi-stakeholder conflicts over natural resources. There have also been several successful examples in developing countries (e.g. Barnaud, Paassen *et al.* 2010; Sandker, Campbell *et al.* 2010 and others). It is unclear whether the North is learning from the South or vice versa (Stringer, Twyman *et al.* 2008; Sultana, Thompson *et al.* 2008); for example, Colfer and Dudley (2011) have applied a form of PM in developing contexts which originated in developed contexts. Some have claimed that application of PM in developed contexts emerged out of but is distinct from the tradition of participatory action research (PAR) which is commonly used for community development in developing contexts (Cyprian, Abega *et al.* 2003 cited in Leys 2010; Voinov and Bousquet 2010; Wadsworth 1998).

The following examples of PM are selected for diversity and representativeness from the most commonly cited cases. These examples illustrate the broad range of issues and places in which PM has been applied:

Examples from developed countries or global 'North':

- Watershed management in the US to manage non-point sources of nutrient run-off into lakes (e.g. nitrogen in Calvert County (Gaddis, Vladich *et al.* 2007); phosphorous in St Alban's, Vermont (Gaddis, Falk *et al.* 2010))
- shared vision planning to manage impacts of increased population pressures on a watershed in the US, at James River, Virginia (Palmer 2007)
- collaborative mapping of local air pollution in UK cities (Yearly, Cinderby *et al.* 2003)
- river basin planning using Bayesian belief networks in Abruzzo, Italy (Castelletti and Soncini-Sessa 2007)
- urban water management to address inefficient over-supply of water in Switzerland through social learning (Pahl-Wostl and Hare 2004)
- building capacity for adaptive co-management using social learning for land use change to hardwood plantation forestry in Australia (Leys and Vanclay 2011).

Examples from developing countries or global 'South':

- Exploring options to manage 'water scarcity' by modelling the social system of water allocation in northern Thailand (Barnaud, Paassen *et al.* 2010)
- exploring trade-offs between conservation and development in high-conservation, high-poverty areas in six cases in Africa and Asia (Indonesia) (Sandker, Campbell *et al.* 2010)
- scenarios for sustainable broom grass management in Zimbabwe (Vanclay, Prabhu *et al.* 2006) as part of a broader PAR project (Mutimukuru-Maravanyika, Prabhu *et al.* 2008)
- land use management planning using companion modelling in Senegal, Africa (D'Aquino, Page *et al.* 2003)
- cross-scale issues in multi-level governance in Indonesia (Smajgl 2010).

When and where will participatory modelling be most useful?

As previously identified, PM is more effective in some situations than in others (see section 'Benefits and limitations of PM', p. 16). The key advantages of PM have been described throughout this report and include the ability to bring a diversity of stakeholders together to better understand or solve a problem by collectively defining systems using the relatively neutral tool of modelling. The main drawbacks of PM are the significant time commitment often required of stakeholders and the associated costs.

Essentially, PM is a much more intensive form of stakeholder engagement than some of the other forms of public participation as outlined in Figure 1, such as fact sheets, public comment, surveys or one-off public meetings. In some situations, however, PM will be preferable over other more general forms of community engagement. This section provides guidance to support the decision whether to use PM in a particular situation or instead to employ more general community engagement approaches. Situations in which PM is generally useful are also outlined (Table 4).

The characteristics of situations in which PM might be most useful are defined in Table 2. A context with two or more of these characteristics could be appropriate for PM (Voinov and Bousquet 2010).

Table 2: Common characteristics of a 'good' participatory modelling context

Characteristic of 'good' PM context	Reason	Example
System (including social) complexity	Limited human capacity to work with complexity can be overcome by modelling	• Tasmanian forest industry restructure, i.e. Tasmanian Forests Intergovernmental Agreement • Interactions of resource management regimes and environmental conditions (e.g. water management)
Data scarcity (Ritzema, Froebrich *et al.* 2010)	If insufficient data is available for evidence-based decisions, PM supports collective problem analysis	• Impacts of 'new' resource management on local communities and/or environment • A new management regime that has potential unknown outcomes
Conflict over the use of a resource	Stakeholders with different views and needs can reconcile these in a context-neutral way by working together on modelling the system dynamics and testing the model	• Commercial harvesting of native forests • Use of agricultural chemicals in an urban watershed
'Cross-scale' issues	Different people may be responsible for different parts of the problem; PM combines different perspectives	• Multi-governance of water resources, i.e. Murray–Darling Basin water management across four states & territories of Australia (http://www.mdba.gov.au) • Large-scale management of public forest for multiple uses
Model already partly developed	Although not essential, if a model exists, participation can be readily invited	• Murray–Darling Basin water management • Land use planning problems

Factors that, if present, can contribute to the success of a PM process are detailed in Table 3.

Table 3: Factors that contribute to the success of participatory modelling

Factor	Reason	Needs
Resources to create and conduct a PM process	Costs can be high for modelling expertise and to support many stakeholders to participate	• Funding • Skills • Time
Willingness (including willingness to participate and willingness of conflicting stakeholders to modify their position)	Participatory modelling relies on the willingness of stakeholders to resolve issues	• Transparency in requirements of participants • Transparency of process limitations (e.g. resource shortages, decision-making influence)
A **context-neutral organisation or individuals** to coordinate or conduct the process	Without facilitation that is seen as neutral by key stakeholders, little progress is likely to be made	• Availability of suitably skilled facilitators • Acceptance of appointed facilitators • Acceptance of terms of reference • Flexibility of process to change with identified needs and objectives
Sufficient **time** for iterations of model-building	Model-building can take time, as does social learning	• Understanding of longevity of process • Development of realistic and encouraging milestones
Potential for **input into decision-making**	Stakeholders are often motivated if they know their participation will have an effect on decisions or outcomes	• Transparency of model influence in decision-making • Flexibility of decision-making influence

Characteristics of 'good' PM situations (Table 2) and factors contributing to the success of PM (Table 3) combine to guide the decision about whether to use PM or other less intensive forms of community engagement in a given situation as depicted in the decision-support tree provided in Figure 4.

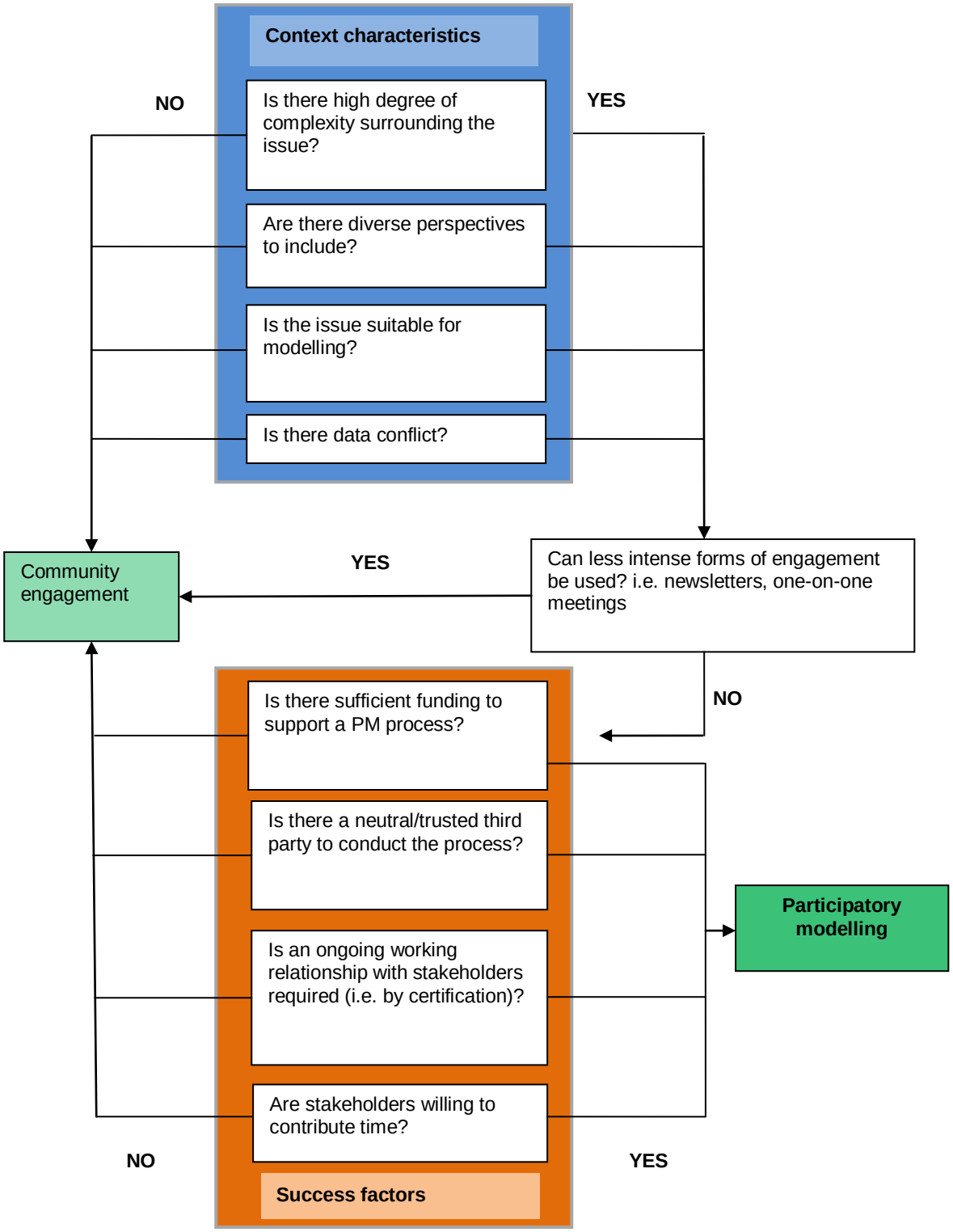

Figure 4: Guide for choosing between simpler forms of community engagement and participatory modelling

Table 4 lists some common generic situations in which PM has been applied that can provide insights into other situations in which PM could be useful.

Table 4: Common situations in which participatory modelling is (or could be) applied

Situation	More detail	Example
Third-party intervention to address complex issue	Third-party organisations such as a research institution or government agency may intervene when an issue has many stakeholders and elements (Leys and Vanclay 2011; Voinov and Bousquet 2010).	• Tasmanian forest industry restructure, i.e. Tasmanian Forests Intergovernmental agreement
Making scientific models relevant for policy and management:		
- Public engagement in scientific model	Scientific models are generally inaccessible to the public and yet public input is sometimes needed to fully explore the issues. Participatory modelling can integrate the 'human dimension' and support policy.	• Murray–Darling Basin management plan (http://www.mdba.gov.au/) • Tasmanian forest industry restructure i.e. Tasmanian Forests Intergovernmental agreement
- Bringing modellers and managers together	Where scientific models are developed in isolation from managers, the technical knowledge can be lost in practice. Participatory modelling can bring otherwise isolated groups into contact.	• Discussed by Borowski and Hare (2007), EU water managers have not had access to or utilised research
Supporting complex decision-making in environmental management	If there is a particular public concern with an environmental management decision, the responsible institution (government body, regional catchment management authority or other) may invite participation in finding solutions or alternatives.	• Public engagement to inform decision-making concerning air pollution in the UK (Hare, Letcher *et al.* 2003)
Supporting shift to adaptive management	Social learning and collective problem-solving can be the 'social technology' that supports a shift towards adaptive management or 'learning to manage by managing to learn'.	• Using social learning in water resource management in the EU (Pahl-Wostl, Sendzimir *et al.* 2007)
Supporting planning and development of management plans	Participatory modelling offers the opportunity to collectively define parameters and simulate the future to identify risks or impacts of scenarios. This supports planning, and provides meaningful opportunity for stakeholder input.	• Development of strategic forest management plans • Development of local government planning schemes
Structured stakeholder engagement, enabling and containing input	Structured methods such as modelling provide a framework within which stakeholders can provide input, and that input can also be 'contained' within the framework of the model and the participatory process.	• Development of strategic forest management plans • Development of local government planning schemes

When might participatory modelling be used in Australian forestry?

Participatory modelling is generally useful for dealing with complexity and cross-scale issues that are otherwise difficult to address. Examples of where PM could be used in Australian forestry might include:

- negotiating major industry reform (such as the 2011 Tasmanian 'Peace Deal'[9] and consequent priorities for the Tasmanian Forests Intergovernmental Agreement (IGA) funding)
- gaining effective community input to forest management strategic plans
- reviewing planning processes for industry development proposals
- developing integrated plans for large-scale forest management activities (such as harvest and haulage of large quantities of woodchips in the Green Triangle region on the border of Victoria and South Australia)
- working through discrete issues raised during strategic planning processes, such as to workshop alternatives and model how they might work, or to work through large-scale changes (such as the incorporation of river red gum forests into conservation reserves in New South Wales and Victoria in 2010[10])
- facilitating reviews of forest policy (such as local government policies about plantation establishment; pest management protocols).

Common objectives and functions of participatory modelling processes

Participatory modelling can fulfil a number of different purposes as described in Table 5. A single PM process may fulfil multiple purposes, particularly because objectives will vary for different individuals and groups (Daniell 2008).[11] Some objectives are more relevant for a decision-making process (e.g. increasing democratic participation), while others are more relevant for a content- or problem-focused process (e.g. increasing solution complexity through modelling). Participatory modelling might achieve different purposes at different points in the process. Also, some objectives might be explicitly addressed while others may be fulfilled indirectly as a benefit of conducting the process. Any or all of the following purposes may be relevant in different circumstances.

[9] The Tasmanian Forests Intergovernmental Agreement http://www.environment.gov.au/land/forests/tasmanian-forests-agreement.html

[10] For further information see: http://www.riverredgums.nsw.gov.au/

[11] Many of the examples in Table 5 are drawn from the same PM processes (e.g. Gaddis, Falk *et al*. 2010) to illustrate the multiplicity of outcomes for a single process.

Table 5: Common objectives and functions of participatory modelling

Objectives and functions of PM	Description	Example
1. Identify the 'right' problem through collective input	Since stakeholders with different world views will perceive 'the problem' differently, defining the problem from a technical or political perspective without stakeholder input may not capture what other stakeholders see as important features of the problem (Antunes, Santos *et al.* 2006; Gregory 2000).	In exploring impacts of plantations (Leys and Vanclay 2011), issues were selected according to community concern and included fire, socioeconomic impacts and pesticide use. Through the process, concerns about fire were swiftly alleviated once it was understood that a separate collaborative committee had been established, and the group could focus on other issues. Therefore, because the process was guided by stakeholder concerns, it could more efficiently address the key issues and change along with stakeholders' knowledge of the issues.
2. Increase and share knowledge of a particular system	This is one of two key purposes of PM as identified by Voinov and Bousquet (2010) and is particularly relevant when a variety of stakeholders hold significant knowledge about the system (or issue) under investigation. Learning—in particular, social learning—is a key outcome of PM processes (Dougill, Fraser *et al.* 2006; Pahl-Wostl and Hare 2004). Learning across the different 'scales' within government, community and industry helps to overcome the issue of scale mismatch where important knowledge is left out (Daniell 2008; Hare, Letcher *et al.* 2003).	In an example in which phosphorus run-off in a watershed was investigated (Gaddis, Falk *et al.* 2010), knowledge was created through the PM process that would not have otherwise been possible. Community members were motivated by their involvement in the project to collect data on urban run-off. This activity convinced other stakeholders that because urban sources of pollution were being investigated it was safe to provide privately held data on agricultural run-off. These data-sets would not have been publicly available without the project, and their combination created a valuable knowledge resource.
3. Enhance creativity and innovation of thinking and solutions	Daniell (2008) lists this as one objective of PM. The involvement of a wider range of stakeholders creates the opportunity for greater creativity in thinking. This happens because stakeholders are required to think outside their usual ways of thinking, and because of the synergy of having several people working on the same problem using the focused method of modelling.	Investigating phosphorus run-off in a watershed (Gaddis, Falk *et al.* 2010), the involvement of stakeholders with decision-making power enhanced the innovation of solutions. This was attributed to these decision-makers understanding the feasibility and cost-effectiveness of different solutions and being able to develop creative alternatives.

4. Increase democratic participation in decision-making and solution-finding	One of the key functions of participatory processes generally is to provide an alternative to representative democracy where experts and politicians dominate the problem-solving landscape. Participatory modelling may be driven by the desire to increase democratic participation.	Investigating phosphorus run-off in a watershed (Gaddis, Falk *et al.* 2010), citizens were given an opportunity to be involved in exploring the underlying issues and creating the solutions and also provided input in ways in which they were interested, such as voluntary water monitoring with 25 monitoring sites established. This provided a good entry point for citizen participation.
5. Elicit public preferences	In the governance or political decision-making environment, PM may serve as a means to better understand public preferences (Korfmacher 2001). This is because PM enables stakeholder preferences and values to be made explicit (Daniell 2008).	Inviting public input into a project studying air quality and pollution in cities in the UK, Yearly *et al.* (2003) were able to elicit public perceptions of air quality, capturing this information in localised maps.
6. Empower community members to understand and deal with issues that affect them	In some situations, a community development organisation or other third party may wish to support community empowerment[12] by creating a PM process. This may also occur when community members (or other stakeholders) expect or want to have a say about a decision or impact.	Investigating phosphorus run-off in a watershed (Gaddis, Falk *et al.* 2010), citizens were empowered to develop a citizen volunteer water quality monitoring program, giving them greater understanding of the impact of urban activities on water quality and opportunity for input into the planning process for watershed management.
7. Build social capacity	Through PM, networks and knowledge are developed increasing social capacity.[13] This may be an important purpose for community development, and also as a strategy of governance (Daniell 2008).	Investigating phosphorus run-off in a watershed (Gaddis, Falk *et al.* 2010), a network of citizens developed when they established the volunteer water quality monitoring program, strengthening their connections and also increasing community-based knowledge of watershed management.

[12] Empowerment in this context means both social cohesion that allows community members to act collectively, as well as sufficient understanding and skills so that community members are not disadvantaged in dealing with external governance relating to the issues.

[13] Social capacity in this context means the ability within the community to take action in favour of their interests and includes social networks and knowledge.

8. Educate	Participatory modelling may fulfill the purpose of education (Korfmacher 2001). One of the principles of good PM is to remain open to the possibility that all participants may learn from the process. Where the purpose of the PM process has some element of empowerment, holding an intention to educate people (in the sense of changing their thinking to a preferred or dominant view) may impede trust.	Investigating phosphorus run-off in a watershed (Gaddis, Falk *et al.* 2010), members of the public learned about the impact of non-point sources of pollution. The 'educational' aspect of the project was therefore achieved because it occurred alongside the participation of motivated participants.
9. Achieve greater legitimacy of modelling outputs	Another key function of PM may be to increase the sense of engagement with and ownership of the model and its outputs (Daniell 2008; Korfmacher 2001).	In the case of citizen engagement in local air pollution management (Yearly, Cinderby *et al.* 2003), a planning solution based on input from local air pollution maps produced by citizens secured the highest number of votes in a questionnaire and was adopted by officials.
10. Increase cooperation and reduce conflict between individuals and groups with different perspectives and/or conflicting interests	Participatory modelling processes often increase cooperation purely because they provide a means of communication that would not otherwise exist. The process can also be designed specifically to address conflicting interests or views (as in mediated modelling, van den Belt 2004). Whether or not it is intentional, reduced conflict is often the result of PM processes due to the process forcing participants to recognise and discuss other viewpoints and to develop a mutual understanding.	Working through issues of water allocation in northern Thailand (Barnaud, Paassen *et al.* 2010), stakeholders commented on the PM process providing the opportunity to openly discuss issues, and hence develop a better understanding of other perspectives. This helped to address the potential for conflict.
11. Utilise modelling capability to increase complexity of solutions	Complex models are available that have the potential to contribute to problem-solving but are not easily and widely understood. PM processes can bring modelling capability into decision-making processes, enhancing the complexity of analysis and consequently the comprehensiveness of derived solutions.	In relation to water management planning in Mexico, Cockerill, Passell & Tidwell (2006) discuss how modelling capability allowed a diverse range of stakeholders to see the complexity in the system that was too difficult to hold only in their mental models.

12. Identify (socially) optimal solutions	Participatory modelling can be part of a problem-solving process. Involving stakeholders in modelling can enhance problem-solving by providing key knowledge not held by experts, and by identifying solutions that are socially preferable.	Developing solutions to address nitrogen pollution, Gaddis *et al.* (2007) noted that the engagement of stakeholders in developing solutions meant that recommendations were expanded to cover a wider range of pollution sources, and were targeted towards solutions that were socially and politically feasible.
13. Identify potential impacts of solution implementation	Participatory modelling, through simulation, can clarify the impacts of identified solutions. This supports decision-making by clarifying the consequences of different solutions, and is noted as a second key objective by Voinov and Bousquet (2010).	Developing alternative forest management plans in central France (Simon and Etienne 2010), stakeholders explored the different impacts of each scenario that was produced through the modelling process.
14. Inform decisions	Participatory modelling is not always directly linked to a decision-making process; however, informing decision-making is often an important aim. In these cases, the modelling outcome would be important and might be translated into a document or scenarios or presented as a model that then is considered during the decision-making process.	In the issue of water availability for irrigation in Northern Thailand (Barnaud, Paassen *et al.* 2010), the result of the modelling process was to produce a majority-favoured solution for increasing water availability and water sharing. This outcome was an input into further decision-making.
15. Instigate actions or improve adoption	Participatory modelling can help to identify and resolve potential barriers to action, both in the sense that the models and simulations identify barriers and ways to resolve them and in the sense that the process creates 'buy-in' to the solutions. Barriers include the feasibility of proposed solutions, buy-in by the broader community, lack of ongoing negotiation processes, and whether participants change behaviours.	In the issue of water availability for irrigation in Northern Thailand (Barnaud, Paassen *et al.* 2010), the PM process dealt with many barriers to action including the lack of awareness of a 'problem' by those benefitting from current water arrangements.

(References: Daniell 2008; Korfmacher 2001; Voinov and Bousquet 2010)

The participatory modelling process

It is commonly acknowledged that the power of PM lies in the process, which actively promotes knowledge sharing, problem-solving, conflict resolution and potentially decision-making:

> *Vanclay (2007) has suggested that the important outcome of participatory modelling is not the model itself, rather the new insights gained through the process.* (Leys 2010, p. 21)

> *The process of the study becomes even more important than the resulting model or method.* (Voinov and Bousquet 2010, p. 1273)

> *The modelling was generally considered to be successful in building shared understanding of issues. This understanding was gained mainly in the discussions held in the process of building the model rather than in the model outputs.* (Sandker, Campbell *et al.* 2010, p. 13)

Typically, a PM process engages a selection of stakeholder representatives so that the number involved in the detailed discussions is more manageable. Most processes engage fewer than 30 people in total (Voinov and Bousquet 2010), although processes on a larger scale have also been conducted (Tidwell, Passell *et al.* 2004; Yearly, Cinderby *et al.* 2003). The select group of stakeholders jointly create a model of the system or resource of concern working to identify socially acceptable alternatives, constantly reviewing implications of alternative management actions and revising the solutions (and model) as needed.

Similar to community engagement (Dare, Schirmer *et al.* 2011), it is important to be flexible in designing a PM process:

> *... participatory processes ought not to be 'method driven'—as is often the case in research projects. Rather, methods should be chosen according to the goals and 'needs' and the dynamics of the process.* (Newig, Haberl *et al.* 2008, p. 386)

The 'major components' of the generic PM process are depicted in Figure 5. Different stages are represented as cards to indicate that the order can (and probably will) be 'shuffled' at any point in the process.

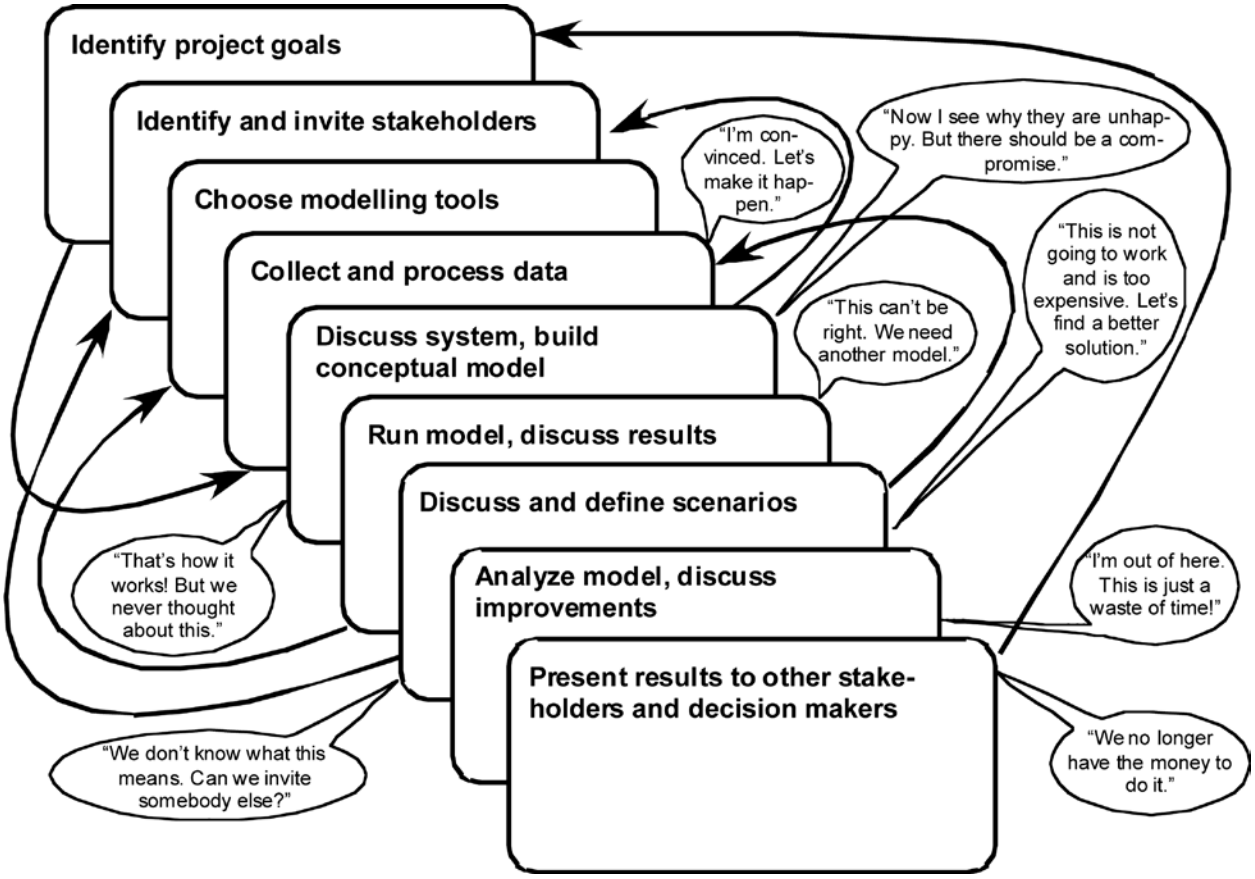

Figure 5: The different stages of a participatory modelling process (Voinov and Bousquet 2010, p. 1273)[14]

It is useful to understand that the stages in a PM process are a hybrid of a number of other processes including modelling, decision-making, project management, and problem-solving, and may require any or all of the steps in each depending on the context. See Table 6 for an outline of the steps that may be relevant for PM.

[14] Reprinted from *Environmental Modelling & Software*, **25**, Voinov, A. and Bousquet, F. Modelling with Stakeholders, p. 1273, 2010, with permission from Elsevier.

Table 6: Processes incorporated within participatory modelling

Participatory modelling is a hybrid of the following processes:				
Modelling	**Participation**	**Decision-making**	**Project management**	**Problem-solving**
Analyse requirements - define model and statement of purpose or function of the modelling exercise - the anticipated use of the results - the model type - the participation mode - the modelling method or software platform Construct model Use model	Determine scope and level of participation required Design process Initiate engagement with stakeholders Conduct process over period of time Evaluate Follow-up (i.e. carry out collective agreements, or report back to community)	Determine issues Gather information - scientific advice/evidence - public opinion Decision-maker - compares alternatives (maybe?) - selects optimum solution	Prepare project proposal Secure funding and support from key players Clarify project goals Plan project activities and timeframes in detail Manage project to achieve milestones Complete project Evaluate project	Identify problem Gather information Develop options Compare alternatives Develop solution

Guidelines for conducting a participatory modelling process

This report aims to provide a starting point and an ongoing reference for those seeking to conduct PM processes in Australian forestry and beyond, and it synthesises much of the available literature on the topic. The guidelines included in this section identify some factors that are important to consider before establishing a process. This section also includes tips for how to conduct a PM process with the greatest chance of success and in line with the principles of PM (see p. 18 for principles). This section draws on the wealth of experience in conducting PM processes internationally and in Australia. These guidelines were compiled from those supplied by Gaddis *et al.* (2010) and Korfmacher (2001), while other key lessons and techniques were drawn from reviews by Hare (2011), Voinov and Bousquet (2010), Renger *et al.* (2008) and Daniell (2008). The guidelines are organised as illustrated in Table 7.

Table 7: Structure of guidelines for conducting a participatory modelling process

Process establishment	Aspects of process	Page information available
	Deciding to use participatory modelling	34
	Initiating participatory modelling	34
Design considerations		
Process of PM	Process design	35
	Setting up evaluation	35
	Selecting stakeholders	35
	Representativeness (risk of stakeholder bias)	36
	Including marginalised voices	36
	Choosing the 'right' problem (for all participants)	37
Engaging stakeholders	Initiating stakeholder engagement	37
	Impact on decisions	37
	Gaining trust through neutrality	38
	Transparency of modelling process	39
Model	Is a model needed?	39
	Model design	39
	Model complexity	40
	Is an expert modeller needed?	40
Modelling roles	Roles for modellers and the team supporting participatory modelling	41
	When participants don't want to use the model	41
	Is model validity important?	42
Outcomes	Decision legitimacy	42
	Representing consensus to capture diversity	43

Process establishment

Deciding to use participatory modelling

A tool to support the decision to use PM was provided in Figure 4 (p. 23). The key is to assess whether contextual factors require PM, whether less intensive (and less costly) alternative engagement strategies are an option, and whether PM is likely to succeed.

Participatory modelling will be most useful when there is

- system (including social) complexity
- the resources and willingness to create and conduct a PM process (including willing community members and other stakeholders)
- differing perspectives with some conflict that stakeholders are willing to resolve through a structured process
- an organisation or individuals who are perceived as adequately neutral to conduct the process
- sufficient time to accommodate iterations of model-building
- potential for input into decision-making.

Examples of where PM might be applicable in Australian forestry were provided on p. 25.

Initiating participatory modelling

In the case study conducted by Leys and Vanclay (2010; 2011) university researchers initiated the PM process. This kind of intervening third party has been labelled a 'bridging organisation'. Bridging organisations have been described in adaptive co-management and resilience literature (e.g. Berkes 2009; Folke, Hahn *et al.* 2005; Hahn, Olsson *et al.* 2006), and are often organisations that have a special position in being able to connect different parties. Bridging organisations also often provide resources for cross-linkages that might otherwise be beyond the scope of individual stakeholders. Intervention from a third party can therefore be critically important to the success of a process, particularly where the organisation is perceived as adequately neutral to the context/setting. Folke, Hahn *et al*. describe bridging organisations as:

> … *providing social incentives to stakeholders to invest in building trust, identification of common interests, and resolving conflict* (Folke, Hahn *et al.* 2005, p. 462).

Those who organise and establish PM processes have the capacity to strongly influence the process. Because of this, Daniell (2008), who specifically studied the establishment of a PM process, urges anyone considering PM to also consider the implications of their decisions. In particular, to consider whether there are any checks and balances to determine whose interests these processes are serving.

Design considerations and tips for conducting participatory modelling successfully

Design considerations and tips—Process

Process design

Process is critically important for achieving objectives in PM. Good process requires early consideration of a number of elements. These include:

- who to involve and in what capacity
- how to manager for power differentials and foster inclusion
- how to structure the process to enable input while also achieving outcomes
- identification of the desired outcomes of the project and how these differ for stakeholders
- how to motivate stakeholders to take part while also managing their expectations
- how to build trust in the process and process facilitators.

Many of these elements are outlined in more detail in this section. Bots and van Daalen (2008) and Hare (2011) also provide detailed discussion on process design.

Setting up evaluation

Participatory evaluation, unlike non-participatory evaluation, is often established in the start-up phase of the project and monitored throughout. Evaluation can help tailor methods to achieve goals more effectively and also to assess how well the organisation and design of the PM process fits with principles such as transparency, openness and inclusion (Daniell 2008). Given that PM is breaking new ground in the area of collective problem-solving and decision-making, evaluation of PM processes is particularly important. Non-participatory forms of evaluation are an option for PM, but Voinov and Bousquet (2010) recommend that where stakeholder involvement is a key component of the process, stakeholder feedback is critical in evaluating PM processes. Where learning and the participatory experience are key objectives, stakeholder participation is the most accurate and meaningful method of evaluation.

Australian-based researchers led the development of a proposal for a PM evaluation framework (see Jones, Perez *et al.* 2009). This framework takes into consideration multiple stakeholders' perspectives and can be applied during a process or retrospectively. An appendix to this report (see p. 52), includes a graphical representation of this framework, showing the evaluation procedure for both designers and participants.

Selecting stakeholders

Selecting appropriate stakeholders is a key to the success of participatory processes, including PM processes:

> *Key lessons for participatory modelling… [include]… the importance of inviting the appropriate stakeholders to achieve impact.* (Sandker, Campbell *et al.* 2010, p. 13)

Stakeholder analysis can assist in identifying and selecting stakeholders by mapping stakeholders with an interest in the issue (see Dare, Schirmer *et al.* 2011). The stakeholders who may be important to consider for inclusion in PM processes are:

- those with concerns about the issue/system
- those with a financial or other non-monetary interest in the issue/system
- those with responsibility for governance or management of the issue/system
- those potentially impacted by the outcomes of the process
- those with the capacity to influence the issue/system (Dare, Schirmer *et al.* 2011).

Representativeness (risk of stakeholder bias)

One of the risks of a participatory process is that those with the most to gain or lose, those with sufficient education and those with the available time tend to become involved to a higher degree (as discussed by Dare, Schirmer *et al.* 2011). In this sense, voluntary participation does not necessarily result in a representative group of people. It is important that these limitations to representativeness are not overlooked:

> *If those directly affected by watershed management decisions are more likely to become and stay active in the modelling process, the subset of the public that chooses to be involved may have a vested interest in a particular outcome. If this is the case, it would not be legitimate to claim that the results of such an exercise comprehensively represented public opinion*. (Korfmacher 2001, p. 164)

Representativeness is most important for achieving PM objectives such as democratic participation and eliciting public preferences. In these cases, it is important to consider how to engage a truly representative range of participants. Reducing the barriers to participation can be helpful; for example, offering a fee or cost reimbursement for attendance at meetings can help if cost is a barrier (which could mean either costs of participation such as travel, or the cost of lost wages). It also helps to focus on building relationships with a broad range of the community rather than just certain segments, for example maintaining relationships with key community organisations (not just those with a stake in the issue).

Including marginalised voices

Some authors have spoken out strongly in favour of a more thorough recognition of the ways in which people are marginalised through participatory processes, particularly in the case of Western researchers intervening in issues in developing countries (e.g. Barnaud, Paassen *et al.* 2010; Colfer and Dudley 2011). In many situations poverty and local power structures mean that those who are most vulnerable to the outcomes of the process do not or cannot participate fully. Colfer and Dudley give a vivid example:

> *A couple of members of the local pygmy population (… among those most directly affected by external decision making about local forests) were seen peering in the window at the proceedings—but had no opportunity to participate in the discussions, which were carried out in French, a language they did not know* (Colfer and Dudley 2011, p. 4)

In developed contexts such as Australian forestry the specifics may be different, but the need to have greater awareness of stakeholders who could be unintentionally excluded is the same. Groups that might encounter difficulties in participating in PM in Australia particularly

include Indigenous people, those who work long hours (and have less time to participate), lower socioeconomic groups, and, particularly in rural areas, people who are not part of the prevailing culture (such as farming culture in predominantly farming communities).

Choosing the 'right' problem (for all participants)

Different stakeholders will define the problem in different ways. Nancarrow (2005) is critical of researchers in general and modellers in particular who do not stop to consider what other perspectives are needed to identify and formulate the problem. This criticism can be extended to decision-makers and experts:

> *Too often we jump to the research or management stage of the process without first building adequate consensus about the nature of the problem and without involving the appropriate stakeholder groups.* (Costanza and Ruth 1998, p. 187)

Some have argued that the problem needs to be collectively determined in order to have a 'truly participatory modelling process' (Daniell and Ferrand 2006). Daniell and Ferrand suggest a fairly radical solution for putting this into practice:

> *[A] participatory modelling group should be formed without any presupposed ideas on exactly what the group members are to do except to try to work together. In this way each of the participants can start at the beginning by forming their own mental models, and then through exchange with the other participants, determine why they want to work together, on what issue or problem, in order to achieve which objectives and by using which methods or processes.* (Daniell and Ferrand 2006, p. 17)

Even if this suggestion is not practical (i.e. to begin the process with a completely blank slate), the useful point to draw from this is to conceptualise the beginning of a PM process as a time for gathering different viewpoints (or collecting the dots) rather than simply defining the problem from an expert perspective (joining the dots) (Daniell and Ferrand 2006). At a minimum, it is important to create space early in the process so that the problem can be collectively refined, as this will generate discussion, provide boundaries and limit the scope of the modelling process.

Design considerations and tips—Engaging stakeholders

Initiating stakeholder engagement

The first task of the initiating organisation will often be to secure support from a wider range of stakeholders. One suggestion from the literature is that it is important to formulate the key question or problem in a way that 'convinces' other stakeholders to collaborate (Etienne, Toit *et al.* 2011). (This was covered in the section 'Choosing the 'right' problem ...' above.)

Impact on decisions

Influence over decisions is a key attraction for many stakeholders. It is therefore important to provide meaningful opportunities for stakeholders to contribute, particularly since they are generally volunteering their time (Korfmacher 2001). Where stakeholder input into decisions is limited, Korfmacher (2001) argues that it is necessary to communicate the limitations of the process clearly. This is particularly important since many PM exercises do not have a clear connection with a decision-making process and might, at best, expect to provide input into these processes in the form of information.

Stakeholders are likely to have greater trust in the model when they perceive the modellers and/or facilitators as relatively neutral with regard to the issue. Conversely, without perceived neutrality, little may be achieved:

> *If models are used in a way that is well adapted to prevailing circumstances, it can indeed be a platform for dialogues. If not, it might be better to just put a glass of water at the table, since mistrust of what is presented might hamper rather than facilitate the process.* (Andersson, Jonsson *et al.* 2010, p. 5)

Accordingly, Voinov and Bousquet (2010) make several references to the importance of neutrality, noting that when modellers are no longer seen as neutral, hiring an external facilitator can introduce another layer of perceived neutrality. In addition, establishing a relationship with the community of stakeholders and having a 'track record' of neutrality can be helpful (see Box 3 for more on neutrality).

Box 3: The myth of neutrality

It is often assumed that a modeller or facilitator can be 'neutral'. In fact, complete neutrality will never exist as each person comes to the process with their own hopes and vision. 'Neutrality' will therefore always be relative in the situation. It might be more helpful to consider neutrality in a facilitator as an acceptance by stakeholders (particularly any with opposing views) of the facilitator's vision and perspective, and a perception that the facilitator/modeller is 'adequately' or 'relatively' neutral to the situation and to the diverse views of participants. It is similarly important that the facilitator endeavours to manage the group dynamics to encourage diversity and inclusion, avoiding any exclusion, as this may be perceived as facilitator bias (Voinov and Bousquet 2010).

However, neutrality may not always be either the best strategy or desirable. For example, Barnaud (*et al.* 2010) intentionally and strategically aimed to influence the process as an external researcher on a project in northern Thailand. Rather than seeking to manipulate or bias the process for her own benefit, Barnaud's aim was to create greater inclusivity for individuals and groups who appeared to be marginalised.

A facilitator's neutrality is always vulnerable to attack from groups who feel that their interests are not served by the process. This is because PM potentially challenges existing structures by shifting power balances, knowledge and ideas in subtle but important ways. Therefore, PM processes, while often representing a refreshing change, also challenge existing methods of problem-solving and decision-making which may mean that distrust is triggered. 'Experts' in particular may be challenged by the introduction of non-expert knowledge (see Treffny and Beilin 2011 and section below on 'Decision legitimacy'). Local power structures may also be threatened by the introduction of non-local modelling experts.

Therefore, despite the potential for PM to provide a neutral platform for dialogue (Voinov and Bousquet 2010), models and modellers will not automatically be perceived as neutral. In order for participants to engage with good faith, they need to be able to understand and verify the accuracy and credibility of the modelling process. Trust can be gained in many ways during the process as well as in the establishment phase, as is the same in other forms of public engagement.

Transparency of modelling process

Transparency is important for building trust in the modelling process. Korfmacher (2001) suggests several ways in which transparency can be achieved, including user-friendly software that is readily accessible, identifying the sources and level of uncertainty in the model, facilitating stakeholder understanding of existing uncertainty in the model parameters, and providing ongoing technical support after the process to facilitate updates to the model.

Korfmacher (2001) also comments on the importance of transparency for situations when expert input might take priority over other (non-expert) input. Korfmacher (2001) suggests that ideally all participants will agree at the outset about when these situations might arise and decide on the appropriate conflict resolution process should there be disagreement at the time of making a modelling decision.

Design considerations and tips—Model

Is a model needed?

Many PM processes revolve around a model or modelling process. In other situations, deciding not to use a model can better support the process and participants, even when the process has been designated as PM. This may occur when the primary aim of the process is community or public engagement, and modelling is useful only to the extent that it supports this. Bots and van Daalen (2008) suggest that the decision not to use a model may occur in the initial phase of analysing project requirements, when process designers reflect on the process objectives and the capacity and interest of the invited stakeholders.

In their guidelines to good PM, Voinov and Bousquet (2010) emphasise the importance of the process over the model, and note that stakeholders will each come with their own idea of which models or tools will be most effective to work through an issue. Negotiation around how to solve the problem is a fruitful place for mutual understanding and resolving conflict. Newig and Fritsch (2009), writing from the perspective of public engagement, urge modellers to be prepared to adapt to the needs of the group rather than pushing their own idea about what needs to happen and how.

This may raise the question of what participatory modelling is if it does not include a model. In processes in which the model is not central, the quality of interactions between group members and the insights or learning that they gain through their interactions are more obviously significant. Leys and Vanclay (2011) ultimately approached their process as a case of social learning after it became clear that the modelling aspect of the project was going to be less significant than anticipated.

Model design

As discussed in earlier sections, many PM approaches use a particular tradition of modelling such as system dynamics or agent-based modelling, which will most likely require the support of an expert. However, technical modelling will not necessarily be the most suitable form. In situations in which modelling expertise or budget is limited, the tools and techniques chosen to support modelling may be selected more freely, although this may require a greater breadth of experience on the part of the facilitator to know which tools and techniques to choose (Newig and Fritsch 2009).

In general, computerised models can support greater complexity and are easier to use for formulating scenarios. Some systems have been set up to support a range of modelling tools for use with PM (e.g. Simile: http://www.simulistics.com/). However, software may at times also restrict modelling options. In addition, depending on the situation, computerisation may not always be desirable (or feasible). For example, Dougill, Fraser *et al.* (2006) adapted the modelling process to the situation to enhance the ease of communication with community members, using flowcharts with community members and then changing to 'storylines' to represent greater complexity.

Model complexity

While greater model complexity tends to enhance a model's accuracy, it does not necessarily result in greater usefulness and usually decreases accessibility (Korfmacher 2001). This inherent paradox of models is particularly challenging when models are used in a participatory way. Models are unavoidably simplifications of reality; the line dividing simple from complex will not always be clear, but the model should be understandable and relevant for all participants.

Model complexity can be managed through effective facilitation of the model development, which was a key finding of Sandker, Campbell *et al.*'s (2010) review of six cases. Good facilitation will help ensure that participants' concerns are addressed, that participants are presented with clear information and that they are given an opportunity to resolve any misunderstandings.

It will be an ongoing dilemma to maintain model integrity while minimising complexity to enhance stakeholder understanding. Some specific methods for reducing complexity are proposed by Haggith and Prabhu (2003). They suggest narrowing the focus of the model to restrict the scope, selecting aspects of the model to simplify *before* model construction, and/or simplifying the model at the point of simulation (e.g. by aggregating results from geographical regions or time spans, i.e. using weeks rather than days).

Is an expert modeller needed?

One drawback of PM is that it can require specific modelling expertise, at least to set up and introduce modelling software to others, in addition to the skills already required to develop complex scientific models in the first place. More frequently, the modeller must play a central part in designing and continuously adjusting the model. Renger *et al.* (2008) call this latter model 'chauffering', and the vast majority of the 71 studies that they reviewed used this method. Korfmacher outlines the dilemma of the need for modelling expertise:

> *Modelling requires skills, knowledge, and expertise that most lay citizens lack ... Providing sufficient training for citizens to understand the technical considerations involved in watershed management can be very time and resource intensive (Rhoads and others 1999).* (2001, p. 164)

To avoid this dilemma, modelling style may be adapted to the needs and skill level available within the stakeholder group. The framework of creating a model will still have benefits even if the modelling process itself is relatively simple.

Roles for modellers and the team supporting participatory modelling

PM practitioners generally consider that multiple roles are required to support a PM process. Richardson and Andersen (cited by Renger *et al.* 2008; Voinov and Bousquet 2010) describe five different roles that include:

a) facilitator: *functions as group facilitator and knowledge broker*

b) modeller: *focuses not at all on group process but rather on the model being formulated*

c) process coach: *a person who focuses not at all on content but rather on the dynamics of individuals and subgroups within the group*

d) recorder: *strives to write down or sketch the important parts of the group proceedings*

e) gate keeper: *a person within, or related to, the client group who carries internal responsibility for the project, usually initiates it, helps frame the problem, identifies the appropriate participants, works with the modelling support team to structure the sessions, and participates as a member of the group*
(Richardson and Andersen 1995, p. 2).

Expert modellers may play one, some or all of these roles in a project or they may be part of a team that shares the roles. In some situations, such as where learning and cohesiveness among stakeholders is a priority, the modeller will want to play a content-neutral, facilitative role in order to create the greatest opportunity for a group of stakeholders to interact with each other.

One word of caution is that the multiplicity of roles in PM may lead to overload for the modeller and possibly confusion among participants. It is important to consider who will be part of the modelling team and what skills they can contribute.

When participants don't want to use the model

Modelling complex systems requires many skills and also a willingness to engage in open inquiry (Sterman 2002). Inviting participants to build and use a model may be overwhelming for some participants. Participatory modelling stakeholders will vary in their ability and also in their desire to engage with models and with the concept of modelling. This inevitably presents a dilemma for modellers if the aim of the process is to engender as much participation as possible. Much work has been done to simplify computer-based models and increase their accessibility for use in PM processes. This work has meant that non-experts are able to engage with models in ways they haven't before.

Despite this, stakeholders still may not have the ability to use the results:

> *Even with training in modelling processes, involved citizens may not have the experience necessary to properly interpret model results. This is especially true in an age of increasingly complex ... models.* (Korfmacher 2001, p. 164)

Even where stakeholders are capable of engaging with the model and using results, they still may choose not to. Leys (2010) notes that participants preferred to have the modeller engage with the software. There may be many reasons for this including cultural (i.e. greater trust in 'experts') and contextual factors (e.g. sufficient trust in the model to sit back) or a personal sense of inadequacy.

Heavy reliance on an expert modeller may be of concern because of the extra costs of using more of a modeller's time and the increased potential for disengagement or lack of ownership by participants. The significance of non-participation in the modelling process also needs to be considered in relation to the aims of the process. If participation in the modelling process is a critical aim of the process or if enhanced usability of the model is a key outcome, then non-participation would be of greater concern.

Is model validity important?

Participatory modelling practitioners often comment that involving 'non-expert' modellers necessitates some comprises in the accuracy and scientific rigour of the model:

> *In some cases the model may have gleaming flaws in terms of the conventional model calibration–validation–verification process, yet will still be useful for stakeholders to reach a consensus and to make the decision.* (Voinov and Bousquet 2010, p. 1274)

These compromises are made in the interests of producing something that has social merit in that it is credible and trustworthy to a greater number of people. Daniell (2008) comments on the importance of maintaining a balance between participant discourse and scientific rigour. Similarly Voinov and Bousquet (2010) allow that participants can contribute to the questions, key model parameters and processes, but state that the structure of the model should be scientifically sound and defensible. In this vein, Daniell (2008) suggests that PM processes should incorporate a requirement that models are theoretically sound as well as operationally complete. The importance of scientific rigour in the model will depend on the intended purpose of the model, as Voinov and Bousquet note:

> *In some cases scientific accuracy and rigour may be compromised for the sake of communication of ideas and achievement of results.* (Voinov and Bousquet 2010, p. 1275)

Design considerations and tips—Outcomes

Decision legitimacy

Decision legitimacy may be questioned because of the inclusion of stakeholder knowledge in decision-making or decision-informing processes. This is because using PM represents, in many cases, a significant departure from the usual, well-accepted protocols for knowledge sharing and decision-making (such as expert or evidence-based advice). While this departure can be an advantage in shaking things up and stimulating different thinking and relating, it may also mean that the process outcomes are seen by stakeholders, managers or decision-makers as less legitimate than the expert-led alternatives. This is a paradox because, generally speaking, the intention of including diverse stakeholder perspectives and engaging stakeholders is to *increase* the legitimacy of decisions.

Legitimacy of outcomes from PM is therefore definitely not assured, either in the sense that outcomes will be widely accepted, or in the sense that solutions will be more sound. There is a genuine risk that information or decisions originating from PM processes with 'lay person' input will be different to expert opinion, and possibly also lead to poorer decisions.

Korfmacher captures the dilemma this could create for decision-makers:

> *Involving the public can ... put decision makers in an awkward position if the citizens' judgments differ from the modelling experts' (Griffin 1999, Tesh 1999).* (Korfmacher 2001, p. 164)

In instances where inadequate public knowledge rules out over expert knowledge, the expert process is delegitimised while the outputs of the public process are overlegitimised (Korfmacher 2001).

Even when lay knowledge offers crucial information, experts may tend to assume that it is of little value or incorrect. This occurs naturally because experts have a strong stake in their particular view and are familiar with a particular method of problem-solving (Treffny and Beilin 2011). It is important to remember that stakeholder input through PM is generally sought because expert opinion is insufficient in and of itself to resolve an issue. Treffny and Beilin (2011) argue that experts need to come to terms with what it means to include other forms of knowledge. Expert knowledge is only one part of solving the puzzle:

> *When facing the uncertainties involved in post-normal problems [i.e. complex issues with insufficient hard data], scientists are lay people as well (Funtowicz and Ravetz, 1993).* (Kloprogge and Sluijs 2006, p. 365)

In designing and conducting PM processes, it is important to consider:

- the perceived legitimacy of the (proposed) PM process when compared with the usual method of decision-making or knowledge sharing
- how stakeholder input might increase the legitimacy of knowledge or decisions
- how stakeholder input might decrease the legitimacy of knowledge or decisions
- which groups or individuals (i.e. experts) might be challenged by the inclusion of other perspectives and how the process of including new perspectives can be managed to maintain a sense of knowledge or decision legitimacy among stakeholders and those who rely on the process outcomes.

To manage the risk of losing decision legitimacy, the process should be designed to include stakeholder input that can contribute positively to a decision, and minimise any input that might weaken the process. Facilitators should also stay aware of how the process is influencing perceived legitimacy and liaise with groups who are challenged by the process to support them to understand the process or to incorporate their concerns into the process design.

Representing consensus to capture diversity

The outputs of participatory processes less often represent true consensus than comprises among different points of view (Korfmacher 2001). Outputs of a PM process should be presented with caution since outputs based on compromise cannot be taken at face value as representative of the public will—if they were presented as such, it would be providing misleading information.

> *Presenting model results as the outcome of a participatory modelling process may imply that engineering constraints, economic costs, and social values have been optimised. This implication hides the fact that model results are inherently uncertain*

> *and that diverse public values may not be fully expressed in a single set of recommendations.* (Korfmacher 2001, p. 165)

Good practice when presenting the outcomes of a PM process is to note where diversity exists, and to present as much of the diversity as possible.

Conclusion

Participatory modelling is a novel engagement strategy that has been applied widely in different contexts of natural resource management. Participatory modelling involves the participation of stakeholders in a process of modelling to create greater understanding of a system of interest. The most important outcomes of PM are enhanced democracy, greater stakeholder engagement, improved quality of management solutions and reduced conflict over resources. The key feature of PM that facilitates these outcomes is the framework of modelling which allows people to develop greater understanding of the issues, learning from each other and from the modelling process in an environment that is relatively neutral.

Participatory modelling represents an important part of the toolbox available to Australian foresters (and other NRM professionals). Further resources for designing and conducting community engagement are available in the *Handbook for operational community engagement within Australian plantation forest management* (Dare, Schirmer *et al.* 2011). Although PM involves a significant time commitment and can therefore also be costly, the form PM takes can be modified to suit the situation. The general principle of collectively modelling a system of interest will support engagement in many situations. Participatory modelling will generally be the most suitable form of engagement when there is a need for a high level of engagement with stakeholders, when there is a management issue that could benefit from the input of a range of stakeholders (who most likely have different views), and when there is sufficient willingness and support for the process from both the stakeholder community and the funding institution(s) (i.e. forest company, state agency, research institution). Generally speaking, PM will be most useful for exploring situations that have management or social complexity, insufficient data to resolve the key issues, conflict over the issues, and/or mismatched responsibility for (or governance of) the area of interest. Thus there are many opportunities (see p. 25) where PM could support engagement in Australian forestry and beyond.

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Appendix

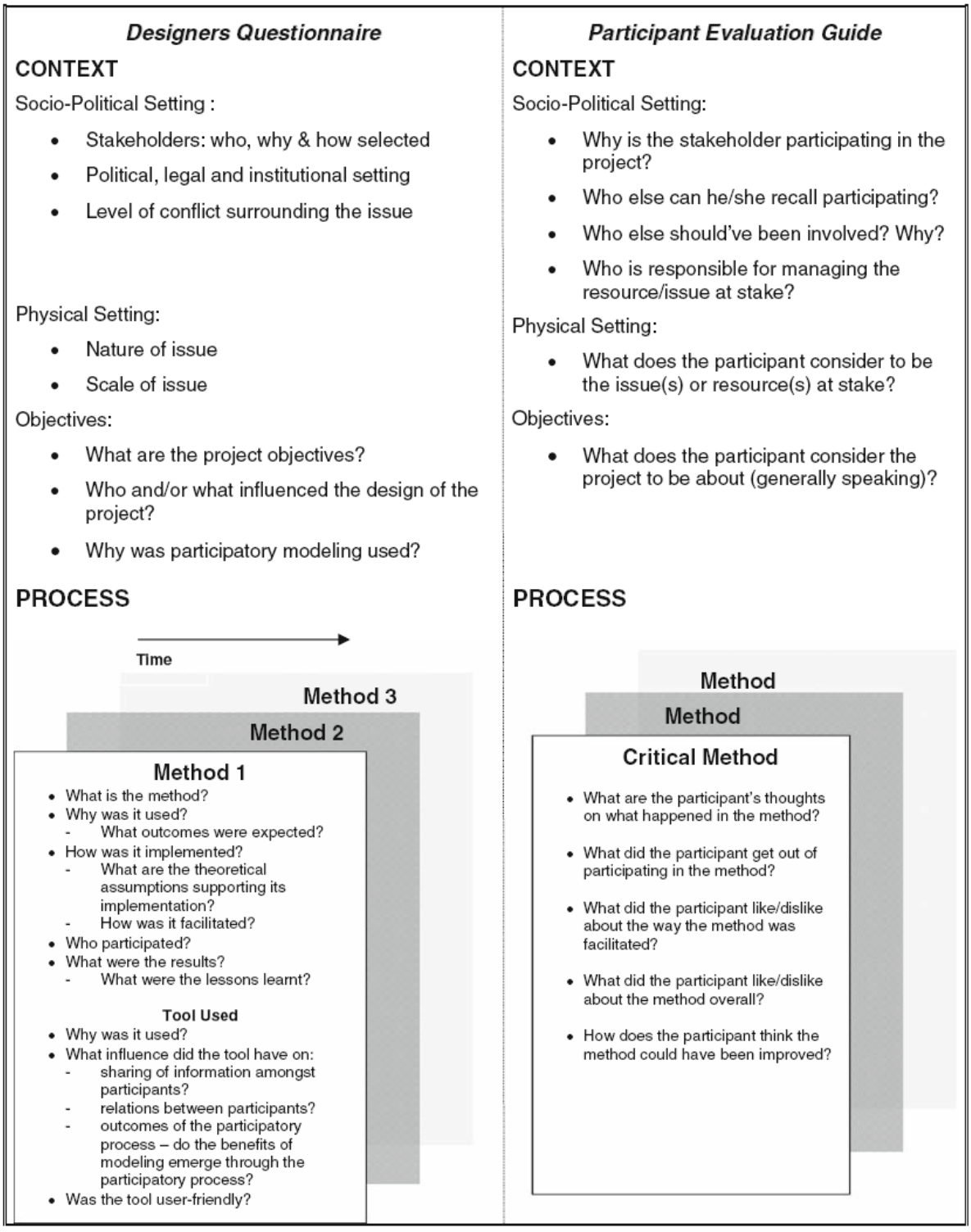

Figure 6: Graphical outline of participatory evaluation framework, called the 'Protocol of Canberra' (Jones, Perez *et al.* 2009)[15]

[15] With kind permission from Springer Science+Business Media: *Environmental Management*, Evaluating Participatory Modeling: Developing a Framework for Cross-Case Analysis, **44**, 2009, 1185, Jones N., Perez, P. et al. Figure 2.

An Australian Government Initiative