MEMO

To:	Kevin Judd
Cc:	Paul Mitchell
From:	Nuno Jeronimo
Date:	18-10-2019
Subject:	Flygers Line Hydraulic Modelling

1. Introduction

DHI has been commissioned by the Flygers Investment Group Limited to assist in the quantification of floodplain management effects associated with the earthworks for a proposed residential development adjoining Flygers Line and Rangitikei Line.

The objective of this memorandum is to provide sufficient detail for a plan change application on the recommended solutions for floodplain management as a result of the proposed development, in order to meet the requirements of Horizons Regional Council One Plan.

Hydraulic modelling for the area was previously undertaken by Philip Wallace (2005[1] and 2008[2]) and by DHI (2015[3]). The level of spatial detail of the aforementioned projects was insufficient to perform a detailed hydraulic analysis of the residential development.

2. Standards

The following District and Regional Council documents identify the design requirements for the stormwater system for the development, which is located in a designated "floodway" (Appendix A). The main documents to consider are the Palmerston North City Council (PNCC) District Plan and the Horizons Regional Council (HRC) One Plan.

Key considerations for the design from these documents are:

- **Climate Change:** The previous standard for delineating flood prone areas of a 1% AEP event was modified to 0.5% AEP to account for the likely effects of climate change.
- **Hydraulic neutrality:** hydraulic neutrality must be achieved such that any more than minor adverse impacts of a 0.5% AEP of the design are avoided or mitigated.
- **Property Floor Levels and Flood Hazard allowances:** building sites for habitable structures must have a finished floor that includes freeboard above the 0.5% AEP flood level; and an identified safe wading zone, if not flood free, no greater than 0.5m above finish ground level and with a maximum water velocity of 1 m/s or any other combination of flood hazard which does not represent risk to human life, infrastructure of property.

[1] Flygers Line Commercial Development: 2-D Hydraulic Modelling of Flood Hazard, P. Wallace, 2005.

[2] Hydraulic Modelling of Lower Manawatu Scheme – No Stopbanks Scenario, P. Wallace, 2008.

[3] Mangaone Stream and Taonui Basin – Floodplain Hazard Assessment, DHI, 2007.

- **Design Requirements:** Design elements must comply with the NZ4404:2010 Land Development and Subdivision Infrastructure Standard. The responsibility for maintenance is part of the requirements and the flood hazard mitigation measures must address the likelihood of failing.

The Lower Manawatu River Flood Control Scheme (LMS), which includes the Mangaone Stream stopbank system, provides flood protection, in a section of the PNCC district, to a 0.2% AEP (1 in 500 year) standard. The Benmore Avenue – Whiskey Creek stopbank (as part of the LMS City Reach Flood Protection Upgrade Project), was scheduled (2018) to be upgraded to the same design standard, adjoining the Flygers Line Spillway stopbank.

3. Site Description

The site is described as Part Section 553 TN OF Palmerston North, Lot 1 DP 389924 and Lot 2 DP 389924 and covers an area of 0.4 km². The site has a steep gradient (Appendix B), with levels across the site (from northeast to southwest) between RL29.0 and RL24.5m (over 800m).

The property is impacted by two major drainage systems, the Taonui Stream from the west and the Mangaone Stream spillway from the north. The two current overland flow paths (OFP) onsite run from the Whiskey Creek drain, at the intersection of Flygers Line with Rangitikei Line. One of the flow paths, a shallow drain, crosses the property and discharges at the southern limit, below an existing dwelling; during larger storm events, the aforementioned flow path merges with a second OFP, an incised drain that runs through the middle of the property and connects, at the south-eastern end, to the Benmore Avenue stormwater network (PNCC).

The site is currently covered in pasture and it is crossed by the North Island gas transmission pipeline.

o Proposed Earthworks

The concept for the site's earthworks has been designed by Resonant and was provided to DHI as an AutoCAD format (.dwg), on the 11th January 2019 and the subsequent email dated 18th of March with additional detail (contours) on the surface model.

The intention of the proposed earthworks is to create suitable level platforms for the proposed buildings. The concept design includes 0.112 km² of earthworks, with a predominance of cut (- 20 000 m³) and reworking of the drainage across the site, particularly, a deviation of the upper section of the drain that runs through the middle of the property (between Part Section 553 TN OF Palmerston North and Lot 2 DP 389924). The earthworks are shown in Figure 1.

Some further refinement will be required during detailed design to ensure the proposed options for flood storage can be accommodated in an effective way so as not to restrict access to the buildings during a floodway or localised storm event.

The original conceptual earthworks design displaces 9,400 m³ of stormwater outside the property limit, with an increase in depth of up to 14cm (above the existing 40cm flood depth), adjacent to the Benmore Avenue stopbank, beyond the southern property limit.

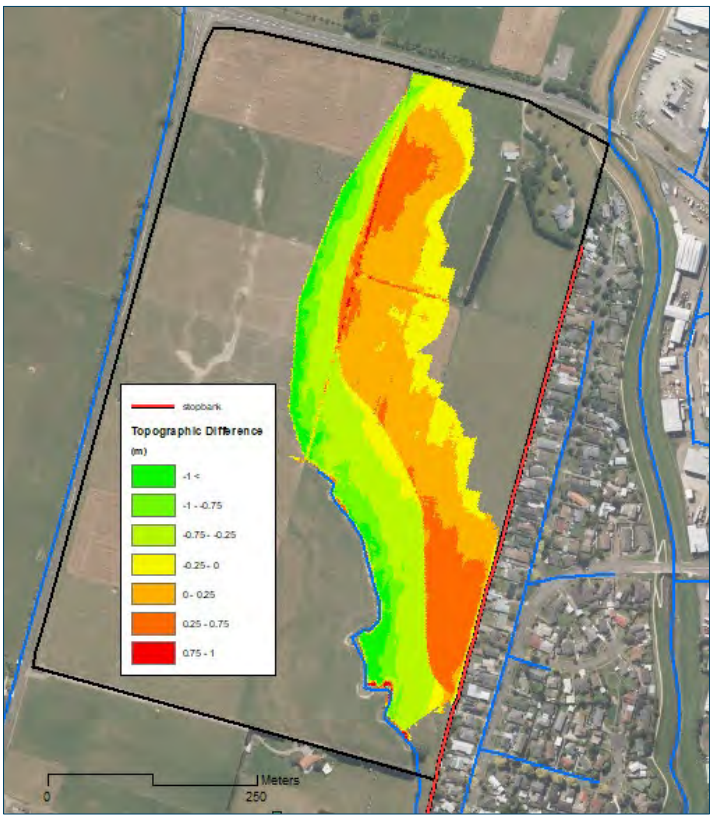

Figure 1 - Flygers Development Earthworks (original concept design)

4. Hydraulic Modelling

A MIKE FLOOD (MIKE 11 + MIKE 21) rectangular grid model of the Whiskey Creek was developed for the site, using boundary conditions from the existing Taonui hydraulic model, more specifically, flows from the 0.5% AEP Existing Development (ED) scenario.

A digital elevation model (DEM) was provided by Horizons on the 21st December 2018, the most recent information available for the study area; this 1m DEM was produced from LiDAR survey obtained in 2005, with a vertical error of ±0.5m. The DEM was combined with survey performed by Resonant on the development site to create a replica of the existing scenario. The topographical model was further refined, excluding most of the baseline survey (with a lower horizontal accuracy), and the 1m DEM was used instead onsite, enforced with the addition of stopbank survey and onsite drain/channel survey obtained by Resonant.

The topography was resampled to create a refined model of the area of interest (2m²), which defined the existing situation. The model initially extended from Milson Line/Mangaone spillway to the intersection of Whiskey Creek with Cloverlea Road (approximately); the downstream boundary was then brought closer to the site, at Rongotea Road, since there was a need to improve run times and no artificial backwater effects were created by the boundaries at the area of interest. The Mangaone Spillway is included in the 2D component of the model with the labyrinth weir raised (Appendix C).

Main culverts were added into the model, at Rangitikei Line, Flygers Line, Gillespies Line and Benmore Avenue. The information was obtained by DHI on the 25th February 2019.

Flygers baseline model follows the assumptions of the Taonui hydraulic model, but includes additional structures and a topographical resolution 12.5x higher, allowing for a better representation of linear features, which could act as blockage or preferential flow paths upstream and within the site.

5. Options Assessment

The initial assessment results show that major infrastructure assets downstream of the development site are not impacted by the development, but there is an increase of flood levels of 14cm downstream the property limit.

These initial results assumed the Flygers Line/Benmore stopbank provides the designed protection level for the 95 Benmore Avenue. Figure 2 shows an analysis comparing the stopbank levels from Horizons (1m) DEM and the surveyed info, overlayed with the Existing Development and Proposed Development levels, for the initial assessment. The graph indicates that by using the raw DEM levels (1m) or the surveyed information we should expect different flood overtopping conditions for Benmore Avenue, at the south-eastern corner of the property boundary.

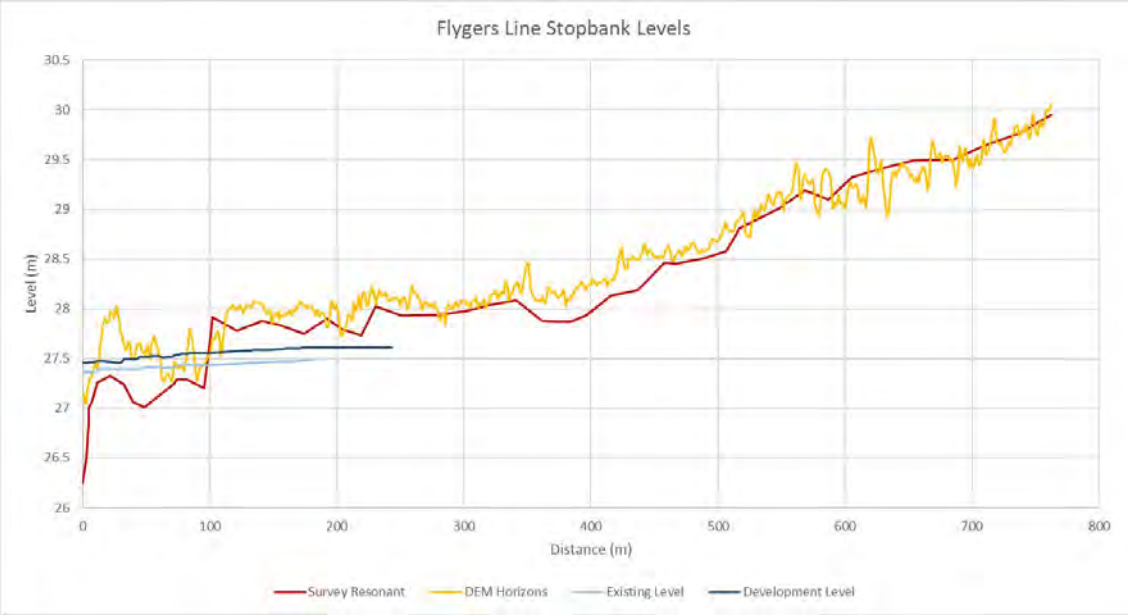

Figure 2 - Flygers Line Stopbank Levels

The initial results have highlighted the need to consider a number of Low Impact Design (LID) measures for the conveyance of Mangaone spillway floodwaters through the property site, in order to retain storage and mitigate any potential adverse impacts of the development offsite.

The options were assessed on the basis of the design principals for the site, which in summary provides for hydraulic neutrality and design requirements.

Table 1 Summary of Stormwater Options to provide attenuation for the site

Stormwater Measure	Commentary
Causeway/bund	Located at the transition between a decrease and increase in flood levels within the property, but also at the southern limit of the property. The aim was to restrict flow to pre-earthworks rates.

Stormwater Measure	Commentary
Detention Pond	A detention pond with a storage of 4600m³ adjacent to Rangitikei Line; this feature would include one outflow control of 225mm.
Swale/diversions	A series of swales were considered across the site to improve connectivity between areas of increased and decreased flood levels.
Benmore Avenue Stopbank upgrade	The stopbank elevations included in the 1m Horizons DEM are conservative and survey from Resonant has shown that it does not provide a 0.5% AEP protection to Benmore Avenue. The flood management of the Flygers site would be simplified with the stopbank upgrade.

Stormwater management from the residential development will be separately assessed, where other LID features could be considered, such as, soakpits, wetlands and permeable pavement.

Options were assessed on the basis of the design principals for the site, which in summary provides for hydraulic neutrality and design requirements.

- **Option 1 – Retention pond and island**

Based on the results of the initial assessment and the estimated volume displaced, a retention pond with a storage of 4600m³ was tested. The outflow discharge was controlled.

In addition, an island at the bottom of the property was included. This island used mostly dry land and its goal was to force flow towards the western side of the property.

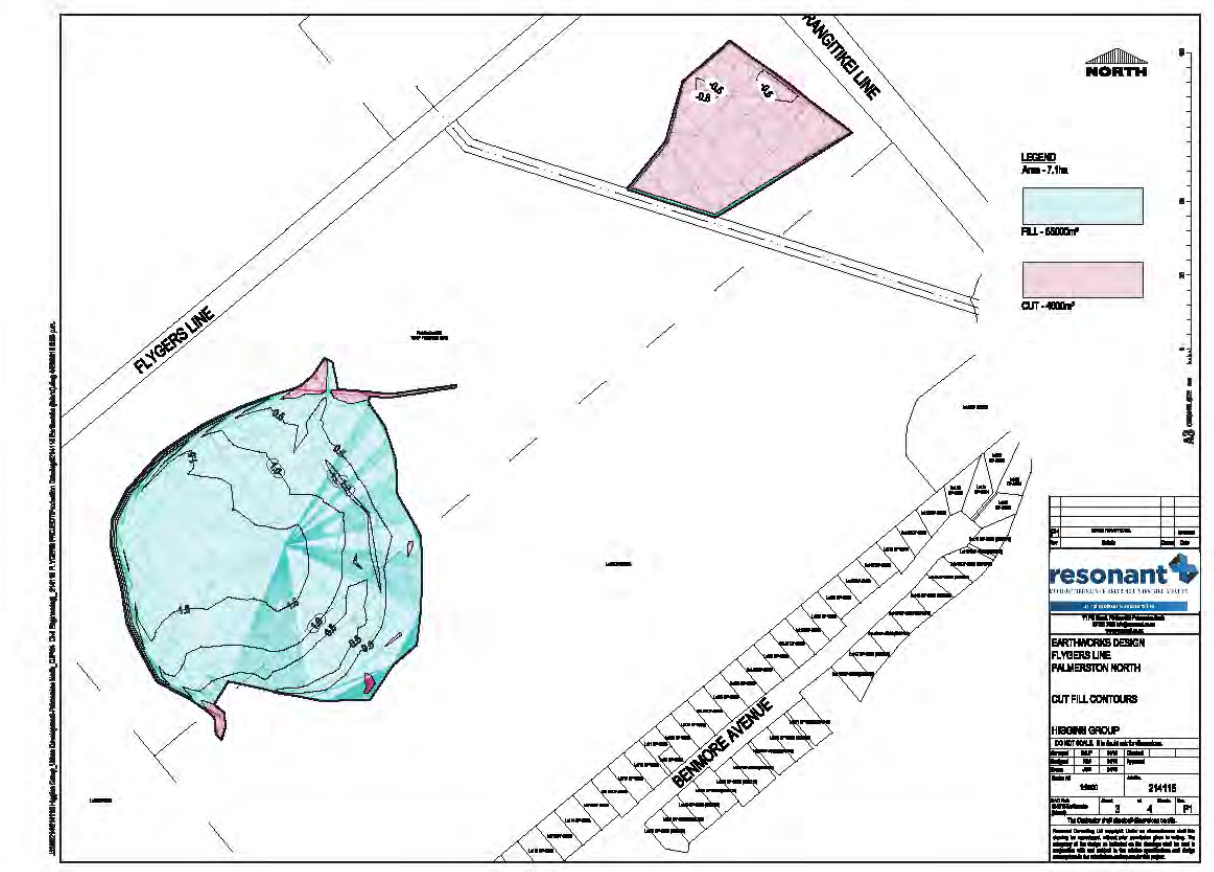

Figure 3 - Concept Design Option 1

- **Option 2 – Causeway and bund**

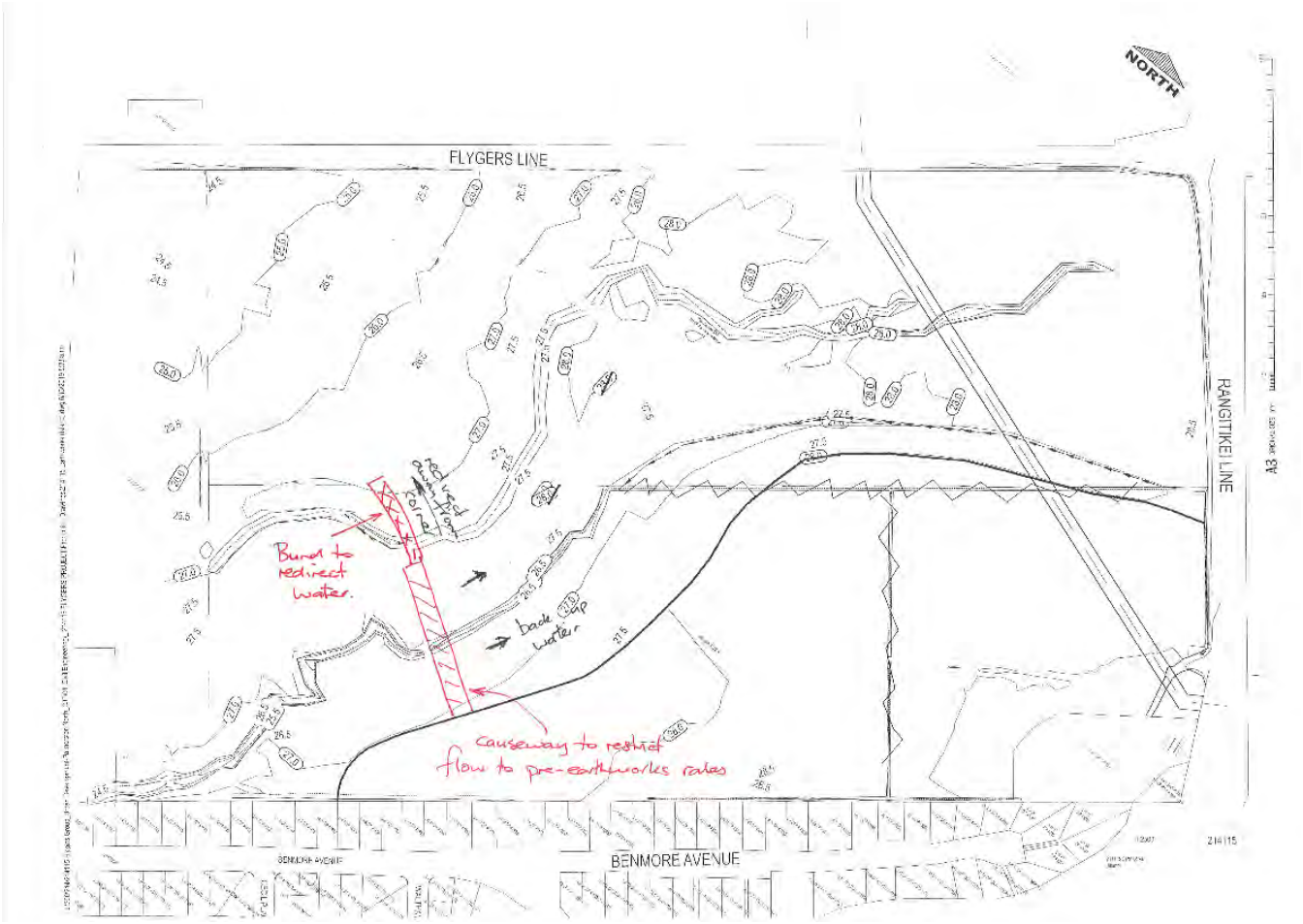

Figure 4 - Concept Design Option 3

The option two included a causeway across the main drain which would restrict flows and retain flood volumes, diverting them to Flygers Line; a bund would be placed at the western end for diversion purposes. The causeway would be placed where the effects of the original proposed earthworks started to create an increase in flood levels downstream.

- **Option 3 – Swales and bund at property limit**

Option 2 with narrowing the blockage and a bund across the property limit at RL26.5m, with two independent retention ponds (left and right bank) and a 1.35m culvert on the main drain (causeway) and improved connectivity between the main OFPs.

- **Option 4 – Online storage in dry land and increased diversion**

Option 4 would retain the main drain configuration (open), but bund the surrounding area to RL 27.5m, with one breach (2m) towards the property limit (to the east), next to the stopbank. The smaller drain, to the west, would also be bunded to 27.5m, with a single 2m breach, with the aim to throttle the flow and divert it further west.

A series of “dry” islands (hatched polygons below) would also be flattened to 27.5m, to ensure connection between the throttled area and the west.

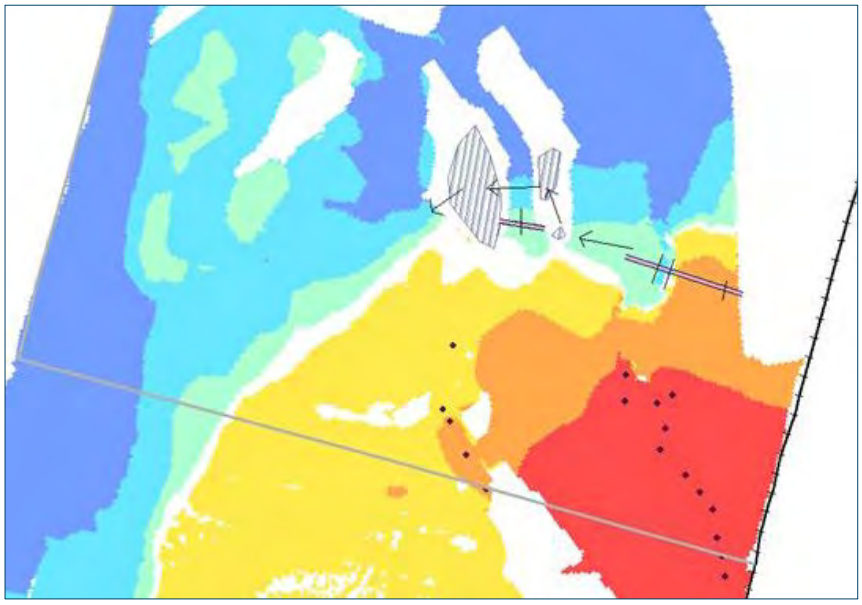

Figure 5 - Option 4 diversion mechanisms

- **Option 5 – Online and offline storage with scruffy domes**

The creation of two online ponds immediately upstream the property limit and divert flow at two locations (upstream and downstream the hollow polygons). This option would add to Option 4 by increasing the diversion towards the west, lowering the levels.

Two scruffy domes would be connected to one offline storage each to divert water once a certain threshold was reached; this scenario would work in conjunction with a bund at the property limit.

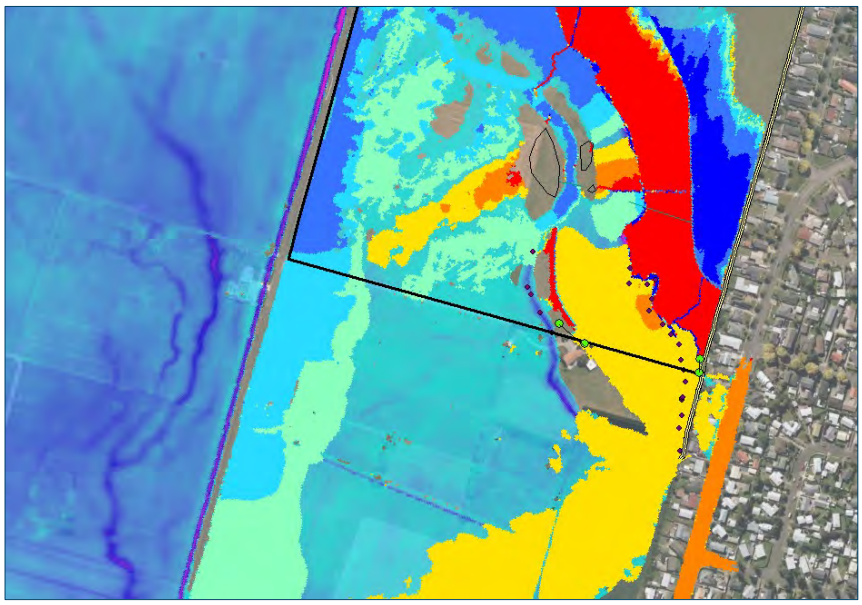

Figure 6 – Option 5 scruffy-domes (green dot)

- **Option 6 – Online and offline storages with improved diversions**

This option includes some of the features from previous options; a swale connecting the two drains (RL26.85m), and minor swales (yellow lines) connecting overland flow paths to the western side of the property via two online ponds (orange polygons). These flow paths are enforced with bunds (RL27.77m) across both drains (red line), but an opening of 2 meters. Two additional retention ponds (light green polygons) were located at the property limit to store peak flood volumes; the features are flooded from the southern end at RL27.6m (western pond) and RL27.4m (eastern pond), with an invert of RL25m.

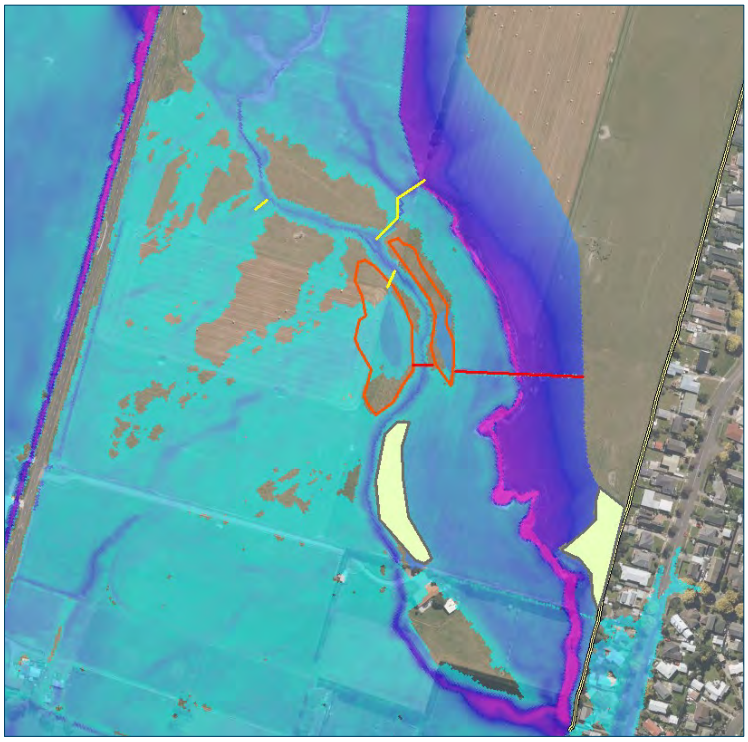

Figure 7 - Option 6 flood retention and diversion mechanisms

The following assumptions were included in all earthworks models/options:

- Land roughness is currently based on the previous Taonui model (25m coarse);
- Structures were modelled without blockages;
- The Flygers/Benmore stopbank uses surveyed levels;
- The local runoff, from the Benmore Avenue stormwater network, which drains into a Whiskey Creek OFP, was not incorporated into the model.

6. Preferred option

Option 6 is the only solution that manages the flood risk to a less than minor impact to adjacent properties. The number of measures included in this option exceed other options, but it is an example of floodplain management that focuses mainly on earthworks, rather than control structures, which are more difficult to maintain. During the detailed design phase these measures can be further refined since their individual impact was not quantified.

This preferred option allows the original design to be maintained while keeping the impact on the downstream area as minor or less than minor (±50mm change in flood level). Annex D shows the existing flood depth results, the proposed earthworks with Option 6 flood depth, level, and a difference map of flood depths between Option 6 and the existing situation.

Recommended building levels will follow existing guidelines, with an appropriate freeboard to be agreed with the HRC/PNCC.

7. References

Horizons Regional Council (2014); *Lower Manawatu Scheme & Ashhurst Stream Scheme.* Palmerston North.

Horizons Regional Council (2014); *One Plan Chapter 9 – Natural Hazards.* Palmerston North.

Palmerston North City Council (2018); *District Plan Section 22 - Natural Hazards.* Palmerston North.

Appendix A – One Plan Schedule J: Floodways and Areas Prone to Flooding

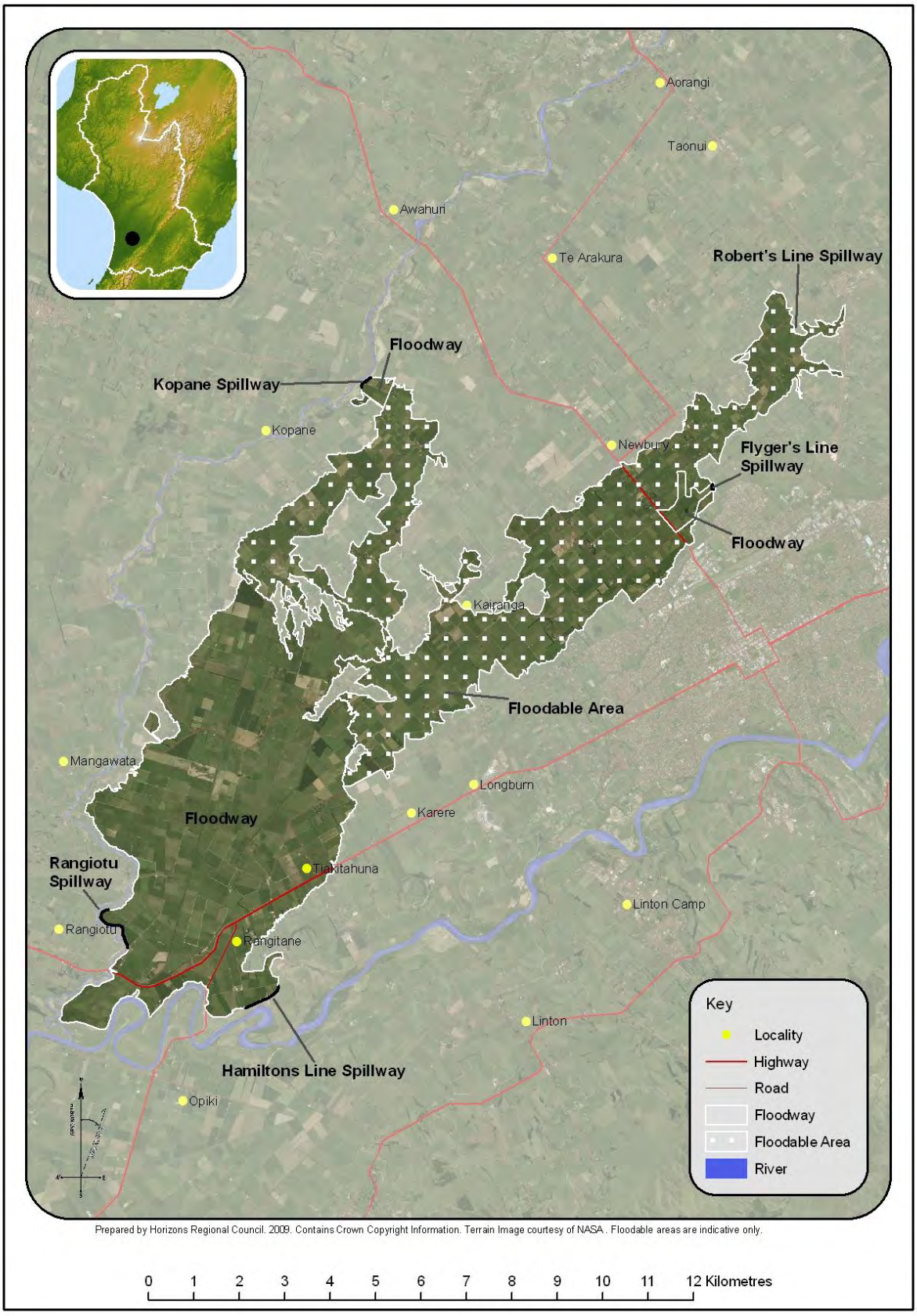

Figure J:2 Taonui Basin spillways, floodways and floodable areas

Appendix B – Existing Topography

NORTH

FLYGERS LINE

RANGITIKEI LINE

Existing Drain

BENMORE AVENUE

Part Section 553
TN OF Palmerston North

Lot 1 DP 389924

Lot 2 DP 389924

Lot 3 DP 3523

Lot 1 DP 48064

Lot 2 DP 48064

Lot 14 DP 40933

Lot 15 DP 40933

Lot 16 DP 40933

Lot 17 DP 40933

Lot 18 DP 40933

Lot 20 DP 40933

Lot 21 DP 40933

Lot 22 DP 40933

Lot 23 DP 43090

Lot 24 DP 43090

Lot 25 DP 43090

Lot 26 DP 43090

Lot 27 DP 43090

Lot 28 DP 43090

Lot 29 DP 43090

Lot 30 DP 43090

Lot 31 DP 43090

Lot 32 DP 43090

Lot 33 DP 43091

Lot 34 DP 43091

Lot 35 DP 43091

Lot 36 DP 43091

Lot 37 DP 43091

Lot 41 DP 43091

Lot 42 DP 43091 [3890847]

Lot 43 DP 43091 [3921128]

Lot 44 DP 43091 [3760539]

Lot 45 DP 43090 [3791579]

Lot 46 DP 43090 [3800126]

Lot 47 DP 43090 [3809382]

Lot 48 DP 43090 [3897928]

Lot 51 DP 43090 [3971145]

Lot 53 DP 43090 [3803251]

Lot 54 DP 43090 [3875616]

Lot 57 DP 40933 [4038109]

Lot 58 DP 40933 [3963112]

Lot 59 DP 40933 [3830779]

Lot 60 DP 40933 [3923482]

Lot 61 DP 40933 [3887889]

A3 ORIGINAL SIZE mm

100 50 25 0

Rev	Details	Drawn	Date
P1	ISSUED FOR APPROVAL		07/04/19

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EARTHWORKS DESIGN
FLYGERS LINE
PALMERSTON NORTH

EXISTING CONTOURS

HIGGINS GROUP

DO NOT SCALE. If in doubt ask for dimensions.

Surveyed	RSJP	04/19	Checked		
Designed	KBJ	04/19	Approved		
Drawn	JGR	04/19			

Scales A3: 1:2500

Job No. 214115

CAD Path: 214115 Earthworks (Island)

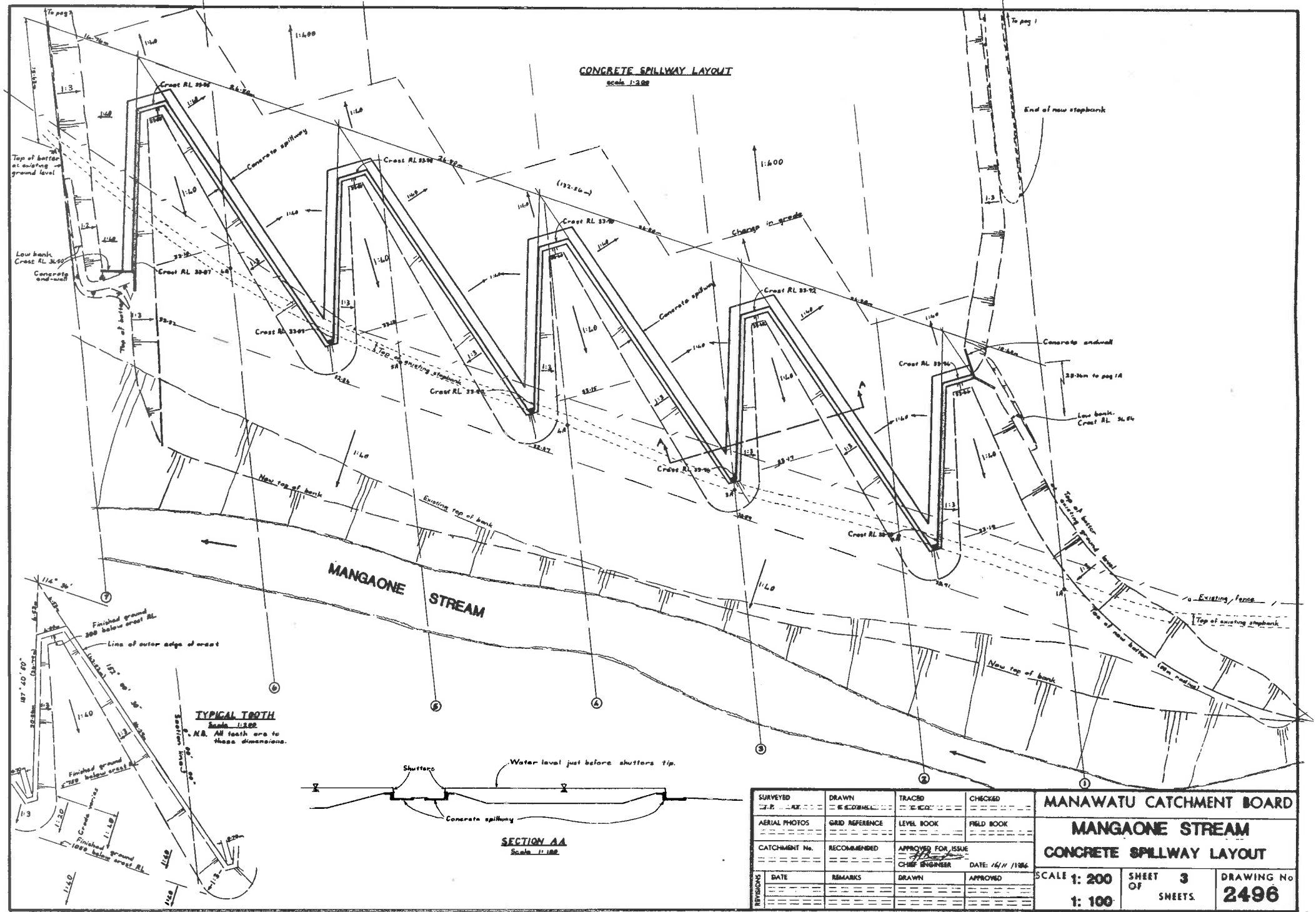
Sheet 1 of 4 Sheets

Rev. P1

The Contractor shall check all dimensions on site.

J:\200\214\214115 Higgins Group_Urban Development-Palmerston North_CJF\04 Civil Engineering_214115 FLYGERS PROJECT\Production Drawings\214115 Earthworks (Island).dwg 4/26/2019 5:52 p.m.

Appendix C – Mangaone Spillway



SURVEYED	DRAWN	TRACED	CHECKED
AERIAL PHOTOS	GRID REFERENCE	LEVEL BOOK	FIELD BOOK
CATCHMENT No.	RECOMMENDED	APPROVED FOR ISSUE CHIEF ENGINEER DATE: 16/11/1984	

REVISIONS	DATE	REMARKS	DRAWN	APPROVED

MANAWATU CATCHMENT BOARD

MANGAONE STREAM

CONCRETE SPILLWAY LAYOUT

SCALE	SHEET	DRAWING No
1: 200 1: 100	3 OF SHEETS	2496

Appendix D – Existing Development Flood Depth, Option 6 Flood Depth, Option 6 Flood Level and Difference Map (Developed O6-Baseline)

Property limit

Max Depth EG

(m)

High : 4.1

Low : 0

Notes

1. Mapped results are produced through hydrodynamic simulation utilising a 2 m x 2 m computational grid.
2. Catchment imperviousness is based on the Existing Development (ED) estimates of imperviousness.

0 250 500 Meters

DHI

Flygers Line Development - Existing Ground

Existing, 200 year-ARI: depth

200 year-ARI rainfall/river flow; 2006 climate; ED catchment imperviousness

Project No.	44801375
Prepared by	N. Jeronimo
Date	29/10/2019
Drawing Ref.	200yrExisting-Flygers Development

Property limit

Max Depth O6

Max: 4.1

Min: 0

Notes

1. Mapped results are produced through hydrodynamic simulation utilising a 2 m x 2 m computational grid.
2. Catchment imperviousness is based on the Existing Development (ED) estimates of imperviousness.

0 250 500 Meters

DHI

Flygers Line Development - Proposed Development - Option 6

Design, 200 year-ARI: depth

200 year-ARI rainfall/river flow; 2006 climate; ED catchment imperviousness

Project No.	44801375
Prepared by	N. Jeronimo
Date	29/10/2019
Drawing Ref.	200yrPD Depth-Flygers Development

Property limit

Max Level O6

(m)

- < 25.5
- 25.5 - 26
- 26 - 26.5
- 26.5 - 27
- 27 - 27.5
- 27.5 - 28
- 28 - 28.5
- > 28.5

Notes

1. Mapped results are produced through hydrodynamic simulation utilising a 2 m x 2 m computational grid.
2. Catchment imperviousness is based on the Existing Development (ED) estimates of imperviousness.

0 250 500 Meters

DHI

Flygers Line Development - Proposed Development - Option 6

Design, 200 year-ARI: level

200 year-ARI rainfall/river flow; 2006 climate; ED catchment imperviousness

Project No.	44801375
Prepared by	N. Jeronimo
Date	29/10/2019
Drawing Ref.	200yrProposed-Flygers Development

Property limit

Afflux Developed O6 - Baseline

Depth (m)

- -0.1 - -0.25
- -0.25 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25

Flood Extent O6

Notes
1. Mapped results are produced through hydrodynamic simulation utilising a 2 m x 2 m computational grid.
2. Catchment imperviousness is based on the Existing Development (ED) estimates of imperviousness.
3. Results are not mapped where the flood depth difference is less than 10 mm.

0 250 500 Meters

Flygers Line Development - Assessment of Flood Effects - Option 6

Design, 200 year-ARI: depth, Proposed Development O6

200 year-ARI rainfall/river flow; 2006 climate; ED catchment imperviousness

Project No.	44801375
Prepared by	N. Jeronimo
Date	29/10/2019
Drawing Ref.	200yrAfflux-Flygers Development