GET THE MODELLING RIGHT FIRST TIME…… A NEW PARADIGM IN MODELLING PROCESSES

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ABSTRACT

Hydraulic modelling has blossomed in the past 25 years due to the IT revolution. Multi-million dollar designs are increasingly reliant on the results produced by computer models. The appeal of today's modelling package is the graphical interfaces and the ability to present floodplains or pipe capacity to a discerning and wider audience. Does this mean the answers are right and all issues are addressed? Would two modellers get different answers using the same modelling package and data? How do clients judge the results and how do they implement the conclusions?

This paper describes an over-arching process that pulls together the key and forgotten elements of a modelling project to ensure they never go over time or over budget. The process is generic in principle and collaborative in nature so that client needs and modeller delivery matches precisely. Surprises during a project that can usually compromise the final outcome are avoided.

The principle structure is a combination of project management, distilling what the client actually needs, the modelling framework, compliance with consenting authorities, future-proofing the models and due diligence. The process is in plain English so that non-modellers (asset managers, planners etc.) can understand the murky world of the modelling process.

A case study is discussed demonstrating how it has helped a client understand their problem better and what outputs they need. It saves the modeller time in not having to do unnecessary tasks.

KEYWORDS

Hydraulic modelling, guidelines, process, research, Modelling Policy Statement™

1 INTRODUCTION

Hydraulic modelling in water resources has blossomed in the past 25 years due to the IT revolution. Previously a few specialists would write proprietary programs to solve flood management problems and design water supply networks. Today computer models are used by a range of professionals, including many with little or no modelling experience. Multi-million dollar designs are increasingly reliant on results produced by computer models. The appeal of today's modelling package is the graphical interfaces and the ability to present floodplains or pipe capacity to a discerning and wider audience. Does this mean the answers are right and all bases are covered? Would two modellers get different answers using the same modelling package and data? How do clients judge the results and how do they implement the conclusions?

2 HISTORICAL CONTEXT

Numerical analysis of physical phenomena has been done for centuries and water resource investigations are no exception. However the advent of silicon chip based computers has made this analysis available to a multitude of practitioners. Over 25 years ago the analysis of water systems using computers was generally academia based and the researchers created software programmes for themselves using various languages and methods. In the past 25 years these personal programmes have been commercialised by the research houses to become competitively priced proprietary products. Examples include Wallingford in the U.K., Delft in the Netherlands and the Danish Hydraulic Institute.

This has meant that during this time the hydraulic modeller has moved from a specialist "boffin" (usually post-graduate qualified) to a mainstream engineer. In 1990 there may have been 10-20 professionals calling themselves full-time modellers. By 2009 this number may have swelled to 100 with a further 300 part-timers. Hydraulic modelling has grown from a two million dollar industry to may be thirty-six million dollars, a growth of 15% per annum. Perhaps two billion dollars of infrastructure decisions are based, partly, on the results of these models. Previously the modeller knew the coding and manipulated it to suit their needs and not other parties. Today we have a "black-box" with more and more stakeholders needing to understand model outputs.

The reason it has gone mainstream is the increasing acceptance by government authorities that hydraulic modellers can provide a comprehensive answer to a complex problem. Therefore, where models used to be built as one-off projects, with support from a physical model, they are now being used for almost every water-based infrastructure problem. This has lead to most engineering consultancy firms in New Zealand employing a hydraulic modeller whereas previously it was a boutique industry of maybe two to three companies. New Zealand has just mirrored what is happening in the rest of the developed industrialised states.

3 RESEARCH FINDINGS

Like the expansion of any phenomena there will be growth pains. Mistakes will be made, ideas will be tested, and successes will be repeated. After 20 years some common issues are emerging that need to be addressed. Not to deal with the issues is wasteful to the tax and ratepayers who ultimately pay for the work. If engineering is a profession and is a noble cause then water resource modelling needs to become accountable.

So what are the recurring issues? To quote two sources:

"... it's predominantly hydraulic modelling projects that go over budget"….. Project Manager from a leading NZ consultancy.

".... I have over 100 pages of tables and plans but I have no idea how to interpret the results to implement the reports findings………." - a Council engineer who procured a $250,000 stormwater management plan

In the past 3 years some informal and formal research was undertaken. Firstly we talked to end-users and asked what issues concerned them and secondly a questionnaire was sent to a random set of 20 asset managers throughout New Zealand and 12 responses were received. Table 1 gives the responses to the questions.

Table 1 – Random questionnaire to Asset Managers

Question	**Response**
Does the Council have a standard methodology when reviewing the results of models within reports?	92% said No
Could the standard of modelling outputs provided by 3rd parties be improved to assist you in your interpretation for decision-making?	100% said Yes
Do you have a formal archiving system for computer models (whether done internally or externally) so they could be easily retrieved and used again 5 years later?	16% said Yes
Do you think your Council's codes of practice covers the complex inputs and outputs now generated by computer models?	84% said Not sure 16% said No
If you apply/review for discharge consents what percentage of the applications have had requests for further information based on the lack of clarity of modelling inputs/outputs?	Average score of 50%
When applications are received, that clearly uses modelling tools, does the applicant's report state the software package used?	100% Sometimes
Do you find that Consultants use software you have never heard of when	66% Sometimes

submitting reports?	34% Never
Do you undertake due diligence on software used in hydraulic analysis to ensure its fit-for-purpose whether used in house or by 3rd party applicants?	66% Never 25% Sometimes 8% said "??"
If you have Consultants do modelling projects for you do you: (as many as you like) Specifically check that the modeller has visited the site?……………………………………33% Ask them to do a Gap Analysis on the data provision so they can advise you on what is missing to complete the requirement job objective?…………………………………………….33% Complete model validation checks e.g. mass continuity, cross-section heights?…………24% List the figures, graphs and tables you need in the final report?……………..……….……0%	
Any other comments *"I've observed that many modellers do not understand the physical system that they are modelling. But are "flying blind" and believing the output of the black box"*	

4 ISSUES RAISED

The results of the research raise a lot of issues. Perhaps the top three issues are:

92% said that the standard of modelling outputs provided could be improved to assist in decision-making. The implication of this is that either there is a grave risk that poor decision-making is occurring when interpreting results, or the clients are not receiving all the information they need to have confidence in the outputs. It could also suggest that the clients will use instinct and experience to solve a problem and make the modelling exercise superfluous.

There is a lack of due diligence on the software products to establish whether they are fit for purpose; this is particularly worrying. It is probably being done on an ad-hoc basis with no formal methodology. A literature review has brought to light three such studies which address the software used and/or the appropriateness of the methodology.

All clients do not have a standard methodology for assessing modelling results. This means that every project gets treated differently even though the same software tool is used, or consent applications are treated differently and reliant on the experience and exactness of the reviewer.

Other issues raised by the research are:

Models get lost or become obsolete very quickly and thus the investment is wasted. The biggest component of a hydraulic model is the construction ready for simulating design events. This requires ground surveys of the assets, flow and water level gauges, calibration, and model build etc. and perhaps make up 80% of the total cost if done properly. Therefore to lose the model or to allow it to become out of date wastes a great deal of money.

Hydraulic modellers do things differently; they are human after all. However in every day life there are standard methodologies that ensure accountability and repeatability. Accountants, surgeons and electricians follow standard procedures. Unfortunately this is not so for hydraulic modelling which is built on experience. This means quality is inconsistent. Clients must be confident that multi-million dollar investments in infrastructure, based on modeller's investigations, will give very similar outcomes no matter who they use.

In many cases hydraulic modellers complain that clients are not clear on what they actually want. The brief is too brief. There needs to be specifications that meet expectations to which the modeller can be measured and success can be assessed.

Many graduates are encouraged to become modellers. Many become bored and move on because the skill is still regarded as specialist. Therefore knowledge is not maintained and developed.

Finally, software vendors have become very successful in developing products that are easier to use. The data rich environment is more easily manipulated, model sizes are greater and the menus are generally intuitive. Unfortunately they have created a black-box that it easy to use and the users expect results to be right. It is style, but lack of substance with many users not understanding whether the results are meaningful. The industry does not encourage good training procedures although software-based courses are available ; they are not compulsory.

5 WHAT IS AVAILABLE NOW

5.1 NEW ZEALAND

There are guidelines available which have been developed within New Zealand by Water New Zealand. The latest version of the water distribution (29 pages) and wastewater version (39 pages) are dated April 2009. The Auckland Regional Council has TP108 for hydrological modelling that has since 2000 become a proxy guideline used by many Regional Councils.

5.2 OVERSEAS

The Indiana Department of Natural Resources provides a checklist when assessing applications within floodplains. It is 14 pages long and asks the engineer to provide a raft of information and print outs from the model, implied to be HEC-RAS. It even asks for a print out of error pages and a justification on why they have not been corrected. There is also the WaPUG River Modelling Guide which is 39 pages long and published in 1998. WaPUG also have water distribution and wastewater guidelines.

All these documents are extremely useful. They are what they say they are – guides. However they do not provide any measure of certainty or framework to judge at the end of the project that the modelling meets client expectations. They are specific to the type of modelling required; some are very long and this will generally ensure nobody uses them constantly.

6 THE NEW PARADIGM

With the issues highlighted by the research and documents presently available, what are the options available for both the practicing modeller and clients procuring their expertise?

Firstly, what is the objective of any process that needs to address these issues?

It could be "A process that enables the modeller to respond to the needs of the client in a specific tangible manner that can then be measurable, transparent and transferable for future use."

The characteristics of any process that can work in practise are

- Universality
- Comprehensive and comprehensible
- Teachable from management to technical level
- All modellers (experienced and inexperienced) will be at the same communication level
- An over-arching umbrella for territorial laws, codes and specifications and industry specifications
- Creates accountability for quality
- Ensures client gets what client wants
- Strong communication tool

The following structure meets these needs.

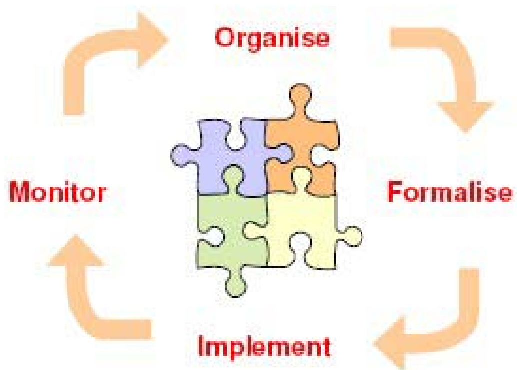
7 STRUCTURE

The new concept is based about a four stage process which is cyclical in nature.

A Modelling Framework to ensure that, when a client commissions a consultant to complete water resource modelling work, there is a pre-designed structure, an understanding of responsibilities and needs of all parties and a definition of measuring success.

The Modelling Policy Statement™ (MPS™) is a core component. It ensures that there is consistency, accuracy and long-term transparency without impinging on the consultant's skill and innovation. Figure 1 shows the four stage cycle.

Figure 1 – The Four Stage Cyclic Process



Section 1 – Organise

This stage sets the scene, the client's expectations, the scope of work and the boundaries. This is driven by the client.

Section 2 – Formalise

This states the general parameters the modeller will be expected to follow. This is driven initially by the client and then agreed to by the modeller.

Section 3 – Implement

This sets the framework of how the work is to be done. It still requires the modeller to use skill and expertise. This is driven initially by the client and then agreed to by the modeller.

Section 4 – Monitor

This can not be completed in the first version of the MPS™. The general structure is set up but the detail is finally agreed before close-off of the project.

The MPS™ Sections are discussed in more detail as follows:

7.1 ORGANISE

This section establishes the needs and expectations of the client. It compiles the necessary project brief and incorporates the statutory framework and standards required to complete the work successfully.

The client needs to consider carefully their core objectives so that it can be communicated to the modeller in the context of the wider project needs.

The MPS™ communicates to the modeller the type of people who will utilise the result, what skills and experience are expected and who will own the data, the final model and the results.

Issues headlined and explained in the MPS™ include:

- Target audience
- Technology
- Skill base due diligence
- Experience requirement
- Ownership and governance

7.2 FORMALISE

This stage is more technical in nature. It sets the modelling parameter framework. It guides the modeller into understanding the acceptable minimum requirements for the methodology. A key component of this work is for the modeller to complete a Gap Analysis Report (in a specified format) that will ensure the client understands at the beginning what the consequences are if there are limitations on data quality. In other words the question is asked:

"What will compromise the modeller's ability to fully complete the project objectives"?

This ensures there are no excuses or surprises when the project is delivered in draft report form.

Other aspects that may be considered in this stage are:

- Survey requirements and needs
- Catchment elements (area, slope, soils, land-use)
- Rainfall inputs
- Calibration data quality (flow gauges, water level gauges, rainfall gauges)

7.3 IMPLEMENT

This stage deals with the methodology being applied and what deliverables are required. It defines and clarifies what a successful outcome will look like to the client. It will include the main content and format of the report so that a peer reviewer can easily check that the modeller has delivered what the modeller agreed. It will also consider what integrity checks need to be executed and reported on.

Other aspects include a critical task list that identifies the point in the project where the client and modeller meet and confirm the way forward. An example of this will be when the model is calibrated.

Other aspects to consider in this stage are:

- Methodology statement
- Assumptions used
- Report of data used
- Decision-making process

7.4 MONITOR

This section is the key step in considering how the models being created are future-proofed and whether the model has fulfilled its purpose. What does the client need to consider to determine if the models need to be improved. For example, advice may be given on better calibration data at specific points, or on the survey of floodplain area that could improve accuracy.

Another aspect for consideration is the minimum content of a peer review so that the modeller will understand at the beginning the outputs expected.

A statement is made on who is responsible for archiving the models, its location and how and when it will be upgraded as new versions of the software are introduced.

Other aspects considered in this stage include:

- Continuity checks
- Calibration checks
- What improvement programmes need to be considered?
- Do you need more or less modelling expertise?
- Resource requirements

All in all there are about 70 different issues that need to be considered at the beginning at the project to ensure that success is clearly defined. Many issues are generic to all types of modelling projects whether they are water supply, river flooding or groundwater extraction.

8 CASE STUDY - A PROJECT IN MOTION

In 2008 the Northland Regional Council sent out a Request for Proposals through the GETS tendering website.

"Undertake the assessment of flood hazard risk and the development of river management plans for identified priority rivers for the purpose of flood risk reduction."

There are 20 flood risk management plans that need to be prepared throughout the region. The RFP was comprehensive and included amongst the usual criteria:

- Anticipated outcomes
- Information availability
- Previous reports
- NRC information technology environment
- Compliance
- Responsibilities of NRC and the vendor
- Selection and engagement process
- RFP evaluation criteria

Given the comprehensive requirements outlined above why did NRC feel that a framework needed to be in place by using a Modelling Policy Statement™?

Because of the diverse nature of the community needs the data available (or lack of it) and the need to identify the right type of modelling consultant, a process was put in place to ensure that no stone was left unturned.

Examples of components that were not part of the original RFP document are:

The purpose for the work had to be articulated to the modellers……..all of them. In this case the key purposes are a) long-term community plan consultation, b) assessment of existing infrastructure, c) a risk analysis and d) a catchment overview. In addition to this the NRC clearly stated that the work was not being undertaken to obtain resource consents. Therefore the energies of the modeller are put into flood risk assessment and not resource planning …. yet.

Coupled with this is a statement that the target audience to inform the modeller that outputs may be seen by the general public. This signals to the modeller that the results and conclusions are to be published in an easy to read fashion, but using Appendix documents to harvest the technical details.

The Modelling Policy Statement™ also describes the requirement of the Gap Analysis Report that must be approved by the NRC before the main modelling work begins. This part of the work allows "breathing-space" for the modeller to assess all the data needs and then report in a formal manner to the client. This is to prevent a situation where the project is almost finished and then somebody discovers data that could have been available at the start which could have changed the course of the project. The benefit of the Gap Analysis Report is for the modeller to declare at the outset that….

"Unless we obtain the following data the MPS™ can not be complied with and the end product will be below your expectation".

This allows a prudent assessment of data before rushing headlong into the work.

For many projects the modeller does not know what Standards or Guidelines are to be used. For this project the following was stated in the MPS™:

The following standards and documents must be complied with at all times:

- *Resource Management Act*
- *The Northland River Management Policy (Appendix 1).*
- *The New Zealand Standard for Managing Flood Risk – A Process Standard (NZS 9401:2008) (Appendix 2).*
- *Surface Water, Document E1, Building Industry Authority*

The following references should be considered:

- *Roughness characteristics of NZ rivers, NIWA, September 1998, ISBN 0-477-02608-7*
- *Guidelines for stormwater runoff modelling in the Auckland Region, Auckland Regional Council, 1999, TP108*

A common issue in hydraulic modelling projects is "What is a good calibration?". Calibration is not an exact science but the client needs to understand the margins of error. The limitations of data can compromise results and mislead end-users. In this MPS™ it has been agreed that:

- *The modelled flow volume should be within at least 15% of that measured by the gauging site for any 24 hour period or the storm duration whichever is shorter*
- *The modelled peak flow should be within 15% of that measured*
- *The modelled peak flood level should be within at least 100mm of that measured*

Another aspect of calibration is the use of bed roughness to control peaks. Sometimes typical bed roughness values can be exceeded to make the model fit but are never formally reported. To ensure reasonable values are used bed roughness benchmarks are tabulated depending on the material. If the values are exceeded then the modeller needs to state the reason and the client gets the opportunity to assess the implications. Table 2 below gives the details for the NRC project.

Table 2 – Bed Roughness Benchmarks

Material	***Preferred***	***Minimum***	***Maximum***
Natural channel free of weed and straight	0.022	0.020	0.025
Ditto with poor alignment	0.040	0.030	0.050
Ditto with weeds and poor alignment	0.010	0.050	0.150
Gravel from weed and straight	0.035	0.030	0.040
Ditto with poor alignment	0.060	0.040	0.080
Gravel with stones and boulders exceeding 150mm average	0.055	0.040	0.080
Lined concrete channels	0.015	0.012	0.017

Finally another section in the MPS™ is the model integrity check. This is a simple exercise that has to be reported. In this case the NRC wanted the following stated clearly in the Appendix for each scenario:

- *Continuity: INFLOWS = OUTFLOWS within the model, anything greater than a 5% difference is unacceptable*

- *Volume: Check that the volume generated by the run-off model is similar to a hand or spreadsheet calculation*

- *Calibration: Are the calibration requirements met?*

This case study demonstrates how clients who are not experienced in modelling can safely deal with a number of issues. Many modellers do many of these tasks based on experience but unless there is formal documentation using a MPS™ (or new modellers who are trained thoroughly), mistakes will continue to occur to the detriment of the profession and client budgets.

9 CONCLUSION

Hydraulic modelling has moved rapidly in the past 25 years. However this does not mean the quality of the work has kept up with technological progress.

Clients experience a myriad of issues when procuring modelling work, often leading to cost over-runs, time delays, repetition and lost information.

A survey of asset managers highlighted that there is no standard methodology for checking modelling results and that 50% of consent reports require additional information due to the poor clarity of modelling results.

There are a number of guidelines for modelling but they can be too specific to the discipline or they do not clearly state the parameters.

A framework based around a Modelling Policy Statement™ has been developed that encompasses and deals with the issues clients face when procuring modelling expertise.

An example of its use for the NRC has shown that key issues need to be articulated to the modeller so that time or money is not wasted. The benefits of the MPS™ are that it:

- Is a “live” document that responds to the needs of the project
- Allows the client to clearly communicate what they want
- Supports consultants to respond positively to client needs
- Creates strong communication and collaboration
- Provides for an easier peer review process (actually reduces its need)
- Ensures modellers are committed to project outcomes – no excuses

With regard to the case study that has been outlined, the NRC felt that:

- The technical parameters may be too prescriptive, experts should already know them
- There is clarity of purpose for both the Council and consultant
- It is easy to understand
- It should reduce the commercial risk – time will tell

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