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Memo

To	Jamie Sirl
CC	Renee Fraser-Smith, Caleb Clarke, Craig Sharman
From	Gustaaf Kikkert
Reviewed by	Eugene Vodjansky
Date	23 July 2021
Job No.	147090
Job name	Rotokauri North Development
Subject	Subcatchment ICMP – Stormwater Management Report

Introduction

On the 13th of July 2021, BBO received the review comments by Morphum Environmental on the stormwater management solutions proposed as part of the sub-catchment ICMP for the Rotokauri North Development. The following are the replies to the comments. For clarity, the original comments have been included in italics. In addition, an updated version of the stormwater report has been attached that takes into account the review comments, where applicable.

Key Points

- The ICMP and Stormwater System Report provide for resolution of many stormwater issues and provide for many important opportunities and outcomes.
- The Hydraulic Grade is a key issue for the development of this area. The system function is difficult to decipher from the ICMP and SSR; there is no summary table and some information is missing (as indicated in the items of this memo). Specifically, it is unclear what the permanent water levels are in the wetlands and at the site discharge points. It would be useful to include in the reports a table that summarises the design water levels, surface area and volumes (permanent, extended detention, and storage above that) for each wetland or storage zone.

BBO reply – A summary table of the wetlands including the elevation and area of the permanent water level, the bund level and the HGL and stored volumes for the 2yr, 10yr and 100yr ARI events, has been added to the text as Table 4-3. These assumed levels were applied in the 1D and 2D stormwater modelling. The permanent water levels in the wetlands are related to the stormwater network outfall levels and the reestablished stream levels, which will be developed as part of detailed design. Hence these assumed levels, will have to be revised through detailed design.

- It is recommended the applicant provide overview long sections through the site, along the stormwater system alignments for the water quality, 2 year, 10 year and 100 year ARI, 24 hour events to confirm that the proposed layout provides adequate capacity for hydraulic grade.

BBO reply – The proposed stormwater management system was designed in a 1D model (EPA SWMM) and tested in a 2d model (HEC-RAS 2D). The 2D model was based on concept level earthworks that accounted for accommodation for stormwater pipe networks. The 2D model clearly shows that the treatment and attenuation/conveyance system has capacity for 100-year ARI drainage, while accounting for climate change. It logically follows that the system will have capacity for the 2-year and 10-year ARI events. Detailed long sections will be provided as part of detailed design.

- Details are required to show how Rotokauri South sub-catchment will be managed and if mitigation will be provided prior to discharging to Wetland G8.

Major sub-catchment Rotokauri South falls within the catchment of basin 3 as part of the Rotokauri Greenway (Beca Limited, 2018). Treatment and attenuation of the flow of basin 3 takes place in the minor arterial wetland G8, hence this wetland also has to treat and attenuate all flow from major sub-catchment Rotokauri South 1. No mitigation will take place prior to the discharging into the pipeline that conveys the flow to wetland G8. Design of wetland G8 is outside the scope of the Rotokauri North sub-catchment ICMP.

- The method for securing the key drainage areas through the private plan change are not clear. For example, what will be the zoning or designation for the areas indicated on Figure 13 of the ICMP as Green Spine/ Area Indicative only.

BBO reply – This is not a sub-catchment - ICMP issue. The SC-ICMP is an information document to support the Plan Change which includes a Structure Plan and new/amended provisions to the HCC District Plan. It is not the job of the SC-ICMP to propose how the detail is incorporated into those documents. This is a planning matter, and is being addressed by the planning workshops held between Tollemache Consultants, HCC and Beca (on behalf of HCC).

However for clarity, unlike the Rotokauri South "greenway", HCC are not funding or responsible for providing the stormwater management. This is a private plan change and the infrastructure for stormwater is to be delivered by the future developers. Designations are not an option for private development.

The Green Spine Areas are shown indicatively on the proposed structure plan to signal where these are anticipated. These are shown on land with titles held by the Plan Change applicant (GSL) and/or a company falling under its umbrella. The Green Spine areas will contain the proposed stormwater infrastructure according to the HCC and WRC stormwater management guidelines.

The Plan change is not the mechanism required to secure these areas, nor is it necessary to locate devices on a Structure Plan. Future resource consent for subdivision and development will create the final areas for stormwater management purposes. Proposed rules of the PPC and existing rules in the HCC District Plan require that further sub-catchments IMCP's be prepared to support development within Rotokauri North. Thus, there is an existing mechanism to ensure that device location, catchments etc adhere to the recommendation of this PPC level sub-catchment ICMP at design stage.

Objectives and Overview

- This SC-ICMP identifies three of the strategic objectives chosen from the Mangaheka and Rotokauri operative ICMP's to focus on: RN Structure Plan, Quantity Control, and Quality Control. Why were the other relevant objective of those ICMPs excluded, e.g., Stakeholder Engagement and Ecological protection and enhancement?

BBO reply: The objectives are not intended as "replacements" to those contained in the Mangaheka and Rotokauri operative ICMP's. They are "in addition to".

- Table 133 (Section 8 of the SC-ICMP) is unclear for Roads. We understand the "Recommended Device Options" to be, treatments for the Lot/Area Type listed, regardless of the location where the treatment is put. If that's correct, then Treatment and Detention should be listed against Roads with recommended option being the main swales and wetlands.

BBO reply: Treatment of road run-off as well as the residential and commercial properties is carried out in the wetlands. This has now been explicitly stated in Table 13.

- Has peak flow mitigation for the Rotokauri South sub-catchments been accounted for in the Rotokauri Arterial Designation (RAD) design for Wetland G8? We note from Paul Ryan's email June 11 2021, following a June 10 meeting between RAD team and PC7 team that "Plan changes 7 needs to:
  - o limit the catchment draining to greenway to match the NOR area
  - o allow for the overflow from the Greenway into mangaheka. (not a RAD NOR issue)."

BBO reply: From the Rotokauri ICMP documentation, it was not directly clear where the proposed catchment boundaries of the Rotokauri South 1 major-subcatchment are. The Rotokauri Greenway – Design Report by Beca shows the boundaries of catchment SC3D (on page 63) that includes the Rotokauri South 1 major sub-catchment. It is assumed that boundaries of SC3D are along the centre of the Greenway, then the major sub-catchment Rotokauri South 1 is estimated to be 73% of catchment SC3D which yields an area of 14.4 Ha.

As part of the pre-development SWMM model a catchment delineation was carried out on the Rotokauri North area which included the current road boundaries and existing culverts. This yielded an area for the Rotokauri South 1 major sub-catchment of 15.3Ha. When identifying the boundaries of the proposed minor sub-catchments, the boundaries of the major sub-catchment Rotokauri South 1 were adjusted to better align with proposed lay-out of the development. This reduced the area of major sub-catchment Rotokauri South 1 to 13.35 Ha. The area from the Rotokauri North area that drains to the greenway therefore matches the NOR area.

The requiring authority's conditions for the Rotokauri Greenway Notice of Requirements includes article 42b ("Maintaining existing sub-catchment drainage patterns up until the development of adjacent sub-catchment") and 42f ("Maintaining the overland flow route to the north of Basins 3 and 4 along the proposed Arterial Road. Documentation relating to the Rotokauri Arterial Transport Network design shall be provided to confirm this has been allowed for."). Hence the overflow from the Greenway into the Mangaheka stream falls outside of the Rotokauri North sub-catchment ICMP.

- Why is WRC TR2018/01 referred to, when TR2020/07 is the latest version of the Waikato stormwater management guideline?

BBO reply: Reference in the document should have been the latest version of the Waikato stormwater management guideline. This has been updated in the latest version of the document.

Overall System Hydraulics

- SC-ICMP Section 8, Table 10: For piped drainage infrastructure, the criteria proposed would enable the HGL to be at any level below the ground. As per email dated 11 June 2021 from Craig Sharman to Renee Fraser-Smith, the applicant should revise so that HGL for 10 year ARI not exceed pipe soffit and also not exceed invert level of subsoil drains at their outlet.

BBO reply: Stormwater pipe outfalls will discharge into treatment wetlands at the PWL. Depth of 10year flood in the treatment wetlands is likely to be greater than the discharge pipe diameter. Due to the flat nature of the site and tailwater levels that will exceed the level of the discharge pipe soffit, it is virtually impossible to ensure the HGL during 10-year flood does not exceed pipe soffit at all locations within development. This will have no negative impact on the performance of the system.

- Terrain: It was noted in Section 6.0 of the SSR, that the terrain model was created from LIDAR then modified by lowering at the wetlands and raising land to provide cover over pipes. We assume that no levels on the boundary of the terrain model were changed in this process. The resultant terrain (shown in Figure 6-1 in the SSR) shows that the topography in Ohote and Te Otamanui appears to match the sub-catchments shown in the concept layout plan in Appendix B. However, has the division of minor sub-catchments been considered in relation to possible future earthworks, roads and minor overland flow paths and how will this be carried through into the Structure Plan?

BBO reply: The division of minor sub-catchment was based on the latest proposed version of the lay-out of the development, including possible earthworks, roads, and overland flow paths. However, it is likely that there will be changes to the lay-out, as the design progresses. The effect of the changes on the stormwater management, including the boundaries of the minor sub-catchment, will be assessed as part of detailed design. The high-level earthworks were laid out to confirm that the use of reticulated stormwater network is feasible, which is what is required for a plan change. We are not proposing changes to the Structure Plan (refer to previous response on planning mechanisms). With regard to the Plan Change, we are demonstrating that drainage of Rotokauri North is hydraulically and operationally feasible.

- Levels: A mannings of 0.035 has been used for the 2D modelled area, is that appropriate for the smaller events when water levels will be lower in the base of vegetation and mannings would likely be higher?

BBO reply: The 2D model was specifically set up to confirm the stream routing and required attenuation volume as obtained from the 1D model. The 2D model was therefore only run for the 100yr ARI storm event. If, during detailed design, the model is run for smaller storm events, then a suitable manning's n will be adjusted for these smaller storm events.

- Existing Outflows: Figure 4 in the SC-ICMP shows an existing catchment outflow crossing Te Kowhai Road, near proposed sub-catchment Ohote 1 C. It appears to have been abandoned in the proposed system. Why and what is the impact of this?

BBO reply: To obtain the existing peak flow rates at the outflow points, the SWMM model does incorporate the existing crossing of Te Kowhai Road at Ohote 1. The run-off that is currently directed to this crossing is therefore not added to the existing flow rates at the Exelby Rd crossing. However, to simplify the proposed model of the stormwater management set up for the sub-catchment ICMP, this crossing was not utilized. In the proposed model, all the run-off is directed toward the Exelby Road culvert outlet instead. To meet the existing flow rates at the Exelby Road crossing therefore required a small amount of additional attenuation. As part of detailed design, use of the Te Kowhai crossing at Ohote 1 will be investigated for draining the backs of lots along Te Kowhai Road. This would be accomplished through the use of swales along the back of properties next to Te Kowhai Road and may reduce the volume of run-off that goes into Wetland Ohote 1.

- Storage: The analysis shown in Table 1 assumed that the "Maximum Volume" values reported in the SWMM "Storage Volume Summary" data is above permanent water level, and the 100 year ARI, 24 hour event data was used. It is unclear why the "Max Pcnt Full" is so low in the 100 year ARI, 24 hour event – please clarify. The reserves were excluded from the total areas in Table 1.

BBO reply: The values reported in the Storage Volume Summary are above the permanent water level. The "Max Pcnt Full" is calculated based on the given storage curve as well as the given max depth for the node. To make sure that the nodes do not pressurize but flood instead, for example for manholes, the max depth for the node is often set to a higher value than "ground level". In the case of the wetlands, this max depth was set to 4m, even thought the storage curve (and therefore "ground level") only went to 2m. All the volume above the 2m of the storage curve is still taken into account when calculating the "Max Pcnt Full". As an example, the max depth for wetland Ohote 2 was changed to 2m, this yielded a "Max Pcnt Full" of 88%.

Stormwater Quantity Control

- SSR Section 7.3 discussed culvert embedment depth. The NZ Fish Passage Guidelines recommend that "culvert invert will be embedded by 25- 50% of culvert height". However, this section explains that 200 mm embedment will be used regardless of culvert height and explains the theory behind this decision, which seems counterintuitive. Please provide stronger evidence or revise design to provide full embedment depths.

BBO reply: The embedment requirement was discussed with Paul Franklin and Eleanor Gee, co-writers of the NZ Fish Passage Guidelines. They clarified that the suggested typical embedment of 25% to 50% of the culvert height was mainly meant for circular culverts. Increasing the embedment depth up to 50% in a circular culvert increases the width of the flow in the culvert. For a particular flow rate, the increased width of the flow yields lower velocities in the culvert which aids fish passage. Increasing the embedment layer does not increase the width of the flow if a box culvert is used. In a box culvert the embedment layer has to be suitable to maintain natural stream habitat and substrates, but not allow a channel to be formed that reduces the flow width in the culvert and increases the velocity. Based on the above, the 200mm embedment layer is proposed for box culverts only. If circular culverts are used, a proper analysis of the impact on the embedment layer on the expected velocities within the culvert will be carried out as part of the culvert design for fish passage.

- Tailwater: The SSR doesn't discuss tailwater conditions used on modelling. We can see that in the 2D model, the initial stored volume in the system was set to 2mm and assume this is just to kick start modelling. How was initial water level in the stream and wetlands accounted for in the model, or was the terrain model developed to sit above the permanent water level?

BBO reply: The outfall structures at Exelby Rd, SH39 and the Mangaheka wetlands control the flow out of the catchments. Due to the attenuation provided within the catchment, the water surface within the catchment will be higher than that downstream of the outfall structures, however it cannot be assumed to have a free outfall. Flow rates or elevation data were not available at any of the outfall locations for determining the tailwater condition. At Exelby Rd and SH39 crossings, a section of channel was added downstream of the culverts/weirs in the SWMM model. The channel ended at the outfall node. The tailwater conditions were obtained by giving the outfall node an appropriate invert level and setting the outfall type to Normal, causing a normal flow calculation for the channel to establish the tailwater. The flow conditions at the outfall point are then calculated based on the upstream channel. For the Mangaheka catchments, a part of the Mangaheka stream was included in the SWMM model to yield appropriate tailwater conditions. The size of the culvert crossing Te Kowhai Rd East was unknown; hence the model was calibrated using elevation data from the report "Mangaheka Integrated Catchment Management Plan – Stormwater 1D Modelling Report" which is an attachment to the Mangaheka ICMP. For the Rotokauri South catchment, the water is conveyed to wetland G8 which is not part of the subcatchment ICMP and hence no tailwater modelling was carried out.

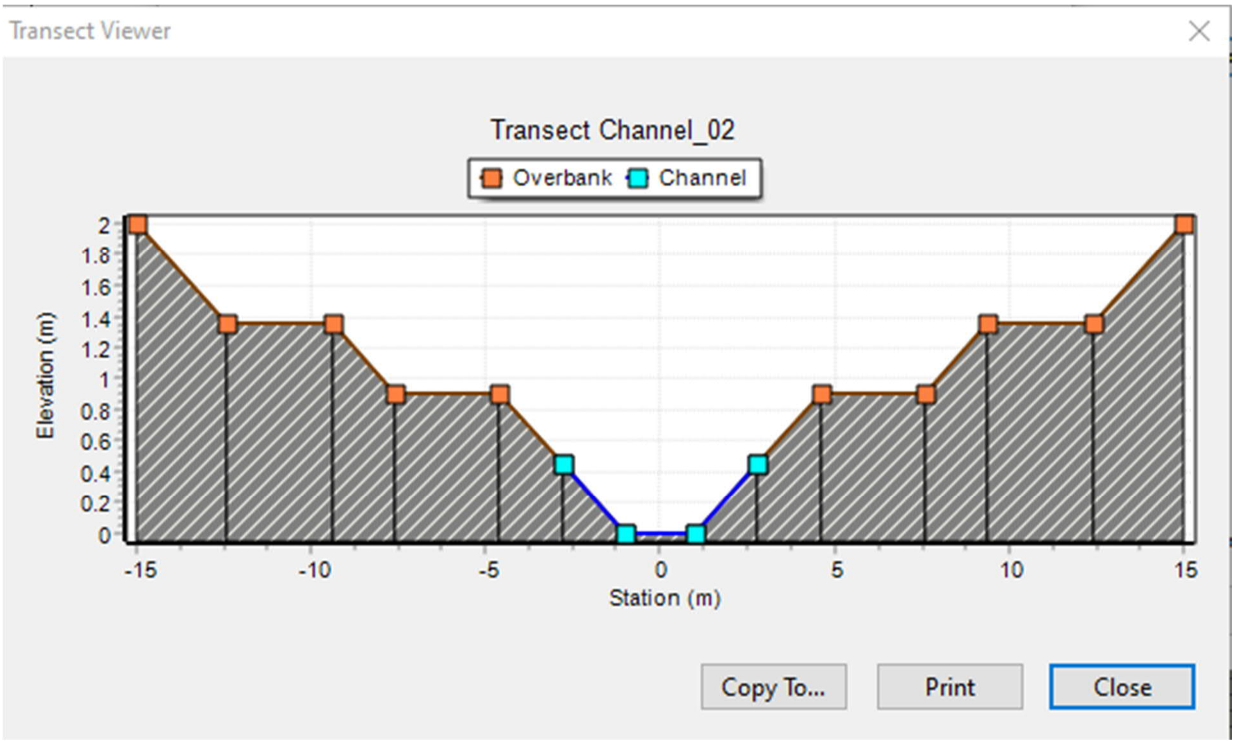
As part of the stormwater management plan, the existing stream will be re-established and will have functional floodplains. The details of the re-established streams will be worked out as part of detailed design. In addition, the initial water levels in the streams are currently not known and hence these were not included in the 1D and 2D models. The cross-sectional profiles used in the 1D and 2D models were instead simplified approximations of the final cross-sections and therefore did not explicitly include the part of the stream that has a permanent flow. For the large storm-events modelled, the details of the stream have little impact on the flow behaviour.

For the wetlands, the invert levels used in the models were at the permanent water level.

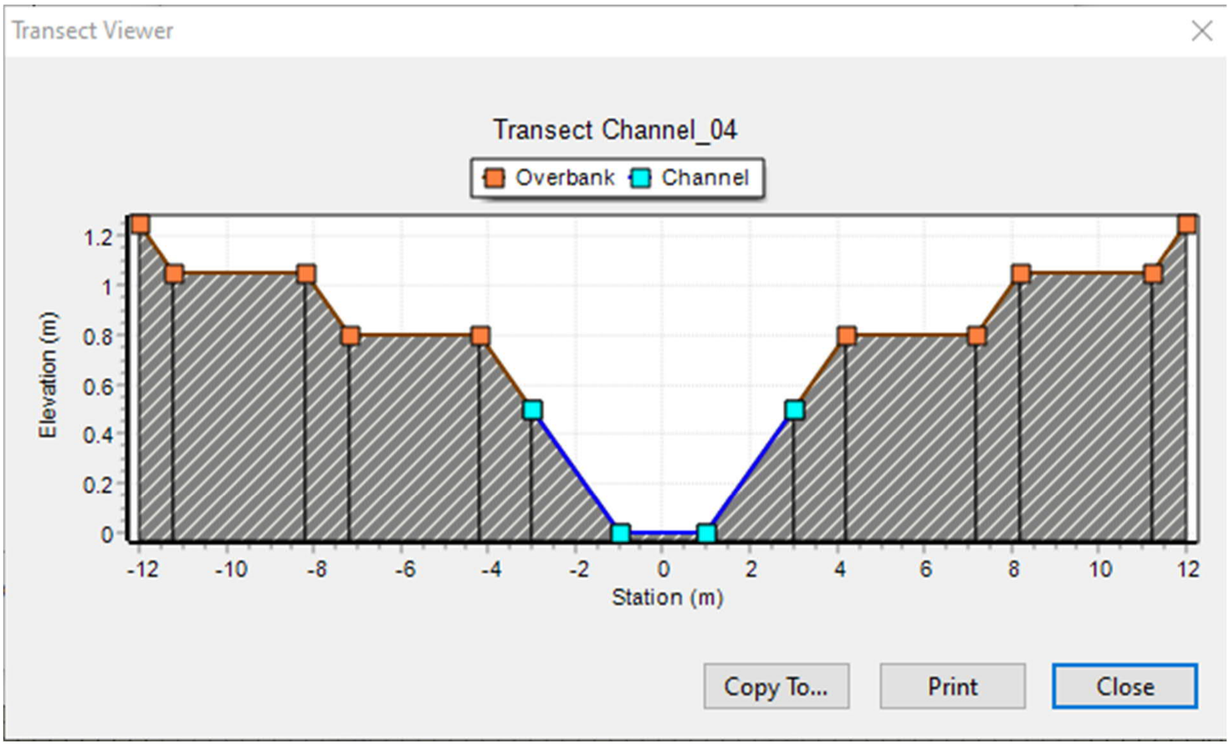
The report has been updated to clarify the above.

- Cross sections: Please provide stream cross sections and the total width of land required to contain a stream channel that conveys the required flow.

As mentioned above in a reply to a previous comment, the cross-sectional profiles used in the 1D and 2D models were simplified approximations of the final cross-sections to be designed as part of detailed design. The proposed batter slopes are 1:4 (V:H) and an example cross-section is shown below for the Ohote and Te Otamanui streams. Away from the wetlands and based on the latest lay-out of the development, the width of land available for the stream cross-section along the Ohote stream varies between 30m and 50m. For the Te Otamanui stream this varies between 27m and 53m.



SWMM model Ohote stream simplified cross-section.



SWMM model Te Otamanui stream simplified cross-section.

- EPA-SWMM-5 is a suitable modelling package to use for estimating runoff and sizing devices. It would be useful for the applicant to include some screen shots or details of the device designs and outlet configurations used in modelling.

BBO reply: Additional details of the device and outlet design for the SWMM model of the stormwater management set up for the sub-catchment ICMP have been added to the report in section 4.4

- The consistency between HEC-RAS and EPA-SWMM results appear to be good so we assume that the volumes and dimensions modelled in the terrain modelled used in HEC-RAS were fed into the SWMM model as inputs. What capacity was assumed for the stream reaches? If this land needs to be designated or translated onto the Rotokauri Structure Plan, please provide stream cross sections and the total width of land required to contain a stream channel that conveys the required flow.

BBO reply: The relevant Structure Plan is the proposed "Rotokauri North Structure Plan" (not the Rotokauri Structure Plan". The HEC-RAS 2D model was generated to model the routed flow in the streams and floodplains and carry out a secondary check of the attenuation volume and flood depths. Therefore, the elevations and dimensions of the wetlands, the elevations and simplified cross-sectional information of the streams and the input run-off flow rates from the 1D SWMM model were used to set up the terrain and boundary conditions of the 2D model. As outlined previously, the Green Spine Areas are shown on the proposed structure plan and are shown on land with titles held by the Plan Change applicant (GSL) and/or a company falling under its umbrella. The Plan change is not the mechanism required to secure these areas – future resource consent for subdivision and development will create the final areas for stormwater management purposes (as per below there is also existing rules that ensure future development adhered to the sub catchment ICMP) . Examples of the simplified stream cross-sections have been provided as part of a reply to a previous comment.

- Comments regarding catchment definitions:
  - Rotokauri South 1 drains in the Rotokarui Arterial Designation area – has this catchment been accounted for in the Wetland G8 design?
  - It was assumed that 50% of the wetland minor sub-catchments is impervious/water. However, many of these sub-catchments appear to be more that 50% impervious in Figure 3-2 eg. Te Otamanui 4A (1.2 ha) appears to be nearer to 90% covered by the wetland itself.
  - The impervious percentage for streams seems low, at 10%. The proposed channel dimensions and baseflow during winter should be used as an indicator of water areas providing effective impervious.
  - What percentage impervious was assumed for Ohote Upstream North, West and East sub-catchments? They are not included in Table 4.1 of the SSR and the runoff coefficients in the SWMM sub-catchment results are consistently lower than the other fully developed sub-catchments.
  - Referring to Table 4-2 in the SSR, is the impervious percentage of 5% suitable for the Mangaheka Upstream catchment?
  - Table 4-1 of the SSR - Were catchment slopes based on the existing surface or estimated for future?
  - The initial infiltration rates for the rainfall to runoff sub-catchment analysis were sourced from Rawls et al. (1983). This comes from USA literature and is typically accepted in the USA. Please provide local references support the infiltration rates and the depression storage values.

BBO reply:

- BBO had a meeting with Beca on June 2nd to coordinate the work. This included a discussion about the area that falls within Rotokauri North that is to be treated by wetland G8. Hence, Beca is aware that this catchment has to be accounted for in wetland G8.
- The areas shown in blue on Figure 3.2 are indicative only. The permanent water level area covers approximately 42% of the wetland areas as indicated in Figure 3.2, while during the

100yr ARI storm event and at maximum water depth, the area covered by water is 62% of the wetland area as indicated in Figure 3.2.

- As part of the stormwater management plan, the existing stream will be re-established and will have functional floodplains. Therefore, the future baseflow during winter is currently not known. Instead, for this high-level analysis, the future stream has been assumed to have a bottom width of 1m to 1.5m, side slopes of 2.5:1 (H:V) and have a baseflow depth of approximately 0.2m. These assumptions are similar to those used for a previously completed stream re-establishment that had a much larger upstream catchment. This yields an estimated the top-width for the stream of 2.2m which would cover approximately 7% of the areas as indicated in Figure 3.2. The 10% used in the SWMM model allows for some additional area during detailed design to include the appropriate sinuosity added to the stream.
- During the modelling of the existing conditions, the impervious percentage was set to 5% for the Ohote Upstream East, West and North sub-catchments. During future developments, these major sub-catchments will require their own treatment and attenuation devices and the proposed peak flow rates from these devices will have to match 80% of the existing peak flow rates. Hence during the modelling of the proposed conditions, the impervious percentage for these catchments was kept at 5% and the rainfall for these catchments was not changed to the rainfall adjusted for climate change, so that the peak flow rates from the catchment remained the same as for the existing condition. Table 4.1 has been updated to include the Ohote Upstream catchments.
- No, the 5% is indeed not appropriate. Based on the land-use of the upstream catchment, the percentage impervious was estimated to be 35.7% which was the value used in the model as per the results in Appendix A. Table 4.1 has been updated accordingly. However, to obtain a reasonable estimate for the tailwater in the Mangaheka stream upstream of the Te Kowhai Rd East without having access to the Te Kowhai Rd East culvert information, the peak water surface elevation was calibrated using data from the report "Mangaheka Integrated Catchment Management Plan – Stormwater 1D Modelling Report" which is an attachment to the Mangaheka ICMP (Hamilton City Council, 2019). This has reduced the impact of the estimated impervious percentage on the tail water condition for the Mangaheka wetlands, which was the only reason why Mangaheka upstream was included in the report.
- For the existing model, the slopes of the major sub-catchment were based on the existing slopes. The existing model was not run with the minor sub-catchments. The proposed model was initially run with the major sub-catchments with slopes based on the existing slopes and was later refined to run with the minor sub-catchments, based on the high-level earthworks model developed to create the initial sub-catchment delineation. Note that for most sub-catchments the difference in the slopes was very small.
- The New Zealand Soil Classification by the New Zealand Geotechnical Society Inc is based on grain sizes that are identical to the grain sizes used as part of the Universal Soil Classification System. The work presented by Rawls et al. (1983) on soil water properties uses the Universal Soil Classification System which, therefore, also works with the New Zealand Soil Classification. In addition, soil water properties are measured using the standard constant head permeability test, which are the same here and in the United States. As water, soil grain size, and gravity are the same in New Zealand and the United States, results obtained from a very comprehensive study in the United Stated are acceptable for use in New Zealand as well. Likewise, Bridge Scour, by Melville (Professor Bruce Melville, Auckland University) and Coleman, is widely referred to in the US and Professor Melville's work forms a significant part of the Hydraulic Engineering Circulars 18 and 23, which are also widely applied in NZ and Australia.

- Inflows: Was the generated flow or accepted flow from external sub-catchments Ohote Upstream West and East (as stated on the catchment layout plan) fed into HEC-RAS as inflow? It should be the larger of, 100% the predevelopment total runoff generated, or the throttled (80% of ED 100yr peak flow) total runoff hydrograph generated from the 24hr 100yr storm on fully developed catchment.

BBO reply: Yes, the generated flows from the external sub-catchments were used as input for the 2D HEC-RAS model for the Ohote Stream. As mentioned above, these flow rates were based on the predevelopment total runoff generated, as future development will be required to match 80% of the predevelopment peak flow rates from these catchments. In addition, as no details of the development for these catchments are known, it is not possible to generate suitable fully developed catchment flow rates.

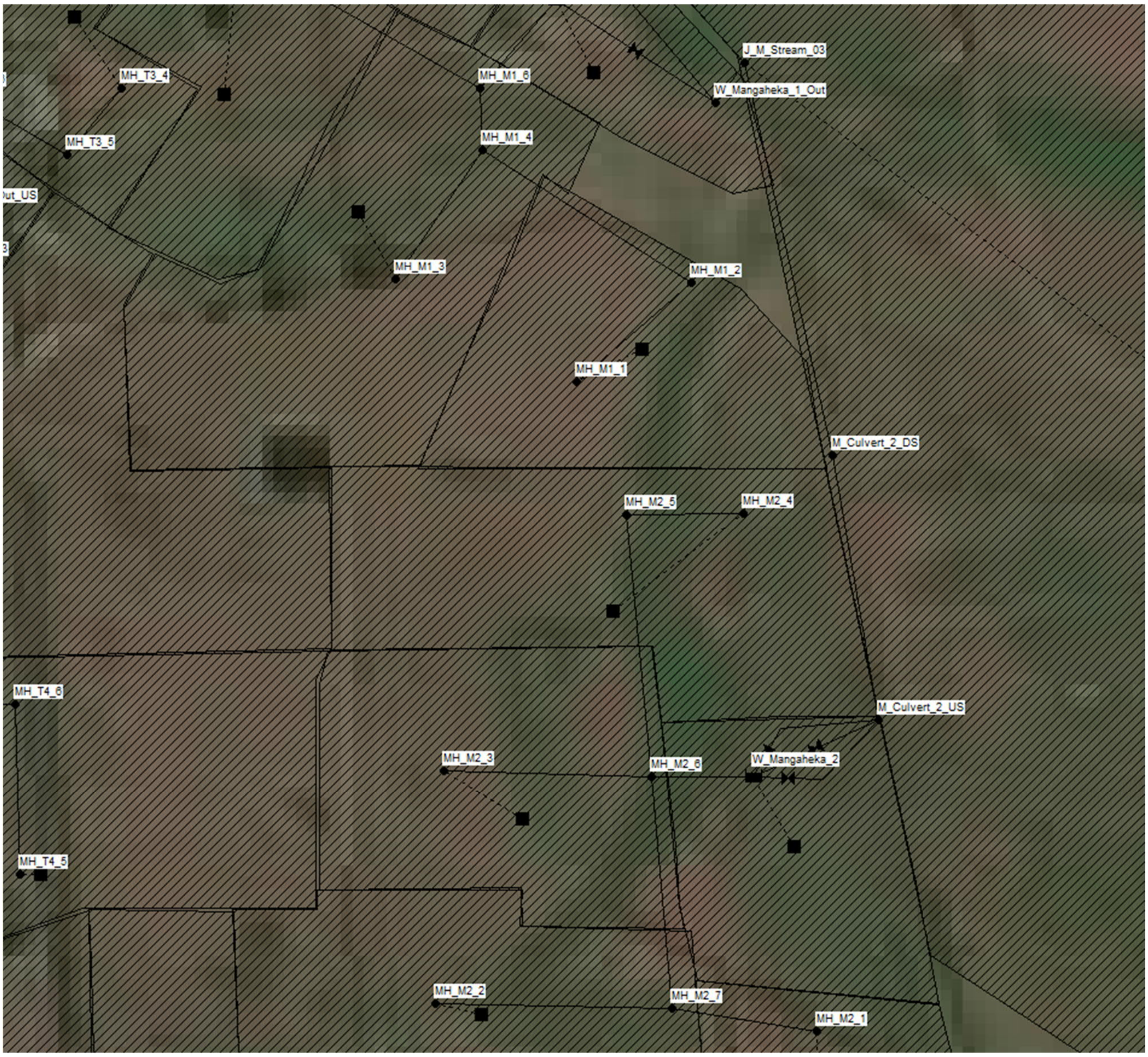
- Events: A Scenario of 50% of 2yr ARI event has been used. Typically, 1/3rd of the 2 year ARI event is used to define frequent storm conditions representing the 95th percentile storm event size.

BBO reply: The 50% of the 2yr ARI event approximates the mean annual flood and is used typically used for a channel forming discharge and the migration trigger for upstream migration of native fish species. The mean annual flood or ½ the 2-year is also applied as the upper limit for which fish passage in culverts, which is consistent with NIWA New Zealand Fish Passage Guidelines, 2018. 1/3 of the 2-year flow is generally applied for determining a stormwater quality volume for treatment.

- Wetlands: It seems that there is one wetland missing from the design. Has the wetland named Mangaheka 2A (1.6ha) in the concept layout been modelled? The storage node at that location in the SWMM model layout image is named W Rotokauri South 1, but a wetland named that isn't on the concept layout plan. Additionally, although difficult to see on the SWMM model layout image, it doesn't look like this network (J148 down to MH S1 4) is connected to the swale between Mangaheka W1 and the culvert. It is mentioned that and that Mangaheka 2A is connected via a pipe – is that intended to go along Burbush Road? Can this be conveyed in an open channel instead?

BBO reply: Initially major sub-catchment Mangaheka 2 was directed southward to discharge in the Rotokauri South drain (at this time this major sub-catchment was referred to as Rotokauri South 1 and the current Rotokauri South 1 was referred to as Rotokauri South 2). During our discussion with Beca about the boundaries of the major sub-catchments, it became clear that it was not possible to discharge Mangaheka 2 southward and instead had to be discharged northward into the Mangaheka. The map of the nodes included in the SWMM model forwarded to Morphum on 7/07/2021 was of an earlier copy of the SWMM model before this change was made while the results in the Appendix A were from the latest copy. This has caused the confusion as indicated by the reviewer.

An updated copy of the map, focused on the Mangaheka 2 sub-catchment is shown below. This includes Wetland Mangaheka 2 and the pipeline that connects the outfall structure of the wetland with swale upstream of the discharge point into the Mangaheka. It may be possible to construct this pipeline as an open channel instead for at least part of its length (it also has to cross two major roads, note that the pipeline follows the minor north-south arterial, not Burbush Rd). Options will be investigated as part of detailed design.



- SSR Section 6.2.1: It is stated that "the highest depth-averaged velocities are found immediately downstream of the inflow points into the wetlands." Why is that? Would expect higher flows to be in the streams rather than the wetlands, particularly in the 100-year ARI event.

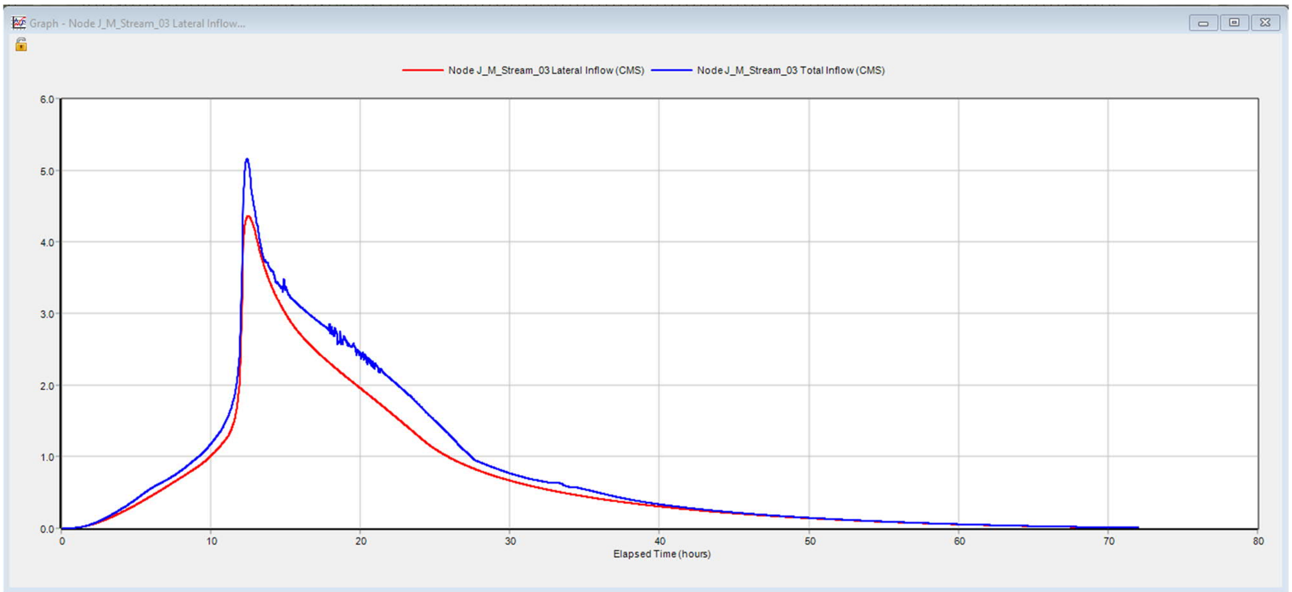
2D hydraulic models provide depth averaged velocities. The velocity of pipe discharge into a treatment wetland must be higher than the velocity within the wetland. The treatment wetlands and attenuation areas are designed to not only reduce velocity but attenuate the peak flow. The inflow points into the wetlands consist of pipes with a diameter of approximately 1m and therefore a cross-sectional area of 0.79 m^2. And the discharge pipes into the wetlands are likely to be pressurized during the 100yr ARI storm event. The streams including the flood plains have cross-sectional areas of up to 30m^2 and are open to the atmosphere. Even though there are 16 different sources of water flowing into the stream and therefore the throttled flow rate in the stream may be larger than the flow rate from a single discharge pipes, continuity indicates that the velocity of the water in the discharge pipes has to be significantly greater than that in the stream.

- Peak flow: The peak flow comparison was done at four locations on the perimeter of the study area, which is a suitable approach assuming that the proposed storage devices are built in approximately the same locations as designed here and are fed by the equivalent catchments as used for this study. How will this be ensured during design phase? E.g. will these areas be designated? How will the structure plan and staging/order of development be managed to meet this?

BBO reply: The "Rotokauri North Sub-catchment ICMP – Stormwater System Report" is being submitted as technical evidence in support of a Plan Change application. As outlined previously, despite having prepared this Sub catchment ICMP the resource consent process still requires ICMP's to be submitted (existing HCC rules and those inserted by the PPC) for review as part of any future stage of development. This is the relevant mechanism for ensuring that the future designs adhere to the proposed approach.

- Peak flow: In Section 8.2 of the ICMP, Table 12 (and SSR Table 5-1) the average flows from SWMM tabular report were listed for Mangaheka instead of the max flow, eg. at Mangaheka_Out node the peak flow was 3.04 m^3/s and average of 0.82 m^3/s was adopted into the Tables. Please clarify why the average flow was included in the report summary, rather than the peak.

Mangaheka_Out is the node downstream of Te Kowhai Rd East and the end of the routed model that begins at the Mangaheka minor subcatchments. Please note that this is not the outflow from the combined Mangaheka 1 and Mangaheka 2 wetlands. This happens at node J_M_Stream_03 (as seen in the updated map of the SWMM model presented above). The discharge flow rate is the difference between the total flow rate at this node minus the lateral inflow from the Mangaheka_Upstream sub-catchment. Using the max flow rate information in Appendix A (p110) would give a discharge estimate for the Mangaheka wetlands of 0.793m^3/s, however the peaks of the flow rates from the sub-catchment and wetlands do not align. Instead, the time-series from the total flow rates and lateral flow rates were obtained as shown below. Subtracting the two time-series and finding the maximum difference yielded a value of 0.8146m^3/s which is the value as presented in Table 5-1.



- Peak flow: The peak flow at Rotokauri South discharge location has been noted as NA in the ICMP and SSR. However, the SWMM results show that the combined peak at the two out nodes in all reported storms are higher than the predevelopment peaks shown in ICMP Section 8.4 Table 11. Can this increase be mitigated in RAD Wetland G8?

BBO reply: The Rotokauri South 1 major sub-catchment falls within the catchment of basin 3 as part of the Rotokauri Greenway (Beca Limited, 2018). Treatment and attenuation of the flow of basin 3 takes place in wetland G8, hence this wetland also must treat and attenuation the flow from major sub-catchment Rotokauri South 1.

- Please provide a table summarising the design water levels, surface area and volumes (permanent, ED, and storage above that) for each storage zone.

BBO reply: A summary table of the wetlands including the elevation and area of the permanent water level, the bund level and the HGL and stored volumes for the 2yr, 10yr and 100yr ARI events, has been added to the text as Table 4-3.

- Rotokauri South ICMP areas will need to comply with Rotokauri ICMP requirements including interim storage and catchment boundaries will need to be maintained. Also, the overflow path from the Rotokauri South catchment into the paleo-channel toward Mangaheka needs to be allowed for.

BBO reply: From the Rotokauri ICMP documentation, it was not directly clear where the proposed catchment boundaries of the Rotokauri South 1 major-subcatchment are. The Rotokauri Greenway – Design Report by Beca shows the boundaries of catchment SC3D (on page 63) that includes the Rotokauri South 1 major sub-catchment. It is assumed that boundaries of SC3D are along the centre of the Greenway, then the major sub-catchment Rotokauri South 1 is estimated to be 73% of catchment SC3D which yields an area of 14.4 Ha.

As part of the pre-development SWMM model a catchment delineation was carried out on the Rotokauri North area which included the current road boundaries and existing culverts. This yielded an area for the Rotokauri South 1 major sub-catchment of 15.3Ha. When identifying the boundaries of the proposed minor sub-catchments, the boundaries of the major sub-catchment Rotokauri South 1 were adjusted to better align with proposed lay-out of the development. This reduced the area of major sub-catchment Rotokauri South 1 to 13.35 Ha. Both values are a reasonable match with estimated value based on the Beca design report.

The requiring authority's conditions for the Rotokauri Greenway Notice of Requirements includes article 42b ("Maintaining existing sub-catchment drainage patterns up until the development of adjacent sub-catchment"). Hence once development of Rotokauri North begins, the paleo-channel toward the Mangaheka no longer has to be allowed for, therefore this issue has not been included in the Rotokauri North sub-catchment ICMP.

Stormwater Quality

- It is not clear the basis for the sizing of the wetlands. Please provide a table summarising the design water levels, surface area and volumes (permanent, ED, and storage above that) for each wetland or storage zone. What percentage of the impervious catchment were the wetlands sized at?

BBO reply: Additional details of the device and outlet design for the SWMM model of the stormwater management set up for the sub-catchment ICMP, including a summary table for the wetlands, have been added to the report in section 4.4.

- ICMP table 6 indicates treatment devices to be used for roads. Are there roads that will not drain to treatment wetlands? What type of device is proposed, this is not indicated in ICMP Table 13.

BBO reply: No, all roads within the sub-catchment will drain to treatment wetlands. Table 13 has been updated to explicitly state that the recommended devices for treatment of road run-off are the communal wetlands.

- ICMP Table 13 indicates that communal devices will have detention 0.5m above water quality volume. It is assumed this refers to extended detention which should be no deeper than 0.35m above water quality volume as per the RITS, please change.

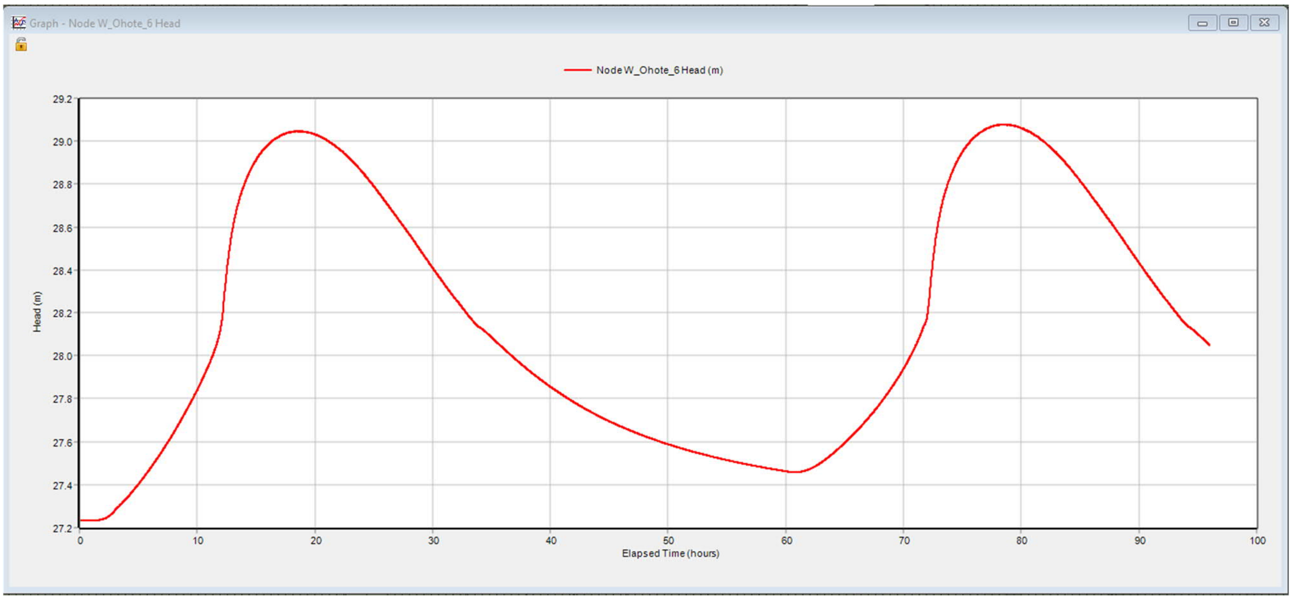
BBO reply: It should not be assumed. The decision between attenuating the 2-year or applying EDV will be made as part of detailed design. This statement has been removed from updated text.

- The ICMP Table 13 provides for no water efficiency measures on affordable housing which is contrary to the HCC District Plan requirements and may not be acceptable to HCC.

BBO reply: Noted. This issue will be discussed with HCC.

- Figures 6-6 of the SSR show that Ohote Wetland 6 is still elevated about 200 mm above starting water level after 72 hours. This long draw down is also noted by 002d in Table 7. What tailwater assumptions were used in the modelling and what is the impact of extended drain down time?

BBO reply: Tailwater assumptions have been stated above in reply to a previous comment and the report has been updated accordingly. The drain down times are a result of the very minimal gradients of the stream and surrounding land and hence the relatively slow natural drainage is replicated as the stormwater infrastructure is built into the existing landscape. During the tail-end of the storms, the water levels in the wetland are controlled by the water levels in the stream. To evaluate the impact of the 200mm of water left in the wetland after 72 hrs, the model was run with a second 100yr ARI storm starting 60 hours after the first so that its peak intensity occurred after 72 hrs. The results at wetland Ohote 6 are shown below. The max HGL in the wetland increased from 29.05m to 29.08m, well within the freeboard of the wetland.



- It seems that the invert of wetlands is below the groundwater table. As stated in the SC-ICMP the groundwater depth is "approximately 0.1 to 1.5m (below ground surface) in the low-lying areas". For example, with the existing ground level at Wetland Ohote 7A at approximately RL29m, the groundwater table may be between RL27.5m and RL28.9m. The initial water levels shown on Figures 6-6 to 6-8 of the SSR wetland are around RL27.3m, indicating that they may be within the groundwater. The image below is from the SRS Appendix A, indicating that the water levels in the 50% of 2-year ARI event may also be below the groundwater level. How has the groundwater level been determined? Will relief points be provided for groundwater flows to be collected without liner floatation? Evidence is required to confirm the risk of wetlands having high normal baseflow disturbing hydraulics, displacing small storm runoff and reducing water quality treatment, and submerging vegetation causing mortalities? Ideally wetlands should be designed at or above normal groundwater level.

BBO reply: Latest data from HDGeo indicates that the groundwater depth varies between 0.1m to 2.5m in the low-lying areas. Text has been updated accordingly.

The current ground water level will be impacted by the re-establishment of the Ohote and Te Otamanui streams. Sub-soil drainage will be installed below the roads surrounding the wetlands and stream and therefore a significant initial draw-down of surrounding ground-water is expected to occur during and immediately after construction of the wetlands and streams, until the ground-water levels have found a new equilibrium. The possible use of suitable liners for is the wetlands is detailed design issue, but geosynthetic clay liners may be an option.

Stream and Culverts

- Please provide typical Stream (Green Spine) dimensions including proposed batter slopes to confirm footprint.

BBO reply: See above for details of cross-sections as part of a reply to a previous comment. As stated earlier, these dimensions are preliminary.

High flow: Have the proposed culverts in Ohote Stream catchment been sized? / What constraints were used in the SWMM to model them? Where is T Culvert 01?

BBO reply: The culverts in SWMM were only sized at a very high level. The Ohote stream culverts were given single barrel circular culverts with diameter of 1.5m. As there is very little head difference between the upstream and downstream ends of the culverts at any time during the storm events, the gradient of the culverts is also very small and the flow rates remain small to meet the pre-development flow rates, the velocities in the culverts are expected to remain small and therefore no problems are anticipated when designing the culverts for fish passage during detailed design. A quick check of the SWMM results for the 50% of the 2yr ARI storm event shows that the estimated maximum cross-sectional velocity of these culverts is about 0.4 m/s. These results therefore also indicate that achieving suitable fish passage design should be relatively straightforward for these culverts.

Culvert T_Culvert_01 is along the Te Otamanui stream between wetlands Te Otamanui 2 and Te Otamanui 4. In a previous lay-out of the development, a street was included connecting the two sides of the Te Otamanui stream and hence the culvert was included in the SWMM model. Its high level design included a single circular barrel with a diameter of 1.05m. In a later version of the lay-out, this connecting road was removed, but discussions that included HCC were ongoing about the inclusion of this connecting road or alternatively a pedestrian/bicycle connection. Because of this uncertainty, the initial culvert was left in the model.

- Low flow: Does the example culvert design explained in SSR Section 7.2.3 (shown to be a 1500 mm square concrete box in the HY-8 image) represent any of the culverts proposed in this project (in size, slope and shape)? It is demonstrated that the designer understands the requirements of the culvert for aquatic organism passage, but this doesn't show that the requirements can be met by the actual three 1.5m diameter culverts at the project boundaries and proposed culverts in the project area.

BBO reply: No, the example given does not represent any of the culverts that are part of the proposed development. The example has been inserted to clearly describe the process that will be used during detailed design to meet the fish passage requirements. Some details on the ability to meet the fish passage requirements for the culverts have been included in the reply to the previous comment.

Other items

- ICMP Section number 3.9.2 occurs twice

BBO reply: Text in ICMP report has been updated accordingly.

- ICMP Table 13 is labelled as Table 133

BBO reply: Text in ICMP report has been updated accordingly.

- SSR Table 6-2 appears to be missing (mentioned in Section 6.2.2) – should this have said Table 4-2?

BBO reply: Yes it should have been. Text has been updated.