

Reply on review of our manuscript HESS-2015-235 "High-frequency monitoring reveals nutrient sources and transport processes in an agriculture-dominated lowland water system" by Anonymous Reviewer #1

We would like to thank Anonymous Reviewer #1 for his effort reviewing our manuscript and his valuable comments which we will take in full consideration in improving our paper. Our replies to his comments are listed below.

Major comment

The study is about how to manage potential eutrophication in a highly-managed Polder system, using high-resolution monitoring. Unfortunately, this monitoring was only carried out from October to April, and so they have completely missed the period when high nutrients may pose a threat by impairing the ecology or causing algal problems. This issue needs to be addressed. What are the implications of not monitoring during the period when bloom risk, biological nutrient uptake and denitrification are at their peak? This seriously reduces the impact of this study.

We agree with reviewer #1 that the half year period of high frequency data are short for allowing a clear explanation of the hydrogeochemical behavior of the polder. The reason behind this half year period was that we started the measurement in Oct. 2014. At time of writing the manuscript, we only had data for a half year. However, we have continued the monitoring during and after writing of the manuscript until Oct 2015. So, at the moment we have a full year of high-frequency nutrient concentration at the polder outlet and we used this data series in the revised manuscript. Shortly, the NO₃ concentrations dropped to almost zero during April and continued to stay low until intensive precipitation events in August. TP concentrations gradually increased from begin June until the end of August and dropped upon the precipitation event in August.

We also have measured suspended sediment continuously (via turbidity) with an OBS sensor combined with SS measurements on grab samples and Total Reactive P during the period Oct. 2014-Oct. 2015. Our original idea was to write second, more hydraulically oriented paper with a focus on erosion and sedimentation of suspended sediment and P from the channel sediment. We realize that not including this data in our manuscript weakens our environmental interpretation of the nutrient behavior in the system and, therefore, added the suspended sediment data and TRP data to the revised version of the manuscript in support of our findings.

Minor comments

8338.4. I'm not sure that this study is highly relevant. It is very site specific.

Highly relevant is a general statement that for improving the water quality it is important to gain insight in the hydrochemical function of the catchment. To our opinion this applies to all type of catchments, whether these are managed or not. In this manuscript we focus on the importance of short-scale events as thaw and rainstorms but also on seasonal dynamics on nutrient dynamics in an agricultural-dominated lowland catchment. This type of catchments can be found in many delta areas worldwide. Increasing system knowledge in such areas is therefore relevant.

8338.11 Change to *"losses via field drains after intensively...."*

Agreed and changed to *"losses via tube drains after intensively...."*

8338.18. Change to *"The rainfall induced. ..."*

Agreed and changed accordingly.

8338.20. Change to *"but this may be then buffered". This study does not directly monitor the drain outputs and the data does not fully support this statement.*

Agreed and changed accordingly.

8338.22. Change highly to *primarily.*

Agreed and changed accordingly.

8339.1. Change loads to *concentration*

To our opinion it is the nutrient loads that matters when considering thread functions of water bodies. Nutrient concentration can be seen as result parameters of loads in combination with biological nutrient uptake or release processes. For instance, dissolved P concentration can be low during spring algae blooms because it is all taken up by the algae. Therefore, we prefer to use loads in this sentence.

8339.3. *Reference needed.*

Agreed, we added a reference to Bouwman et al. (2013)

8339.5. Change to *"Aim to improve water quality"*

Agreed and changed accordingly

8339.7. *What other sources? Sewage effluent is a major one that doesn't get mentioned in throughout the paper.*

We rephrased this into *"other sources like sewage effluent"*.

There is a wastewater treatment plant located within our study area. The effluent discharge is with an average of 0.35 m³/sec low compared to the discharge from the polder. The TP concentration in the effluent is maximal 0.5 mg/l. The TP load from the wastewater treatment plant to the Lage Vaart in the period Oct-Apr equals approximately 2700 kg compared to the export load from the Lage Vaart to the Markermeer of 10500 kg in the same period. For NO₃ this equals 8100 kg and 308000 kg NO₃-N. There are no other sources of sewage effluent like septic tank to the surface water within the Lage Afdeling drainage area. We added this to the M&M section 2.1 and discussed the limited impact of sewage in section 4.1.

8340.20 *"has revealed the presence"*

Agreed and changed accordingly.

8340.23. *Managed, rather than human controlled?*

Agreed and changed accordingly.

8340.26. A scientific paper shouldn't really be referencing Wikipedia as information source.

Agreed we removed this reference.

8341.9. Algal growth is another potential mechanism for nutrient retention.

The residence time of water have an impact on all kinds of nutrient retention mechanisms, whether they are biological, chemical or hydrological. This sentence is not meant to given an overview of these kinds of mechanisms. We rephrased this sentence into: "which may impact biogeochemical or hydrological in-stream processes controlling nutrient retention".

8342.15. A confining layer of what? Nearly nil? How long is the main river channel?

We rephrased this sentence into: "The geohydrology of the Flevoland polder area is generally described by a confining clay layer of Holocene origin, with a thickness of less than 0.5 m in the northeast to over 7 m southwest".

8342.19. Is ripening an accepted term? I haven't heard it before.

Soil ripening is, to our knowledge, an accepted term to describe soil formation after land reclamation. A soil ripening index is developed by Kim et al. (1993).

8343.22. Why didn't they do high-resolution monitoring through the spring and summer months? This is a major omission.

See response on major comment.

8344. The method descriptions are overlong and need to be reduced.

We reduced the method description.

8345.7. Change Transparency to turbidity?

The Secchi depth was measured in the field so transparency is to our opinion correct.

8348.14. Seasonal, rather than mid-term?

Agreed and changed accordingly.

8348.20. This is where summer data would really strengthen the paper.

We agree with this, see our reply to the major comment

8349.10. Change to decreased during wet periods to a concentration of approximately.

Agreed and changed accordingly.

8348.15. There is an increase in TP concentration during low flow. What are the sources? This may indicate that there are point inputs. Does the polder receive any sewage effluent from septic tanks and wastewater treatment plants? Whether they are present or not, this should be mentioned in the site description.

See comment before. The effect of the WWTP on the TP concentration at the pumping station seems to be limited. The Lage Vaart channel is with a cross section of 100 m² rather large compared to the WWTP effluent load. Between the WWTP and the pumping station the discharge from the nature area Oostvaardersplassen enters the Lage Vaart (location 6 in Figure 7). This discharge is three times larger than the discharge of the WWTP. This implies that there is limited flow of the WWTP effluent towards the pumping station during no pumping conditions which is also shown by the low NO₃ concentrations during no pumping conditions. The increase of TP during no pumping condition can be related to the discharge from the Oostvaardersplassen. This water has relative high TP concentrations (Fig. 7). We added the paragraph below to the discussion section 4.1.2:

“The effect of the WWTP on the TP concentration at the pumping station seems to be small. During no pumping conditions there is limited flow of the WWTP effluent towards the pumping station. The discharge load from the channel that drains the nature area Oostvaarderplassen enters the Lage Vaart between the WWTP and the pumping station and is 2 to 3 times higher than the WWTP discharge load. This induces a small water flow in de opposite direction of the pumping station during no pumping conditions. The discharge water from the Oostvaardersplassen has relative high TP concentrations (Fig. 7) and may contribute to the increase in TP concentration at the pumping station during no pumping periods”.

8351.3. The increase in TP during cold weather is a really interesting observation. It may also be due to river biofilms detaching from surfaces and entering the water column. This was observed in the River Frome, UK in Bowes, M.J., Smith, J.T., Neal, C., 2009. The value of high-resolution nutrient monitoring: A case study of the River Frome, Dorset, UK. J. Hydrol., 378(1-2): 82-96.

This is an interesting observation and this could be a source of the increase TP concentration but to our opinion this does not influence the NO₃ concentration and conductivity of the channel water in the range that we have measured. Together with the changes in NO₃ and TP concentrations, an increase of the turbidity (from 8 to 57 FTU), a decrease in the TRP concentration (from 0.06 to 0.02 mg P/l) and decrease of the conductivity (from 235 to 122 mS/cm) (Fig. S1) was observed. To our opinion this strongly points to soil surface runoff and transport of particulate P. However, we discussed this in the revised version of the manuscript.

8354.5 Natural or urban areas. Could the decrease be due to denitrification?

This sentence describes the winter situation. Denitrification is limited then.

8355.20. Is it really all agricultural? Could there be any other potential NO₃ inputs from sewage?

The NO₃ load from the WWTP is limited compared to the NO₃ load from the polder to the Markermeer. We added this to the manuscript. The low NO₃ concentrations during the summer months (April-August) indicate that NO₃ input from sewage to the surface water is also limited.

8356.28. Delete levels

Agreed and changed accordingly

8357.10 and 11. Change from half to mid-November.

Agreed and changed accordingly

8357.27. If the nitrate is being transported rapidly via interflow and tube drains, why does it take 5 days to get maximum NO₃ concentrations? Doesn't this imply that nitrate delivery to the pumping station is via a much slower route? The Lage Vaart river stretch appears to be only approx 12km

long, so the nitrate signal at the pumping point should occur extremely rapidly after rainfall. I'm therefore not sure that your conclusions about tube flow are correct.

This statement might indeed be somewhat confusing. The flow velocities in a polder area are maximised by the capacity of the pumping station. This results in a delay between rainfall and peak concentrations at the pumping station. The 5 days is the average travel time of the water in the field ditches, sub-channels and main channels. Van den Eertwegh (2002) calculated a mean annual residence times of water in the Lage Vaart main channel of 6.6 days. Catchment mean residence times of water vary strongly upon precipitation events and are much shorter after wet conditions (van der Velde et al., 2012). As a consequence, the residence time in the main channel is shorter during wet conditions. If we only look at the volume of Lage Vaart main channel and pretend that there are no connecting sub-channels between the pumping station and the agricultural area it took already more than one day with continuous pumping to refresh all the water in the channel stretch of approximately 12 km between the pumping station and the beginning of the agricultural area. We added this statement and this reference to the manuscript.

8362-3. Very wordy. Lots of repetition.

Agreed, we shortened this section

Figure 1 is very unclear and needs improving. The town names are illegible. It is unclear that the area to the north of the map is lake / sea. The numbered monitoring points are not referred to in the text. Do these towns have wastewater treatment works? If so, please add them to the map.

Agreed and changed accordingly

References

- Bouwman, A. F., Bierkens, M. F. P., Griffioen, J., Hefting, M. M., Middelburg, J. J., Middelkoop, H., and Slomp, C. P.: Nutrient dynamics, transfer and retention along the aquatic continuum from land to ocean: towards integration of ecological and biogeochemical models, *Biogeosciences*, 10, 1-22, 10.5194/bg-10-1-2013, 2013.
- Kim, D. J., Feyen, J., Vereecken, H., Boels, D., and Bronswijk, J. J. B.: Quantification of physical ripening in an unripe marine clay soil, *Geoderma*, 58, 67-77, [http://dx.doi.org/10.1016/0016-7061\(93\)90085-Y](http://dx.doi.org/10.1016/0016-7061(93)90085-Y), 1993.
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