

Initial Response to Reviewers 1 and 2

Determination of vadose and saturated-zone nitrate lag times using long-term groundwater monitoring data and statistical machine learning

Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2020-169>, 2020.

We are grateful to the reviewers for their thoughtful comments, which will improve the paper. Our initial responses to the first two reviews are indented below and shown in blue text.

We also note that the following disclaimer should be applied to the discussion paper:

This draft manuscript is distributed solely for purposes of scientific peer review. Its content is deliberative and pre-decisional. Because the manuscript has not yet been approved for publication by the U.S. Geological Survey (USGS), it does not represent any official USGS finding or policy.

Reviewer 1

Geology/Hydrogeology is missing. Provide a hydrogeological map, cross section, hydraulic characteristics of the aquifer etc.

In the revised manuscript we will provide a cross section similar to those available in other publications focused on the Dutch Flats area. We will also add additional hydrogeological descriptions in the text.

Add more information about nitrate and its processes.

In the revised Section 2.1 (Site Description) we will include more denitrification information, including more detail on findings from prior research in the area. Previous work suggests that denitrification is not extensive in the groundwater in this area.

Fig1. Change the maps. The figure needs to be more attractive. Add coordinate system.

We will update the figure to include graticules. The figure includes a colored topographic map with appropriate symbology and detail necessary for the paper. We are uncertain what is meant by the suggestion to make the figure more attractive (e.g., overall figure should be changed?, improve resolution?, other?). We will also add a north-south vertical section showing the extent of the aquifer and schematic of groundwater flow directions.

The literature is out of date.

We agree, as publication of machine learning models has recently been very rapid. We will update the manuscript with literature that has been published while the manuscript was in review.

Discuss the role of Nitrate isotopes for future contribution in this concept. Recent article provide the interaction between surface and groundwater bodies using nitrate isotopes which might be helpful in future works.

We are aware of some studies involving statistical approaches and N and O isotopes (e.g., <https://doi.org/10.1002/2015WR018523>; <https://doi.org/10.1016/j.jconhyd.2015.07.003>) but are unsure if these are the articles referred to by the reviewer.

In general, nitrate isotope ratios in the aquifer are fairly uniform (e.g., $d_{15}N = +4 \pm 2$ per mil) and consistent with recharge beneath fertilized agricultural land elsewhere. Previous work indicated a possible minor downward increase in $d_{15}N$, which could be related to different recharge sources or historical changes in fertilizer/manure ratios. Evidence of denitrification (from dissolved gases and isotopes) was mostly limited to some of the deepest wells near the bottom of the aquifer. The effect of major canal leakage is considered largely to be nitrate dilution (i.e., relatively little nitrate addition, at least from the upgradient canals). Additional isotope data might be useful for documenting temporal shifts in recharge sources, or irrigation return flows to the river; however, it is difficult to know exactly the location or size of the contributing area for each well, especially the deeper ones. We will clarify some of these points, though a detailed discussion likely is beyond the scope of this paper.

Reviewer 2 (Scott Gardner)

The study presents the environmental setting well in terms of soil, climate, and land use, however, more specific information (cross-sections or maps) on the geologic setting would be useful in evaluating spatial variability in lag times.

In the revised manuscript we will provide a cross section similar to those available in other publications focused on the Dutch Flats area. We will also add additional hydrogeological descriptions in the text.

The distance between the monitoring wells evaluated and the screens that are sampled to the sources of nitrate (probably fields) are not touched on in the manuscript and might be useful in explaining variance in lag times. Perhaps land use might also be important to consider nearby the wells, as interception, evapotranspiration, and other land use specific processes could be relevant to nitrate lag times.

Thank you for pointing this out. We do note some general trends over larger spatial areas, where wells north (upgradient) of the canals are lower in nitrate due to the absence of row crop production. The vast majority of wells are surrounded by agricultural fields, and we are lacking detailed year-to-year records of fertilizer application or crop production. We do focus in the paper on the proximity of wells to irrigation canals, which have been shown in past work to substantially impact groundwater nitrate concentrations due to focused recharge of lower-nitrate groundwater. We will add a couple additional sentences to the manuscript to expound on this information.

line 17 - I am not sure you need to include the part about it not being common to have unsaturated velocities slower than saturated, this has been the case in other studies and is not out of the ordinary (fractured bedrock aquifers, karst, etc.)

We agree that there are environments where this might be expected. We will clarify that this statement is a generalization for unconsolidated surficial aquifers receiving distributed recharge.

line 79 - perhaps provide a reference explaining the importance of canals in the region for readers that are not familiar with the study area.

Although documented extensively elsewhere, we will insert a brief comment to emphasize the importance of the canals. The impact of canals will also be illustrated in a new figure summarizing the hydrologic setting. Thank you for pointing this out.

line 107 - here and everywhere after it is not clear what is meant by screen length, is this the depth bgs that the screen begins, or the size of the screen?

In the revised manuscript we will define this as "length of screened interval."

please clarify line 157 - what is meant by 'bootstrapped' readers which are unfamiliar with computer science jargon may have trouble with this please clarify.

In the revised manuscript we will define this term.

line 234 - what was the reasoning behind selecting 1 standard deviation for an acceptable range of results? If this selection was arbitrary then it should be made clear.

In the revised manuscript we will note that the range based on 1 standard deviation was considered a reasonable range of recharge rates that might be considered based on prior research in the area.

figure s1 please change the colours on the nitrate concentrations to better contrast the results

Figure S1 will be updated to provide more distinction between the different results.