Abstracts of Most Pertinent Studies to Barton and Onion Creek Watershed Rule Stakeholders Meeting
January 16, 2009

Davis, J. 1986 Water Quality Evaluations and Use Attainability Analyses of Six Colorado River Tributaries - Hays, Travis, and Bastrop Counties, Texas. (Draft). Texas Water Commission, 1986.

Water quality evaluations and use attainability analyses were conducted on six Colorado River tributaries located near the Austin metropolitan area, including Gilleland Creek, Wilbarger Creek, Slaughter Creek, Bear Creek, Dry Creek, and Walnut Creek. The evaluations were conducted in response to rapid development occurring in the watersheds of these creeks and the increasing demand to utilize them as effluent receiving streams. Slaughter creek included a site 3 km downstream from the recharge zone boundary where the entire flow was observed to disappear in the streambed. It was not know at the time if this percolation contributed to the Edwards aquifer, but it was noted that this should influence treatment levels acceptable for the creek. The advanced primary production occurring in the lower reaches despite very low nutrient concentrations indicated that the creek has a very low capacity for assimilating nutrients. "Even small point source nutrient inputs might stimulate enough additional primary productivity to induce a level of alga metabolism that would cause critically low diel dissolved oxygen minima, and thus adversely impact aquatic life in the stream." Bear creek was also found to be without any point source dischargers although at the time, an application for discharge just above 1626 had been "denied by the Texas Water Commission on July 18, 1986 primarily due to the potential for contamination of the Edwards Aquifer". As on Slaughter Creek, surface water percolation into the streambed was observed shortly downstream of the Edwards Aquifer zone boundary. Nutrient assimilative capacity was also found to be very low in Bear Creek, and "point source nutrient inputs appear to pose the primary threat to existing water quality. Even minor inputs could promote excessive plant growth and result in use impairment." In general for all of the creeks evaluated, it was found that these systems are "highly sensitive to environmental disturbance, and have low assimilative capacities. Their low flow volumes provide little dilution for wastewater effluents, and result in generally sluggish flow velocities, a lot degree of instream turbulence, and low atmospheric reaeration rates. Their shallowness and high water clarity generally allows sunlight penetration to the bottom, which makes them particularly sensitive to nutrient inputs that can cause excessive proliferation of algae and associated water quality problems." Despite this conclusion, the report ends with a statement that "discharge of high quality effluent could actually enhance some intermittent or dry reaches by creating perennial flow, providing that nutrient levels aren't excessive".

Short, R.A. 1988. Final Report - Phosphorous Study on the Tributaries of the Colorado River. Interagency Cooperation Contract Number 14-70025. Aquatic Station, Southwest Texas State University. San Marcos, Texas. 25 July 1988

In this study of the water quality conditions present at 20 sites located in 7 different streams systems, considerable variation in nutrient loads and algal growth was found amoht sites. Sites with low phosphorous (<20 ug/L) in general had little or no apparent growth of filamentous algae (these included BSCZ creeks Bear, Slaughter, and Onion). Sites with moderate phosphorous (20-50 ug/L) often had extensive growth of filamentous algae and were primarily streams receiving some wastewater effluent. Higher concentrations also often had heavy growth of filamentous algae. The N:P ratios determined for these streams indicated that the potential for phosphorous limitation was extremely high. However, some of the creeks studies did turn out to be nitrogen

limited. In general, the study concluded that "Hill Country streams are not significantly impacted at the present time but do show the potential for water quality degradation in terms of excessive algal growth if nutrient levels are increased." In this study, the threshold using older clay pot techniques to determine nutrient limitations was proposed at between 50 and 100 ug/L.

Mabe, Jeffrey A.. 2007. U.S. Geological Survey (USGS). Nutrient and Biological Conditions of Selected Small Streams in the Edwards Plateau, Central Texas, 2005-06, and Implications for Development of Nutrient Criteria. U.S.G.S. Scientific Investigations Report 2007-5195. 46 pp.

During the summers of 2005 and 2006 the U.S. Geological Survey, in cooperation with the Texas Commission on Environmental Quality, evaluated nutrient and biological conditions in small streams in parts of the Edwards Plateau of Central Texas. Land-cover analysis was used to select 15 small streams that represented a gradient of conditions with the potential to affect nutrient concentrations across the study area, which comprises two of four subregions of the Edwards Plateau ecoregion. All 15 streams were sampled for water properties, nutrients, algae, benthic invertebrates, and fish in summer 2005, and eight streams were resampled in summer 2006. Streams that did not receive wastewater effluent had relatively low nutrient concentrations and were classified as oligotrophic; streams receiving wastewater effluent had relatively high nutrient concentrations and were classified as eutrophic. Nutrient concentrations measured in the least-disturbed streams closely matched the U.S. Environmental Protection Agency nutrient criteria recommendations based on estimated reference concentrations. Nitrogen/phosphorus ratios indicated streams not affected by wastewater effluent might be limited by phosphorus concentrations. Algal indicators of nutrient condition were closely related to dissolved nitrogen concentrations and streamflow conditions. Ambient dissolved nitrogen concentrations (nitrite plus nitrate) were positively correlated with benthic algal chlorophyll-a concentrations. The correlation of benthic algal chlorophyll-a with instantaneous nitrite plus nitrate load was stronger than correlations with ambient nutrients. Increased nutrient concentrations were associated with increased macroalgae cover, wider diel dissolved oxygen ranges, and reduced diel dissolved oxygen minimums. Benthic invertebrate aquatic life use scores generally were classified as High to Exceptional in study streams despite the influence of urbanization or wastewater effluent. Reductions in aquatic life use scores appeared to be related to extremely low flow conditions and the loss of riffle habitats. Benthic invertebrate aquatic life use scores and several of the metrics used to compute composite aquatic life use scores tended to increase with increasing total nitrogen concentrations. Fish community aquatic life use scores generally were classified as High or Exceptional with the exception of a few samples collected from streams receiving wastewater effluent that were classified as Intermediate. Fish community aquatic life use scores and several fish community metrics were positively correlated with nutrient concentrations and macroalgae cover. The majority of the positive correlations among nutrient concentrations, macroalgae cover, and fish metrics were strongly influenced by relatively high nutrient concentrations. Both benthic and planktonic chlorophyll-a measures were related to nutrients, but this study indicates that benthic chlorophyll-a was the better choice for monitoring nutrient enrichment because (1) the relation between benthic chlorophyll-a and nutrients was stronger, and (2) a strong relation between benthic chlorophyll-a and nutrients persisted after removal of the sites influenced by wastewater effluent, which indicates superior ability of benthic chlorophyll-a to discriminate between conditions at lower nutrient concentrations. The transect-based algal abundance estimate technique is a useful tool for identifying eutrophic conditions, assessing nuisance algal growth, and making broad comparisons among sites, but it appears to lack the fine resolution to identify lesser degrees of nutrient enrichment. Several individual benthic invertebrate and fish metrics were correlated with nutrient conditions, but correlations were generally positive and the reverse of what would be expected when nutrient enrichment causes a proliferation of algal growth and

stream degradation. However, the benthic invertebrate functional feeding group metrics showed some promise as measures of nutrient condition.

Turner, Martha. 2006. Predicted impacts from the proposed Hays County Water Control and Improvement District #1 Discharge in Bear Creek and Barton Springs. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-06-07.

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 NH3-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.

Herrington, C., and M. Scoggins. 2006. Potential impacts of Hays County WCID No. 1 proposed wastewater discharge on the algae communities of Bear Creek and Barton Springs. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-06-08.

A direct wastewater discharge has been proposed to Bear Creek in the contributing zone of the Barton Springs portion of the Edwards Aquifer from the Hays County Water Control and Improvement District No. 1 (HCWCID1) WWTP serving the Belterra and surrounding developments in Hays County. This discharge will change the flow regime and nutrient loads to both Bear Creek and Barton Springs (Slade 2006, Miertschin and Obenour 2006, COA 2006). Field and lab experiments were conducted to assess the potential alteration of the existing algal community density and structure of both Bear Creek and Barton Springs due to increased nutrient loading if the discharge permit is approved. The question of what is an acceptable level of nutrient addition to these aquatic systems to avoid nuisance algae impacts was also investigated. Periphytometers (Matlock et al 1998) were deployed in the field and sestonic algae growth bioassays (Kiesling et al 2001) were conducted in the lab in July 2006 to determine the limiting nutrient controlling periphytic and sestonic algae growth. Additional sestonic algae growth bioassays were conducted to establish a dose-response relationship for the limiting nutrient to estimate critical nutrient threshold concentrations. A light/dark bottle test (SM 10200J , APHA 1995) was conducted to provide current sestonic algae production rates for use in modeling. Results of this experimentation support the hypothesis that these water bodies are highly oligotrophic and that any nutrient additions of the type proposed by the Belterra wastewater

discharge permit will significantly increase algal productivity and likely change their current trophic status.

Herrington, C. 2008. LA-QUAL (version 8.0) modeling of potential water quality impacts to Bear Creek from proposed HCWID#1 wastewater discharge. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-08-03.

The Texas Commission on Environmental Quality (TCEQ) has issued a draft permit for Hays County Water Control and Improvement District #1 to discharge treated wastewater effluent directly to the headwaters of Bear Creek, Hays County, Texas. The steady-state LA-QUAL model was used to predict water quality of Bear Creek under varying conditions using reach definitions and advective hydraulic characteristics previously used by TCEQ in their Tier 2 non-degradation assessment of the permit. TCEQ concluded that degradation did not occur because effluent nutrients were assimilated in Bear Creek just above the Barton Springs Edwards Aquifer recharge zone. Further modeling determined that predicted concentrations are very sensitive to estimated decay rates and ambient water temperature input values. Predicted concentrations with the proposed discharge permit are above TCEQ screening levels as well as long-term ambient averages for multiple constituents at the upper recharge zone boundaries in some conditions.

Herrington, C. 2008. Extension of an LA-QUAL (version 8.0) model for the proposed HCWID#1 wastewater discharge to realistic Bear Creek temperature and flow conditions. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-08-04

Multiple steady-state LA-QUAL(version 8.0) models for varying temperature and flow conditions were evaluated and used to generate a time-series prediction of water quality impacts from the proposed HCWID#1 discharge to Bear Creek at the upper boundary of the Barton Springs portion of the Edwards Aquifer Recharge Zone. LA-QUAL predicted output is sensitive to dilution (amount of natural creek flow present) and temperature (removal rates are temperature-dependent), and the use of multiple models is a more accurate representation of the temporal variability in flow and temperature. Using this approach, the proposed HCWID#1 discharge is predicted to degrade the water quality of Bear Creek and the Edwards Aquifer. However, this analysis is still only a conservative approximation of the actual degradation expected and does not simulate more dynamic ecological responses such as nutrient spiraling or storm event driven sediment resuspension.

Herrington, C. 2008. Impacts of the proposed HCWCID 1 wastewater discharge to Bear Creek on nutrient and DO concentrations at Barton Springs. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-08-05

The impacts of the proposed Belterra (HCWCID 1) discharge, located in the contributing zone of the Barton Springs portion of the Edwards Aquifer, on concentrations of nutrients in Barton Springs were evaluated using a karst aquifer model (Barrett and Charbeneau 1996, Turner 2006). Additionally, the change in Barton Springs dissolved oxygen was estimated based on change in biochemical oxygen demand in creek recharge to the aquifer generally following previous City of Austin method (COA 2006). Both analyses utilized predicted daily Bear Creek concentrations with and without the proposed discharge generated from a series of LA-QUAL models (Herrington 2008) as an input data source. As drafted, the proposed discharge is predicted to increase concentrations of nitrogen and phosphorus in Barton Springs and decrease Barton

Springs dissolved oxygen. These estimates could be improved with a more spatially detailed karst aquifer model; however, they are the best possible using accepted methods currently available.

Barton Springs/Edwards Aquifer Conservation District, 2006. Summary of 2005 Groundwater Dye Tracing, Barton Springs Segment of the Edwards Aquifer, Hays and Travis Counties, Central Texas. BSEACD Report of Investigations 2006-530. Austin Texas.

The Barton Springs/Edwards Aquifer Conservation District and the City of Austin, injected non-toxic organic dyes into four karst features within the western portion of the Barton Springs segment of the Edwards Aquifer in May 2005. The objectives of the study were to determine time-of-travel, direction, and destination of groundwater flow, and to better delineate the groundwater divide between the Barton Springs and San Antonio segments of the Edwards Aquifer south of Onion Creek. The study was conducted during relatively high-flow conditions while Barton Springs discharged at 104 cfs. Rapid groundwater flow rates from creek and upland recharge features to Barton Springs were documented and ranged from 2.3 to 7.4 miles per day. This study revealed a hydraulic connection between Cripple Crawfish Cave in Onion Creek and San Marcos Springs under the study conditions. Cripple Crawfish Cave was injected with dye that was detected at wells and both Barton and San Marcos Springs, although the concentrations at San Marcos were small compared to Barton Springs. A previous injection of Cripple Crawfish Cave in 2002, under different hydrologic conditions, was not detected at San Marcos Springs. These results indicate that the groundwater divide separating the Barton Springs and San Antonio segments may fluctuate according to hydrologic (and hydraulic head) conditions. Groundwater flow routes were documented in the eastern and confined portion of the Barton Springs segment of the Edwards Aquifer and further support a flow route along the eastern boundary of the aquifer.

Barton Springs/Edwards Aquifer Conservation District, 2004. Summary Of Groundwater Dye Tracing Studies (1996-2002), Barton Springs Segment Of The Edwards Aquifer, Texas

Conclusions:

The Barton Springs segment of the Edwards Aquifer is composed of three primary groundwater basins: the Cold Springs, Sunset Valley, and Manchaca groundwater basins. Each groundwater basin has preferential groundwater flow routes that generally trend to the northeast, parallel to regional faults, and converge towards the springs. Although the groundwater basin divides are generally defined in this study, additional tracing is necessary to more accurately delineate the divides under varying aquifer conditions.

Groundwater dye tracing indicates that Cold Springs is hydraulically linked to surface water recharging from the upper portions of Williamson and Barton Creeks on the recharge zone. Barton Springs is hydraulically linked to water recharging from Slaughter, Bear, Little Bear, and Onion Creek watersheds and lower portions of Williamson and Barton Creek watersheds on the recharge zone.

Groundwater flow rates appear to vary with (1) the proximity and connection to major preferential groundwater flow routes and with (2) varying groundwater flow conditions. Under moderate and high groundwater flow conditions at Barton Springs, groundwater generally travels approximately 4 to 7 miles per day along the major groundwater flow routes, but only about 1 mile per day from the western side of the recharge zone to the eastern side. During low flow conditions at Barton Springs, groundwater moves at rates of about 0.6 miles per day to 1 mile per day across the aquifer.

This groundwater tracing study provides valuable information necessary to improve wellhead protection, to anticipate the fate of a hazardous material spill on the recharge zone, to assist in developing effective monitoring strategies, to prioritize purchases of water quality/quantity protection lands, and to evaluate sites for potential recharge enhancement.

Barton Springs/Edwards Aquifer Conservation District and the City of Austin Watershed Protection and Development Review Department. 2004 Groundwater Tracing Study of the Barton Springs Segment of the Edwards Aquifer, Southern Travis and Northern Hays Counties, Texas. Austin, Texas.

Executive Summary:

Groundwater tracing conducted in the Barton Springs segment of the Edwards Aquifer from 1996 through 2000, has provided new insight on groundwater flow directions and velocities. A groundwater tracing study performed by the Barton Springs/Edwards Aquifer Conservation District and the City of Austin has measured groundwater velocities and destinations from 17 natural recharge features and one well within the Barton Springs segment. A total of 20 traces were conducted in all the major contributing watersheds supplying water to Barton Springs, including Barton, Williamson, Slaughter, Bear, Little Bear, Onion Creeks, as well as the Blanco River, This study accomplished its data quality objectives by detecting 85% of the traces in at least one monitoring site.

To conduct the traces, up to five distinct organic tracers were used: f1uorescein, rhodamine WT, eosine, sulforhodamine B, and pyranine. The tracers were injected into caves, sinkholes, and other recharge features and were generally flushed into the aquifer with about 10,000 gallons of water, In one trace, dye was poured into a well that was flushed with creek water flowing adjacent to the well. Activated charcoal receptors were placed at wells and springs where tracer arrival was possible, .in order to adsorb cumulative concentrations over the placement duration. Grab samples were also collected to measure tracer concentrations at specific times. Potentiometric surface, geological, and cave maps were used to estimate groundwater-f1ow paths in between the injection points and tracer detection sites.

The results of this study demonstrate that groundwater recharging the Barton Springs segment in the Barton and Williamson Creek watersheds travels either north or northeast towards either Barton or Cold Springs (ES-l). Portions of the upper Recharge Zone of Barton Creek (from the Mount Bonnell Fault down to the Loop 360 crossing) and Williamson Creek (from Highway 290 down to the Brush Country Road crossing) contribute flow to Cold Springs and other springs on the south bank of the Colorado River rather than Barton Springs. The groundwater in this area generally converges to a preferential flow path, referred to as the Cold Springs Flow Route, located roughly through Travis Country subdivision and subparallel to Walsh Tarlton Road in Rollingwood. The Cold Springs groundwater basin within the Barton Springs segment of the Edwards Aquifer is about 12 square miles in size.

Recharge entering into the remaining downstream portions of the Recharge Zone within the Barton and Williamson Creek watersheds generally discharges from the Main outlet of Barton Springs and Upper Barton Springs. The boundaries of the source area for this groundwater basin, referred to as the Sunset Valley groundwater basin, is roughly bounded by Slaughter Lane to the south. Mopac Expressway to the west, and Westgate Boulevard to the east. The Sunset Valley groundwater basin is about 12 square miles in size. The identified preferential groundwater flow path that feeds Upper Barton Springs is referred to as the Sunset Valley Flow Route that trends in

subsurface beneath the City of Sunset Valley to the vicinity of Loop 360 and Barton Creek and eventually Barton Springs. The Sunset Valley groundwater basin also provides partial flow to Main Barton Springs. Upper Barton Springs becomes dry when the other three Barton Springs outlets decline to a combined flow of 40 cubic feet per second (cfs). During these periods of low groundwater levels, all of the source area for Upper Barton Springs discharges solely from the Main Barton Springs.

Groundwater recharging the Barton Springs segment in the Slaughter, Bear, Little Bear, and Onion Creek watersheds generally flows east towards a wide potentiometric trough that parallels the east side of Manchaca Road from Manchaca/San Leanna northeast to Barton Springs. The Manchaca groundwater basin includes portions of the unconfined Recharge Zone as well as confined Artesian Zone, and is about 120 square miles in size. The primary identified preferential groundwater flow path for recharge from these watersheds is referred to as the Manchaca Flow Route. A secondary groundwater flow path within this groundwater basin, discovered from later tracer injections in 2002, has been called the Saline-Line Flow Route. Groundwater recharging these watersheds feeds the Manchaca groundwater basin and discharges from the Main, Eliza, and Old Mill outlets of Barton Springs. Under some conditions, Slaughter Creek watershed may supply Upper Barton Springs through overflow routes, based on cave observations at the water table near the estimated divide separating the Sunset Valley and Manchaca groundwater basins and from detections of tracer moving across this divide following storms.

The traces have shown relatively rapid flow rates for first dye arrivals of ahout half a mile to 1 mile per day during very low groundwater-flow conditions to over 4 miles per day from selected injection points during D1odera.tcto high groundwater-flow conditions. Even during low groundwater-flow conditions where the injection was performed at one of the more distant injection points, Barber Falls (Site N) on Onion Creek, the tracer traveled at least 15 miles to arrive to arrive at Barton Springs 14to 16 days later. Most of the traces were conducted under low water-level conditions.

Groundwater flow rates vary with (l) the proximity and connection to major preferential groundwater-flow paths and (2) groundwater-flow conditions. Under moderate and high groundwater-flow conditions at Barton Springs (greater than 35 cfs), groundwater generally travels about 4 to 7 miles per day along the major groundwater-flow paths, but moves at a rate of about 1 mile per day to move from the western side of the Recharge Zone to the eastern side. During low flow conditions of less than 35 cfs at Barton Springs, ,groundwater velocities of about 1 mile per day to 0.6 mile per day across the aquifer were measured. Five tracers injected under low groundwater-flow conditions were not recovered from any discharge spring, although two of these were recovered in nearby wells. The three major preferential groundwater-flow paths appear to be strongly influenced by geological fault trends.

In most cases, the peak concentration reached the discharge spring within hours after the initial arrival of the tracer, suggesting a system with a high component of advection relative to dispersion and diffusion. Tracer recoveries are calculated to range from 0% up to about 77%, with a mean recovery of about 16% and a median recovery of about 4.2%. The amount of tracer recovery did not vary directly with distance from the injection point to the discharge springs. The rapid travel rates and strong tracer recoveries measured during the study suggest that distant groundwater recharge sites, including those in the Williamson, Slaughter, Bear, Little Bear, and Onion creek watersheds, are strongly connected hydraulically to Barton Springs.

The results of this groundwater tracing study provide information necessary to improve wellhead protection, to anticipate the fate of a hazardous material spill on the Recharge Zone, to assist in

developing monitoring strategies, to prioritize purchases of water quality/quantity protection lands, and to evaluate sites for potential recharge enhancement. This study has helped identify some preferential groundwater flow paths that arc the major sources of Barton and Cold Springs.

Additonal Algae Modeling Using WASP for BSCZ Streams
Example Upper Bear Creek

WASP Modeling of Upper Bear Creek

WASP is a predictive model designed for dealing with conventional water quality problems including eutrophication. This model helps users "interpret and predict water quality responses to natural phenomena and man-made pollution for various pollution management decisions". (USEPA 1988). The interactions between planktonic algae and nutrients are modeled. Thus this model is more likely to accurately predict nutrient (and chlorophyll *a*) concentrations than a model which simply applies decay coefficients to nutrients like those used for the HCWCID1 permit.

The WASP model was run for the winter season for five years (1999, 2000, 2002, 2003, and 2004) representing all flow conditions in Bear Creek: very low, low, average, high and very high. The model was set up to predict the influence of effluent discharges under Settlement conditions and thus was run only from December through April when effluent discharges are mostly likely with the Settlement. Summer conditions, which might be the worst for algal blooms have not yet been modeled. Modeled wastewater effluent conditions included constant discharge at 0.5 MGD as specified in the draft permit and intermittent discharges as specified under the Settlement Agreement. Plant limits for water quality included: TP = 0.1 mg/L, NH3-N = 2 mg/L, NO3-N = 4 mg/L, BOD=5 mg/L DO = 5 mg/L. Intermittent discharge conditions included 15 days of Storage, 201 acres for land application, and 0.35 MGD maximum daily discharge, with discharge occurring only when the storage pond was full and the ground was saturated or frozen.

Model results are plotted for Bear Creek from the headwaters to the recharge zone for:

- 0.5 MGD effluent
    1. chlorophyll *a*
    2. total phosphorus
    3. total nitrogen
- intermittent discharge (settlement conditions)
    1. chlorophyll *a*
- worst case conditions – intermittent discharge (settlement conditions)
    1. flow and chlorophyll a for 2004 – low creek flow, high effluent % of flow
    2. flow and chlorophyll a for 2003 – very high creek flow, effluent volume high

The chlorophyll a concentrations are for the water column. Benthic (bottom) algae can be predicted from the phosphorus and nitrogen concentrations. Trophic levels are used to show levels of change in the creek. When nutrients are at eutrophic levels, benthic algae is typically at nuisance levels for recreational and aesthetic uses.

Modeling to predict nutrient and DO levels at Barton Springs has not been done yet using the WASP model output. However it is expected from the predicted increases in levels at the recharge zone under the draft permit that there will be significant increases in nutrients at the Pool and significant decreases in DO due to additional oxygen consuming material entering the aquifer. The nutrient increases may lead to increases algal production in the pool, and the DO declines under low flow conditions could impact the Barton Springs salamander adversely.

The predicted average increase at the recharge zone under the settlement conditions for one plant is small. However changes under worst case conditions are of concern. Additional modeling is

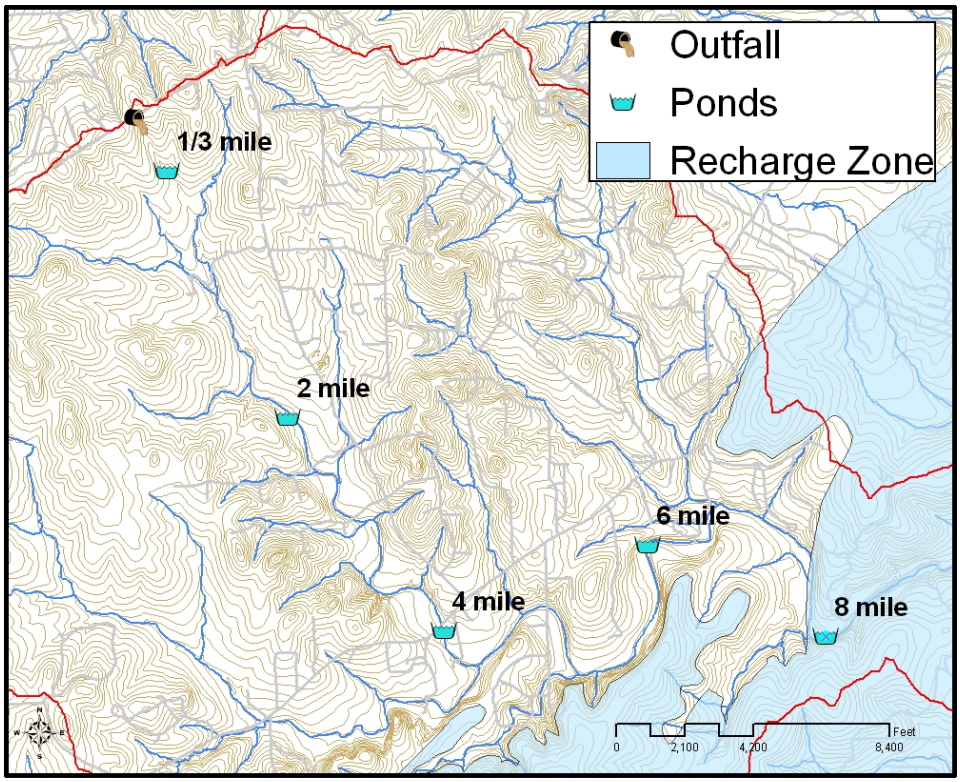
necessary to determine the frequency and magnitude of DO declines in the aquifer under worst case conditions.

All predictions were done for one wastewater plant in the headwaters of the stream. Additional wastewater treatment plants located throughout the watershed will increase the proportion of the creek which becomes eutrophic and increase the potential impacts on Barton Springs and the salamander.

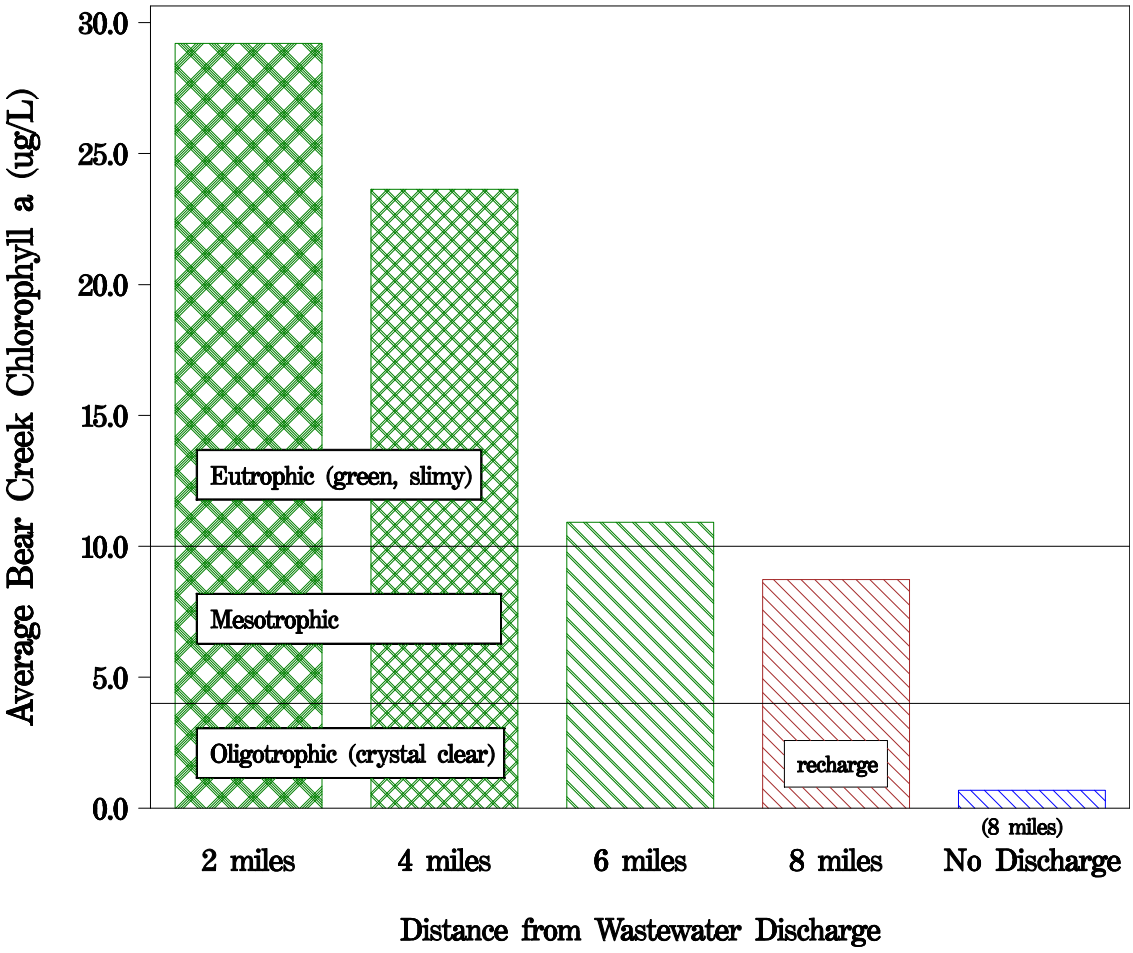
Additional data is currently being collected in Bear Creek to improve the calibration of the WASP model under oligotrophic condition.

In the following charts, the "No Discharge" bar reflects current conditions with no wastewater effluent discharged to the creek at the recharge boundary (8 miles). It should be compared to the "8 miles" bar which is at the same location but with effluent discharge.

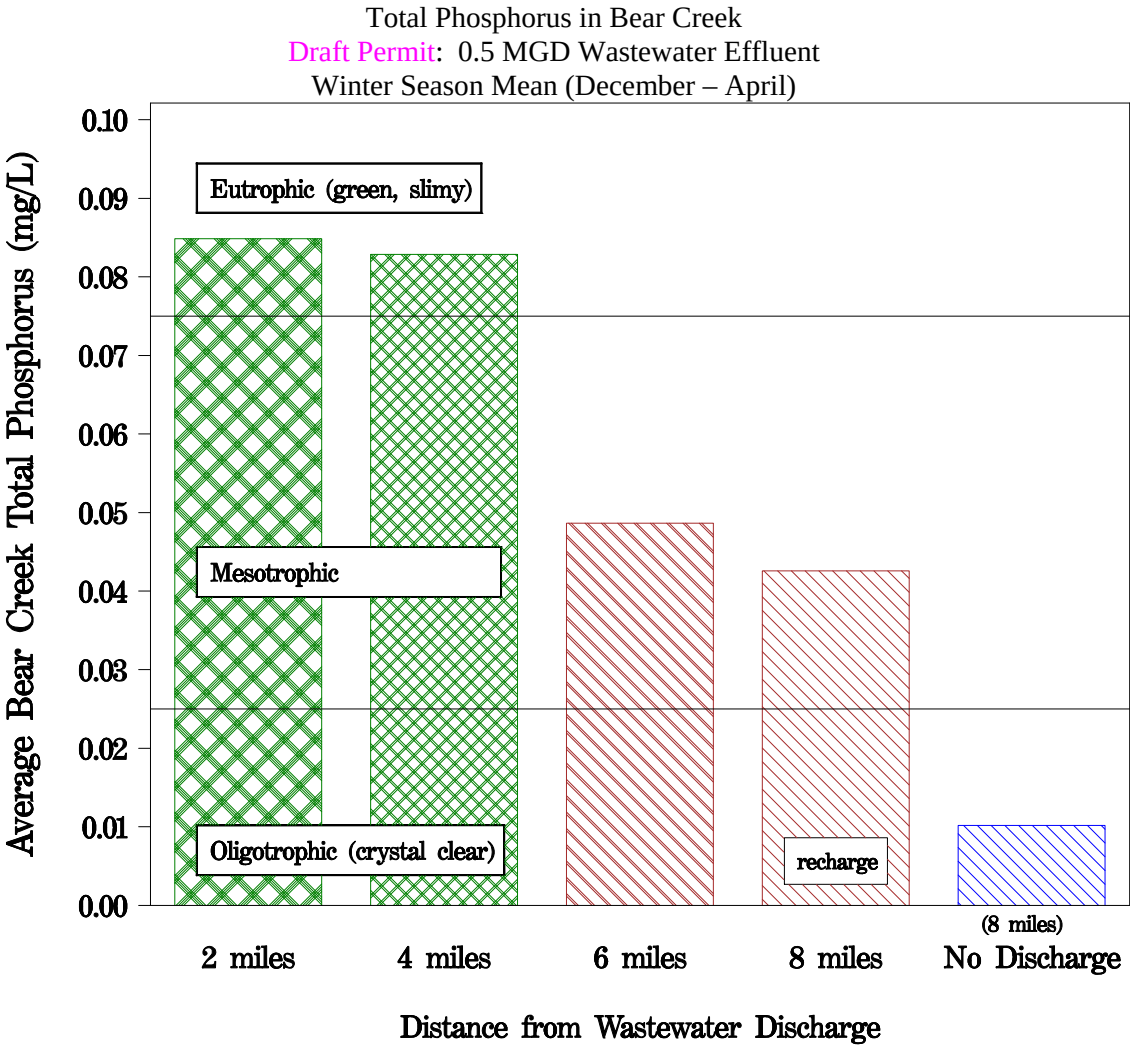
All of the bar charts reflect average conditions over 5 seasons (months of December – April).



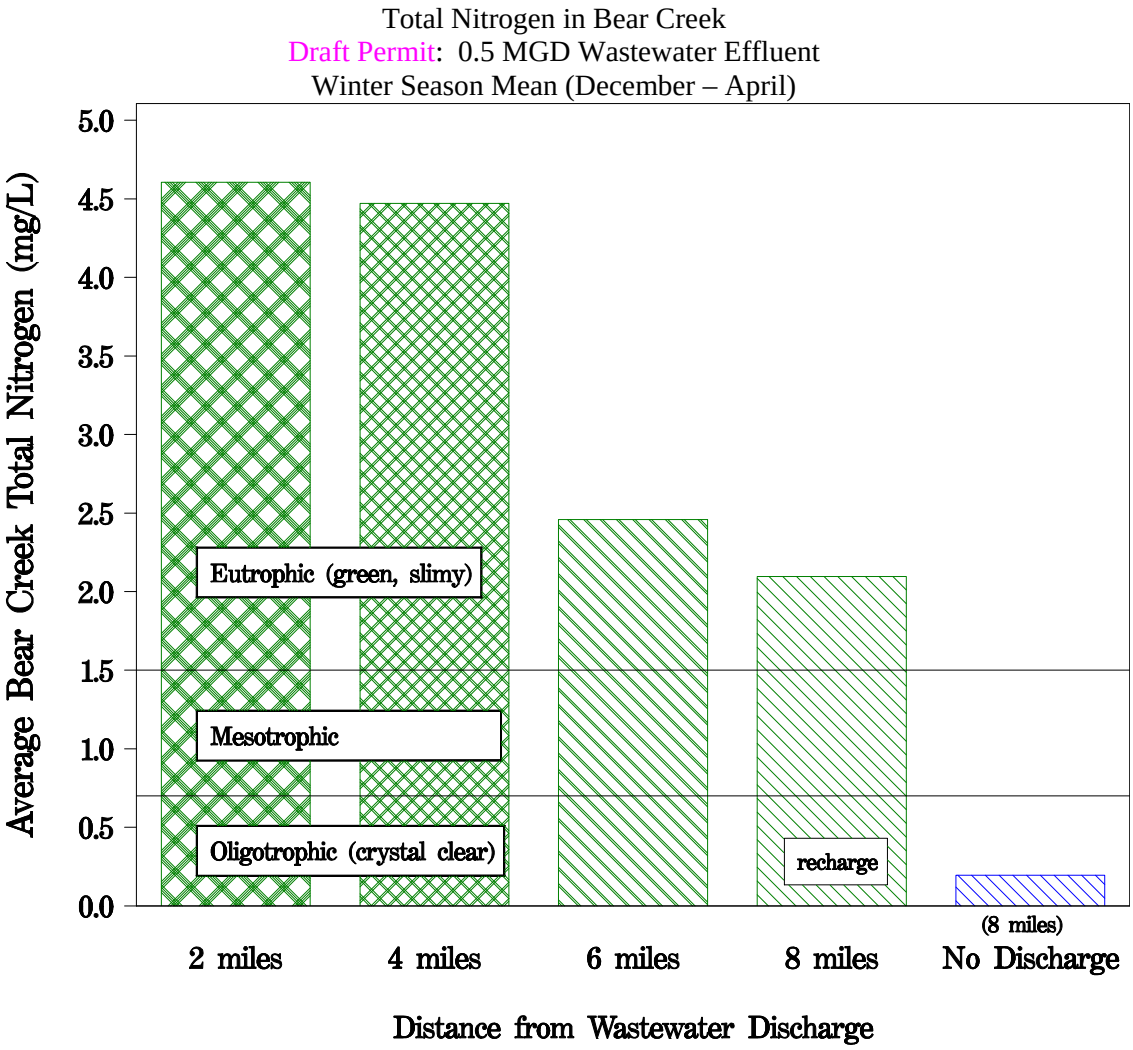
Chlorophyll *a* in Ponds in Bear Creek
Draft Permit: 0.5 MGD Wastewater Effluent
Winter Season Mean (December – April)



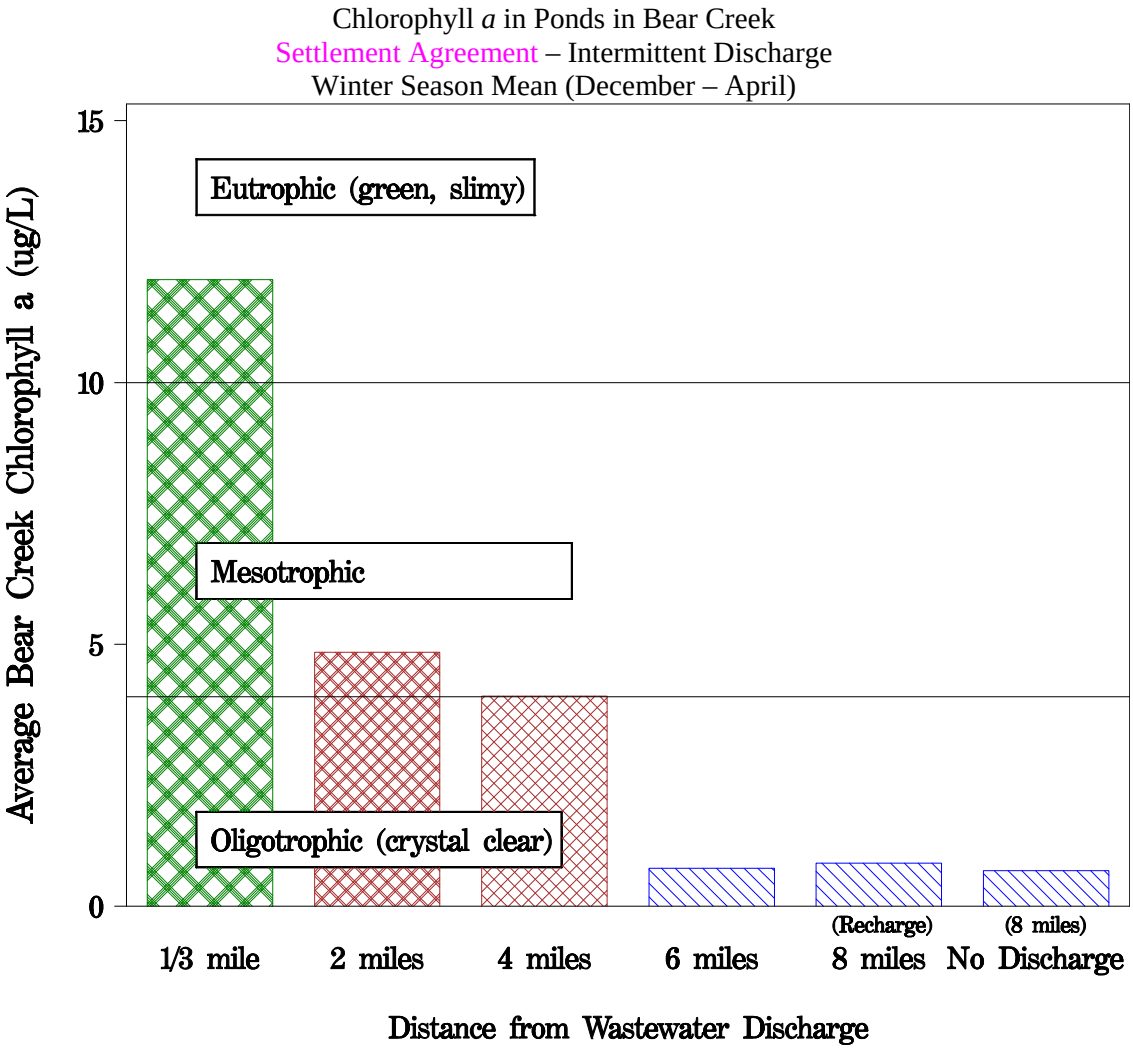
The creek is predicted to be eutrophic (green and slimy) for 6 miles and mesotrophic to the recharge boundary. The concentrations are one to two trophic levels higher than under current conditions. The concentration at the recharge boundary is 13 time higher than under no discharge. Additional wastewater treatment plants located through out the watershed would increase the percent of the creek which becomes eutrophic.



The creek is predicted to be eutrophic (green and slimy) for 4 miles and mesotrophic to the recharge boundary. The concentrations are one to two trophic levels higher than under current conditions. The concentration at the recharge boundary is 4 time higher than under no discharge. Additional wastewater treatment plants located through out the watershed would increase the percent of the creek which becomes eutrophic.



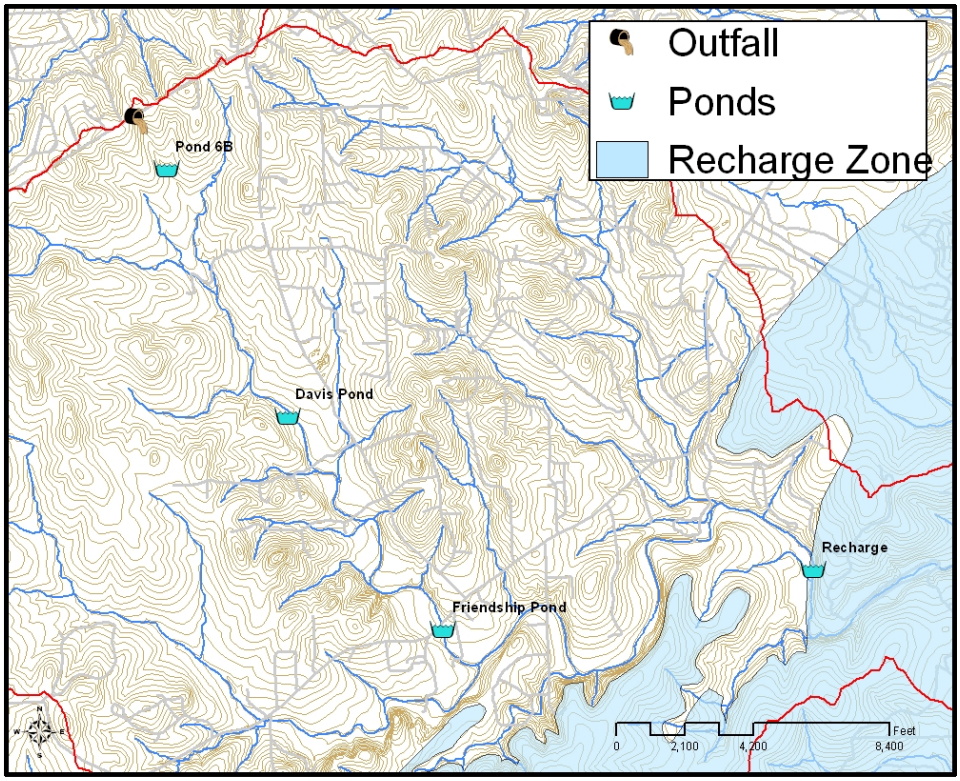
The creek is predicted to be eutrophic (green and slimy) all the way to the recharge boundary. The concentrations are two trophic levels higher than under current conditions. The concentration at the recharge boundary is 11 time higher than under no discharge. Additional wastewater treatment plants located through out the watershed would increase the percent of the creek which becomes eutrophic.



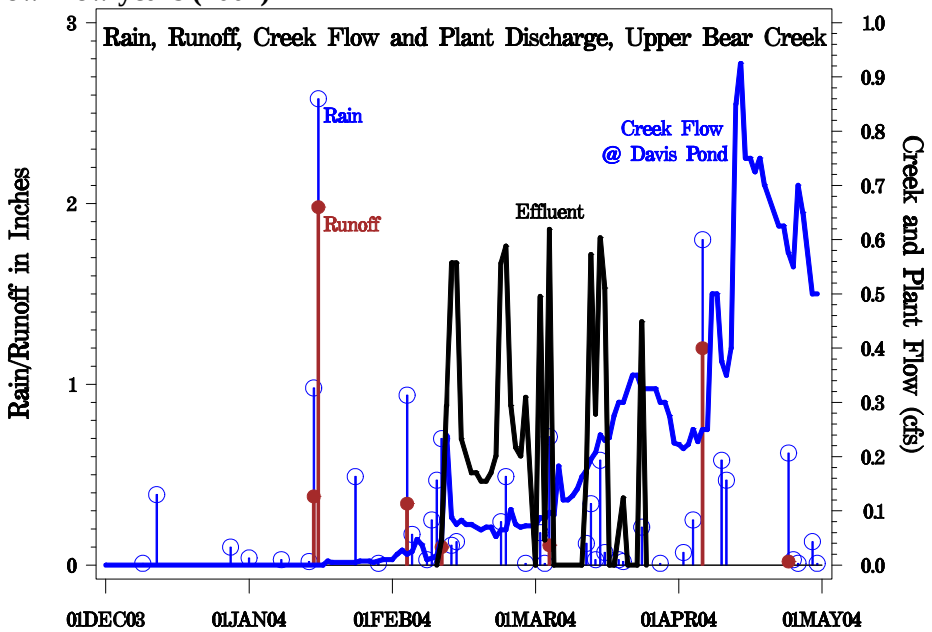
The creek is predicted to become eutrophic only near the treatment plant, and mesotrophic for 4 miles. On the average, with the discharge 8 miles from the recharge zone under the settlement agreement, chlorophyll a concentrations are only slightly elevated at the recharge zone. Worst case conditions are pertinent to understanding potential impacts to the aquifer and the Barton Springs salamanders and the differences are much greater under worst case conditions. Additional wastewater treatment plants located through out the watershed would increase the percent of the creek which becomes eutrophic

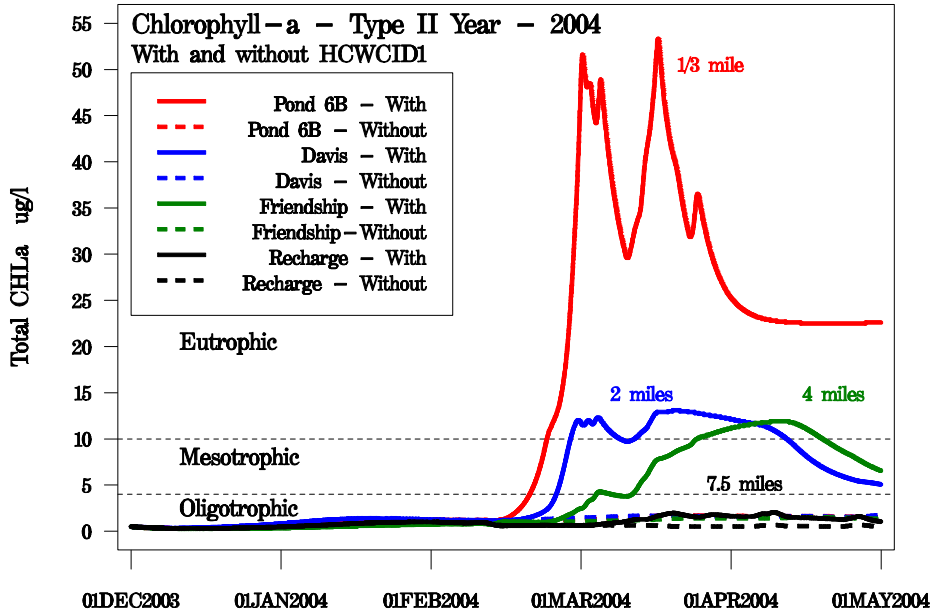
Worst Case Conditions under the settlement agreement:

Chlorophyll *a* predictions for low flow years and for very high flow years: In low flow years discharges occur and there is very little flow to dilute them. In the highest flow years, the ground is saturated more often leading to higher effluent discharges.



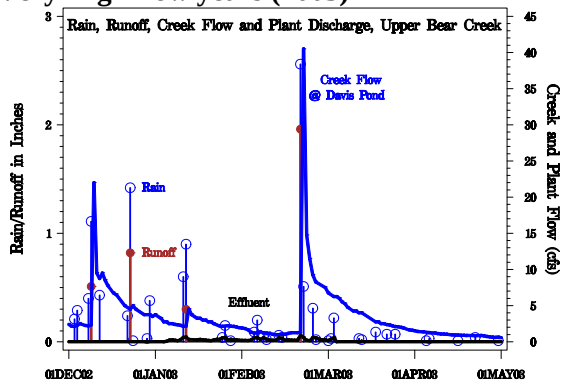
Low Flow years (2004)

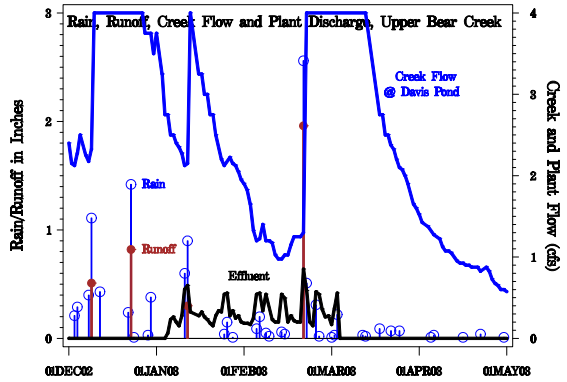


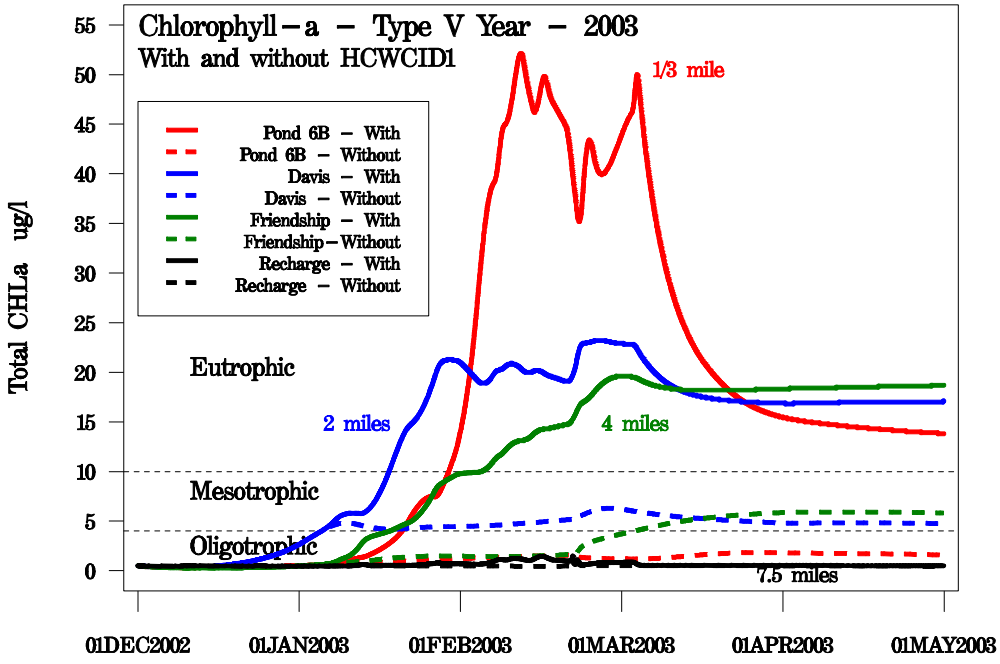


Effluent dominates the creek flow for more than one month. The creek becomes eutrophic for periods of a month or more for 4 miles. Concentrations double near the recharge zone. Algae build-up during the eutrophic period will be scoured later on with the potential for entering the aquifer as oxygen consuming material.

Very High flow years (2003)







Effluent flows continuously into the creek for approximately two months. Four miles of the creek become eutrophic for a period exceeding 3 months. Additional modeling is needed to determine when the creek might return to oligotrophic conditions. Storm loading changes the tropic level from oligotropic to mesotrophic but the wastewater effluent boosts the chlorophyll a levels well into the eutrophic range. Algae build-up during the eutrophic period will be scoured later on with the potential for entering the aquifer as oxygen consuming material.

Summary:

WASP modeling:

- models nutrient-planktonic algae interactions
- predicts that a major portion of the creek will become eutrophic under draft permit conditions (0.5 MGD)
- predicts higher concentrations of DO consuming material (chlorophyll a) entering the aquifer than under current conditions. This implies potential impacts to the endangered Barton Springs salamander.
- predicts higher concentrations of nutrients at the recharge boundary than were predicted by models using only nutrient decay coefficients. This implies potential increases in algae at Barton Springs Pool
- predicts a trophic level increase in half of the creek above the recharge zone under settlement conditions
- predicts extended periods of eutrophication in half of the creek above the recharge zone under settlement conditions
- Ongoing work: data collection for better model calibration and extension of the modeling periods to cover all seasons.

Multiple wastewater treatment plants:
The introduction of one wastewater treatment plant into this sensitive region will cause changes in stream trophic levels and potentially impact the endangered Barton Springs salamander. If you add multiple plants at intervals along the creek, you can expect the much greater changes than are predicted for one plant.

Table of concentrations for plotting multiple plant scenarios:

	Settlement	0.5 MGD	None	0.5 MGD	None	0.5 MGD	None
Distance	Chla			TP		TN	
1/3 mile	11.96						
2 miles	4.85	29.2	1.45	.0849	.0109	4.6	.213
4 miles	1.01	23.6	1.32	.0829	.0115	4.47	.222
6 miles	0.73	10.9	0.5	0.486	.0103	2.46	.194
8 miles	0.82	8.7	0.68	0.421	.0102	2.1	.195

Additional Biological Assessment of BSCZ Stream Impacts from Direct Discharge

- Although large trophic shifts are clear indicators of ecological degradation, using trophic status averaged over long periods of time will not accurately represent the magnitude and frequency of algae bloom phenomenon that are expected in high nutrient streams.
- Most algae communities respond to environmental changes in a typically opportunistic manner. When light, temperature and nutrients are good, they explode and persist as long as they can

dominate. The nutrient supply from wastewater, either continuous, or in pulse events will greatly increase the potential for algae blooms.

- Due to sediment sequestration and downstream trophic cascades, it is likely that there will be dramatic bloom events in these wastewater-dominated systems, both planktonic and filamentous, that degrade ecological function over relatively large spatial and temporal scales. These events would only be blips in overall trophic function, averaged over a 5 year period, but would often be very "unpleasant" from any kind of aesthetic and/or recreational perspective.

Literature Summaries on Groundwater Contaminant Transport Pertinent to Barton/Onion Watershed Stakeholders

Nico Hauwert, 1/9/2008

I. Phosphorus transport in sandy aquifers

Robertson, W.D., 2008, Irreversible Phosphorus Sorption in Septic System Plumes?: Groundwater, Vol. 46, no. 1, p. 51-60.

Summary: In a sandy aquifer system over long term discharge, phosphorus is not permanently attenuated (lost) but does travel relatively slowly in the groundwater In a septic system plume constructed in a sand aquifer and monitored over 16 years, decay of phosphorus was essentially absent within the plume. The lack of decay could be attributed in part to the long period of discharge saturating a relatively localized area above the water table where P precipitation normally occurs. Across a 16 m plume, the terminal PO4-P concentrations approached those underneath the tile bed. Calcareous terraines are particularly weak in sorption of P because they tend to be supersaturated in hydroxyapatite. Over long periods, any sorbed P can be later mobilized. Within the groundwater and over long periods, decay is unlikely and not detected (within a half life of 30 years), retardation of P limits the extend of the P plume at this time. While unretarded chloride has already traveled 170 m to lake Erie from the septic system, due to greater retardation the P is expected to require about 200 years to reach the lake in that aquifer system.

Walter, D.A., B.A. Rea, K.G. Stollenwerk, and J. Savoie, 1996, Geochemical and hydrological controls on phosphous transport in a sewage-contaminated sand and gravel aquifer near Ashumut Pond, Cape Cod, Mass.: USGS Water-Supply paper 2463. Washington, DC. (do not have this paper but was referenced in Robertson 2008)

Summary: A 600 m phosphorus plume developed in a sand and gravel aquifer since 1936 below large sewage infiltration beds.

Robertson, W.D. and J. Harman, 1999, Phosphate plume persistence at two decommissioned septic system sites: Groundwater vol 37, no. 2, p. 228-236.

Summary: Even four years after decommissioning a septic system, the 80 m long phosphorus plume concentrations remained unchanged and the front continues to advance. Ontario Province regulations assume all of the P mass loading from septic systems ultimately migrate through the groundwater.

II. Nitrate Transport in Karst Aquifers

Panno, S.V. and W.R. Kelly, 2004, Nitrate and herbicide loading in two groundwater basins of Illinois plain: Journal of Hydrology, vol. 290, p. 229-242.

In a karst aquifer, about 21-31% of nitrogen loading applied as fertilizer and 4-5% of atrazine loading applied in the groundwater basin was measured to discharge from springs. Fertilizer application doubled the background concentrations of nitrate in the springs.

Vesper, D.J., C.M. Loop, W.B. White, 2001, Contaminant transport in karst aquifers: Theoretical and Applied Karstology, vol. 13-14, p. 101-111.

Summary: Water soluble contaminants like nitrate move with the groundwater and diminish downstream due to dilution from other sources. Metals tend to be transported on sediment due to adsorption. Pathogens like bacteria readily travel through large openings in karst aquifers, but their die off rates are yet uncertain. Some investigations showed no degree of die off of indicator bacteria.

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