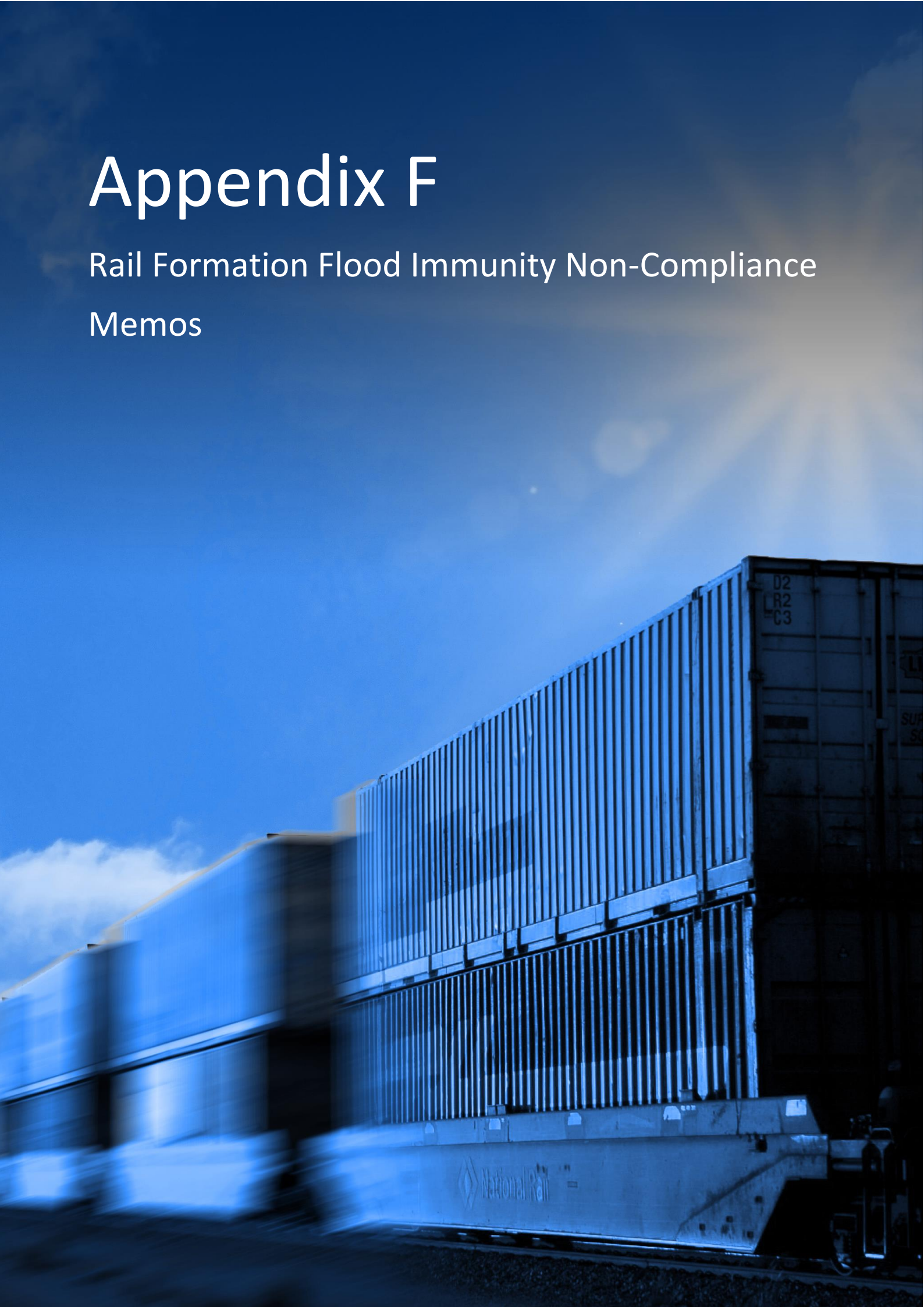
Appendix F

Rail Formation Flood Immunity Non-Compliance Memos



IRDJV
World Square
Level 27,
680 George Street,
Sydney New South Wales, 2000
Tel: +61 7 3854 6200

Memo

Project Name	Technical and Approvals Consultancy Services: Parkes to Narromine
To	Rob Zeirzer, ARTC Project Manager; Reannan Ellaby, ARTC Design Manager
From	Daniel Blake, IRDJV Project Manager; Rob Leslie, IRDJV Hydrology & Flooding Lead; David Keane, IRDJV Flooding & Cross Drainage Lead
Subject	Rail Formation Flood Immunity Non-conformances Ch449.355km – Ch449.585km
Our Ref	3-0001-240-IHY-00-ME-0005_A
Date	Wednesday, 11 July 2018

1. Introduction

At the 70% design stage, several locations were identified where the required minimum Top of Formation (ToF) design flood immunity identified through the ARTC Flooding Multi-Criteria Analysis (MCA) was not achieved. As part of the design development from 70% to 100% design many these non-conformances have been resolved. However, a limited number of non-conforming locations remain and the following memo provides a detailed description of the flood risk to the rail line and design rationale for the remaining non-conformance for one of these instances which occurs between Ch449.355km – Ch449.585km.

2. Non-conformance to required flood immunity – (Ch449.355km-Ch449.585km)

The non-conforming flood immunity occurs over 230m between Ch449.355km and Ch449.585km close to the southern tie in point of the project with existing track (Figure 2.1 and Figure 2.2). The flooding MCA process requires the ToF level to be set to a 1% AEP flood immunity. The limitations of the rail design require a tie in to existing rail level and two level crossings in a 500m section meaning the rail design cannot achieve the 1% immunity level required.

Figure 2.1 Location: Extent of non-conformance denoted by blue cloud (part 1)

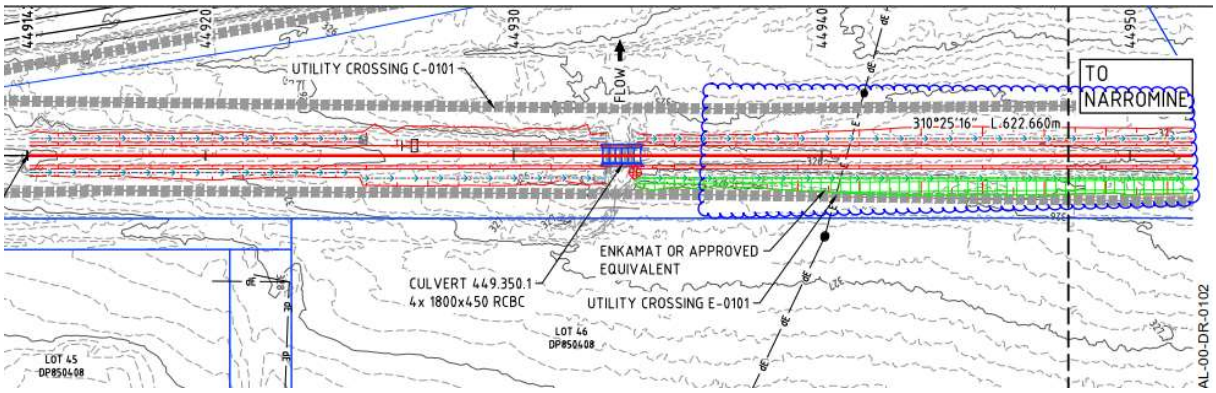
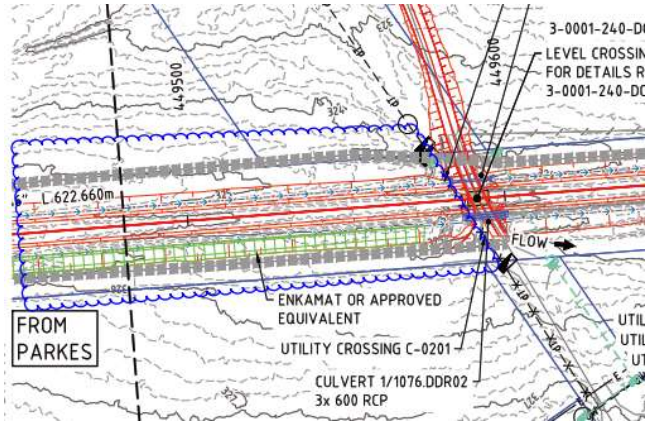
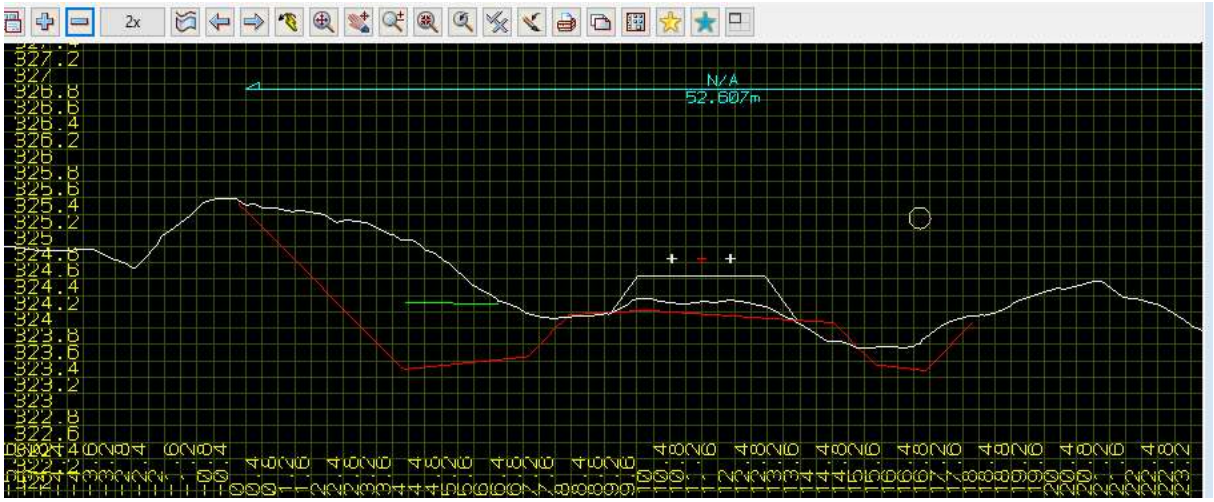


Figure 2.2 Location: Extent of non-conformance noted by blue cloud (part 2)



The details of the current non-conformance at the worst-case location are provided in Figure 2.3 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.3 Non-conforming Cross-section



Legend

Green line: LAC01 DES38 1AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

Figure 2.4 provides a long section of the rail formation where the non-conformance occurs across the 360m of rail alignment.

Figure 2.4 Non-conforming Long Section Profile

Legend

Green line: LAC01 DES38 1AEP design flood grid

Blue line: LAC01 EX13 1AEP existing flood grid

Red line: Design Formation (ToF)

White line: Existing Topography

3. Design background and rationale

Rail Alignment/Longitudinal Drain Design

This section is located within approximately 200m from the tie in into the existing track at the southern extent of the project. Raising the alignment at this location to meet the flood immunity requirement would impact two level crossings and result in formation raising over approximately 1.5km (449.5km to 451km) to the north of the area of non-conformance. This track section is already designed on a gradient of 1in101 therefore modifying this section of track will either require long length of rail to be impacted vertically and or introduction of steep gradient. Steepening this grade may impact operations for Inland Rail traffic and will also impact trains entering onto the Inland Rail track from the North-West Connection and the Parkes Intermodal terminal.

Rail longitudinal drains have already widened to 3.0m in this section to cater for larger flows entering the cess drain and to reduce the frequency of formation inundation.

Cross Drainage Design

Several design iterations have been undertaken at this location to reduce the flood levels and achieve compliance through provision of cross drainage and long drainage capacity. Table 3.1 demonstrates the increase in cross drainage adopted post 70% design.

Table 3.1 Cross Drainage design progression

Location	70% design	100% Design
449.350	4 x 1800W x 450H RCBC	5 x 1800W x 600H RCBC
1/1076.DDR02	3 x 600 RCP	4 x 750 RCP

Review of the long section and cross section plots in Figure 2.3 and Figure 2.4 demonstrates that the flood level is reduced in the design case when compared to the existing case. Further increases in the cross-drainage capacity at this location were tested with minimal reduction in flood level achieved. This demonstrates that a significant increase in the cross-drainage capacity would be required to achieve a 1% AEP formation flood immunity, which is not a cost-effective solution.

Proposed Mitigation Measures

Proposed mitigation to improve track flood reliance is to either construct additional earthworks above rail formation level or provide gabions or similar treatment to protect the track structure

4. Flood risk parameters

The flood parameters requested by ARTC to allow the assessment of flood risk at this location is provided Table 4.1. The information has been extracted at the worst location in terms depth of inundation into the ballast. Further details are provided in Figure 4-1 with flood level plotted against time to provide a detailed picture of the flood event.

Table 4.1 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	**1% AEP**			
Design Formation Level or Design Flood Level (mAHD)	325.744 – 324.070	325.87 – 324.329	325.708 – 324.05	325.707 – 323.895
Submergence Depth (Max depth) (mm)	N/A	0.225	0	0
Velocity (m/s)	N/A	0.832	0.788	0.788
Duration of flooding above formation (hrs)	N/A	0.667	0	0
Length of formation inundation (m)	N/A	230	0	0

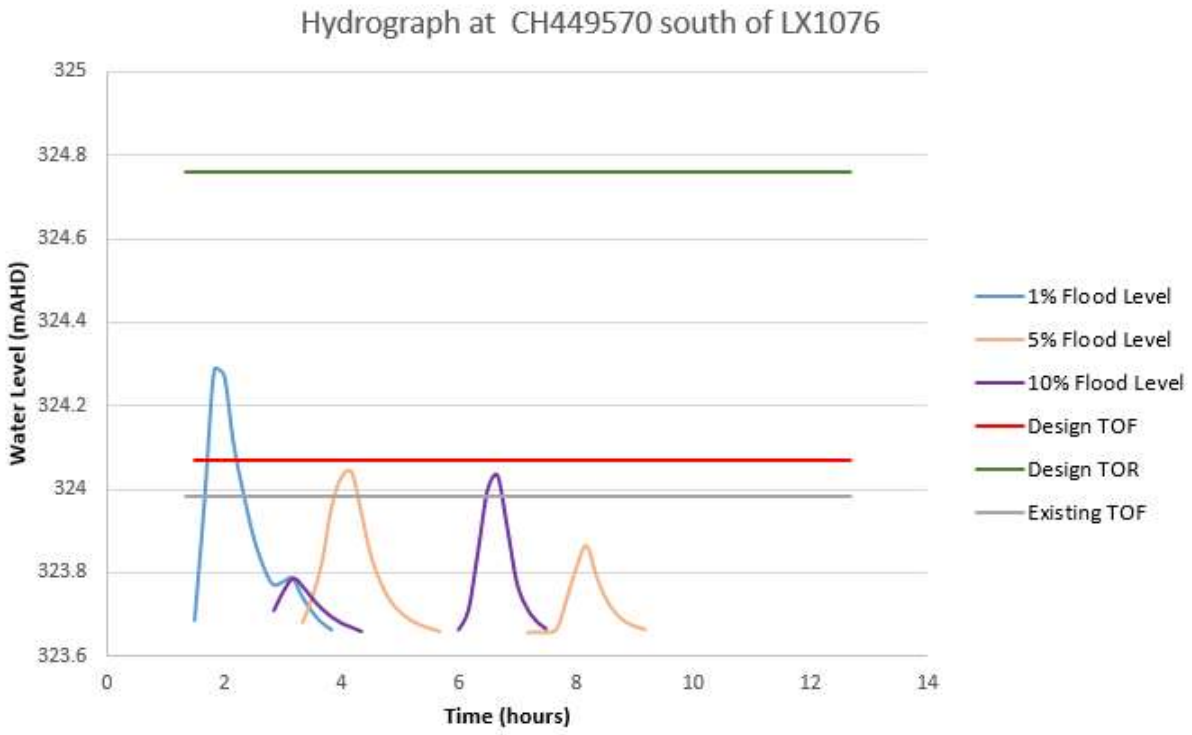


Figure 4-1 Hydrograph: Upstream of LX1076 at Ch449.570km

5. Conclusion

This document provides information on the non-conformance of the rail formation flood immunity at Ch449.355km to Ch449.585km. Key conclusions are as follows:

- The MCA process identified a 1% AEP flood immunity for the formation at this location. Due to constraints noted below, the formation has <1% AEP immunity at this location;
- The required flood immunity has not been met at this location due to the constraint posed by the tie-in to the existing rail level and 2 level crossings;
- While the required formation flood immunity is not achieved, the rail line does not overtop at this location in events up to the 1% AEP;
- Key flood risk parameters at this location for the 1% AEP event are as follows:
  - Ballast submergence depth = 225mm;
  - Velocity at top of formation = 0.832m/s;
  - Time of submergence of formation = 0.667 hours; and
- If the risk is deemed unacceptable then suitable mitigation measures for further investigation would include provisions of protective earthworks / gabions / other treatment to the formation where significant inundation depths and velocities occur.

Yours sincerely,

Rob Leslie

Rob Leslie
IRDJV Hydrology & Flooding Lead

IRDJV
World Square
Level 27,
680 George Street,
Sydney New South Wales, 2000
Tel: +61 7 3854 6200

Memo

Project Name	Technical and Approvals Consultancy Services: Parkes to Narromine
To	Rob Zeirzer, ARTC Project Manager; Reannan Ellaby, ARTC Design Manager
From	Daniel Blake, IRDJV Project Manager; Rob Leslie, IRDJV Hydrology & Flooding Lead; David Keane, IRDJV Flooding & Cross Drainage Lead
Subject	Rail Formation Flood Immunity Non-conformances Ch458.280km – Ch458.965km
Our Ref	3-0001-240-IHY-00-ME-0006_A
Date	Wednesday, 11 July 2018

1. Introduction

At the 70% design stage, several locations were identified where the required minimum Top of Formation (ToF) design flood immunity identified through the ARTC Flooding Multi-Criteria Analysis (MCA) was not achieved. As part of the design development from 70% to 100% design many these non-conformances have been resolved. However, a limited number of non-conforming locations remain and the following memo provides a detailed description of the flood risk to the rail line and design rationale for the remaining non-conformance for one of these instances which occurs between Ch458.280km and Ch458.965km.

2. Non-conformance to required flood immunity – (Ch458.280km – Ch458.965km)

The non-conforming flood immunity occurs over 685m between Ch458.280km and Ch458.965km close to the tie in point of the project with Nanardine Lane Level Crossing LX1080 and along Nanardine Crossing Loop (Figure 2.1 and Figure 2.2) The flooding MCA process requires the ToF level to be set to a 1% AEP flood immunity. The limitations of the rail design require a tie in between Nanardine Crossing Loop and Nanardine Lane Level Crossing meaning the rail design cannot achieve the 1% immunity level required.

Figure 2.1 Location: Extent of non-conformance denoted by blue cloud

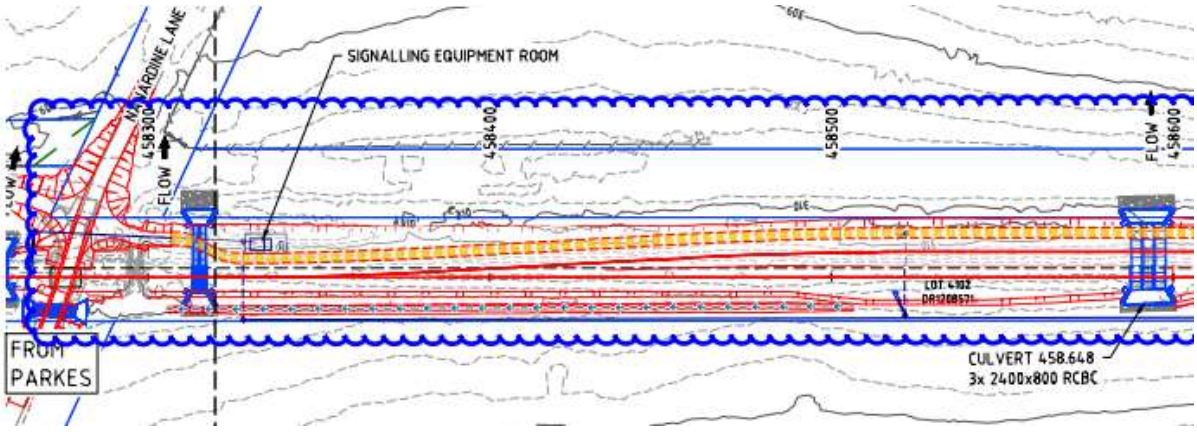
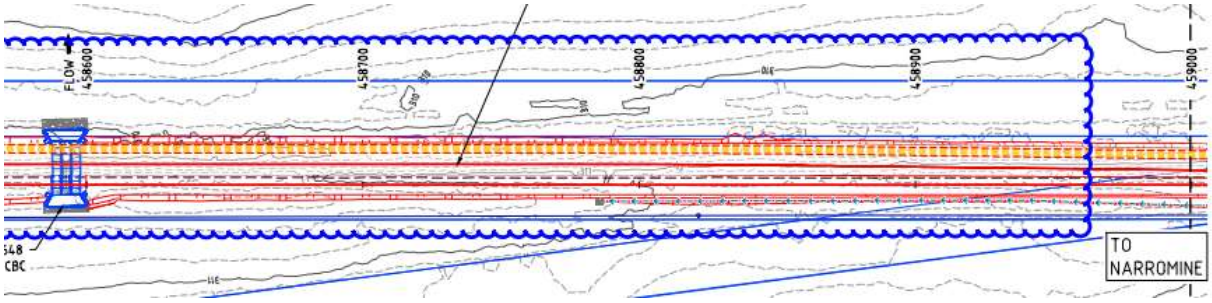


Figure 2.2 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.3 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.3 Non-conforming Cross-section at 458.365km

Legend

Blue Line: LAC01 DES43 1AEP design flood grid

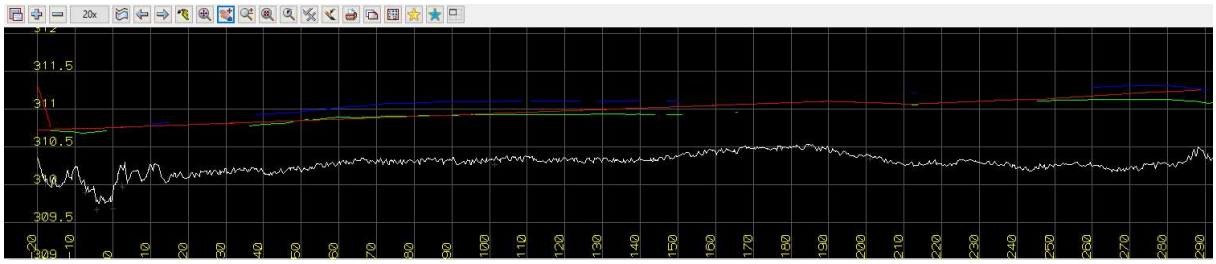
Green line: LAC01 DES43 5AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

Figure 2.4 and Figure 2.5 provides a long section of the rail formation where the non-conformance occurs across the 685m of rail alignment.

Figure 2.4 Non-conforming Long Section Profile Ch458.280km to Ch458.450km



Legend

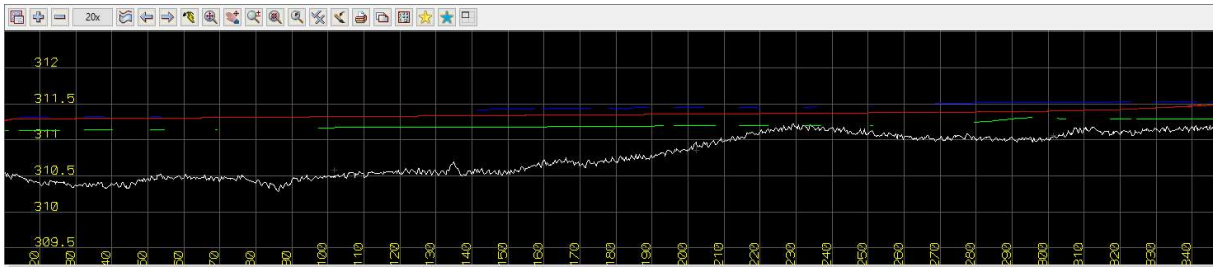
Blue Line: LAC01 DES43 1AEP design flood grid

Green line: LAC01 DES43 5AEP design flood grid

Red line: Design Formation (ToF)

White line: Existing Topography

Figure 2.5 Non-conforming Long Section Profile Ch458.450km to Ch458.965km



Legend

Blue Line: LAC01 DES43 1AEP design flood grid

Green line: LAC01 DES43 5AEP design flood grid

Red line: Design Formation (ToF)

White line: Existing Topography

3. Design background and rationale

Cross Drainage Design

Several design iterations have been undertaken at this location to reduce the flood levels and achieve compliance through provision of cross drainage and long drainage capacity. Table 3.1 demonstrates the increase in cross drainage adopted post 70% design.

Table 3.1 Cross Drainage design progression

Location	70% design	100% Design
1/1080.DDR1	5 x 600W x 450H RCBC	3 x 900W x 600H RCBC
458.323	2 x 1800W x 900H RCBC	2 x 1800W x 900H RCBC
458.648	3 x 1800W x 600H RCBC	3 x 2400W x 800H RCBC

There is limited opportunity to further increases the cross-drainage capacity at this location without lifting the level crossing road level to achieve cover over the drainage. This would in turn block additional overtopping flow to the south and require more cross drainage capacity under the level crossing. Increasing flow capacity at the two rail cross drainage structures would result in non-conforming flood impacts downstream of the rail in lower order events (<1% AEP) and limits this as a potential solution. This demonstrates that either lifting the rail formation, level crossing or adding additional cross drainage capacity would be required to achieve a 1% AEP formation flood immunity, which is not a cost-effective solution.

Proposed Mitigation Measures

Proposed mitigation to improve track flood reliance is to either construct additional earthworks above rail formation level or provide gabions or similar treatment to protect the track structure.

4. Flood risk parameters

The flood parameters requested by ARTC to allow the assessment of flood risk at this location is provided Table 4.1. The information has been extracted at the worst location in terms depth of inundation into the ballast. Further details are provided in Figure 4-1 with flood level plotted against time to provide a detailed picture of the flood event.

Table 4.1 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	**1% AEP**			
Design Formation Level or Design Flood Level (mAHD)	310.730 – 311.550	310.836 – 311.545	310.707 – 311.295	310.656 – 311.255
Submergence Depth (Max depth) (mm)	N/A	0.165	0	0
Velocity (m/s)	N/A	1.39	0	0
Duration of flooding above formation (hrs)	N/A	0.5	0	0
Length of formation inundation (m)	N/A	685	0	0

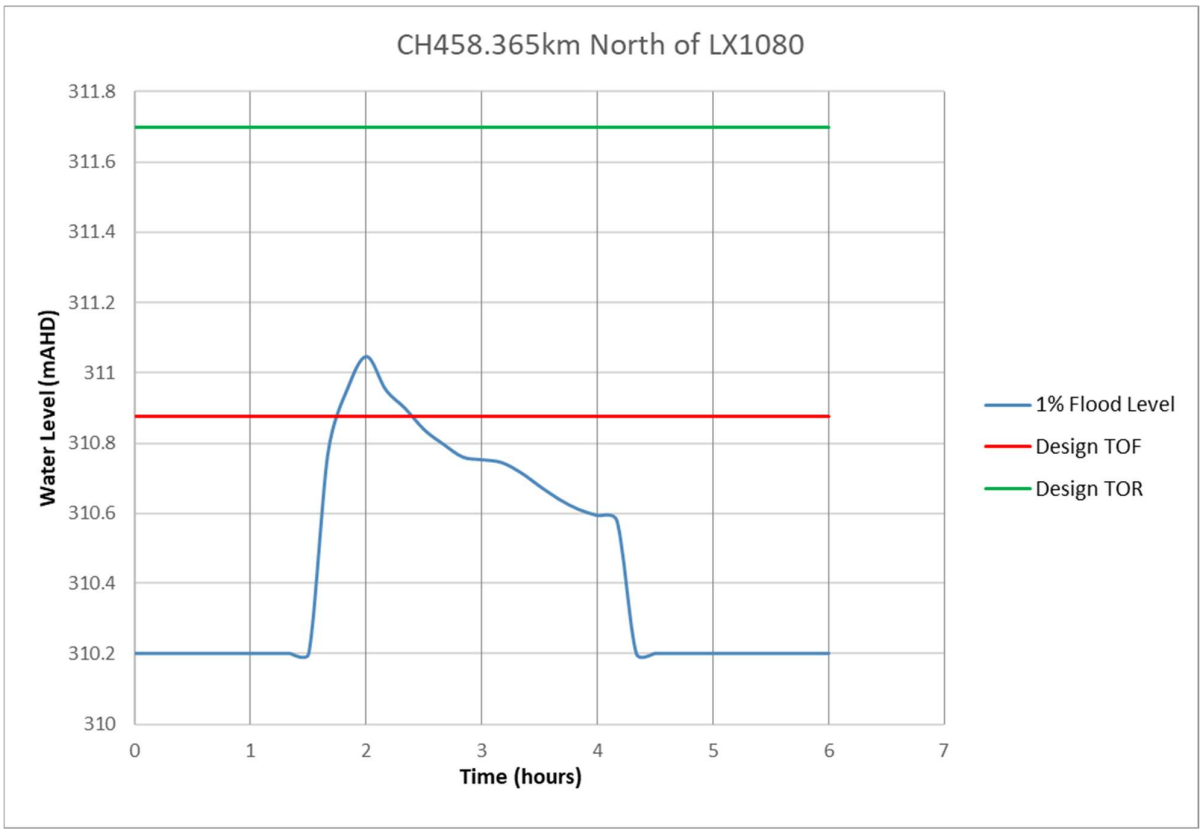


Figure 4-1: Upstream of LX1080 at Ch458.365km

5. Conclusion

This document provides information on the non-conformance of the rail formation flood immunity at Ch458.280km to Ch458.965km. Key conclusions are as follows:

- The MCA process identified a 1% AEP flood immunity for the formation at this location. Due to constraints noted below, the formation has <1% AEP immunity at this location;
- The required flood immunity has not been met at this location due to the constraint posed by the tie-in to Nanardine Lane level crossing;
- While the required formation flood immunity is not achieved, the rail line does not overtop at this location in events up to the 1% AE;
- Key flood risk parameters at this location for the 1% AEP event are as follows:
  - Ballast submergence depth = 165mm;
  - Velocity at top of formation = 1.23m/s;
  - Time of submergence of formation = 0.5 hours; and
- If the risk is deemed unacceptable then suitable mitigation measures for further investigation would include provisions of protective earthworks / gabions / other treatment to the formation where significant inundation depths and velocities occur.

Yours sincerely,

Rob Leslie
IRDJV Hydrology & Flooding Lead

IRDJV
World Square
Level 27,
680 George Street,
Sydney New South Wales, 2000
Tel: +61 7 3854 6200

Memo

Project Name	Technical and Approvals Consultancy Services: Parkes to Narromine
To	Rob Zeirzer, ARTC Project Manager; Reannan Ellaby, ARTC Design Manager
From	Daniel Blake, IRDJV Project Manager; Rob Leslie, IRDJV Hydrology & Flooding Lead; David Keane, IRDJV Flooding & Cross Drainage Lead
Subject	Rail Formation Flood Immunity Non-conformances Ch473.890km – Ch473.897km
Our Ref	3-0001-240-IHY-00-ME-0007_A
Date	Wednesday, 11 July 2018

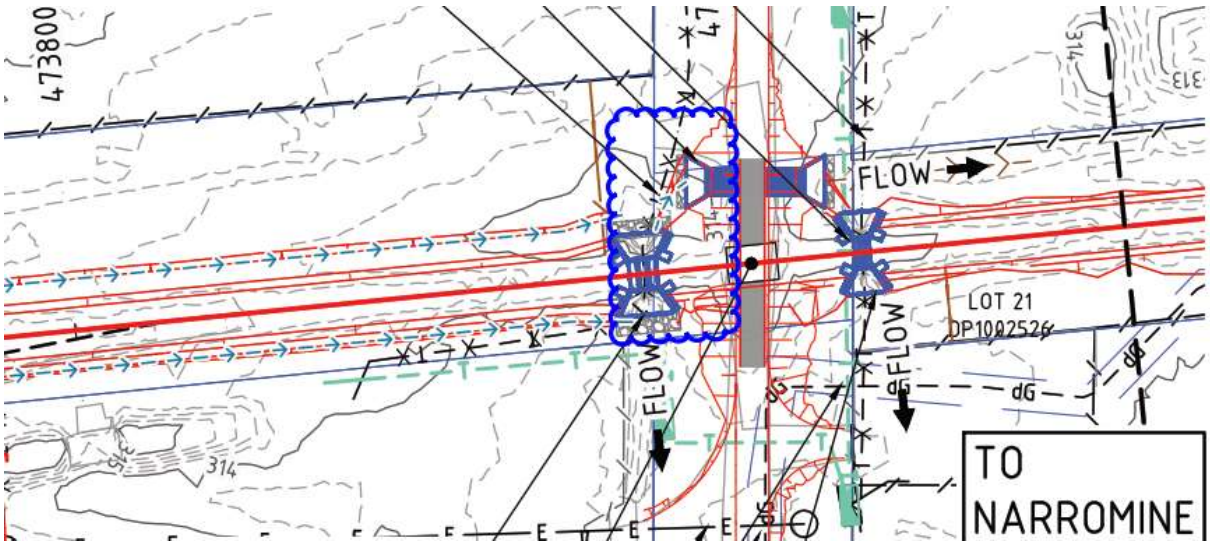
1. Introduction

At the 70% design stage, several locations were identified where the required minimum Top of Formation (ToF) design flood immunity identified through the ARTC Flooding Multi-Criteria Analysis (MCA) was not achieved. As part of the design development from 70% to 100% design many these non-conformances have been resolved. However, a limited number of non-conforming locations remain and the following memo provides a detailed description of the flood risk to the rail line and design rationale for the remaining non-conformance for one of these instances which occurs between Ch473.890km and Ch473.897km.

2. Non-conformance to required flood immunity – (Ch473.890km – Ch473.897km)

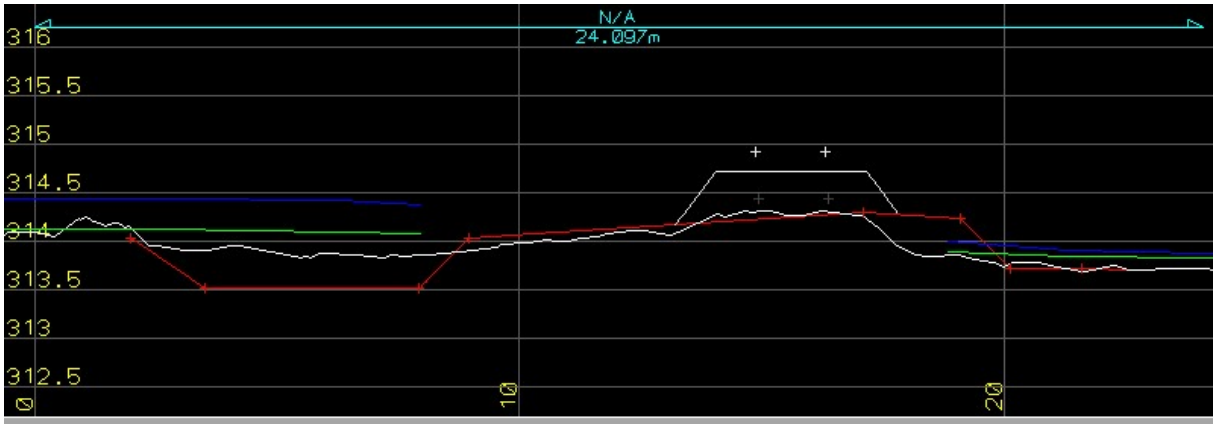
The non-conforming flood immunity occurs over 10m between Ch473.890km and Ch473.897km close to the tie in point of the project with Alectown West Road Level Crossing LX1084 (Figure 2.1) The flooding MCA process requires the ToF level to be set to a 1% AEP flood immunity. The limitations of the rail design require a tie in between Alectown West Siding (Ch473.450km) and Alectown West Level Crossing meaning the rail design cannot achieve the 1% immunity level required.

Figure 2.1 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.2 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.2 Non-conforming Cross-section at 473.893km



Legend

Blue Line: BOG01 DES47 1AEP design flood grid

Green line: BOG01 DES47 5AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

Figure 2.3 provides a long section of the rail formation where the non-conformance occurs across the 10m of rail alignment.

Figure 2.3 Non-conforming Long Section Profile Ch473.890km to Ch473.897km

Legend

Blue line: BOG01 DES47 1AEP design flood grid

Green line: BOG01 DES47 5AEP design flood grid

Red line: Design Formation (ToF)

White line: Existing Topography

3. Design background and rationale

Cross Drainage Design

Several design iterations have been undertaken at this location to reduce the flood levels and achieve compliance through provision of cross drainage and long drainage capacity. Table 3.1 demonstrates the increase in cross drainage adopted post 70% design.

Table 3.1 Cross Drainage design progression

Location	70% design	100% Design
1/1084.DDR1	3 x 600W x 450H RCBC	5 x 600W x 450H RCBC

There is limited opportunity to further increase the cross-drainage capacity at this location without lifting the level crossing road level to achieve cover over the drainage. This would in turn block additional overtopping flow to the south and require more cross drainage capacity under the level crossing. This demonstrates that either lifting the rail formation, level crossing or adding additional cross drainage capacity would be required to achieve a 1% AEP formation flood immunity, which is not a cost-effective solution.

Proposed Mitigation Measures

Proposed mitigation to improve track flood reliance is to either construct additional earthworks above rail formation level or provide gabions or similar treatment to protect the track structure.

4. Flood risk parameters

The flood parameters requested by ARTC to allow the assessment of flood risk at this location is provided Table 4.1. The information has been extracted at the worst location in terms depth of inundation into the ballast. Further details are provided in Figure 4-1 with flood level plotted against time to provide a detailed picture of the flood event.

Table 4.1 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	**1% AEP**			
Design Formation Level or Design Flood Level (mAHD)	314.174	314.419	314.081	314.081
Submergence Depth (Max depth) (mm)	N/A	0.245	0	0
Velocity (m/s)	N/A	1.14	0	0
Duration of flooding above formation (hrs)	N/A	1.2	0	0
Length of formation inundation (m)	N/A	10	0	0

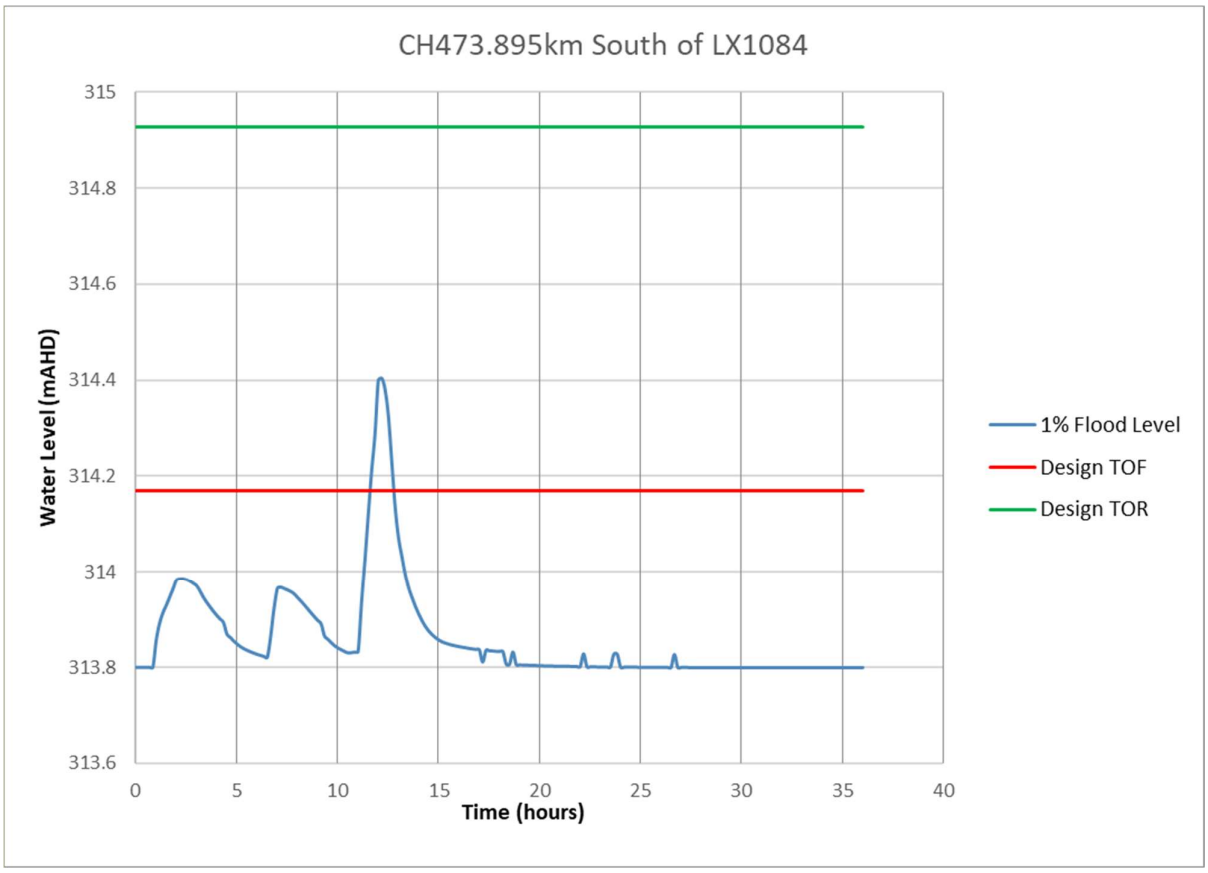


Figure 4-1: Upstream of LX1084 at Ch473.895km

5. Conclusion

This document provides information on the non-conformance of the rail formation flood immunity at Ch473.890km to Ch473.897km. Key conclusions are as follows:

- The MCA process identified a 1% AEP flood immunity for the formation at this location. Due to constraints noted below, the formation has <1% AEP immunity at this location;
- The required flood immunity has not been met at this location due to the constraint posed by the tie-in between Alectown West Siding (Ch473.450km) and Alectown West Level Crossing;
- While the required formation flood immunity is not achieved, the rail line does not overtop at this location in events up to the 1% AEP;
- Key flood risk parameters at this location for the 1% AEP event are as follows:
  - Ballast submergence depth = 245mm;
  - Velocity at top of formation = 1.14m/s;
  - Time of submergence of formation = 1.2 hours; and
- If the risk is deemed unacceptable then suitable mitigation measures for further investigation would include provisions of protective earthworks / gabions / other treatment to the formation where significant inundation depths and velocities occur.

Yours sincerely,

Rob Leslie

Rob Leslie
IRDJV Hydrology & Flooding Lead

IRDJV
World Square
Level 27,
680 George Street,
Sydney New South Wales, 2000
Tel: +61 7 3854 6200

Memo

Project Name	Technical and Approvals Consultancy Services: Parkes to Narromine
To	Rob Zeirzer, ARTC Project Manager; Reannan Ellaby, ARTC Design Manager
From	Daniel Blake, IRDJV Project Manager; Rob Leslie, IRDJV Hydrology & Flooding Lead; David Keane, IRDJV Flooding & Cross Drainage Lead
Subject	Rail Formation Flood Immunity Non-conformances Ch497.745km – Ch499.100km
Our Ref	3-0001-240-IHY-00-ME-0008_A
Date	Wednesday, 11 July 2018

1. Introduction

At the 70% design stage, several locations were identified where the required minimum Top of Formation (ToF) design flood immunity identified through the ARTC Flooding Multi-Criteria Analysis (MCA) was not achieved. As part of the design development from 70% to 100% design many these non-conformances have been resolved. However, a limited number of non-conforming locations remain and the following memo provides a detailed description of the flood risk to the rail line and design rationale for the remaining non-conformance for one of these instances which occurs between Ch497.745km and Ch499.100km.

2. Non-conformance to required flood immunity – (Ch497.745km – Ch499.100km)

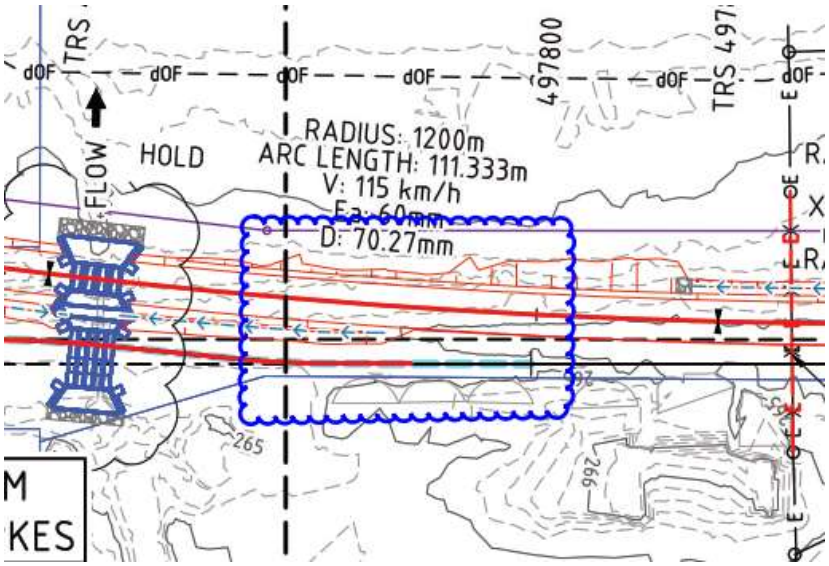
The non-conforming flood immunity occurs at 4 locations over a distance of 1355m between Ch497.745km and Ch499.100km. The locations are summarised as follows:

- Ch497.745km to Ch497.800km (55m) – 5% AEP Flood immunity required;
- Ch498.110km to Ch498.225km (105m) – 10% AEP Flood immunity required;
- Ch498.400km to Ch498.800km (400m) – 5% AEP Flood immunity required;
- Ch498.995km to Ch499.100km (105m) – 5% AEP Flood immunity required; and

The flooding MCA process requires the ToF level to be set to either 5% or 10% AEP flood immunity. The limitations of the rail design require a tie in to the Peak Hill existing siding, Level Crossing LX1091 and LX1092 meaning the rail design cannot achieve the immunity level required.

2.1 Ch497.745km to Ch497.800km – 5% AEP Flood immunity required

Figure 2.1 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.2 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.2 Non-conforming Cross-section at Ch497.775km

Legend

Blue Line: BOG03 DES36 1AEP design flood grid

Green line: BOG03 DES36 5AEP design flood grid

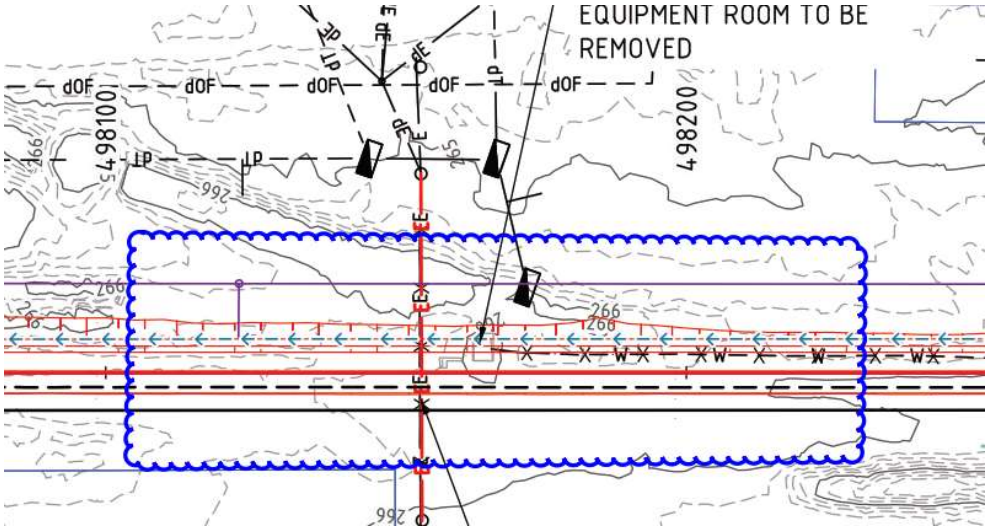
Yellow line: BOG03 DES36 10AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

2.2 Ch498.110km to Ch498.225km – 10% AEP Flood immunity required

Figure 2.3 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.4 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.4 Non-conforming Cross-section at Ch498.165km

Legend

Blue Line: BOG03 DES36 1AEP design flood grid

Green line: BOG03 DES36 5AEP design flood grid

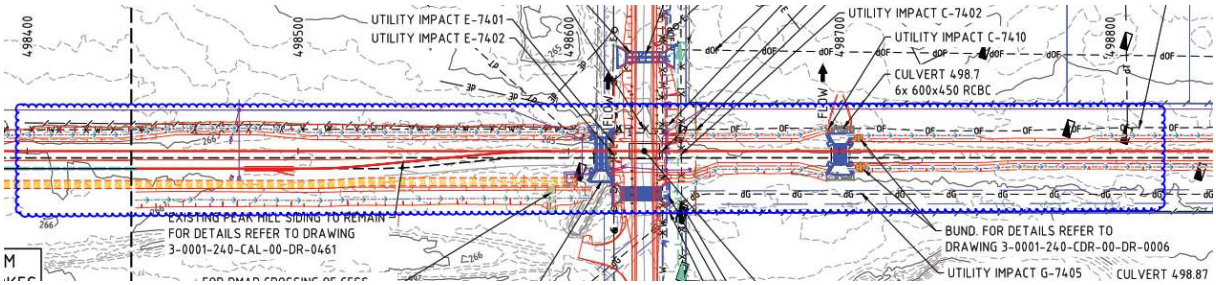
Yellow line: BOG03 DES36 10AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

2.3 Ch498.400km to Ch498.820km – 5% AEP Flood immunity required

Figure 2.5 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.6 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.6 Non-conforming Cross-section at Ch498.590km

Legend

Blue Line: BOG03 DES36 1AEP design flood grid

Green line: BOG03 DES36 5AEP design flood grid

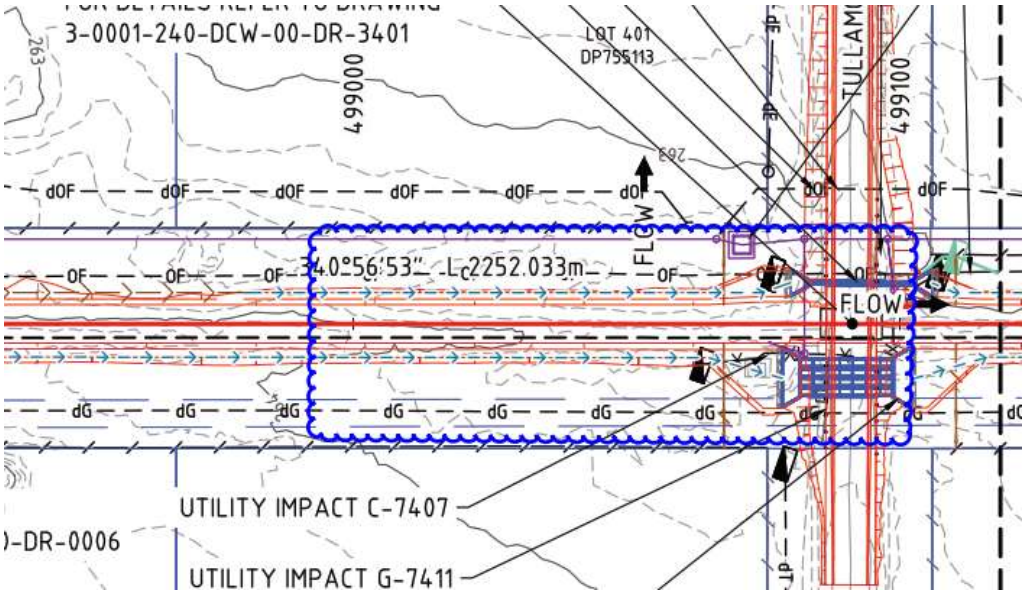
Yellow line: BOG03 DES36 10AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

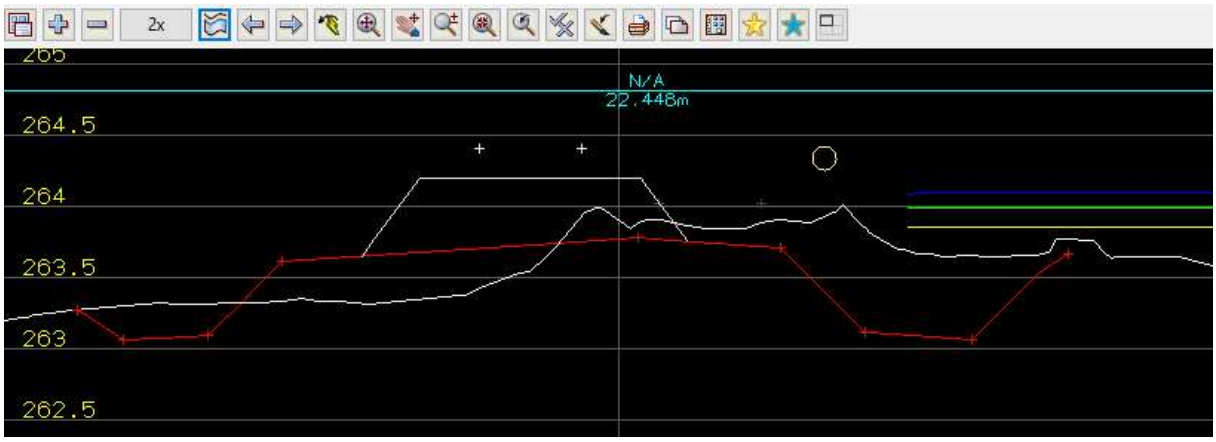
2.4 Ch498.995km to Ch499.100km – 5% AEP Flood immunity required

Figure 2.7 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.8 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.8 Non-conforming Cross-section at Ch499.065km



Legend

Blue Line: BOG03 DES36 1AEP design flood grid

Green line: BOG03 DES36 5AEP design flood grid

Yellow line: BOG03 DES36 10AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

3. Design background and rationale

Cross Drainage Design

Several design iterations have been undertaken at this location to reduce the flood levels and achieve compliance through provision of cross drainage and long drainage capacity. Table 3.1 demonstrates there has been limited scope for increasing the cross-drainage capacity at this location due to the limitations of tying into the existing rail formation level, tying into existing roads at level crossings and not having flood impacts downstream of the existing rail line by pushing additional flow downstream. This demonstrates that either lifting the rail formation, level crossing or adding additional cross drainage capacity would be required to achieve a 1% AEP formation flood immunity, which is not a cost-effective solution.

Table 3.1 Cross Drainage design progression

Location	70% design	100% Design
498.061	3 x 600W x 450H RCBC	3 x 600W x 450H RCBC
498.625	2 x 1800W x 600H RCBC	2 x 1800W x 600H RCBC
1/1091.DDR1	10 x 600W x 450H RCBC	6 x 600W x 450H RCBC
498.7	6 x 600W x 450H RCBC	6 x 600W x 450H RCBC
498.87	2 x 2400W x 600H RCBC	5 x 1200W x 450H RCBC
1/1092.DDR2	6 x 1800W x 600H RCBC	5 x 1500W x 600H RCBC

Proposed Mitigation Measures

Proposed mitigation to improve track flood reliance is to either construct additional earthworks above rail formation level or provide gabions or similar treatment to protect the track structure.

4. Flood risk parameters

The flood parameters requested by ARTC to allow the assessment of flood risk at this location are provided in Table 4.1 to Table 4.4. The information has been extracted at the worst location in terms depth of inundation into the ballast. Further details are provided in Figure 4-1 to Figure 4-4 with flood level plotted against time to provide a detailed picture of the flood event.

4.1 Ch497.745km to Ch497.800km

Table 4.1 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	5% AEP			
Design Formation Level or Design Flood Level (mAHD)	264.974	265.175	265.075	264.971
Submergence Depth (Max depth) (mm)	N/A	0.201	0.101	0
Velocity (m/s)	N/A	0.95	0.93	0
Duration of flooding above formation (hrs)	N/A	1.0	0.75	0

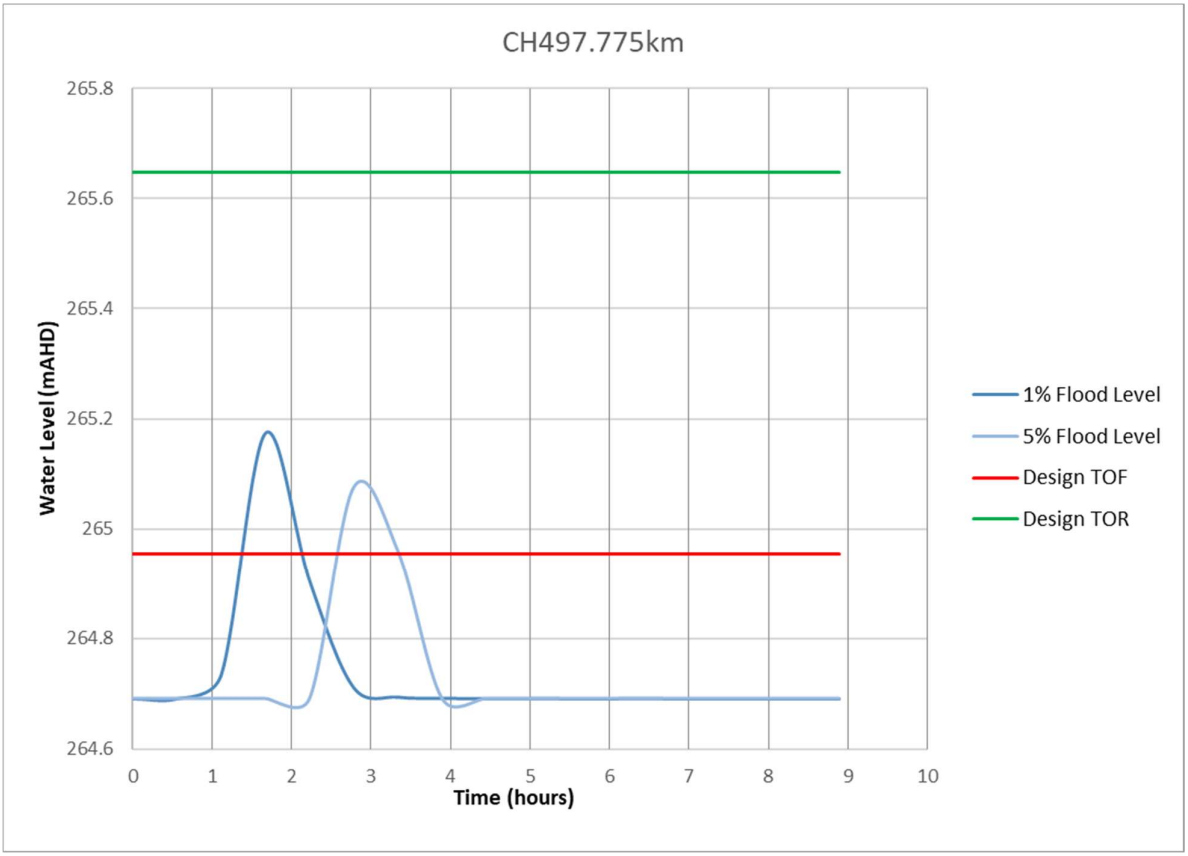


Figure 4-1: Ch497.775km

4.2 Ch498.110km to Ch498.225km

Table 4.2 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	10% AEP			
Design Formation Level or Design Flood Level (mAHD)	265.830	266.106	266.098	266.084
Submergence Depth (Max depth) (mm)	N/A	0.276	0.268	0.254
Velocity (m/s)	N/A	0.99	0.99	0.99
Duration of flooding above formation (hrs)	N/A	2.2	1.7	1.1

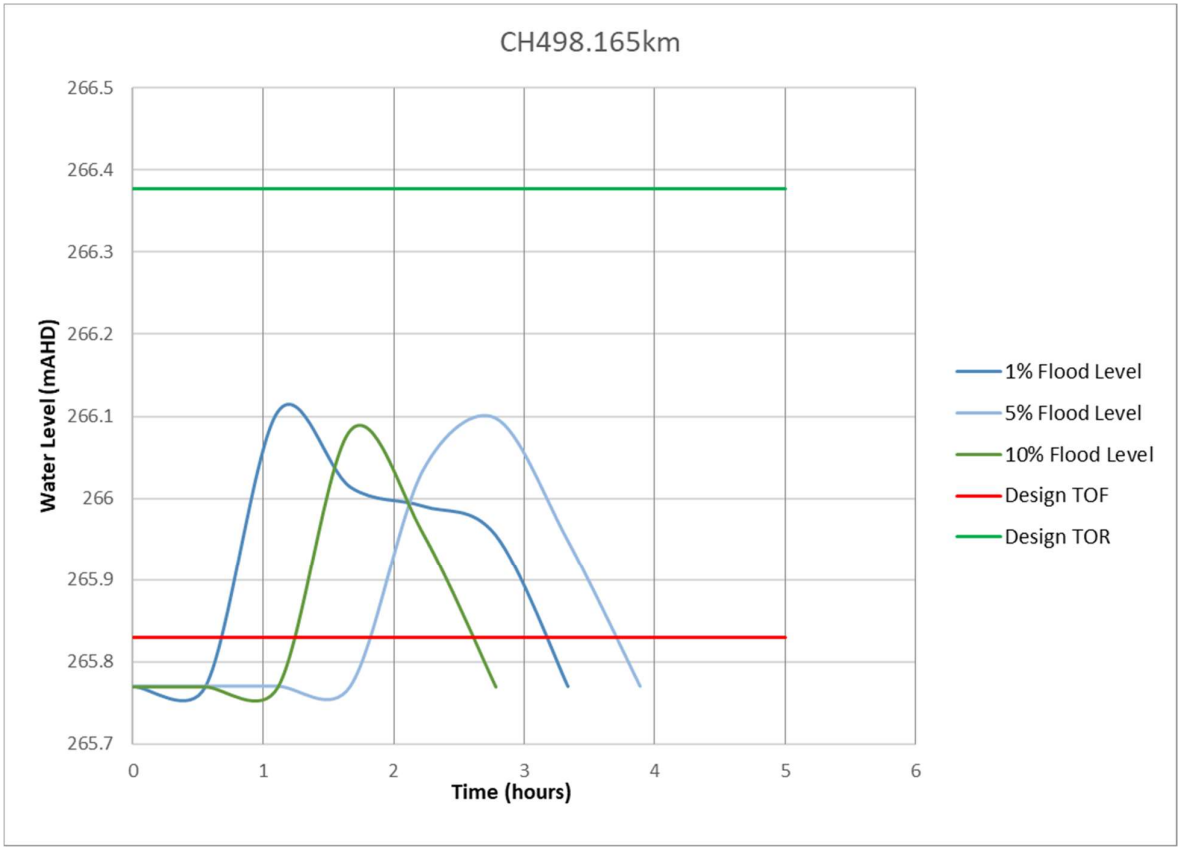


Figure 4-2: Ch498.165km

4.3 Ch498.400km to Ch498.800km

Table 4.3 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	5% AEP			
Design Formation Level or Design Flood Level (mAHD)	265.459	265.614	265.526	265.330
Submergence Depth (Max depth) (mm)	N/A	0.155	0.067	0
Velocity (m/s)	N/A	1.4	1.4	0
Duration of flooding above formation (hrs)	N/A	0.6	0.5	0

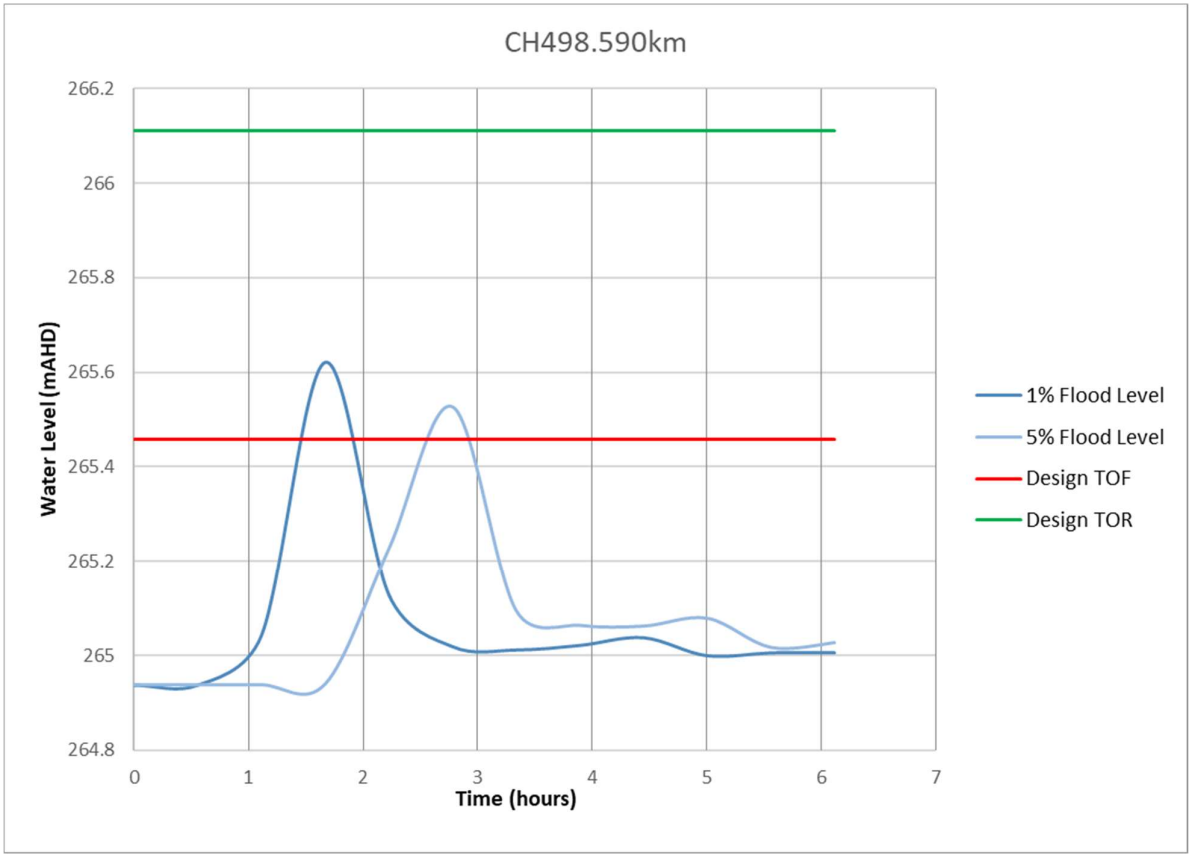


Figure 4-3: Ch498.590km

4.4 Ch498.995km to Ch499.100km

Table 4.4 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	**5% AEP**			
Design Formation Level or Design Flood Level (mAHD)	263.702	264.080	263.979	263.846
Submergence Depth (Max depth) (mm)	N/A	0.378	0.277	0.144
Velocity (m/s)	N/A	1.8	1.7	1.1
Duration of flooding above formation (hrs)	N/A	0.6	0.8	0.5

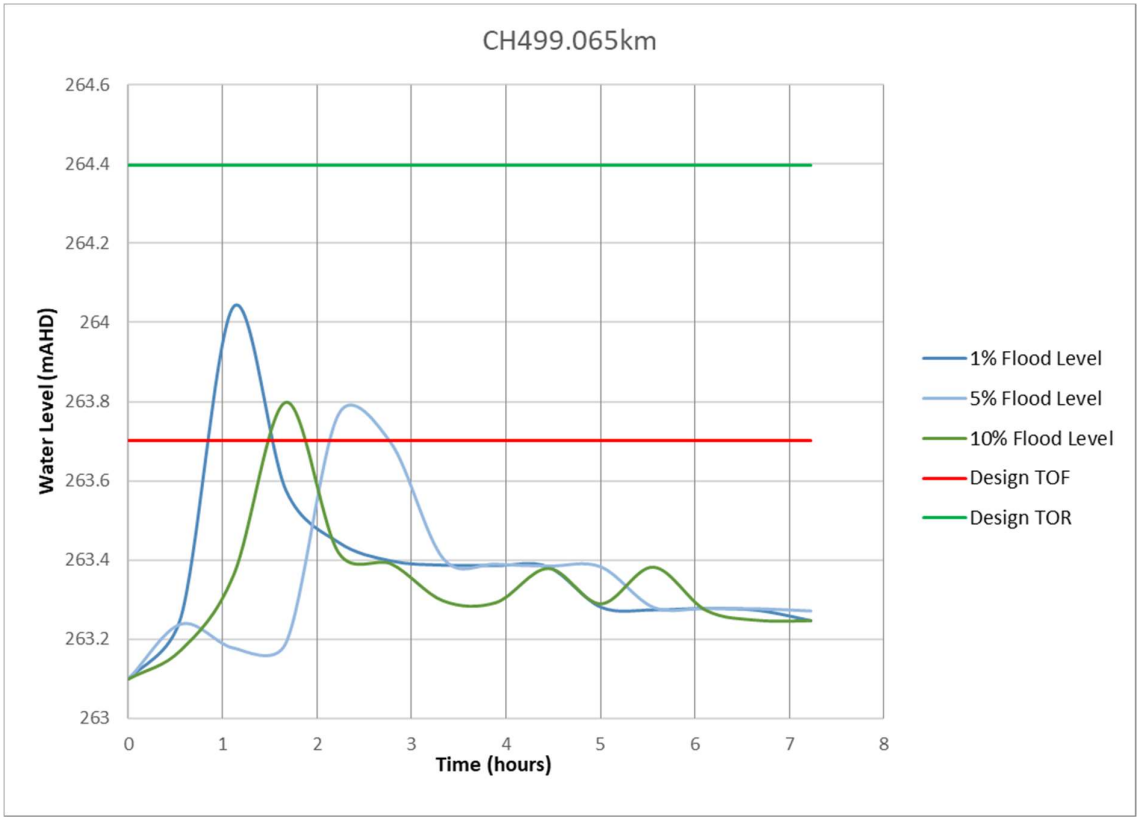


Figure 4-4: Ch499.065km

5. Conclusion

This document provides information on the non-conformance of the rail formation flood immunity at Ch497.700km to Ch499.100km. Key conclusions are as follows:

- The MCA process identified a 5% and 10% AEP flood immunity for the formation at this location. Due to constraints noted below, the formation has less than the required immunity at this location;
- The required flood immunity has not been met at this location due to the constraint posed by the tie in of the design to the Peak Hill existing siding, Level Crossing LX1091 and LX1092;
- While the required formation flood immunity is not achieved, the rail line does not overtop at this location in events up to the 1% AEP;
- Key flood risk parameters at this location for the 1% AEP event are as follows:
  - Ballast submergence depth = 378mm;
  - Velocity at top of formation = 1.8m/s;
  - Time of submergence of formation = 2.2 hours
- If the risk is deemed unacceptable then suitable mitigation measures for further investigation would include provisions of protective earthworks / gabions / other treatment to the formation where significant inundation depths and velocities occur.

Yours sincerely,

Rob Leslie

Rob Leslie
IRDJV Hydrology & Flooding Lead

IRDJV
World Square
Level 27,
680 George Street,
Sydney New South Wales, 2000
Tel: +61 7 3854 6200

Memo

Project Name	Technical and Approvals Consultancy Services: Parkes to Narromine
To	Rob Zeirzer, ARTC Project Manager; Reannan Ellaby, ARTC Design Manager
From	Daniel Blake, IRDJV Project Manager; Rob Leslie, IRDJV Hydrology & Flooding Lead; David Keane, IRDJV Flooding & Cross Drainage Lead
Subject	Rail Formation Flood Immunity Non-conformances Ch538.870km – Ch538.900km
Our Ref	3-0001-240-IHY-00-ME-0009_A
Date	Wednesday, 11 July 2018

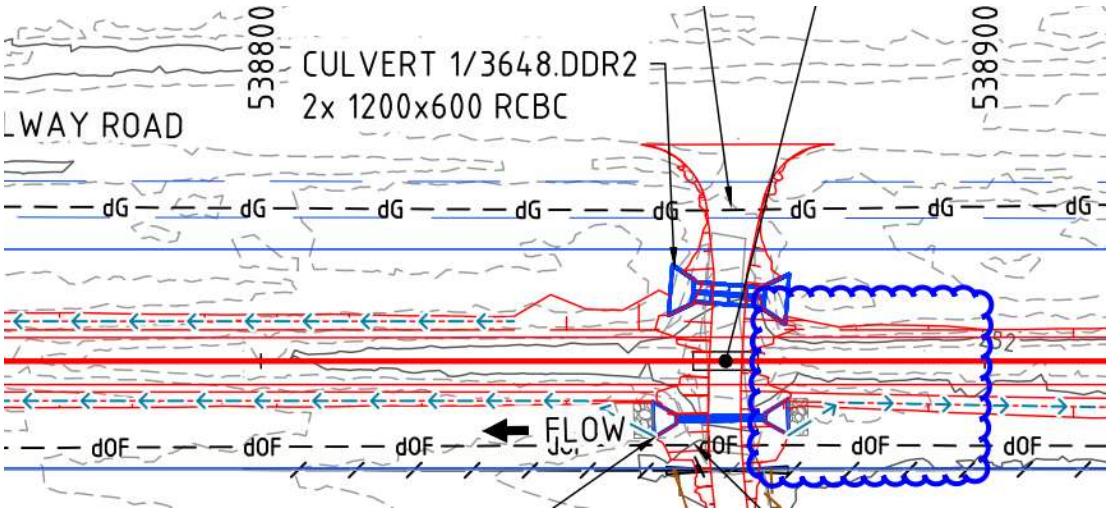
1. Introduction

At the 70% design stage, several locations were identified where the required minimum Top of Formation (ToF) design flood immunity identified through the ARTC Flooding Multi-Criteria Analysis (MCA) was not achieved. As part of the design development from 70% to 100% design many these non-conformances have been resolved. However, a limited number of non-conforming locations remain and the following memo provides a detailed description of the flood risk to the rail line and design rationale for the remaining non-conformance for one of these instances which occurs between Ch538.870km and Ch538.900km.

2. Non-conformance to required flood immunity – (Ch538.870km – Ch538.900km)

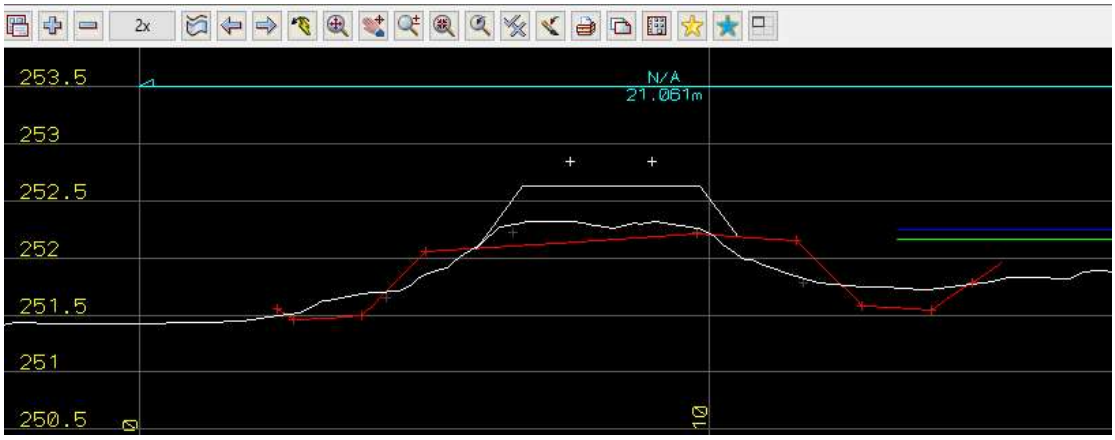
The non-conforming flood immunity occurs over 30m between Ch538.870km and Ch538.900km close to the tie in point of the project with Level Crossing LX3648 (Figure 2.1) The flooding MCA process requires the ToF level to be set to a 1% AEP flood immunity. The limitations of the rail design require a tie in between Level Crossing LX3648 and Peak Hill Railway Road meaning the rail design cannot achieve the 1% immunity level required.

Figure 2.1 Location: Extent of non-conformance denoted by blue cloud



The details of the current non-conformance at the worst-case location are provided in Figure 2.2 with a cross section of the flood levels shown against the formation design. This cross section demonstrates that the ballast is inundated but no overtopping of the rail will occur in the 1% AEP event.

Figure 2.2 Non-conforming Cross-section at Ch538.875km



Legend

Blue Line: BOG01 DES47 1AEP design flood grid

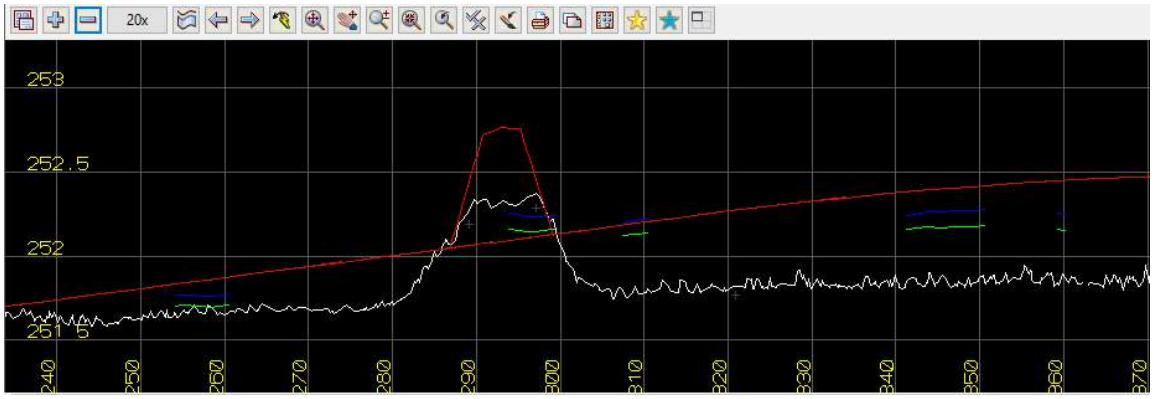
Green line: BOG01 DES47 5AEP design flood grid

Red line: Design Formation

White line: Design Ballast/Existing Topography

Figure 2.3 provides a long section of the rail formation where the non-conformance occurs across the 30m of rail alignment.

Figure 2.3 Non-conforming Long Section Profile Ch538.870km to Ch538.900km



Legend

Blue line: BOG01 DES47 1AEP design flood grid

Green line: BOG01 DES47 5AEP design flood grid

Red line: Design Formation (ToF)

White line: Existing Topography

3. Design background and rationale

Cross Drainage Design

Several design iterations have been undertaken at this location to reduce the flood levels and achieve compliance through provision of cross drainage and long drainage capacity. Table 3.1 demonstrates the increase in cross drainage tested post 70% design.

Table 3.1 Cross Drainage design progression

Location	70% design	Maximum Design Tested	100% Design
1/3648.DDR1	4 x 600W x 450H RCBC	6 x 600W x 450H RCBC	1 x 600W x 450H RCBC

The design iterations tested at this location demonstrate that increasing the cross-drainage capacity has limited impact and does provide the flood immunity required. Providing flood immunity by lifting the Rail and level crossing road level would block additional overtopping flow to the South and require more cross drainage capacity under the level crossing. This demonstrates that either lifting the rail formation, level crossing or adding additional cross drainage capacity would be required to achieve a 1% AEP formation flood immunity, which is not a cost-effective solution.

Proposed Mitigation Measures

Proposed mitigation to improve track flood reliance is to either construct additional earthworks above rail formation level or provide gabions or similar treatment to protect the track structure.

4. Flood risk parameters

The flood parameters requested by ARTC to allow the assessment of flood risk at this location is provided Table 4.1. The information has been extracted at the worst location in terms depth of inundation into the ballast. Further details are provided in Figure 4-1 with flood level plotted against time to provide a detailed picture of the flood event.

Table 4.1 Flood model results

	Rail Formation Design	1% AEP	5% AEP	10% AEP
ARTC Minimum Flood Immunity Requirement	1% AEP			
Design Formation Level or Design Flood Level (mAHD)	252.161	252.289	252.164	252.104
Submergence Depth (Max depth) (mm)	N/A	0.130	0	0
Velocity (m/s)	N/A	0.5	0	0
Duration of flooding above formation (hrs)	N/A	2.0	0	0
Length of formation inundation (m)	N/A	30	0	0

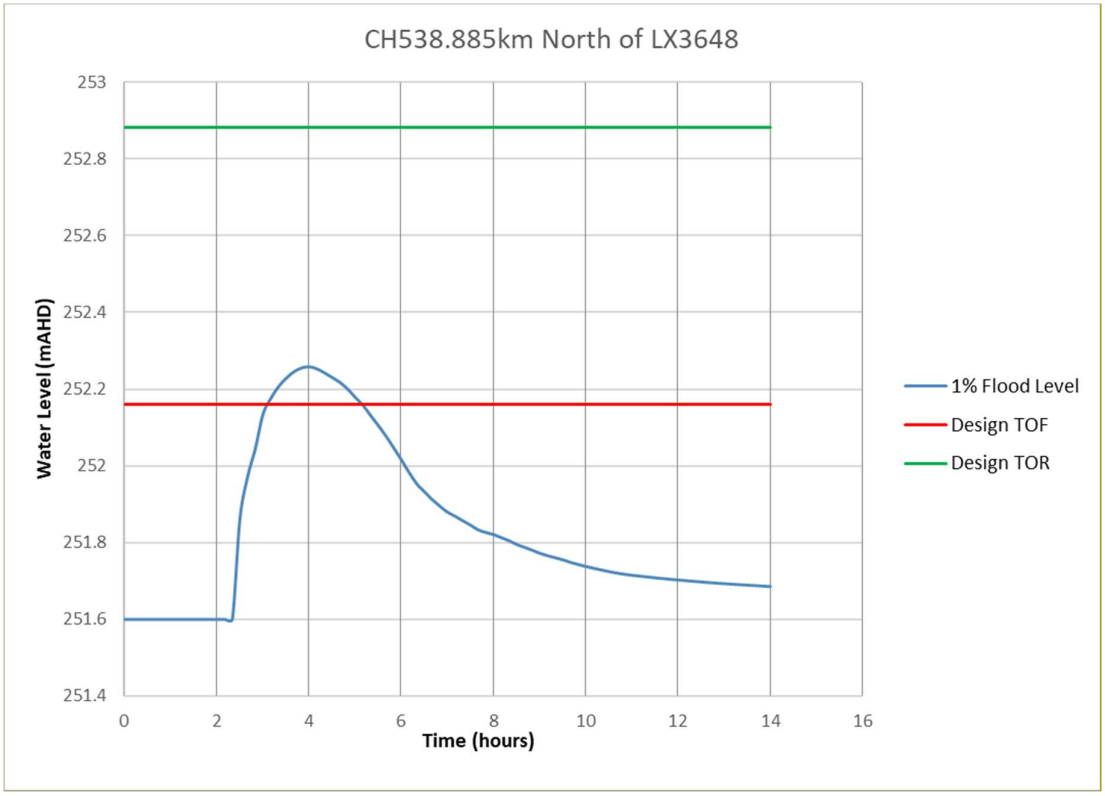


Figure 4-1: Upstream of LX3648 at Ch538.875km

5. Conclusion

This document provides information on the non-conformance of the rail formation flood immunity at Ch538.870km to Ch538.900km. Key conclusions are as follows:

- The MCA process identified a 1% AEP flood immunity for the formation at this location. Due to constraints noted below, the formation has <1% AEP immunity at this location;
- The required flood immunity has not been met at this location due to the constraint posed by the tie-in between Level Crossing LX3648 and Peak Hill Railway Road;
- While the required formation flood immunity is not achieved, the rail line does not overtop at this location in events up to the 1% AEP;
- Key flood risk parameters at this location for the 1% AEP event are as follows:
  - Ballast submergence depth = 130mm;
  - Velocity at top of formation = 0.5m/s;
  - Time of submergence of formation = 2 hours; and
- If the risk is deemed unacceptable then suitable mitigation measures for further investigation would include provisions of protective earthworks / gabions / other treatment to the formation where significant inundation depths and velocities occur.

Yours sincerely,

Rob Leslie

Rob Leslie
IRDJV Hydrology & Flooding Lead