The Natural Disaster Relief and Recovery Arrangements (NDRRA) Fitzroy Project

Some important lessons learned from real scour at bridges

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Introduction
Introduction (cont.)

• Purpose of this study
  ▪ Understand the characteristics of the flood event triggered in the region by Cyclone Marcia in February 2015
  ▪ Understand the cause of scour at all bridges
  ▪ Design and procure quick and robust mitigation measures.
Cyclone Marcia, 20 February 2015

- Category 5, Cyclone Marcia made landfall at its peak strength at Shoalwater Bay (northwest of Yeppoon on 20th February 2015).
- Heavy rainfall associated with tropical cyclone Marcia affected catchments extending from the far eastern parts of Fitzroy River catchment south to the Queensland - New South Wales border.

Background photo by Keith Edkins - Created by Keith Edkins using Wikipedia:WikiProject Tropical cyclones/Tracks. The background image is from NASA. Animation and Tracking data is from NOAA., Public Domain, https://commons.wikimedia.org/w/index.php?curid=38456784
Cyclone Marcia, 20 February 2015

(cont.)

• The heaviest rainfall was recorded over the Don and Dee Rivers and Callide Creek in the Fitzroy River catchment
• Up to 300 mm of rainfall was recorded in 6-8 hours during the afternoon and evening of 20 February as tropical cyclone Marcia tracked through the region
• Flooding above major flood levels occurred in: Don and Dee Rivers, Callide Creek in the Fitzroy River catchment and Burnett River and Three Moon Creek in the Burnett River catchment.

Based on data provided by the Bureau of Meteorology and the State of Queensland, Department of Natural Resources and Mines, 2015, Licensed under a Creative Commons Australia Attribution License
Fitzroy region bridges

• 11 bridges and one large culvert in State Controlled roads heavily scoured in Fitzroy Region during Cyclone Marcia in February 2015

• Limited information about flooding characteristics (levels, velocities, potential scour depths) for most bridges.

Source: Banana Shire Council
Fitzroy region bridges (cont.)

- Repair under NDRRA program (like for like, no betterment). Robust solution required to avoid reoccurrence
- Efficient design for prompt procurement and repair
- Locally and readily available solutions favoured.
## Bridge structures inspected

<table>
<thead>
<tr>
<th>Structure</th>
<th>Type of abutment protection</th>
<th>Pier type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larcom Creek</td>
<td>Standard Rock Spillthrough (SRS)</td>
<td>5 x 500 mm octagonal raked piles</td>
</tr>
<tr>
<td>Gracemere Creek</td>
<td>Standard Type 2 earth spillthrough – shotcrete added</td>
<td>4 x 450 octagonal vertical piles</td>
</tr>
<tr>
<td>Grevillia Creek</td>
<td>SRS</td>
<td>Rectangular bull nose (3.0 x 0.45 m)</td>
</tr>
<tr>
<td>North Kariboe Creek</td>
<td>Minimal – some grouted and dumped rock</td>
<td>Timber piers 4 x 300 diameter</td>
</tr>
<tr>
<td>Collards Creek No. 2</td>
<td>SRS</td>
<td>2 x 1000 diameter concrete columns</td>
</tr>
<tr>
<td>Collards Creek No. 5</td>
<td>Grouted rubble masonry toe wall; Rockfill to above flood level; Compacted earth fill</td>
<td>2 x 1200 diameter concrete columns</td>
</tr>
<tr>
<td>Callide Creek</td>
<td>Retaining walls – grouted rockfill added</td>
<td>Rectangular bull nose (8.4 x 0.9 m)</td>
</tr>
<tr>
<td>Nankin Creek</td>
<td>Vertical concrete retaining walls – grouted rockfill added to A</td>
<td>5 x 450 octagonal/square piles/piers</td>
</tr>
<tr>
<td>Moore’s Gully</td>
<td>Vertical concrete retaining walls</td>
<td>Rectangular (11.3 x 0.4/0.7 m)</td>
</tr>
<tr>
<td>Little Roundstone Creek</td>
<td>Vertical concrete retaining walls – SRS added to A</td>
<td>5 x 310UC piles</td>
</tr>
<tr>
<td>Jambin Rail Overpass</td>
<td>Vertical concrete retaining walls</td>
<td>Single 2.4 m diameter concrete pier</td>
</tr>
</tbody>
</table>
## Summary of damage

<table>
<thead>
<tr>
<th>Structure</th>
<th>Level of abutment protection damage</th>
<th>Level of local pier scour</th>
<th>Level of general contraction scour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larcom Creek</td>
<td>Orange</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td>Gracemere Creek</td>
<td>Orange</td>
<td>Orange</td>
<td>Orange</td>
</tr>
<tr>
<td>Grevillia Creek</td>
<td>Red</td>
<td></td>
<td>Orange</td>
</tr>
<tr>
<td>North Kariboe Creek</td>
<td>Orange</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>Collards Creek No. 2</td>
<td>Red</td>
<td>Red</td>
<td>Orange</td>
</tr>
<tr>
<td>Collards Creek No. 5</td>
<td>Red</td>
<td>Red</td>
<td>Orange</td>
</tr>
<tr>
<td>Callide Creek</td>
<td>Red</td>
<td>Red</td>
<td>Orange</td>
</tr>
<tr>
<td>Nankin Creek</td>
<td>Red</td>
<td></td>
<td>Orange</td>
</tr>
<tr>
<td>Moore’s Gully</td>
<td>Orange</td>
<td>Red</td>
<td>Orange</td>
</tr>
<tr>
<td>Little Roundstone Creek</td>
<td>Red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jambin Rail Overpass</td>
<td>Orange</td>
<td>Orange</td>
<td>Red</td>
</tr>
</tbody>
</table>

**Red** = severe damage/scour  **Orange** = significant damage/scour  **Blank** = minimal damage-scour
Grevillia Creek abutment
NDRRA project methodology

• Site inspection
• Options workshop
• Hydraulic and scour analysis
• Structural considerations
• Remedial protection works design
• Approval processes
• Construction.
Hydraulic and scour analysis

- Replicated Cyclone Marcia or 1% Annual Exceedance Probability (AEP) event conditions at 11 crossings (hydrology and hydraulics)
- Combination of 1D and 2D modelling, depending on data availability
- Water levels, velocities, shear stress and scour depths.
## Velocities

<table>
<thead>
<tr>
<th>Structure</th>
<th>Average Velocity 1D (m/s)</th>
<th>Maximum Velocity 1D (m/s)</th>
<th>Maximum Velocity 2D (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larcom Creek</td>
<td>3.2</td>
<td>4.5</td>
<td>5 (southern abutment)</td>
</tr>
<tr>
<td>Gracemere Creek</td>
<td>3.3</td>
<td>4.5</td>
<td>4.5 (northern abutment)</td>
</tr>
<tr>
<td>Grevillia Creek</td>
<td>3.9</td>
<td>4.8</td>
<td>N/A</td>
</tr>
<tr>
<td>North Kariboe Creek</td>
<td>3.6</td>
<td>4.8</td>
<td>N/A</td>
</tr>
<tr>
<td>Collards Creek No. 2</td>
<td>3.5</td>
<td>4.5</td>
<td>5.8 (northern abutment)</td>
</tr>
<tr>
<td>Collards Creek No. 5</td>
<td>2.9</td>
<td>3.9</td>
<td>4.1 (northern abutment)</td>
</tr>
<tr>
<td>Callide Creek</td>
<td>3.1</td>
<td>3.9</td>
<td>3.0</td>
</tr>
<tr>
<td>Nankin Creek</td>
<td>4.2</td>
<td>6.3</td>
<td>N/A</td>
</tr>
<tr>
<td>Moore’s Gully</td>
<td>3.2</td>
<td>4.0</td>
<td>5.3 (just upstream of bridge)</td>
</tr>
<tr>
<td>Little Roundstone Creek</td>
<td>3.3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Jambin Rail Overpass</td>
<td>N/A</td>
<td>N/A</td>
<td>4.5 (downstream of overpass)</td>
</tr>
</tbody>
</table>

Red = severe damage/scour  Orange = significant damage/scour
Hydraulic and scour analysis (cont.)

- 2D modelling allows more realistic flow patterns and local velocities and shear stresses (not average as in 1D)
- Maximum velocities do not always correlate to maximum flood levels
- More computational effort and more accurate hydrology required
- Able to identify conditions within stream and floodplain and allows easy comparison with observed flooding conditions
- Local high velocities up to 6 m/s at locations where scour is observed.
Hydraulic and scour analysis (cont.)

Collards Creek Bridge # 5

$V_{\text{max}} = 4.5 \text{ m/s}$
Hydraulic and scour analysis (cont.)

Jambin rail overpass
Hydraulic and scour analysis (cont.)

Larcom Creek
Hydraulic and scour analysis (cont.)

Larcom Creek Bridge
Hydraulic and scour analysis (cont.)

Collards 2 bridge
Hydraulic and scour analysis (cont.)

Larcom Creek Bridge
Velocity (V) and Shear stress (τ)

- \( \tau = \gamma R S \)
  - R - Hydraulic radius (m), S - channel slope (m/m), \( \gamma \) - Specific weight (N/m\(^3\))

- \( \tau = \rho f V^2 \)
  - V - velocity (m/s), f - friction factor [], \( \rho \) - density (kg/m\(^3\))

In 1D and 2D models, shear stress is always depth averaged.

### Table 1: Shear stress \( \tau \) as a function of mean velocity \( V \) and dimensionless friction factor \( f \).

<table>
<thead>
<tr>
<th>V (m/s)</th>
<th>Low 0.0020</th>
<th>Average 0.0035</th>
<th>High 0.0050</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3.5</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>14.0</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>31.5</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>56.0</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>87.5</td>
<td>125</td>
</tr>
<tr>
<td>6</td>
<td>72</td>
<td>126.0</td>
<td>180</td>
</tr>
</tbody>
</table>

\[ \tau_0 \rho L = \gamma_w A L \sin(\alpha) \]

\[ \tau_0 = \gamma_w R_{ll} S \]
Velocity (V) and Shear stress (τ) (cont.)
Mitigation

- Sizing to withstand similar flooding conditions
- Large rock required
- Rock protection, gabion retaining wall systems MassBloc®, Keppel Blocks
- Standardised treatments, specifications, construction activities.

### Structure Mitigation Measures

<table>
<thead>
<tr>
<th>Structure</th>
<th>Mitigation Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larcom Creek</td>
<td>¼ tonne rock, Keppel blocks</td>
</tr>
<tr>
<td>Gracemere Creek</td>
<td>¼ and ½ tonne rock</td>
</tr>
<tr>
<td>Grevillia Creek</td>
<td>½ tonne rock</td>
</tr>
<tr>
<td>North Kariboe Creek</td>
<td>½ tonne rock</td>
</tr>
<tr>
<td>Collards Creek No. 2</td>
<td>1 and 2 tonne rock, MassBloc® and Keppel blocks</td>
</tr>
<tr>
<td>Collards Creek No. 5</td>
<td>½ tonne rock, Keppel blocks</td>
</tr>
<tr>
<td>Callide Creek</td>
<td>Light rock (d₅₀=400)</td>
</tr>
<tr>
<td>Nankin Creek</td>
<td>¼ and 1 tonne rock, Keppel blocks</td>
</tr>
<tr>
<td>Moore’s Creek</td>
<td>¼ and ½ tonne rock</td>
</tr>
<tr>
<td>Little Roundstone Creek</td>
<td>½ tonne rock</td>
</tr>
<tr>
<td>Unnamed Culvert</td>
<td>¼ tonne rock, gabion baskets</td>
</tr>
<tr>
<td>Jambin Rail Overpass</td>
<td>Light (d₅₀=400) and ½ tonne rock, Keppel Blocks</td>
</tr>
</tbody>
</table>
Mitigation (cont.)

- Moore’s Creek
- Existing pier scour
- Significant scours during event
- Routine Level 1 and Level 2 inspections critical in showing NDRRA eligibility
- Repairing damage sustained during event
- Future poof solution – 1% AEP.
Mitigation (cont.)

Moore’s Creek – reinstate scours

Scouring of 1.7 m

08/10/2015 – View up-stream
Mitigation (cont.)

Moore’s Creek – reinstate scours

Scouring of 1.6 m

21/08/2013

08/10/2015
Mitigation (cont.)

Moore’s Creek – reinstate scour
Mitigation (cont.)

Collards Creek No. 2

- Stone pitching removed
- Drop in bed level
- Reinstate abutments with rock protection
- MassBloc ® and Keppel Blocks
Mitigation (cont.)

Collards Creek No. 2 - modelling
Mitigation (cont.)

Collards Creek No. 2 – stone pitching removed

19/01/2015

14/07/2015

Abutment A

Abutment B
Mitigation (cont.)

Collard’s Creek No. 2 - drop in bed level – 2.1 m

01/10/2015

09/05/2016
Implementation (cont.)

Collard’s Creek No. 2 – construction progress Abutment A
Implementation (cont.)

Collard’s Creek No. 2 – construction progress Abutment A
Implementation (cont.)

Collard’s Creek No. 2 – construction progress Abutment B
Implementation (cont.)

Collard’s Creek No. 2 – construction progress Abutment B
Implementation (cont.)

Collard’s Creek No. 2 – completed works Abutment A
Implementation (cont.)

Collard’s Creek No. 2 – completed works Abutment B
Lessons learnt

- All sites experienced velocities > 3 m/s.
- Standard grouted rock spill throughs are not as robust as some people think.
- Rigid abutment protection has generally performed poorly.
- Comprehensive hydraulic modelling necessary to predict velocities.
- Contraction and local pier scour depths are consistent with overserved scour (not as conservative as thought).
- A range of protection measures required (not one size fits all).
- New products (for example concrete mass blocks) present a feasible alternative to large size riprap.
Thank you