Proposed
Hurunui and Waiau River Regional Plan

And Proposed Plan Change 3 to the Canterbury Natural Resources Regional Plan

Section 42A Report
September 2012

Salmon and jet boat passage and river bird habitat

Prepared by

Maurice Duncan

Hydrologist

Environment Canterbury
Regional Council
Kaunihera Taiao ki Waitaha

1. Introduction

1.1 Author

1. My name is Maurice John Duncan. I am a hydrologist employed by NIWA. I have an M .Ag. Sc. in Agricultural Engineering from Lincoln College. I have worked for NIWA and its predecessor organisations for 43 years. I have been building and running two–dimensional hydrodynamic models since 1995 and have modeled many of the large braided rivers in Canterbury primarily to develop relationships between flow and instream physical habitat. My first experience in developing relationships between flow and instream habitat was for the Rakaia River in 1985. Since then I have presented evidence at a number hearings, including Environment Court Hearings, on instream habitat, based on hydrodynamic models.

2. The scope of my evidence relates to the adequacy of proposed minimum flows for adult salmon passage and jet boat passage. In addition I address the effects of the proposed flow regimes on river bed bird nesting and feeding habitat**.** I confirm that the issues addressed in this statement of evidence are within my area of expertise. I note in the body of my evidence where I rely on simulated flows supplied to NIWA by Dr Jeff Smith of the Canterbury Regional Council. I understand those simulated flows assume no losses between Marble and Mouse Points.

3. The data, information, facts, and assumptions I have considered in forming my opinions are set out in the part of the evidence in which I express my opinions. The reasons for the opinions that I express in this evidence are set out in the part of the evidence in which I express my opinions.

4. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

5. The literature or other materials which I have used or relied upon in support of my opinions are listed in Appendix A.

1.2 Content of the officer's report

6. This report is prepared under the provisions of section 42A of the Resource Management Act 1991 (RMA).

2.0 2D hydrodynamic modelling

8. My opinions on salmon and jet boat passage rely upon 2D hydrodynamic modelling of braided reaches of the Hurunui River and Waiau River and criteria on the depths required for salmon and jet boat passage. I organised the field surveys and carried out the modelling. 2D modelling is carried out by developing a detailed digital terrain model of the river reach. The model presents a steady stream of water flowing from the upstream end of the reach, to the downstream end of the reach according to equations representing the physics of shallow water flow and the experiment is continued until outflow equals inflow. The model was used to present a range of flows. The model is calibrated by comparison with measured depths and

velocities, and aerial photographs of wetted extent. Among the model outputs are depths and velocities that are used with habitat use data to calculate the available physical habitat called hereafter weighted useable area (WUA).

9. My opinion on salmon and jet boat passage also relies on riffle depth surveys where the minimum depth of the deepest part of riffles over long reaches of the rivers was measured. In addition my opinion relies on the experiences of jet-boating the rivers at low flows. Riffle depth surveys were carried out on both the Hurunui and Waiau Rivers.

10 The Hurunui River model represents a river reach that is 1295 m long in the direction of flow and 604 m wide and is located ~1 km downstream of the State Highway 7 Bridge in a braided section of the gravel bed river. It was surveyed using digital photogrammetry for dry locations, GPS-located echo-sounding of deeper wetted channels and GPS located elevations by wading shallower wetted channels. The model and results are described in more detail in Duncan and Shankar (2004). The modelled reach is representative of a much longer reach of the river (Duncan and Shankar 2004).

11 The Waiau River model represents a river reach that is 2832 m long in the direction of flow and 1732 m wide and is located ~ 2 km downstream of Caithness Road that joins State Highway 7 at Mouse Point. Again this is a braided section of the gravel bed river. It was surveyed using laser altimetry for dry locations, GPS-located echo-sounding of deeper wetted channels and GPS located elevations by wading shallower wetted channels. The model and results a described in more detail in Duncan and Bind (2008). The modelled reach is representative of a much longer reach of the river (Duncan and Bind 2008).

12 The models provide mean water depths and mean velocities for a number of relevant flows for model cells that were 1 m x 1 m on both rivers. All cells with an average depth of ≤ 20 mm were treated as being dry. This is considered acceptable (Golder Associates 2007) because the mean water depth is of the same order as the mean surface particle size of 25 mm in the Hurunui River (Duncan and Shankar, 2004) and 36.5 mm in the Waiau River (Duncan and Bind, 2009).

3.0 Salmon passage

2.1 Habitat calculations.

13 Calculation of WUA requires two separate pieces of information. First calculations require the mean depth and mean velocity for each cell from the 2D model for a particular flow. Second, calculations require a relationship between water depth and the suitability of that depth for the species or life stage being considered and a similar relationship between velocity and the suitability of that velocity for the species or life stage being considered. For example, if the water is shallow and slow it is suitable for common bully, but not if the water is deep and fast. This information is normally combined by multiplying the cell area by the depth and velocity probabilities and summing this for the entire modelled reach. This total is then divided by the reach length to standardise the assessment. This exercise is repeated for each modelled flow to get a relationship between flow and WUA, i.e., flow versus physical habitat.

14 Adult salmon and jet boats require more water depth and flow than other fish so that if habitat is available for adult salmon and jet boats then it can generally be assumed that there is suitable habitat for other fish.

2.2 Salmon passage

15. The adult salmon minimum depth and maximum velocity criteria were taken from Thompson (1972) as summarised in Stalnaker & Arnette (1976). Those criteria indicate that if the water depth is greater than 0.24 m then salmon passage in unimpeded. If there is more than 0.2 m of water depth salmon passage is possible but there may be some abrasion of their bodies and this may affect their fecundity.

16. Adult salmon migrate upstream from December to April with higher numbers in February March and April (Dr Don Jellyman, NIWA pers. comm.). In the Hurunui River in December and January the proposed minimum flow is 15 m^3/s and modelling shows there should be sufficient depth (more than 0.24 m) for unimpeded passage in those months. In February to April the proposed minimum flow is 12 m^3/s, prior to storage being developed, and the modelling shows that for the modelled reach there was sufficient depth for passage. The shallowest parts of the rivers are in riffles.

17 To check whether the model reach was typical in respect of riffle depth, a riffle survey of a 17 km long reach was surveyed by measuring the deepest part of the shallowest cross-section of many riffles along the river. The riffle depth survey showed a minimum depth of 0.25 m, which is sufficient for passage, when the flow was 13.5 m^3/s.

18. In the Waiau River in December and January the proposed minimum flows, prior to storage being developed, are 25 and 20 m^3/s respectively. Modelling and riffle depth measurements show there should be sufficient depth for unimpeded passage at those flows. In February, March and April the proposed minimum flows, prior to storage being developed, are 15, 15 and 20 m^3/s respectively. The riffle depth survey over an 18 km long reach showed minimum riffle depths of 0.26 m in the modelled reach at a flow of ~18 m^3/s and on that basis minimum flow of 15 m^3/s should be sufficient to provide the minimum depth for salmon passage of 0.24 m.

19. Detailed examination of the Waiau River model output when the flow was 15 m^3/s shows short sections of the major channels with depths of less than 0.2 m. These predicted shallow portions were inconsistent with the riffle depth survey. The inconsistency could be due to insufficient bathymetric data to define those areas or some other artefact of the modelling as they are at odds with the riffle depth survey. Considering the whole Mouse Point to Waiau Township reach, it is quite possible that there will be locations where there is insufficient water depth at a flow of 15 m^3/s for salmon passage, especially if the river loses flow downstream of the modelled reach, or if flows spread across more braids, than in the modelled reach.

.

3.0 Jet-boat passage

20. Jet-boat suitability curves were developed from criteria in Mosley (1983) as listed in MFE (1998). These criteria indicate minimum widths and depths of 5 m and 0.1m respectively and a maximum velocity of 4.5 ms^{-1}. The preferred values are for width >5 m, depths >0.6 m (minimum depth over riffles of 0.2 m) and velocity of <4.5 ms^{-1}. These criteria were interpreted to mean that if the water depth was more than 0.3 m then there was sufficient water for jet boating. Experienced jet boaters agree that a depth of 0.3 m is adequate for jet boating, but jet boats can be operated in shallower water (pers. comm. Rob Gerard, Canterbury Regional Council). However, it only takes one impasse to stop a jet boat. Typically in a braided river this is due either to a boulder bar spreading the water so that there is no boatable channel, or by the river braiding into many very small channels, none of which contain navigable water. Skilled and experienced boaters will manage at lower flows than learners or inexperienced drivers (pers. comm. Rob Gerard, Canterbury Regional Council).

3.1 Hurunui River

21. The modelling indicates jet-boat passage is possible when the flow is 10 m^3/s in the Hurunui River. Caution needs to be exercised when interpreting modelled flows to determine jet-boat passage depth as the model returns the average depth of water over the cell and does not take into account the depth of water over cobbles that may be protruding from the bed and may compromise jet-boating. However, during the course of field work the study reach was traversed when the flow was approximately 13 m^3/s. The boat used was a large and heavy work boat that needs more water depth than lighter recreational jet boats.

22 The lowest proposed minimum monthly flow is 12 m^3/s, prior to storage being developed and the winter minimum flow for non-consumptive takes is 10 m^3/s. At 10 m^3/s the modelled water depth in parts of the main braid was between 0.1 and 0.3 m. This water depth should be sufficient for jet-boat passage for a skilled driver. However, the geomorphology of the river bed is constantly changing, so at times the river may be navigable at 10 m^3/s and at other times it may not.

3.2 Waiau River

23. The modelling indicates jet boat passage is possible at 15 m^3/s which is the lowest minimum flow proposed for the Waiau River, prior to storage being developed. During the course of field work the study reach was traversed with a large and heavy jet boat when the measured flow was 15.3 m^3/s. A longer reach than the modelled area was also able to be jet boated when the flow was 18 m^3/s.

24. From the riffle depth survey carried out when the flow was ~ 18 m^3/s we know that the modelled reach is likely to be navigable when the flow is 15 m^3/s. However, during the riffle depth survey *t*he downstream extent was limited by lack of certainty of navigable water for the surveying jet boat (Duncan and Bind, 2008). This means that it is unlikely that the whole river could be navigated when the flow is at the lowest minimum flow of 15 m^3/s. In addition, if there are water losses from the river downstream of Marble Point, or if the

water spreads out over more braids than in the modelling reach, then the minimum flow of 15 m^3/s may not be sufficient to ensure jet-boat passage between Waiau Township and Marble Point. Because braided river morphology is constantly changing, the river may be navigable at 15 m^3/s at one time but may need considerably more flow at others times to obtain sufficient depth for navigation.

25. In conclusion, while most of the Waiau River could be jet boated by a skilled driver when the flow was 15 m^3/s, a flow of 20 m^3/s is probably required for a jet boat driver with average skill to traverse the entire reach between Waiau Township and Marble Point. Most jet boaters would be more comfortable boating with 25-30 m^3/s (pers. comm. Rob Gerard, Canterbury Regional Council).

4.0 River bed bird nesting and feeding habitat

4.1 Nesting habitat and river flows

26. The nesting habitat analysis of Duncan et al. (2008) showed that mammalian predators (cats, rats, hedgehogs and mustelids) can swim across the Hurunui and Waiau Rivers. However, work reported in Boffa Miskell and Urtica Consulting (2007) indicates that if mammalian predator population pressures are low, predators are reluctant to cross flowing water bodies of even modest dimensions. Consequently bird breeding is more successful on river bed islands than it is on the mainland.

27. I used the 2D models to assess the relationships between the number of islands and river flow and to assess which flow provides the maximum area of islands. The analysis considered islands greater than 0.25, 0.5, 1 and 2 hectares. Many river breeding birds feed in the slow shallow waters at the edge of channels. I therefore also analysed the relationship between island wetted perimeter and flow to assess the impact of flows on bird feeding opportunity.

28. Because vegetation provides cover for mammalian predators, it is also important that the islands are vegetation free. In addition, because exotic plant growth occurs on the highest points of islands, birds are forced to nest at lower points. These lower areas expose the birds to the risk of inundation from smaller and more frequent floods. It is therefore important that there is at least one large (>mean annual flood) flood each year to keep islands free from vegetation.

4.2 Hurunui River

29. Figure 1 shows the relationship between river flow and the total area of islands larger than the threshold sizes. The relationships between flow and number and perimeter of islands are very similar. At the proposed minimum flow during the main breeding period from September to December of 15 m^3/s, the area of islands, regardless of threshold size, is at a minimum. The maximum area of islands is reached when the flow is 40 m^3/s (Figure 1).

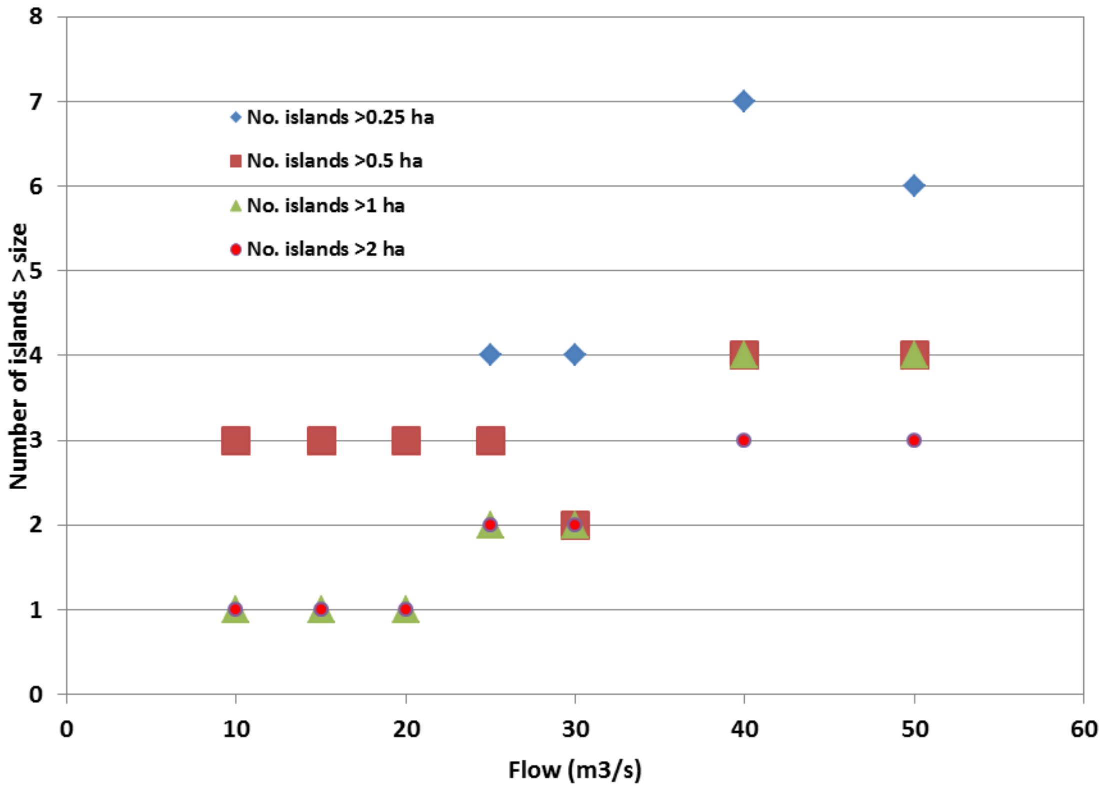

Figure 1: The relationship between flow and number of islands greater than threshold sizes for the Hurunui River downstream of SH6.

4.3 Waiau River

30 Figure 2 shows the relationships between flow and the number of islands in the Waiau River for islands greater than a threshold range of sizes from 0.25 to 2 ha. The number of islands of all sizes is largest at 40 m^3/s and is approximately constant at flows greater than 35-40 m^3/s.

31. The total area of islands is dominated by the area of the large islands and including small islands does not appear to significantly increase the area available for breeding. The area of islands is greatest at 10 m^3/s and falls steadily until a flow of 40 m^3/s is reached and falls more slowly until the flow reaches 146 m^3/s.

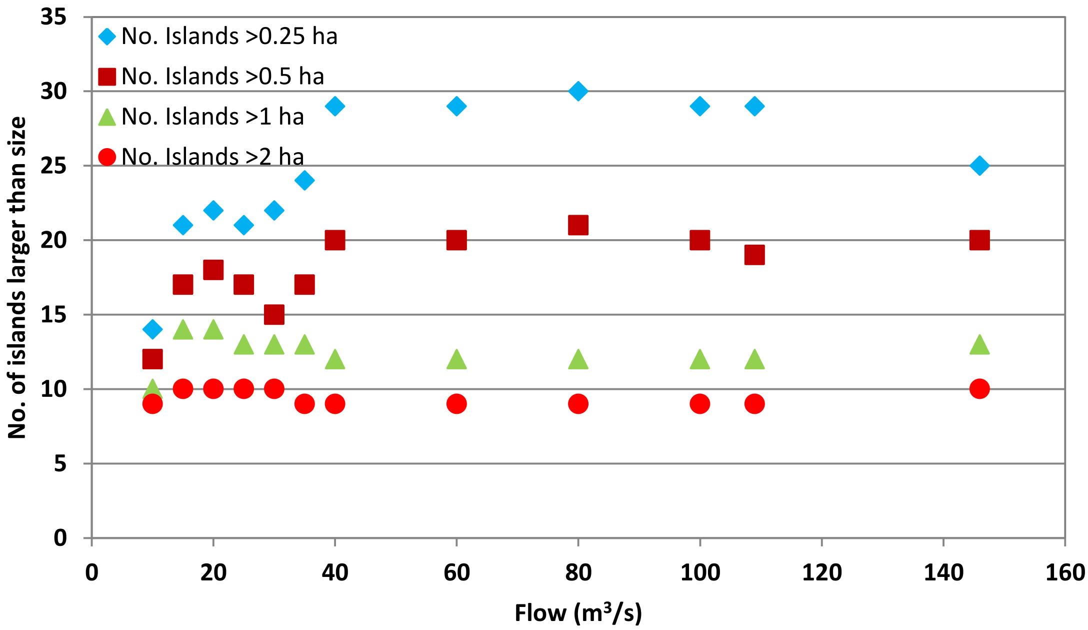

Figure 2: The relationship between flow and number of islands greater than threshold sizes for the Waiau River modelled reach at Mouse Point.

5.0 River bed bird feeding habitat

32. River bed bird feeding habitat assessment was based on the relationship between flow and three aspects. First, I assessed the relationships between flow and habitat for the invertebrates that the river bed birds are feeding on (invertebrate WUA). I used hydraulic habitat preference for invertebrates in general and a specific set of hydraulic habitat preferences for mayflies (*Deleatidium*). Second, I assessed the relationship between flows and the feeding habitat (feeding WUA) for Wrybill and Black-fronted Tern. Third, I assessed the duration when flows were at thresholds as defined by these flow - invertebrate WUA and flow - feeding WUA relationships.

5.1 Hurunui River

33. Figure 3 shows that flows of 15-25 m^3/s maximise invertebrate food production WUA. Mayfly (*Deleatidium)* WUA is constant from 10 to 20 m^3/s and then rises evenly as flows increase. So given the flat response of Wrybill feeding WUA to flow change, Wrybill feeding may be best served by flows of 15-25 m^3/s as is shown in Figure 3 (Duncan and Shankar 2004). As predation by introduced mammals is probably limiting Wrybill populations more than food production, flows that maximise the number of islands also need to be considered.

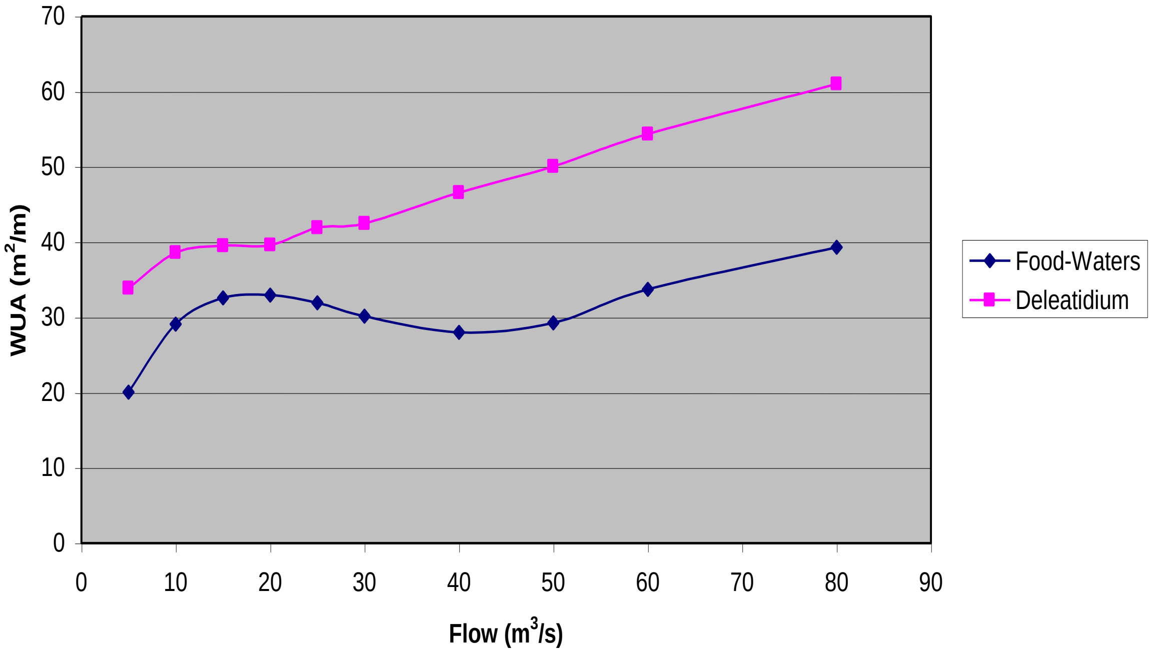

Figure 3: WUA *vs.* modelled flow for benthic invertebrate food production for the Hurunui River

34. WUA for Wrybill feeding is low for virtually the whole flow range (Figure 4). Maps of WUA (Duncan and Shankar, 2004) (not shown) show that most of the WUA is of low quality (values <0.2 where the range is from 0 to 1, where 0 equals no habitat and 1 equals prefect habitat) and is confined to the edges of channels. The river is quite incised at flows less than 20 m^3/s and there are few areas of shallow riffles that would be particularly suitable for Wrybill feeding. As flows increase over the range 20 m^3/s to 40 m^3/s, formerly dry channels begin to flow and more edge habitat becomes available (Figure 4). At flows of more than 40 m^3/s there is a slight decline in WUA as the flow becomes swifter and the width of the suitable edge habitat narrows.

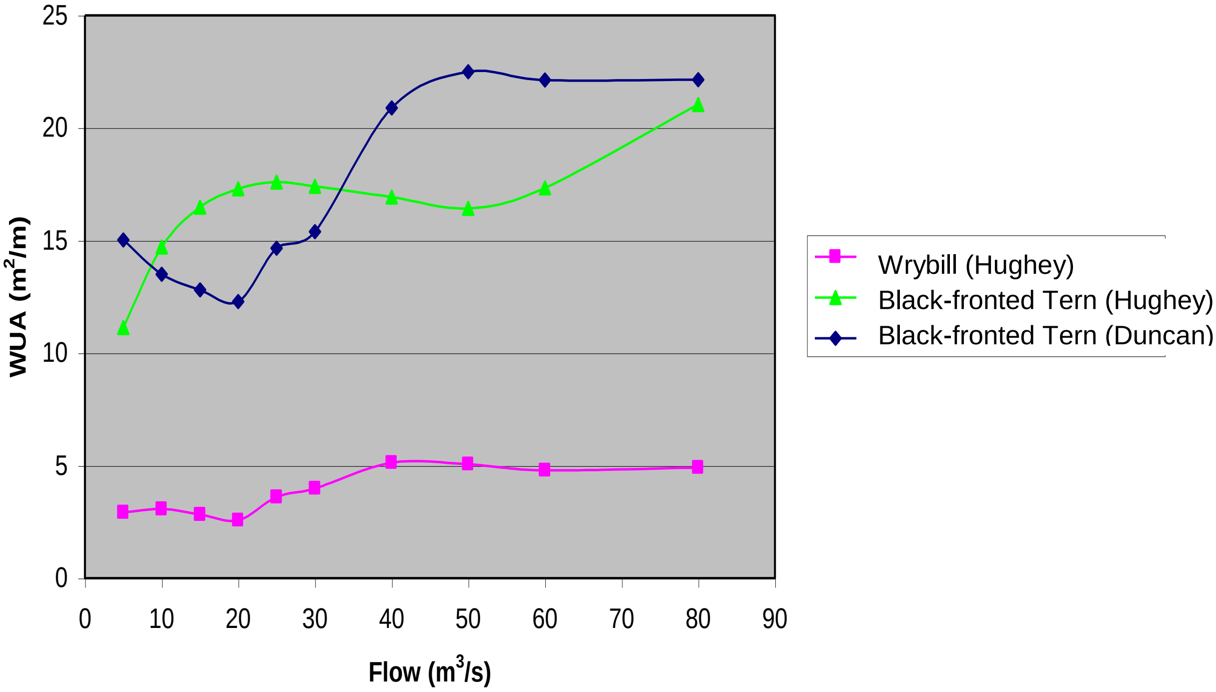

Figure 4: WUA vs. modelled flow for bird species/prey in the Hurunui River. The Hughey Black-fronted Tern curve is for feeding on drift (Lalas 1977) and the Duncan curve (Duncan et al. 2003) is for feeding on fish.

35. The minimum flow during the breeding season is 15 m^3/s. At this flow Wrybill WUA is close to the minimum. Minimum flows of 25 m^3/s and 40 m^3/s would increase the WUA available at 15 m^3/s by 45% and 65 % respectively; however invertebrate food production does not increase as much over this flow range as is shown in Figure 3 (Duncan and Shankar 2004).

36. Black-fronted Tern feed on two types of prey in rivers: benthic invertebrates, which they will take when they are abundant, and small fish. WUA for invertebrate feeding (Hughey/Rangitata curve, Lalas, 1977) peaks at 25 m^3/s, whereas the fish-feeding curve (Duncan/Waimakariri curve, Duncan et al. 2003) peaks at about 50 m^3/s when water is flowing in the small side braids, but is not too deep (Figure 4). Black-fronted Tern are probably opportunist feeders taking whatever food is most easily obtained. Thus, in common with the Wrybills, they may be best served by flows of 15 to 25 m^3/s that maximise invertebrate food production (Duncan and Shankar 2004). Black-fronted Tern nests also require protection from mammalian predators. The maximum area of islands is reached when the flow is 40 m^3/s (Figure 1).

38. Dr Hughey will comment on the ecological significance of these findings.

5.2 Waiau River

39 Food production increases steeply to 25 m^3/s and then continues to increase at a slower rate as is shown in Figure 5 (Duncan and Bind 2008).

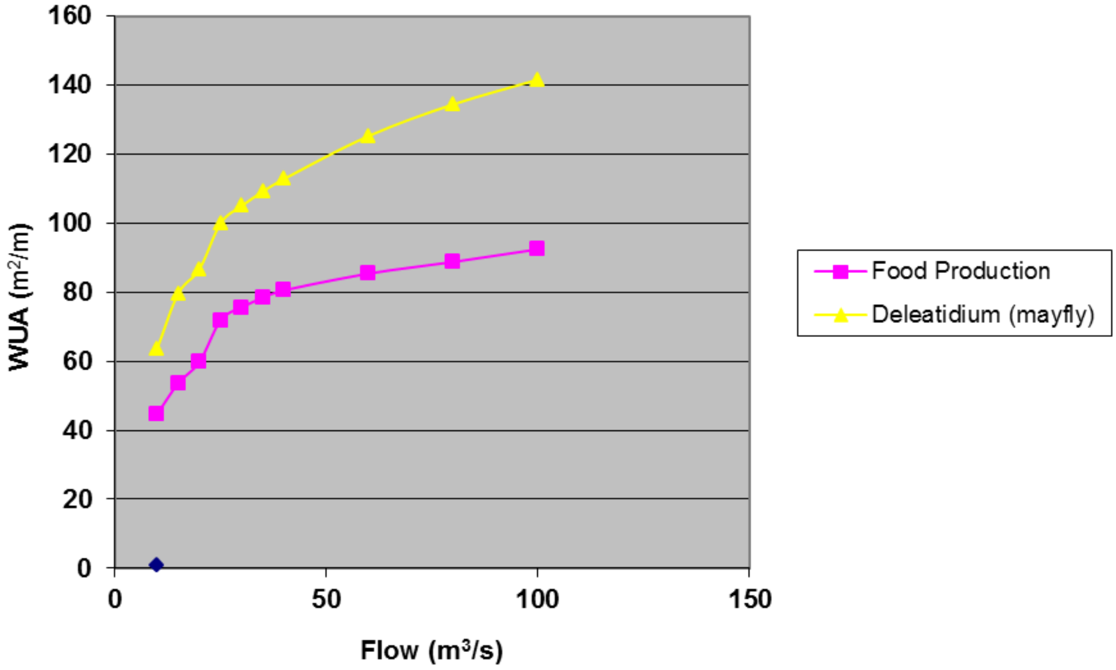

Figure 5: **WUA *vs.* modelled flow for benthic invertebrate food production in the Waiau River.**

40. WUA for Wrybill feeding in the Waiau River is low for virtually the whole flow range as is shown in Figure 6. Maps of WUA show it is of low quality (values <0.2) and is confined to the edges of channels (Duncan and Bind 2008). The river is quite incised at flows less than 15 m^3/s and there are few areas of shallow riffles that would be really good for Wrybill feeding. WUA increases over the flow range 10 m^3/s to 15 m^3/s as more braids begin to flow and more edge habitat becomes available. At flows of more than 25 m^3/s there is levelling off of WUA as the flow becomes swifter and the width of the suitable edge habitat becomes constant.

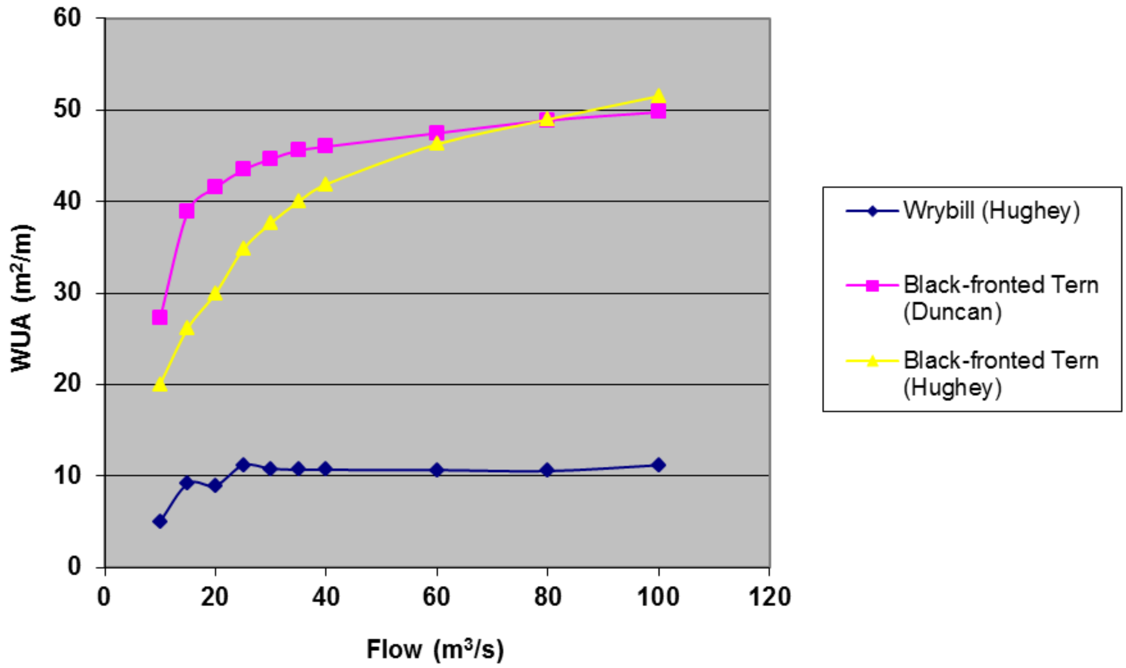

Figure 6: WUA vs. modelled flow for bird species/prey in the Waiau River. The Hughey black-fronted Tern curve is for feeding on drift (Lalas 1977) and the Duncan curve (Duncan et al 2003) is for feeding on fish.

41. As predation by introduced mammals is probably limiting Wrybill populations more than food production, flows that maximise the number of islands also need to be considered. The presence of flowing water will deter mammalian predators from venturing on to islands if the population pressure is kept low by trapping (Boffa Miskell 2007).

42. Black-fronted Tern are probably opportunist feeders taking either invertebrates or fish, depending on what is available and easiest. Black-fronted Tern habitat for invertebrate feeding (Hughey/Rangitata curve, Lalas, 1977) and for fish-feeding (Duncan/Waimakariri curve, Duncan et al. 2003) increases much more slowly at flows over 40 m^3/s (Figure 6). Black-fronted Tern nests also require protection from mammalian predators.

43. The proposed minimum flow during the main breeding period from September to December is 25 m^3/s (20 m^3/s when there is storage). Twenty cumecs or more is sufficient flow to provide feeding habitat for Wrybill and 25 m^3/s will provide adequate invertebrate production to maintain Wrybill.

44. For Black-fronted Terns drift habitat is still increasing steeply at flows greater than 20 m^3/s or 25 m^3/s and minimum flows of 35 or 40 m^3/s would be more appropriate, however the rate of increase in invertebrate food production does decrease at flows greater than 25 m^3/s.

6.0 Consideration of effects of alternative water allocation scenarios during the bird breeding season

6.1 Hurunui River water allocation scenarios

45. To assess the effects alternative water allocation scenarios for the Hurunui River during the bird breeding season, I have relied on a residual flow analysis provided by Dr Jeff Smith, Surface Water Scientist for the Canterbury Regional Council. I have further analysed the residual flows predicted for each water allocation scenario. The residual flow is the flow that is left in the river assuming the minimum flow is adhered to and the maximum allocation for the water allocation scenario being considered is being taken whenever it is allowed. The analysis considers only the flows during the main river bird breeding season i.e., September to December.

46. The water allocation scenarios analysed for the Hurunui River are described in the evidence of Dr Snelder and were:

- Natural flows- no abstraction.
- Status quo – Abstraction of 6.2 m^3/s
- Scenario 1 – An A Block allocation of 7 m^3/s
- Scenario 2 –An A Block allocation of 7 m^3/s plus a B Block allocation of 10 m^3/s and B Block gap of 5 m^3/s.
- Scenario 3 - ABC seasonal scenario that includes a C Block allocation of 0 m^3/s for December to February (summer), 16.5 m^3/s for March to May and September to November (autumn and spring) and 33 m^3/s for June to August (winter).
- Scenario 4 - ABC all year that includes a C Block allocation of 33 m^3/s all year.

47. To explore the effect of the different flow regimes on river bed bird nesting and feeding, flows during September to December for an average year (1987) and a dry year (1973) were considered.

48 For food production, 25 m^3/s is a threshold above which the rate of increase in food production declines. For nesting, 40 m^3/s is threshold below which the number of islands decreases.

49. The analysis considered the number of days the flow was held at the minimum flow and the number of days the flow was above 25 m^3/s and 40 m^3/s. Flows of 25 m^3/s and 40 m^3/s are threshold flows for riverbed bird food production and island area respectively. Flows less than 20 m^3/s are not desirable as the number of islands for breeding is at a minimum at this flow or lower.

50. Figure 7 shows the effect of the proposed flow regimes on these threshold levels of flow during September to December for an average year (1987) in

the Hurunui River. It shows that as the amount of abstraction increases the number of days flows are flat-lined at the minimum flow increases and the number of days flows are above the threshold flows reduces. For water allocation scenarios 3 and 4 there are substantial reductions in the number of days when these threshold flows are exceeded and increases in the number of days when flows are at the minimum flow. Thus, even during an average year, water allocation scenarios 3 and 4 are likely to substantially reduce food availability and the protection of breeding birds from predators.

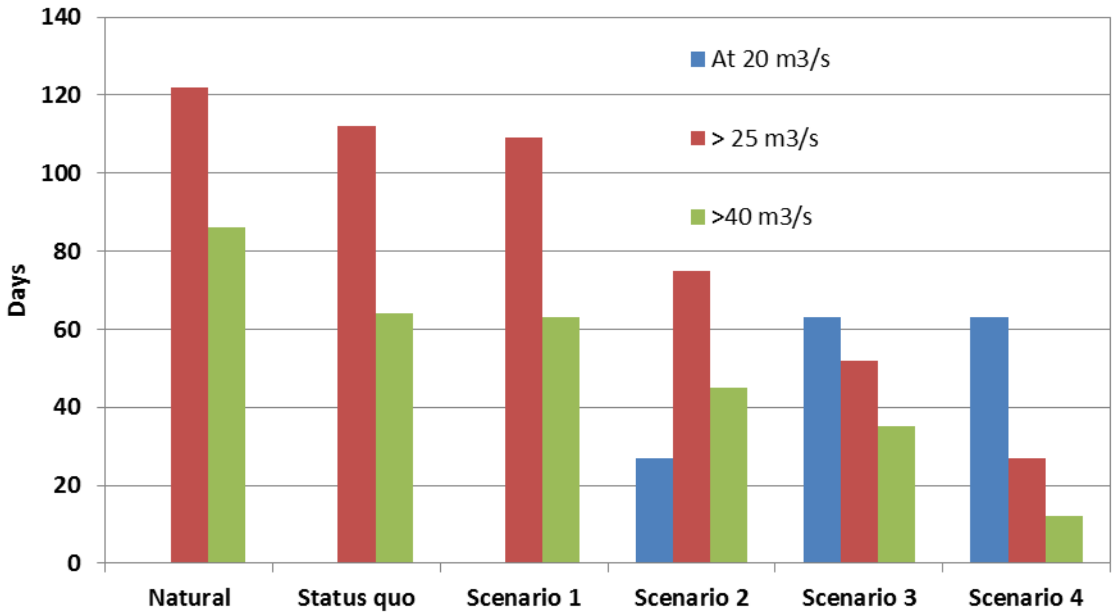

Figure 7. The time during the period from September to December (122 days) when flows are at the minimum flow (20 m^3/s) or above threshold flows of 25 and 40 m^3/s in an average year (1987) in the Hurunui River for the water allocation scenarios.

51 Figure 8 shows similar data to Figure 7 but for a dry year (1973) in the Hurunui River. It shows similar trends to the average year, but there are more days at the minimum flow and much fewer days with flows above the thresholds.

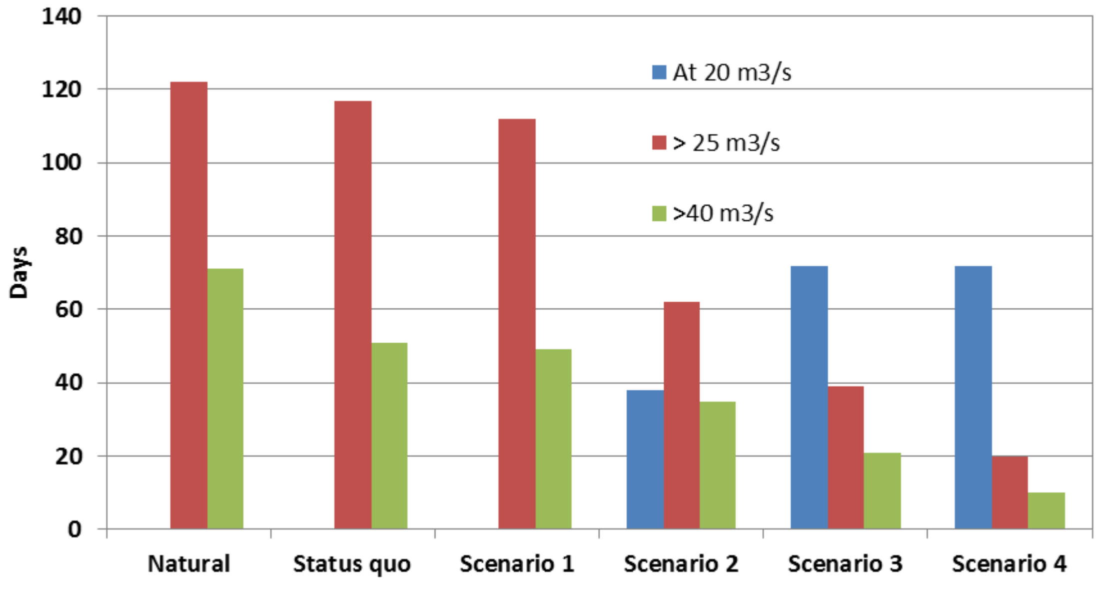

Figure 8. The time during the period from September to December (122 days) when flows are at the minimum flow (20 m^3/s) or above threshold flows of 25 and 40 m^3/s in a dry year (1973) in the Hurunui River for the water allocation scenarios.

52. The differences between the statistics for average and dry years are less than expected because the average and dry years were chosen on the basis of flows over a whole calendar year. For these years (1987 and 1973) there were only small differences in flow during the bird breeding season (September to December).

6.2 Waiau River flow regimes

53. To assess the effects alternative allocation scenarios for the Waiau River during the bird breeding season, I have relied on a residual flow analysis provided by Dr Jeff Smith, Surface Water Scientist for the Canterbury Regional Council. I have further analysed the residual flows predicted for each water allocation scenario during the main breeding season i.e. September to December.

54. The water allocation scenarios analysed for the Waiau River are described in the evidence of Dr Snelder and were:

Natural flows- no abstraction.

Scenario 1 – An A Block allocation of 18 m^3/s.

Scenario 2 – An A Block allocation of 18 m^3/s plus a B Block allocation of 11 m^3/s and B Block gap of 2 m^3/s.

Scenario 3 – An A Block allocation of 35 m^3/s.

Scenario 4 – An A Block allocation of 18 m^3/s plus a B Block allocation of 53 m^3/s and B Block gap of 2 m^3/s.

Scenario 5 – An A Block allocation of 71 m^3/s.

There are two minimum flows. The first applies to the A block and the second to both the B and B+C Block water allocation scenarios. The difference is due to the 2 m^3/s gap between the A and B Blocks. Both values are required to enumerate the duration that flows were flat-lined at the minimum flow.

55. For food production, 25 m^3/s is a threshold above which the rate of increase in food production declines and 35 m^3/s is a threshold above which the rate of increase in Black-fronted Tern WUA declines. For nesting, 35 m^3/s is threshold below which the number of islands decreases.

56. Figure 9 shows the periods that flows are at the minimum flow or above the threshold flows for an average year for each water allocation scenario. Figure 10 shows the periods that flows are at or above the minimum flow or above the threshold flows for a dry year for each water allocation scenario.

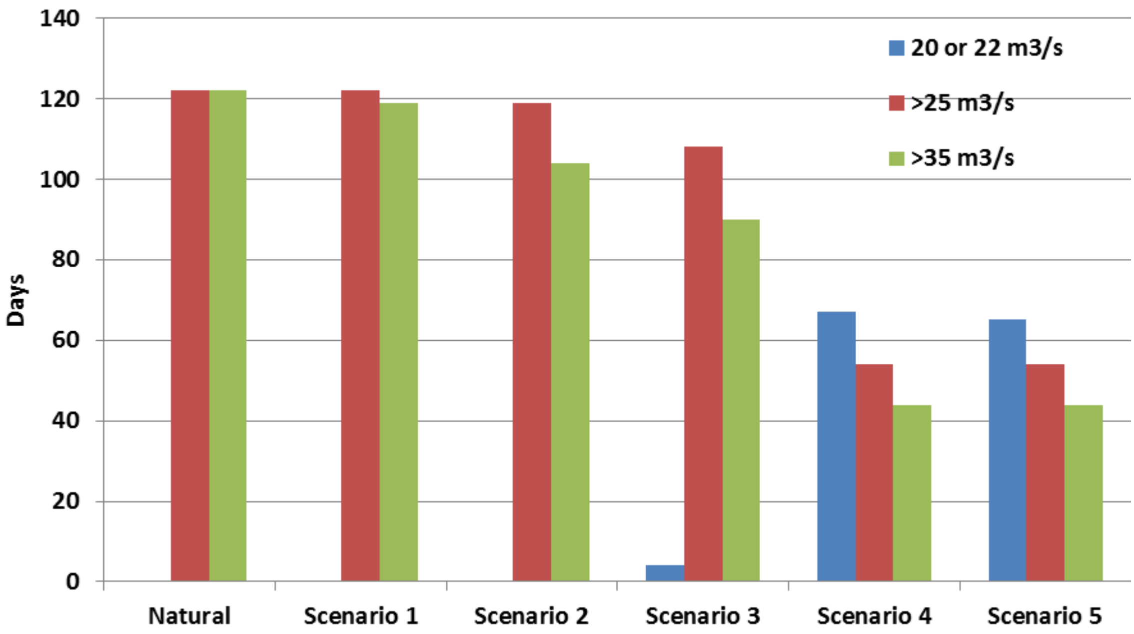

Figure 9. The time during the period from September to December (122 days) when flows are at the minimum flow (20 or 22 m^3/s) or above threshold flows in an average year for the storage option for the Waiau River for the water allocation scenarios.

57. Water allocation scenario1 has very little effect on threshold flows in an average year.

58. With water allocation scenario 2 there is very little time when flows are less than 25 or 35 m^3/s compared to the natural flow.

59. With water allocation scenario 3 there is a short period when flows are flat-lined at the minimum flow and there is a decrease in the time when flows are above threshold levels.

60. With water allocation scenarios 4 and 5, flows are at the minimum flow of 20/22 m^3/s for over half the time and flows are only above 35 m^3/s for about one third of the time, compared to the natural or water allocation scenario 1 flows.

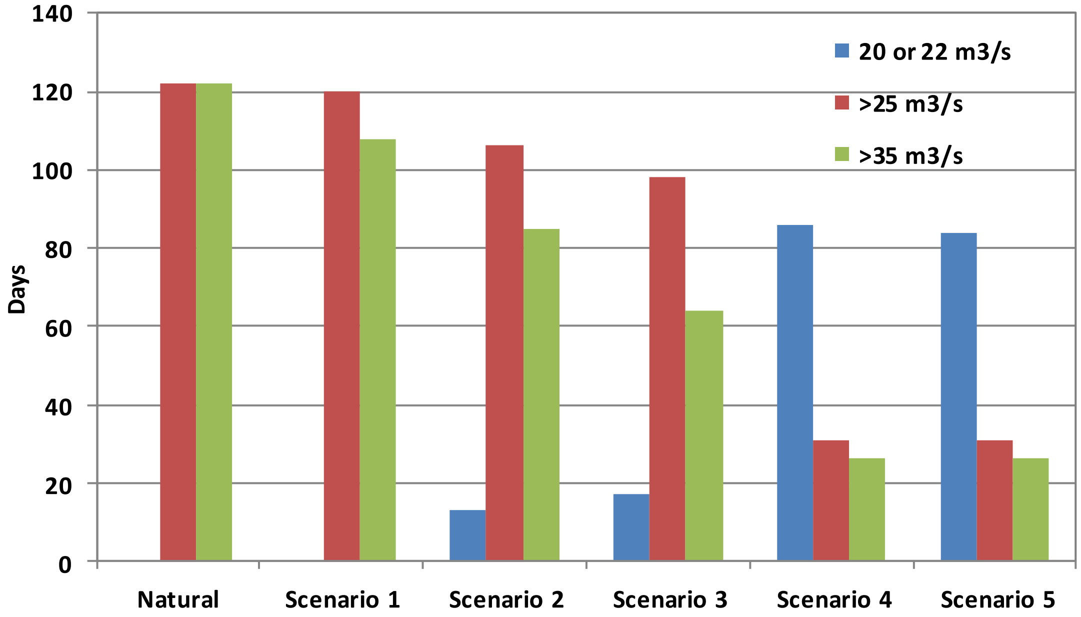

Figure 10. The time during the period from September to December (122 days) when flows are at the minimum flow (20 or 22 m^3/s) or above threshold flows in a dry year for the storage option in the Waiau River for the water allocation scenarios.

61. In a dry year in the Waiau River, water allocation scenario1 would result in only a small decrease in the time flows are greater than threshold flows, compared to an average year and the natural flow.

62. In a dry year, water allocation scenario 2 would cause a short period when the flow is at the minimum flow. This flow is associated with a reduced number of islands for breeding. There is also a significant reduction in the time when flows are greater than 35 m^3/s compared to an average year.

63 Water allocation scenario 3 in an average year shows slight increase in the period of flat-lining, and a reduction in flows over threshold levels compared to Scenario 2, but in a dry year there are large changes in relation to the natural flow and to Scenario 3 in an average year.

64. In a dry year, water allocation scenarios 4 and 5, in comparison with an average year, there is a further substantial increase in the number of days at the minimum flow and substantial decrease in the time when flows are greater than 25 m^3/s and 35 m^3/s.

65 Dr Hughey will provide more detailed interpretation of the impacts of these water allocation scenarios for the ecology of birds.

7.0 Summary

66 In order to provide a simple summary of my findings under each of the water allocation scenarios, I have used the ‘scenario evaluation tables’ that are fully described in the evidence of Mr Norton. The scenario evaluation tables are a simple, colour-coded, visual summary that summarise the extent to which I

expect the HWRRP objectives and policies will be achieved under each scenario. I have used the same logic in constructing my tables as my colleagues[1] so that the key conclusions from each technical assessment can be easily integrated to provide an overall picture of the consequences of each scenario.

Table 2. Likelihood of achieving HWRRP outcomes in the Hurunui River at Mandamus under the six flow allocation scenarios.

ACHIEVES…	Scenarios…					
	Natural	**Status Quo**	**Scenario1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Salmon passage	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly
Jet boat passage	Probably	Probably	Probably	Probably	Probably	Probably

Table 3. Likelihood of achieving HWRRP outcomes in the Waiau River at Marble Point under the six flow allocation scenarios.

ACHIEVES…	Scenarios…					
	Natural	**Scenario1**	**Scenario2**	**Scenario3**	**Scenario4**	**Scenario5**
Salmon passage	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly
Jet boat passage	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly

67 My overall conclusions for each river are set out below:

Hurunui River:

- Salmon passage is adequate at the minimum flow.
- Jet-boat passage is only possible at the proposed minimum flow for skilled drivers.
- The number if islands providing nesting habitat in the Hurunui River is a minimum at the minimum flow of 15 m^3/s and a maximum at 40 m^3/s.
- Scenario 1 has little impact on flat-lining at the minimum flow or on the time above threshold flows.

[1] Ned Norton, Ken Hughey, Ton Snelder, Murray Hicks, Maurice Duncan, Donald Jellyman

- Scenario 2 has a significant impact on the period at the minimum flow and on reducing the time when the flows are above threshold levels.
- Scenarios 3 and 4 result in long periods of flat-lining and large increases in periods when flows are less than thresholds, posing a risk of not achieving HWRRP objectives related to river bed birds.

Waiau River:

- Salmon passage is adequate at the minimum flow.
- At the proposed minimum flow there are very likely to be reaches that are not navigable by jet boats.
- The number of islands in the Waiau River is at a maximum when the flow is 40 m^3/s.
- Scenario 1 has no effect on flat-lining at the minimum flow and little effect on the time flows are less than threshold values
- Scenario 2 results in a short period of flat-lining in a dry year and has some effect on the time flows are less than threshold values.
- Scenario 3 results in a period of flat-lining and has a significant effect on the time flows are less than threshold values.
- Scenarios 4 and 5 result in long periods of flat-lining and very significant increases in the periods when flows are less than thresholds. These scenarios are associated with a risk of not achieving the HWRRP objectives.

68. Dr Hughey will provide detailed interpretation of the impacts of these flow management scenarios on the ecology of river birds.

M Duncan

24 September 2012

Annex A – References

Boffa Miskell. (2007). Black-fronted tern trial: effects of flow and predator control on breeding success. Report prepared for Meridian Energy Ltd, April 2007. 15 p.

Duncan, M.J.; Hughey, K.F.D.; Cochrane, C.H.; Bind, J. (2008). River modelling to better manage mammalian predator access to islands in braided rivers. In: *Sustainable Hydrology for the 21st Century*, Proc. 10th BHS National Hydrology Symposium, Exeter. 487–492.

Duncan. M.J.; Bind, J. (2008). Waiau River instream habitat based on 2-D hydrodynamic modelling. NIWA Client Report CHC 2008-176. 72 p.

Duncan, M.J.; Shankar, U. (2004). Hurunui River habitat 2-D modelling. NIWA Client report: CHC2004-011. 53 p.

Duncan, M., Sagar, P., Kelly, G., Wild, M. (2003). Habitat use of Waimakariri River by Black-Fronted Terns. NIWA Client Report CHC2003-013. 15p.

Golder Associates. (2007). Waimakariri River flow, Habitat availability and angling suitability: two-dimensional modelling results. Golder Kingett Mitchell. 21 p.

Hughey, K.F.D. (1985). Hydrological factors influencing the ecology of riverbed breeding birds on the plains' reaches of Canterbury's braided rivers. PhD. thesis. University of Canterbury, Christchurch.

MFE. (1998). Flow guidelines for instream values. Volume A. Ministry for the Environment, Wellington.

Mosley, M.P. (1983b). Flow requirements for recreation and wildlife in New Zealand rivers – a review. *Journal of Hydrology (New Zealand) 22(2)*: 152-174.

Lalas, C. 1977. Food and feeding behaviour of the black-fronted tern, *Chlidonias hybrida albostriatus*. MSc thesis, University of Otago, Dunedin.

Stalnaker, C.B.; Arnette, J.L. (1976). Methodologies for the determination of stream resource flow requirements: an assessment. Report prepared for U.S. Fish and Wildlife Service, Office of Biological Services Western Water Allocation, by Utah State University, Logan, Utah.

Thompson, K.E. (1972). Determining stream flows for fish life. Pp 31-55. *In*: Proceedings of the Instream Flow Requirement Workshop, Pacific North West River Basin Commission, Portland, Oregon.