 

http://www.youtube.com/watch?v=5mMtDX5i0Nk

Australian Rainfall and Runoff

A guide to runoff estimation

ENGINEERS AUSTRALIA

ARR Project 10 People and Vehicle Stability

ARR Project 15 2D Flood Modelling in Urban Areas

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ARR CURRENT STATUS

Important points are

- Over 20 years since last revision with only one chapter revised in that period.
- Significantly longer records now available.
- IFD (rainfall) data over 25 years old.
- Written before a computer on every Engineers desk
- Climate change concerns
- $4 Million in funding from DCCEE

Projects

	Project	Projects that directly incorporate climate change	Projects that deal with the effects of climate change	Projects which update methods /approaches
1	Development of intensity-frequency-duration information across the country			
2	Spatial patterns of rainfall			
3	Temporal pattern of rainfall			
4	Continuous rainfall sequences at a point			
5	Regional flood methods			
6	Loss models for catchment simulation			
7	Baseflow for catchment simulation			
8	Use of continuous simulation for design flow determination			
9	Urban drainage system hydraulics			
10	Appropriate safety criteria for people			
11	Blockage of hydraulic structures			
12	Selection of an approach			
13	Rational Method developments			
14	Large to extreme floods in urban areas			
15	Two-dimensional simulation in urban areas			
16	Storm patterns for use in design events			
17	Channel loss models			
18	Interaction of coastal processes and severe weather events			
19	Selection of climate change boundary conditions			
20	Risk assessment and design life			
21	Communication Strategy			

ARR Book Releases

- Book 1 –Scope and Philosophy - Mar 2012
- Book 2 – Rainfall Estimation - Dec 2012
- Book 3 – Peak Flow Estimation - Dec 2011
- Book 4 – Catchment Modelling - June 2012
- Book 5 – Flood Hydrograph Estimation - Dec 2012
- Book 6 – Flood Hydraulics - June 2012
- Book 7 – Application of Catchment Modelling Systems - Dec 2012
- Book 8 – Large to extreme flood estimation - June 2013
- Book 9 – Runoff in Urban Areas - Dec 2012

ARR Project 10
People and Vehicle Stability

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Acknowledgements – Ron Cox, Tom Shand and Matt Blacka - WRL


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Safety of people and vehicles in areas of high flow such as may occur in streets and floodways during floods or broader coastal areas in the event of a tsunami

Safety criteria - depth & velocity of flow

Foster & Cox (1973)

Flume exposure testing of 9 and 13 year olds

Simple depth vs velocity safety criteria

Preliminary and limited laboratory work

Affected by age, size and weight

Psychological factors (confident or fearful)

Orientation of child to flow (stand, sit, turn)

Clothing and footwear

Hazard Criteria Adopted

Limited work at WRL for ACT generally used in adoption of flood hazard criteria (NSW and beyond)

Current AR&R specify human safety limit for floodway design as DxV = 0.4 $m^2 s^{-1}$

Figure 1 - DPW 1986

EMA advice is that wading by adults becomes difficult and dangerous when the depth of still water exceeds 1.2 m or when the velocity of shallow water exceeds 0.8 m/s and for various combinations of DxV between these limits.

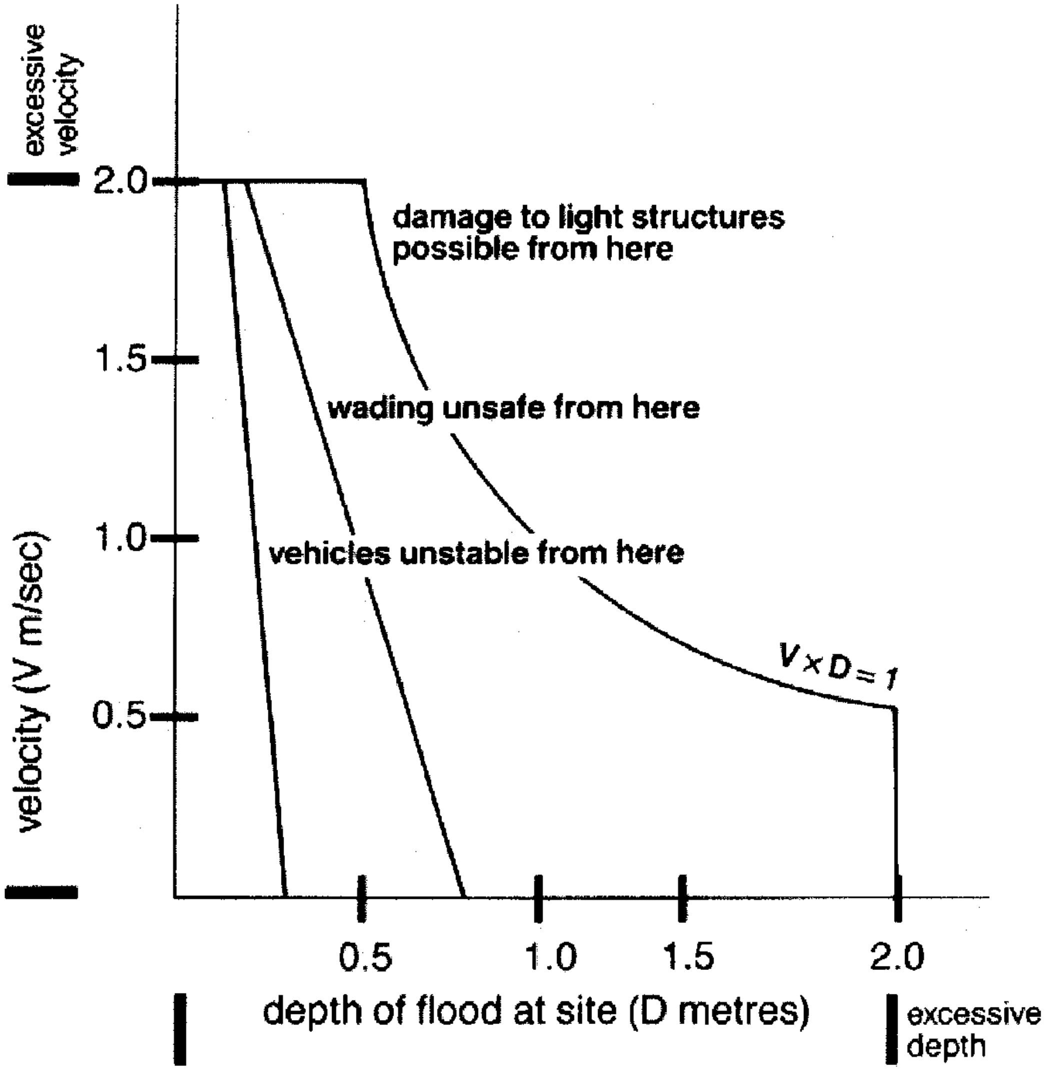

Figure 1
Hazard Rating
DPW NSW 1986

Laboratory Tests: World Data Base

- Foster & Cox (1973)
- Abt, Wittler, Taylor and Love (1989)
- Takahashi, Endoh & Muro (1992)
- Karvonen et al - RESCDAM (2001)
- Cox, Yee & Ball (2004)
- Jonkman and Penning-Rowsell (2008).

Testing - Abt etal (1989) – 20 adults (M&F)

D=0.4-1.2m, V=0.8-3m/s, DV=0.7-2.1 $m^2 s^{-1}$, HM=62-173 mKg

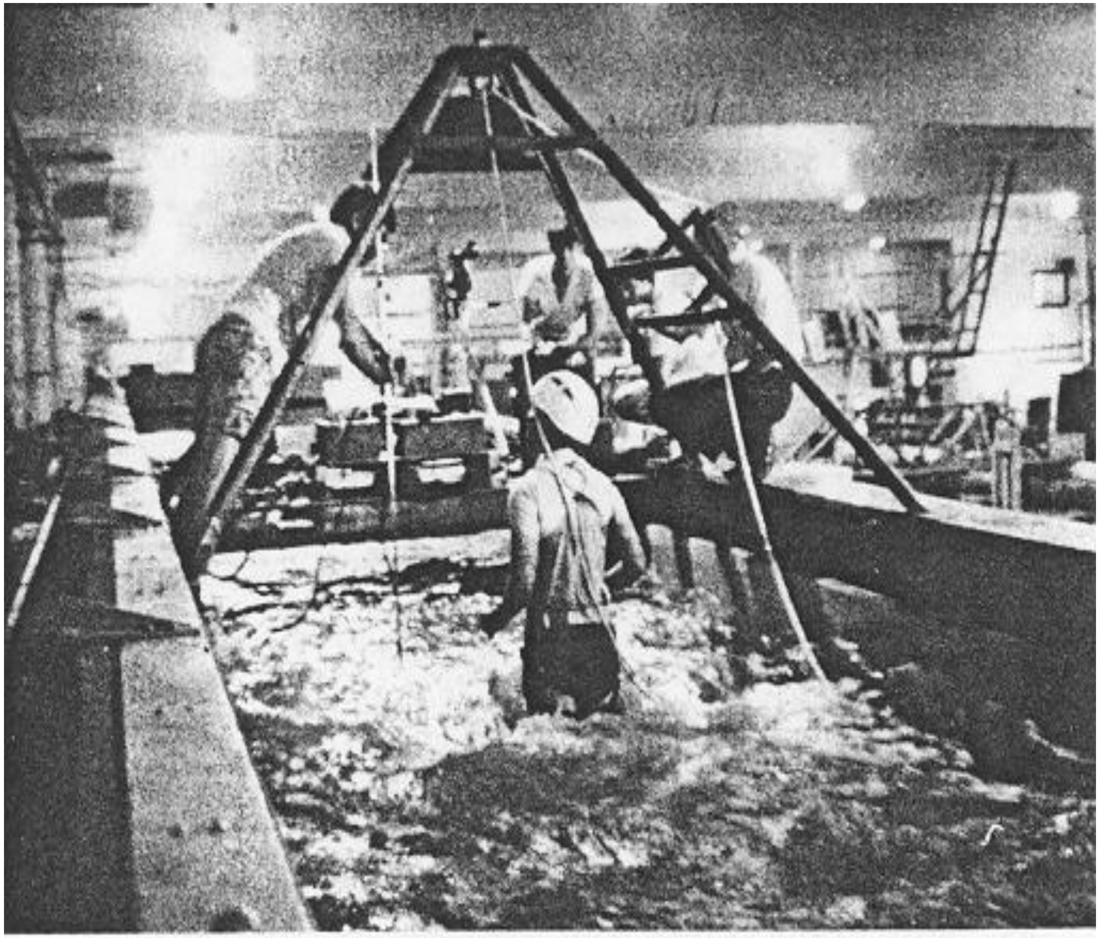

Figure 3. Safety Mechanism for Human Subjects.

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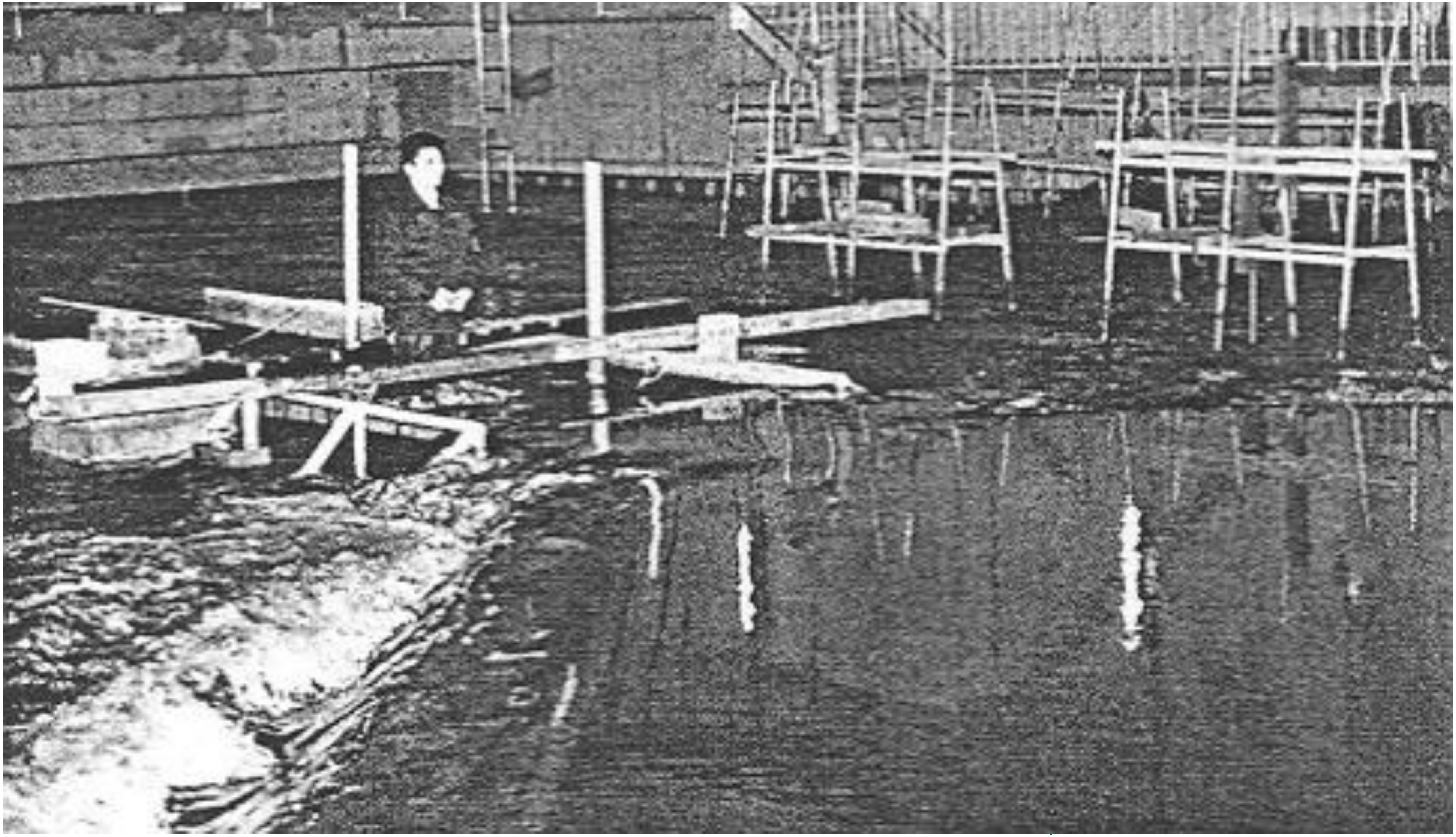
Test - Takahashi et al (1992) - 3 adult males

D=0.4-0.9 m, V=0.6-2 m/s, DV=0.6-1.3 $m^2 s^{-1}$, HM=107-134 mKg

Flow funnelled from headbox to short flume



Takahashi, Endoh & Muro (1992)

Port safety criteria in Japanese literature

Prototype human testing

Depth, velocity, friction and drag measured

3 subjects in different clothings

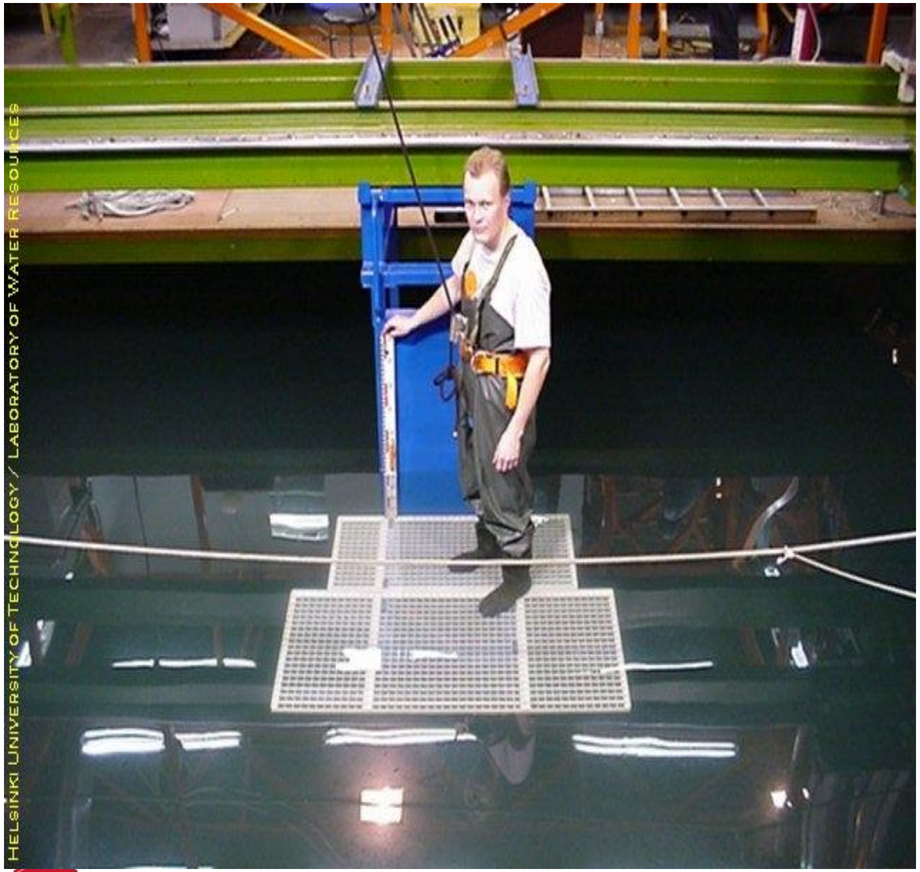
Different shoes and contact surfaces

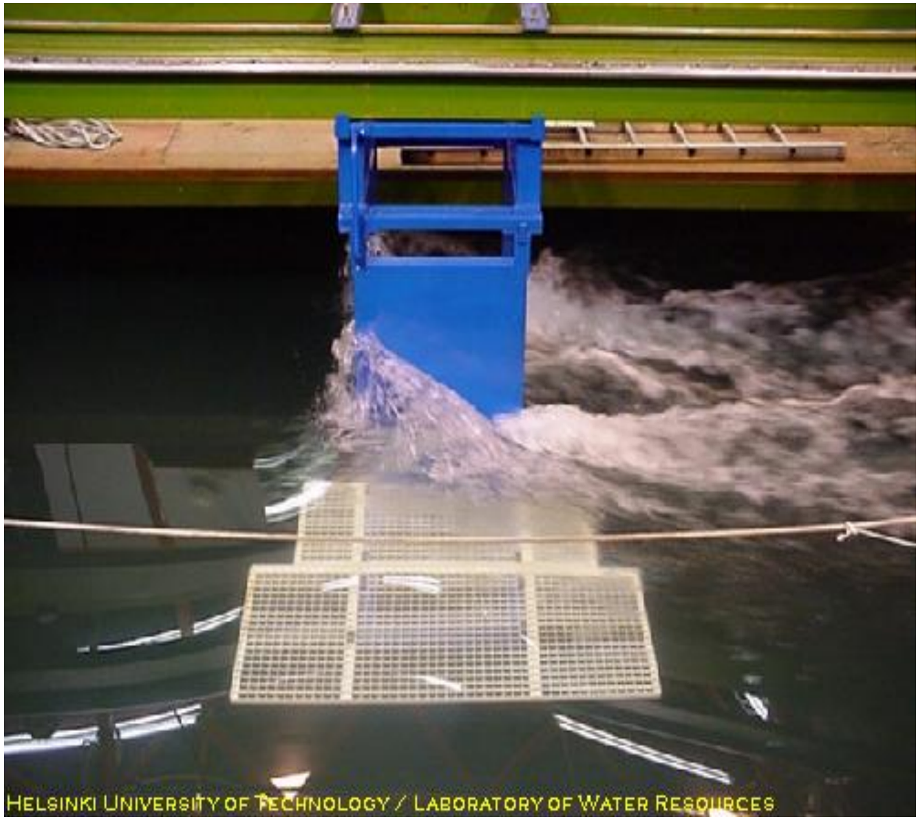
Different orientations to the flow

RESCDAM (2001) – 7 adult rescuers (M&F)

$D=0.4\text{-}1.1$ m, $V=0.6\text{-}2.6$ m/s, $DV=0.6\text{-}1.3$ $m^2 s^{-1}$, $HM=77\text{-}195$ mKg

Move subjects through water to ascertain conditions in which rescue workers can operate



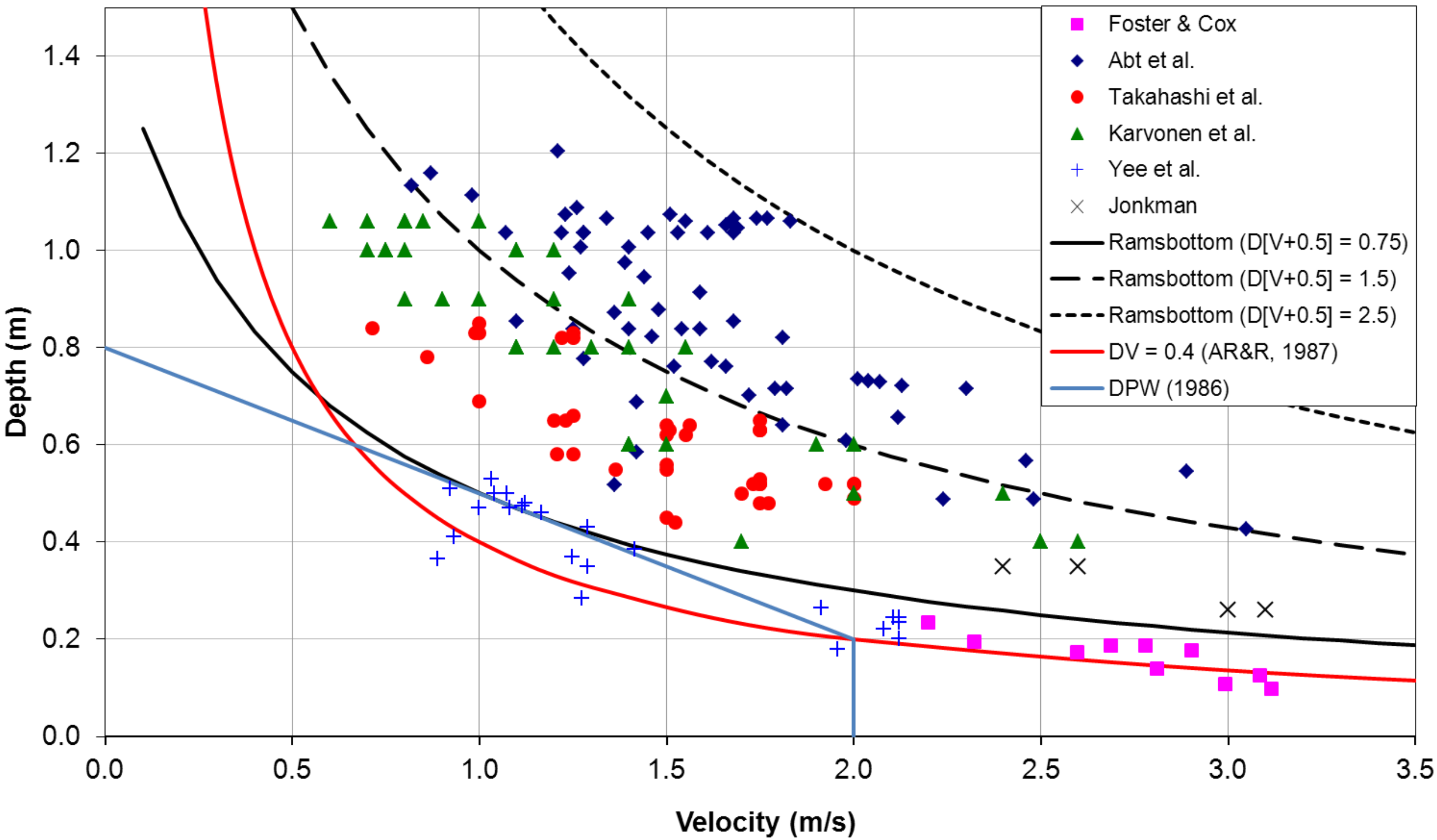


Cox, Yee & Ball (2004)

D=0.1-0.5 m, V=0.9-2 m/s, DV=0.3-0.6 $m^2 s^{-1}$, HM=21-33 mKg

Extension of Foster & Cox testing of smaller children – 4 (M&F) from 6 to 8 yrs

Overview - D vs V



Abt et al data ??

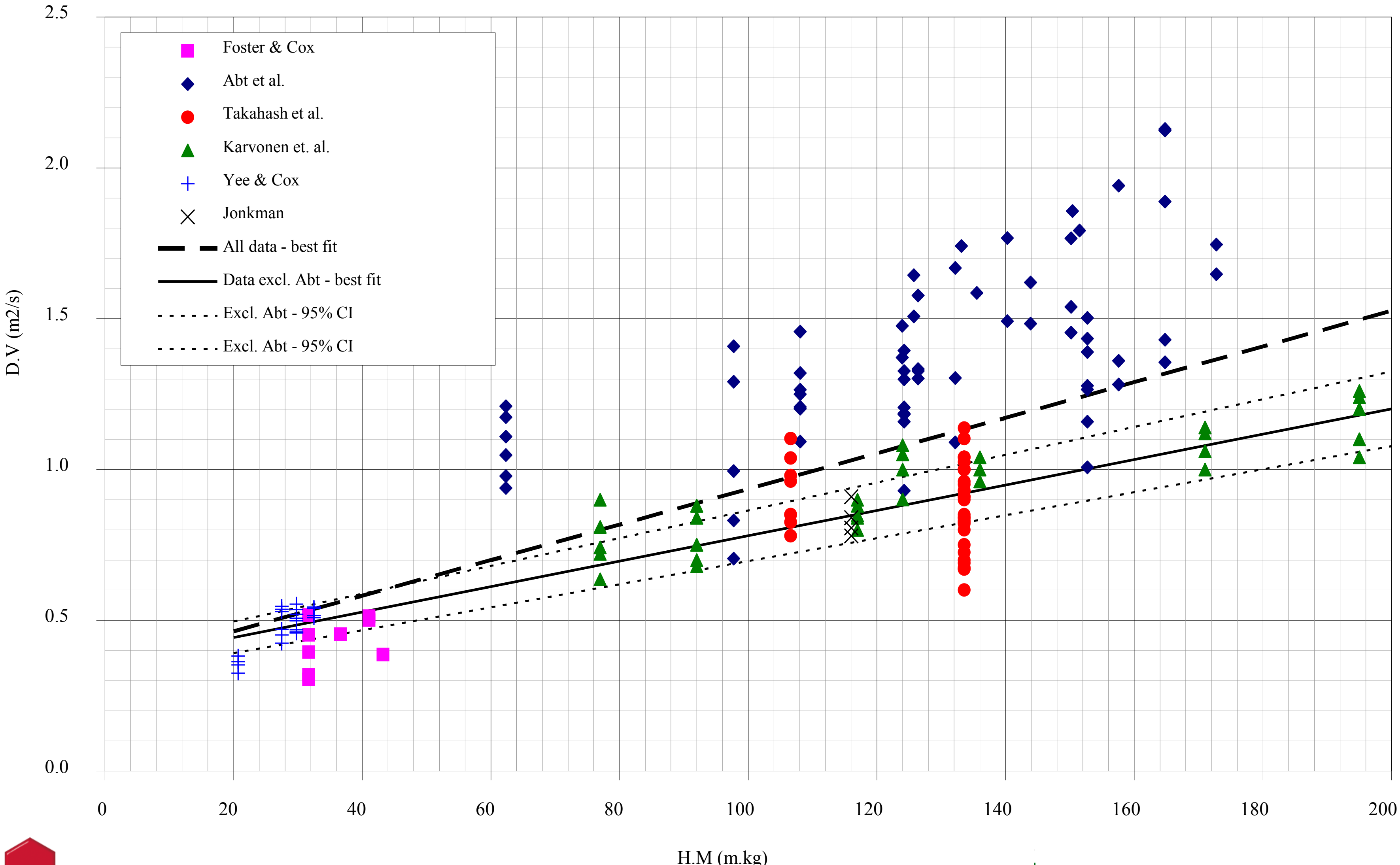
Abt et al. (1989) data shows much higher stability than all other data for adults – this cannot be fully explained

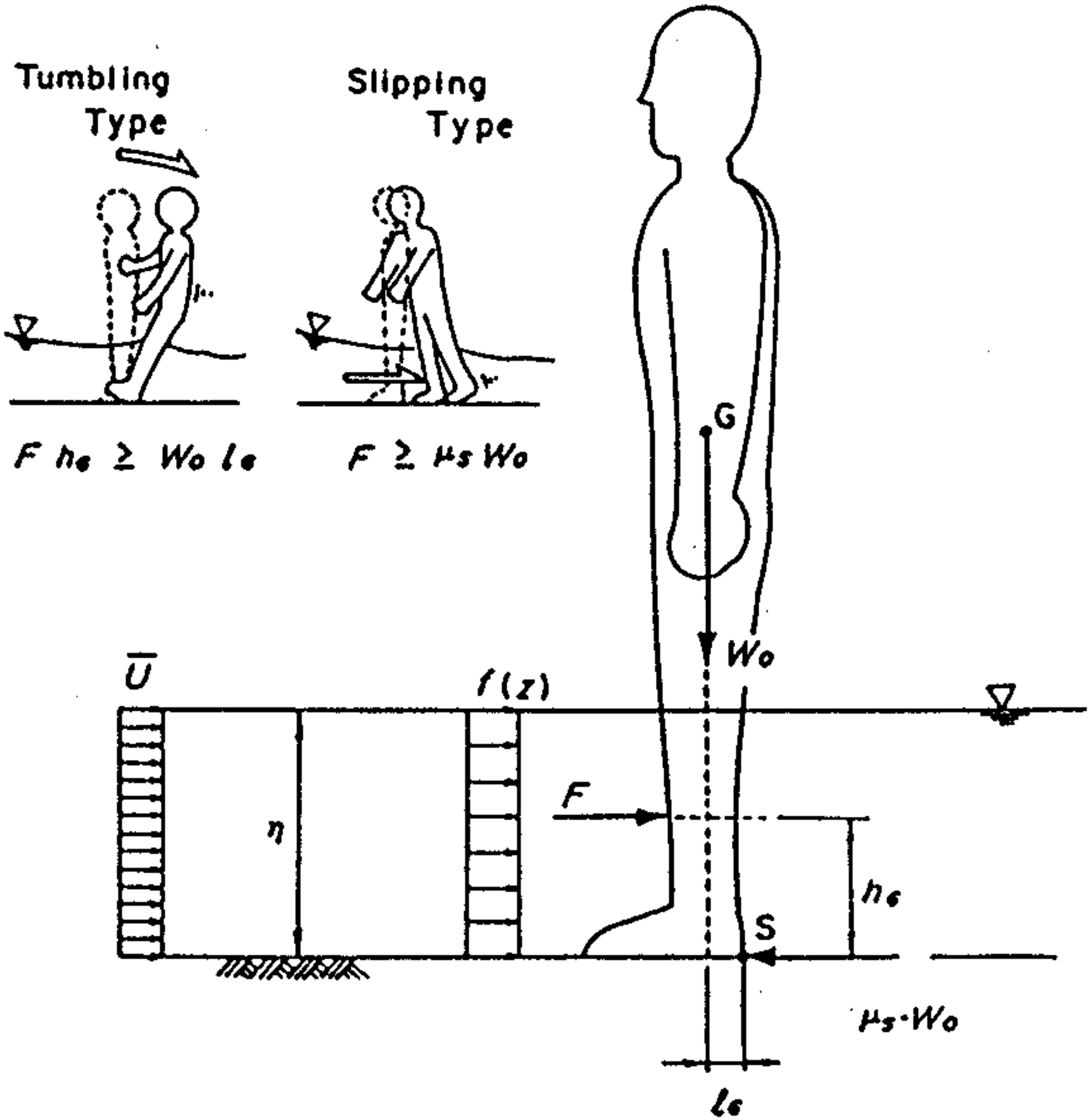
Partially explained in that the experiments determined the absolute limit of stability of the subjects (personal communication with Abt 10 October 2003) who were made to fail as opposed to determining if safety was compromised so defining the limits for a safe rescue action which was the objective of the Karvonen et al. (2000) study.

Clothing had lower drag than that for tests by Takahashi et al. (1992) and Karvonen et al. (2000) and subject performance was noted to improve with practice.

Ramsbottom et al. (2004) concluded that, based on a Student T test, the data of Abt et al is statistically significantly different to that of Karvonen et al which is consistent with all other test data.

Overview - DxV vs HxM





Human Safety Failure Modes

Computational models

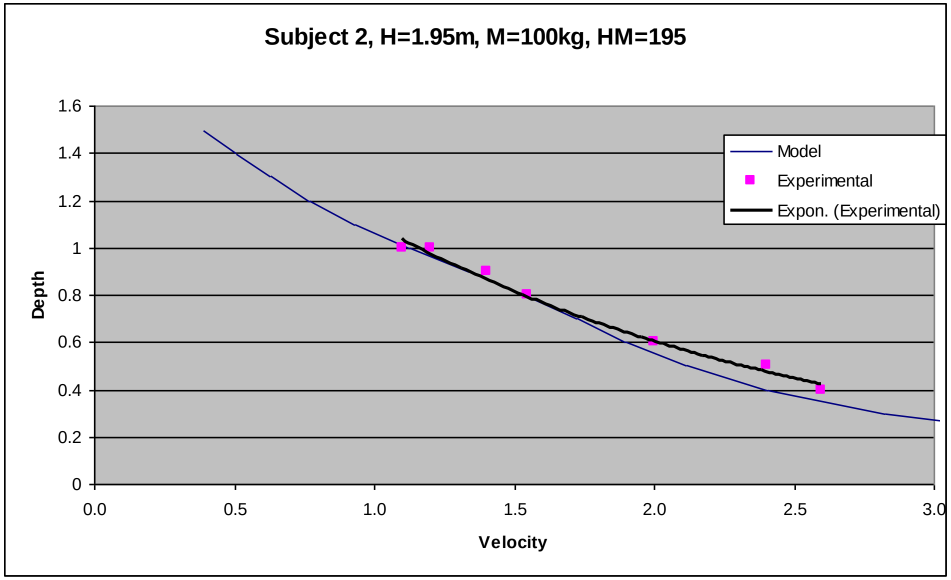
Yee (2003) developed a predictive computational model based on the work of both Takahashi et al. (1992) and Keller and Mitsch (1993).

The model incorporates velocity, depth (up to 1.5 m), subject height, mass and body shape, drag, friction, buoyancy and moment stability mass lever arm (distance from heel to centre of gravity).

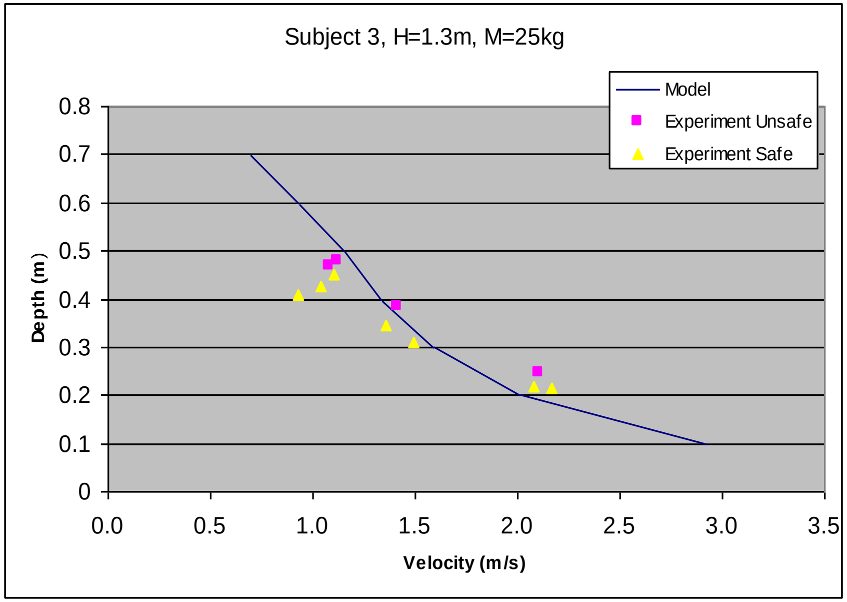
The model predicts both sliding (friction) or tumbling (moment) failure.

Yee computational model vs tests

RESCDAM (2001)
Subject 2 - 1.95m 100Kg



Yee (2003)
Subject 3 - 1.3m 25Kg

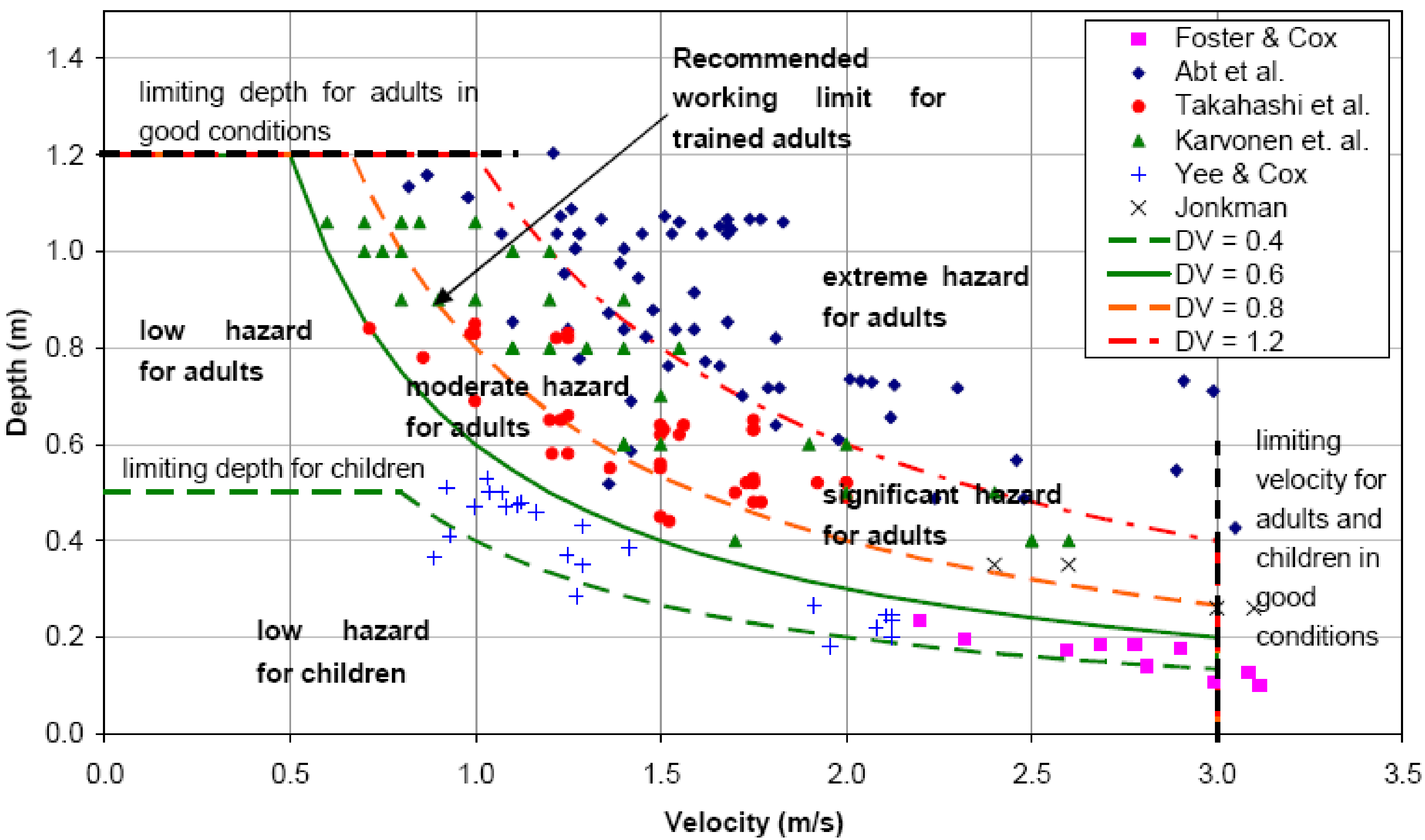


Application of Yee (2003) to all data

	Foster and Cox (1973)	Yee (2003)	Takahashi et. al. (1992)	Karvonen et al. (2000)	Abt et. al. (1989)
Friction coefficient	0.4	0.4	0.6	0.45	0.6
Drag coefficient	0.8	0.8	1.0	1.0	0.8
Moment stability mass lever arm	0.04 H	0.04 H	0.06 H	0.06 H	0.12 H

It is noteworthy that the lever arm for the Abt et al. data had to be increased to 0.12 H as the reported "trained" subjects used muscle/body balance to better resist the flow - effectively increasing the moment stability mass lever arm.

Proposed hazard regimes



Proposed hazard regimes

<table>
<tr><th>DV (m^{2}s^{-1})</th><th>Infants, small children (H.M ≤ 25) and frail/older persons</th><th>Children
(H.M = 25 to 50)</th><th>Adults
(H.M > 50)</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0 – 0.4</td><td rowspan="5">Extreme Hazard; Dangerous to all</td><td>Low Hazard[1]</td><td rowspan="2">Low Hazard[1]</td></tr>
<tr><td>0.4 – 0.6</td><td>Significant Hazard; Dangerous to most</td></tr>
<tr><td>0.6 – 0.8</td><td rowspan="3">Extreme Hazard; Dangerous to all</td><td>Moderate Hazard; Dangerous to some[2]</td></tr>
<tr><td>0.8 – 1.2</td><td>Significant Hazard; Dangerous to most[3]</td></tr>
<tr><td>> 1.2</td><td>Extreme Hazard; Dangerous to all</td></tr>
</table>

Discussion

- The most important factors affecting human stability in floodways are firstly depth and secondly velocity.
- Depth dictates what type of failure is to occur, either sliding (friction) or tumbling (moment) failure.
- High depths increase buoyancy and reduce friction underfoot.
- Low depth-high velocity flows may cause instability but the chances of drowning are less than in the more dangerous deepwater situations

Overview

- The current AR&R guideline of D*V=0.4 m^2/s is suitable for children (H*M 25 to 50 mKg) BUT conservative for healthy adults who if trained could be expected to work in conditions up to D*V= 0.8 m^2/s.
- Extreme hazard is indicated for all adults at D*V > 1.2 m^2/s.
- Small children with H*M less than 25 mKg are not safe at D*V as high as 0.4 m^2/s.
- It is most likely that many frail/older persons may also not be safe under this criteria.
- Small children and frail older persons are unlikely to be safe in any flow regimes - care is required in locating aged care and retirement villages as well as childcare centres and kindergartens.

Discussion - other factors

It should be noted that loss of stability could occur in lower flows when adverse conditions are encountered including:

- Bottom conditions: uneven, slippery, obstacles
- Flow conditions: floating debris, low temperature, poor visibility, unsteady flow and flow aeration
- Human subject: standing or moving, experience and training, clothing and footwear, physical attributes additional to height and mass including muscular development and/or other disability, psychological factors
- Others: strong wind, poor lighting, definition of stability limit (i.e. feeling unsafe or complete loss of footing).

Vehicle stability update

- Vehicle stability criteria expressed as depth D X velocity V are based on experimental investigations of stationary vehicle stability by Bonham and Hattersley (1967) and Stone and Gordon (1973) and theoretical analysis Keller and Mitsch (1993).
- Substantial changes in vehicle planform area, vehicle weight and ground clearance - likely that earlier criteria no longer hold for contemporary vehicles.
- An extensive literature review did not discover any further relevant research data and showed that international standards by and large referenced these same Australian research publications.

Figure 4 Model Ford Falcon at 1:25 scale used by Bonham and Hattersley (1967)

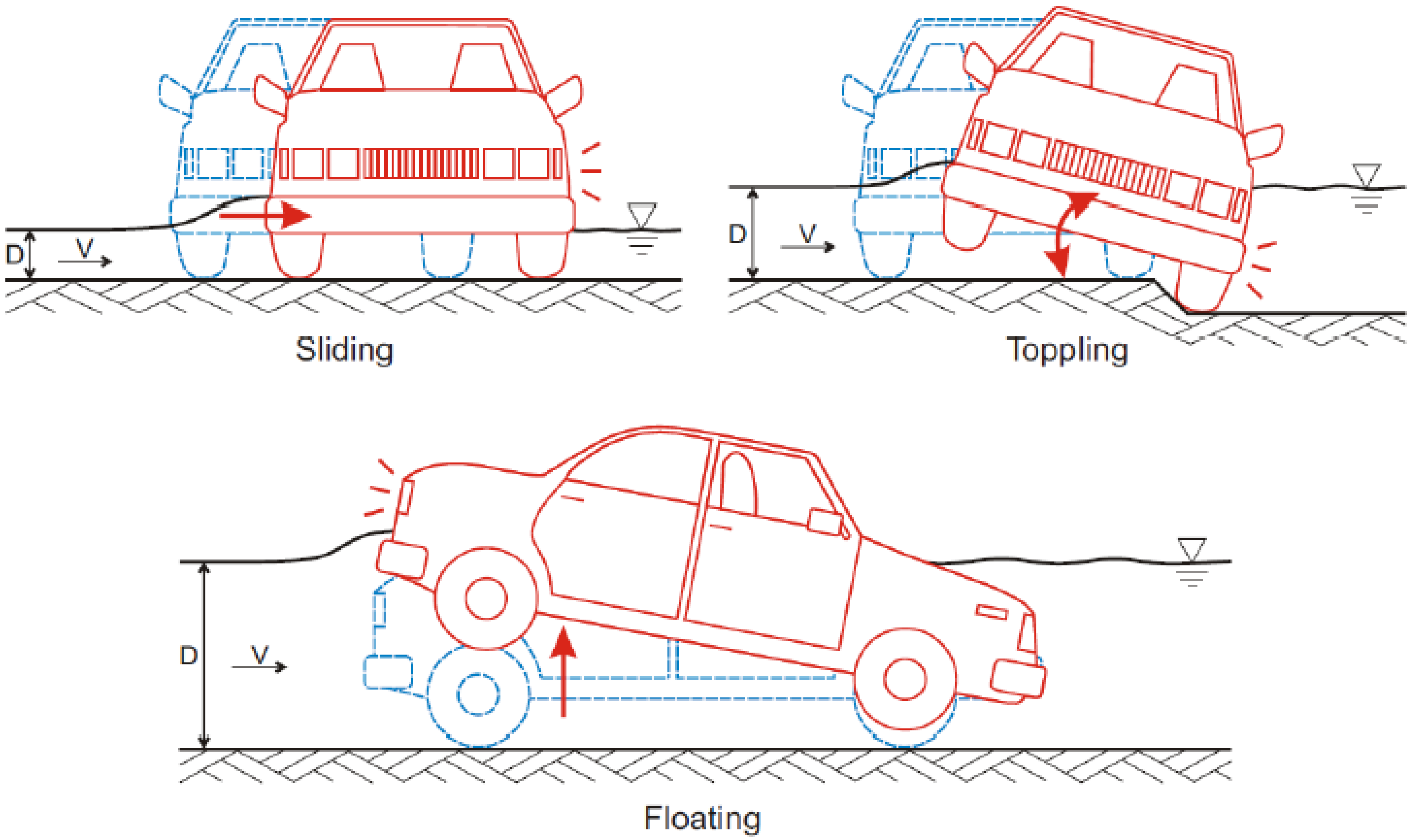
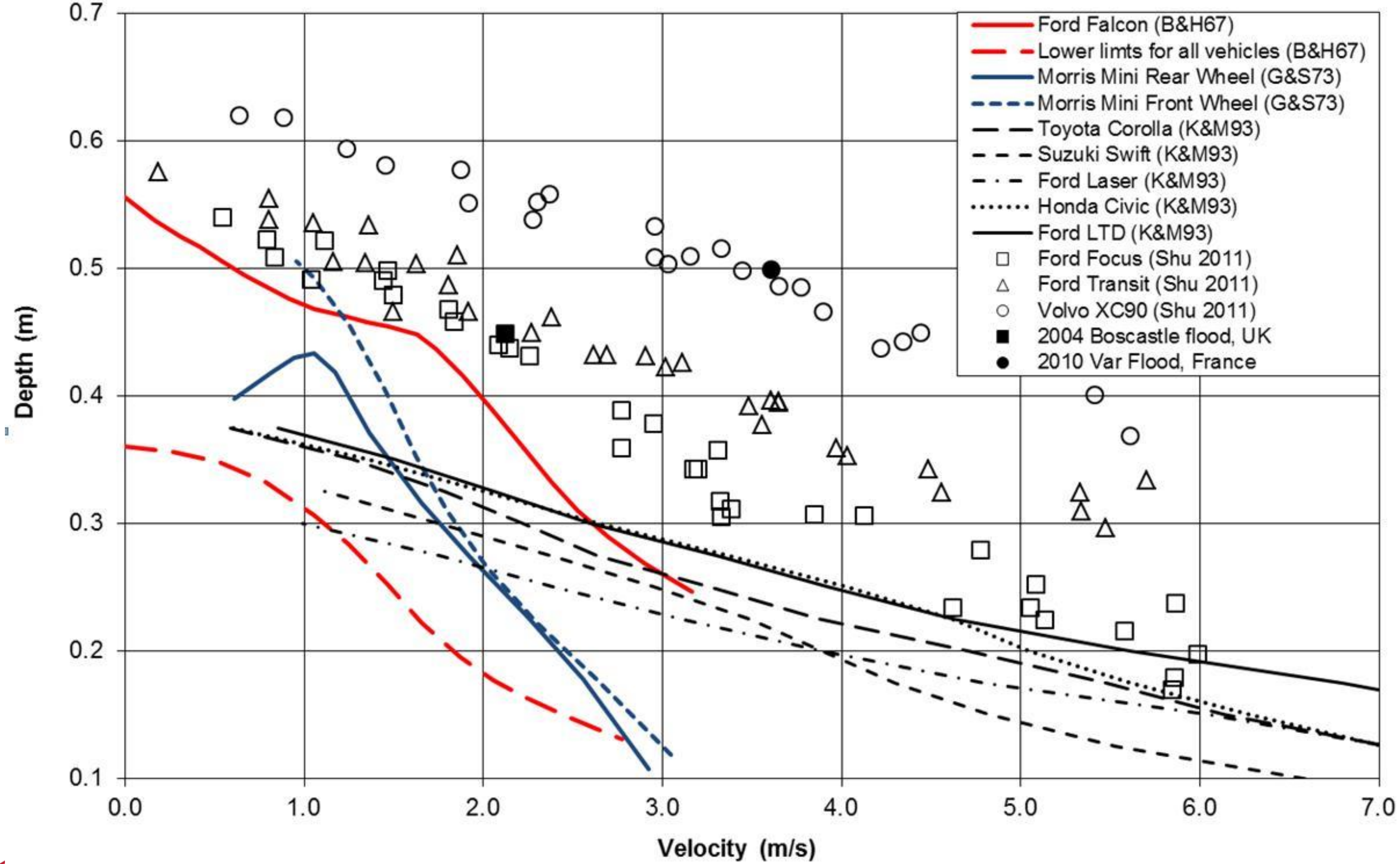

D
V
Sliding
D
V
Toppling
D
V
Floating

Figure 2 Typical small car of the early 1970's (A: Morris Mini) and prototype for the model testing undertaken by Stone and Gordon (1973) compared to a typical small car of 2010 (B: Toyota Corolla).

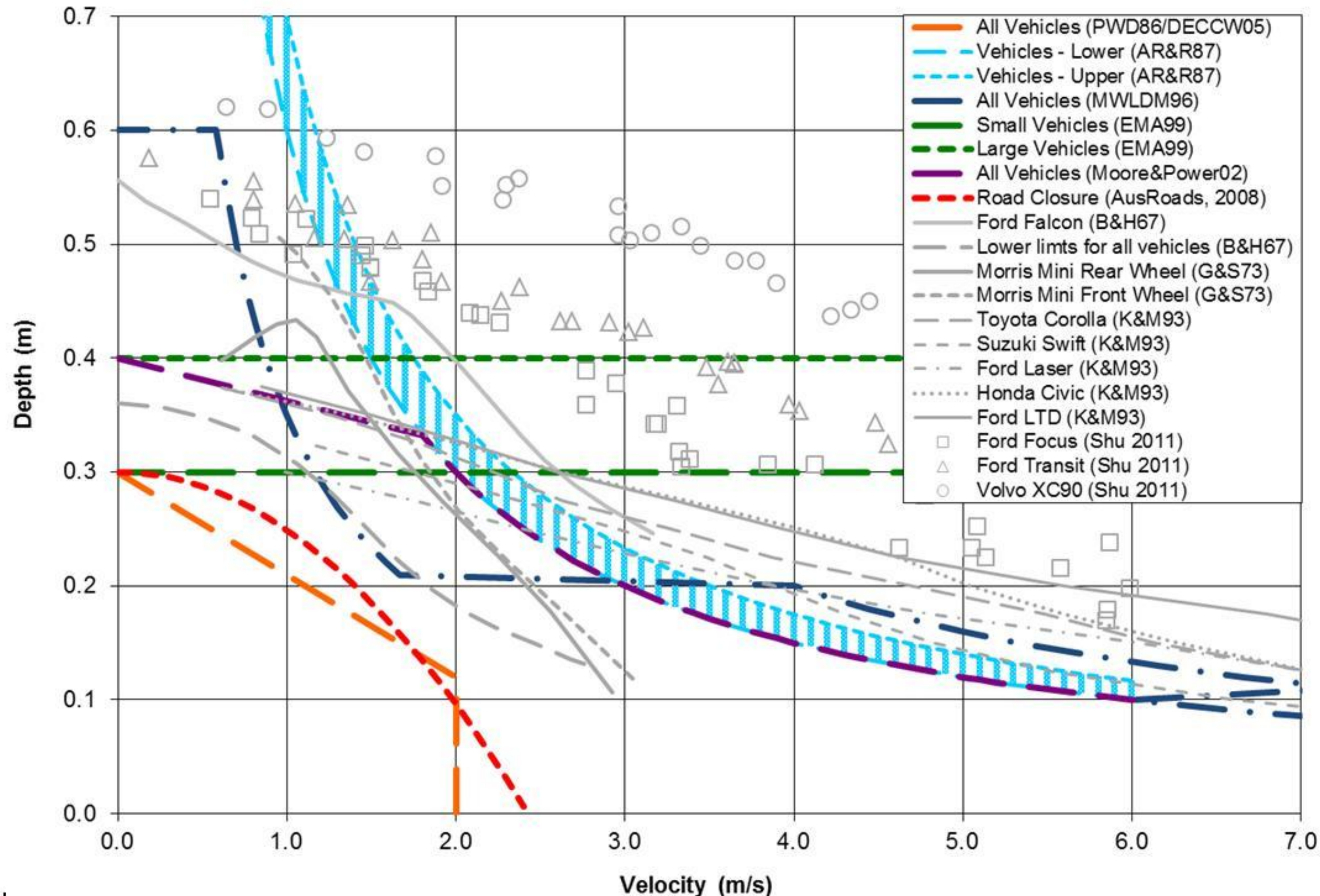
Vehicle stability update

- Existing guidelines and recommendations for limits of vehicle stability have been compared to experimental and analytical results.
- With the exception of the Public Works Department (1986)/NSW Floodplain Development Manual (2005) and AusRoads (2008) criteria, all other criteria are found to be non-conservative at some flow regime when compared to experimental and computational test results.

Vehicle stability update



Vehicle stability update



Vehicle stability update

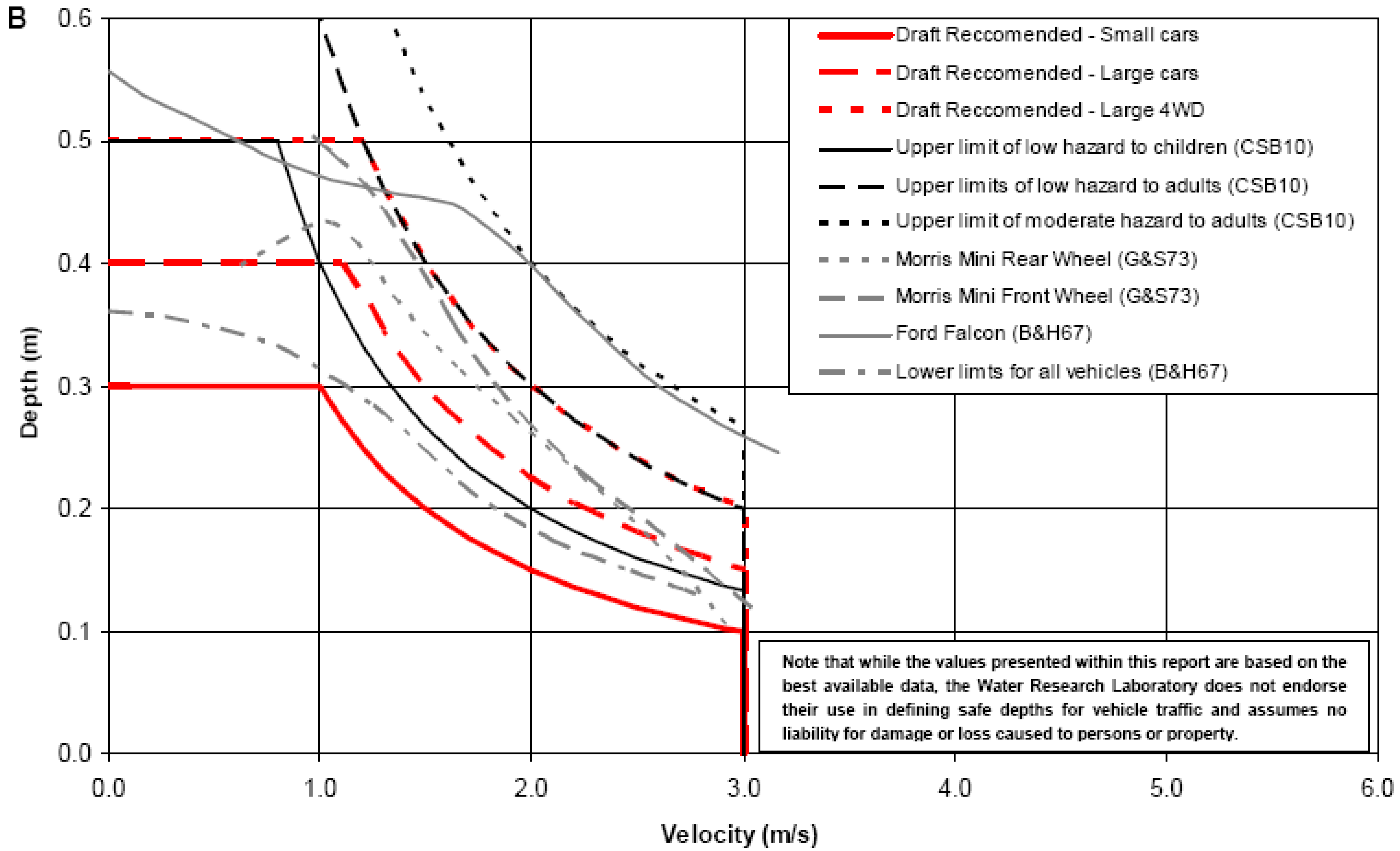
- Based on the available experimental and analytical data, ***Draft, interim*** criteria for stationary vehicle stability are proposed for three vehicle classes
- small passenger cars, large passenger cars and large 4WD vehicles
- Floating and high velocity limits are proposed – between which constant D×V relations are recommended in accordance with proposed human stability criteria.
- For all flow conditions in all vehicle classes, the proposed vehicle safety criteria remain below the moderate hazard criteria for adults (Cox, Shand and Blacka, 2010) ie DXV < 0.6 m^2/s.

Vehicle stability update

Proposed *DRAFT INTERIM* criteria for stationary vehicle stability

Class of vehicle	Length (m)	Kerb Weight (kg)	Ground clearance (m)	Limiting still water depth[1]	Limiting high velocity flow depth[2]	Limiting velocity[3]	Equation of stability
Small passenger	< 4.3	< 1250	< 0.12	0.3	0.1	3.0	$DV \leq 0.3$
Large passenger	> 4.3	> 1250	> 0.12	0.4	0.15	3.0	$DV \leq 0.45$
Large 4WD	> 4.5	> 2000	> 0.22	0.5	0.2	3.0	$DV \leq 0.6$

[1] At velocity = 0 ms^{-1}; [2] at velocity = 3ms^{-1}; [3] at low depth


B
Depth (m)
Velocity (m/s)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Draft Reccomended - Small cars
Draft Reccomended - Large cars
Draft Reccomended - Large 4WD
Upper limit of low hazard to children (CSB10)
Upper limits of low hazard to adults (CSB10)
Upper limit of moderate hazard to adults (CSB10)
Morris Mini Rear Wheel (G&S73)
Morris Mini Front Wheel (G&S73)
Ford Falcon (B&H67)
Lower limts for all vehicles (B&H67)
Note that while the values presented within this report are based on the best available data, the Water Research Laboratory does not endorse their use in defining safe depths for vehicle traffic and assumes no liability for damage or loss caused to persons or property.

People safety – dependent upon design, planning, awareness, warning and evacuation