Proposed
Hurunui and Waiau River Regional Plan

Section 42A Report
June 2012

Assessment of effects of different flow regime scenarios on native riverbed nesting birds of the Hurunui and Waiau rivers

Prepared by

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1. Introduction

Author

1.1 My name is Kenneth FD Hughey. I am a Professor of Environmental Management in the Faculty of Environment, Society and Design at Lincoln University. I have been working at Lincoln University since 1995. Prior to then I worked for the Department of Conservation in a variety of research and management positions. Between 1984 and 1987 I worked for the New Zealand Wildlife Service. My principal qualifications are MSc (Resource Management) and PhD (Resource Management).

1.2 Although this is a Council Hearing, I have read the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note dated 1 November 2011. I have complied with that Code when preparing my written statement of evidence and I agree to comply with it when I give any oral evidence.

1.3 The scope of my evidence relates to an evaluation of different flow regime management scenarios for both the Waiau and Hurunui rivers with regard to their potential effects on native riverbed nesting birds. I confirm that the issues addressed in this statement of evidence are within my area of expertise.

1.4 My PhD thesis, completed in 1985, concerned the habitat requirements of birds nesting on braided rivers in Canterbury, specifically the Rakaia and Ashley rivers. Since that time I have continued my research into birds of braided rivers and have undertaken research regarding birds on almost all significant eastern South Island braided rivers, some on the West Coast and more recently others in Tasman District and in Hawkes Bay and Gisborne districts. This work has been published in peer reviewed journals and reports and has frequently been used in evidence at a variety of different hearings.

1.5 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.

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

1.7 The literature or other material which I have used or relied upon in support of my opinions are presented in the relevant part of the text where referred to.

1.8 The examinations, tests, or other investigations on which I have relied are presented in the relevant part of the evidence**.** The persons who carried out those examinations, tests or other investigations are also identified there**.**

2. Content of the officer's report

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

3. Explanation of terms and coding used in the report

Guild	A group of species that exploits the same kinds of resources in comparable ways. On braided rivers they are primarily identified by characterising the main microhabitats and the depth of water that species used for feeding and then grouping the species with similar characteristics together. Generally, species within guilds also have similar nesting and roosting habitats. Full definitions of the guilds found on New Zealand rivers are given in O'Donnell (2000)
Log Scale	A logarithmic scale is a scale of measurement using the logarithm of a physical quantity (in this case river flow) instead of the quantity itself. Take a chart whose vertical y-axis has equally spaced increments that are labelled 1, 10, 100, 1000, instead of 1, 2, 3, 4. Each unit increase on the logarithmic scale thus represents an exponential increase in the underlying quantity for the given base (10, in this case). Data presentation on a logarithmic scale is helpful when the data covers a large range of values, for example a river which might have a mean annual low flow of around 70 m^3/s, a mean flow of around 200 m^3/s, and a peak flood flow of around 4000 m^3/s. The use of the logarithms of the values rather than the actual values therefore reduces a wide range to a more manageable size, and provides for better interpretation around key values (flows) of interest.
m^3/s	Cumec (A measure of river flow. One (1) cumec is the equivalent to one (1) cubic metre per second or alternatively 1,000 l/s)
'Threatened or at risk'	A generic term describing the sum of classifications used by the Department of Conservation to define species at various stages of population decline, conservation threat etc. Full definitions of all classifications are given in Miskelly et al. (2008)
Weighted Usable Area (WUA)	An index of the capacity of a river reach to support the species (e.g., wrybill) and life stage (e.g., adult or chick) being considered. WUA is expressed as actual area or percentage of habitat area predicted to be available per unit length of river at a given flow. It is the total area having a certain combination of hydraulic and substrate conditions, multiplied by the composite probability of use by birds, fish, or instream value for a certain use (e.g., bird feeding, salmon passage or torrent fish habitat) for the combination of conditions at a given flow.

4. Relative importance of Waiau and Hurunui rivers for native birdlife

Habitat

4.1 Native birds of braided rivers require two principal habitat types:

a. terrestrial riverbed islands for nesting and some feeding; and

b. aquatic habitat for feeding.

4.2 There is a close relationship between the two. Floods are the main means by which habitat islands are maintained in a relatively vegetation-free state, and flows around islands provide a 'moating' effect to limit the impact of mammalian predators.

4.3 The Hurunui River, from its confluence with the Mandamus downstream, and the Waiau downstream of Leslie Hills Bridge contain sections of braided and single channel habitat. Landcare Research (Wilson 2001) mapped the extent of land classified as river from the New Zealand Land Cover Database and the New Zealand Land Resource Inventory. The large habitat area of both rivers (Waiau 7412ha; Hurunui 5138ha – see Hughey et al. 2010)), in combination with suitable river flows means that habitat is extensive enough on both rivers to support a high diversity of aquatic bird species.

Guilds, species diversity and conservation status

4.4 There are six guilds of species that occupy the mid to lower reaches of both rivers. Almost all species characteristic of braided rivers are present (except black stilt), with 12 of those present being species considered 'threatened or at risk' (Table 1). There are nationally significant populations of black-fronted tern (likely in excess of >5% of total population), black-billed gull and banded dotterel on each river.

Table 1. Species richness, foraging guild and conservation status of native riverbed bird species on the Hurunui and Waiau rivers (Source: Hughey et al. 2010; pers. obs.).

Species	Scientific name	Conservation status (Source: Miskelly et al. 2008)	Foraging guild						
			Open water divers	Deep water waders	Shallow water waders	Dabbling waterfowl	Aerial hunting gulls and terns	Swamp specialists	Riparian wetland species
black shag	*Phalacrocorax carbo*		✓						
pied shag	*P. varius*	Nationally vulnerable (B.3.)	✓						
little shag	*P. melanoleucos*		✓						
spotted shag	*Stictocarbo punctatus*		✓						
white-faced heron	*Ardea navaehollandiae*			✓					
pied stilt	*H. himantopus*	Declining (D.1.)		✓					
spur-winged plover	*Vanellus miles*			✓					
New Zealand oystercatcher	*Haematopus ostralegus finschi*	Declining (D.1.)		✓					
variable oystercatcher	*H. unicolor*			✓					
wrybill	*Anarhynchus frontalis*	Nationally vulnerable (B.3.)			✓				
banded dotterel	*Charadrius bicinctus*	Nationally vulnerable (B.3.)			✓				
black- fronted dotterel	*C. melanops*				✓				
paradise shelduck	*Tadorna variegata*					✓			
grey duck	*Anas superciliosa*	Nationally critical (B.1.)				✓			
grey teal	*A. gracilis*					✓			
NZ shoveler	*A. rhynchotis*					✓			
black-fronted tern	*Chlidonias albostriata*	Nationally endangered (B.2.)[1]					✓		
white-fronted tern	*S. striata*	Declining (D.1.)					✓		
Caspian tern	*S. caspis*	Nationally vulnerable (B.3.)					✓		
black-billed gull	*Larus bulleri*	Nationally endangered (B.2.)					✓		
red-billed gull	*L. scopulinus*	Nationally vulnerable (B.3.)					✓		
southern black-backed gull	*L. dominicanus*						✓		
NZ pipit	*Anthus novaeseelandiae*	Declining (D.1.)							✓
welcome swallow	*Hirundo tahitica*								✓
NZ kingfisher	*Halcyon sancta*								✓

[1] Species reclassified from Serious Decline to Nationally Endangered due to improved knowledge and continuing decline. Species is very susceptible to predation and disturbance. Ashburton R. population declined from 750 in 1981 to 200 in 1990 (Hitchmough *et al.* 2007).

Overall importance

4.5 The River Values Assessment System (RiVAS) has been applied to the native birdlife of Canterbury's braided rivers (Hughey et al. 2010) and also not to those of Tasman and Gisborne districts and to Hawkes Bay region. RiVAS is a tool that allows individual river values to be objectively evaluated and given national, regional or local importance rankings. In summary the tool is based on a method known as Multi Criteria Analysis and requires:

a. Identification of the main attributes of the value

b. Identification and evaluation of the usability of a single indicator for each attribute of the value

c. Using the best available data – scientific and/or expert opinion – to populate each indicator for each attribute of the value

d. Determination of thresholds of relative importance for each indicator, i.e., high, medium, low (and sometimes 'nil')

e. Conversion of each indicator score, subject to application of the threshold, to ordinal values of typically 3=high, 2=medium, 1=low, and sometimes 0=nil

f. Summation of these ordinal values into a total score and determining criteria for assessing national, regional or local significance of the value.

4.6 Hughey et al. (2010) first applied the RiVAS method to native birdlife in Canterbury rivers – Canterbury was chosen for four main reasons:

a. much data are available on the native birds of Canterbury rivers

b. much river bird expertise resides in Canterbury (in DOC, at universities, in ECan and at the CRIs)

c. Canterbury's braided rivers are generally considered to be amongst the most important bird habitats in New Zealand

d. Several other methods have been used in Canterbury, thus providing a useful context for comparative evaluation.

4.7 Application of RiVAS involved following the steps outlined in section 4.5 and then removing rivers of comparatively very low importance from the set to be evaluated. This left a set which almost by default included rivers that would be considered of national, regional or local importance.

4.8 Application of RiVAS showed that the Hurunui and Waiau are nationally important rivers for native birds, a ranking which in my opinion equates to the rivers being of outstanding value to aquatic birds.

4.9 RiVAS for native birds has now been applied to three other regions of New Zealand: Tasman (Gaze et al. 2010), Hawkes Bay (Cheyne et al. 2012), and Gisborne (Bull et al. 2012)). As expected far fewer rivers would be ranked as nationally important for native birdlife, i.e., indeed only one, the lower Tukituki in Hawkes Bay has achieved a national ranking. What this comparative assessment reaffirms is the high level of relative importance of Canterbury's mostly braided rivers for native birdlife.

5. Habitat use considerations

Seasonal patterns of river use by different guilds

5.1 Different guilds and the species within these guilds have typical seasonal patterns of river use (Table 2). These patterns are important because they help identify critical times of the year when habitat management considerations are greatest. An examination of Table 2 shows that for deep water waders, shallow water waders, and aerial hunting gulls and terns, all migratory species, the main period of river use is the August to January period, particularly September-December the peak of the breeding season. It is during this time period that habitat need considerations are greatest.

Nesting

5.2 The species of greatest conservation concern, i.e., black-fronted tern, black-billed gull, banded dotterel and wrybill, breed on both rivers. There is much research indicating that breeding success is highest when nests are on islands, and when these islands are substantially devoid of standing vegetation (particularly exotic species such as willow, lupin and gorse)(see for example the work of Boffa Miskell and Urtica Consulting (2007), Duncan et al. (2008), Rebergen et al. (1998)).

5.3 The main threats to nesting habitat are from:

a. Encroachment of exotic vegetation onto islands used for nesting – such vegetation typically occupies the higher profile sections of islands thus forcing birds to nest at lower altitudes therefore exposing them to higher frequency but smaller magnitude floods which reduces nesting success;

b. Exotic vegetation encroachment which creates a habitat for rabbits, and also therefore for mammalian and avian predators which not only predate rabbits, but also birds; and

c. Flows around islands drying up thus increasing the likelihood of predator access to islands and thus of predation.

5.4 Interestingly, mitigation of these threats is all flow related, i.e.,

a. Periodic large floods, preferably occurring outside of the breeding season, helps clear islands of exotic vegetation growth although whether flooding alone is sufficient on both rivers is a matter requiring further research;

b. Bank full discharges can also clear islands of predators;

c. Medium and lower flows provide a moat effect around islands.

5.5 In sections 7 and 8 of my evidence I examine the various flow scenarios to assess whether these flow requirements are being sustained or not, in terms of nesting habitat on the Waiau and Hurunui rivers, respectively.

Table 2. Examples of seasonal use of rivers by bird species guild (↔), and the core breeding seasons ( ) for deep water and shallow water wading bird guilds and aerial hunting gulls and terns.

Guild	Example species (Common name)	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Open water divers	black shag												
Deep water waders	NZ pied oyster-catcher												
Shallow water waders	banded dotterel												
Dabbling waterfowl	paradise shelduck												
Aerial hunting gulls and terns	black-fronted tern												
Riparian wetland species	kingfisher												

Foods and feeding

5.6 The species of greatest conservation concern, i.e., black-fronted tern, black-billed gull, banded dotterel and wrybill, also feed mostly on both rivers. There is much research into the foods and feeding of these species. From this research we know that most feeding is on aquatic invertebrates, especially on the mayfly *Deleatidium* sp. (see Hughey 1997), and that nesting densities of some bird species are highest where habitat conditions provide the greatest feeding opportunities (i.e., where the amount of river braiding is greatest – see Hughey 1998).

5.7 The main threats to feeding habitat and food supply are from:

a. Reduction of low flows to the point where minor channels dry up and food supplies are lost – for territorial species this can lead to an increase in energy needed to expand and defend their territories; and

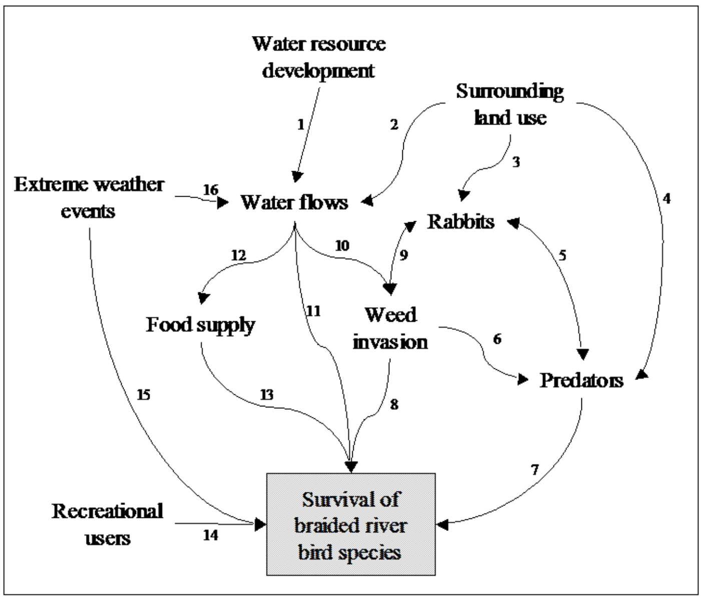
b. Floods which also reduce food supply, with obvious consequences if these floods are frequent and occur in the breeding season.

5.8 In sections 7 and 8 I examine the various flow scenarios to assess whether these flow requirements are being sustained or not, in terms of feeding habitat and food supply on the Waiau and Hurunui rivers, respectively.

Interacting flow-habitat relationships

5.9 Figure 1 shows diagrammatically how some of the matters raised in sections 5.2 to 5.8 are connected – these connections are often synergistic and important to understand, e.g., while floods can destroy nests they are essential for 'resetting' the bed of the river and helping control exotic vegetation encroachment.

Figure 1. Relationships of some of the key factors impacting on survival of braided river birds (Adapted from Keedwell 2004)



Examples of hypothesised interactions between the different factors in Figure 1 include:

a. river flow is modified by abstraction, damming or a combination of the two, changing river flows and flood frequencies and magnitudes;

b. surrounding land use directly impacts on water quality and river management including flood protection schemes which reduce the area of active riverbed;

c. rabbit control on farmland lowers rabbit abundance;

d. differing land use practices changes habitat availability for predators;

e. predator abundance is altered by changes to rabbit abundance but also helps control rabbit abundance;

f. vegetation on riverbeds provide cover for predators;

g. predators prey on eggs, chicks and adults;

h. weeds, clog up breeding habitat (e.g., lupins) and alter feeding habitat (e.g., the invasive aquatic weed didymo);

i. vegetation provides cover and food for rabbits, but some weed species are controlled by rabbit grazing;

j. lowered water flows and floods allow vegetation to establish on riverbed or in the river (e.g., didymo);

k. floods destroy nests, but with freshes also act as controls on terrestrial and aquatic weeds (e.g., didymo);

l. lowered water flows can alter abundance of aquatic insects and feeding areas;

m. food abundance can influence survival of young or condition of breeding adults;

n. fishers, campers and four-wheel drivers can destroy nests or disturb breeding birds;

o. extreme cold spells can kill eggs and chicks; and

p. high rainfalls can cause floods.

6. Approach to evaluating effects of different flow scenarios on the habitat needs of riverbed nesting birds

6.1 Consistent with other colleagues giving evidence for the CRC, my evaluation is based on the following approach:

a. Defining a desired outcome for riverbed nesting birds of the Waiau and Hurunui rivers;

b. Examining the flow management scenarios to assess which will 'almost certainly' achieve the outcome across the spectrum to which is most 'unlikely' to achieve the outcome, i.e., a probability assessment;

c. Consistent with the above identifying the level of uncertainty around each of these risk assessments; and

d. Classifying each of the scenarios within the context of a risk to the outcome-uncertainty of knowledge matrix for each river.

6.2 There is considerable uncertainty associated with predicting the effects of each scenario on bird populations and their associated habitats for the Waiau and Hurunui rivers. To illustrate how uncertainty varies between scenarios, predictions are first expressed using a four-class system whereby scenarios are judged 'almost certainly', 'probably', 'possibly' or 'unlikely' to achieve the desired bird outcome. This is achieved by:

a. assessing each season's flow hydrograph against nesting and feeding and food related habitat criteria to assess flow adequacy for birds in that season; and

b. summing each season's evaluation into an overall set and determining the proportion of seasons with flows in each of the 4 classes.

6.3 This overall evaluation is then considered in terms of the level of uncertainty about that prediction using a three-class system of 'high', 'medium' and 'low' levels of uncertainty (Table 3). The combination of evaluating probability and uncertainty for each scenario is then shown in a 'best' (green) to 'worst' (red) matrix (Table 4) for each river.

Table 3. Probability of achieving the desired bird outcomes and associated levels of uncertainty about the reliability of the assessment.

Outcome achievement probability		Level of uncertainty about the measure of risk	
Scale	Interpretation	Scale	Interpretation
Almost certainly	More than a 95% chance that on average 15 years out of 20 when the outcome will be achieved	High	Little empirical ground-truthed supporting evidence
Probably	More than an 80% chance that on average 15 years out of 20 when the outcome will be achieved	Medium	Some but limited empirical ground-truthed supporting evidence
Possibly	A greater than 50% chance that on average 15 years out of 20 when the outcome will be achieved	Low	Much existing field work and published research
Unlikely	More than a 50% chance of outcome not being achieved, i.e., most years key needs will not be met		

Table 4. Overall scenario evaluation matrix. Note: any scenario that is 'green' is better than any that is 'lighter green' or 'yellow' and 'red' is worst.

		Uncertainty		
		Low	Medium	High
Probability (chance of achieving outcome)	Almost certainly			
	Probably			
	Possibly			
	Unlikely			

6.4 In summary, the predictions are based on an integrated consideration of several lines of evidence including:

a. Empirical island-flow modelling (Duncan 2012, Duncan et al. 2008, based on habitat-area needs defined by Hughey 1997);

b. Empirical food production-flow modelling (Duncan 2012, based on understanding bird feeding requirements defined by Hughey 1998 and Lalas 1977 for wrybill and black-fronted tern respectively);

c. Empirical bird feeding-flow modelling (Duncan 2012, based on habitat preferences derived from Hughey (1985), Hughey (2001) and Duncan et al. (2003);

d. Empirical understanding of nesting periods for riverbed nesting birds and the influence of flows (Hughey 1985).

6.5 Based on the material presented in sections 5.1 5.9 of my evidence the desired outcome proposed for river nesting birds in the middle to lower reaches of the Waiau and Hurunui rivers involves:

a. Providing sufficient nesting and feeding habitat and associated resources to secure the existing populations of threatened and at risk bird species on the Waiau and Hurunui for the long term.

b. This then means that flow related habitat needs are required to be met on at least 15 out of 20 years on average, recognising that in some years nature (floods and extreme low flows) already marginalises these needs.

c. These habitat needs, because species can repeat nest, need to be met >80% of the time (or around 3 out of 4 months) during a breeding season.

6.6 What follows is a river by river evaluation of habitat provision related to the water allocation scenarios, first for the Waiau and then for the Hurunui.

7. Scenario analysis for the Waiau River

7.1 The allocation blocks for the Waiau are as follows:

a. A Block minimum flows are 20 m^3/s all year

b. B and C Block minimum flows are 40 m^3/s and 51 m^3/s respectively for the whole year.

c. A Block allocation of 20 m^3/s

d. B Block allocation of 11 m^3/s

e. C Block allocation of 42 m^3/s

7.2 The scenarios to evaluate potential effects on bird habitat are:

a. Natural flows – no abstraction.

b. Scenario 1 – An A Block allocation of 18 m^3/s (referred to in figures as ABlock18).

c. 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 (referred to in figures as ABlock18Gap2BBlock11).

d. Scenario 3 – 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 (referred to in figures as ABlock18Gap2BBlock53).

e. Scenario 4 – An A Block allocation of 35 m^3/s (referred to in figures as ABlock35).

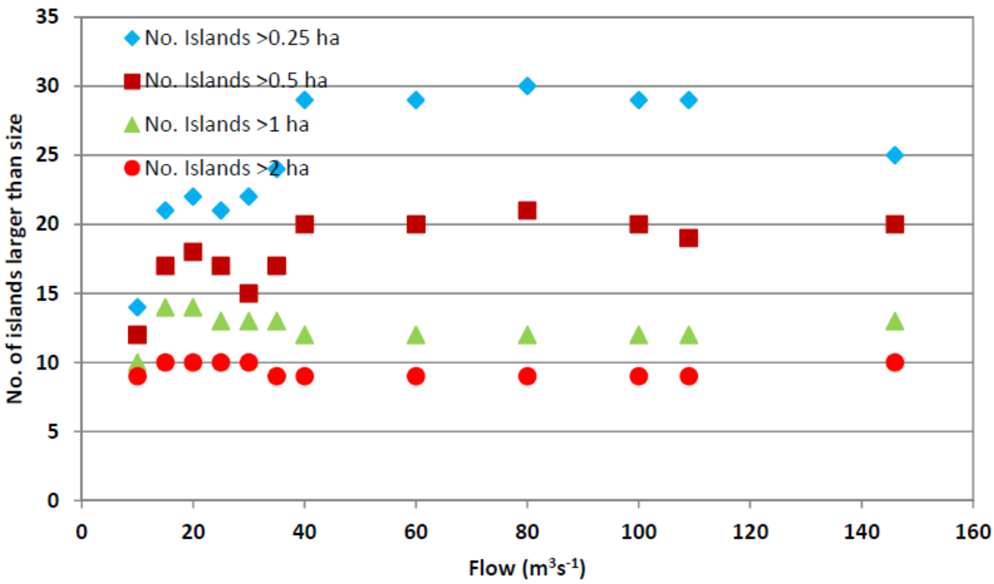
f. Scenario 5 – An A Block allocation of 71 m^3/s (referred to in figures as ABlock71).

7.3 Physical bird habitat modelling information in the following subsections is drawn from Duncan (2012) and Duncan and Bind (2009), some of which is based on my own habitat preference work (Hughey 1985 – wrybill; 2001 – Rangitata terns). It is then complemented by my own field experience and knowledge of birdlife on the Waiau and other Canterbury rivers (e.g., Hughey et al. 2010) and New Zealand rivers, e.g., Tasman rivers (Gaze et al. 2010), Hawkes Bay rivers (Cheyne et al. 2012) and Gisborne rivers (Bull et al. 2012).

<u>Nesting</u>

7.4 Figure 2 shows the relationship between the number of islands and flow on a modelled reach of the Waiau downstream of the Leslie Hills bridge. In summary it shows that as flows increase over the modelled range of 10 to 50 m^3/s the number of islands >0.25ha reaches a peak at 40 m^3/s. Note that while the number of larger (>1 and >2ha) islands remains largely static over the range of modelled flows, the number of smaller islands (>0.25ha) increases rapidly with flow over the range of 10-40 m^3/s. It is this mix of both large and small islands which appears most likely to maximise habitat security for nesting birds.

Figure 2. Relationship between flow and number of islands greater than threshold sizes for the Waiau River downstream of Leslie Hills bridge (Source: Duncan 2012).



<u>Foods and feeding</u>

7.5 Models of both bird feeding (Figure 3) and prey production (Figure 4) in relation to river flow are available for the Waiau. Consistent with previous interpretations (see for example Duncan 2012) of these models flows most suitable for feeding and food production are around 25 m^3/s for key species. I concur with Duncan (2012) about how the physical structure of feeding habitat changes at lower flows and becomes less suitable for wrybill in particular.

Figure 3. Weighted Usable Area (WUA) vs modelled flow for bird feeding/prey – Waiau River. The Rangitata (Hughey 2001) black-fronted tern curve is for feeding on invertebrates; the Waimakariri (Duncan et al. 2003) curve is for feeding on fish (Source: Duncan 2012).

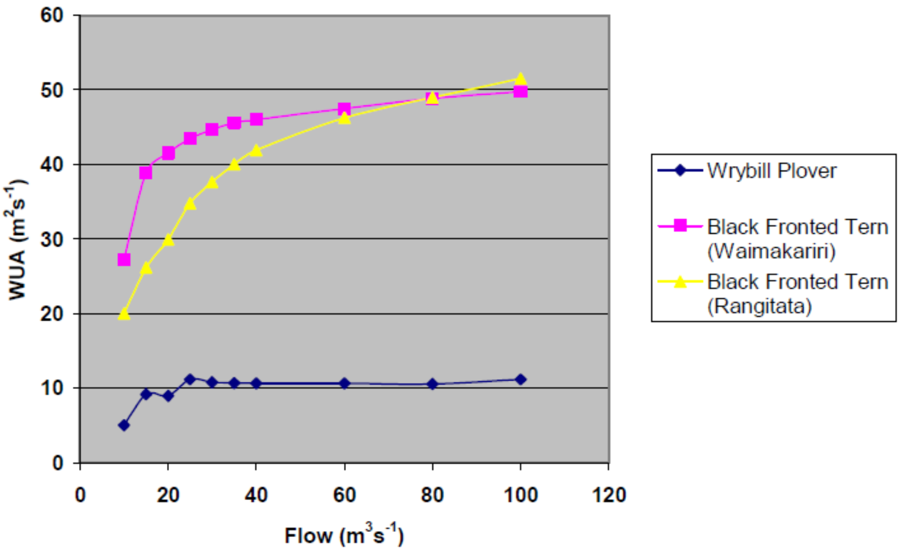
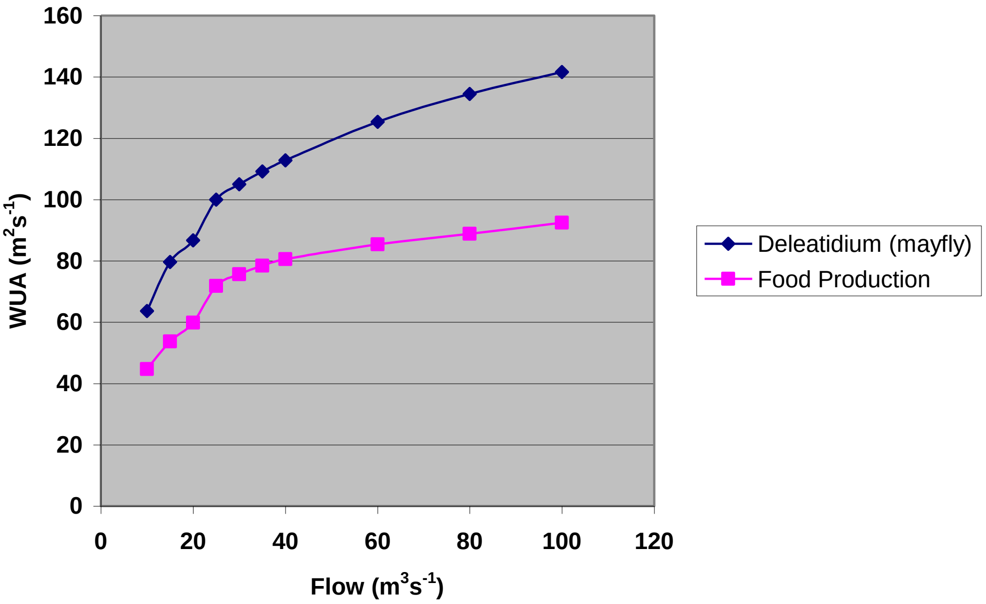


Figure 4. WUA vs modelled flow for benthic invertebrate food production – Waiau River (Source: Duncan and Bind 2009)



<u>Evaluation of scenarios for nesting and feeding birds using the Waiau River</u>

7.6 Integrating the findings from the above is challenging. Islands are necessary for nesting and water is needed for feeding. However, it appears likely the controlling factor for birds in these two rivers is nesting habitat, i.e., if nesting habitat requirements are met in relation to river flow then it is assumed feeding and food requirements will also be met. I do not consider that defined nesting and feeding and food habitat criteria need to be met every day of every breeding season in order to satisfy bird habitat requirements, in the longer term. However, as a guiding principle I consider human-regulated flow related habitat needs should be met on at least 15 out of 20 years on average, recognising that in some years nature (floods and extreme low flows) already marginalises these needs.

7.7 For nesting birds then, and based on the modelling in sections 7.4 and 7.5, flows of around 40 m^3/s are best on the Waiau, while flows of around 25 m^3/s are best for feeding and food production. These flow requirements are now examined against the range of allocation scenarios in terms of which are 'almost certainly', 'probably', 'possibly' or 'unlikely' to sustain nesting habitat requirements and feeding and food requirements respectively. To begin this evaluation Figure 5 shows a set of hydrographs of the Waiau in a typical year while Figure 6 is for a dry year. Note carefully that the y-axis on all graphs is a log scale.

7.8 In the typical year scenario graphs (Figure 5) the following conclusions can be drawn about bird habitat for each scenario:

a. *Natural* (i.e., the black hydrograph in each graph) flows are always in excess of the 25 and 40 m^3/s feeding and nesting flow lines, i.e., habitat needs are 'Almost certainly' provided for in terms of feeding and islands for nesting;

b. Scenario 1 'Almost certainly' provides also for bird habitat needs because for almost all of the time the red curve is above the 40 m^3/s line;

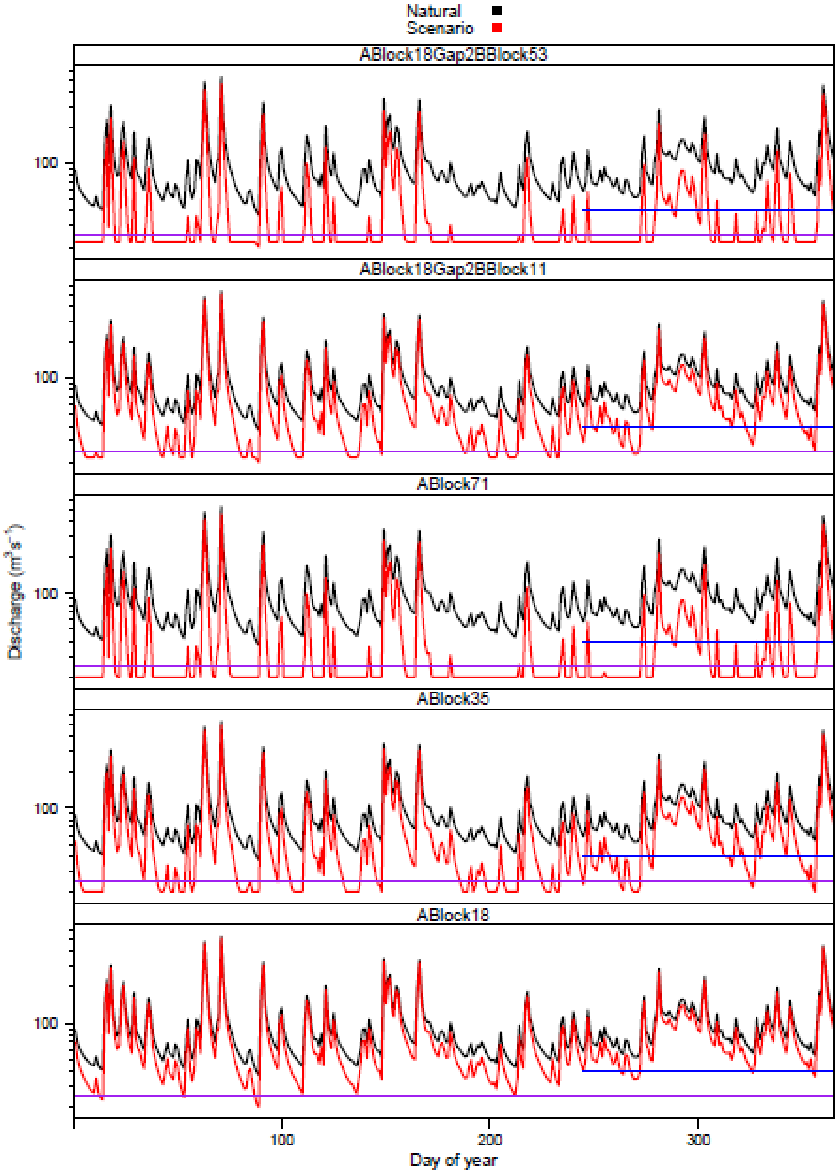
c. Scenario 2 'Probably' provides for bird habitat needs. Modelled flows do drop below the 40 m^3/s curve but for less than 1/3rd of the time;

d. Scenario 3 is 'Unlikely' to meet bird habitat needs – flows are mostly under both the nesting and feeding desired flows and would likely be disastrous for birds if repeated in a high proportion of breeding seasons;

e. Scenario 4 is similar to b) above and will 'Almost certainly' provide for bird habitat needs;

f. Scenario 5 is similar to d) above and is 'Unlikely' to meet bird habitat needs.

Figure 5. Flow hydrographs for the Waiau River in a typical year (1987). Plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the five management scenarios – note: the blue horizontal line is the best for nesting flow (40 m^3/s) and the purple horizontal line is the best flow for feeding and food production (25 m^3/s). Note that the vertical axis (discharge) is a log scale (Source: Snelder pers. comm. 2012).



7.9 In the dry year scenario graphs (Figure 6) the following conclusions can be drawn about bird habitat for each scenario:

a. *Natural* (i.e., the black hydrograph in each graph) flows are always in excess of the 25 and 40 m^3/s feeding and nesting flow lines, i.e., habitat needs are 'Almost certainly' provided for in terms of feeding and islands for nesting;

b. Scenario 1 'Almost certainly' provides also for bird habitat needs because for almost all of the time the red curve is above the 40 m^3/s line;

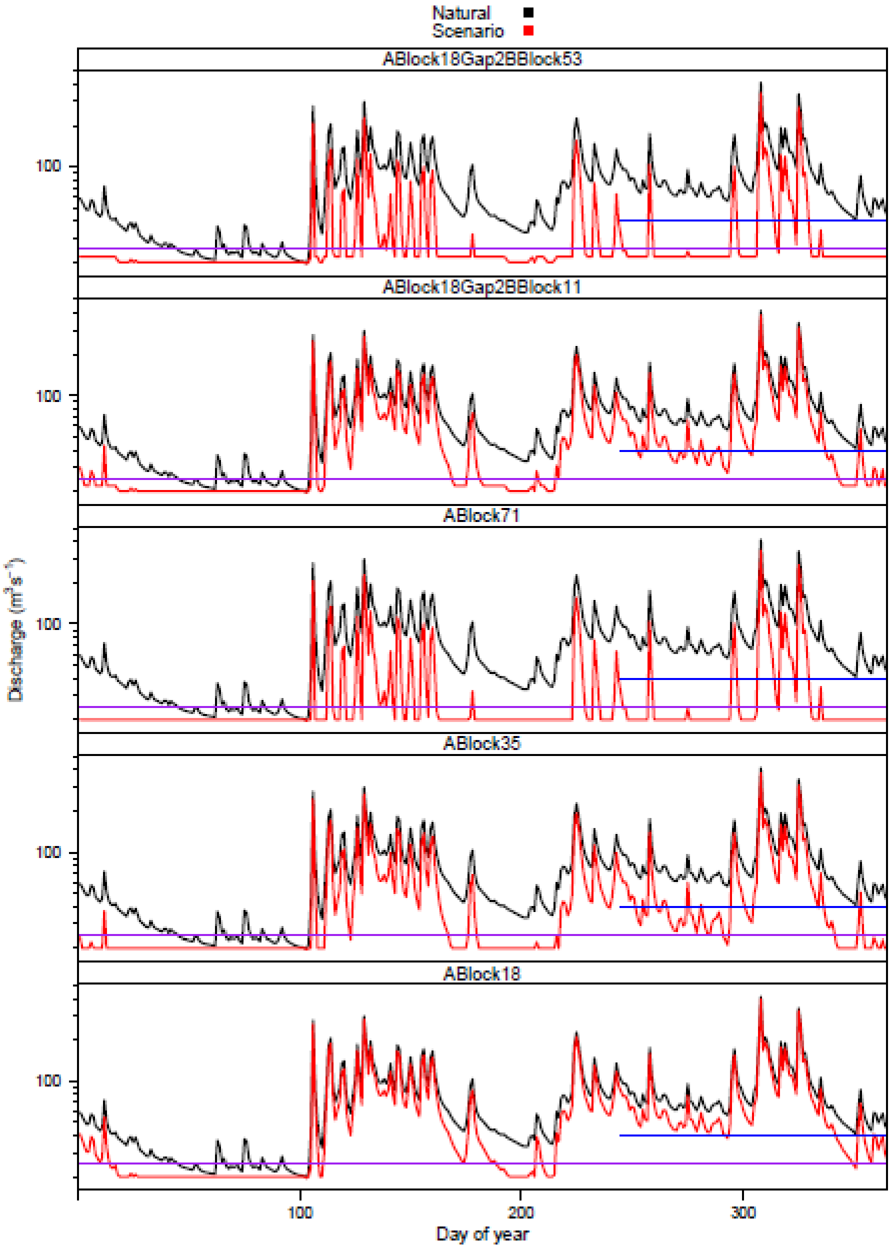
c. Scenario 2 ‘Possibly’ provides for bird habitat needs. Modelled flows drop below the 40 m^3/s curve for around ½ of the time but are mostly also above the 25 m^3/s feeding and food production line;

d. Scenario 3 is ‘Unlikely’ to meet bird habitat needs – flows are mostly under both the nesting and feeding desired flows and would likely be disastrous for birds if repeated in a high proportion of breeding seasons;

e. Scenario 4 is similar to b) above and will ‘Almost certainly’ provide for bird habitat needs;

f. Scenario 5 is similar to d) above and is ‘Unlikely’ to meet bird habitat needs.

Figure 6. Hydrographs for Waiau River in a dry year (1973). Plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the five management scenarios – note: the blue horizontal line is the best for nesting flow (40 m^3/s) and the purple horizontal line is the best flow for feeding and food production (25 m^3/s). Note that the vertical axis (discharge) is a log scale (Source: Snelder pers. comm. 2012).



7.10 Interpretation of the above two graphs, for the typical and dry years respectively, shows little difference between the two. On this basis all 40 years of hydrographs have been evaluated in a similar way (Table 5). While the evaluation is comparatively simple it does indicate that there are four scenarios that will 'Almost certainly' (*Natural*) or 'Probably' (*Scenario 1*, *Scenario 2*, *Scenario 4*) provide for bird habitat needs, and two that are 'Unlikely' to provide these needs (namely *Scenario 3 and Scenario 5*).

Table 5. Evaluation of Waiau River breeding season flow scenarios in terms of probability of providing for bird nesting and feeding habitat needs. The following decision criteria were applied to each of 40 annual hydrographs. Criteria applied to each seasonal hydrograph:

a. If flows are above the 40 m^3/s line almost all of the time, i.e., >80%, then they 'Almost certainly' meet bird habitat needs;

b. If flows are above 40 m^3/s for >66% then they 'Probably' meet bird habitat needs;

c. If flows are above 40 m^3/s for around 50-65% of time then they 'Possibly' meet bird habitat needs;

d. Otherwise flows are 'Unlikely' to meet bird habitat needs.

Expert judgement was also used: if flows are 'tailing' off at the end of the season and drop below the 40 m^3/s line this is acceptable as breeding is nearly over; If flows are above the 40 m^3/s line for the first couple of months of breeding then this too is good. Where judgements 'are on the border' then in both circumstances the more positive evaluation is given. If large floods push the hydrograph above cut-off criteria then a downward classification is given.

Scenario		Almost certainly (AC)	Probably (PR)	Possibly (PO)	Unlikely (UN)
Natural	No. yrs	39	0	1	0
	% yrs	97.5	0	2.5	0
	%yrs AC+PR	97.5			
Scenario 1	No. yrs	34	3	2	1
	% yrs	85	7.5	5	2.5
	%yrs AC+PR	92.5			
Scenario 2	No. yrs	23	9	5	3
	% yrs	57.5	22.5	12.5	7.5
	%yrs AC+PR	80			
Scenario 3	No. yrs	1	10	6	23
	% yrs	2.5	25	15	57.5
	%yrs AC+PR	27.5			
Scenario 4	No. yrs	24	9	4	3
	% yrs	60	22.5	10	7.5
	%yrs AC+PR	82.5			
Scenario 5	No. yrs	1	10	7	22
	% yrs	2.5	25	17.5	55
	%yrs AC+PR	27.5			

7.11 Based, on the above it is clear there is increasing risk to bird nesting as scenarios increasingly exploit water in the breeding season. Having made this point I do however have to provide a proviso. Wet breeding seasons that contain many floods can be absolutely disastrous to breeding, i.e., virtually all nests can be flooded away in a succession of bank-full or similar events, but of course also clear islands of vegetation. Understanding the nature of these relationships is fraught with challenges but a precautionary approach would err on the side of caution in terms of reducing flows in the breeding season, especially in terms of nesting.

7.12 The above analysis is now complemented by Table 6, in terms of which scenarios are best to worst for birds, taking account of uncertainty in terms of the predicted effects. There is a high degree of certainty around the 'Almost certainly' and 'Unlikely' to meet outcome scenarios, and also for the *Ablock18 scenario*.

Table 6. Scenario evaluation matrix for flow-related bird habitat requirements on the Waiau. Note: any scenario that is 'green' is better than any that is 'lighter green' or 'yellow', and 'red' is worst.

		Uncertainty		
		Low	Medium	High
Probability (chance of achieving outcome)	Almost certainly	Natural		
	Probably	Scenario 1	Scenario 2, Scenario 4	
	Possibly			
	Unlikely	Scenario 3, Scenario 5		

8. Scenario analysis for the Hurunui River

8.1 The allocation blocks for the Hurunui are as follows:

a. A Block minimum flows of 15 m^3/s September to April and 12 m^3/s for May to July with 13 m^3/s August.

b. B and C Block minimum flows are 27 m^3/s and 37 m^3/s respectively from September to April and 19 m^3/s and 29 m^3/s for the rest of the year.

c. A Block allocation of 7 m^3/s

d. B Block allocation of 10 m^3/s

e. C Block allocation of 33 m^3/s

8.2 The scenarios to evaluate potential effects on bird habitat are:

a. Natural flows – no abstraction.

b. Status quo – Abstraction of 6.2 m^3/s.

c. Scenario 1 – An A Block allocation of 7 m^3/s.

d. 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.

e. 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).

f. Scenario 4 - ABC all year that includes a C Block allocation of 33 m^3/s all year.

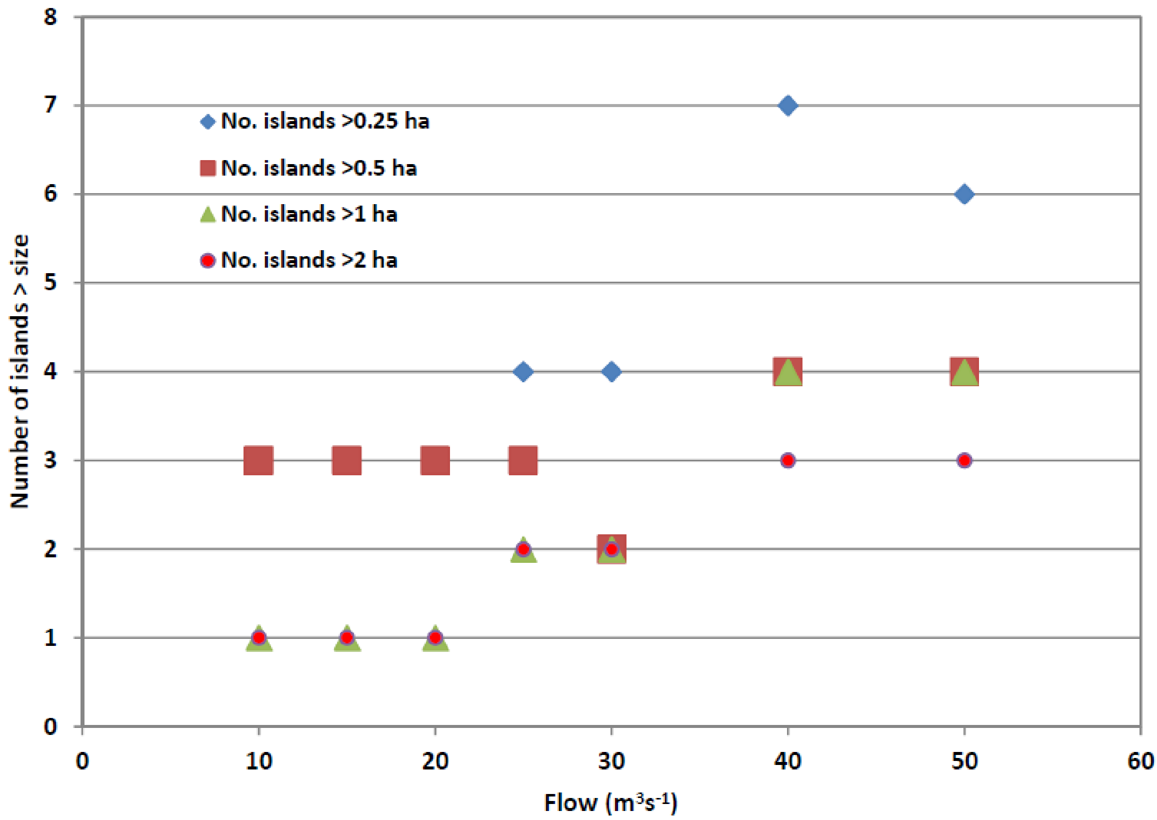
8.3 Information in the following subsections is drawn largely from Duncan (2012), Duncan et al. (2008) and Duncan and Shankar (2004) some of which is based on my own work (Hughey 1985 – wrybill; Hughey 2001 – Rangitata terns). It is then complemented by my own field experience and knowledge of birdlife on the Hurunui and other Canterbury rivers (e.g., Hughey et al. 2010) and New Zealand rivers, e.g., Tasman rivers (Gaze et al. 2010), Hawkes Bay rivers (Cheyne et al. 2012) and Gisborne rivers (Bull et al. 2012).

<u>Nesting</u>

8.4 Figure 7 shows the relationship between the number of islands and flow on a modelled reach of the Hurunui downstream of State Highway 6. In summary it shows that as flows increase over the modelled range of 10 to 50 m^3/s the number of islands >0.25ha reaches a peak at 40 m^3/s.

8.5 Generally I agree with Duncan's conclusion (2012: 22) about this relationship, i.e., "…the proposed minimum flow from September to December of 15 m^3/s does not maintain habitat for riverbed nesting birds. The natural 7 day average minimum flow for this period is 45.2 m^3/s (Duncan and Shankar, 2004), so nature provides about optimum nesting habitat, whereas the proposed minimum flow for the breeding season provides for less than one third of that". The implication is simple – by reducing the number of islands there is a greater chance that predators will move across previously disconnected areas and thus increase predation potential. No one knows by how much this potential increases, but we do know any water is a barrier of sorts.

Figure 7. Relationship between flow and number of islands greater than threshold sizes for the Hurunui River downstream of SH6 (Source: Duncan 2012)



Foods and feeding

8.6 Both the feeding of birds (Figure 8) and production of their key foods (Figure 9) have been modelled in relation to changing river flows. Consistent with previous interpretations analysis of these two figures indicates that adequate habitat and food production is likely to be present at flows of around 25 m^3/s. The arguments presented by Duncan (2012) are supportive of, and help explain the derivation of this figure.

Figure 8. WUA vs modelled flow for bird feeding/prey – Hurunui River. The Hughey (2001) black-fronted tern curve is for feeding on invertebrates; the Duncan curve is for feeding on fish.

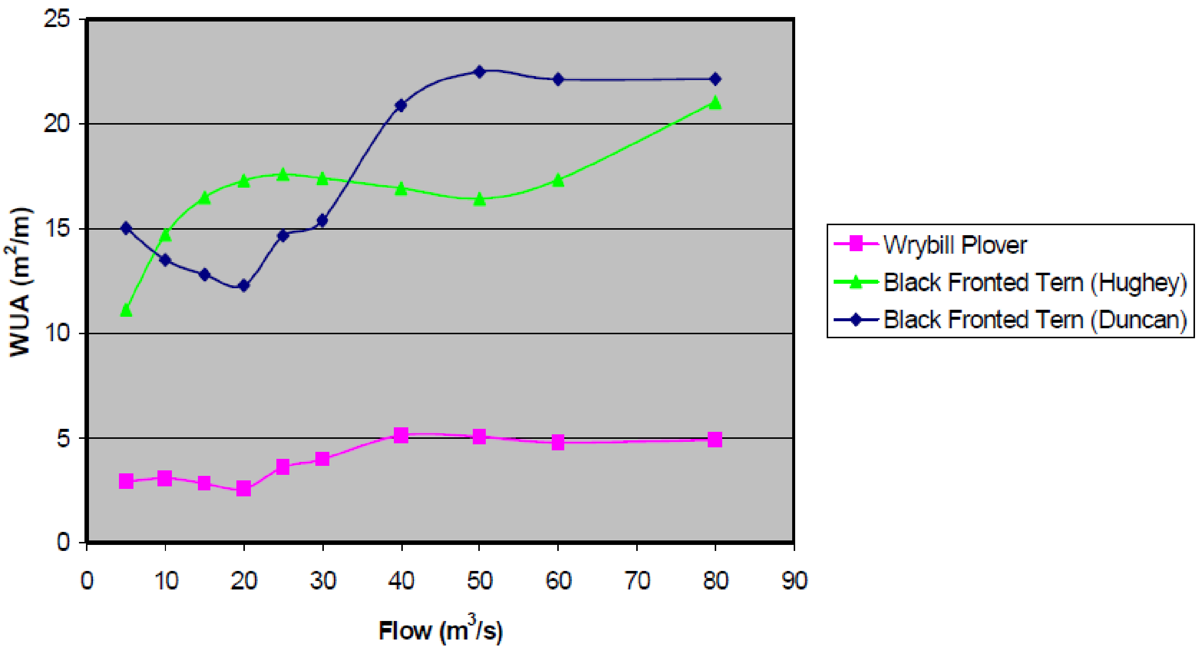
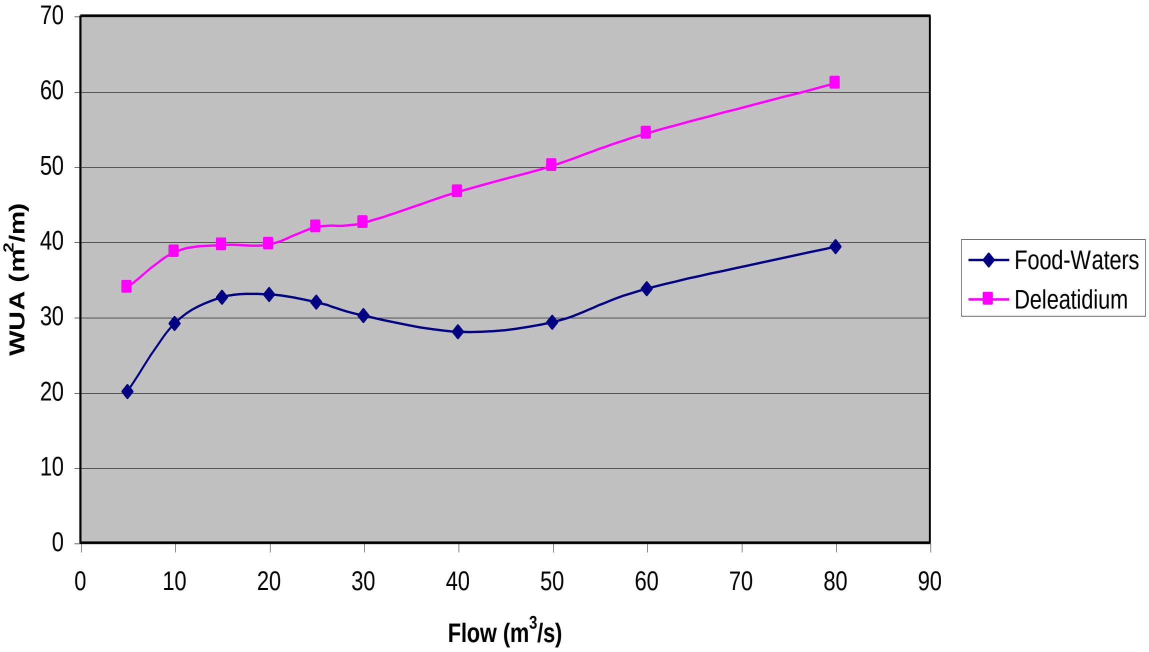


Figure 9. WUA vs modelled flow for benthic invertebrate food production – Hurunui River (Source: Duncan and Shankar 2004)



8.7 As noted for the Waiau analysis integrating the findings from the above is challenging. Islands are necessary for nesting and water is needed for feeding. Again it is assumed the controlling factor for birds is nesting habitat, i.e., if nesting habitat requirements are met in relation to river flow then it is assumed feeding and food requirements will also be met. I do not consider that defined nesting and feeding and food habitat criteria need to be met every day of every breeding season in order to satisfy bird habitat requirements, in the longer term. However, as a guiding principle I consider human-regulated flow related habitat needs should be met on at least 15 out of 20 years on average, recognising that in some years nature (floods and extreme low flows) already marginalises these needs.

8.8 For nesting birds then, and based on the modelling in sections 6.1 and 6.2 flows of around 40 m^3/s are best on the Hurunui, while flows of around 25 m^3/s are best for feeding and food production. These flow requirements are now examined against the range of allocation scenarios in terms of which are 'almost certainly', 'probably', 'possibly' or 'unlikely' to sustain nesting habitat requirements and feeding and food requirements respectively. To begin this evaluation Figure 10 shows a set of hydrographs of the Hurunui in a <u>typical</u> year, Figure 11 sums the breeding season data in terms of the proportion of time flow is above 20, 25 and 40 m^3/s, while Figures 12 and 13 present the same comparable data for a <u>dry</u> year.

8.9 In the <u>typical</u> year scenario graphs (Figure 10) the following conclusions can be drawn about bird habitat for each scenario:

a. *Natural* (i.e., the black hydrograph in each graph) flows are always in excess of the 25 m^3/s feeding and food production line and are 'there or thereabouts' of the 40 m^3/s nesting flow lines, i.e., habitat needs are 'Probably' provided for in terms of feeding and islands for nesting;

b. The *Status quo* flows are, at best, 'Probably' marginally sufficient for nesting but adequate for food and feeding requirements for almost all of the time;

c. Scenario 1 is at best 'Possibly' providing for nesting habitat needs but does provide for feeding and food requirements;

d. Scenario 2 is 'Unlikely' to provide for nesting habitat needs. Modelled flows drop below the 40 m^3/s curve more than half of the time;

e. Scenario 3 is 'Unlikely' to meet bird habitat needs – flows are mostly under both the nesting and feeding desired flows and would likely be disastrous for birds if repeated in a high proportion of breeding seasons;

f. Scenario 4 is similar to e) above and is 'Unlikely' to provide for bird habitat needs, either nesting or feeding.

Figure 10. Hydrographs for Hurunui at Mandamus for 1987, a typical year. Plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the five management scenarios – note: the blue horizontal line is the best for nesting flow (40 m^3/s) and the purple horizontal line is the best flow for feeding and food production (25 m^3/s). Note that the vertical axis (discharge) is a log scale (Source: Snelder pers. comm. 2012).

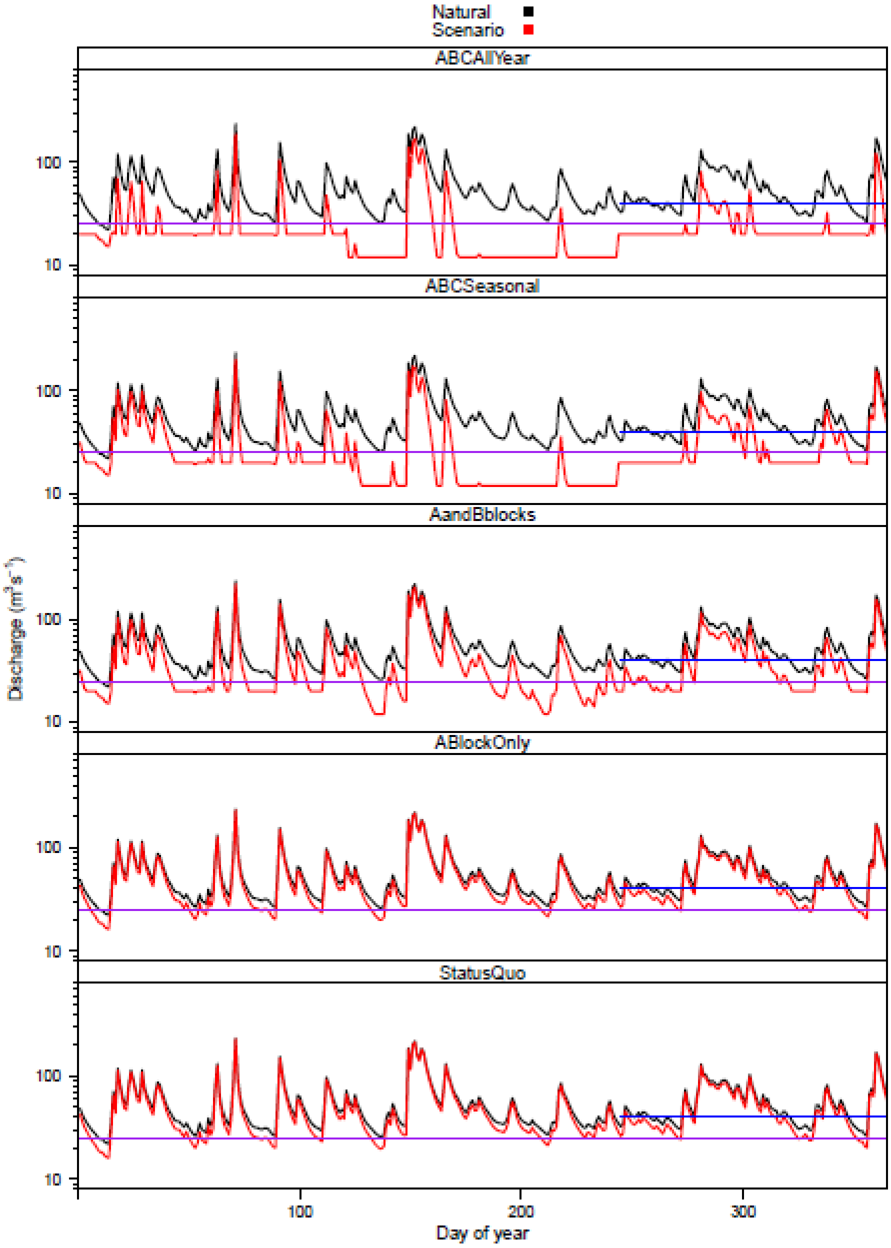
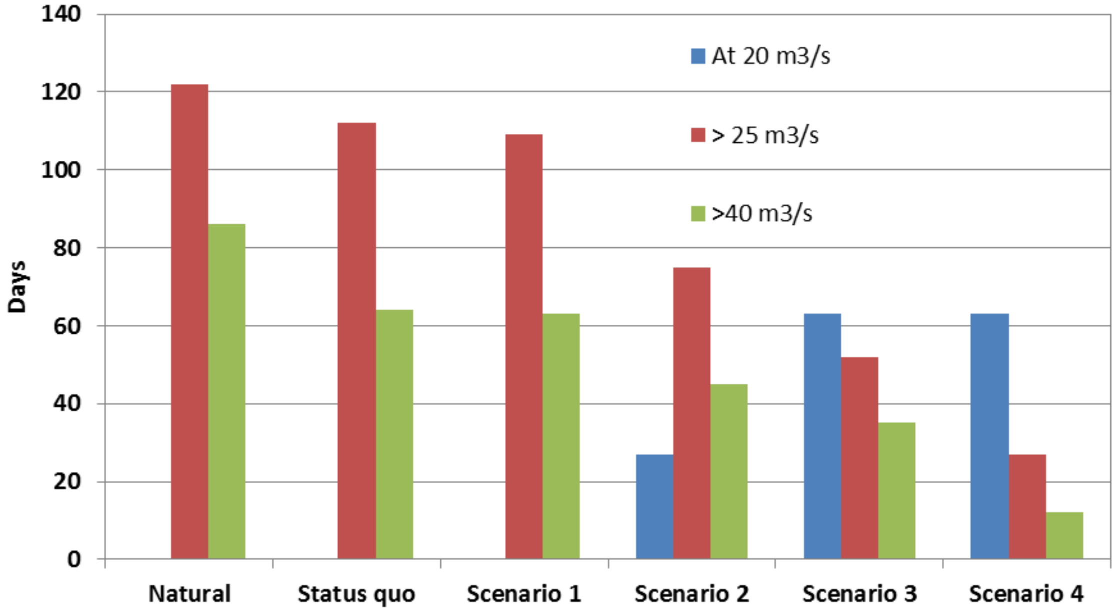


Figure 11. Time during September to December (122 days) when flows are at the minimum or above critical levels in a typical year (Note: green is good and blue is bad for nesting) (Source: Duncan 2012).



8.10 In the dry year scenario graphs (Figures 12 and 13) the following conclusions can be drawn about bird habitat for each scenario:

a. *Natural* (i.e., the black hydrograph in each graph) flows are always in excess of the 25 m^3/s feeding and food production line and are 'there or thereabouts' of the 40 m^3/s nesting flow lines, i.e., habitat needs are 'Probably' provided for in terms of islands for nesting;

b. The *Status quo* flows are, at best, 'Probably' marginally sufficient for nesting but adequate for food and feeding requirements for almost all of the time;

c. Scenario 1 is at best 'Possibly' providing for nesting habitat but adequate for food and feeding requirements for almost all of the time;

d. Scenario 2 is 'Unlikely' to provide for nesting habitat needs. Modelled flows drop below the 40 m^3/s curve more than half of the time, but are 'Possibly' alright for feeding and food habitat;

e. Scenario 3 is 'Unlikely' to meet bird habitat needs – flows are mostly under both the nesting and feeding desired flows and would likely be disastrous for birds if repeated in a high proportion of breeding seasons;

f. Scenario 4 is similar to e) above and is 'Unlikely' to provide for bird habitat needs, either nesting or feeding.

Figure 12. Hydrographs for Hurunui at Mandamus for 1973, a dry year. Plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the five management scenarios – note: the blue horizontal line is the best for nesting flow (40 m^3/s) and the purple horizontal line is the best flow for feeding and food production (25 m^3/s). Note that the vertical axis (discharge) is a log scale (Source: Snelder pers. comm. 2012).

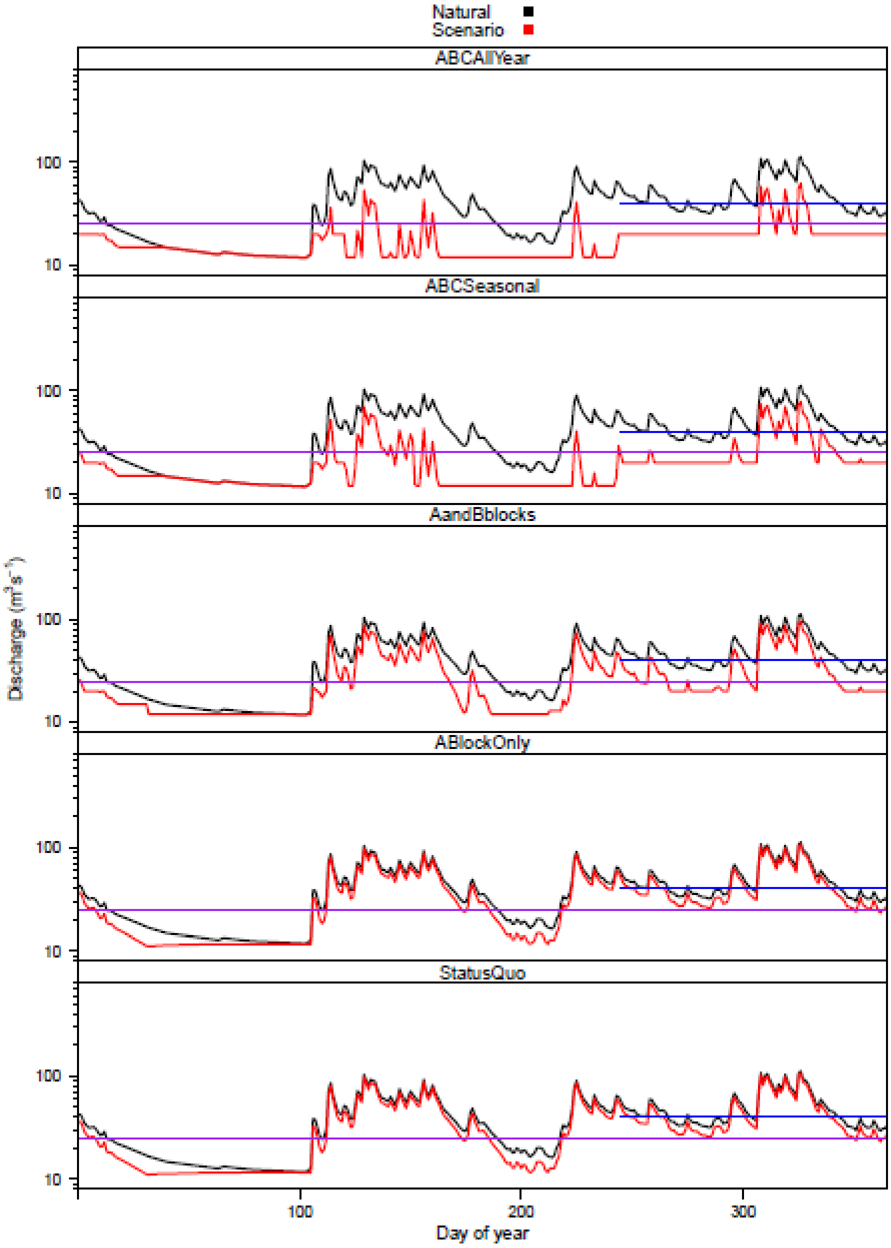
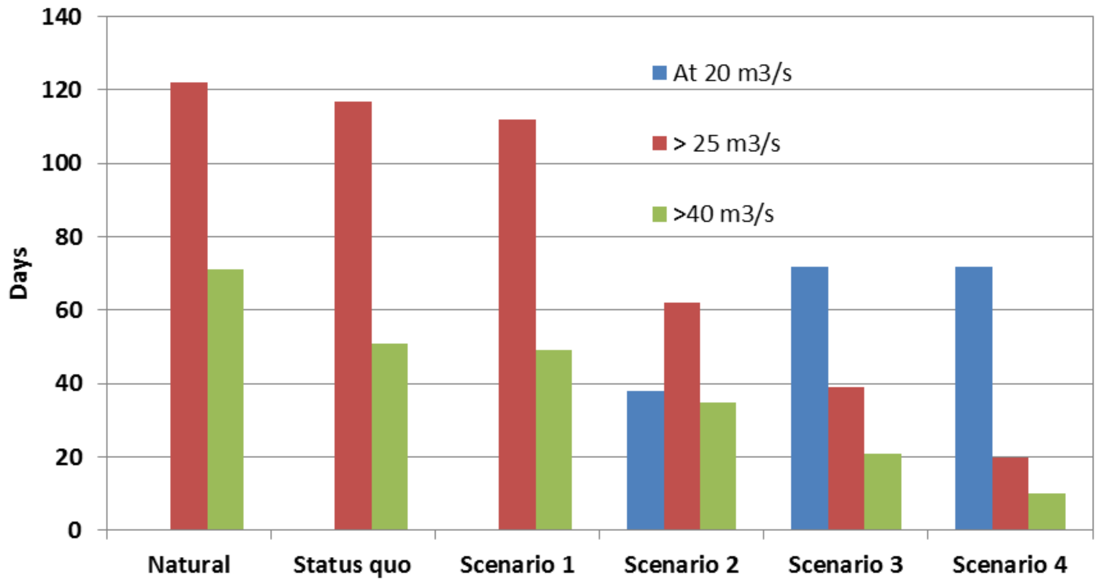


Figure 13. Time during September to December (122 days) when flows are at the minimum or above critical levels in a dry year (Note: green is good and blue is bad for nesting) (Source: Duncan 2012).



8.11 Interpretation of Figures 10 and 12, for the typical and dry years respectively, shows little difference between the two. On this basis all 51 years of hydrographs (1960-2010) have been evaluated in a similar way (Table 7).

8.12 Interpretation of the evaluation undertaken for the Hurunui differs to the Waiau. Waiau flows are typically higher during the breeding season at the low-medium range of flows considered important for bird habitat. As a consequence the evaluated scenarios mostly meet bird habitat needs over a range of scenarios (see Table 5) when 'Almost certainly' and 'Probably' are combined. Such is not the case for the Hurunui and even Natural and Status quo flows are marginal. As a consequence I have combined AC, PR and PO with the understanding that with full exploitation of the complying scenarios considerable mitigation will be required, i.e., large scale and effective and ongoing weed control and possibly also in some years extensive predator control.

8.13 While the evaluation is comparatively simple (and could be much more complex) it does indicate:

a. No scenarios where a combination of Almost certainly (AC) and Probably (PR) occur in at least 75% of years;

b. Three scenarios that with a combination of AC+PR+PO will exceed the 75% threshold, namely:

i. Natural

ii. Status quo

iii. Scenario 1;

c. One scenario that with a combination of AC+PR+PO is achieved in 70% of years, namely:

d. Scenario 2;

e. Two scenarios that with a combination of AC+PR+PO perform very poorly in most years, namely:

   i. Scenario 3 – 69% of years ‘Unlikely’ to achieve desired outcomes

   ii. Scenario 4 – 92% of years ‘Unlikely’ to achieve desired outcomes.

Table 7. Evaluation of Hurunui River breeding season flow scenarios in terms of probability of providing for bird nesting and feeding habitat needs. The following decision criteria were applied to each of 51 annual hydrographs:

a. If flows are above the 40 m^3/s line almost all of the time, i.e., >80%, then they 'Almost certainly' meet bird habitat needs;

b. If flows are above 40 m^3/s for >66% then they 'Probably' meet bird habitat needs;

c. If flows are above 40 m^3/s for around 50-65% of time then they 'Possibly' meet bird habitat needs;

d. Otherwise flows are 'Unlikely' to meet bird habitat needs.

Expert judgement was also used: if flows are 'tailing' off at the end of the season and drop below the 40 m^3/s line this is acceptable as breeding is nearly over; If flows are above the 40 m^3/s line for the first couple of months of breeding then this too is good. Where judgements 'are on the border' then in both circumstances the more positive evaluation is given. If large floods push the hydrograph above cut-off criteria then a downward classification is given.

Scenario		Almost certainly (AC)	Probably (PR)	Possibly (PO)	Unlikely (UN)
Natural	No. yrs % yrs	20 39	15 29	9 18	7 14
	%yrs AC+PR	69			
	%yrs AC+PR+PO	87			
Status quo	No. yrs % yrs	17 33	17 33.3	10 19.6	7 14
	%yrs AC+PR	67			
	%yrs AC+PR+PO	86.6			
Scenario 1	No. yrs % yrs	17 33	14 27	12 24	8 16
	%yrs AC+PR	61			
	%yrs AC+PR+PO	85			
Scenario 2	No. yrs % yrs	7 14	10 20	19 37	15 29
	%yrs AC+PR	33			
	%yrs AC+PR+PO	70			
Scenario 3	No. yrs % yrs	0 0	8 16	8 16	35 69
	%yrs AC+PR	16			
	%yrs AC+PR+PO	32			
Scenario 4	No. yrs % yrs	0 0	0 0	4 7.8	47 92
	%yrs AC+PR	0			
	%yrs AC+PR+PO	7.8			

8.14 Based on the above it is clear there is increasing risk to bird nesting as scenarios increasingly exploit water in the breeding season. Having made this point I do however have to provide a proviso. Wet breeding seasons that contain many floods can be absolutely disastrous to breeding, i.e., virtually all nests can be flooded away in a succession of bank-full or similar events, but of course also clear islands of vegetation. Understanding the nature of these relationships is fraught with challenges but a precautionary approach would err on the side of caution in terms of reducing flows in the breeding season, especially in terms of nesting.

8.15 The above analysis is now complemented by Table 8, in terms of which scenarios are best to worst for birds, taking account of uncertainty in terms of the predicted effects. There is a high degree of certainty around the ‘Probably’ and ‘Unlikely’ to meet outcome scenarios. There is high uncertainty around the AandBblocks scenario.

Table 8. Scenario evaluation matrix for bird habitat requirements on the Hurunui. Note: any scenario that is ‘green’ is better than any that is ‘lighter green’ or ‘yellow’ and ‘red’ is worst.

		Uncertainty		
		Low	Medium	High
Probability (chance of achieving outcome)	Almost certainly			
	Probably	Natural, Status quo, Scenario 1,		
	Possibly			Scenario 2
	Unlikely	Scenario 3, Scenario 4		

9. Overall evaluations of the flow management scenarios for the Waiau and Hurunui rivers

9.1 It is important to note the key bird species occur on both rivers, although the Waiau is more important for wrybill. Habitat requirements are the same and modelling indicates best nesting flows and feeding and food production habitat flows are also the same, i.e., 40 m^3/s for nesting and 25 m^3/s for feeding and food production on both rivers. This is important because it means a standard set of evaluations can then be applied to both rivers.

9.2 It is easier to meet the flow related habitat need requirements of birds on the Waiau than on the Hurunui because breeding season flows on the Waiau are higher. As a consequence a wider range of flow allocation scenarios exploiting larger potential takes can be envisaged as likely still meeting habitat needs on the Waiau than on the Hurunui. However, on both rivers the more the planned flow exploitation then also the more mitigation that will be required, especially on the Hurunui.

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