Flooding and Stormwater Issues
Proposed Spectator Events and Education Zone
Awatea Street Site

18 December 2007

David Hamilton & Associates Ltd
Consulting Engineers
3 McMillan St
Maori Hill
Dunedin 9010
New Zealand

Phone: 64 3 466 7225
Fax: 64 3 466 7227
Mobile: 021 338 555
Email: david@davidhamilton.co.nz

1. **Introduction**

1.1 The proposed new spectator events and education zone site is situated close to the Otago Harbour and has the Water of Leith on the South West side of the site. Opoho Stream is conveyed through a double-barrelled box culvert beneath the site that is land reclaimed from the upper harbour. See Figure 1 attached that outlines these features and shows the flooding threats to the proposed zone.

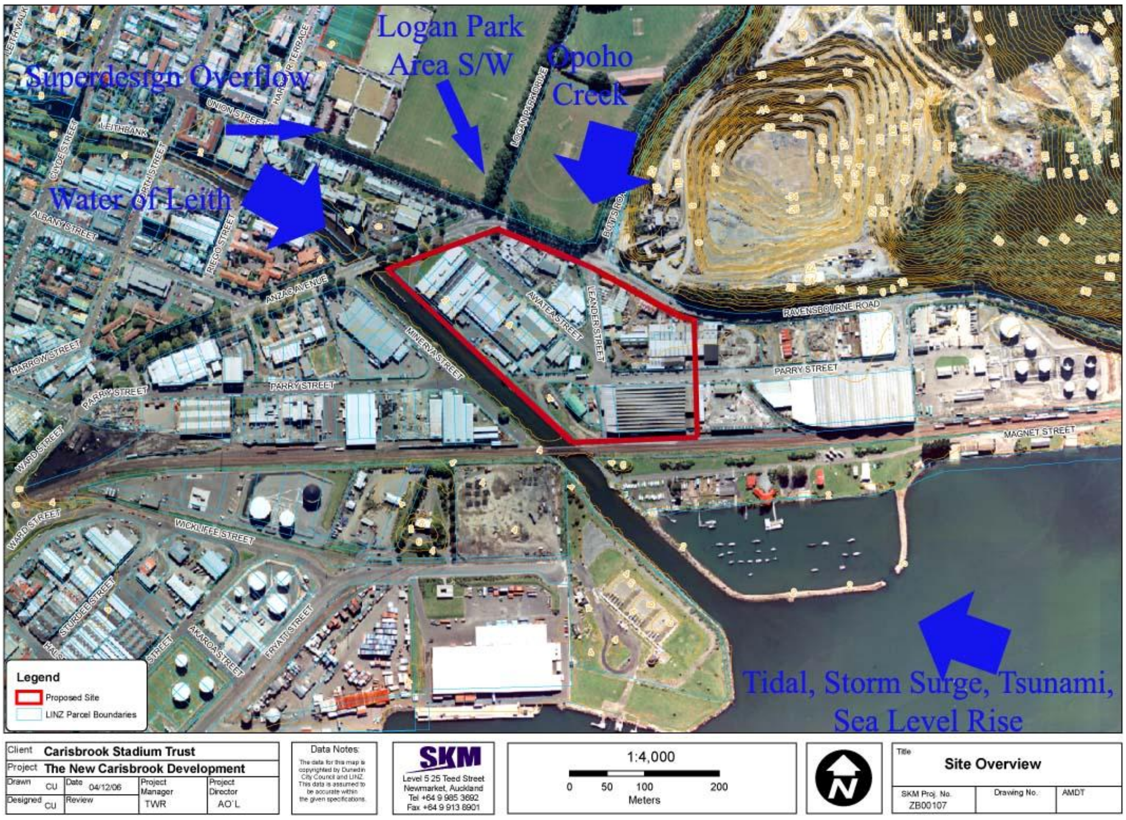

Figure 1: Site Overview Plan modified to show flooding threats

1.2 The purpose of this report is to consider the criteria for disposal of stormwater from any proposed development within the zone and to address any potential flooding risks to such development or any potential flooding risks from such development to adjacent property.

1.3 The report updates a December 2006 summary report for the feasibility study for a new stadium entitled “Flooding and Stormwater Issues – Feasibility Study – Proposed New Stadium – Awatea Street Site” report to SKM by David Hamilton & Associates Ltd. This current report now incorporates survey data that confirms the levels for the neighbouring boat harbour, railway and Logan Park areas.

1.4 The report considers the various hazards and recommends a minimum floor level.

Existing Situation

2. Waterway Design Standards
Water of Leith

2.1 The Water of Leith has been subject to a recent design review of the channel. This has been undertaken by Opus for the Otago Regional Council. The Opus report "Lower Leith Hydraulic Modelling Report" dated October 2004 details the capacity of the various sections of channel.

2.2 The catchment has an area of 45 km^2 and the design 100 year annual recurrence interval (ARI) flood event is calculated as 171 m^3/s (Log Pearson 3 type frequency distribution).

2.3 The highest astronomical tide level corresponds to a level of 101.36m (Otago datum). This equates to 1.36m above mean sea level (MSL) Dunedin.

2.4 The soffit level (underside of bridge beams) and deck level of the bridges closest to the zone, as shown in Parsons et al (2004) report, are shown as Table 1.

Bridge	Model Chainage (m)	Soffit Level (m)			Deck Level (m)
		Left Bank	Apex	Right Bank	
Forth Street (overflow channel)	636	104.13	-	104.13	105.1
Anzac Avenue	960	104.10	-	104.28	not known
South Island Main Trunk Railway Bridge	1317	102.90	-	102.90	not known

Table 1: Road bridge levels crossing Water of Leith below the Lindsay Creek confluence. Levels to Otago datum.[1]

2.5 Parsons et al assumed a harbour water level of RL101.0m. The 100-year flood was able to pass by the proposed area to be rezoned with substantial freeboard under these scenarios.

2.6 There are a number of other bridges in this reach. Table 2 taken from Parsons et al (2004) compares the actual freeboard at each bridge with the

[1] ***Part Parsons et al (2004) Table 1***

existing channel geometry against the design flood event and the recommended freeboard values. Negative freeboard values indicate surcharging on the deck beams on the upstream side of the bridge.

2.7 The freeboards as shown in Table 2 for the Anzac Ave and Railway bridges and are 2.3m and 1.8m respectively. There is potential in larger events (Parsons et al modelled 200 and 500 year ARI flood events) for some overflows above the Union and Forth Street bridges. An inspection of the terrain indicates that this would not be a major breakout. Large flood flows in the lower reaches of the Water of Leith channel past the proposed zone would also become super-critical (higher velocity) if tidal conditions are below mean sea level.

Bridge	Recommended Design Freeboard (m)	Actual Freeboard for Existing Channel (m)
Dundas St	0.6	-1.08
University Footbridge at St Davids St	0.6	-0.25
Union St	0.75	0.65
Leith St footbridge	0.9	1.26
Clyde St	0.75	-0.45
Forth St	0.6	0.00
Anzac Ave	0.6	2.30
Railway	0.6	1.80

Table 2: Summary of freeboard values for the 100 year ARI design flood event for bridges along the Water of Leith between the Lindsay Creek confluence and the harbour[2]

2.8 Figure 2 below shows the backwater profile from the Union St Bridge to the harbour. The blue dashed line in this figure represents the backwater profile in the secondary overflow channel below the Forth Street Bridge. Figure 2 is taken from Parsons et al (2004).

[2] ***Parsons et al (2004) Table 5***

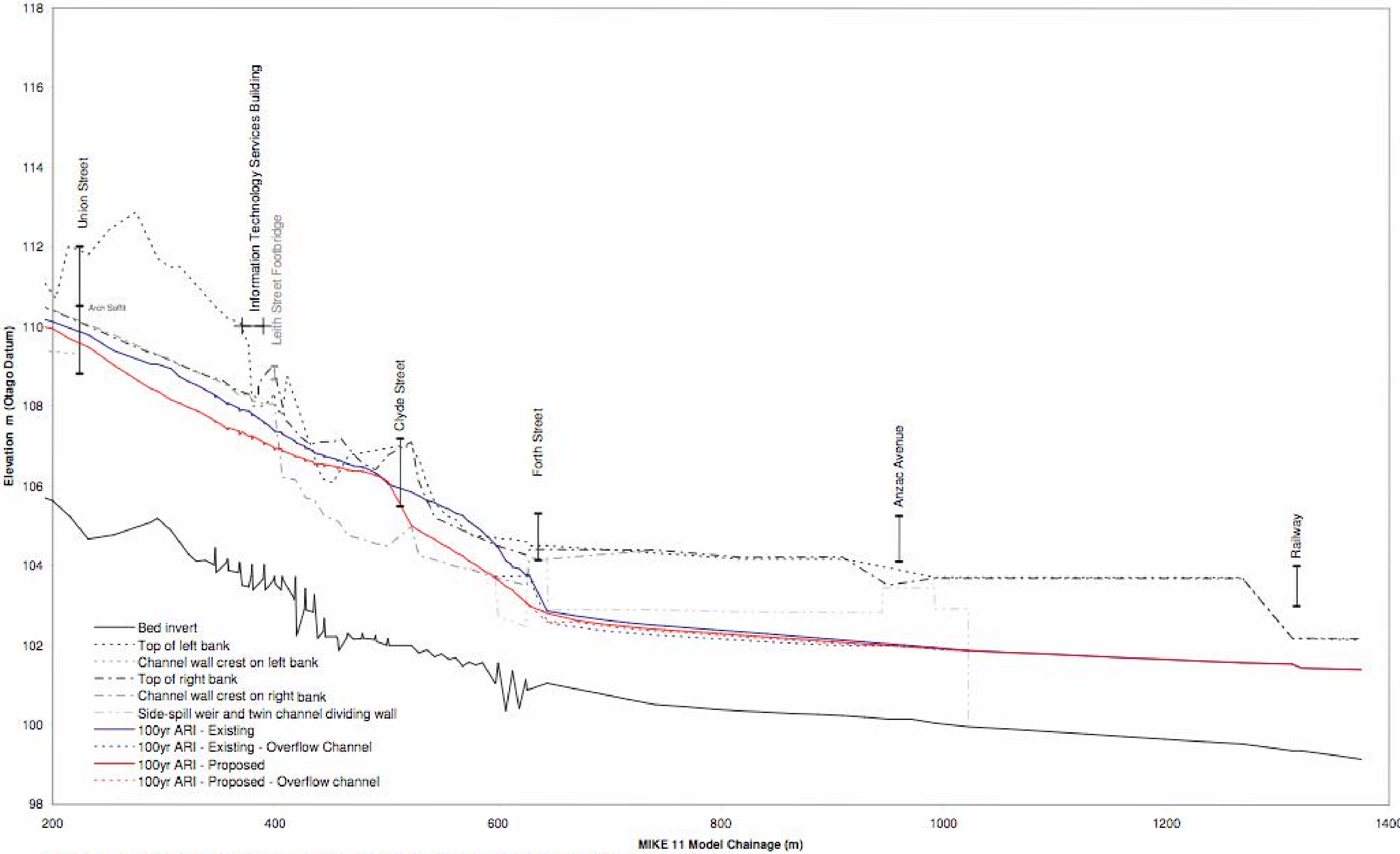

Figure 6.1a 100 year ARI flood profiles of the Water of Leith from the Harbour to the Union St Bridge

Figure 2: Longsection of Water of Leith channel showing 100 year ARI water

2.9 The existing double-barrelled culvert extends from Logan Park (corner Butts Road and Ravensbourne Road) through to the Water of Leith between the railway bridge and the boat harbour. The long section and cross section of the culvert have been provided by DCC. The plans are dated 1926 which coincides with the Dunedin Exhibition of 1925-26 that was held on newly reclaimed land at Logan Park.

2.10 Photo 1 and Figure 3 show details of the culvert inlet.

Photo 1: Photo of entrance to Opoho Creek culvert upstream of Ravensbourne Rd. Concrete wall level on right at ~RL102.6m

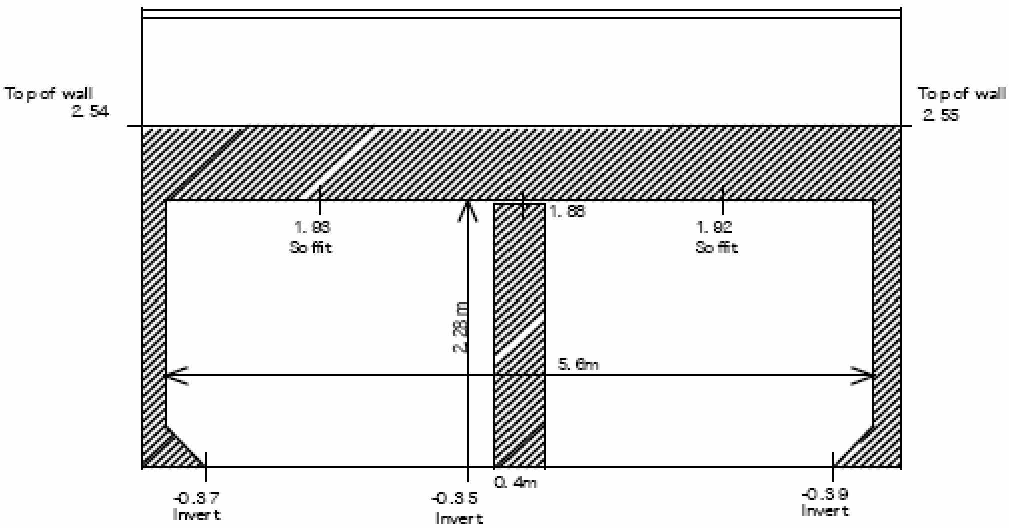

Figure 3: Opoho Creek culvert inlet dimensions as confirmed by Paterson Pitts Partners survey 2007

2.11 The culvert is 337 m (1106 ft) long and the invert gradient over most of the length is at 1 in 1000 (S=0.001). Culvert barrels are 2.59m wide by 2.285m high (8'6" wide by 7'-6" high) with chamfered corners. Total combined waterway cross section is 11.35 m^2 for this culvert.

2.12 Culvert hydraulic capacity without surcharging is calculated to be about 8m^3/s per barrel or a total of 16 m^3/s (This has assumed a roughness factor for Mannings n of 0.018 that is relatively rough for a concrete culvert but the condition of the floor and walls would need to be inspected to confirm a roughness factor. It is however expected to be conservative.). This flow is considered reasonable as the culvert is expected to have a free outfall (i.e. not submerged or drowned), as the downstream soffit is RL 101.64m (Otago datum). This is higher than the highest astronomical tide of RL 101.36m (Opus).

2.13 The sidewalls just upstream of the culvert are at RL 102.55m. The Butts Road footpath level is at RL103.0m just upstream of the culvert entrance and increases up the road to the north.

2.14 Should the Opoho Creek culvert surcharge spill could occur into Logan Park and the Union Street East area. Ground levels in Logan Park are available from Paterson Pitts Partners survey of October 2007 (appended as Appendix 2).

2.15 The Opoho Creek catchment extends from sea level up to an altitude of about 403m asl. Total catchment area is 271 ha. It is substantially rural in character but includes part of Logan Park and the Logan Park High School and a small residential area along Signal Hill Road at Opoho. Catchment cover includes pasture, native bush, scrub and gorse, and pinus radiata plantations. Soils are primarily silty clay and silt loam. The 1% Annual Exceedance Probability (AEP) design flood (Q_{100}) has been assessed as in the range 12-15 m^3/s (see section 2.3 below). The culvert is therefore of sufficient capacity for the 1% AEP event.

2.16 The floor of Logan Point Quarry on the corner of Butts Rd and Ravensbourne Road is now substantially below ground level with its own catchment. This water is pumped out to the Opoho Creek culvert from time to time though a relatively small pipe. The quarry does not need to pump at times of flooding in Opoho Creek.

3. Stormwater
DCC Stormwater Pipes

3.1 In addition to Opoho Creek there are stormwater mains running along Union Street East that collect from the Otago Polytechnic campus and residential areas as well as part of the zone and Logan Park and feed into the Opoho Creek culvert downstream of the double culvert entrance. The main size is 1500mm diameter from Union St East. The invert level is RL100.344m on the north corner of Butts Rd and Ravensbourne Rd corner. Approximate maximum flow from this culvert without surcharging is 2.0 m^3/s. Local stormwater problems do arise occasionally as shown by Photo 2.

Photo 2: Photo 10 December 2006. Ravensbourne Road looking east towards Butts Road corner

3.2 Should these stormwater mains surcharge or there be a spill overflow from the Water of Leith under super design flood conditions Logan Park playing fields can act as a temporary flood detention area. The levels of Logan Park (from Paterson Pitts Partners survey October 2007 Job Ref 11808 attached as Appendix 2) show an area of over 10 hectares with levels at RL 103.1m or lower. Parts of Logan Park are at RL 102.4 to RL 102.6m. Spill back into the Opoho Creek channel and thence through the box culvert would commence above RL102.8m. Ponding up to RL103.1m could be accommodated in the super design situation if it occurred now although sports buildings in Logan Park would be flooded. The floor levels of these buildings are tabulated in Table 6 on page 14. This would involve stormwater detention storage of more than 50,000 cubic metres.

Zone stormwater

3.3 The existing stormwater from the zone is discharged either into the Opoho Creek culvert or to the Water of Leith. This can be discharged without the need for pumping for buildings at or above ground level. Basement areas below ground level may require pumped drainage.

4. Hydrology
Flood Estimation Opoho Creek

4.1 The flood estimation methods used and discussion are appended. Two methods were used to derive the estimated design flood in Opoho Creek: Regional Flood Estimation and the Rational Method as set out in the BIA Document E1/Verification Method VM1. The Rational Method was calculated using the updated rainfall intensity figures derived by Raineffects Limited that take into account increase in rainfall intensity with altitude within the catchment. The Raineffects data also provides for climate change as recommended by the Ministry for the Environment. The Regional Flood Estimation technique makes use of historical data while the Rational Method as applied here allows for climate change impact on rainfall intensities. The outcome of these analyses is summarized in Table 3. The adopted figure of 15 m^3/s for Opoho Creek is considered suitable for any existing or proposed developments in the Zone.

Method	**1% Annual Exceedance Probability Design Flood Flow m^3/s**
Regional Flood Estimation	12 ± 3.4 m^3/s (8.6 to 15.4 m^3/s)
Rational Method	14.96 m^3/s
Adopted 1% AEP Design Flood	15 m^3/s

Table 3: Design Flood Summary

Site Stormwater

4.2 The Dunedin City updated design rainfall figures are described and graphed in the Appendix. Table 4 shows the design rainfall intensity for 10 year ARI and 50 year ARI with the associated runoff coefficient ***C*** for types of development that may occur within the zone, either now or in the future.

	10 year ARI	**50 yr ARI**
Design rainfall figure ***i*** (10 minutes)	67 mm/hr	93 mm/hr
Roof areas Runoff Coefficient ***C***	0.90	0.90
Asphalt or Concrete Paved Runoff Coefficient ***C***	0.85	0.85
Playing area if open Runoff Coefficient ***C***	0.30	0.30

Table 4: Recommended design parameters for on site works using 10 minute rainfalls

4.3 The values in Table 4 can be used with the Rational Formula provided in BIA Acceptable Solutions E1 Surface Water to determine design stormwater runoff for sites close to sea level in Dunedin.

5. Otago Harbour

5.1 NIWA (2005) has undertaken an analysis of extreme sea level based on historic events. Based on this information the 100-year extreme sea level for Otago Harbour is RL 101.90m.

5.2 Climate change impacts of 0.3-0.5m by 2100 have been recommended for mean sea level impacts. The addition of 0.5m makes the design figure for the zone for maximum water level without wave action as RL 102.4m. To this freeboard must be added. At the zone location protection is provided by:

- Boat harbour breakwater at ~ RL 102.0m that will force waves to break
- Main Trunk Railway line at ~ RL 104.1m at Leith bridge grading down to RL 102.5m directly north of the eastern breakwater on the boat harbour, to the east of the stadium boundary
- Vertical walls on Water of Leith channel crest levels at ~ RL 103.7m.

5.3 A study carried out by Tonkin & Taylor Ltd for ORC in 1997 also assessed likely tsunami risk. A far field tsunami (South America) was estimated to produce a still water tsunami level of RL 101.7m at Dunedin (allows for 0.2m climate related sea level rise and to occur at high spring tide), as there is a damping effect as a wave propagates up the harbour. The return period for such an event is 350 years for the tsunami and 4000 years for the tsunami to coincide with high tide.

5.4 It is normal practice to provide for freeboard above design water levels. Freeboard provides a safety factor including allowance for uncertainties and such things as uneven settlement of land, or wash from a boat. It is considered that a design freeboard of 1.0m should be used for the marine hazards in Otago Harbour as suitable where new buildings of a communal non-residential category are to be constructed.

6. Combined events

6.1 While a storm surge occurring at the same time as the peak discharge from the Opoho Creek culvert may occur, surcharge from such an event would spill into Logan Park as identified in section 2.2 above. The height of the Water of Leith sidewalls at about RL 103.7m will generally contain a combined Water of Leith flood and storm surge.

6.2 It is not considered necessary to carry out a rigorous analysis of the probability of a combined event as it will be a much smaller probability than the 1% annual exceedance probability (AEP) event.

7. Assumptions for Development

7.1 It is assumed that the nature of developments in the zone could lead to a high proportion of the site being developed as buildings and carparking.

Stormwater generated from within the zone can be discharged by gravity into the Water of Leith without requiring additional Dunedin City Council stormwater mains. Should basements for carparking or other uses be developed then such basements may require pumped discharge of drainage and stormwater.

7.2 Buildings to be developed within the Zone will be required to meet surface water design standards in the Building Code.

7.3 The “Approved Document for New Zealand Building Code Surface Water” issued by the Building Industry Authority at Clause E1, has requirements relating to performance:

“**E1.3.1** Except as otherwise required under the Resource Management Act 1991 for the protection of other property, surface water, resulting from an event having a 10% probability of occurring annually, and which is collected or concentrated by buildings or site work, shall be disposed of in a way that avoids the likelihood of damage or nuisance to other property.”

“**E1.3.2** Surface water, resulting from an event having a 2% probability of occurring annually, shall not enter buildings.”
[This clause applies to Housing, Communal Residential and Communal Non-residential buildings. The proposed zoning falls into the latter category – refer BIA Clause A1 Classified Uses paragraph 4.0.2 and 4.0.3]

7.4 Although Dunedin City Council building requirements for a commercial building normally would not require the 2% standard to be applied as above, the Building Industry Association definitions do apply for a communal non-residential buildings which is what university buildings and sports facilities such as a stadium are classified as.

7.5 The Otago Regional Council recommends a standard of an annual exceedance probability (AEP) of 1% for buildings on floodplains.

8. Changes Arising from Zone

8.1 The existing site is utilised for industrial type buildings that are relatively impervious. The site is adjacent to the Water of Leith with a large waterway connecting directly to the Otago Harbour.

8.2 Proposed developments are not expected to increase the stormwater runoff from the site.

8.3 With the site being immediately adjacent to the Water of Leith it would be possible for all stormwater from the site to be discharged directly to that channel without utilising existing stormwater drains.

8.4 A spectator events and education zone is expected to have fewer water quality discharge issues for stormwater to the Water of Leith and Harbour than an industrial zoning. Until the exact nature and extent of buildings, carparking and open space is known this is difficult to quantify.

8.5 Impacts from the development on other properties in relation to surface water from the Water of Leith and Opoho Creek are not expected as the original design capacities of the channels are adequate. Local Logan Park area stormwater outlets will not be compromised by the proposed zone.

8.6 The opportunity with a redevelopment is to ensure that surface water flooding issues, storm surge and tsunami impacts from the sea and local stormwater issues are appropriately addressed.

9. Mitigation

9.1 In order to ensure that new development takes into account the current knowledge on coastal impacts and climate change it is recommended that minimum floor levels be established for new buildings that are required to meet the Building Code Surface Water standard.

9.2 The following Table 5 summarises the information for surface water flooding threats identified above.

Hazard	Design WL RLm (Otago Datum)	Recommended freeboard m	Recommended Minimum floor level based on threat RL m (Otago Datum)
Water of Leith Q100 level at Anzac Ave	102.0	0.6	102.6
Opoho Creek culvert inlet design flow Q100	102.0	0.6	102.6
Potential surcharge in Logan Park if Leith water exits left bank upstream, Opoho Creek culvert surcharges, or local stormwater pipes surcharge in super design event	103.1	0.6	103.7
Otago Harbour Storm surge incl 0.5m climate change	102.4	1.0	103.4
Otago Harbour Tsunami incl 0.5m climate change	102.0	1.0	103.0

Table 5: Derived minimum floor levels from different hazards (Otago datum)

9.3 Existing floor levels for sporting facilities at Logan Park are shown in Table 6 for comparative purposes.

Sporting building at Logan Park	Ground floor level (RL m Otago datum)
Hockey	102.57
Rugby changing sheds	102.74
Bowling Club	102.87
Cricket grandstand	102.86
Recreational Services	102.83

Table 5.2: Comparison with floor levels of sports buildings at Logan Park (source PPP)

9.4 A minimum floor level of RL 103.7m = 3.7m above MSL Dunedin is recommended for communal non-residential buildings in the proposed zone. This is considered sufficient to provide a freeboard of at least 0.6m for floods of an annual exceedance probability of 1% from all the various sources. Such a floor level would also permit gravity drainage to the Water of Leith for local stormwater.

9.5 This level is below some of the existing ground at the site and assumes that if this minimum level is used that site work will provide adequate site drainage for on-site stormwater. A higher floor level can of course be used.

10. Conclusion

10.1 The proposed spectator events and education zone is on land that was reclaimed about eighty years ago. Provisions for stormwater from Opoho Creek and the Logan Park area made at the time are still satisfactory. The Water of Leith channel adjacent to the site has a large capacity over this section and a sufficiently high concrete wall to contain flood flows and predicted realistic storm surges or tsunami effects. Proposed developments will produce similar site stormwater runoff to that existing and this can be channelled directly through existing outlets or through new outlets directly to the Water of Leith.

10.2 The creation of a new zoning for spectator events and education purposes does not increase the potential flooding threat to other properties.

10.3 A minimum floor level is recommended at 3.7m above mean sea level, for buildings that are required to meet the Building Code surface water criteria.

Acknowledgements

Acknowledgements are made to:

Pascal Balley of Otago Regional Council
David Dewhirst and Melanie Stevenson of Dunedin City Council
David Stewart of Raineffects Ltd
Tom Halpin of SKM
Paterson Pitts Partners for survey data

References

David Hamilton & Associates Ltd (December 2006) "Flooding and Stormwater Issues – Feasibility Study – Proposed New Stadium – Awatea Street Site" report to SKM

David Hamilton & Associates Ltd (June 2006) "Otago Regional Council Hydrologic & Hydraulic Guidelines", 49p.

McKerchar, A I and Pearson, C P (1989). "Flood Frequency in New Zealand". Publication No.20 of the Hydrology Centre, Division of Water Sciences, DSIR, Christchurch, 87p.

Parsons, T G, Webby, M G and Blyth, T "Water of Leith from Botanic Gardens to Otago Harbour Hydraulic Modelling Report" Opus for ORC. Oct 2004, 72p.

Stewart, D (December 2006). Method for Calculating Rainfall Intensity and Duration Values for the Greater Dunedin City Area. Part 1 Method Development. Part 2 Method Application. Raineffects Limited for DCC.

Tonkin & Taylor Ltd (June 1997). "Otago Region Tsunami and Storm Surge Study Final Report" for ORC.

Webby, M G, Blyth, T and Parsons, T G (January 2005). "Water of Leith and Lindsay Creek Design Philosophy for Achieving Minimum Design Flood Standard". Opus for ORC. 129p.

Wild, Bell & Walsh (NIWA 2005) "Otago Extreme Sea Level Analysis"

Appendix 1: Hydrology

A.1 Local hydrological data

ORC provided this tabular data (Table A.1) in their Hydrologic & Hydraulic Guidelines, 2006. Only the closest relevant catchments are shown.

Otago Region Hydrological Sites Mean and Median Annual Floods							
Siteno	**River**	**Sitename**	**Map Reference NZMS 260**	**Mean Annual Flood m3/s**	**Median Annual Flood m3/s**	**Catch-ment Area km2**	**Mean Annual Flood as Specific Discharge m3/s/km2**
73105	Waikouaiti Sth Br	Lawsons	I43:196044	47.9	46.4	74.1	0.65
73501	Leith	University Foot Br	I44:169798	46.4	47.3	45	1.03
73507	Lindsays Ck	North Rd Br	I44:176811	12.2	11.8	11.7	1.04
74324	Silverstream	Taieri Depot	I44:021783	61.9	65.7	92	0.67

Table A.1: Local hydrological stations summary data

Based on these figures one would expect a mean annual flood for the Opoho Creek to be about 1.3 to 1.5 $m^3/s/km^2$ or 3.6 to 4.2 m^3/s for the catchment area to the Opoho Creek culvert entrance. A figure of 4 m^3/s is adopted as the mean annual flood to be used for the purposes of calculation of the design flood using the regional flood estimation technique.

A.2 Regional Flood Estimation

Regional Flood Estimation (McKerchar & Pearson "Flood Frequency in New Zealand") Figure 4.9 shows a $q_{100.}$ ratio of 3.0 $\pm$ 28% for the 1% annual exceedance probability event (AEP). This would give a 1% annual exceedance probability (AEP) flood event, Q_{100} of 12 $m^3/s \pm 3.4\ m^3/s$ or between 8.6 m^3/s and 15.4 m^3/s.

A.3 High Intensity Rainfall Design Figures

A.3.1 Time of Concentration

The duration of the rainfall event to choose should match the time of concentration for the catchment. This is the time for water to travel from the farthest point in the catchment to the site of the modification. Its determination requires knowledge of the catchment characteristics (channel slope, flow length, catchment area, elevation difference) and can be calculated by a number of methods (Ramser-Kirpich, Bransby-Williams, US Soil Conservation Service, Nomographs). BIA Document E1/Verification Method VM1 includes two of these methods.

A time of concentration of 30 minutes has been adopted for the catchment to the entrance of the Opoho Creek double-barreled culvert under the proposed zone.

The Building Industry Authority method states that the minimum time of concentration that should be used is 10 minutes.

A.3.2 Raineffects Ltd Update for DCC

Following high intensity rainstorms in February 2005 and April 2006 the DCC has sought an update for rainfall intensity design curves for Dunedin. Raineffects Limited has undertaken this work.

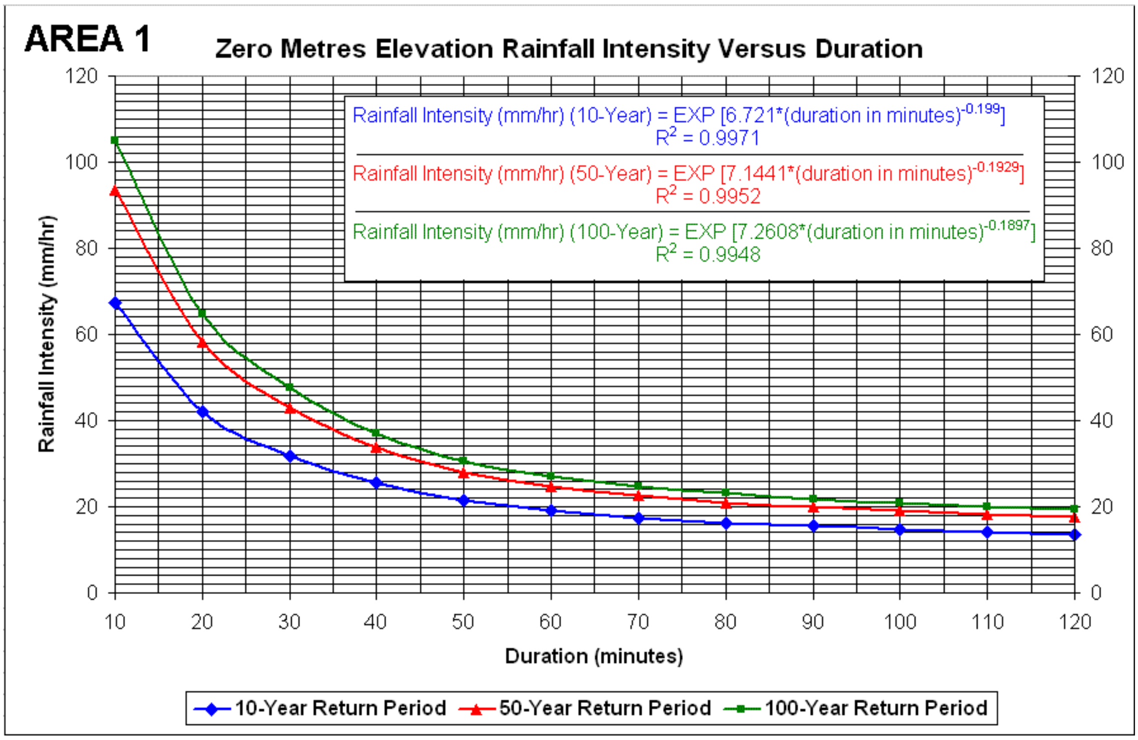

Figure A.1: The 10-minute 50-year rainfall intensity is 93mm/hr. The 10-minute 10 year local stormwater design figure is 67 mm/hr

The design curves for sea level Dunedin are shown as Figure A.1. The methodology uses a series of graphs for different elevations. It makes provision for increased intensities associated with climate change. This methodology has been published and is available from the DCC ("Method for Calculating Rainfall Intensity and Duration Values for the Greater Dunedin City Area" Prepared for Dunedin City Council by David Stewart Raineffects December 2006. Part 1 Method Development. Part 2 Method Application). This data has been used to derive a design flood using a second method as a comparison with the Regional Flood Estimation technique.

A.4 Design Flood Standard Opoho Creek - Rational Formula

The derived 1% AEP (Q_{100}) design flow for Opoho Creek using the Rational Formula and the new DCC rainfall intensity curve method for average catchment rainfall intensity yields a flow of 14.96 m^3/s, say 15 m^3/s. This compares reasonably with the Regional Flood Estimation technique. The Regional Flood estimation technique is based on historic data approach whereas the new high intensity rainfall curves for Dunedin City make an allowance for climate change higher intensity rainfalls as recommended by the Ministry for the Environment.

Figure 4: Survey information from surrounds of Stadium site by Paterson Pitts Partners October 2007