WASP Model Analysis of a City of Dripping Springs Proposed Wastewater Treatment Plant Discharge to Onion Creek

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Abstract

The Water Quality Analysis Simulation Program (WASP) is a U.S. Environmental Protection Agency program commonly used to model water quality responses including impacts from nutrient enrichment. City of Austin Watershed Protection Department staff have used the program to predict algal growth under low and high nutrient concentrations in Austin streams. In 2015, the City of Dripping Springs submitted an application for a wastewater discharge permit to the Texas Commission on Environmental Quality (TCEQ). The application seeks authorization to discharge 995,000 gallons per day of treated effluent into Onion Creek in the contributing zone of the Barton Springs Segment of the Edwards Aquifer. Included in the application are the following proposed effluent limits: 5 mg/L carbonaceous 5-day biochemical oxygen demand, 2 mg/L ammonia as nitrogen, and 0.5 mg/L total phosphorus as phosphorus. The application did not include a proposed limit for total nitrogen. The City of Austin built and calibrated a WASP model for the section of Onion Creek from immediately upstream of the proposed discharge confluence to the boundary of the Barton Springs Segment of the Edwards Aquifer Recharge Zone (19 miles) to evaluate the potential water quality impact of the proposed discharge permit. The WASP model was calibrated with data collected by the City of Austin from 2014 to 2015. After calibration, a 15 year scenario that did not include any wastewater discharge was run to simulate a baseline benthic chlorophyll a data set. Additionally, a 15 year scenario was run including input conditions for the proposed discharge permit to simulate a discharge benthic chlorophyll a data set. For the baseline scenario the model showed Onion Creek directly downstream of the proposed discharge location in an oligotrophic state each year. However, when the scenario included discharge, Onion Creek's trophic status changed to mesotrophic state from 2001 to 2015. Additionally, the discharge scenario between the years 2001 to 2015 showed Onion Creek remained in the mesotrophic state for approximately 9 to 12 miles downstream of the discharge location depending on the flow of Onion Creek each year.

Introduction

The City of Dripping Springs applied to the Texas Commission on Environmental Quality (TCEQ) for a new Texas Pollutant Discharge Elimination System permit to discharge treated wastewater effluent into the Onion Creek Watershed in the Contributing Zone of the Barton Springs Segment of the Edwards Aquifer. An engineering firm hired by the City of Dripping Springs submitted a Preliminary Engineering Planning Report (PEPR) that proposed 0.5 million gallons per day of effluent from a wastewater treatment plant (WWTP) be directly discharged into a tributary of Onion Creek. The proposed discharge location was approximately 15 miles upstream of the Barton Springs Segment of the Edwards Aquifer Recharge Zone boundary and in an area underlain by the Upper Glen Rose member of the Trinity Aquifer (Johns 2014).

The PEPR indicated that direct discharge can provide an environmentally "good long term solution for effluent disposal from a Regional WWTP in this area…" (CMA Engineering 2013). No data analysis or water quality modeling was provided to support these conclusions. In the permit application to TCEQ, the City of Dripping Springs proposed discharging up to 995,000 gallons per day of effluent into Onion Creek with treatment standards of 5 mg/L carbonaceous 5-day biochemical oxygen demand (BOD), 2 mg/L ammonia as nitrogen, and 0.5 mg/L total phosphorus as phosphorus.

The City of Austin (COA) has an interest in maintaining the water quality of Onion Creek. COA has purchased or obtained conservation easements for 9,524 acres of Water Quality Protection Lands in the Onion Creek Watershed at a cost of approximately $66 million dollars to date in order to protect the integrity of Onion Creek and the Edwards Aquifer.

Surface water in the contributing zone of the Edwards Aquifer, which includes Onion Creek, has previously been shown to be sensitive to nutrient enrichment (Herrington and Scoggins 2006; Herrington 2008a; Herrington 2008b; Mabe 2007; Richter 2010; Turner 2010). In aquatic systems, nutrients such as nitrogen and phosphorus support the growth of algae and aquatic plants. Nutrient enrichment can occur from the increase of either nitrogen or phosphorus to the aquatic system and can cause an increase in algal biomass to the extent that entire reaches of streams show aesthetic degradation (Wharfe et al. 1984, Biggs 1985, Biggs and Price 1987, Welsh et al. 1988), loss of pollution-sensitive invertebrate taxa (Quinn and Hickey 1990), clogging of water intake structures (Biggs 1985), and degradation of dissolved oxygen and pH levels in the water column (Quinn and Gilliland 1989).

Because no data analysis or water quality modeling accompanied the PEPR, the COA constructed a Water Quality Analysis Simulation Program (WASP) model to assess the creek's response, which will demonstrate the potential impacts of nutrient enrichment on the surface water of Onion Creek. Due to the connectivity between Onion Creek and local groundwater resources, impacts to the surface water of Onion Creek can impact local groundwater resources.

WASP Model & Methods

The Water Quality Analysis Simulation Program (WASP) is a program maintained by the US Environmental Protection Agency (US EPA) and is used to "predict the water quality responses to natural phenomena and man-made pollution" (US EPA 1988).

The COA used an 'Advanced Eutrophication' model type in WASPv7.5 to simulate benthic algae biomass in Onion Creek in response to the proposed City of Dripping Springs WWTP discharge. The model used by the COA is consistent with TCEQ analysis (2006) that showed benthic (attached) algal chlorophyll *a* could be a better indicator of nutrient enrichment than water-column chlorophyll *a* in small, fast flowing Texas streams. Flow type in the WASP model was set to 1-D Network Kinematic Wave with a Euler solution technique, which is a typical solution technique for hydrodynamic models (US EPA 2009).

Time functions and parameters included in the model were solar radiation, fraction of daily light, light extinction, ammonia benthic flux, phosphorus benthic flux, and sediment oxygen demand. Average monthly solar radiation and fraction of daily light were calculated from data obtained from the National Climatic Data Center (NOAA Satellite and Information Service). Ammonia benthic flux, phosphorus benthic flux, and sediment oxygen demand were set to 0.015 mg/m^2-day, 0.015 mg/m^2-day, and 1.0 g/m^2-day, respectively, for each WASP segment based on previous COA WASP modeling efforts. Light extinction was calculated and set to 0.813/meter for each WASP segment based on photosynthetic photon flux data collected using a quantum meter at Onion Creek on April 24, 2014.

Initial segmentation of the model was created through the use of the WASP Builder in BASINSv4.1. In order to calibrate the WASP model, the COA collected data at several locations along Onion Creek. The length of several WASP segments was altered so that WASP output better aligned spatially with COA sample locations and the proposed Dripping Springs WWTP discharge (Figure 1, Table 1).

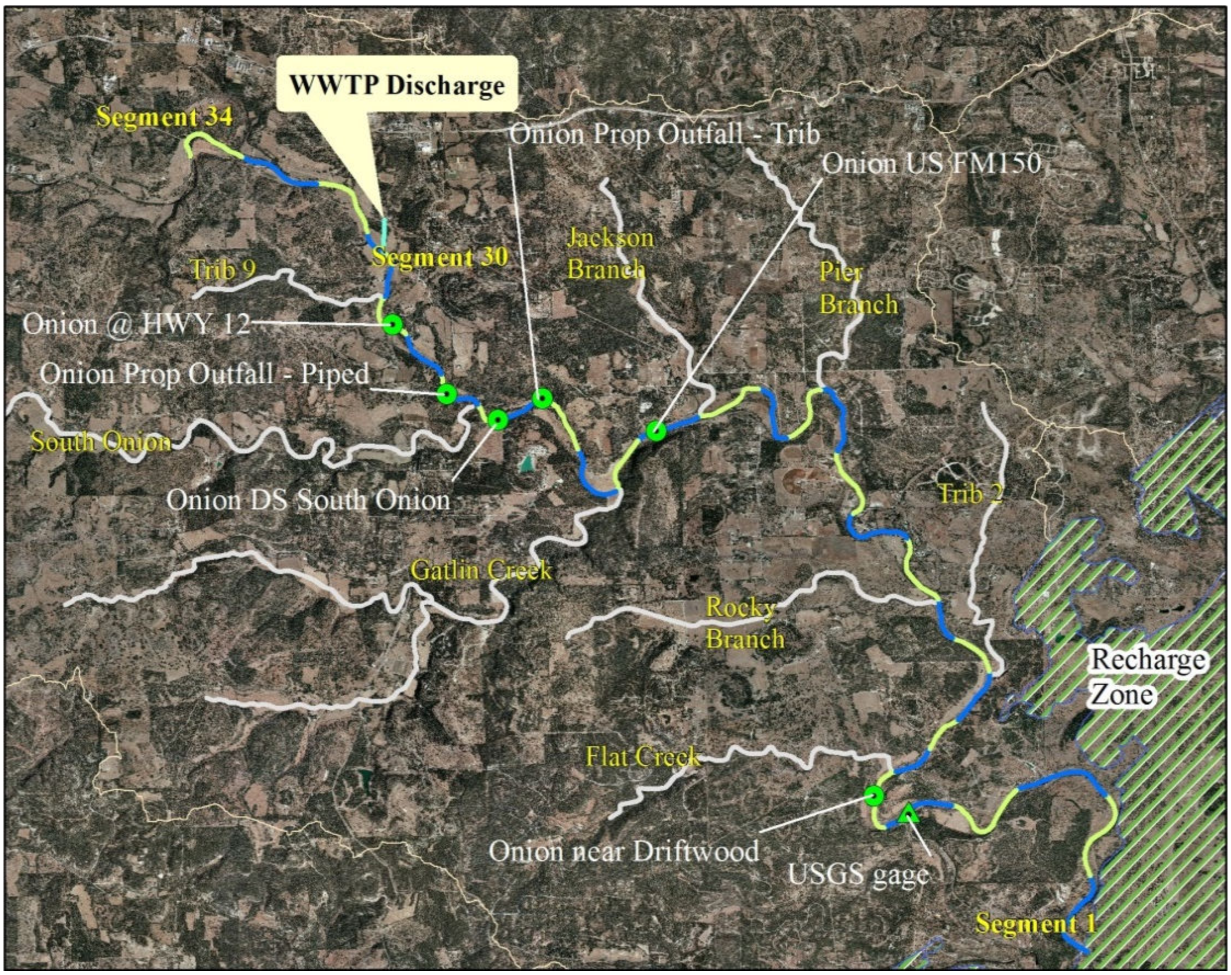

Figure 1: Map of Onion Creek watershed modeled area. WASP segments begin at the recharge zone with Segment 1 and continue to Segment 34 where the model on Onion Creek was initiated. Even WASP segments are yellow while odd WASP segments are blue. The WWTP discharge was input into the WASP model just upstream of Segment 30. Baseline loads and flows are input into Segment 34, Flat Creek, Trib 2, Rocky Branch, Pier Branch, Jackson Branch, Gatlin Creek, South Onion, and Trib 9. Green points are locations along Onion Creek where samples were collected.

COA sample locations were selected based on site access, available substrate, and COA understanding of discharge outfall locations previously considered by the City of Dripping Springs. Specifically, Onion Prop Outfall – Trib and Onion Prop Outfall – Piped were the two locations that were previously proposed as WWTP discharge locations. The final point of the WWTP discharge was selected further upstream. The Onion @ HWY 12 site location was visited once but was dropped from the sample collection list due to lack of safe access to the creek along HWY 12.

Table 1: WASP segment length, width, and slope for Onion Creek mainstem. COA sampling, USGS gage, and proposed Dripping Springs WWTP discharge locations are listed with the WASP segment to which they are associated.

WASP Segment	**Onion Location**	**Length (m)**	**Width (m)**	**Slope**
Segment 1		1642.00	33.00	0.00233
Segment 2		1642.00	19.32	0.00233
Segment 3		1642.00	26.54	0.00233
Segment 4		1642.00	26.50	0.00233
Segment 5	USGS gage 08158700	1229.00	20.02	0.00229
Segment 6	Onion near Driftwood (COA sample location)	1229.00	18.78	0.00229
Segment 7		704.50	23.58	0.00132
Segment 8		704.50	22.96	0.00132
Segment 9		1018.00	23.00	0.00035
Segment 10		870.00	20.60	0.00406
Segment 11		751.00	24.66	0.00404
Segment 12		1308.00	19.20	0.00243
Segment 13		1308.00	29.10	0.00243
Segment 14		1308.00	20.30	0.00243
Segment 15		1308.00	29.30	0.00243
Segment 16		1151.67	19.50	0.0011
Segment 17		1151.67	15.70	0.0011
Segment 18		1151.67	13.70	0.0011
Segment 19	Onion US FM150 (COA sample location)	1027.00	13.73	0.00144
Segment 20		1027.00	13.00	0.00144
Segment 21		1205.67	21.70	0.00333
Segment 22		1205.67	24.67	0.00333
Segment 23	Onion Prop Outfall – Trib (COA sample location)	803.78	22.24	0.00333
Segment 24	Onion DS South Onion (COA sample location)	401.89	23.50	0.0033
Segment 25		467.65	20.87	0.00211
Segment 26	Onion Prop Outfall – Piped (COA sample location)	467.65	21.80	0.0021
Segment 27		935.33	20.11	0.00211
Segment 28	Onion @ HWY 12	935.33	17.38	0.00211
Segment 29		659.45	31.30	0.00319
Segment 30	WWTP Discharge	200.00	16.45	0.0032
Segment 31		459.45	16.05	0.0032
Segment 32		1318.90	26.50	0.00319

Segment 33		1318.90	25.60	0.00319
Segment 34	Model initiation	1318.90	25.00	0.00319

The remaining sites were sampled 5 times from early 2014 to late 2015 (Table 2) for water quality, benthic cover, benthic macroinvertebrate, and field parameter suites. Water quality parameters were analyzed from grab samples taken at each location, benthic cover parameters were analyzed from composite rock scrapings collected from at least 9 rocks located within a riffle at each site, and field parameters were collected by a sonde and a Marsh McBirney flow meter. Data collection followed COA standard procedures (WRE SOP 2016). Sampling was delayed occasionally due to scheduling conflicts between COA staff and private property owners, inclement weather, and periods of no flow in Onion Creek.

Table 2: Sampling schedule for Onion Creek sites. Includes the number of water quality (WQ) samples collected each sample event and the number of rocks composited for the benthic cover parameter suite.

Date	**03/12/2014**		**04/24/2014**		**07/24/2014**		**08/07/2015**		**12/16/2015**	
Site	WQ	BEN.	WQ	BEN.	WQ	BEN.	WQ	BEN.	WQ	BEN.
Onion Prop Outfall - Piped	3	9 rocks	Dry	Dry	Dry	Dry	3	--	3	9 rocks
Onion DS South Onion	3	9 rocks	1	9 rocks	1	9 rocks	3	--	3	9 rocks
Onion Prop Outfall – Trib	3	10 rocks	1	9 rocks	1	9 rocks	3	--	3	9 rocks
Onion US FM 150	3	10 rocks	1	9 rocks	1	9 rocks	3	--	3	9 rocks
Onion near Driftwood	3	11 rocks	1	9 rocks	1	9 rocks	3	--	3	9 rocks

While benthic macroinvertebrates were collected for this project, the data is not pertinent to the building of a WASP model. Thus benthic taxonomy will not be addressed in this report. The full list of parameters collected for the water quality, benthic cover, and field parameter suites can be seen in Table 3.

Table 3: List of parameters associated with the water quality, benthic cover, and field parameter suites collected by COA staff.

Parameter Suite	**Type**	**Parameter**
Water Quality	Nutrients	Ammonia as N, Nitrate+Nitrate as N, Total Kjeldahl Nitrogen as N, Orthophosphorus as P, Phosphorus as P
	Phytoplankton Biomass	Chlorophyll *a*, Pheophytin
	Organics	Organic Carbon
	Solids	Total Suspended Solids, Volatile Suspended Solids
	Ions/Minerals	Alkalinity, Chloride, Boron, Sodium, Magnesium, Calcium, Potassium, Sulfate, Fluoride, Strontium
Benthic Cover	Stoichiometry	Ammonia as N, Nitrate+Nitrite as N, Total Kjeldahl Nitrogen as N, Orthophosphorus as P, Phosphorus as P, Organic Carbon
	Solids	Total Suspended Solids, Volatile Suspended Solids
	Benthic Biomass	Chlorophyll *a*, Pheophytin
Field	Physical	Dissolved Oxygen, Water Temperature, pH, Conductivity, Instantaneous Flow

Parameters collected in the benthic cover parameter suite were reported in mg/L from the lab but were converted to mg/m^2. Total nitrogen was calculated by adding nitrate+nitrite and total Kjeldahl nitrogen. Benthic ash free dry weight (AFDW) was estimated from volatile suspended solids. The ratio of AFDW, organic carbon, total nitrogen, total phosphorus, and chlorophyll *a* at each site was calculated and the average ratios were included as 'Benthic Algae' constants in the WASP model. Other constants used in the model were initially taken from previous COA WASP modeling efforts in local water bodies but may have been altered in calibration for Onion Creek (Appendix A).

Initial conditions for nutrients and benthic algae biomass in calibration and validation were set to the average values of data collected by COA on the March 12, 2014, sampling event because it was the closest sampling event in time to the beginning of the simulation (Table 4). Inorganic and total phosphorus samples were always under the detection limits of 0.004 mg/L and 0.008 mg/L, respectively. Initial conditions for inorganic phosphorus were set to half of the detection limit concentration while organic phosphorus was set to 0.003 mg/L. For WASP segments that were not sampled, initial conditions for nutrients and benthic algae biomass were set to match the values of the closest COA sample location. For example, all WASP segments downstream of the Onion near Driftwood site were assigned initial values equal to the values that existed at Onion near Driftwood.

Table 4: Initial conditions used in WASP segments that are associated with the average values for samples collected on March 12, 2014.

Location	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Inorganic Phosphorus (mg/L)	Organic Phosphorus (mg/L)	Benthic Algae (g DW/m^2)
Onion Prop Outfall – Piped	0.0187	0.095	0.227	0.002	0.003	2.5
Onion DS South Onion	0.014	0.031	0.163	0.002	0.003	5.6
Onion Prop Outfall – Trib	0.012	0.0198	0.119	0.002	0.003	1.2
Onion US FM150	0.012	0.101	0.126	0.002	0.003	2.1
Onion near Driftwood	0.016	0.0556	0.15	0.002	0.003	1.8

Daily flows and loads were input into WASP segments for Flat Creek, Trib 2, Rocky Branch, Pier Branch, Jackson Branch, south and north forks of Gatlin Creek, South Onion Creek, Trib 9, and segment 34 (most upstream location within the model for mainstem Onion Creek) (Figure 1). Flows at each of these inputs was estimated as a percentage of the flow at USGS gage 08158700 based on drainage area at the input location relative to the drainage area at United States Geological Survey (USGS) gage 08158700 (Table 5).

Table 5: Percent of drainage area at each flow input for the WASP model compared to the drainage area at USGS gage 08158700.

WASP segment	Percentage of drainage area
Flat Creek	5.76%
Trib 2	2.50%
Rocky Branch	3.74%
Pier Branch	4.38%
Jackson Branch	4.33%

North Gatlin Creek	4.13%
South Gatlin Creek	8.60%
South Onion Creek	19.32%
Trib 9	1.47%
Onion mainstem (segment 34)	25.47%

Daily loads were input into the same WASP segments. Loads were divided into storm loads and baseflow based on the amount of flow at USGS gage 08158700. If the daily flow at the gage was 50% higher than the previous days flow than the load that day was considered to be a storm load following established COA procedures. Otherwise, loads were considered baseflow. Baseflow loads were calculated as simply the baseflow concentration multiplied by the daily flow while the storm loads were calculated as the storm concentration of the pollutant multiplied by the change in flow. Baseflow and storm concentrations used in the load calculations can be seen in Table 6. Storm concentrations were taken from other COA work where stormwater event mean concentrations were developed for areas of similar drainage area and percent impervious cover (Glick 2009).

Table 6: Pollutant concentrations used in the baseflow and storm load calculations for the WASP model. EMC represents stormwater event mean concentration.

Parameter	Baseflow (mg/L)	Storm EMC (mg/L)
Ammonia	0.01	0.038
Nitrate	0.03	0.233
Organic Nitrogen	0.15	0.594
Inorganic Phosphate	0.002	0.022
Organic Phosphorus	0.003	0.022

For the modeling scenario that included the Dripping Springs WWTP discharge, additional flow and loads were input into the WASP segment labeled as WWTP Discharge in Figure 1. Loads were calculated by multiplying the WWTP pollutant concentrations by the proposed discharge of 995,000 gallons per day. WWTP pollutant concentrations were taken as a combination of the requested permit concentrations and adding nitrate and organic nitrogen concentrations based on other WWTP with no total nitrogen limits (Porras 2013) (Table 7).

Table 7: Pollutant concentrations used in the WWTP discharge load calculations for the WASP model

Parameter	WWTP (mg/L)
CBOD	5
Ammonia	2
Nitrate	25
Organic Nitrogen	2
Inorganic Phosphate	0.5

Results

Flow

Prior to calibration for nutrients or benthic algae biomass, the modeled flow was compared to the flow at USGS gage 08158700 to ensure the model was simulating flow through Onion Creek accurately. Modeled flow was taken from WASP segment 5, which is the closest segment to the location of the USGS gage. There was no significant difference between the daily gage flow and daily model flow at WASP segment 5 from January 1, 2000 to October 26, 2015 (Table 8; Figure 2, 3).

Table 8: Daily mean (95% confidence intervals) and median flow (cfs) for USGS Gage 08158700 on Onion Creek and the modeled WASP flow in Segment 5 from January 1, 2000 to October 26, 2015. Statistics for the difference between the daily observed and daily modeled flows during this time period are also presented. No significant difference existed between the daily observed and modeled flow.

Parameter	Mean	95% CI	Median
Gage Flow (cfs)	45.59	41.17 to 50.01	4.70
Model Flow (cfs)	43.76	39.59 to 47.94	4.53
Percent Difference	-0.90	-2.02 to 0.23	--

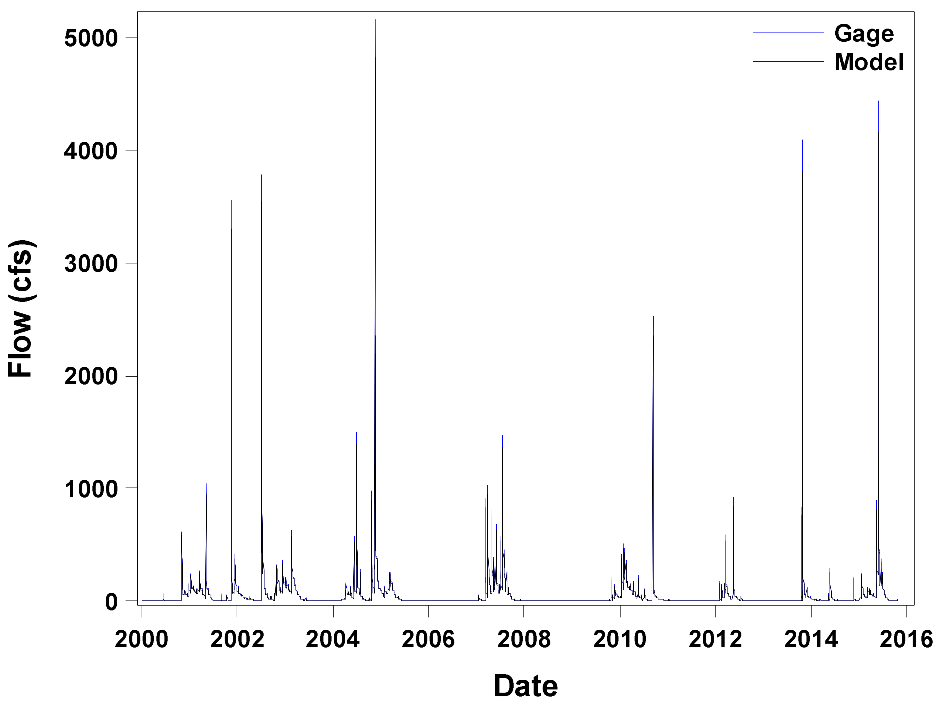

Figure 2: Flow at USGS Gage 08158700 on Onion Creek vs WASP modeled flow at a similar location (WASP Segment 5).

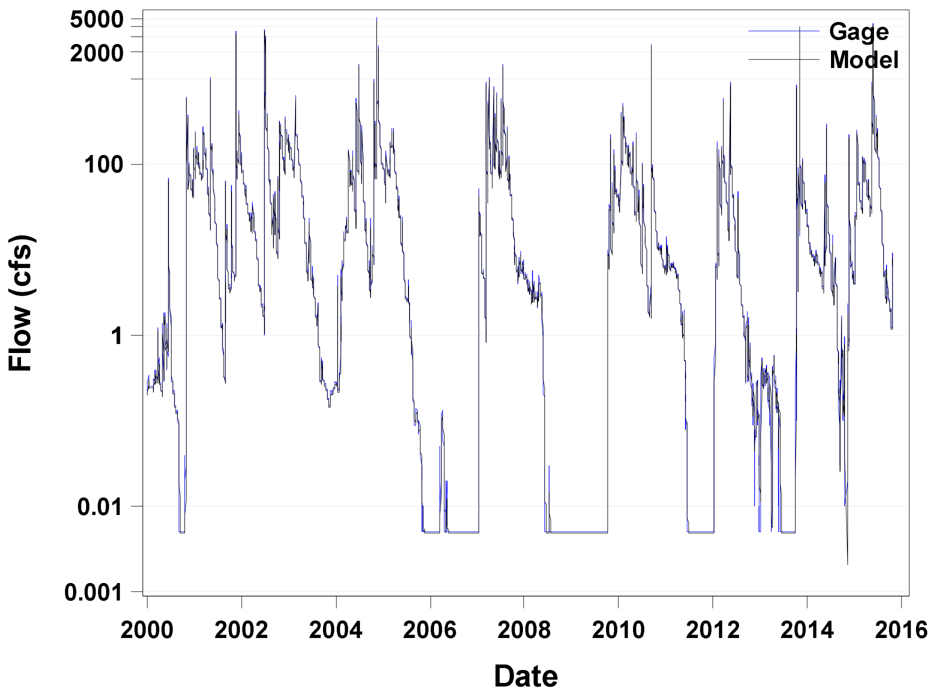

Figure 3: Flow at USGS Gage 08158700 on Onion Creek vs WASP modeled flow at a similar location (WASP Segment 5) on a log scale to better visually assess differences during low flow.

Calibration: Nutrients and Algae

Calibration scenarios were run from January 1, 2014, to October 26, 2015. During this time period the COA conducted 4 out of 5 of its sampling events with one sample occurring after the scenarios time period ended. The WASP segment and COA sample collection location closest to the USGS gage were used for model calibration. Model constants were adjusted until the water column nutrients (ammonia, nitrate, organic nitrogen, inorganic phosphorus, and total phosphorus), benthic biomass, nitrogen in the benthic algae, and phosphorus in the benthic algae output from WASP segment 6 were similar to collected data at Onion near Driftwood (Figure 4). Orthophosphorus was collected in the field and matched with inorganic phosphorus output from the model. The final model constants used to attain this calibration can be seen in Appendix A. While most of the modeled water column nutrients and benthic nutrient concentrations are well within range of collected data, the modeled benthic biomass and chlorophyll *a* did not match the level collected in July 2014. Biomass and chlorophyll *a* tend to increase in the model as nitrogen and phosphorus available to the cells increase, the temperature of the water is optimal, and there is enough available light. Inputs for light are on a monthly basis so it is difficult for the model to predict every daily change to algal biomass. The model predictions should be viewed as a more generalized prediction of algal biomass in Onion Creek.

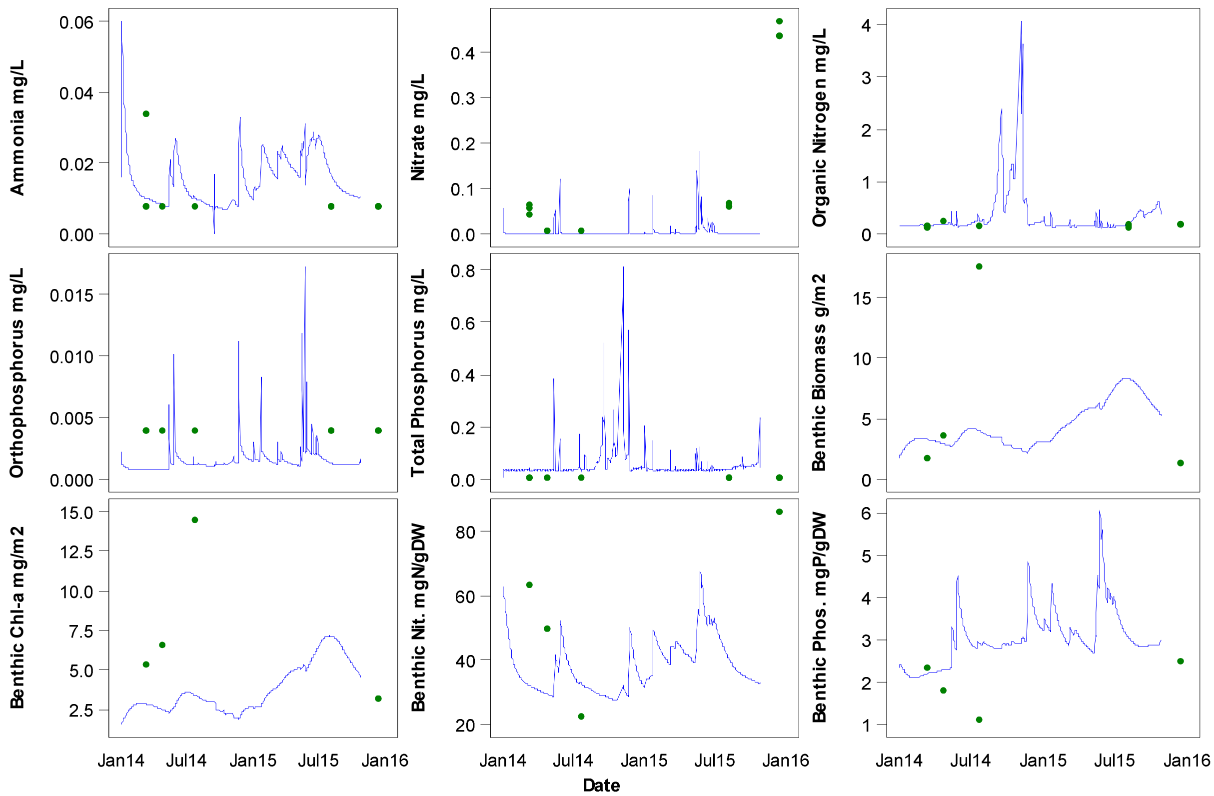

Figure 4: WASP model output for segment 6 (blue line) and data collected by COA at Onion near Driftwood (green dots).

Once the model was calibrated to the Onion near Driftwood site location, the other COA site locations were used to validate the model results. Output from WASP segment 19 was paired with data collected at Onion US FM 150 (Figure 5), output from WASP segment 23 was paired with data collected at Onion Prop Outfall – Trib (Figure 6), and output from WASP segment 24 was paired with data collected at Onion DS South Onion (Figure 7). Onion Prop Outfall – Piped was not used in validation as only two points of data were collected and only one of those points was within the simulation run time. The nutrient output was well within range of the collected data at Onion US FM 150. Modeled benthic biomass and chlorophyll *a* was close to collected data points in 2014. The concentrations were slightly elevated in the model for 2015 when compared to 2014, but no data was collected from the benthic cover during this time period for comparison to the model output. Modeled output was well within range of collected data at Onion Prop Outfall – Trib and at Onion DS South Onion. Since the model output was generally in the range of collected data at all site locations, the output should be able to be used for general estimates at any point within the modeled portion of Onion Creek.

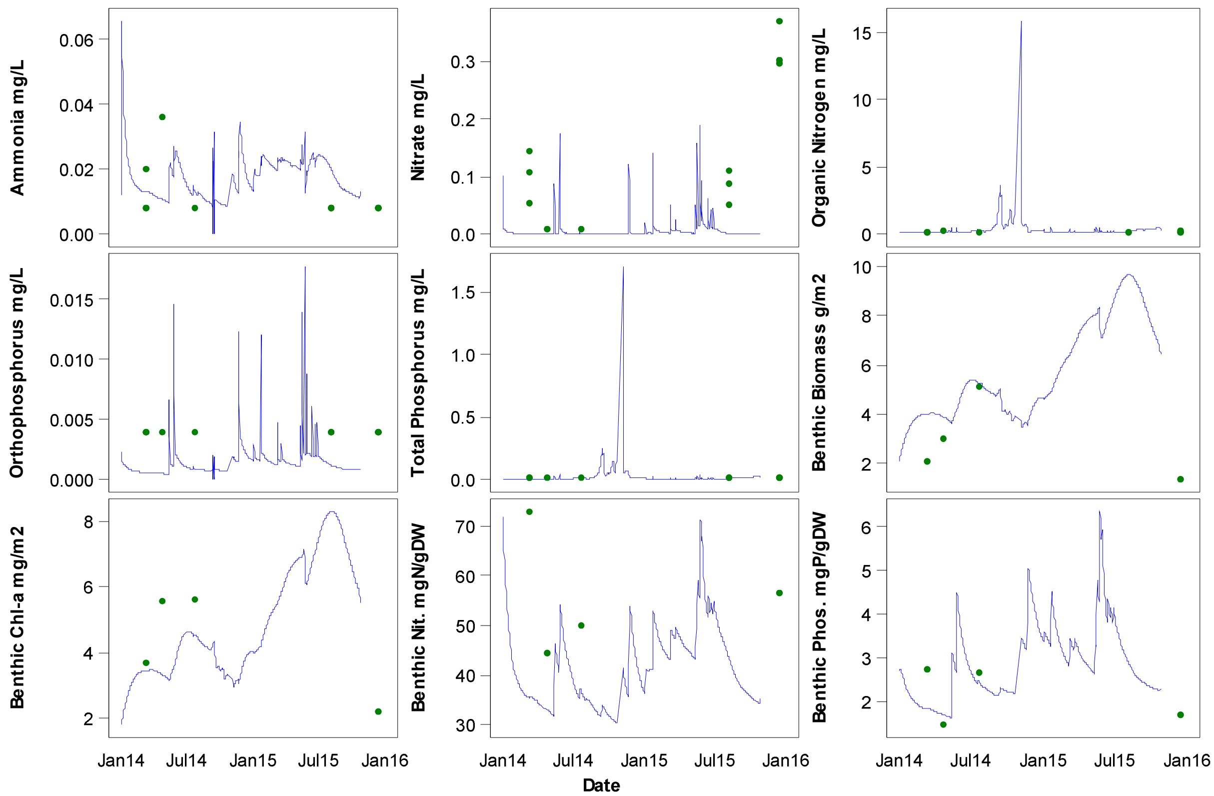

Figure 5: WASP model output for segment 6 (blue line) and data collected by COA at Onion US FM 150 (green dots).

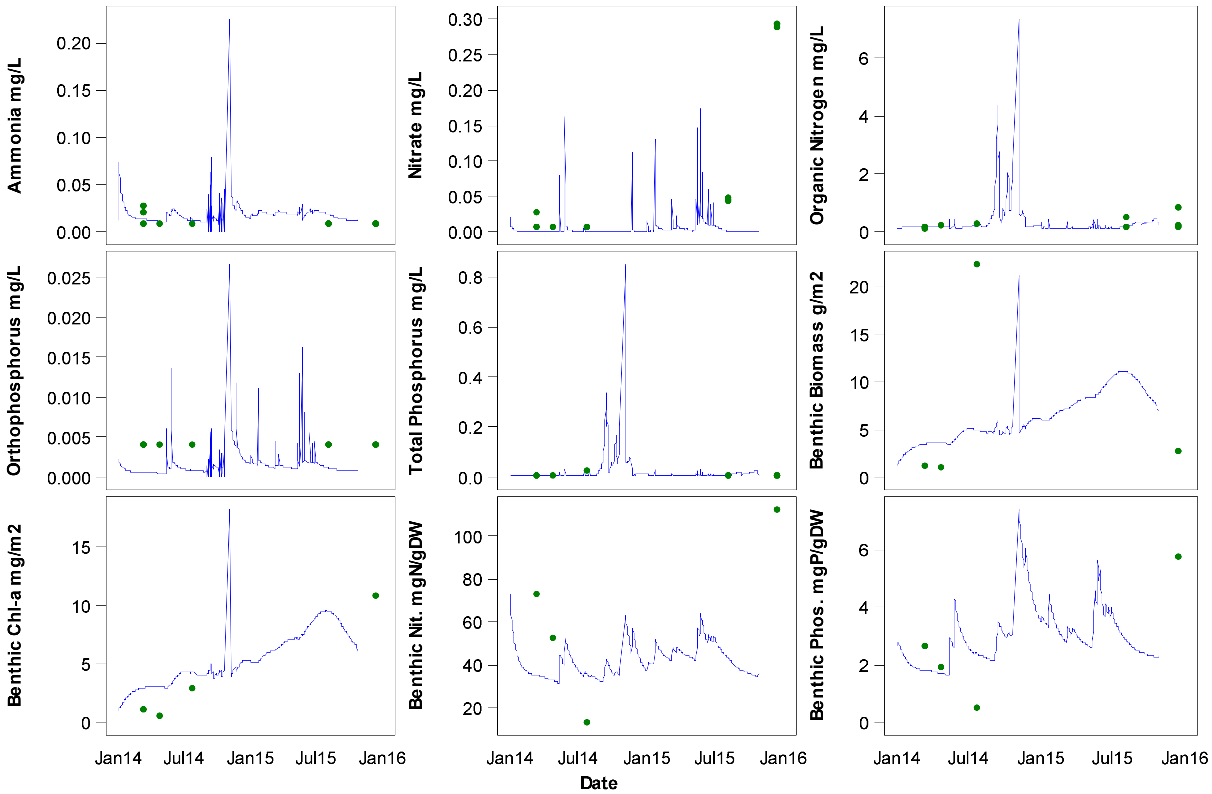

Figure 6: WASP model output for segment 6 (blue line) and data collected by COA at Onion Prop Discharge –Trib (green dots).

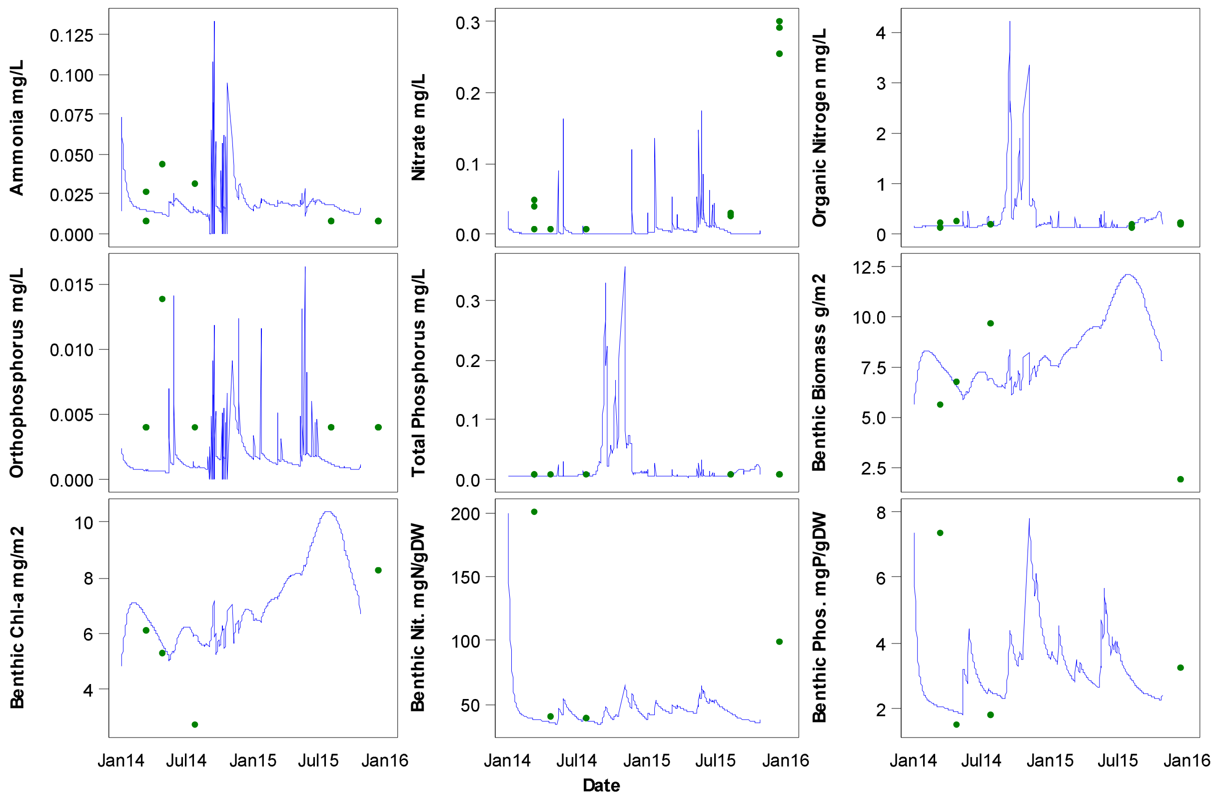

Figure 7: WASP model output for segment 6 (blue line) and data collected by COA at Onion DS South Onion (green dots).

Baseline and Discharge Scenarios

Following calibration for nutrients and algae biomass, two scenarios were run in WASP to determine the potential impact of the proposed Dripping Springs WWTP discharge. Both scenarios were run from January 1, 2000, to October 26, 2015. The first scenario had no further inputs into the model and was considered the Baseline scenario. The second scenario included a wastewater discharge of 995,000 gallons per day input into the WASP segment labeled WWTP Discharge with nutrient loadings described above for the Dripping Springs WWTP discharge and was considered the Discharge scenario.

Annual mean benthic chlorophyll *a* in Onion Creek was calculated for both scenarios at a distance of 200 m (656 ft.) downstream of where the WWTP discharge is proposed to intersect Onion Creek (Figure 8). This was done to get a detailed comparison of mainstem Onion Creek immediately downstream of the discharge under both scenarios. In the Baseline scenario, annual mean benthic chlorophyll *a* at this location is always under 25 mg/m^2 and in most years is actually under 10 mg/m^2. This would clearly indicate that Onion Creek is in an oligotrophic status according to an oligotrophic/mesotrophic threshold of 36 mg/m^2 suggested by Dodds (2006) for systems where phosphorus is most likely a limiting factor in algae growth like many Austin creeks. Under the Discharge scenario, the annual mean benthic chlorophyll *a* concentrations are approximately 50 mg/m^2 from 2001 to 2015. The annual mean benthic chlorophyll *a* concentration in 2000 was above 30 mg/m^2 and more than 6 times the Baseline scenario annual mean. The mean concentration in 2000 was not above the suggested threshold due to the fact that benthic algae concentrations begin very low and slowly rise during the first year of the discharge. With the exception of the first year of the scenario, the proposed discharge would drive productivity in Onion Creek directly downstream of the WWTP discharge from an oligotrophic status well into the mesotrophic status range.

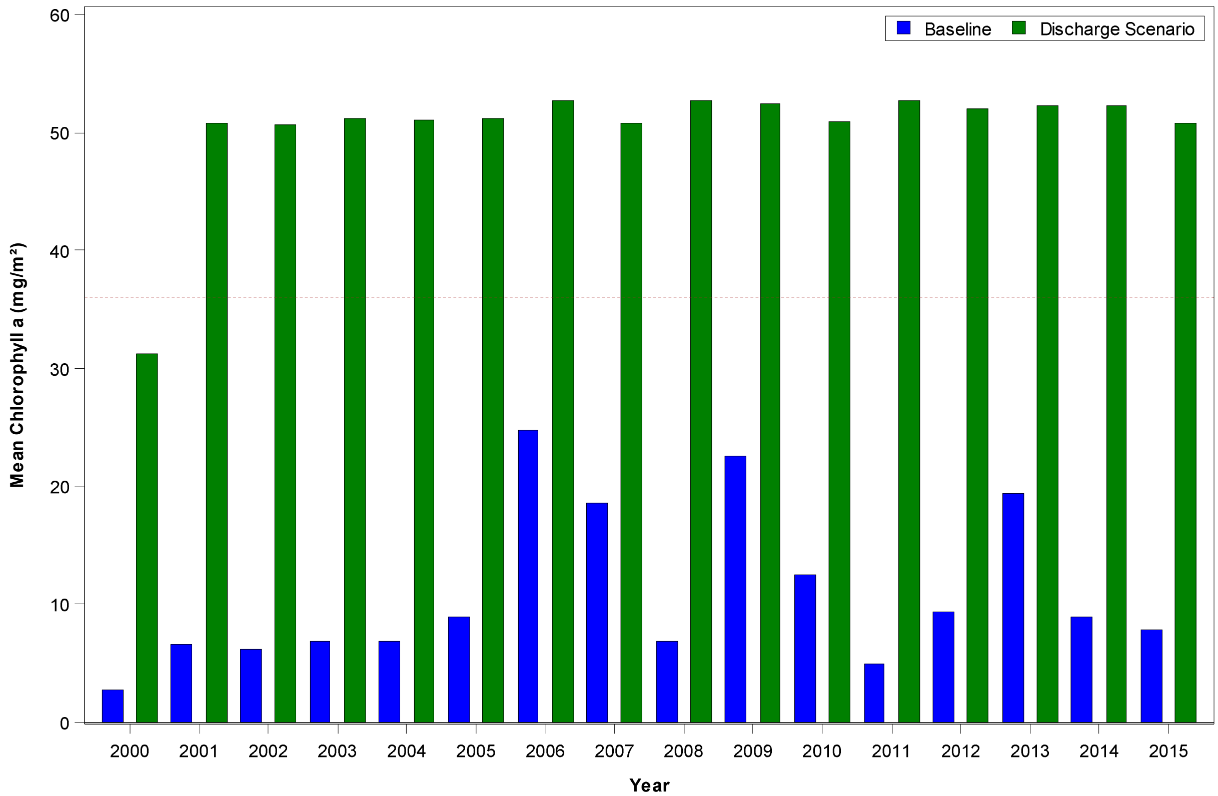

Figure 8: Annual mean benthic chlorophyll *a* (mg/m^2) from modeled data on Onion Creek at a distance of 200 m (656 ft.) from where the Dripping Springs WWTP effluent would enter Onion Creek. Means for the Baseline scenario where no effluent is discharged are blue while means for the Discharge scenario are green. Onion Creek would be considered in an oligotrophic state in the Baseline scenario but in a mesotrophic state in the Discharge scenario using the threshold proposed by Dodds (2006).

To evaluate the spatial extent of water quality impacts from the proposed WWTP discharge, yearly plots of the of the annual mean benthic chlorophyll *a* were constructed from the point where the discharge enters Onion Creek to the Edwards Aquifer Recharge Zone boundary (Figure 9). Under the Discharge scenario Onion Creek will be in a mesotrophic status for 14099.43 to 19644.43 m (8.76 to 12.20 miles) depending on the year. On the map in Figure 1, that would be a considerable stretch of Onion Creek from the point where the WWTP discharge enters Onion Creek to either just downstream of Pier Branch (8.76 miles) or extending down to just upstream of Trib 2 (12.20 miles). Under the Discharge scenario, the concentration of benthic chlorophyll *a* does not return to baseline concentrations prior to reaching the recharge zone boundary with the exception of the year 2006 which was a dry year.

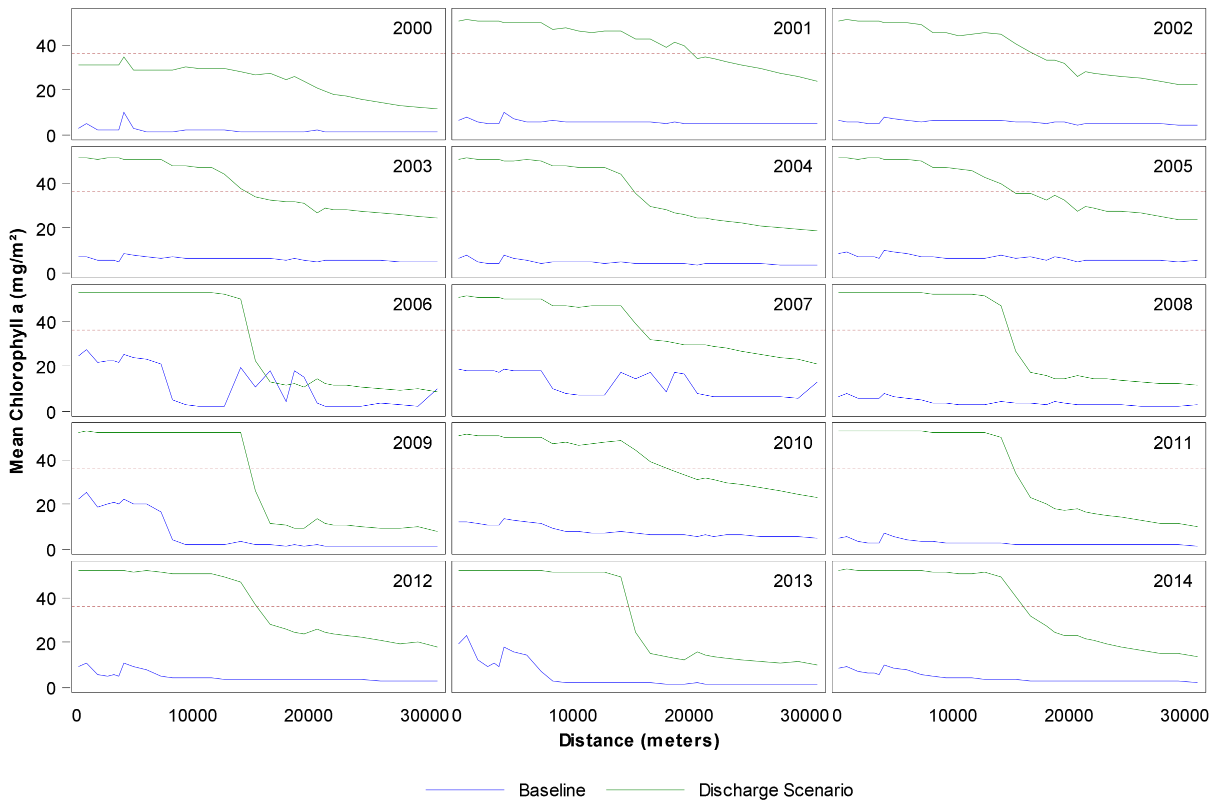

Figure 9: Annual mean chlorophyll *a* against distance (meters) from the WWTP discharge. Blue lines indicate chlorophyll *a* concentrations without the discharge while green lines indicate chlorophyll *a* concentrations with the discharge. The brown line indicates the threshold between oligotrophic and mesotrophic status based on benthic chlorophyll *a* (36 mg/m^2) proposed by Dodds (2006). In the presence of the WWTP discharge, Onion Creek will degrade to a mesotrophic status at the point of discharge and remain in that status for 14099.43 to 19644.43 m (8.76 to 12.20 miles) depending on the year.

Conclusion

The predicted increase in benthic chlorophyll *a* due to nutrient enrichment from the proposed City of Dripping Springs WWTP effluent shows that Onion Creek would be degraded from a low productivity oligotrophic system to a higher productivity mesotrophic system for approximately 9 to 12 miles depending on rainfall in a given year.

Discussion

More stringent nutrient treatment standards, reductions in effluent volume, lower discharge frequency, discharging only when Onion Creek ambient flow is above some threshold, or expansion of land application of effluent would reduce the potential for degradation to this portion of Onion Creek. Such restrictions can be modeled to determine what concentration of nutrients, volume of effluent, and discharge frequency would impact the creek the least. Before a discharge permit is issued to the City of Dripping Springs by TCEQ, restrictions developed from additional analysis should be examined and a protective set of conditions written into the permit. The current proposal should not be accepted as it results in significant degradation of the water quality of Onion Creek based on the modeling results in this report.

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Appendix A: Nutrient and Algal Constants.

Inorganic Nutrient Kinetics	
Nitrification Rate Constant @ 20 C (1/day)	0.13
Nitrification Temperature Coefficient	1.08
Half Saturation Constant for Nitrification Oxygen Limit	2
Denitrification Rate Constant @ 20 C (1/day)	0
Denitrification Temperature Coefficient	1.04
Half Saturation Constant for Denitrification Oxygen Limit	0.1
Organic Nutrients	
Detritus Dissolution Rate (1/day)	0
Dissolved Organic Nitrogen Mineralization Rate Constant	0.075
Dissolved Organic Nitrogen Mineralization Temperature Coefficient	1.08
Dissolved Organic Phosphorus Mineralization Rate Constant	0.22
Dissolved Organic Phosphorus Mineralization Temperature Coefficient	1.08
CBOD	
CBOD(1) Decay Rate Constant @ 20 C	0.4
CBOD(1) Decay Rate Temperature Correction Coefficient	1.05
CBOD(1) Half Saturation Oxygen Limit	0.4
Dissolved Oxygen	
Oxygen to Carbon Stoichiometry Ratio	2.67
Global Reaeration Rate Constant @ 20 C	7
Light	
Light Option	1 – uses input light
Include Algal Self Shading Light Extinction in Steele	0
Background Light Extinction Coefficient	0.813
Benthic Algae	
Benthic Algae D:C Ratio	9.2
Benthic Algae N:C Ratio	0.41
Benthic Algae P:C Ratio	0.017
Benthic Algae Chla:C Ratio	0.0079
Benthic Algae 02:C Production	2.69
Growth Model	1 – First Order
Max Growth Rate	0.4
Temp Coefficient for Benthic Algal Growth	1.05
Carrying Capacity for First Order Model	500
Respiration Rate Constant	0.2
Temperature Coefficient for Respiration	1.06
Internal Nutrient Excretion Rate Constant	0.1
Temperature Coefficient for Nutrient Excretion	1.05
Death Rate Constant	0.15
Temperature Coefficient for Algal Death	1.05

Half Saturation Uptake Constant for Extracellular Nitrogen	0.1
Half Saturation Uptake Constant for Extracellular Phosphorus	0.02
Light Option	2 – Smith
Light Constant for growth	135
Benthic Algae ammonia preference	0.025
Minimum Cell Quota of Internal Nitrogen for Growth	10
Minimum Cell Quota of Internal Phosphorus for Growth	0.5
Maximum Nitrogen Uptake Rate	100
Maximum Phosphorus Uptake Rate	10
Half Saturation Uptake Constant for Intracellular Nitrogen	10
Half Saturation Uptake Constant for Intracellular Phosphorus	2
Fraction of Benthic Algae Recycled to Organic N	0.1
Fraction of Benthic Algae Recycled to Organic P	0.1
Phytoplankton	
Nitrogen to Carbon Ratio	0.25
Phosphorus to Carbon Ratio	0.025
Carbon to Chlorophyll Ratio	50
Maximum Growth Rate Constant @ 20 C	1
Phytoplankton Growth Temperature Coefficient	1.08
Optimal Temperature for Growth	20
Shape parameter for below optimal temperature	0.05
Shape parameter for above optimal temperature	0.05
Respiration Rate Constant @ 20 C	0.01
Respiration Temperature Coefficient	1.045
Death Rate Constant	0
Death Rate due to salinity toxicity	0
Grazability	0
Half-Saturation Constant for N	0.1
Half-Saturation Constant for P	0.1
Nitrogen fixation	0 – no
Optimal Light Saturation	125
Fraction of Death Recycled to Organic N	0.5
Fraction of Death Recycled to Organic P	0.5