Appendix Q

Ecological Assessment Report

Ecology of the upper Kruse's Drain; and impact of baseflow reduction and stormwater treatment from the Foodstuffs SI development site

Prepared for:

Foodstuffs South Island Limited

AEL Report No. 162

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Final Report

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Contents

1 Executive Summary

Foodstuffs (South Island) Limited propose to culvert a length of Lydia Street Drain, for an approximate distance of 225 m, as part of a development of their land in Redwood to establish a supermarket, retail, office and resilience hub.

This report addresses the concern of the loss of baseflow on downstream aquatic values (in Kruse's Drain) which could result from piping this 225 m length.

The baseflow gain over the culverted reach in Lydia Street Drain was approximated in the field and found to be minor over approximately 360 m of channel. Given that proposed culverting will only prevent a proportion of the estimated baseflow gain (c. 0.25 L/s), the effective loss of baseflow is considered to be less than minor (i.e. less than 0.25 L/s). Available information on downstream ecology in Kruse's Drain, indicated that the ecology in Kruse's Drain, and Lydia Street Drain, was found to be both degraded and tolerant of shallow depths and low flows. We consider that the fauna is therefore tolerant of the minor baseflow loss.

Surrounding ground near the proposed culverted reach was found to be contaminated with hydrocarbons originating from a source outside of Foodstuffs property. Thus, given ground contamination, I recommend that the Lydia Street Drain baseflow is best served by culverting the baseflow through it. The culverting option would provide more net benefit to the downstream ecology, by preventing ground contaminants from entering the channel baseflow, with only a negligible loss of (contaminated) baseflow.

The development will increase the proportion of impervious hardstand in the development's stormwater catchment, and the hardstand will be subject to increased vehicle traffic associated with the supermarket. However, none of the existing stormwater is treated and a proportion discharges directly into Lydia Street Drain which has very little baseflow. Our investigation revealed high historic zinc levels in sediment within the receiving environment.

Given the impervious nature of the development area, the high traffic loadings, and the ecological sensitivity of receiving waters, a high-quality stormwater treatment was proposed. Our investigation, in association with a civil engineering assessment, indicates that the most effective stormwater treatment system would be provided by bioretention and infiltration systems where these can be feasibly installed. Biological deactivation is the most effective way of removing toxic contaminants (hydrocarbons and dissolved metals) which are characteristic of urban trafficked catchments.

2 Introduction

Foodstuffs South Island Limited own a block of land west of the Main North Road in the vicinity of 171 Main North Road, and propose to re-develop a significant proportion of this land parcel. All stormwater runoff from this site, and adjacent catchments, are currently untreated and discharge into a tributary of Kruse's Drain along the northern border of the property. This waterway is termed hereafter as Lydia Street Drain.

The proposal involves the demolition of an earthquake-damaged multi-story 1960s brick building, which will be replaced with a new supermarket and carpark facility north of the existing company administration office.

Lydia Street Drain follows the north border fence line of the Foodstuffs property, see CCC's GIS Utilities database (App. I, Fig. i). The nature of the development requires safe pedestrian passage around and through site. For this reason, it is proposed that the drain be culverted (1350 mm dia.) from Main North Road upstream (i.e. west) for 225 m. The remaining 80 m will remain in its existing state.

The applicant originally sought to pipe the full 306m length of the Lydia Street Drain. Since lodgement in August 2018, further design work and ecological investigations have been undertaken. The Council requested some open channel remain, so the applicant proposed an alternative design to minimise the extent of piping in October 2018, which reduced the length of piping to 65m with the remainder remaining as a boxed drain with a boardwalk placed over the top. The boardwalk was proposed to provide safe pedestrian access along the path of the open drain portion. While this revised design was viewed as a more favourable ecological outcome, the option has not been pursued given Council as the asset owner confirmed December 2018 they do not view it as an acceptable outcome and CCC would be unwilling to authorise the boardwalk option under the Water Supply, Wastewater and Stormwater Bylaw 2014, due to insufficient access for drain maintenance. The applicant has refined the design further to retain an 80m length of the existing boxed drain and pipe the remainder (a 225m length instead of the original 306m). This current revised design is discussed in this ecological assessment.

In the preparation of this report the following information has been reviewed:

- Papanui Supermarket, Retail, Office and Resilience Hub Site Plan Drawing RC02, undated
- Rough and Milne Papanui Pak n' Save Master Plan, Drawing L 1.0, Rev.E, dated 20/5/19
- Rough and Milne Papanui Pak n' Site Landscape Plan, Drawing L 1.1, Rev. E, dated 20/5/19]\
- Rough and Milne Papanui Pak n' Site Landscape and Urban Design Report, Rev. F, dated 24/5/19.
- Site Stormwater Design Advice Memo and Stormwater Preliminary Sketch (Keegan Brogden, 171259/C/2 SK C39, dated 4th April 2019.

3 Objective

The objective was to provide an ecological assessment of the effects of piping 225 m of Lydia Street Drain (retaining the remain length as existing open box drain). After consultation with CCC, further investigation was required, including:

- Assessment of the baseflow contribution from Lydia Street Drain in respect to downstream habitat values (i.e. downstream of Main North Road);
- Consideration of how the proposed site stormwater treatment could maximise protection of instream values in the receiving environment of Lydia Street Drain, but in particular the downstream receiving waters; Kruse's Drain and the Styx River.
- Input was also requested on a stormwater treatment design to protect instream values in the receiving waters

4 Physical description of Lydia Street Drain and Kruse's Drain

The Lydia Street Drain is a tributary of the Kruse's Drain network (App. I, Fig. i, CCC GIS utility map). It rises approximately 360 m west of Lydia Street, and extends eastward for 770 m to Main North Road. The drain is subject to direct stormwater inputs from residential and commercial land to the north, as well as hardstand runoff from Foodstuffs property to the south (App. I, Fig. i).

Lydia Street Drain is culverted under the Main North Road/Northcote Road intersection (for 91 m), where significant baseflow is provided by two underground piped inflows from the Kruse's Drain catchment (App. I, Fig. i). The now-combined Kruse's Drain flow through the grounds of St Bede's College. Within the grounds of St. Bede's College, most of the Kruse's Drain length has recently been converted from boxed drain to a naturalised waterway. This involved the removal of the boxing, bank re-grading, and planting the re-graded slopes with native trees and shrubs. However, downstream of St. Bede's College, the channel reverts to a boxed drain to Grimseys Road. From Grimseys Road, the waterway is culverted under the road, and under Kruse's Place for approximately 200 m until it opens out on undeveloped pasture land. The drain forms an open channel with battered banks to the confluence with Horners Drain.

5 Methods

The following field itinerary was followed (Table 1) when Kruse's Drain and Lydia Street Drain were at baseflow, as attested by local rainfall and rivers (Figs. 1a, b). Before the early September rain event, the groundwater level (27th August, 11.054 m RL) was just under long-term (from 1999) median levels (11.074 m RL, App. I, Fig. ii). Thus, our observations were expected to represent those at typical median groundwater levels.

Lydia Street Drain water levels were checked in February to determine water permanence in mid-summer, after over a month with little rain (Fig. 1c).

Table 1. Field itinerary for the investigation of the potential impacts of piping Lydia Street Drain.

Date	Comments
17th September 2018	Visual assessment of Lydia Street Drain
18th September 2018	Flow gauging of Kruse's Drain
22nd September 2018	Physical assessment of Kruse's Drain through St. Bedes College
18th February 2019	Visual assessment of Lydia Street Drain

Rainfall 25.4mm from Fri 31 Aug 2018 to Thu 20 Sep 2018

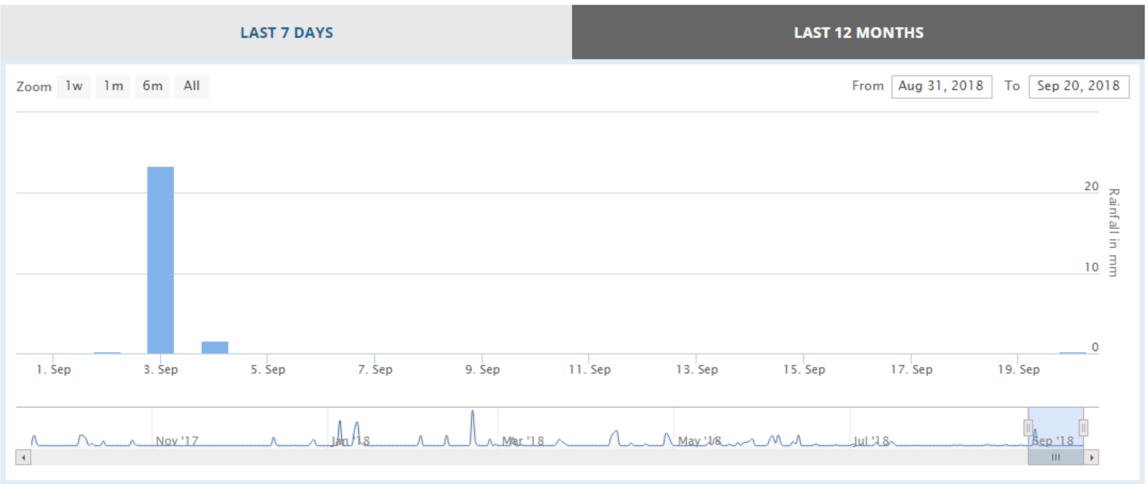

Figure 1a. No rainfall at the local Firestone factory at Langdon's Road since 4th September 2018.

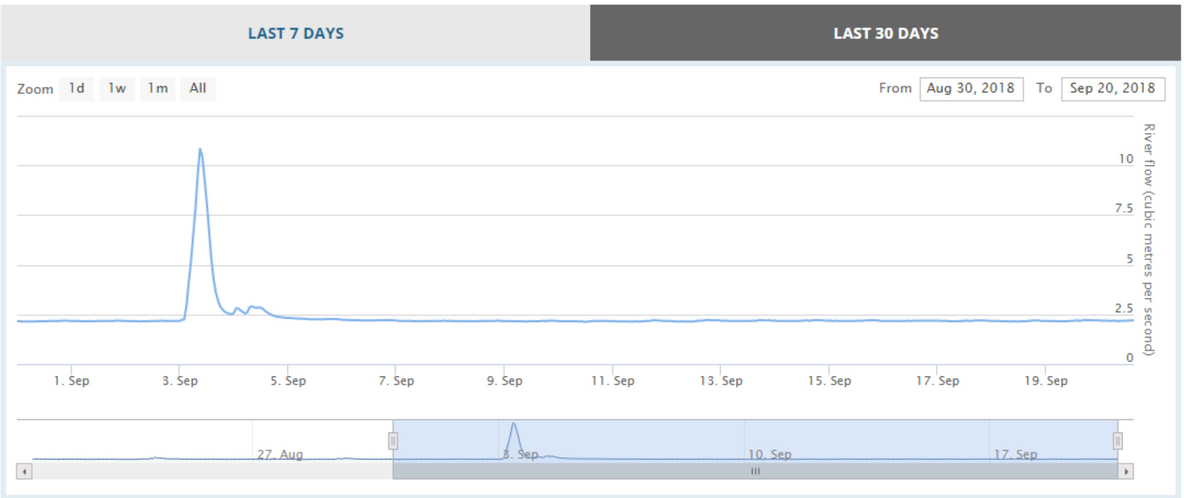

Figure 1b. The Avon River (Gloucester St) has been at baseflow for approximately two weeks.

Rainfall 6.8mm from Fri 18 Jan 2019 to Mon 18 Feb 2019

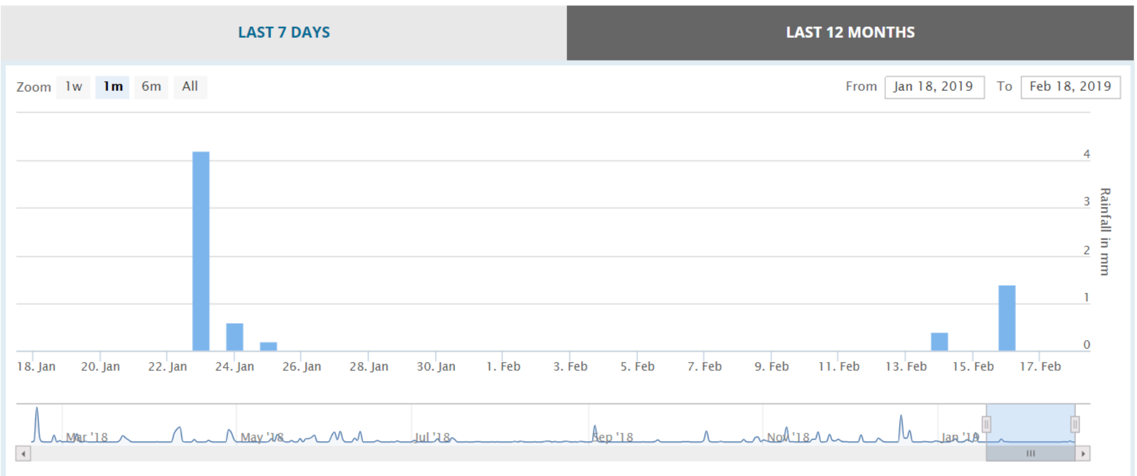

Figure 1c. No rainfall exceeding 5 mm was recorded at the local Firestone factory at Langdon's Road in the month preceding the survey on 18th February 2019.

5.1 Flow gauging Kruse's Drain

Flow gauging was conducted on Kruse's Drain downstream of St. Bede's College at baseflow using standard hydrological methods with a hydrological wading rod and mini-Ott meter (Fenwick 1994).

6 Results

6.1 Lydia Street and Kruse's Drain baseflow

In September the flow in Lydia Street Drain was too low to be flow-gauged. A visual estimate of flow at the end of Lydia Street was 0.25 L/s, while the flow at the Main North Road was visually estimated to be 0.5 L/s. Downstream of the St Bede's College grounds, the flow of Kruse's Drain was gauged as 2.8 L/s.

In February 2019 the flow in Lydia Street Drain was also too low to be gauged. From Lydia Street downstream for 200 m, water was pooled and disconnected. From this point downstream to Main North Road (c. 105 m) flow was estimated to be 0.25 L/s. Therefore, the baseflow gain in Lydia Street Drain is approximately 0.25 L/s, with the bulk of the baseflow contribution downstream of the Main North Road provided by Kruse's Drain which added a further 2.3 L/s in September 2018.

6.2 Visual assessment of Lydia Street Drain

6.2.1 September 2018

Based on Google Earth aerial imagery and CCC GIS, all 772 m of Lydia Street Drain, has been developed into the typical wooden vertical-sided drain with spreader boards every 2 m or so (Fig. 2). The only exception in treatment is where the channel is culverted under Lydia Street for approximately 12 m. Along the length, through Foodstuff lands, the bed of Lydia Street Drain is predominantly a mixture of coarse sand, with a depth of 10 cm over a firm base of clay or gravel. At the time of the survey (17th September 2018), the baseflow was clear, composed of a shallow trickle a few centimetres deep. The old boxing and spreader boards were largely intact, albeit, bowed in places. There was some sign of lateral spread along the banks above the boxing, and the boxing, while sound, did not appear to have been repaired since the 2010/11 earthquake sequence. Therefore, in its sound state, the cladding and the sand substrate did not provide refuge for potential fish inhabitants. The channel was well-shaded from the north by adjacent fencing, and small trees and shrubs. No aquatic plant life was observed in the very shallow water.

Lydia Street Drain is subject to apparent gross pollution. Hydrocarbon films were observed near the drain's trash rack outlet at Main North Road (Fig. 3), with one anthropogenic point source identified (Fig. 4) not attributable to Foodstuffs (SI). Another hydrocarbon film (Fig. 5) was observed in the waterway near Lydia Street. While the source of the hydrocarbons was not determined, it was clear that it was not attributable to a discharge from Foodstuffs. This is because there are no stormwater inputs from Foodstuffs entering Lydia Street Drain at, or upstream, of Lydia Street (App. I, Fig. i).

6.2.2 February 2019

The February survey found that many of the large old trees shading Lydia Street Drain on the true right (south) bank had been felled because of the risk of either collapsing into the drain, thus creating a flooding hazard, or falling across the truck access route (R. Parrish, pers. comm, Fig. 6). Along the 200 m reach immediately downstream of Lydia Street, the drain bed was predominantly gravel of varying embeddedness into the surrounding silt (Figs. 7, 8). Further downstream, where water connectivity appeared to be permanent, the stream bed was more embedded, and common duckweed (*Lemna minor*) was prolific (Fig. 9). The presence of duckweed reflects the low summer base flow. The baseflow was clear, but only a few centimetres deep. At the time, some concrete blocks were found to be impounding water 240 m downstream of Lydia Street (Fig. 10).

Figure 2. Lydia Street Drain east of Lydia Street. The drain base was wet with a trickling baseflow.

Figure 3. A hydrocarbon film (not from foodstuffs) was evident upstream of the trash rack at Main North Road.

Figure 4. Local ground contamination beside Lydia Street drain. This was sourced to a neighbouring property north of the Foodstuffs site. A hydrocarbon film was also present in the water.

Figure 5. Hydrocarbon films were observed upstream of that in Fig. 4, but the source was not traceable.

Figure 6. Trees on the true right (south) bank of Lydia Street Drain have been recently felled.

Figure 7. Damp gravel in Lydia Street Drain.

Figure 8. Embededd hard substrate in Lydia Street Drain.

Figure 9. Duckweed and soft sediment in Lydia Street Drain.

Figure 10. Concrete debris damming water in Lydia Street Drain.

6.3 Flow status of Lydia Street Drain and Kruse's Drain

Based on our observations, Lydia Street Drain does not completely dry over the summer and autumn months (December to March inclusive). Between rain events, water levels in drains equilibrate with shallow groundwater levels. Our observations suggest that the drain lacks surface flow near Lydia Street, but picks up enough groundwater to have a small (i.e. a trickle) baseflow at Main North Road. Therefore, the flow status of Lydia Street Drain varies between seasonally intermittent at Lydia Street, when the groundwater level is below the bed in the summer months, but above the bed in the winter. In contrast, further downstream at the Main North Road, the flow status is perennial (i.e. flows all year round), and the bed is below the groundwater level at all times of the year.

The fall of the drain invert, and the groundwater level range, is sufficient for the flow status to change across the Food Stuffs property boundary. For example, the shallow groundwater level in North Christchurch at Horseshoe Lake Road, (e.g. CCC No. 2 Drain site) varies seasonally with a December-March median 8 cm below the overall median (CCC data 1999-2017). The winter to dry-season groundwater level range is 17.6 cm (CCC data 1999-2018).

Between Lydia Street and Main North Road, the estimated baseflow gain was 0.25 L/s (spring and summer estimates). Assuming the proposed culvert is perfectly sealed, the spring baseflow feed into Kruse's Drain would be reduced by 0.25 L/s. In contrast to Lydia Stream Drain, Kruse's Drain, the receiving waterway of Lydia Street Drain, receives continuous baseflow from its headwaters in Papanui, and is perennial, reflected in its ecological values, and discussed below.

The loss of baseflow would represent an approximate 9% loss of the perennial baseflow as gauged downstream of St Bede's College. Evaluation of the latest physical habitat models for resident fish (Jowett & Richardson 2008), suggests that some slight reduction in baseflow depth and velocity will not have a significant impact on resident fish as they prefer very shallow depths (Figs. 11-14, upland bully, common bully (poss.), and shortfin eels).

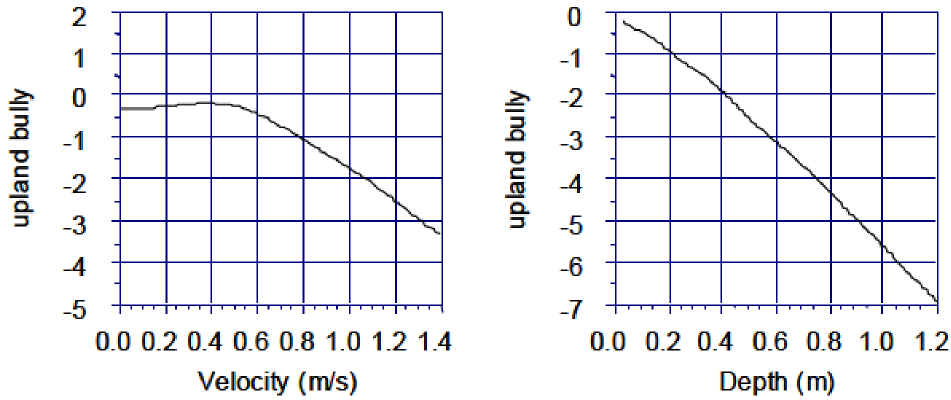

Figure 11. Additive logistic model of physical habitat probability of use for upland bully.

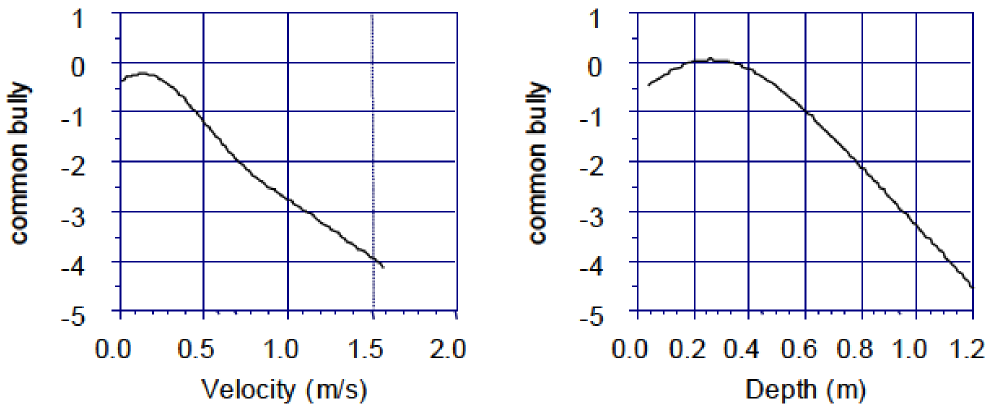

Figure 12. Additive logistic model of physical habitat probability of use for common bully.

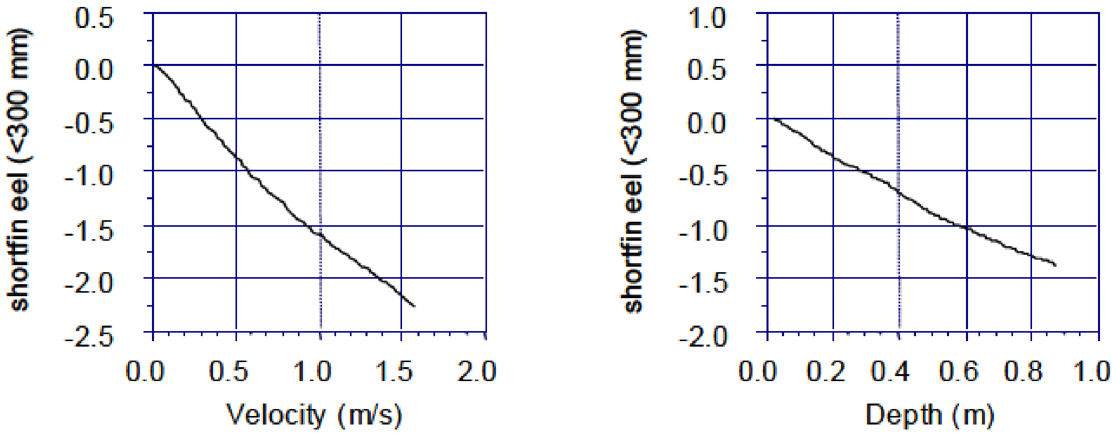

Figure 13. Additive logistic model of physical habitat probability of use for small shortfin eel.

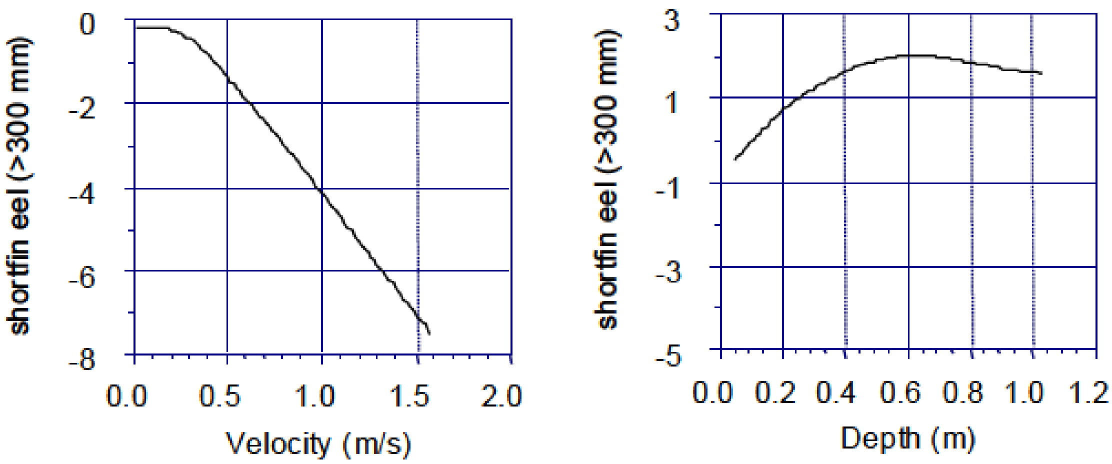

Figure 14. Additive logistic model of physical habitat probability of use for larger shortfin eel.

6.4 Aquatic ecology of Lydia Drain and Kruse's Drain

To our knowledge, there is no ecological data for Lydia Drain. However, there is some ecological data available for the downstream reaches of Kruse's Drain (Site 6 in McMurtrie et al. 2005). This sample site is near where the Christchurch Northern Corridor crosses the waterway, north of Queen Elizabeth Drive.

Although the physical habitat of this site was 'above average' in respect to the remainder of Kruse's Drain, stream health measures scored poorly compared to other drains in Mairehau, and waterways around Christchurch (McMurtrie et al. 2005). The Urban Community Index (UCI) was -0.9, and its Macroinvertebrate Community Index (MCI) was 60, representing a stream health degraded by urban and rural contaminants. An MCI score of 60 represents quite/very "poor" stream health, as an MCI < 80 is regarded as poor (Stark & Maxted 2007). A total of 13 macroinvertebrate taxa were recorded, numerically dominated by segmented worms, snails and chironomid (midge) larvae (raw data from McMurtrie et al. 2005). These predominant taxa are associated with poor stream health.

6.5 Aquatic ecology of the Styx River downstream of the Kruse's Drain confluence

The ultimate receiving environment for treated stormwater contaminants from the development is the lower Styx River *via* Horners Drain. While Horners Drain is currently a channelised waterway draining mostly rural Marshland District, the Styx River has significantly higher biodiversity and instream values than Kruse's Drain and Horners Drain.

The Styx River and Horners Drain are both subject to regular monitoring as part of the CCC ecological monitoring program. Horners Drain has the highest sediment zinc concentration recorded from the catchment (790 mg/kg *in* Instream Consulting Ltd 2018), and has moderate levels of lead, the latter being of historic sources. Clearly zinc from urban sources has become concentrated downstream in the lower Horners Drain, although levels of hydrocarbons were low at this site. Despite the high levels of zinc in the sediment, the 2018 recording of the pollution-sensitive *Pycnocentria* (MCI=7) suggests improving water quality after historic contaminant loading.

The Styx River is monitored at Marshland Road, downstream of the Horners Drain confluence with the most recent ecological material probably collected by AEL in January 2019. AEL recorded low numbers of pollution-sensitive mayflies (*Deleatidium, MCI score 8/10*) and the uncased caddisfly *Psilochorema sp, MCI score 8/10*, and markedly higher stream health scores (MCI 74-91 representing borderline fair water quality) than reported in the 2018 ecological report (c. 62, poor water quality).

In summary, there is recent evidence that stream health in the Styx River receiving environment for the development is improving. This is all the more reason to ensure that stormwater treatment from highly development sub-catchments like Lydia Stream Drain is of the highest possible quality.

7 Ecological Effects of the Development Proposal

We have considered aspects of the development proposal in light of the aquatic ecology in the receiving environment. We consider the receiving environment to be, in downstream order, Lydia Street Drain, Kruse's Drain (i.e. downstream of the Main North Road), Horners Drain, and ultimately the Styx River. Potential impacts are listed below:

- Effects of Baseflow loss
- Effects of Stormwater contaminants on receiving waterways

7.1 Impact of baseflow loss on Kruse's Drain ecology from culverting flow from Lydia Street to Main North Road

For the Lydia Drain reach extending from the Main North Road to 225m upstream, a perforated pipe was considered to allow groundwater infusion and mitigate the loss of any baseflow loss from conventional piping. However, in this reach, there is obvious actual and potential contamination of the soils and groundwater from sources beyond Foodstuffs boundary or control. It would be more advantageous for the Kruse's drain ecology to be isolated from these groundwater contaminants than the slight loss of baseflow caused by piping this short reach. Due to the groundwater contamination, the option of a perforated pipe is not recommended. Moreover, Council would not allow this open drain reach to be board-walked due to maintenance access issues and possibly public safety.

In summary, the loss of baseflow caused by piping is minor, because the assessed baseflow gain over the entire 305 m reach was only c. 0.25 L/s, therefore baseflow loss from piping a sub-section must be less than 0.25 L/s, and impact we regard as less than minor (i.e. < 0.25 L/s). In addition, we assert that the local aquatic fauna in Kruse's Drain has a degree of resilience to some baseflow loss (see Figs. 11-14).The baseflow impact further downstream is further ameliorated by natural surface water gain and habitat remediation.

The 80 m reach immediately upstream of the piping and Lydia Street is proposed to remain as a boxed culvert rather than to be piped, as per the initial design plans. There was little sediment contamination along this reach.

7.2 Proposed stormwater treatment

Instream ecological values in urban environments are reported as being compromised by stormwater contaminants within their catchments with water quality decreasing as the proportion of impervious area increases (Suren & Elliott 2004). This is particularly relevant to the Lydia Stream Drain catchment, due to its small size, high proportion of impervious surfaces, and its unattenuated untreated stormflow inflow. Another feature of the proposal is high actual traffic volume, the number of parked cars, and ongoing activity based on heavy vehicles, fork-lift activity

The demise of ecological values in urbanised catchments, in particular, aquatic invertebrate diversity, is reported world-wide, and is referred to as 'urban stream syndrome'. The mechanism causing the loss the invertebrate values is linked to chronic levels of pesticides, heavy metals, hydrocarbons and other contaminants typically found in urban stormwater discharges.

Proposed on-site stormwater treatment will be important for maintaining ecological values in Kruse's Drain and ultimately, the Styx River. Currently, the development area is composed of approximately 25% pervious (gardens, lawns, and gravel borders), 27% (old roofing material), and the remainder (48%) mostly car parking and truck loading. None of the existing stormwater runoff is treated before discharge into Lydia Stream Drain or Kruse's Drain.

For the proposed development, the proportion of pervious area (gardens) will decrease to approximately 9%, with the remaining impervious area composed of new roofing (c. 33%), with hardstand for heavy trucks, forklift loading and supermarket car parking forming 58%.The forklift and trucking activity on the catchment area to the west side of the supermarket is likely to continue in the near future, although trucking activity is expected to cease after 2020 with a change in land use (Michelle Ruske, pers. comm. Aurecon). We expect untreated stormwater runoff to be high in dissolved zinc and dissolved copper (from tyre and brake pad wear), and hydrocarbons (esp. dripping engine oil from the carpark). For this reason, we recommend a high level of stormwater treatment, especially for dissolved metals and hydrocarbons. Well-maintained biological systems are more effective than mechanical filtration systems at deactivating dissolved metals and hydrocarbon, and the relative treatment performance of biological vs. filtration systems is discussed in a technical appendix (App. II). Given the traffic loading in this catchment, and the value of the receiving waters, biological systems which retain and treat contaminants will be used where feasible.

As part of this development, Foodstuffs propose to treat stormwater runoff from their hardstand using various treatment devices and methods. The division of the hardstand area to the east and west of the proposed supermarket also divides treatment methods.

First-flush (first 25 mm) stormwater from the carpark access roadways to the north (Area B), and some of the eastern carpark (Area E) will be treated by biological infiltration basins using proposed greenspace in the vicinity of, and even within, the traffic roundabout. Cleaned stormwater (and overflow in excess of 25 mm rain volume) will be discharged into the northern 7500 stormwater outlet. The stormwater treatment of the carpark east of the proposed supermarket will be of high standard involving two separate bio-retention treatment systems for contaminants in the stormwater runoff. Two Stormwater 360 Filterra® enclosed cells are proposed, running in parallel, to treat the carpark area, with another Filterra® unit to treat the vehicle entry point to the south and its associated basement ramp (Areas F & G, on the engineering plan). In addition, there will be preliminary treatment of stormwater entering the carpark sumps to be treated by rooting media around the carpark trees (Stratavault™), before discharging to the stormwater drain from the development area.

The existing hardstand to the west of the proposed supermarket (Area C) is subject to extensive tyre scrub from fork-lift operation and parking trucks, and presently has no stormwater treatment (Fig. 11). It is not feasible to pipe stormwater from Area C into the proposed bio-retention systems to the east of the supermarket. Instead, the raised ground level in this area will allow sufficient hydrostatic head for a propriety cartridge filter-type device (e.g. Stormwater 360 StormFilter or equivalent) before discharge to the existing 7500 stormwater drain to the south of the development. The space required for the roof stormwater attenuation tank on the south wall of the supermarket prevents further treatment of stormwater downstream of the cartridge filter.

Stormwater runoff from the supermarket roof is considered clean and the untreated stormwater from this source will be discharged to the attenuation tank mentioned above. Attenuated discharge from the tank will discharge into the existing 750 dia stormwater pipe running towards the Main North Road. There is insufficient room for stormwater treatment of roof runoff given the size of the attenuation tank, and treatment is considered unnecessary given its clean source.

Some small areas will remain without treatment, a length of the truck laneway (Area A), and the down ramp to the supermarket basement (Area D). Carpark stormwater from the adjacent and existing retail site on the corner of Northcote Road and Main North Road will remain untreated and discharge into the lower piped section of Lydia Stream Drain. Low carpark levels make stormwater from this area impossible to treat effectively.

Figure 11. Stormwater drainage from existing busy hardstand areas, which drain to Lydia Street Drain, will be treated to remove contaminants.

7.3 Effects of Stormwater contaminants on receiving waterways

Council rules require treatment of stormwater from new developments, but the standard is not specified. While the impervious area of the development site has increased, the proposed treatment of the impervious area has increased from zero, to a generally high standard as outlined in the previous section. Emphasis has been on designing a system which is effective at heavy metals and hydrocarbons which are considered to be the most toxic to aquatic ecosystems.

AEL maintains the stormwater treatment is clearly an improvement on the status quo where no treatment occurs, and the treatment system may be considered as representing a higher level of treatment than typically expected by Council.

7.4 Landscape Mitigation and Design

Foodstuffs have proposed to plant the 80 m reach immediately downstream of Lydia Street with native plants to improve the proposal from an ecological perspective. Planting the reach with natives will provide a small measure of shading to the waterway and limit overland sediment inputs, however planting will primarily benefit the terrestrial ecology and have a more aesthetic role than provide ecological function. There is no width to slope the banks from their existing vertical orientation, so the existing box drain structure will remain. The species list provided by Rough and Milne Landscape Architects (App. III) has been negotiated with AEL in respect to ecological benefits for local biota, both terrestrial and aquatic.

For example, the large carpark has scattered landscaped islands and borders with native plants and features to enhance terrestrial ecology. As mentioned above, the roundabout and adjacent green space in addition to aesthetic appeal, incorporate rain gardens to maximise stormwater treatment to benefit aquatic ecology in the receiving waterways.

7.5 Public relations

AEL considers that an environmentally friendly design of the carpark will provide an opportunity to show the public what a large, locally-owned company is doing to help improve both the aquatic and terrestrial environment within our city. Placards can be installed along the main walkway, and each one can illustrate a different aspect of the design. One placard can show how rain gardens and grass swales work to improve water quality, while providing valuable habitat for wildlife. The second can depict the path of the treated stormwater from "source to sea", showing some of the fauna in the catchment that Foodstuffs is endeavouring to protect. The third placard can show how the rock gardens are providing terrestrial habitat for some of our invertebrates and lizards. Foodstuffs have confirmed that they are agreeable to the provision of placards as part of the landscape design of the site to educate the public on the proposed stormwater treatment measures throughout the site.

7.6 Summary of Environmental Effects

AEL has had:

- a significant input into the assessment of the ecology of the direct, and indirect receiving environments.
- an assessment of baseflow loss from the proposal of culverting some of the existing open channel.
- a significant input into the stormwater treatment design and proposal, many of which have been implemented into the stormwater treatment design.

On the assumption the stormwater and landscaping designs are built to the specification provided above, we are of the view that any adverse impacts of the development, including the implementation of some piping, will have less than minor adverse impact on the aquatic ecology and instream habitat. In addition, there is a high chance that the significant improvement in stormwater treatment and ecologically sensitive landscaping will improve aquatic values downstream of the development.

8 Conclusion

It was evident that Lydia Street Drain has significant point-pollution sources outside of Foodstuffs land, which has led to shallow-ground and surface water contamination along the reach to be culverted, and consequently Kruse's Drain further downstream. Culverting the baseflow through the contaminated reach would be beneficial to downstream ecology by preventing enduring contaminants in the soil from infusing into the baseflow. For this reason, an earlier engineering option, to allow some groundwater infusion by use of a perforated culvert is not recommended. The ecological benefit from isolating the culverted baseflow from contaminated land out-weighs the reduction in baseflow along the reach and stormwater treatment is implemented. Leaving the upstream 80 m (i.e. the reach downstream of Lydia Street) un-piped will minimise baseflow loss to less than an estimated 0.25 L/s.

Proposed stormwater treatment of existing hardstand areas that well exceeds the bare minimum standards will benefit the ecology in downstream reaches (Horners Drain) where historic contaminant levels of metals is high. Investigations by AEL, along with civil engineering assistance from Powell Fenwick (Keegan Brogden) suggest that bioretention and infiltration devices (swales, rain garden, Filterra®) will provide an effective stormwater treatment system for this heavy-traffic catchment.

9 Acknowledgements

I thank Clinton Webb (AEL) for assistance in the field and Clinton and Mark Taylor for reviewing the draft manuscript. Technical assistance for the Filterra stormwater treatment system was provided by Stormwater 360.

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11 Appendix I. CCC Utilities GIS

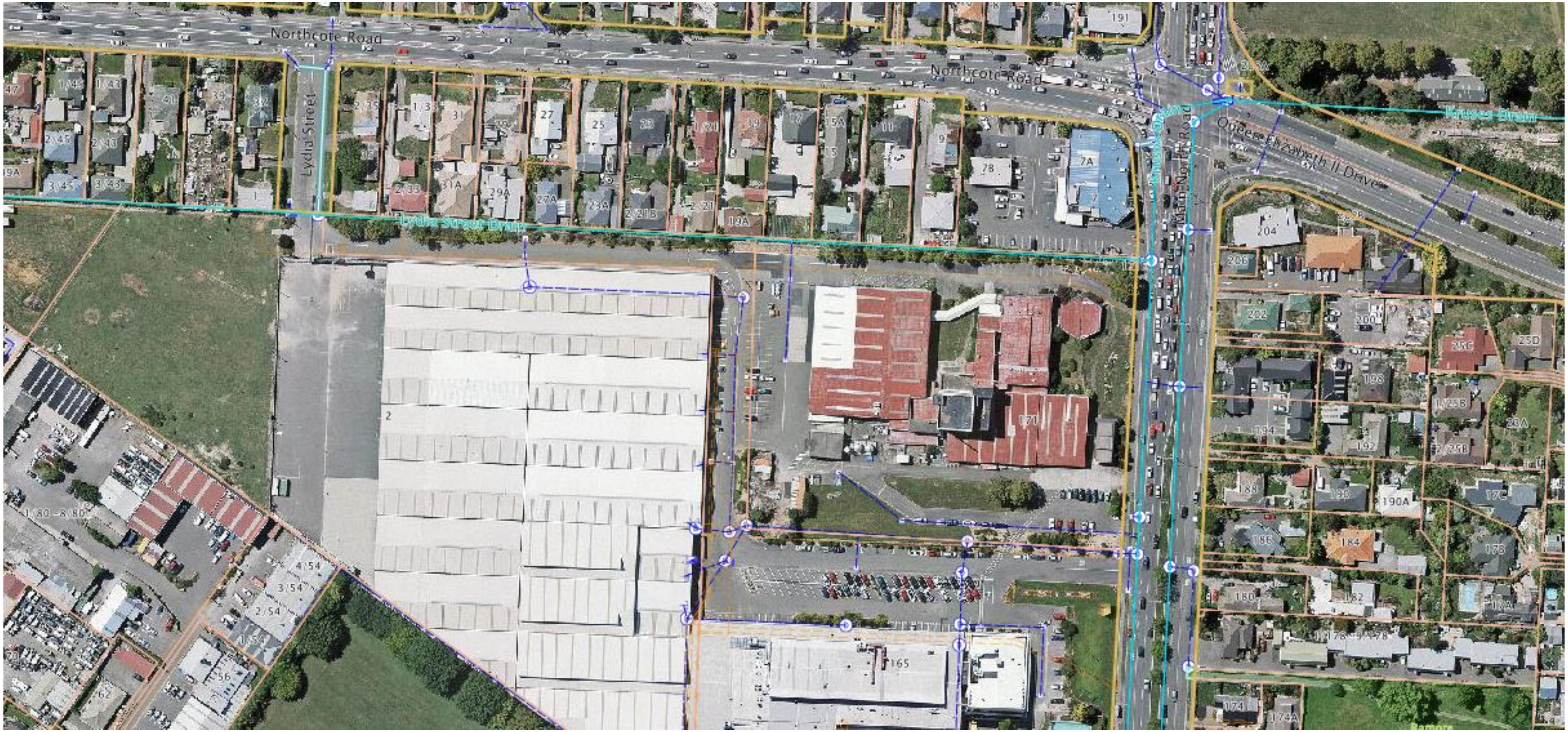

Figure i. Piped stormwater inputs (dark blue) linking to drainage channels (torquoise) entering Lydia Street Drain (snipped from CCC Utiliites GIS). Lydia Street Drain discharges into the piped Kruse's Drain network under the Main North Road before flowing through St. Bedes College.

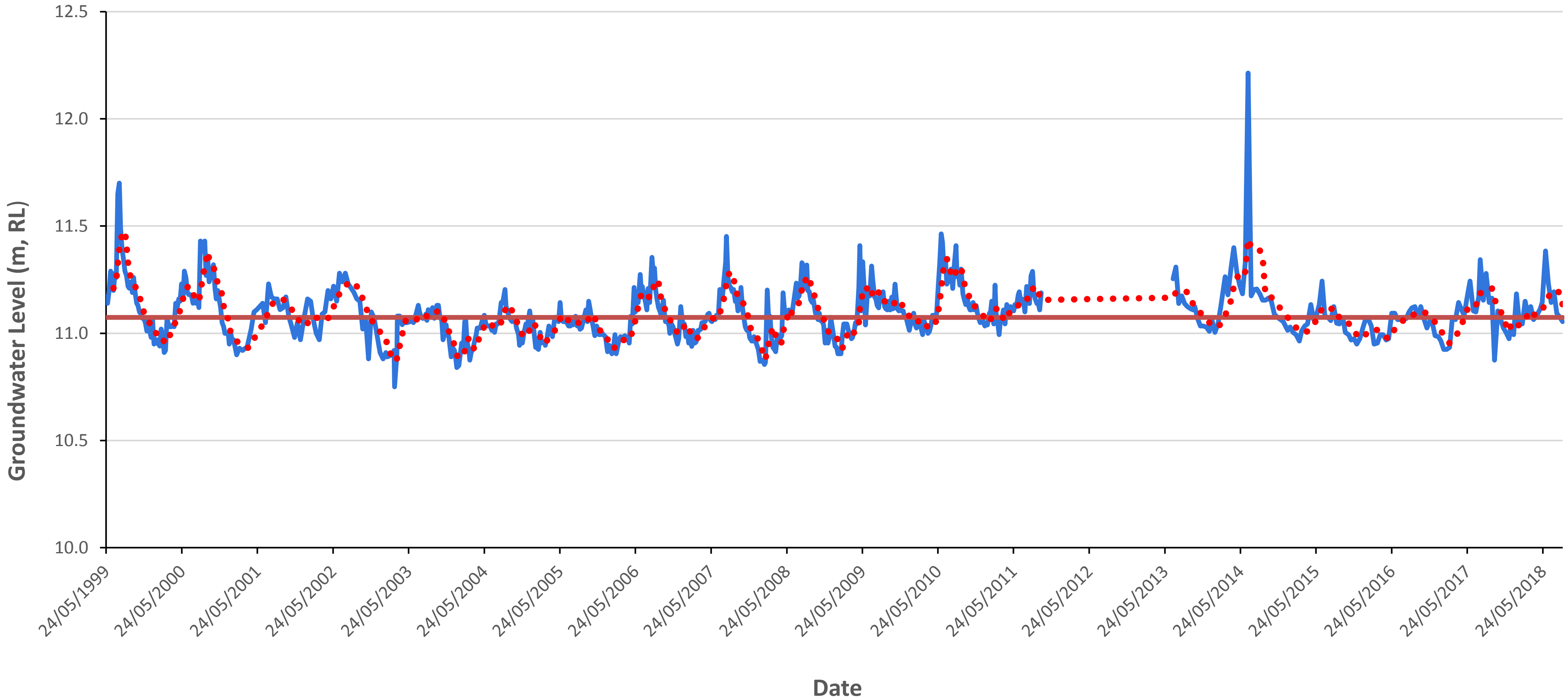

Figure ii. Groundwater level plot from north Christchurch (No. 2 Drain CCC station, 4.7 km away). Horizontal line = overall median level (11.074 m RL, n = 706), red dotted line = 6-point (3 month) moving average. The dry-season median (December-March) = 10.99 m RL, n = 219. There is an approximate 2-year break in the data series.

12 Appendix II. Stormwater treatment and performance in urban catchments

Dissolved metals form the bioavailable portion of toxic metals and thus their removal is one of the most critical factors to consider when designing stormwater treatment systems. The performance results of stormwater treatment by either cartridge or bioretention for dissolved metals is variable (NSF International 2004; Morgan 2011; Seattle Public Utilities 2012). A brief review of the existing literature shows StormFilter™ removal rates for dissolved zinc range from -23.9% - 17% and from -17.1% - 16% for dissolved copper (NSF International 2004; Seattle Public Utilities 2012). In comparison removal rates in rain gardens range from 72 – 80% for dissolved zinc and -100 – 58% for dissolved copper (Muthanna et al. 2007; Chapman & Horner 2010). Possible explanations for the variable performance are complex, however the lack of system maintenance has been ascribed as one reason for low performance.

Due to generally superior treatment ability of bioretention/rain garden facilities compared to cartridge-type stormwater treatment devices, AEL recommends, where feasible, either a Filterra® or standard rain garden design over physical cartridge stormwater treatments such as a StormFilter™. A Filterra® treatment system is essentially a compact rain garden within a sealed concrete container containing specialised media and providing a high stormwater infiltration rate, and reported contaminant removal. Filterra® treatment systems are maintained by replacing a thin top layer of ordinary garden mulch, and occasionally the media is reverse flushed by means of a fitted stand pipe to prevent the specialised media clogging. With these precautions, the media does not require excavating and replacing unlike a conventional rain garden (Anton Carr, Stormwater 360, pers. comm.) Based on our investigations, the Filterra system provides a similar treatment ability to a standard rain garden, but with a smaller footprint, appropriate where the proportion of treatment space is small compared to the area to be treated.

Conventional rain gardens require some ongoing maintenance to maintain biofiltration and stormwater treatment performance, and these are outlined in the CCC rain garden design manual (Table 10 *in* Christchurch City Council 2014). Complete replanting and disposal of sediments is required every 20 years, depending on how well the system has been maintained (Christchurch City Council 2016).

Grass swales can be used to pre-treat stormwater before entering rain gardens or Filterra® systems, which will extend the lifespan. Ideally grass should be 100- 150 mm long and swales a minimum of 60 m (Auckland Regional Council 2003; Christchurch City Council 2003). Where a 60 m length cannot be achieved, low check-dams can be installed to improve retention time.

13 Appendix III. Proposed plant list (Rough and Milne Landscape Architects, 24th May 2019)

Figure i. Plant list for the development Landscape and Urban Design Report, Version F (24 May 2019).

INDICATIVE SPECIES LIST

Carparking and Street Frontage Trees
Suggested species to include:
Alnus cordata
Cordyline australis
Platanus 'Autumn Glory'
Pseudopanax spp.
Upright Tulip *Liriodendron tulipifera fastigiata*

Amenity / Ornamental Planting
Suggested species to include:
Arthropodium spp.
Carex testacea
Chionochloa flavicans
Hebe spp.
Ligularia reniformis
Lomandra 'Tanika'
Lophomyrtus 'Red dragon'
Muehlenbeckia astonii
Penstemon spp.
Poa cita
Pittosporum spp
Phormium 'Green Dwarf'
Phormium 'Dark Delight'
Rudbeckia spp.
Griselinia 'Broadway Mint'
Corokia 'Geenty's Green'
Acaena inermis 'Purpurea'
Coprosma kirkii
Coprosma acerosa 'Hawera'
Muehlenbeckia axillaris
Parahebe 'Snowcap'
Pimelea prostrata
Thymus spp.

Rain Garden Planting
Suggested species to include:
Apodasmia similis
Arthropodium cirratum
Astelia 'Westland' and 'Silver Spear'
Carex virgata
Chionochloa flavicans
Coprosma spp.
Dianella spp.
Muehlenbeckia axillaris
Pittosporum spp.
Acaena inermis 'Purpurea'

Habitat Enhancement Planting
Suggested species to include:
Cordyline australis
Pseudopanax spp.
Astelia 'Westland' and 'Silver Spear'
Arthropodium spp.
Coprosma spp.
Muehlenbeckia astonii
Pittosporum spp
Phormium 'Green Dwarf'
Phormium 'Dark Delight'
Griselinia 'Broadway Mint'

Lydia Street Planting
Suggested species to include (amenity / ornamental planting):
Carpodetus serratus
Plagianthus regius
Parsonsia heterophylla