SUMMARY OF PREDICTED OUTCOMES FROM ECOLOGICAL BAYESIAN NETWORK (BN)

(See the full technical report by Richard Storey, NIWA - 'Effects *of land and water management on ecological aspects of major rivers in the Ruamāhanga River catchment' for more detail*)

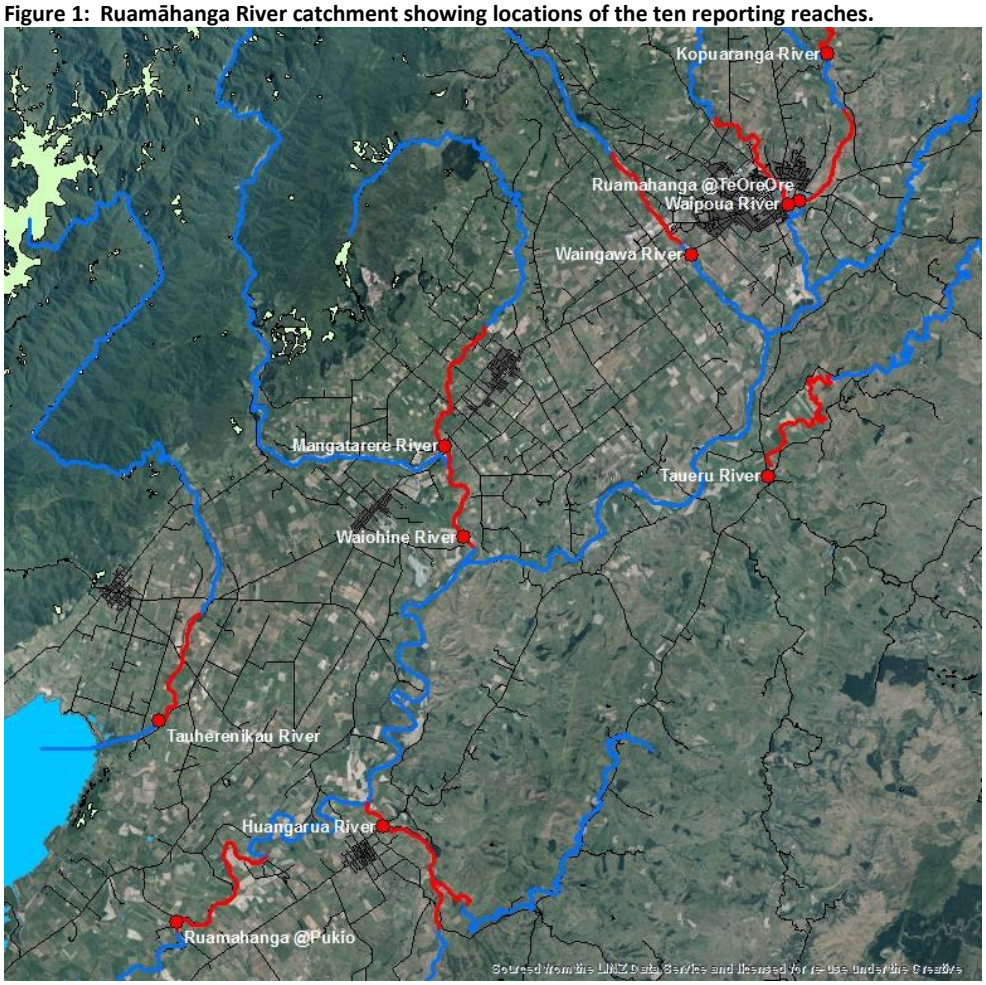
Overview of Bayesian Network Predictions

Ruamāhanga Bayesian Network (BN) was designed to show the predicted outcomes of different land and water management options for selected ecological, recreational and aesthetic attributes of large gravel-bed rivers in the Ruamāhanga Whaitua. It does this by showing the consequences of different scenarios ('Business as Usual – BAU', Silver and Gold) on key ecological attributes.

Outputs are presented for 10 reporting reaches, each 6-9 km long:

- Two on the Ruamāhanga River; and
- Eight on major (fourth-order or larger) tributaries.

Figure 1: Ruamāhanga River catchment showing locations of the ten reporting reaches.



Overall, only a few attributes show more than minor changes in any of the three scenarios compared to baseline. Silver and Gold scenarios show some differences in outcomes compared to BAU. There

are no differences between Silver and Gold by 2080, but some attributes change earlier in Gold than in Silver. There are several reasons why the changes in attributes are relatively small. They are as follows:

a) Some of the changes in the main drivers (reduced concentrations of dissolved nutrients, suspended solids, increased riparian tree cover, and a shift from river discharge to land-based wastewater treatment disposal) are minor.

b) Other important drivers of ecological outcomes, such as flow regime, change very little or not at all among the scenarios.

c) The reporting reaches are all on moderately large rivers (mostly fourth-order or larger), which are relatively insensitive to changes in factors such as riparian vegetation.

Periphyton

Periphyton rate of growth is controlled primarily by nutrient supply, light, and temperature, whereas biomass loss is primarily due to grazing by macroinvertebrates and high flow events that scour periphyton from the substrate. Periphyton requires dissolved nutrients from the surrounding water, in particular *dissolved inorganic nitrogen* (DIN) consisting of ammonia, nitrate and nitrite, and *dissolved reactive phosphorus* (DRP), in order to grow. Therefore, provided light is not limiting, and growth is not impeded by frequent floods, periphyton biomass is strongly correlated with the concentration of dissolved nutrients in river water.

Predictions at the baseline

- Expected value of periphyton biomass is in band B for most sites (50-120 mg/m2);
  With two sites (Huangarua and Kopuaranga) in band C; and
- One site (Mangatarere) in band D

Kopuaranga and Mangatarere have med-high concentrations of DRP and/or DIN, while Huangarua has med-low concentrations of nutrients but warm water temperatures and a low density of grazers.

The Bayesian network tends to overestimate low values and underestimate high values of periphyton biomass compared to actual measurements in the *Regional State of Environment* (RSOE) monitoring programme. However, the relative values among sites agree well between the Bayesian network and RSOE data, with the exception of Mangatarere for which the BN overestimates periphyton biomass.

IMPORTANT greater attention should be given to the relative values among sites and among scenarios than to the absolute value of any particular site or scenario.

Predictions for Gold and Silver 2080

- Expected value of periphyton biomass is in the B band for most sites
- Two sites (Kopuaranga and Mangatarere) are in C and D bands respectively.

The greatest changes in periphyton biomass relative to baseline occur in:

- Huangarua - decreases of about 30% (from 170 mg/m2 to 114 mg/m2 average during the summer period December to March) in Silver (by 2080) and in Gold (by 2040). This is the only site to show a change in NOF band (from C to B);
- Taueru - decreases of about 40% (from 92 mg/m2 to 57 mg/m2) in Silver and Gold (each by 2040); and
- Waingawa - decreases of about 35% (from 81 mg/m2 to 53 mg/m2) in Silver and Gold (each by 2040).

The main cause of the decreases in periphyton biomass is decreases in "nutrient sufficiency", which represents the most limiting of *dissolved inorganic nitrogen* (DIN) and *dissolved reactive phosphate* (DRP). Although DIN and DRP concentrations decrease at all sites in Gold and Silver scenarios, changes in nutrient sufficiency occur only in these three rivers at the timestep described.

Table 1: Expected values of periphyton biomass (mg Chl. a / m2) at baseline and under scenarios BAU, Silver and Gold in the years 2025, 2040 and 2080

	Baseline	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua	170	170	170	170	170	170	114	170	114	114
Kopuaranga	162	162	162	162	162	162	162	162	162	162
Mangatarere	230	230	230	230	230	230	230	230	230	230
Ruamahanga @Pukio	88	88	88	88	88	88	88	88	88	88
Ruamahanga @TeOreOre	88	88	88	88	88	88	88	88	88	88
Taueru	92	92	92	92	92	57	57	92	57	57
Tauherenikau	76	76	76	76	76	76	76	76	76	76
Waingawa	81	81	81	81	53	53	53	53	53	53
Waiohine	83	83	83	83	83	83	83	83	83	83
Waipoua	110	110	110	110	110	110	110	110	110	110

Possible further reductions of periphyton

Based on this BN predictions, it appears that the further improvements would be difficult to achieve for the following reasons:

- Riparian shading which influences the temperature and light is at maximum at Gold and Silver;
- Reducing days of accrual would require increasing the frequency of high flows beyond the natural regime; and
- It is hard to predict what impact would have increase of the density of invertebrate grazers.

The only means for further reducing the pariphyton biomass is reduction in dissolved nutrients (DRP and DIN). The BN predictions show if the concentrations of dissolved nutrients can be reduced to the low category, periphyton biomass cold be reduced by >50% in Kopuaranga and Mangatarere, and smaller reductions could occur in Ruamāhanga, Waiohine and Taueru.

Table 2: Potential responses in periphyton biomass to further reductions (beyond Gold and Silver) in dissolved nutrients.

	DRP in Gold or Silver 2080	DIN in Gold or Silver 2080	Periphyton biomass with low DRP or DIN	Change in periphyton biomass
Huangarua	Low	Med	114	0
Kopuaranga	Med-high	Med-high	79	-83
Mangatarere	High	Med-high	108	-122
Ruamahanga @ Pukio	Low-med	Med	57	-31
Ruamahanga @Te OreOre	Low-med	Med	57	-31
Taueru	Low-med	Med-high	40	-17
Tauherenikau	Low	Low	76	0
Waingawa	Low	Low-med	53	0
Waiohine	Low-med	Med	56	27
Waipoua	Low	Med-high	110	0

*DRP = dissolved reactive phosphorus. DIN = dissolved inorganic nitrogen. Low DRP is <5 ppb, Low DIN is <98ppb. Periphyton biomass is in units of mg Chl. a / m2.

Macroinvertebrate community index (MCI)

The condition of the macroinvertebrate community (MCI) was considered the most appropriate performance measure for macroinvertebrate community condition in this Bayesian network

The main effects of pastoral land use on macroinvertebrates in rural streams (not considering changes to the riparian zone) are via increased inputs of silt, nutrients and organic matter. Nutrient inputs affect macroinvertebrates mainly through their effects on increased periphyton biomass, which can alter the type and quantity of food available to macroinvertebrates and change the physical habitat.

Predictions at the baseline

- All sites have MCI values between 80 and 100 (classed as 'fair' according to the national classification system).

The BN tends to underestimate MCI scores by 10-15 units compared to RSOE results. However, the relative values among sites agree well between the Bayesian network and RSOE data, with the exception of Kopuaranga and Taueru for which the BN estimates are high relative to other sites.

IMPORTANT greater attention should be given to the relative values among sites and among scenarios than to the absolute value of any particular site and scenario.

Predictions for Gold and Silver

MCI shows only very small changes in any scenario.

- The greatest increase is in the Waipoua River (4 MCI points between BAU and Silver/Gold);

- The greatest decrease in the Tauherenikau River (1.5 MCI points between baseline and all scenarios).

Only changes of 10 MCI points or more are typically considered ecologically significant.

In the BN, MCI depends on deposited fine sediment, % change in mean annual low flow (MALF), mean summer water temperature and periphyton biomass. The reasons why differences in MCI are so small between scenarios are as follows:

a) Deposited fine sediment does not change at any site under any scenario because it is controlled primarily by the flood regime of rivers, which does not change under any of the three scenarios;
b) % change in MALF is <5% for most sites under most scenarios. Exceptions are Huangarua, Taueru and Tauherenikau, which all show a 5-50% decline in MALF relative to baseline in all scenarios. However, change in MALF has only a weak effect on MCI score; and
c) Mean summer water temperature stays unchanged in almost all sites under almost all scenarios. Only Waipoua shows a change in mean summer water temperature state.

Table 3: Expected values MCI at baseline and under scenarios BAU, Silver and Gold in the years 2025, 2040 and 2080

	Baseline	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua	85	84	84	84	84	84	85	84	85	85
Kopuaranga	92	92	92	92	92	92	92	92	92	92
Mangatarere	91	91	91	91	91	91	91	91	91	91
Ruamāhanga @ Pukio	83	83	83	83	83	83	83	83	83	83
Ruamāhanga @ TeOreOre	86	86	86	86	86	86	86	86	86	86
Taueru	94	93	93	93	93	94	94	93	94	94
Tauherenikau	97	96	96	96	96	96	96	96	96	96
Waingawa	92	92	92	92	94	94	94	94	94	94
Waiohine	99	99	99	99	99	99	99	99	99	99
Waipoua	82	82	82	82	82	86	86	86	86	86

Table 3A: MCI classes based on the values in Table A according to the national classification system

	Baseline	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Kopuaranga	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Mangatarere	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Ruamāhanga @ Pukio	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Ruamāhanga @ TeOreOre	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Taueru	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Tauherenikau	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Waingawa	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Waiohine	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Waipoua	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair

The MCI classes in Table 3A are based on generic MCI thresholds that are widely used in New Zealand to describe ecological quality, and are not accurate descriptors of the state of macroinvertebrate health in the Wellington Region. The generic national MCI thresholds do not account for the natural variation between rivers in the Wellington Region and the rest of the country, or the variation between different types of rivers within the region. For those reasons scientists from the Cawthron institute were commissioned in 2014 to define river class specific MCI thresholds for the Wellington Region that describe poor, fair, good and excellent ecological quality. Based on the model results, a set of thresholds were identified for each river class. The 'excellent' ecological condition threshold was defined as the 25th percentile of the predicted MCI 'reference' scores, the 'poor'/'fair' threshold was defined as the 5th percentile, and the 'good' threshold was defined as halfway between the two. These thresholds are the most appropriate for describing the state of macroinvertebrate community health in the Wellington Region, and should be considered above the generic national thresholds when setting objectives for ecosystem health. The predicted MCI classes under the Wellington classification system are described in Table 4.

Table 4: GWRC MCI classification (based on the BN results) specific to individual river classes within the Wellington Region (different classification to national classification in Table 3A)

	Baseline	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Kopuaranga	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Mangatarere	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Ruamāhanga @ Pukio	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Ruamāhanga @ TeOreOre	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Taueru	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Tauherenikau	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Waingawa	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Waiohine	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Waipoua	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Trout size and abundance

The trout node attempts to estimate the state of the trout population in a way that relates to its value for angling.

Predictions at baseline

Trout size and abundance are described as poor to medium among the reporting reaches at current state. This is mainly because of low water clarity at all sites (<1.4 m average daily clarity during the summer period December to March) and because of generally poor trout prey index (e.g., <10% at Waiohine and Ruamāhanga at Pukio; 10-20% at Ruamāhanga at Te Ore Ore).

However, since data were not available to calibrate the BN at baseline, more attention should be given to relative values among the different scenarios rather than to absolute values.

Predictions at Gold and Silver

Trout size and abundance does not change at any site under any scenario, relative to baseline.

The reasons that no differences seen among scenarios are as follow:

a) % habitat area is >90% in all sites under all scenarios except in Huangarua (where it decreases to 63% in all scenarios compared with baseline). However, because trout size/abundance is already poor at this site, a decrease in habitat area makes no difference.
b) Visual water clarity is <1.4 m at all sites under all scenarios, because suspended solids is >7.7 g/m^3 under all scenarios. To achieve visual water clarity of >1.4 m would require suspended sediment concentration of 6 g/m^3 or less. For example, improving clarity to 2 m could raise trout size/abundance to 20-80% probability of being "good" at some sites that are currently medium, e.g., Kopuaranga, Mangatarere, Taueru, and Waiohine. Achieving 2 m water clarity would require *total suspended sediment* (TSS) to be less than about 2 g/m^3.
c) Trout prey index does not vary among the scenarios at any site except Waipoua where it increases from 6% (baseline) to 28% (all other scenarios) due to a decrease in temperature.

Fish Index of Biotic Integrity (IBI), and probability of occurrence of eels, redfin bullies and inanga

Prediction at baseline

At baseline, Fish IBI scores (a measure of fish community health) range from 49 to 55, which places all reporting reaches in the "good" category (>32). The probability of eels being present is 85-97%, the probability of redfin bullies 67-79% and the probability of inanga 68-85%.

Based on experience, we believe the IBI scores to be higher than expected for the Ruamāhanga River catchment and that scores indicative of "fair" to "good" are more likely.

However, interpretation of scenario results should focus on relative change rather than absolute values.

Prediction for Gold and silver

There was no change in fish community condition (using IBI scores) or probability of occurrence of eels, inanga and redfin bully under any scenario at any site, except the Waingawa River. The Waingawa River shows very slight improvements in fish community condition and the occurrence of eel, redfin bully and inanga.

The lack of change in fish nodes is not overly surprising because all of these nodes depend on barriers to migration, the abundance of deep pools and deep runs, bankside cover and deposited fine sediment cover. In most cases these factors, that are considered key drivers of fish in the Ruamāhanga River and its main tributaries, are not altered by the scenarios (ie, habitat for fish does not change). An exception is the extent of riparian vegetation which increases significantly at some reporting reaches (e.g. Taueru, Ruamāhanga at Pukio, Waingawa) under Silver and Gold scenarios and thus should lead to an increase in "bank edge cover". However, bank edge cover needs only to exceed 20% of bank length for it to provide sufficient habitat for the presence of a fish species to be likely, and this is achieved at baseline in all reporting reaches except Waingawa. Increases in bank edge cover are still considered beneficial for the fish community and the sites where this increased significantly (Taueru, Ruamāhanga at Pukio, Waingawa) will likely have higher fish abundance.