Authors' Reply to Referee #1

Major issues:

Specific comments:
L202 Were stock numbers normalized by total catchment area or by area of grassland per catchment? If the former, please comment on whether there were scenarios of under-estimation of stock density due to non-grassland area.
We added the identifier 'total' before catchment area to avoid confusion. We addressed the 2nd issue in section 5.2 where we acknowledge that "Our catchment-scale analyses limit our interpretation of specific situations, …" In this section, we also identify physiographic locations that will likely have higher livestock densities. If desired, we can add a few sentences in the Results that report maximum livestock densities at the 1 ha pixel scale.

L240 Were all the landscape variables independent of each other?
No. We report the correlations among landscape variables in section 4.1. At the end of section 4.1, we state that: "we used the following subset of minimally correlated physiographic variables for subsequent multivariate analyses: catchment slope (S_c), silt-clay percentage ($SC\%$), phosphate retention (P_{ret}), and median flow (Q_{50})."

L392 Did the sites that had positive relationships between NOx and Q coincide with those which had positive relationships between P and Q?
In terms of TP v Q, yes because almost all sites (73/77) displayed a positive relationship between TP and Q. In terms of DRP, all but 3 displayed the same pattern. We added this relationship: 'Dissolved reactive phosphorus (*DRP*) generally increased with Q for most sites, including all the same sites that displayed a positive relationship between NO_x and Q except three (GS2, HM1, HM2).'

L436 Can some explanation for the 'Nineteen of the catchments experienced significant or 'meaningful' decreases in CDOM since 1989.' be provided?
We added: "…,possibly due to the loss of wetlands across NZ."

L770 I assume a reduction in N input to streams due to increased wetland coverage would be at a pollution swap cost of increased greenhouse gas emissions. The authors may wish to consider including a comment around this.
The answer to this question is not straightforward. For wetland restoration, greenhouse gas emissions from wetlands (methane mainly, not much nitrous oxide although we don't have enough knowledge) tend to be compensated by carbon sequestration, thus in the long-term freshwater wetlands may be better than 'carbon-neutral'. By restoring wetlands with forested cover, a sink for GHGs might be provided. We also think that the area restored would be too small for GHG emissions to be an issue (*note the C sequestration from potential added trees). If the areas restored were to be substantial, we should then also consider that that area could be

converted FROM pastoral areas where animals contributing to GHG emissions could be removed (thus compensating out). A good reference for this is:
Bridgham, S.D., Moore, T.R., Richardson, C.J. et al. Landscape Ecol (2014) 29: 1481. doi:10.1007/s10980-014-0067-2
Note their conclusions: "Because wetlands provide many ecosystem services in addition to C sequestration, it is short-sighted to suggest that wetlands should not be created or restored because of their [GHG] emissions." We can discuss this in our paper, but as you see, to do justice to this complex issue would require a further paragraph in an already long ms.

Technical comments:
Note: We have rewritten the Abstract (see response to Editor), so abstract comments may no longer apply.
L16 Can a more specific phrase than 'outweighs' be used?
Changed to: has a more extensive and appreciable impact

L16-17 check grammar – missing word been i.e. ': : :been cleaned up: : :'
Corrected as suggested.

L21 Suggest reword 'from 1989 and 2014' to 'from 1989 to 2014'
Corrected as suggested.

L 22 Suggest breaking in to two sentences: 'The NRWQN consisted of 77 sites: : :'
Changed as suggested.

L26 Please clarify if 'nitrate-nitrite nitrogen' means both nitrate-N and nitrite-N, possibly by using the term 'total oxidized nitrogen'.
Changed to: dissolved oxidized nitrogen

L28 Suggest 'greatest negative impact'
Changed as suggested.

L34 Suggest rewords as ' and mobilized nutrients.'
Reworded as suggested.

L35 Suggest reword as '..expertise in fields of geospatial analysis: : :'
Reworded as suggested.

L45 and L48 Please provide appropriate references as these cause-effect relationships may not be ubiquitous
We added the McDowell et al. (2008) reference which documents these effects for rivers in general and specifically for New Zealand.

L52 Re 'Historically, water quality in rivers was managed to meet minimal standards' In rivers where? And what is meant by minimal standards?

This is a statement about global rivers in general. We realize that the reference we used was for U.S. rivers, so we added another, more global reference (Boesch, 2002) and one specific to NZ (Howard-Williams et al., 2010). We also revised the sentence to say 'minimally acceptable standards or maximum pollutant load limits.'

L84 and throughout. Suggest avoiding abbreviations in the first word of a sentence
We corrected this instance and will correct other instances in the revision.

L85 Suggest rewords as ': : :highest rates of agricultural land intensification: : :'
Reworded as suggested.

L86-87 I suggest the NZ example would be of value to other developed countries that are intensifying, and possibly of less relevance to developing countries, where point source issues may still dominate water quality problems. Please consider.
Good point. We believe it is relevant to both developed and developing countries. Thus, we removed 'some developing.'

L123 suggest adding words for clarity ': : :..(NRWQN), which is operated and maintained by: : :'
Added as suggested.

Table 1 An added column containing references to the methods used to analyse each parameter would be helpful.
Analytical methods for all variables can be found in one reference: Davies-Colley et al. (2011). We added to the Table 1 caption: Details on analytical methods can be found in Davies-Colley et al. (2011). We can add an extra column detailing each method, but it would make this table much larger, equivalent to one full page.

L147 Which DEM is referred to as 'This DEM: : :'? and why was rescaling from 25m to 30m resolution required?
We added that we rescaled 'in order to align with other gridded spatial datasets.' We also clarified in the next sentence that 'This 25-m DEM …'

L150 Please describe the River Environment Classification (REC, v2.0) to the extent that your methods can be repeated by a reader.
This is a publically available dataset, described by Snelder et al. (2010). We added: "…,the national hydrography dataset derived from a 30-m hydrologically correct DEM (Snelder et al., 2010)."

L153 Suggest italicising 'sensu'
Italicized.

L154 Suggest reword as 'ratio of the total length of REC streams to catchment area..'
Reworded as suggested.

L169 Please define 'annual water yield'
We clarified that this is: total volume of water leaving the catchment in a year.

L180 Please clarify the meaning of ': : :and maps land use for 2008 and 2012 as well for 12 classes.', particularly re 12 classes of what?
We revised the sentence as follows: "Accordingly, LUCAS uses 1990 as its reference year and maps land use in 12 classes for 2008 and 2012."

L191-192 Past tense if probably appropriate here.
Both sentences converted to past tense.

L210 Suggest reword as 'Land disturbance, defined here as bare soil, : : :'
Revised as suggested, but added "Land disturbance, defined here as bare soil resulting from vegetation loss, …".

L212 Can you describe the extent to which you, or de Beurs et al (2016) ground-truthed the disturbance index against measures of bare soil, to give the reader confidence in the method?
We added the following to the end of section 3.3: MODIS disturbance data were visually validated against 7500 random pixels from Landsat imagery and corresponding 15 high resolution Orbview-3 and Ikonos images. The overall accuracy of the disturbance index based on Landsat data was 98%.

L231-232 Please clarify what is meant by 'actual values' in this context.
We meant correlation parameters (Pearson's r values), but recognize this as written, was confusing. We have removed this term to avoid confusion.

L371 and 372 Please clarify – COND and pH decreased with increasing Q?
The word 'increasing' was added to both sentences for clarity.

L396, 451 Check spelling of phosphorus
Corrected both of these, and L445 as well.

L513. Which four nutrient variables are referred to here?
The four nutrient variables in Table 8, which is referenced at the end of the sentence. For clarity, we added: "Dissolved oxidized nitrogen (NO_x) was not proportional to PF, or any other independent variable in the stepwise regression."

Figure 5 What does the direction of the symbol arrows mean? Also, I suggest using the explanation in the text 'catchments that exceed ANZECC guidelines for DRP are indicated in by grey-filled markers' rather than the current caption text because the latter is hard to understand.
Figure caption revised as suggested. Explanation of arrow direction was also added: "Arrows indicate direction of trend over the 26 years inclusive from 1989 if significant (dashed) or meaningful (solid). No arrow means the trend was not significant."