
BEFORE THE CANTERBURY REGIONAL COUNCIL

in the matter of: the Resource Management Act 1991

and: application CRC190445 by the
Christchurch City Council for a
comprehensive resource consent to
discharge stormwater from within the
Christchurch City area on or into
land, into water and into coastal
environments

and: **Antonio and Kerrie Rodrigues...**
Submitter

Statement of evidence of Robert Potts

Dated: 24 October 2018

STATEMENT OF EVIDENCE

A. INTRODUCTION

- 1 My name is Robert John Potts.
- 2 I hold the qualification of NZCE (Civil), BE(Hons)(Ag), Dip Hydrology, CPEng and I have also completed the *Making Better Decisions* course. I am a Member of IPENZ, Water NZ (ex-Chairman of SWANS-SIG), NZ Land Treatment Collective (ex-President). I am currently the Chairman of Water NZ's OSET Management and Audit Group Committee.
- 3 I am currently employed by Lowe Environmental Impact Limited as an Environmental Engineer.
- 4 I have worked in the area of Agricultural and Water Resources Engineering since 1977, firstly with Ministry of Agriculture and Fisheries, then from 1986 – 1988 in private practice in England, then from 1989 to 1994 with Lincoln University, and from 1994 I have worked in private practice.
- 5 I have been involved in numerous stormwater and flood plain assessments, assisting developers, councils and as a Hearing Commissioner.
- 6 My involvement with the issues faced by the Rodrigues began in 2015 and I have visited the site and surrounding area numerous times.
- 7 In preparing my evidence, I have also read the application, evidence of Brian Norton, Tom Parsons and Graham Harrington and the relevant parts of the Officers section 42A Report prepared by Michael Law. I have also met with Mr Harrington and Mr Parsons in relation to flooding mechanisms of the Lower Styx River but this was not specifically regarding the application currently before the hearing panel. I have also read the paper Mr Harrington presented to the Water NZ Conference in 2012 on Earthquake Effects on the Styx River.

B. SCOPE OF EVIDENCE

- 8 In my evidence provide the following:
 - 8.1 Comments on the application with respect to effects on the Rodrigues property, i.e. flooding effects in the Lower Styx River;

- 8.2 Comments on applicants' evidence and Mr Harrington's conference papers;
 - 8.3 Comments on the relevant parts of Officer's Report regarding the Lower Styx River flooding; and
 - 8.4 Possible mitigation measures to address the effects on the Rodrigues property.
- 9 I confirm that I have read and agree to comply with the Code of Conduct for expert witnesses contained in the Environment Court Practice Note (dated December 2014). I have complied with the Code of Conduct in preparing this evidence and I agree to comply with it while giving oral evidence before the hearing committee. Except where I state that I am relying on the evidence of another person, this written evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence.

C. EXISTING FLOODING ISSUES

- 10 The location, details and history of flooding of the Rodrigues property, including photos of the flooding and neighbouring fill, have been provided to you by Mrs Kerrie Rodrigues.
- 11 Flooding is very serious at this site as it remains there for prolonged periods, thus destroying soil/plant health by not allowing air into soil voids.
- 12 From a safety/hazard point of view, CCC modelling shows that in the existing developed scenario up to 800 mm ponding occurs within the property in a 2% AEP (50 year) event, with 400 – 600 mm at the house site. The proposed Global Stormwater consent allows an increase of 100 mm ($\pm 20\%$, thus in essence up to 120 mm increase) above 2012 levels. When considering that $> 1,000$ mm depth is considered a safety hazard, 800 mm + 120 mm is getting close to this trigger. Add to this the impact of future climate change and sea level rise, then water levels will most likely be considered a hazard in the future.
- 13 NIWA and international experts are making statements that what we are seeing now as a 1 in 10 year event will be more akin to annual events if climate change remains unchecked. This means that the flooding, and duration of flooding, will get worst and it is only a matter of time before an event will enter the dwelling.

- 14 The ground level around the house is at an elevation ranging from 10.38 to 10.68 m and the house floor level is either at 10.76 or 11.00 m RL (split level) post-earthquake.

D. COMMENTS ON AEE AND APPLICATION, CONDITIONS, FURTHER INFORMATION

Section 6.11

- 15 *Policy 4.17 of CLWRP requires stormwater run-off volumes and peak flows to be managed so that they do not cause or exacerbate the risk of inundation, erosion or damage to property or infrastructure downstream or risks to human safety.*
- 16 In Section 4, the application states *"this report includes discussion surrounding flood risk and mitigation throughout Ōtautahi/Christchurch, including the implications arising after the Canterbury recent series of earthquakes. The CSNDC and associated stormwater management plans address stormwater run-off volumes and peak flows. One of the general principles of the proposed conditions of the CSNDC, include the reduction of the adverse effects of flooding, and requires stormwater management plans to include mitigation measures for potential flooding, and to identify the locations of areas subject to flood hazards. These measures are intended to manage the flood risk so that there will be no exacerbation of the risk to human safety, or of inundation of people's property or infrastructure"*.
- 17 Although Section 4 infers that Policy 4.17 will be adhered to by stating that there will be no exacerbation of inundation of people's property, I do not consider that allowing a 100 + 20 mm increase in flood depth in an area already suffering from prolonged inundation meets the Policy.

Mitigation Methods - Section 9.1.2 Greenfield Sites

- 18 In this section, CCC state: *"As a minimum, CCC requires first flush treatment and attenuation of the post-development peak 2% AEP flow to pre-development levels"*.

Section 9.2 Best Management Practice Flood Risk

- 19 CCC State: *"As well as mitigation of the effects of increased run-off, management of flood risk within the wider catchment is necessary. This involves a range of management tools, from planning*

measures (e.g., restricting development in flood prone areas) to engineering solutions (e.g., stopbanks)".

Section 10 Consideration of Alternatives

- 20 In this section CCC state: *"In terms of flood management, part of the development of the SMPs is to consider determining the most appropriate water quantity mitigation option for the catchment e.g., options for sizing detention basins. In the case of the Pūharakekenui/Styx River SMP, it was shown that the standard detention option, which requires significantly larger basins (and higher construction and land purchase costs), only provides a minor reduction in water levels during a 2 % AEP event of 48 hours compared to the partial detention option. It was therefore proposed to provide partial detention as it provides ratepayers with the most economic option and an acceptable environmental result".*
- 21 There is numerous discussions within the AEE and in particular the above three sections regarding Best Management Practices (BMP), however, this is mostly to do with water quality and not water flows or volumes (quantity) – I will discuss this later.

Conditions

- 22 **"Partial Detention** means storage within first flush basins plus additional storage through flooding of wetland areas to an average depth of 500 mm discharging over a minimum of 96 hours for the critical 2 percent annual exceedance probability design storm event".
- 23 Although there is some quantification of wetland depth and drainage period, what is required by Developers to provide for partial detention is not quantified, i.e. what size wetland is required, as flows/volumes do not need to be neutral.
- 24 Condition 4 requires the SMP to be updated after 10 years. However, in the document CRC160056 – Additional Explanation on Various Matters, under a question regarding how compliance with Table 6 targets will be assessed and reported, CCC state that *"Targets for modelled rivers (Styx, Avon, Heathcote and Halswell) will be assessed using CCC's stormwater models to compare the baseline scenario with the MPD scenario, or any partial development scenario in between. The models will be updated with new developments and calibrated with new events and reported in the annual report if there are significant changes in the catchment or upgrades to the modelling, or otherwise five yearly".*

- 25 This is also discussed by the Officer in s42a Report regarding recalibrating/updating models after every large event and every 5 years. I consider that if the 5-year reassessment of the model shows any inaccuracies of the information presented to this hearing, or flooding effects at the Rodrigues property, are greater than minor, that the SMP needs to be reviewed, i.e. as a maximum of 5-yearly intervals. The consent itself may also have to be reviewed and mitigation implemented to reduce effects to those initially predicted if effects are shown to be more than minor.

S92 Response - Groundwater Quantity Effects

- 26 "Q 39) *What is the potential impact on the management of stormwater and flooding as a result of possible groundwater level rise associated with sea level rise?*"
- 27 CCC Response: *"Sea level rise within the term of this consent is unlikely to have any significant effect on the groundwater level rise which will not be accommodated by the existing open channels (releasing higher groundwater levels into the network and pumping systems already in place. All new stormwater systems and upgrades of existing systems are none-the-less designed with sea level rise of up to 1 m in mind. Either the capacity to manage sea level rise of up to 1 m is designed into the facilities or the potential to adapt the system to increasing sea level rise is embodied into the design".*
- 28 This is not the case with the modelling. A sea level rise (SLR) of 0.5 m has allowed for. I also note the change in SLR within the last 7-years of 200 – 300 mm, as discussed later in my evidence.

E. STYX STORMWATER MANAGEMENT PLAN

- 29 *"Stormwater detention has been based on the 'partial detention' option because it reduces the total footprint of the facilities by 14 % (when compared to 'full detention') without significantly increasing flood risk".*
- 30 *"Cranford Basin has the potential to provide an enhanced storage facility that could provide retrofit treatment and detention for existing development as well as allowing limited new development around its fringes".*
- 31 *"The SMP process provides a vehicle whereby such options can be canvassed and is the reason why the Cranford Basin catchment is being considered as part of the Styx SMP".*

- 32 It is not clear if Cranford Basin is included in the modelling undertaken although the area has been included within the SMP. It can also provide attenuation to the Avon River. The concern for flooding in the Lower Styx is if Cranford Basin adds additional area to the Styx Catchment, as shown in plans, that it will release additional volume into Styx River (if it goes here) and add to ponding. However, it may be part of the mitigation package for flooding within the Styx by diverting Styx Catchment flows into it for attenuation but the SMP is too vague to understand what is proposed. Will it assist with Styx flood mitigation, or will it exacerbate?
- 33 Figures' 1 and 2 show Earlham St outside of the SMP area but Figures' 6 and 9 show the Styx Catchment and this includes Earlham St. Earlham St is in the Styx Flood Management Area, so cannot just be left out of the SMP.
- 34 *"Modelling indicates that the design storm duration for maximum depth and extent of ponding in the lower Styx floodplain occurred after a 48 hour design storm event (4 tide cycles).*
- 35 *There is also evidence of general settlement of land in the Brooklands area in the range of 100 mm to 300 mm which has raised concerns about the vulnerability of the area to storm and tidal flooding. Initial repairs have been undertaken, with further repairs still necessary, with significant costs estimated to provide flood protection for the Brooklands area.*
- 36 *The extensive house damage and need for area-wide land remediation has resulted in the Government decision to retreat from the Brooklands area, and include it in the 'red zone'. This reduces the need to further enhance flood protection works along the lower tidal reach of the Pūharakekenui/Styx River. It also, to some extent, lessens the risk of flood damage from a possible moderate increase in flood level in the Pūharakekenui/Styx River at Brooklands from increased development upstream.*
- 37 *The Christchurch City Council Surface Water Strategy (Christchurch City Council 2009) sets out the Christchurch City Council's surface water management goals from 2009 to 2039. Its purpose is to direct the Christchurch City Council's decision-making relating to surface water. It sets out a vision, goals and objectives. The nine goals of the Surface Water Strategy are:*
- 1) Improving the water quality of our surface water resources.*
 - 2) Reducing the adverse effects of flooding.***
 - 3) Improving the ecosystem health of surface water resources.*
 - 4) Protecting and restoring Ngāi Tahu values associated with surface water resources.*

- 5) Supporting a range of recreation activities on and around waterways.
- 6) Protecting heritage values associated with surface water.
- 7) Protecting and enhancing the landscape values of surface water.
- 8) Supporting community involvement in surface water management.
- 9) Manage stormwater in an efficient manner that supports Goals 1 – 8.
- 38 *The Styx SMP Area is one of the catchments outlined in the Surface Water Management Strategy and the preparation of this Styx SMP is consistent with the provisions of the Surface Water Management Strategy.*
- 39 *The post-earthquake decisions to **abandon the developments at Brooklands means that small increases in flood levels in the larger lower Styx floodplain will have very minor adverse effects.** (my emphasis) The SMP proposes therefore to provide a high level of water quality treatment but only partial upper catchment detention so that the development is possible of a greater area of suitable land in the upper catchment. Fortunately, the Styx river mainstream is fairly deeply incised in the upper catchment and thus has sufficient conveyance capacity to manage the increased flows to the lower floodplain.*
- 40 *Generally, all facilities have been designed to treat runoff from the first 25 mm of rainfall in any storm. A range of stormwater detention options from Standard Detention (detention of additional runoff resulting from urban development for storms up to the design 2% AEP storm), to Partial Detention (additional storage provided by back flooding to 500 mm depth over wetlands) and Cranford Basin storage was tested. Implementation of the Partial Detention option is recommended because the total footprint of facilities is reduced by over 15 ha compared to the Standard Detention option **without increasing flood damage significantly.** The cost to Council of the Partial Detention option is estimated to be approximately \$72 million spread over the next 35 years and \$43 million over the next 10 years from 2012/13”.*
- 41 In relation to the above statement I have the following comments. The whole of Brooklands has not been abandoned. The above statements are somewhat contradictory. The Surface Water Management Strategy is said to be adhered to, i.e. reducing adverse effects of flooding (note **bolding** added by me) but only partial detention is proposed. There is no indication of what "without increasing flood damage significantly" (note **bolding** added by me) means. Any increase to areas already seeing inundation for prolonged periods is significant to the residents living in those areas. Apart from very early optioneering, there is no

reporting of the difference in flood levels with Full Detention of Partial Detention and what the difference in cost is and how much would be borne by developers and ratepayers.

Section 3.3 of Blueprint

- 42 *"CCC have adopted the MfE guidelines in respect of sea level rise (SLR). A half metre allowance has been added to the boundary conditions at the mouth of the Styx River at Brooklands in all the river modelling carried out for the SMP investigations. However, recent science now supports a median SLR prediction of approximately one metre by 2090. The consequences of SLR on existing urban development in the medium term have been somewhat dissipated by zoning Brooklands, an area most at risk from SLR, red post quakes. Nevertheless, the effect of one metre SLR at least on any proposed development needs to be taken into account".*
- 43 This is not the case as Section 6.2 of the Blueprint "Scenarios Modelled" states 0.5 m SLR allowed for.
- 44 *"The Styx River tide-gates (see Section 3.2.3) form an important medium term defence from SLR. However, the tide-gates will need to be supplemented with stopbanks along the western edge of Brooklands Lagoon if these areas are to be protected in the face of SLR".*
- 45 I do not believe that CCC have included these stopbanks as part of the mitigation package. As discussed below, although tidal, I consider the Brooklands Lagoon forms part of the Styx River system as do the tidal reaches upstream of the tidal gates.

Section 5.3 of Blueprint

- 46 *"The entire suburb of Brooklands has been zoned red and approximately 66 houses will require to be re-built in Spencerville. Severe damage to land was evident in the banks of the lower reaches of the Styx River where lateral spread opened up cracks as wide as 300 mm. Local drains showed the effects of liquefaction with grey silt or sand appearing and also there was evidence of the beds of streams being heaved upward as the banks moved inward toward the streams. This heave was most obvious in the constructed diversion on the lower Styx River right bank at approximately 1025 Lower Styx Road where the bed heaved about 500 mm. A similar effect was observed in the exit drain from Wilsons Swamp (near Kainga) where the bed also heaved by approximately 500 mm and subsequently raised the water level in Wilsons Swamp. There is evidence that there has been general*

settlement of the land in the Brooklands area of approximately 200 mm. This has raised concerns about the vulnerability of the area to both storm and tidal flooding.

- 47 *Preliminary investigations have indicated that the cost of providing stopbanking and pumping protection for Brooklands settlement from a 1% AEP storm or tidal event would be likely to exceed \$6 million. This action is unlikely to be taken now that Brooklands has been zoned red”.*
- 48 As above, the entire suburb of Brooklands has not been red zoned. The cost of mitigating additional flood damage to the properties not red zoned needs to be weighted against the costs of only requiring partial detention up-catchment. It may be less expensive for CCC and Developers to buy out the remaining properties so that the area of flood storage in this area can be managed as a proper flood management area, rather than stop banks and pumps, or Standard Detention.
- 49 *“At all locations peak flood levels under extreme catchment rainfall conditions were higher or equal to those under extreme high tide conditions. The ground surface used in the modelling originally was pre-earthquake. In later computer runs the ground surface was derived from a post-earthquake LiDAR digital terrain model”.*
- 50 There are no post-earthquake results for full attenuation options to assess what differences there would be.
- 51 *“Table 7 shows 80 – 110 mm increase in Brooklands ponding area for partial detention 50/48 with modified outlets.*
- 52 *The Standard Detention option is considered to meet the flood mitigation objective for the Styx catchment: “To accommodate expected urban growth over the next 35 years without a significant increase in the cost of flood damage to the community.”*
- 53 *The depth (and therefore the extent) of flooding in Brooklands ponding area will increase with development, but the increase in depth is expected to be no more than 110 mm once on average every 50 years. The flooding is entirely contained within a Flood Ponding Area designated in the City Plan (Variation 48). Flood damage resulting from this infrequent inundation of pastoral farmland is likely to be small. Flooding nuisance to the residents of Brooklands will dissipate over time as the suburb is gradually abandoned as a consequence of being within the earthquake “red zone”.*
- 54 *Implementation of the Partial Detention option in preference to Standard Detention is preferred because the necessary detention*

facilities have a smaller area footprint and would therefore, be significantly cheaper to implement with relatively small increases in flood depth in the receiving waters”.

- 55 As discussed in numerous places throughout this evidence, this is not the case here as the Brooklands area is not being fully abandoned. CCC state that Standard Detention accommodates expected growth but is promoting Partial Detention only to save costs and ignoring residents within Variation 48 designated land.

F. COMMENTS ON EVIDENCE

Tom Parsons

- 56 *Cl "21. The scope of the consent is to manage the effects of stormwater discharges into and out of the stormwater network from urban development. Sea level rise is independent of these discharges however there are three areas of impact:*
21.1 Direct increases to tidal flood risk. This is outside the scope of the consent and not discussed further;
21.2 Change in receiving environment effects of stormwater discharges. Greater areas will be dominated by tidal flood risk (which will potentially have reduced sensitivity to incremental discharges due to the relative changes in level). There will also be areas where fluvial flood risk (i.e. flooding from the rivers) will increase due to tidally influences. These areas are likely to see increased sensitivity to stormwater discharge quantities; and
21.3 Reduction in stormwater system capacity due to higher water levels at the network discharge point reducing the period over which gravity networks can discharge effectively”.
- 57 I agree with Mr Parsons assessment above. Tidal influences will impact on river flooding.
- 58 *"The SMPs will need to explore potential future flood risk, the impacts of climate change and the impacts on the existing drainage network. However, over the period of the proposed consent duration sea level rise predictions are modest (as compared to later in the century). This signals that sea level rise will become increasingly important in future consents”.*
- 59 This may possibly be the case if a 25 year consent is granted but it is incremental, i.e. in 25 years-time, the argument will be the difference in levels for the next 25 years, etc. It is also somewhat at odds to Mr Harrington’s clause 58, that is discussed later.

- 60 CI 42. *".....The Heathcote, Styx and Halswell models are at an earlier stage of development. It is not yet currently clear if sufficient budget will be made available to complete the Halswell and Styx model upgrades. These updated models will provide greater confidence in the predicted flood levels and allow the re-evaluation of the target water levels set within Schedule 7 of the proposed consent conditions. This is reflective of the cyclic nature of model development and as a result flood level predictions the absolute target levels will change with future model modifications. As a result I would not recommend a fixed or absolute water level to be used as an attribute target level within Schedule 7. In the interim the existing models can be used to evaluate compliance with the proposed consent conditions (i.e. for testing the effects of future development) but will provide lower confidence in absolute flood level predictions".*
- 61 I understand the uncertainties and the complexity in developing models. However, the uncertainty is an issue for people already having their sections inundated for long periods with events smaller than the 10% AEP. I also understand that as time moves on and more flooding statistics are obtained, the 2% AEP event will get bigger than what is currently being modelled, although a 16% increase in intensity has been allowed for.

Graham Harrington

- 62 CI 18. *".....In the Styx catchment the storage volume in the lower floodplain "Flood Ponding Area" designated in the District Plan can be relied upon to remain and ensure that these areas will not have their flood storage capacity diminished over time".*
- 63 But CCC recently granted consent for a neighbour of the Rodrigues on Earlham Street to build within the FPA. Other properties nearby have also been built with floors above the 0.2% AEP level and this has resulted in a lot of fill around the dwelling and out-buildings. In addition, fill has been brought in by property owners adjacent to the Rodrigues and this has altered drainage patterns.
- 64 CI 58. *"A series of high tide events in Christchurch over the last 2 years, which were higher than have ever been recorded, has prompted a 2018 review of the tide statistics for Christchurch. These were previously reviewed as recently as 2011. The 2018 review has established a new set of statistics for the recording sites around Christchurch which, for tide events of 1 in 100 years (or 1% AEP), are 200 mm to 300 mm higher than the equivalent 2011 tide statistics. The tide record is over a much shorter period of time than the rainfall record. The Ferrymead tide site started recording in 1974. The shortest record is from Bridge St bridge tide gauge,*

which began recording in 1997. It is reasonable to assume that the longer sampling period of 9 years, from 2011 to 2018 would inevitably contain more extreme events, however it is also reasonable to conclude that this change is partly due to accelerating sea level rise. Further discussion of this matter is beyond the scope of this Application, however it does show that the Council uses the data collected to better understand what is happening in the local environment. It is also relevant to my evidence below in relation to the maintenance of the Council's flood models and to my evidence below in relation to the situation of the residents in the Lower Styx catchments in particular".

- 65 It is a concern that there has been that much of a shift in tides in just 7-years. I also disagree with Mr Harrington that further discussion on SLR is beyond the scope of the application. As pointed out by Mr Parsons, tide levels are related to flooding levels. Tides impact on Brooklands Lagoon and this impacts on the opening of tidal gates and these impact on water levels upstream. When the gates open, the volume of water held back by the gates then enter the lagoon and, as tides come back in again, may flow overland into Brooklands.
- 66 Cl 72. *"The earthquake did however cause the land to settle around the Styx River and elsewhere and there is evidence of bank slumping and some bed heave. This has led to some swampy areas around the former banks of the Styx River and the appearance that the river has a greater flow because the water level is at a higher level with respect to the land level. Coupled with this is the ongoing sedimentation of the lower Styx channel and apparently more vigorous growth of weed in the channel. Unsurprisingly the Styx residents are concerned about this and would like to see more resources applied to river channel maintenance by way of dredging and weed management by way of weed harvesting. This would effectively be an operational response rather than a matter covered by this Application. The Council has undertaken two dredging projects in the reach of the River near Spencerville and it is possible to identify some short term benefits of this work by way of water level reductions. It is very difficult to identify if this work has had any sustained improvement in water levels because of the continually varying flows and the varying state of the weed in the river".*
- 67 I do not agree that this is not part of the application. Management of weed growth and sedimentation is being relied on to reduce flooding effects is therefore needs to be locked into the SMP or conditions, i.e. when and how frequent dredging and weed removal occurs, or triggered by baseflow river levels.

- 68 CI 73. *"The residents further assert that the flows in the lower river have increased as a result of inadequately mitigated development upstream in the catchment. The upstream developments have detention facilities which are constructed according to standards specified in the Styx SMP which are designed to mitigate flood flows up to a 50 year event (2% AEP) with some reliance on additional storage in the Flood Ponding Area designated in the District Plan, in the lower catchment floodplain. However there is no evidence of increases in peak flood flows (as distinct from levels) or changes in base flows (as distinct from levels) that the local residents would have experienced in recent times. I discuss this matter further below".*
- 69 The residents notice river levels and not flows. By way of example, refer to the Statement of Observations filed by Kerrie Rodrigues with her original submission.
- 70 CI 74. *"I would expect that inadequately mitigated flows from urbanised areas would result in higher peak river flows in rainfall events and a reduction in longer term base flows. This is because the rain has not been absorbed into the ground and slowly released over time from the groundwater. This would particularly be the case in the summer, where you would expect the river levels to be very low. In fact the converse is true. The river levels (not flows) in the summer post-Christmas are significantly higher than in the winter.*
- 71 CI 75. *The graph below (Figure 1) shows flows recorded in the main stem of Styx River at Radcliffe Road which is a few hundred metres upstream of the Marshland Rd bridge. Visually, there is no obvious trend over time of increasing or decreasing base flows (as distinct from water levels). The highest recorded peak flow occurred back in 1996. The highest subsequent flow was in 2013 and there are series of moderate flow events in 2014, coinciding with the floods in Christchurch City, but these are all smaller than the 1996 event and also smaller than the 2013 event.*
- 72 76. *My main point is that the general nature of the base and peak water flows (as distinct from water levels relative to ground level) has not obviously changed and hence the claims by the Styx residents that inadequately mitigated upstream development is having a significant effect on flooding in the lower reaches of the river are unsubstantiated. Changing the mitigation rules or even removing developments upstream would not fix this issue".*
- 73 I can't agree with the entirety of the above statements. Mr Harrington jumps between comparing water levels and flows in the three clauses above. Yes, you would expect some reduction in baseflow but there are so many other factors at play when looking

at flows and water levels. There are upflows from deeper artesian aquifers that are driven by rainfall and the Waimakariri River further up the Canterbury Plains, some with a reasonable time lag. River levels post-Christmas as per CCC evidence can be impacted on significantly by weed in the river and the seasonal trends may be as a result of this. River levels impact on flow recording systems.

- 74 In addition, absolutely no inference can be drawn between the difference in flood peak events in 1996 and 2013 as there are a lot more variables than just developed impervious area to consider, such as rainfall intensity, direction of the storm over the catchment, storm duration, and antecedent moisture conditions. The modelling undertaken by CCC shows that there is a difference between non-developed and developed land but this has not been reported for all scenarios using post-earthquake levels.
- 75 Cl 83. *"From my point of view the most pressing issue to be addressed is also beyond the scope of this Application and it is the future effects of sea level rise that are evidenced by the recent incursions of high tides from Brooklands Lagoon along Earlham St and also from Brooklands Lagoon into Spencer Park".*
- 76 As above, I do not agree with Mr Harrington that sea level rise can be ignored and is outside the scope of these applications. Tide levels are part of the known environment and in the Styx River case impact on the critical duration of flood – 48 hours. SLR is a predicted issue to be taken into account in design, just as rainfall intensity increases due to climate change are taken into account.
- 77 Cl 95. *"KF and AD Rodrigues. Raise concerns about ongoing flooding issues on their property and the upstream discharges that drain into the Styx River. Similar concerns were raised at the hearing on the Styx Stormwater Discharge Consent CRC131249. Appendix A is the evidence presented by the Council (Roy Eastman since deceased) on this matter at that hearing. I agree with and adopt that evidence. This demonstrates that above floor flooding from the Styx River would not occur at the Rodrigues' address in a 1 in 50 year event – which is the normal criterion for assessing such flooding risk. This assessment makes allowance for climate change assumes full development upstream and stormwater mitigation according to the standards used in this catchment. This area of Earlham St is low lying – and is indeed below many of the recent moderate to extreme tide events in Brooklands Lagoon. The sand hills (or mounds) along the edge of the lagoon have until recently prevented tidal flooding in the Earlham St area however tidal flooding did occur in July 2017 and again in February 2018 with the extreme and "highest on record" tides that occurred. These events coincided with continuing moderate rainfall events*

which meant that groundwater levels remained high and above ground level for several months. This matter would not be resolved by changes to the management of stormwater upstream of this location. It is therefore a local issue and is not related to this stormwater consent Application”.

- 78 I disagree with Mr Harrington. The flooding issues are all related. Flooding has occurred frequently at the site since the earthquakes. The flood pathway may possibly be from Brooklands Lagoon (not confirmed) but this only occurred during the moderate flood events recorded in the Styx River and have not occurred at other times. The Styx has critical duration of 48 hours, i.e. 4 tide cycles, meaning that water is backing up behind the gates when the tide is high for longer periods before there is sufficient hydraulic head to start forcing Styx River flood water through the gates and into the lagoon. The lagoon will therefore have more water trying to drain from it during the tide cycle and will be backed up when the tide comes in again. This may be sufficient for water from the lagoon to flow back into Brooklands; this will be a mix of water draining from the Styx over the 4 tide cycles and sea water. Brooklands Lagoon is part of the Styx system, it just happens to be on the other side of the tidal flood gates.
- 79 Flood nuisance is not just inundation of dwelling floors. Short-term flooding of properties is usually acceptable, however, long-term inundation that is occurring following events in the Styx causes many other issues, such as poor soil health, vegetation die-off, mould/mildew within house substructure, quality of life and occupant health. These do not go away immediately following the water draining away.

Harrington Comment on Officer’s Report Schedule 7 objective (s42a)

- 80 Cl 112. *“Paragraph 402 of the S42A suggests that an objective be included in Schedule 7 which would state “ Stormwater run-off volumes and peak flows are managed so they do not cause or exacerbate the risk of inundation, erosion or damage to property or infrastructure downstream or risks to human safety”. In an absolute sense it would be difficult to comply perfectly with such an objective. In the Styx catchment for example there has been a deliberate allowance for additional flooding depth in the lower Styx floodplain and there are smaller allowances in the Avon for some possible creep in water levels. In hill catchments there is some possibility of erosion in the steep streams which is mitigated by the requirement to install storage tanks on new developments. My preference would be for such a statement to be a guide but for the practicality of it to be worked out through the SMP process”.*

- 81 I agree with the Officer. The FMA in the Lower Styx was not a designated area when the Rodrigues purchased their property and existing dwelling in May 1990. The land was already held in 5 separate titles. At that time of purchase there were no designations over the land under the relevant planning instruments. They were granted land use consent to erect dwellings on the under-sized titles in August 2006. The land was then designated a FMA, but not a FPA. At that time, a subdivision consent was also secured, but this simply re-arranged the existing titles into a better configuration, rather than create new titles. The subdivision consent has subsequently lapsed and has not been renewed but the land use consent was renewed in November 2016. At that time the land was zoned rural however the Natural Hazards decision, as it relates to the application site, had no legal effect. Although still with an underlying Rural Zoning, the property is a lived in dwelling. Although I agree with the intent of what Mr Harrington and previously Mr Eastman are suggesting, i.e. partial attenuation only is required as there is a large floodplain near the coast and additional inundation may not be important on rural land. But this FMA contains dwellings that were there before it was designated a FMA and is not a constructed storage area specifically for flood mitigation. Therefore, flows and volumes should be managed so that they do not exacerbate the risk of inundation.

Eastman's Evidence

- 82 There are numerous statements in witnesses evidence and Mr Eastman's evidence about Council using BMPs. In most cases, I would agree with this, particularly for water quality reasons. However, BMP for quantity (flows and volumes) are to firstly protect FMAs by not allowing filling and/or building (and this is not the case) and full detention/attenuation to neutralise the effect of change in land use. A BMP would not result in an additional 100 + 20 mm of inundation within a property that is already suffering from prolonged inundation.
- 83 Mr Eastman comments that weed changes Manning's 'n' from 0.05 to 0.15 and can change water levels by 600 mm. This can't be ignored and has to result in weed management requirements in the SMP or in consent conditions.

Harrington Paper to Water NZ Conference

- 84 Under the heading *Fluvial Flooding: In the lower reaches (below Marshlands Road) flooding is influenced by the tide, the tide gates and the volume of flood water. Flooding about Brooklands is more dominated by storage in the flood plain upstream of the tide gates rather than channel capacity. When the tide gates are closed flood water ponds behind the flood gates eliminating the influence of*

channel capacity. As a result the flood extent and depth is driven by flood volume (i.e. the total depth of rainfall) and the shape of the flood plain.

- 85 Under the heading Coastal Flooding: *Overtopping of the sand dunes behind Brooklands Lagoon in extreme tide events (allowing for storm surge and barometric effects) has been identified as a potential flooding scenario. The inundation of Brooklands could result and the risk of this flooding will significantly increase with sea level rise. However, there are significant restrictions to tidal flooding due to the limited period during which the tide level is predicted to overtop the trough in the sand dunes. The level of flooding in the Styx River due to Overtopping of the sand dunes is constrained by the available conveyance and the friction of the ground surface.*
- 86 I agree with the above two statements in Mr Harrington's paper. Stormwater volume is key to effects and during a storm the volume arriving at the flood gates is greater from more impervious or low pervious areas than pervious areas – runoff generally varies from about 30% (pervious) of rainfall to 85% (impervious) of rainfall. Although the total volume of rainfall may eventually arrive at the floodgates via groundwater flows, the time lag means that it discharges slowly into the river when levels allow and it provides river base flow.
- 87 Groundwater, river flow, flood volume, tide levels on the Lagoon are all related.
- 88 The CCC modelling shows flooding in the Existing Development scenario of between 400 and 600 mm at the Rodrigues house site and up to 800 mm elsewhere within their property. From the figures in the GHD modelling report, the area inundated by more than 200 mm flood depth increases from 388 to 452 ha in a 50 year event. These scenarios are all using post-earthquake land levels with the Rodrigues land about 300 mm lower following the earthquakes.
- 89 The issue is the CCC assessment of effects is based on an allowing up to an additional +100 mm (with 20% variability) flood depth above the 2012 flood levels. However, using the post-earthquake LIDAR information, the 2012 existing flooding situation is significantly greater than historical flooding, i.e. the Existing Development baseline they are starting with is not what has been seen in the past by residents.
- 90 So CCC's conclusion that the partially mitigated development upstream does not increase flooding by more than 100 mm (+20 mm) downstream may be correct but is misleading to land owners

in the area that are now seeing prolonged flooding in small to moderate events that they never saw before.

G. COMMENTS ON OFFICERS REPORT

- 91 I am in general agreement with Mr Laws. However, I do not see merit in additional performance monitoring locations in the Styx River, although I agree with the CCC proposal to include more monitoring locations to inform future model calibration.
- 92 I agree with the 5-yr modelling review, or following events greater than 5% AEP (20 year).
- 93 I am in agreement on a limit on volume increase as I believe water level increase alone does not reflect the effect that the inundation has on land in Brooklands and the time taken to drain.
- 94 I also agree with his concern on the use of 2012 as the baseline year due to perception issues (as I have outlined above).

POSSIBLE MITIGATION MEASURES

- 95 There are no bullet proof engineering solutions that will satisfy all the issues identified above, i.e. flooding from the Styx River directly or via the Brooklands Lagoon, although some will mitigate partially. Due to high groundwater and predicted sea level rise, possible mitigation measures to reduce flood risk at the Rodrigues property are limited to:
- 95.1 Bunding the property to prevent floodwater from entering it. This option will need a number of pumps to reduce groundwater levels to below the root zone. Pumping would need to be with either diesel operated pumps or diesel generator backup (electric pumps are less reliable due to power cuts in big storm events). This option leaves the site vulnerable from emergency egress due to the floodwaters outside the bund;
- 95.2 Lifting the house and important outbuildings and placing fill under them as well as a sufficient platform so the house is not an isolated island and egress is maintained for emergency access. This option provides certainty to the 200 year event but like the bunding option, could isolate the Rodrigues during flood events unless the roads are also lifted. It does not deal with flood inundation and high groundwater issues elsewhere on the property. The Proposed Christchurch Replacement District Plan (Stage 1) requires that the minimum finished floor level (FFL) be 12.3 m RL in terms of the CCC datum. Based on the existing road crown and the potential land elevation of

neighbouring properties, it is recommended that the minimum ground level be 10.85 m RL in terms of the CCC datum. The depth of fill required to achieve the minimum FFL is on average 1.8 m – 1.95 m above current land levels.

- 95.3 Abandon the dwellings so that the area can be managed as a FMA.
- 95.4 Installing drains with flap valves to allow water to drain to flow back into the Styx River or Brooklands Lagoon following inundation. Obviously this option does not stop inundation but merely reduces the duration of the ponding.

CONCLUSIONS

- 96 If further mitigation is not provided, then it is only a matter of time before the Rodrigues dwelling is inundated. Current statistics and modelling show this is not likely to occur in a 50 yr event but in future, the current 50 year event will be more frequent, and the new 50 yr event will be larger and could inundate floor levels. Add to this the uncertainty in the modelling and the closeness of predicted flood levels to floor levels, then there is reason for concern.
- 97 With the infilling that has occurred in the area - on red zone sites, new developments, and neighbouring rural land; drainage patterns have been altered and water does not drain away and stays for months. This is exacerbated by higher groundwater levels due to consolidation from earthquakes, and by sea level rise.
- 98 BMPs for water quantity are not proposed. BMP would be to not allow any further development within the FMA, removal of recent fill within it, including the CERA filling and Standard Detention of developed sites upstream.
- 99 The Styx River is used as the main stormwater conveyance device so management of it for these purposes is no different from keeping grills over culverts free of debris. So management of nuisance weed growth and sediment are important to keeping capacity and reducing river levels. The frequency of this needs to be outlined in either conditions of consent or the SMP, with a trigger based on river baseflow levels if growth results in more frequent removal being required.
- 100 Sea level rise is part of the predicted environment and is already being seen. It is no different to predicted increase in rainfall intensity. Sea levels impact on the flood levels required to force water out of the tidal gates (difference in head between the river level and sea/tide level). It is not beyond the scope of these applications as indicated by modelling that has a 0.5 m rise included.

101 Flood nuisance should not be exacerbated by allowing 100 + 20 mm additional inundation within areas with dwellings. If the area is to be managed as a flood ponding area, then the dwellings need to be abandoned.

Dated: 24 October 3018

A handwritten signature in black ink, appearing to read 'RJP', with a long horizontal flourish extending to the right.

Robert John Potts