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Specialist Knowledge.
Practical Solutions.

# International Public Works Conference – Hobart, Aug 2019 Implications of Fluvial Debris on the long-term serviceability of Bridges

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Date – 28 August 2019

# Overview
# A knowledge gap between bridge designers/managers and hydrologists?

- Why bridges fail
- Australian Codes and Guidelines and their requirements
- Debris
- Scour
- Hydrology
- Hydraulic assessments
- CFD
- Concluding comments

# Bridge failure modes

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- Why do bridges fail?

  - FLOODS – ranks as No 1 in Tasmania and No 3 worldwide– through debris, trees, scoured foundations, extreme events washouts of abutments/embankments
  - Combination of issues – e.g. wind, fatigued gusset plates and high temporary loads, ship impact (Lake Illawarra on Tasman Bridge in 1975),
  - Infrastructure issues, exceeded design loadings, poor maintenance

# Hoggs Bridge on Mersey River

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# Hoggs Bridge on Mersey River

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# Tayatea Bridge in the Tarkine

# Tayatea Bridge in the Tarkine

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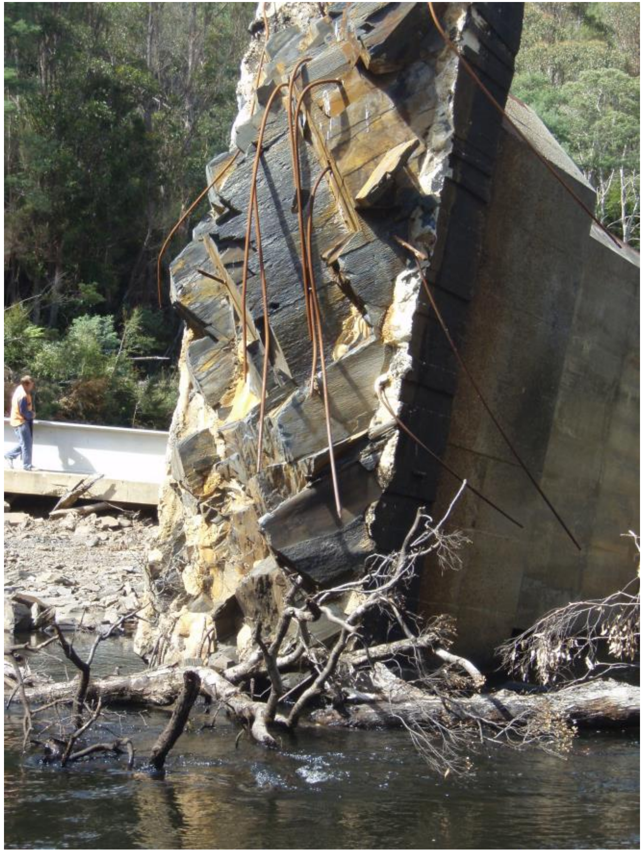

# Kimberley Rail Bridge

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# Kimberley Rail Bridge

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# Australian practice and Guidelines

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- Australian Bridge Code AS5100.2.2010 (2017)
- Australian Rainfall and Runoff 2016 & later 2019
- Austroads Guide to Bridge Technology Part 8: Hydraulic Design of Waterways
- Austroads Design Guidelines for Scour Chapter 8, Section 5
- Queensland DTMR Supplement to Austroads Chapter 8

Each of these have their own purpose but do not 'speak to each other'

# AS 5100.2.2017/Amendment 1:2017 (p1)
# Chapter 16

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16.1 Designed to resist the effects of water flow and wave action, including debris, log impact, scour and buoyancy

16.2 Velocity – for each limit state (i.e. each span & each pier)

- Substructures: V for **critical ARI*** through a bridge opening averaged over the depth of flow and over the relevant bridge span
- Superstructure and debris loading: V=> approach surface velocity
- Log and vessel impact: at the level of impact being considered and = 1.4xV
- Adverse effect of scour at each limit state

16.3 Limit States

- ULS: All floods up to 2000 year ARI: Load factor 1.3
- SLS: All floods up to the SLS defined flood (between 20 year and 100 year ARI depending on the criticality of the asset): Load factor 1.0

# AS 5100.2.2017/Amdt 1:2017
# Chapter 16

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16.4 Forces on piers

16.5 Forces on superstructure

16.6 Forces due to debris

- Min 1.2m debris mat

No guidance on how to calculate hydrology, hydraulics, scour, actual debris mat, local velocity changes.

# Flood estimation

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- Australian Rainfall & Runoff (2016)
  - Rainfall
    - Critical durations
    - Temporal patterns
- Bureau of Meteorology (2017)
  - IFD to 1:2000 AEP
  - Rainfall radar loops as images
  - Continuous recording pluvios
- State and BOM
  - Long term rainfall records
- The traditional focus of hydrology has been on keeping the road or rail dry, rather than keeping it standing up in a flood under debris loads and scour

BoM flood history- by state
http://www.bom.gov.au/tas/flood/fld_history/
Real time http://www.bom.gov.au/australia/flood/
DPIPWE (Tas) water monitoring sites
TheWist http://wrt.tas.gov.au/wist
Rainfall www.bom.gov.au/climate/data/stations
River http://www.bom.gov.au/tas/flood/index.shtml?ref=hdr

# Austroads – Scour
# Qld TMR – Supplement to Austroads

Austroads

- Direction for estimation of general bed and local scour for the protection and design of piers to Service Level State.
    - Increase column length and loads increase depending on column ends (fixed or allowed to rotate)
- Scour protection for abutments is critical
    - Often abutments fail first

Queensland Transport and Main Roads Supplement to Austroads Chapter 8

- Recommends the use of two-dimensional hydraulic models
- Comments that 1D models might represent pressurised but perhaps not vertical contraction
- Computational Fluid Dynamics (CFD) used in complex flow patterns, local accelerations and spiral flow patterns

# Serviceability considerations

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- AEP of bridges – usually 1% AEP
  - Deck level can be higher than 1% AEP
  - Or soffit 600mm above 1% AEP
- At what immunity should we protect against scour?
- Should scour protection be provided to embankments?  (upstream and downstream)
- Railway embankments – ballast will mobilise if critical shear stress is 50 to 80 $N/m^2$

# Case studies

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1. Edith Creek Railway bridge  - Northern Territory
2. Low Road bridge – South-East Queensland
3. Railway bridge Tasmania
4. Arterial Road Bridge Queensland
5. Four bridges in Papua New Guinea

# Case Study 1: Edith Creek railway bridge - Original Construction (2003 dry season)

Acknowledgement
*Dr Jeevan Senthilvasan*

# Case Study 1: Flood Event December 2011

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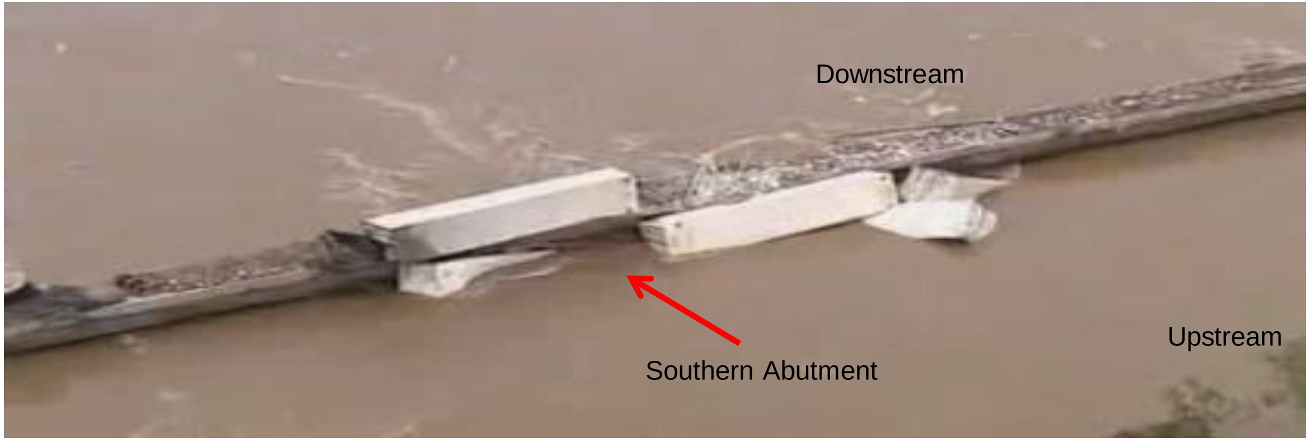



Acknowledgement
*Dr Jeevan Senthilvasan*

# Case Study 1: Southern Approach

Acknowledgement
*Dr Jeevan Senthilvasan*

# Case Study 1: Hydraulic Action

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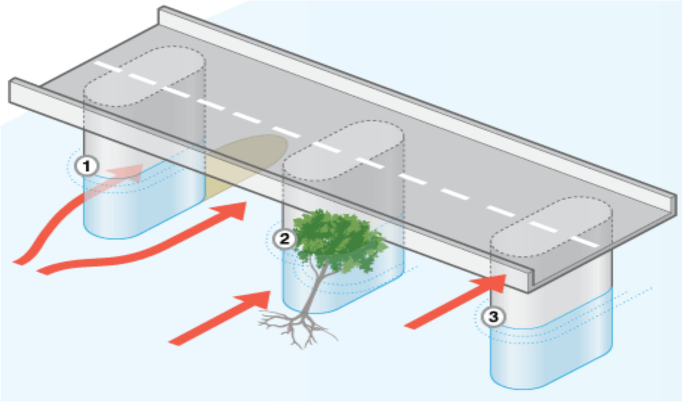
- Spread footing
  - Risk from scour when scour level reaches base of footing
  - Less lateral capacity even before the scour reaches the base.
- Pile foundation
  - Loss of skin friction and bearing capacity, scour increases unsupported length of piles
- Overtopping of approach
  - Overtopping and turbulent flow adjacent to approach embankments can lead to erosion and scour of the side slopes and toes of the embankments




# Case Study 2:  Kimberley Railway bridge Tasmania

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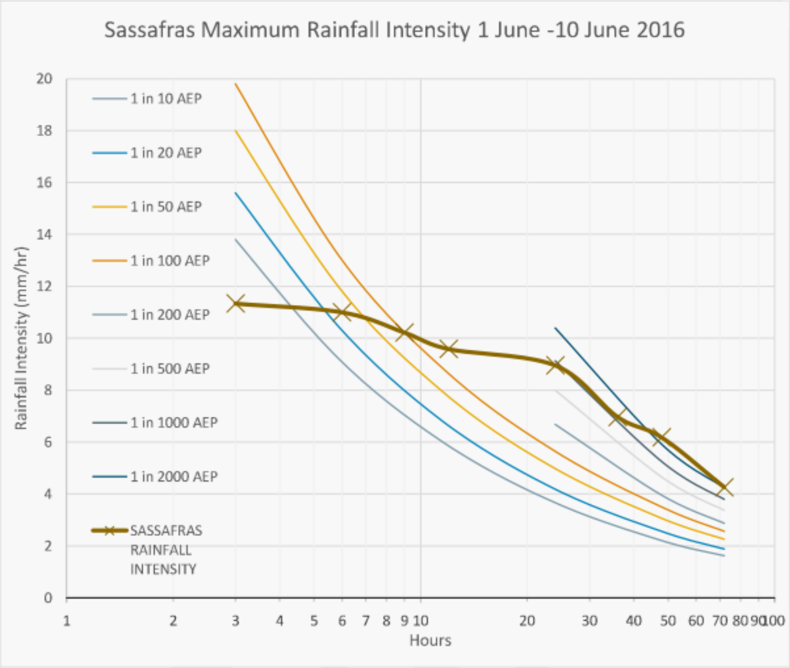
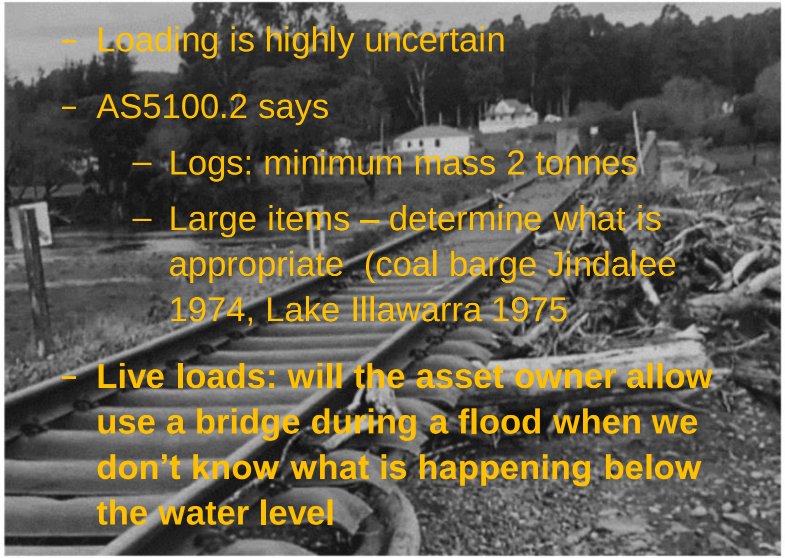



Figure 14 Sassafras recorded rainfall intensities



- Loading is highly uncertain
- AS5100.2 says
  - Logs: minimum mass 2 tonnes
  - Large items – determine what is appropriate  (coal barge Jindalee 1974, Lake Illawarra 1975
- **Live loads: will the asset owner allow use a bridge during a flood when we don't know what is happening below the water level**

# Case Study 3: Debris & scour below pile cap

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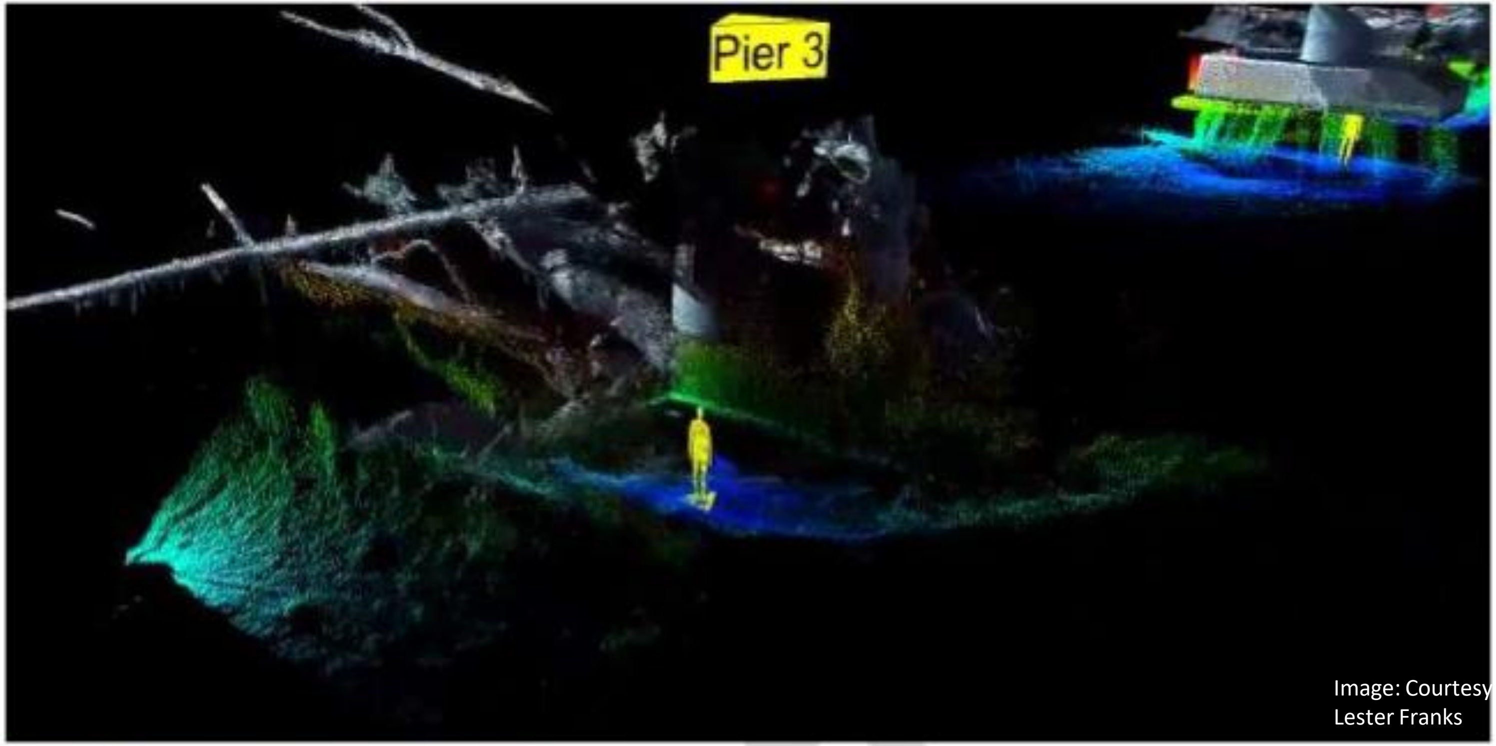


Figure 12 Central Pier underwater scan cloud

# Case Study 3: Debris & scour below pile cap

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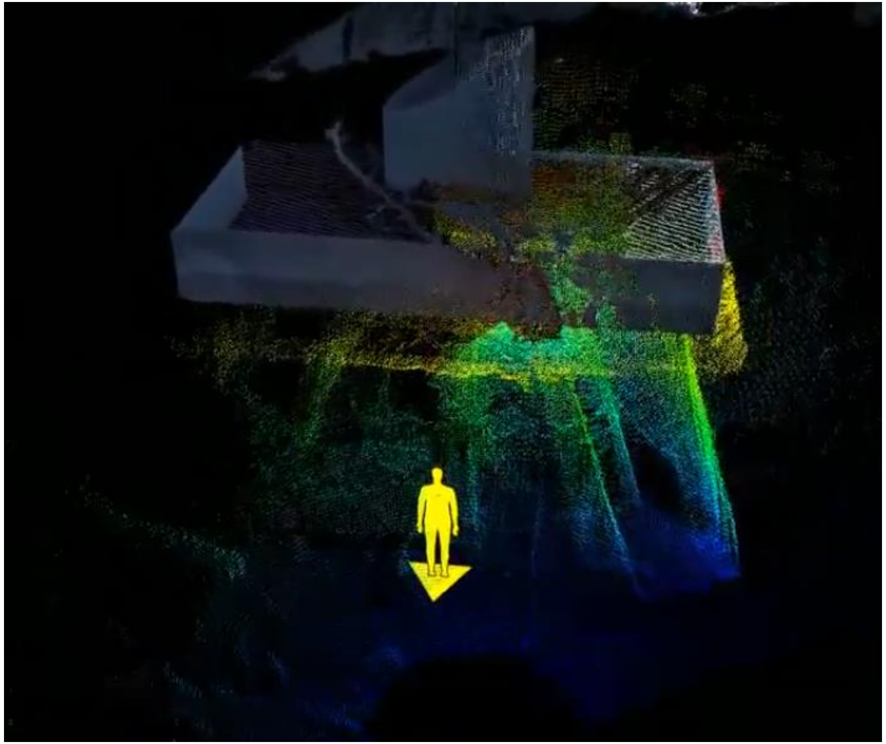

# Case Study 3: Debris & scour below pile cap

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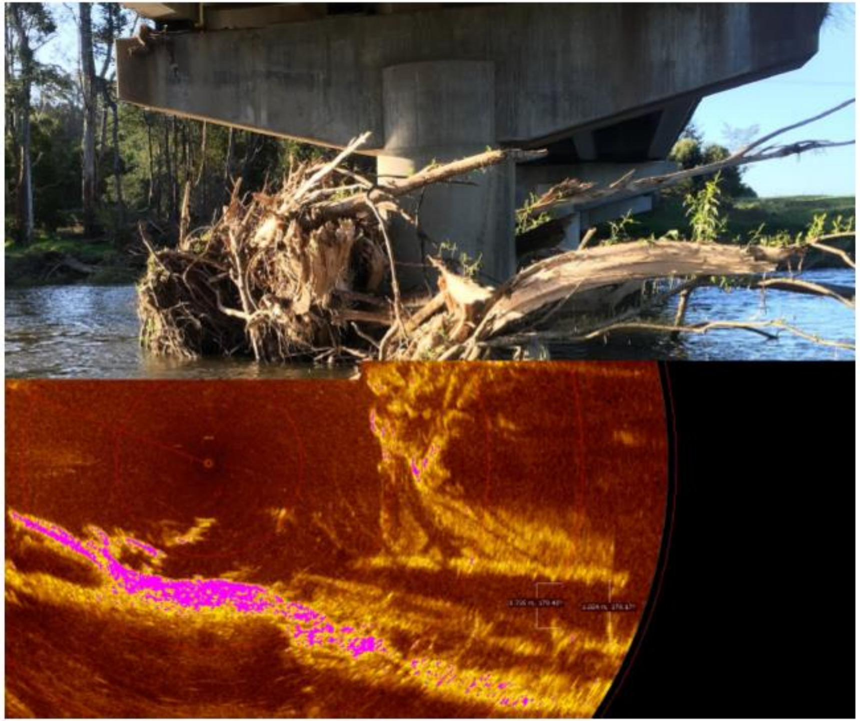

Figure 10: Pier 3 Southern face undermining

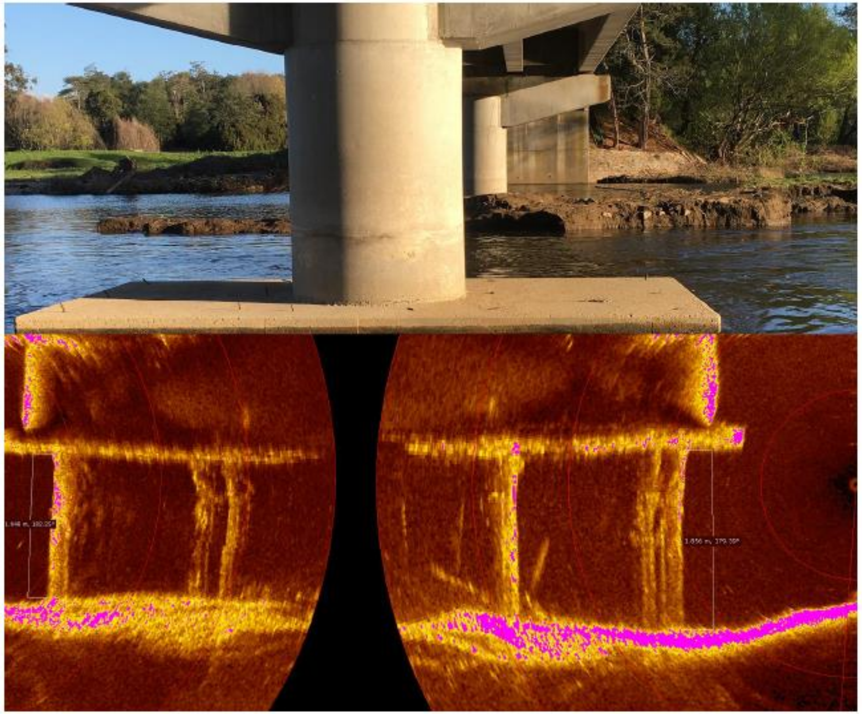

Figure 9: Pier 2 Northern Face, looking south, extensive undermining and pile exposure

# Velocity profiles

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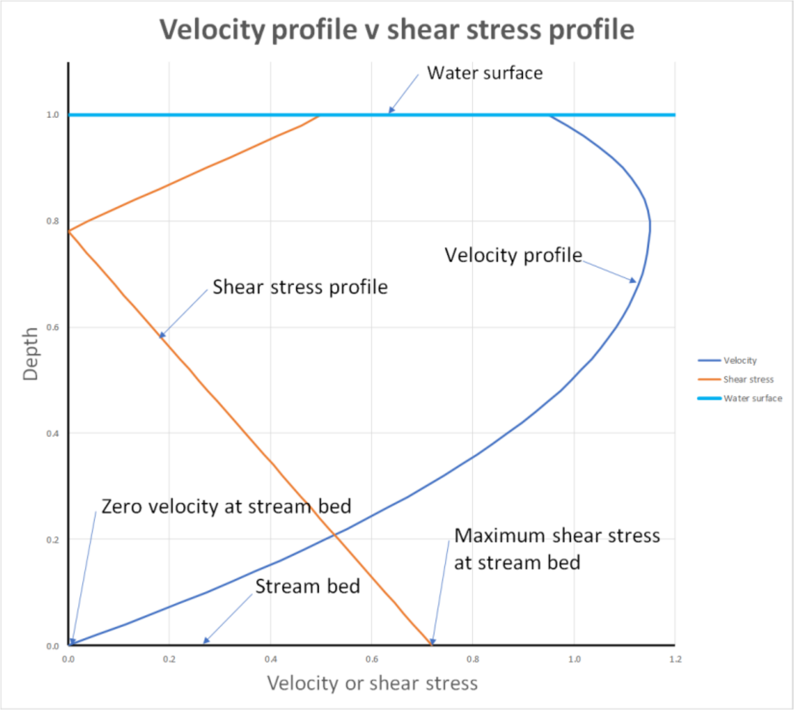


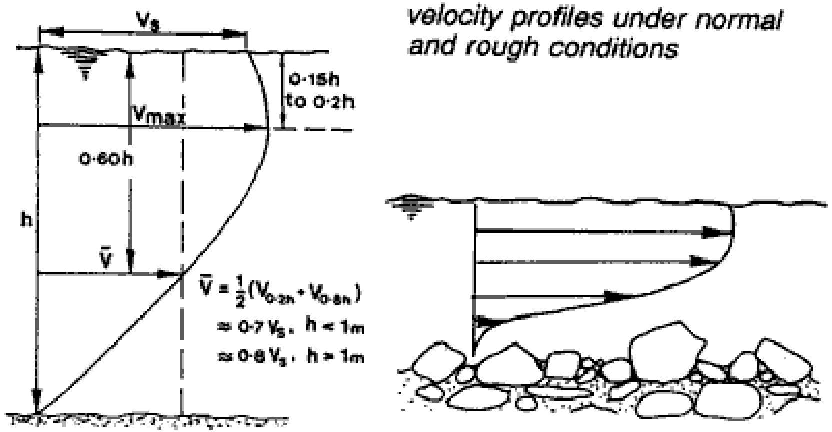

# Case Study 4: Arterial road bridge CFD modelling

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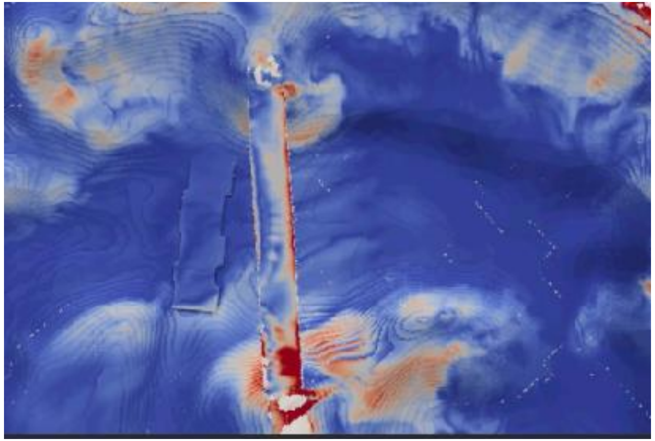
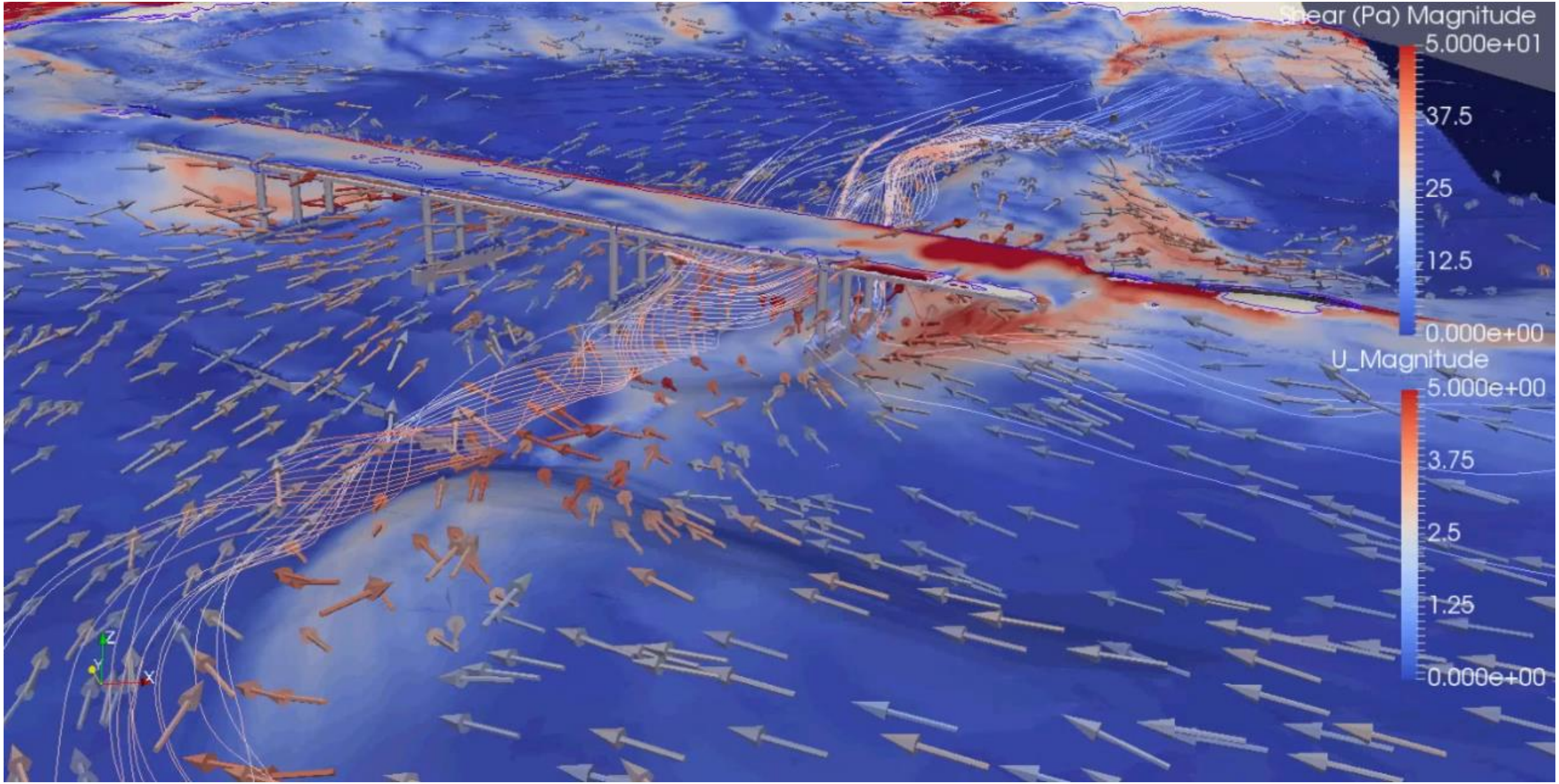
- CFD modelling provides more certainty of bridge hydraulic loads, shear stresses
- Reduces capital costs
- Forensic analysis of bridge failures
- Reduces lifetime risk



# Case Study 4: Arterial road bridge CFD modelling



# Case Study 5: CFD modelling 4 bridges PNG

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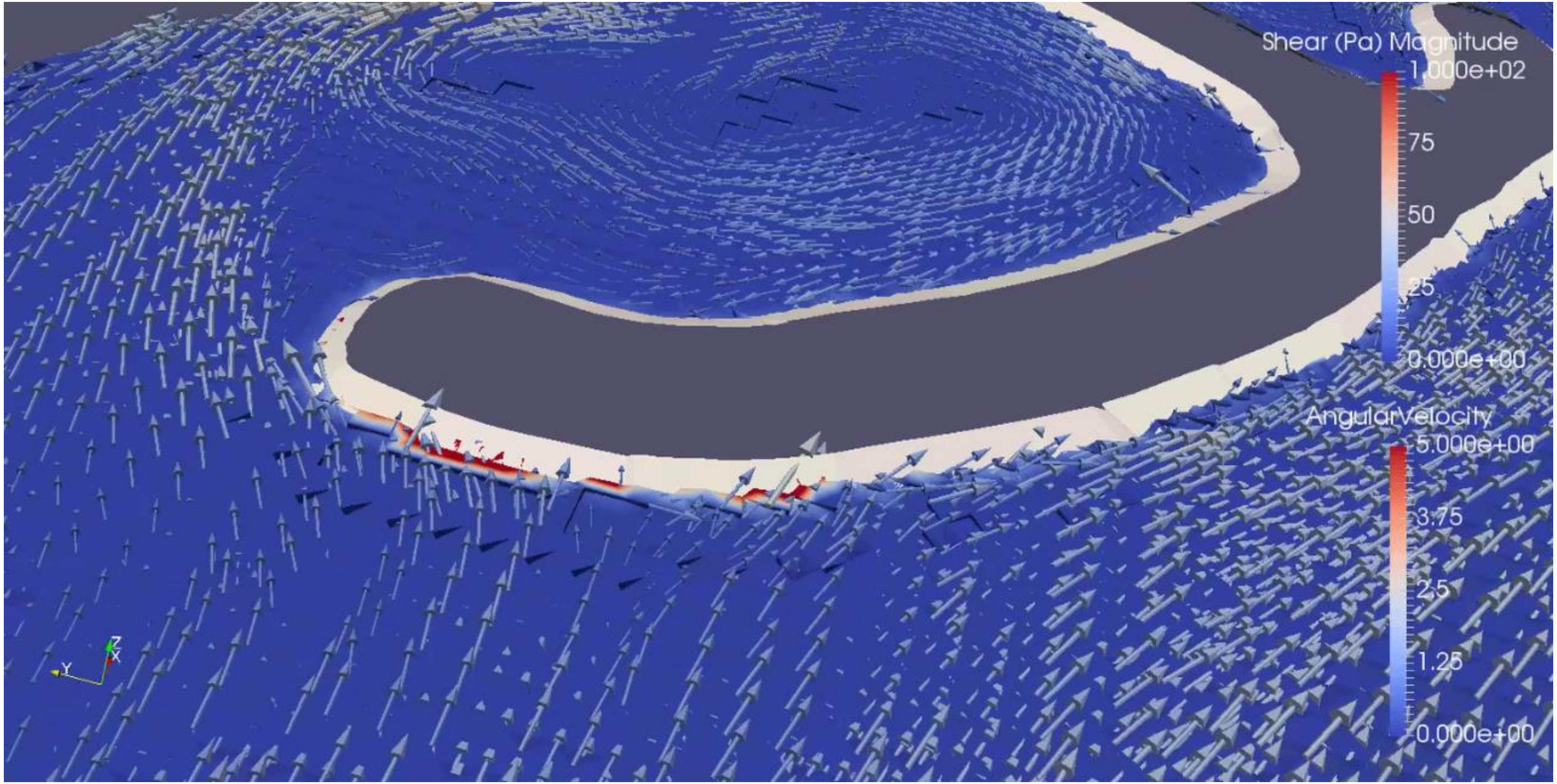

# Conclusions

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- Flooding and related issues (scour, debris) is the number one cause of bridge failure in Tasmania. It deserves significant consideration in both design and asset management
- During design
  - Do hydraulic engineers adequately inform the bridge designers?
  - Do bridge designer clients tell us what they need?
  - Does the asset owner ensure appropriate consideration has occurred?
- Establish the road network function design standard
  - It is general use or does it have importance pre/post flood emergency and recovery
  - 1% immunity (combination of flood, debris and scour?), Immunity of the network or the bridge, or both
- Design Basis
  - Debris, likelihood, what loads and when?
  - What velocity and shear stress information is needed and where?
  - Do we have sufficient geotechnical information to adequately assess scour?
  - Who should approve the scour design methods? the hydraulic engineer, geotechnical engineer or structural engineer? Each have a responsibility.

Any questions?

# Acknowledgements


Pitt&sherry's design team leaders

- Richard Cassidy
- Ben Hart
- Martin Jacobs

Former colleagues

- Dr Andrew Sonnenberg
- Dr Jeevan Senthilvasan