WILLIAMSON CREEK ENVIRONMENTAL DATA REVIEW

Chris Herrington, Analyst, Environmental Resource Management Division, Watershed Protection & Development Review Department, City of Austin.

ABSTRACT

Available environmental quality data for the Williamson Creek Watershed, Texas, from 1974 through 2001 were evaluated to generate a summary of impacts to the sediment, biota, and water quality. Environmental data, descriptive metrics, and summary indices were used as assessment methods. Williamson Creek faces continued pressure from increasing population and development within watershed boundaries, but it remains above average in comparison to other area creeks and has showed short term improvement in several areas. .

City data indicate that overall watershed rankings for Williamson Creek surface waters improved drastically from 1996 to 2000 in comparison to other Austin-area watershed scores. Although benthic macroinvertebrate community, non-contact recreation, and physical integrity data yielded scores that decreased from 1996 to 2000, water quality, sediment quality, contact recreation, and diatom community ratings improved from 1996 to 2000 sampling events. Water quality assessments show that Williamson Creek was above average relative to other Austin watersheds in 1996, and improving in 2000. Unusually elevated concentrations of nitrogenous nutrients and total phosphorus are observed at the Pleasant Valley site during both storm and non-storm flow conditions, and DO levels are depressed at this location. Nitrogen and phosphorus nutrient concentrations are generally improving over time in Williamson Creek. Additional improvements over time are indicated in Williamson Creek surface water TSS, TOC, dissolved arsenic, and dissolved magnesium. The only concern for Williamson in statewide rankings is due to elevated fecal coliform levels during storm events.

INTRODUCTION & WATERSHED DESCRIPTION

Williamson Creek, located in south Austin, Texas, flows approximately 17.5 miles (28 km) from headwaters located northwest of Oak Hill, Texas, east to a confluence with Onion Creek in McKinney Falls State Park. Draining approximately 19,373 acres (78 km^2), the watershed has an estimated total of 17.9% impervious cover and is the second largest suburban watershed in Austin. Williamson Creek comprises approximately 3% of the total area of Travis County, and an estimated 4.9% of the City of Austin up to and including the 5-mile ETJ. Although the creek bifurcates into two major branches near Manchaca Road, the southern fork is consistently dry and generally lacks a strongly defined channel.

The Williamson Creek watershed is dominated by undeveloped (43% of total area) and residential (33% of total area) land uses according to City of Austin 1995 land use information. National Land Cover Database (NLCD) information also indicates that majority of the drainage area is comprised of residential (22% high intensity residential, 12% low intensity residential) and forested upland land cover (14% deciduous forest, 18% evergreen forest comprised mainly of live oak and cedar species).

The majority of watershed drainage area (approximately 50%) is comprised of well-drained, shallow to very shallow gravely clay loam soils overlying limestone or chalk on gently undulating slopes. Available water capacity is typically low, and soils exhibit moderately slow to slow permeability when wet. The Brackett soil series (USDA, 1974) is the dominant soil type accounting for 18% of the total watershed area and comprising most of the headwaters of the drainage area.

The headwaters of Williamson Creek lie over the Edwards Plateau physiographic region, while the middle and lower reaches cross Rolling Prairie and Colorado River Terraces (Garner & Young, 1976). The average elevation difference within the watershed is approximately 567 feet from headwaters to mouth, and the average creek bed slope is 0.6% (Chan & Associates, 1997).

The Barton Springs portion of the Edwards Aquifer bisects Williamson Creek, and the watershed is estimated to contribute 3% of the total recharge to the Barton Springs portion of the aquifer (Barrett and Charbeneau, 1996), thereby resulting in potential impacts to endangered species living in Barton Springs. Approximately 26% of the watershed lies over the recharge zone, accounting for approximately 10% of the total land area of the Barton Springs segment of the Edwards Aquifer. There are 17 known recharge features within the watershed boundaries which have been identified by CoA field staff. These critical environmental features are primarily caves and sinkholes.

At some point in the past, Williamson Creek may have been a larger watershed that partially flowed together with Barton Creek until the hydraulic forces of Barton Springs pirated the original headwater area into the current Barton Creek watershed (Woodruff, 1977).

Two rare Texas plants, the common shooting star (Dodecatheon meadia) and the Texas bluegrass (Poa arachnifera), are known to occur within the Williamson Creek watershed, as well as the endangered golden-cheeked warbler bird (USACOE, 1980).

In May 1986, the Williamson Creek wastewater treatment facility, located upstream of McKinney Falls State Park and discharging into Williamson Creek, was decommissioned. The plant, which had operated since 1963 (Bhattarai, 2002), was presumed to be the source of high bacterial counts observed at the pools within the state park resulting in a swimming ban in 1981 that was not lifted by Parks and Wildlife staff until 1994. The swimming ban was lifted in part due to the isolation and remediation of a failing septic system leaking into Williamson Creek near the Jimmy Clay Golf Course in September 1994 (CoA, 1994). A centralized sewage collection system for the golf course was completed with connection to the central sewer system in October1996.

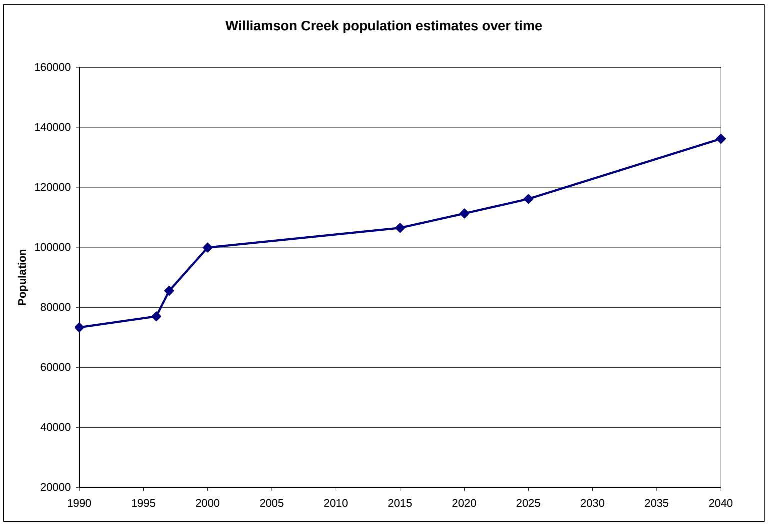
Additionally, several ponds on the Roy Kizer Golf Course which contained both surface runoff and reclaimed wastewater were found to be leaking resulting in high levels of nitrate in Williamson Creek springs. The high levels of nitrogen in the wastewater as well as increased groundwater flows through soils enriched by wastewater sludge were the source of the nitrogen contamination. After protracted negotiations, an agreement to seal the ponds with bentonite was finally reached in 1999.

Development within the Williamson Creek watershed, initiated primarily during the 1950s (Chan & Associates, 1997), appeared fairly steady throughout most of the 1990s, although large spikes in construction have occurred in the mid-1980s and again in the late 1990s according to CoA Permit Inspection and Environmental Review Database records, as presented in Figure 1. Projected increases in population and development estimate that by 2040, impervious cover in Williamson Creek could nearly double, rising to 31% (Chan & Associates, 1997), as estimated population within watershed boundaries rises to more than 136,000 persons.

Figure 1. Williamson Creek estimated number of building permits within watershed boundaries and percentage of total city-wide permits over time.

Using US Census Bureau data and estimates of growth within the watershed, population over time within watershed boundaries are presented in Figure 2. While the number of people living within the boundaries of the Williamson Creek drainage area will clearly increase, rising an estimated 86% from 1990 to 2040, the overall proportion of Travis County residents within the watershed will actually decrease from 12% in 1990 to an estimated 5% in 2040.

Figure 2. Williamson Creek estimated population over time.



METHODS

Monitoring locations

For the purposes of analysis, surface water sites on Williamson Creek were aggregated into 7 groups, presented in table 1 in upstream to downstream order.

Table 1. Surface water sites included in analysis in upstream to downstream order.

Site Name	Basin Acreage	% impervious cover	Latitude, Longitude
Mowinkle Drive	2,039	9.57	
US 290	4,092	10.64	30.23362, 97.85688
Brush Country Blvd	4,320	10.85	30.22609, 97.84176
Manchaca Road	12,002	14.28	30.22130, 97.79369
IH 35	15,558	17.51	30.19633, 97.75969
Pleasant Valley Rd	17,600	18.18	30.18929, 97.73293
McKinney Falls State Park	19,372	17.89	30.18886, 97.72230

Because the southern fork of Williamson Creek is consistently dry, all monitoring sites upstream of Manchaca Road are located on the northern fork. Several site photos are included in Appendix A.

Estimation of Onion Creek receiving water contaminant concentrations are based on mean concentrations from the monitoring site located within McKinney Falls State Park above the upper falls on Onion Creek (latitude 30.18787, longitude 97.72215).

Sediment data were collected by CoA from the mouth of Williamson Creek at McKinney Falls for the Environmental Integrity Index project, and additional data were collected by the USGS from the Brush Country site.

Groundwater analyses was conducted on 10 wells sampled by the USGS located within Edwards limestone formations in the upper half of the watershed, as well as data collected by CoA staff from 9 springs located in alluvial Terrace and Buda formations in the lower half of the watershed. Wells and springs were analyzed together, as spring sampling generally occurs at the point of discharge and theoretically should not be different from properly sampled wells. Again for analysis purposes, springs and wells in very close proximity were analyzed together for the purposes of this report, and are presented in table 2.

Table 2. Groundwater sampling locations within the Williamson Creek watershed.

Site Name	Lat / Long	Basin Acreage	% Imp Cover	Geologic Formation	Soil Series	Site Group
Well YD-58-50-215	30°13’40” / 97°48’38”	0.23	0.0	BSZ/Edwards	Denton (DeB)	Undeveloped
Well YD-58-50-101	30°13’18” / 97°51’39”	0.23	0.0	BSZ/Edwards	Speck (SsC)	Single-family
Well YD-58-50-220	30°13’17” / 97°48’37”	0.23	0.0	BSZ/Edwards	Tarrant (TaB)	Single-family
Well YD-58-50-406	30°11’49” / 97°50’36”	0.46	0.5	BSZ/Edwards	Heiden (HeB)	Undeveloped
Well YD-58-50-216	30°13’57” / 97°47’34”	0.69	36.67	BSZ/Edwards	Volente (VuD)	Transportation
Well YD-58-50-520	30°12’27” / 97°48’08”	0.92	15.0	BSZ/Edwards	Urban Land (UsC)	Septic
Well OW2-5	30°13’37” / 97°50’29”	4321.9	10.85	BSZ/Edwards	Tarrant (TcA)	Single-family
Jimmy Clay Spring	30°10’59” / 97°44’13”	0.23	0.0	Terrace	Frio (Fo)	Golf Course
IH 35 Spring	30°12’10” / 97°45’35”	0.92	41.25	Terrace	Eddy (EuD)	Transportation
Long Bank Spring	30°11’11” / 97°44’28”	0.23	0.0	Terrace	Houston Black (HnA)	Undeveloped
Berry Yard Spring	30°13’36” / 97°47’47”	150.8	45.78	Buda	Volente (VuD)	Single-family
Sloan Spring		2.98	20.0	Terrace	Ferris (FhF3)	Septic

Groundwater wells located in the Barton Springs Zone Edwards limestone members would be expected to have shorter residence times than the Terrace and Buda springs which occur in alluvial deposits.

Population Information

Estimates of Williamson Creek watershed population in 1990 and 2000 are generated by clipping census block files with watershed boundary files in ArcView, and then adjusting population estimates with the fractional area of the remaining blocks. Future projections are obtained by clipping traffic serial zone files with watershed boundaries, and then multiplying area-adjusted City of Austin Smart Growth and Capital Area Metropolitan Planning Council (CAMPCO) estimates on future population within the 1990 and 1997 traffic serial zones, respectively.

Geographic Data

The majority of geographical information incorporated in this report are generated and maintained by CoA staff. However, additional information was obtained to provide a more comprehensive assessment of Williamson Creek.

National Land Cover Database (NLCD) information, produced as a cooperative effort between the United States Geological Survey (USGS) and the Environmental Protection Agency (EPA), was obtained through the Texas Water Development Board.

Soil data comes from SSURGO soil surveys compiled by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (USDA, 1995), with soil series descriptions from the USDA Soil Conservation Service (1974).

Flow Separation

As constituent concentrations and sources of potential impact are markedly different during storm-influenced and baseflow conditions, storm water quality data were separated and analyzed apart from non-storm influenced water quality data using current ERM criteria presented in table 3.

Table 3. Storm flow sampling criteria.

Estimated Rainfall in Watershed	Flow Type Criteria
< 0.1 inches	Not storm influenced
0.1 to 0.25 inches	Storm influenced for next 24 hours
0.25 to 1.0 inches	Storm influenced for next 48 hours
> 1 inches	Storm influenced for next 72 hours.

Three Flood Early Warning System (FEWS) gages distributed throughout the watershed were selected to better represent the headwaters, mid-reach, and mouth of Williamson Creek. The gages used for estimation of Williamson Creek rainfall are shown in table 4.

Table 4. FEWS gages used to estimate rainfall for Williamson Creek.

Gage #	Location	Latitude	Longitude
1000	6300 US 290 West	30.18167	97.74583
1020	5000 Manchaca Rd	30.22138	97.79306
1120	6500 S. Pleasant Valley Rd	30.23528	97.86000

For historical data where no FEWS gage information was available, rainfall in Williamson Creek was estimated using National Weather Service (NWS) gage information from the Austin-Bergstrom Airport.

Stream Flow Data

The USGS has operated several different in-stream gages on Williamson Creek since 1975, presented in table 5, as well as conducted at least one recharge flow loss study (Slade et al, 1982). Note that the Oak Hill and Brush Country Boulevard gages are located within the recharge zone on the northern (main) fork of Williamson Creek, and that the Manchaca Road gage is located below the confluence of the northern and southern forks.

Table 5. USGS flow gages in upstream to downstream order.

GAGE	Location	Drainage Area (sq. miles)	Latitude, Longitude	Period of Record
08158920	Oak Hill	6.30	30°14'06", 97°51'36	01/10/1978-03/08/1993,
08158922	Brush Country Blvd.	6.79	30°13'34", 97°50'28"	03/11/1993-09/30/2000
08158930	Manchaca Rd.	19.0	30°13'16", 97°47'36"	10/01/1984-09/30/1985, 01/29/2000-09/30/2000
08158970	Jimmy Clay Rd.	27.6	30°11'21", 97°43'56"	09/11/1975-09/30/1986

Mean daily flow data were associated with water quality sample events using the closest gage with available data.

Environmental Quality Data

All available environmental quality data from local and state regulatory agencies were included for analyses, with the general period of record from 1974 to 2001. All data included in analyses are maintained within the Field Sampling Database of the CoA-ERM.

The USGS has collected surface water quality and flow information from several gages typically located above the recharge zone near Oak Hill since 1974, with strong emphasis on integrated storm flow sampling and water budget analyses of the Edwards Aquifer. Groundwater quality data from 10 wells located primarily in the mid-reaches of the watershed has also been collected periodically since 1978.

CoA-ERM and volunteers have collected surface water, habitat, sediment, and biological data, in Williamson Creek since 1993 for various projects with objectives ranging from characterizing bacterial levels in McKinney Falls State Park swimming areas to ranking Williamson Creek with other watershed throughout the city using an integrated environmental integrity index (EII). Groundwater quality data have also been collected by CoA staff since 1994 from 9 different spring discharges located typically in the lower reaches of the watershed.

Additional bacteriological data collected by Texas State Parks and Wildlife Department staff from McKinney Falls State Park and Texas Watch volunteer monitoring field information were included in analyses.

Comparison of Williamson Creek constituent concentrations to concentrations in Onion Creek receiving waters was performed by ranked ANOVA on 18 concurrent sampling events from 1993 to 2000 at the Williamson Creek mouth site in McKinney Falls versus the Onion Creek monitoring location upstream of the confluence with Williamson Creek and above the upper falls within McKinney Falls State Park.

Flood and Erosion Control Assessments

Information on Williamson Creek flooding and erosion problems are provided in this report as summaries of the assessments located in the City of Austin Watershed Protection Master Plan: Phase I Watersheds Report (2001), with additional historical information from the United States Army Corps of Engineers (1980). Data collection and analysis methodologies for current City of Austin assessments are presented in detail in the master plan document, and although no new analyses were performed for this report, the information was included to provide a more comprehensive reference document for the Williamson Creek watershed.

Data Analysis Methods

All data were tested to determine spatial and temporal trends using the SAS Software System, version 8. Statistical significance for this report is defined by a type I, or false rejection of a true hypothesis, error ($\alpha \leq 0.05$) of 5% corresponding to one type I error in 20 experimental trials (Sokal and Rohlf, 1995).

Means and summary statistics for data sets that did not contain censored data points, or data below reporting levels also known as 'less-thans,' were computed using traditional methods described in the SAS PROC UNIVARIATE procedures (SAS, 1990a). Summary statistics for data sets with censored data points were calculated using non-parametric robust log-probability plotting methods (Helsel and Cohn, 1988; Helsel and Hirsch, 1992). Although historical data analyses used substitution methods for estimating censored data points, usually as one-half of the detection limit (Town Lake Report, 1992), these methods have no applied basis and perform poorly in comparison to distribution estimation or robust methods (Gilliom and Helsel, 1986; Helsel and Cohn, 1988). The log-probability regression method is recommended over maximum-likelihood estimation methods since it is distribution independent, avoids all transformation bias, and typically exhibits lower root mean square error rates (Helsel, 1990; Helsel and Cohn, 1988).

Comparisons to determine significant differences between grouping variables were performed on ranked data sets using analysis of variance tests in the SAS PROC GLM (SAS, 1989) in combination with Duncan's multiple-range mean comparison test to explore other potential statistically significant groupings (Duncan, 1975). Data were ranked to avoid the normal data distribution assumption of parametric ANOVA procedures as well as to account for censored data points, similar to the procedures for a rank-sum test (Helsel and Hirsch, 1992).

Trend analysis were performed using ordinary least-squares (OLS) methods in the SAS PROC REG (SAS, 1989) on ranked data sets and with correlation analysis using Spearman's non-parametric ranked correlation test (Sokal & Rohlf, 1995). Trends observed from the OLS methods on ranked data sets containing censored observations were confirmed using Cox Proportional Hazards regression methods adapted from biological statistical methods and applied using the SAS PROC PHREG (Allison, 1995). Although originally designed for left-censored survival data, the Proportional Hazards, or Maximum Partial Likelihood, method can be applied to right-censored data through simple transformation for a robust semi-parametric regression analysis (Allison, 1995; Helsel, 1998).

RESULTS

Surface Flow

From 1/10/1978 through 9/30/1986, USGS measured flow simultaneously at the Oak Hill gage just inside the upstream boundary of the recharge zone on the northern (main) fork of Williamson Creek and at the Jimmy Clay gage near the mouth of Williamson Creek (below confluence of northern and southern forks). During this time period, the Oak Hill gage was dry (no flow) on 1,192 days when the Jimmy Clay gage maintained at least 0.01 ft^3/s daily average discharge. Over the period of record, the Jimmy Clay gage maintained an average daily discharge of 5.88 ft^3/s greater than the flow recorded at the Oak Hill gage. However, the Oak Hill gage recorded a mean daily flow equal to or greater than the flow at the Jimmy Clay gage in 11% of the data, with no clear pattern in occurrence by month or over time.

For 365 days from 10/01/1984 to 09/30/1985, flow was measured simultaneously at three gages (Oak Hill, Manchaca, and Jimmy Clay). For 86% of the time, mean daily flow at the Manchaca gage below the recharge was greater than or equal to flow at the Oak Hill gage, located above the recharge zone. In the days when Oak Hill recorded higher mean daily flow values, the difference was typically within 2 ft^3/s. However, mean daily flow at the most downstream Jimmy Clay gage was only greater than or equal to mean daily discharge at the Manchaca gage 55% of the time, indicating the strong potential for a non-recharge associated flow loss in the creek reach from Manchaca Road to Jimmy Clay Road. When the Jimmy Clay gage recorded a higher mean daily flow than the mid-reach Manchaca gage, the average increase was 6.5 ft^3/s. However, when the Jimmy Clay gage recorded a lower mean daily flow than the Manchaca gage, the average loss was 11.1 ft^3/s.

In the 246 days of consecutive measurement at the Brush Country and Manchaca gage, the mean daily flow at Manchaca was greater than the mean daily flow at Brush Country in all cases when Manchaca registered a non-zero flow, with an average recorded increase of 3.6 ft^3/s.

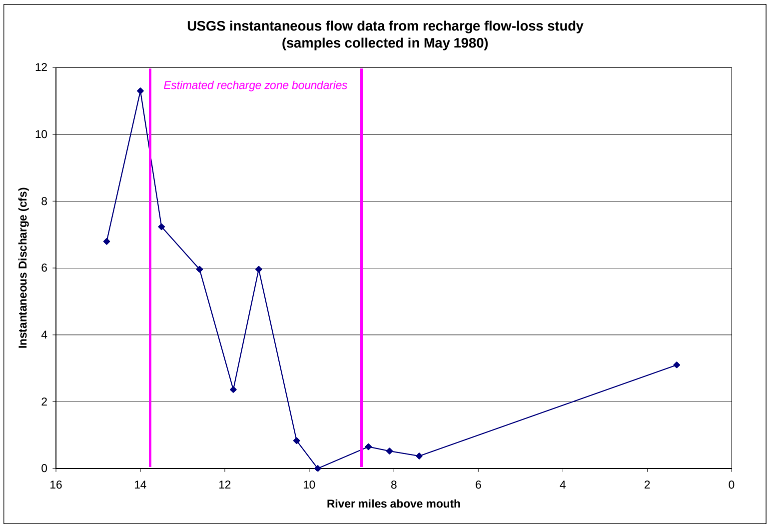
No trend at any gage in percent of time at which flow was less than or equal to 1 ft^3/s over time. However, the effect of water loss to groundwater recharge is clearly evident in the number of days with mean flow below 1 ft^3/s, as shown in table 6. If we estimate elevated flow conditions as any day with mean flow above the 85th percentile at Jimmy Clay (9.3 ft^3/s), then no trend in increasing number of days of elevated flow conditions are evident at any site.

Table 6. Percentage of time at which USGS flow gages measured mean daily flow values ≤ 1 ft^3/s.

GAGE	% OF TIME AT ≤ 1 FT^3/S
08158920	66
08158922	95
08158930	37
08158970	25

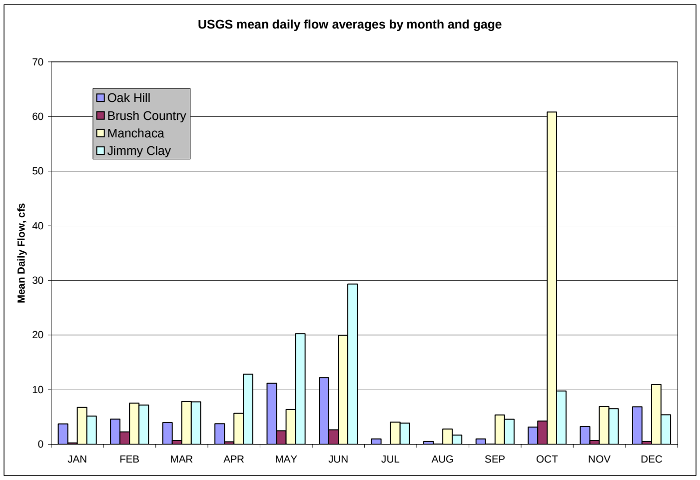
In May 1980, the USGS conducted a survey of instantaneous flow values at numerous cross-sections in Williamson Creek, and the results shown in figure 3 again show the impact of the recharge zone on Williamson Creek flows.

Figure 3. USGS instantaneous flow values from recharge flow loss study, 05/1980.



Monthly average mean daily flows by gage further demonstrate the difference between gages within and downstream of the recharge zone, as shown in figure 4. Note that the general patterns follow mean monthly rainfall, although the large monthly flow measured at the Manchaca gage is from a more limited dataset (only 2 years of operation) than other gages and thus is more biased by large storm events.

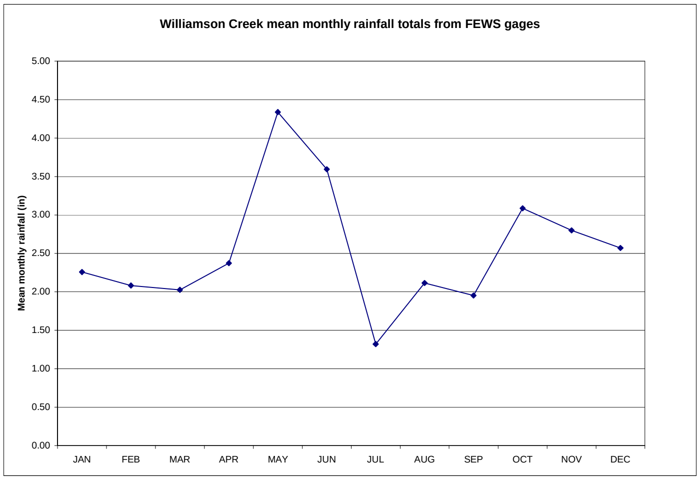
Figure 4. Mean daily flow averages by month and gage for Williamson Creek using USGS data.



Rainfall

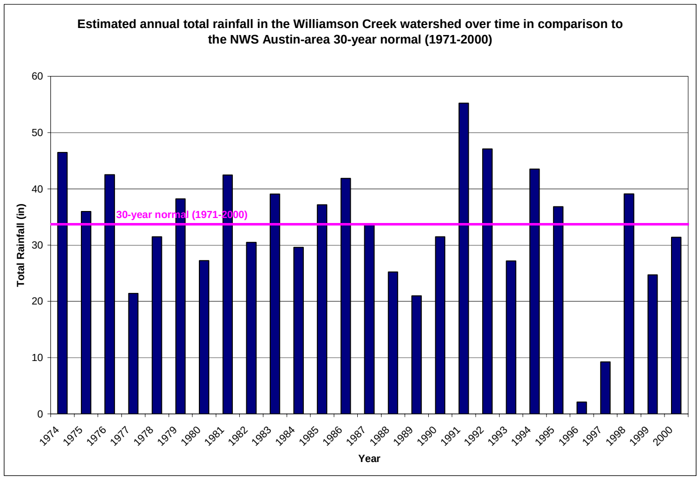
Mean monthly rainfall estimates from FEWS gages within the Williamson Creek watershed are presented in figure 5. General patterns of wet and dry seasons follow patterns typical within the Austin area.

Figure 5. Mean monthly rainfall in Williamson Creek Watershed.



Annual total precipitation using rain averages from FEWS gages (and airport rainfall totals when FEWS data are unavailable) within the Williamson Creek are presented in figure 6. Note that although some years experienced above average rainfall, the estimated 30-year normal is good representation of average conditions. Also note the extreme drought experienced in 1996 and 1997, as well as large amount of rain which fell in 1991.

Figure 6. Annual total estimated Williamson Creek precipitation in comparison to National Weather Service 30-year normal (1971-2000).



Flood Assessment

Flooding problems in the watershed are prevalent, especially in the lower reaches of the creek near the Creek Bend neighborhood which rated a city-wide priority of “very high” for flooding problems. Similarly, a significant number of drainage complaints were received by the City of Austin for localized flooding, in which storm water runoff overwhelms storm drain systems and flood roadways, primarily from the mid-reach of the watershed (City of Austin Watershed Protection Department, 2001). There are a number of structures and roadways threatened by flood waters within the watershed, as shown in table 7.

Table 7. Number of structures and roadways in Williamson Creek threatened by floodwaters of varying frequency storms.

# of Flooded Structures				# of Flooded Roadways			
2-Yr Storm	10-Yr Storm	25-Yr Storm	100-Yr Storm	2-Yr Storm	10-Yr Storm	25-Yr Storm	100-Yr Storm
58	199	295	454	9	14	17	18

Early assessments performed by the United States Army Corps of Engineers (1980a) indicate that on an average annual basis, Williamson Creek experiences $175,000 in 1979 dollars, or $465,935 in 2001 dollars by adjusting for inflation using the consumer price index (U.S. Census Bureau, 2001), in flood damages. Monetary damage estimates for a single 100-year flood event exceed $3 million in 1979 dollars, or more than $8 million in 2001 dollars, as approximately 1,195 acres would be flooded.

However, the majority (81%) of the 85 Williamson Creek reaches evaluated for flooding in 1997 ranked in the low to very low city-wide problem ranking. Because Williamson Creek is considered a developing watershed, some of the preferred solution options for flood control are property acquisition, culvert replacement, and regional floodwater detention.

Erosion Assessment

Williamson Creek is experiencing accelerating creek erosion, and shows signs of channel instability with a predicted increase in channel size greater than 25% (CoA WPD, 2001). In 10 of 13 mainstem reaches evaluated for erosion potential, widening was listed as a primary geomorphic problem indicating a strong potential for future creek bank failures. Overall geomorphic assessments indicate that the majority of

Williamson Creek is in a transitional state (Chan & Associates, 1997), and increasing runoff is degrading the integrity of the natural channel (CoA WPD, 2001).

Although no primary structures or roadways are currently threatened by channel bank erosion, as many as 66 sites on Williamson Creek (or approximately 14% of the total number of future problem sites in phase I watersheds) have been identified as threatened by potential future erosion (CoA WPD, 2001).

Although some areas in the mid-reach and mouth areas of Williamson Creek rated as high or very high erosion potential priority areas, the majority of watershed ranked as low to very low city-wide for erosion problems (CoA WPD, 2001). Because Williamson Creek is considered a developing watershed, some of the preferred solution options for erosion control are detention and wet ponds.

Hazardous Spill Summary

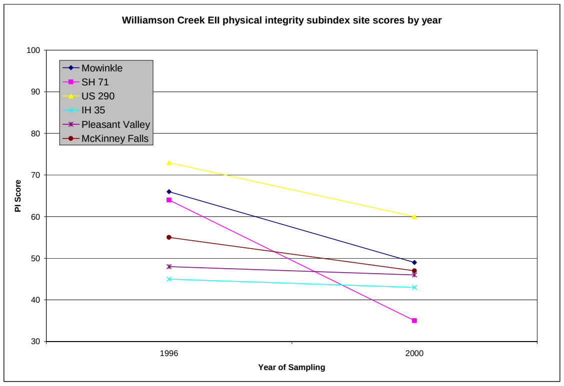
Using information from the CoA-ERM Spill Complaint and Response Database, there were approximately 394 spill events logged from 1998 to 2001 within the Williamson Creek drainage area. Of these spills, 41% were of a significant size as to require a high priority response by city staff. An additional 42% of spill events in Williamson Creek were primarily accidents involving petroleum product loss or leaking sanitary sewage lines. According to CoA-WPD masterplan assessments, Williamson Creek currently ranks as a “moderate spills risk.” However, as development increases within Williamson Creek, future estimates of spills risk in the drainage area increase to the ranking of “high spills risk.”

Non-Contact Recreation and Physical Integrity (Habitat) Assessment

Non-contact recreation EII assessments of Williamson Creek sites in 1996 to 2000 remained fairly constant, with only two of the six monitored locations showing any degradation. In 1996, the Williamson Creek non-contact recreation score ranked Williamson Creek as average, with 50% of the other watersheds in Austin scoring better. However, in more recent 2000 assessments, Williamson Creek rankings fell placing the watershed as better than only 28% of other Austin creeks.

Physical integrity, or habitat evaluation, assessments, reveal that ratings for all monitored sites decreased from 1996 to 2000 assessments, as shown in figure 7. However, there was little change in the relative city-wide ranking of Williamson Creek habitat, with rankings placing the drainage area as better than approximately 50% of the other Austin watersheds.

Figure 7. Williamson Creek physical integrity EII scores over time by site.

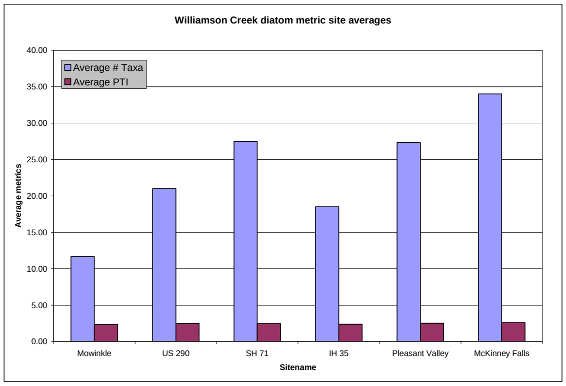


Evaluation of individual physical integrity metric scores reveal that although the total scores significantly decreased from 1996 to 2000 assessments, there were no significant decreasing temporal trends for any individual metric when data from all sites are combined for analysis.

Diatom Assessment

Average pollution tolerance index (PTI) values for diatom samples yield no significant differences between Williamson Creek sites and show no longitudinal trends in upstream to downstream sites, as shown in figure 8. However, the average number of taxa at the McKinney Falls site is significantly greater than the upstream Mowinkle site.

Figure 8. Williamson Creek diatom metric site averages.



While taxa richness exhibits no significant temporal trend when data from all sites are combined for analysis, long-term data at the McKinney Falls site indicates an increase in number of distinct taxa over time, presented in figure 9. Similarly, although there is a slightly non-significant (p=0.06) decreasing trend in average diatom PTI values over time, the mouth site again yields a slight increasing trend in PTI values, as shown in figure 10.

Figure 9. Williamson Creek diatom taxa richness by site over time.

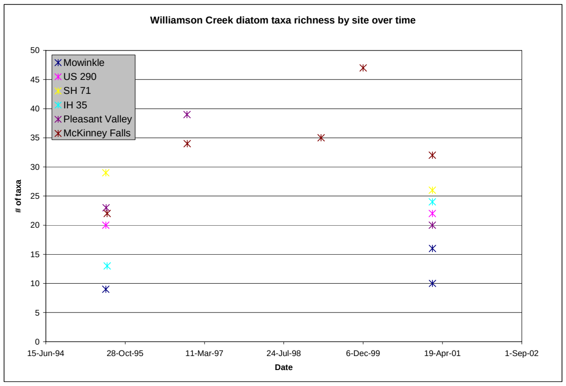
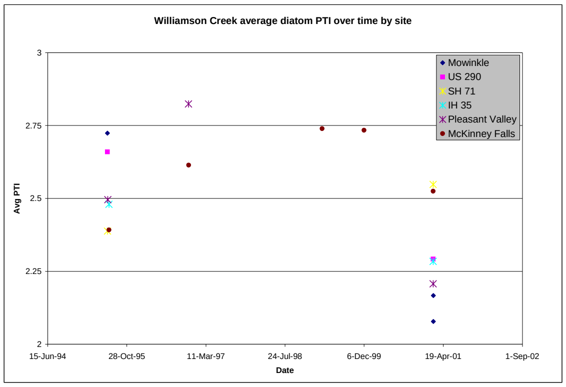


Figure 10. Williamson Creek diatom PTI values by site over time.

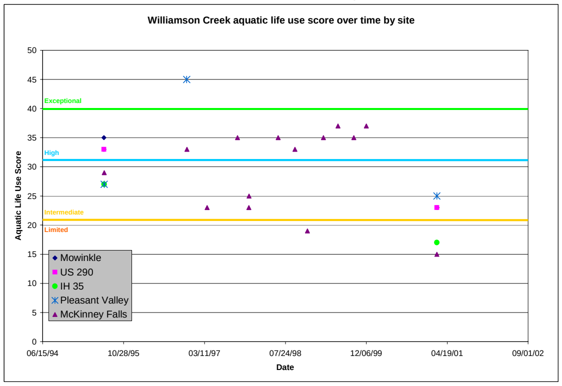


EII assessments by watershed indicate that in 1996, the Williamson Creek diatom sub-index score of 26 was below average, with 67% of the other watersheds in the city ranking better than Williamson Creek. In 2000, however, the Williamson Creek diatom sub-index score improved to slightly above average and now ranks better than 48% of the watersheds assessed to date.

Benthic Macroinvertebrate Assessment
Williamson Creek EII benthic macroinvertebrate sub-index scores decreased at all six sites from 1996 to 2000 assessments, yielding an overall significant decreasing trend. Although the 1996 Williamson Creek benthic macroinvertebrate watershed EII sub-index score was below average for all watersheds and ranked better than only 17% of the watersheds in the city, 2000 watershed scores improved Williamson Creek ranking to a level currently better than 62% of studied watersheds.

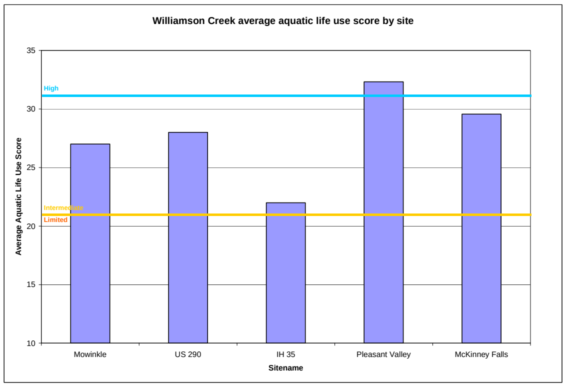
Using TNRCC assessment methodology (TNRCC, 2001) to calculate an aquatic life use score for Williamson Creek benthic macroinvertebrate samples, as shown in figure 11, reveals a significantly decreasing trend over time when data from all sites are combined for analysis, primarily due to lower 2000 EII sample scores.

Figure 11. Williamson Creek aquatic life use score by TNRCC methods over time by site.



Overall site average aquatic life use scores reveal that the majority of the Williamson Creek sites rank as intermediate by benthic macroinvertebrate data, with the exception of the Pleasant Valley site that yields an average of high value, presented in figure 12. Note that there is no significant difference between any of the average aquatic life use site scores.

Figure 12. Williamson Creek aquatic life use average site scores.

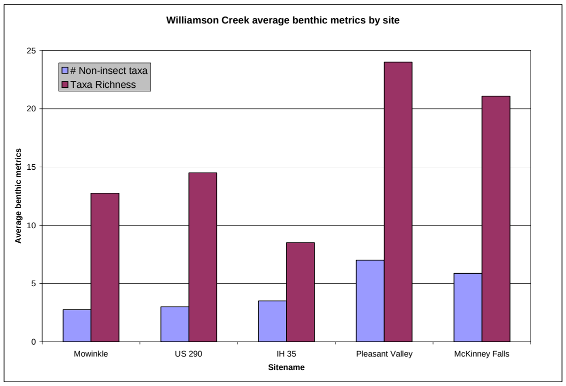


Assessment of individual benthic metrics shows significantly decreasing temporal trends for the following ephemeroptera, plecoptera, and trichoptera-related (EPT) metrics: EPT/EPT+Chironomidae, number of ephemeropteran taxa, number of EPT taxa, percent of EPT individuals,

No change over time is observed in the Hilsenhoff Biotic Index, number of dipteran taxa, number of intolerant taxa, number of non-insect taxa, taxa richness, percent collector-gatherer functional feeding guild, percent chironomidae, percent dominance (top 1 or top 3 taxa), percent dominant functional feeding group, percent elmidae, percent filterer functional feeding guild, percent predator functional feeding guild, and tolerance ratio.

No statistically significant difference in average site metric scores are observed for any of the benthic macroinvertebrate metrics assessed. However, poorest scores are typically observed within the IH 35 reach, while higher average scores are typically observed at the downstream Pleasant Valley and McKinney Falls locations. This pattern is most clearly evident in the average taxa richness metric, presented in figure 13.

Figure 13. Williamson Creek average number of non-insect taxa and total taxa richness by site.

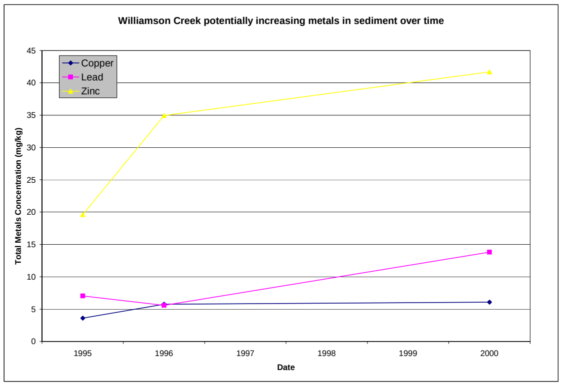


Sediment Assessment

Analysis of available data on metals in Williamson Creek sediment reveals that all measured values of arsenic, copper, lead, mercury, nickel, silver, and zinc in sediment, were below both the TNRCC (2001) 85th percentile screening levels and Probable Effects Levels (PELs). However, 2 of 3 measurements of cadmium in 1995 and 1996 were above the 0.55 mg/kg TNRCC screening level, although both exceedances were below the 3.53 mg/kg freshwater PEL for cadmium. The cadmium sample in 2000, however, was below both the screening level and PEL.

Comparison of 1995/1996 and 2000 EII sediment sampling events for metals reveals that copper, lead, and zinc, results were higher in 2000 sampling events than in the 1995 and 1996 samples as shown in figure 14, although a lack of data prevents accurate temporal trend assessments. Arsenic, cadmium, and mercury, however, exhibited no increase in concentration over time.

Figure 14. Williamson Creek potentially increasing metals in sediment over time.



No data is available at this time of any volatile organic compounds in sediment for which TNRCC screening criteria exist.

However, data from all 59 semi-volatile organic (PAHs) parameters in Williamson Creek sediments were below detection limits, and all measured oil and grease values in sediments were below the 85th screening level.

Data on pesticides in sediment show that only 1 sample for 2,4-D in 1997 exceeded the TNRCC 85th screening level of 38.5 μg/kg, and no 2,4-D PEL exists. However, all measurements of DDD, DDE, DDT, Aldrin, Chlordane, Dursban, Dieldrin, Endosulfan I & II, Endosulfan Sulfate, Endrin, Heptachlor, Heptachlor Epoxide, Hexachlorobenzene, Methoxychlor, Pentachlorobenzene, and Toxaphene in sediment (17 parameters in total), were below detection limits.

Data for all other 80 parameters analyzed in Williamson Creek sediments that are not covered by TNRCC assessments were below detection limits.

Williamson Creek scored above average in both 1996 and 2000 EII assessments, with overall sediment index rankings increasing Williamson Creek index scores from better than 69% of other Austin watersheds in 1996 to better than 88% of other Austin watersheds in 2000.

Surface Water Quality Assessment

City-wide rankings of Austin watersheds using the water quality sub-index of the EII show that in initial assessments conducted from 1996 to 1999, Williamson Creek was above average and out-scored 73% of other watersheds. More recent 2000 to 2002 assessments, though incomplete at the time of this report, already show moderate improvement for the Williamson Creek watershed as it currently ranks better than 90% of other Austin watersheds.

Water quality sub-index scores improved from 1996 to 2000 sampling years for all Williamson Creek sites except the most-upstream Mowinkle site, as shown in figure 15. Contact recreation sub-index site scores which are based on fecal coliform counts remained fairly constant for all sites, although a marked improvement was observed in the Pleasant Valley and IH 35 sites from 1996 to 2000, as shown in figure 16. Overall contact recreation rankings of Williamson Creek versus other Austin watersheds improved from 1996 (Williamson ranked better than only 41% of other watersheds) to 2000 (Williamson ranked better than 91% of other watersheds) sampling years.

Figure 15. Williamson Creek EII water quality sub-index site scores by year.

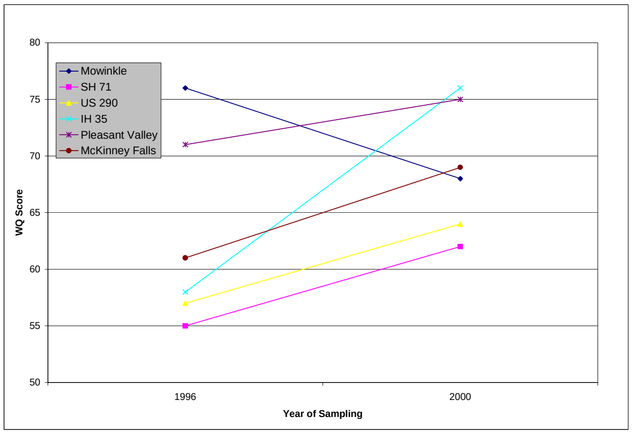
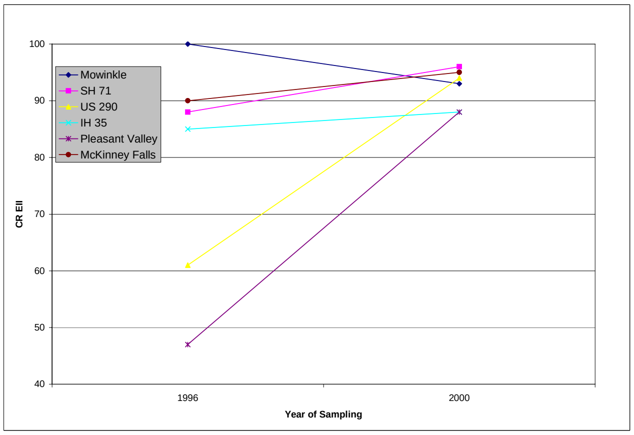


Figure 16. Williamson Creek contact recreation EII sub-index site scores by year.



Comparison testing and graphical analyses of average parameter concentrations by site during non-storm influenced flow conditions reveal generally increasing longitudinal trends from upstream to downstream Williamson Creek sites for nitrogenous nutrients (ammonia in figure 17, nitrate+nitrite in figure 18), two dissolved positive ions (potassium in figure 21, sodium in figure 22), total chloride (figure 19), and total sulfate (figure 20). Unusually elevated concentrations of ammonia, TKN, and nitrate+nitrite, are observed at the Pleasant Valley site in both storm and non-storm influenced conditions. TKN mean concentrations, however, are less at the McKinney Falls point of discharge to Onion Creek than upstream US 290 concentrations in both storm and non-storm flow conditions, as shown in figure 24. Extremely high relative values of total phosphorus are also observed at the Pleasant Valley site, as shown in figure 23.

Figure 17. Mean Williamson Creek total ammonia by flow type and site.

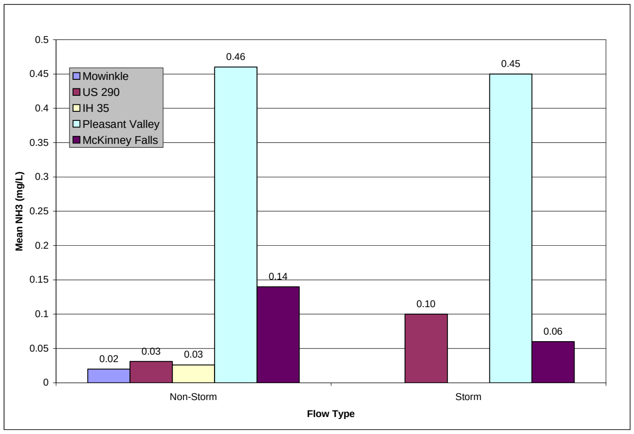


Figure 18. Mean Williamson Creek nitrate+nitrite by flow type and site.

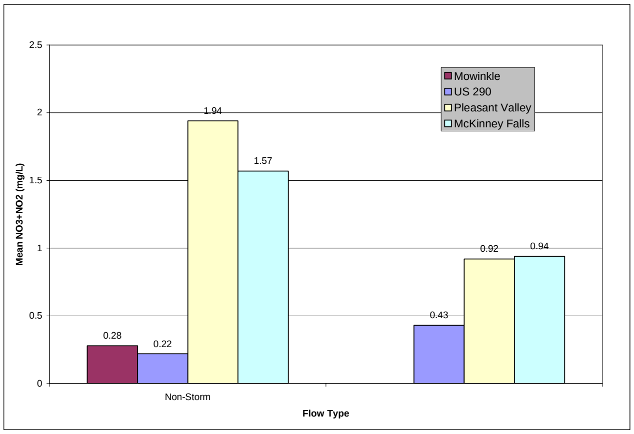


Figure 19. Mean Williamson Creek total chloride by flow type and site.

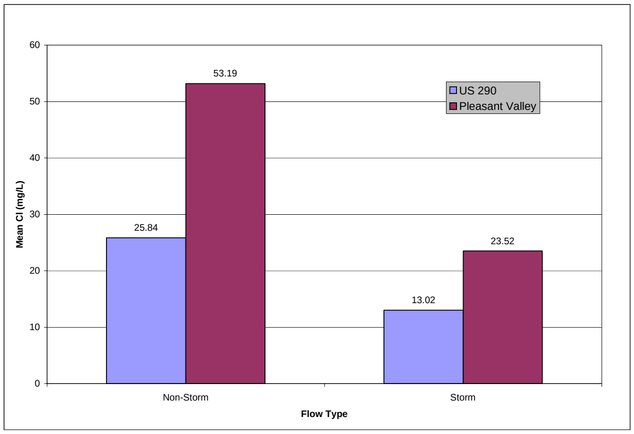


Figure 20. Mean Williamson Creek total sulfate by flow type and site.

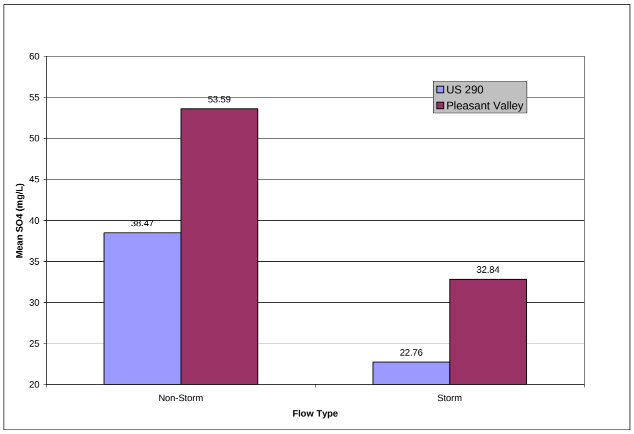


Figure 21. Mean Williamson Creek dissolved potassium by flow type and site.

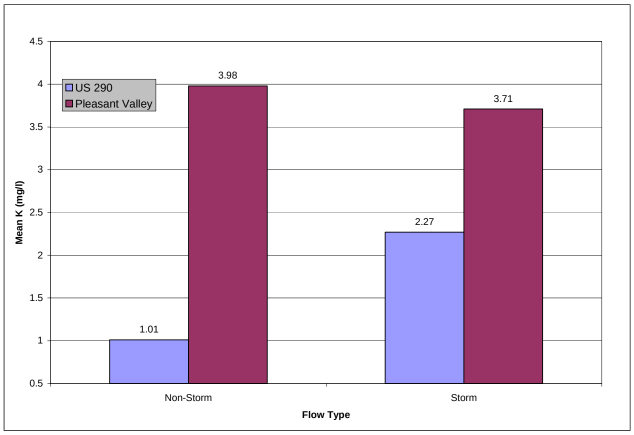


Figure 22. Mean Williamson Creek dissolved sodium by flow type and site

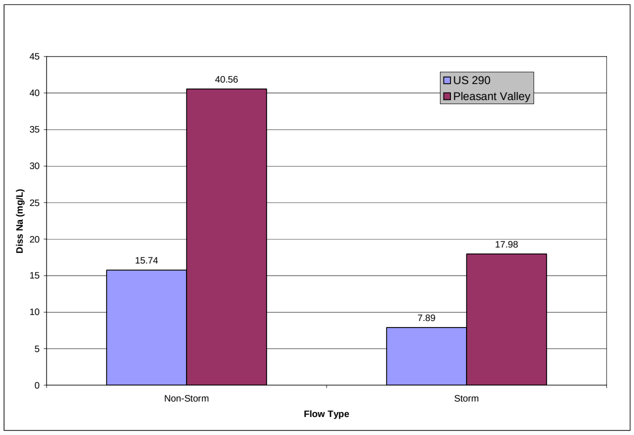


Figure 23. Mean Williamson Creek total phosphorus by flow type and site.

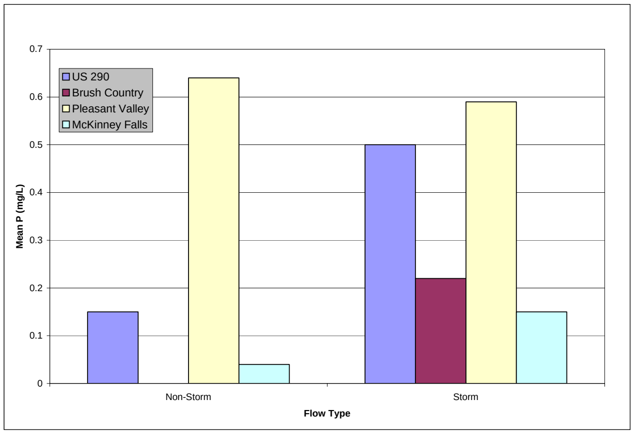
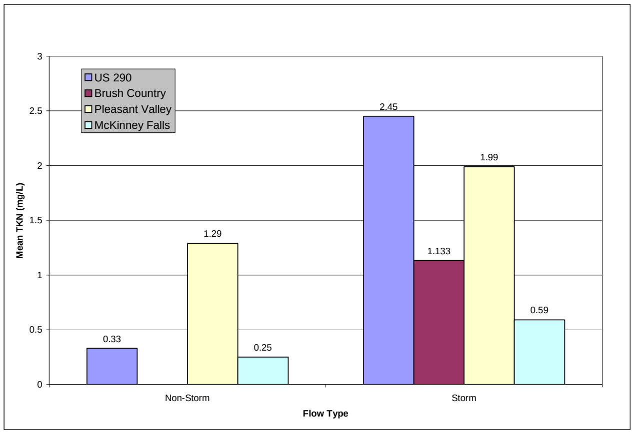
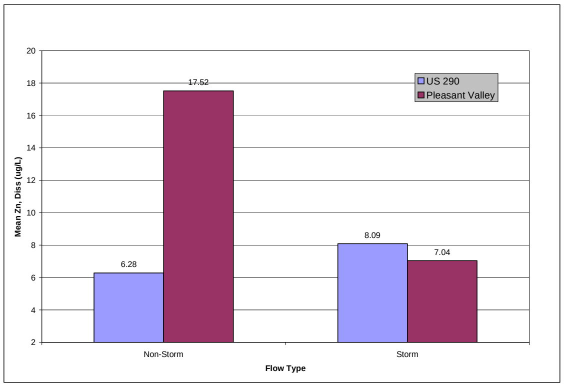


Figure 24. Mean Williamson Creek total TKN by flow type and site.



Although there is no significant difference between mean site concentrations in storm flow conditions, mean dissolved zinc is significantly greater at the more downstream Pleasant Valley site than the US 290 site in non-storm influenced flow conditions, as shown in figure 25.

Figure 25. Mean Williamson Creek dissolved zinc by flow type and site.



Conversely, Williamson Creek appears to be decreasing the levels of alkalinity (figure 26) and several dissolved metals (cadmium in figure 27, copper in figure 28, lead in figure 29, magnesium in figure 30) from upstream to downstream sites during non-storm influenced flow conditions.

Figure 26. Mean Williamson Creek total alkalinity by flow type and site.

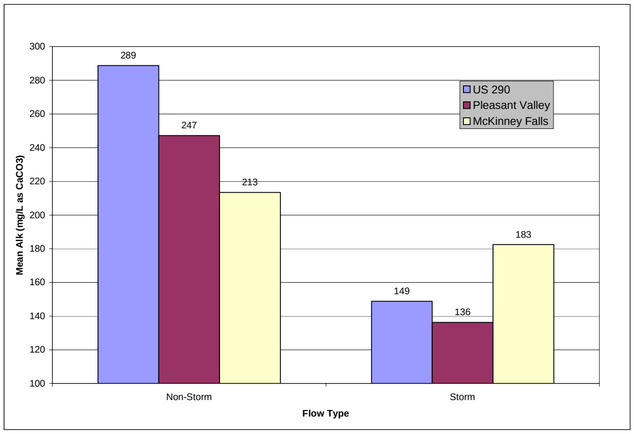
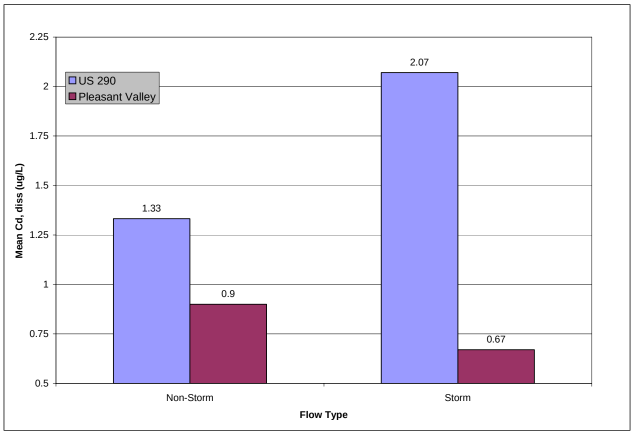


Figure 27. Mean Williamson Creek dissolved cadmium by flow type and site.

Figure 28. Mean Williamson Creek dissolved copper by flow type and site.



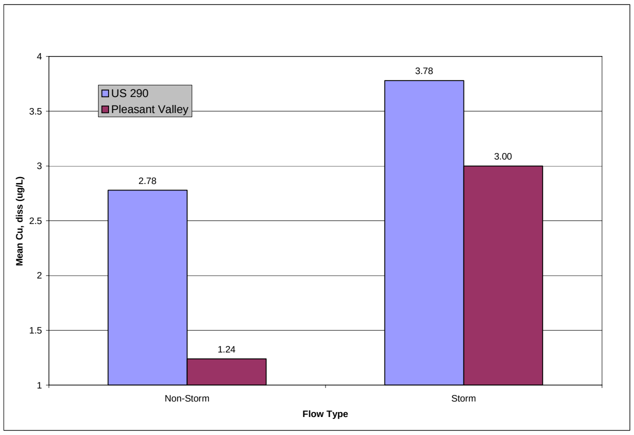


Figure 29. Mean Williamson Creek dissolved lead by flow type and site.

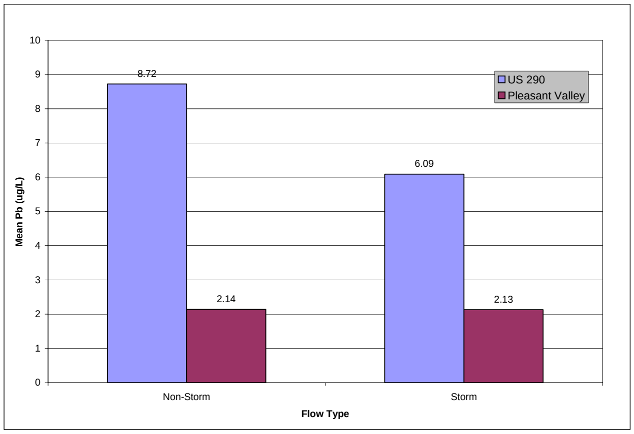
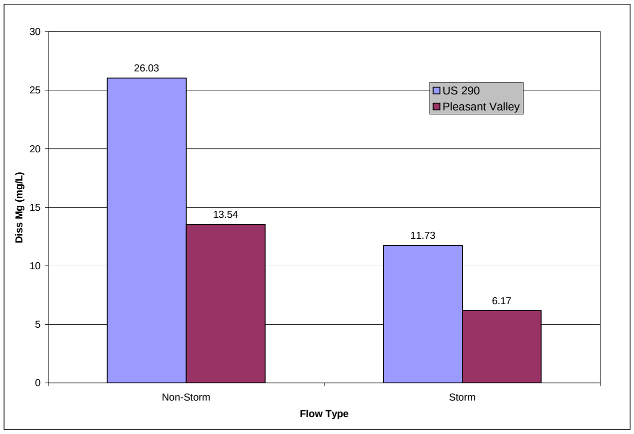
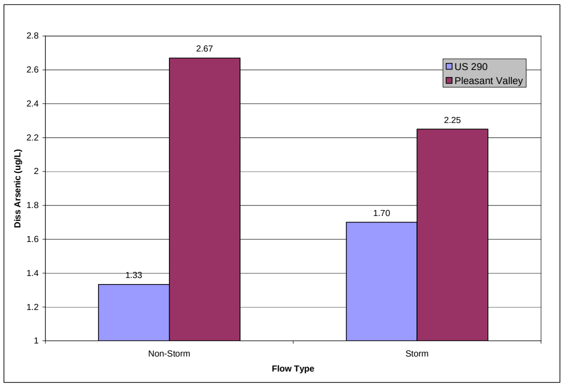


Figure 30. Mean Williamson Creek dissolved magnesium by flow type and site.



Although data is available at a limited number of sites, dissolved arsenic concentrations are significantly greater at the more downstream Pleasant Valley site than at the US 290 site, as shown in figure 31.

Figure 31. Mean Williamson Creek dissolved arsenic by flow type and site.



BOD exhibits opposite longitudinal patterns in site means under storm and non-storm conditions, as shown in figure 32. In storm flow conditions, a similar decreasing longitudinal trend in TOC concentrations are observed from upstream to downstream sites as shown in figure 33. As BOD is driven by the decomposition of organic matter, the trend in BOD is directly correlated to the trend in TOC.

One potential explanation of the decrease in TOC under storm flow conditions is that increased flows at downstream sites result in dilution of carbon material. Flow dilution or concentration of BOD or TOC cannot be used to explain the observed patterns in BOD under non-storm flow conditions, however, as instantaneous flow measurements at the time of CoA sample collection do not correlate with mean BOD levels, as shown in figure 35, and no increasing spatial trend in TOC is evident in non-storm conditions. A nearly identical pattern is observed in organic nitrogen concentrations, as shown in figure B15.

Figure 32. Mean Williamson Creek BOD by flow type and site.

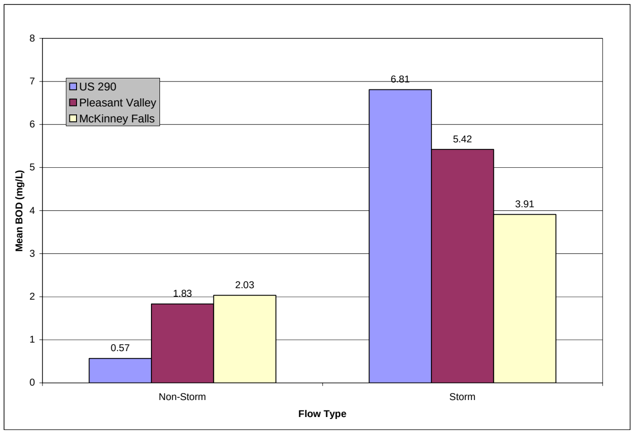


Figure 33. Mean Williamson Creek TOC by flow type and site.

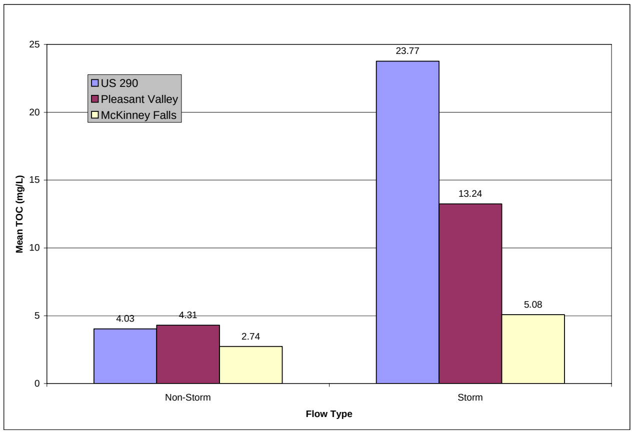


Figure 34. Mean Williamson Creek instantaneous stream flow in non-storm flow conditions by site.

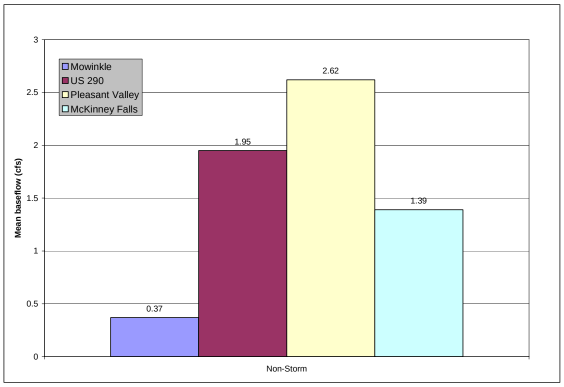
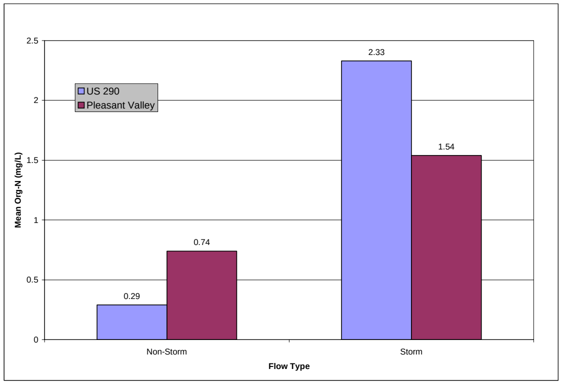
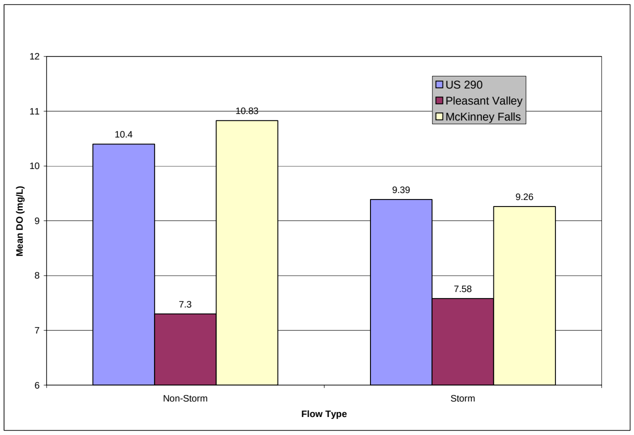


Figure 35. Mean Williamson Creek organic nitrogen by flow type and site.



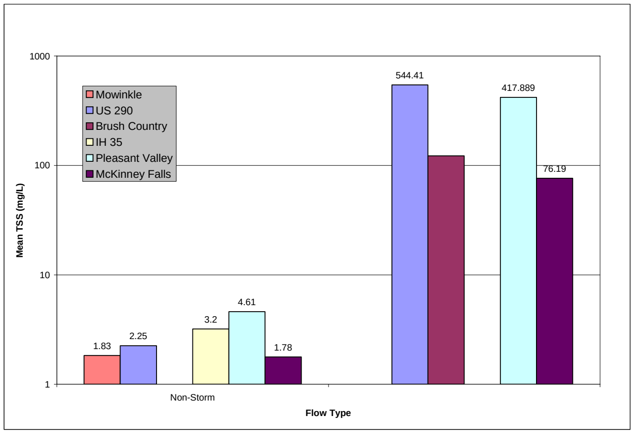
Dissolved oxygen is depressed at the Pleasant Valley site, as shown in figure 36, although there is no significant difference between upstream and downstream mean DO levels. Even when compensated for temperature differences, the percent of DO saturation at the Pleasant Valley site is significantly lower than other locations included in analyses.

Figure 36. Mean Williamson Creek DO by flow type and site.



TDS/Conductivity exhibits an interesting decreasing pattern from the headwaters to the mid-reach, with increasing dissolved solids from mid-reach to mouth, as shown in figure 37. Note that the TNRCC 2002 screening criteria for TDS is 500 mg/L, which is approached by Mowinkle mean concentrations.

Figure 37. Mean Williamson Creek TDS by flow type and site.



Both TSS (figure 38) and VSS (figure 39) exhibit elevated storm flow mean concentrations at the Mowinkle and Pleasant Valley sites.

Figure 38. Mean Williamson Creek TSS by flow type and site.

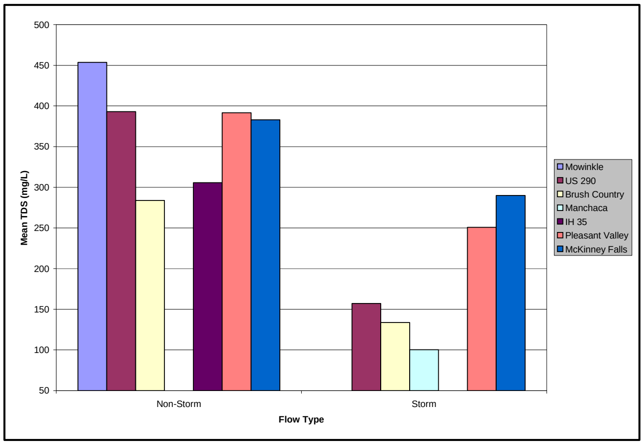
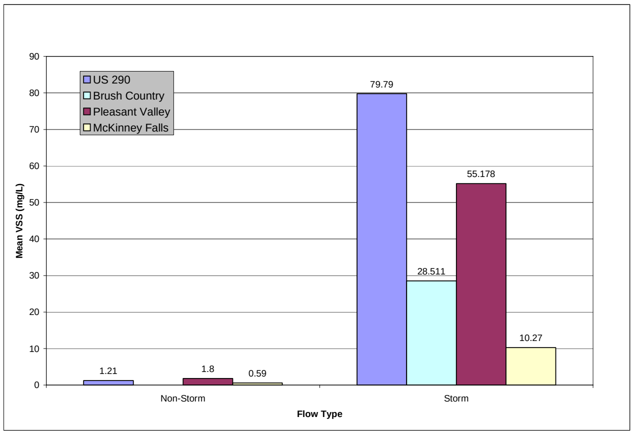


Figure 39. Mean Williamson Creek VSS by flow type and site



No significant difference is evident in mean site concentrations of dissolved calcium, fecal coliform, total orthophosphorus (?), or pH. Although mean pH values are relatively unchanged between sites, the IH 35 monitoring location exhibits depressed pH under non-storm flow conditions, as shown in figure B16. As expected, mean water temperature increases with increasing distance downstream as shown in figure B24, although the size and of this elevation in temperature is slight, and there is no significant difference between sites.

Figure 40. Mean Williamson Creek pH value by flow type and site.

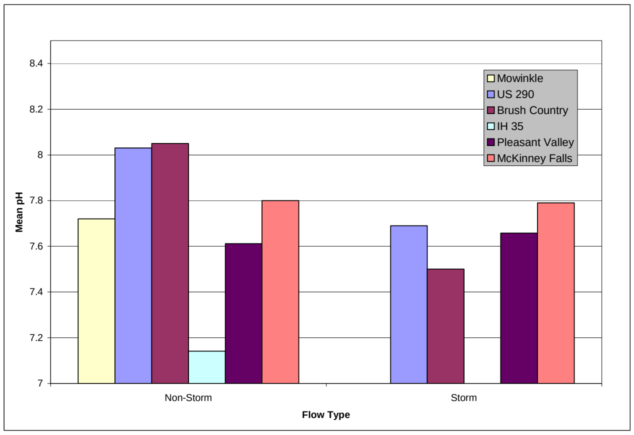
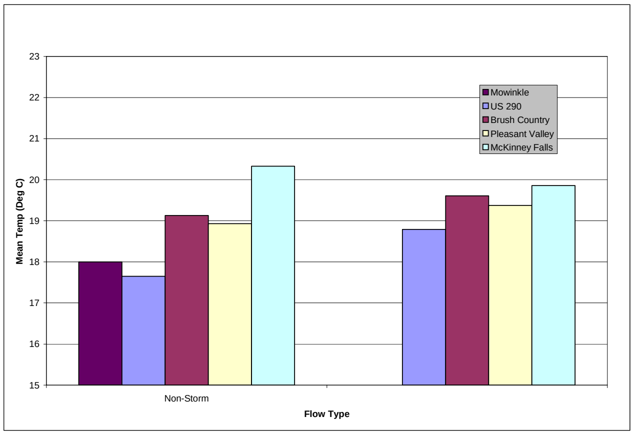


Figure 41. Mean Williamson Creek water temperature by flow type and site.



Direct comparison of mean parameter concentrations at the Williamson Creek mouth site to mean concentrations of Onion Creek receiving waters immediately upstream of the confluence reveal that Williamson Creek and Onion Creek waters are generally not significantly different. However, mean concentrations of total phosphorus and levels of fecal coliform bacteria are significantly greater in Williamson Creek relative to Onion Creek during storm flow conditions only. Mean ammonia, TKN, and

TOC, concentrations during non-storm influenced conditions are significantly greater in Onion Creek than Williamson Creek. No other parameter with available data included in the analysis exhibited a significant difference in mean concentration between the two creeks.

Correlation analyses of Williamson Creek surface water constituent concentrations with discharge measured at USGS gaging stations yield many theoretically expected connections between water quality and flow. Solids and clarity (TSS, VSS, and turbidity), indicator bacteria (fecal coliform), BOD, and TOC are all directly related to discharge with maximum concentrations observed during storm flow conditions. Additionally, several nitrogen (ammonia, organic nitrogen, total nitrogen, TKN) and phosphorus (dissolved orthophosphorus, total orthophosphorus, and total phosphorus) nutrient parameters are also positively related to discharge and exhibit maximum concentrations during storm flow. Dissolved solids (TDS/Conductivity), alkalinity, and hardness, are inversely related to flow and experience maximum concentrations under non-storm conditions as anticipated.

Several dissolved ions (calcium, magnesium, and sodium) as well as total chloride and sulfate are also inversely related to flow and exhibit maximum concentrations under non-storm flows. However, dissolved potassium is directly correlated with flow and mean storm concentrations are significantly greater than non-storm concentrations.

No significant correlation with flow or difference between mean storm and non-storm concentrations were uncovered for the majority of dissolved metals (cadmium, arsenic, lead, zinc), physical parameters (DO, temperature, pH), or surprisingly nitrate+nitrite which would expected to increase under storm-runoff loading as fertilizer, animal wastes, and atmospheric deposition of nitrogen are washed into Williamson Creek. However, dissolved copper is significantly and directly related to discharge.

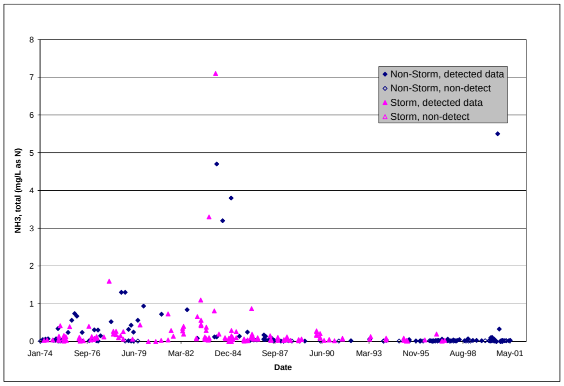
In a simple attempt to determine how groundwater discharge in the Williamson Creek watershed effects surface water constituent levels, mean comparison testing was employed using data from all surface monitoring locations in combination with spring and well data. As expected, watershed surface water concentrations were higher than groundwater concentrations for DO, bacteria, pH, phosphorus (total phosphorus, dissolved orthophosphorus, total orthophosphorus), TOC, ammonia, TKN, and organic nitrogen (in storm flow only). Conversely, mean alkalinity and temperature were significantly higher in groundwater than surface water, as expected.

However, it appears that Williamson Creek groundwater is a source of both magnesium and total nitrate+nitrite to the surface waters of Williamson Creek, as mean concentrations for both parameters are significantly greater in groundwater under both storm and non-storm conditions.

Most likely due to storm water run-off dilution of surface water, the parameters TDS, dissolved calcium, dissolved sodium, chloride, and sulfate, exhibit significantly higher groundwater concentrations during storm flow conditions relative to surface water mean concentrations. During storm flows, dissolved lead and fluoride also exhibit significantly higher groundwater mean concentrations. No significant difference in dissolved barium, boron, and cadmium between surface and groundwater mean concentrations are observed in either storm or non-storm flow conditions.

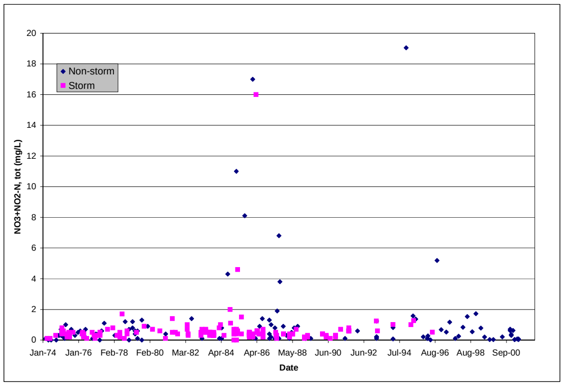
Temporal trend analyses reveal that nitrogen and phosphorus nutrient concentrations in Williamson Creek are generally improving over time as would be expected with the removal of wastewater discharge and the remediation of a leaking septic system and effluent pond. Total ammonia yields significantly decreasing trends over time in both storm and non-storm flows when data from all sites are combined, as shown in figure 42. Although recent concentrations have clearly declined to near-detection limits levels in comparison to the extremely high values observed in 1984 (prior to the decommissioning of the wastewater treatment plant), a recent survey in August 2000 measured a total ammonia value of 5.5 mg/L at the McKinney Falls site indicating continued nutrient contamination from unknown sources.

Figure 42. Williamson Creek total ammonia over time in storm and non-storm flows.



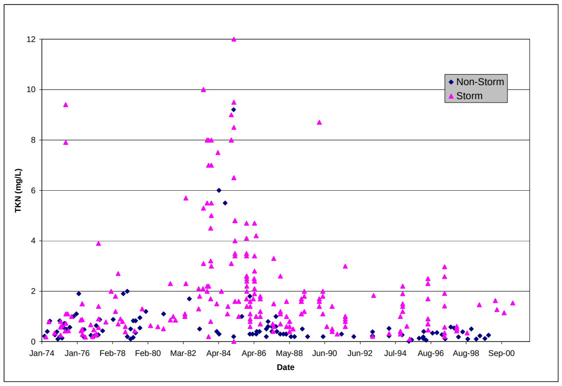
No statistically significant trends are evident in total nitrate+nitrite concentrations over time, as shown in figure 43, although elevated concentrations from 1985 through 1987 during non-storm flow conditions may also be attributable to the wastewater treatment plant. Note the extreme value of 19 mg/L observed in 1994 that began the investigation into the contamination from the decommissioned treatment plant.

Figure 43. Williamson Creek total nitrate+nitrite over time in non-storm and storm flows.



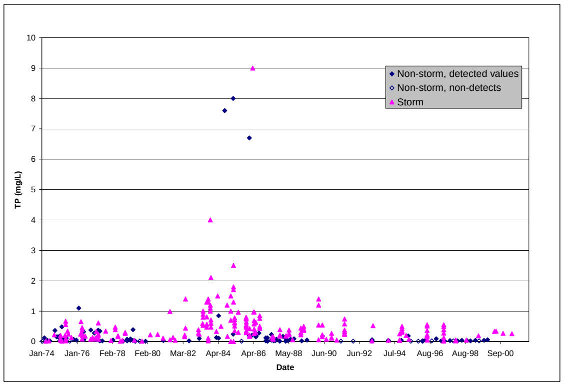
TKN levels in Williamson Creek also exhibit significant decreasing trends over time in both storm and non-storm flow conditions, as shown in figure 44. This decrease corresponds to similar significant trends observed in organic nitrogen (note that TKN is the sum of organic nitrogen and ammonia) during storm flow conditions, although a lack of recent data restrict analyses of organic nitrogen.

Figure 44. Williamson Creek TKN over time in non-storm and storm flows.



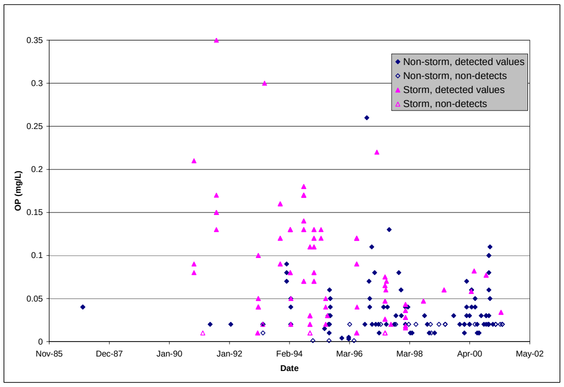
Total phosphorus concentrations in Williamson Creek show improvement over time, as shown in figure 45, with dissolved phosphorus concentrations (not graphed) also yielding a significantly decreasing trend over time during storm flow conditions. Similar to ammonia values, a period of elevated phosphorus concentrations were recorded around 1984 potentially due to the discharge from wastewater lagoons of the now decommissioned Williamson Creek Wastewater Treatment Facility.

Figure 45. Total phosphorus concentrations over time in Williamson Creek.



Combining dissolved and total orthophosphorus concentrations to maximize the amount of available data shows significantly decreasing orthophosphorus levels over time during storm flow conditions, as shown in figure 46. Orthophosphorus concentrations under non-storm influenced flow conditions reveal no clear or statistically significant temporal trend.

Figure 46. Dissolved and total orthophosphorus over time in Williamson Creek.



Additional improvements over time in Williamson Creek surface waters are observed in suspended solids (TSS in figure 47) and organic carbon (TOC in figure 48), both of which exhibit statistically significant decreasing temporal trends in concentration during storm flows. Note the clear effect in TSS concentrations in the spring of 1986 when the Williamson Creek WWTP was decommissioned.

Dissolved arsenic (in non-storm flows) and dissolved magnesium (in storm flows) also yield a decreasing trend in concentration over time, although a lack of data after 1995 prevent confirmation of these continuing improvements.

Figure 47. Williamson Creek TSS over time in storm and non-storm flows.

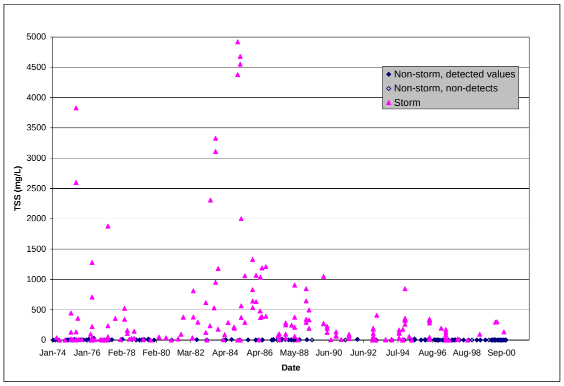
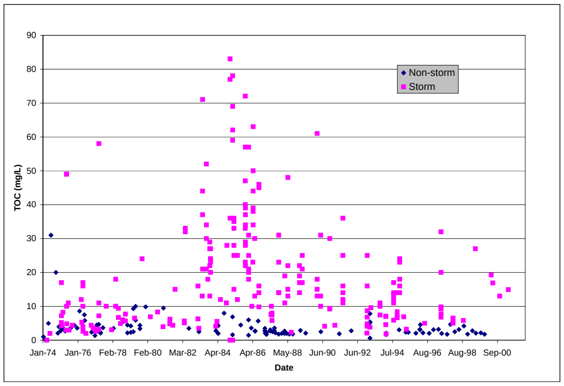


Figure 48. Williamson Creek TOC over time in storm and non-storm flows.



Chloride and sulfate concentrations in Williamson Creek, however, show statistically significant degradation over time in non-storm flow conditions, as shown in figure 49 and 50, although the reduction in data during recent years clearly demands additional future sampling to confirm these trends.

Figure 49. Williamson Creek total chloride over time in storm and non-storm flows.

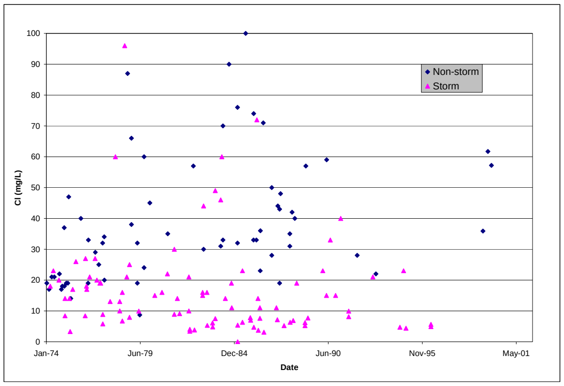
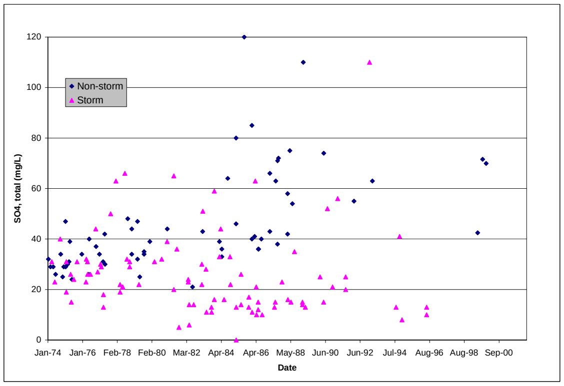


Figure 50. Williamson Creek total sulfate over time in non-storm and storm flows.



Another curious trend in Williamson Creek surface water is the slight, though significant increase in acidity over time, as shown in the pH values in figure 51. This decreasing temporal trend corresponds to decreases in total alkalinity, presented in figure 52, although the source of decrease in pH in Williamson Creek is unknown.

Figure 51. Williamson Creek pH values over time in non-storm and storm flows.

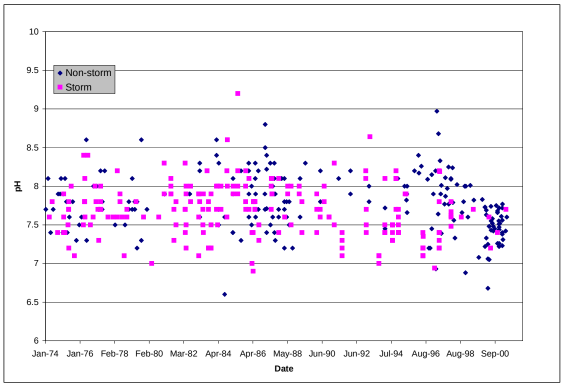
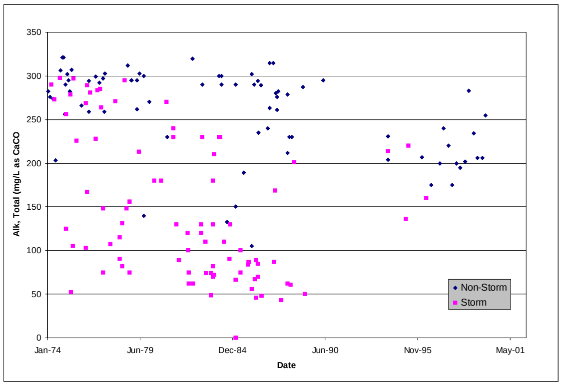
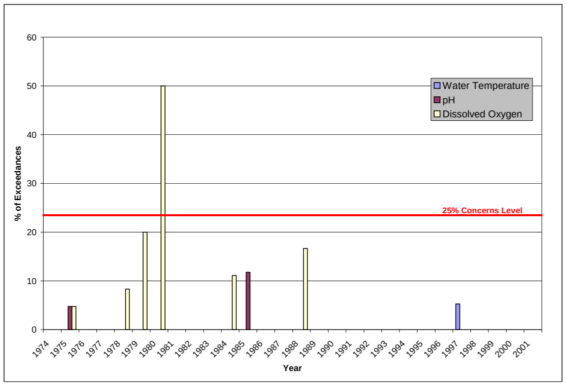


Figure 52. Williamson Creek total alkalinity over time in non-storm and storm flow.



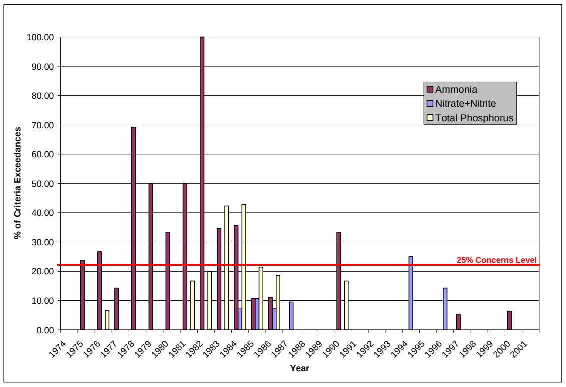
Comparison of Williamson Creek physical parameters (temperature, pH, and DO) in water indicate that Williamson Creek is of no concern and not impaired. In no year since 1990 have pH or DO exceeded criteria, and in no year since 1980 have exceedances for any physical parameter exceeded 25% entering a level of concern, as shown in figure 53.

Figure 53. Williamson Creek physical surface water parameters in comparison to TNRCC 2002 screening criteria.



Nutrient parameter (ammonia, nitrate+nitrite, total phosphorus) analyses indicate that Williamson Creek surface water is also of no concern and not impaired. Early data, though biased by small sample sizes typically weighted more towards storm-influenced conditions as well as degradation from wastewater discharge, indicates fairly consistent impairment for ammonia from 1975 to 1985 (shortly before the treatment plant was taken off-line), although no nutrient parameter has exceeded the 25% concerns level since 1995 as shown in figure 54. It should be noted that in no sample has orthophosphorus exceeded TNRCC screening criteria.

Figure 54. Williamson Creek surface water nutrient parameters in comparison to TNRCC 2002 screening criteria.



Williamson Creek is also of no concern for TDS, chloride, or sulfate, since in no year since 1974 has the annual average exceeded the screening criteria. However, elevated annual averages measured in 1999, potentially due to constructed remediation efforts on the ponds at the Roy Kizer Golf Course, suggest a potential increase in concentration although a lack of data in years before and after provide no confirmation as shown in figures 55 and 56.

Figure 55. Williamson Creek TDS annual surface water averages (note that TNRCC 2002 screening criteria is 500 mg/L).

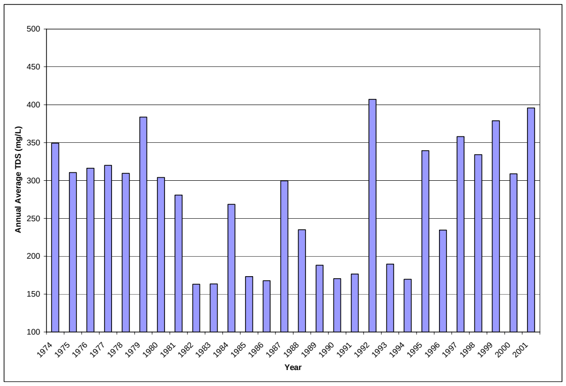
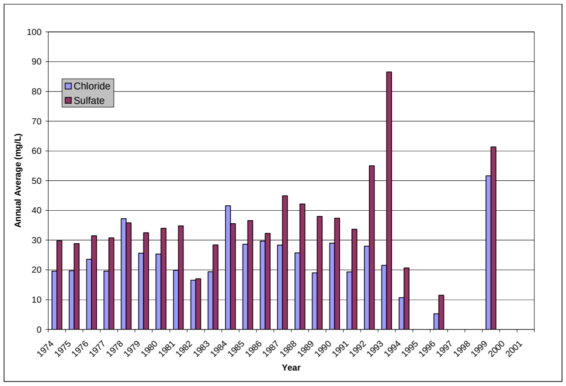
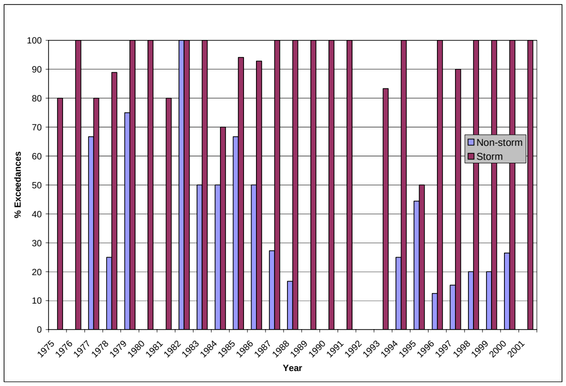


Figure 56. Williamson Creek chloride and sulfate annual surface water averages in comparison to TNRCC screening criteria (note that criteria for both parameters in 100 mg/L).



The geometric mean of Williamson Creek fecal coliform bacteria from 1995 to 2001 is 227 col/100mL when all data sources are included for analyses, which exceeds the 200 col/100mL screening criteria for contact recreation use. Within these 118 samples for fecal coliform, approximately 30% of the time bacteria levels exceed 400 col/100mL single-sample screening level as shown in figure 57, indicating that Williamson Creek is not supporting Contact Recreation use, and is a Tier 2 primary concern. However, recent 305(b) water quality assessments on Williamson Creek do not show impairment since USGS fecal coliform data were excluded from analysis due to quality assurance issues.

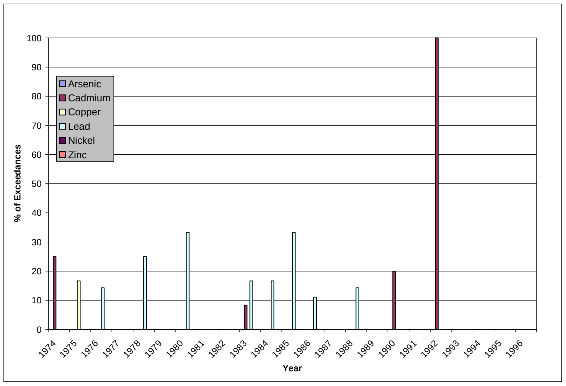
Figure 57. Williamson Creek fecal coliform percentage of exceedances of TNRCC 2002 screening criteria over time by flow type.



Evaluation of organic substances in water for the protection of aquatic life could only be conducted for the pesticides Carbaryl (Sevin), Dieldrin, Malathion, and Parathion, which had samples collected as recently as May 2000. In no sample was the freshwater acute criteria ever exceeded since initial data in 1975, and in no recent sample was the freshwater chronic criteria exceeded.

Dissolved metals data show that no sample has ever exceeded acute or chronic criteria for dissolved arsenic, dissolved nickel, or dissolved zinc, as shown in figure 58. Only one sample from 1975 was in exceedance of the chronic criteria for dissolved copper. Although a number of lead samples exceeded the chronic criteria from 1974 to 1988, no exceedance has been recorded in any later samples. Approximately 4 samples have exceeded chronic criteria for dissolved cadmium, with the most recent exceedance recorded in 1992. However, no dissolved metals have been measured in Williamson Creek since 1996, so a more accurate assessment cannot be performed.

Figure 58. Williamson Creek dissolved metals in water in exceedance of TNRCC 2002 chronic toxicity screening criteria.



Exploring potential effects of development on water quality in Williamson Creek through correlation analyses of water contaminants with percent impervious cover in the individual drainage basins upstream of the monitoring locations show that increasing impervious cover correlates to increasing concentrations of nitrogen (ammonia and nitrate+nitrite), dissolved arsenic, chloride, sulfate, dissolved fluoride, dissolved sodium, and TSS in Williamson Creek in both storm and non-storm flow conditions. Increasing impervious cover also correlates with increasing acidity (or decreasing pH) as well as decreasing alkalinity and decreasing DO.

Organic material appears to exhibit mixed relationships with impervious cover, as BOD, TOC, organic nitrogen and TKN, are directly correlated with impervious cover in non-storm flow conditions but inversely correlated with impervious cover during storm flows.

TDS exhibits an altogether different pattern of negative correlation in non-storm flows and positive correlation in storm flows.

Both total phosphorus and dissolved magnesium, however, are inversely correlated with impervious cover. The reason for the discrepancy in total phosphorus, which is typically transported to streams attached to sediments, and TSS is unclear.

Groundwater Assessment

All values of dissolved and total zinc, dissolved (since 1982) and total arsenic, and dissolved cadmium are below detection limits and were not analyzed further.

In general, higher mean groundwater concentrations are observed at springs in Terrace and Buda alluvial formations occurring the lower portion of the Williamson Creek watershed than concentrations observed at wells in the Edwards limestone formation. Parameters for which mean levels are significantly higher in Terrace/Buda springs include alkalinity and dissolved calcium, chloride, DO, fecal coliform, dissolved iron, dissolved manganese, total nitrate+nitrite, total orthophosphorus, total and dissolved phosphorus, sulfate, and TDS. The only groundwater parameters which exhibited higher mean concentrations at Edwards wells were dissolved magnesium, pH, total TKN, and water temperature. No other parameter yielded a significant difference between the two geologic groups, including ammonia which is expected to display higher concentrations at downstream sites due to readily-identifiable contributing sources such as golf course effluent irrigation.

Analyses of differences in groundwater concentrations based on surface water flow conditions reveals that the majority of parameters assessed in Williamson Creek groundwater exhibit no difference between storm and non-storm surface flow periods. However, during surface storm flow conditions, concentrations of organic nitrogen and TKN, as well as dissolved lead, are significantly greater in Williamson Creek groundwater. Conversely, levels of alkalinity, dissolved barium, dissolved fluoride, dissolved magnesium, dissolved manganese, dissolved silica, and total nitrate+nitrite are significantly greater during non-storm influenced surface flow conditions, indicating potential dilution from surface water during storm events.

Correlation analyses reveal few statistically significant inverse relationships between groundwater parameters and estimated impervious cover within surface drainage areas. Only total alkalinity, dissolved silica, and water temperature measurements decrease with increasing impervious cover. However, organic nitrogen, dissolved ammonia (although there is no trend in total ammonia concentrations), dissolved potassium, dissolved calcium, dissolved copper, dissolved fluoride, dissolved sodium, and sulfate exhibit statistically significant increasing trends with increasing surface impervious cover.

This pattern appears to be nearly reversed when comparing groundwater concentrations in Williamson Creek to surface drainage area. Only dissolved potassium, dissolved calcium, and dissolved copper exhibit statistically significant positive relationships to increasing estimated surface drainage area. However, alkalinity (and hardness), dissolved manganese, dissolved barium, dissolved silica, dissolved boron, water temperature, dissolved and total magnesium, total potassium, dissolved and total orthophosphorus, and nitrate+nitrite all yield significant inverse relationships with drainage area.

Comparative analyses of groundwater site mean concentrations reveals little significant difference between sites for dissolved calcium, total copper, total iron, total fluoride, total lead, organic nitrogen, dissolved ammonia, DO, total orthophosphorus, pH, total phosphorus, turbidity, and water temperature. However, elevated concentrations of alkalinity, TDS, chloride, total nitrate+nitrite, dissolved orthophosphorus, dissolved phosphorus, and fecal coliform bacteria are observed at the Jimmy Clay golf course site. Maximum mean total ammonia concentrations were observed at the YD-58-50-220 site, a member of the single family site group, although minimum dissolved lead concentrations were observed at this well. Another single family site, OW2-5, exhibits maximum mean dissolved and total TKN, dissolved copper, and dissolved lead concentrations, but also yields minimum mean dissolved iron and dissolved silica levels.

Comparing USGS wells and CoA-monitored springs reveals that total alkalinity is generally higher at springs (measured by CoA after 1994) than USGS wells (measured before 1990). Total ammonia is generally lower at CoA-monitored springs than USGS wells, with the notable exception of a 0.18 mg/L value at Roy Kizer (a golf course site) measured on September 1995, although no trend is evident.

Single samples for several parameters at numerous sites reveal interesting information although the lack of sufficient data prevents a complete assessment. Single samples of DO were below 2 mg/L at Jimmy Clay and below 1 mg/L at IH 35 (January 1997). Dissolved iron (a high value of 310 µg/L measured in December 1994), dissolved sodium, and (total and dissolved) phosphorus were extremely high in one sample at the Berry Yard Spring, Total orthophosphorus concentrations at the Sloan Spring were also elevated in a single sample.

Site group analysis parallels the between-site comparison as the golf course sites, driven by Jimmy Clay concentrations, exhibit maximum alkalinity, chloride, nitrate+nitrite, total sodium, total potassium, orthophosphorus, TDS, (most acidic) pH, dissolved phosphorus, and sulfate mean concentrations. Sulfate is also elevated at transportation land use influenced sites, along with dissolved boron, dissolved fluoride, dissolved magnesium, dissolved potassium, and dissolved sodium. Single family land use sites exhibit minimum DO values (with maximum DO mean values at undeveloped sites) and more basic pH levels. It is interesting that undeveloped groundwater sites exhibit elevated nitrate+nitrite levels, as well as higher temperature measurements.

Additional interesting site group comparison observations include:

- Alkalinity at undeveloped sites is significantly greater than single family sites.
- Lower ammonia concentrations are observed at septic and undeveloped sites in comparison to other site groups.
- Both chloride and sulfate minimum mean concentrations are seen at septic sites.

Temporal trend analysis reveals that Williamson Creek concentrations of dissolved calcium and total chloride are increasing over time. However, the observed increasing trend in total chloride may be the result of increased concentrations observed at the Jimmy Clay/Roy Kizer and Long Bank spring sites, which exhibit higher concentrations and greater variations than other sites and have been monitored more frequently in recent years. Long-term monitored wells show no change or even slight decreases in chloride over time. Other potentially increasing trends are observed for total copper, total orthophosphorus, and DO.

High TDS readings are increasing in frequency over time, although more recently sampled CoA springs are generally higher in TDS in comparison to wells measured by USGS, and analyses of each data set individually reveal no strong long-term trends. At the site level, however, it appears that while Jimmy Clay TDS may be increasing, Roy Kizer TDS may be decreasing thereby nullifying an overall trend.

The number of detected total lead measurements are also increasing although there is no trend evident the in the more long-term dissolved lead data set. High recent data for dissolved iron seems to conflict with slightly decreasing trends observed in total iron. Williamson Creek groundwater appears to be more acidic in pH over time, although the decreasing trend is very slight. Interesting spikes in total phosphorus concentrations demand further investigation and analyses to determine potential sources of phosphorus input to Williamson Creek groundwater.

Although there is no trend in the more long-term dissolved lead data set, increases in the number of detected data points for total lead at CoA-monitored springs (Roy Kizer and Long Bank) are evident in recent data.

Improving temporal trends in Williamson Creek groundwater include total ammonia and TKN, as well as dissolved potassium. Although total TKN is generally higher historically at USGS wells in comparison to CoA springs and no clear trend is evident in CoA spring data, USGS wells do show decreasing TKN concentrations over time.

CONCLUSIONS

Williamson Creek faces continual pressure from increasing population and development within watershed boundaries.

At the present time, there is no statistically significant increase in the frequency of low or high flow days in Williamson Creek according to USGS flow gage data.

Flooding problems in the watershed are prevalent, particularly in the lower reaches of the watershed, and there are a number of roadways and buildings threatened by flood waters. Williamson Creek is also experiencing accelerating creek erosion, with channel widening occurring as a primary geomorphic problem in 10 of 13 assessed creek reaches. Increasing impervious cover within the watershed will most likely exacerbate these problems.

Although current city-wide watershed rankings place Williamson Creek at a moderate risk for hazardous spills, future estimates of spills risk in the drainage area are projected to increase to the high risk level.

EII data indicate that Williamson Creek non-contact recreation and physical integrity ratings decreased from 1996 to 2000 measurements in comparison to other Austin-area watershed scores.

Diatom data for the entire Williamson Creek watershed show little change over time, although EII rankings indicate improvement relative to other Austin-area drainage basins.

Although benthic macroinvertebrate data yielded EII scores that decreased from 1996 to 2000, overall watershed rankings for Williamson Creek improved drastically. The lower 2000 EII scores, in combination with decreasing EPT taxa metrics, also result in a statistically significant decreasing trend in aquatic life use scores by TNRCC methodology over time. Williamson Creek currently ranks as an intermediate aquatic life use according to CoA data.

Although sediment data show that concentrations of copper, lead, and zinc may be increasing in Williamson Creek, no contaminant in sediment was above applicable probable effect levels and Williamson Creek EII rankings improved from 1996 to 2000 sampling events.

EII water quality assessments show that Williamson Creek was above average relative to other Austin watersheds in 1996, and improving in 2000. Site water quality sub-index scores improved at all sites except the most upstream Mowinkle site. Contact recreation scores, based on fecal coliform counts, remained nearly constant for all sites although the IH 35 and Pleasant Valley sites exhibited a marked improvement from 1996 to 2000 sampling events, elevating Williamson Creek to a status better than 91% of other Austin watersheds for EII contact recreation scores.

Generally increasing longitudinal trends are observed from upstream to downstream Williamson Creek sites for nitrogenous nutrients, chloride, sodium, potassium, and sulfate. Conversely, Williamson Creek appears to be decreasing the concentrations of alkalinity and several dissolved metals from upstream to downstream sites. Both BOD, organic nitrogen, and TOC increase from upstream to downstream sites under non-storm flows, although the opposite pattern is observed during storm flow conditions.

Unusually elevated concentrations of nitrogenous nutrients and total phosphorus are observed at the Pleasant Valley site during both storm and non-storm flow conditions, and DO levels are depressed at this location.

Comparison of Williamson Creek and Onion Creek concentrations at the confluence reveal that the two watersheds are not markedly different in water quality, although mean concentrations of total phosphorus and fecal coliform may be greater than Onion Creek under storm flow conditions.

Groundwater recharge to Williamson Creek may be a source of magnesium and nitrate+nitrite to surface waters as these parameters exhibit significantly higher mean groundwater concentrations during both storm and non-storm surface flow conditions.

Nitrogen and phosphorus nutrient concentrations are generally improving over time in the Williamson Creek. Additional improvements over time are potentially observed in Williamson Creek surface water TSS, TOC, dissolved arsenic, and dissolved magnesium.

Chloride and sulfate levels in Williamson Creek surface water, however, are increasing over time although a reduction in sampling frequency suggest additional monitoring. Acidity levels in Williamson Creek, though slight and of an unknown origin, are also increasing over time and correlate with observed decreasing trends in alkalinity.

Williamson Creek is not impaired and of no concern according to TNRCC 303(d) assessments for physical, nutrient, TDS, organic, pesticide, dissolved metal, or chloride and sulfate parameters. However, fecal coliform data show that Williamson Creek is not supporting a contact recreation use and is a Tier 2 primary concern according to TNRCC methodologies.

Higher mean groundwater concentrations for the majority of analyzed parameters are observed at springs in the Terrace/Buda formations in the lower reaches of the watershed relative to the concentrations observed in the wells occurring in Edwards limestone in the upper portion of the watershed.

Elevated levels of alkalinity, TDS, chloride, nitrate+nitrite, dissolved orthophosphorus, dissolved phosphorus, and fecal coliform bacteria are observed at the Jimmy Clay golf course site.

Williamson Creek groundwater concentrations of chloride and dissolved calcium may be increasing over time, although concentrations of ammonia and TKN reveal improving temporal trends.

RECOMMENDATIONS

Additional monitoring of chloride and sulfate to confirm potentially degradation over time from these surface water parameters.

REFERENCES

Allison, P. D. 1995. Survival analysis using the SAS® System: a practical guide. SAS Institute, North Carolina.

Barrett, Michael E., and R. J. Charbeneau. 1996. A parsimonious model for simulation of flow and transport in a karst aquifer: the University of Texas at Austin Center for Research in Water Resources Technical Report 269.

Bhattarai, Raj, Regulatory Manager, City of Austin Water/Wastewater Department. Personal communication. 27 July 2002.

Raymond Chan & Associates. 1997. Williamson Creek Watershed Erosion Assessment (C.I.P. #485-617-2000), prepared for the City of Austin Drainage Utility Department.

City of Austin Environmental Resource Management Division. 1992. Town Lake Report.

City of Austin Watershed Protection Department. 2001. Watershed Protection Master Plan: Phase I Watersheds Report. 2001. Watershed Protection Report Series CoA-WPD 2001-02.

Duncan, D. B. 1975. T-tests and intervals for comparisons suggested by the data. Biometrics 31:339-359.

Garner, L. E., and K. P. Young. 1976. Environmental geology of the Austin area: an aid to urban planning. Bureau of Economic Geology, University of Texas at Austin, Report of Investigations no. 86.

Gilliom, R. J. and D. R. Helsel. 1986. Estimation of distributional parameters for censored trace level water quality data. Water Resources Research 22:135-155.

Helsel, D. R. 1990 Less than obvious: statistical treatment of data below the detection limit. Environmental Science and Technology 24:1766:1774.

Helsel, D. R. 1998. Personal Communication on statistical methods.

Helsel, D. R., and R. M. Hirsch. 1992. Statistical Methods in Water Resources. Elsevier Science Publishers, Amsterdam.

Helsel, D. R., and T. A. Cohn. 1988. Estimation of descriptive statistics for multiply censored water quality data. Water Resources Research 24:1997-2004.

SAS Institute Inc. 1989. SAS/STAT® Users Guide, Version 6, 4th ed., volumes 1 and 2. SAS Institute Inc, North Carolina.

SAS Institute Inc. 1990a. SAS® Procedures Guide, Version 6, 3rd ed. SAS Institute Inc, North Carolina.

SAS Institute Inc. 1990b. SAS/GRAPH® Software: Reference, Version 6, 1st ed., volume 1. SAS Institute Inc, North Carolina.

Sokal, R. R., and F. J. Rohlf. 1995. Biometry, 3rd ed. W. H. Freeman and Company, New York.

Woodruff, Jr., C. M. 1977. Stream piracy near the Balcones Fault Zone, Central Texas. Journal of Geology 85:4, pp. 483-490.

United States Army Corps of Engineers. 1980. Williamson Creek expanded flood plain information study general report. Volume II.

United States Army Corps of Engineers. 1980. Walnut and Williamson Creek expanded flood plain information study general report. Volume III.

United States Census Bureau, Statistical Compendia Branch. 2001. Statistical abstracts of the United States.

United States Department of Agriculture Natural Resources Conservation Service. 1995. Soil Survey (SSURGO) Geographic Database. Miscellaneous Publication Number 1527. January 1995.

United States Department of Agriculture Soil Conservation Service, in cooperation with the Texas Agricultural Experiment Station. 1974. Soil Survey of Travis County.

A Appendix A. Site Photos.

Mouth of Williamson Creek (looking downstream) at the confluence with Onion Creek in McKinney Falls State Park.

Lower mid-reach of Williamson Creek (looking downstream) near IH 35.

Upper mid-reach of Williamson Creek (looking upstream) near Joe Tanner Road.

Headwaters of Williamson Creek (looking upstream) near Mowinkle Drive.