Davie Lovell·Smith

INFRASTRUCTURE REPORT FOR PROPOSED PLAN CHANGE, LIFFEY SPRINGS
June 2008

1. Introduction

This report addresses the future infrastructure servicing of Lot 1 Deposited Plan 388824 and held in Certificate of Title 355094. The property is approximately 28ha in size. The site has been recently used as an orchard. The site is relatively flat but dominated by numerous windbreak hedgerows. The property also contains a residential house and numerous out buildings. This residence is not connected to the Lincoln urban infrastructure. The house and out-buildings will be removed as part of the construction.

Edwards St bounds the site to the north, while to the west is the residential subdivision known as Lincoln Dale. The remainder the site is bounded by rural land. To the southwest is the LI Creek, while on the southeast is the LII River. The source of the LII is a substantial spring, located on the eastern boundary of the site.

It is proposed that the property be rezoned for residential and business purposes. The proposed rezoning would provide for approximately 5500m^2 of Business 1 land and approximately 200 residential sections, together with large reserves areas and the appropriate roading.

2. Water Supply

When developed, the area will reticulate into the existing Selwyn District Council system. This will include a connection to a blank end on Edward Street and provision for a future connection across the Zeestraten land to a pipe crossing underneath Liffey Stream from Lincoln Dale to Ryelands.

The water supply system will be sized to meet the flow and pressure required by the New Zealand Fire Service Code of Practice. Hydrants will be placed at the required intervals. It is expected that a network analysis will be carried out to prove flows as part of the engineering approval.

It is understood that if a development requires more water than is currently available within a community water supply scheme, then the Selwyn District Council usually installs a new bore and water is abstracted into the general reticulation for the township in question. Water management for individual allotments will be examined at the time of subdivision consent.

3. Stormwater

Recent experience on neighbouring sites has shown us that there is the very occasional area of gravels suitable for discharge of stormwater to ground. However, it is most likely that these types of gravels will be unavailable. Stormwater will therefore need to be treated, stored and discharged appropriately to the LII River.

Depending on the timing of the release of the Integrated Catchment Management Plan for Lincoln and the associated global discharge consent, the area may require Discharge Consent from Environment Canterbury. The proposed system involves the reticulation of stormwater down the centre of the main spine road. The stormwater will then be piped to a first flush pond at the southern end of the site. From here the stormwater will then flow through into a retention pond prior to discharging into the LII River.

The first flush pond is sized to contain the first 25mm of rainfall off the impermeable areas of the development. This design is in accordance with the Christchurch City Councils "Waterways Wetlands and Drainage Guide". The stormwater will be filtered through a layer of permeable media prior to being discharged to the retention pond.

The retention pond will be excavated to a depth of 1.5m below the watertable. This is a considerable excavation but this depth is required to ensure that the pond does not become overcome by weed. It is expected that the material removed will be greater than the additional volume of water required for storage resulting from additional runoff. Our sub consultants URS Ltd have confirmed that stormwater treatment area provided is of sufficient size to provide for the treatment and detention of stormwater from both the Liffey Springs development and any future development of 'Zee Straten' land to the west. (Attachment A)

The discharge from the pond to the LII River will be controlled to replicate existing runoff flows. The control will be in the form of a throttled pipe.

All secondary flow will empty onto the streets, gravitate along the streets to the lowest point of the site and into the immediately adjacent first flush pond. In the case of extreme storm events, the ponds will fill before overtopping an armoured spillway into the LII River. As we expect the retention storage volume to be greater than what is required we would expect that under extreme storm conditions the LII River will actually backflow into the retention pond and assist in local flood relief. In short, the retention pond proposed will improve the existing flood hazards.

It is expected that the site will have a relatively high water table. Consequently it is expected that there will be extensive dewatering of the roads by subsoil drainage. This water will be directed to the retention pond as it will be clean and the continual flow will help with the ponds water quality.

The stormwater concepts have been formulated in association with Landcare Research and the Lincoln Envirotown Trust. The use of the swales, first flush treatment and retention are considered to be in keeping with the general principles of Low Impact Design and waterway protection.

4. Sewage

A concept design for the site provides for a single sewage pumping station at central position of the site. This pump station is in accordance with the draft Lincoln Structure Plan. The pump station will be sited and designed to incorporate a gravity system of pipes servicing all of the proposed development lots. The pump station will connect via a rising sewer main to the Lincoln Dale pump station. The rising sewer is to be laid in the proposed roading infrastructure to the narrow pedestrian access linking into Lincoln Dale. From here the rising sewer will pass through an existing duct pipe under Perthshire Crescent to the existing reserve and adjacent Lincoln Dale pump station. As the walkway between Lincoln Dale and the application site has been vested in Council as Recreation Reserve, the approval of the Department of Conservation will be necessary for any easement to provide for this connection.

The Selwyn District Council has confirmed that there is a capacity issue with the treatment plant and disposal via the pipe to Christchurch. We are currently working through this matter with Council staff. It is noted that once the capacity issue has been addressed there will likely be a requirement for an upgrade of the Lincoln Dale – Treatment Plant rising sewer main. As described in our recent report to the Selwyn District Council regarding the progressive upgrading of the sewer system, it is proposed that the length of 100mm rising sewer pipe in Ryelands be abandoned and a new link be made. The Selwyn District Council has recently laid a new rising sewer pipe from the treatment plant to the LI Creek. It is proposed that this pipe be connected to the existing 150mm pipe in Lincoln Dale. It is also expected that the pumps in the Lincoln Dale Pump Station may need to be reconfigured to meet the new flows and pipe headlosses.

Alternatively, Council may wish to consider a direct pumping line from the proposed development, under the LI Creek, to the recently laid council main.

All infrastructure will be constructed in accordance with recognised standards. The trenching is expected to be predominantly in silts and clays and where these trenches coincide with a road they will have a full depth of granular backfill. All sites will be serviced with a gravity sewer connection to 1m inside the net area of the property.

5. Roading and Access

The road and carriageway widths will comply with the SDC District Plan with the exception of the main spinal route, which has a wider width. The pavement depths will be designed to suit the soil conditions. The kerbs in the cul-de-sacs are to be full upstand kerbs to allow for kerb adaptors. The other streets will have the standard SDC mountable kerb. The surface of the road will be asphalt. Some roading features such as thresholds, intersections and Cul de sac heads may be surfaced with cobblestones or other suitable materials.

The main access to the site will be from Edwards Street, which will require some road widening in the vicinity of the intersection. This road widening would simply be splays similar to that being utilised at Lincoln Dale and some widening on the opposite side of the Edward St.

The main route along the centre of the proposed development will be a split carriageway grading to a swale along the central islands. This method of Low Impact Design has been utilised successfully on a number of projects. The swale will be gentle enough to mow easily and will be interspersed with landscaping.

The site is relatively flat, but does have a slight fall in places. To ensure that the entire site drains to the stormwater ponds, the road along the LII River has had to be graded at 1in 500. This grade is considered to be the absolute minimum and every effort will be made in the detailed design to ensure the grade is improved.

The 50kph speed restriction zone has recently been moved to the west of the site and the associated traffic calming was constructed as part of Lincoln Dale. Sight lines from the entrance to the development are clear. There is approximately 175m separation between the Lincoln Dale entrance and this proposed entrance. The intersection and associated upgrades are discussed further in the traffic assessment by ViaStrada Limited.

Provision is made for a road connection east-west across the site. This connection will eventually be made to a proposed road connecting Ryelands to Lincoln Dale as well as through land to the east to join with Ellesmere Road.

6. Power and Telephone

Any development of the subject site will be able to be for power and telecom to the industry standards. The infrastructure will be laid underground in the roading network. Kiosk sites for the power supply will be provided subject to the power design. These sites will be created as separate lots and will be vested in Orion.

7. Earthworks

The site is expected to be geotechnically sound following our experiences on Lincoln Dale. We will be expecting to uncover a number of springs but intend to deal with these as we did in Lincoln Dale by excavating out any affected material and replacing it with hardcore backfill and drainage. We expect to be placing subsoil drainage into a number of the roads that will also control groundwater levels.

We will carry out a site investigation prior to earthworks. We would propose that a suitable geotechnical preliminary investigation would involve approximately 20 scala penetrometers and associated auger bore holes across the site.

Once again from local knowledge we would expect to find clays and fine silts being the most common form of soil. These soils would make winter excavation very wet and difficult. Construction of the subdivision works would most likely occur during the summer months. Excavation over summer months usually causes dust problems and therefore a water cart will need to be retained onsite at all times.

It should also be noted that the containment of stormwater flows during the construction process will need to be particularly stringent to prevent any discharge to the LI Creek and LII River. To this end it a silt control management plan be required during construction, and will be approved by SDC and Ecan. Any such work will be undertaken in that is compiled in accordance with Environment Canterbury's Erosion and Sediment Guidelines 2007.

All earthworks are to be carried out in accordance with NZS4431:1989 and will involve the stripping of topsoil to stockpile, the bulk cut to fill earthworks and finally reinstatement of the topsoil and grass. It is expected that the earthworks will be a balanced cut and fill and no material will be removed from site unless it is of an unsuitable nature.

R E P O R T

Liffey Springs Subdivision, Stormwater Modelling Updated May 2008

Prepared for

Broadfield Estates Ltd

PO Box 25028

Christchurch

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Project Manager:

Helen Shaw
Senior Associate
Water Resources Engineer

URS New Zealand Limited
Level 5, Landsborough House
287 Durham Street, Christchurch
PO Box 4479, Christchurch New Zealand
Tel: 64 3 374 8500
Fax: 64 3 377 0655

Project Director:

Sioban Hartwell
Principal Water Resources Engineer

Date: 22 May 2008
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Status: Final

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Introduction

Liffey Springs subdivision is located on Edward Street in Lincoln. The site runs approximately North to South and covers an area of approximately 34 hectares. The site boundaries include the L1 ('Liffey Stream') and the L11 rivers. The L1 flows through the Lincoln township and meets the L11 immediately downstream of the development site. The L11 is spring fed and it originates within the area to be developed.

This study involves the development and use of a hydrological model for the subdivision, in order to determine the change in runoff due to development of the site. Stormwater mitigation design was not part of the scope of works for this project, however details of the proposed mitigation were provided to URS by Davie Lovell Smith Ltd, and incorporate stormwater detention designed to avoid increased flood risk in the L1/L11 system. The approach is to essentially provide a compensatory storage volume for stormwater runoff produced due to increased imperviousness in the development. The influence of the L1/L11 water levels on performance of any retention type structures have not been considered in this study.

This report, produced in May 2008, is based on previous modelling undertaken in 2006 and 2007, with adjustments made to consider changes in density of development on the site.

2.1 Stormwater Modelling

2.1.1 Hydrological Model

Introduction

Hydrological modelling has been carried out using MOUSE (Version 2007) rainfall-runoff kinematic wave Model B. This model applies hydrological losses to the rainfall to create runoff. The runoff is then routed over the surface of the subcatchment to the outlet of each sub-catchment. Refer to Appendix A for MOUSE runoff hydrographs for both the existing and future development scenarios. Tables 1 and 2 below provide a summary of the hydrological parameters used in the model

Catchment

The Liffey Springs development has been modelled as a single catchment (19b) based on planning information supplied by the Davie Lovell Smith. The total catchment area is approximately 34.0 ha, including the Liffey Springs and Zee Straten block areas. A further catchment, called Lincoln, is the contributing area upstream of the development site. This has been modelled as an input to a Hydraulic model, if required at a later stage, however hydrological runoff from this greater area has not been utilised in this assessment.

Catchment land uses and imperviousnesses have been assumed as listed below. Christchurch City Council's publication 'Waterways, Wetlands and Drainage Guide' (2003) has been used to develop imperviousness assumptions for the land uses. Tables 1 and 2 provide catchment descriptions in terms of the model inputs required. The model differentiates between impervious steep and flat; in this case, buildings are assumed to have 'steep' impervious areas, while paved areas and roads have 'flat' imperviousness. As a single catchment, the future development is assumed to have a total imperviousness of approximately 47%.

- Living 1 - 19.7 ha, 30% impervious (25% building, 5% paving)
- Living 1A5 - 1.9 ha, 40% impervious (35% building, 5% paving)
- Roads – 5.4 ha, 100% impervious
- Reserve area – 4.9 ha, 0% impervious
- Ponds – 2.1 ha, 100% impervious (rainfall falling on ponds contributes directly to water volume)

Table 1 – Catchment Descriptions for the Existing Land Use Scenario

ID	Area, ha	Length, m	Slope 1/x	Slope, o/oo	Depression storage, mm	Initial Infiltration, mm/hr	Ultimate Infiltration, mm/hr	Impervious area (steep), %	Impervious area (flat), %	Pervious area, %
19B	34.00	1200.00	855	1.17	2	35	3.35	0	0	100
Lincoln	338.52	2040.00	500	2.00	2	35	2.2	11.3	19.7	69
Total	**372.52**									

Table 2 – Catchment Descriptions for the Future Land Use Scenario

ID	Area, ha	Length, m	Slope 1/x	Slope, o/oo	Depression storage, mm	Initial Infiltration, mm/hr	Ultimate Infiltration, mm/hr	Impervious area (steep), %	Impervious area (flat), %	Pervious area, %
19B	34.00	1200.00	855	1.17	2	35	3.35	21.7	25.3	53.0
Lincoln	338.52	2040.00	500	2.00	2	35	2.2	11.3	19.7	69
Total	**372.52**									

Catchment Surface Gradient

The hydrologic model requires the ground surface slope. This is required so the runoff time can be accounted for when the flows are routed across the catchment. This information was obtained from local contour information provided by Davie Lovell Smith and the NZ map series 1:50,000 topographical map series. Although the area is essentially flat the "steep" impervious areas identified in Tables 1 and 2 refer to roofed areas across the development.

Depression Storage

The default value of 2mm has been adopted for all subcatchments.

Infiltration Rates

Soil types are directly linked to infiltration rates used in the hydrological model. MOUSE uses an initial infiltration rate and an ultimate infiltration rate. The relationship between the two is described by an exponential decay curve. Infiltration rates are subjective and are highly dependant on antecedal conditions for the catchment. Soil maps were obtained from Environment Canterbury and used to determine an average infiltration value for the catchments. Five main soil types were identified in the catchments and an average ultimate infiltration rate of 3.35mm/hr was determined for the development site.

From past experience of using MOUSE Model B it is known the hydrological model is very sensitive to infiltration rates, particularly the ultimate infiltration rate. Infiltration rates are smallish loss rates applied across the entire subcatchment which are a hydrological loss before any runoff for the subcatchment is generated. A sensitivity analysis was undertaken using 1mm and 2mm ultimate infiltration rates for the site.

Rainfall Hyetographs

The rainfall hyetograph procedure used is from Pearson's, 1992 (Ref 1) study for Christchurch. Refer to Appendix B for a spreadsheet example of the procedure, noting that there is both with and without Climate Change scenarios. Based on historical storm analysis for the Christchurch area (including the Lincoln area), the standard dimensionless hyetograph for rainfall intensity shape is triangular and peaks at 0.7 storm duration (time). Pearson's procedure suggests that for design storms of less than six hours duration an assessment should be made on moving the peak between 0.2 to 0.8 of full storm duration. For this study the peak at 0.7 storm duration (time) is adopted; varying the position of the peak has not been evaluated.

Climate Change

It is recommended that local government consider the effects of climate change, MfE, 2004 (Ref2). As per the MfE recommendations three scenarios have been evaluated: Low, Medium and High annual mean increases in temperature. For this study only the medium scenario is used in the rainfall hyetograph procedure to give one climate change scenario. Climate change predictions vary across the country with an increase in temperature providing either an increase or decrease in mean annual or mean winter precipitation depending on the location. The Medium scenario for the Christchurch area predicts that temperatures will increase by 1.7 °C by 2080. In this location even though mean winter rainfall will decrease rainfall depths during extreme events such as the 3 hr 2% Annual Exceedence Probability (AEP) design rainfall event may increase by 12.2%. Refer to the MfE publication, which is available on their website, for more detailed information.

Design Storms

The 20%, 10%, 5% and 2% AEP design rainfall events have been modelled. The storm that generates the largest peak runoff flow from the developed site is defined as the storm with the critical duration for the development site.

3.1 Hydrological Modelling Results

Peak discharges and runoff volumes have been described in Table 3 for the 2% AEP (Annual Exceedence Probability, equivalent to a 1 in 50 year storm) design rainfall event. It can be seen that the 3 hour 2% AEP design rainfall event is the critical storm duration for the future development scenario, producing a maximum discharge rate of 1.7 m^3/s. For the developed (future) scenario. An additional 4,614 m^3 in runoff volume is produced over the duration of the storm when compared to the existing (undeveloped) situation.

Table 3 – 2%AEP Runoff Rates & Volumes

2% AEP Event	Current	Future		Current	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
0.5 hr	0.3	1.0	0.7	1291	3391	2100
1 hr	0.5	1.4	0.9	2980	5979	2999
2 hr	0.8	1.7	0.8	6255	10214	3960
3 hr	1.0	1.7	0.7	8410	13023	4614
6 hr	1.0	1.5	0.5	12464	18591	6127
12 hr	0.9	1.2	0.3	16332	24794	8462
24 hr	0.6	0.8	0.2	18230	31133	12903

Refer to Appendix C for the full set of Hydrological Results for 20%, 10%, 5% and 2% AEP design rainfall events.

3.2 Sensitivity Analysis Results

A sensitivity analysis of the hydrological model was performed. The only parameter changed was the ultimate infiltration rate. From past experience with this type of hydrological model, this rate is the only parameter that has a significant effect on the results. The 3.35mm/hr rate, which was determined from an assessment of soil maps in the area, seems quite high for the heavy/poor draining soils which are known to be present in the Lincoln area. Two sensitivity runs have been conducted; one using an ultimate infiltration rate of 2mm/hr and the other 1mm/hr. The results can be seen in Table 4 and 5 below.

Table 4 – 2%AEP Runoff Rates & Volumes for an Ultimate Infiltration Rate of 2mm/hr

2% AEP Event	Future	Future		Future	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
Ultimate Infiltration Rate (mm/hr)	3.35	2		3.35	2	
2 hr	1.7	1.7	0.0	10214	10555	341
3 hr	1.7	1.7	0.0	13023	13546	523
6 hr	1.5	1.5	0.0	18591	19450	859

Table 5 – 2%AEP Runoff Rates & Volumes for an Ultimate Infiltration Rate of 1mm/hr

2% AEP Event	Future	Future		Future	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
Ultimate Infiltration Rate (mm/hr)	3.35	1		3.35	1	
2 hr	1.68	1.76	0.08	10214	11534	1319
3 hr	1.72	1.83	0.11	13023	14999	1976
6 hr	1.52	1.66	0.14	18591	21627	3036

Only the 2, 3 and 6 hour storm duration events have been run to check that the critical storm duration for the peak runoff, has not changed. It can be seen for both sensitivity runs the event that produces the peak runoff rate remains at 3 hours. If an ultimate infiltration rate of 2mm/hr is to be adopted, an extra 523 m^3 of runoff for the 3hour 2% AEP design rainfall event will be produced. If a more conservative rate of 1mm/hr is to be adopted an extra 1976 m^3 of runoff would be produced when compared with the runoff produced using an infiltration rate of 3.35mm/hr.

3.3 Climate Change Results

As mentioned earlier one climate change scenario has been run for this study which is the 3 hour 2% AEP design rainfall event. This is using an ultimate infiltration rate of 2mm/hr from the sensitivity analysis above. Table 6 below provides the results of this analysis.

Table 6 – Future 2% AEP Runoff Rate & Volume including Climate Change

2% AEP Event	No Development with CC	Future with CC		No Development with CC	Future with CC	
	Peak Flow (m3/s)	Peak Flow (m3/s)	Increase (m3/s)	Volume (m3)	Volume (m3)	Increase (m3)
3 hr	**1.3**	**2.0**	**0.7**	**12422**	**15591**	**3170**

As the model results show, allowing for potential climate change effects in the stormwater detention design could require an additional 3170 m^3 of runoff on top of the [1]**5137 m^3** already resulting from the change in landuse.

3.4 Stormwater Mitigation Proposal

Davie Lovell Smith have advised that compensatory storage can be provided on the site between the maximum water table level and existing ground level – the pond design has volumes of 2,500 m^3 and 6,400 m^3 for first flush and extended detention respectively.

It is assumed that the full pond (first flush plus detention storage) volume provided is available for mitigation storage, and noted that the 8,900 m^3 available exceeds the required 3,170 m^3 required for hydrological neutrality under current climate conditions, and also caters for increased storage requirements assuming a medium climate change scenario.

[1] Value obtained from adding 4614 m^3 (from the 3.5 mm/hr infiltration rate) and 523 m^3 (the increased runoff by adopting a 2 mm/hr runoff rate).

The median value from the sensitivity analysis of 2mm/hr in Table 4 has been used to provide a conservative storage volume that allows for some modelling uncertainty - the second sensitivity analysis scenario, in Table 5, using 1mm/hr is considered to be too conservative when compared to a 3.35mm/hr infiltration rate provided by an assessment of soils in the area.

For a 3 hour 2% AEP rainfall event a total of 5,137 m^3 of storage would need to be provided to achieve hydrological neutrality for the site.

By providing a minimum of 5,137 m^3 of compensatory storage this will cater for the increased runoff due to the development for all events up to and including the 2% AEP design rainfall event. For all events smaller than the 2% AEP design rainfall, event there will be a net increase in floodplain storage available in the L1/L11 system. It is understood this will be achieved by having inlets into a storage basin area to allow both the L1 and L11 to flood into this area and utilise the storage available.

The effects of climate change have been considered and the MfE (Ref 2) publication procedure has been followed to produce a medium climate change scenario which may require an extra 3,170 m^3 of storage to be provided from the present time to 2080 to counteract these effects. This needs to be considered in the design of any stormwater retention system for the subdivision, and as indicated above, there is currently sufficient on-site storage to allow for climate change effects (as per a 'medium' climate change scenario).

1) Pearson, C.P. 1992. Frequency of High Intensity Rainfalls in Christchurch. Hydrology Centre Report Number CR92.11. Hydrology Centre, Christchurch.

2) Ministry for the Environment 2004. Preparing for Climate Change-A guide for local government in New Zealand, New Zealand Climate Change Office, Wellington.

3) Christchurch City Council 2003. Waterways, Wetlands and Drainage Guide. Christchurch City Council, Christchurch.

Appendix A - Runoff Hydrographs for Existing and Proposed Situations for the 3 Hour 2% AEP Event

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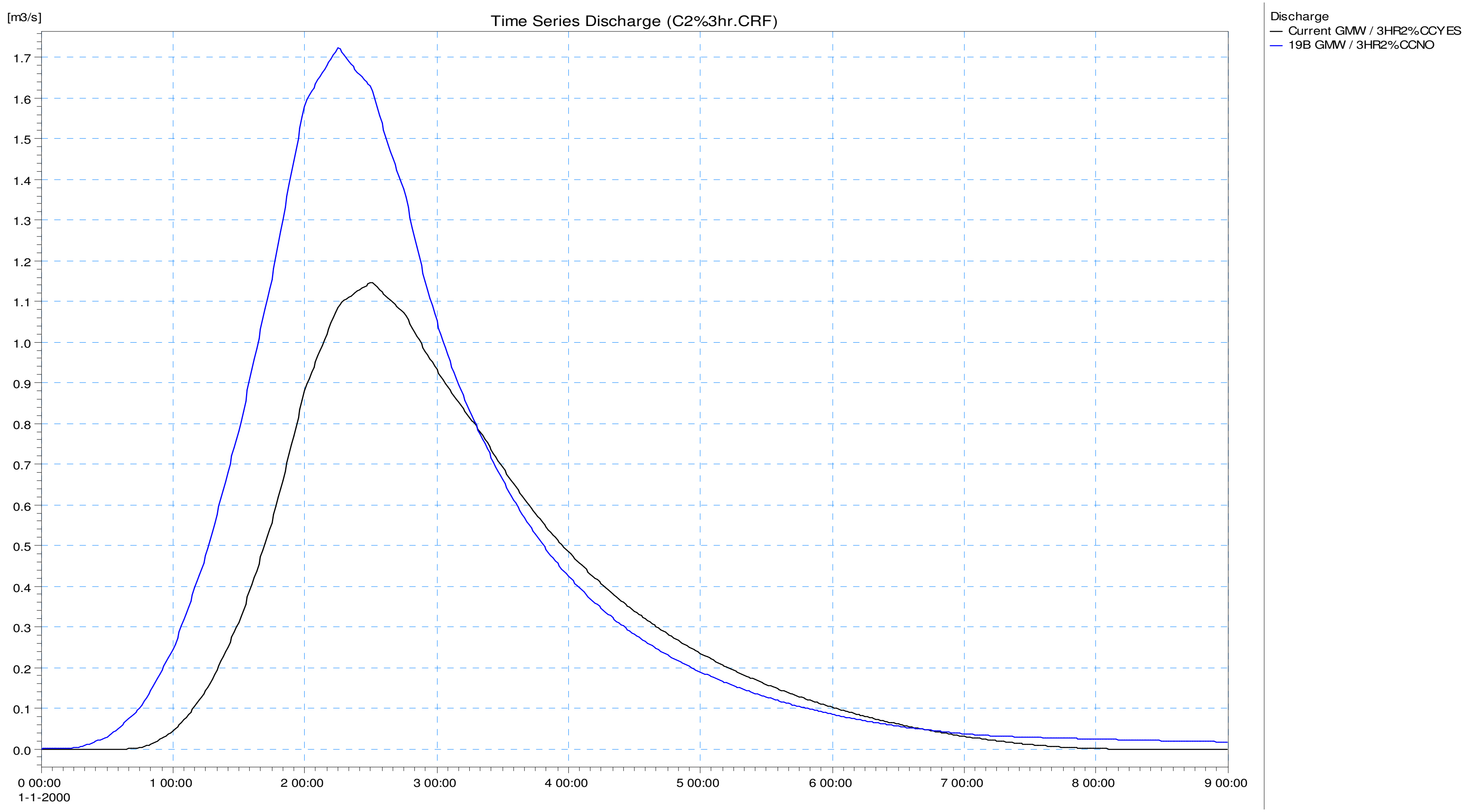


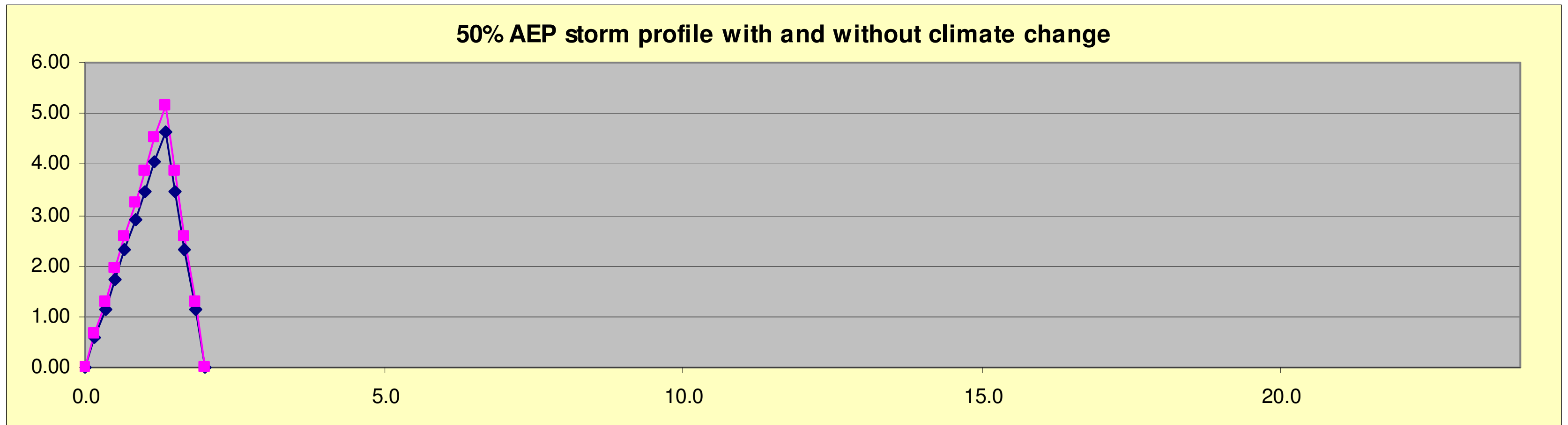
Appendix B - Rainfall Hyetograph Procedure

Christchurch Design Storm Hyetographs

Mark III (URS Modified)

Duration	*(hours)*	***2***	a =	14.66	**Units**	t = hours
	M24	57	b =	0.427		i = um/s
	ARF	0.95				Design Storm Rainfall (DSR) = mm
Climate Change °C		1.70	+			

			50% AEP	No CC	With CC	20% AEP	No CC	With CC	10% AEP	No CC	With CC	5% AEP	No CC	With CC	2% AEP	No CC	With CC	1 % AEP	No CC	With CC
MD	*(mm)*	***19.7***	***DSR***	***16.7***	***18.6***	***DSR***	***24.9***	***27.9***	***DSR***	***30.7***	***34.4***	***DSR***	***36.5***	***41.0***	***DSR***	***44.4***	***49.9***	***DSR***	***50.4***	***56.6***
iPeak	*(mm/hr)*	***19.7***	***iPeak***	***16.7***	***18.6***	***iPeak***	***24.9***	***27.9***	***iPeak***	***30.7***	***34.4***	***iPeak***	***36.5***	***41.0***	***iPeak***	***44.4***	***49.9***	***iPeak***	***50.4***	***56.6***
	t	***i***	***t***	***i***	***i***	***t***	***i***	***i***	***t***	***i***	***i***	***t***	***i***	***i***	***t***	***i***	***i***	***t***	***i***	***i***
0.00	0.0	0.0	0.0	0.0000	0.0000	0.0	0.0000	0.0000	0.0	0.0000	0.0000	0.0	0.0000	0.0000	0.0	0.0000	0.0000	0.0	0.0000	0.0000
0.08	0.2	2.5	0.2	0.5787	0.6446	0.2	0.8647	0.9676	0.2	1.0663	1.1950	0.2	1.2679	1.4230	0.2	1.5409	1.7322	0.2	1.7490	1.9660
0.17	0.3	4.9	0.3	1.1573	1.2891	0.3	1.7295	1.9353	0.3	2.1326	2.3900	0.3	2.5357	2.8461	0.3	3.0819	3.4643	0.3	3.4980	3.9321
0.25	0.5	7.4	0.5	1.7360	1.9337	0.5	2.5942	2.9029	0.5	3.1989	3.5850	0.5	3.8036	4.2691	0.5	4.6228	5.1965	0.5	5.2470	5.8981
0.33	0.7	9.9	0.7	2.3147	2.5783	0.7	3.4590	3.8706	0.7	4.2652	4.7800	0.7	5.0714	5.6922	0.7	6.1637	6.9287	0.7	6.9960	7.8642
0.42	0.8	12.3	0.8	2.8933	3.2229	0.8	4.3237	4.8382	0.8	5.3315	5.9750	0.8	6.3393	7.1152	0.8	7.7047	8.6608	0.8	8.7450	9.8302
0.50	1.0	14.8	1.0	3.4720	3.8674	1.0	5.1885	5.8059	1.0	6.3978	7.1700	1.0	7.6071	8.5383	1.0	9.2456	10.3930	1.0	10.4939	11.7962
0.58	1.2	17.2	1.2	4.0506	4.5120	1.2	6.0532	6.7735	1.2	7.4641	8.3650	1.2	8.8750	9.9613	1.2	10.7865	12.1251	1.2	12.2429	13.7623
0.67	1.3	19.7	1.3	4.6293	5.1566	1.3	6.9179	7.7412	1.3	8.5304	9.5600	1.3	10.1429	11.3843	1.3	12.3275	13.8573	1.3	13.9919	15.7283
0.75	1.5	14.8	1.5	3.4720	3.8675	1.5	5.1885	5.8060	1.5	6.3979	7.1701	1.5	7.6073	8.5384	1.5	9.2457	10.3931	1.5	10.4941	11.7964
0.83	1.7	9.9	1.7	2.3147	2.5784	1.7	3.4591	3.8707	1.7	4.2653	4.7801	1.7	5.0715	5.6923	1.7	6.1639	6.9288	1.7	6.9961	7.8644
0.92	1.8	4.9	1.8	1.1574	1.2892	1.8	1.7296	1.9354	1.8	2.1327	2.3901	1.8	2.5358	2.8462	1.8	3.0820	3.4645	1.8	3.4982	3.9323
1.00	2.0	0.0	2.0	0.0001	0.0001	2.0	0.0001	0.0001	2.0	0.0001	0.0001	2.0	0.0001	0.0001	2.0	0.0001	0.0002	2.0	0.0002	0.0002



Appendix C - Design Storm Hydrological Modelling Results

Appendix C - Design Storm Hydrological Modelling Results

Model Results

20% AEP Event	Current	Future		Current	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
0.5 hr	0.06	0.38	0.32	235	1346	1111
1 hr	0.14	0.55	0.41	749	2034	1286
2 hr	0.25	0.71	0.46	1770	4577	2806
3 hr	0.31	0.74	0.43	2493	5970	3477
6 hr	0.32	0.68	0.36	3602	8556	4953
12 hr	0.25	0.53	0.27	4042	11156	7114
24 hr	0.31	0.35	0.04	2492	13490	10998

10% AEP Event	Current	Future		Current	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
0.5 hr	0.12	0.55	0.43	483	1898	1415
1 hr	0.24	0.79	0.54	1315	3484	2169
2 hr	0.40	0.98	0.58	2952	6177	3225
3 hr	0.48	1.02	0.53	4068	7985	3917
6 hr	0.51	0.91	0.40	6011	11477	5465
12 hr	0.43	0.72	0.29	7406	15100	7694
24 hr	0.27	0.49	0.23	6825	18441	11616

5% AEP Event	Current	Future		Current	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
0.5 hr	0.19	0.75	0.56	794	2505	1711
1 hr	0.36	1.04	0.68	1976	5149	3173
2 hr	0.58	1.26	0.69	4282	7853	3571
3 hr	0.68	1.31	0.62	5827	9752	3925
6 hr	0.73	1.16	0.43	8662	14460	5798
12 hr	0.61	0.92	0.32	10999	19106	8106
24 hr	0.41	0.64	0.22	11382	23706	12324

Appendix C - Design Storm Hydrological Modelling Results

2% AEP Event	Current	Future		Current	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
0.5 hr	0.3	1.0	0.7	1291	3391	2100
1 hr	0.5	1.4	0.9	2980	5979	2999
2 hr	0.8	1.7	0.8	6255	10214	3960
3 hr	1.0	1.7	0.7	8410	13023	4614
6 hr	1.0	1.5	0.5	12464	18591	6127
12 hr	0.9	1.2	0.3	16332	24794	8462
24 hr	0.6	0.8	0.2	18230	31133	12903

Appendix C - Design Storm Hydrological Modelling Results

Climate Change

2% AEP Event	No Development with Climate Change	Future with Climate Change		No Development with Climate Change	Future with Climate Change	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
3 hr	1.3	2.0	0.7	12422	15591	3170

Sensitivity Analysis

2% AEP Event	Future	Future		Future	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
Ultimate Infiltration Rate (mm/hr)	3.35	2		3.35	2	
2 hr	1.7	1.7	0.0	10214	10555	341
3 hr	1.7	1.7	0.0	13023	13546	523
6 hr	1.5	1.5	0.0	18591	19450	859

2% AEP Event	Future	Future		Future	Future	
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	Increase (m^3/s)	Volume (m^3)	Volume (m^3)	Increase (m^3)
Ultimate Infiltration Rate (mm/hr)	3.35	1		3.35	1	
2 hr	1.68	1.76	0.08	10214	11534	1319
3 hr	1.72	1.83	0.11	13023	14999	1976
6 hr	1.52	1.66	0.14	18591	21627	3036