Responses to questions raised by the Collaborative Stakeholder Group members following the economic-modelling presentation on 26 August 2015

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Catchment-level model

1. Can the relative cost of achieving the limit associated with individual contaminants be calculated? If so, this will provide further information regarding what types of improvement are realistic to achieve.

Response: The catchment-level model studies nine attributes. These are chlorophyll *a* (median and maximum), Total Nitrogen, Total Phosphorus, nitrate (median and 95th percentile), *E. coli* (median and 95th percentile), and water clarity. The model can be run to see what changes are required to meet any limits for any subset of these nine, including individual attributes. This can be done for the limits defined under each scenario, as well. The main thing is to identify which runs will be most important to evaluate with the model, given the high amount of information that can be generated and the limited time available to generate and discuss this output.

2. Can we isolate the cost of achieving contaminants other than nitrogen, which other work has shown to be very costly to mitigate?

Response: As outlined in the response to point #1, this is very possible to study within the model. The key requirement is to identify which runs are most important to conduct, to make the job of computing, assembling, and discussing the data more efficient.

3. If a public/private benefits split was to be calculated, how would this affect the outcomes for farmers given that they are the ones to be targeted?

Response: Both the catchment- and regional-level models, but especially the latter, are defined such that different costing models can be evaluated. However, at present, no such benefit splits have been conceptualised by the CSG and therefore are not studied in the current work.

4. How are land-use change options staged or introduced spatially?

Response: Land-use change is determined within the model. Land-use allocation is selected from among the full set of mitigations included in the model, on a relative cost basis. If it is the cheapest way to achieve certain limits, then it will be selected given the identification of least-cost solutions in the model. However, the extent to which this occurs varies. The report presents two approaches for studying land-use change; one constrains land-use change to within historical patterns observed in each subcatchment, while another allows fully-flexible land-use transition. Both forms of analyses show consistent trends with respect to the cost of mitigation, but are also markedly different with regards to the extent of land-use change selected by the model.

Constraining land-use recognises that land-use change is not fully flexible in the short-term, while also being more consistent with the baseline data used in the model (e.g. those data regarding hydrological information). In contrast, fully flexible land use allocation provides a snapshot of potential long-term changes required to meet water-quality goals, though it is more problematic to identify appropriate data for such a time.

Overall, land-use change is a challenging mitigation option to study within the types of model utilised in this study. Both the catchment- and regional-level models represent an "average" year; therefore, they abstract away from the passage of time and various important processes that change over time (e.g. milk price, the transition of one land-use to another).

5. How are decisions made regarding which de-intensification options were appropriate?

Response: The set of mitigations incorporated in the model were developed utilising expert opinion, past studies, and advice from industry organisations (e.g. DairyNZ, HortNZ, and Beef and Lamb NZ). This involved, but was not limited to, broad caucusing of mitigation experts from around New Zealand in a number of targeted workshops. These workshops included a review of initial data that we had available from the Economic Impact Joint Venture, a review of updated data gathered from extensive literature review and interviews, and a workshop focused on appropriate edge-of-field interventions. The full set of mitigations that have been represented in the model has now been reviewed twice by Ross Monaghan and Richard Muirhead at AgResearch.

6. Is the scale of impact realistic? Can these numbers be believed?

Response: Generally, model output highlights that the catchment-, regional-, and national-level costs associated with each evaluated scenario are substantial. The Waikato River Independent Scoping Study, although different in its detail, showed substantial costs as well.

Moreover, these costs remain significant even when land-use change is allowed to occur with full flexibility. Some factors suggest that the cost could be higher in reality. For example, the adoption of all mitigations will not be instantaneous and in reality uncertainty will reduce the degree to which mitigations can be located where they achieve the most cost-effective abatement. However, other factors suggest that the cost could be lower in reality. For example, the high levels of unemployment that have been identified in the regional-level modelling would drive down wages, which could lead to higher production and more affordable products in the market that, in turn, could stimulate more demand and employment. (These complexities are not fully captured within the regional-level modelling, given the cost and scarcity of appropriate data—see Section 4.1 in the report for further discussion). Overall, we believe that while some factors could either increase or decrease the magnitude of the cost estimates we have derived, the conceptual insights offered by the modelling are intuitive and consistent with previous work and other experiments performed with the model. Indeed, it is our belief that even with a broad changes in the cost of different mitigations, the aspirational levels of water-quality improvement defined in scenarios 1–3 are likely to impose significant economic costs at the catchment, regional, and national scales. When the CSG 'lands' on a preferred scenario or scenario set, the sensitivity of model outputs to variation in model inputs will be undertaken.

7. What is the human cost of these estimated impacts?

Response: It is difficult to estimate the full human cost of the estimated impacts. Model output suggests that the impacts are likely to be highly variable across space; that is, both within and across Freshwater Management Units. Moreover, model output suggests that the proposed scenarios will have substantial negative impacts on income and employment. The human cost of these impacts will be drawn out in more detail in the narrative being developed as part of the integrated-assessment package.

8. Why were levels of mitigation adoption so disparate across different mitigation options? For example, in the PowerPoint table summarising Table 5 in the report, some dairy mitigations were above 80%, other sectors had 30–40% uptake, and even some win-win options had only 30%.

Response: There are a number of reasons why the rate of adoption for various mitigations differs greatly across the set of abatement options for the different scenarios. First, there is only a limited range of farms across which some mitigations can be used. For example, lowrate effluent application is only suitable for dairy farms on poorly-drained soils. Accordingly, it achieves a maximum level of use on around 15% of farms for the constrained land-use analysis (see Table 5 in the report). Second, there is already some adoption of most mitigation practices within the catchment, which limits the capacity for further adoption to take place. For example, a win-win strategy (improved phosphorus management) is actually adopted across *all* pastoral farms in scenarios 1–3. Table 5 in the report shows that the level of adoption for this practice is 57% and 24% on dairy and drystock farms, respectively. The total level of utilisation for this mitigation practice reaches 100% across both types of farming when baseline levels of adoption are considered. Third, some mitigation options are broadly popular because they are cost-effective "low-hanging fruit". One example is the remediation of 2-pond systems. The high degree of adoption that occurs for this mitigation across all scenarios is not because of any preference for mitigation defined across sectors; rather, the model selects it because it is a cost-effective way to reduce a broad range of contaminants, including both nitrogen and microbial losses to water.

9. At what stage are more expensive mitigations chosen?

Response: The economic model identifies the given set of mitigations, out of all of those possible combinations defined within the model, required across the landscape to achieve the limits set out within each scenario at *least cost*. Other objectives could be utilised to select the most-suitable management plan. However, using cost as a measure of the suitability of alternative management plans is commonplace in both national and international evaluations of water-quality improvement. This is because of the central importance that many communities and stakeholders place on cost when seeking to compare different environmental policies or goals. Accordingly, because the model identifies the least-cost way of satisfying each set of limits, more-expensive mitigations are only selected when the limits for water-quality improvement become more stringent. Indeed, a key finding outlined within the report is that catchment-level profit declines relative to its current level across Scenarios 1–3, regardless of any assumptions made regarding land-use change, given the aspirational levels of water quality defined therein.

10. Can the model indicate the degree of uptake of new land-uses? Currently, the focus seems to be on existing sectors, which seems to limit the number of options considered.

Response: The model focuses on the primary existing land uses and point sources within the catchment. This decision reflects a scarcity of resources (time, budget, and information) that has prevented a broader definition of industries to include, while also recognising that the land uses and point sources considered are the primary drivers of contaminant loadings to water within the catchment. New land uses could be considered within the model, but the cost of including them may be too high to warrant this, given that their inclusion may add little further insight. It is important to note that forest-to-dairy conversion was not studied, as this activity would likely increase pressures on water quality.

11. Dairy production under a high pay out relies upon significant support from the drystock sector (e.g. through support of heifer and winter grazing). How is this accounted for, especially in Scenario 4?

Response: The dairy sector within the model is split into milking-platform and dairy-support components. Each representative (milking-platform) dairy farm has associated with it a required level of winter grazing, for both replacements and mature cows. A relationship is included in the model that ensures that this demand for winter grazing is met by the capacity to winter dairy replacements/cows on both dairy-support land and drystock farms that winter these animals. (The latter is possible given that a number of the representative farms defined for the drystock sector in the model include a dairy-support component.) In this way, it is ensured that changes in land use across dairy and drystock sectors remain coherent and interdependent, at a general level.

12. Why in scenario 4 in the unconstrained land-use scenario, do the hectares allocated to drystock farming reduce so drastically, when they are much higher in the more-restrictive scenario 1?

Response: The evaluation of scenario 4 with unconstrained land-use change identifies a key strategy of converting a lot of drystock land to forest, to manage the significant load of nitrogen to come in the Upper Waikato. Beyond that, greater reductions in nitrogen, phosphorus, sediment, and microbial loads encompassed within the other scenarios require a more broad set of mitigations, and necessitating a less-extreme response within the drystock sector.

13. How is the sale of cows/shares etc during land-use transition a benefit over 25 years?

Response: The row for land-use transition in Table 2 of the report represents the explicit revenues and costs associated with land-use transition. Examples of such revenues are the sale of processor shares and cows when dairy farms are converted to forest or drystock enterprises. An example of such a cost is the construction of a woolshed when converting from dairy farming to drystock production. These revenues and costs have been annualised at a rate of 8% over 25 years.

Annualisation means conversion to an annual equivalent amount, so that the large lump sum associated with the sale or purchase of these capital assets can be compared, without bias, to annual values (such as losses in annual operating profit). We annualise them so we essentially can compare "apples with apples". For example, if we asked somebody to select between an abatement option that would require a stand-off pad to be built at a capital cost of $500 per cow or one that would involve reducing supplement use at a cost of $50 per cow, the latter appears much cheaper. However, the capital cost associated with the stand-off pad is much higher and likely to be spread across time through debt. Thus, we annualise the cost to make it comparable to the cost attributable to reduced supplement feeding. In this case, $500 per cow, when annualised at 8% over 25 years, is $47 per cow and thus the stand-off option compares quite well with the supplement option when we utilise the correct evaluation technique. Indeed, it is important to recognise that this method of annualisation is an established technique and typical practice within financial evaluation.

14. How are price collapses dealt with in respect to the sale of assets during land-use transition?

Response: Transition benefits from land-use change can arise from the sale of assets. An example is the sale of cows when a dairy farm is converted to a drystock farm. The scale of benefits associated with this action are held fixed in the model, regardless of the total level of conversion that occurs. This is possibly misleading, in that broad-scale conversion away from dairy production could lead to an oversupply of dairy cows, and thus lower the prices received for these animals. However, this distortion may be minimised across time given that all dairy farms are unlikely to downscale in a single period, and the staging of such de-intensification across time in reality may prevent such high price distortions occurring.

15. Where is arable farming in the model?

Response: Arable farming is obviously an important sector within the Waikato region. However, the model focuses on the primary existing land uses and point sources within the catchment and, as such, arable farming is not explicitly represented. This decision reflects a scarcity of resources (time, budget, and information) that has prevented a broader definition of industries to include, while also recognising that the land uses and point sources considered are the primary drivers of contaminant loadings to water within the catchment.

16. If phosphorus is driven down hard, could that meet targets for chlorophyll-a, without targeting N at all?

Response: This response is possible, and could be studied in the model. The model contains a statistical relationship among chlorophyll-a and the concentrations of Total Nitrogen, Total Phosphorus, and ratios of these two attributes at nine sites along the main stem of the Waikato River. This allows analysis of the benefit associated with targeting phosphorus loads to water, rather than nitrogen loads.

17. How equally are mitigation options applied across the different subcatchments within the catchment?

Response: Figures 4–7 in the report highlight how the mitigation of the different contaminants (nitrogen, phosphorus, microbes, and sediment) differ across each subcatchment for each scenario. These maps indicate strongly that to achieve cost-effective mitigation and meet the limits for water quality that vary greatly across space under each scenario (Table 1 in the report), it is necessary to utilise mitigation options to much different extents across the subcatchments within the study region.

18. There is a tension between the catchment-level model and the regional model. The catchment-level model identifies options that meet limits at least cost; thus, it seeks to minimise the cost to farmers. However, when we take these results and consider their regional- and national-level implications in Section 4 of the report, the costs and implications for the farmer are not fed back into the catchment-level model. For example, farmers may survive but their processing plants may not. How does the model deal with such an issue?

Response: This is an insightful technical question. The flow of data between the catchment- (Section 3) and regional-level (Section 4) models is very much linear, in that the catchment-level optimises, and then data is sent to the regional-level model that then computes the effects at the FMU, regional, and national scales. The best way to respond to the limitation identified within this question, and ensure that output is therefore coherent across all scales, is to optimise the models together. An input-output model, as utilised in this study (Section 4), is not appropriate for this purpose because it does not optimise. Rather, it is standard to link a computable general equilibrium (CGE) model to a catchment-level model of the kind applied here. Creation of a multi-regional CGE model that reports down to the level of each FMU would necessitate the construction of a Social Accounting Matrix (SAM) for the local area. There is a lack of information pertaining to interrregional investment flows upon which to complete this task. Additionally, linking a CGE model to the catchment-level model is a major piece of work and is beyond the scope of this project, given the time and budget requirements for this research (it would likely take a year and an investment of around a million dollars). Accordingly, to date, this type of work has not been undertaken within New Zealand for the analysis of water-quality limits.

19. Are we confident that impacts on small towns have been fully identified between scenarios?

Response: The catchment- and regional-level models predict how the economic prosperity of the subcatchments, FMUs, region, and nation will be affected by the proposed scenarios. This is a key input to the integrated-assessment package, which will focus on how the scenarios impact the social fabric of the region, especially the vitality of small towns.

20. When will the mitigation report be provided to the Collaborative Stakeholder Group?

Response: The focus of the modelling group has been the delivery of the modelling work to the CSG under tight time frames. This will likely continue in the near term, as we seek to address the 2nd round of scenario modelling. We will attempt to provide the mitigation report to the CSG as soon as we can, recognising these other commitments. The mitigation report has now been peer-reviewed a number of times, and once updated will be ready to share with the stakeholder group.

21. Can the model be used to make any assessment about what mitigations can deliver the most benefit in the shortest amount of time?

Response: The best that the model can likely do in this regard is identify how far we can go towards reaching limits across the full set of sites by adopting a given mitigation or set of mitigations to varying extents. The model is not suited to identifying which mitigation will achieve what “in the shortest amount of time” given that it focuses primarily on a single point in time. However, some insights about likely adoption rates could be drawn from studies of the diffusion of abatement technologies across populations of farmers. Of course, once implemented not all mitigations have an ‘instant’ effect (the most obvious example being N mitigations on the farm in catchments where there is a long groundwater residence time).

22. What effect will increasing horticultural production per unit area, due to the loss of land for housing development, have for water quality?

Response: The loss of land for housing development is an issue for which the model has not been designed to evaluate. Even though it is likely important, especially to the horticultural industry, it has not been a primary issue thus far in the Healthy Rivers process and thus has not been a focus of the modelling work. Nevertheless, this type of intensification could be expected to increase sediment and nutrient losses from this source.

23. Are the abatement-cost curves based on linear, exponential, or punctuated cost increases?

Response: There are two types of abatement-cost relationships included in the model; those estimated for representative farms, and those represented for discrete mitigations (e.g. farm plans, effluent management, edge-of-field mitigations). The amount of money attributed to abatement from each source is presented in Table 2 and Table 5 for the constrained and unconstrained land-use analyses, respectively. The relationships for each representative farm are discrete, as they are associated with discrete management options. For example, if we adopt a stand-off pad and reduce nitrogen fertiliser use by 25%, then the implications of this discrete strategy for profit and leaching are estimated. However, the shape of the abatement-cost relationships are a mixture, varying within and between sectors. Some define win-win relationships (i.e. profit increases while leaching decreases), while others are strictly increasing (i.e. profit decreases while leaching decreases). In contrast, the costs associated with the discrete mitigations are linear. More data surrounding these relationships will be presented in the mitigation report, once this is complete.

24. Is it defensible or reasonable to assume that no new land-use options or technologies are considered?

Response: It is entirely possible that new land-use options and innovative technologies may be developed. However, it is difficult to characterise them. For inclusion in the model, we need to know for each potential mitigation technology: their cost, their efficacy in terms of the reduction they achieve for each contaminant, and the farms or point sources where they can be applied. Without such information, it is difficult to assess the potential of new land-use options or abatement technologies. The CSG has not requested that such new land uses or technologies are assessed in the model, and the Technical Leaders Group would caution that such an exercise would become highly speculative. Perhaps simply recognising this possibility in a narrative way – given the long-time frames we are looking at then it is entirely reasonable to speculate that new research could deliver these.

25. What are the cost of different mitigation options considered within the model? For example, in Table 2 we do not see anywhere the use of feedpads or de-intensification.

Response: The cost of the different mitigation options utilised in the model is outlined in Table 2 and Table 5. De-intensification options are included in the representative-farm data for each sector, outlined in the *Sector Profit* part of each of these tables. Likewise, feedpad options are also included in the representative-farm data for the dairy farms defined in the model. The cost of these options are therefore also outlined in the *Sector Profit* part of each of these tables. Ultimately, most of these data pertaining to de-intensification of the representative farms came from the Economic Impact Joint Venture process in the Waikato, which focused primarily on mitigation of nitrogen loadings.

26. What happens to the Waikato economy if changes like those estimated in the report are also applied to other parts of the Waikato region, such as the Hauraki, that will also be subject to limit-setting processes?

Response: The impacts of the limits defined within the Healthy Rivers process are the focus of the report. These include consideration of effects in the Waikato region, but outside of the catchment that is the focus of our work. Nonetheless, this work does not consider the impact that other limit-setting processes will have in these other parts of the Waikato. Based on the analysis contained in the report, it may be proposed that the setting of limits in these other regions, such as the Hauraki, are likely to reinforce the negative economic implications for the Waikato Region that have been predicted here to accompany improved water quality in the Waikato and Waipa River catchments.

27. Do the scenarios include multiplier effects that consider differences in the cost of cleaning up the water over time?

Response: The model is a steady-state or equilibrium model (see response to point #30 for more information). However, in terms of its application within the Healthy Rivers process, the CSG might choose to consider the scenarios they have developed as alternative outcomes along a timeline of change.

28. What are the wealth effects of land-use change, given that water-quality limits will likely impact land values?

Response: Land-use change and reduced profits in the agricultural sector due to limit-setting processes will likely influence land values. The effect of restrictions on land-use intensity and land values is the subject of ongoing work, both by industry and central government, but there is current little definitive work available that can be utilised to predict how these effects can be considered in the context of the Healthy Rivers process.

29. Do the loss of profit figures include the cost of mitigation?

Response: Yes, they do. This can be appreciated from Table 2 and Table 8, which both show the costs associated with discrete mitigations, alongside more general variation in farm profits experienced within individual sectors due to limit setting.

30. Is the model dynamic or steady-state?

Response: The model is a steady-state model, representing an average year. In keeping with standard practice (e.g. Doole, 2010; Daigneault et al., 2012), the time path of adaptation is not included in the model, because:

1. The scarcity of data related to many relationships represented in the model is compounded when variation over time in key drivers of management behaviour (e.g. output price, input price, productivity, climate, innovation) is high and difficult to predict. An example is attempting to predict milk price variation over the next few years, and how this influences mitigation costs for dairy farmers and related industries.
2. Dynamic models are difficult to develop and utilise (Doole and Pannell, 2008).
3. Output from intertemporal models is heavily biased by the starting and endpoint conditions defined during model formulation (Klein-Haneveld and Stegeman, 2005).

Overall, these issues provide a strong justification for the employment of a steady-state modelling framework. In terms of the process here, the CSG might choose to consider the scenarios they have developed as alternative outcomes along a timeline of change.

References

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Klein-Haneveld, W.K., and Stegeman, A.W. (2005), 'Crop succession requirements in agricultural production planning', *European Journal of Operational Research* 166, pp. 406–429.

31. What is the relative share of costs between local government and industrial point source discharges?

Response: The cost of point source remediation is mainly falling on industrial point sources. Around 80% of the projected cost falls on two point sources, one industrial and one municipal.

32. Can this model be used over time to update our evaluations as new mitigations come into play. For example, low-input farming systems may become more widespread, so could the model runs be repeated utilising abatement-cost relationships that take this into account?

Response: Yes, this is possible.

Regional level model

33. How are out-of-region economic effects factored in? For example, there is an important post-harvest processing sector for horticultural products in Auckland. How are sectors such as this considered?

Response: The model is a multi-regional model. Flow-on implications to, and from, connections to other regions are fully accounted for, within any limitations associated with available data. The model includes a "rest of New Zealand" region for this purpose.

34. Predictions regarding local government employment under the regional modelling shows there to be a negative relationship relative to current state as limits become more stringent. This conflicts information presented during the last CSG meeting, which

highlighted that the Waikato Regional Council would need at least 50 more Full Time Equivalent staff to assist with the development and implementation of farm plans. Can this inconsistency be explained?
Response: We have assumed that the implementation plans would be a contracted service, rather than occur within local government, and as such this has been split across agricultural services, professional services, and the construction industry.

35. Even a small (10–15%) decrease in horticultural output will lead to very significant increases in the cost of vegetables for consumers. Is this considered?
Response: Price effects are not considered in our modelling. To consider such impacts we would need to move from Input-Output analysis to Computable General Equilibrium. Timeframes and budgets, however, prohibited the use of this type of tool (see Section 4.1 in the report for more discussion on this point).

36. How is total revenue reflected within the model in terms of the value added component in horticulture? Is this perhaps included in the “Other primary” field?
Response: Yes. The report focuses on the reporting that is produced for 16 aggregated industries. However, this aggregation is performed over 107 individual industries in the Input-Output model, which includes horticulture. It is a straightforward task to add another industry to the list of the 16 aggregated reporting industries to make the impacts associated with ‘horticulture’ more explicit.

37. Does the model take into account the impact of extra wood-processing plants when forestry increases by so much in the unconstrained land-use change scenario?

Response: Yes. If forestry outputs increase, the model would produce a corresponding change in wood-processing as per the relationships inherent in the underlying input-output table. Forward linkages impacts to processors are fully accounted for.

38. Why is the effect on exports zero for horticultural produce?

Response: Garry McDonald has yet to provide a response, but to our knowledge this reflects an overarching assumption that the primary market for horticultural products in the Lower

Waikato is domestic. It will obviously good to explore the implications of this through discussion with Garry McDonald, if this assumption is not accurate.

General questions to Technical Leaders Group

39. Given that Total Nitrogen and Total Phosphorus in the *tributaries* are included in the model, shouldn't they be included as attributes?

Response: No. Tributary nutrients have to be considered when managing the main stem phytoplankton (as is done in the model). Targeted tributary nutrient limits are not needed to control tributary periphyton, which appears to be controlled by other factors within acceptable levels. Putting N and P limits on the tributaries would add more complexity and would not be cost-effective.

40. How can we make decisions that divide these costs over time sensibly? How can time help?

Response: This is another more complicated question. The model is not suited to studying this aspect (see response to point #30 above for more discussion). In terms of the process here, the CSG might choose to consider the scenarios they have developed (and will develop) as alternative outcomes along a timeline of change.

41. Can we improve the way that phosphorus and nitrogen concentrations calculated in the model are altered by changes in flow rate? For example, if we lose flow through the return of this water to the Wanganui River, can this be modelled?

Response: Yes. We could predict the effect of reduced Taupo flow on concentrations of nutrients and residence time in the hydro lakes. Modifications to the model would be necessary to deal with the subsequent changes in residence time (if that proves significant), which are not included explicitly at present.

42. What is the effect of focusing limits only on microbial loads in summer, when most-swimming activity will likely occur?

Response: Focusing on the summer period makes it more achievable to meet *E. coli* levels for swimmability. For example, in the Lower Waikato main stem, the river median 95%ile E. coli concentration at 4 sites was a D when assessed at all times of the year, but a B when assessed for November–April (summer) at non-flood-flow conditions. However, Waipa sites have high failure rates, even in summer—this may be related to increased livestock access to unfenced streams in summer but perhaps this could be targeted more.

43. Can the effect of focusing limits only on microbial loads in summer be modelled?
Response: This should be possible, but it will need some careful thought and data analysis.

Vision and Strategy

44. Can we go back to the Waikato River Authority for revision of the Vision and Strategy or to provide insight regarding appropriate time frames?
Response: Not a TLG question

45. The Vision and Strategy requires swimmable water, but also prospe

rous communities. How can we reconcile these factors when the report shows that they conflict with one another so markedly?
Response: Not a TLG question.

46. The CSG has to put in effect the Vision and Strategy. How can we legally provide this when model output suggests that we know it cannot be met?
Response: Not a TLG question.