CASE STUDY: UNDERSTANDING SECONDARY OVERLAND FLOWPATHS IN URBAN CATCHMENTS

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ABSTRACT

Secondary overland flowpaths are a key design component of an urban stormwater catchment's response to storm rainfall that engineers take account of in the provision of stormwater infrastructure. However, the complexity, function and effects of secondary overland flowpaths are not generally communicated effectively to non-technical audiences, e.g. non-technical professionals and the wider public.

This paper presents a case study of a residential subdivision in Palmerston North where the independent quantification of secondary overland flowpaths by the author assisted in the resolution of a dispute (that was to be litigated in the High Court) about the effects of overland flowpaths paths on adjacent property.

It is intended that the case study highlight the importance of stormwater managers and technical professionals understanding and communicating the extent and effects of overland flowpaths in urban catchments.

KEYWORDS

Urban Stormwater Management, Secondary Overland Flowpaths

PRESENTER PROFILE

Jesse Adams is a Chartered Professional Engineer experienced in the investigation, analysis and design of stormwater and waterway infrastructure. Jesse is based in Good Earth Matters Consulting’s Palmerston North office and provides stormwater services nationally for public and private sector clients in support of catchment management, asset management, and resource consenting processes.

1 INTRODUCTION

Secondary overland flowpaths are a key component of an urban stormwater catchment's response to storm rainfall, and their provision recognises that it is impractical to provide a primary stormwater network which can cope with all possible rainfall events.

The provision of secondary overland flowpaths is formalised in New Zealand engineering guidance documents such as the New Zealand Building Code 1992 (Verification Method E1/VM1 of Clause E1 Surface Water) and NZS4404:2010 the New Zealand Standard for Land Development and Subdivision Infrastructure, yet the complexity, function and effects they pose are typically not communicated effectively to the general public and non-technical audiences.

This paper stems from an engagement to assist Palmerston North City Council (PNCC) in the resolution of a dispute (that was to be litigated in the High Court) about the effects of secondary overland flowpaths on an adjacent property.

This complex scenario had a range of factors at play, but at the core was the requirement for the stormwater managers and technical stormwater professionals involved to communicate to non-technical professionals (lawyers) and a member of the public (plaintiff) how the primary and secondary components of a stormwater network functioned, and the potential implications for downstream properties.

Using this case study, this paper intends to highlight the importance of stormwater managers and technical professionals communicating the extent and effects of overland flowpaths in urban catchments by:

- Discussing the technical analyses undertaken and how they informed the understanding of the catchment functions, that is how the stormwater pipe network and secondary overland flowpaths interact in this specific case study; and
- Identifying key learnings for urban stormwater management in terms of understanding, and communicating, the extent and effects posed by secondary overflow paths in urban catchments.

2 CASE STUDY BACKGROUND

In 2014, a private developer (the plaintiff) pursued a legal claim of 'nuisance' against PNCC in the High Court with respect to a piped discharge from the existing Pacific Heights subdivision into the Johnstone Drive Gully, Aokautere, in which the plaintiff was constructing their own residential subdivision.

The claim of 'nuisance' in law relates to an unreasonable interference with someone else's land, and was pursued by the plaintiff after many years of litigation with PNCC. The basis of the claim was that the plaintiff did not want to accommodate the stormwater discharge from the upstream Pacific Heights subdivision into their stormwater infrastructure, despite earlier commitments to do so through the relevant resource consent processes.

Overall, this was a complex legal scenario with a range of factors at play. However, at the core of the dispute was that no consensus could be reached by the plaintiff, lawyers and stormwater managers regarding if, and to what extent the Pacific Heights subdivision stormwater infrastructure had affected the magnitude of peak stormwater flows in the Johnstone Drive Gully (which is located in the plaintiff's property). Contributing to the confusion, both the plaintiff and defendant had sought expert technical opinions on the matter which had reached contrasting conclusions.

The author was engaged by PNCC to provide a third, independent opinion on the potential effects of the Pacific Heights subdivision on the magnitude of peak stormwater flows into the Johnstone Drive Gully.

3 CHANGES IN THE JOHNSTONE DRIVE GULLY CATCHMENT AS A RESULT OF THE PACIFIC HEIGHTS SUBDIVISION

The Johnstone Drive Gully and the Pacific Heights subdivision are located in the Palmerston North suburb of Aokautere, on the southern side of the Manawatu River. Aokautere incorporates a mixture of residential, institutional, and rural land uses, and its stormwater catchments are characterised by a network of incised gullies that discharge to the Manawatu River.

The Johnstone Drive Gully catchment is shown pre and post the development of the Pacific Heights subdivision in Figure 1. The land which is the subject of the litigation is located immediately downstream of the Pacific Heights subdivision, and is also identified in both figures.

Figure 1: Johnstone Drive Gully Catchment Pre and Post the Development of the Pacific Heights Subdivision

The pre development scenario, depicted using 2002 aerial imagery, shows the ephemeral Johnstone Drive Gully and the 8.6ha catchment draining to the boundary of the plaintiff's property in rural land uses. Note residential development is beginning in the wider area with the development of sections on Pacific Drive in the upper left hand corner.

The post development scenario, depicted using 2014 aerial imagery, includes Stages 1 and 2 of the Pacific Heights subdivision and shows the 8.2ha catchment serviced by the reticulated stormwater pipe network. As of 2014, the earthworks, roading and stormwater services for Stages 1 and 2 of the Pacific Heights subdivision have been completed, but a significant proportion of sections have yet to be developed. Note that the technical analysis of the post development scenario discussed in latter sections of this paper considered the worst case scenario to estimate potential adverse effects and assumed that all residential sections would be developed within the catchment.

Note that in 2014 the plaintiff, independent of the Pacific Heights subdivision, has commenced the filling of the Johnstone Drive Gully immediately downstream of the Pacific Heights subdivision discharge point for the development of residential sections.

A high level comparison of pre and post development scenarios highlights that from a stormwater servicing perspective, the development of the Pacific Heights Subdivision has:

- Reduced the catchment area draining to the plaintiffs property boundary;
- Modified the catchment hydrological characteristics by increasing impervious area;
- Modified the primary drainage network by the filling of the upper portion of the Johnstone Drive Gully and the construction of a primary stormwater pipe network; and
- Modified the wider topography of the Johnstone Drive Gully catchment via earthworks, which will have altered the interaction of the primary drainage network with secondary flow paths in the wider area. Across the subdivision, the road carriageways sit below the level of the residential sections, promoting the carriageways as secondary overland flowpaths.

4 STALEMATE IN THE INTERPRETATION OF STORMWATER SYSTEM FUNCTION AND EFFECTS

Technical opinions were sought by both the plaintiff and the defendant to define the magnitude of the change in peak flows into the Johnstone Drive Gully that had resulted from the changes outlined in Section 3.

A stalemate scenario resulted where the technical opinions estimated changes in peak flow that were different by an order of magnitude, despite both using the same method of analysis (the Rational Method). Additionally, no gauged flow record for the Johnstone Drive Gully was available to validate either of the conflicting opinions.

From the perspective of non-technical professionals involved in the stalemate scenario, i.e. the lawyers, the order of magnitude difference in technical opinions was counterintuitive and elicited the question: Why is there an issue in defining the potential effects for such a small catchment, especially given the scenario of residential subdivision development is a common one?

The rationale for this question is understandable, but it also highlights that a miscommunication had occurred between technical and non-technical professionals in this instance as the question overlooks that:

- Independent of size, the catchment has an inherent degree of complexity in the interaction of primary and secondary components of the stormwater system in both the pre and post development scenarios; and
- There is a degree of uncertainty involved in all engineering analysis which is derived from the integrity of the analysis inputs, methodology and assumptions.

In recognition of the catchment complexity, and analysis uncertainty, PNCC sought a third independent opinion from the author. This is discussed in the following section.

5 DETAILED TECHNICAL ANALYSIS OF STORMWATER SYSTEM FUNCTION AND EFFECTS

5.1 METHODOLOGY

The detailed assessment of the effects of the Pacific Heights subdivision development on peak flows to the Johnstone Drive Gully utilised a hydrological model of the pre development catchment and integrated hydrological and hydraulic models for the post development catchment. The use of these models allowed the quantification of the relevant hydrological and hydraulic contributors to the peak stormwater discharge to the Johnstone Drive Gully, that is, the approach recognised that peak stormwater flows into the Johnstone Drive Gully are reliant on both the physical processes that generate stormwater runoff (hydrological component), and the manner in which the stormwater generated moves through the post development stormwater pipe network, and over the topography of the subdivision if the capacity of the stormwater pipe network is exceeded (hydraulic component).

Analysis was completed for a range of annual exceedence probability events of 24 hour duration, inclusive of the 20% AEP storm event which is the level of service required by PNCC for the primary stormwater network, and the 1% AEP storm event is PNCC's specified level of protection for residential building floor levels.

In the absence of an appropriate flow record to derive flow estimates or to calibrate outcomes, a sensitivity analysis was undertaken of key hydrological parameter assumptions, and the consequential effects of parameter sensitivity on the conclusions drawn on the relative change in flows from pre to post development scenarios.

5.2 OUTCOMES

As an outcome the detailed analysis communicated to both technical and non-technical parties involved in the litigation that the catchment response to a storm event is complex and that:

- Secondary overland flowpaths have an important role in controlling stormwater peak flows into the Johnstone Drive Gully; and
- Depending on the relative annual exceedence probability of the storm event experienced, there is the potential for either adverse or beneficial downstream effects.

5.2.1 IMPORTANT ROLE OF SECONDARY OVERLAND FLOWPATHS

The key finding of the detailed analysis was that the carriageway of Monaco Grove, in conjunction with a secondary overland flowpath that forms via a walkway in the Pacific Heights subdivision, act as a detention area to control secondary overland flowpaths from the subdivision into the Johnstone Drive Gully. This complexity in catchment function had not been captured in the analysis contributing to the stalemate scenario discussed in Section 4.

When accounting for secondary overland flowpaths in the post development catchment, and the constraints the subdivision topography pose on the flowpaths, the total discharge to the Johnstone Drive Gully was estimated to consist of the following which are shown schematically in Figure 2:

- A discharge from the stormwater network outfall into the Johnstone Drive Gully, whose capacity is fixed by the physical characteristics of the primary stormwater network;

- A secondary overland flowpath through the walkway from Monaco Grove into the Johnstone Drive Gully in events greater than the 2% AEP storm. The walkway is shown in Figure 3; and

- Minor secondary overland flowpaths from small diameter stormwater pipes in private properties in Monaco Grove directly into the Johnstone Drive Gully. The relative contribution of these overflows to the coincident peak discharge to the gully is essentially negligible.

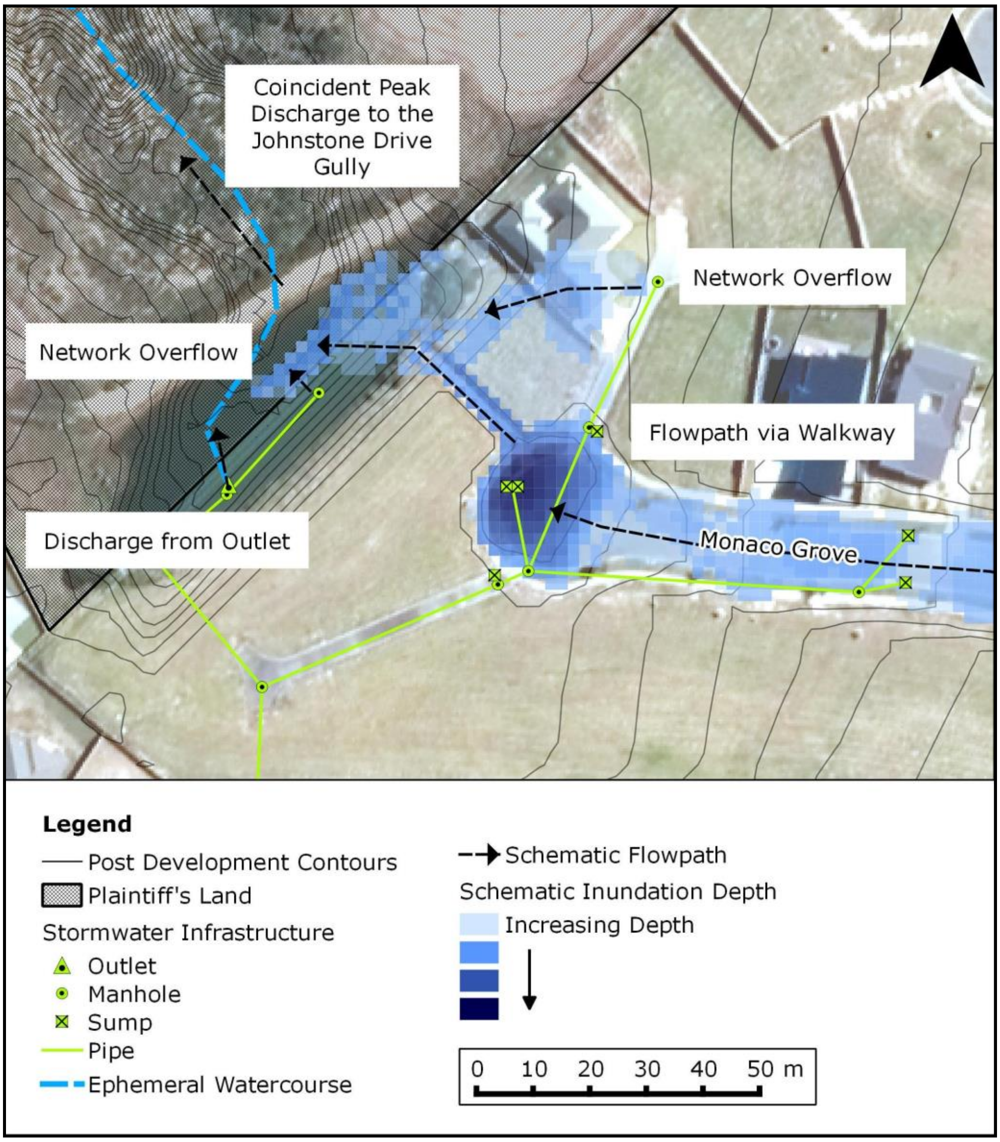

Figure 2: Schematic of the Coincident Post Development Stormwater Discharge to the Johnstone Drive Gully

Figure 3: Walkway Secondary Overland Flowpath – Taken from Monaco Grove and Looking Towards the Johnstone Drive Gully

5.2.2 POTENTIAL FOR EITHER ADVERSE OR BENEFICIAL EFFECTS

The complexity of catchment function was further emphasised by considering the effects of the multiple constraints noted above on peak flows into the gully, relative to the pre development scenario across a range of annual exceedence probability storm events. Again, this complexity in catchment function had not been captured in the analysis contributing to the stalemate scenario discussed in Section 4.

Figure 4 summarises the relative comparison of peak flows for the 20%, 10%, 2% and 1% AEP storm events of 24 hour duration, and highlights that:

- In the 20% AEP storm event, the design level of service of the primary network, a relative increase in peak flows from to the Johnstone Drive Gully is predicted to occur from the full development of the Pacific Heights subdivision. In this storm event the coincident peak discharge from the subdivision is predicted to consist of a discharge from the primary network outlet and negligible overflows from some small diameter pipes in private property.

  This finding indicates that overall, the development of Stage 1 and Stage 2 of the Pacific Heights subdivision has modified the hydrologic characteristics and increased stormwater peak flows.

  Note that this outcome, and the magnitude of the increase, was in general agreement with one of the technical opinions provided using a Rational Method analysis.

- In this catchment, the 10% AEP storm event is the point at which the constraints in the primary and secondary components of the stormwater system mitigate increases in peak flows into the gully, and essentially no relative change in peak flow to the gully occurs.

In this storm event the design level of service for the primary stormwater network is exceeded, but the coincident peak discharge from the subdivision to the gully is predicted to consist of a discharge from the primary network outlet and negligible overflows from some small diameter pipes in private property.

That is, the configuration of the primary stormwater system and subdivision topography in Monaco Grove act as a detention area to mitigate the effects of increased runoff volumes from changes in the catchment land use.

- In the 2% and 1% AEP events, the level of service of the primary network is exceeded, and the coincident peak discharge from the subdivision to the gully consist of a discharge from the primary network outlet, a secondary overland flowpaths via the Monaco Grove walkway and overflows from some small diameter pipes in private property.

  The relative change in peak flows is predicted to decrease, i.e. the development of the subdivision provides additional protection downstream properties, as the fixed physical constraints the stormwater pipe outfall and the subdivision topography (in particular the flowpath through the Monaco Grove walkway) impose constraints on flows into the Johnstone Drive Gully.

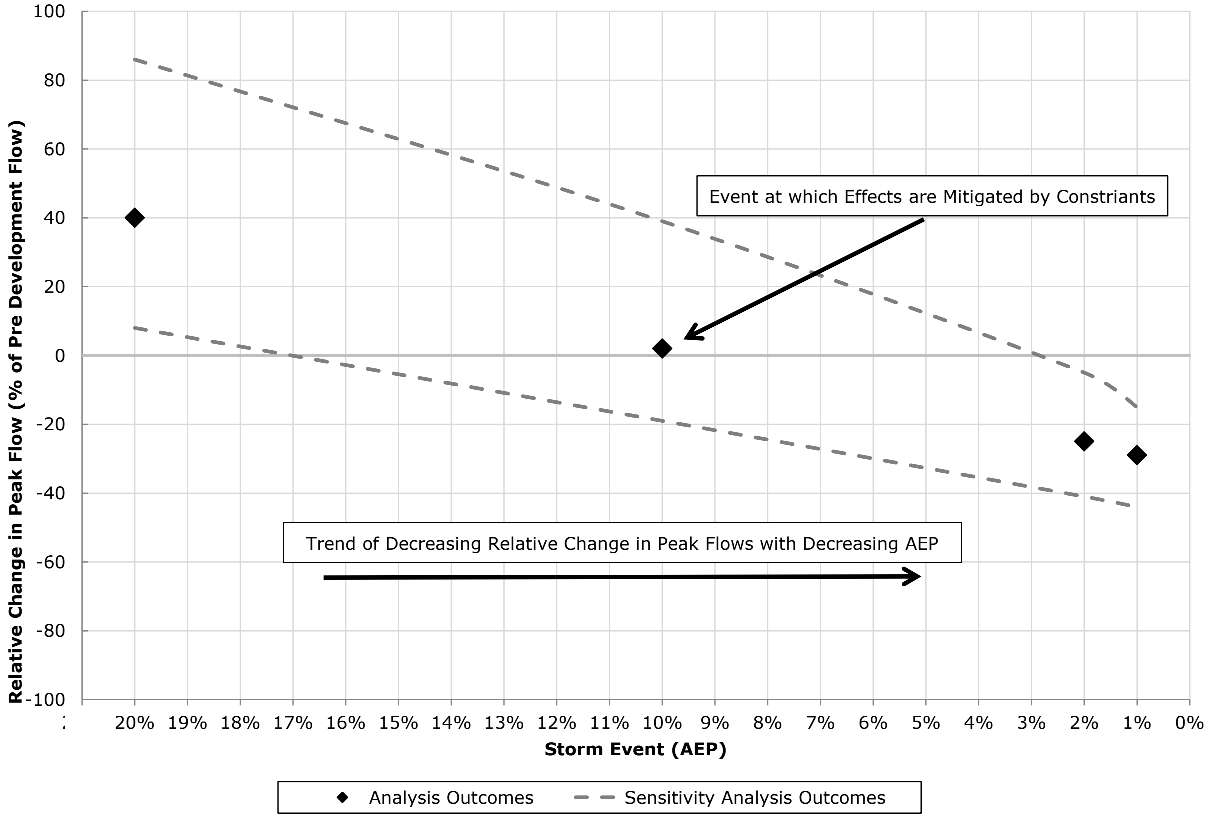

Figure 4: Change in Peak Flows to the Johnstone Drive Gully for the 20% AEP, 10% AEP, 2% AEP and 1% AEP Storm Events of 24 hour Duration Relative to the Pre Development Scenario.

6 LESSONS FOR URBAN STORMWATER MANAGEMENT

This paper has presented a case study where understanding and communicating the function and extent of secondary overland flowpaths was essential in quantifying the potential effects of a residential development on downstream properties.

Whilst the analysis discussed is specific catchment, the case study highlights three wider lessons about communication in stormwater management that can be applied to prevent similar confrontational scenarios occurring in the future:

1. The clear communication of how a catchment functions (both primary and secondary network components) is required to avoid future adverse effects;

2. The clear communication of assumptions, limitations and uncertainties is required for any assessment of effects methodology; and

3. The concept of hydraulic neutrality needs to be clearly communicated so that expectations for development are achieved.

6.1 COMMUNICATION OF CATCHMENT FUNCTION

The clear communication of how a catchment functions (both primary and secondary network components) is required to avoid future adverse effects.

Retrospective quantification and communication of the catchment function was at the core of the presented case study. This retrospective analysis was required despite the completion of the relevant design and consent approval processes prior to development occurring.

Now armed with the understanding of catchment function, this information can be used to avoid future adverse effects downstream of the Pacific Heights subdivision. This is possible as it is understood that the carriageway and walkway in Monaco Grove are key features in the catchment's response in rainfall, in that they essentially act as a detention area. Avoidance of future adverse effects downstream can be achieved with the communication, and thus retention, of the geometry and levels of these features.

In application to the wider context, this demonstrates that the communication of catchment function is essential to identify key catchment infrastructure/features that require protection to avoid future adverse effects.

6.2 COMMUNICATION OF UNCERTAINTY, ASSUMPTIONS AND LIMITATIONS

The clear communication of assumptions, limitations and uncertainties is required for any assessment of effects methodology.

All engineering analysis involves uncertainty from input data design assumptions, calculation methodologies and the interpretation of results. This uncertainty needs to be understood, and communicated.

This is emphasised in the case study with the question posed by non-technical professionals (lawyers) involved in the stalemate scenario: Why is there an issue in defining the potential effects for such a small catchment, especially given the scenario of residential subdivision development is a common one?

This question highlights that a miscommunication had occurred, as it does not acknowledge that the scenario can be analysed in numerous ways, each with different assumptions, limitations and bounds of uncertainty.

In application to the wider context, this demonstrates that the clear communication of uncertainty, limitations and assumptions is essential for any technical stormwater analysis to be interpreted in context.

6.3 COMMUNICATION OF THE CONCEPT OF HYDRAULIC NEUTRALITY

The concept of hydraulic neutrality needs to be clearly communicated so that expectations for development are achieved.

The concept of hydraulic neutrality is a key mitigation philosophy to avoid adverse effects from development. Whilst it is not a direct topic of the analysis presented here, the findings are relevant to the practical implementation of hydraulically neutral development.

The Pacific Heights subdivision has the potential to either cause adverse or beneficial effects on downstream properties depending on the annual exceedence probability of the storm event experienced. In the wider context of hydraulically neutral development, this emphasises that clear communication is required:

- To define the target design criteria for hydraulically neutral mitigation measures; and
- To ensure that the target design criteria encompass an appropriate breath of possible scenarios, inclusive of the residual effects associated with events that lie outside of the target design criteria.

Additionally, the findings serve to further emphasise the above lessons for stormwater management, in that an objective and factual assessment of hydraulic neutrality is required to be undertaken in the context of the wider catchment function, and interpreted in the context of the relevant bounds of uncertainty, limitations and assumptions.

6.4 SUMMARY

In summary, the key message in the above, is that as stormwater specialists and managers, technical expertise alone is not sufficient. Technical expertise needs to be underpinned with clear communication which is able to be understood by both technical and non-technical professionals involved.