From:	NSW Government
To:	Flood Inquiry
Subject:	Floods Inquiry
Date:	Friday, 29 April 2022 9:13:18 PM
Attachments:	2018_ASFPM_VanDrie_etal_Who_is_Responsible_for_Checking_Final.pdf SAVING MILLIONS_IN_Local_Gov_Version_E_2013.pdf 2008_HAZARD_FP08_PAPER 24 -26.pdf

Your details

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Last name	VanDrie
Email	
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Submission details

I am making this submission as	An academic/researcher
Submission type	I am making a personal submission
Consent to make submission public	I give my consent for this submission to be made public

Share your experience or tell your story

Your story

I am a Flood Modelling Expert, and co-Author of a very popular Industry Hydrologic Model called WBNM, and I am a contributor to the Free and Open Source Project funded by the Federal Government through Geoscience Australia and the Australian National University. I have previously reached out the the Premier of NSW and QLD about flooding issues. My main issue, is the way in which the Flood Modelling Industry operates and interacts with Local Government. In my last Role with Central Coast Council (Planning Engineer Hydrology) I spend a lot of time reviewing flood models and reports. I have found that many flood models are done quite poorly, with in most cases Local Government no longer having the level of expertise to properly check the models. (I presented a Paper titled Who is Responsible for Checking your Flood Model?, in 2018 in Phoenix Arizona. https://cupdf.com/document/who-is-responsible-for-checking-flood-models-2019-10-21-who-is-responsible-for.html) The State Department that oversees the flood plain management program, is meant to provide Technical oversight, but in reality there is little technical review. The are several aspects of flood modelling which is done poorly, from the determination of spatial variation of design rainfall, to the industry approach in determining hazard. This approach has essentially not changed since the 1970's. I have previously approached the review of ARR with a view to determining a better approach to defining Hazard. (On this point I presented a paper at a conference putting forward a potentially better approach, https://www.researchgate.net/publication/306286853_HAZARD_-Is_there_a_better_definition_Impact_of_Not_accounting_for_buildings). Flood modelling for larger catchments is done particularly poor. The current Flood models struggle to properly deal with steep terrain and faster segments of the stream. Many flood models include evidence of this in the model files, as consultants alter parameters to try to stabilise models. I would like the opportunity to provide a great deal more insight, and a long on going proposal I have put forward to vastly improve the flood modelling outcomes. Please provide me with to opportunity to provide you this insight.

Regards Rudy Van Drie

Terms of Reference (optional)

The Inquiry welcomes submissions that address the particular matters identified in its Terms of Reference

1.1 Causes and contributing factors	Cause, poorly informed public, and poor warning coming from modelling and mapping that does not address directly the needs of the community.
1.2 Preparation and planning	Preparation starts with having access to the best modelling and mapping of the catchments behaviour. Critical output is not provided, for example, the Froude Number is one output that is under utilised. It is the one parameter that clearly provides a description of the flood behaviour and event the appearance of flood flow, but few consultants discuss it, as several models being used by the industry become unstable in slightly higher Froude numbers.
1.6 Any other matters	I think there is a critical series of issues, that cold be relative easily addressed and improved. I have long held the belief that Local Government rather than simply engaging Consultants to prepare flood studies and flood maps, should actually own and run all of its flood models, and be far better versed in the process of running and interpreting flood model output. This is currently not what is happening. There is an almost universal reliance on consultants, who's focus is not quality outcomes, but maximizing profits.

Supporting documents or images

Attach files

- 2018_ASFPM_VanDrie_etal_Who_is_Responsible_for_Checking_Final.pdf
- SAVING MILLIONS_IN_Local_Gov_Version_E_2013.pdf
- 2008_HAZARD_FP08_PAPER 24 -26.pdf

HAZARD :- Is there a better definition? & Impact of Not accounting for buildings!

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***Abstract**:*

The basic derivation of "Flood Hazard" is based on the determination of "Hydraulic Hazard" and the assessment of various factors as defined in Appendix L of the Floodplain Development Manual 2005. The primary determinant being related to the momentum of the flow or, "Velocity x Depth". Further it is common in flood studies of urban areas to utilise methods by which the residential areas within the urban area is set at a very high roughness value in an attempt to account for the influence of obstacles to the flow such as buildings and fences. What impact does this have on identifying VxD and Hazard? This paper explores the impact of not specifically accounting for the presence of these obstacles and also explores potential methods to derive a parametric equation that may provide a better scope and range for identifying a more quantitative method of differentiating Hazard. This paper has in effect two parts. Part one describes a proposed new definition of Hydraulic Hazard. Part two uses the technique to investigate and report on the inadequacies in the current practice of adopting a high roughness value to attempt to model the impact of obstacles in an urban environment.

1.0 INTRODUCTION

Identifying "Hazard" is a major component of flood studies and floodplain risk management studies. The evolution of defining what hazard is should be focussed on attempting to derive a method that is simple to apply yet provides the greatest scope and flexibility in differentiating (or delineating) the extent and severity of a hazardous condition. Howells, McLuckie, Low & Avery (2004) provide a reasonable discussion on the evolution of "hazard" in the context of flooding. Further there is some discussion on the limited delineation provided by adopting the current recommended methods as described in the NSW Floodplain Development Manual 2005 (FPDM2005). Current practice in effect limits the delineation of "hazard" to one of two possible categories:

1. Low Hazard
2. High Hazard

(Note there is a band sometimes referred to as intermediate or medium hazard.)

However this limited delineation is extremely limiting in the information in can convey.

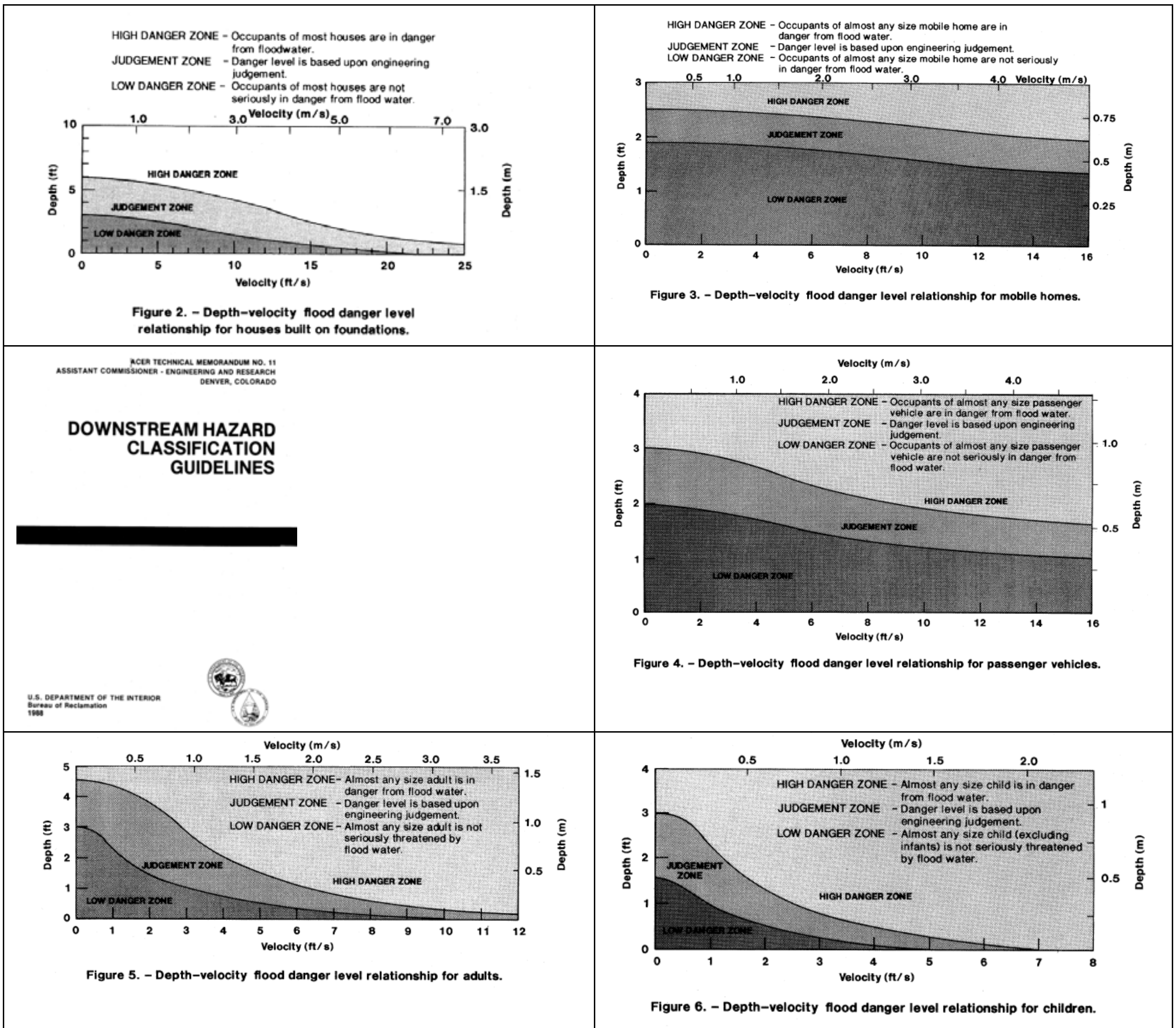
2.0 IDENTIFYING HAZARD

In the US Trieste (1988), provides a methodology whereby a series of hazard curves derived from Velocity and Depth information is additionally related to items at risk of the hazard. The specific items include:

1. Houses built on Foundation
2. Mobile Homes
3. Passenger Vehicles
4. Adults
5. Children

A series of 2 curves provide delineation of 3 zones for each of the 5 items (Figs. 1 – 5). This method is based on work by Black (1975), Ruh-Ming (1984) and David (1987).
More info from: https://www.nwo.usace.army.mil/nfpc/fpbib/ace10.htm

He also mentions that duration of exposure to hazard (as well as several other factors) should be accounted for, in determining hazard within the judgement zones. The hazard classification outlined by Trieste deals only with lives in jeopardy as opposed to “estimated loss of life”.



Figs. 1-5 Hazard methodology by Trieste (1988)

This methodology would presumably be reflected in the creation of 5 separate maps for each of the types of items exposed to hazard.
It should be noted that although this methodology was developed in 1988, they are still current practice in the US as stated by Harrington (2003).

2.1 FPDM 2005 Approach

By comparison the FPDM2005 method also provides two lines that create three zones of hazard (Fig 6&7). However there is only one family of lines to cover all cases. The FPDM has in some ways extended the range of differentiation by utilising "Hydraulic Categorisation". But what is the underlying value in these categories? This question is not the subject of this paper however further discussion can be found in the paper by Rigby & Roso (2008) {this conference}. So in effect we have 6 categories that appear to have no underlying parametric approach to differentiate them. This is a situation that the author feels should be avoided at all costs, as it has the potential to become too subjective rather than definitive.

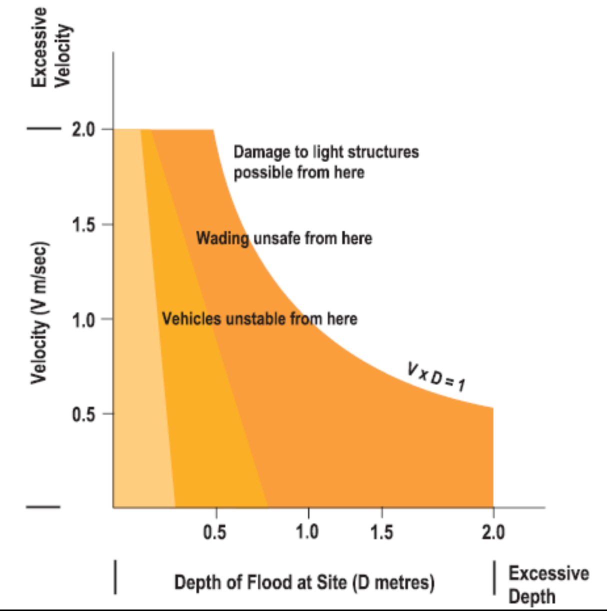


Fig. 6. FPDM Fig. L1

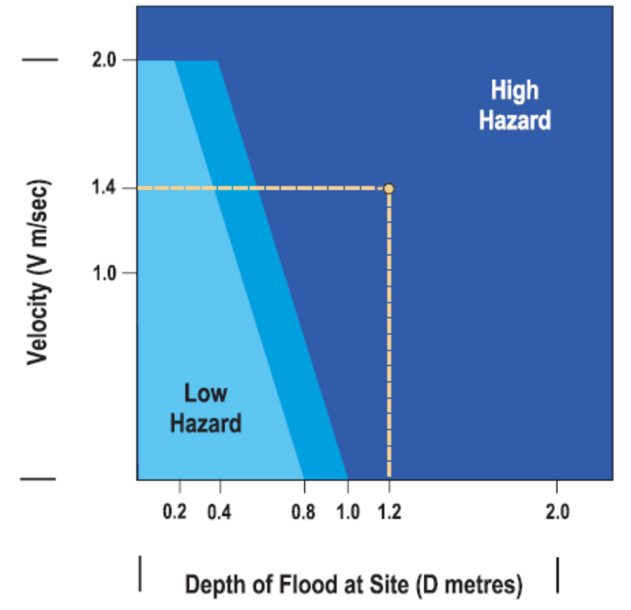


Fig. 7. FPDM Fig. L2

From the Fig. L2 in the FPDM2005 it is clear that the simplistic relation that defines the differentiating line between Low Hazard and higher Hazard is:

Approximate equations that make up the FPDM plots are as follows:

A. For Fig. L1:

1. Vehicles unstable from here:

Depth = Velocity x (-.092) +0.3155 (For Velocity 0 -2m/s) **Eqn. 1**

2. Wading Unsafe From here:

Depth = Velocity x (-.092) +0.3155 (For Velocity 0 -2m/s) **Eqn. 2**

3. Damage to light structures possible from here:

Depth = 1 / Velocity (For Velocity 0 – 2m/s) **Eqn. 3**

B. For Fig. L2:

1. Low Hazard Below this Line:

Depth = Velocityx(-0.3) + 0.8 (For Velocity in the Range 0 - 2m/s) **Eqn. 4**

2. High Hazard above this Line

Depth = Velocity x (-0.3) + 1.0 (For Velocity in the Range 0 - 2m/s) **Eqn. 5**

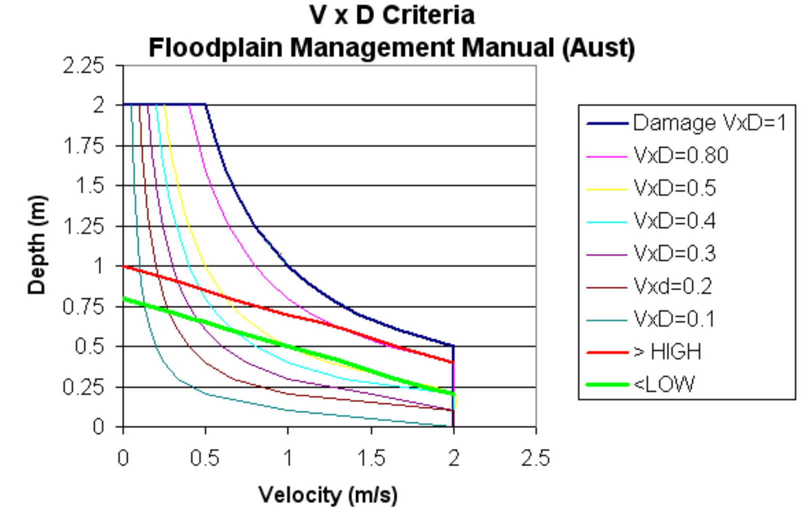
These relationships are relatively easy to use to colour a 2 dimensional computational domain to produce a hazard map. But what does it mean, what does it represent and how useful is it, and how can this usefulness be extended?

By plotting these lines over plots of Velocity x Depth, you can get a bit of a “feel” for what these lines represent.

The fact that the line identifying areas that are deemed low hazard, has a range of VxD values from 0.18 to around 0.53 shows that the line is actually not strongly related to VxD. Similarly the line that represent that an area is deemed high hazard has a range from 0.23 to 0.83 once again not at all strongly related to VxD.

It would appear that these lines were derived by simply connecting 2 points on a graph and do not have a relationship with the underlying intrinsic value of VxD.

This can be seen in Fig. 8.



The current lines that delineate Hazard do not reflect any particular value of VxD, the underlying plotted data.

	Velocity x Depth	
	L -Int	Int - H
Min	**0.18**	**0.23**
Max	**0.53**	**0.83**
Mean	**0.46**	**0.74**
Aver	**0.42**	**0.65**
Range	**0.35**	**0.60**

Fig. 8. VxD and the FPDM Hazard Lines.

So why then relate Hazard to VxD?
Velocity x Depth, does not identify Depth with minimal velocity as being hazardous. Is that why the two straight lines evolved in the FPDM plots? : - To effectively cut off the influence of velocity over depth at high depths and low velocities?

If this is the case, potentially there is a better derivation that will lead to the newly defined hazard having a relationship with the underlying plotted data. So, what style of parametric equation can be plotted to provide better insight into a value for Hazard? It is clear that more research is required to identify what potential for damage exists for a range of Depths and Velocities that exists on the floodplain.

3.0 A new Alternative Approach to Hazard Definition

The answer to the question (is there a better relationship to define hazard?) may be reflected in analysing the Trieste plots.

The first outstanding difference is that the FPDM HAZARD lines are straight lines, whilst the Trieste plots are curves. What is influencing the shape of the curve? Secondly the vertical axis is depth rather than velocity, so in effect they are more like the FPDM plots rotated through 90 degrees (Fig. 9 &10).

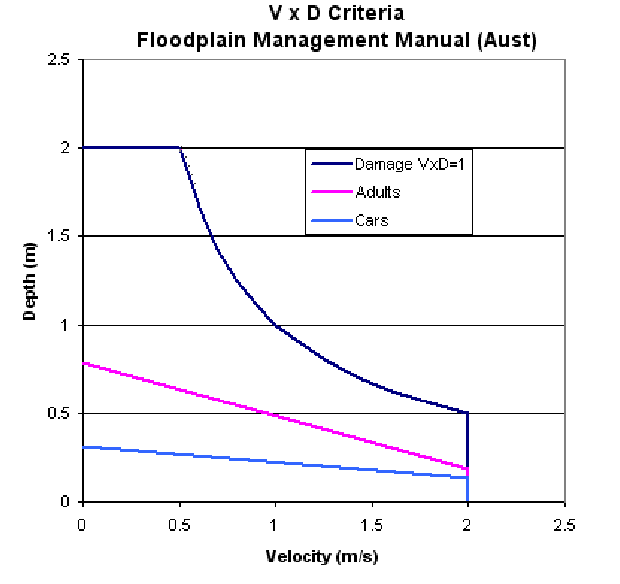


Fig. 9 FPDM L1 Rotated 90 degrees

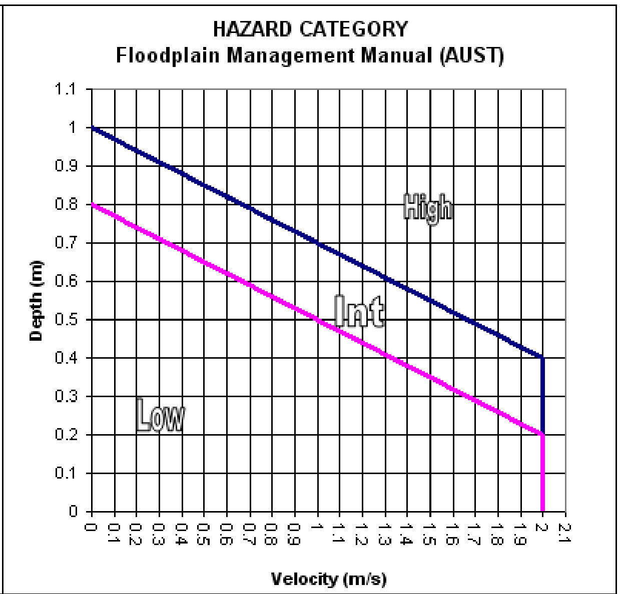


Fig. 10 FPDM L2 Rotated 90 degrees

The curves are essentially almost (half) a bell shape. The classic form of a bell shape form of equation is the equation for a solitary wave, which is a hyperbolic cosine equation. However potentially it is even simpler.

An investigation was undertaken to attempt to formulate an expression that could reflect the shape of Trieste plots and provide a close representation of the FPDM lines, with a singular value. That is that the definition of hazard could be related to a value directly related to a single expression.

After many and various expression were tested, the following seemed to provide some merit:

HAZARD = Depth + Velocity^2 x Depth ie: (D + V ^{2} xD) **Equation 6.**

By plotting this parametric equation of directly derived values it can be seen that in fact potentially, now a single line provides a transition over the previous two lines in the FPDM plot. Further, conveniently the underlying parametric value of this line is 1.

So that 1 now represents the differentiation between Low and High Hazard. In addition it appears that a value of 2 is closely aligned with the current VxD=1 (deemed potentially damaging to light structures) Figs. 11 & 12. Possibly other values higher than 2 may relate to damage to other structures? In deed the current limit for vehicles is well represented by a constant value of 0.4 and the current limit for wading for an adult is also reasonably well represented by the new HAZARD function with a constant value of 0.75 Figs. 11 & 12.

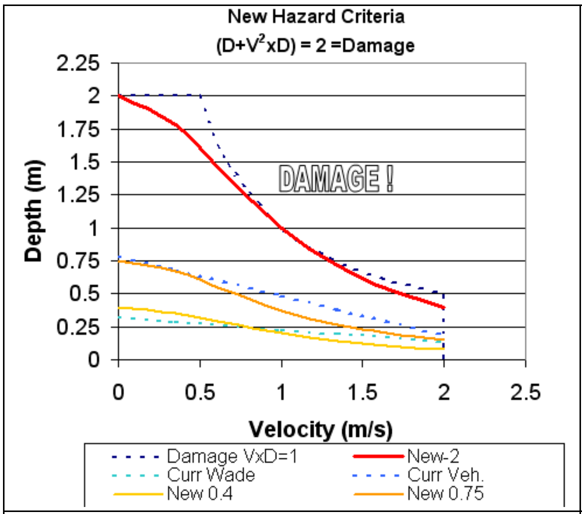


Fig. 11. Note the current hydraulic criteria are well depicted at values of 0.4, 0.75 and 2.0

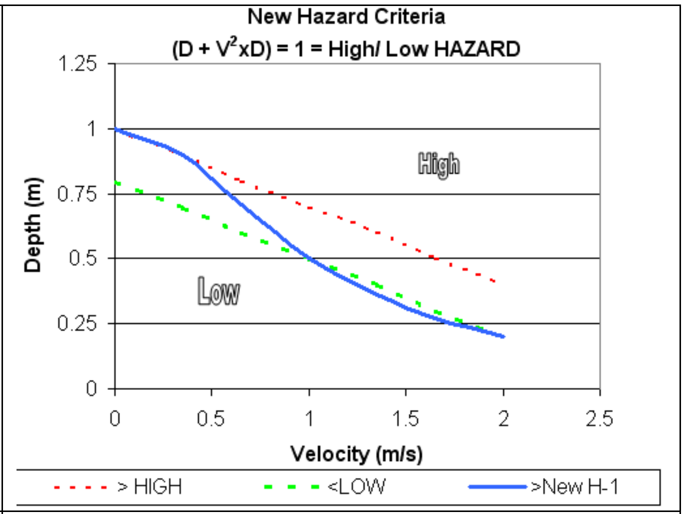


Fig. 12. Line between Low Hazard and High hazard is set at the New function value = 1

Now that there is a parametric relationship that relates directly to Hazard, 2 dimensional plots of this expression can provide significant insight into the source of hazard. For instance a graded (shaded) colour plot of the new expression over the floodplain will show how hazard propagates and moves throughout the floodplain. In fact further to that the time of arrival and the duration of the new hazard values at various locations potentially provide much greater insight into RISK.

Further, animations of this parameter if utilised will provide an amazing amount of insight in the evolution of hazard during an event. It should be noted that there appears to be a serious data gap in determining what values of VxD present what amount of hazard. However regardless of whether or not a situation is quite clearly hazardous, it seems that there are always people willing to RISK the HAZARD.

Fig. 13. Note regardless of the obvious evidence of HAZARD, some people can't help but over expose them selves to RISK

4.0 Influence of Obstacles on HAZARD Flood behaviour

It has been shown that although VxD, (momentum) provides some useful insight into flood behaviour, it fails to adequately identify hazard, particularly in deep, slow moving floodwater.

A common approach in 2-Dimensional flood modelling of urban environments is to artificially adopt a very high Manning's roughness (of up to 1.0). The aim of this is to some how account for the influence of major obstacles in the flood plain in urban areas, such as houses. However knowing that Q =V*A, and also knowing that more energy is required to accelerate flow if it needs to be squeezed between buildings, it is obvious that this approach has the potential to both underestimate the velocity between (and down stream of) buildings and underestimate the depth in front of buildings as the total energy is forced to increase to drive the flow between the buildings.
Therefore as both Velocity and Depth may actually be higher it is therefore also obvious that the resulting hazard (VxD) may also be considerable higher.
This potentially results in many areas being identified as low hazard when in fact they could be substantially highly hazardous areas.

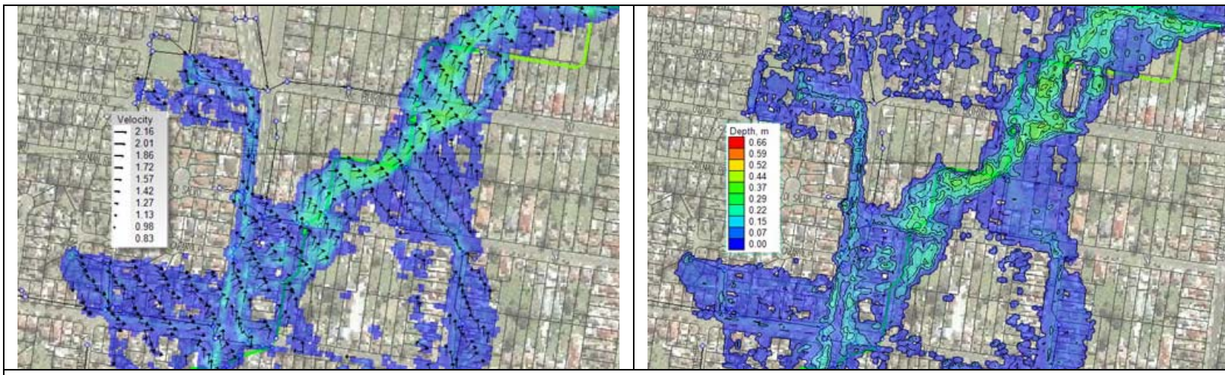


Fig. 14. Typical approach of modelling urban environment

This paper investigate this by comparing an analysis of the same urban area modelled in two ways:

1. As is commonly done by providing artificially higher Manning's n
2. Deliberately including the houses in the topography, to model the effect

Further this section of the paper also utilises the new method described above to provide a much more flexible range of delineation of hazard in these two scenarios, the aim being to highlight the danger of the most common practice.

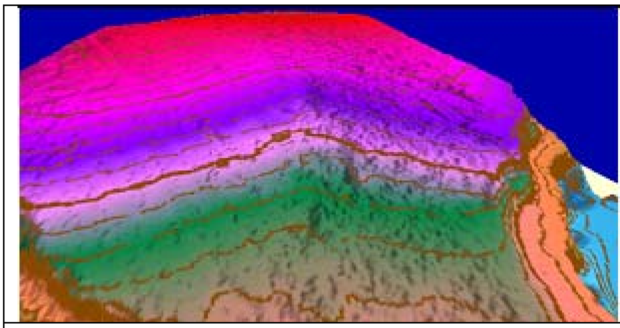


Fig. 15. General Terrain to be modelled


Fig. 16. Terrain with Houses and Draped Air Photo

The following images show precisely the difference in the terrain being modelled. The base terrain is identical, except that one includes structures (buildings).

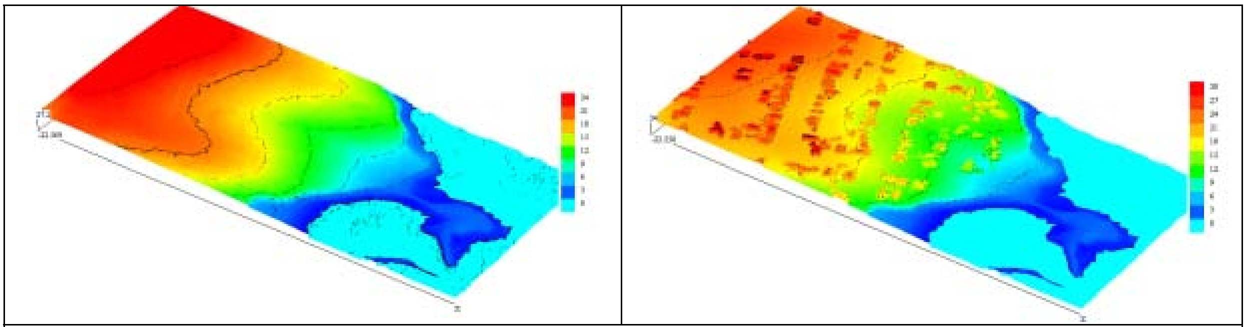


Fig. 17, Comparison of Terrain Models. Note Flow is from Left to Right.

The aim of the exercise is to show the potential influence and impact of not accounting for these obstacles as obstacles.
This was done by modelling three scenarios:

1. Terrain only with a normal Manning's n (n = 0.04)
2. Terrain with artificially raised Manning's n (n = 1.00)
3. Terrain with normal Manning's n but with obstacles present.

It must be stated that the approach was to simply adopt the ALS data as is with no refinement, to create a very fine 0.5m DEM. In some instances the underlying ALS almost fully blocked some smaller flow paths. In the future it may be worth considering placing more regular shaped obstacles on the terrain, to investigate the impact even more precisely. The model used for this analysis was the ANUGA model. It is an unstructured Grid, Finite Volume model. Its particular strength is in being able to easily handle shocks and sudden transition from sub to super critical flow.

5.0 RESULTS of ANALYSIS:

The results provide some startling insight. The influence of increasing Manning's n does provide in some areas a similar estimate of the extent of inundation, as the floodwaters are forced to disperse due to the high roughness. However the velocity is artificially very much reduced over the whole domain. In addition storage effects are not accounted for as well: - leaving the down stream area of inundation much wider than reality. Similarly the maximum depth is quite similar, although it is occurring over a much greater area. The example where the buildings are specifically accounted for shows that the buildings form dams with spillways between them. This results in raised water levels upstream of the buildings and high velocity plumes between them.

FLOW DEPTH COMPARISON:
The overview of flow depth shows that the raised Manning value over estimates depth generally and underestimates velocity. The case with buildings included clearly forms a dam effect. See Figs. 20 – 22.

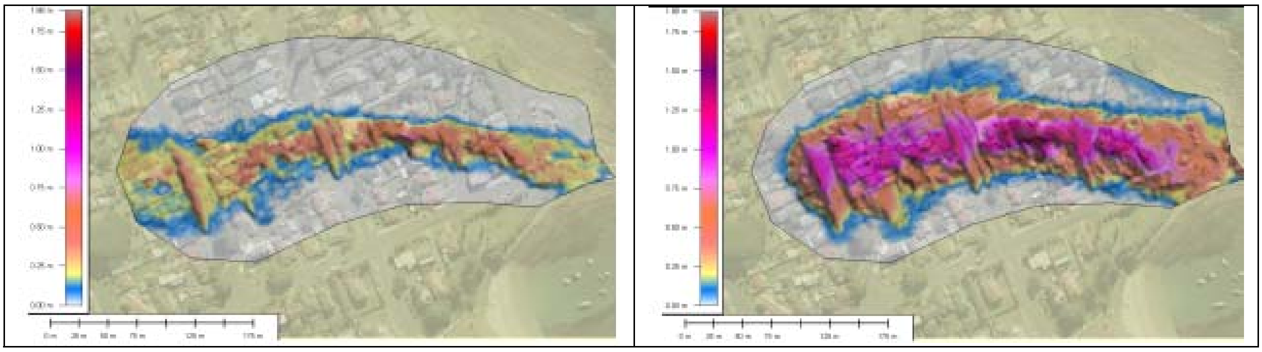


Fig 18. n = 0.04, Max Depth = 0.833m	Fig. 19 n = 1.00 Max D = 1.64m

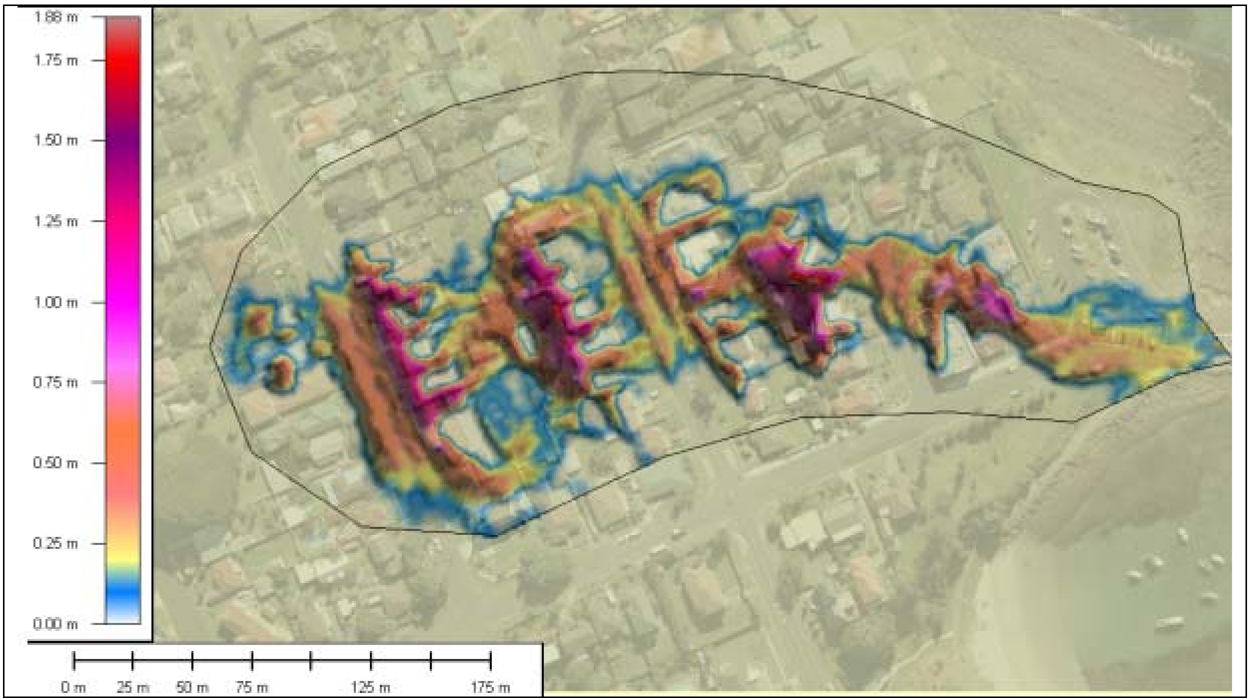


Fig. 20. Houses present (Note Damming effect of Houses) Max Depth = 1.884m

VELOCITY x DEPTH COMPARISON:
The VxD product shows that the raised Manning's scenario has a much lower VxD even though the Depth is higher than the "Normal" roughness case.

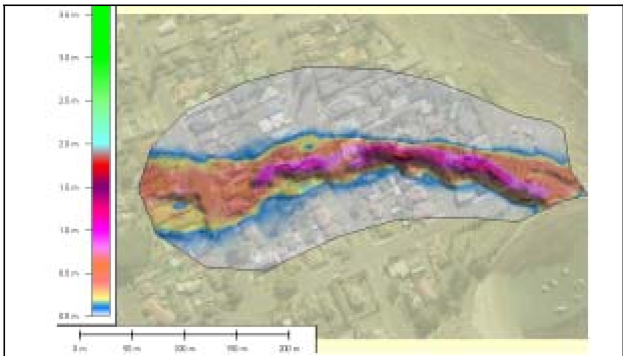


Fig.21. VxD, Max Haz = 1.754

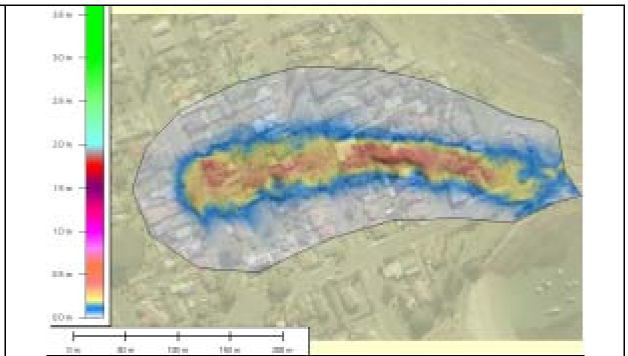


Fig. 22. VxD, Max Haz = 0.534

Once again the case where the buildings are included shows that the VxD is upto twice as high as the "Normal" case and up to 7 times higher than the raised Manning case. This is now starting to highlight the impact of the high velocity plumes, and general higher velocity, whilst also showing the influence of depths ~ 1.0m deep.

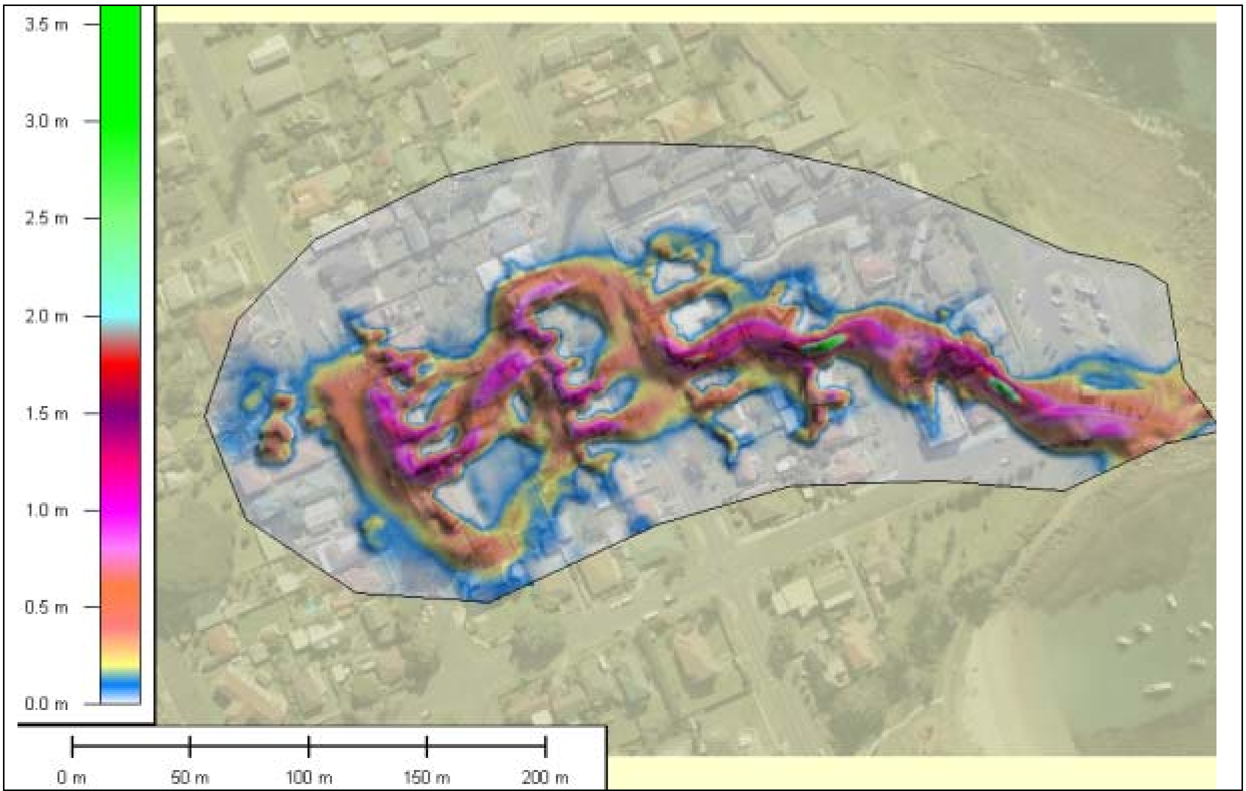


Fig. 23. VxD, Max Hazard = 3.641 (Note the flow being deflected)

NEW HAZARD DEFINITION COMPARISON:
By defining HAZARD as shown in Equation 6 above, this single equation will delineate areas of LOW: HIGH hazard as those below and above 1.0. In addition it will provide a greater range of values to aid interpret behaviour and separate the nature of hazard. Finally it has an intrinsic mechanism to honour the apparent hazard of deep water even if it is moving relatively slowly.

Mapping of this is through a simple SINGLE equation can be easily applied and automated. The results clearly show that the common practice of adopting a raised roughness leads to a significant underestimation of hazard in the urban environment.

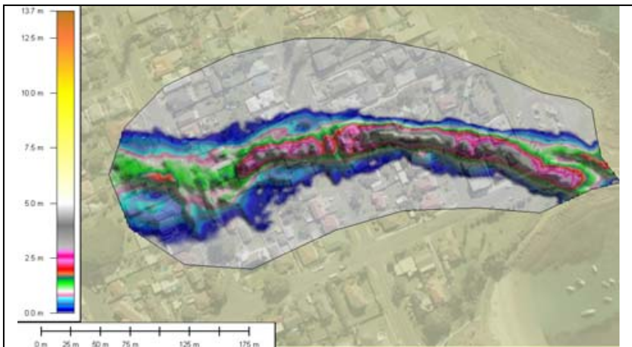


Fig. 24. New Hazard, Max Haz = 5.403

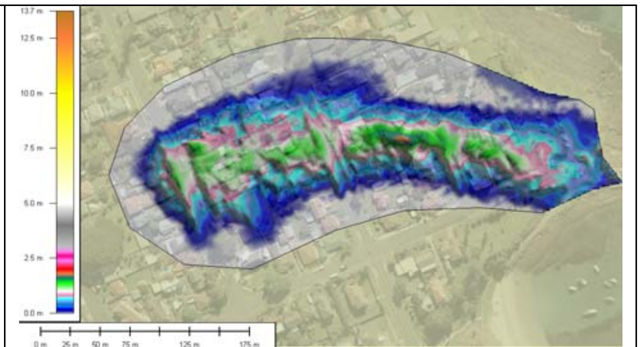


Fig. 25. New Hazard Max Haz = 1.807

The parametric equation shows that the influence of building is to increase hazard very substantially as indicated by values above 3.0 and up to 13.0 between buildings. This is potentially damaging to dwellings and shows to what extent the adopted practice of using a raised roughness misrepresents hazard. What about fence I hear!

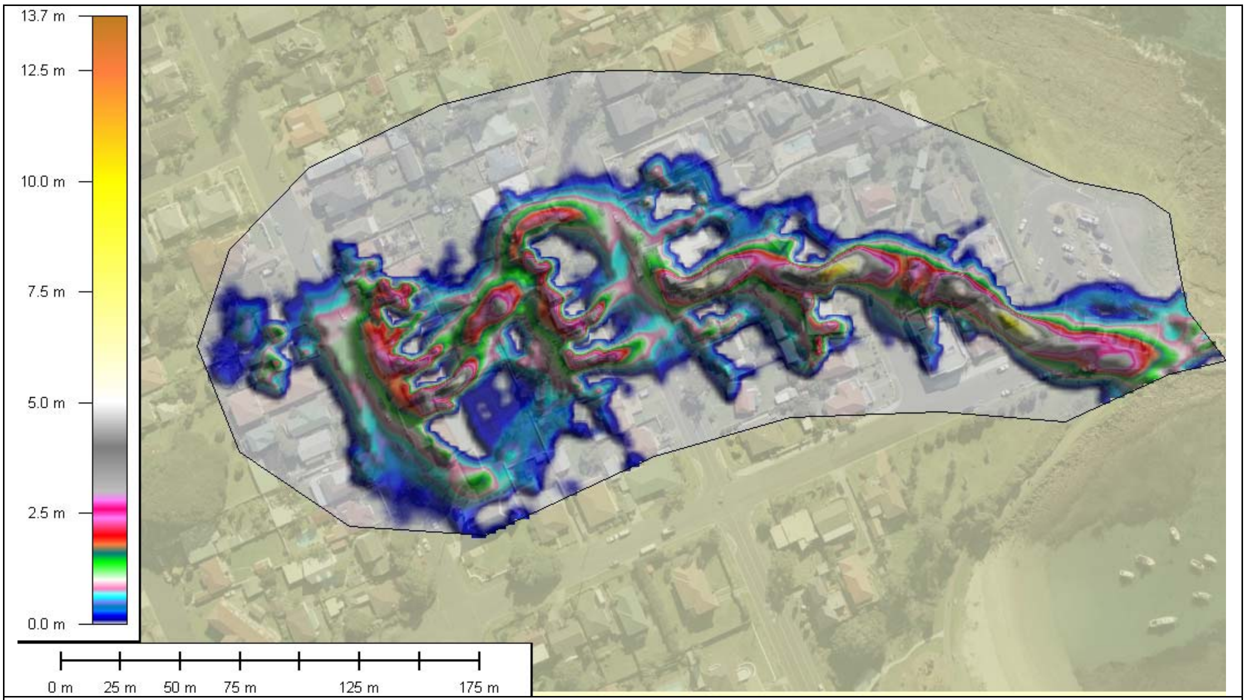


Fig. 26. New Hazard Plot Max Haz = 13.738 highlighting the misrepresentation

The accurate depiction and understanding of what constitutes a hazard and where these hazardous environments are is the ultimate goal of the role of Floodplain Risk Management. Our urban environments potential are much more hazardous then currently being depicted using our current approach. Not only is the methodology of using raised roughness underestimating the danger, the current reliance on simply Velocity and Depth leaves little scope to differentiate flood dangers.

The following image provides some very typical urban flooding scenarios, which are considerably more hazardous then what the current methods depict.

Fig. 27. Urban Flood Flow behaviour

Fig. 28. Extremely Hazardous

In extreme cases the fast flowing floodwater can lead to significant damage of buildings.

	
Fig. 29. High velocities	Fig. 30. Damage to brick building

TAKE HOME MESSAGE

- Current practice using Velocity x Depth may not be the most effective indicator of hazard.

- A parametric relationship has been derived that provides much greater insight to not only hazard, but also its behaviour and associated risk.

- Although the derived parametric expression may not be the ultimate (best) expression of hazard it is potentially much more useful and easier to apply than current methods.

- The equation derived in this paper may provide a more robust method that is easy to apply and provides a greater range of values to interpret hazard, included the convenience of delineating LOW from HIGH hazard with a value of 1.0.
-
- **HAZARD = Depth + Velocity^2 x Depth ie: (D + V ^{2} xD)**
-

- Further development of the principles outlined in this paper will not only provide a more easily applied and uniform approach, with a more sound basic principle than the current method, it will also allow the potential categorisation of the likely level of damage sustained to items at risk of exposure to floodwater with "New Hazard" greater than 1.

- The parametric equation presented provides an opportunity to define a Hazard Number in a similar fashion to the role of the Froude number. Where anything below 1 is Sub Hazard (Low Hazard) and anything above 1 is "Super Hazard" (High Hazard), indeed numbers above 1 can now also potentially be related to level of potential damage or severity.

- Common current methods of modelling urban areas with artificially elevated roughness values DO NOT accurately depict hazard in those areas. General hazard is under estimated.

ACKNOWLEDGEMENTS

We gratefully acknowledge the help provided by Ole Nielsen of Geoscience Australia, in assisting to explain and augment the ANUGA code which allowed the quick review of the parameters discussed herein. We also acknowledge the efforts of Irene Schymitzek in writing some code to allow very fast manipulation of output data.

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Who is Responsible for Checking Flood Models?

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ABSTRACT

In Australia the authority that is responsible for Flood Modelling and Flood Mapping is local government. With the ongoing perceived increase in frequency of severe flooding from extreme rainfall there is considerable responsibility to best inform the community of the impact of flooding with regard to determining hazard and risk.

However since around the early 90's local government has seen a severe decline in their internal expertise. Most council's now rely almost entirely on external consultants to advise on, and prepare flood mapping for their communities.

This paper highlights the importance of applying best engineering practice when undertaking flood modelling as flood modelling informs many of Council's functions such as identification of flood mitigation options, land use planning, development controls, but also inform decision making from others in the area of emergency management, house or land purchase, and in some cases insurance pricing. This paper also discusses what tools could be put in place to provide more guidance to Council's staff to ensure minimal checks and balances are performed and what set of skills and resources would be required to use these tools.

1. INTRODUCTION

Wollongong City Council covers an area of around 684km2 of which approximately 320km2 flows directly down the Illawarra Escarpment to the Ocean. These catchments are also predominantly highly urbanised and subjected to very significant flooding in extreme events. Most of the heavily urbanised catchments have had flood studies completed. Figure 1 show the Wollongong City LGA (red) and the catchments flowing to the east (light green) and the catchment for which flood studies have been completed (dashed orange).

Wollongong City Council has had a relatively long and extensive history in the production of flood studies due in part to the number of independent catchments traversing from the Illawarra escarpment to the Ocean and the frequency of relatively large flood events. The almost biblical 1984 event in Dapto set the stage for the 1985 Mullet Creek Flood Study for example. Since that time Council has spent an estimated $5million in various studies covering 17 catchments (Noting that a considerable portion of funding came through state funded programs). Some catchments have had 3 or 4 flood studies completed and for various reasons have still been found to have questionable results in key locations.

For Council as a client, to the consultants completing flood studies, this raises a very important question, ***"Who is Responsible for Checking Flood Models?"***

Plausibly there is a second question that follows this; "Who is burdened with the plausible costs of incorrect information?"

It is understood that to date there has never been a case of a claim against a Consultant regarding Professional Indemnity as related to errors discovered in flood studies (*personal communication with insurers*).

2. HISTORIC LEVEL OF CHECKING

The Floodplain Management Process in NSW has since its inception been a partnership between Local Government and the NSW State Government. The State provides at least 50% of the funding for those studies under the funding program. In addition the State is flagged as providing expertise and guidance (particularly to smaller council without in-house resources). However throughout the flood study process it is not clear as to how much checking has been undertaken and by whom?

As a funding agency there is at least an inferred responsibility to the State to check the quality of the product they have funded, as there is for the Council. However it appears that at both levels, the lack of either in-house expertise, time or available resources (such as access to hydrologic or hydraulic models) prevent the relevant checks to be performed. Yet again it is very unclear and even more poorly documented as to what checks have been undertaken to ensure flood models are indeed accurate representation of catchment behaviour and hence a quality produced final document informing of flooding and associated hazards.

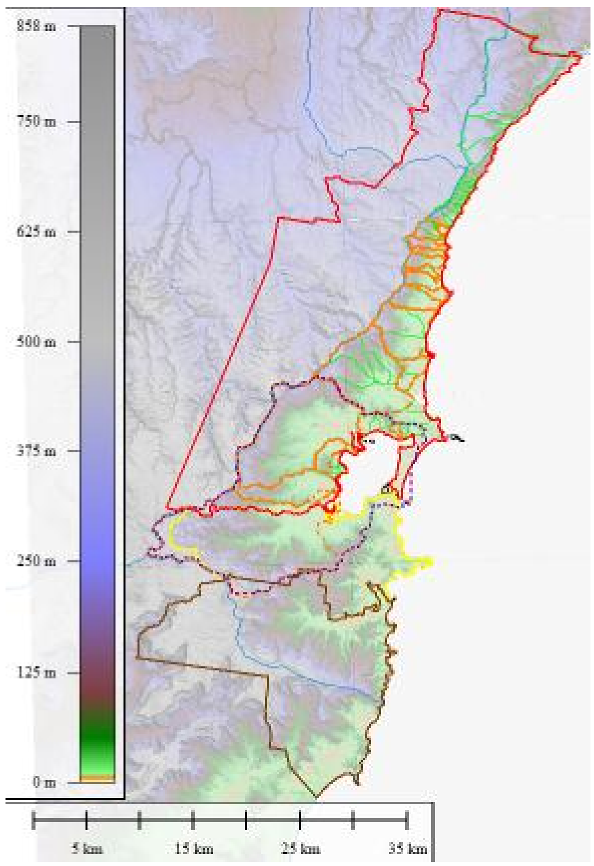

Figure 1 – Wollongong City Council LGA and Catchments

3. CHECKING AND TYPE OF ERRORS DISCOVERED

In many cases the process of producing a flood study is lengthy (many years) expensive and complex, involving many stakeholders including community representatives in floodplain management committees. Throughout this process to date, the flow of information is primarily related to a document, being the draft flood study and its associated mapping. To date the only time more discoverable data is provided to the council, is at the hand-over of the final product when mapping products in the form of gridded computer data files are provided.

At this time council utilises tools such as WaterRide and other GIS based tools to update its internal flood mapping and reporting capabilities. There is usually not much time available or tools readily available to undertake extensive checking of results. However in time as various council officers access the data for the production of flood certificates for example various types of anomalies are discovered. Similarly in particular areas where council may have design projects for a new bridge for example at times curious outcomes are discovered.

Wollongong City Council has the benefit of its own internal modelling capability so at this point when resources are available, a check model is at times built and potentially the underlying cause of the anomaly or error is discovered. Such as, for example the hydrologic model hydrographs having been applied in a poor location to properly reflect catchment conditions.

At this point it is difficult to discover how the problem was not discovered by the consultant through their internal Quality Assurance (QA) procedures, as council is not provided with details of the level of checking undertaken during the production of the flood study.

Council has only this year taken the time and effort to check in very fine detail the inputs that have gone into constructing a 1D/2D model and found some very concerning issues. In addition ongoing use of output has identified a considerable number of anomalies.

In short, council has found various types of errors that appear as either a problem with the processing of results to produce the final gridded maps, or are clearly errors in the modelling methodology.

These include:

- Instabilities at culverts, or wrongly reported afflux
- Culverts poorly or wrongly placed
- Poor model construction resulting in glass walls and elevated flood levels
- Glass walls poorly placed
- Poor Hydrology being used as input
- Poor sub area subdivision in the hydrologic model
- Use of lumped storage in 2D flow areas
- Missing minor tributaries
- Missing major overland flow areas
- Cross catchment flows not identified
- Cross section locations and spacing not being representative
- Poorly defined manning's roughness
- Poor description of building polygons resulting in excessive obstruction blockage
- Extent of model insufficient to cover flow extent

It is noted that various models do have the ability to create a vast array of check and log files that would give some insight into the model build process. However these files are sadly not often offered or provided to council as method to check models.

It is clear that the current QA processes are failing in their ability to ensure quality models and mapping is produced through the flood study process.

4. IMPACT OF ERRORS

The obvious danger once a flood study is adopted is the direct impact of the information being made available to various people including the community and insurance companies for example.

There is a direct impact on the community in terms of setting floor levels for development, limiting development based on defined hazards and risk precincts and the impact on insurance premiums.

There have been examples of flood studies influencing flood insurance premiums that were later shown to be incorrect. This leaves council in a precarious position. As to date some aspects of the law related to this have not been tested, for example, regarding the liability for premiums that have been incorrectly applied.

Council has to have some level of ownership of the quality of its flood studies for a number of reasons, but primarily that it has an obligation to its community to best inform it regarding hazard and safety.

There is also an obligation to **"use the community's money wisely"** and get value from flood studies and ensure communities are not burdened with erroneous flood data.

5. CHECKING CAPABILITY

Many Local Government Authorities in NSW do not have the specific expertise in flood modelling to fully understand and check the complexities within the process. Even fewer have the ability to build and run models. However Wollongong City Council has this ability. At times, when sufficient resources are made available, a shadow check model has been run, and there have been many benefits to council in identifying problems with Consultants' flood modelling that have been rectified prior to the flood study becoming an adopted document. Notwithstanding this, problems have slipped through in cases where no check model was run.

Wollongong City Council has at times utilised the Free and Open Source 2D finite Volume solver known as ANUGA (Nielsen et al 2005), to build shadow check models in conjunction with the flood study process. The ability of the ANUGA model to have rainfall applied directly to the entire catchment (Rigby & VanDrie, 2008) has identified where hydrographs have been applied poorly by consultants in their models for example, and also identified significant flow paths missed by the consultant.

6. BETTER APROACHES

In 2016 Wollongong City Council revised its 2002 "Blockage" Policy which has triggered the need to revisit all of its completed flood studies. This also has been an opportunity to identify the various issues with previous flood studies with a view to have them addressed and corrected. This included for instance an almost forensic approach to deconstructing and extracting data from flood models produced by consultants for council. This process has identified that it seems that generally consultants undertake little or no checking of models. This is a dilemma as all contracts have specific clauses that require QA processes that are assumed to include (or at least inferred) the need to check models.

In order to try to ensure that a higher level of checking is undertaken by the consultant, there has been a deliberate move to insist on consultants preparing and maintaining "Model Build" reports.

6.1. Model Build Report

The concept of a model build report is that it is a live document that is maintained for the duration of the flood study process, to record the initial model build and any changes or additions to the models. This document is to be maintained such that at every point in time there is adequate description and data recorded in the report that reflects the current state of the models used. From the initial model build having a record of the data used and how various portions of data have been used, to each subsequent change and addition being recorded. For examples the addition of cross section data, or culvert and bridge data, or any other updated feature or aspect of the model is to be recorded.

The "Model Build" report is a running commentary of the consultant's interaction with the process of building and running their models. This report will identify where for example an issue was identified that required a change or addition to the model.

This clearly places the responsibility of not only checking the model but also verifying that a check has been done, onto the consultant.

This to some extent may reduce the need for council to have its own shadow check model.

However depending on available resource there may still be comfort to council in continuing with the currently beneficial process of having the check model process in tandem.

6.2. Introducing a Warranty Clause in Contracts

When Councils accept a new subdivision there is usually a mandatory 12 month warranty clause where a contractor is held responsible for the maintenance after handover. This approach may be worth considering in the case of flood studies or a withholding period, until significant checks are undertaken.

If a consultant's final payment were to be withheld for a period of 12 months whilst errors were discovered, would that provide enough leverage for the Council to hold the consultant to account to rectify the discovered errors? Is there a potential that fewer issues would arise?

This is an approach that is surely worth considering when the outcomes are usually long lasting (the study is usually adopted for years before it is redone) and costly, as typical costs of flood studies is in the $100,000's, as it involves an associated set of processes including community consultation and at times need for survey data, for example.

6.3. Shadow Check Models

The major problem with having two models (in general) is that both models have to equally "be representative" of catchment conditions. This relies on the data flow between council and the consultant being open and transparent. There have been times in the past when consultants have been reluctant to hand over portions of or all of the modelling inputs prior to the finalisation of the process. However in recent times the consultants have been more willing to share their input data, as they recognise it has the potential to benefit both parties.

As the consultants model has features added such as culvert and bridges, or additional cross section data, this data has to also be applied to the shadow model.

The overall outcome however is that at some point Council will hold a library of flood models that if kept up to date is capable of reproducing or updating future flood mapping due to any changes such as:

- Policy changes (Blockage, AR&R, etc)
- Terrain Changes (New LIDAR, Development etc.)
- Rainfall and Climate changes

This raises the possibility of council becoming an autonomous flood modelling authority over its LGA.

The notion of a "City Wide Flood Modelling Framework" warrants to be explored further.

7. THE FLOOD MODELLING FRAMEWORK CONCEPT

As Council continues to build and update its library of flood models, there comes a time when it asks itself are we **"using the community's money wisely"***.

Clearly as an outcome of having been driven to a point of building check models, there is a case that there is now a potential to develop an autonomous flood modelling capability. In considering this, there may also be further benefits. It should be noted this concept has been investigated with very impressive results to date for all of the ACT (VanDrie,Milevski, 2014).

7.1. What is a Flood Modelling Framework

In short, it is building an interface to feed data to a modelling system such that the process to some extent is semi-automated. This allows for example as new data becomes available such as new LIDAR, for the models to be rerun and checked and compared to previous runs and updated mapping to be produced.

This also includes terrain changes resulting from major developments such as new subdivisions, major road upgrades or any other land use changes that may have the potential to influence flood behaviour. Similarly with the inevitable changes to climate data such as rainfall, and downstream control boundaries such as Ocean levels, there is also a need to update flood modelling and mapping.

A "Framework" allows the models to be run at the scale of the catchment or even all the catchments at once. The counter being that the same framework can also run sub models within catchment to provide very highly detailed flood models that can be used to assist in the design of various structures.

All these roles benefit council considerably.

But wait there's more!

7.2. Flash Flood Warning System

Once a framework is established data links can also be established so that the framework can be used to run in a fast mode with coarser resolution using rainfall estimates from radar for example. Given that the radar data has to some extent the ability to show what rainfall is on its way, there is a forecasting capability that could drive a flash flood warning system.

Given the very short and steep and hence fast response times of the Wollongong catchments this is an extremely beneficial outcome.

7.3. Flood Community Feedback Framework

In conjunction with other projects being developed currently in Council such as:

- the culvert blockage monitoring program and
- Beach Berm Monitoring program, and
- Community Flood Data Collection program (Photo, and flood observation data)

The framework could become a data repository that not only stores the data but uses it both for improving validation, and plausibly to improve real time flood estimates. For example if there is evidence of a major blockage in the system it could be included in the real time runs to estimate the impact with the approaching rainfall (gathered from radar estimates).

The notion of community gathered data is gaining momentum in many areas, and the usual sparsity of flood level data after a major flood event could be vastly improved. In fact the data feed could be live during floods, to serve as a communal warning framework. To identify to the community that roads are no trafficable for example.

7.4. Proof of Concept Trial

In order to initiate the move toward autonomous flood modelling, Council has embarked on setting up a single large catchment for testing proof of concept. The Fairy Cabbage Tree Creek catchment has a long history of studies being undertaken and also disruptive flood events. The aim is to trial the concept of the three components identified above. In addition the concept of a Flood Modelling Framework will need to be tested against the current Framework for Floodplain Management in NSW including the Local Government Act and Floodplain Development Manual.

8. CONCLUSIONS

Wollongong City Council LGA has a significant history of flooding and producing flood studies. This has incurred a considerable cost that is and will continue to be ongoing. It has been found that none of the studies undertaken to date have been error free. The source of error is not always clear if it relates to modelling or post processing. As a result, in recent years Council has initiated the use of Shadow 2D Flood models as check models to ensure the consultant's models are at least producing consistent results. However in the longer term this could lead to a level of autonomy in flood modelling not seen in Local Government before.

With regard to the initial question of who is responsible for flood models. Ultimately the burden of errors is worn by council, and the consultant walks away at the completion of the contract with little or no mechanism available to correct errors. It is therefore concluded that the notion of a warranty clause in the contract could be extremely beneficial.

9. RECOMMENDATIONS

In revisiting the question "Who is responsible for Checking Flood Models", clearly there is a fundamental onus on the consultant to check and confirm that the model is producing the highest quality product as required by the client. The Client (Council) is in many instances totally reliant on the consultant due to the lack of internal expertise. However when you purchase a product there is to some extent the notion of "Buyer Beware" where there is at least an underlying responsibility to be happy with the product you paid for.

But unlike items purchased, when it comes to flood studies costing $100,000's there is no Warranty Period, or After Sales Service, to correct obvious wrongs. To some extent this is a fundamental flaw in the current process. It is recommended that flood management authorities undertaking flood modelling through consultants seriously consider the notion of a warranty clause in their contracts. Further in the case of councils with libraries of models, and expertise (available or acquirable) the concept of autonomous flood modelling appears to be worth exploring.

10. ACKNOWLEDGMENTS

This work was conducted in collaboration with input from other council staff in providing details of expenditure on flood modelling.

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<u>*2013*</u>

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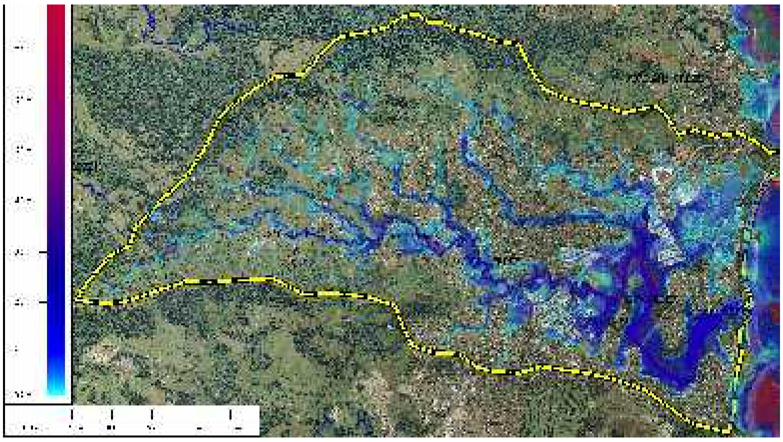
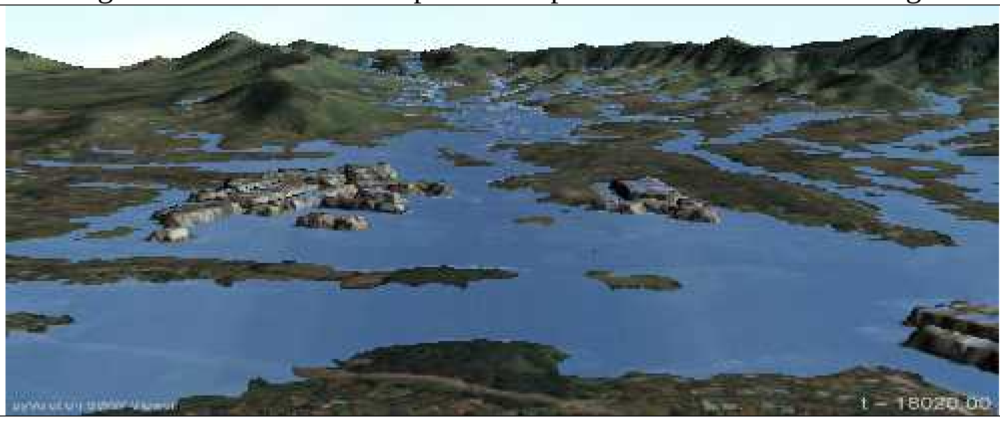
BUILDING CAPACITY IN LOCAL GOVERNMENT TO UNDERTAKE FLOOD HAZARD MAPPING IN HOUSE

Including the Influence of CLIMATE CHANGE



Eg: Coffs Creek Flood Depth & Perspective overview of flooding



A Concept Document by Rudy Van Drie
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and
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If there are any queries regarding this report all questions should be directed to:

……………………………….
Rudy Van Drie
Report Author:
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DOCUMENT HISTORY:		
Document Version	Dated	Released to:
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Final C	05/04/2010	Email to LGA's
Final D	24/03/2012	Updated to reflect Changes to ANUGA
Final E	21/02/2013	Inclusion of details of NCI, National Computational Infrastructure

CONTENTS:

0.0 EXECUTIVE SUMMARY:

Currently Australian Communities have funded $Millions through their local Councils on Flood Mapping. Further the general lack of sustainable dynamic outcomes of that process is leading to the community enduring ongoing damage in the $Millions each time there is a significant flood event and further ongoing costs in reviewing and updating flood studies. Again in 2009/2010 more than $8million of tax payers money will be spent. Refer to:
http://www.environment.nsw.gov.au/grantsandfunding/FloodplainRiskManagementProgramGrants.htm

In Australia, Local Government is burdened with the responsibility of providing its local community with the required information in order to evaluate the level of hazard on any particular parcel of land. General speaking with regard to water related hazards these relate to flooding from rainfall events and Ocean related hazards, such as storm surge, beach erosion and sea level rise. It is understood that the NSW department of Planning required these hazards to be identified and mapped for the 2009 Local Environmental Plans (LEP's). This was once purely reliant on Council's engaging Consultants to undertake various studies to identify Risk and Hazard associated to Ocean events and Flood events.

However the relatively recent development of a FREE and OPEN SOURCE SOFTWARE package called ANUGA potentially provides local government with the tools to provide this capability in-house.
In December 2006 the Australian Federal Government through Geoscience Australia (GA) released a 2-Dimesnional Shallow Water Wave (SWW) equation solver. The software has been jointly developed by GA and the Australian National University (ANU). The software is called ANUGA. Although development of this software was specifically to target modelling a tsunami striking the coast line with robust shock capturing and handling of the wet/dry interface, the model has been extended to river and urban flooding. In addition the software provides close links to GIS platforms and through this mechanism also provides the ability for Council's to update and maintain flood affectation notices on all properties that are flood affected.

The model is being used world wide and also being validated by various institutions including:-

- University of Queensland
- Heriot Watt University UK
- http://www.sbe.hw.ac.uk/online/mod/resource/view.php?id=138

In addition Geoscience Australia has indicated their commitment to continually improve the model and add additional features such as erosion and sediment transport for instance: See:-
https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=69370
The document you are about to read highlights the most cost effective process available in getting Local Government into a position where they can be self sufficient in building maintaining and running their own flood models, closely linked to GIS to ensure adequate information is available to both the Council and the community with

regard to flooding. In addition it provides an example where the approach is being implemented.

0.1 EXECUTIVE SUMMARY FOOTNOTE

It is noted that the Western Australian Planning Minister Mr. John Day recently announced the use of a "New modelling tool to assess climate change impact", highlighting that:

"ANUGA is a powerful tool for analysing hydrodynamic and hydrologic information and forecasting potential inundation, or assessing inundation risk."

"When this model is developed, it will enable State and local government to investigate mitigation options for a range of hydrodynamic hazards."

"It will be the first of its kind in Australia and provide an invaluable planning tool for all levels of governments to predict how storm surges and sea level rises will react to potential barriers. This tool will assist in determining the effectiveness of proposed infrastructure."

"This enables governments to ensure we are prepared to predict and manage these hazards, particularly in areas of high urban development such as Busselton and Bunbury. "

"The State Government is committed to a high standard of risk management and this is just one of a number of projects in coastal towns we are initiating to better plan for the future.
"

"The Department of Planning will provide important historical and environmental data for the project, and Geoscience Australia will equip its model with the necessary capabilities to provide the scenarios."

"This model will be unique as most existing storm surge models are not able to combine the surge arising from atmospheric forcing with the flooding component, although these often occur together in a storm surge event."

Refer to:
http://www.mediastatements.wa.gov.au/Pages/WACabinetMinistersSearch.aspx?ItemId=132660&minister=Day&admin=Barnett

1.0 INTRODUCTION:

Generally speaking to date most Local Governments have been fully dependent on consultants to provide flood information for its use. This is usually facilitated at least in part or in whole through the Flood Mitigation Programs partly funded by the State Government. This being the case it is often the case that the State Department has a strong influence on selecting the consultant. Over the past 15 years or more, in excess of $100 Million has been spent and at the 2008 Floodplain Management Authorities annual general meeting it was revealed that less than 10% of the state had been successfully flood mapped. Clearly this is a less than satisfactory outcome.

By contrast in Germany Authorities adopted an approach some 20 years ago to engage consultants not to provide flood studies as a static snapshot in the form of a report, but rather they were engaged to develop models on the Authorities Servers which were continually maintained so as to ensure the Authority had a current relevant up to date dynamic flood model. This approach has proven itself to be extremely cost effective and timely in producing outcomes.

Since the release of the ANUGA software several Councils have utilised the software essentially initially to check on work completed by consultants (Wollongong City Council {Dr. Petar Milevski}), but since then also to undertake flood analysis in house. (Wollongong City Council & Shoalhaven City Council {Matthew Apolo}).

Further Shellharbour City Council have engaged a German Consultant with an Australian presence (Hydrotec / Hydro-Oz) to provide a flood map of the entire Council area of operation some 25 catchments.

This therefore has identified the potential cost savings of rolling out the German concept into Australia utilising locally supported Software developed by the Federal Government.

Therefore although once the exclusive domain of the engineering and scientific consulting professions both Ocean impact modelling and even Flood modelling are potentially emerging as an important central aspect of Local Government IT managers particularly those related to Geographical Information Systems (GIS) and planning considerations such as Section 149 Certificates. Both Ocean Impact and Flood modelling are now required to identify hazards for Local Environmental Plans (LEP's). The extremely complex science of fluid dynamics also once only dealt with by specialist consultants is now being undertaken by several local governments in house. The true reliance of accurate modelling is in fact accurate data. As local government generally are the custodians of the data it makes sense that they also are the custodians of the required models. The prevalence of Airborne Laser Survey (ALS) Data which provides high resolution high density data provides another set of challenges in how to ensure that the models are optimised. That is, how the data is thinned, without compromising quality. This requires a new set of skills and tools.

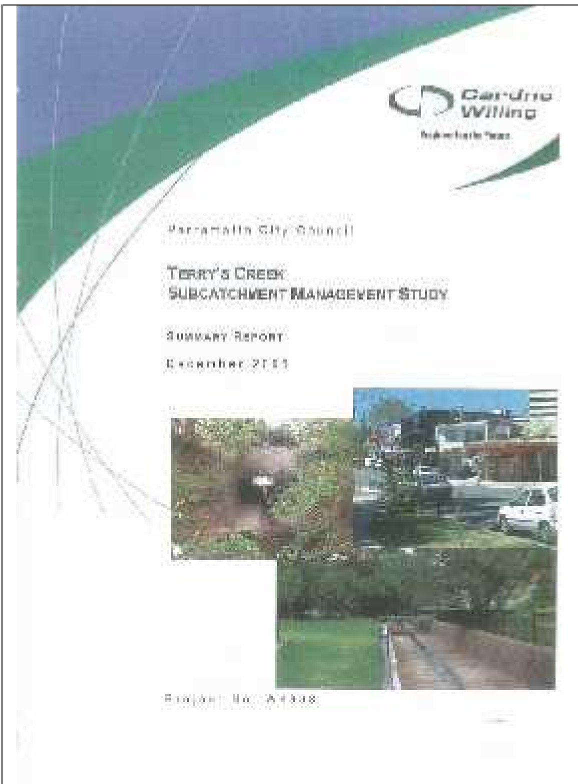
In addition, most local Councils hold vast amounts of terrain data, both current and historical. Many Councils have available to them years of archived survey data. However a relatively recent process of providing data is the use of Airborne Laser Scanning (ALS) which is also known as LIDAR. Many Councils have or acquiring ALS data. This data is ideal for use with ANUGA to develop a detailed flood model.

This paper aims to empower local government by alerting it of highly capable FREE tools that will enable it to continually update and improve aspects of Ocean and Flood inundation mapping to aid in identifying the hazards posed by these events.
This remainder of this document describes the development of the Software the intent and the process for introducing into local government to provide the most comprehensive cost effective means of maintaining flood mapping capabilities within local Councils.

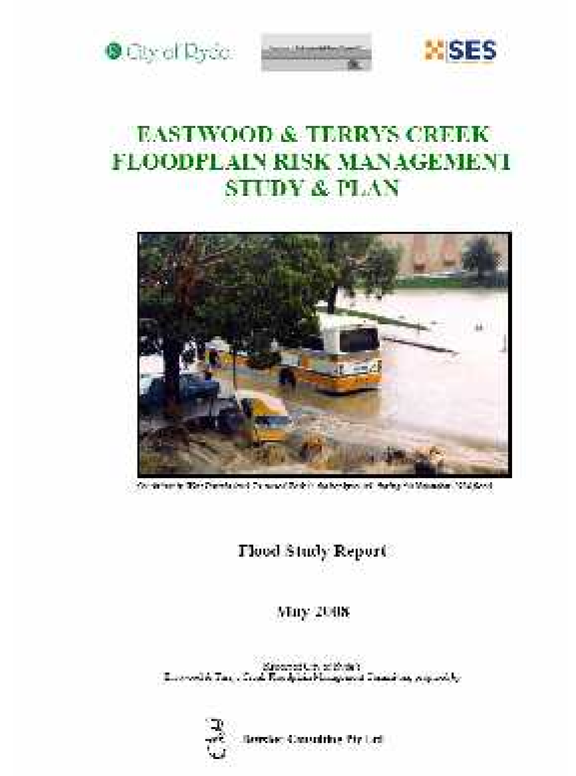
2.0 HISTORIC APPROACH:- "The Flood Study"

Most local government authorities have been reliant on having Flood Studies completed in order to document flood extent and flood hazard. In more recent times this may have included the use of GIS mapping of results to aid communicate the results and facilitate the provision of flood information to the public. In fact some consulting firms have even produced specialist software applications such as "Water Ride" to specifically provide seamless integration of flood information on the GIS and the provision of "Flood Certificates" for 149 certificates.

However most flood studies have a limited lifespan as changes within the catchment may change flood behaviour and make the flood study irrelevant or redundant. At this point an updated flood study is required.



2005 Flood Study of Terry's Creek Ryde



2008 Flood Study of Terry's Creek Ryde

Some catchments have 4 or 5 or more studies completed each of which only ever provide a snapshot of flooding at the time the study was done. Each new study replaces the previous study, and all records including those on the GIS must be updated.

2.0 A Better Approach:- Live Dynamic Flood Models?

In 1996 the author of this document whilst presenting a research paper at the International Conference on Urban Drainage (ICUD) in Hannover Germany, met a German consulting engineer, who described an approach successfully implemented in Germany for the previous 10 years or so. The approach described a way by which the catchment authority was able to continually update its flood mapping almost automatically. Once significant changes were recorded on the land use layer of the GIS, a process was invoked to run an updated flood model, and produce a new up to date flood extent layer in the GIS.

This highly linked relationship between the GIS and the Flood model software allowed and ensured that at any time, an updated flood model could be produced that used the most up to date data in the GIS. The most fundamental mechanism in the approach is the GIS data, followed by the linkages created between data and model, followed by the flood modelling software.

A core part of their business was in setting up models on the computer systems of the catchment authorities. Another was the provision of the software. However in 2010 there is now available a host of useful Free software. In fact even the Australian Government is getting involved in providing Free software, as it is seen at a Federal level to be the most cost effective way to build capacity nation wide.

3.0 ANUGA, The FREE Software:- WHERE WHAT AND HOW?

3.1 Where:- Birth of the ANUGA model :- Geoscience Australia Mandate

In 2002 the then Australian Federal Government set several mandates, one of which was to "Build Capacity", for the identification of hazards and management of risk. Details are documented in the 2002 Federal Budget and the 2002 COAG review.

Details are also reflected at the following internet links:
http://www.ga.gov.au/about/corporate/workprogram/2006_07/gemd_wp.jsp
http://www.ga.gov.au/urban/projects/nrap/dmap_background.jsp

One of Geoscience Australia's stated key priorities is to:
"deliver natural hazard risk assessment methods, databases and decision support tools in support of the Disaster Mitigation Australia Package."

Another is to:
"deliver an operational capability to support critical infrastructure protection in Australia".

At the end of 2004 the Indian Ocean Boxing Day tsunami provided a very clear focus for identifying hazard. As a result the Joint Australian Tsunami Warning Centre (JATWC) http://www.bom.gov.au/tsunami/ was set up.

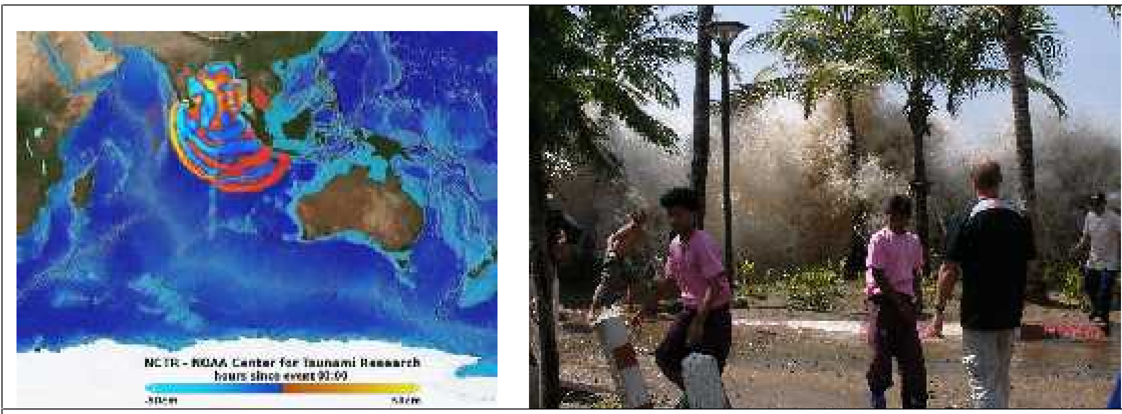


Fig. 1. – The 2004 Boxing Day Tsunami, Trigger For The ANUGA Model

During this process it was apparent that although there were abundant good deep water Ocean models that could predict the propagation of a tsunami across the Ocean, there was a lack of modelling capability that identified what would happen when such a wave would strike the coastline (particularly a built up {urban} coastline). Hence the ANUGA model was formulated by Nielsen et al (2005) from previous work completed by Zoppou and Roberts (1999) on a robust algorithm for handling supercritical flow entering upon dry land.

It is further understood that the United Nations and the Indonesian and Australian Governments have committed resources to establish a "Disaster Recovery Facility" in Indonesia. One of the key tasks of that facility involves using ANUGA to model tsunami to aid in evacuation management for example.

3.2 WHAT IS ANUGA?

The ANUGA manual describes it as:-

- "*The core of ANUGA v1.0 is the fluid dynamics module, called shallow_water, which is based on a finite-volume method for solving the Shallow Water Wave Equation. The study area is represented by a mesh of triangular cells. By solving the governing equation within each cell, water depth and horizontal momentum are tracked over time. A major capability of ANUGA v1.0 is that it can model the process of wetting and drying as water enters and leaves an area. This means that it is suitable for simulating water flow onto a beach or dry land and around structures such as buildings. ANUGA v1.0 is also capable of modelling hydraulic jumps due to the ability of the finite-volume method to accommodate discontinuities in the solution.*"

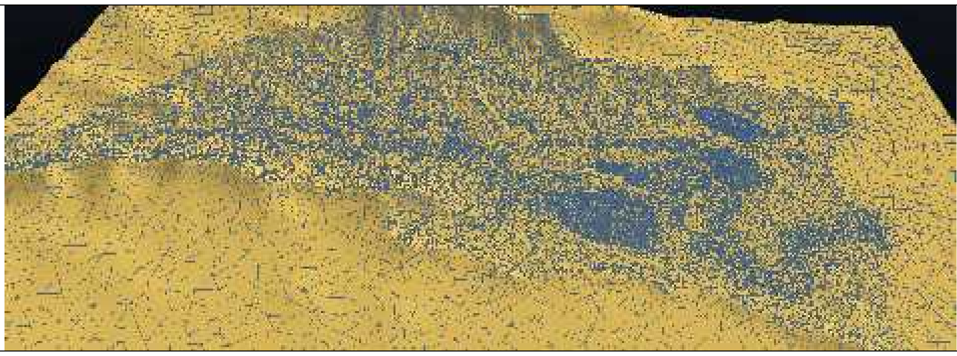


Fig. 2. Triangular grid model of the Coffs Creek Catchment

3.3 HOW:- Does ANUGA OPERATE?

The model is based on complex mathematical procedures developed by Kurganov (2001) and Toro (1992) and others that ensure the model remains stable even in extreme conditions. Many other models are simply not able to resolve the complex flow dynamics of shock waves which ANUGA does. As such it has a very wide area of application. Further details of the model and its algorithm and how it is applied can be found in the user manual and source code which can be downloaded from the internet at no cost at: http://sourceforge.net/projects/anuga. The other notable point about the model as described in the manual is that it is written in Object Oriented Programming (OOP) language called Python. This provides it with several exceptional qualities regarding extensibility.

The model was released as Free & Open Source Software (FOSS) meaning that every user has access to the computational code. This allows every user with the capability and will, to add or improve the content of the original code. The original code is then updated on the source forge web site making the enhancements available to every one. A compact yet full description of ANUGA has been covered by others. *(Rigby and Van Drie, 2008) (Nielsen et al 2006 - 2009).* For more details, please refer to the following link. https://datamining.anu.edu.au/anuga/wiki/ .

Essentially an ANUGA model is run, by providing pointers to data sets, and setting some parameters. The process of setting up a model is relatively minimal compared to that of preparing and checking terrain data.

3.4 WHAT CAN ANUGA BE USED FOR?

As mentioned the ANUGA model was specifically written to model the impact of waves (tsunami) striking the dry coastline and if required accurately interacting with obstacles such as buildings and the like. However the general solution being based on the SWW equation solved with a finite volume approach provides the potential to utilise the model for far more wide ranging flow scenarios. Here in is given a brief overview of some of the application it is being trialled for. The range of application is from a thimble to a 110km2 catchment.

To date ANUGA has been applied to model:

- *Coastal Inundation from Tsunami and storm surge*
- *Complex Flood Modelling*
- *Urban Flood Models*
- *Pre & Post Development Flood Assessment for Development Control*
- *Dam Break*
- *Bridge Hydraulics*
- *Energy Dissipater behaviour*
- *HAZARD IDENTIFICATION*
- *FLOOD Evacuation Planning*

Specific examples of its application are provided in section 4.0.

3.5 WHAT COMPUTING POWER IS REQUIRED TO RUN ANUGA:

As described above ANUGA is somewhat unique in several ways.

- Firstly it (ANUGA) is totally FREE

- Secondly it runs via a TOTALLY FREE computational language (Python)

- It runs on any platform, Windows, Mac, Linux, Unix

- It uses blocking technology, meaning it can intelligently manage the work load sent to the CPU so as to allow it to run on even relative old low power computers (although the runs will take much longer)

- It can be run in parallel on multiple workstations and multi-core CPU's. This allows very very large simulations to run relatively quickly especially if sufficient computing power is available. For example Geoscience Australia have 21 Node Linux Cluster each with 4 core CPU's and 32Gb of Memory. SO that equates to 84 CPU's and 672 Gb of Memory all used to complete a run (very fast).

3.6 Introducing the NCI (National Computational Infrastructure):

The home page of this organisation puts it succinctly as:

The mission of National Computational Infrastructure (NCI) is to* provide Australian researchers with world-class high-end computing services*.

The National Computational Infrastructure, Australia's national high-end computing service, is an initiative of the Australian Government, hosted by The Australian National University. NCI's mission, to foster ambitious and aspirational research objectives, and to enable their realisation through world-class high-end computing services, is advanced through both cutting-edge infrastructure and internationally renowned expert support.

http://nci.org.au/

Discussions to date with the NCI Director Prof. Lindsay Botten and Dr. Ben Evans the Associate Director (Research, Engagement and Initiatives), have established that there is a real opportunity for their facility to host flood models for Councils at a moderate cost. This potentially provides local government with a very impressive and fast capability to run flood models (faster than real time).

http://nci.org.au/facilities-and-services/national-facility/current-peak-system/

	SGI Altix 3700 Bx2 (2005-Sept 2009) 	Sun Constellation (Vayu) (April 2010-) 
CPUs/Cores	1920 (Intel Itanium2 1.6 GHz)	11936 (Intel Xeon 2.93 GHz – Nehalem series)
Main memory	5.5 Tbytes	36 Tbytes (7x)
Storage	40 Tbytes	800 Tbytes (20x)
Performance Peak	14 TFlops	140 TFlops (10x)
Sustained	21K SPECFP_rate	240K SPECFP_rate (12x)
Resources	16.8M hrs p.a.	110M hrs p.a. (6.5x)
Power	approx 300 kW	approx 605 kW (2x)

Check it again:- 11,936 Xeon CPU's !!!!

NCI CONTACTS:	
Professor Lindsay Botten **NCI Director** T: F:	**Dr Ben Evans** **Associate Director (Research, Engagement and Initiatives) NCI** T:

3.7 Geoscience Australia's Commitment to Model Development:

In September 2008 Geoscience Australia held the first ANUGA Workshop. The aim was to discuss the direction and any other issues regarding the future of the ANUGA model. An outcome of that workshop was a commitment to further develop the model to make it comparable with other Urban Flood analysis models. This was actioned within GA and a budget allocated. The result to date has been a public statement of commitment found at:

https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=69370 which highlights the work currently underway and work planned for the model.
Other details can also be found at:

https://datamining.anu.edu.au/anuga/wiki/AnugaPublications

4.0 SPECIFIC EXAMPLES:

As stated ANUGA has now been applied to many different and varied scenarios. The following images provide a brief overview of the extent of application within a Local Government Context.

COFFS HARBOUR TSUNAMI ASSESSMENT:

Fig. 3. Tsunami approaching Coffs Harbour

Fig. 4. At 400 Seconds (Note Reflective Waves)

BEACH RUNUP AND STORM SURGE:

Fig. 5. – Multiple Waves, Runup, Setup, (Needs an Erosion Algorithm)

URBAN FLOOD MODEL:

Fig. 6. – Urban Flood With Buildings Included

PRE and POST DEVELOPMENT FLOOD ASSESSMENT

Fig. 7. – Development Assessment Pre & Post Developed Site

DAM BREAK SCENARIO ASSESSMENT FOR THE NSW DAM SAFETY COMMITTEE

Fig. 8. – Dam Break Flood Wave In Urban Environment

BRIDGE HYDRAULICS with Complex Pier Hydraulic influences.

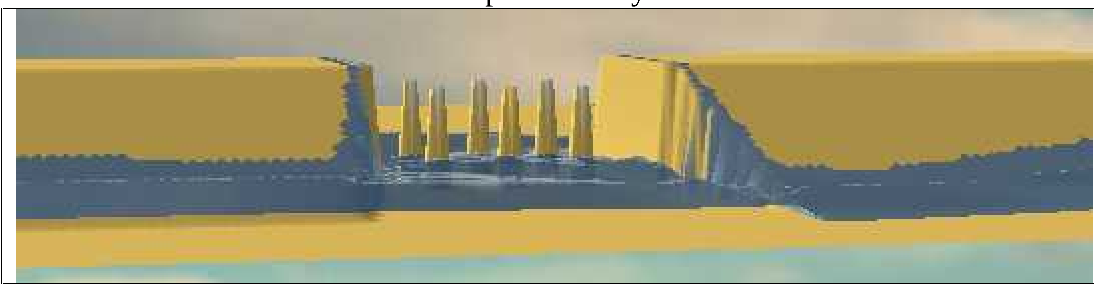
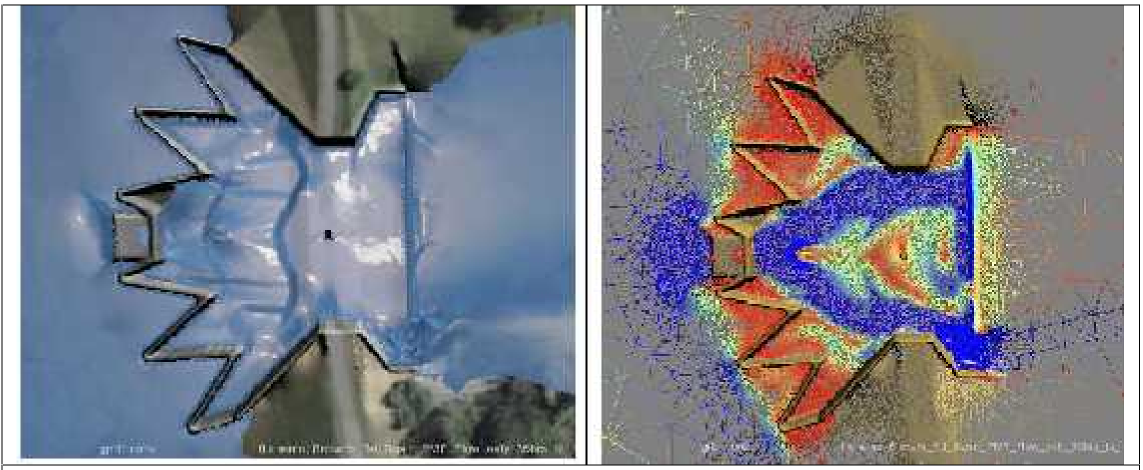
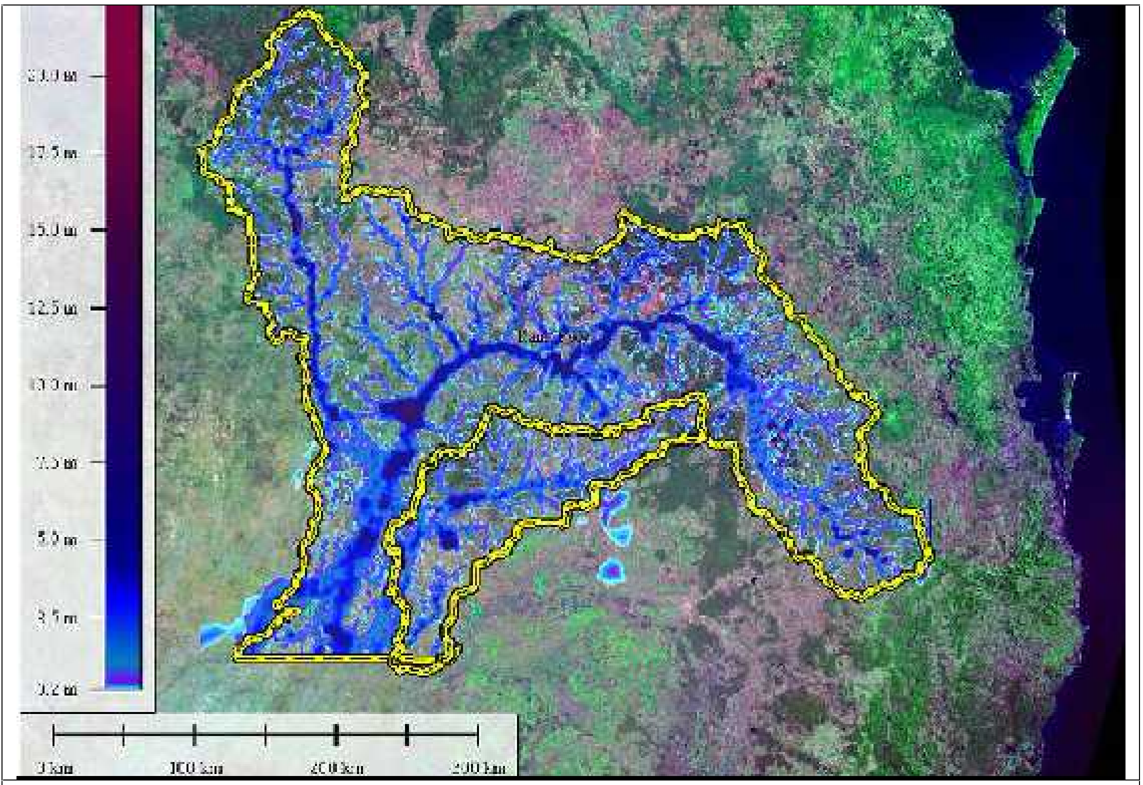


Figure 9 – Bridge Hydraulics including the columns in the Model



Extremely detailed hydraulic modelling of the Brokers Rd. Basin Labyrinth Weir



1:500 year event on the entire Condamine-Balonne River ~85,000km2.

5.0 GIS LINKAGES:

As stated a primary outcome of flood modelling is the identification of the number of flood prone properties within a Council Area. In addition identification of hazard through depth and velocity of flood water is also a clear warranted outcome.
Most Councils have a GIS mapping system, within this system there exists an ability to extract data from flood modelling results that allows the data to be attributed to

each parcel of land. This is an extremely powerful mechanism that enables Council to record the results of both historic events and planning flood levels.

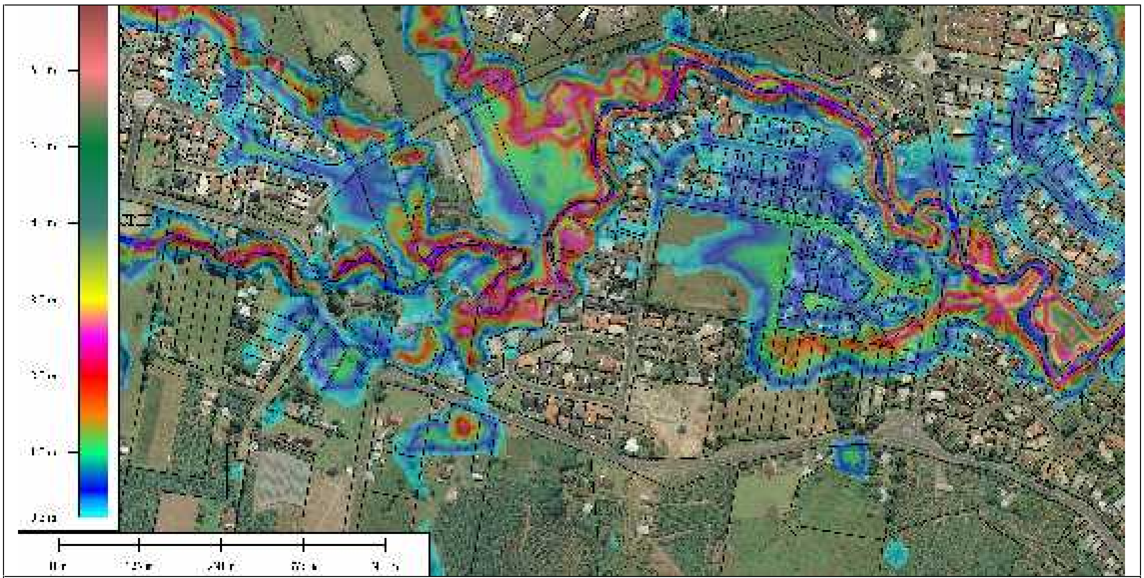


Fig. 10. Typical GIS overlay of Lot Boundaries, Air Photo and Flood Depth.

ANUGA comes with a host of inbuilt functions and tools that make the task of creating GIS compatible layers simple and easy. In addition it is possible to create tables that allow Council officers to quickly and easily assess whether a particular parcel of land is flood prone, to what depth and what level of hazard is presented on that particular land parcel.

5.1 SECTION 149 FLOOD CERTIFICATES:

From this data and the process described it is a relatively simple task to create a mechanism by which Section 149 Certificates include Flood Data. These "Flood Certificates" , can be issued with ease to ensure community is informed and the development industry also remains informed.

6.0 KEEPING THE COMMUNITY SAFE:- IDENTIFYING HAZARD

Of the Councils that currently have the Flood Prone Land mapped within their area, very few have the capability to produce detailed 3 dimensional animations of the flood event, to highlight the behaviour characteristics and level of hazard the community is exposed to. ANUGA provides a viewer that allows the Council to provide a fly over animation of the catchment and flooding during a modelled flood event. This provides an ideal capability with which to educate/inform the community about the flood behaviour.

Further with a specific focus on hazard, it was recently highlighted at the 2008 Floodplain Management Authorities Conference that current practices in 2D flood models are masking the extent of true hazard. Current methodologies do not include buildings in the flood model. Instead an artificially increased roughness is applied in an attempt to mimic the impact of buildings. This was shown by researches VanDrie

(2008) to under estimate the flood hazard significantly. Many of the flood-modelling tools used today have difficulty including buildings into the model domain. However this does not present a problem to ANUGA due to its flexible triangular grid.
It is noted that in discussions held with staff of BMT WBN in December 2009, there are plans for the popular TUFLOW model to have a flexible grid model rather than only the current fixed grid model (and move to finite volume instead of finite difference).

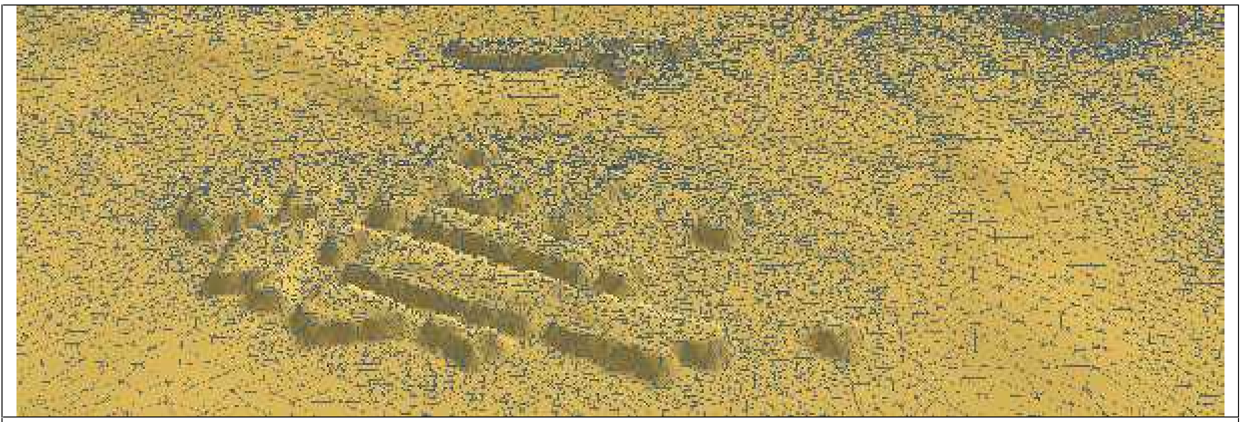


Fig. 11. Inclusion of Buildings to assess REAL hazard resulting from confined flow

The inclusion of buildings in this manner allows the identification of hazard in built up urban streets, where flow is confined and concentrated due to the presence of buildings and other obstacles.

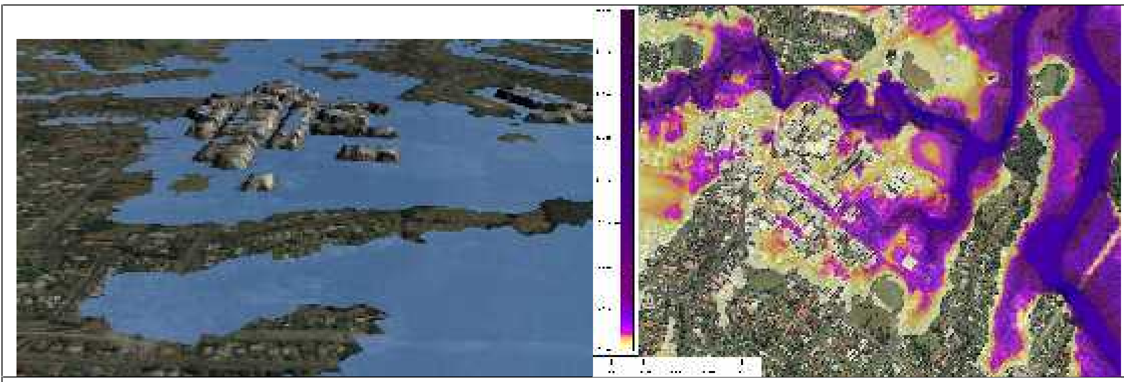


Fig. 12. Animation of Flood and detailed identification of Hazard in Coffs Harbour CBD

6.1 FLOOD EVACULATION PLANNING:

The concept described above can be extended further with several other in built tools in the ANUGA arsenal. The ability to provide a time series of depth, velocity, hazard and numerous other parameters, provides Councils with a means to determine the timing with which roads become inundated, and unsafe to cross during flood events.

This insight into timing of road inundation provides a capability to use the data for evacuation planning for example. This information can be provided to SES controllers to aid in the deployment of resources, as the likely available time for evacuation can be determined.

6.2 FLOOD DAMAGE:

The framework in the ANUGA model also provides for a way to semi automate damage estimates for a modelled flood event.

6.3 INFLUENCE OF CLIMATE CHANGE:

The unprecedented “ENERGISING OF THE ATMOSPHERE” that we have all witnessed all round the world is not about to provide calm seas and gentle weather patterns. As atmospheric DENSITY increases and human activities continue to result in additional ENERGY in the atmosphere, we can expect it to result in much more violent weather patterns, we can expect to see much greater extremes in weather.

- Higher Rainfall Intensity and total volumes in storm events, leading to more severe flooding and erosion in rivers
- Dryer dry spells and more severe droughts
- Increased wind speeds resulting in larger Ocean waves and beach attack
- Higher temperatures during summers
- Potentially more severe cold snaps and snow storms in cold climate winters.

Some how local government needs to get into a position to gain knowledge about the potential impact to their local community. Gaining this knowledge while there is no clear definition is extremely difficult and will result in the need to model and then re-model the impacts as the knowledge consolidates.
The cost of current modelling requirements is already out of reach for many Councils who are reliant on consultants to complete the work. There is no way that these Councils will be in position to complete the level of modelling required, let alone complete subsequent remodelling as climate change estimate change.

The only realistic approach is for local government to gain skills in at least managing and owning their own models, or better still building and updating their own models as required to keep abreast with climate change developments.

7.0 BUDGET ISSUES:

The author of this report having previously held roles with several Councils as follows:

- Wollongong City Council , Flood plain management Engineer, Development Control Engineer
- Wingecarribee Shire Council , Development Control Engineer
- Shoalhaven City Council , Strategic Design Engineer
- Shellharbour City Council , Senior Design Engineer

Is well aware of the typical budget spent on identifying flood prone land by most councils.

As such you are invited to undertake a review of expenditure in this area over the last 10 – 20 years by your Council. I am sure you will be shocked at the cost to your community of identifying flood prone lands and the lack of sustainable outcomes that have been delivered. A sustainable outcome is one that is capable of reproducing answers over time. Nearly ALL Councils have limited their expenditure to Static Snapshot Flood Studies, very few if any have ventured into developing their own modelling capability. A static snapshot flood study by its very nature is something that needs to be updated from time to time as land use changes or climatic conditions change. You must all be aware of the need to assess the potential impact of climate change!

A dynamic approach utilising in-house modelling capability is seen as the only way to produce sustainable outcomes. The only Councils in NSW that I am aware of that have developed extensive modelling capability is Wollongong City Council through it's current Flood plain Engineer Dr. Petar Milevski.

We are aware that Shellharbour City Council have utilised the expertise of German Consultants Hydrotec through its Australia link HydroOz, to undertake a Zero Pass & First Pass assessment of Flooding over its entire area of operation, some 25 catchments.

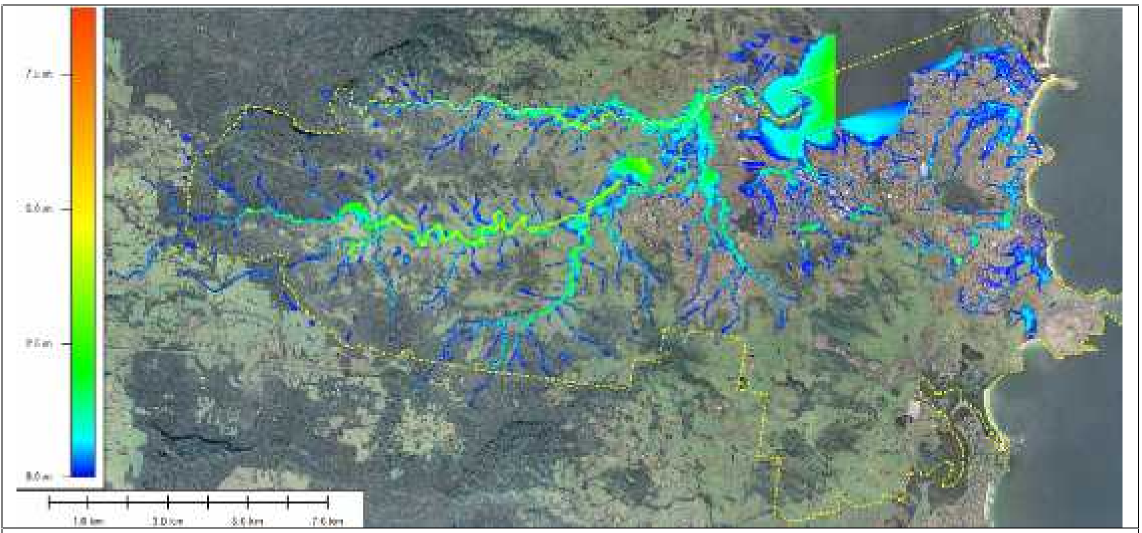


Fig. 13. Shellharbour City Council Zero Pass Concept:- 2D Model of 25 Catchments

7.1 REVIEW OF BUDGET SPENT ON FLOOD MAPPING & FLOOD STUDIES:

Upon reviewing the total expenditure to date on attempts to identify flood prone lands and hazard associated from flooding, you may be wondering if the current approach is providing the community with an acceptable cost:benefit. The overwhelming finding in Germany was NO it was not. In contrast the change in philosophy to moving to In-House Flood Modelling capability is a resounding YES. Authorities with their own flood models, can easily adapt their models to account for future proposed development and in some cases with a push of a button create an up to date flood layer, or even a future flood layer based on undertaking proposed flood mitigation work.

This provides council with the outcomes it needs to justify expenditure and attract funding.

8.0 DATA AVAILABILITY:

Of course the most important aspect of input for accurate flood models (& Ocean Impact Models) is the terrain data and bathymetric data. It is becoming more common for Councils to acquire Aerial Laser Survey (ALS) or LIDAR as it is also known. However this is expensive and may be out of the reach of many smaller Councils. Are there any other data sources?

The federal government has committed itself to establishing a "National Digital Elevation Model", as stated in the following COAG statement.

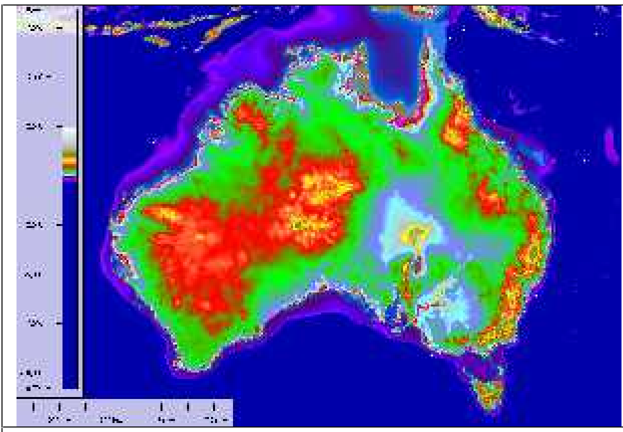
"*…..Develop a national digital elevation model (DEM) for the whole of Australia, with vulnerable regions being mapped using very high-resolution images. This would involve linked topographic and bathymetric information at a resolution relevant to decision-making.* (COAG: National Climate Change Adaptation Framework, 2006)"
Source: http://www.anzlic.org.au/nedf.html

8.1 FREE DATA

There are several sources of FREE topographic data, which in the absence of anything else or in conjunction with local survey is suitable for undertaking flood studies. Some of this data is relatively coarse and requires additional data to locally improve data quality. The data ranges from 120 arc second (3.3km) grid through 9 arc second (250m) grid, then 3 arc second (90m) and 1 arc second (30m). Finally there are plans to release (~2010) a 10m Australian National Data set.

8.1.1 GLOBAL DATA 120 arc Second INCLUDING BATHYMETRY:

There is a GLOBAL data set of terrestrial and bathymetric data, however it is relatively coarse at 0.0333 arc degrees (2 minutes).

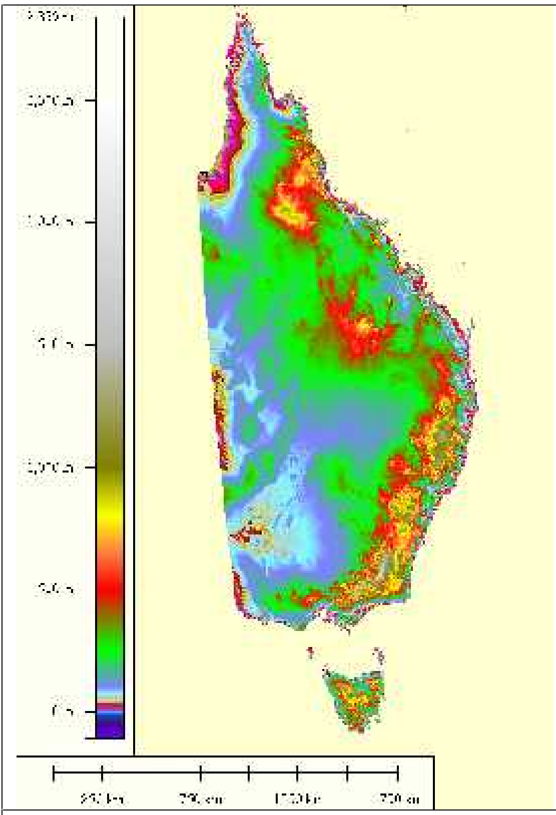
	DESCRIPTION=ETOPO2v2c_f4.nc PROJ_DESC=Geographic (Latitude/Longitude) / WGS84 / arc degrees PROJ_DATUM=WGS84 PROJ_UNITS=arc degrees EPSG_CODE=4326 COVERED AREA=80278365866 hectares NUM COLUMNS=10800 NUM ROWS=5400 PIXEL WIDTH=0.03333 arc degrees PIXEL HEIGHT=0.03333 arc degrees MIN ELEVATION=-10791 meters MAX ELEVATION=8440 meters ELEVATION UNITS=meters BIT_DEPTH=24
Fig. 14. Coverage of 120 Second Data (includes bathymetry)	

8.1.2 GEODATA 9 Second DEM Version 2:

GEODATA 9 Second DEM Version 2 is a gridded digital elevation model computed from topographic information including point elevation data, elevation contours, stream lines and cliff lines. Grid spacing is 9 seconds in longitude and latitude (approximately 250 metres). Contains AUSLIG digital data product information, sample data, 9 second DEM data (encrypted). The 9 Second DEM is a cooperative effort of the Geoscience Australia and Centre for Resource and Environmental Studies(CRES) at the Australian National University.

8.1.3 NASA SRTM 3 arc second , 90m GRID DATA (Terrestrial):

In February, 2000 NASA undertook a mission called the Shuttle Radar Topography Mission (SRTM). The outcome was the FREE release of a Global 3 arc second (90m) grid terrain data set and a 1 arc second (30m) grid for North America.



DESCRIPTION=90Mdem_EAST_SECTOR.gmp
PROJ_DESC=Transverse Mercator / AGD66 / meters
PROJ_DATUM=AUSTRALIAN GEODETIC 1966
PROJ_UNITS=meters
PIXEL WIDTH=91.91 meters
PIXEL HEIGHT=93.64 meters
ELEVATION UNITS=meters
BIT_DEPTH=24

Fig. 15. 90m SRTM DATA of the East Coast

This data is a seamless 3-Dimensional terrain model of all of Australia with a data point every 90m.

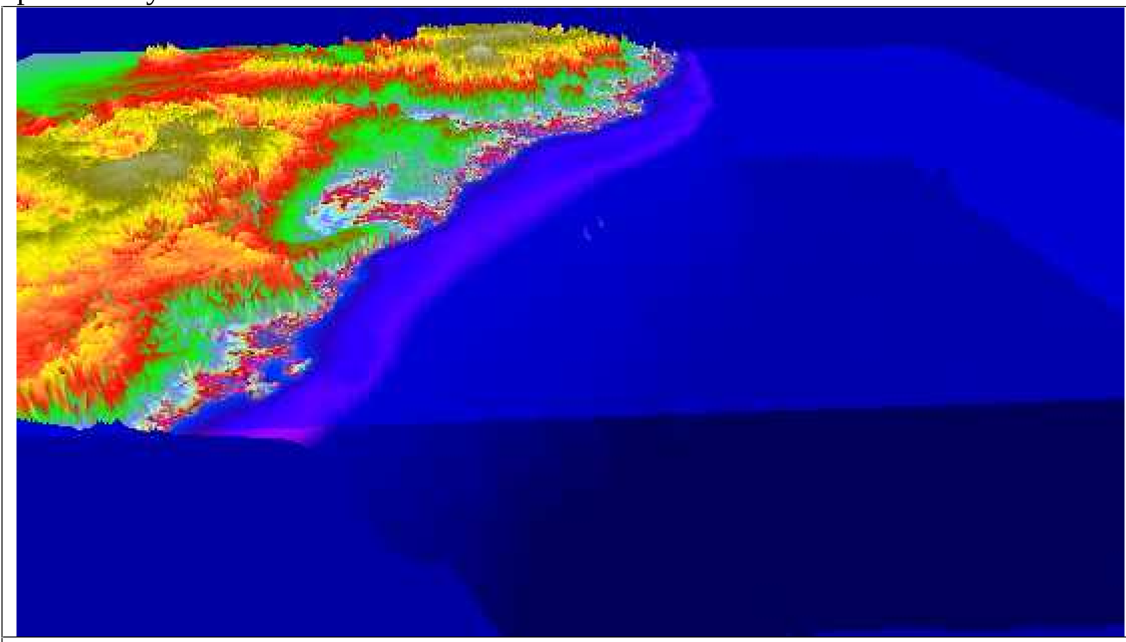


Fig. 16. Merged 3 second (90m) DEM with 120 second DEM (with bathymetry)

8.1.4 CSIRO 1 arc second 30m DEM

The One-second SRTM Digital Elevation Model project is part of the Water Information Research and Development Alliance between CSIRO's Water for a Healthy Country Flagship and the Bureau of Meteorology. As the name suggests this product is also a derivative of the original 2000 Space Shuttle Mission. It is not clear if this data is as yet available but it is meant to be available in 2010.

http://www.csiro.au/science/One-second-SRTM-Digital-Elevation-Model.html#

8.1.5 GEOSIENCE AUSTRALIA National 10m DEM:

This data set has been openly discussed for at least the last 2 years. However as yet it has not been released. This would make an excellent base data set to add locally derived data to. It is urged that any one interested in the work described in this document approach political leaders and authorities to finalise this work and release the DEM data set as soon as possible.

8.1.6 Local COUNCIL Terrain DATA:

Councils hold vast amount of terrain data, in various forms of survey of their local areas. This may be in the form of drawings and survey for development proposals or Councils own designs for works undertaken. Several Councils also have the luxury of ALS data. A review of Councils plan room, or electronic plan register (of autocad drawing etc.) will more than likely identify a significant amount of useful topographic data. It is important to realise that this local accurate data can be merged with various levels of the coarser data described above to provide a very good overview of the terrain within a catchment. This provides an excellent opportunity to utilise a lot of the available data for a very worth while purpose.

8.2 DATA SUMMARY:

It is more than likely that most Councils have access to a range of data that cumulatively when stitched together can provide a relatively good terrain model for the purposes of undertaking flood studies and / or Ocean impact assessments. Councils should review the data available to them, so as to enlighten them of what level of flood analysis can be undertaken with the data available.
Further it is likely that current moves at a federal level will look at the provision LIDAR or ALS at a national level in the future. It makes sense to make this data widely available and to continually update this information in a similar fashion as aerial photos.

9.0 LOCAL COUNCIL COMPUTING POWER:

UPDATE !

Please review section 3.6 above to identify an option to run models on the Australian Governments "National Computational Infrastructure".

It may come as some surprise to some people to realise that local Councils generally have formidable computing power in their servers. Generally Councils have considerably more capacity than your average consulting office (even the larger consultants). It is more often the case that most analysis done by consultants is done on a desktop environment. Most Councils running corporate type applications on their servers have the ability to utilise that computing power for solving complex flood models that will run quite quickly on multiple servers. Recall that ANUGA can be run in parallel with the aid of some very clever code called PYPAR (Python Parallel). This module will intelligently dynamically divide the work load across any number of computational nodes.

What does this mean?

This means that quite large complex analysis that may take several weeks to run on a single high end workstation, may be run overnight on Councils servers.

Note that although this is very do-able it will take some time to establish the protocols at a whole of business level within Council to allow it to occur, as often other processes may be run overnight on Council servers.

10.0 THE WAY FORWARD:

In short Local Government holds the DATA, has the COMPUTING POWER and now has access to sophisticated SOFTWARE through ANUGA to enable it to not only manage its own models, but to also be directly involved in setting up and maintaining its own complex river flood and Ocean impact models.

This is the way in which local government can provide its community with a much more cost effective approach:- for Councils to develop and then maintain their own models. The FREE release of the ANUGA software allows this to come to fruition with minimal resource allocation from the Council. This can be seen by the Wollongong City Council example discussed in Section 12 below.

It therefore makes sense for Councils to have staff trained in the use of ANUGA such that the Council can create, and maintain flood models of its catchments. Of course there is an alternate option to have consultants maintain the models on Councils behalf. This is also a good outcome as long as Council maintains ownership of the model on their own computer system.

The provision of models may be in one of several forms:

- Catchment Hydrologic Models Linked to Site Specific 2D Hydraulic Models (ANUGA) { Note the hydrology component can be provided for FREE by utilising the FREE WBNM model downloadable from the University of Wollongong.}

- Develop an ANUGA model of the entire catchment applying rainfall to the entire catchment. (Combined Hydrologic/Hydraulic approach).

11.0 ANUGA INSTALLATION AND TRAINING:

Although Geoscience Australia currently does not provide training in the use of ANUGA, in 2008 it did conduct a 2 day workshop. It is likely that these workshops may occur from time to time. However in the mean time there is a growing USER Community developing their own specific skills. The author is currently one of the most experienced ANUGA USERS and is also involved in the further DEVELOPMENT of the model.

As such the author is capable of aiding Councils in acquiring and installing the FREE software. In addition there is also the potential to request tuition in the use of the model.

It is likely that the author will announce an ANUGA TRAINING COURSE in the near future. Council staff attending such a training course will be armed with the ability to develop flood models for their Councils.

Further it is likely that as well as the user community through the ANUGA site, there will be established a Local Government USER's Group, so as to enable exchange of ideas and development that is pertinent to local government, For example tips and tricks in running pre and post development scenarios for development control.

11.1 HYDROLOGIC MODEL TRAINING:

In order to ensure Councils and Council staff can feel comfortable with the output gained from their own ANUGA models it is usually a desire to have a secondary checking mechanism. This can be provided in several forms. However one of the simplest and most robust form is to run parallel models that have a different conceptual basis. This has been done very successfully by Wollongong City Council for example. The use of the WBNM model, which is a lumped hydrologic model, to compare catchment behaviour provides an excellent check to the use of the ANUGA model.

The Author of this document is also a Co-Author of the FREE Hydrologic Model WBNM. This model is relatively easy to learn and use. It provides a robust means for determining the flow response from a catchment. It is highly recommended that any one about to embark on using the ANUGA model also become familiar with using WBNM. The author is qualified to provide training in the use of WBNM from simple to the most complex of models.

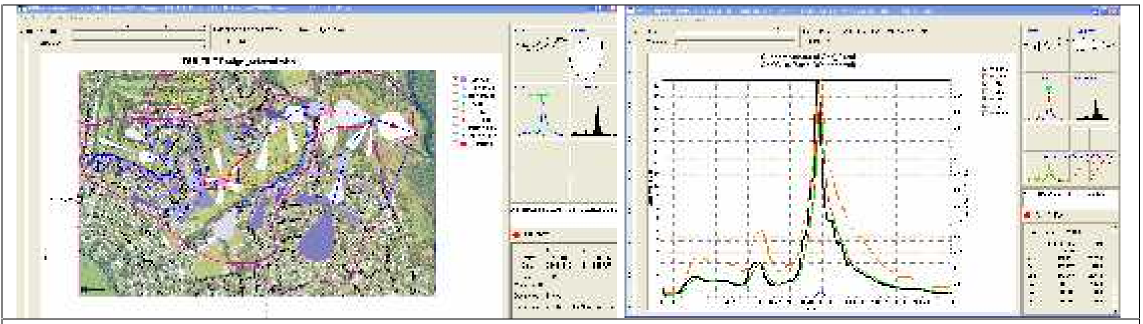


Fig. 17. A Typical WBNM Model and resulting Flow Hydrographs.

11.2 ANUGA HYDRAULIC MODEL TRAINING

Building a robust representative flood model of a catchment involves much more than simply running the model. There are a host of processes involved in reviewing and preparing data such as terrain and rainfall data. Specific skills are required to successfully proceed through the multitude of processes all of which the author has extensive expertise. These skills can be passed on in a series of workshops or training sessions to Council staff.

To date this has been done with two Councils; - Wollongong City Council and Shoalhaven City Council.

Of these two examples Wollongong has applied the model to the greatest range and variety of applications to date.

The most common methodology utilised in the industry is to provide the results of the hydrologic model as flow input into the hydraulic model. This is a relatively straight forward process to set up in ANUGA.

It is proposed that in the near future a Workshop / Course will be advertised in which this process will be fully explained and reviewed for new users.

11.3 ANUGA COMBINED HYDROLOGIC / HYDRAULIC MODEL TRAINING:

ANUGA also has the ability to apply the rainfall directly to the 2- Dimensional hydraulic model, thereby eliminating the need to set up a independent hydrologic model. This currently seems to be a unique capability to only very few models as discussed in a recent research paper by Clark (2008).

Once again it is proposed that Workshops /courses on the ANUGA model will also cover setting up direct hydrology in ANUGA.

11.4 SUPPORT:- LOCAL GOVERNMENT ANUGA USERS GROUP:

It is envisaged that one of the most effective ways to get various local government officers up to speed in setting up and running ANUGA models, is through the formulation of a Local Government ANUGA Users Group. The aim of the Group is to promote the use of the model and its further development as well as enhance the skills of the users or members of the group.

Tackling issues related to climate change and the role of extensive remodelling as parameters are revised will require a concerted co-operative approach to ensure that every one is using a consistent and most appropriate methodology to account for rainfall intensity and volume changes and sea level impacts. ANUGA is capable of dealing with all of these. In addition it is envisaged that ANUGA will also be provided with the ability to model both River Erosion and Beach Erosion in the future as development continues. This is seen as the next big issue to be thrashed out by government. That is, the potentially destructive nature of climate change on our environment. The ANUGA framework is already setup to allow erosion and depositional routines to be added.

12.0 TESTIMONIAL (Example Application of Concept):

12.1 Wollongong City Council:

After initially being introduced to an example application of the ANUGA model by Rudy Van Drie it was decided that Wollongong City Council would attempt to set up a complex model of a catchment. This was done to compare the results from other modelling methods with ANUGA. Although this was an ambitious task it has proven highly worthwhile as the catchment behaviour was found to remarkably different than reported in other studies, in fact an adjoining catchment was found to divert considerable flows into the subject catchment. This and other examples are further discussed below. In short Wollongong City Council has gained an extremely valuable tool in the ANUGA software as the following passages will highlight.

12.1.1 Learning to use ANUGA

Dr. Petar Milevski of Wollongong City Council was initially approached by Rudy Van Drie to undertake a 1 day intensive training course in the use of ANUGA. After setting up several simple models, with ongoing guidance Petar has been able to set up and run highly complex full catchment analysis.

12.1.2 Setting up the initial model

Wollongong City Council has the benefit of having acquired high resolution terrain data for most of it’s catchments via aerial laser survey (ALS) otherwise known as LIDAR. This provides the basis for the terrain in the ANUGA model. ANUGA is capable of using this data directly, and a relatively simple set of instructions is used to import the data and then refine the triangular mesh as required in areas of interest.

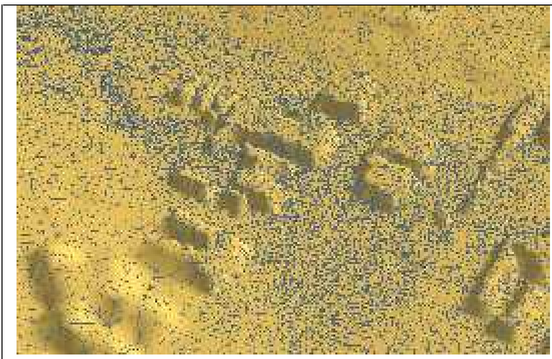


Fig. 18. Flexible triangular grid allows for detail where its required

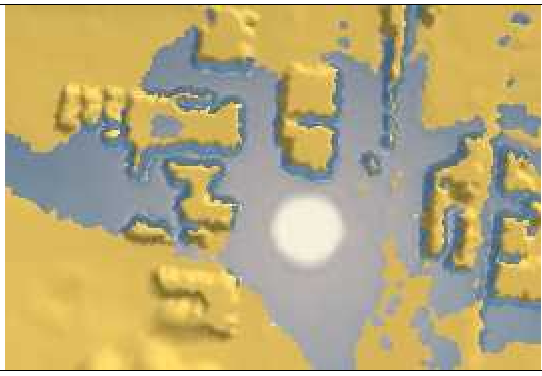


Fig. 19. Such as flood flows between buildings along creek lines.

As can be seen the ability to refine mesh resolution allows for the inclusion of buildings in the model, that truly can account for the impact of structures on the flood behaviour.

12.1.3 Running the Model

Once the run file (Script) is written it can be run as an interpreted Python script. The run or evolution of the model is done for a specified duration with results recorded at predefined intervals. The calculations are generally undertaken at sub-second time steps and are therefore highly accurate and dynamic and able to account for extreme flow conditions including hydraulic jumps, waves and reflective shocks.
Although the run times for ANUGA are quite long the results are remarkable and usually very accurate. The model is extremely robust. Generally once the model is running it never crashes. One way of speeding up the model development is to initially run coarse models before setting up and running the final fine model. Once the model is run all results are placed in a "SWW" file which contains the elevation, stage (m) {water elevation) and X & Y momentum. From these values many other parameters can be determined such as velocity, hazard, energy etc.

12.1.4 Reviewing Results

ANUGA is provided with several ways of reviewing the model results. By far the most impressive is the animated viewer which allows the user to fly over the terrain whilst viewing the flood event. Although this does not provide specific details of flood depth and the like the expanding and contracting flood extent as well time frame of flooding are both easily viewed and determined.

In addition to the animated viewer there is a 3rd party FREE software program called Mirone which allows viewing of any quantity including depth, velocity, hazard, froude etc.

ANUGA also has a suite of routines to extract result plots directly, such as hydrographs, time series plots of depth and velocity and section plots of depth and velocity at any specified time step or at the maximal value.

Finally ANUGA also has built in functions that make the transfer of results to other platforms very easy. It is a simple matter to create a flood depth layer for the GIS for instance.

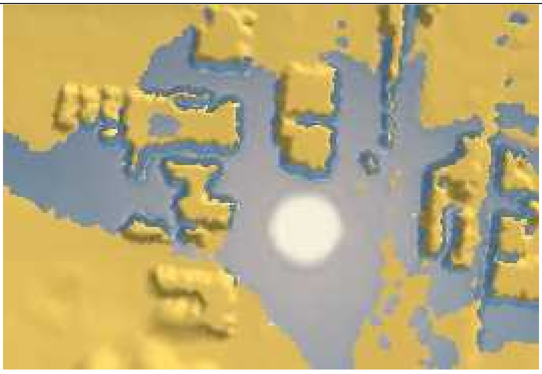
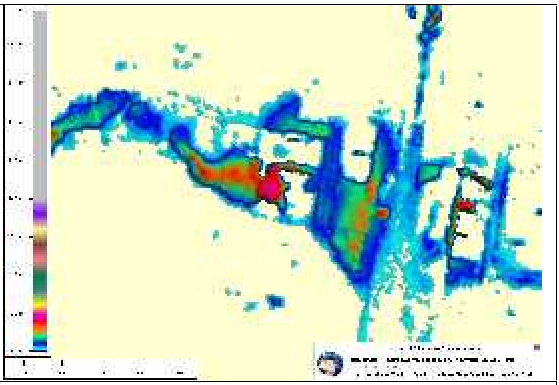
	

Fig. 20. Once again ANUGA SWW file in default viewer (without air photo overlay)	Fig. 21. Depth DEM produced from results (SWW) file

12.1.5 Importing results into other software

Those council's (like Wollongong) who own "WaterRide" will be happy to know that Water Ride has the ability to import the ANUGA output directly. This makes it extremely efficient for extracting all manner of results.

However those who do not have "WaterRide" more than likely have a GIS application at their disposal. ANUGA provides GIS compatible output of any parameter. Therefore plotting the water elevation, depth velocity, level of hazard and flood extent is extremely simple.

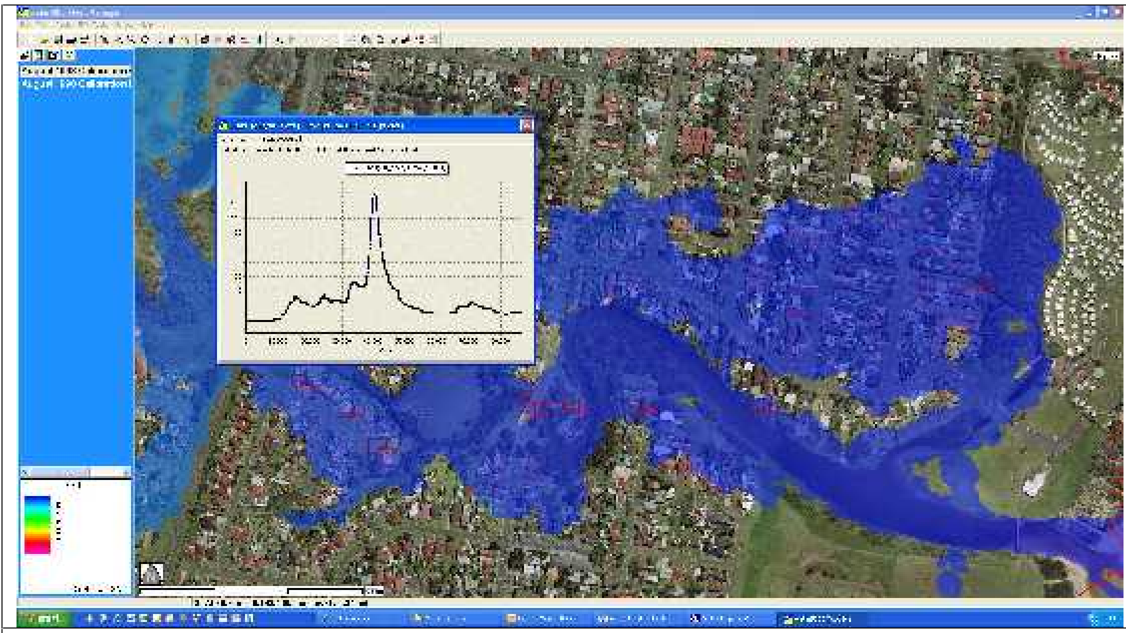


Fig. 22. Screen Shot of Water Ride with plots etc…

12.1.6 CASE STUDIES IN WOLLONGONG (Applications)

Council IT staff had to install the ANUGA software and the PYTHON computer language onto computers. Once installation was complete, staff utilised Council GIS to prepare data files for the ANUGA run files.

12.1.6.1 J.J.Kelly Catchment Wollongong CBD

Council undertook in house modelling of the JJ Kelly catchment to assess the flooding regime within this catchment. Very little was known about how flood waters travelled through this catchment and the impact they would have on property. The purpose of the modelling was to determine the impacts of extreme storm events and to determine whether Council would need to prepare a flood study in accordance with the Floodplain development manual.

It was found that there was significant flood affectation within the catchment to warrant further investigations. In 2012 Council engaged a consulting firm to prepare a flood study. Petar was in a position to ensure the consultants errors were exposed as they occurred ensuring the project remained as close as possible to the projected time line.

12.1.6.2 Towradgi Creek Catchment

Although Council had previously engaged consultants to undertake the formal Towradgi creek flood study, it was noted by a resident that a portion of the catchment known to be flood affected was not shown to be flood affected in the study. In addition it was seen that this would be an opportunity to trial the ANUGA software.

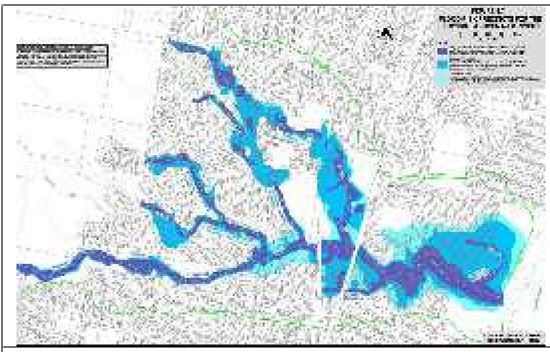


Fig. 23. Current adopted Flood Study Results

Fig. 24. Detail of central lower portion

The previous study was completed by running a hydrologic model and then using the hydrograph output as input into the chosen hydraulic model. Therefore likewise Council staff developed a detailed WBNM2007 model of the catchment and extracted hydrographs at sub area centroid. The hydrographs where then applied to the terrain model in ANUGA. In addition the GIS land use layer was used to assess terrain

surface roughness. This is the only adjustable parameter in a hydraulic model and is at times abused to get obtain calibrations.
The following images show the extent of terrain roughness segregation and the resulting results of flood extent.

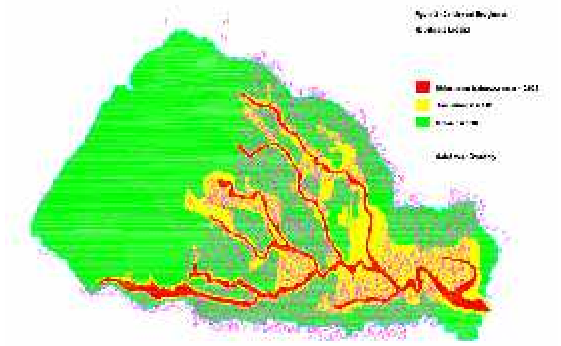
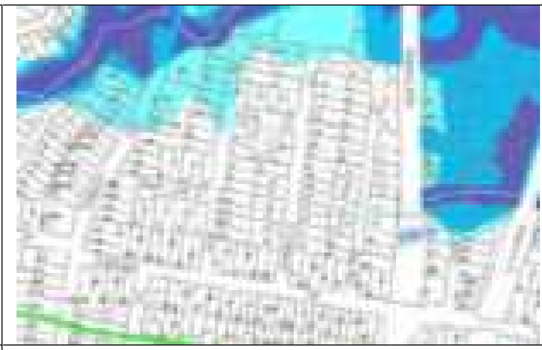


Fig. 25. Allocation of surface roughness to the ANUGA model	Fig. 26. Results of ANUGA model

It was immediately observed that a significant diversion is present that was not identified by the previous flood study. The resulting overland flow described exactly the behaviour observed by residents

	
Fig. 27. ANUGA model identifies significant additional flood affected area	Fig. 28. Recall previous adopted flood study

The results were quite impressive.

Even more impressive was the fact that when the resulting stage time series were compared at locations where recorded levels existed the calibration was far better than that provided in the adopted flood study.

The adopted study shows that generally the consultants calibration run overestimates the flood level by around 500mm for the majority of the 24 hr flood event, even though at the peak of the flood the two coincide. Whereas the ANUGA results almost duplicate the recorded levels for nearly the entire event except for at the peak. The difference at the peak was due to ANUGA not yet having a bridge routine. (Currently being added).
Clearly the blue line in the following image follows the black line over a greater range than does the red line.

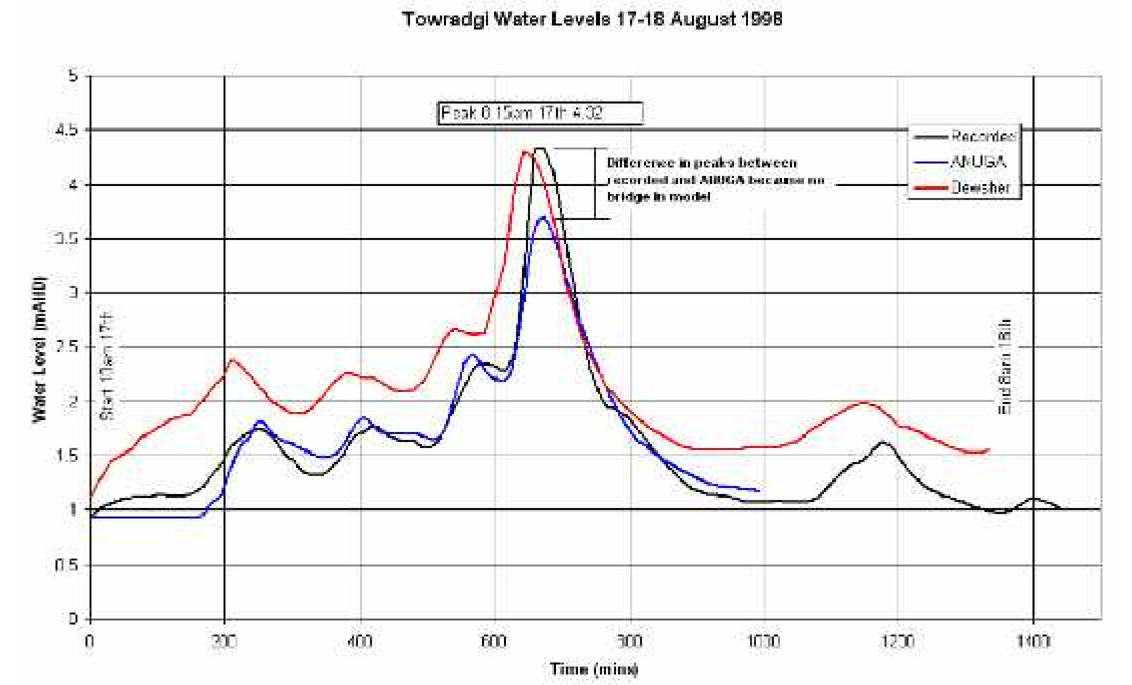


Fig. 29. Comparison of calibration runs ANUGA v's adopted flood study

The viewer also provides a very rich and simple interface to explain and discuss flooding with other council staff and the public.

Fig. 30. ANUGA Animation with air photo overlay and Towradgi creek flood event 1998

12.1.6.3 Other Examples

Wollongong Council has now setup and run many models using the FREE ANUGA software. Each model has provided specific insight into flood behaviour which has aided in advising the local community immensely.

12.1.7 Using ANUGA as a DESIGN Tool

Wollongong City Council had the need to review the design of a Detention Basin particularly the spillway flow behaviour and impacts downstream through an existing urban area. A consultant had provided a design report although the design report was found to have missed significant aspects of flow behaviour. The ANUGA model of the basin identified uncontrolled overtopping, resulting in a redesign of the spillway. In addition several houses were removed in a solution scenario.

Fig. 31. Existing condition analysis

Fig. 32. Solution Scenario 1

The final design included a deflection wall and removal of several houses.
The results were then used to justify a Voluntary Purchase Scheme (VPS) to buy back the most flood affected properties (above floor inundation).

Fig. 32. Final scheme including deflection walls and Voluntary purchase

A further example required rapid assessment of catchment flow in order to provide the details of the impact of a proposed bridge. Due to the ability of ANUGA to provide a flexible and highly refined mesh, the impact of the bridge piers on flood levels could be investigated.

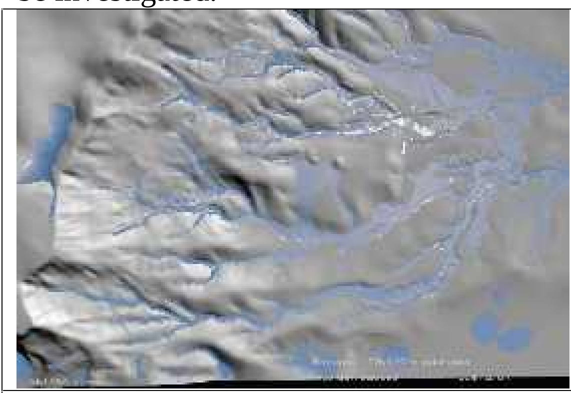


Fig. 33. Rainfall directly on the entire catchment

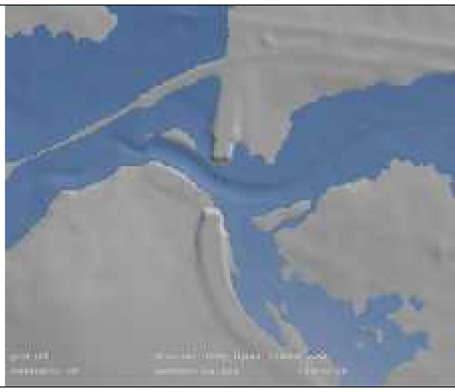


Fig. 34. Location of proposed bridge

There is no other model that the author is aware of that has this ability or level of flexibility. The ability to model the rainfall effects over an entire catchment, yet also capture the detail of the impact of bridge piers is currently unique to ANUGA.

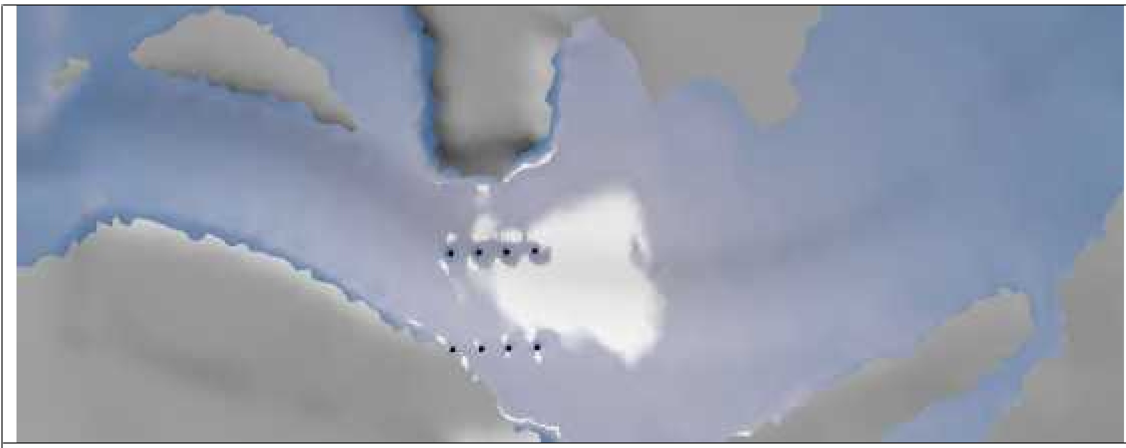


Fig. 35. Detail of Bridge Piers within the catchment model

12.1.8 Benefit of Wollongong City Council running its own models

The benefits to Council having in house 2D modelling capability are enormous. On many occasions, Council has been able to very quickly set up a 2D model, apply rainfall or hydrographs and have results over night. There have been many instances where a DA has been lodged, the flood study reviewed and Council officers know that there were issues with the flood study but had no way of proving that there was an issue.

With ANUGA, those issues quickly come to light once the model is set up and run and viewed in 3D. This is an invaluable tool to possess to aid in development assessment to ensure the community is protected from inappropriate development.

ANUGA has saved Council thousands of dollars that that would have been otherwise spent getting Consultants to do various analyses and design work. But the biggest saving is the time saving. To engage a consultant requires lots of time consuming procurement procedures to be followed, money to be found etc. With an in house 2D modelling capability, an experienced Hydraulic Engineer has the ability to quickly model and produce results at a fraction of the cost and time that would be taken by a consultant, with no bias in the results as the Council engineer is trying to protect the community against inappropriate outcomes from both council design projects and those from the development industry.

12.2 Shoalhaven City Council:

Matthew Apolo the Project Design Engineer at Shoalhaven City Council has been using the ANUGA model for a number of small to medium catchment and flow analysis scenarios.

It is the intention in the near future to form a Local Government ANUGA users group, to share experiences and knowledge. Included in this will be a news letter to subscribers to showcase work completed by members of the group.

13.0 RESISTENCE TO THIS CONCEPT:

This concept has been discussed since 1996 in a host of forums to date, from workshops and conferences to meetings and submissions. However it is clear that for whatever reason there is scepticism and criticism of the concept. It is as if no-one wants to “rock the boat”, the fact that $Millions are being used up with little return does not appear to change the status quo. It is clear that current consultants will see this concept as a threat as it empowers local councils to undertake their own flood modelling, effectively cutting the consultants out of a lucrative market. However less obvious is the resistance from various state government departments, who see it as their role to manage the entire program state wide. The fact that more than $100Million has been spent with an outcome that less than 10% of the state has been flood mapped over 15-20 years does not seem to deter their will of maintaining control.

This concept puts a greater level of control back into the hands of Councils. In fact the word empowering is quite applicable.

However as discovered in Germany almost 25 years ago this does in fact open a different market for consultants once it is embraced. In fact it is likely that many Council’s may not have sufficient staff to allocate one or more to specifically manage their own flood models. In these cases it is likely that consultant will be brought in to create models on Councils computer systems as is done in Germany. The Council still owns and manages the models on their systems, but then can call on any other consultant to aid model development, refinement and management.

14.0 ONGOING DEVELOPMENT AND SUPPORT OF ANUGA:

OPEN SOURCE SOFTWARE:
ANUGA was with specific purpose, setup as a “Free and Open Source Software” (FOSS) project. The lead author Dr. Ole Nielsen argued and fought very hard for this to be the case.

The benefits of using Open Source Software over commercial products has been understood and documented for some time.
For example in Europe as far back as 2000 the “COUNCIL OF THE EUROPEAN UNION COMMISSION OF THE EUROPEAN COMMUNITIES”, in their action plan stated the following goal:-

- Promote the use of open source software in the public sector and e-government best practice through exchange of experiences across the Union (through the IST and IDA programmes).

In the UK in 2004 the government introduced a policy called:- “ Open Source Software within UK Government”. In 2011 there is now a Procurement Policy introducing “Open Standard” requirements.

However it is taking quite some time to infiltrate into the broader community particularly into sectors of Australian government.

The Australian government through AGIMO has released **Circular No: 2010/004, which states:**

- The purpose of this AGIMO circular is to inform agencies of the requirement to consider open source software in all software procurements. This policy is subject to the opt-out arrangement described in Estimates Memorandum 2010/02.

Therefore all levels of government in Australia have been given a mandate to attempt to utilise open source software over commercial equivalents in both an attempt to save money but also promote open source development.
There are very clear benefits to the Open Source approach which include:-

- A development community is built around the product, which gives the product a life of its own
- Protocols are such that it is not possible to sabotage the product
- It fosters a standardised approach in doing things.
- The cost of software acquisition and maintenance is massively reduced.
-

ONGOING DEVELOPMENT OF ANUGA:

In September 2010 GA and the ANU formed an ongoing collaborative agreement to continue to develop the ANUGA model. Key items include:

- integrating 1D structures (bridges, culverts and pipes) into ANUGA,
- reducing model run times by enabling the software to run in parallel with these structures,
- improving the inflow boundary condition and
- testing ANUGA against a suite of hydraulic tests for the purposes of validation

Latest documents on ANUGA can be found at: http://anuga.anu.edu.au/wiki

Further there is now a slowly growing development community for example:

- In Australia Rudy Van Drie Developed the Culvert Routine and Rainfall Routine making it suitable for flood modelling over entire catchments
- In the USA at the University of Colorado a researcher has developed erosion and deposition routines, making it possible to model geomorphological impacts (not yet adopted in standard releases).

From this it is clear that there is a considerable commitment from the original development bodies to continue to evolve the ANUGA model. However importantly in addition there is now a active development community building around the ANUGA model that is likely to further develop the model, as it starts to take up a life of its own.

15.0 CONCLUSIONS:

It is concluded that to date although $100’s millions have been spent on flood mapping just in NSW and sadly only around 10% of flooding has been mapped (FMA

2008). This needs to change and change much more rapidly as there is now an ever increasing need to undertake further modelling including potential Climate Change impacts. As such it is likely that the most cost effective approach available is for each Local Government authority to become custodians of flood models that impact their areas of operation.

It is further concluded that Local Government has access to the DATA required to set up its own models. Local Government has access to impressive COMPUTATIONAL POWER through its servers.

Finally it is concluded that through the availability of the FREE and OPEN SOURCE 2-dimensional hydrodynamic software known as ANUGA it makes it possible for Local Government to setup and maintain its own River Flood and Ocean Impact models at comparatively minimal cost.

16.0 RECOMMENDATIONS:

It is recommended that local government seriously consider the possibility of setting up their own flood models and maintaining those models so as to provide a dynamic re-mapping capability in-house for flooding as development and other issues impact the need to re-assess flooding within their areas.

It is recommended that senior management in council briefly research the aims of the release of the ANUGA platform and determine for themselves the likely savings to be made in both dollars and time (as expressed by Dr. Petar Milevski of Wollongong City Council).

It is further recommended that if your Council may be interested in acquiring the skills to install setup and run ANUGA models staff should contact the author as follows: .

Alternatively if Council has an interest in setting up, owning and managing its own models on their computer systems and requires assistance to set up these models also feel free to contact the author of this document.

Finally it is recommended that Council staff interested in gaining skills to setup models join the Local Government ANUGA Users Group to share information and skills, and start enjoying the benefits that Wollongong City Council has gained from utilising this FREE resource.

17.0 acknowledgements

The authors wish to acknowledge the support and assistance of Dr. Ole Nielsen of Geoscience Australia, and Dr. Petar Milevski of Wollongong City Council for writing section 12 and the use of models and data provided for this paper.

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