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Dear Ms. Stormo,

Please find attached my peer-review of the staff report. In particular, I address the questions outlined in my charge document. I assert that I have no conflict of interest.

Sincerely,

Alexandria Boehm

Digitally signed by Alexandria Boehm
DN: cn=Alexandria Boehm, o=Stanford University, ou=Dept Civil and Environmental Engineering, email=aboehm@stanford.edu, c=US
Date: 2010.09.09 22:47:07 -07'00'

1) Use of the USGS study as the main scientific basis for the proposed Basin Plan Amendment.

The use of the USGS study is sound. The authors of the USGS study have compiled available historical water level and nitrate data and have shown that nitrate levels have increased in specific units of the aquifer since water was imported and used to augment the aquifer. Spikes in nitrate are evident in the portions of the aquifer where water levels have risen due to artificial recharge. Spikes are coincident with the recharge events.

Although it would have been nice to have even more historical water level and nitrate data, they simply do not exist. The available data are sufficient to logically conclude that increases in nitrate were concurrent with the water level increases due to recharge in portions of the aquifer.

The USGS team used multiple lines of evidence to explore whether or not nitrate in the groundwater is from sewage: they used chemical tools (isotopes, organic compounds, chloride), historical data sets, and modeling (including simple models and sophisticated models). The chemical analyses allowed the formulation of mixing diagrams that show the mixing of imported water, septage and naturally occurring groundwater in portions of the aquifer. The presence of caffeine and pharmaceuticals, even at very low levels, suggests that septage is present in the groundwater. The isotopic analysis of nitrate indicated that samples with the highest levels of nitrate were consistent with a septage source. All these techniques are state of the art and standard. There are not additional techniques that are presently in use to identify source of nitrate in groundwater that could have been used.

The USGS report is well written, logical, and scientifically sound. Its use is appropriate as a scientific basis for the amendment.

2) Modeling used in USGS study.

Two types of models were used in the report. Mixing models were used in the form of mixing diagrams to assess what waters compose the high nitrate groundwater, as well as simple mass balance models to test whether mixing of the groundwater with septage would give rise to concentrations observed. Sophisticated numerical models based on mass balance that account for convection, dispersion, etc were used for prediction of water level and nitrate in the future. Below, I will discuss the numerical models and their application as the mixing models are discussed later.

The numerical modeling used in the USGS study is state of the art. Authors used MODFLOW-96 and MOC3D for groundwater flow and solute transport, respectively. The models were used in two ways: first to model historical observations and test the understanding of the mechanism of contamination, and second to predict the effects of new conjunctive uses of the Yucca Valley aquifers on nitrate concentrations and water levels. MODFLOW predicted water level quite well when simulations were compared to measurements in the aquifer. Trends in nitrate and nitrate levels were predicted

reasonably well with MOC3D. Even though there is a paucity of data to compare the models too, the available data are predicted well. The success of the model indicates the conceptual model where the rise in groundwater levels due to recharge entrains septage in the unsaturated zone and causes elevated nitrate is appropriate.

The authors used trial and error to chose some model parameters and openly admit that the result is that the model is probably not the only model that could be developed to predict water level and nitrate concentrations. However, the ability of the model to predict historical water levels and nitrate concentrations given inputs from septage, irrigation, and imported water provides a strong piece of evidence septage is the source of nitrate in the aquifer. When the modeling results are considered in light of the rest of the evidence provided in the USGS report, it strongly supports the idea that septage is the source of nitrate in the aquifer.

3) Adequacy of data used in the USGS study.

The data collected and mined for the USGS study together are adequate in supporting the conclusion that septage is to blame for the high nitrate levels in the aquifer in the Warren Subbasin. The authors used state of the art techniques to measure chemical constituents. They showed anthropogenic chemicals, albeit at low concentrations, in the aquifer. They showed high delta-N15 values consistent with a septage source. The use of organic carbon and fluorescence was inconclusive. It would have been nice if the authors had more delta-N15 data for the septage end-member, but scientists agree that sewage has a high delta-N15 of nitrate, so there is not a huge need to better characterize the end member. Nitrate to chloride ratios also point to septage as a source of pollution. These data, taken together with the time series data on nitrate and groundwater level, and the modeling simulation results, support that septage is a source of nitrate to the aquifer.

4) Relationship of septic tank discharges to ground water recharge efforts used in the USGS study.

The USGS authors present two conceptual models to explain how septage could be causing the high nitrate levels in the groundwater and why the nitrate became elevated when the groundwater rose. They provide sufficient evidence and logic to conclude that the rising groundwater levels due to artificial recharge have entrained nitrate rich septage in the unsaturated zone. They show that assuming reasonable vertical migration speeds of 0.07 to 1 ft/d, it would take the septage 1.2 to 17 years to reach the aquifer. However, high nitrate was not seen in the wells in the subbasin until well after this, which suggests that vertical migration of the septage was not the cause of the high nitrate levels[1]. The authors go on to show that given the volume of pore space in the unsaturated zone, the septage discharge to the subbasin could be held up in the unsaturated zone. In addition, the timing of the increase in nitrate was coincident with the commencement of the artificial recharge program. The authors conduct a simple mixing cell model to determine

[1] A comment later in this report refers to a section in the staff report that incorrectly states that nitrate increases due to vertical migration of the septage.

if the nitrate concentrations observed after recharge in the midwest and mideast aquifers began can be explained by mixing of septage already present in the pore spaces in the moisture and water with 10 mg/l nitrate as it rose to fill the unsaturated zone. The simple model predicts nitrate concentrations in the same range as those observed in the field. This simple model, together with the more complex model numerical model supports the conceptual model where the rising water levels, due to artificial recharge, entrain septage already present in the aquifer to create high nitrate concentrations.

5) Groundwater data collected subsequent to the USGS study from 2002-2010.

Data presented in appendix D of groundwater level and nitrate concentrations in the Midwest hydrogeologic unit suggests that nitrate concentrations have become lower in particular wells since the publication of the USGS report. However, nitrate is still higher than 10 mg/L nitrate as nitrate in all wells in 2010 (10 mg/L nitrate as nitrate is the background level in groundwater, and 44 mg nitrate as nitrate is EPA standard). In addition, the staff report mentions on page 26 that in 2009, nitrate at 18.4 mg/L nitrate as N (EPA level is 10 mg/L nitrate as N) was measured in the East unit, which had low nitrate at the time of the USGS report.

The data presented in the USGS report indicates that there is a large amount of septage entering the ground in the subbasin and suggests the unsaturated zone has limited ability to denitrify. I do not think that the limited data provided in appendix D can be used to logically conclude that future groundwater quality threats will not be an issue or to prove that the downward trend will continue and nitrate will decrease to less than 10 mg/L nitrate as nitrate.

Another issue that is not discussed in the USGS is the potential for waterborne pathogens to be present in the groundwater, particularly viruses. If nitrate from septage was found in the groundwater, then there is a possibility that human pathogens could also be present. Granted there are various removal mechanisms for pathogens in the subsurface, but the possibility of their presence does exist. This is something that should be looked into in the near future if possible. The staff report does acknowledge this issue, which is good and appropriate.

6) Staff Report a) Does the Staff Report omit any important issues? b) Is the scientific portion of the proposed rule based upon sound knowledge, methods and practice?

The staff report does not omit any issues. However, I think it would be strengthened with the following considerations:

A) Page 10 of the report, last paragraph. The report claims that the "downward migration of the septic system effluent locally contaminated groundwater with nitrate and pathogens" (quote is not exact). There are two problems with this sentence. The first is that the USGS report actually concluded that the most probably manner in which the groundwater became contaminated was by the water table rising due to infiltration of

State Water Project water which subsequently entrained septage in the unsaturated zone. So the description of the mechanism whereby the groundwater became contaminated is not accurately described in the sentence. Second, no data were provided in my review packet that showed elevated concentrations of pathogens in the groundwater. While I am certain they would likely be found if analyses were done, there is not a scientific basis to state this. I suggest re-phrasing this sentence.

B) Page 18, last paragraph. It would be good to point out that nitrate, besides affecting human health, also can seriously adversely affect ecosystem health. Although Yucca Valley is in the dessert and there is minimal exfiltration of groundwater, any above ground septage leakage or groundwater exfiltration into surface waters could lead to eutrophication and possibly changes in vegetation, etc.

C) Page 23, top partial paragraph. It would strengthen the report if the staff explained what lines of evidence were used in the USGS report. I would suggest something along the lines:

"USGS used multiple lines of evidence to show that septage adversely impacts water quality in the Warren Subbasin aquifer. They used historical well data (groundwater level and nitrate), as well as land use information, isotopes of nitrogen, measurements of caffeine and pharmaceuticals, as well as sophisticated, state of the art groundwater flow and solute transport models to show unequivocally that septic effluent has adversely impacted the quality of groundwater in portions of the Warren Subbasin. They also showed that continued and expanded conjunctive use of the aquifers in the future could cause high nitrate concentrations in large portions of the aquifer."

7) Additional comments on staff report.

I felt the staff report was very well written and highlights the evidence for failing septic tanks in the Yucca Valley area – something that is not covered in the USGS report. This result, in conjunction with all the evidence provided by the USGS, indicates that the proposed amendment to the basin plan is needed and scientifically warranted.