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3-awb95.00

Dear Laura

**Peer Review –**
**Infrastructure Performance During June 2015 Flood Event**

Thank you for your invitation to conduct a peer review of DCC's 30 November 2015 report on the June 2015 flood event. The scope of the review, as set out in your letter of engagement, was:

> To conduct an independent peer review of the report Infrastructure Performance during June 2015 Flood Event. The review should include consideration of the analytical approach, and the conclusions drawn from it.
>
> In particular, the review should examine the flow balance presented in the report and the conclusions drawn from it. It should also consider the influence of groundwater in the performance of the South Dunedin stormwater drainage system.

This letter presents the findings of our review.

## 1 Comments on Event Overview

The report opens with a brief synopsis of the June 2015 storm event, its hydrology and effects. The report presents Otago Regional Council data comparing the storm event spatially and with previous events, and references ORC estimates of storm return period, with appropriate cautions about both the statistical complexity and the interpretation of such estimates.

We notice that the 1968 rainfall event is missing from the quoted rankings, presumably because the 24hr rainfall was recorded over two calendar days.[1] While this may seem important in that it would change the ranking of the 2015 storm, the fact remains that the

[1] This point is discussed in Paragraph 59 of DCC's report.

2015 storm was a very significant event, which exceeded what the stormwater system was designed to manage.

## 2 Comments on Historical DCC Stormwater Design Approach

In common with older-established parts of many NZ cities, stormwater from individual South Dunedin properties (roofs, yards and driveways) discharges predominantly to the street channel, to be collected (typically at the end of block) via mud tanks into Council's stormwater system.[2] This high reliance on a relatively small number of mud-tanks creates a limitation that is not present in more modern subdivisions where all roofs and yards are independently connected to Council's pipe system, creating surplus inlet capacity. Consequently, the blockage or other hydraulic limitations of individual mud tanks will create greater effects in South Dunedin than in a modern subdivision elsewhere.[3]

The *Dunedin Code of Subdivision and Development* (2010) provides overall runoff coefficients for calculating stormwater runoff. Incorporated in these coefficients is an allowance for runoff from impervious surfaces and a reduced allowance for runoff from pervious surfaces (recognizing some runoff will be lost through soakage to ground). This approach is consistent with that taken by other TAs. Aerial photograph assessment carried out for the 3-waters study showed that parts of South Dunedin already exceed the *Code of Subdivision and Development* runoff coefficients (i.e. levels of imperviousness).

Modern stormwater systems comprise both primary (e.g. piped) and secondary (overland flow) components. The secondary systems are typically the gullies and undulations in the topography that excess runoff will follow once the primary systems reach capacity. Because South Dunedin is so flat and close to sea level, there are virtually no effective overland flow paths. All runoff that cannot be piped away or soaked to ground must be stored (as floodwater) until capacity becomes available in the underground drainage system. Modern stormwater codes, including DCC's, typically call for primary systems to be designed for the 1% AEP storm where secondary flow paths are absent. The South Dunedin stormwater system is not designed to convey 1% AEP storm flows.

DCC's report correctly notes the trend for increasing imperviousness over time in the catchment. Even though much of South Dunedin is "mature" in the sense that all sections are fully built-on, total imperviousness continues to increase as a result of extensions/alterations, multi-unit developments and additional paving.

DCC's has committed to maintaining key levels of service into the future (paragraph 16). This is, in effect, a commitment to progressive system capacity *upgrading* to cater for increasing imperviousness and climate change. (The Ministry for the Environment recommends that new infrastructure should allow for a 2.0 degree mid-range climate

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[2] We understand that some properties have their stormwater pipes directly connected to the wastewater system, however the number of such properties is uncertain.
[3] Note however that mud tanks are most efficient in low velocity situations (i.e. flat topography like South Dunedin) where ponded water can enter from all sides.

change, which equates to an approximately 12-16% increase in peak rainfall intensity for a year 2090, 10% AEP storm.)

## 3 Comments on Stormwater System Management

While system maintenance is obviously an important factor in the performance of any stormwater system stressed by a large storm, this is particularly so in the case of South Dunedin where there are no effective overland flow paths, and there is a high reliance on a relatively small number of mud tanks to provide system entry.

As a "mature" catchment, silt generation should be fairly low in South Dunedin, but it is still important that mud tank sumps are cleared periodically to ensure their outlets do not become blocked.

The lack of back-entries on typical mud tanks also makes them prone to grate blockage by leaves and litter. Such blockage typically occurs during the course of a storm, when it is difficult for the maintenance contractor to attend in a timely manner.[4]

Notwithstanding our comments above about the lack of redundancy with respect to inlet capacity, and the potential for pit blockage if not properly maintained, we are inclined to the view that these will have had a mostly localised effect during the course of the 2015 storm, since the Portobello Rd pump station record shows that it was unable to shift all flow arriving in any case.

## 4 Comments on Flow Balance Calculations

A simple flow-balance spreadsheet was prepared by Council officers to generate figures 4, 6, 7 & 8 in the 30 November 2015 report. Actual 10 minute rainfall depths from the June 2015 storm were converted into flows/volumes. Actual (or ideal) pump flows/volumes were deducted, as were pipe storage and estimated losses to ground, to arrive at estimates of surface flood storage. This volume was then converted to an indicative flood depth for the area known to have flooded.[5]

The analysis is considered suitable for the purpose intended, which is to illustrate the relative impacts of different pumping and soakage scenarios on total flood volumes and depths.

Two pump scenarios were tested, one based on actual pump recorded flows and one based on the pump station operating to its full design potential. For these runs, soakage to ground was assumed to drop to zero approx. 6 hours after the onset of heavy rain (see comments in Section 5). Two more comparative runs were conducted with continuous

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[4] Contractors typically have a list of high-risk sites that automatically become priority for attendance during a storm. More generally, this problem can often be addressed easily by residents clearing the grates with a garden fork.

[5] It should be recognized that flood depths in particular are intended as a useful indication only, principally to validate that flood volumes are in the right range, and are not intended to reflect a "real" depth.

soakage losses throughout the duration of the event. As expected the total quantum of surface flood storage indicated in this scenario was substantially reduced, although this is likely to reflect an unrealistic, lower-bound scenario as the soil is likely to have become saturated at some point during the course of the storm. With its pore storage filled, the rate of soakage would fall off markedly.

The report notes the break-out of flow from the surrounding hill catchments into the South Dunedin catchment (paragraph 42) and provides photographic evidence of this occurring (Fig 5). The analysis makes no attempt to quantify this effect, presumably due to the difficulty of determining an appropriate flow profile. Like South Dunedin, these catchments have no adequate overland flow paths (other than spilling into the South Dunedin catchment) and are not designed for the 1% AEP flow. It can be concluded that flow transfer from the St Clair and Orari St catchments would have worsened flooding in the South Dunedin catchment.

Similarly flow transfers to or from the wastewater system are not considered in the analysis, as it is impractical to do so.

## 5 Comments on the Potential Impact of Groundwater Levels

The scope of this review does not extend to examination of South Dunedin soil types and permeabilities, nor groundwater flow characteristics, however a number of general observations can be made based on the data provided.[6] These observations are provided in the hope that they will provide useful context for our review comments on the DCC analysis at the end of this section.

Much of South Dunedin is less than 1m above mean sea level. This not only affects surface drainage, creating a need for stormwater disposal by pumping, but also has significant implications for stormwater soakage. Average (i.e. dry weather) groundwater levels at ORC's groundwater monitoring bores are 0.5-0.9m below ground level and therefore only slightly above sea level. The fact that groundwater levels are even as low as they are may be a reflection of continuous draw-down by "leaky" pipes[7] and pumping.[8] The amount of rain water that can be disposed via soakage to ground is dependent on the pore storage available in the soil above groundwater level, and also the hydraulic head available to drive water sideways through the soil (which is a relatively inefficient process at low hydraulic heads).

Stormwater disposal to soil soakage may be quite effective during small, regular rain events, when the unsaturated zone acts as a "sponge", storing water to seep away slowly over a long period of time. As the rainfall intensity increases a point may be reached where the applied rainfall is greater than the soil's ability to soak it away, resulting in

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[6] *Coastal Otago Flood Event, 3 June 2015.* Report to Otago Regional Council Technical Committee, 22 July 2015.

[7] In the past it was common practice to omit rubber sealing rings from stormwater pipes laid below groundwater level to assist in drawing down the water table. Sewer infiltration may also contribute to groundwater drawdown.

[8] An example of this is at Culling Park, where ORC records show that groundwater level is sometimes *below* sea level.

surface ponding even though some soil layers below are not fully saturated. However, during a very heavy, prolonged rainfall event the soil storage capacity may even be filled completely, resulting in excess runoff ponding on the surface. The precise point in a given storm event when soil pore storage becomes filled is beyond the scope of this review, or the preceding DCC report.

Returning to the DCC report, the DCC analysts chose to ignore the effects of soakage to ground beyond the first 6 hours of heavy rainfall (10.30am on 3 June) at which stage 43mm of rain had fallen, and surface flooding had started to be observed. This assumption appears reasonable, based on the observations, the level of sophistication of the overall analysis and the other assumptions inherent in the analysis.

The importance of soakage is demonstrated by the fact that the estimated flood volumes differ by more than 100% between the two soakage scenarios.[9] This aspect clearly deserves more research as it will have a big impact on potential future upgrading costs. The "true" 2015 storm behaviour probably lies somewhere between the two modelled scenarios (although this reviewer considers it more likely to tend towards the lower soakage – Figure 6 –estimate).

# 6 Comments on Conclusions About Pump Station Performance

The report provides a commentary on the management of the Portobello Rd pump station, both generally and during the 2015 flood event. This reviewer is not in a position to comment on pump station operation in detail, but offers the following observations.

The report acknowledges that the pump station was incapable of operating to its full potential during the storm event and references actions that have been taken to prevent a similar situation arising in future. These actions are supported.

The analysis shows that the pump station capacity shortfall caused flooding experienced by the community to increase in extent, depth and duration. DCC's analysis suggests that the flood depth may have increased by approximately 200mm[10] as a result of the pump station capacity limitation.

# 7 Conclusion

The following conclusions can be drawn with respect to the June 2015 flood event:

1. It involved an exceptionally heavy, long-duration rainfall, generating a quantum of runoff that exceeded the design capacity of the Portobello Rd stormwater pump station. Such a storm, had it occurred anywhere else in NZ, would still have overwhelmed the primary stormwater system.

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[9] 367,000 vs 167,000 $m^3$

[10] As per earlier footnote, this is considered a "useful indication" at best.

2. The available subsurface storage (both in-pipe and soil pore storage) appears to have been fully utilised –at least in some locations – resulting in surface storage (i.e. flooding).

3. Operational difficulties (blocked screens and pump control limitations) further reduced the capacity of the Portobello Road stormwater pumps.

4. The DCC analysis demonstrates that if the Portobello Rd pump station been capable of operating to its full potential, surface flooding would have been reduced in depth, extent and duration.

5. The hydraulic limitations associated with mud tanks may have prevented Council's pipes from flowing full, however since the Portobello Rd pumps were operating below capacity this was probably of primarily local significance.

6. Even if the Portobello Rd pump station had operated to capacity, significant surface flooding would still have occurred around South Dunedin.

7. The lack of secondary flow paths means that any shortfall in the primary system is much more serious than elsewhere in the city. Many modern stormwater codes of practice, including DCC's own COP, call for the primary system to be designed for a 1% AEP event where there is no adequate secondary flow path.

8. It is recommended that Council re-visit the South Dunedin stormwater system design parameters in light of changed imperviousness, updated rainfall data, climate change, and the lack of secondary flow paths.

9. It is recommended that Council conduct further research into the availability of soakage during extreme rainfall events, and into the transfer of flow from the St Clair and Orari St catchments.

10. It is recommended that Council investigate ways to enhance pipe inlet capacity across South Dunedin.

In summary, Council's 2010 *3-Waters Strategic Direction Statement* sets a target of maintaining or improving the level of service set in 1964. In reality the current level of service has probably dropped below the 1964 level due to increased imperviousness and other factors.

Whether or not the 1964 level of service is appropriate to meet today's community expectations is a relevant topic for community debate,[11] [12] properly informed by options studies and cost estimates. The 2015 storm event has been a useful catalyst for opening

[11] It is recognized that the *3-Waters Strategic Direction Statement* determined this issue six years ago, but there is nothing like a major storm event to generate increased public interest and understanding.
[12] We note for example that the return periods and associated storm durations upon which the Portobello Rd pump station design was based do not meet DCC's current Code of Practice.

this debate, however the event was of sufficient magnitude that flooding would have occurred in any case.

DCC's 30 November 2015 report is commendable for its frankness in addressing these issues, and is a useful starting point for a wider debate. We consider that DCC's analysis provides a useful insight into the impact of soakage behaviour and pump station operation on overall stormwater system performance, and shows that both are highly significant factors. The impact of mud tank performance is less clear, but may have been a much more significant factor if the Portobello Rd pump station had performed to its potential.

We conclude that the analysis underpinning DCC's 30 November2015 report is fit for purpose, and the conclusions of the report are robust.

I trust these comments will be helpful as Council and the community navigate a path forward.

Regards

W J Bird

Warren Bird
Principal Environmental Engineer
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