



# Watershed Protection Development Review

## Predicted Impacts from the Proposed Hays County Water Control and Improvement District #1 Discharge in Bear Creek and Barton Springs

### Abstract

*The Hays County Water Control and Improvement District No. (HCWCID1) has applied to TCEQ for a TPDES permits for discharge of 800,000 gpd of treated (5 mg/L BOD, 5 mg/L TSS, 2 mg/L NH<sub>3</sub>-N) wastewater to Bear Creek immediately downstream of US Highway 290, approximately 7.8 miles above the recharge zone of the Barton Springs segment of the Edwards aquifer. In order to evaluate the potential surface and groundwater impacts of this discharge WPDRD staff used the available flow and water quality data along with previously developed models for Barton Springs and Bear Creek. An evaluation under a variety of flow conditions was performed with respect to nutrient concentrations and dissolved oxygen levels in Barton Springs. Relative pollutant loadings to the aquifer were also estimated with and without the HCWCID1 discharge. Results of these calculations indicate that at the ultimate permitted flow and quality anticipated from the WWTP, the discharge will 1) contain 94% of the dissolved phosphorus load to Barton Springs under low flow conditions, 2) potentially push Barton Springs Pool from the oligotrophic state to a mesotrophic one, further exacerbating current nuisance algae conditions, and 3) reduce DO up to 1 ppm at low flows potentially to levels which could be harmful to the Barton Springs salamander. Using more liberal assumptions for decay and assimilation of nutrients in surface waters, these potential impacts were reduced, but still significant. All of these results support evaluation of either treatment to near background levels for nutrients and oxygen demanding substances, or reduction in the service area or development intensity to a level which would allow land application at appropriate agronomic rates for soil conditions.*

### Introduction

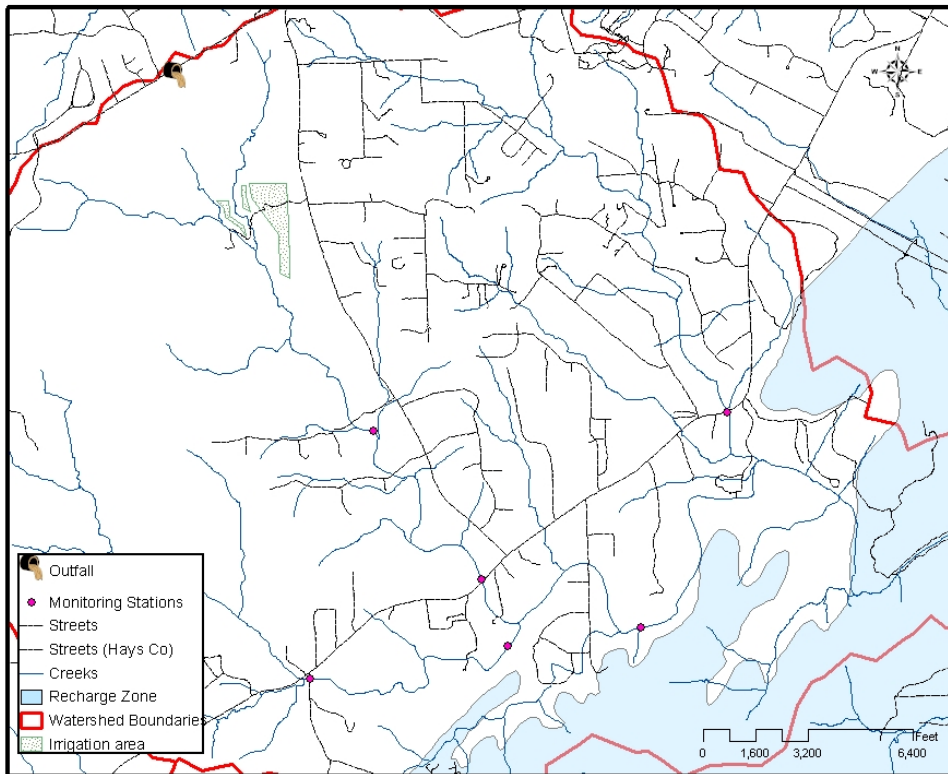
The Hays County Water Control and Improvement District No. (HCWCID1) has requested a wastewater discharge permit for 800,000 gal/day (1.24 cfs) of treated sewage. The treated wastewater would flow directly into Bear Creek immediately downstream of US Highway 290, approximately 7.8 miles above the recharge zone as shown in Figure 1. The requested Wastewater Treatment Plant (WWTP) permit limits and the pollutant load to Bear Creek are shown in Table 1. The service area for the WWTP will include the current and future phases of the Belterra subdivision and adjacent developments.

**Table 1. HCWCID1 Load from Permit Limits**

HCWCID1	Conc (mg/L)	Daily Load (lbs/day)	Annual Load (lbs/year)
Ammonia	2	12.27	4,480.99
NO <sub>2</sub> +NO <sub>3</sub> *	8.69	53.31	19,469.90
BOD	5	30.67	11,202.48
TP	1	6.13	2,240.50
TSS	5	30.67	11,202.48

*\*Not typically limited by permit, based on effluent chemical analyses by LCRA in permit application.*

Bear Creek monitoring locations and Belterra Outfall



**Figure 1. Map of the Bear Creek Monitoring Locations and the HCWCID1 Outfall**

The HCWCID1 wastewater discharge, if approved, would potentially impact the surface and groundwater resources in the discharge route including Bear Creek, Onion Creek, water wells drawing from the Barton Springs segment of the Edwards Aquifer, and Barton Springs Pool under various flow conditions. The following calculations estimate the degree of wastewater impacts to the aquifer and the concentrations in the Main Barton Springs (Parthenia) discharge to Barton Springs Pool.

### **Phosphorus and Nitrogen Loading to Aquifer**

The water quality and flow data for Onion, Slaughter, Bear, and Barton creeks were collected at USGS gaging stations located in or above the recharge zone. Nitrogen, phosphorus, and flow data from 1984 through 1996 were used in the analysis. Mean concentrations in storm flow and base flow were determined from these data as shown in Tables 2 and 3. The concentrations from Bear Creek were used for both Bear and Little Bear creeks due to the minimal amount of data available from the recently installed Little Bear USGS station. The loads to the aquifer were estimated as the sum of the loads from each recharging creek. Individual creek loads were determined by multiplying the daily observed flow by the mean concentration for the appropriate flow category (storm or baseflow) for each of the creeks. Flow was assumed to be storm flow if the daily average flow was more than one and one half times the previous day's flow (CRWR 1996). During storm flow approximately ½ of the total phosphorus is suspended (Turner, 2006). Very little of the suspended portion of the load reaches Barton Springs and thus it was not included in the calculations for the loading to the aquifer.

**Table 2. Average Concentration of Total Phosphorus 1984 - 1996**

<b>Creek</b>	<b>Mean Baseflow Total Phosphorus (mg/L)</b>	<b>Mean Stormflow Total Phosphorus/Dissolved Phosphorus (mg/L)</b>
Barton	0.009	0.170/0.085
Williamson	0.110	0.430/0.22
Slaughter	0.007	0.071/0.036
Bear (and Little Bear)	0.009	0.043/0.022
Onion	0.011	0.141/0.071

**Table 3. Average Concentration of Total Nitrogen 1984-1996.**

<b>Creek</b>	<b>Mean Baseflow Total Nitrogen (mg/L)</b>	<b>Mean Stormflow Total Nitrogen (mg/L)</b>
Barton	0.50	1.29
Williamson	0.88	2.79
Slaughter	0.59	1.39
Bear (and Little Bear)	0.61	0.92
Onion	0.55	0.68

The concentrations of nitrogen and phosphorus in Bear Creek with the permitted flow and quality anticipated from HCWCID1 were modeled using LA-Qual (an upgrade of Qual-TX). The modeling was done by James Miertschin and Associates, Inc. for the BS/EACD (Miertschin, 2006). Miertschin predicted the concentrations at the recharge zone shown in Table 4. Low flow is the HCWCID1 discharge of 1.24 cfs plus 0.17 cfs of baseflow. Flow during the wet weather scenario is 24.6 cfs at the recharge zone boundary.

**Table 4. Predicted Concentrations of Total Phosphorus and Total Nitrogen at the recharge zone in Bear Creek using LA-Qual**

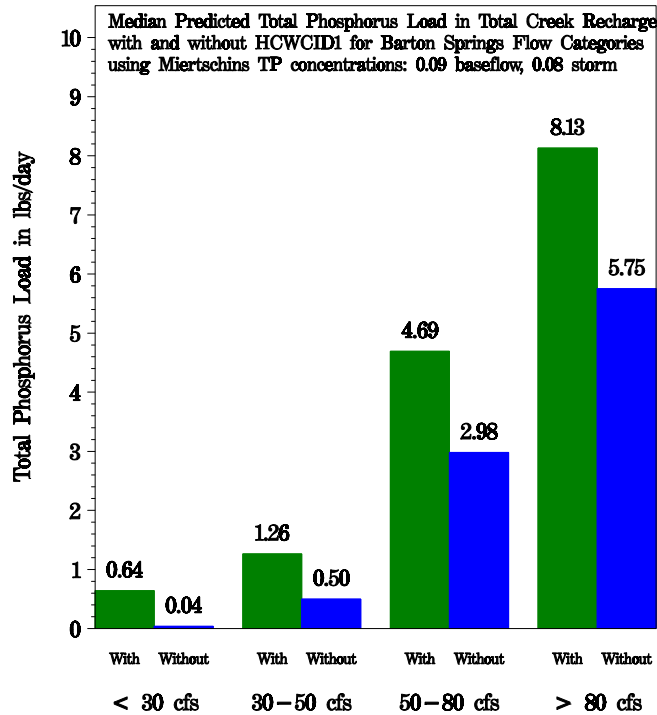
<b>Condition</b>	<b>TP in mg/L at recharge</b>	<b>TN in mg/L at Recharge</b>
Low Flow, High temperature	0.03	0.76
Low Flow, Moderate Temperature	0.09	1.66
Low Flow, Cold Temperature	0.22	3.92
Wet Weather Scenario (Max-Day; 16 cfs)	0.08 (dissolved = 0.04)	1.84

In order to use these predictions for estimating loads to the aquifer and concentrations at Barton Springs over a multi-year period, the following assumptions were made:

- 1) Cold temperature scenarios approximately balance out the hot temperature scenarios on an annual basis, so the moderate temperature condition can be used for long term estimates.
- 2) Low flow concentrations can be used as conservative estimate of higher baseflow conditions. Miertschin noted that “higher stream flow results in an increase in constituent dilution, but a decrease in load decay resulting from shorter travel times”. Model runs at higher baseflow conditions could refine these numbers.
- 3) The Wet Weather Scenario concentrations can be used for all storm flow conditions in long term estimates.

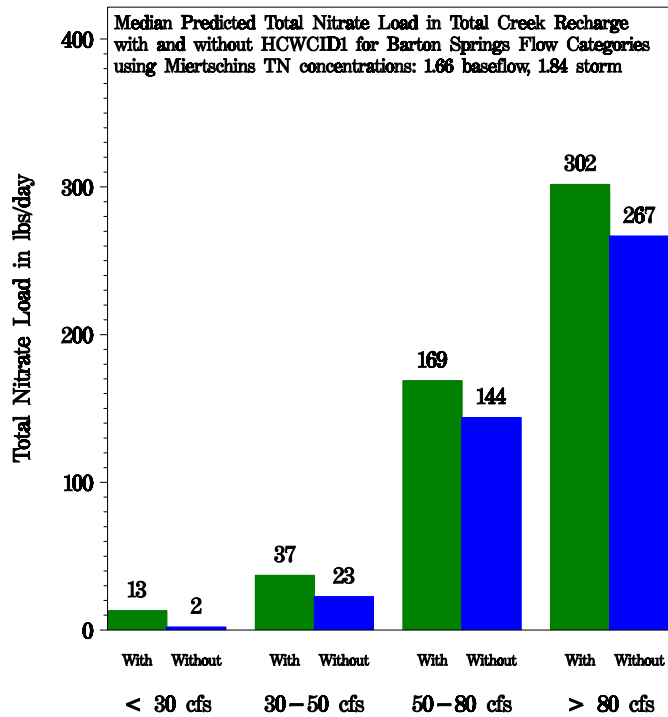
4) All of the base flow TP is dissolved and ½ of the storm flow TP is dissolved.

The total phosphorus loads to the aquifer from Onion, Slaughter, Bear, Little Bear, Barton and Williamson Creeks' recharge, with and without the HCWCID1 discharge, are shown in Figures 2 and the total nitrogen loads are shown in Figure 3.



**Figure 2.** The phosphorus load from total creek recharge to the Barton Springs Segment of the Edwards Aquifer with and without the HCWCID1 Discharge

At low flows the HCWCID1 discharge is estimated to contribute about 94% of the phosphorus load and 85% of the nitrogen load to the aquifer. At high flows 32% of the phosphorus load and 12% of the nitrogen load would be estimated to originate from HCWCID1. The low flow estimates are likely to be more accurate than the high flow estimates due to assumption 2 above.



**Figure 3.** The nitrogen load from total creek recharge to the Barton Springs Segment of the Edwards Aquifer with and without HCWCID1 Discharge

## Phosphorus and Nitrogen Concentrations at Barton Springs

A simulation model of water quality and quantity in the Barton Springs portion of the Edwards Aquifer was developed by Dr. Michael Barrett (UT Center for Research in Water Resources (CRWR)) and applied to nitrogen levels in the Aquifer (Barrett and Charbeneau, 1996). This model was adapted for phosphorus simulations by City of Austin staff with assistance from Dr. Barrett (Turner, 2006). The model was run with and without the HCWCID1 discharge to determine phosphorus and nitrogen concentrations at Barton Springs. Results of these simulations are provided in Figures 4 and 5.

Trophic status of freshwater streams and rivers can be estimated from Chlorophyll-a, total nitrogen, and phosphorus concentrations (Dodds et al. 1998). Using suggested literature concentration ranges for each trophic category, the HCWCID1 discharge is predicted to push Barton Springs Pool from the oligotrophic category into the mesotrophic category at low flows. Nitrate concentrations in Barton Springs Pool are already in either the mesotrophic or the eutrophic category. The increase in nitrate concentrations due to the HCWCID1 discharge is not anticipated to affect the algal community at the pool as much as the increase in phosphorus because phosphorus is anticipated to be the limiting nutrient except during large storms. This was determined from TN:TP ratios in historical monitoring data. While trophic status has less significance in a dynamic, semi-natural, managed pool environment, such designations are indicators of the frequency, severity, and duration of nuisance algae conditions. These are expected to increase as the trophic status moves towards eutrophic.

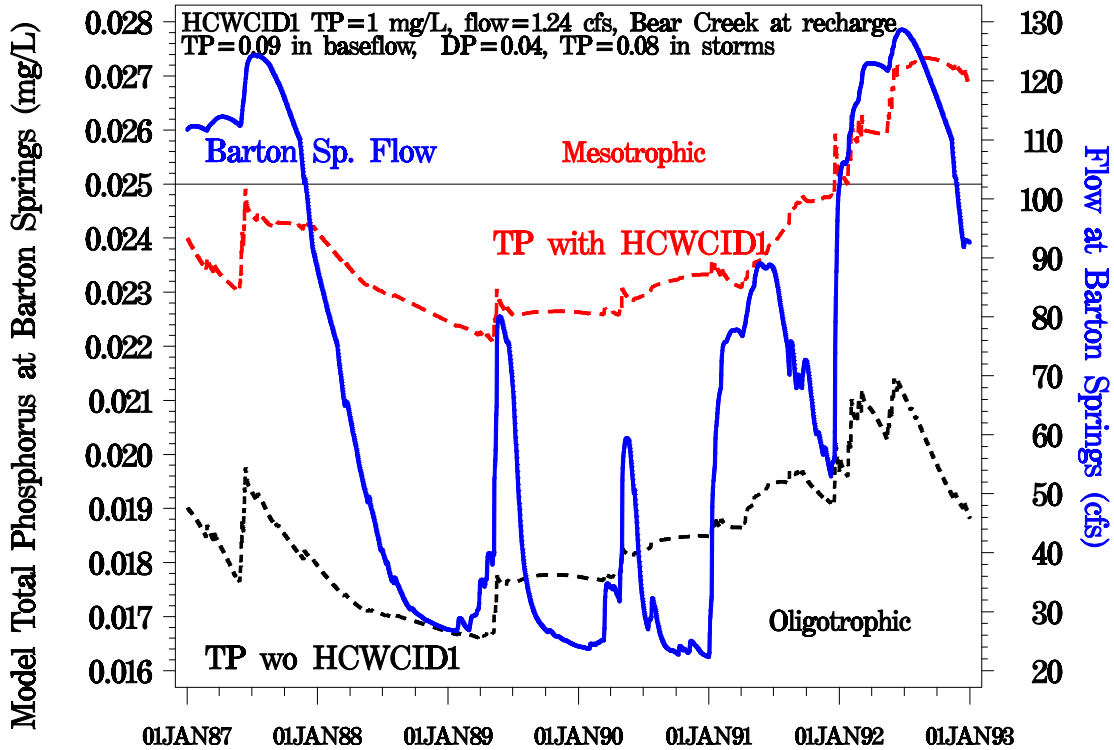


Figure 4. Predicted total phosphorus concentrations at Barton Springs from the UT-CRWR groundwater model with additional inputs from the HCWCID1 WWTP.

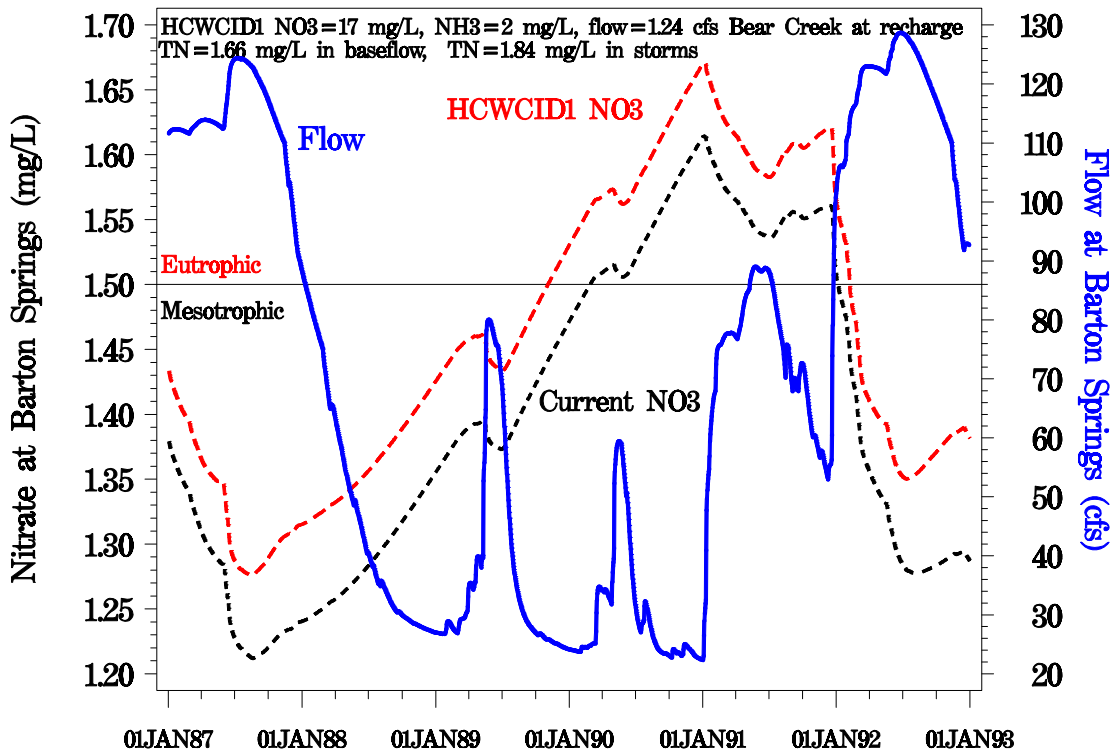


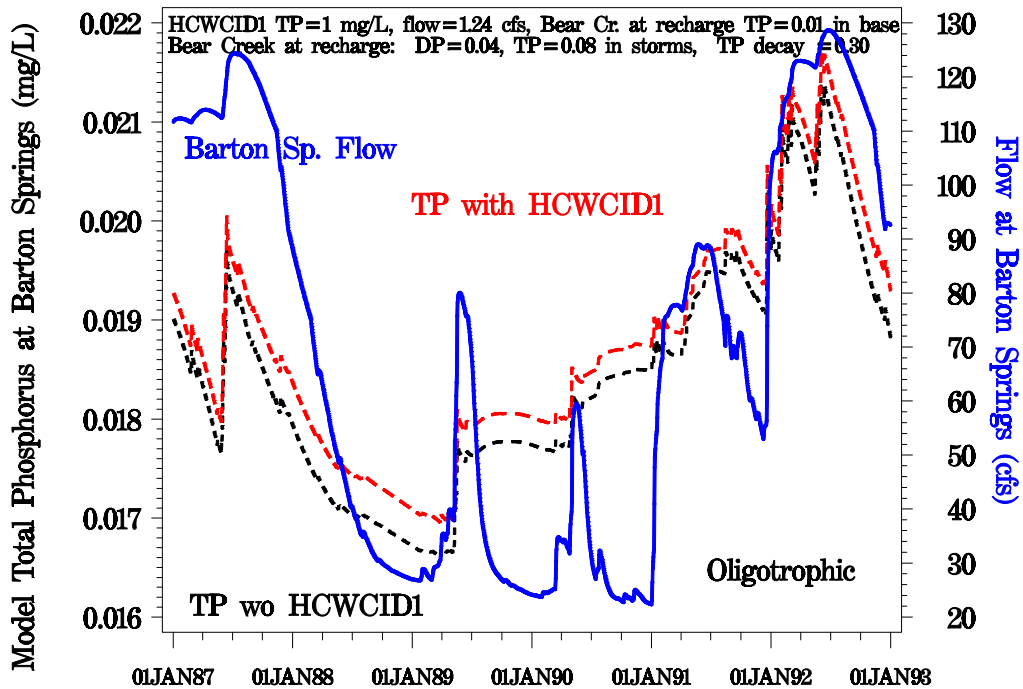
Figure 5. Predicted total nitrogen concentrations from the UT-CRWR groundwater model with additional inputs from the HCWCID1 WWTP.

## Sensitivity of Phosphorus Predictions to LA-Qual Model Decay Rates

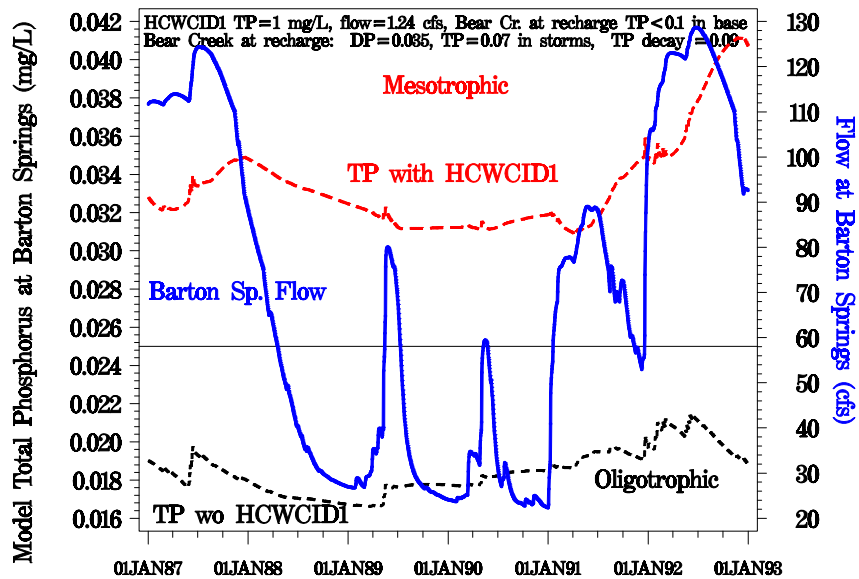
Miertschin modeled phosphorus as a non-conservative material with a first order decay rate, instead of modeling chlorophyll-a and macrophytes. The decay rate of 0.16/day was chosen. This is the mean of the total phosphorus decay rates used in five studies in Texas creeks with similar geologic and climatic conditions. To examine the sensitivity of the models to this rate, the Bear Creek LA-Qual model and the UT-CRWR groundwater model were run with the minimum, median and maximum phosphorus decay rate from the five studies and the results were compared to those using the mean decay rate. The results are shown in Table 5 and Figures 6-8.

**Table 5. Sensitivity Results for Phosphorus Decay Rate**

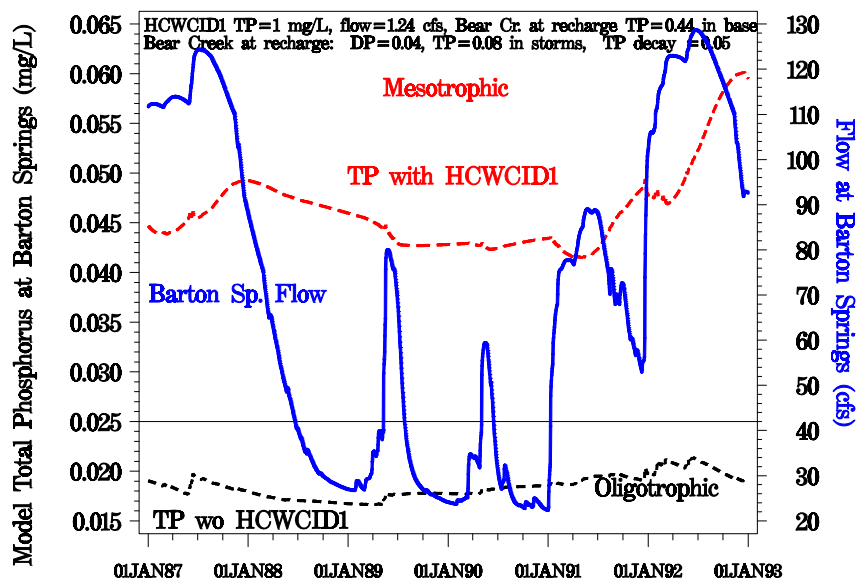
Scenario	LA-Qual Bear Creek at Recharge Zone				UT-CRWR Barton Springs
	BOD (mg/L)	DO (mg/L)	TN (mg/L)	TP (mg/L)	Average TP increase from HCWCID1 (mg/L)
Low Flow, Moderate Temperature, TP decay = 0.05/day (minimum)	1.03	8.18	1.60	0.44	0.028
Low Flow, Moderate Temperature, TP decay = 0.09/day (median)	1.03	8.18	1.60	0.24	0.015
Low Flow, Moderate Temperature, TP decay = 0.16/day (mean)	1.03	8.19	1.60	0.10	0.006
Low Flow, Moderate Temperature, TP decay = 0.30/day (maximum)	1.03	8.20	1.60	0.01	0.0003



**Figure 6.** Predicted total phosphorus concentrations at Barton Springs from the UT-CRWR groundwater model with additional inputs from the HCWCID1 WWTP with the maximum phosphorus decay rate of 0.30/day.



**Figure 7.** Predicted total phosphorus concentrations at Barton Springs from the UT-CRWR groundwater model with additional inputs from the HCWCID1 WWTP with the median phosphorus decay rate of 0.09/day.



**Figure 8.** Predicted total phosphorus concentrations at Barton Springs from the UT-CRWR groundwater model with additional inputs from the HCWCID1 WWTP with the minimum phosphorus decay rate of 0.05/day.

For the minimum and median decay rates, the Barton Springs trophic status is predicted to be mesotrophic. For the mean rate the trophic state ranges over the oligotrophic to mesotrophic, and for the maximum decay rate the pool remains in the oligotrophic state. Therefore, while it is possible due to natural buffering or local ecosystem influences not represented in the literature trophic studies that no change in algae conditions will occur in the pool, it is more likely that nuisance algae conditions will increase due to the additional nutrient loading from HCWCID1.

## BOD Loading to Aquifer and Recharge Concentrations

A linked parameter model of dissolved oxygen (DO) has not been developed for BOD/NH<sub>3</sub>-N/DO kinetics within the Barton Springs Edwards aquifer. In order to estimate an equilibrium state, or worst case condition, at Barton Springs, the average BOD concentrations entering the aquifer in total creek recharge, with and without the HCWCID1 discharge, were calculated. BOD mean concentrations in storm and baseflow were determined as shown in Table 6. For the nutrients, the loads to the aquifer were determined by multiplying the daily observed flow times the mean concentration for the appropriate flow category (storm or baseflow) for each creek and then summing for all of the recharging creeks.

**Table 6. Average Concentration of BOD 1984 - 1996**

Creek	Mean Baseflow Total BOD (mg/L)	Mean Stormflow Total BOD (mg/L)
Barton	0.36	3.45
Williamson	0.58	7.6
Slaughter	0.71	2.43
Bear (and Little Bear)	0.57	1.5
Onion	0.58	1.71

Two methods were used for estimating the discharge route decay of BOD concentrations from HCWCID1. First, the LA-Qual model predictions shown in Table 7 were used (Mierschin, 2006), and second a constant reduction was assumed (Slade, 2006).

In the LA-Qual model, the growth, death, and decay of algae and macrophytes, which would add BOD to the system were not simulated. Therefore, the LA-Qual predictions can be viewed as a lower bound on the BOD entering the aquifer.

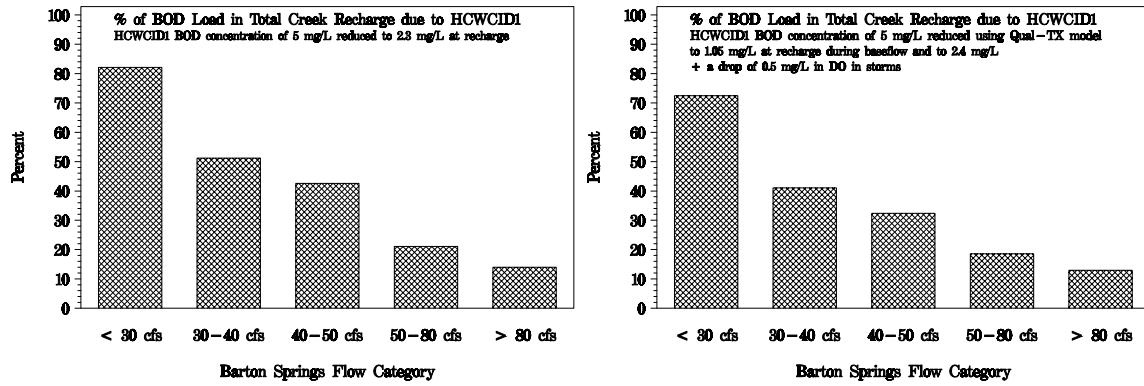
**Table 7. Predicted Concentrations of BOD at the Recharge Zone in Bear Creek using LA-Qual**

Condition	BOD in mg/L at recharge
Low Flow, High temperature	0.47
Low Flow, Moderate Temperature	1.05
Low Flow, Cold Temperature	1.89
Wet Weather Scenario (Max-Day; 16 cfs)	2.4 + drop in DO of 0.5 mg/L

In order to use these predictions for estimating loads to the aquifer and concentrations at Barton Springs over a multi-year period, the same assumptions for cold temperatures and low flow concentrations as used in nutrient predictions were appropriate. Similarly it was assumed that the Wet Weather Scenario concentrations could be used for all storm flow. Mierschin's predicted DO for storm flow is 0.5 mg/L less than the current average in storms. Therefore, the effective BOD at recharge during storms is 2.8 mg/L.

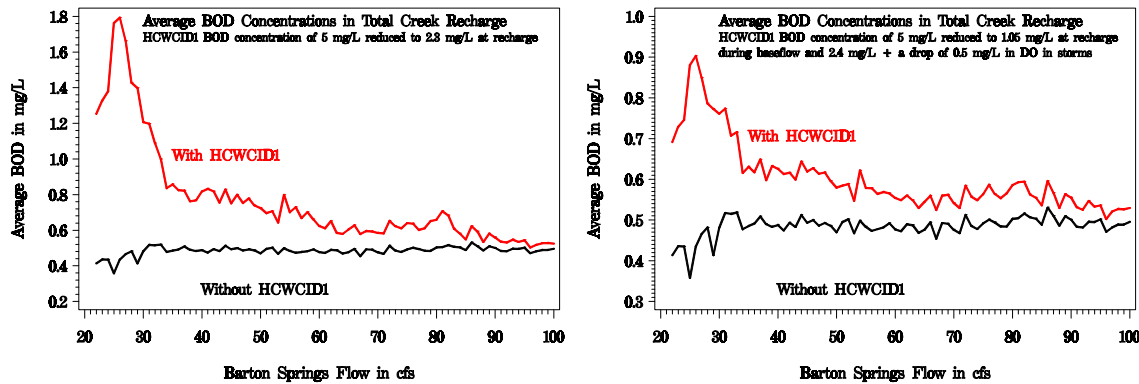
In the second method, the BOD decay was not modeled, but was estimated to decrease from 5 mg/L to 2.3 mg/L before entering the aquifer (Slade, 2006).

Due to the relatively low baseflow background loading, a high percentage of the BOD load to the aquifer would be due to the HCWCID1 discharge under both methods of calculation as shown in Figure 9.



**Figure 9.** The percent of the BOD load from total creek recharge to the Barton Springs Segment of the Edwards Aquifer which would be due to the HCWCID1 Discharge using Slade's BOD decay estimate (left) and the LA-Qual model BOD decay estimate(right).

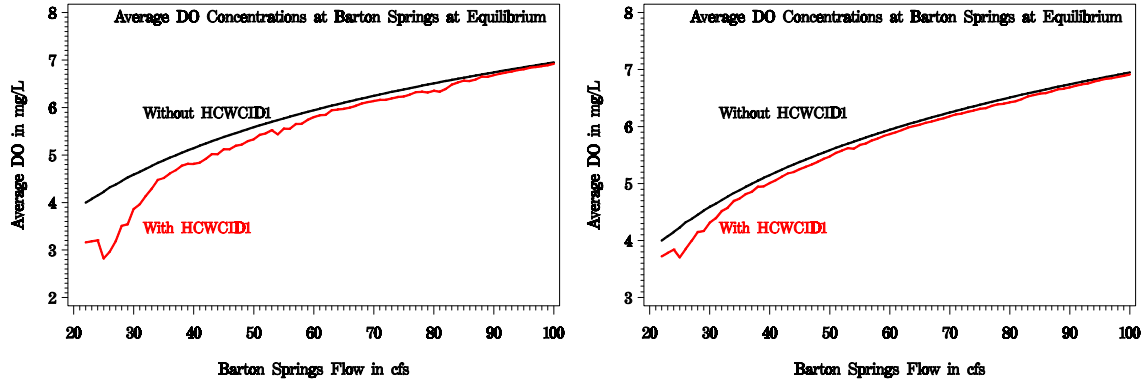
The averages of the BOD concentrations for flows from 1984 – 1996 up to 100 cfs are plotted in Figure 10. The variation shown is due to the range of storm flows across the range of Barton Springs discharge flows. The difference between the red and the black lines is the addition in BOD concentration entering the aquifer that is due to the HCWCID1 discharge.



**Figure 10.** Average BOD Concentrations in Total Creek Recharge with and without the HCWCID1 discharge using Slade's BOD decay estimate (left) and the LA-Qual model BOD decay estimate(right).

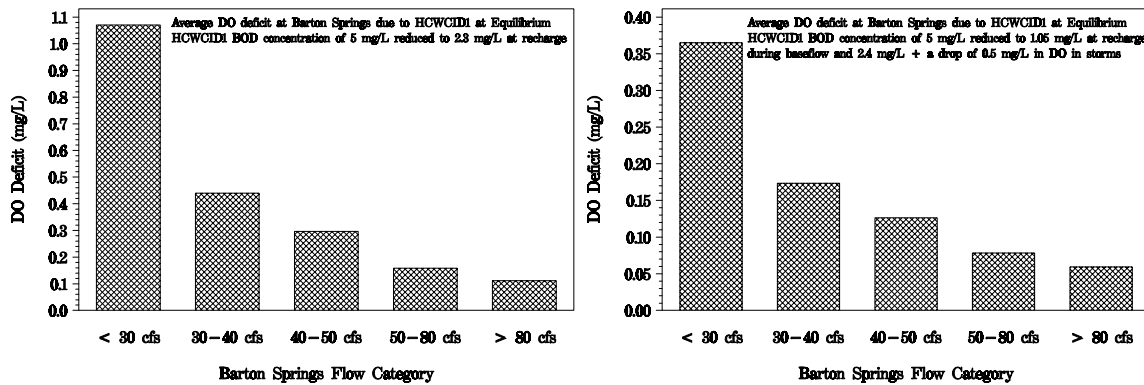
## Dissolved Oxygen Concentrations at Barton Springs

The relationship between spring flow and DO concentration at Barton Springs was documented in previous data analyses (Turner, 2004). The regression equation relating these parameters ( $DO = -2.18 + 1.98 * \log_e(\text{Flow})$ ) is plotted in Figure 11. It was assumed that, under worst case conditions, the additional BOD added to the aquifer recharge from the HCWCID1 subdivision would be consumed by microbial respiration resulting in an equivalent drop in DO at Barton Springs. Subtracting this estimated BOD from DO estimated from the regression equation provides a lower bound on the DO levels at Barton springs with the HCWCID1 plant in operation. Figure 11 shows the DO at Barton Springs without the HCWCID1 discharge and the lower bound with the HCWCID1 discharge. The actual DO should be somewhere between the black and the red line because the system is not anticipated to be in equilibrium. This is primarily because flows entering the aquifer change faster than flows leaving the aquifer. The longer the discharge at Barton Springs remains constant, the closer the DO concentrations should come to the red line.



**Figure 11.** Predicted DO Concentrations at Barton Springs with and without the HCWCID1 discharge at equilibrium using Slade's BOD decay estimate (left ) and the LA-Qual model BOD decay estimate(right). The predicted decrease in DO concentrations from the HCWCID1 discharge is a worst case or a lower bound on the DO.

To provide adequate protection for the endangered salamanders at Barton Springs worst case conditions which would occur during a prolonged drought could reasonably be assumed. Figure 12 shows the worst case DO deficits averaged over flow categories at Barton Springs. The potential drop of over 1 mg/L in DO at flows under 30 cfs represents a concern for salamander recovery which is also being evaluated in the ongoing BS/EACD Habitat Conservation Plan with respect to DO toxicity thresholds.



**Figure 12.** The worst case or lower bound DO deficits at Barton Springs due to the HCWCID1 discharge averaged over flow categories using Slade's BOD decay estimate (left ) and the LA-Qual model BOD decay estimate(right).

## Conclusions

Given the above evaluation, the HCWCID1 discharge at permitted flow and quality could

- Contribute 94% of the dissolved phosphorus load and 85% of the nitrogen load to Barton Springs under low flow conditions
- Contribute 32% of the dissolved phosphorus load and 12% of the nitrogen load to Barton Springs under high flow conditions

- Potentially push Barton Springs Pool from the oligotrophic status to mesotrophic, indicating an increase in nuisance algae conditions.
- Reduce DO up to 1 ppm at low flows, indicating an increase in potential toxicity to the endangered Barton Springs salamander..

All of these results support evaluation of either treatment to near background levels for nutrients and oxygen demanding substances, or reduction in the service area or development intensity to a level which would allow land application at appropriate agronomic rates for soil conditions.

## References

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