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| **IN THE MATTER OF** | The Resource Management Act 1991 |
| **AND** | |
| **IN THE MATTER OF** | Lake Rotorua Nutrient Management – **PROPOSED PLAN CHANGE 10** to the Bay of Plenty Regional Water and Land Plan |

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**SUMMARY OF STATEMENT OF EVIDENCE OF PROFESSOR GRAEME JOHN DOOLE**

**ON BEHALF OF THE BAY OF PLENTY REGIONAL COUNCIL**

**Evidence topic: Economic impacts of Plan Change 10 at the catchment level**

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## Introduction

1. My full name is **Graeme John DOOLE**. I am currently a Professor of Environmental Economics at the University of Waikato. My qualifications and experience are set out in full in my evidence in chief (EIC) filed 20 January in this matter and I do not repeat them in this summary of my evidence points. Likewise, the background to my evidence, statement of independence, and compliance with the expert witness code of compliance are confirmed and relied upon, but are not repeated here.

2. My evidence is about the report: "On-farm effects of diverse allocation mechanisms in the Lake Rotorua catchment", of which I am a co-author (with Oliver Parsons, DairyNZ, and Alvaro Romera, DairyNZ). Herein, I performed part of the economic analysis (under contract to Dairy NZ). The project was undertaken jointly with the Bay of Plenty Regional Council (BOPRC). I refer to this report hereafter as the "Parsons et al." report and to the model applied therein as the "Parsons model".

## Scope of Evidence and Summary

3. A key part of Plan Change 10 concerning water quality in the Lake Rotorua catchment involves the *allocation* of a given number of nitrogen-loss entitlements to different land uses. These land uses must maintain nitrogen loss at or below their

allocated level, or buy entitlements from another party that has a surplus. The Parsons model predicted the economic effects of different allocation mechanisms at the **catchment level**. Farm data generated by Lee Matheson (Perrin Ag) was an input to the Parsons model. The output from the Parsons model was used by Market Economics to identify the economic impacts of selected allocation mechanisms at the **district, regional, and national levels**.

4. My evidence provides a commentary on the modelling results, and then addresses four general questions that analyse and confirm the suitability of the processes behind the Parsons et al. report:

   (a) Is the model framework appropriate for this form of analysis?

   (b) What is the justification for the calibration method used?

   (c) What is the justification for the equilibrium approach used?

   (d) What is the justification for the deterministic approach used?

5. My evidence explains the research project, process, and results, and provides information/analysis on the structure of the Parsons model. My evidence focuses specifically on the model structure which is (a) within my area of expertise, and (b) the area of my expert input into the report.

6. The Parsons et al. report was a joint project and the authors had responsibility for their sections. My evidence does not focus on the sections written by others. This includes sections "3.2 Input data"; "4.4 Implications of scenarios for land prices"; and "4.5 Implications of scenarios for debt servicing and equity". Also, this includes Appendices 1–5, which present the farm-level data generated by Lee Matheson.

*Background to the report: collaborative brief development and feedback loop*

7. The project brief was developed collaboratively between BOPRC, DairyNZ, Beef + Lamb New Zealand, and Rotorua Stakeholder Advisory Group (StAG) members. Draft output was presented to the StAG committee between March–July 2015, and feedback was incorporated in the report up to and including August 2015. As such, the Parsons et al. report represents the work of a large group of people across a broad range of organisations. The report provided direct information for the StAG, BOPRC, other stakeholder groups, and Market Economics.

8. The project involved working with stakeholders to ensure that the application was aligned with their knowledge of the problem and context. The StAG played a central role, especially regarding: the design of the allocation mechanisms put forward for assessment, the determination of what results were important to present and understand, and contributing to the iterative development of the model. StAG did not participate in the selection of the modelling framework, given a scarcity of project resources (e.g. data, budget, time).

*Report objective: Evaluation of the economic implications of different nitrogen-allocation mechanisms*

9. The objective of the report was to evaluate the broad effects of proposed nitrogen allocation for producers in the Lake Rotorua catchment. The allocation mechanisms evaluated are listed in my EIC, para 16. The Parsons et al. report chiefly focuses on how farm profit (as represented by Earnings Before Interest and Tax) changes **within the catchment** under different allocation mechanisms and trading contexts.

10. A variety of economic-modelling techniques can be used to assess the impacts of environmental policies. I have applied many of these to problems in water management. The most-suitable method depends on the context, chiefly the issue(s) of concern and resource availability. The Parsons model is based on a framework known as the Land Allocation and Management (LAM) model (Doole, 2012, 2015). It has been widely applied both nationally and internationally.

11. The Parsons model incorporates the trading of nitrogen-leaching rights in a simulated market. Nitrogen prices were generated inside the model based on the supply and demand of entitlements. In the absence of frictions, trading continues until an equilibrium is reached whereby there are no further gains from trading.

12. The predictions in the Parsons model were made under two different trading contexts. In the first context, land-use change was either unlimited or was constrained to be equal to or below 5,000 ha. The 5000 ha limit was valuable because it aligned with stakeholder expectations, captured effects not included in the model (e.g. risk, lifestyle impacts), and allowed for an analysis of changing this limit that was easily accessible, given its simplicity relative to more-complicated procedures for limiting land use (see paragraphs 22–26 below for further information). In the second context, entitlements traded were either unlimited (all economically desirable trades took place) or bound at 50% of that level. Suboptimal

trading occurs if land owners retain more than their economically-efficient level of entitlements. For landowners, retaining excess entitlements could be useful to partially insure against market, climate, environmental and political risks.

*Results of the report*

13. The main findings from the simulation of the allocation mechanisms in the Parsons model are provided in paragraph 20 in my EIC. These results are based on efficient trading, except where stated otherwise. Where trading is efficient and no constraints are placed on land-use change, the results for any allocation mechanism are the same because trading is sufficiently flexible for the most-profitable pattern of land use and land management to be attained. However, the distributional impacts vary depending on the way that entitlements are allocated.

14. Key findings for the efficient-trading outcome include:

(a) Modest increases in catchment profit due to changes in land use and land management. Profit increased by 14% and 15% when land-use change was limited at 5000 ha and optimised, respectively.

(b) Increased area of plantation forest due to its lower levels of nitrogen loss. Forest area increased by 61% and 85% when land-use change was limited at 5000 ha and optimised, respectively.

(c) Reduced incentives for intensive dairy farming due to its high nitrogen loss. Limiting nitrogen reduced optimal dairy area, cow numbers, urea application, and supplement use by 39, 37, 56, and 27%, with unconstrained land-use change.

(d) Increased need for dairy farmers to purchase nitrogen entitlements to remain economically viable. The ability to transfer entitlements allowed nutrient-efficient dairy systems to be sustained.

(e) Trading frictions may occur in the market for nutrient entitlements. Catchment profit decreased by around 5% with frictions, mainly because landowners could not purchase sufficient entitlements to optimise land use.

(f) Increase in the price of nitrogen entitlements from \$118 and \$60 kg $N^{-1}$ in the 5,000 ha and optimised land-use change scenarios, respectively, to \$444 kg $N^{-1}$ when frictions existed in the entitlements market. This demonstrated that trading frictions could compromise the purchase of nitrogen entitlements by producers and the incentives fund.

(g) Uneven distribution of financial impacts across sectors and the catchment. Different allocation mechanisms created further variation. Dairy farms must purchase nitrogen to continue operating in all scenarios. Ssheep-and-beef farms and forestry mainly benefit from the ability to sell allocated nitrogen.

(h) Increased per-hectare income for all farmers. The biggest increases were for forestry and dairy support, mostly because dairy and drystock farmers shifted to these sectors and sold assets (e.g. livestock).

(i) The impact on dairy farm profitability was greater under allocation mechanisms that involved more re-distribution of nitrogen entitlements (such as natural-capital and equal-allocation mechanisms). This reflects dairy farmers having to purchase more entitlements to remain in dairy production.

15. These conclusions would vary if the input data for profit and nitrogen-leaching rates were altered. As examples, changes in the milk price could be expected to change farm profit, while an update of Overseer could change nitrogen-loss data. The impact of the former is limited by using average prices.

**Summary of analysis:**

16. My evidence confirms that the modelling approach undertaken is consistent with good practice.

**Basis of my opinion**

*Is the LAM framework appropriate for this form of analysis? Yes, I believe it is.*

17. In line with the LAM approach, the Parsons model described the Lake Rotorua catchment as a landscape divided into many different partitions. Each partition is described in terms of its average rainfall, its soil type, a representative farm system, and the size of that partition. This allowed a rich description of spatial and sectoral diversity, while also matching model complexity with the availability of information.

18. For each representative farm, Lee Matheson determined the profit and nitrogen-loss levels for different management strategies. These strategies were outlined in

modelling protocols developed for each sector. Developing these protocols focused discussion on the feasibility of alternative farmer responses among domain experts.

19. An alternative approach could have represented individual farms in the Parsons model. This is difficult given a lack of data, the reluctance of land owners to provide income data, model size, privacy legislation, and its high cost (Doole et al., 2011).

20. The Parsons model used an automated search process to identify the set of mitigations that maximised catchment profit for a given set of circumstances (Bazaraa et al., 2006). This approach aligns with adoption theory (Pannell et al., 2006), is common in economics (Merel and Howitt, 2014), introduces less bias than if human trial-and-error is used, and allows the efficient identification of optimal trading outcomes in complex models.

21. It is rare to test the impact of frictions in the trading of leaching entitlements. However, it is of significant practical relevance. In applied research, it is often found that the majority of farmers are risk averse (Pannell et al., 2006). Risk aversion can motivate hoarding of entitlements, as these make farms more resilient in the face of market, climate, environmental, and political variation (Robb et al., 2001; Marsh et al., 2014).

*What is the justification for the calibration method used in the Parsons model? It best reflects the context of this modelling.*

22. Calibration is the process whereby input data and/or model structure is adapted, so model output better describes reality. This includes replicating the current state and improving the realism of the predicted response to regulation. Calibration is necessary because many models—such as that applied in the Parsons et al. report—often do not include all factors that impact land-use decisions (e.g. existing skills, preferences).

23. Two primary means exist to calibrate optimisation models of the kind applied in the Parsons et al. report. One involves manipulating the relative profitability of each land-use to improve the degree to which the model reflects the current state (e.g. Daigneault et al., 2012). This method is known generally as positive mathematical programming (PMP) (Howitt, 1995). Another involves making sure that model outcomes are within the set of historical observations (Chen and Onal, 2012).

24. PMP methods involve non-statistical or statistical estimation. The first is widely applied in New Zealand in the NZFARM model (Daigneault et al., 2012). Non-statistical methods have been strongly criticised given their lack of theoretical basis

(Heckelei and Wolff, 2003), arbitrary selection of calibration data (Heckelei et al., 2012), failure to utilise data estimated outside of the current state (Heckelei and Britz, 2000), and departure from profit data estimated for each land use (Doole and Marsh, 2014). For these reasons, this approach is not employed here.

25. In contrast, statistical PMP methods are the state-of-the-art for model calibration (Merel and Howitt, 2014). However, these require rich historical land-use data and knowledge of advanced statistical-estimation techniques; neither of which were available here. Both PMP approaches are also difficult to explain to stakeholders, which complicates the use of model output.

26. The historical land-use data approach (Chen and Onal, 2012) could not be applied given a lack of data and because future land-use trends will be altered by the new regulatory mechanism (Lamblin et al., 2000).

27. The extent of land-use change that occurred in the model was instead influenced through the consideration of land-use partitions, transition costs, relative profits, market frictions, and land-use change constraints. The use of land-use change constraints was motivated by: an opportunity to link with the StAG, the limited capacity of the model to deal with some factors important to land-use change (e.g. complexity, compatibility), flexibility, transparency, ease of use, and low data needs.

*What is the justification for the equilibrium approach used in the Parsons model? It is the most efficient for this purpose.*

28. No transition over time is included in the model. This equilibrium approach is valuable for several reasons:

    (a) There was little data available that characterised how the farming population would be expected to adapt over time to different allocation mechanisms.

    (b) There was little data available that characterised how the farming population would be expected to adapt over time to variation in key drivers of management (e.g. prices, innovation, climate).

    (c) Temporal models are difficult to develop and apply, due to their size and cost (Doole and Pannell, 2008).

*What is the justification for the deterministic approach used in the Parsons model? It is the standard approach for water policy models. Other methods are more costly and difficult to apply, while also seldom providing richer insight.*

29. The model contained economic and biophysical data that is consistent with long-term averages. As such, input data is represented by a single, point estimate and not a statistical distribution. This is known as a “deterministic” approach.

30. This approach is utilised for several reasons:

    (a) It is standard in models developed for the assessment of water-quality and/or water-quantity policy. Indeed, no economic model incorporating statistical distributions for input data and a comparable level of complexity to the Parsons model has been used to assess water policy within New Zealand.

    (b) Deterministic models are easier to develop and apply than models that represent data described by statistical distributions. This makes them less costly and therefore favourable from a project-resourcing perspective.

    (c) Detailed information describing the realistic variation evident in temporal data can be difficult and/or expensive to obtain, more so than averages.

**Reports/Update**

The report was peer-reviewed (Phil Journeaux, AgFirst).

**Conclusion**

31. In my opinion, the economic model applied in the Parsons et al. (2015) report to assess the biophysical and economic impacts of different nitrogen-allocation mechanisms in the Lake Rotorua catchment is consistent with good practice.

**Appendices**

32. Parsons, O.J., Doole, G.J., and Romera, A.J. (2015), *On-farm effects of diverse allocation mechanisms in the Lake Rotorua catchment*, BOPRC/DairyNZ, Hamilton. See my evidence in chief for appendices and all references.

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