Vehicles and Buildings in Flood Waters

11

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By G P Smith

Water Research Laboratory

School of Civil and Environmental Engineering

WRL Report 2015/11

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Flood waters have the potential to cause great damage. When buildings, vehicles and people are in the path of flood waters they can be susceptible to being lifted, pushed and/or rolled along by the flood flows.

In the simplest terms, the damage and danger that flood waters might cause can be related to

21 m/s or 75 km/h. Large flip bucket spillways on major dams are typically designed for flow speeds in the order of 15 to 20 m/s (55 to 70 km/h).

(source: http://www.couriermail.com.au/news/queensland/wivenhoe-put-under-pump-to-save-region/story-e6freoof-1226552717108)

Peak naturally occurring flow speeds can also be estimated by considering evidence of flood water level slopes or by the types of rock and soil material eroded by flows after floods have passed through a floodplain and the flood waters have subsided.

The flow speeds required to erode different types of river bed material have been measured in controlled tests. Information from these tests is often used to design construction works to stabilise river banks and channels. Information from the tests show that flow speeds of 16 km/h (4.4 m/s) would erode 0.2 m diameter rocks (Chow, 1959). Similarly, design guidelines aimed at providing rock protection for river banks recommend 0.5 tonne rock to remain in place in 16 km/h (4.5 m/s) flow speeds and 4 tonne rock to withstand flows of 22 km/h (6.0 m/s) (Main Roads Western Australia).

In summary, the most extreme observed natural flows occur in steep, rock lined river channels or at large flow structures like dam spillways. In these extreme cases under large flow rates, flow speeds can peak at 75 km/h at the base of large dam spillways like Wivenhoe Dam. Flow speeds in river rapids have been measured at 22 km/h and have been reported by estimation as high as 55 km/h.

Flow speeds on an alluvial floodplain, like the Lockyer Creek floodplain where extreme erosion of vegetation and top soil has occurred might have experienced flow speeds up to 14 to18 km/h (4 to 5 m/s). Flow speeds on floodplains are rarely higher than 20 km/h, even in extreme cases.

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Department has recently completed a major revision of national best practice in floodplain management (AEM Handbook 7, 2014)

In summary, the review found that:

- People and vehicles can become unstable in relatively shallow and slow moving flows;
- In slow moving flows, small cars can become buoyant when flow depths exceed and large four wheel drive vehicles can become unstable when flow depths are above ;
- Fit adults walking thr3(s 27(l)-(adu)4(l)-5(t)-5(s).9 13(n)6( )-127-3(w)5( ))-4(:)-3( )rcan beco 1(N4

When considering the amount of danger and damage that flood waters can cause, its helpful to have a frame of reference. Some simple examples are provided below:

- A swimmer in the Olympic final of the 100m freestyle swims at about (2 m/s). It follows then, that if an average person fell into flood waters 1 or 2 metres deep travelling at 7.2. km/h they would have extreme difficulty saving themselves;

- Water is heavy. Each of water weighs about (1000kg). If a house is exposed to a floodplain flow and travelling at most brick construction buildings would be liable to failure by the walls collapsing from the weight and impact of the water. If flow speeds increase to flow, becoming projectiles in the flow. Heavy rafts of debris may also build up on buildings and other structures, adding to the load on the structure and increasing the likelihood of the structure failing.

In flows and deeper, with flow speeds greater than there is the potential for the flow to move large rocks and boulders which would have the impact of water borne projectiles, making the flows extremely dangerous. Individuals exposed to such flows are at extreme risk.

In flood flows deep all vehicles including small trucks are vulnerable to being pushed off the road, even in slow moving flows. Once pushed off the road into deeper water they may sink, putting the occupants lives at risk. Light framed buildings will be vulnerable to failure in flows deep even if the flows are moving extremely slowly (e.g.) as this depth of flow would subject the structure to large forces that could push the whole structure over. If Queenslander style homes on high stumps are not tied down to the stumps, n5( )-31BTwo many cases, large individual pieces of debris will move more or less at the same speed as the flow, becoming projectiles in the flow. Heavy rafts of debris may also build up on buildings and other structures, adding to the load on the structure and increasing the likelihood of the structure failing.

In flows and deeper, with flow speeds greater than there is the potential for the flow to move large rocks and boulders which would have the impact of water borne projectiles, making the flows extremely dangerous. Individuals exposed to such flows are at extreme risk.

Flows above deep are extremely dangerous irrespective of the flow velocity. Any vehicle caught in deep water is in extreme danger. Flows of this depth have enormous force and

The information presented above shows that flood waters travelling at relatively slow flow speeds can move with great force. Evidence shows that:

- Small cars can become buoyant and be washed off roads in flows as shallow as ;
- Primary age children and the elderly can become unstable and lose their footing in flows as shallow as ;
- Large four wheel drive vehicles can become unstable when flow depths are above ;
- Fit adults walking through floodwaters can become unstable when flow depths exceed ;
- Residential buildings are at risk of failure once flood flows are greater than deep in combination with flow speeds greater than (1 m/s);
- All building types, including concrete reinforced industrial buildings, are prone to failure once flood flows are greater than deep in combination with flow speeds greater than (2 m/s).

Laboratory tests on rocks and analysis of scour and erosion after flood waters have receded show that vast amounts of soil, gravel and rocks can be moved by flows travelling at speeds of 7 to 11 km/h. On this basis, it would be rare for flood speeds on an alluvial floodplain, such as in the Lockyer Valley, to exceed 20 km/h. Flood speeds greater than 60 km/h are only seen at large man-made structures and are unlikely to ever occur in a natural floodplain.

This report represents my expert opinion on flood water hazards prepared to address the Letter of Instructions (ref: DOC/15/133134) provided to me by the Grantham Floods Commission of Inquiry. In preparing this report, I have relied on the listed references and my knowledge of the subject gained over my 24 years of engineering practice.

Grantley Smith, 13 August 2015

Grantham Floods Commission of Inquiry

Reference number: DOC/15/133134

Grantley Smith
Principal Engineer and Manage
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110 King St
Manly Vale NSW 2093,

Dear Grantley

GRANTHAM FLOODS COMMISSON OF INQUIRY ±STABILITY OF PEOPLE, VEHICLES AND BUILDINGS IN FLOOD WATER ±LETTER OF INSTRUCTION S

Engagement as a water hazard expert for the Grantham Floods Commission

The Grantham Floods Commission of Inquiry (the Commission) has been established to make a full and careful inquiry with respect to the flooding of the Lockyer Creek between Helidon and Grantham on 10 January 2011.

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Grantham quarry and the impact the existence or breach of that quarry had on the flooding at Grantham.

Grantham i.e. a rural town with a range of buildings of different structures (brick, wood and prefabricated), all one or two stories in height and where buildings are generally well spread out.

Grantley Smith BE, MEngSc, CPEng

Manager

Never Stand Still | Faculty of Engineering

Grantley Smith is Manager of the Water Research Laboratory (WRL) of the University of New South Wales. WRL is a leading international research and consulting laboratory utilising numerical modelling, physical modelling and field data collection to provide expert solutions in the areas of water, coastal and environmental engineering and groundwater. As Manager and Principal Engineer, Grantley is responsible for all commercial and applied research projects, financial operations, ongoing professional development of staff and the maintenance and development of WRL's facilities and techniques.

Grantley is an Australian expert in the fields of physical and numerical modelling of water. In his 22 years as a professional engineer, Grantley has developed his skills on a broad range of projects providing assessment and solutions for water engineering and water resources investigations. He has particular expertise in the selection and application of appropriate numerical models to support design solutions, planning and management across the water spectrum. Numerical modelling projects have been undertaken using 1D, 2D and 3D hydrodynamic and water quality models.

Grantley has specialist expertise in water resources management through a hands-on career investigating catchment processes. He is acknowledged by his peers as an expert in the application of numerical models to catchments and floodplains and was instrumental in the pioneering use of 2D hydrodynamic models for floodplain flow prediction and inundation mapping. His experience gained through direct participation in the evolution of floodplain modelling has provided him with an outstanding knowledge of the application and interpretation of appropriate numerical models to support environmental planning, management and forecasting for floodplains. Grantley is a lead author and key contributor to reports supporting the revision of Australian Rainfall and Runoff, most recently contributing to guidelines for appropriate use of 2D numerical models to floodplains. He is also a co-contributor to guidelines setting safety criteria for people and vehicles in floods.

Qualifications

BE Hons (Civil Engineering), UQ
MEngSc (Water Engineering), UNSW

Affiliations

CPEng (Chartered Professional Engineer)
NPER (National Professional Engineers Register, Australia)
Australia Water Association
Immediate Past Chair, Engineers Australia Sydney Water Panel
Chair, 34th Hydrology and Water Resources Symposium

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Rivers and Flooding
Newcastle City-Wide Floodplain Risk Management Plan, NSW
Lower Hunter River Floodplain, NSW
Ironbark Creek Floodplain, NSW
Middle Creek Flood and Sediments, NSW
Woy Woy Flooding, NSW
Darling River, Bourke - Louth, NSW
Dark Creek Flooding, NSW
River Murray Environmental Flow Easements, NSW
Haslam Creek Hydraulic Investigation, NSW
Frenchs Creek FPMS, NSW
Warrah Creek Flooding ,NSW

Project Summary

Year	Project	Position & Activities
2015	Newcastle Voluntary Purchase Assessment	Project Manager and Technical Expert. Analysis of design flood conditions on an urban overland flowpath in Newcastle NSW. Assessment of the vulnerability of buildings on the flowpath to failure during flood. Design and assessment of voluntary purchase scenarios to limit potential loss of life and residential damages during flood.
2015	Toowoomba Overland Flood Study	Expert Reviewer Expert advice and review of the proposed methodology for the Toowooomba Overland Flood Study.
2015	Flood Fatalities Literature Review	Lead Author Literature review for the Australian Government National Flood Risk Action Group (NFRAG) on methods to estimate fatalities during flood conditions.

2014	Flood Hazard Technical Guideline	Author, Flood Hazard Guideline. Preparation of technical guideline to support recently released national best practice manual for floodplain management
2014	Flood Hazard ±background report	Project Manager and technical expert. Prepartion of a literature review and fundamental research into hazard on floodplains. Investigation of quanitifcation of flood hazard and recommendation of hazard vulnerability guidelines for people, vehicles, buildings and infrastructure on floodplains
2014	Temperate Peat Swamps on Sandstone	Expert Reviewer Literature review to investigate the impacts of long wall mining on temperate peat swamps os sandstone in Blue Mountains and Illawarra. Critical Analysis of Temperate Highland Peat Swamps on Sandstone Literature colaltion and Evaluation of Mitigation and Remediation Techniques.
2013	Coincidence of Catchment and Ocean Flooding Stage 2 - Recommendations and Guidance	Author and Principal Investigator Collation, analysis and development of guidance for the NSW Government on the joint occurrence of coastally driven and catchment driven flooding for design purposes.
2013	Safety Design Criteria for People and Vehicles	Author and Principal Investigator Report for Australian Rainfall and Run1 0 G2f0(t)9( )-2o3(a)19(n)19( )-2floo

2010	ARR Project 15, Floodplain Flow Blockages in Urban Areas	Lead Researcher and Project Manager: Development of detailed physical and numerical models of the Merewether floodplain in Newcastle NSW. Assessment of various 2D numerical modelling techniques to determine suitability and accuracy as applied for representation of urban floodplain flow behaviour.
2010	Hunter River Water Quality Model	Project Manager and Modelling Expert: Development of a hydrodynamic and advection dispersion model of the Hunter River tidal pool. Assessment of the influence and impact of adjusted wastewater treatment plant outflows to the river as part of the assessment of a catchment wide water re-use scheme for the Lower Hunter River valley.
2010	Ord River Irrigation Scheme	Expert Reviewer: Review of surface water aspects of a development proposal to expand the

2008	Middle Creek Flood Study and Sediment Transport Study	Project Director: Development of a linked 1D/2D floodplain model to assess the impact of sand extraction on flow behaviour in a semi urban creek system.
2008	Woy Woy Flood Study	Project Director: Development of an integrated 2D surface water/3D groundwater model for the flood assessment of a sandy coastal floodplain on the NSW central coast.
2007	Expert Assistance - Hunter River Flood Emergency	Flood Forecasting Expert: Expert advice supplied to NSW State Emergency Service for Hunter River Flood Emergency. Analysis of real-ti P H I O R R G U H F R U G V Forecasting of flows and impact areas to determine potential requirement for evacuation. Go/no go advice for evacuation procedures.
2007-2008	Koondrook Perricoota Hydraulic Modelling	Project Director/Senior Technical Adviser: Analysing the hydraulic behaviour of the Koondrook forest using a MIKE-FLOOD model spanning 100km. The investigation focuses on maximising the advantages of hydraulic structures with environmental flows to inundate the forest for given criterion.
2007-2008	Darling River Flood Study - Bogan River Junction to Louth	Project Manager: Development and calibration of a 2D model of the Darling River floodplain near Bourke. Estimation of design flows by flood frequency analysis. Design floodplain behaviour estimation using a representative flow hydrograph derived from historical flood information.
2007	Balickera Pump Station, 3D Flow Model Analysis	Project Director: Development of a full 3D model description us L Q2âY4 'Y¡™ I' S Kp 0 RS Q

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2005	Lavington Catchment Flood Study	Project Director: Flood Study for the Thurgoona Catchment in Albury.
2004-2005	)UHQFK¶V &UHHN)ORRG Management Study and Plan	Project Manager: Development of a dynamically linked 2D overland flow/pipe network model for analysis of storm water flooding of an urban residential catchment in the Warringah Council Local Government Area. Community Consultation SURJUDP WR JDLQ KLVWRULFDO ³ORFDO NQ also to engage community interest in the management of the floodplain. Model calibration and verification. Design flood predictions. Integration of study outcomes into &RXQFLO¶V *,6 SOD Development and W work shopping of flood mitigation options. Integration of mitigation options into a Floodplain Management Plan for the catchment.
2004-2005	Stockton Beach Coastal Processes Study	Project Director:

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2004	Tumut 3 Turbine Upgrade - Head Race and Tail Race Channel Surge Ming	Project Manager: Tumut 3 power station, part of the Snowy Hydro Scheme is to have its 6 turbines up-rated. The up-rating of the turbines has the potential to change the operational regime of the power station in terms of maximum and minimum operational water levels in the head race and tail race channels. DHI were engaged to undertake detailed 3D numerical model analysis of the headrace and tailrace channels using the software package NS3, a full Navier Stokes solution for free surface flow. The NS3 model was successfully calibrated to measurements taken specifically for the study. The calibrated model was then used to predict surge levels in the head race and tail race channels for a range of station stoppage and start-up scenarios.
2004	Chaffey Dam Break Modelling	Project Manager: Development of a hydraulic model for hypothetical dam failure of Chaffey Dam in NSW. Preparation of flood impact mapping.
2003/2004	Illawarra Waste Water Strategy - Ocean Outfall Design	Project Manager: Design of Ocean outfall to meet stringent licensing criteria for ne>e>e>e>e>n

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1999	Vistula River, Poland	Implementation of Floodwatch GIS flood monitoring system, including MIKE-11 fully dynamic FF module for realtime flood forecasting on the Vistula River, Poland.
1998-1999	Mona Vale Golf Course Water Quality Management Study, Australia	Review of water quality in golf course ponds, design of water quality management strategies, design of monitoring programme to define loads into the golf course. Modelling of long-term loads and evaluation of existing pond sizes to meet long-term course requirements. Setting of criteria and levels of compliance. Design of monitoring programs.
1998-1999	Careel Creek Flood Study, Australia	Detailed flood modelling of the Careel Creek catchment at Avalon on Sydney¶V 1RUWKHUQ %HDFK est Analysis for the reticulated stormwater drainage system using the fully dynamic MOUSE modelling system. Identification of stormwater overflows. Full integration of the MOUSE stormwater drainage model with a MIKE-11 model of surface drainage and open channel flows to determine flood depths. Integration of model results LQWR &RXQFLO¶V *,6 GHFLVLRQ VXSSRUW V\V
1998-1999	Wallsend/Plattsburg High Definition Flood Study, Australia	Development and calibration of hydrologic and hydraulic models to include all flood affected areas in the Wallsend/Plattsburg catchment in western Newcastle. Definition of flood level, velocity and hazard on a property by property basis. Integration of flood model results with Council¶V *,6 D databasing systems. Full documentation and transferral of models and GIS interface system to Council.
1998	Mona Vale Golf Course Water Quality Monitoring, Australia	Collection and analysis of stormwater flow parameters, CTD data and water quality samples. Range of wet weather storm events, average and dry weather conditions.
1998	Channel Stabilisation, Illawarra	Concept design of channel stabilisation and rehabilitation works for a

1997	Dam Break Study of Woronora Dam, Australia	1D modelling of hypothetical failure of the Woronora Dam and the Woronora and Georges River floodplains. Prediction of inundation areas and floodwave travel times. Identification of infrastructure at risk. Estimation of population at risk and loss of life. Recommendation for dam hazard rating.
1997	Ingleside/Warriewood, Australia	Development of hydrologic and hydraulic models to establish the effects of urbanisation on flooding for several catchments on Sydney's Northern Beaches. Testing of several flood mitigation options.
1995-1997	Water Supply Reservoir Dambreaks, Australia	1D and 2D dambreak analysis on ten reservoirs in Sydney. Prediction of inundation areas and flood wave travel times. Calculation of likely

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1991	Turbidity Plume Study, Australia	Investigation of the effect dredging for marine aggregates might have on turbidity levels in the ocean near the dredging unit.
1991	Cooks River Dispersion Study, Australia	Calibration of MIKE-11 hydrodynamic and transport dispersion models to recorded data on Cooks River

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