Projected Water Quality Degradation for Bear Creek at Ranch Road 1826 Resulting from Direct Discharge Wastewater Permit Requested by Hays County WCID # 1

Prepared for the Hays Trinity Groundwater Conservation District

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Background

In January 2006, Hays County Water Control and Improvement District Number 1 filed a permit request (permit number WQ0014293001) with the Texas Commission on Environmental Quality (TCEQ) for a wastewater direct discharge permit. The permit would allow a maximum discharge of 800,000 gallons per day (1.24 ft^3/s) and impose a limit of 5, 5, 2, and 1 milligram per liter (mg/l) for biochemical oxygen demand-5 day (BOD), total suspended solids (TSS), ammonia nitrogen (NH_4), and phosphorus (P), respectively. The effluent would be discharged in the streambed of Bear Creek immediately downstream from US Highway 290. Within this report, the word “wastewater” refers only to discharge related to the above referenced permit.

Purpose and Scope of Report

The purpose of this report is to document and qualify a statistical analysis of the affect of the proposed wastewater on the existing water-quality of Bear Creek downstream from the proposed wastewater discharge site. The analysis is performed for a site on Bear Creek about a mile downstream (east) from Ranch Road 1826, at a US Geological Survey (USGS) streamflow and water-quality gaging station (fig. 1). The station is at the western edge of the Balcones Fault Zone near the eastern edge of the Upper Glen Rose Limestone outcrop and the upstream end of the Edwards aquifer recharge zone.

The analysis assumes that the maximum permitted quantity and water-quality concentrations for the wastewater are released, and assumes that none of the wastewater load is lost or removed in route to mix with streamflow at the gaging station. It is rumored that some of the effluent may be used for irrigation within the subdivision and not discharged to the streambed but no such details were provided in the permit application. Therefore, the assumption is made that all of the discharged wastewater is available for conveyance to the gaging station about 5.1 miles downstream from the wastewater discharge point.

The analysis is limited to the four water-quality constituents presented above and limited to a mathematical comparison of maximum permitted wastewater loads to existing water-quality loads calculated for and based on streamflow and water-quality data for the gaging station. The water-quality loads at the station were calculated for various flow conditions. Simplified assumptions described later were used to estimate the wastewater quality as expected to exist at the station. A comprehensive water-quality model involving advective-dispersive mass transport and reaction equations would provide a better estimate of the wastewater quality at the station (especially for BOD) and may be commissioned by other governmental entities in the near future.

Physical and Hydrogeologic Setting

The Bear Creek watershed lies within portions of Hays and Travis Counties. The upper part of the watershed (about 12 square miles), the portion of the basin considered in this report, overlies the Upper member of the Glen Rose Limestone (the Upper Trinity aquifer) and is within the recharge zone for the Trinity aquifer and the contributing zone for the Edwards aquifer associated with Barton Springs. The southern extension of the Mount Bonnell fault crosses Bear Creek just east of the USGS gauging station juxtaposing the younger Edwards aquifer rocks into lateral contact with the Upper Glen Rose Limestone. As Bear Creek flows eastward from the USGS gauging station it crosses several miles of faulting in the Balcones Fault Zone and the recharge zone of the Edwards aquifer. About 2 miles east of the downstream end of the Edwards Aquifer recharge zone, Bear Creek forms a confluence with Onion Creek, which discharges to the Colorado River east of Austin.

The study area represents the stream reach and associated basin for the Bear Creek watershed upstream from the streamflow gaging station on Bear Creek about a mile east of Ranch Road 1826, and about 5.1 stream-channel miles downstream from the proposed wastewater discharge site on Bear Creek (fig. 1). Selected characteristics for the Bear Creek basin upstream from the station are presented below:

Drainage area – 12.2 square miles
Main channel length – 5.49 miles
Main stream channel mean slope – 55.55 feet per mile

The drainage area is measured from USGS topographic maps (scale, 1:24,000, and the other two characteristics are measured from USGS topographic maps (scale, 1:100,000). These data are from Asquith and Slade (1996, p. 21).

Geology

The Upper member of the Glen Rose Limestone, which outcrops on the study area, is composed of alternating beds of limestone, dolomite, and chalky clay, known as marl. The “stairstep” topographic profile that dominates the Hill Country terrain results largely from contrasting rates of erosion between the beds of relatively resistant limestone, dolomite and comparatively soft marl. The Upper Glen Rose Limestone is particularly permeable where it is fractured and (or) where fossils or other soluble constituents have dissolved away, leaving honeycomb-like crevices on the outcrop, in the subsurface, or both. Where such features are extensive enough to form caves or sinkholes on the surface or cavernous porosity in the subsurface, the groundwater system is vulnerable to contamination by pollutants introduced at land surface. In some places, such features may breach enough of the subsurface to provide direct conduits between surficial, upgradient parts of the watershed and downstream reaches of Bear Creek.

Groundwater Hydrology

The Upper Glen Rose Limestone comprises the upper several hundred feet of the Trinity aquifer in the study area and forms the Upper Tinity Aqufier (figure 2). The aquifer is recharged primarily as precipitation infiltrates upgradient parts of the watershed and percolates downward to the water table. Once precipitation has infiltrated the subsurface, the water flows toward progressively lower elevations—from generally upland, interstream areas toward Bear Creek. Typically, however, the downward movement of groundwater is impeded by beds of limestone that are interspersed throughout the aquifer. Groundwater flows laterally atop these relatively impermeable interbeds more readily than vertically through them. Consequently, much of the infiltrated precipitation emerges from seeps and springs along the tops of such interbeds where they are exposed along the road cuts, cliffs, and steeper hillsides in the Bear Creek watershed. Much of this “rejected recharge” eventually discharges as surface-water runoff and forms the base-flow of Bear Creek. The remainder of the infiltrated precipitation continues its downward migration to recharge the Lower Glen Rose Limestone (part of the Middle Trinity aquifer). Stratigraphic units and their water-bearing properties representing the area are presented by Ashworth (1983, p12.).

As a result of the area’s rugged topography, the faulted, fractured and porous aquifer outcrops, and relatively shallow water table, the Bear Creek watershed is susceptible to water-quality degradation, including sediment contamination that could result from disturbances in the area’s fragile ecosystem, from urban development in the basin, and especially from wastewater discharges introduced in the area. Steep slopes, thin soils, and sparse vegetation in the basin add to the susceptibility of the watershed. Both surface-water and groundwater vulnerabilities make Bear Creek and its tributaries—as well as the underlying Trinity aquifers—susceptible to water-quality degradation actuated by land-use changes and wastewater discharges anywhere within the watershed.

The Trinity aquifer is actually a series of three (3) differentiated aquifers: the Upper Trinity, the Middle Trinity, and the Lower Trinity. The Upper Trinity Aquifer includes the water bearing zones of the Upper Glen Rose Limestone. The Middle Trinity Aquifer includes the water bearing zones of the Lower Glen Rose Limestone, the Hensel Sand Member and Bexar Shale Member of the Travis Peak Formation, and the Cow Creek Limestone. The Lower Trinity aquifer encompasses the Sligo Limestone and Hosston Sand.

Various studies have established some hydrologic communication between the Upper Trinity and the Middle Trinity, and between the Middle Trinity and the Lower Trinity. The Glen Rose Limestone (Upper and Middle Trinity aquifers) is considered a leaky aquifer system with perched water tables. Its hydrologic characteristics are determined by the lithology of individual beds and geologic structure. The Upper and Lower Glen Rose (Upper and Middle Trinity aquifers) are hydrologically connected due to the lack of a dominant confining bed of significant aerial extent. Eventually, water percolates downward in the formation creating perched groundwater conditions or discontinuous aquifers of limited lateral extent at various depths (Ashworth, 1983).

The primary sources of direct recharge to the Trinity Aquifer in the study area are from rainfall on the outcrop, and seepage losses through headwater creeks into the Upper Member of the Glen Rose Limestone (Mace, 200). The Trinity Aquifer system is an important groundwater supply in the vicinity of the study area.

Use of Bear Creek Water

The study area and recharge zone of the Bear Creek watershed provide recharge to the Edwards aquifer associated with Barton Springs. Much of the base flow and part of storm runoff in the basin recharges to the aquifer within the recharge zone. Bear Creek contributes a mean discharge of about 5 ft^3/s to the aquifer, but contributes at least 33 ft^3/s during storm runoff periods when the streamflow is at least that value (Slade and others, 1986, p 51).

Also, many Trinity aquifer wells are within the study area (figure 2), and many Edwards aquifer wells exist along subsurface flow paths from recharge within this creek as it travels to Barton Springs. The water-quality for these wells is affected by recharge from Bear Creek and thus is susceptibility to degradation due to disturbances or wastewater within the basin. These wells provide water for municipal, domestic, agricultural, and industrial uses—many thousands of people within these areas use the aquifer as their sole source water supply.

Additionally, about 10 percent of the flow from Barton Springs originates as recharge from Bear Creek (Slade and others, 1986, p 51). Therefore, the water quality in Bear Creek also affects the water quality of Barton Springs.

Approach

A summary of the approach used to meet the report objective is presented below.

Quality of Wastewater at the Discharge Site and at the Downstream Gaging Station
1. Calculate, for each of the four water-quality constituents, the wastewater load at the wastewater discharge site.
2. Estimate, based on predicted changes during the route, the concentrations and loads for the wastewater as expected to exist at the downstream USGS gaging station.

Streamflow Conditions (Discharge Percentiles) for the Gaging Station
3. Calculate, based on the long-term streamflow database, percentiles (exceedence probabilities) for streamflow discharges. For example the 50 percentile discharge represents the median flow and the 75 percentile discharge is exceeded 75 percent of the time.

Existing Streamflow Water Quality at Gaging Station
4. Develop, based on the long-term water-quality database for the station, an equation to predict, for each of the four water-quality constituents, stream water-quality concentrations based on streamflow discharge.
5. Calculate, based on the equations, the stream water-quality concentration for each constituent and for each streamflow discharge associated with the discharge percentiles.
6. Calculate, for each constituent, the water-quality load for the streamflow discharge associated with each discharge percentile.

Water-Quality for Mixture of Streamflow and Wastewater
7. Calculate, for each discharge associated with the discharge percentiles, the load and concentration for the mixture of streamflow and wastewater.
8. Calculate and present, for each constituent and for each discharge percentile, a mathematical summary of the water-quality degradation in existing streamflow caused by the wastewater.

Quality of Wastewater at the Discharge Site and at the Downstream Gaging Station

The wastewater permit would allow a maximum discharge of 800,000 gallons per day (equivalent to 1.24 ft^3/s) and impose a limit of 5, 5, 2, and 1 milligram per liter (mg/l) for biochemical oxygen demand-5 day, total suspended solids, ammonia nitrogen, and phosphorus, respectively. The effluent would be discharged in the streambed of Bear Creek immediately downstream from US Highway 290. The assumption was made that the maximum permitted discharge was released with water-quality concentrations at maximum permitted levels, and that none of the wastewater was lost or withdrawn in route to the gaging station about 5.1 stream miles downstream from the release.

Although data identifying gains or losses in channel flow (Slade, and others, 2002) could not be identified for the study reach of Bear Creek (contributing zone for the Edwards aquifer), such studies were conducted for contributing zone reaches on nearby Barton and Onion Creeks (Slade, 1986, p 43). The studies indicate that Onion Creek and Barton Creek did not loose base flow, thus recharge to the Glen Rose Limestone under these creek reaches may be minimal. Therefore, the assumption was made that base flow on Bear Creek lost as recharge to the Trinity aquifer reaches would be minimal, if any. Also, no withdrawals or diversions from Bear Creek in the study area were identified. Finally, bank storage and transpiration losses probably are minimal from the stream channel because it is composed of rock and lacks extensive vegetation. Therefore, wastewater discharge losses in the reach probably would be minimal from the discharge point to the station.

Biochemical Oxygen Demand

In the route to the gaging station, the BOD concentration would decrease based on physical, chemical, and biological reactions, and through dilution with runoff during wet conditions. As stated in the "Purpose and Scope of Report" section above, it is not within the scope of this report to conduct a sophisticated water-quality model to estimate decay in BOD concentrations within the study area reach. However, a simplified analysis was performed to estimate the wastewater BOD concentration as expected to occur at the gaging station. The analysis is dependent upon the wastewater time of travel from the discharge point to the station, and probably represents the upper limit for the expected BOD wastewater concentration at the station. The approach for calculating the travel time is lengthy, and is presented in Appendix 1.

The calculated travel time of 18 hours (Appendix 1) is predicted for stream discharges between 1.0 and 1.5 ft^3/s at the station, which approximates the median discharge of 1.1 ft^3/s (presented later). The data for streamflow measurements **(**Appendix 2**)** show that streamflow velocities increase with increased discharges. Therefore, for stream discharges less than the median discharge, the travel time could be longer than 18 hours and for discharges exceeding the median discharge, the time of travel could be less than 18 hours, either which would change the BOD concentration for wastewater at the station.

The wastewater BOD concentration at the gaging station is estimated by the following exponential equation:

$$BOD_{\text{at station}} = BOD_{\text{initial}} \text{ x } e^{rt}$$

where,
$BOD_{\text{at station}}$ = Wastewater BOD concentration at gaging station,
BOD_{initial} = Wastewater BOD concentration at discharge point = 5 mg/l,
x = multiplied by,
e = a constant value and base of the natural logarithm = 2.718, rounded to the nearest 0.001,
r = BOD decay default value = 1.047 (U.S. Environmental Protection Agency, 1995, p. 50), and,
t = time, in days for transport of water from discharge point to gaging station = 18 hours

The decay value (r) ranges from 1.0 to 1.1 (U.S. Environmental Protection Agency, 1995, p. 50), however, use of these values changes the resulting concentration only a few percent.

Based on the calculation, the wastewater BOD concentration at the station would be 2.3 mg/l. Therefore, the wastewater concentration of 2.3 mg/l was compared to BOD values at the station.

Total Suspended Solids

Concentrations for total suspended solids in water are considered to be relatively conservative, thus the assumption was made that the maximum permitted limit of 5 mg/l would exist in the wastewater from the discharge point to the gaging station. Therefore, the TSS concentration for wastewater (5 mg/l) was directly compared with TSS concentrations in streamflow at the station.

Ammonia Nitrogen

The four major forms for nitrogen in water in order of increasing oxidation state, include organic nitrogen, ammonia nitrogen (NH_4), nitrite nitrogen (NO_2) and nitrate nitrogen (NO_3). With exposure to oxygen in water, the wastewater ammonia will change to states of NO_2 and NO_3. However, the sum of the concentrations for the three expected states of nitrogen in the wastewater (NH_4, NO_2, and NO_3) is assumed to be conservative in time and space. Therefore, the maximum permitted ammonia concentration in wastewater (2 mg/l) was compared to values for suspended and dissolved concentrations for ammonia, nitrite, and nitrate nitrogen.

Phosphorus

Phosphorus concentrations for wastewater are expected to be primarily in dissolved state rather than suspended. The assumption was made that at least part of the dissolved phosphorus in wastewater could be transformed to suspended state during conveyance to the station. Therefore, the phosphorus concentration in wastewater (1 mg/l) was compared to total phosphorus concentrations (dissolved and suspended concentrations) at the station.

Streamflow Conditions (Discharge Percentiles) for the Gaging Station

The USGS operates a program of streamflow-gaging stations throughout the United States (Wahl, and others, 1995). One of the stations, installed in July 1979 and still in operation, is on Bear Creek below Ranch Road 1826. Based on about 25 complete water years (October 1, 1979 to September 30, 2004) of published daily-mean streamflow discharge values (Appendix 2), the exceedence probabilities for the discharge values were calculated. No large impoundments, withdrawals or substantial land-use changes were identified in the basin, thus the entire database was assumed to represent current (2006) flow conditions. The discharges for selected streamflow conditions (exceedence probabilities) are presented in table 1. As the table shows, the median discharge (the discharge exceeded one-half of the time) is 1.1 ft^3/s, which is less than the maximum permitted wastewater discharge of 1.24 ft^3/s. Also, about 14 percent of the time, no flow exists at the station.

It should be noted that the use of daily-mean discharges for calculating flow percentiles probably cause increasing bias in discharges associated with increasing percentiles. For example, large discharges such as 40 ft^3/s (exceeded 2 percent of the time based on daily-mean discharges) could occur for short durations during days for which the daily mean discharge was less than 40 ft^3/s. However, 40 ft^3/s also could occur during days when the daily-mean discharge exceeds 40 ft^3/s, thus the bias associated with percentiles based on daily-mean discharge values probably is minimal except for extremely large discharges.

Existing Streamflow Water Quality at Gaging Station

Existing streamflow loads were calculated for discharges associated with selected exceedence probabilities. A load is a water-quality constituent that is moved or carried by streams, reported as weight of material transported during a specified time period, such as pounds per day or tons per year. A load represents the product of the streamflow discharge and the concentration for a constituent. For example, the product of a streamflow discharge (in ft^3/s) and a water-quality concentration (in mg/l) multiplied by 5.4 produces the load of the constituent, in pounds per day. Load values can be instantaneous if based on instantaneous values for streamflow and water-quality concentration, or represent a daily load if based on values for daily-mean streamflow and daily-mean concentration.

A preliminary review of the water-quality data did not indicate a temporal trend in concentrations—therefore, the entire database was assumed to represent current (2006) water-quality conditions.

A common approach was used to calculate the water-quality loads for each of the four water-quality constituents. All available water-quality data and associated instantaneous streamflow discharges were aggregated for discharges equal to or less than 14 ft^3/s, the stream discharge exceeded only 10 percent of the time (table 1).

This database represents most of the water-quality data at the station—samples for greater discharges were not used because wastewater loads were not compared with large stream discharges (those less than the 10 percentile). The linear relation between values for large discharges and water-quality typically differ from the relation for smaller discharges, and limiting the database to a smaller range in values could provide a better equation and lower its prediction error.

Some of the data for all constituents except BOD have reported concentrations less than the water-quality detection threshold. For these samples, values used for developing the regression equations were revised to represent one-half of the threshold value.

A linear regression equation was developed, for each of the four water-quality constituents, to predict values for water-quality concentration based on values for streamflow discharge. The water-quality constituent was used as the dependent variable and discharge was used as the independent variable.

The Watershed Protection and Development Review Department of the City of Austin have collected and analyzed several stream samples for three sites on Bear Creek, including about four samples for TSS, Nitrogen, and Phosphorus on Bear Creek near the USGS gaging station. However, this database is small compared to the database for the USGS, thus theses data were not included in developing the equations. Also, the data might have been collected, preserved, and/or analyzed differently than the USGS data.

Biochemical Oxygen Demand

Water-quality concentrations and associated instantaneous streamflow discharges for BOD at the station are presented in table 2. Based on these data, a linear regression equation for predicting values of BOD concentrations based on values for streamflow discharge was developed (fig. 3). The equation and associated standard error of estimate and coefficient of determination are presented in table 4, along with a statistical summary for the BOD water-quality data used to develop the equation.

The regression equation was used to calculate a water-quality concentration value for each discharge value associated with the selected streamflow conditions (percentiles) in table 1. The resulting water-quality values are presented in table 5**.**

Total Suspended Solids

Water-quality concentrations and associated instantaneous streamflow discharges for total suspended solids at the station are presented in table 2. Based on these data, a linear regression equation for predicting values of TSS concentrations based on values for streamflow discharge was developed (fig. 3). The equation and associated standard error of estimate and coefficient of determination are presented in table 4, along with a statistical summary for the TSS water-quality data used to develop the equation.

The water-quality data used to develop the equation is based on TSS data for discharges greater than 0.05 ft^3/s and less than 15 ft^3/s. Extremely small discharges often contain high values of TSS due to bed material that can become suspended during the sampling process.

The regression equation was used to calculate a water-quality concentration value for each discharge value associated with the selected streamflow conditions (percentiles) in table 1. The resulting water-quality values are presented in table 5**.**

Total Ammonia, Nitrite, and Nitrate nitrogen

Water-quality concentrations and associated instantaneous streamflow discharges for total (dissolved and suspended concentrations) of ammonia, nitrite, and nitrate nitrogen at the station are presented in table 3**.** Based on these data, a linear regression equation for predicting values of total HN_4, NO_2, and NO_3 concentrations based on values for streamflow discharge was developed (fig. 4). The equation and associated standard error of estimate and coefficient of determination are presented in table 4, along with a statistical summary for the water-quality data used to develop the equation.

The regression equation was used to calculate a water-quality concentration value for each discharge value associated with the selected streamflow conditions (percentiles) in table 1. The resulting water-quality values are presented in table 5**.**

Total Phosphorus

Water-quality concentrations associated instantaneous streamflow discharges for total phosphorus at the station are presented in table 2**.** Based on these data, a linear regression equation for predicting values of TP concentrations based on values for streamflow discharge was developed (fig. 4). The equation and associated standard error of estimate and coefficient of determination are presented in table 4, along with a statistical summary for the TP water-quality data used to develop the equation.

The regression equation was used to calculate a water-quality concentration value for each discharge value associated with the selected streamflow conditions (percentiles) in table 1. The resulting water-quality values are presented in table 5.

Findings--Water-Quality for Mixture of Streamflow and Wastewater

Biochemical Oxygen Demand

The BOD water-quality load (pounds per day) resulting from mixing of the wastewater and streamflow were calculated for each of the selected existing streamflow percentiles, as was the water-quality concentration (table 6). A comparison of the water-quality loads for the wastewater and existing streamflow is presented in the columns at the top of the table, and a comparison of the water-quality concentrations is presented in the columns at the bottom of the table. As the table shows for the flow mixture, wastewater dominates the loads and concentrations for low flows and provides a substantial part of the loads and concentrations even during high flows. As expected, the dominance decreases with increased streamflow but even at the 10 percentile flow, wastewater comprises 19 percent of the total load.

For the existing median discharge, the wastewater would comprise 54 percent of the total streamflow (streamflow and wastewater), and represents 77 percent of the total water-quality load. The wastewater load dominance is due to the difference in BOD concentration for existing streamflow and the wastewater. The BOD concentration of existing streamflow ranges from 0.70 to 0.89 mg/l for discharges from 0.01 to 14 ft^3/s (the 10 percentile discharge). However, the BOD wastewater concentration is 2.3 mg/l—a value 3.2 times higher than the BOD value of 0.72 mg/l for median streamflow conditions.

Total Suspended Solids

The TSS water-quality load (pounds per day) resulting from mixing of the wastewater and streamflow were calculated for each of the selected existing streamflow conditions, as was the water-quality concentration (Table 7**).** A comparison of the water-quality loads for the wastewater and existing streamflow is presented in the columns at the top of the table, and a comparison of the water-quality concentrations is presented in the columns at the bottom of the table. As the table shows for the flow mixture, wastewater dominates the loads for low flows and provides a substantial part of the loads even during high flows. As expected, the dominance decreases with increased streamflow.

For the existing median discharge, the wastewater would comprise 54 percent of the total streamflow (streamflow and wastewater), and represents 41 percent of the total water-quality load, because the TSS concentration is less than that for existing streamflow. The TSS for existing streamflow ranges from 7.7 to 12.8 mg/l for discharges from 0.01 to 14 ft^3/s (the 10 percentile discharge) and the TSS wastewater concentration is 5 mg/l. However, for median streamflow conditions, the total TSS load (streamflow and wastewater) at the station would increase from 47.5 to 80.5 pounds per day due to the wastewater.

Total Ammonia, Nitrite, and Nitrate

The total NH_4, NO_2, and NO_3 water-quality load (pounds per day) resulting from mixing of the wastewater and streamflow were calculated for each of the selected existing streamflow conditions, as was the water-quality concentration (table 8**)**. A comparison of the water-quality loads for the wastewater and existing streamflow is presented in the columns at the top of the table, and a comparison of the water-quality concentrations is presented in the columns at the bottom of the table. As the table shows for the flow mixture, wastewater dominates the loads and concentrations for low flows and provides a substantial part of the loads and concentrations even during high flows. As expected, the dominance decreases with increased streamflow but even at the 10 percentile flow, wastewater comprises 32 percent of the total load.

For the existing median discharge, the wastewater would comprise 54 percent of the total streamflow (streamflow and wastewater), and represents 95 percent of the total water-quality load. The wastewater load dominance is due to the difference in nitrogen concentration for existing streamflow and the wastewater. The nitrogen concentration of existing streamflow ranges from 0.10 to 0.38 mg/l for discharges from 0.01 to 14 ft^3/s (the 10 percentile discharge). However, the wastewater ammonia concentration is 2 mg/l—a value 17 times higher than the ammonia, nitrite, and nitrate value of 0.12 mg/l for median streamflow conditions

Total Phosphorus

The total phosphorus water-quality load (pounds per day) resulting from mixing of the wastewater and streamflow were calculated for each of the selected existing streamflow conditions, as was the water-quality concentration (table 9**)**. A comparison of the water-quality loads for the wastewater and existing streamflow is presented in the columns at the top of the table, and a comparison of the water-quality concentrations is presented in the columns at the bottom of the table. As the table shows for the flow mixture, wastewater dominates the loads and concentrations for low flows and provides a substantial part of the loads and concentrations even during high flows. As expected, the dominance decreases with increased streamflow but even at the 10 percentile flow, wastewater comprises 74 percent of the total load

For the existing median discharge, the wastewater would comprise 54 percent of the total streamflow (streamflow and wastewater), and represents 99 percent of the total water-quality load. The wastewater load dominance is due to the difference in TP concentration for existing streamflow and the wastewater. The TP concentration of existing streamflow ranges from 0.011 to 0.030 mg/l for discharges from 0.01 to 14 ft^3/s (the 10 percentile discharge). However, the wastewater P concentration is 1 mg/l—a value 77 times higher than the P value of 0.013 mg/l for median streamflow conditions.

Analysis of Findings

Biochemical Oxygen Demand

Regarding stability of concentrations, BOD probably represents the most non-conservative of the four constituents. Although National Primary Drinking Water Regulations and National Secondary Drinking Water Regulations do not address BOD, large concentrations of the constituent are associated with algal growth and lack of biological activity in streams. BOD concentrations downstream from the wastewater discharge site are subject to substantial reductions with addition of oxygen and mixture with runoff. A water-quality model designed to predict BOD values and based on physical site conditions could be used to better predict BOD concentrations in Bear Creek.

Total Suspended Solids

TSS concentrations in wastewater are lower than those in existing streamflow at the station. However, it is unknown how much of the TSS in existing streamflow is from organic material or suspended sediment. Suspended sediment data would document the TSS content (Gray and others, 2000 and U.S. Geological Survey, 2000), but such data do not exist. Most of the TSS in wastewater is expected to be organic material rather than suspended sediment, thus the wastewater might cause an increase in suspended organic material at the gaging station.

Total Ammonia, Nitrite, and Nitrate

National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2002a) impose a limit of 1 mg/l for nitrite nitrogen and 10 mg/l for nitrate nitrogen for public water systems. With addition of oxygen, the ammonia nitrogen in wastewater (2 mg/l) would change to states of nitrite and nitrate nitrogen as the wastewater was conveyed.

Many studies have linked nitrogen in water to algal problems in streams. Nitrogen concentrations as low as 0.28 to 0.30 mg/l have been associated with nuisance growth of periphyton, a matrix of algae and heterotrophic microbes in water (U.S. Environmental Protection Agency, 2000, p. 101). Also, nitrogen concentrations as low as 0.25 to 0.30 mg/l have been associated with plankton (tiny open-water plants, animals or bacteria) at euthropic levels (U.S. Environmental Protection Agency, 2000, p. 101).

Therefore, the nitrogen levels as would be permitted for the wastewater, pose threats regarding the growth of algae in Bear Creek. Also, the wastewater would be discharged near the headwaters of the Bear Creek basin, in a stream reach with minimal drainage area and where the flow is nonexistent or extremely low most of the time. Therefore, the wastewater would receive minimal dilution from existing streamflow most of the time, especially in the upper reaches of the creek proximate to the wastewater discharge site.

Total Phosphorus

Although phosphorus is not identified as a constituent in the National Primary Drinking Water Regulations, many studies have documented the effects of phosphorus on algal growth and production of suspended and attached algae in streams. A recent study on tributaries to Lake Waco in Texas shows that 6 of 19 sites were phosphorus limited, meaning that phosphorus concentrations control algal growth in the stream sites (Kiesling and others, 2001, p.32). The same study documents that 2 of the sites are nitrogen limited and both constituents were limited for 2 more sites. Therefore, 53 percent (10 of 19) of the stream sites were limited by nitrogen or phosphorus.

The same study shows that phosphorus levels as low as 0.05 mg/l have produced as much as one-half of the average algal biomass in the streams studies (Kiesling and others, 2001, p. 34, fig. 12) and shows that phosphorus concentrations as low as 0.20 mg/l cause full maximum algae production in streams. (Kiesling and others, 2001, p. 37).

Under section 303c of the Clean Water Act, the U.S. Environmental Protection Agency recommends that States establish water-quality criteria, and provides background material and recommendations for limits of nutrients (nitrogen and phosphorus). Such information and data are presented for Region IV, which includes Texas (U.S. Environmental Protection Agency, 2001). Water-quality data for streams in Subecoregion 30 within Region IV, which represents the Edwards Plateau (including the study area), were used to present “Reference conditions” for nutrients in the subecoregion. Based on data for about 41 streams, 0.27 mg/l represents the 25 percentile for total nitrogen in streams in the subecoregion, and, based on about 50 streams, 0.008 mg/l represents the 25 percentile for total phosphorus (U.S. Environmental Protection Agency, 2001, p. 19). These values are substantially lower than those for the wastewater permit (2 mg/l for nitrogen and 1 mg/l for phosphorus).

U.S Environmental Protection Agency recommendations for nutrient criteria for Region IV are 0.56 mg/l for total nitrogen and .023 mg/l for total phosphorus. (U.S Environmental Protection Agency, 2002b).

Probably the most effective measure for reducing phosphorus in wastewater involves restrictive use of phosphate detergents. Data compiled for the six largest waste-water treatment facilities in Metropolitan Atlanta, Georgia, indicate an 83-percent reduction in the phosphorus load discharged to the Chattahoochee River from 1988 to 1993 because of restricted use of phosphate detergents and upgraded treatment of municipal wastewater (Wangsness and others, 1994). Also, the City of Austin has noted a drop in phosphorus levels as received at their wastewater treatment plants after the city imposed a ban on phosphates in detergents.

Conclusions

Based on the wastewater concentration of nitrogen and phosphorus, and analyses of studies relating the affects of these nutrients on algae in streams, it is likely that algal blooms will develop and grow in Bear Creek between the wastewater discharge site and the upstream end of the Edwards aquifer recharge zone, especially during all but high-runoff periods.

Organic Compounds in Wastewater

A recent study by the USGS shows that a broad range of chemicals found in residential, industrial, and agricultural wastewaters commonly occurs in mixtures at low concentrations downstream from areas of intense urbanization and animal production. The chemicals include human and veterinary drugs (including antibiotics), natural and synthetic hormones, detergent metabolites, plasticizers, insecticides, and fire retardants. One or more of these chemicals were found in 80 percent of the 139 streams sampled. Half of the streams, which are located throughout the Nation, contained 7 or more of these chemicals, and about one-third of the streams contained 10 or more of these chemicals (Buxton and Kolpin, 2002).

Although organic compounds in wastewater are not address by TCEQ standards, many dozens of reports have documented occurrences of wastewater-source organic compounds, including pharmaceuticals, in streams and aquifers throughout the Nation (Appendix 2**,** 3 hyperlinks).

One of the studies reports that organic compounds from wastewater discharges have been documented in karstic aquifers such as the Edwards aquifer (Vroblesky, 1997).

Wastewater represents the only flow in the creek during dry periods and dominates flow in the creek during all but higher than normal flow periods. Therefore, the wastewater would receive no or minimal dilution from storm runoff. Especially for such periods, any loss of wastewater to the Trinity aquifer could pose a threat to wells due to organic compounds in wastewater.

Wastewater Quality Degradation for Trinity Aquifer Wells in the Study Area

On April 5, 2006, personnel from the Watershed Protection Department of the City of Austin conducted a streamflow gain-loss study on Bear Creek in the study area (table 10). The study was conducted during relatively steady-flow conditions--the discharge remained almost constant at 0.58 ft^3/s throughout most of the day for the gaging station on Bear Creek (http://waterdata.usgs.gov/tx/nwis/dv/?site_no=08158810&agency_cd=USGS).
However as the table shows, almost all the flow was lost from site 4 to 5 and from site 7 to 8, but large gains occurred from site 5 to 6, from 9 to 10, and from 10 to 11. Additionally large losses occurred from site 13 through 15 but a large gain occurred from site 15 to 16. Probably at least some of the losses and gains are due to flow entering and leaving gravel deposits in the streambed--streamflow might be lost where gravel deposits become thicker and streamflow gains could be occurring where gravel deposits become thinner. (Nico Hauwert, City of Austin, oral commun.).

The discharge losses and gains represent a substantial portion of the total flow, thus the study is inconclusive regarding the potential discharge loss to Bear Creek in the study from the proposed wastewater discharge. For example, it is not know if the flow lost at the sites represents the same water that is gained in downstream reaches on the creek. If such is the case, it is likely that most if not all the proposed wastewater would remain in the streambed rather than being lost to the Upper Glen Rose Limestone, thus the wastewater discharge probably would present only a minimal threat to the water-quality in the many wells in the area (fig. 2). However, it is possible that some or most of the flow lost in the upper reaches does not represent the same water that is gained in downstream reaches. If such is the case, the wastewater discharge could provide recharge to the Upper Glen Rose Limestone, which could pose a water-quality threat to wells in the area.

Although it is likely that only few local wells are developed in the Upper Glen Rose Limestone (the Upper Trinity Aquifer), there are many local wells developed in the adjacent Lower Glen Rose Limestone, which partially comprises the Middle Trinity Aquifer. Substantial leakage could be occurring from the Upper to the Lower Glen Rose Limestone.

Little information or data exist regarding the sources, quantity, or water-quality of recharge to the Trinity aquifers in the Bear Creek basin, and little information exists regarding the amount, movement or water-quality of groundwater in the area. Therefore, the affect of the wastewater discharge on the Trinity aquifer is unknown, as is the affect of land development on the aquifer.

Water-Quality Degradation for Edwards Aquifer Wells and Barton Springs

The wastewater likely would degrade the water quality for at least some wells, especially those in the Edwards aquifer proximate to Bear Creek or between Bear Creek and Barton Springs. During high-flow periods, storm runoff would cause at least some dilution of the wastewater quality, thus recharge would represent a combination of runoff and wastewater. Increased volumes of runoff cause increased dilution which represents a decreased threat for water-quality degradation in wells.

However, water-quality degradation for wells is especially likely for low-flow periods, during which the streams providing recharge to the aquifer are not flowing or near no flow. For these periods, which can be extensive (many months to more than a year), the wastewater would represent all or almost all recharge to the aquifer, because, as of the date of this report, no direct discharges to the Barton Springs part of the Edwards aquifer are permitted by the TCEQ. As shown in the analyses herein, the wastewater quality is much worse than that for Bear Creek, which is representative of the water-quality for the other five major creek providing recharge to the Barton Springs part of the aquifer. Therefore, during at least dry periods, the water quality for some wells and for Barton Springs likely would have degraded water quality.

Recommendations

Especially needed is a study that documents streamflow gains or losses on the reach of Bear Creek in the study area that would convey the proposed wastewater. The study should be conducted when the discharge in the upper reach is about 1.2 ft^3/s, that approximating the discharge for the proposed wastewater. Also needed is a dye study for Bear Creek in the study area. A bulk due injection should be made in the upper reach of Bear Creek when the discharge there is about 1.2 ft^3/s. Sampling for the dye should be conducted at or near Ranch Road 1826 so that the travel time for dye concentrations from the leading edge through the trailing edge can be determined. Based on these data, the volume of dye in water sampled at Ranch Road 1826 can be determined and compared to the dye volume injected. Based on these analyses, the discharge of water lost to groundwater in the reach can be determine for the creek discharge associated with that of the proposed waterwater. Finally, a study should be conducted that identifies the sources, amounts, and water-quality of recharge to the Upper and Middle Trinity aquifer in the study area, along with the hydrologic and hydraulic properties for both aquifers in the study area.

Many Edwards aquifer wells exist in possible flow-path areas between the recharge zone on Bear Creek and Barton Springs, the discharge point for most of the recharge from the creek. These wells include water uses for municipal, domestic, and industrial supplies for many thousands of people.

The affect of the proposed wastewater on the water-quality of the wells and on the water-quality of Barton Springs is unknown. However, substantial degradation would be caused by the wastewater on the water-quality of Bear Creek, thus water quality for the wells and Barton Springs also could be degraded. Therefore, it is suggested that a detailed analyses be conducted that would identify the affect that the proposed wastewater would have on the water-quality of wells and Barton Springs.

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Appendices

Appendix 1.—Estimation of Wastewater Time of Travel from Discharge Site to Gaging Station

Data indicating the wastewater travel time for the reach was not found. However, the documentation for the wastewater-application permit included a single dye tracer study done for only the upper reach of Bear Creek, which represents about one-half of the study area reach (R.J. Brandes, 2005). The dye study was used to calibrate a water-quality model for the permit application, but is not pertinent for determining time of travel for the wastewater discharge point to the gaging station.

Discharge from a hydrant flushed the dye downstream from its injection point on Bear Creek. However, the creek discharge (including hydrant flow) during the dye study was estimated to be between 500,000 and 600,000 gallons per day (R.J. Brandes, p. 3), which is less than the maximum permitted discharge. Also, it is not known how much time passed between the initial hydrant release and the release of the dye, thus it is unknown if any or all stream channel depressions were full when the dye was released. If the traveling dye encountered any non-full depressions, its travel time could be substantially delayed as dye-laden water fulfilled such storage before continuing downstream. Such a case would produce travel times less if not much less than steady-state flow conditions would produce. Finally, the dye study represented a slug (instantaneous) injection, rather than a sustained continuous injection. Because of the effects of transient storage, the time of travel and dispersion characteristic revealed by the slug injections could differ from those indicated by a sustained injection (Jobson, 1996) and (Runkel and Bencala, 1995).

Because of a lack of dye studies qualified to document the wastewater time of travel from the discharge point to the station, the travel time was assumed to represent the mean velocity in the stream, based on streamflow measurements at the gaging station. As of March 2006, about 206 streamflow discharge measurements had been made at the station (Appendix 2), for which 13 of the measured discharges were between 1.0 and 1.5 ft^3/s—values that approximate the median flow of 1.1 ft^3/s (presented earlier) for the station. For these measurements, the mean stream velocity ranges from 0.3 to 1.0 ft/s, with a mean value of about 0.6 ft/s. The discharge measurements were made in a reach of the stream where the streambed slope is about 23 ft/mile (USGS topographic map, scale 1:24,000, Signal Hill Quadrangle). However, as documented earlier, the mean channel slope for the stream reach from the headwaters (proximate to the discharge point) to the station is 55.55 ft/mile, thus the mean velocity of the stream for the reach should be greater than measured at the station. A mean steam velocity was estimated for the reach based on Manning's equation (Chow, 1959, p. 99).

$V = 1.486/n \text{ x } R^{2/3} \text{ x } S^{1/2}$
where,
V = mean velocity in channel (ft/s),
n = coefficient of channel roughness (dimensionless),
R = Hydraulic radius = cross sectional area (ft^2) / wetted perimeter (ft), and,
S = gradient of energy head slope = channel slope for uniform channel (ft/ft).

The assumption was made that the low flow channel for Bear Creek is uniform from the wastewater discharge site to the station, thus based on Manning's equation the mean velocity is proportional to the square root of the channel slope. Therefore, the mean velocity calculated for the 5.1 mile reach is 0.93 ft/s, based on the equation below:

$V_{\text{reach}} = V_{\text{at station}} \text{ x } (S_{\text{reach}}{}^{0.5} / S_{\text{at gage}}{}^{0.5})$

Where,
V_{reach} = mean velocity for reach (ft/s),
$V_{\text{at station}}$ = mean velocity at gaging station = 0.6 ft/sec,
x = multiplied by,
S_{reach} = mean channel slope for reach = 55.55 ft/mile = 0.01052 ft/ft, and,
$S_{\text{at station}}$ = channel slope at gaging station = 23 ft/mile = 0.00436 ft/ft.

The travel time for the reach is calculated as the reach length divided by the mean stream velocity for the reach as indicated below:

Travel time = mean stream velocity x steam reach length = $\dfrac{5.1 \text{ miles x } 5280 \text{ ft/mile}}{0.93 \text{ ft/s}}$ =

= 28,900 seconds = 8.0 hours

However, based on the USGS topographic map (Signal Hill quadrangle, scale 1:24.000), eight ponds or pools were identified on Bear Creek in the reach. The total length of the ponds is about 0.8 miles. The stream velocity was assumed to be 0.10 ft/s through the ponds and 0.93 ft/s through the remaining 4.3 miles of stream reach. Based on these assumptions, the time of travel calculates to be about 18 hours.

Appendix 2.—Hyperlinks for Data References in Report

Hyperlink to streamflow discharge measurements for station Bear Creek below Ranch Road 1826:
http://nwis.waterdata.usgs.gov/tx/nwis/measurements?search_site_no=08158810&search_site_no_match_type=exact&sort_key=site_no&group_key=NONE&sitefile_output_format=html_table&column_name=agency_cd&column_name=site_no&column_name=station_nm&column_name=lat_va&column_name=long_va&column_name=state_cd&column_name=county_cd&column_name=alt_va&column_name=huc_cd&begin_date=&end_date=&set_logscale_y=1&format=html_table&pre_format=on&date_format=YYYY-MM-DD&rdb_compression=file&list_of_search_criteria=search_site_no

Hyperlink to daily-mean streamflow discharges for gaging station Bear Creek below Ranch Road 1826:
http://nwis.waterdata.usgs.gov/tx/nwis/discharge?site_no=08158810&agency_cd=USGS&begin_date=&end_date=&set_logscale_y=1&format=rdb&date_format=YYYY-MM-DD&rdb_compression=value&submitted_form=brief_list

Hyperlink to selected USGS reports about organic compounds in wastewater:
http://pubs.er.usgs.gov/pubs/index.jsp?jboEventVo=PubResultView&jboEvent=Search&view=adv&pxfield_title=organic+wastewater&pxfield_year=&pxfield_year_start=&pxfield_year_end=&pxfield_auth_first=&pxfield_auth_last=&pxfield_series=&pxfield_rpt_year=&pxfield_rpt_seq=&pxorderby=0&performSearch=Search+Now

Hyperlink to “National Reconnaissance of Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in Streams”: http://toxics.usgs.gov/regional/emc_surfacewater.html

Hyperlink to USGS search engine inquiry for “wastewater” and “organic” identified 299 reports, conferences, projects, abstracts, and other information:
http://search.usgs.gov/query.html?col=usgs&op0=%2B&fl0=&ty0=w&tx0=wastewater&op1=%2B&fl1=&ty1=w&tx1=+organic&op2=&fl2=title%3A&ty2=w&tx2=+&dt=an&inthe=604800&ady=16&amo=3&ayr=2006&bdy=24&bmo=3&byr=2006&nh=10&rf=0&lk=1&sc=1&charset=iso-8859-1&ql=a&sc=1&qt=

Figures and tables

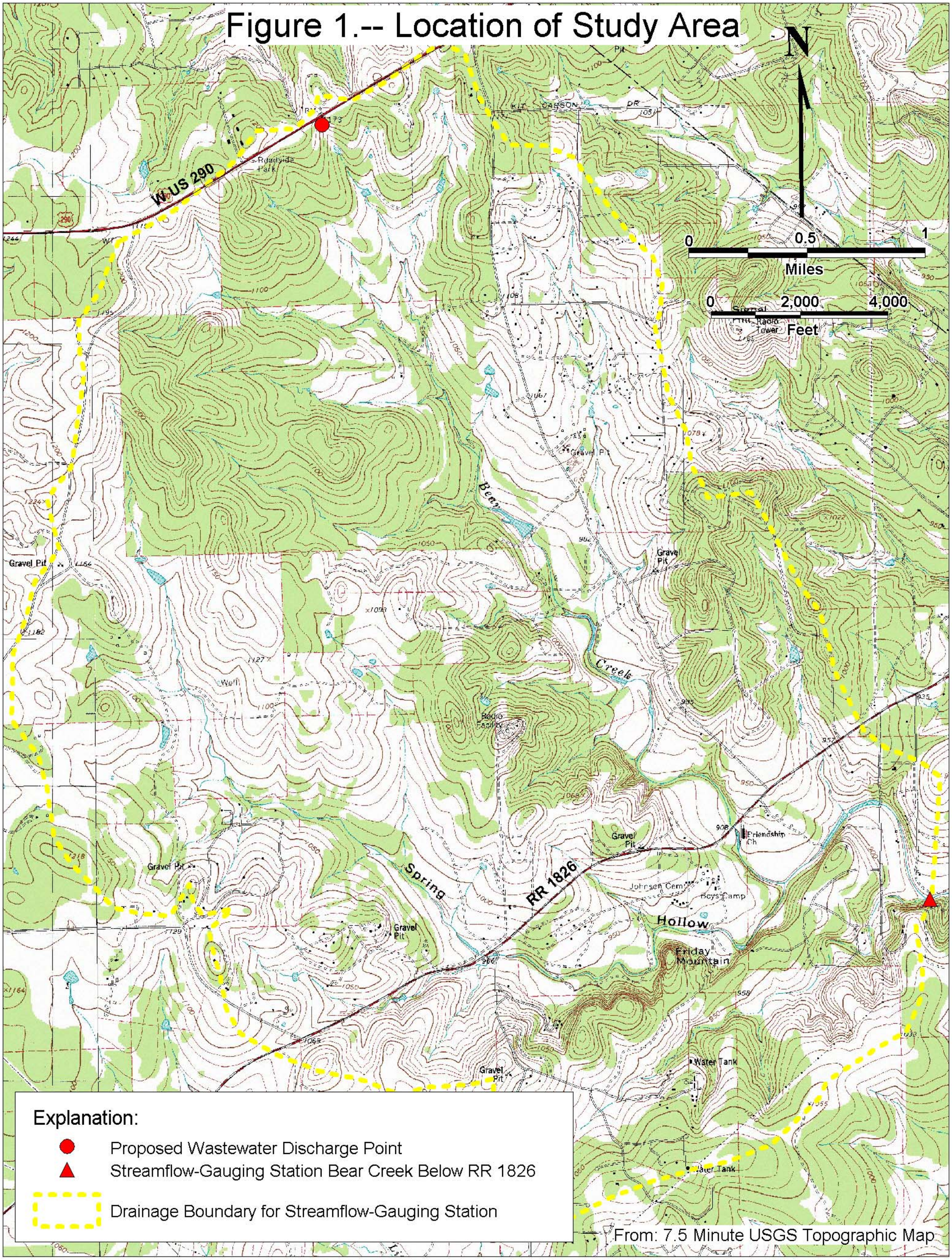


Figure 1.-- Location of Study Area

From: 7.5 Minute USGS Topographic Map

Figure 2. Surficial Geology and Well Location Map

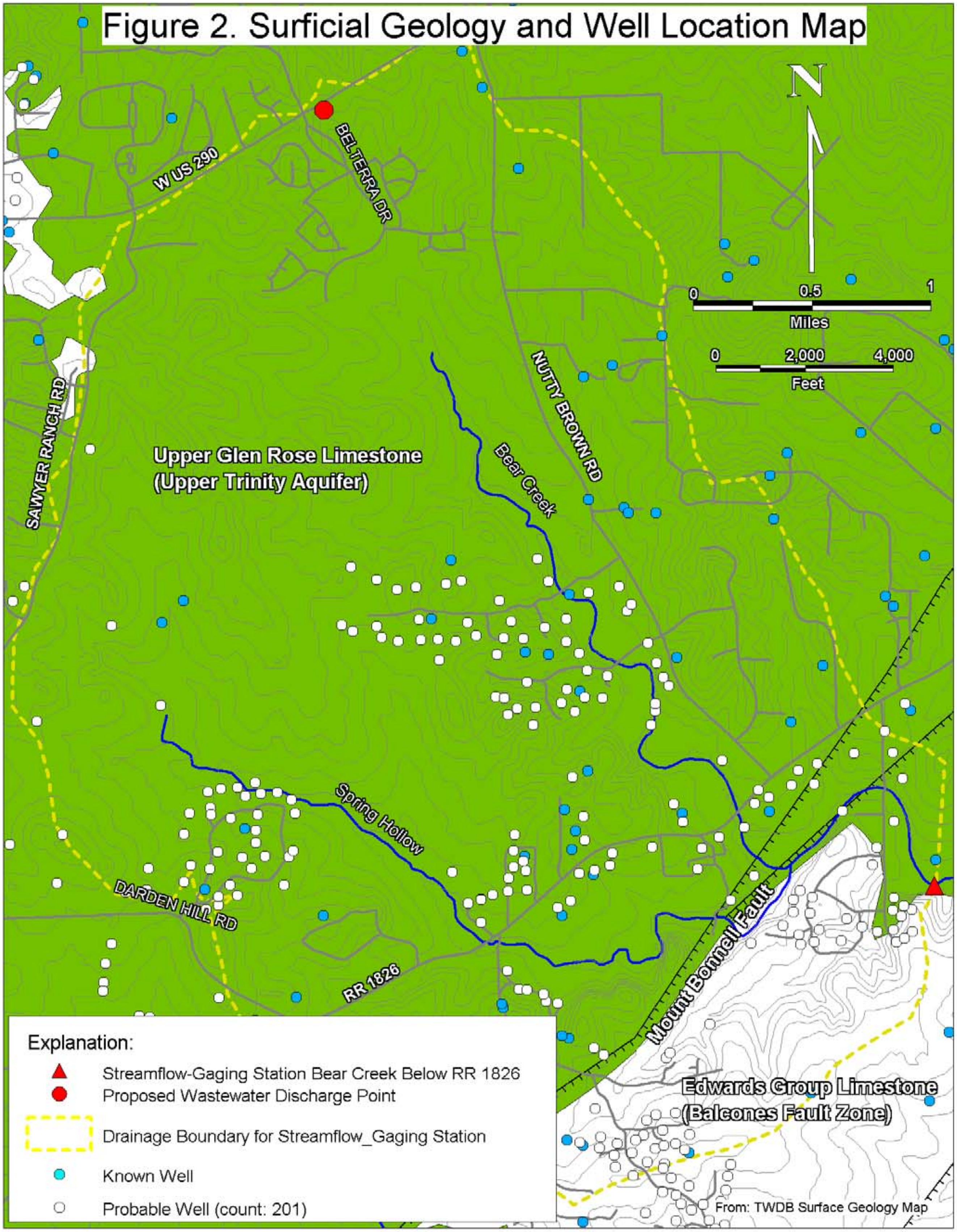
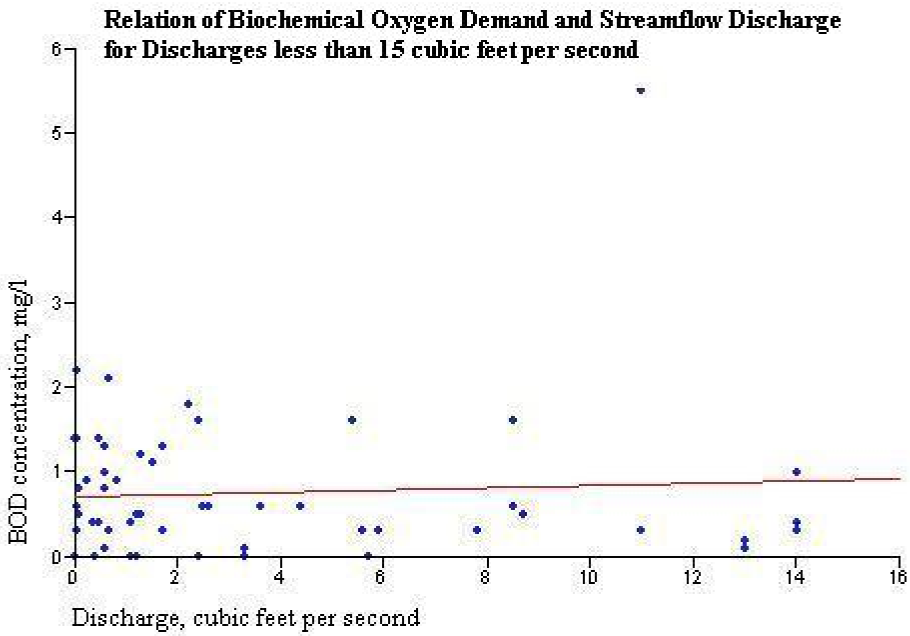


Figure 3.—Relation of BOD and TSS to Streamflow Discharges for Bear Creek at Ranch Road 1826



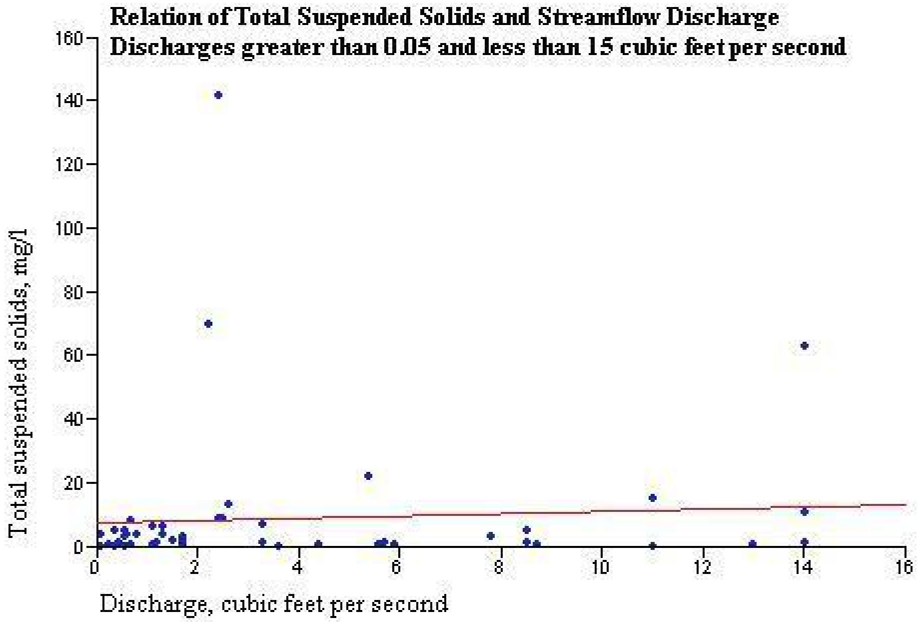
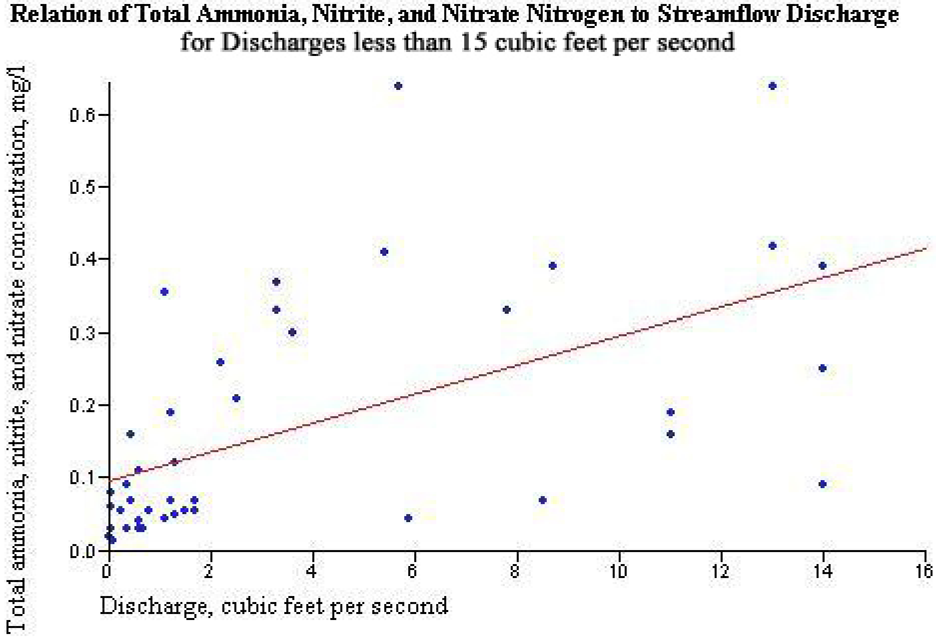


Figure 4.—Relation of Total Ammonia, Nitrite, and Nitrate Nitrogen, and Total Phosphorus to Streamflow Discharges for Bear Creek at Ranch Road 1826



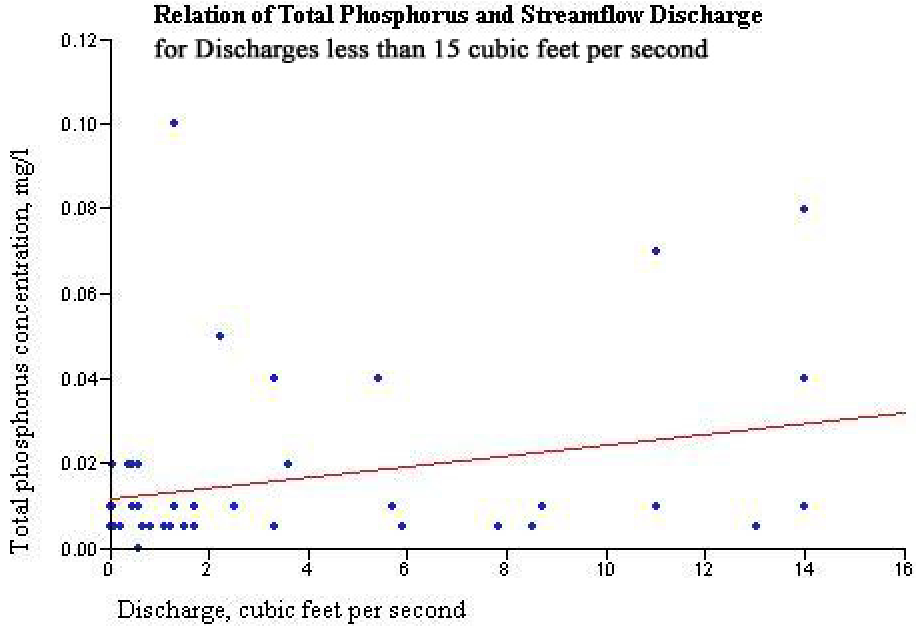


Table 1.—Discharges for Selected Exceedence Probabilities for Bear Creek below Ranch Road 1826.

High value	1000 ft^3/s
Low value	0.00 ft^3/s
Mean	6.38 ft^3/s
Data count	9161 values, based on data from October 1, 1979 through September 30, 2004
Missing data count	0
Zero data count	1313

Discharge Exceedence Probability (in percent)	Associated Discharge (in ft^3/s)
0.01	1000
1.00	66.0
2.00	40.0
3.00	32.0
4.00	28.0
5.00	23.0
10.00	14.0
15.00	10.0
20.00	7.2
Mean	6.38
25.00	5.2
30.00	3.8
35.00	2.9
40.00	2.1
45.00	1.5
50.00	1.1
55.00	0.89
60.00	0.62
65.00	0.40
70.00	0.20
75.00	0.07
80.00	0.04
85.00	0.01
86.00	0.00
90.00	0.00
95.00	0.00
100.00	0.00

Table 2.— BOD, TSS, and Total P concentrations for Bear Creek below Ranch Road 1826

Data collected, analyzed, and published by the U.S, Geological Survey, and represent all available data for discrete water-quality samples analyzed for the parameters presented

Presented below are definitions for parameter codes used in table column headings

Sample_dt – date of sample, month, date, year
p00061 - Discharge, instantaneous, at time of sample, cubic feet per second"
p00310 - Biochemical oxygen demand, water, unfiltered, 5 days at 20 degrees Celsius, milligrams per liter"
p00530 - Residue, total nonfilterable, milligrams per liter"–Total Suspended Solids
p00535 - Loss on ignition, from nonfilterable residue, milligrams per liter"
p00540 - Residue, fixed nonfilterable, milligrams per liter"
p00665 - Phosphorus, water, unfiltered, milligrams per liter"-Total phosphorus, suspended and dissolved concentrations
p00666 - Phosphorus, water, filtered, milligrams per liter"-Dissolved phosphorus
p71886 - Phosphorus, water, unfiltered, milligrams per liter as phosphate"

< - Actual value is known to be less than the value shown

sample_dt	p00061	p00310	p00530	p00535	p00540	p00665	p00666	p71886
3/1/1978	0.06	0.8	0	0		0.01		
4/10/1978	0.66	2.1	8	3		< .010		
6/7/1978	2.2	1.8	70	10		0.05		
9/8/1978	0.01	1.4	45	8		0.01		
9/27/1978	0.35	0.4	0	0		0.02		
11/6/1978	1.3	0.5	4	0		0.01		
12/18/1978	3.3	0.1	1	1		0.04		
1/12/1979	30	0.4	6	1		0.01		
2/23/1979	409	5.2	898	160		0.09		
3/21/1979	74	1.6	66	5		0.01		
4/25/1979	30	0.5	1	0		0.02		0.06
6/12/1979	11	0.3	0	0	0	0.01		0.03
9/11/1979	1.2	0	1	1	0	< .010		0
10/31/1979	0.57	1	5	4	1	0		0
1/16/1980	0.57	0.8	0	0	0	0.01		0.03
1/28/1981	3.6	0.6	0	0	0	0.02		0.06
6/17/1981	132	0	11	11	0	0.08		0.25
8/19/1981	2.5	0.6	9	6	3	0.01		0.03
4/22/1982	5.4	1.6	22	5	17	0.04		0.12
7/26/1982	0.57	0.1	3	< 2		0.02		0.06
2/9/1983	14	1	63	40	23	0.04		0.12
3/1/1983	8.7	0.5	< 1	< 1		0.01		0.03
2/28/1984	1.3	1.2	6	2	4	< .200		
4/17/1984	0.45	1.4	< 2	< 2		0.01		0.03
2/20/1985	5.7	0	1	1		0.01		
6/6/1985	204	6.2	146	22	124	0.11		0.34
8/13/1985	0.37	0	5	4		0.02		
1/29/1986	3.3	0	7	5		< .01		
4/9/1986	1.2	0.5	1	1		< .01		
5/1/1986	28	2.1	28	10		0.03		
5/1/1986	16	2.1	14	4		0.02		
6/23/1986	14	0.3	1	1		0.08		
8/21/1986	0.45	0.4	1	1		0.02		
1/13/1987	13	0.1	< 1	< 1		< .01		
2/18/1987	7.8	0.3	3	3		< .01		
5/11/1987	1.7	1.3	< 1	< 1		0.01		
5/29/1987	56	2.6	19	10		0.03		
6/4/1987	300	1.1	44	10		0.05		
7/17/1987	16	0.7	1	< 1		0.1		
8/5/1987	1.7	0.3	2	< 1		< .01		

sample_dt	p00061	p00310	p00530	p00535	p00540	p00665	p00666	p71886
11/3/1987	0.04	0.3	4	< 1		< .01		
2/16/1988	0.8	0.9	4	< 1		< .01		
4/25/1988	0.22	0.9	< 1	< 1		< .01		
5/17/1989	29	0.6	< 1	< 1		0.01		
5/17/1989	49	1	12	2		0.02		
5/17/1989	186	1.2	40	< 1		0.02		
6/6/1989	8.5	0.6	1	1		< .01		
8/16/1989	0.02	0.3	3	< 1		< .01		
4/23/1990	1.5	1.1	2	2		< .01		
7/19/1990	0.02	0.3	5	5		< .01		
1/10/1991	28	0.9	27	14		0.03		
2/4/1991	105	0.7	20	6		< .01		
2/26/1991	13	0.2	< 1	< 1		< .01		
5/29/1991	5.9	0.3	< 1	< 1		< .01		
8/13/1991	0.05	2.2	< 1	< 1		< .01		
8/15/1991	11	5.5	15	15		0.07		
2/12/1992	1.1	0	6	5		< .01		
4/5/1992	19	0	5	5		< .01		
4/5/1992	24	0.1	5	5		< .01		
4/6/1992	16	0	4	4		< .01		
6/19/1992	14	0.4	11	11		0.01		
7/29/1992	1.1	0.4	< 1	< 1		< .01		
1/13/1993	2.4	0	9	< 1			0.03	
3/16/1993	5.6	0.3	< 1	< 1			< .01	
5/17/1993	4.4	0.6	< 1	40			0.03	
7/15/1993	2.6	0.6	13	4			0.08	
2/14/1994	0.03	0.6	11	7			0.05	
2/22/1994	2.4	1.6	142	19			0.28	
2/22/1994	8.5	1.6	5	3			0.02	
3/21/1994	0.6	1.3	4	3			0.03	
8/29/1994	0.01	0	25	15			< .01	
12/5/1994	1.7	0.3	3	7		< .01	< .01	
6/7/1995	26	0.6	< 1	6		< .01	< .01	
3/4/1996	0.05	1.4	22	16		0.02	< .01	
10/15/1996	0.08	0.5	4	2		< .01	0.01	
2/5/1997	0.66	0.3	< 1	< 1		< .01	< .01	
6/6/1997	304	1	10	6		< .01	< .01	
6/6/1997	338	1.1	31	9		< .01	< .01	
6/6/1997	434	3.8	174	28		0.11	< .01	
6/6/1997	258	3.6	106	18		0.07	< .01	

Table 3.--Nitrogen Concentrations for Bear Creek below Ranch Road 1826

All data collected, analyzed, and published by the U.S, Geological Survey, and represent all available data for discrete water-quality samples.
Presented below are definitions for parameter codes used in table column headings

sample_dt - Date of sample, month, date, year
p00061 - Discharge, instantaneous, cubic feet per second
p00600 - Total nitrogen, water, unfiltered, milligrams per liter
p00605 - Organic nitrogen, water, unfiltered, milligrams per liter
p00608 - Ammonia, water, filtered, milligrams per liter as nitrogen
p00610 - Ammonia, water, unfiltered, milligrams per liter as nitrogen
p00613 - Nitrite, water, filtered, milligrams per liter as nitrogen
p00615 - Nitrite, water, unfiltered, milligrams per liter as nitrogen
p00620 - Nitrate, water, unfiltered, milligrams per liter as nitrogen
p00623 - Ammonia plus organic nitrogen, water, filtered, milligrams per liter as nitrogen
p00625 - Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen
p00630 - Nitrite plus nitrate, water, unfiltered, milligrams per liter as nitrogen
p00631 - Nitrite plus nitrate, water, filtered, milligrams per liter as nitrogen
< - Actual value is known to be less than the value shown

sample_dt	p00061	p00600	p00605	p00608	p00610	p00613	p00615	p00620	p00623	p00625	p00630	p00631
3/1/1978	0.06		0		< .010		0.01	0				
4/10/1978	0.66	0.3	0.27		0.01		< .010	0.02		0.28	0.02	
6/7/1978	2.2	0.76	0.5		0.08		0.02	0.16		0.58	0.18	
9/8/1978	0.01	0.41	0.39		0.01		< .010	0.01		0.4	0.01	
9/27/1978	0.35	0.52	0.49		0.01		< .010	0.02		0.5	0.02	
11/6/1978	1.3	0.94	0.89		0.01		0.01	0.03		0.9	0.04	
12/18/1978	3.3	0.76	0.39		0.05		0.01	0.31		0.44	0.32	
1/12/1979	30	1.4	0.13		< .010		0.02	1.3		0.13	1.3	
2/23/1979	409	3	2.6		0.06		0.02	0.32		2.7	0.34	
3/21/1979	74	0.76	0.54		0.01		0.02	0.19		0.55	0.21	
4/25/1979	30	0.61	0.14		0.02		< .010	0.45		0.16	0.45	
6/12/1979	11	0.44	0.28		0.01		< .010	0.15		0.29	0.15	
9/11/1979	1.2	0.37	0.18		0.18		0.02	0		0.36	0.01	
10/31/1979	0.57	0.48	0.44		0.01		0	0.03		0.45	0.03	
1/16/1980	0.57	0.13	0.1		0		0	0.03		0.1	0.03	
1/28/1981	3.6	0.6	0.3		0.05		0	0.25		0.35	0.25	
6/17/1981	132	1.2	0.69		0.06		0	0.42		0.75	0.42	
8/19/1981	2.5	0.71	0.5		0.05		0	0.16		0.55	0.16	
4/22/1982	5.4	1	0.6		0.16		0.02	0.23		0.76	0.25	
7/26/1982	0.57		0.64		0.06		< .020			0.7	< .100	
2/9/1983	14	0.8	0.41		0.09		0.02	0.28		0.5	0.3	
3/1/1983	8.7	0.6	0.21		0.09		< .020			0.3	0.3	
2/28/1984	1.3				0.07		< .010			0.2	< .100	
4/17/1984	0.45				0.11		< .010			0.3	< .100	
2/20/1985	5.7				0.04		< .010			0.4	0.6	
6/6/1985	204				0.13		0.04			1.1	0.2	
8/13/1985	0.37				0.04		< .01			0.2	< .10	
1/29/1986	3.3				0.03		< .01			0.4	0.3	
4/9/1986	1.2				0.02		< .01			0.2	< .10	
5/1/1986	28				0.03		0.01			0.5	< .10	

sample_dt	p00061	p00600	p00605	p00608	p00610	p00613	p00615	p00620	p00623	p00625	p00630	p00631
5/1/1986	16				0.02		0.01			0.4	0.1	
6/23/1986	14				0.05		< .01			0.2	0.2	
8/21/1986	0.45				0.02		< .01			0.2	< .10	
1/13/1987	13				0.04		< .01			0.4	0.6	
2/18/1987	7.8				0.03		< .01			0.4	0.3	
5/11/1987	1.7				0.02		< .01			1.3	< .10	
5/29/1987	56				0.03		0.02				0.2	
6/4/1987	300				0.03		0.02			1	0.1	
7/17/1987	16				0.08		< .01			0.4	< .10	
8/5/1987	1.7				< .01		< .01			0.6	< .10	
11/3/1987	0.04				0.01		< .01			0.4	< .10	
2/16/1988	0.8				< .01		< .01			0.4	< .10	
4/25/1988	0.22				< .01		< .01			0.2	< .10	
5/17/1989	29				0.04		0.03			< .20	0.3	
5/17/1989	49				0.04		0.01			< .20	0.3	
5/17/1989	186				0.03		0.01			0.3	0.3	
6/6/1989	8.5				0.02		< .01			< .20	< .10	
8/16/1989	0.02				0.01		< .01			0.2	< .10	
4/23/1990	1.5				< .01		0.01			0.3	< .10	
7/19/1990	0.02				0.03		< .01			0.3	< .10	
1/10/1991	28				0.02		< .01			0.3	0.4	
2/4/1991	105				< .01		< .01			0.4	0.5	
2/26/1991	13				0.02		< .01			< .20	0.4	
5/29/1991	5.9				0.02		< .01			0.5	< .05	
8/13/1991	0.05				< .01		0.01			< .20	< .05	
8/15/1991	11				0.02		0.04			0.6	0.17	
2/12/1992	1.1				< .01		< .01			< .20	0.35	
4/5/1992	19				< .01		< .01			< .20	0.11	
4/5/1992	24				< .01		< .01			< .20	0.11	
4/6/1992	16				< .01		< .01			< .20	0.12	
6/19/1992	14				0.02		< .01			< .20	0.07	
7/29/1992	1.1				0.02		< .01			0.2	< .05	
1/13/1993	2.4			0.02		< .010			0.2			0.093
3/16/1993	5.6			0.01		< .010			< .20			0.27
5/17/1993	4.4			0.02		< .010			< .20			< .050
7/15/1993	2.6			< .010		< .010			< .20			< .050
2/14/1994	0.03			< .010		< .010			< .20			< .050
2/22/1994	2.4			0.03		< .010			< .20			< .050
2/22/1994	8.5			0.02		0.01			0.3			0.064
3/21/1994	0.6			0.02		< .010			0.3			< .050
8/29/1994	0.01			0.02		< .010			0.6			< .050
12/5/1994	1.7			< .01		< .010				< .20		0.11
6/7/1995	26			0.03		< .010				0.3		0.18
3/4/1996	0.05			< .01		0.01				0.3		< .05
10/15/1996	0.08			< .01		0.03				< .20		< .05
2/5/1997	0.66			< .01		0.02				< .20		0.11
6/6/1997	304			0.03		< .010				0.22		0.31
6/6/1997	338			0.03		< .010				< .20		0.32
6/6/1997	434			0.04		< .010				1		0.28
6/6/1997	258			< .01		< .010				0.88		0.19

Table 4.--Regression Equations for Estimating Water-Quality Concentrations and Statistical Summaries for Water-Quality Database, Bear Creek below Ranch Road 1826

All water-quality values in milligrams per liter
All streamflow discharge values in cubic feet per second

Characteristics for Regression Equations

Water-quality Constituent	Regression equation	Standard error of estimate(SE)	Coefficient of determination (R^2)
Biochemical Oxygen Demand	BOD = 0.700 + (0.014 x Dis.)	0.86	0.005
Total Suspended Solids	TSS = 7.66 + (0.364 x Dis.)	24	0.0045
Total NH_4 + NO_2 + NO_3	T NH_4+NO_2+NO_3 = 0.097 + (0.02 x Dis.)	0.14	0.32
Total Phosphorus	TP = 0.012 + (0.0013 x Dis.)	0.02	0.08

Characteristics for Water-Quality Databases

Water-quality Constituent	Number of data values	Mean	Median	Standard deviation	Variance	Skew coefficient
Biochemical Oxygen Demand	56	0.75	0.5	0.86	0.74	0.43
Total Suspended Solids	48	9.1	2.0	24	565	0.63
Total NH_4 + NO_2 + NO_3	43	0.17	0.09	0.16	0.03	0.19
Total Phosphorus	47	0.02	0.01	0.02	0.0004	0.36

Note: Total NH_4 + NO_2 + NO_3 represent the sum of total concentrations (suspended plus dissolved concentrations) for ammonia, nitrite, and nitrate nitrogen.

Regression equations and statistical summaries for all constituents are based on all water-quality samples with associated streamflow discharges less than 15 ft^3/s, except for the equation for TSS which is based on discharges greater than 0.05 ft^3/s and less than 15 ft^3/s.

Table 5.—Water-Quality Concentrations Predicted by Regression Equations for Discharges Associated with Selected Exceedence Probabilities

Exceedence Probability (in percent) (in ft^3/s)	Associated Discharge (ft^3/s)	Associated water-quality concentration based on regression equation, mg/l			
		BOD	TSS	T NH_4+NO_2+NO_3	Total P
0.01	1000				
1	66				
2	40				
3	32				
4	28				
5	23				
10	14	0.89	12.8	0.38	0.03
15	10				
20	7.2	0.80	10.3	0.24	0.021
Mean	6.38	0.79	10.0	0.22	0.020
25	5.2	0.77	9.6	0.20	0.018
30	3.8	0.75	9.0	0.17	0.016
35	2.9				
40	2.1	0.73	8.4	0.14	0.014
45	1.5				
50	1.1	0.72	8.0	0.12	0.013
55	0.89				
60	0.62	0.71	7.9	0.11	0.012
65	0.4				
70	0.2	0.70	7.7	0.10	0.012
75	0.07	0.70	7.7	0.10	0.012
80	0.04	0.70	7.7	0.10	0.011
85	0.01	0.70	7.7	0.10	0.011
86	0				
90	0				
95	0				
100	0				

Note: T NH_4+NO_2+NO_3 represents total (dissolved and suspended) concentrations for ammonia, nitrite, and nitrate nitrogen

Regression equations presented in table 4

Table 6.— Biochemical Oxygen Demand Streamflow and Wastewater Loads and Concentrations for Selected Streamflow Conditions

BOD Streamflow and Wastewater Loads

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow load (lbs/day)	Total load (Streamflow plus wastewater) (lbs/day) [2]	Percent of total load due to wastewater (percent)	Ratio of Wastewater load to streamflow load (ratio)
10	14.00	15.20	8%	67.00	82.00	19%	0.23
20	7.20	8.40	15%	31.00	46.00	33%	0.50
mean	6.38	7.62	16%	27.20	42.60	36%	0.57
25	5.20	6.40	19%	22.00	37.00	42%	0.70
30	3.80	5.00	25%	15.00	30.00	51%	1.03
40	2.10	3.30	38%	8.30	24.00	64%	1.90
50	1.10	2.30	54%	4.30	20.00	77%	3.60
60	0.62	1.84	67%	2.40	17.80	86%	6.40
70	0.20	1.44	86%	0.76	16.20	95%	20.00
75	0.07	1.31	95%	0.26	15.70	98%	59.00
80	0.04	1.28	97%	0.15	15.60	99%	103.00
85	0.01	1.25	99%	0.04	15.40	100%	385.00
86	0.00	1.24	100%	0.00	15.40	100%	--

[1] - Wastewater discharge represents 1.24 ft3/s

[2] - BOD Wastewater load represents 15.4 pounds per day, based on BOD concentration of 2.3 mg/l at gaging station

BOD Streamflow and Wastewater Concentrations

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow concentration (mg/l)	Streamflow plus wastewater concentration (mg/l) [2]	Increase in concentration due to wastewater (percent)
10	14.00	15.20	8%	0.89	1.01	13%
20	7.20	8.40	15%	0.80	1.03	29%
mean	6.38	7.62	16%	0.79	1.04	32%
25	5.20	6.40	19%	0.77	1.07	39%
30	3.80	5.00	25%	0.75	1.14	52%
40	2.10	3.30	38%	0.73	1.33	82%
50	1.10	2.30	54%	0.72	1.58	119%
60	0.62	1.84	67%	0.71	1.79	152%
70	0.20	1.44	86%	0.70	2.08	197%
75	0.07	1.31	95%	0.70	2.21	216%
80	0.04	1.28	97%	0.70	2.25	221%
85	0.01	1.25	99%	0.70	2.29	227%
86	0.00	1.24	100%	--	2.30	--

[1] - Wastewater discharge represents 1.24 ft3/s

[2] - Based on BOD wastewater release concentration of 5 mg/l decaying to 2.3 mg/l at gaging station

Table 7.—Total Suspended Solids Streamflow and Wastewater Loads and Concentrations for Selected Streamflow Conditions

TSS Streamflow and Wastewater Loads

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow load (lbs/day)	Total Load (Streamflow plus wastewater) (lbs/day) [2]	Percent of total load due to wastewater (percent)	Ratio of Wastewater load to streamflow load (ratio)
10	14.00	15.20	8%	968	1001	3%	0.03
20	7.20	8.40	15%	400	433	8%	0.08
mean	6.38	7.62	16%	344	377	9%	0.10
25	5.20	6.40	19%	270	303	11%	0.12
30	3.80	5.00	25%	185	218	15%	0.18
40	2.10	3.30	38%	95.3	128	26%	0.35
50	1.10	2.30	54%	47.5	80.5	41%	0.69
60	0.62	1.84	67%	26.4	59.4	56%	1.25
70	0.20	1.44	86%	8.3	41.3	80%	3.98
75	0.07	1.31	95%	2.9	35.9	92%	11
80	0.04	1.28	97%	--	--	--	--
85	0.01	1.25	99%	--	--	--	--
86	0.00	1.24	100%	0	33	100%	--

[1] - Wastewater discharge represents 1.24 ft3/s

[2] - TSS wastewater load represents 33 pounds per day, based on TSS concentration of 5 mg/l

TSS Streamflow and Wastewater Concentrations

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow concentration (mg/l)	Streamflow plus wastewater concentration (mg/l) [2]	Increase in concentration due to wastewater (percent) [3]
10	14.00	15.2	8%	12.8	12.1	-5%
20	7.20	8.40	15%	10.3	9.6	-7%
mean	6.38	7.62	16%	10.0	9.2	-8%
25	5.20	6.40	19%	9.6	8.8	-8%
30	3.80	5.00	25%	9.0	8.1	-10%
40	2.10	3.30	38%	8.4	7.2	-14%
50	1.10	2.30	54%	8.0	6.5	-19%
60	0.62	1.84	67%	7.9	6.0	-24%
70	0.20	1.44	86%	7.7	5.9	-23%
75	0.07	1.31	95%	7.7	5.2	-32%
80	0.04	1.28	97%	--	--	--
85	0.01	1.25	99%	--	--	--
86	0.00	1.24	100%	--	5.0	--

[1] - Wastewater discharge represents 1.24 ft3/s

[2] - Based on TSS wastewater concentration of 5 mg/l

[3] - Wastewater lowers TSS values in streamflow by percentage shown

Table 8.—Total Ammonia, Nitrite, and Nitrate Nitrogen Streamflow and Wastewater Loads and Concentrations for Selected Streamflow Conditions

Total NH4, NO_2, and NO_3 Streamflow and Wastewater Loads

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow load (lbs/day)	Total load (Streamflow plus wastewater) (lbs/day) [2]	Percent of total load due to wastewater (percent)	Ratio of Wastewater load to streamflow load (ratio)
10	14.00	15.20	8%	29	42.4	32%	0.46
20	7.20	8.40	15%	9.3	22.7	59%	1.4
mean	6.38	7.62	16%	7.6	21.0	64%	1.8
25	5.20	6.40	19%	5.6	19.0	71%	2.4
30	3.80	5.00	25%	3.5	16.9	79%	3.8
40	2.10	3.30	38%	1.6	15.0	89%	8.4
50	1.10	2.30	54%	0.71	14.1	95%	19
60	0.62	1.84	67%	.37	13.7	98%	36
70	0.20	1.44	86%	.11	13.5	99%	122
75	0.07	1.31	95%	.038	13.4	100%	353
80	0.04	1.28	97%	.022	13.4	100%	609
85	0.01	1.25	99%	.005	13.4	100%	2,680
86	0.00	1.24	100%	0	13.4	100%	--

[1] - Wastewater discharge represents 1.24 ft^3/s

[2] - NH_4, NO_2, and NO_3 Wastewater load represents 13.4 pounds per day, based on NH_3 concentration of 2 mg/l

Total NH_4, NO_2, and NO_3 Streamflow and Wastewater Loads

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow concentration (mg/l)	Streamflow plus wastewater concentration (mg/l) [2]	Increase in concentration due to wastewater (percent)
10	14.00	15.20	8%	.38	0.51	34%
20	7.20	8.40	15%	.24	0.50	108%
mean	6.38	7.62	16%	.22	0.51	132%
25	5.20	6.40	19%	.20	0.55	175%
30	3.80	5.00	25%	.17	0.63	271%
40	2.10	3.30	38%	.14	0.84	500%
50	1.10	2.30	54%	.12	1.14	850%
60	0.62	1.84	67%	.11	1.38	1150%
70	0.20	1.44	86%	.10	1.74	1640%
75	0.07	1.31	95%	.10	1.90	1800%
80	0.04	1.28	97%	.10	1.94	1840%
85	0.01	1.25	99%	.10	1.98	1880%
86	0.00	1.24	100%	--	2.00	--

[1] - Wastewater discharge represents 1.24 ft^3/s

[2] - Based on NH_4 wastewater concentration of 2 mg/l

Table 9.— Total Phosphorus Streamflow and Wastewater Loads and Concentrations for Selected Streamflow Conditions

Total P Streamflow and Wastewater Loads

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow load (lbs/day)	Total load (Streamflow plus wastewater load) (lbs/day) [2]	Percent of total load due to wastewater (percent)	Ratio of Wastewater load to streamflow load (ratio)
10	14.00	15.20	8%	2.3	9.0	74%	2.9
20	7.20	8.40	15%	0.82	7.52	89%	8.2
mean	6.38	7.62	16%	0.69	7.39	91%	9.7
25	5.20	6.40	19%	0.51	7.21	93%	13
30	3.80	5.00	25%	0.33	7.03	95%	20
40	2.10	3.30	38%	0.16	6.86	98%	42
50	1.10	2.30	54%	.077	6.78	99%	87
60	0.62	1.84	67%	.040	6.74	99%	168
70	0.20	1.44	86%	.013	6.71	100%	515
75	0.07	1.31	95%	.0045	6.70	100%	1,490
80	0.04	1.28	97%	.0024	6.70	100%	2,790
85	0.01	1.25	99%	.00059	6.70	100%	11,400
86	0.00	1.24	100%	0	6.70	100%	--

[1] - Wastewater discharge represents 1.24 ft3/s

[2] - P Wastewater load represents 6.70 pounds per day

Total P Streamflow and Wastewater Loads

Exceedence probability (percent)	Associated existing streamflow discharge (ft^3/s)	Streamflow plus wastewater discharge (ft3/s) [1]	Total discharge represented by wastewater (percent)	Existing streamflow concentration (mg/l)	Streamflow plus wastewater concentration (mg/l) [2]	Increase in concentration due to wastewater (percent)
10	14.00	15.20	8%	0.030	0.109	260%
20	7.20	8.40	15%	0.021	0.166	690%
mean	6.38	7.62	18%	0.020	0.179	795%
25	5.20	6.40	19%	0.018	0.208	1,100%
30	3.80	5.00	25%	0.016	0.260	1,500%
40	2.10	3.30	38%	0.014	0.385	2,600%
50	1.10	2.30	54%	0.013	0.545	4,100%
60	0.62	1.84	67%	0.012	0.678	5,600%
70	0.20	1.44	86%	0.012	0.863	7,100%
75	0.07	1.31	95%	0.012	0.947	7,800%
80	0.04	1.28	97%	0.011	0.969	8,700%
85	0.01	1.25	99%	0.011	1.00	9,000%
86	0.00	1.24	100%	—	1.00	--

[1] - Wastewater discharge represents 1.24 ft3/s

[2] - Based on P wastewater concentration of 1 mg/l

Table 10.--Data for Streamflow Gain-Loss Study on Bear Creek in the Study Area

Site#	Bear Creek site of discharge measurement	DistanceUpst1826 FM1826	XUTM	YUTM	Date	Start	End	Flow (cfs)	Cond (uS/cm)	Staff
	Belterrra Property Line on Bear Creek (reference only not measured)	12550	3042175	10038119						
1	Downstream of Belterra on Davis Ranch - Charles and Roger's Sampling Site.	12250	3042310	10037880	4/5/2006	16:45	17:00	0.28	660	JB/CO
2	Upstream of Davis Pond 50 ft.	11310	3042276	10036962	4/5/2006	15:05	15:26	0.45	620	JB/CO
3	Dnst of Davis Pond 3-4. Ac.(Fault obs 200' upst)	9200	3043830	10035780	4/5/2006	13:44	14:24	0.42	510	JB/CO
4	Dnst. Low water Crossing - Stearns Ranch	8420	3043962	10035015	4/5/2006	12:22	12:40	0.54	500	JB/CO
5	Culvert under Wyldwood Hills (bucket meas.)	8020	3044060	10034624	4/5/2006	11:57	12:10	0.0065	#N/A	NH/JB
5	Culvert under Wyldwood Hills (bucket meas.)	8020	3044060	10034624	4/5/2006	17:30	17:35	0.0002	#N/A	NH/JB
6	Dnst. Wyldwood Hills about 100' below springs	7940	3044130	10034588	4/5/2006	11:05	11:38	0.34	520	JB/CO
6	Dnst. Wyldwood Hills about 100' below springs	7940	3044130	10034588	4/5/2006	17:45	18:00	0.42	#N/A	NH/JB
7	Dam between Wyldwood and Evergreen	6440	3044793	10033634	4/5/2006	16:33	16:45	0.50	#N/A	NH/BM
	Evergreen Way Road crossing (reference only not measured)	5600								NH/BM
8	leakage below dam about 300 ft Dnst Evergreen Way (no flow over)	5300	3045640	10032968	4/5/2006	10:45	11:00	0.003	420	NH/BM
9	First spring about 800-900 ft dnst of Evergreen Way at sharp creek bend	4750	3046108	10032991	4/5/2006	11:15	11:30	0.03	500	NH/BM
10	Low Water Crossing 1200 ft Dnst Evergreen Way	4400	3046188	10032467	4/5/2006	12:00	12:20	0.31	530	NH/BM
11	Bedrock Floor at metal Barn Between Dam and Bluff	3550	3046058	10031471	4/5/2006	12:40	13:00	0.50	560	NH/BM
12	Below washed out 2nd LWX dnst of Evergreen Way at start of south bluff	3130	3045918	10031035	4/5/2006	13:30	13:45	0.49	570	NH/BM
13	Narrow channel above waterfall, about 300 feet dnst of fenceline	2100	3046710	10030850	4/5/2006	14:00	14:15	0.62	550	NH/BM
14	Fenceline about 670 feet upst of FM 1826	670	3047865	10030470	4/5/2006	14:30	14:45	0.22	580	NH/BM
15	Gravel bar about 300 ft upstream of FM 1826	300	3047980	10030140	4/5/2006	9:15	9:30	0.14	580-590	JB/BM
15	Gravel bar about 300 ft upstream of FM 1826	300	3047980	10030140	4/5/2006	15:15	15:25	0.15	580	NH/BM
16	FM 12826 Culvert @ Friendship Church	0	3048116	10029839	4/5/2006	9:00	9:30	0.7		NH

Note: Third column presents stream channel distance (in feet) from site to Ranch Road 1826