SIMPACT - Salinity Modeling for Policy and Catchment Management in the Lower Murray-Darling Basin

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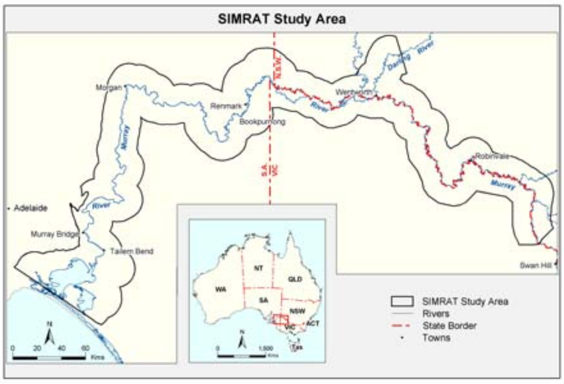
EXTENDED ABSTRACT

In the Lower Murray-Darling Basin (MDB), rising groundwater levels increase discharges of saline water to the River Murray which causes degradation of water resources and floodplain ecosystems. A number of State Government policies and activities, as well as Basin wide strategies under the Murray-Darling Basin Commission (MDBC) have been developed to manage these impacts.

The development of these policies and strategies relies on the best available information and understanding of the issues. SIMRAT is a GIS based model, which has been used to inform policy development and catchment management in the region. It couples two analytical hydrogeological models to quantify salinity impacts and benefits to the River Murray from land use change.

The first model calculates how long changes to deep drainage take to appear as recharge to saline aquifers. The second models the groundwater flows to quantify how much saline groundwater will be delivered to the River Murray over a certain period of time.



SIMRAT has influenced salinity policy development, delivered outputs required by policy and continually challenged our understanding of salinity management issues in the region.

This paper considers a number of applications of SIMRAT for both intra and inter-state initiatives within the lower Murray-Darling Basin:

In South Australia, the model has supplied spatial information for salinity policy formulation. It has also underpinned quantitative assessment of impacts from past development of irrigation as well as techniques for administering estimation of impacts from future irrigation development.

In support of the MDBC Basin Salinity Management Strategy, SIMRAT has become a peer reviewed, accredited model for assessing the impacts of interstate water trade between the three lower MDB states of South Australia, Victoria and New South Wales.

Recharge outputs have been used as inputs to more complex MODFLOW models that detail actual and proposed groundwater pumping schemes.

Groundwater flux outputs have been used as inputs to floodplain modeling to assist floodplain conservation and management policies.

The model has been used to estimate salinity impacts of vegetation clearance as well as potential benefits from revegetation.

Model runs are also contributing to larger scale projects combining environmental, social and economic impacts of Catchment Plans.

SIMRAT fulfils a niche in the Lower MDB, as a standard robust tool for recharge and salinity assessment across a large area. The flexibility of the model enables a range of information products to feed discussions and investigations in support of policy development and implementation, catchment management decision making and hydrogeological visualisation.

1. INTRODUCTION

Under natural conditions, the salt stored in the lower parts of Australia's Murray-Darling Basin (MDB) was kept in place by hydrogeological equilibrium. Landscape modification by European settlers such as vegetation clearance and the establishment of irrigation industries disturbed that equilibrium and began mobilizing salt through the groundwater towards the River Murray. Hydrological and ecological modification such as the construction of locks and weirs on the river, and the introduction of exotic plant and animal species in combination with salinity issues are continuing to degrade the riverine environment.

At risk from this degradation is not only a large and important ecological region of the continent but also a valuable resource base for Australia that generates considerable value in agricultural production, is home to more than 3 million people and supplies drinking water to a million more.

Salt mobilisation in the lower MDB is caused by rising groundwater levels which increase discharges of highly saline groundwater to the River Murray. The rising groundwater is caused by a change in activity at the surface that influences drainage past the root zone and subsequently alters aquifer recharge rates.

To achieve sustainable agricultural activity, these processes must be understood and appropriate land use/management strategies be put in place. State government policies and programs as well as Basin wide strategies have been developed and implemented to manage these impacts.

The South Australian River Murray Salinity Strategy (DWR 2001) was one of the first policy initiatives to address salinity as a key issue for South Australia. The Basin Salinity Management Strategy (MDBMC 2001) outlines the Murray-Darling Basin Commission (MDBC) commitment to managing increasing salinity in the River Murray and has provided the framework for much of the model development to date.

This paper describes the development and application of SIMRAT, a GIS based model that assesses the magnitude of salinity impacts on the River Murray caused by changes to root zone drainage (RZD). The main parameters that influence river salinity in the area are drainage rate, depth to groundwater, aquifer transmission properties, distance to discharge and time. SIMRAT produces outputs in a variety of units and formats that allows particular aspects of the salinity issue to be explored.

Importantly, the paper highlights the collaborative nature of the models development and the opportunities that have been embraced to produce a consistent modelling approach to related questions that occur over a large area and multiple jurisdictions.

2. SIMPACT DEVELOPMENT

In the late 1990s, a number of MODFLOW models had been developed over specific areas to look at groundwater responses under irrigation districts and from groundwater pumping schemes (AWE, 1999).

In such areas of high impact hydrogeological activity, these numerical models were informative and cost effective in answering the questions posed of them. In an attempt to 'fill the gaps' between these models, a GIS framework was devised to estimate salinity impacts of new irrigation development, and provide a regional perspective on the relative magnitude of impacts to highlight areas where irrigation should be encouraged for long term sustainability. This was known as SIMPACT1 (Miles et. al. 2001)

Utilising vertical infiltration rates and type curves generated from MODFLOW runs (Watkins and Waclawik 1996), SIMPACT1 informed the early development of salinity zoning policy in South Australia (DWR 2001). SIMPACT1 highlighted the value of a GIS framework a) in visually communicating salinity related issues and b) collating a database of salinity related data layers. Backed by this, improvements were explored to replace the Watkins and Waclawik method with equations to make the model more dynamic in dealing with the spatial variation of hydrogeological parameters in the landscape.

Firstly, revision of the method for calculating vertical infiltration timelags uncovered more detailed algorithms for drainage increases (Cook, 1992) and decreases (Cook and Connor 2002). Secondly, CSIRO had developed the Unit Response Equation (URE), an analytical approach to calculating aquifer discharge responses from changes to aquifer recharge (Knight et al 2002). These models provide the analytical engines for SIMPACT2 (see Figure 1).

Also around the same time, the MDBC was developing a tool to assess the salinity impacts of interstate water trade (URS Australia 2002). This was part of the requirement under the BSMS to

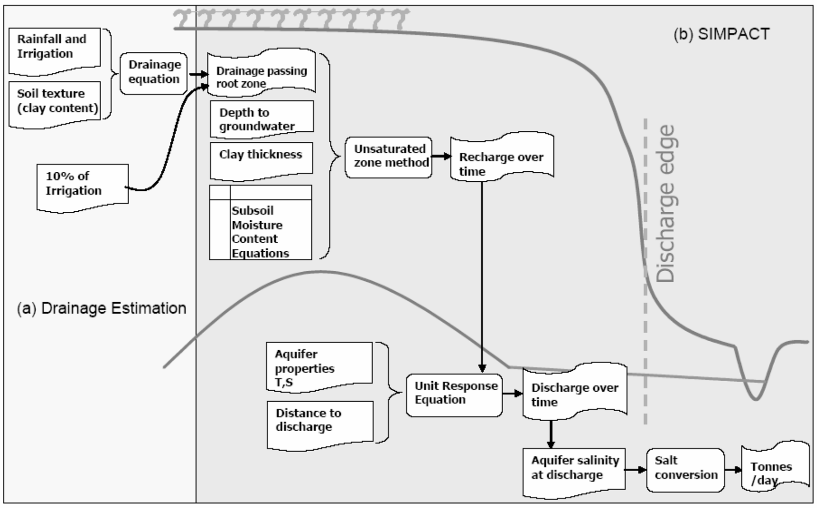


Figure 1: illustrates the conceptualisation of SIMRAT

account for any actions that increased or decreased salinity in the River.

The tool was a spreadsheet based model (iRAT – Interim Rapid Assessment Tool) that utilised the URE. This model was looking for improvements in handling spatial variability and transparency of record keeping.

At this stage, a collaborative approach came together with the direction of producing an improved SIMPACT and an improved iRAT with assessment capabilities across the whole region in SA, NSW and Victoria. Overseen by the Basin Salinity Management Strategy Implementation Working Group (BSMIWG) of the MDBC, the collaboration involved 4 departments from 3 state governments, 4 private consultants and CSIRO (see section 6). The focus of this effort was the generation of a tool for assessing the salinity impacts of interstate water trade (known as SIMRAT). Four of the above organizations did the bulk of the development with others involved in the steering committee, peer review of the model, and as potential users of the final product.

Knowingly, a major bi-product of this effort was to be a groundwater/landuse assessment tool that would have wider potential than just water trade assessment. This eventually became available to address wider questions throughout the region as discussed in this paper. From these applications it was evident a GIS/analytical approach could be more appropriate in some circumstances than numerical groundwater tools such as MODFLOW.

NSW and Victorian portions of the SIMRAT area were now at the beginning of the data collation process, while the South Australian portion was relatively data rich having spent some years refining data for SIMPACT1. It is with this database that South Australia was able to proceed with a number of applications of SIMRAT as soon as accreditation was agreed to by BSMSIWG in September 2004.

Technical specifications for SIMRAT (version 2.0.1) and all supporting documentation are currently being loaded onto the Catchment Modelling Toolkit website (www.toolkit.net.au). Details regarding input parameters and model conceptualisation are contained therein.

Parallel to the development of SIMRAT was the increased understanding of salinity impacts on the River Murray and the Basin. SIMRAT provided a visually easy to understand product which was critical in supporting policy development in South Australia. Through the development of this policy, SIMRAT was also used to provide tailored outputs for implementation of policies, as well as continually challenging the understanding of landuse/landscape processes on which policy was developed by constantly incorporating the best science available. A number of these initiatives are discussed below.

3. APPLICATIONS

Numerical models such as MODFLOW are proven tools for detailed hydrogeological investigations. They require heavy paramaterisation and calibration procedures and are good at assessing the hydrological impact of actions when the totality of processes are understood. E.g. to assess the impact of an irrigation development, a MODFLOW model needs to know the hydrological history of surrounding irrigation and drainage to accurately describe the movement of subsurface water. Analytical models (such as the URE) however have an advantage in assessing individual actions without needing to detail surrounding hydrology. If the model exhibits linearity (as the URE does), it is able to aggregate impacts case by case. This opens up potential applications in a GIS framework by allowing each grid cell to act as a model and be aggregated. Major project opportunities facilitated by this are described below.

3.1. South Australian Salinity Policy

Miles et al (2001) clearly showed there were areas of relatively higher and lower risk of irrigation induced salinity across the landscape in South Australia. With irrigation developments increasing on the back of the wine boom and water trade, policies were being sought to minimize future salinity risks to the River Murray, and promote a sustainable irrigation industry.

With limited salinity credits available and salinity impacts increasing over time, South Australia could proactively reduce additional salinity impacts on the River by encouraging new irrigation development into lower impact areas through innovative policy development.

SIMRAT was used to run a scenario that assessed a 'standard' irrigation development generating 120mm of RZD. This output a map of the whole region showing a continuum of impacts such a standard irrigation operation would have in 100 years.

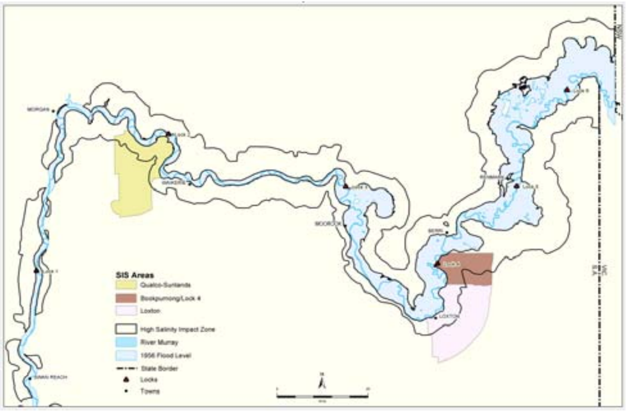
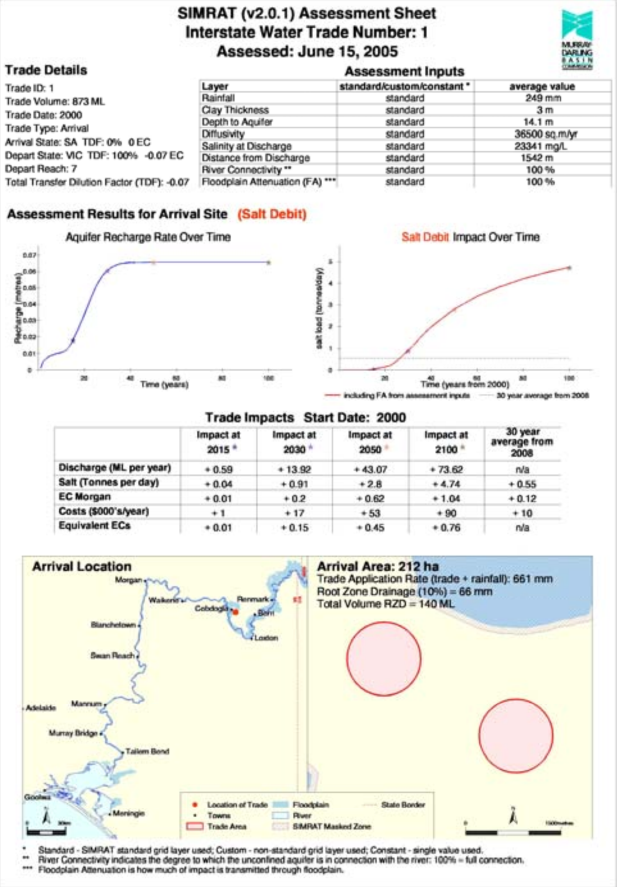


Figure 2. SA High Salinity Impact Zones in the Riverland. SIS areas represent Salt Interceptiuon Scheme Zones.

It was then a policy decision as to where the threshold would lie that defines the line between high and low impact. A figure of 0.02 tonnes/ha/day in 100 years was chosen, and that line has become the basis of the salinity zoning policy which governs irrigation water trade as of July 2005 (Figure 2).

3.2. Individual Water Trade Assessments

In addition to being able to assess landscape scale impacts, SIMRAT has the capacity to assess individual water trades for potential salinity impacts. As part of the requirements under the BSMS, SIMRAT was accredited as 'fit for purpose' (MDBC 2005) to assess the impacts of Interstate Water Trade. This accreditation was pivotal in the MDBC requirement to document the impact of Interstate Trade on the salinity registers. It was also pivotal in the ability of South Australia to post its salinity impact from all irrigation development since 1988 on the MDBC Salinity Register.



SIMRAT (v2.0.1) Assessment Sheet
Interstate Water Trade Number: 1
Assessed: June 15, 2005

Trade Details

Trade ID: 1
Trade Volume: 873 ML
Trade Date: 2000
Trade Type: Arrival
Arrival State: SA TDF: 0% 0 EC
Depart State: VIC TDF: 100% -0.07 EC
Depart Reach: 7
Total Transfer Dilution Factor (TDF): -0.07

Assessment Inputs

Layer	standard/custom/constant *	average value
Rainfall	standard	249 mm
Clay Thickness	standard	3 m
Depth to Aquifer	standard	14.1 m
Diffusivity	standard	36500 sq.m/yr
Salinity at Discharge	standard	23341 mg/L
Distance from Discharge	standard	1542 m
River Connectivity **	standard	100 %
Floodplain Attenuation (FA) ***	standard	100 %

Assessment Results for Arrival Site (Salt Debit)

Trade Impacts Start Date: 2000

	Impact at 2015 *	Impact at 2030 *	Impact at 2050 *	Impact at 2100 *	30 year average from 2008
Discharge (ML per year)	+ 0.59	+ 13.92	+ 43.07	+ 73.62	n/a
Salt (Tonnes per day)	+ 0.04	+ 0.91	+ 2.8	+ 4.74	+ 0.55
EC Morgan	+ 0.01	+ 0.2	+ 0.62	+ 1.04	+ 0.12
Costs ($000's/year)	+ 1	+ 17	+ 53	+ 90	+ 10
Equivalent ECs	+ 0.01	+ 0.15	+ 0.45	+ 0.76	n/a

Arrival Location

Arrival Area: 212 ha
Trade Application Rate (trade + rainfall): 661 mm
Root Zone Drainage (10%) = 66 mm
Total Volume RZD = 140 ML

* Standard - SIMRAT standard grid layer used; Custom - non-standard grid layer used; Constant - single value used.
** River Connectivity indicates the degree to which the unconfined aquifer is in connection with the river: 100% = full connection.
*** Floodplain Attenuation is how much of impact is transmitted through floodplain.

Figure 3. Water Trade Summary Sheet including examples of typical input parameter values.

To undertake these assessments, SA developed a trade database to both feed inputs to SIMRAT and receive the results. Through locating all irrigation water trades since 1988 and assessing them with SIMRAT, South Australia successfully entered the Salinity Registers in 2004. (Kirk et al, 2004).

An important component in the transparency of the trade impact modeling is the one page summary sheet that records the inputs and outputs of the assessment at a glance (Figure 3). By displaying model run details, input parameter values, outputs graphs, and location maps, a succinct yet comprehensive summary of the modeling process is transparently available. The development of this assessment sheet is a good example of the policy driving the outputs required from the model.

3.3. Providing Inputs to MODFLOW

SIMRAT is not a detailed groundwater model able to show groundwater contours over time. Its ability lies in rapidly summarising the impacts of actions in a certain location. MODFLOW is still the appropriate model for Salt Interception Scheme (SIS) planning and design. One function that MODFLOW does not perform however is calculation of time lags through the unsaturated zone i.e. water movement from the surface to the aquifer. SIMRAT does contain such algorithms (see Figure 1) and has been used to generate recharge rates over large areas for feeding into MODFLOW models. This method has produced a grid of recharge values for the SA region ranging from <1mm to 12mm (avg 4.9mm). This improves on the accuracy of previous estimates (Cook et al 2004). Generation of such inputs for MODFLOW has now occurred in 3 model areas covering most of the riverine environment between the SA/Vic. Border and Tailem Bend. Conventional irrigation related drainage estimates have been coupled with SIMRAT outputs in these areas to assist design of SIS and also help understand the magnitude of the legacy impacts of land clearance over the last 50-90 years.

The combination of these two models highlights the importance of model development in continually challenging our understanding of landscape processes and history. As we improve our understanding of landscape our policy development also improves.

3.4. Floodplain Impacts Model

Floodplain degradation is a major issue in South Australia, with the floodplain known to store salt entering the River from the highland areas. While an increase in drainage at any cell location generates an increased groundwater flux (and hence salt load) at the floodplain edge, SIMRAT itself does not describe how that increased flux is distributed laterally along the floodplain. When questions were asked of SIMRAT to assist modeling investigations into how much the floodplain transmits or attenuates groundwater and salt, some additional functions were required.

Again in collaboration with CSIRO, distribution algorithms for the URE were developed (Rassam et al 2004) and applied to SIMRAT outputs describing where on the floodplain, impacts from historical irrigation and clearing would be expressed (e.g. Figure 5).

The aim of this project is to develop a tool to identify areas of the floodplain at risk from impacts set in train but yet to manifest, as well as future irrigation development scenarios. Such a tool will assist in prioritising areas of the floodplain for conservation, in the development of watering plans, and in the formulation of policy directions that will deliver floodplain protection.

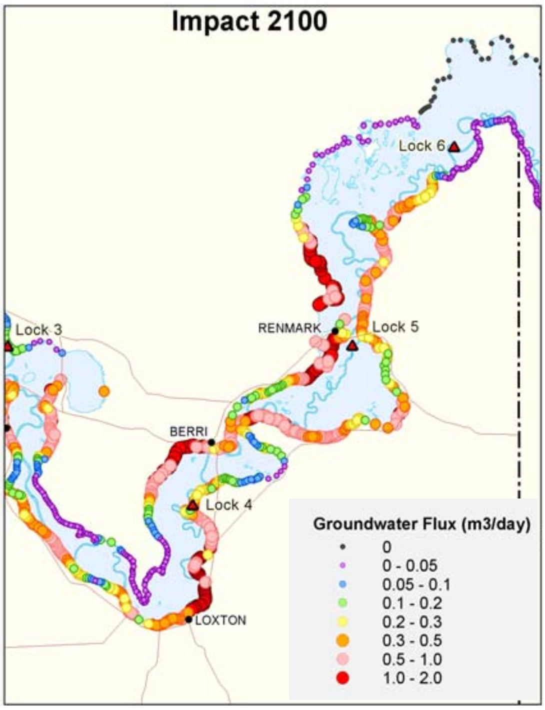


Figure 5 Example of discharges distributed for input to Floodplain Impacts Model

3.5. Revegetation Options for Salinity Management

After assessing the impact of vegetation clearance, SIMRAT was also used to assess the salinity benefits revegetation may afford. Clearance increases recharge and so revegetation decreases recharge. SIMRAT was used to estimate todays impacts from clearance some 80 years ago, and then estimate future benefits if revegetation occurred today.

Drainage under native mallee vegetation is estimated at approximately 0.1mm/y (Cook et al 2004). Assuming all clearance occurred in 1920, recharge rates as of 2004 (from method described in section 3.3) were modelled as being reduced to 0mm/y by revegetation.

Considering the low drainage rates involved, the uncertainty of the timing of clearance and the large hydrologic influence of nearby irrigation, this project was more about prioritizing areas that may show benefits from revegetation than actually generating precise salt load amounts. The results of this work highlighted the variation in benefit from revegetating on different soil types, shown in Figure 6. It also provided input into salinity policy development which was considering options for generating salinity credits.

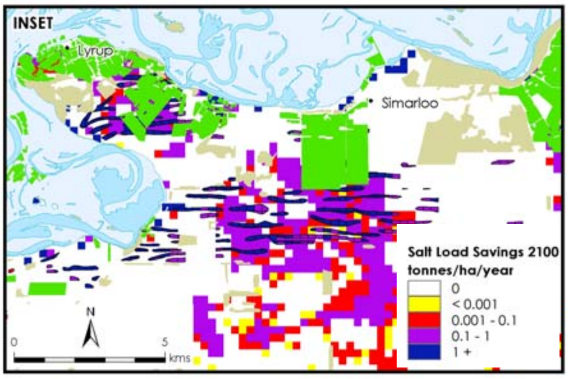


Figure 6 illustrates greater benefits from revegetation on sand dune features north of Bookpurnong (Wang et al, in prep.)

3.6. Lower Murray Landscape Futures

The Lower Murray Landscape Futures (LMLF) project is developing a modeling framework to bring together a variety of aspects associated with landscape change. By looking at resource condition targets in catchment management plans, the environmental, social and economic impacts of future landscapes are being assessed.

SIMRAT is providing the spatial framework for the groundwater and salinity impact components. In analysing potential impacts from existing investment strategies, this tool will allow regional stakeholders to assess landscape scenarios based on drivers of change such as policy and economics.

4. FUTURE DIRECTIONS

It has been recognised that some operational improvements are possible to the SIMRAT framework. While the model is relatively simple to operate, one must have an ArcInfo GIS licence. This could be prohibitive to the potential usability of the model from a cost perspective. In addition, the potential for future enhancements could be greater in an object-oriented programming environment .

The Invisible Modelling Environment (TIME) developed by the CRC for Catchment Hydrology (www.catchment.crc.org.au) is a development framework for creating, testing and delivering environmental simulation models. It can accommodate spatial and temporal modeling in the one platform as in SIMPACT. With some additional development particularly in the area of the summary sheet, platform transfer will open up even more operability as well as transport to other regions of hydrogeological similarity. TIME is currently being investigated as part of the LMLF project, as the platform to support SIMRAT into the future.

5. CONCLUSIONS

The projects described in this paper illustrate the wide range of applications of the SIMRAT model and how it is informing, being informed by and challenging policy development, particularly in South Australia. It shows that GIS techniques are customising outputs specifically for projects at hand with confidence that outputs are underpinned by the same analytical groundwater techniques.

The rigorous accreditation and peer review process developed under the BSMS has provided confidence in the base methodologies of SIMRAT. The GIS framework coupled with the rapid assessment capacity of the analytical models has created many new opportunities and perspectives over the traditional numerical groundwater modeling information base.

One advantage of SIMRAT is the transparency of the input data and the relative simplicity of the conceptualisation. Input parameters are accessible and signed off as the best available for the purpose. Data updates and management are critical to its successful long term use. Utilising a web based management system, updates will be communicated to the user community via a central location.

A positive outcome from the process of developing and accrediting a model that covers such a wide area, is the collaborative way that a ‘simple’ approach has been found to tackle a common issue. By reaching agreement on a regional methodology, valuable relationships have been affirmed. Across multiple state jurisdictions, private and public organisations have come together to produce a tool that is open and available to all, and not under the sole operation of a limited few.

The development of SIMRAT has been a good example of how model and policy development can work together for mutual benefit. Through an environment of collaboration and good communication between those developing the policy and the model developers, policy can give direction to developers and modelers can influence policy direction.

Models are built to answer questions, the critical part is asking the right questions. In this region where answers to many questions are driven by a common set of physical processes, SIMRAT is shown as contributing responses to those questions not as the sole solution but as a flexible tool for use in concert with existing tools and within a community of relationships.

6. ACKNOWLEDGEMENTS

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