

**Tyler Coulee  
Storm Water Assessment  
and Management Plan**

City of Bismarck  
Bismarck, North Dakota



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## Executive Summary

This report is written to partially fulfill the City of Bismarck's Environmental Protection Agency (EPA) Section 319 Grant obligations for completing a water quality assessment of the Tyler Coulee Watershed. The Tyler Coulee Watershed is located within the northwestern portion of the City. A portion of the watershed is located beyond the extraterritorial area of the City within Burleigh County. A 1,900-acre watershed drains via Tyler Coulee via an intermittent stream with an average slope of approximately 2.3%. Tyler Coulee is a tributary of the Missouri River.

This study's purpose is to evaluate the water quality characteristics and hydrology of the watershed and to develop a plan for managing the increasing peak discharges, the resulting erosion and water quality issues associated with urbanization. Within this context, three specific goals were established:

- The collection of water quality, precipitation and hydrology data to assess the condition within the watershed;
- Estimate loads for various water quality parameters; and
- Develop a master plan, which recommends Best Management Practices (BMPs) to remedy existing and prevent future water quantity and quality problems within the context of continuing urbanization.

Five water quality samples were collected during the late fall of 2000 and the early spring of 2001 at each location. These samples were analyzed for solids, nutrients, bacteria, trace metals and physical characteristics (e.g., water temperature). Drawing conclusions based on a limited dataset like the one collected during this study is difficult. The data do suggest that water quality within Tyler Coulee is representative of an urbanizing watershed. Additional sampling is necessary to determine whether the differences in water quality between Tyler Coulee and Hay Creek, a tributary traversing the east side of Bismarck, is real for select parameters. On-site and regional BMPs as well as erosion control practices should be considered to protect water quality.

The United States Environmental Protection Agency's Storm Water Management Model (SWMM) was selected for modeling the hydrologic response of the watershed. This model was calibrated using rainfall and runoff data from the watershed for two storm events.

Improving two existing regional detention basins (i.e., Valley Drive Detention Basin West and Overland Road Detention) and constructing one new regional detention basin (Burnt Boat Drive & Tyler Parkway Detention Basin) is recommended to reduce post development peak flow rates. No modifications are planned for several other existing regional detention basins. By modifying Valley Drive Detention Basin West and Overland Road Detention and constructing the Burnt Boat Drive & Tyler Parkway Detention Basin, peak flow rates for the 2-year, 10-year and 100-year (6-hour) will be controlled at Clairmont Road. A new channel is also recommended in Pioneer Park to reduce the frequency of flooding. Several regional extended detention basins are also recommended for the reduction of sediment loads and other potential water quality issues related to future development. The Opinion of Probable cost for the master planned features is estimated at \$1,626,000.

## 1.0 Introduction

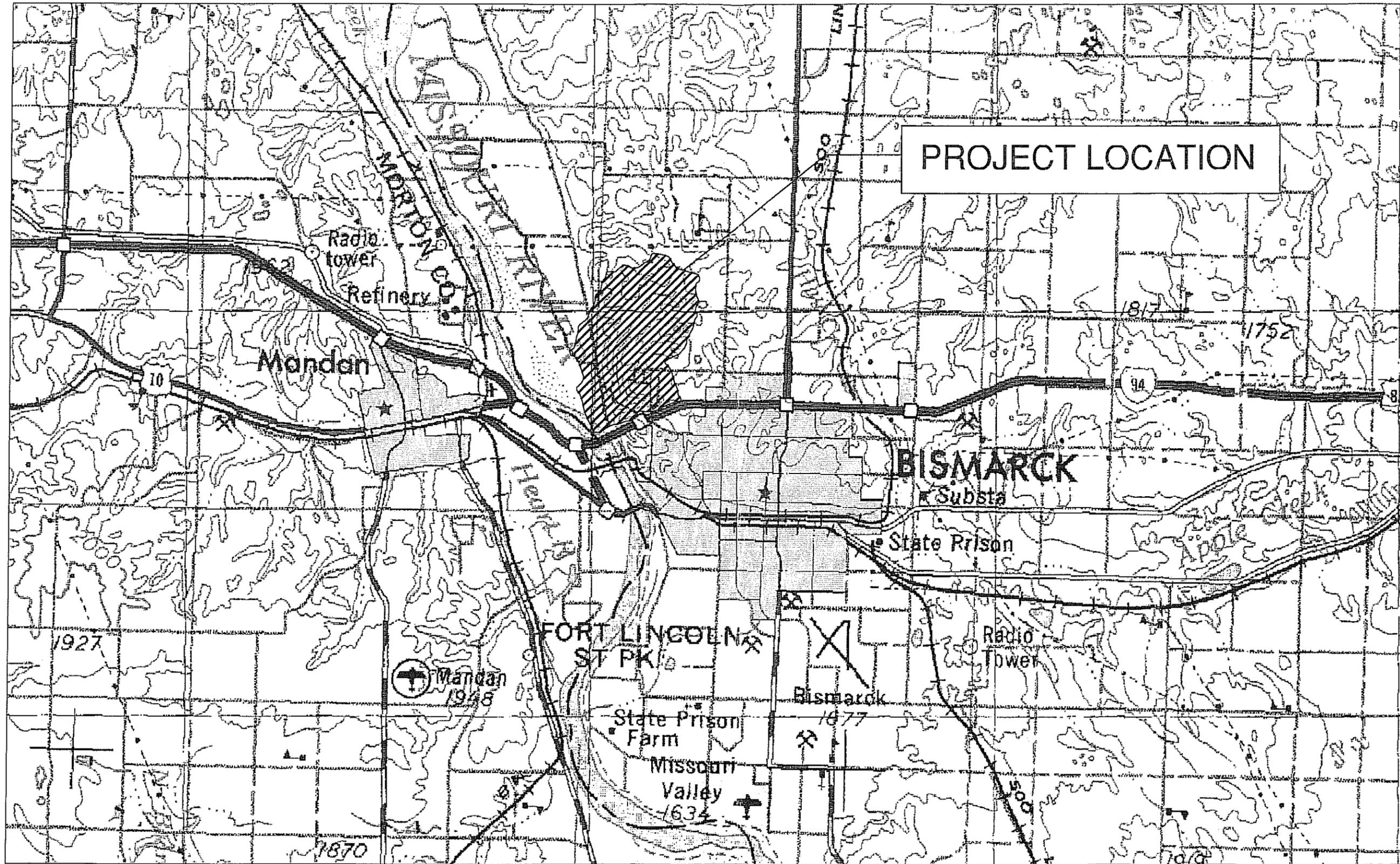
This report is written to partially fulfill the City of Bismarck's Environmental Protection Agency Section 319 Grant obligation for completing a water quality assessment of the Tyler Coulee Watershed. The watershed is located in northwestern Bismarck (Figure 1). The watershed consists of approximately 1,900-acres of land (Figure 2 [back pocket of report]). The watershed contains a steeply incised channel that has come under increasing pressure, because of the erosive force of increased peak flows associated with new development. These affects are most evident in subwatersheds TC 6-4 and TC 7 (Figure 2).

Subwatershed TC 6-4, located downstream of Tyler Parkway, receives runoff from the 302-acres of subwatersheds TC 6-2, TC 6-3 and TC 6-1 that formerly drained into the Jackman Coulee Watershed to the south of Interstate 94 (I-94). These drainage areas were diverted into the Tyler Coulee Watershed in the early 1960s during the construction of I-94. Consequently, subwatershed TC 6-4 now receives the combined runoff from subwatersheds TC 6-2, TC 6-3 and TC 6-1, which are nearly fully developed. The broad valley of TC 6-4 has eroded significantly, creating a new channel where none previously existed, since the diversion. The City previously place riprap within the channel traversing the broad valley to stem erosion, with only limited success.

Pioneer Park is located in subwatershed TC 8. A channelized (i.e., man-made) coulee through the park is the main conveyance system for water received from the Tyler Coulee Watershed. Because of increasing watershed wide development and the increased runoff from subwatershed TC 6-4, flood events now cause the loss of park use at least once every year.

The purpose of this report is to evaluate the water quality and hydrologic characteristics of the Tyler Coulee Watershed and to develop a master plan for managing the increasing peak flows, potential erosion and water quality issues. Within this context, three specific project goals have been established:

- The collection of water quality, precipitation and hydrology data to assess the condition within the watershed;



**PROJECT LOCATION**



PROJECT LOCATION MAP

TYLER COULEE  
STORM WATER QUALITY AND MASTER PLAN  
CITY OF BISMARCK, NORTH DAKOTA

Scale AS SHOWN	Drawn by B.G.J.	Checked by J.E.J.	Project No. 1012-600	Date 10-9-00	FIG. 1
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CAD. REF.

- Estimate loads for various water quality parameters; and
- Develop a master plan, which recommends Best Management Practices (BMPs) to remedy existing and prevent future water quantity and quality problems within the context of continuing urbanization.

## **2.0 Setting**

Tyler Coulee is an intermittent tributary to the Missouri River. The watershed is located near the northwestern city limits of Bismarck, North Dakota (Figure 1). Tyler Coulee was once part of the Burnt Creek Watershed. However, due to the diversion of Burnt Creek, Tyler Coulee now has a separate, distinct watershed. The lower portion of Burnt Creek is located directly west of Tyler Coulee. Specifically, the Tyler Coulee Watershed is contained within Sections 17, 18, 19, 20, 29 and 30 of (Hay Creek) Township 145 North, Range 55 West.

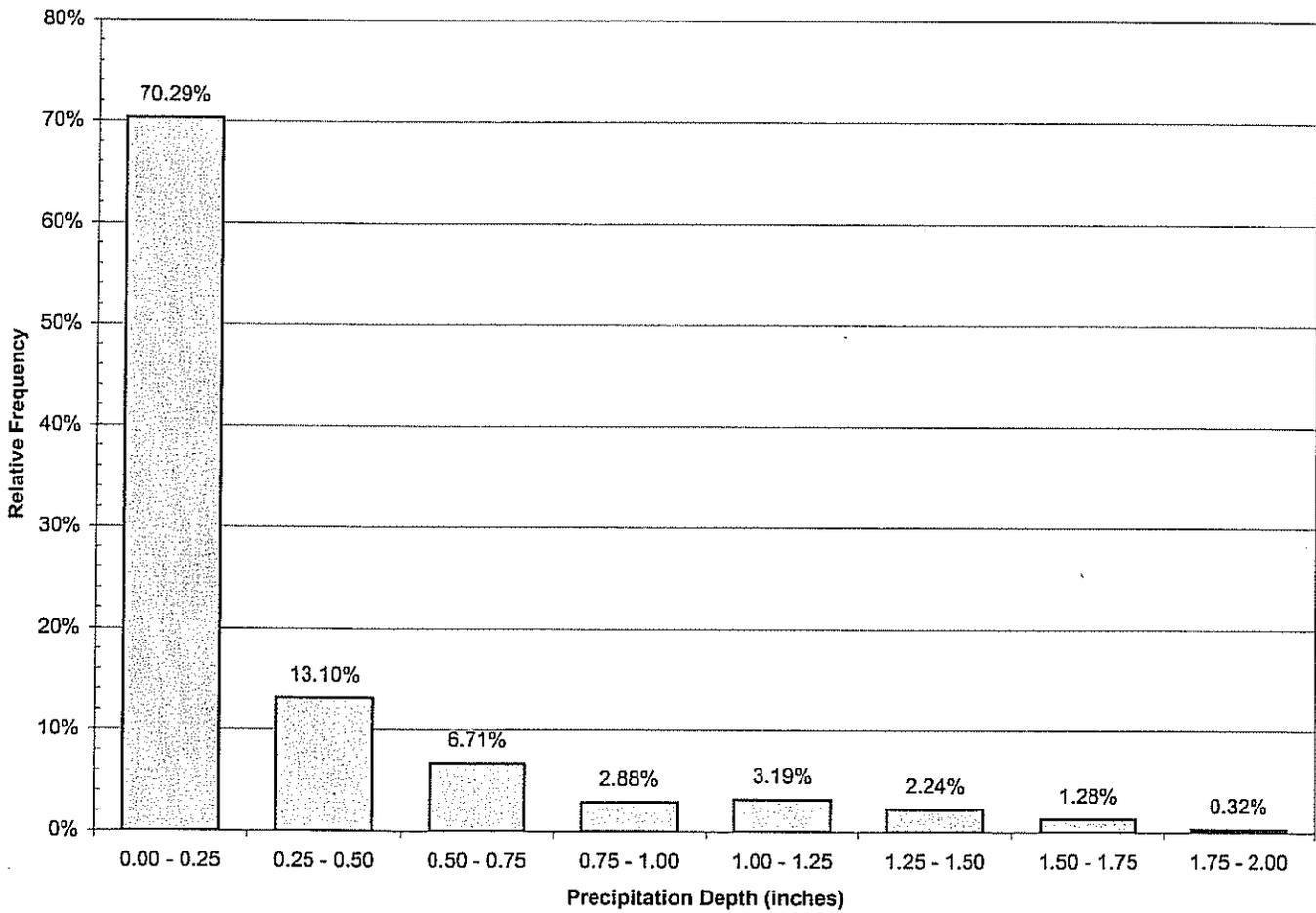
### **2.1 Climate**

The climate of the south-central region of North Dakota surrounding the Bismarck area can be described as semi-arid, typically continental in character. Summers are warm, but there are not many hot days and very few hot and humid days. Winters tend to be long and quite cold. The mean annual temperature is 41.6 °F and on average, monthly temperatures range from 70.4 °F in July to 9.3 °F in January. The temperature extremes are 108 °F and -45 °F, both occurring in 1936. Mean annual precipitation is 15.5 inches with approximately 76% or 11.8 inches falling between the months of April and September. Approximately 50% of Bismarck's annual precipitation falls during May, June and July. Figure 3 shows the relative frequency distribution of rainfall events in Bismarck. Because of relatively warm and dry climate conditions throughout the summer months mean annual evaporation is approximately 34 inches. Therefore, most hydrologic systems suffer from a shortage or deficit of surface flows.

### **2.2 Physical Characteristics**

The landscape that characterizes the Tyler Coulee Watershed is a direct result of past glacial activity. The natural drainage pattern of the Tyler Coulee Watershed forms a

**Figure 3**  
**RELATIVE FREQUENCY DISTRIBUTION OF PRECIPITATION IN BISMARCK, ND**



dendritic system that extends throughout the basin. The branches of the primary channel form several deep, high-gradient ravines that fan out as the upper and outer reaches of the watershed are approached.

### **2.3 Hydrologic Characteristics**

The Tyler Coulee Watershed consists of a well-defined drainage area that encompasses 1,900 acres (2.97 mi<sup>2</sup>). Several roads that serve as important transportation corridors traverse portions of the watershed; i.e., River Road, Burnt Boat Drive, Valley Drive, Tyler Parkway, Century Avenue and I-94. The outlet of the Tyler Coulee Watershed is located at the Missouri River in Pioneer Park. The upper reaches of the watershed are bound by a natural ridge and at its furthest eastern extent stretch approximately 2.3 miles from the outlet. The Tyler Coulee Watershed is approximately 1.5 miles wide at its widest point.

To accommodate the difference in elevation between the highest topographical features of the watershed and the outlet at Pioneer Park, the channel forms a deep valley within the bounds of the watershed. The elevation at the watershed outlet and the elevation at the upper reaches differ by approximately 270 feet, resulting in an average basin slope of 2.2%.

The soils within Tyler Coulee Watershed are also a direct result of past glacial activity. Nearly all of the drainage area that comprises the Tyler Coulee Watershed is mantled with thin to moderate layers of glacial drift. The majority of the soils is classified as loams and silt loams. However, soils surrounding the flood plains are typically silt loams and clays. Different soil types have different infiltration characteristics. Fine-textured soils, such as clay, generally produce a higher rate of runoff than do coarse-textured soils, such as sand. In general, the higher the rate of infiltration, the lower the quantity of storm water runoff.

Soils have been divided into groups called "hydrologic soil groups" (HSGs) to describe their potential to produce runoff. HSGs for various soils are identified in soil surveys published by the Natural Resources Conservation Service (NRCS). These groups are based on infiltration and transmission rates. Soils are classified into HSGs to indicate

the minimum rate of infiltration obtained for bare soil after prolonged wetting. The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. The HSG also indicates the transmission rate, which is the rate water moves within the soil. This rate is controlled by the soil profile.

The four hydrologic soil groups used to classify runoff potential are:

- *Group A* soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 inch per hour).
- *Group B* soils have moderate infiltration rates when thoroughly wetted. They consist chiefly of moderately deep-to-deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 inch per hour).
- *Group C* soils have low infiltration rates when thoroughly wetted. They consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 inch per hour).
- *Group D* soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 inch per hour).

Group D soils generally occur in sloping areas of the Tyler Coulee Watershed while, Group B soils tend to occur in flatter areas of the watershed. Because a large portion of the watershed is characterized by Group D soils, post-development runoff rates may not differ as dramatically from pre-development runoff rates as is typical of other urbanizing areas.

## **2.4 Land Use**

Most of the current land use in the Tyler Coulee Watershed is naturally occurring grassland used for pasture with a small percentage of residential and commercial property. The estimated current land use is:

- Parks and Undeveloped Grassland – 60%
- Residential – 35%
- Commercial – 5%

Future land use projections show a trend towards additional residential development along the northern and eastern portions of the watershed. The timeframe for the development is not certain, but a tentative schedule has been established (Figure 4 [back pocket of report]). Future development will be dictated by demand for new residential property as well as growth within the city. The projected changes will adjust the land use to the following:

- Parks and Undeveloped Grassland – 30%
- Residential – 63%
- Commercial – 7%

These land use percentages have been used to develop the post-development (ultimate) conditions model along with the zoning classifications identified by the City of Bismarck.

### **3.0 Monitoring Methods**

#### **3.1 Goals and Objectives**

Water quality monitoring programs are implemented to potentially achieve a number of goals and objectives. These goals and objectives can include: 1) generally assessing and characterizing water quality; 2) understanding how specific biological, chemical or physical processes affect water quality; 3) evaluating the affect of watershed scale factors (e.g., land use patterns) on water quality concentrations and loads; and 4) estimating the effectiveness of specific BMPs in reducing pollutant loads. (Loads are expressed as the mass of a substance passing a location within a certain period of time. Loads are typically expressed in the units of pounds/year or kilograms/year.) A program can be designed to simultaneously achieve a single goal or multiple goals.

The ability to attain water quality monitoring goals and objectives with a short duration monitoring program (i.e., one year) like the one undertaking during this study is to some extent luck. Luck is needed to have multiple runoff events, which occur during all seasons and represent the range in the magnitude of precipitation and runoff events. Some luck is also needed for the proper function of all of the equipment installed and used to collect the samples and measure the amount of precipitation and runoff.

The original goals and objectives for monitoring water quality within Tyler Coulee as described by the Sampling and Analysis Plan included:

- Establishing baseline water quality characteristics of the Tyler Coulee Watershed;
- Developing information to support land use planning;
- Aiding in the development of a storm water master plan for the Tyler Coulee Watershed, by calibration of a runoff and water quality model;
- Developing information to evaluate the effectiveness of BMPs;
- Providing data necessary to establish stable stream design criteria for the primary conveyance channel throughout the watershed; and
- The development of data that could be used to estimate city-wide loads for various land use types.

After considering and evaluating the actual data collected, this study represents an assessment of the water quality within Tyler Coulee. The intent of a water quality assessment is to understand whether the concentrations and loads of substances like sediment, nutrients and trace metals in runoff exceed what might be considered typical for a watershed similar to Tyler Coulee, thereby indicating a potential problem. By quantifying loads, the source of a water quality problem can be determined. Land areas within the watershed that contribute higher loads per unit area (i.e., pounds per acres per year) are generally targeted for water quality improvement measures. Quantifying and estimating loads accurately requires a greater level of monitoring effort than simply characterizing the concentrations. The accurate estimation of loads requires greater monitoring intensity (i.e., sampling frequency) under varying seasonal and hydrologic conditions (single versus multi-year).

Because the number of samples collected came primarily during the late fall and early spring months, were relatively few in number, and were insufficient to calculate loads, the data collected during this study are best used to assess how the concentrations in runoff (i.e., water quality) within Tyler Coulee compare to other areas both similar and dissimilar in nature. A “benchmark” approach is used to establish similarity (see Section 4.1).

### 3.2 Monitoring Locations

Several monitoring locations were selected to assess the water quality (and hydrologic) characteristics within the Tyler Coulee Watershed. These data were also to be used to provide information for the development of a watershed model. This information was to include statistical relationships between concentrations and discharge. The following is a brief description of the monitoring locations (see Figure 2):

- Ash Coulee Drive, which is the outlet of subwatershed TC 1-2 and represents undeveloped, undisturbed native prairie in the watershed;
- Burnt Boat Drive & Tyler Parkway, which is the outlet of subwatersheds TC 6-4, TC 6-2 and TC 6-3 (Figure 2). This location represents previously developed, urbanized areas and a small portion of the I-94 drainage area;
- Valley Drive Detention Basin West, which is the outlet of subwatershed TC 4 (Figure 2) and the drainage area upstream of Valley Drive. This location represents a developing portion of the watershed, with residential development occurring during the study;
- Clairmont Road, which is the outlet of Subwatershed TC 5-4 (Figure 2) and near the lower end of the Tyler Coulee watershed. This location integrates the water quality conditions from upstream.

These locations were selected to provide water quality and hydrology data for representative areas, from which concentrations could be characterized and loads computed.

### 3.3 Water Quality Monitoring

Water quality samples were collected using two methods at the locations shown in Figure 2. An ISCO 3700 automated sampler was used at the Clairmont Road location to obtain water quality samples during runoff events. The ISCO 3700 automated sampler was placed in the middle portion of the 84-inch culvert. By placing the automated sampler near the outlet of the watershed, samples were collected throughout the duration of a runoff event representing an integration of the entire watershed's runoff.

Grab samples were collected at the three remaining locations during runoff events at the downstream end of the structures. Collecting samples at the downstream end of the structures ensured completely mixed conditions at the time of collection. Ideally, grab samples would have been collected on the rising limb, near the peak and on the falling

limb of the runoff hydrograph at these three locations. Due to the constraint of getting to the location multiple times during a runoff event, only one grab sample was collected during the runoff event. This single sample is therefore, used to represent the entire runoff event, even though this may or may not be true.

Employees of the City of Bismarck Waste Water Treatment Facility collected the samples. Most often, grab samples were collected within several hours after initiation of a rainfall event that resulted in runoff. A rainfall event was defined as having greater than 0.25 inches of precipitation occurring within a short enough duration to produce runoff. The period of water quality sample collection began in July of 2000 and ended September of 2001. Table 1 shows the sampling dates for each water quality monitoring location in 2000 and 2001.

Fifteen water quality parameters were measured for each water quality sample. Three of the parameters were measured in the field:

- Water Temperature (T);
- Dissolved Oxygen (DO); and
- pH.

The following nutrients were analyzed at the North Dakota Department of Health (NDDH) Laboratory:

- Total Kjeldahl Nitrogen (TKN);
- Nitrate plus Nitrite Nitrogen ( $\text{NO}_3 + \text{NO}_2$ );
- Ammonia Nitrogen ( $\text{NH}_3$ );
- Total Phosphorus (TP); and
- Dissolved Phosphorus (DP).

The remaining parameters were analysis by the City of Bismarck at the Wastewater Treatment Facility. These parameters included:

- Total Zinc (Zn);
- Total Chromium (Cr);
- Total Hardness (TH);
- Total Alkalinity (TA);
- Total Suspended Solids (TSS);

**Table 1  
DATA COLLECTION SUMMARY**

Location	Dates Sampled				Water Quality
	Precipitation	Flow	Stage		
Ducks Unlimited	7/20/2000				
	7/25/2000-11/6/2000 5/9/2001-8/22/2001	NA	NA	NA	NA
Valley Drive	7/13/2000-7/24/2000	7/13/2000 - 9/5/2000	7/13/2000-9/5/2000	10/31/2000	
	8/15/2000-11/6/2000	9/25/2000 - 11/6/2000	9/25/2000-11/6/2000	11/2/2000	
	5/9/2001-8/22/2001	3/27/2001 - 8/22/2001	3/27/2001-8/22/2001	3/7/2001 4/3/2001 5/30/2001	
Horizon Middle School	7/13/2000-7/24/2000				
	8/15/2000-11/6/2000 5/9/2001-8/1/2001	NA	NA	NA	NA
Ash Coulee Drive					
	NA	No flows recorded	NA	10/31/2000 11/2/2000 3/7/2001 4/3/2001 5/30/2001	
Burnt Boat Drive & Tyler Parkway					
	NA	7/13/2000-11/16/2000 5/25/2001 - 8/22/2001 9/2/2001-9/10/2001	7/13/2000-11/16/2000 5/25/2001 - 8/22/2001 9/2/2001-9/10/2001	10/31/2000 11/2/2000 3/7/2001 4/3/2001 5/30/2001	
Clairmont Road					
	NA	7/10/2000-7/11/2000 7/13/2000 - 11/3/2000 4/24/2001 - 7/25/2001	7/10/2000-7/11/2000 7/13/2000 - 11/3/2000 4/24/2001 - 7/25/2001	10/31/2000 11/2/2000 3/7/2001 4/3/2001 5/30/2001	

NA - Not applicable.

- Total Dissolved Solids (TDS); and
- Fecal Coliform (FC).

The trace metals (Zn and Cr) were selected as indicators of contamination within urban runoff.

### **3.4 Precipitation and Hydrologic Monitoring**

To understand the relationship between precipitation and runoff, precipitation and hydrologic monitoring was essential. Three continuous recording precipitation gages were placed within the Tyler Coulee Watershed (Figure 2). These gages were located near the Clairmont Road location at the Ducks Unlimited Office, at Valley Drive Detention Basin West, and at the Horizon Middle School. These locations were selected to maximize the aerial coverage across the watershed.

The three precipitation gages provided time-depth relationships recorded at 0.01-inch increments. From July of 2000 through September of 2001, rainfall data were downloaded twice per month or after each substantive rainfall event to ensure they functioned properly (See Appendix A for the raw data). Precipitation data were summarized as daily totals.

Discharge data were measured at four locations within the Tyler Coulee Watershed. A staff gage was placed on the upstream end of a 24-inch CMP under Ash Coulee Drive (Subwatershed TC 1-2 - see Figure 2). Because of the small drainage area, little runoff occurred to this site. The runoff that did occur was insufficient for an accurate estimate of discharge, but did allow the collection of a limited number of samples for water quality analysis.

Depth and velocity were measured in the 72-inch RCP at the Burnt Boat Drive & Tyler Parkway outlet using a Starflow™ Doppler velocity-area recorder. The velocity component of the meter proved to be unreliable at times because of the failure to correct instrument drift. Therefore, the depth data were used to compute discharge using a rating curve based on pipe size and slope.

An electronic Telog™ continuous recorder was placed on the upstream side of the Valley Drive Detention Basin West (Subwatershed TC 4 - see Figure 2) for the continuous measurement of stage. These stage data were converted to discharge using a rating curve based on pipe size and slope.

Depth and velocity data were collected using an ISCO™ 4150 Doppler velocity-area flow recorder (paired with the automated water quality sampler) in the 84-inch RCP at Clairmont Road. Unfortunately, the meter coded the velocity with an error code on many occasions. However, the depth data appeared reliable and was used to compute discharge. Discharge was computed using the pipe size and slope to develop a rating curve. All electronic measurements were recorded at a quarter hour interval and summarized as daily discharge.

## **4.0 Tyler Coulee Monitoring Results**

### **4.1 Water Quality**

Placing water quality data<sup>1</sup> into proper context can be difficult. Placing the data into proper context when the number of samples is limited is even more difficult. Therefore, some method is needed for the comparison of data between different studies. The use of “benchmarks” is one method. Benchmarks can be: 1) central tendency values (i.e., mean or median concentrations), the range and maximum concentrations; for other areas with similar characteristics including land use (e.g., urban areas); 2) water quality standards established by the NDDH; and 3) other water quality data for the City of Bismarck. Only the benchmark based on the NDDH standards has any regulatory meaning; i.e., standards for surface waters that need to be maintained to achieve the intended use. The other benchmarks simply establish a frame of reference for comparison purposes.

Understanding the limitations of the Tyler Coulee data is important. These limitations primarily relate to sample size and when during the year storm water samples were collected. Samples were collected primarily during the late fall of 2000 and the early spring of 2001 and therefore, are not representative of an entire year. The data are compared by site, regardless of whether the sampling location represents a discrete

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<sup>1</sup> Appendix B provides a description of the various water quality parameters.

catchment outfall or an in-stream location. Because five samples were collected at most locations during the study, both the individual concentrations (Table 2) and descriptive statistics are presented (Table 3) to assess Tyler Coulee water quality.

The descriptive statistics do not represent an annual period because most samples were collected for only a portion of the year. The samples collected represent two late fall events, two spring snowmelt events and one spring rainfall event. One-half the detection limit was substituted for some values when calculating the descriptive statistics for ammonia (0.005 mg/l), dissolved phosphorus (0.002 mg/l), chromium (0.5 ug/l), zinc (3 ug/l) and fecal coliform bacteria (5 mpn/ml). Flow rates are available only for the samples collected during the fall of 2000 and were generally near 1 cfs. No correlation between concentration and discharge is possible with the data collected, preventing the accurate calculation of load estimates.

#### 4.1.1 Comparison to NURP Data

One benchmark is the central tendency data for water quality information collected for other urban areas. Water quality data for other urban areas was characterized during the National Urban Runoff Program (NURP) and provides an opportunity for comparison to the Tyler Coulee data. NURP data were collected between 1978 and 1983. Sampling was conducted for 28 NURP projects, which included 81 specific sites, and more than 2,300 separate storm events (see Table 4). Comparing NURP central tendency values (median concentrations) to the Tyler Coulee data (mean concentrations) is done for relative comparison purposes.

The use of mean concentrations for comparison is necessary for the Tyler Coulee data because of the small sample size. The Tyler Coulee water quality data are compared to the NURP data, even though the mean is the central tendency value for the Tyler Coulee data, while the median is the central tendency value for the NURP data. Assuming normally distributed concentrations, for large datasets there should be little difference between mean and median values.

Table 2  
WATER QUALITY RESULTS FOR TYLER COULEE

	Date	Instantaneous Discharge (cfs)	Temp. (°C)	pH	Dissolved Oxygen (mg/l)	Total Hardness (mg/L of CaCO <sub>3</sub> )	Alkalinity (mg/l as CaCO <sub>3</sub> )	Specific Conductance (umhos/cm)	Fecal Coliform (mpn/100 ml)	Total Suspended Solids (TSS) (mg/l)	Total Dissolved Solids (TDS) (mg/l)	Total Phosphorus (mg/l)	Dissolved Phosphorus (P) (mg/l)	Total Nitrogen (mg/l)	Total Kjeldahl Nitrogen (TKN) (mg/l)	Ammonia (NH <sub>3</sub> ) (mg/l)	Nitrate + Nitrite (NO <sub>3</sub> +NO <sub>2</sub> ) (mg/l)	Total Zinc (ug/l)	Total Chromium (ug/l)
Class III Surface Water Quality Standards & Criteria			ND	7.0 - 9.0 (Class I)	Not < 5 mg/L	None	None		200/100 mpn/ml Class I (5/1-9/30)	30 mg/l municipal effluent	None	0.1 mg/L (interim guideline)	None	None	None	5.69 (mg/l) acute (Class I)	1.0 mg/L (interim guideline)	Aquatic Life 789 ug/l 1-hr conc.; 720 ug/l 4-day conc.	Aquatic Life Cr (III) 6.3 mg/l 1-hr. conc.; Total Cr 1.11 mg/l 4-day conc.
Averaging Period			ND	Instantaneous	7 Day	ND	ND		30 Day	30 Day	ND	ND	ND		ND	Instantaneous	ND		
Ash Coulee Drive	10/31/2000	ND	12.5	8.06	12.10	2110	480	4150	300	7	2790	0.295	0.278	11.00	6.41	<0.005	4.59	18.0	<1
	11/2/2000	ND	6.5	8.24	12.60	2310	500	3750	10	5	2650	0.045 <sup>#</sup>	0.321 <sup>#</sup>	17.40	3.30	0.423	14.10	16.0	<1
	3/7/2001	ND	1	8.44	10.40	210	230	288	500	21240*	191	2.29*	0.300	2.20	1.35	0.389	0.85	464.0	75.1*
	3/21/2001	ND	6.4	7.76	9.30	830	230	1810	<10	5	1150	ND	ND	ND	ND	ND	ND	83.0	<2
	4/3/2001	ND	2.8	8.16	10.30	1900	400	330	<10	6	2170	0.006	<0.002	12.70	1.10	0.125	11.60	27.0	3.5
	5/30/2001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.056	0.023	11.80	1.20	0.021	10.60	ND	ND
Valley Drive Detention	10/31/2000	1.38	13	8.60	11.60	1330	360	2801	530	39	1840	0.109	0.102	1.08	0.49	0.275	0.59	7.0	<1
	11/2/2000	1.12	5.3	8.65	12.00	1110	300	2220	1420	32	1460	0.045 <sup>#</sup>	0.359 <sup>#</sup>	8.08	1.78	0.420	6.30	9.0	
	3/7/2001	ND	0.6	8.47	10.50	1570	500	3500	<10	106	2310	2.050	0.998	12.20	1.10	0.280	11.10	<6	4.5
	3/21/2001	ND	2	8.30	12.00	900	310	1970	120	159	1270	ND	ND	ND	ND	ND	ND	75.0	5.6
	4/3/2001	ND	2.3	8.20	12.20	1450	570	3190	240	34	2110	0.032	<0.002	5.42	1.27	0.340	4.15	<25	<2
	5/30/2001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.055	0.011	2.30	0.35	0.015	1.95	ND	ND
Burnt Boat Drive & Tyler Parkway	10/31/2000	1.72	13.5	8.40	8.30	110	70	167	1000	42	137	0.051	0.046	10.20	1.89	1.330	8.31	23.0	<1
	11/2/2000	1.02	5.9	8.36	10.00	80	120	165	1580	40	110	0.092	ND	0.54	0.32	0.172	0.22	37.0	1.8
	3/7/2001	ND	4.5	8.31	9.40	180	110	497	220	384	327	1.010	ND	3.16	3.03	1.180	0.13	84.0	14.1
	3/21/2001	ND	4.5	7.90	11.80	140	170	545	10	35	347	ND	ND		ND	ND	ND	74.0	<2
	4/3/2001	ND	2.2	8.22	12.00	70	160	584	30	108	385	0.222	0.052	1.97	1.12	0.487	0.85	81.0	7.5
	5/30/2001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.161	0.139	0.32	0.15	0.102	0.17	ND	ND
Clairmont Road	10/31/2000	ND	12.8	7.93	9.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	11/1/2000 & 11/2/2000	0.32	ND	8.50	10.80	700	220	690	ND	196	960	0.051	0.043	18.50	3.20	1.370	15.30	18.0	6.9
	11/3/2000	ND	ND	ND	ND	1070	560	2130	ND	24	1400	0.032 <sup>#</sup>	0.32 <sup>#</sup>	10.50	3.14	0.326	7.36	<6	<1
	3/7/2001	ND	0.3	8.51	10.00	1250	420	3020	10	9.5	1990	0.258	0.240	9.65	1.96	0.382	7.69	<6	<1
	3/21/2001	ND	1.8	8.38	11.80	910	330	2110	80	444	1380	ND	ND	ND	ND	ND	ND	82.0	13.9
	4/3/2001	ND	3.2	8.48	11.80	1350	410	2590	1350	142	1720	0.116	0.004	6.84	0.48	0.314	6.36	107.0	3.0
	5/30/2001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.186	0.004	2.55	0.20	0.040	2.35	ND	ND

\*ND = No Data

Zinc and Chromium standards assume hardness of 1100 mg/l as calcium carbonate.

\* Data deleted from the calculation of descriptive statistics.

<sup>#</sup> Data are suspect because total phosphorus is less than dissolved. Criteria for metals assume 1,000 mg/l hardness.

Table 3  
 DESCRIPTIVE STATISTICS FOR TYLER COULEE WATER QUALITY DATA<sup>2,3</sup>

	Minimum	Mean	Maximum	Standard Deviation	Sample Size
<b>Ash Coulee Drive<sup>4</sup></b>					
<sup>1</sup> pH	7.6	8.07 <sup>*</sup>	8.44	NA	5
Dissolved Oxygen (mg/L)	9.3	10.9	12.6	1.2	5
Total Hardness as CaCO <sub>3</sub> (mg/L)	210	1472	2310	812	5
Alkalinity (mg/L as CaCO <sub>3</sub> )	230	368	500	118	5
Conductivity (umhos/cm)	288	2066	4150	1638	5
Fecal Coliform (mpn/100mL)	5	164	500	203	5
Total Suspended Solids (mg/L)	5.0	5.8	7.0	0.8	4
Total Dissolved Solids (mg/L)	191.0	1790.2	2790.0	984.9	5
Total Phosphorus (mg/L)	0.006	0.538	2.290	0.881	5
Dissolved Phosphorus (P, mg/L)	0.002	0.184	0.321	0.145	5
Total Nitrogen (mg/l)	2.2	11.0	17.4	4.9	5
Total Kjeldahl Nitrogen (mg/L)	1.10	2.67	6.41	2.04	4
Ammonia as N (mg/L)	0.005	0.193	0.423	0.179	5
Nitrate+Nitrite as N (NO <sub>3</sub> +NO <sub>2</sub> , mg/L)	0.9	8.3	14.1	4.9	5
Zinc (ug/L)	16	36	83	27	4
Chromium (ug/L)	0.5	16.1	75.1	29.5	5
<b>Valley Drive Detention</b>					
pH	8.2	8.41 <sup>*</sup>	8.65	NA	5
Dissolved Oxygen (mg/L)	10.5	11.7	12.2	0.6	5
Total Hardness as CaCO <sub>3</sub> (mg/L)	900	1272	1570	240	5
Alkalinity (mg/L as CaCO <sub>3</sub> )	300	408	570	108	5
Conductivity (umhos/cm)	1970	2736	3500	574	5
Fecal Coliform (mpn/100mL)	5	463	1420	509	5
Total Suspended Solids (mg/L)	32.0	74.0	159.0	50.7	5
Total Dissolved Solids (mg/L)	1270.0	1798.0	2310.0	388.4	5
Total Phosphorus (mg/L)	0.032	0.458	2.050	0.796	5
Dissolved Phosphorus (P, mg/L)	0.002	0.294	0.998	0.375	5
Total Nitrogen (mg/l)	1.1	5.8	12.2	4.0	5
Total Kjeldahl Nitrogen (mg/L)	0.35	1.00	1.78	0.52	5
Ammonia as N (mg/L)	0.015	0.266	0.42	0.136	5
Nitrate+Nitrite as N (NO <sub>3</sub> +NO <sub>2</sub> , mg/L)	0.6	4.8	11.1	3.7	5
Zinc (ug/L)	3	21	75	27	5
Chromium (ug/L)	0.5	2.4	5.6	2.2	5
<b>Burnt Boat Drive &amp; Tyler Parkway</b>					
pH	7.9	8.20 <sup>*</sup>	8.4	NA	5
Dissolved Oxygen (mg/L)	8.3	10.3	12.0	1.4	5
Total Hardness as CaCO <sub>3</sub> (mg/L)	70	116	180	40	5
Alkalinity (mg/L as CaCO <sub>3</sub> )	70	126	170	36	5
Conductivity (umhos/cm)	165	392	584	186	5
Fecal Coliform (mpn/100mL)	10	568	1580	622	5
Total Suspended Solids (mg/L)	35.0	121.8	384.0	133.8	5
Total Dissolved Solids (mg/L)	110.0	261.2	385.0	114.3	5

Table 3  
DESCRIPTIVE STATISTICS FOR TYLER COULEE WATER QUALITY DATA<sup>2,3</sup>

	Minimum	Mean	Maximum	Standard Deviation	Sample Size
Total Phosphorus (mg/L)	0.051	0.307	1.010	0.356	5
Dissolved Phosphorus (P, mg/L)	0.046	0.264	0.821	0.323	4
Total Nitrogen (mg/l)	0.3	3.2	10.2	3.6	5
Total Kjeldahl Nitrogen (mg/L)	0.15	1.30	3.03	1.07	5
Ammonia as N (mg/L)	0.102	0.654	1.33	0.51	5
Nitrate+Nitrite as N (NO <sub>3</sub> +NO <sub>2</sub> , mg/L)	0.1	1.9	8.3	3.2	5
Zinc (ug/L)	23	62	91	27	5
Chromium (ug/L)	0.5	5.0	14.1	5.2	5
<b>Clairmont Road</b>					
pH	7.93	8.29 <sup>1</sup>	8.51	NA	5
Dissolved Oxygen (mg/L)	9.3	10.7	11.8	1.0	5
Total Hardness as CaCO <sub>3</sub> (mg/L)	910	1145	1350	169	4
Alkalinity (mg/L as CaCO <sub>3</sub> )	330	430	560	83	4
Conductivity (umhos/cm)	2110	2463	3020	375	4
Fecal Coliform (mpn/100mL)	10	646	1350	520	5
Total Suspended Solids (mg/L)	9.5	154.9	444.0	174.7	4
Total Dissolved Solids (mg/L)	1380.0	1622.5	1990.0	251.4	4
Total Phosphorus (mg/L)	0.032	0.129	0.258	0.084	5
Dissolved Phosphorus (P, mg/L)	0.004	0.122	0.320	0.132	5
Total Nitrogen (mg/l)	2.6	9.6	18.5	5.2	5
Total Kjeldahl Nitrogen (mg/L)	0.20	1.80	3.20	1.27	5
Ammonia as N (mg/L)	0.04	0.486	1.37	0.457	5
Nitrate+Nitrite as N (NO <sub>3</sub> +NO <sub>2</sub> , mg/L)	2.4	7.8	15.3	4.2	5
Zinc (ug/L)	3	49	107	47	4
Chromium (ug/L)	0.5	4.5	13.9	5.5	4

<sup>1</sup> pH mean = e<sup>(SUM(ln(pH))/n)</sup>

<sup>2</sup> All runoff samples were collected late fall 2000 and spring 2001. Three samples were collected during or following snowmelt. Therefore, data should be considered more characteristic of spring runoff than average runoff quality.

<sup>3</sup> One-half the minimum detection limit substituted for some values for the purposes of calculating the descriptive statistics.

<sup>4</sup> Sample collected 3/7/02 at Ash Coulee Drive deleted for select parameters because of excessive solids.

Table 4

URBAN RUNOFF WATER QUALITY CHARACTERISTICS

Pollutant	Units	Residential	Mixed	Commercial	Open/Urban Areas
Total Suspended Solids (TSS)	mg/l	101	67	69	70
Zinc (Zn)	ug/l	135	154	226	195
Total Kjeldahl Nitrogen (TKN)	mg/l	1.90	1.29	1.18	0.97
Nitrate + Nitrite	mg/l	7.36	5.58	5.72	5.43
Total Phosphorus	mg/l	.383	.263	.201	.121

Source: Nationwide Urban Runoff Program (US EPA 1983)

Comparison of the Tyler Coulee and NURP data shows the Tyler Coulee data is generally similar to the NURP data. The comparison suggests that the water quality within Tyler Coulee is not abnormal relative to other urban areas. Interestingly, it seems that the Ash Coulee sampling location has the highest nutrient concentrations relative to the NURP data and the other Tyler Coulee sites, even though the upstream drainage area is undisturbed native prairie. This probably reflects the very low flow rates at the time of sample collection. Perhaps the best parameter for comparison to the NURP data is Total Suspended Solids. This parameter is quite similar between Tyler Coulee where the mean concentrations range from 5.8 to 154.9 mg/l and NURP median for residential land use is 101 mg/l.

4.1.2 Comparison to NDDH Standards

A second benchmark is comparison to the water quality criteria and standards established by the NDDH for surface waters. The comparison is made even though water quality criteria and standards typically represent central tendency values for durations quite different than for the samples collected within Tyler Coulee. The standards can be

based on average values for a long time period (e.g., one year) or a shorter duration (e.g., 4-day average). Tyler Coulee is classified by the NDDH as a Class III water body. Because Class III streams do not have criteria for some parameters, criteria for Class I stream are included in Table 2.

Water quality concentrations within Tyler Coulee are generally less than standards and criteria established by the NDDH for the protection of aquatic life. Standards and criteria for aquatic life are used for comparison purposes because that is the use of water within Tyler Coulee.

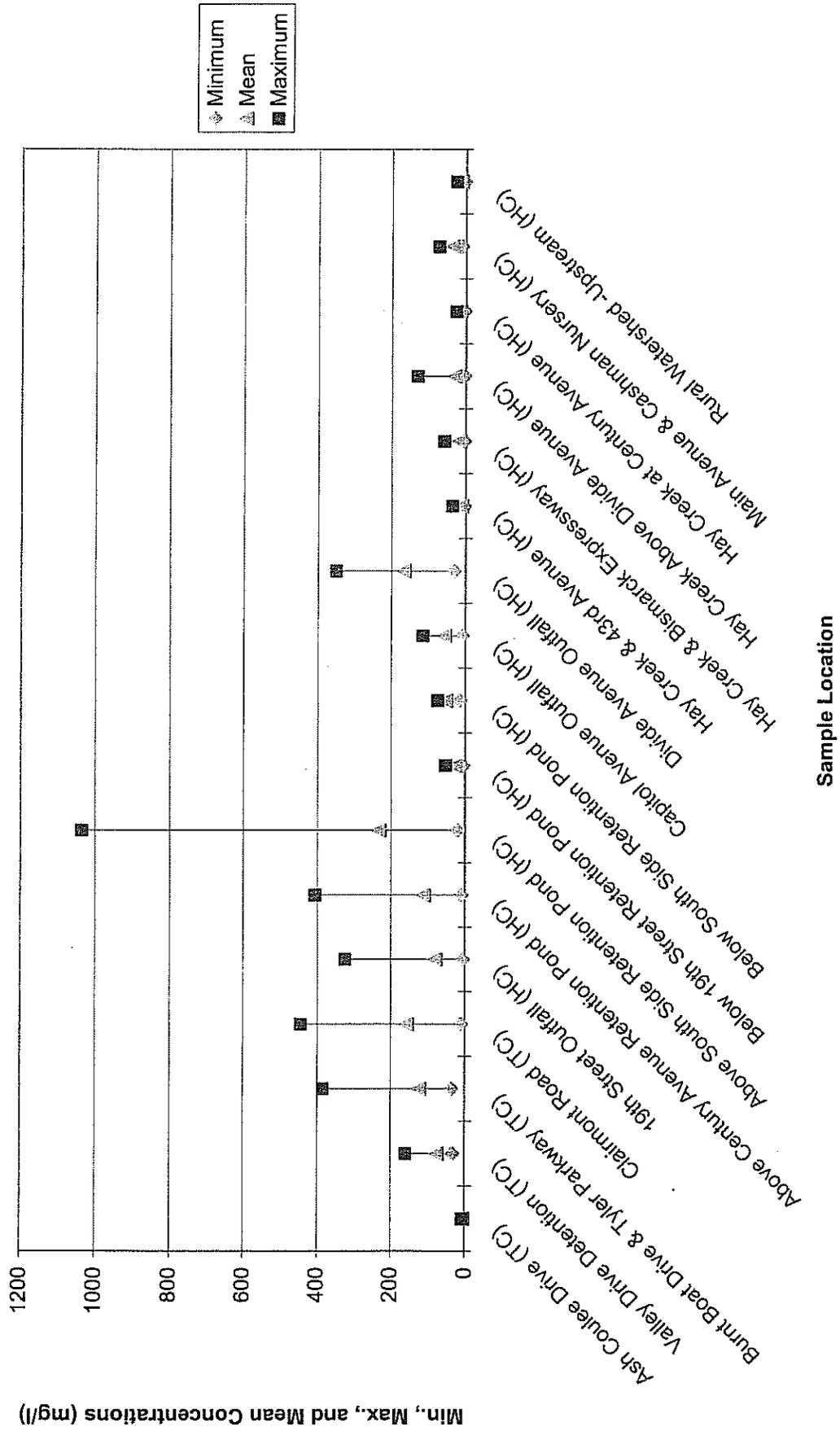
#### 4.1.3 Comparison to Hay Creek

The third benchmark is comparing the Tyler Coulee data to central tendency values, the concentration range and maximum concentrations for “other” Bismarck water quality data. A limited comparison is made to data collected from 1999-2000 in Hay Creek, a tributary traversing the eastern edge of Bismarck. Hay Creek is a low gradient, intermittent Class III stream. Hay Creek originates approximately eight miles northeast of the City of Bismarck and flows in a southerly direction along the east side of Bismarck toward its confluence with Apple Creek. The drainage area is much larger than Tyler Coulee; i.e., 36.9 square miles. The watershed has been subject to extensive use and development.

Hay Creek water quality data were collected from March of 1999 until October of 1999 and in May of 2000. The Tyler Coulee water quality data were collected in October of 2000 and March through May of 2001. Therefore, samples taken at Tyler Coulee and Hay Creek were not during the same time period and represent different hydrologic and seasonal conditions. The comparison is made looking at concentration levels only to get a general idea of the differences between the watersheds.

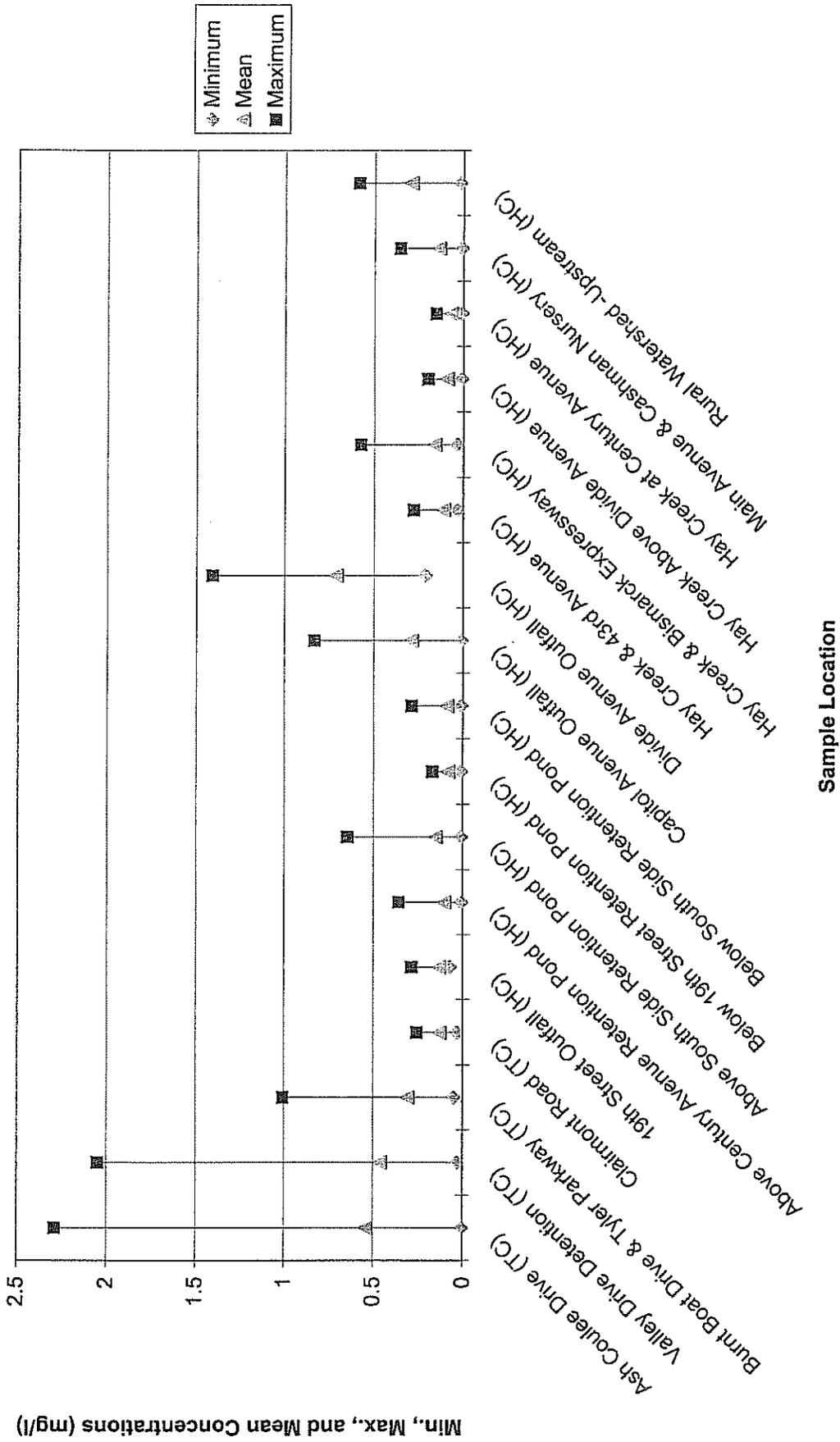
Three parameters were selected for comparing the Tyler Coulee and Hay Creek data; i.e., Total Suspended Solids (Figure 5), Total Phosphorus (Figure 6) and Total Nitrogen (Figure 7). These parameters were selected because the data are available for both watersheds and of greatest interest because of their affects – sedimentation and

Figure 5  
Tyler Coulee (TC) vs. Hay Creek (HC) - Total Suspended Solids



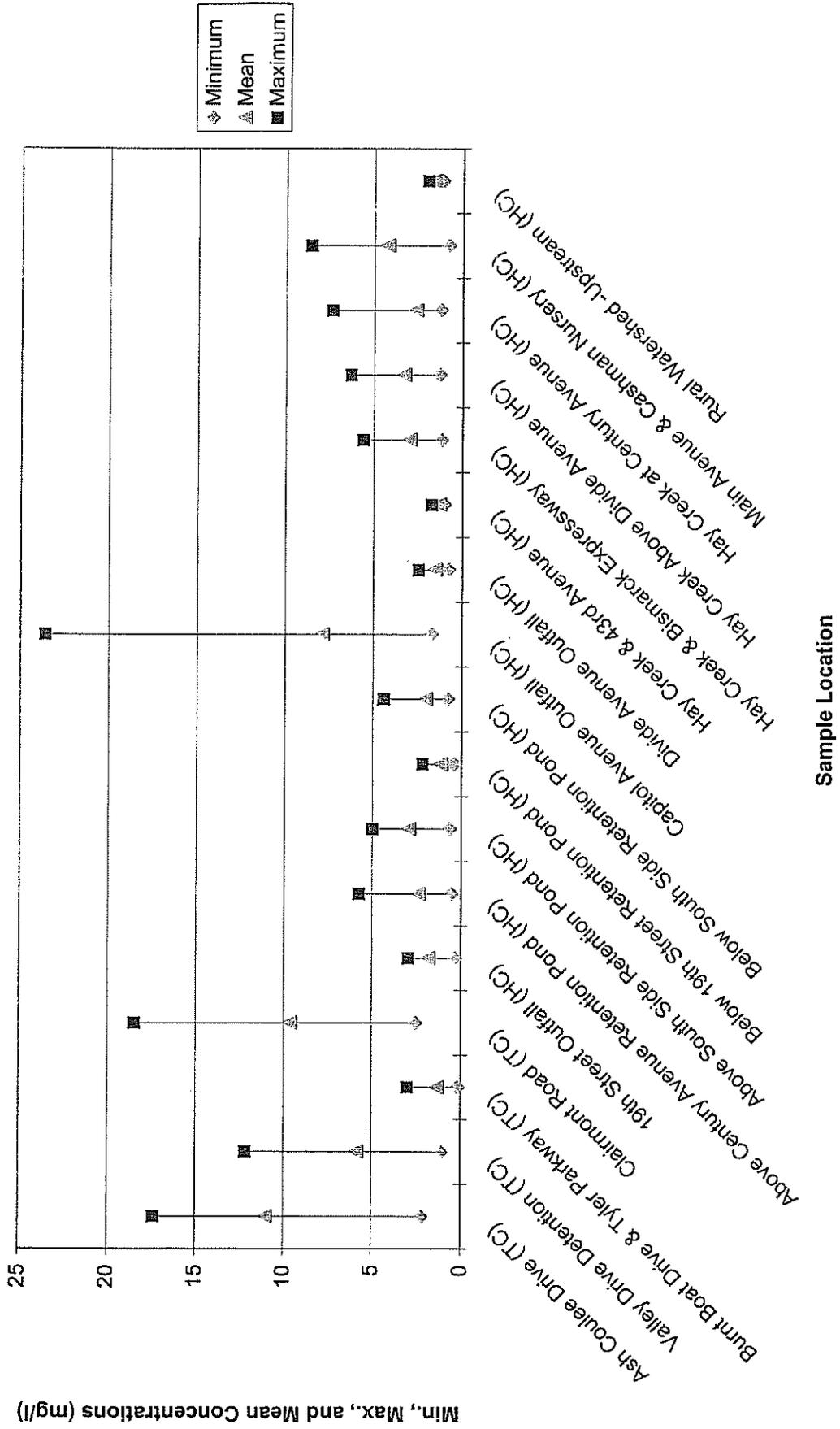
Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

Figure 6  
Tyler Coulee (TC) vs. Hay Creek - Total Phosphorus



Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

Figure 7  
 Tyler Coulee (TC) vs. Hay Creek (HC) - Total Nitrogen



Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

eutrophication, respectively. (The reader is encouraged to make additional comparisons using the data presented in Appendix C.) The Tyler Coulee data show a considerably greater range of concentrations than the Hay Creek concentrations for these parameters. The maximum concentrations are considerable greater within Tyler Coulee than Hay Creek as well as the mean concentrations.

This difference is not necessarily indicative of water quality problems in Tyler Coulee and is more likely related to the fact that: 1) the Tyler Coulee data include the initial snowmelt runoff event in early spring. Concentrations are known to be considerable greater for this type of event because of the build-up of mass during the winter months within the snow pack. Melting snow tends to release the greatest proportion of the accumulated mass early in the melting process; 2) only a limited number of samples were collected during late fall and early spring in Tyler Coulee. Summer rainfall events resulting in higher discharges were not sampled. These events are typically more "dilute" and were sampled in Hay Creek; 3) the Hay Creek data represent a considerably larger sample size. Additional monitoring would be necessary to confirm whether a difference exists between these watersheds.

#### 4.1.4 Water Quality Summary

Drawing conclusions based on a limited dataset like the one collected during this study is difficult. The data do suggest that water quality within Tyler Coulee is representative of an urbanizing watershed. Additional sampling is necessary to determine whether the differences in water quality between Tyler Coulee and Hay Creek for select parameters are real. The data however, do not suggest nothing should be done to protect water quality within Tyler Coulee. On-site and regional BMPs as well as erosion control practices should be considered to protect water quality.

## 4.2 **Precipitation and Hydrology**

The primary purposes of precipitation and hydrology monitoring are to: 1) estimate discharge and determine whether there is a predictive relationship between discharge and concentration; 2) estimate runoff volume so loads can be estimated; and 3) for model calibration. Paired instantaneous discharge and concentration through the

range of discharges (i.e., variety of return period events) is needed for computing accurate load estimates. (Daily mean discharge can be substituted for instantaneous discharge with some loss in accuracy.)

Only on two occasions in the fall of 2000 were paired instantaneous discharge and concentration data collected (Table 2). The instantaneous discharges were similar at all locations for these events. Therefore, there is no predictive relationship as concentration is independent of discharge. The absence of a predictive relationship prevents using the water quality model to estimate loads.

The discharge data could be used to estimate annual loads simply by multiplying annual runoff volume and mean concentration, provided the mean concentration is representative of an entire year. The Tyler Coulee water quality data are not representative of an entire year and therefore, should not be used to estimate annual loads by this method.

Most storm events during the study generated discharges of 70 cfs or less at Burnt Boat Drive & Tyler Parkway (Appendix A). Discharges at Valley Drive Detention Basin West were greater, approaching 300 cfs during runoff events in June and July of 2001. The data for Clairmont Road show discharges approaching 25 cfs during 2000. This seems reasonable given the discharges from upstream were similar. However, the 2001 Clairmont Road data are suspect, because discharges are considerably less than Valley Drive Detention Basin West and Burnt Boat Drive & Tyler Parkway on the same day.

The runoff data are useful for ensuring the hydrology model is "calibrated." The term calibrated is used here in the sense that the model should behave predictably and reasonably estimate peak flows and volumes (see Section 6.1, Model Development). The rainfall data are reasonably similar among the sites, because of the relatively small watershed area. The gage at the Horizon Middle School appeared to malfunction during a portion of 2001. Malfunction of this type of gage usually results from plugging of the throat leading to the tipping mechanism on the gage.

## 5.0 Overview of BMP Issues and Use

When an area is urbanized because of development, natural drainage patterns are modified as runoff is channeled into streets, storm sewers, paved channels and straightened grassed waterways. These modifications can increase the velocity of overland flow and flow rate within the conveyance system. This decreases the time required to convey runoff to the outlet of a watershed. The amount of time to reach peak discharge is also reduced. Peak runoff rates and volumes increase.

Urbanization can also increase pollutant loads. There are two main reasons why urbanization increases pollutant loads. First, the volume, duration and rate of runoff are typically increased as an area is developed, providing a greater capacity to transport pollutants. Secondly, some materials (i.e., soils and pollutants) are more easily picked up and suspended in runoff as the vegetation is reduced and the percentage of impervious surface increased. Pollutant loads can increase for a number of pollutants (Table 5).

**Table 5**

### STORM WATER POLLUTANT, SOURCES AND RELATED IMPACTS

Storm Water Pollutant	Examples of Sources	Related Impacts
Nutrients: Nitrogen, Phosphorus	Animal waste, fertilizers, failing Septic systems	Algal growth, reduced clarity, other problems associated with eutrophication (oxygen deficit, release of nutrients and metals from sediments)
Sediments: Suspended and Deposited	Construction sites, other disturbed and/or non-vegetated lands, eroding banks, road sanding	Increased turbidity, reduced clarity, lower dissolved oxygen, deposition of sediments, smothering of aquatic habitat including spawning sites, sediment and benthic toxicity
Organic Materials	Leaves, grass clippings	Oxygen deficit in receiving water body, fish kill.
Pathogens: Bacteria, Viruses	Animal waste, failing septic systems	Human health risks via drinking water supplies, contaminated swimming beaches
Hydrocarbons: Oil and Grease, PAHs (Naphthalenes, Pyrenes)	Industrial processes; automobile wear, emissions & fluid leaks; waste oil.	Toxicity of water column and sediment, bioaccumulation in aquatic species and through food chain
Metals: Lead, Copper, Cadmium, Zinc, Mercury, Chromium, Aluminum, Others	Industrial processes, normal wear of auto brake linings and tires, automobile emissions & fluid leaks, metal roofs	Toxicity of water column and sediment, bioaccumulation in aquatic species and through the food chain, fish kill

**Table 5 (cont.)**

**STORM WATER POLLUTANT, SOURCES AND RELATED IMPACTS**

<b>Storm Water Pollutant</b>	<b>Examples of Sources</b>	<b>Related Impacts</b>
Pesticides: PCBs, Synthetic Chemicals	Pesticides (herbicides, insecticides, fungicides, rodenticides, etc.), industrial processes	Toxicity of water column and sediment, bioaccumulation in aquatic species and through the food chain, fish kill
Chlorides	Road salting and uncovered salt storage	Toxicity of water column and Sediment
Trash and Debris	Litter washed through storm drain networks	Degradation of the beauty of surface waters, threat to wildlife

BMPs are used to ameliorate the affects of urbanization. BMPs are the practices, techniques, and measures that prevent or reduce water pollution and reduce discharges as a result of an urbanizing landscape. BMPs include, but are not limited to, structural and nonstructural controls such as regulatory controls, as well as operation and maintenance procedures.

All BMPs have similar implementation considerations. These include:

- Flood Damage Reduction Goals, such as:
  - Reducing peak discharges and stages
  - Safely conveying runoff downstream
- Water Quality and Environmental Goals, such as:
  - Removal of phosphorus, total suspended solids, metals, etc.
  - Water temperature changes
  - Downstream channel erosion protection
  - Wetland creation
  - Wildlife habitat (i.e., protection, enhancement or creation)
- Community Acceptance, including:
  - Safety risks
  - Construction costs
  - Special assessment cost distribution
  - Maintenance costs
  - Land cost

- Nature of the Watershed
  - Developed: retrofit options
  - Undeveloped: prediction of future development and system requirements
  - Selection of Treatment System
  - Selection of appropriate detention systems
  - Selection of associated BMPs which may include retention areas

These issues have been considered in selecting the BMPs for the Tyler Coulee Watershed.

In Bismarck, winter hydrologic conditions (ice, snow and snowmelt) present special considerations. An extensive review of BMP selection and design in cold climates was performed by the Center for Watershed Protection (Storm Water BMP Design Supplement for Cold Climates, 1997). In this review, the major considerations for cold-climate snowmelt and storm water management were identified as:

- *Pipe Freezing* - Most BMPs rely on some piping system at the inlet and outlet. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, frozen pipes reduce the treatment capability of BMPs (by restricting or completely blocking the inflow or outflow to the BMP) and can increase the potential for flooding.
- *Ice Formation on the Permanent Pool* - BMPs that have a permanent pool of water form ice, causing two problems. First, the permanent pool's volume is reduced. Ice can take up as much as three feet of permanent pool space, often about half the depth and volume. Second, the intended movement of runoff through the pond is compromised. Specifically, runoff entering an ice-covered pond has two options, neither of which provides sufficient pollutant removal. In one case, runoff is forced under the ice, causing scouring of bottom sediments. In the other case, runoff flows over the top of the ice, receiving very little treatment at all. The sediment that does settle on the top can easily be resuspended by subsequent runoff events.
- *Oxygen Levels During Ice Cover* - In cold regions, ice cover can restrict oxygen exchange between the air-water interface in ponds and lakes. In addition, warmer water sinks to the bottom during ice-cover because it is denser than the cool water near the surface. Thus, although biological activity is limited in cooler temperatures, most decomposition takes place at the bottom, sharply reducing oxygen concentrations in bottom sediments. In these anoxic conditions, nutrients and metals retained in the sediments can be released, reducing the BMP treatment efficiency.

- *Settling Velocities* - Settling is the most important removal mechanism in many BMPs. As water becomes cooler, its viscosity increases, reducing particle velocity. In fact, particle-settling velocity is about 50% faster with water temperatures at 68 °F than at 40 °F. This reduced settling velocity influences pollutant removal in any BMP that relies on settling.
- *Frost Heave* - Heaving is caused by the expansion of pore water as it freezes under the ground's surface. An additional, and perhaps more important source is the formation of ice lenses, or layers of ice, below the soil surface. The primary risk associated with frost heave is the damage of structures such as pipes or concrete materials used to construct BMPs.
- *Reduced Infiltration* - The rate of infiltration in frozen soils can be limited, especially when ice lenses form. As a result, BMPs that rely on infiltration to function may be ineffective when soil is frozen, which in cold climates can be a significant portion of the year. It is important to note, however, that some frozen soils can continue to infiltrate water year-round, depending on soil porosity and water content.
- *Short Growing Season* - Vegetation is central to the proper function of some BMPs (wetlands and grass filter strips, for example). When the growing season is shortened, establishing and maintaining this vegetation is more difficult. During construction of a BMP system, the "envelope" for planting grass, wetland vegetation or other plant material is reduced. Also, the range of usable plants is more limited in cold climates than in more moderate climates. Finally, many plants are dormant during the winter months. This results in decreased efficiency for BMPs in which plants are used to help attenuate or filter runoff transport of chlorides into the environment, any reduction in chloride runoff that can be achieved through the proper storage or reduced application rate is recommended.
- *High Runoff Volumes and High Pollutant Loading During Spring Snowmelt* - Polycyclic aromatic hydrocarbons (PAHs) in runoff from the snow pack can exceed drinking water standards. Cyanide concentrations can be high in snowmelt runoff because of cyanide added to salt to prevent clumping. Trash and debris usually accumulate in snow piles during snow plowing operations. During the winter, these materials can be blown off of snow piles. During snowmelt, they can be carried into receiving waters.
- *Snow Management* - The management of snow, in terms of snow removal and storage can have significant water quality affects. Plowing snow directly into lakes, streams or wetlands can cause this. Lack of containment of sediments suspended in the snow storage areas can also affect water quality every spring.
- *Special Maintenance* - BMPs designed to function effectively in summer are often disrupted by winter and spring events. Inspection and maintenance during spring runoff should be a consistent feature of storm water treatment systems in cold climates. In terms of the tributary watershed, intensive street

and catch basin cleaning in early spring in anticipation of spring snowmelt events is required.

Although this study did not identify all of these specific issues in the Tyler Coulee watershed, it is quite possible that some of these pollutants could become troublesome in the future as the watershed develops. Therefore, the recommended BMPs anticipate future water quality issues for Tyler Coulee.

## **6.0 Storm Water Master Plan**

The purpose of a Storm Water Master Plan is to identify and describe the storm water facilities necessary to protect health and safety, improve water quality and to provide an Opinion of Probable Cost for construction. The storm water facilities generally include the conveyance system (i.e., pipes, open channels and streets), structural Best Management Practices (BMPs) (e.g., regional storage facilities) and limits on where development might occur to prevent erosion of the land surface, open channels and protect important ecological features. This information is needed to establish expectations for the City and developers interested in developing the area. The information can also be used to establish a development impact charge.

Master plans contain different levels of engineering detail, depending upon how much information is available. Site-specific master plans are prepared for small areas (tens of acres) when there is a good deal of information about parcel locations, street design, and final grading. Regional master plans (several square miles and larger) are prepared to identify and describe the storm water facilities when specific detail about parcel locations, street design, and final grading is lacking.

This master plan represents a regional master plan for the storm water primary trunk system. The specific purpose is to identify and describe the regional storm water primary trunk system for the Tyler Coulee watershed. Within Tyler Coulee this primarily consists of storm water detention basins, which are connected by open channels. Because of the relatively steep topography within the Tyler Coulee Watershed, open channels are a dominant feature of the regional storm sewer system. Because not all components of the system can be identified at the present time, this master plan includes information

about the present and future hydrology (i.e., peak flow rates and elevations), for the specific purpose of storm water management.

The master planning process requires various assumptions be made about the future conditions within the Tyler Coulee Watershed. These assumptions include the type of development and where it occurs, the design and orientation of the streets, final grading, and limitations on where development occurs. For a portion of the Tyler Coulee watershed yet to be developed, no specific plans are available, street design is lacking and final grades have not yet been established. Therefore, existing topography has been used to development the model.

All storm water facilities identified within this plan are based on these assumptions, which can and will change as planning and development occurs. Therefore, caution is warranted when using the information presented. The reader must understand the ramifications of the assumptions and how they affect the location and size of the facilities recommended. Site-specific master plans will be needed, building upon the information presented by this plan. The hydrologic model and the plan should be updated to reflect the actual planned development or constructed conditions.

## **6.1 Model Development**

The US EPA's Storm Water Management Model (SWMM) was selected for modeling the hydrologic response of the watershed. This model was selected because it is a comprehensive computer model used for analyzing hydrology and water quality. The model can be applied to both rural and urban settings. Single-event (one storm) and continuous simulation (back-to-back storms with dry periods between them) can be performed for areas having storm sewers, combined storm and sanitary sewers and open channel including natural waterways. The model can be used to estimate discharge, runoff volume, stage, pollutant concentration and load. The EXTRAN Block is especially suited to pressurized flow in pipe systems including storm sewers. The model solves the complete dynamic flow routing equations (St. Venant Equations) for the accurate simulation of backwater, looped connections, surcharging and pressure flow.

The SWMM hydrologic analyses were based upon unit hydrograph methods. Unit hydrograph methods transform a rainfall hyetograph (event) into a direct runoff

hydrograph. A unit hydrograph reflects the time-distribution of flow at the outlet of a watershed for a 1-inch rainfall for a specific duration. Unit hydrographs can be developed from stream gage and precipitation data if available for a watershed. Watershed size, shape, land use, slope and length are characteristics that influence the size and shape of the unit hydrograph.

Synthetic unit hydrograph methods are commonly used in hydrologic modeling to generate runoff hydrographs. Soil Conservation Service (SCS – now NRCS), Snyder and Clark are commonly used synthetic unit hydrograph methods. A SCS unit hydrograph with a Type II precipitation distribution was used for hydrologic modeling within Tyler Coulee during master plan development.

The parameters with the most affect on the hydrograph shape in the SWMM model are the time of concentration, abstraction losses, and the curve numbers. The time of concentration is the time that it takes water to travel from the most distant part of the watershed to the point of interest (usually the outlet). The time of concentration affects the peak rate of runoff and the shape of the hydrograph. Generally, the shorter the time of concentration, the more peaked the hydrograph. Hydrology textbooks describe several methods to calculate the time of concentration. For Tyler Coulee, the time of concentration in each watershed was estimated using travel velocities ranging from 2 feet per second to 5 feet per second depending on watershed slope and cover type. The time of concentrations ranged from 10 minutes in very steep developed basins to 160 minutes in relatively flat undeveloped watersheds.

Abstraction losses reflect an areas ability to intercept and store water at the beginning of a storm. The Tyler Coulee Model used abstraction losses varying from 0.2 to 0.4 inches depending on soil permeability, watershed slope and the amount of development.

Runoff curve numbers reflect how much rainfall becomes runoff. Curve numbers range up to 100. The curve numbers for Tyler Coulee watersheds ranged from 69 to 87, reflecting the relative impermeability of the watershed. Model parameters are provided in Appendix D.

Two different runoff events were used for the purposes of model calibration. During calibration, the time distribution for an actual precipitation event was entered into the model and the flow rates computed. The July 21, 2000 event was used for calibration because it was one of the larger runoff events, which occurred early in the model development process. The event had measured rainfall and runoff data. Figures 8, 9, and 10 present the hydrographs for the Valley Drive Detention Basin West, Burnt Boat Drive & Tyler Parkway, and Clairmont Road locations, respectively. Calibration consisted of matching peak discharges and runoff volumes for the event, by adjusting the “shape factor” within the SWMM model and the abstraction losses, respectively.

The model reproduced the hydrograph time to peak, while peak flows tended to be less than the measured values. Modeled peak flows less than the measured peak flows are not necessarily reflective of a “poor” calibration. The measured data represent instantaneous peak discharges, measured over an averaging period less than the modeled time step. Consequently, greater monitored peak flows are not unexpected. Some of the monitoring data are suspect, especially at Clairmont Road. For example, the measured discharges at Clairmont Road for the calibration event are substantially less than the sum of the upstream contributing discharges. The model assumes the rainfall is evenly distributed across the entire Tyler Coulee watershed, with no spatial variation. This in reality is unlikely. Given these limitations, the model calibration seems reasonable. Modeled and measured stages at Valley Drive Detention West are similar as are discharges and stages at Burnt Boat Drive & Tyler Parkway.

## **6.2 Design Goals**

This master plan has been developed in accordance with the City’s storm water ordinance and design manual. One of the more prominent aspects of the ordinance is the need to limit the peak flows from the 2-year, 10-year, and 100-year (6-hour) events after development to those prior to development. Additional design goals related to the specific features of the Tyler Coulee Watershed include the desire to provide locations where sediment loads can be reduced and to reduce the frequency of flooding within Pioneer Park. Maintaining the natural character of the coulee to the extent possible, is also a priority.

Figure 8  
Valley Drive Detention Basin Time Series (July 21, 2000)

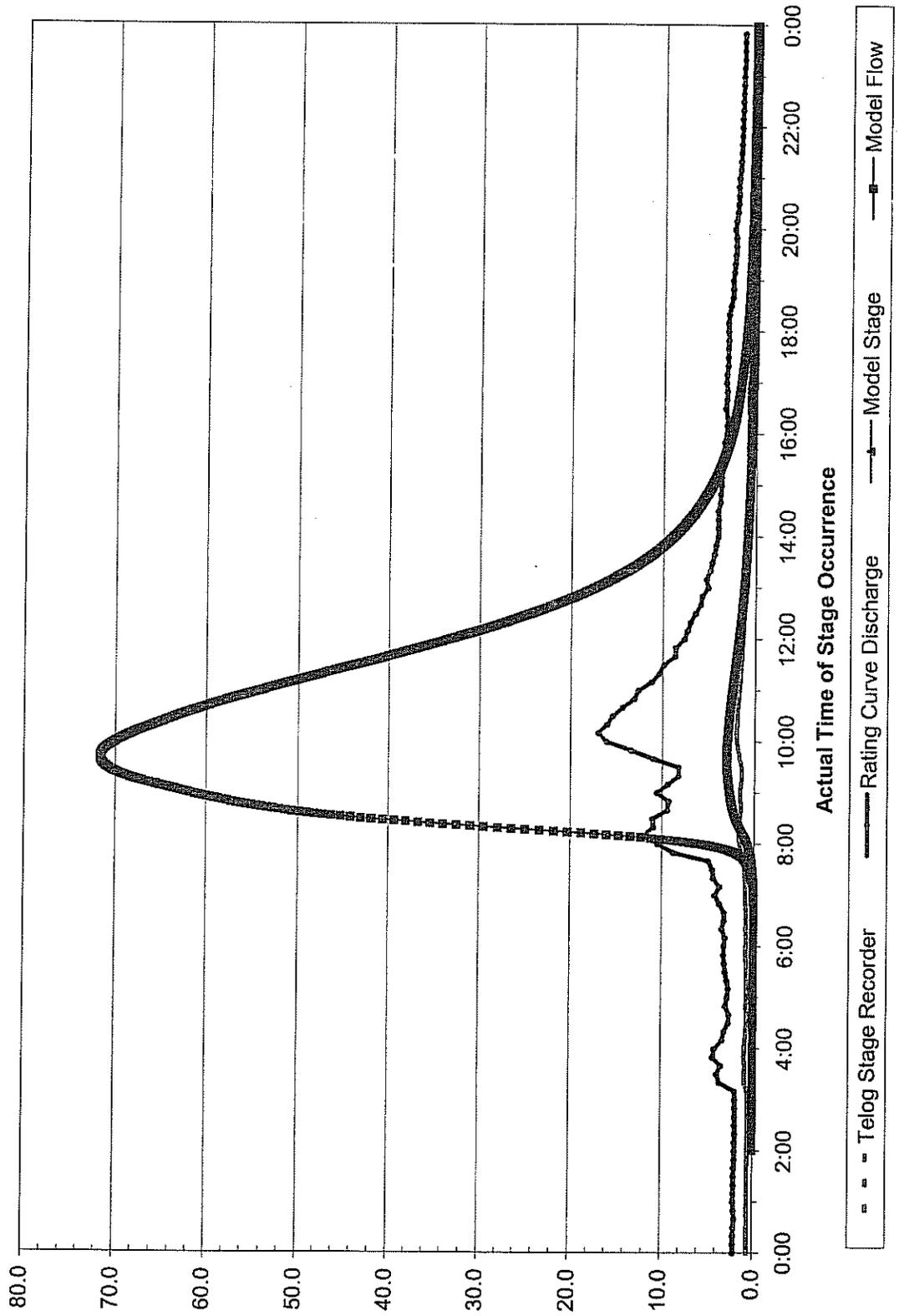


Figure 9  
Discharge Hydrograph at Burnt Boat Drive and Tyler Parkway (July 21, 2000)

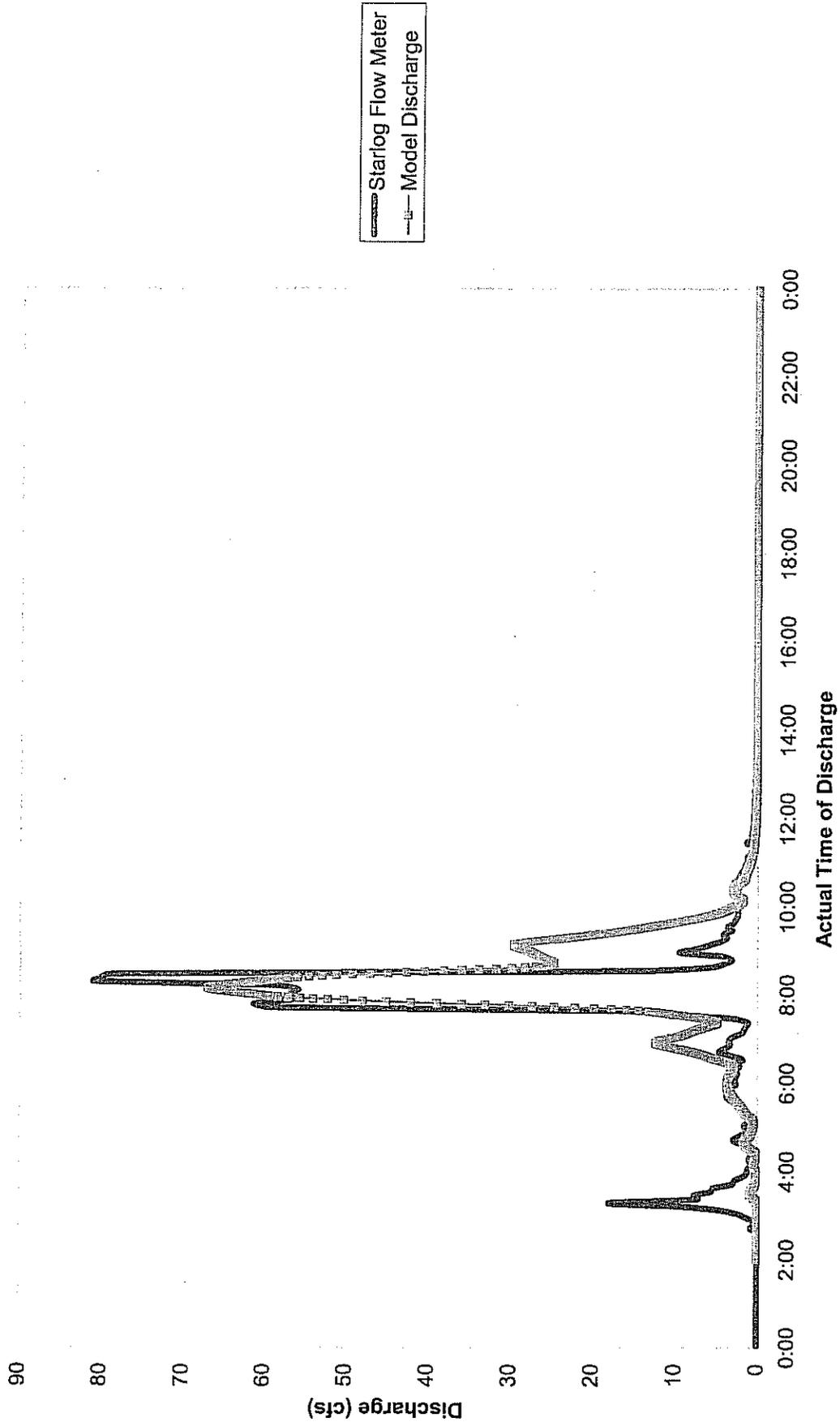
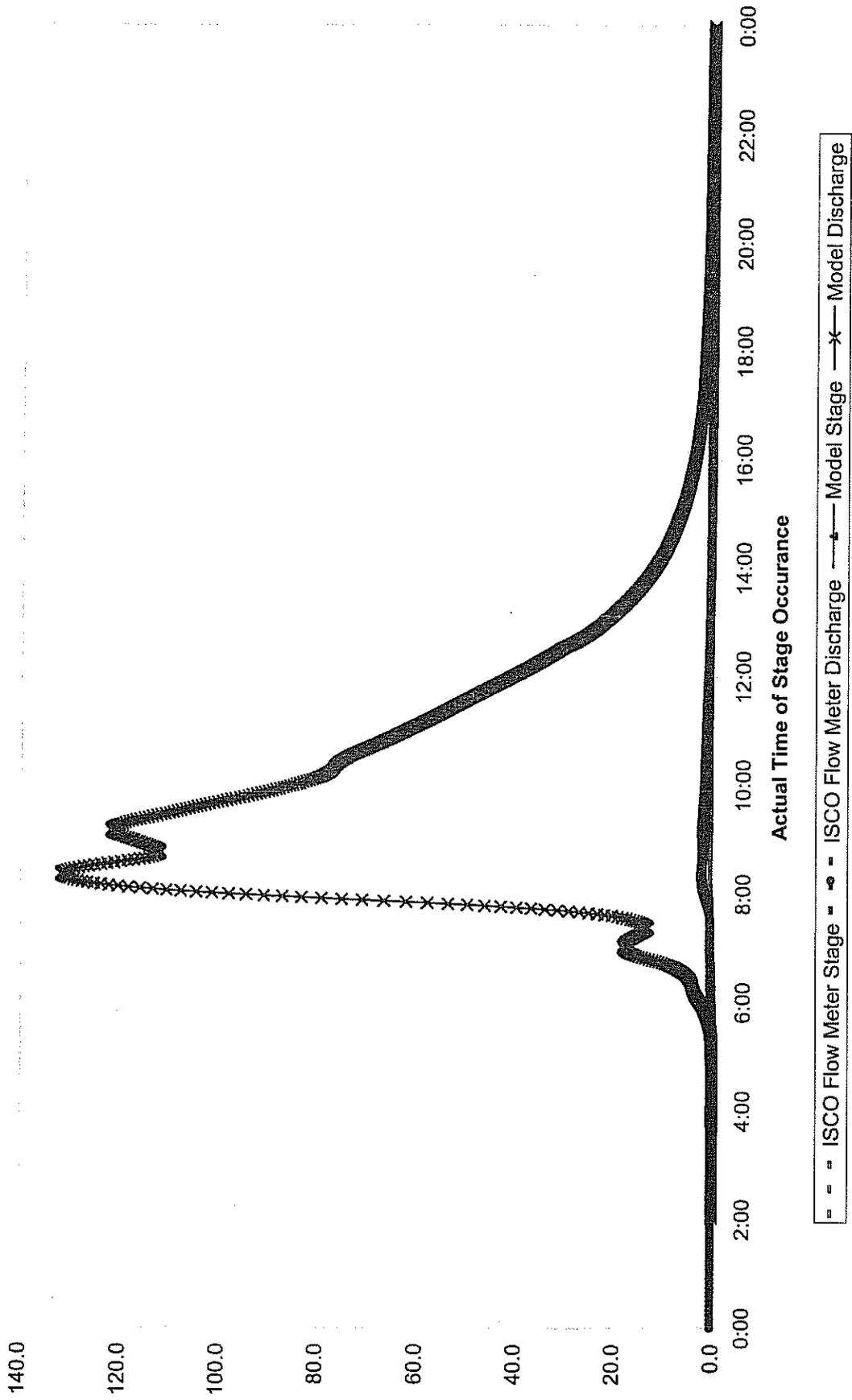


Figure 10  
Stage and Discharge Hydrograph at Clairmont Road (July 21, 2000)



## 6.3 Regional Storm Water Facilities

### 6.3.1 Uncontrolled, Existing and Proposed Hydrology

The SWMM model was used to predict fully developed uncontrolled, existing and proposed peak discharges (Table 6). Fully developed, uncontrolled peak discharges reflect ultimate development within the Tyler Coulee watershed, in the absence of the existing storage within Valley Drive Detention Basin West, Overland Drive and to some extent upstream of Clairmont Road, for the less frequent floods. The existing peak discharges reflect the currently constructed storage. The proposed discharges reflect the addition of storage near the intersection of Burnt Boat Drive & Tyler Parkway and modifications of the Valley Drive Detention Basin West and Overland Road Detention structures (see Section 6.3.2 below).

Water surface elevations at locations where there is important existing and proposed storage within the Tyler Coulee Watershed, were also computed by the SWMM model (Table 7). The results show that some storage occurs because of the existing topography, even in the absence of an engineered structure.

### 6.3.2 Regional Detention for Peak Flow Reduction

Because of the topography of the Tyler Coulee Watershed, there are a number of opportunities to use storage to reduce the fully developed, uncontrolled peak discharges. Several regional detention basins have already been constructed, which reduces the need for additional basins. Existing regional detention basins include Valley Drive Detention Basin West, Valley Drive Detention Basin East, Overland Road Detention Basin, Morgan Court Detention Basin North, and Morgan Court Detention Basin South. Improvements to two existing and the construction of one new regional detention basin is recommended for reducing peak flows within the Tyler Coulee Watershed.

Table 6

**PEAK DISCHARGES (CFS) PREDICTED BY THE SWMM MODEL AT  
SELECT LOCATIONS**

Subwatershed (model node)	2-year (6-hour)			10-year (6-hour)			100-year (6-hour)		
	Existing	Fully Developed Uncontrolled	Proposed	Existing	Fully Developed Uncontrolled	Proposed	Existing	Fully Developed Uncontrolled	Proposed
Ash Coulee Drive (TC 1-1)	20/0*	36/0*	41/0*	39/0*	49/48*	39/0*	40/0*	79/200*	40/0*
Ash Coulee Drive (TC 1-2)	15/0*	15/0*	15/0*	15/0*	29/123*	16/0*	16/0*	37/275*	16/0*
Watershed T1 Outfall (TC 1-3)	60	105	78	122	306	140	215	793	250
Overland Road Detention Basin (TC 1-4)	32	36	36	48	55	50	102	110	105
Watershed T2 Outfall (TC 2)	108	215	177	218	470	377	428	1058	659
Valley Drive Detention Basin West (TC 4)	78	122	44	138	172	58	187	219	70
Morgan Court Detention Basin (TC 3-3)	30	64	62	120	171	156	291	357	316
Valley Drive Detention Basin East (TC 3-1)	64	68	67	81	83	82	90	90	90
Burnt Boat Drive & Tyler Parkway Outfall (TC 6-2)	117	124	73	195	226	148	384	426	293
Clairmont Road (TC 6-4)	120	208	131	270	385	280	449	537	454
River Road (TC 7)	130/0*	214/0*	145/0*	297/0*	407/0*	311/0*	497/46*	522/131*	502/65*

Existing model reflects storage presently in-place. Fully developed uncontrolled model reflects storage presently in-place. Proposed model reflects existing improved and additional proposed storage.

\*Pipe Flow/Weir Flow (overtopping)

Table 7

**WATER SURFACE ELEVATIONS COMPUTED BY THE SWMM MODEL AND  
THE CORRESPONDING STORAGE AT SELECT LOCATIONS**

	Existing		Fully Developed Uncontrolled		Proposed	
	Stage (msl)	Storage (acre-feet)	Stage (msl)	Storage (acre-feet)	Stage (msl)	Storage (acre-feet)
<b>Overland Road Detention Basin</b> <i>Invert = 1829 Embankment Height = 1857</i>						
2-year	1834.6	1.2	1835.6	1.6	1835.6	1.6
10-year	1839.4	4.0	1840.4	4.8	1840.4	4.8
100-year	1843.6	9.0	1844.2	10.0	1844.3	10.2
<b>Valley West Detention Basin</b> <i>Invert = 1682.3 Embankment Height = 1708.53</i>						
2-year	1686.7	3.5	1690.5	10.2	1691.5	13.2
10-year	1692.4	16.3	1696.9	39.1	1697.4	42.2
100-year	1698.9	53.6	1704.0	103.4	1703.7	100.1
<b>Valley East Detention Basin</b> <i>Invert = 1784 Embankment Height = 1798</i>						
2-year	1789.2	0.5	1789.6	0.7	1789.6	0.7
10-year	1791.0	3.1	1791.4	3.9	1791.3	3.7
100-year	1792.5	8.9	1792.8	10.8	1792.7	10.6
<b>Clairmont Road</b> <i>Invert = 1647.85 Embankment Height = 1652.1</i>						
2-year	1651.8	2.1	1653.8	4.4	1652.1	2.4
10-year	1655.1	6.4	1657.5	11.1	1655.3	6.8
100-year	1659.4	15.9	1662.6	28.1	1659.6	16.3
<b>Burnt Boat Drive &amp; Tyler Parkway</b> <i>Invert = 1775 Embankment Height = 1782</i>						
2-year	1777.2	0.9	1777.6	1.8	1777.0	3.5
10-year	1778.4	4.5	1778.9	6.7	1778.8	8.6
100-year	1779.8	12.4	1780.3	17.1	1781.9	18.0

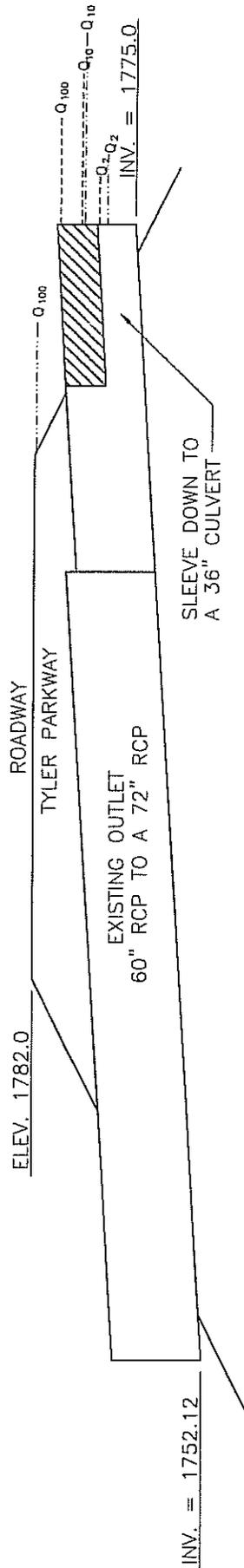
Existing model reflects storage presently in-place. Fully developed uncontrolled model reflects storage presently in-place. Proposed model reflects existing improved and additional proposed storage.

One new regional detention basin within the watershed with a primary purpose of peak flow control is proposed. The detention basin is proposed to remedy increased peak flows from along Century Avenue and the flow diverted into Tyler Coulee from along I-94. This area is contributing to substantive erosion problems downstream of the Burnt Boat Drive & Tyler Parkway outfall. The proposed detention basin consists of 18.3 acre-feet of flood storage with a basin surface area of 3.2 acres. The conceptual design assumes a detention basin bottom elevation at 1775 msl. The outlet would consist of a 36-inch culvert with an upstream invert elevation of 1775 msl with a 1% slope under Tyler Parkway (Figure 11). Based upon the available topographic information, the maximum depth is 7 feet measured from the bottom of the detention basin to the crown of Tyler Parkway (1782 msl). This also assumes the Tyler Parkway road embankment serves as the embankment for the detention basin. The detention basin reduces the 2-year, 10-year and 100-year peak discharges by 38%, 24% and 24%, respectively (Table 6) and results in a 100-year flood elevation close to the elevation of the road crown on Tyler Parkway.

The final detention basin design at the Burnt Boat Drive & Tyler Parkway location should explore alternatives that would increase the storage area. Since space for this detention basin appears limited, it may be desirable to locate the storage farther upstream from Tyler Parkway with a control structure that functions similar to the conceptual design presented here. A probable location would be between Century Avenue and I-94 further east of the proposed location.

Two culverts are located under Ash Coulee Drive. A 30-inch RCP with an upstream invert elevation at 1864.0 msl and a slope of 5% serves as the outlet of subwatershed TC 1-1. The top of the road embankment is at 1875.3 msl. A 24-inch CMP with upstream invert elevation at 1852.35 msl and a slope of 3.7% serves as the outlet of subwatershed TC 1-2. The top of the road embankment is at elevation 1863.6 msl. The proposed conditions SWMM model indicates that 3.5 acre-feet of storage is needed to prevent overtopping at the 30-inch RCP and 5.6 acre-feet is needed at the 24-inch RCP.

BURNT BOAT DRIVE & TYLER PARKWAY DETENTION BASIN  
CONCEPTUAL DESIGN AND HYDROLOGIC ELEMENTS



EVENT	FLOW RATE (cfs)		WATER SURFACE ELEV. (ft. msl)	
	FULLY DEVELOPED CONDITION	FULLY DEVELOPED WITH DETENTION	FULLY DEVELOPED CONDITION	FULLY DEVELOPED WITH DETENTION
Q <sub>2</sub>	93	28	1777.5	1777.0
Q <sub>10</sub>	175	58	1778.9	1178.8
Q <sub>100</sub>	216	75	1780.3	1781.9

LEGEND

- = WATER SURFACE FROM A FULLY DEVELOPED WATERSHED WITH EXISTING DETENTION.
- - - - - = WATER SURFACE FROM A FULLY DEVELOPED WATERSHED WITH DETENTION BASINS.

HYDRAULIC DATA

TYLER COULEE  
STORM WATER QUALITY AND MASTER PLAN  
CITY OF BISMARCK, NORTH DAKOTA

Scale AS SHOWN  
Drawn by B.G.J.  
Checked by J.E.J.  
Project No. 1012-600  
Date 1.1-14-01  
Fig. 11

PREPARED BY



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FAX: (763) 493-5572

NOTE:

- PROPOSED CONDITION ASSUMES A 3.2 ACRE DETENTION POND WITH 7-FOOT AVERAGE DEPTH AND 3:1 SLOPES, CONTAINING 18.3 ACRE-FOOT OF STORAGE, IS CONSTRUCTED UPSTREAM OF THIS ROAD.
- SEE APPENDIX D FOR STAGE-STORAGE RELATIONSHIP.

The Overland Road Detention Basin presently consists of a 24-inch RCP with an upstream invert elevation of 1829.0 msl at a slope of 3.125%. The 24-inch RCP terminates at a manhole with a 72-inch grated, drop inlet structure at elevation 1840.3 msl. The manhole invert elevation is at 1826.3 msl. The discharge from the manhole through the embankment to the outlet consist of a 36-inch RCP that increases near the outlet to a 48-inch RCP with an internal ring energy dissipater. The invert elevation of 48-inch RCP at the outlet is 1823.0 msl. The top of the embankment is at 1857 msl. The estimated storage at the top of the embankment is 49 acre-feet. No modification the Overland Road Detention Basin is recommended. The present detention basin is effective in reducing peak flows and no modifications are proposed.

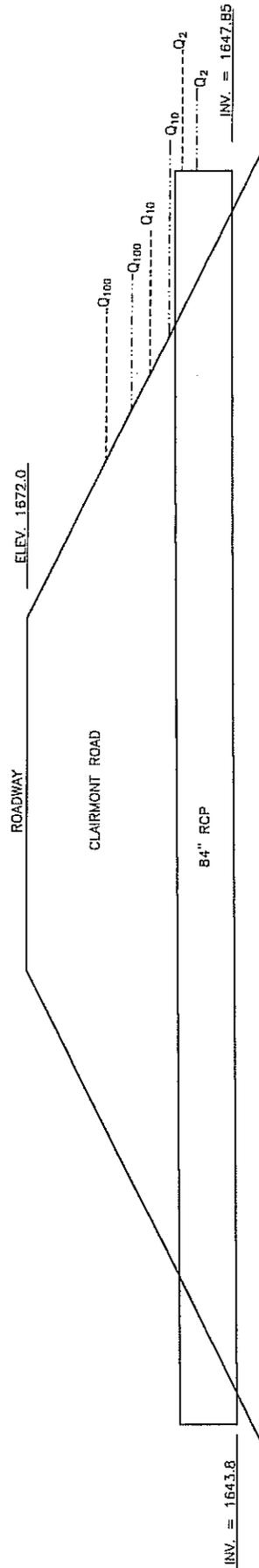
Valley Drive Detention Basin East consists of a 36-inch RCP outlet with an upstream invert elevation at 1784 msl and a nominal slope of 8.8%. The top of the embankment is at elevation 1798 msl. The detention basin contains approximately 98 acre-feet of storage to elevation 1798 msl. No modification of this detention basin is proposed, as peak flows do not increase substantially following development.

The Morgan Court North and Morgan Court South Detention Basins presently provide limited peak flow reduction. Each of the detention basins consists of an 18-inch PVC outlet. The invert elevation for Morgan Court North outlet is at 1736.58 msl. The invert elevation for Morgan Court South outlet is also at 1736.58 msl. Neither basin has sufficient storage to reduce peak flow rates substantially downstream.

Because sufficient storage is present within the other regional detention basins within the Tyler Coulee Watershed, no modifications to these detention basins is proposed for the purposes of peak flow reduction. The detention basins do serve the purpose of reducing sediment loads and should be maintained in their present condition. These structures should be modified if downstream channel erosion develops in the future.

The Valley Drive Detention Basin West presently consists of a 48-inch RCP outlet at invert elevation 1682.3 msl. The top of this embankment at elevation 1708.53 msl is also intended to serve as a future roadway for crossing Tyler Coulee. The potential storage to the top of the embankment is 172 acre-feet. The outlet for the Valley

# CLAIRMONT ROAD HYDRAULIC DATA



EVENT	FLOW RATE (cfs)		WATER SURFACE ELEV. (ft. msl)	
	FULLY DEVELOPED CONDITION	FULLY DEVELOPED WITH DETENTION	FULLY DEVELOPED CONDITION	FULLY DEVELOPED WITH DETENTION
Q <sub>2</sub>	208	131	1653.6	1652.1
Q <sub>10</sub>	385	280	1657.5	1655.3
Q <sub>100</sub>	537	454	1662.6	1659.6

### LEGEND

- = WATER SURFACE FROM A FULLY DEVELOPED WATERSHED WITH EXISTING DETENTION.
- = WATER SURFACE FROM A FULLY DEVELOPED WATERSHED WITH DETENTION BASINS.

NOTE:

\* SEE APPENDIX D FOR STAGE-STORAGE RELATIONSHIP.

### HYDRAULIC DATA

TYLER COULEE  
STORM WATER QUALITY AND MASTER PLAN  
CITY OF BISMARCK, NORTH DAKOTA

Scale AS SHOWN  
Drawn by BGJ  
Checked by JEJ  
Project No. 1012-600  
Date 11-14-01  
Fig. 13

PREPARED BY



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Drive Detention Basin West is to be modified. The modified outlet would consist of a 24-inch RCP with an upstream invert elevation at 1682.3 msl at a slope of 2% leading to a 72-inch diameter manhole with a grated, drop inlet structure at the approximate elevation corresponding to the 100-year flood (1704.0 msl) (Figure 12). The modified Valley Drive Detention Basin West along with the other improved and proposed storage reduces the 2-year, 10-year and 100-year peak discharges by 44%, 58% and 63%, respectively, compared to the existing condition (Table 6).

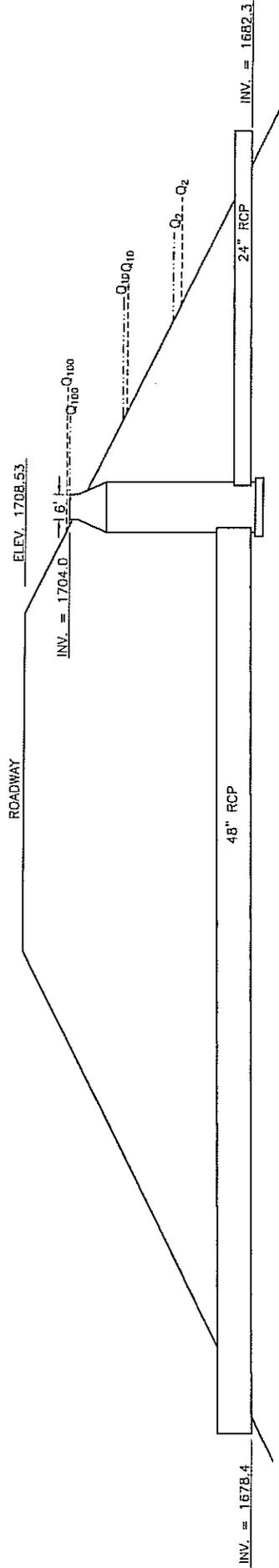
A 84-inch RCP at invert elevation 1647.85 msl and a slope of 2.016% is located under Clairmont Road (Figure 13). The road embankment has a crown elevation of 1672.0 msl. The road provides access to Promitory Point north of Tyler Coulee. The amount of storage at elevation 1672.0 msl is an estimated 81.0 acre-feet. The area along the north branch of Tyler Coulee contains many large oak trees of aesthetic and ecological importance. Because this area is likely to become future park and the developer has requested the trees not be flooded, additional storage at Clairmont Road has not been considered and no modifications to the existing structure is proposed. The existing and proposed detention basins upstream of Clairmont Road are sufficient to maintain post development peak flows at or below existing peak flows (Table 6).

Geotechnical analysis of the embankments is necessary prior to modifying the outlet structures. The proposed outlet structure modifications will in some cases, result in storage durations exceeding 2 days. The modifications may also trigger dam safety requirements.

### 6.3.3 Tyler Coulee Conveyance System

The natural channel within the Tyler Coulee watershed serves as the primary storm water conveyance system. A limited amount of storm sewer (pipe) delivers water to Tyler Coulee. Much of the storm water runoff is delivered by the street system to the natural swales and coulees. This is likely to be the case in the future as well. There is considerable risk of eroding these coulees and the main channel as development occurs, if peak flows and the resulting velocities are not maintained below allowable levels.

# VALLEY DRIVE DETENTION WEST CONCEPTUAL DESIGN AND HYDROLOGIC ELEMENTS



EVENT	FLOW RATE (cfs)		WATER SURFACE ELEV. (ft. msl)	
	FULLY DEVELOPED CONDITION	FULLY DEVELOPED WITH DETENTION	FULLY DEVELOPED CONDITION	FULLY DEVELOPED WITH DETENTION
Q <sub>2</sub>	122	44	1690.5	1691.5
Q <sub>10</sub>	172	58	1696.9	1697.4
Q <sub>100</sub>	219	70	1704	1703.7

**LEGEND**

- = WATER SURFACE FROM A FULLY DEVELOPED WATERSHED WITH EXISTING DETENTION.
- - - - - = WATER SURFACE FROM A FULLY DEVELOPED WATERSHED WITH DETENTION BASINS.

NOTE:

• SEE APPENDIX D FOR STAGE-STORAGE RELATIONSHIP.

**HYDRAULIC DATA**

TYLER COULLEE  
STORM WATER QUALITY AND MASTER PLAN  
CITY OF BISMARCK, NORTH DAKOTA

Scale AS SHOWN | Drawn by BGJ | Checked by JEJ | Project No. 1012-600 | Date 11-14-01 | **Fig. 12**

PREPARED BY



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Channel cross-sections were surveyed at several locations for this project. Unfortunately, the cross-sections were often based on as few as three points, an insufficient number to accurately characterize the channel. These data were used when possible along with the surveyed channel profile to characterize the channel and compute channel velocities. Channel velocities for the 100-year, 6-hour discharge are of short duration and generally ranged 3.3 feet per second to 8.3 feet per second. Assuming vegetation is present, these velocities should not result in substantive erosion. However, if vegetation is absent erosion will occur. The modeled velocities also are averages, representing the average channel slope. Localized steep slopes and curves in the channel will certainly result in local accelerations and higher velocities. Additional analysis is needed using better cross-section data and the predicted peak flow rates (Table 6) to assess potential channel erosion.

The existing erosion between the Burnt Boat Drive & Tyler Parkway outlet and Clairmont Road should be repaired. The 2-year, 6-hour and 100-year, 6-hour discharges are 73 cfs and 293 cfs, respectively. A two-stage open channel design is recommended. A base flow channel sufficient for the 2-year discharge should be constructed within a second channel designed to convey the 100-year discharge. The upstream base flow channel invert would be at an approximate elevation of 1752 msl and terminate at Clairmont Road (1647.85 msl). The 100-year channel functional design consists of a trapezoidal channel with a 5-foot bottom width, 3h:1v side slopes, a depth of 4-feet and an average slope of 3.5%. Final design will need to evaluate the use of drop structures at select locations near Clairmont Road where the channel grade is steepest.

The area adjacent to the Tyler Coulee channel has considerable natural and ecological character and represents an important aesthetic component within the watershed. The Bismarck Parks and Recreation Department has planned a trail system along the channel, capitalizing on the natural character of the area. Therefore, efforts should be made to preserve the natural character of the channel and the area adjacent to the channel, while also using it for storm water conveyance. Peak flows need to be carefully managed for this to successfully occur. The regional detention basins play an important role in managing these peak flows. The function of the regional detention basins has been designed accordingly.

Reducing the frequency of flooding within Pioneer Park is also a project goal. Flooding presently occurs on average once every other year. Many years, flooding occurs multiple times within the same year. This limits the use of the park at key times during the summer months. The Parks and Recreation District has requested conceptual design of a new channel for reducing the frequency of flooding. The preferred design is one incorporating natural and ecological features.

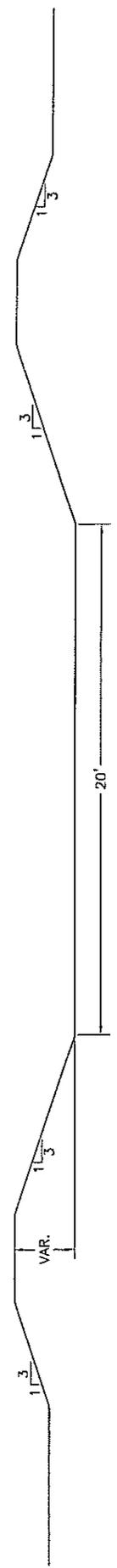
A new channel can be constructed to convey up to the 100-year discharge along its current alignment without flooding (Figure 14). Design for protection from a 100-year flood is intended for planning purposes only, and may be reduced if greater risk of flooding is acceptable. The invert elevation of the proposed channel at River Road is 1639.05 msl and the channel would have a slope of 0.47%. The analysis assumes no backwater affects from the Missouri River and the capacity could be reduced depending upon an allowable risk level, established by the City and the Parks and Recreation Department. Natural characteristics could easily be incorporated into the design by constructing a two-stage channel. A smaller, meandering base flow channel could be designed and constructed within the proposed overflow channel. The proposed overflow channel effectively becomes a floodplain channel if this operation is pursued.

#### 6.3.4 Extended Detention for Water Quality Improvement

Extended detention basins for water quality improvement and where modest peak flow reduction are necessary, are recommended for the Tyler Coulee Watershed. Figure 15 shows a typical extended detention basin. However, the primary purpose of the extended detention basins is to reduce sediment loads from upstream areas. Identifying the locations of each basin is difficult. The reason is the location and design is site specific depending upon the drainage area, local topography, and the proposed plat and final grading plan. Several potential preliminary locations have been identified (Figure 2). These locations are representative areas where extended detention should be considered. The appropriateness of these and additional locations must be reviewed upon submittal of a proposed plat. Two locations seem most likely, based on the modest peak flow increases. These locations include enhancing Morgan Court Detention North and South and at the outlets of subwatersheds and TC 2.

# PIONEER PARK CONCEPTUAL CHANNEL DESIGN

CHANNEL CAPACITY  
 $Q_{100} = 552 \text{ cfs}$   
 $V_{AVE} = 5.5 \text{ fps}$



- NOTE:
- BERM HEIGHT VARIES FROM 4 FEET AT THE OUTLET TO 7 FEET AT RIVER ROAD.
  - INVERT ELEVATION AT RIVER ROAD DOWNSTREAM OF BOX CULVERT IS 1634.9 MSL.
  - CHANNEL SLOPE IS 0.37%.

TYPICAL DETAILS

TYLER COULEE  
 STORM WATER QUALITY AND MASTER PLAN  
 CITY OF BISMARCK, NORTH DAKOTA

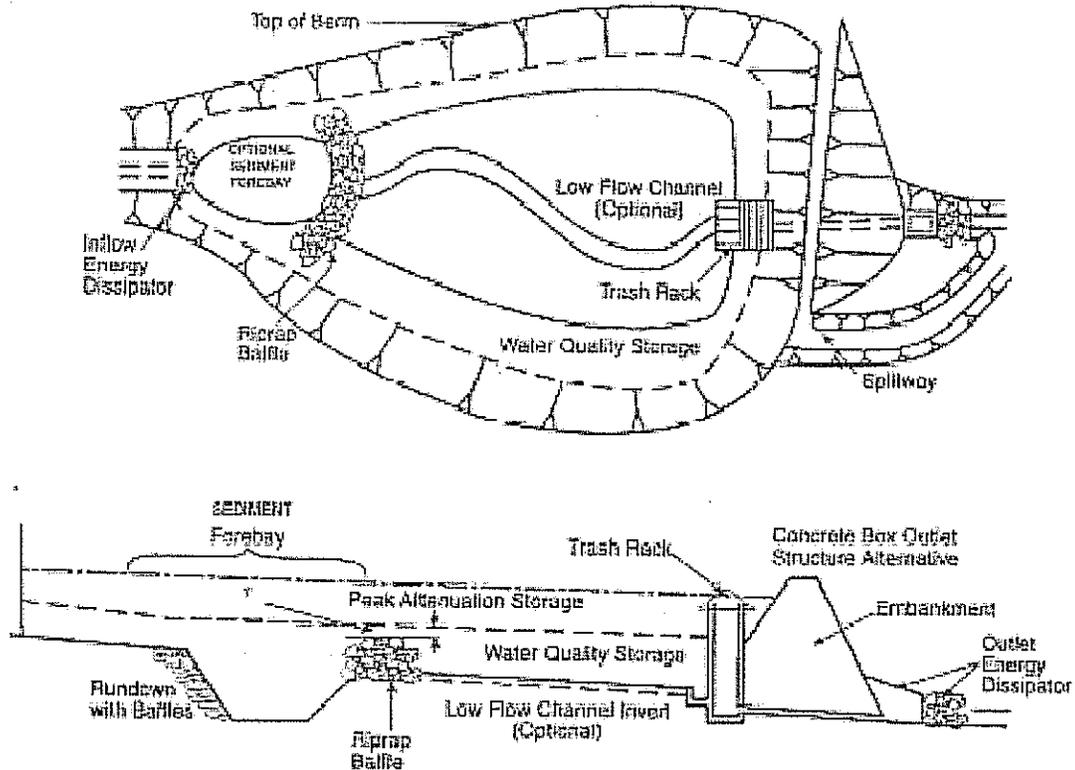
Scale	AS SHOWN	Drawn by	BGJ	Checked by	JEJ	Project No.	1012-600	Date	11-14-01
PREPARED BY									



**HOUSTON ENGINEERING, INC.**  
 10900 73rd Ave. North, Suite 106  
 Maple Grove, MN 55369  
 PHONE: (763) 483-4522  
 FAX: (763) 483-4572

Figure 15

TYPICAL CONCEPT DESIGN FOR AN EXTENDED DETENTION BASIN



(Adapted from Best Design and Construction Standards, Fairfax County, Virginia, 1998)

The modeling results show there are two additional locations where storage could be implemented to reduce the fully developed, uncontrolled peak discharges. The amount of storage is small compared to the larger regional detention basins intended to control flood flows (e.g., Valley Drive Detention Basin West). The use of extended detention basins is more suitable for these locations. These locations are Morgan Court and the outlet of subwatershed TC 2. The following recommended designs need to be evaluate relative to water quality improvement goals during final design.

The Morgan Court North and Morgan Court South Detention Basins presently provide limited peak flow reduction. Each of the detention basins consists of an 18-inch PVC outlet. The upstream invert elevation for the Morgan Court North outlet is at

1736.58 msl. The upstream invert elevation for the Morgan Court South outlet is at 1729.48 msl. These structures were modeled as one within the SWMM model, with the intent of providing a planning level analysis to specify the functional characteristics necessary for peak flow reduction but also to provide water quality improvement.

To reduce the fully developed, uncontrolled peak discharges to the proposed condition, new storage is needed at the outlet to the Morgan Court subwatershed (TC 3-3). An embankment constructed to an elevation of 1740.0 msl and an outlet consisting of a 48-inch RCP with an upstream invert elevation at 1729.48 msl at a slope of 3.8% would comprise the embankment and outlet, respectively. The detention basin would need to provide 1.1 acre-feet of storage at 1730.6 msl, 3.1 acre-feet of storage at 1732.5 msl and 6.7 acre-feet at elevation 1736.1 msl. The modeling analysis assumed the outlet pipe carries the discharge to the Valley Drive Detention Basin West.

Additional storage could also be implement within TC 2 to reduce the fully developed, uncontrolled peak discharges to the proposed condition. An embankment constructed to an elevation of 1735.0 msl and an outlet consisting of a 78-inch RCP with an upstream invert elevation at 1710.0 msl at a slope of 0.9% would comprise the embankment and outlet, respectively. The detention basin would need to provide 3.7 acre-feet of storage at 1713.7 msl, 6.7 acre-feet of storage at 1716.5 msl and 11.2 acre-feet at elevation 1721.2 msl.

The following general criteria are useful for identifying the need for an extended detention basin, in the absence of a specific recommended location:

- Minimum contributing drainage area of 50 acres;
- Maximum drainage area is dependent upon available storage and outlet design;
- Minimum of 10-year sediment storage volume;
- Minimum hydraulic residence time of 24-hours for the storm water treatment design storm volume and a preferred hydraulic residence time of 48 hours;
- Fit the shape to the landscape;
- Forebay maximum depth sufficient to prevent scouring (generally greater than 3 feet); and

- Positioned near the upper and middle portions of the Tyler Coulee Watershed, as the larger regional detention system is intended for flood control purposes on a larger scale.

The use of extended detention basins for this project is considered a regional BMP with the primary purposes of water quality improvement and aesthetic enhancement.

Sediment and the associated pollutants, such as trace metals and nutrients, are the pollutants most effectively controlled by extended detention basins. If the outlet is designed as a skimmer, floating debris and organic matter can also be effectively trapped. If a permanent pool or shallow marsh area is included in the design, some removal of fine sediment and soluble nutrients can be achieved. Extended detention basins are also some of the best facilities for treating spring and winter runoff, because of how ice conditions affect the flows. Storage areas without extended detention have minimal storage above the ice surface. Therefore, treatment is often bypassed. In addition, extended detention basins are very effective for controlling the moderate runoff resulting from more frequent but smaller rainfall events, an important factor in reducing downstream stream bank erosion and sediment loads.

Extended detention basins can be effective for removing particulate pollutants from urban runoff. The efficiency of an extended detention basin depends largely upon the surface overflow rate. The primary treatment process for most basins is settling. Pollutants attached to sediment particles exhibit settling characteristics similar to those of sediment. Lead, for example, has a strong affinity for sediment and its removal curve is very similar to that of sediment. Zinc, on the other hand, has a substantial portion of its load in the soluble form. Almost all of the zinc that is removed by extended detention is the portion that is attached to sediment.

Phosphorus acts similarly to zinc in that slightly less than half of the phosphorus is usually dissolved (although this is watershed specific) and is not removed through sedimentation. Nitrogen has an even lower removal rate because of the high percentage that is typically in a soluble form. If additional removal of nutrients is desired, several alternative designs can be used. For example, a permanent pool of the extended detention basin can be designed and managed as a wetland treatment system or deep pond.

Biological and chemical transformations in the pool and wetland can provide some removal of soluble nutrients between events. The permanent pool of water in the marsh will also provide a much higher removal efficiency of suspended solids for very small runoff events by providing a relatively long residence time between storms for settling.

The lower stage of extended detention basins can be designed for several management schemes. The lower stage can be normally dry, have a permanent pool of water or have a shallow marsh established in it. Those with a shallow marsh or permanent pool of water typically will be more effective for pollutant removal than those that are normally dry. This is because they will provide sediment storage and allow quiescent settling to occur.

When designing an extended detention basin, it's important to recognize that small storms (typically about a 2-year-return-frequency event) that produce less than ½-inch of runoff deliver the majority of the pollutants throughout an average year. If small storms are not considered in the design, their effects may not be adequately treated.

The minimum recommended water quality volume for extended detention is the total volume of runoff from a storm with a return frequency of once in about 2 years. In areas such as Tyler Coulee, the water quality storage volume is often considered to be about 0.5 inch of runoff for all impervious areas in the watershed.

The design detention time can be achieved by adjusting the outflow rate from the basin. As the outflow rate is decreased, the detention time and the required temporary storage volume will be increased. The outlet device can then be designed to provide the desired maximum outflow rate of about 6 cubic feet per second per acre of storage surface area for the water quality storage volume and appropriate rates for the more frequent events. A multiple-stage outlet design is usually needed to provide extended detention of small (less than two-year event) storms while allowing a higher discharge rate for larger storms passing through the basin. This keeps the storage volume down to a reasonable level.

Adequate sediment storage should also be provided in these storage areas, usually to hold 5 to 25 years of sediment accumulation. A forebay at the inlet to the sediment basin can be used to trap coarse sediments, such as road sand, and large debris, such as

leaves and branches. If sediment is removed from the forebay or the entire basin on a more frequent basis, the sediment storage volume in the basin may be reduced. A common maintenance cycle would be about five years.

The shape of the storage area should be selected keeping several considerations in mind. First of all, it should be designed in such a way that turbulence in the main treatment area is minimized. Forebays are the most commonly recommended method for turbulence reduction. Reducing the turbulence will reduce the chance for re-suspending previously deposited materials. It will also result in conditions more conducive to settling while the storage is filling. Second, the inlet and outlet should be positioned in such a way that short-circuiting in the basin is minimized. Third, the slopes in the basin should be flat enough that they are relatively easy to maintain. Slopes of 4:1 (horizontal: vertical) or flatter are recommended. In some cases, slopes flatter than 4:1 may be required because of soil-mechanics considerations. Accessible slopes leading into the basin should not be steeper than 3:1.

The following considerations can be used in extended detention basin design that will help reduce operation and maintenance costs without a significant increase in construction costs.

- Keep all slopes 4:1 or flatter whenever possible for safety and so that vegetation can be maintained easily.
- All extended detention outlet devices should be protected from clogging. All devices should have aboveground access for cleanout, should this be necessary.
- Vehicle access should be at least 10 ft wide and no steeper than 15% should be provided. The planned maintenance access should never include travel on an emergency spillway unless the spillway has been designed for vehicles.
- On-site sediment disposal sites should be provided whenever possible. The cost of sediment cleanout increases drastically when sediment must be disposed of off site. Such disposal sites must be located above the project water lines to avoid reducing the available storage.

These storage areas could also incorporate some dead storage (permanent water storage), which is the primary characteristic of a quiescent storage area. Such storage areas are designed to primarily treat runoff in the storage area between events by inter-event settling and biological and chemical activity.

Storage volume ideally should provide an average hydraulic residence time of approximately 15 days for summer months. Sediment storage must be added to this volume to compute the total storage volume.

The depth of storage is usually restricted to 3 to 8 feet. Settling during events is not a design consideration, but re-suspension is still a major concern. If storage depths are greater than 8 ft, the storage area may be subject to temporary thermal stratification. This may result in releases of phosphorus from the anoxic or nearly anoxic bottom sediments. The phosphorus quantities may then be mixed back into the upper layer of the water by flow or wind-generated currents.

The most common shape to promote plug flow is one that has a length-to-width ratio of 3:1 or more. This ratio may not be practical in some situations where site restrictions determine the shape. In some cases, energy dissipaters, inlet flow diffusers, baffles or flow directional berms can be used to prevent short-circuiting in storage facilities with small length-to-width. Other ways to increase plug-flow characteristics are to construct variable bottom depths or use two or more storage areas in series that have a total volume equal to or more than the required treatment volumes and areas.

It is important to remember that such basins will be extensively flooded during major runoff events, requiring some sort of high flow or emergency spillway. Because of this, such storage areas may not be appropriate for outlets constructed at road crossings, as the outlets will be frequently overtopped. Any embankment, principal spillway or emergency spillway constructed in conjunction with an extended-detention basin should meet specific design criteria such as NRCS Standard 378, Ponds, (NRCS, February 1995).

#### 6.3.5 Development Control BMPs

Development control BMPs are the procedures and methods that can be used to control where or how development occurs, thereby reducing the likelihood of future problems. The City of Bismarck storm water ordinance contains many existing policies and procedures with the same purpose. The use of natural channels as the conveyance system and the desire to maintain the natural character of these area, represent a unique challenge for managing storm water. This section presents recommendations for

consideration by the City of Bismarck, when developing storm water master plans for areas like the Tyler Coulee watershed. Some of these recommendations may be in conflict with the existing ordinance and should be considered on a case-by-case basis when appropriate.

The focus of storm water management has historically focused on reducing the frequency and severity of flooding. Storm water systems are specifically designed to increase hydraulic efficiency through higher velocities, low roughness (e.g., storm sewers, paved gutters and waterways) and to be self-cleaning. This traditional approach implicitly accepted significant change from the pre development hydrological condition as a reasonable and unavoidable consequence of land development. The development control BMPs presented here provide a mechanism for alleviating problems that cannot be avoided in the traditional site planning process.

A good starting point is to identify goals that will help direct the choice of practices and strategies for site development toward those that would reduce the root causes of adverse impact on hydrology and water quality. Two goals seem particularly appropriate for the City of Bismarck:

- *Restriction of Development in Critical Areas* – One way to avoid adverse impacts of development is to develop comprehensive site plans that prevent construction activity in the most sensitive areas. New developments should be restricted from the shoreline of waterways, within natural waterways and their floodplains, or in areas dominated by steep slopes, dense vegetation or erodible soils for the following reasons:
  - *Shoreline* - Vegetated shoreline is a critical part of nature's system for cleansing runoff water of pollutants. Once the vegetation is disturbed, erosion increases. Runoff from construction close to the receiving waters is hard to control, making measures to reduce pollutant delivery much more difficult and expensive.
  - *Natural Drainageways* - Natural drainageways contribute large amounts of runoff directly to receiving lakes or streams. Once disturbed, their vegetation becomes difficult to reestablish making them high-energy, high volume conduits for moving considerable amounts of pollutants to receiving waters. Site plans that disturb these areas often result in much larger peak flows that have to be managed and treated (and much greater costs to remediate) than would be required by using other areas of the site for the same purpose.

- *Steep Slopes* –Steep slopes are of considerable concern within Tyler Coulee because they are common. Generally, the steeper the slope, the greater the erosion hazard. Because of the effects of gravity and the reduced friction between soil particles on steep slopes, less energy is needed to dislodge and transport soil particles.
- *Erodible Soils* - When denuded of vegetation, areas with easily eroded soils yield greater volumes of transported soil than those with erosion resistant soils. Proactive planning can avoid disturbing erodible soils in the land development process, so that erosion and sedimentation problems will be avoided.

These sensitive areas as discussed above, can be set-aside as natural open space areas. Within Tyler Coulee these are the areas immediately adjacent to the natural channel. They can also be used as buffer spaces between land uses on the site or to buffer land uses on adjacent sites. Where preservation needs exceed the needs for open space, cluster development under the Planned Unit Development (PUD) provisions of the City zoning code can usually be used to avoid sensitive areas, while preserving the gross density allocated to the parcel. The second goal consists of reproducing hydrologic conditions:

- *Reproduction of Hydrologic Conditions* - Reproducing hydrologic conditions is a goal that can be addressed comprehensively in site planning by looking at reproducing the full spectrum of hydrological conditions; i.e., peak discharge, runoff volume, base-flow levels, and maintenance of water quality. This involves developing standards and a philosophical approach within the context of site planning. Runoff volume and water quality are greatly affected by development practices, which can be mitigated by the configuration of the drainage paths and vegetative cover.
  - *Preserve Vegetation* - Healthy vegetative cover is an important factor in preventing erosion. Disturbance of areas with a well-established vegetative cover causes the greatest increase in erosion risk. Wooded areas with under story cover are the most runoff-absorbent types of cover in the landscape. Destruction of such vegetation adds significant expense to the construction budget for clearing, and destroys trees, which are an inherently valuable attribute of the site. Destruction of a given area with dense vegetative cover produces a greater impact than destruction of the same area of sparse vegetative cover. Destruction of a large area of a given vegetative cover produces greater effects than destruction of a small area of the same vegetative cover. A good site plan preserves large areas of existing dense vegetation.
  - *Fit Development to the Terrain* - Choose road patterns to provide access schemes that match landform. For example, in rolling or dissected terrain

(typical in much of Tyler Coulee), use strict street hierarchies with local streets branching from collectors in short loops and cul-de-sacs along ridgelines. This approach results in a road pattern that resembles the branched patterns of ridgelines and drainageways in the natural landscape, facilitating the development of plans, which work with the landform and minimize disruption of existing grades and natural drainage. Where the topography is characteristically flat, the use of fluid grids may be more appropriate. In this type of scheme, interrupting and bending the grid around natural drainageways can minimize the concentration of runoff and the resulting increases in erosive discharges and velocities. Artificial grassed waterways can be used to maintain natural drainageways. They can often be constructed (at very gentle slopes to maximize pollutant removal), at the back of lots or along the street right-of-ways, to channel runoff to natural drainageways without abrupt changes of direction.

- *Preserve and Utilize Natural Drainage* - This means keeping pavement and other impervious surfaces out of low areas, swales and valleys. This can be accomplished by preparing site plans in which roads and parking are high in the landscape and along ridges wherever possible.
- If natural vegetated drainageways are preserved in the site-planning process, flood volumes, peak discharges and base flows will be held closer to their predevelopment levels and distribution in the watershed. Trace metals, hydrocarbons and other pollutants will have a much greater opportunity to become bound to the underlying soil. Infiltration, to the extent it can be encouraged along the entire drainageway will not only contribute to the reduction of runoff volumes, but also allow nutrients to be taken up by the vegetation lining the drainageway.

To achieve these goals, four planning steps are suggested, which include site inventory and mapping, subdivision planning, use of clusters on the site and adaptation of lots to the site.

- *Site Inventory and Mapping* - Using a topographic map of the site as a base, critical site areas (shorelines, natural drainage areas, steep slopes, erodible soils and significant native vegetation), should be located. The boundaries of these areas will define the areas having the potential to be significantly impacted by construction. For example, when plotting a natural drainageway, mapping its flow line and the area of the adjoining side slopes that, if disturbed, would cause a loss of integrity in its hydrologic function will define a potential impact area. Following are additional suggestions for mapping potential impact areas:
  - *Shoreline* - Map the water edge and the adjoining areas of riparian vegetation along the waterways.
  - *Natural Drainage ways* - Map flow lines of natural drainage paths and adjacent areas to top of bank.

- *Steep Slopes* - Map slope categories, which correspond to the different lot/housing-type combinations to aid matching units to the land and thus avoid excessive, lot grading. As a guide, use the slope categories to establish the "boundaries" for the mapping units used. For example, for slopes of 0 to 4%, use flat lots with streets parallel to the contours and rambler housing units. For slopes of 4 to 8%, use sloped lots, with streets parallel to the contours and split-entry or walkout housing units. For streets that run perpendicular to the contours, use side-to-side, split-level housing. For slopes of 8 to 10 %, use sloped lots with split-level housing units. For streets that run perpendicular to the contours, use side-to-side, split-level housing units. Slopes steeper than 10 % should not be used for residential lots.
- Porous Soils and Erodible Soils - These can be located using the county soil surveys done by the NRCS. The boundaries should be mapped and verified with field checks.
- In addition to the mapping units suggested, add information that shows the extent of post development flooding. This will be useful in determining the areas that could suffer tree mortality from flooding.
- *Subdivision Planning* - Subdivision planning can be accomplished by working on an overlay of the inventory map. Clusters of houses should be arranged so that drainageways and preserved areas fall along the back lot lines between clusters as much as possible. This will provide buffer spaces between clusters. Clusters should also be positioned so roads follow ridges or join high points as much as possible. Trial grades for both roads and lot clusters should be developed to ensure that slope guidelines are met and to determine the area disturbed by earthwork operations. Layout and slopes should be adjusted as needed to minimize disturbed areas without compromising existing drainage patterns. It is very important to not create new uncontrolled drainage outlets on steep slopes, especially within a watershed like Tyler Coulee.
- *Adapt Clusters to the Site* - By working out the objectives and problems of lot-street relationships in a systematic and generalized way in advance, opportunities arise to capitalize on the physical characteristics of the site to minimize impact and maximize amenities. Systematic lot layout avoids many of the pitfalls encountered by siting the roads before the lots, especially the error of siting the roads through the best home sites. Again, PUD provisions in the zoning code may provide the flexibility in zoning and subdivision standards needed to accomplish many of the following objectives in the context of a comprehensively designed subdivision:
  - Setbacks can be reduced to lessen the per-unit amount of paved area via shortened driveways and entry walks. For example, a setback of 20 feet is adequate to allow a car to be parked in the driveway without encroaching into the public right-of-way and it reduces driveway and walk pavement by 30% or more compared to a setback of 30 feet. Of course setbacks are often used to separate the home from the noise of the street. Reducing the

setback and maintaining this goal can be accomplished by carefully limiting the number of lots on a local access street, which, in turn, keeps traffic volume (and with it traffic noise) to a minimum.

- On street parking lanes can be reduced to one or eliminated on local access roads with less than 200 ADT (average daily traffic) on cul-de-sac streets and 400 ADT on two-way loops. This can reduce impermeable road surface area per unit by 25 to 30%. Moreover, the complete elimination of on street parking would still provide four parking spaces per unit (two in the garage and two in the driveway). If low ADT's can be maintained, moving vans and occasional overflows can be parked on a street without parking and not seriously obstruct routine and emergency access.
  - Sidewalks can be limited to one side or eliminated on local access roads with less than 200 ADT on cul-de-sac streets and less than 400 ADT on two-way loops. This can reduce impermeable cover per unit by 4 to 8%.
  - Shallow, grassed roadside swales can be used instead of curb and gutter storm sewer systems to handle runoff and provide snow storage. This is only feasible up to net densities of six to eight units per acre. Above that, it is difficult to commit land to swales. Placing roads high or along the ridges where the drainage area that contributes runoff to the swales is minimized can facilitate the use of roadside swales. An interesting fact is that in post-World War II housing developments, the use of such roadside swales was standard. It often resulted in a net decrease in runoff and soil loss levels compared to those generated by the predevelopment agricultural conditions. The choice of vegetation for the swales is critical to minimizing maintenance. Properly designed transitions between the pavement edge and turf grass areas are key to the success of roadside swales. Where off street parking is a concern, turf reinforcement systems such as pavers and turf reinforcement mat systems along the pavement edge can be considered.
- *Adapt Lots to the Site* – Building to lot relationships should be designed to match site conditions and meet hydrologic objectives. PUDs, cluster development, and the use of restrictive covenants, separately or in combination, provide flexibility to create unit lot prototypes that have the potential to reduce, rather than increase, runoff peaks, volumes and velocities. Examples of the concept follows:
    - Slope mapping as discussed previously can be used to design unit-lot relationships in the context of the overall site topography. As much as possible unit floor plans should be compatible with site slopes. Schematic cross sections through various street-lot combinations will help develop concepts that match the site.
    - Pavement and roof areas can be minimized. Very often, zoning requirements imply large amounts of paving or do not restrict all of the impervious surfaces on home sites. However, measures such as deed

restrictions could be an appropriate tool in limiting total impervious surface area below that permitted by zoning. It is not unusual to have 2,200 square feet (ft<sup>2</sup>) of total impermeable surface (roofs, walks, drives, patio, etc.) on a ¼-acre lot. It is possible to reduce the amount of impervious surfaces by as much as 25% compared to typical development and still maintain single level building footprints (house plus garage) of 1,400 to 1,600 ft<sup>2</sup> per unit. Living space totals can also be increased to 1,800 to 3,300 ft<sup>2</sup> by using split-entry, two-story or walkout floor plans.

- PUD provisions can be used for cluster development to enable the use of narrower lot frontages so that the area of road pavement required to serve a given lot area can be reduced. With careful site planning, this can significantly reduce the per-unit amount of impervious surface generated by development. Clustering will also yield further savings by reducing the cost of street and utility extension needed to serve a given number of lots.
- Rethinking conventional commercial development plans has great potential for reducing impervious surfaces in commercial development. In a typical "strip" commercial development very little natural open space is maintained due to the amount of space consumed by parking. In addition, this type of site design encourages automobile use. If the linear nature of developments is changed to a "U shape", parking needs can be reduced. Additionally, compact and pervious overflow parking spaces can be used to minimize parking area needs. An added advantage is that such designs encourage pedestrian traffic by arranging the buildings in a U shape, reducing walking distances.

## **7.0 Master Plan Summary and Opinion of Probable Cost**

One additional and the modification of one existing regional detention basin is recommended. A new regional detention basin is recommended near the intersection of Burnt Boat Drive & Tyler Parkway. An outlet modification is also recommended for Valley Drive Detention Basin West. The construction of two new extended detention basins are intended to provide water quality improvement and reduce peak flows at Morgan Court and below Tyler Parkway (TC 2). A new channel through Pioneer Park is needed to reduce the frequency of flooding. Repairs to the open channel between the Boat Drive & Tyler Parkway outlet and Clairmont Road are also necessary. The Opinion of Probable Cost for the construction of the features is as follows:

- An estimated \$235,000 for a new regional detention basin near the intersection of Burnt Boat Drive & Tyler Parkway (Table 8);
- An estimated \$146,000 for improvements to the Valley Drive Detention Basin West (Table 9);

- An estimated \$192,000 for construction of the Pioneer Park channel (Table 10);
- An estimated \$110,000 for construction of the Burnt Boat Drive & Tyler Parkway outlet channel (Table 11);
- An estimated \$82,000 for extended detention basins at the outlet of Morgan Court (TC 3-3) and the outlet of subwatershed TC 2 at approximately \$41,000 each (Table 12)
- As many as 20 additional on-site extended detention basins for an approximate total of \$820,000 (assumed to be constructed in the natural valley with minimal adjustments).

The total estimated Opinion of Probable Cost for these is \$1,626,000. These Opinions of Probable Cost are exclusive of land acquisition or easement costs and do not include appurtenant items such as roads. The cost of additional geotechnical analysis or lining up the upstream embankment face of the detention basins is also excluded.

Table 8

**BURNT BOAT DRIVE & TYLER PARKWAY DETENTION BASIN  
OPINION OF PROBABLE COST**

Description	Unit	Amount	Unit Cost	Total Cost
36" R.C.P. CL. II	L.F.	50	\$55.00	\$2,750.00
60" x 36" Eccentric Reducer	Each	1	\$1,000.00	\$1,000.00
36" Flared Inlet	Each	1	\$770.00	\$770.00
Trash Guard	Each	1	\$760.00	\$760.00
Excavation	C.Y.	35500	\$3.00	\$106,500.00
Compaction	C.Y.	200	\$3.00	\$600.00
Riprap	Ton	450	\$55.00	\$24,750.00
Turf Establishment	S.Y.	5000	\$7.30	\$36,500.00
Erosion Control	L.S.	1	\$500.00	\$500.00
			Subtotal	\$174,130.00
Contingency (20%)				\$34,830.00
Engineering Design, Construction Observation and Surveying @ 15%				\$26,120.00
			Total	\$235,080.00

**Table 9**

**VALLEY DRIVE DETENTION BASIN WEST  
OPINION OF PROBABLE COST**

<b>Description</b>	<b>Unit</b>	<b>Amount</b>	<b>Unit Cost</b>	<b>Total Cost</b>
48" R.C.P. CL. II	L.F.	260	\$100.00	\$26,000.00
24" R.C.P. CL. III	L.F.	50	\$25.00	\$1,250.00
24" Flare Inlet	Each	1	\$385.00	\$385.00
Trash Guard	Each	1	\$425.00	\$425.00
72" diameter manhole	L.F.	22	\$550.00	\$12,100.00
72" Diameter Grate Inlet	Each	1	\$1,600.00	\$1,600.00
Casting Assembly-Manhole R&C	Each	1	\$1,160.00	\$1,160.00
Excavation	C.Y.	1000	\$3.00	\$3,000.00
Compaction	C.Y.	200	\$3.00	\$600.00
Riprap	Ton	450	\$55.00	\$24,750.00
Turf Establishment	S.Y.	5000	\$7.30	\$36,500.00
Erosion Control	L.S.	1	\$500.00	\$500.00
			Subtotal	\$108,270.00
Contingency (20%)				\$21,650.00
Engineering Design, Construction Observation and Surveying @ 15%				\$16,240.00
			Total	\$146,160.00

**Table 10**

**PIONEER PARK CHANNEL RESTORATION**

<b>Description</b>	<b>Unit</b>	<b>Amount</b>	<b>Unit Cost</b>	<b>Total Cost</b>
Excavation	C.Y.	5000	\$3.00	\$15,000.00
Compaction	C.Y.	500	\$3.00	\$1,500.00
Riprap	Ton	1120	\$55.00	\$61,600.00
Turf Establishment	S.Y.	8600	\$7.30	\$62,780.00
Erosion Control	L.S.	1	\$1,500.00	\$1,500.00
			Subtotal	\$142,380.00
Contingency (20%)				\$28,480.00
Engineering Design, Construction Observation and Surveying @ 15%				\$21,360.00
			Total	\$192,220.00

Table 11

**BURNT BOAT DRIVE & TYLER PARKWAY OUTLET CHANNEL  
OPINION OF PROBABLE COST**

Description	Unit	Amount	Unit Cost	Total Cost
Excavation	C.Y.	5800	\$3.00	\$17,400.00
Compaction	C.Y.	580	\$3.00	\$1,740.00
Drop Structures	L.S.	2	\$2,500	\$5,000.00
Turf Establishment	S.Y.	7630	\$7.30	\$55,700.00
Erosion Control	L.S.	1	\$1,500.00	\$1,500.00
			Subtotal	\$81,340.00
Contingency (20%)				\$16,270.00
Engineering Design, Construction Observation and Surveying @ 15%				\$12,200.00
			Total	\$109,810.00

Table 12

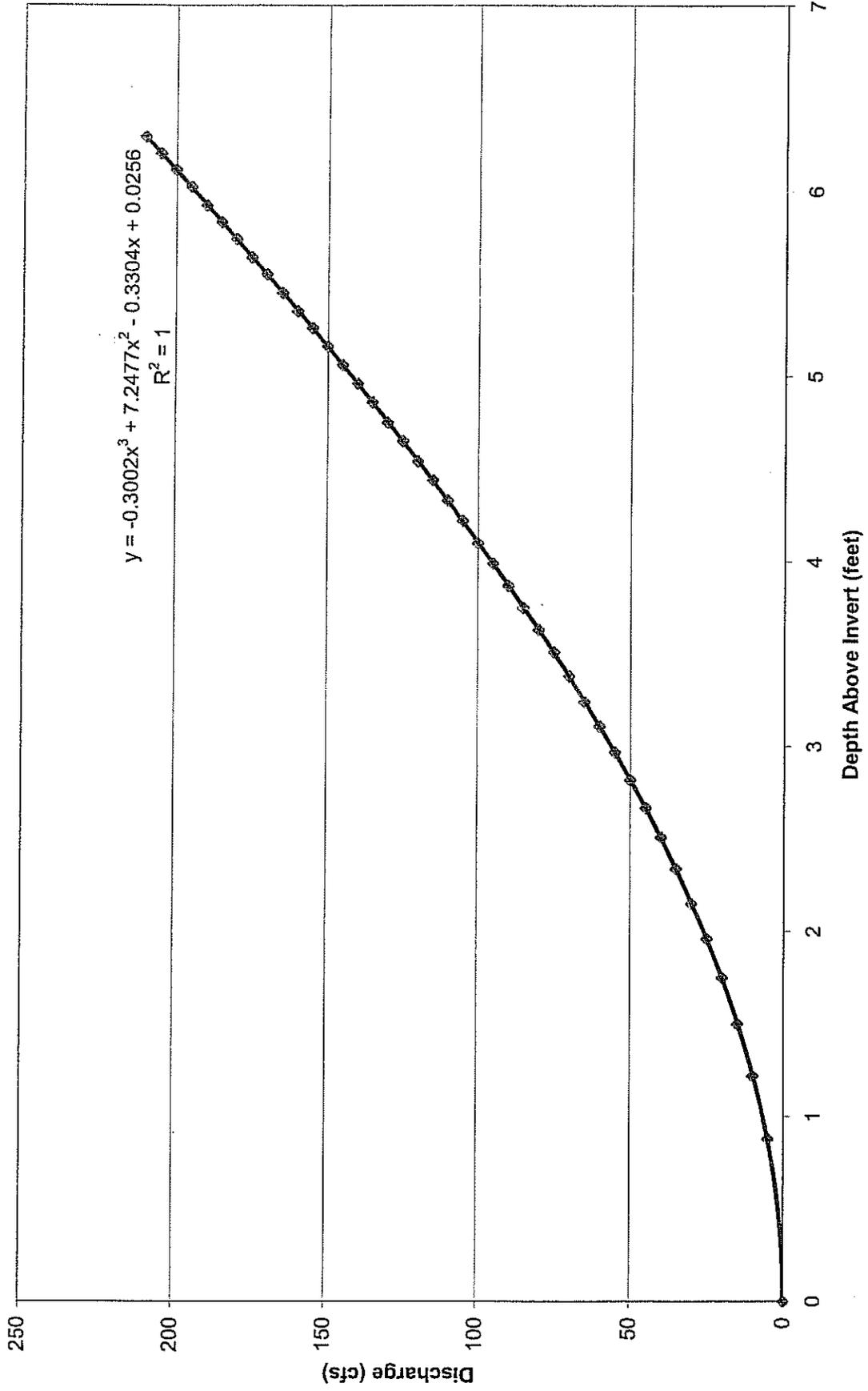
**TYPICAL EXTENDED DETENTION POND CONSTRUCTION**

Description	Unit	Amount	Unit Cost	Total Cost
24" R.C.P. CL. III	L.F.	50	\$25.00	\$1,250.00
24" Flare Inlet	Each	1	\$385.00	\$385.00
48" R.C.P. CL. II	L.F.	50	\$100.00	\$5,000.00
72" diameter manhole	L.F.	10	\$550.00	\$5,550.00
Trash Guard	Each	1	\$425.00	\$425.00
Casting Assembly-Manhole R&C	Each	1	\$1,160.00	\$1,160.00
Excavation	C.Y.	3500	\$3.00	\$9,680.00
Compaction	C.Y.	350	\$3.00	\$1,050.00
Riprap	Ton	70	\$55.00	\$3,850.00
Turf Establishment	S.Y.	200	\$7.30	\$1,460.00
Erosion Control	L.S.	1	\$500.00	\$500.00
			Subtotal	\$30,260.00
Contingency (20%)				\$6,050.00
Engineering Design, Construction Observation and Surveying @ 15%				\$4,540.00
			Total	\$40,850.00

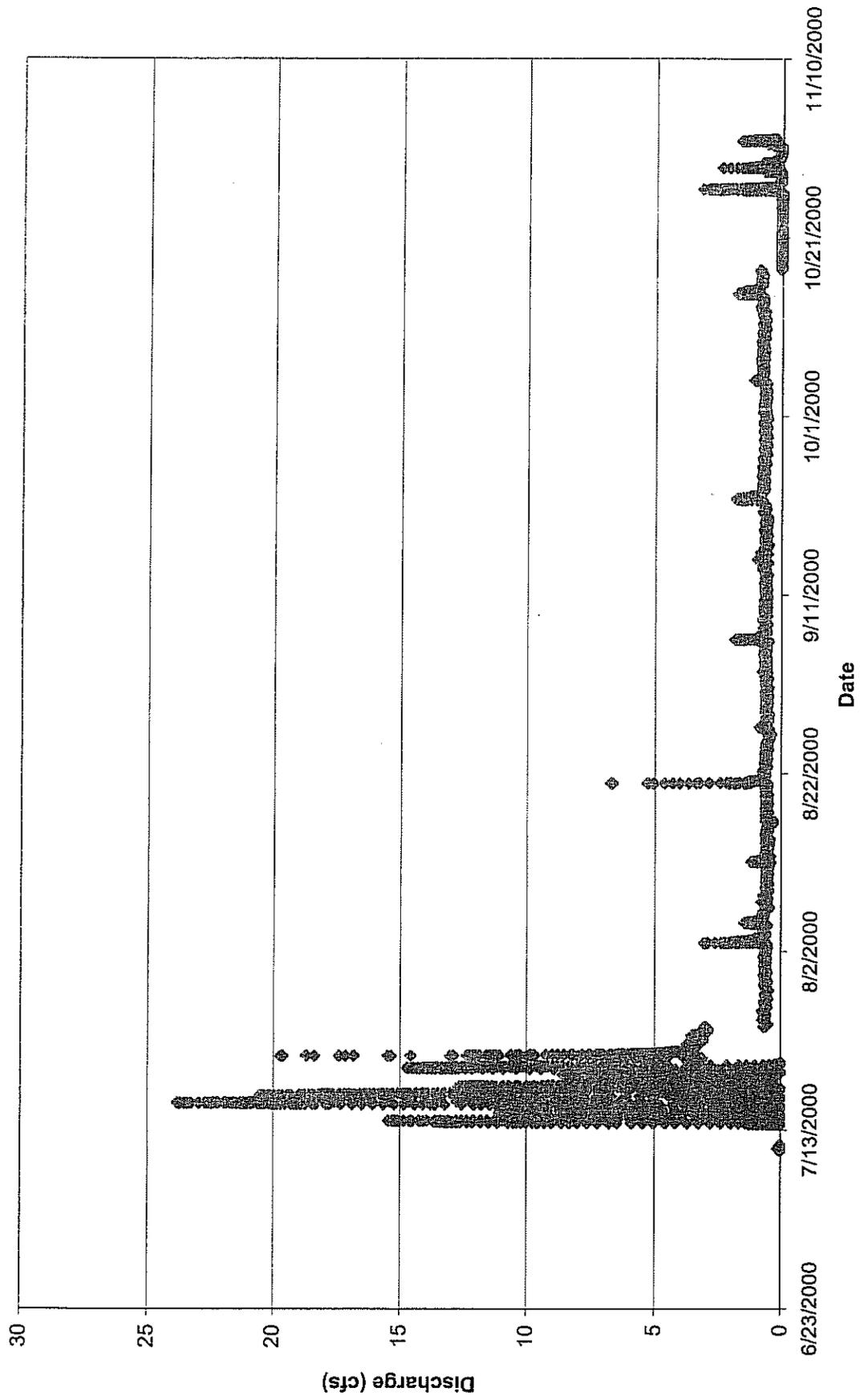
**APPENDIX A**

**Rainfall and Hydrologic Data**

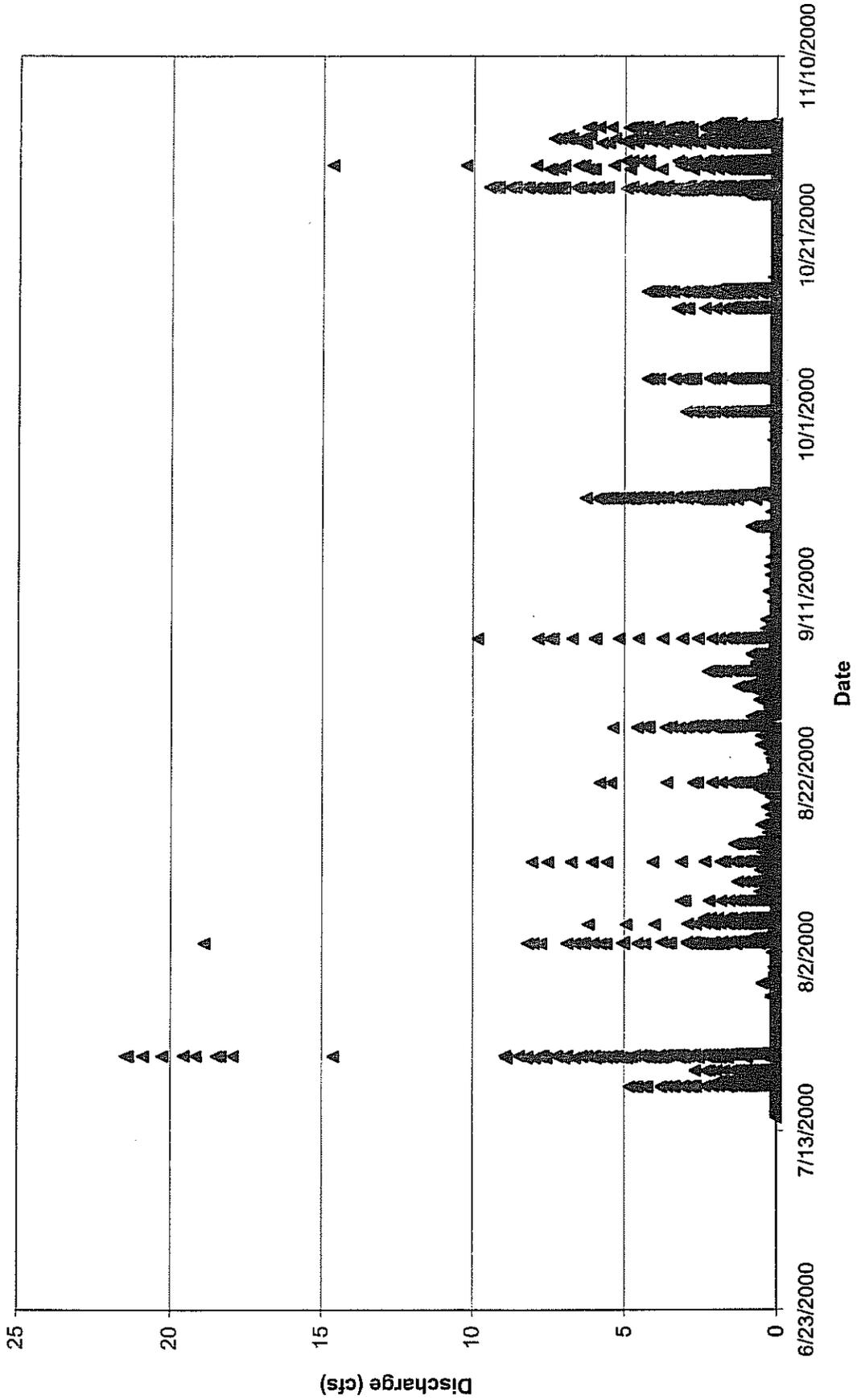
Clairmont Road Rating Curve



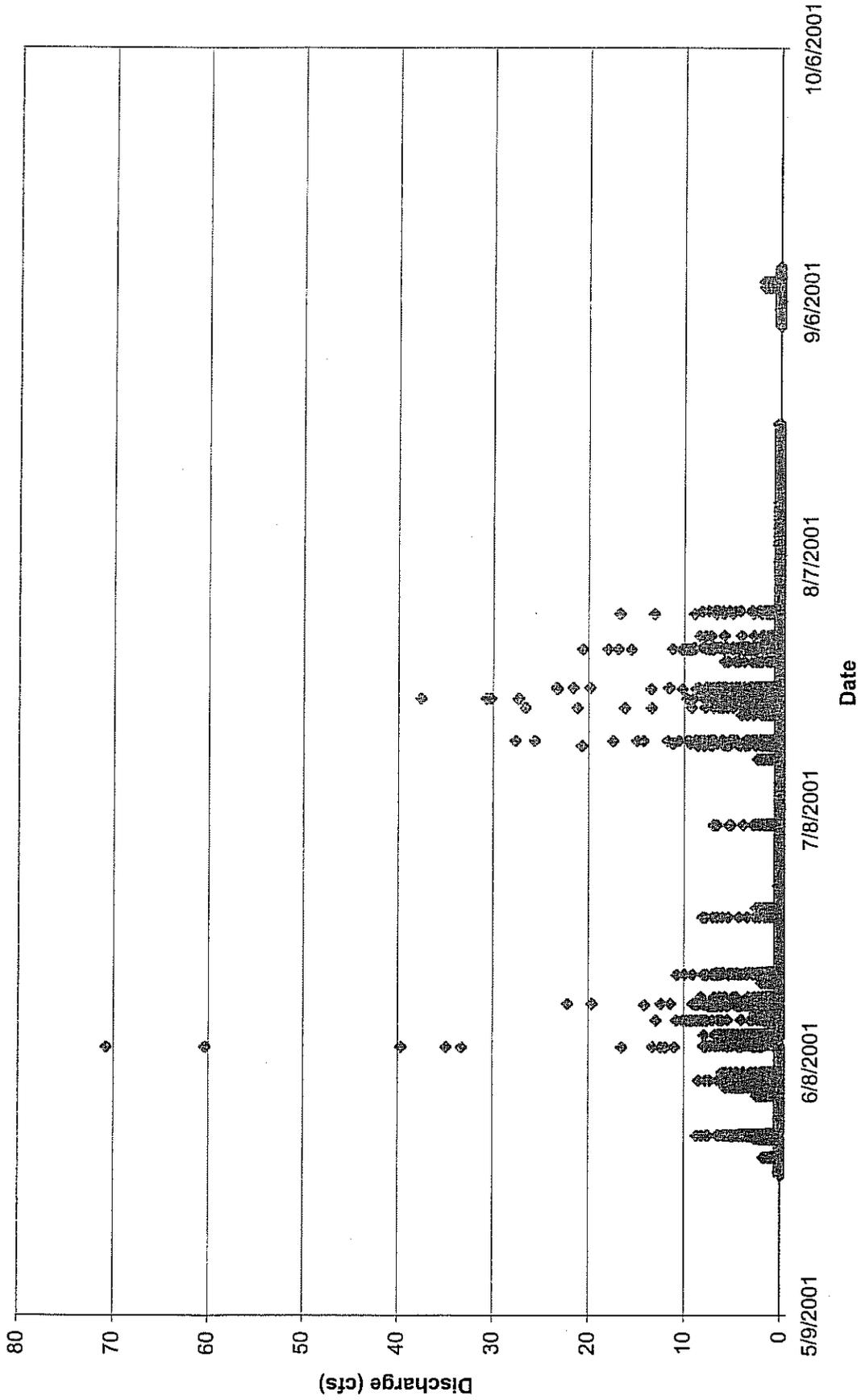
# Year 2000 Clairmont Road Discharge



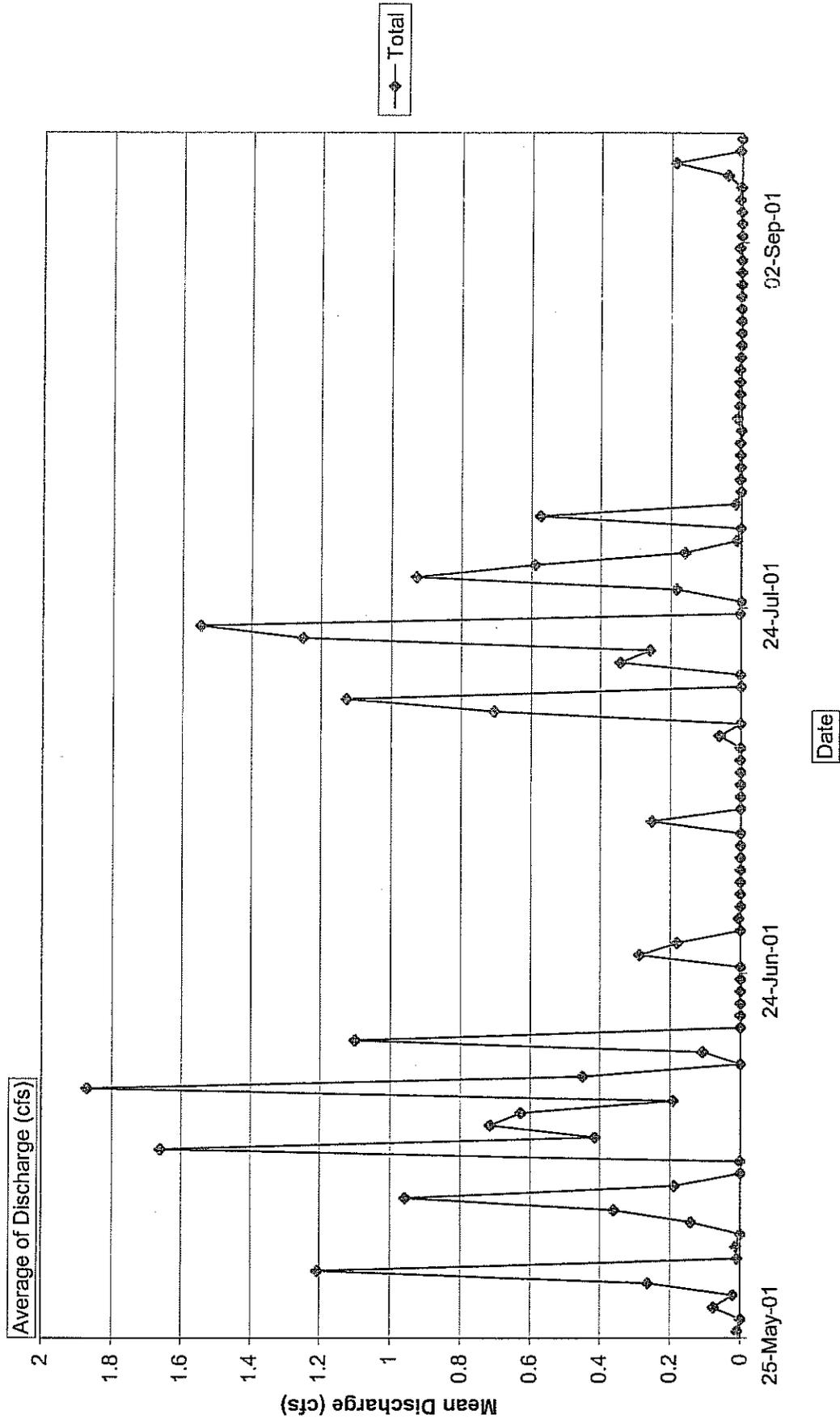
# Year 2000 Burnt Boat Drive & Tyler Parkway Discharge



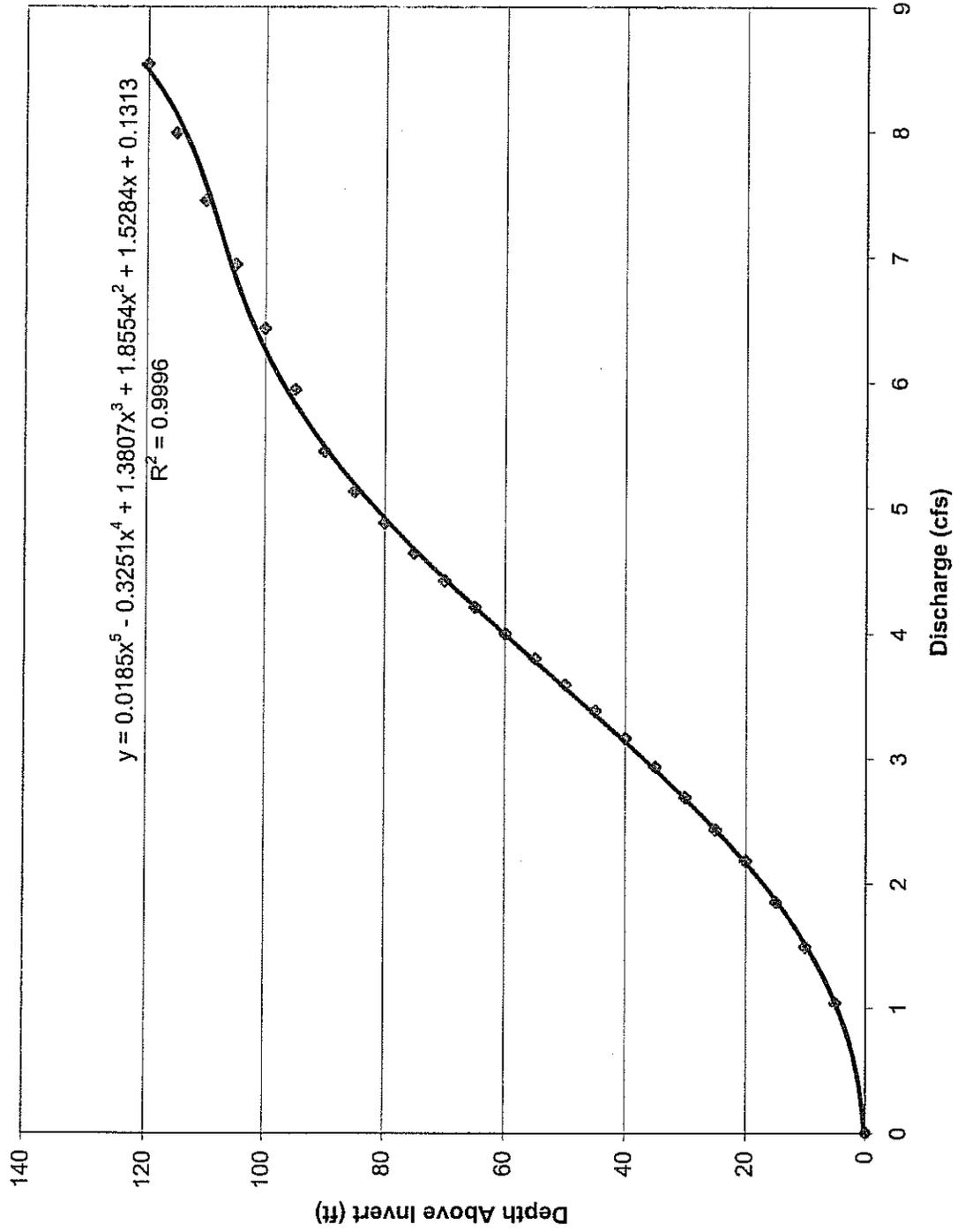
# Year 2001 Burnt Boat Drive & Tyler Parkway Discharges



2001 Burnt Boat Drive & Tyler Parkway Daily Mean Discharge

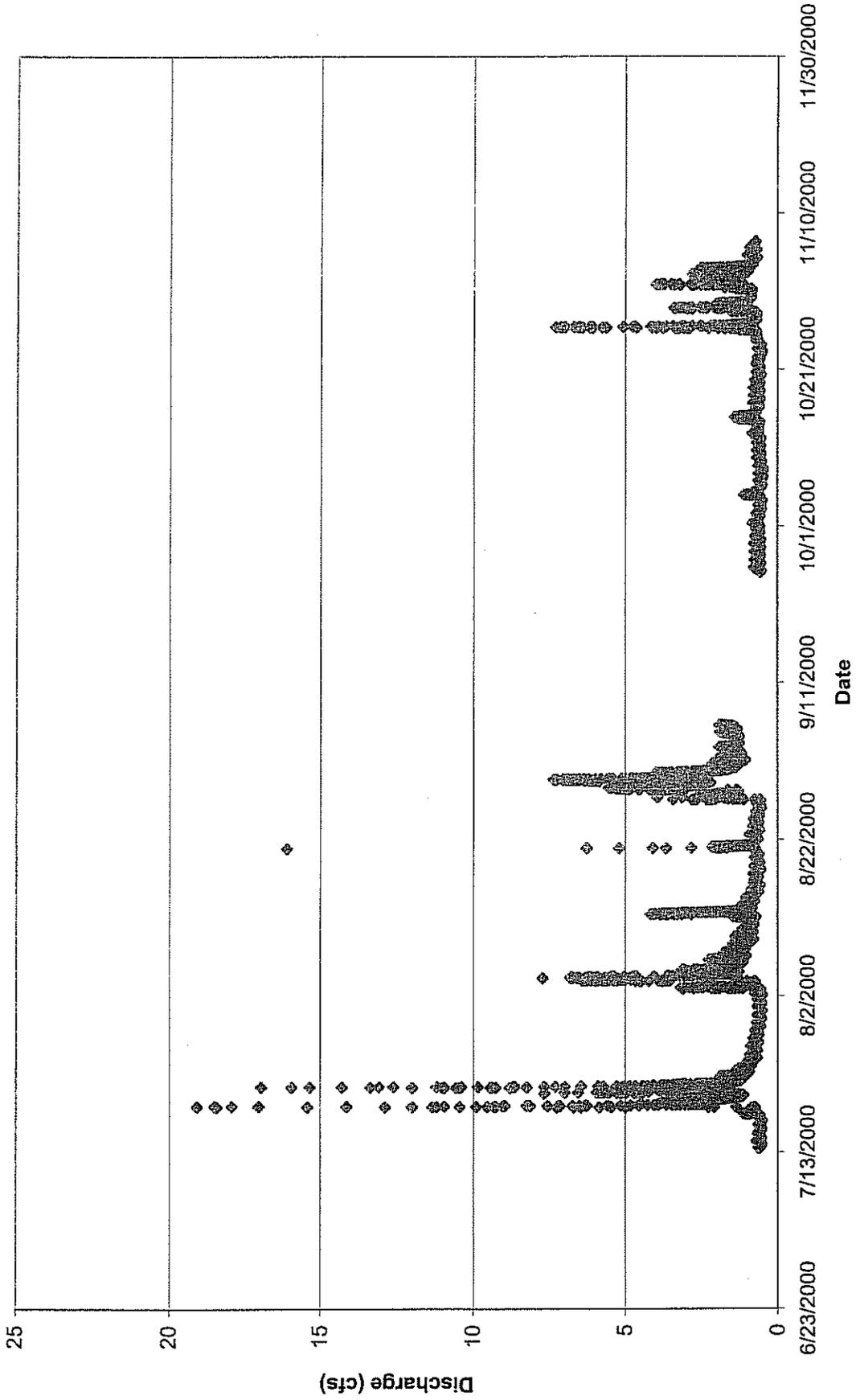


Valley Drive Detention Rating Curve

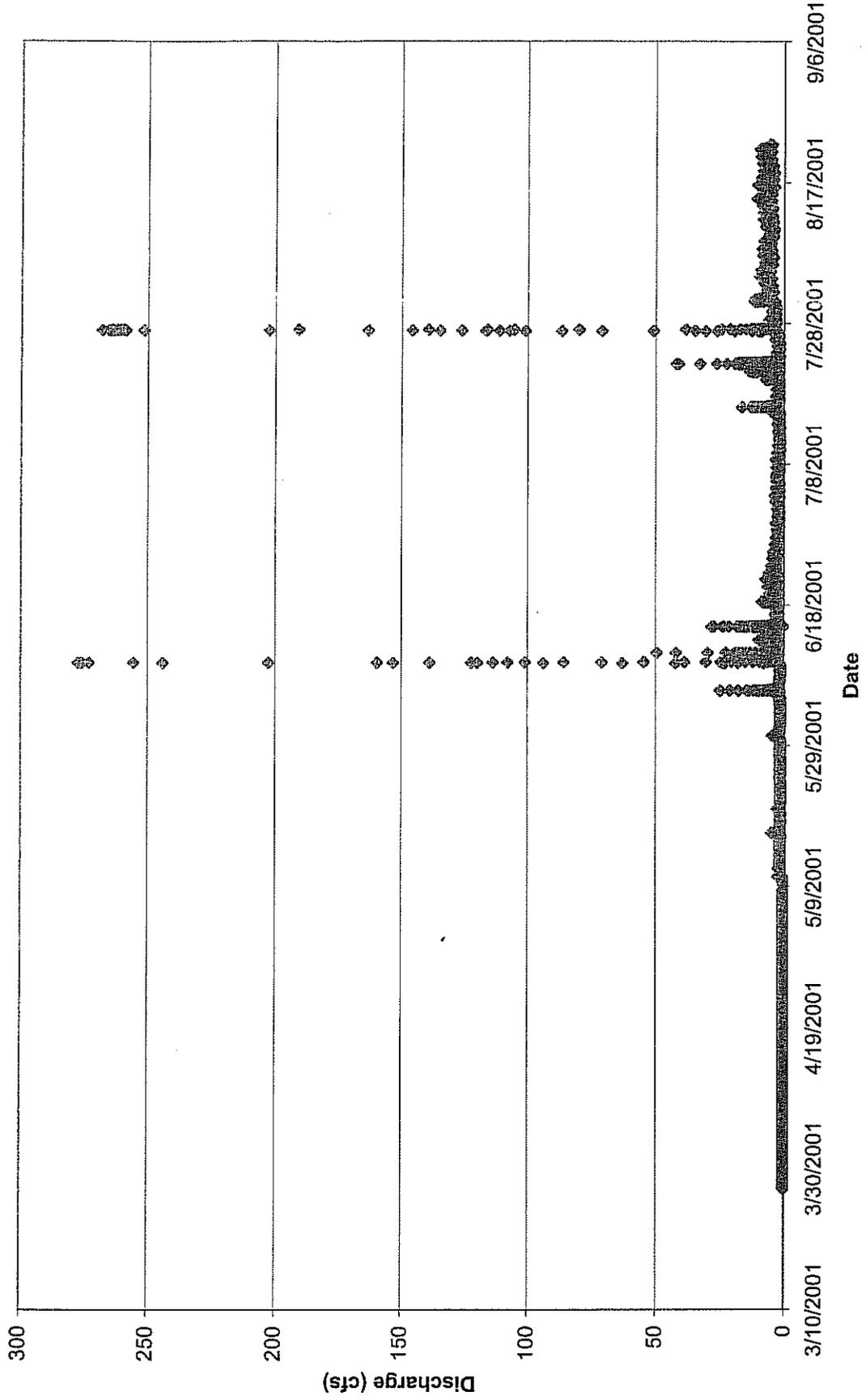


◆ Discharge (cfs)  
— Poly. (Discharge (cfs))

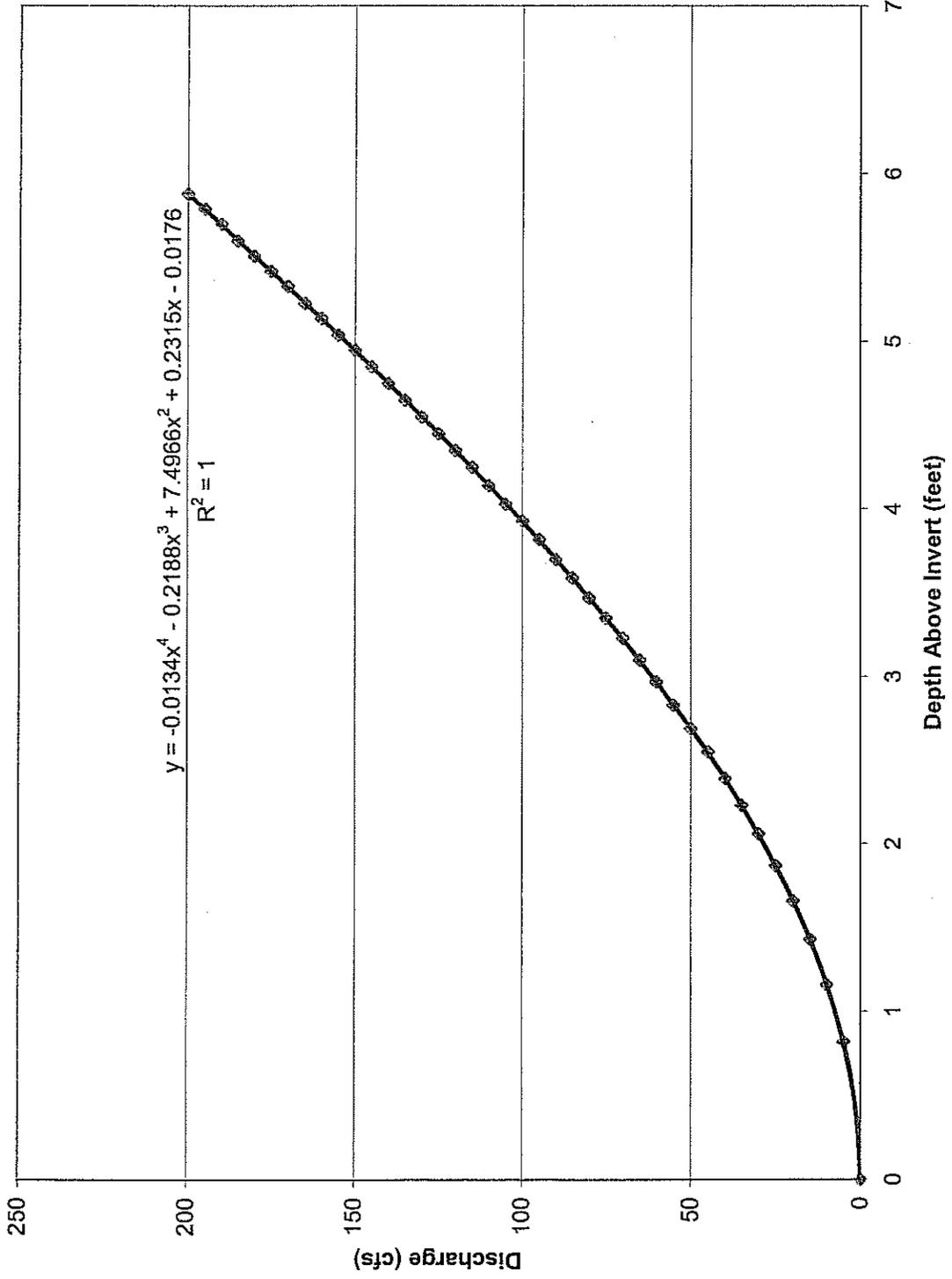
Year 2000 Valley Drive Detention Discharge (cfs)



# Year 2001 Valley Drive Detention Discharge



Burnt Boat Drive & Tyler Parkway Rating Curve



# Year 2001 Clairmont Road Discharge

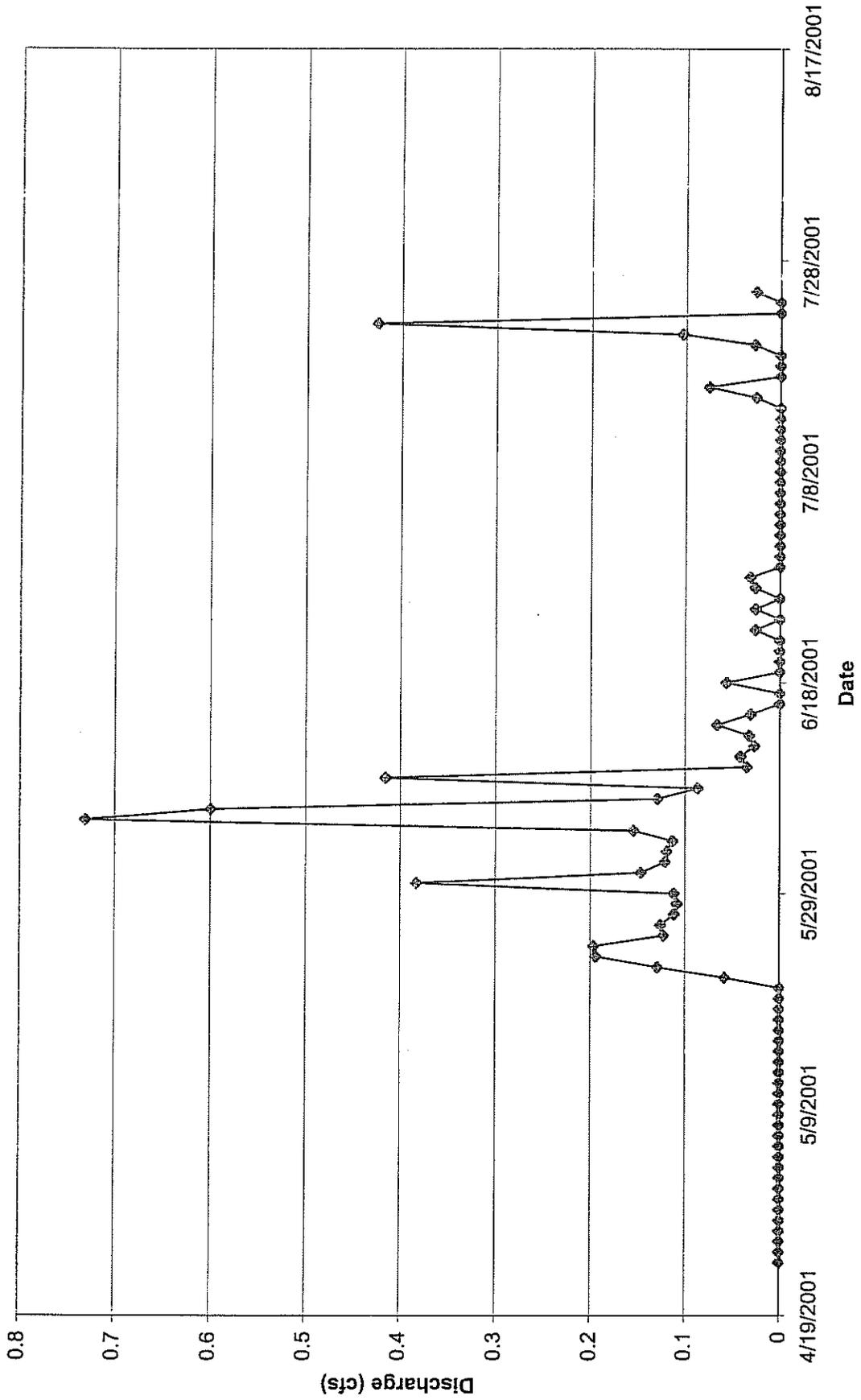


Figure  
Valley Drive Detention Basin Time Series (June 5, 2001)

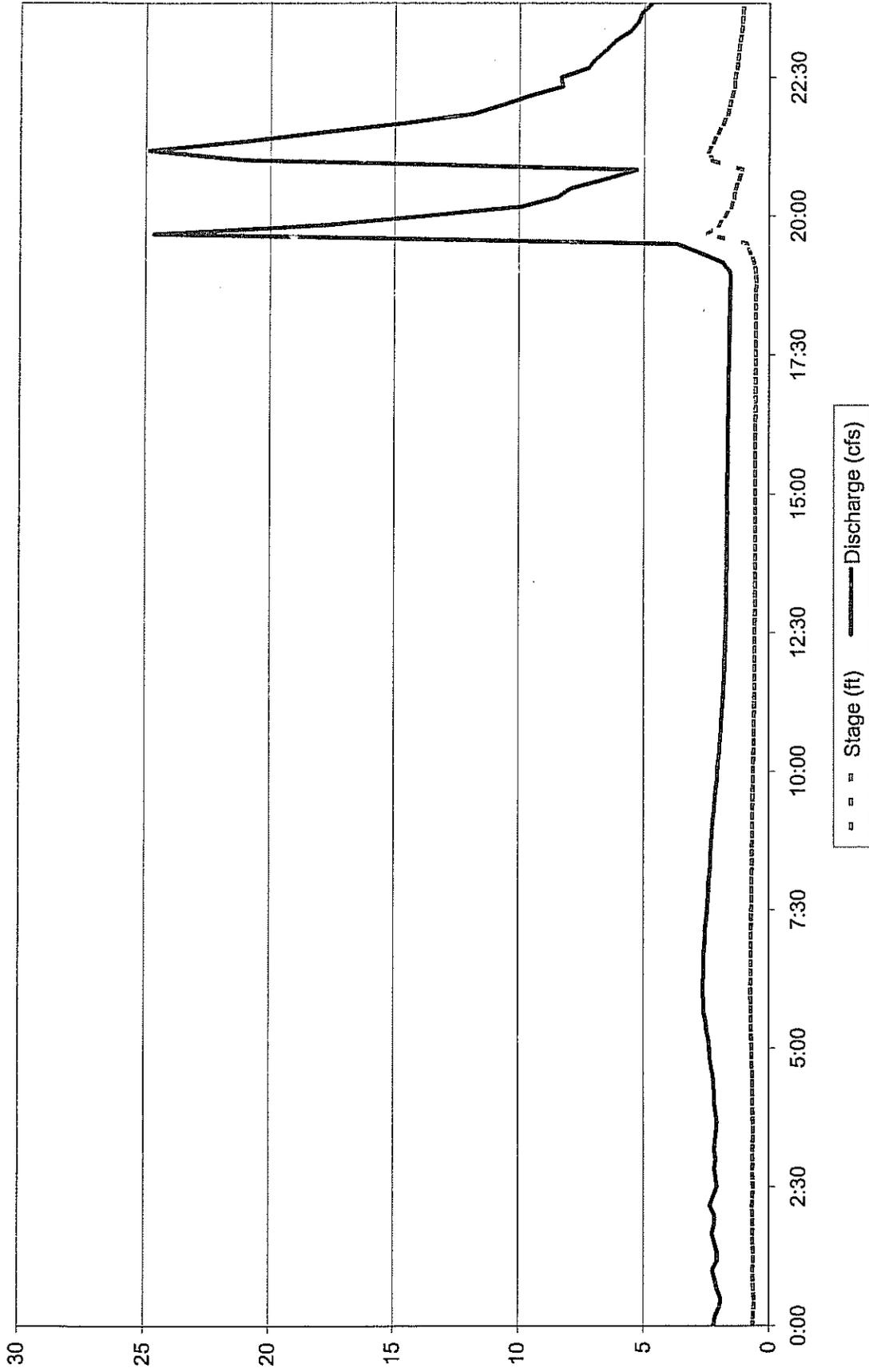
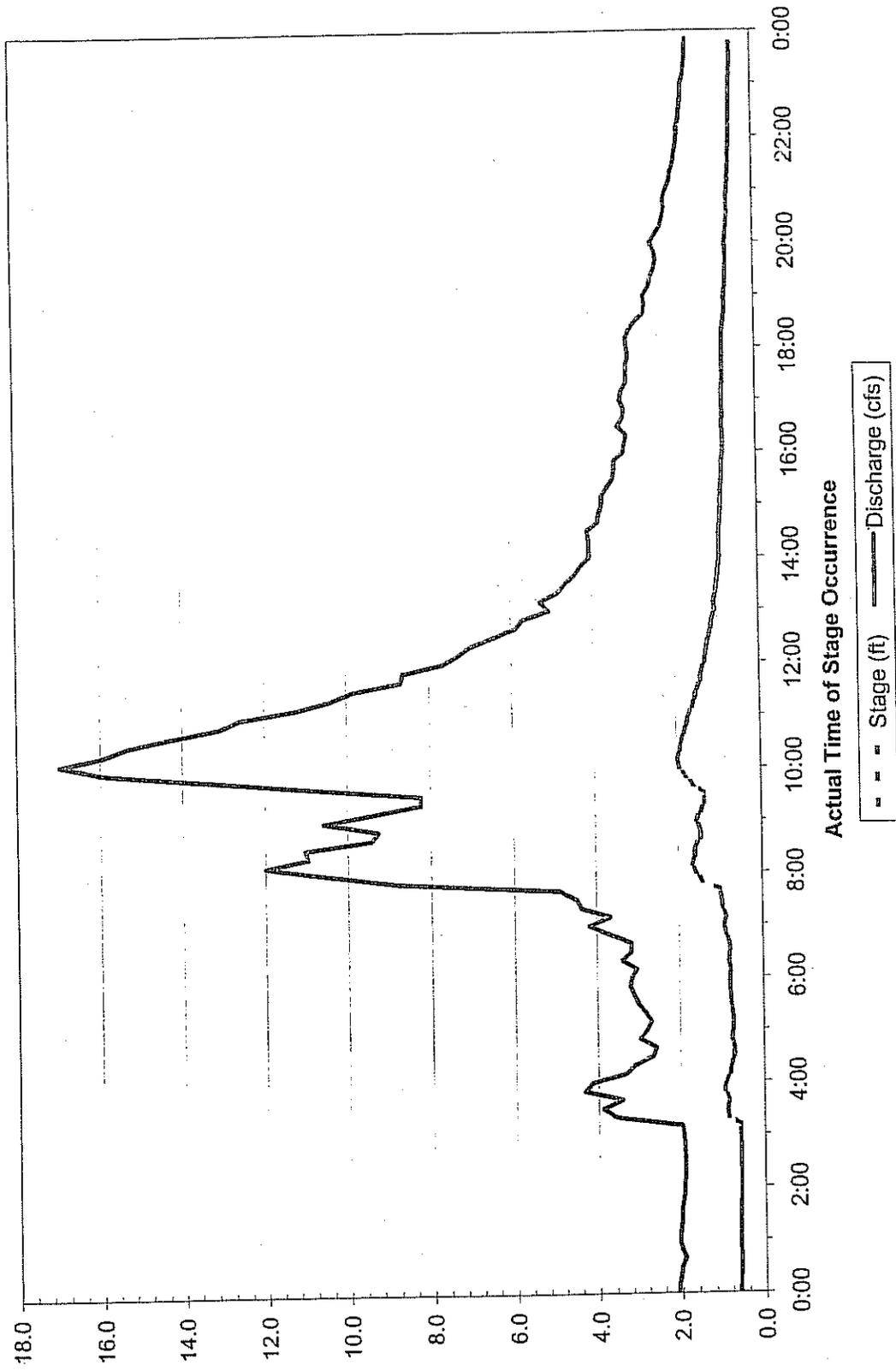
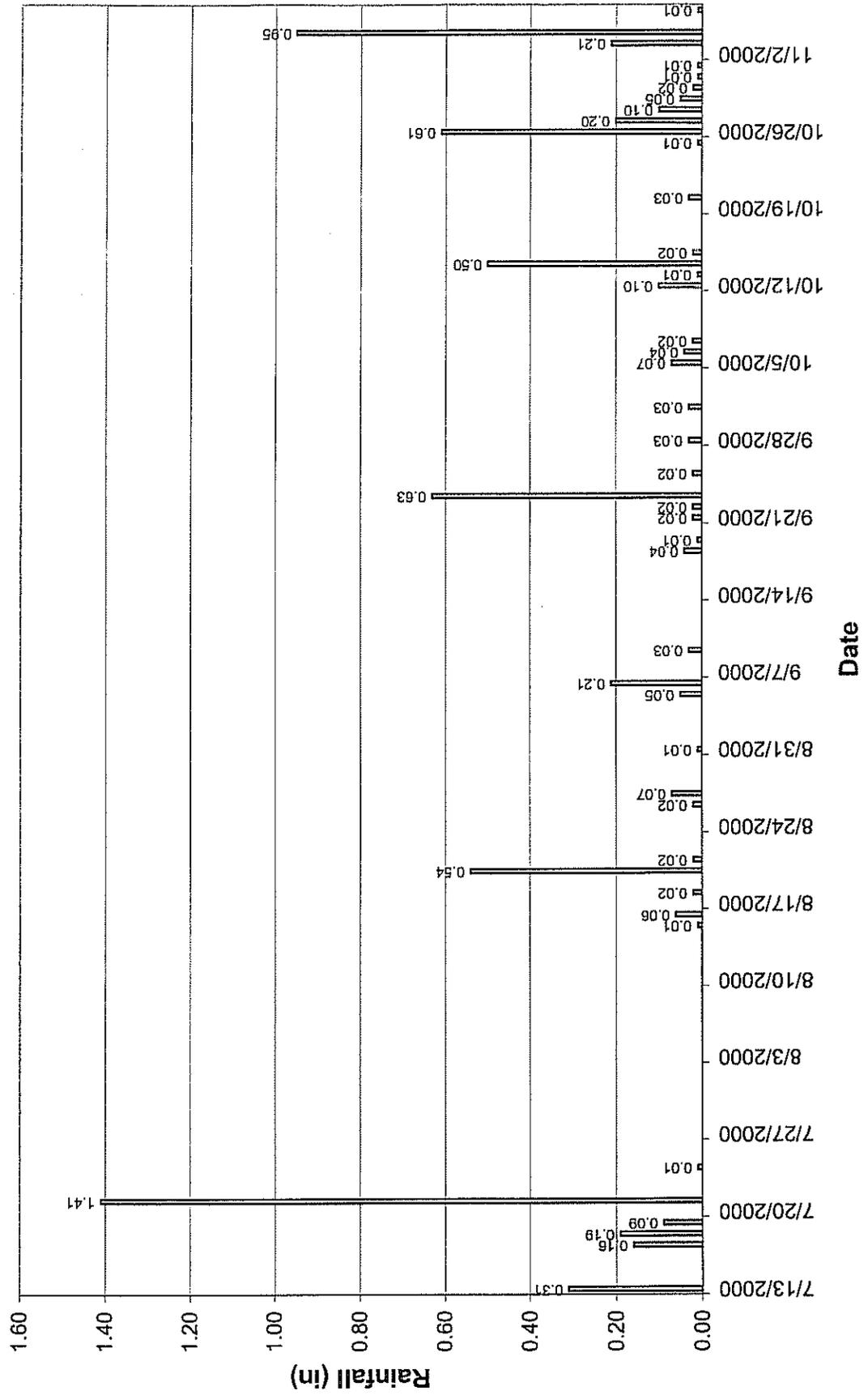


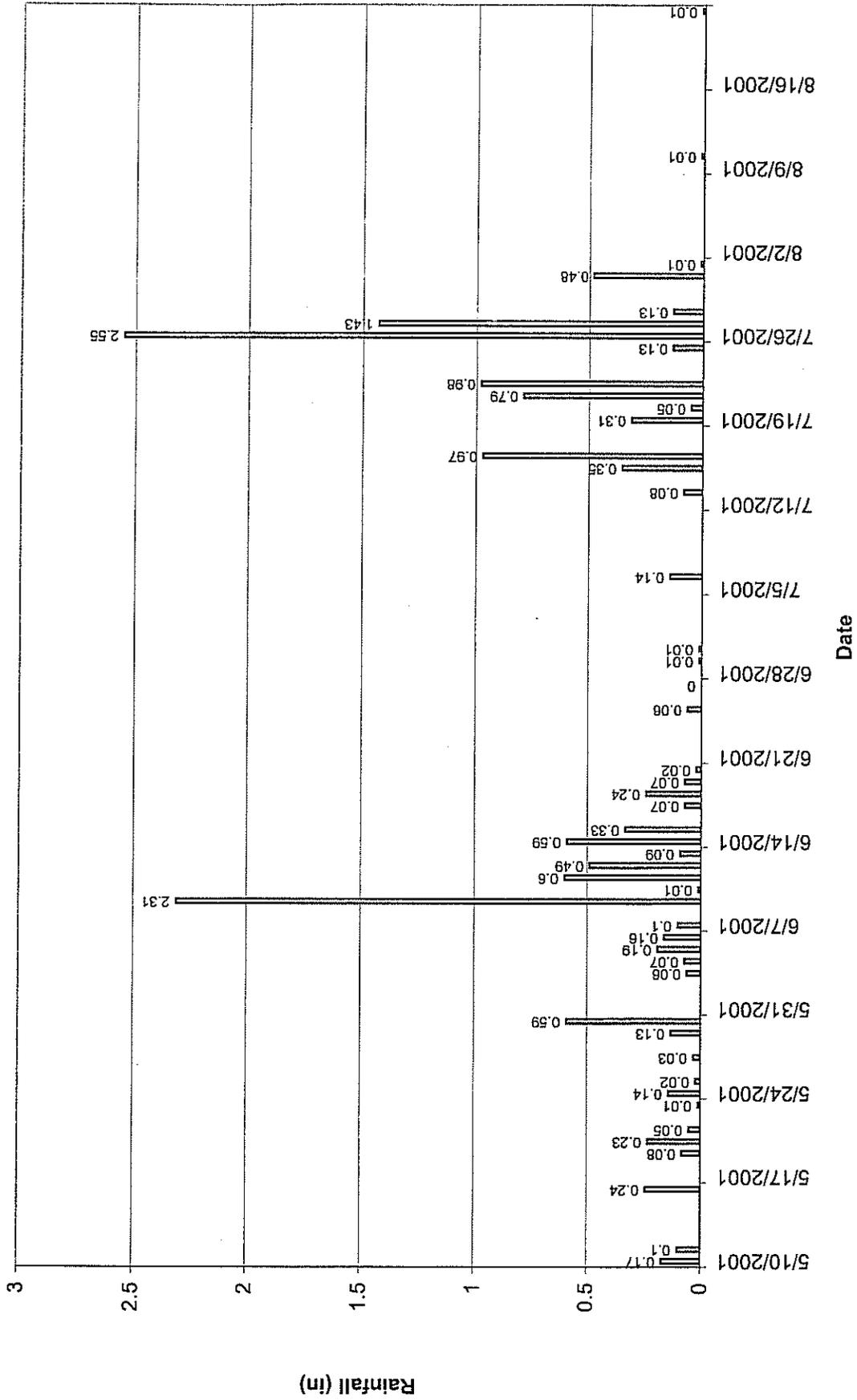
Figure 6  
Valley Drive Detention Basin Time Series (July 21, 2000)



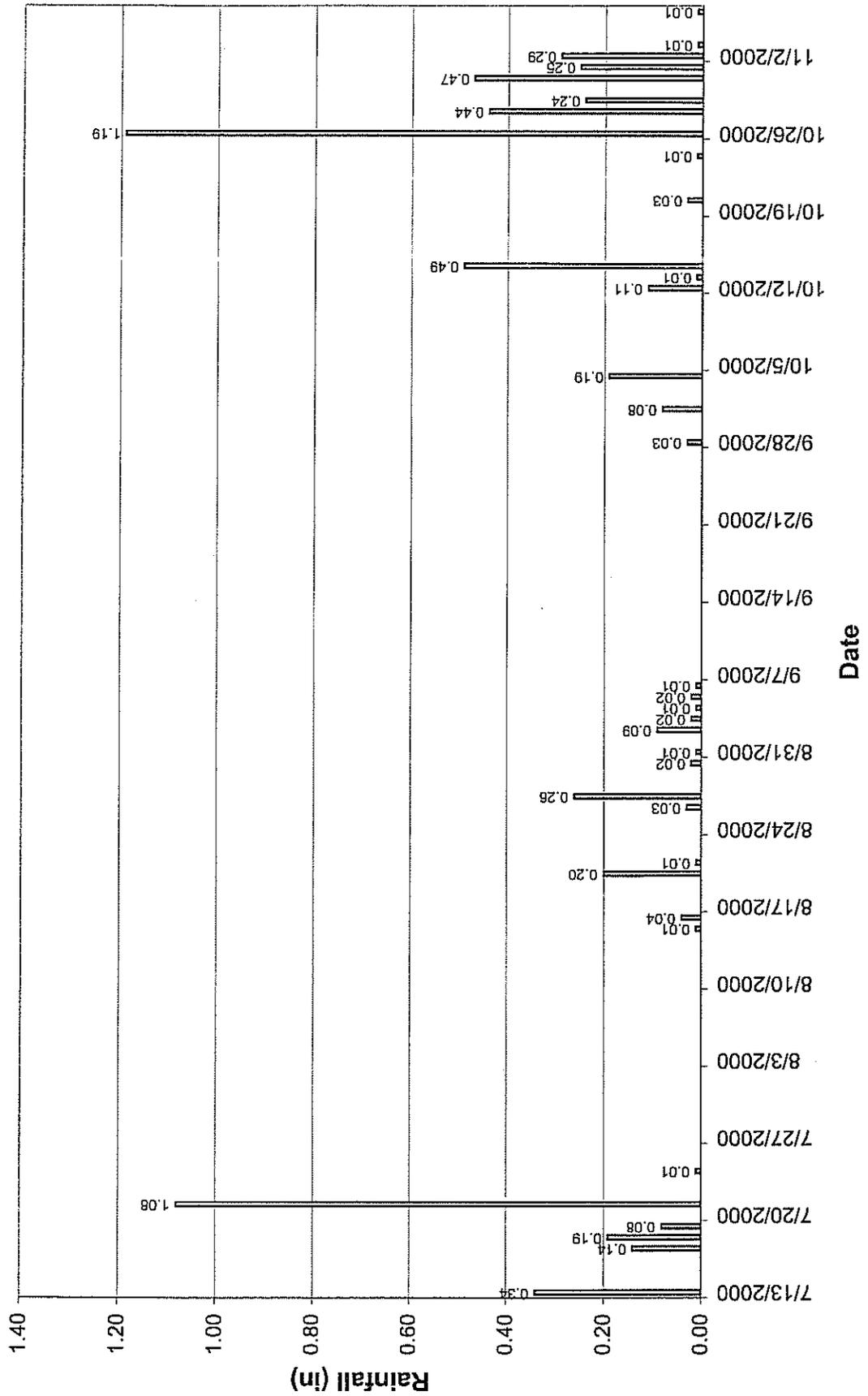
# Ducks Unlimited Daily Rainfall Totals 2000



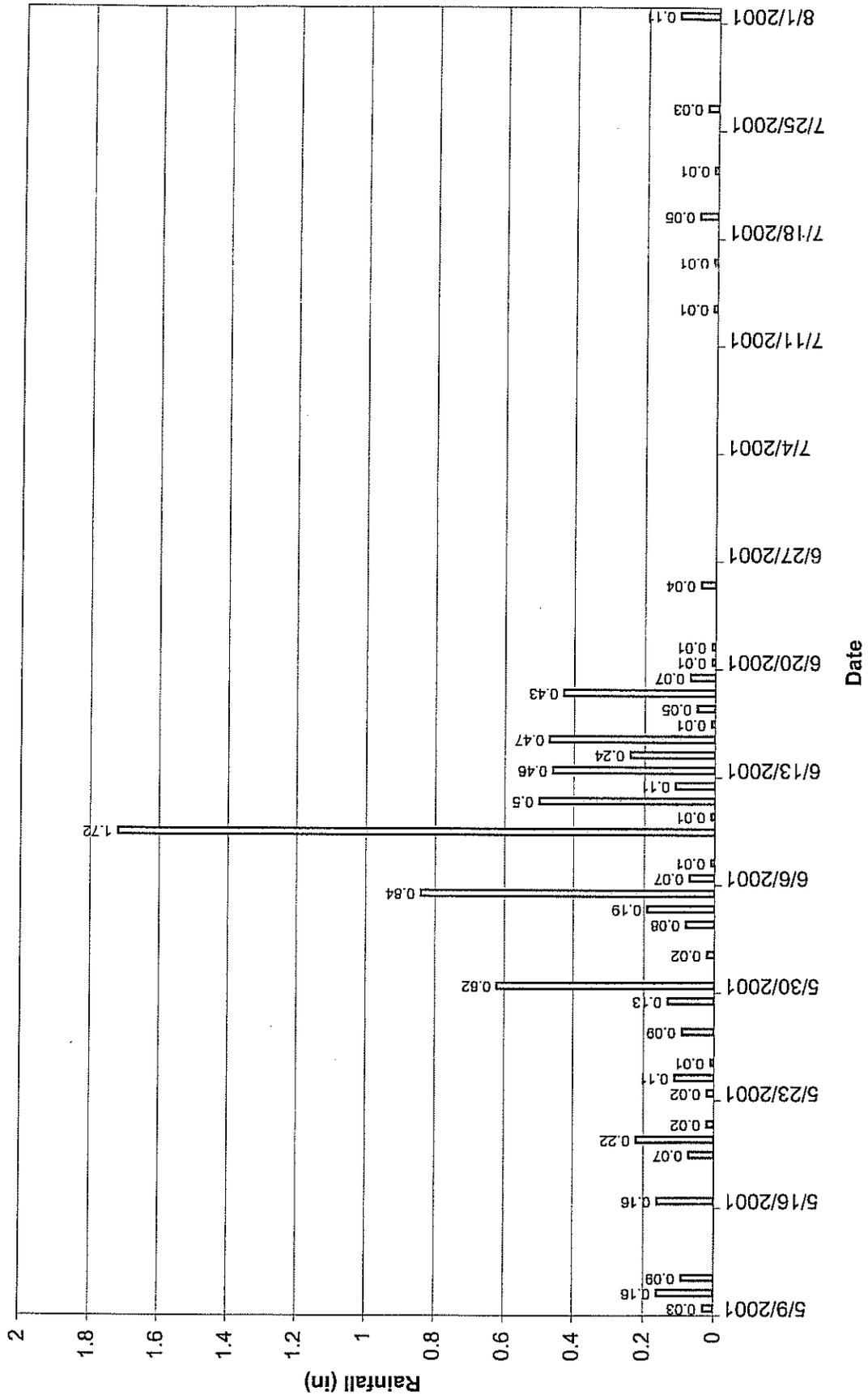
# Ducks Unlimited Daily Rainfall Totals 2001



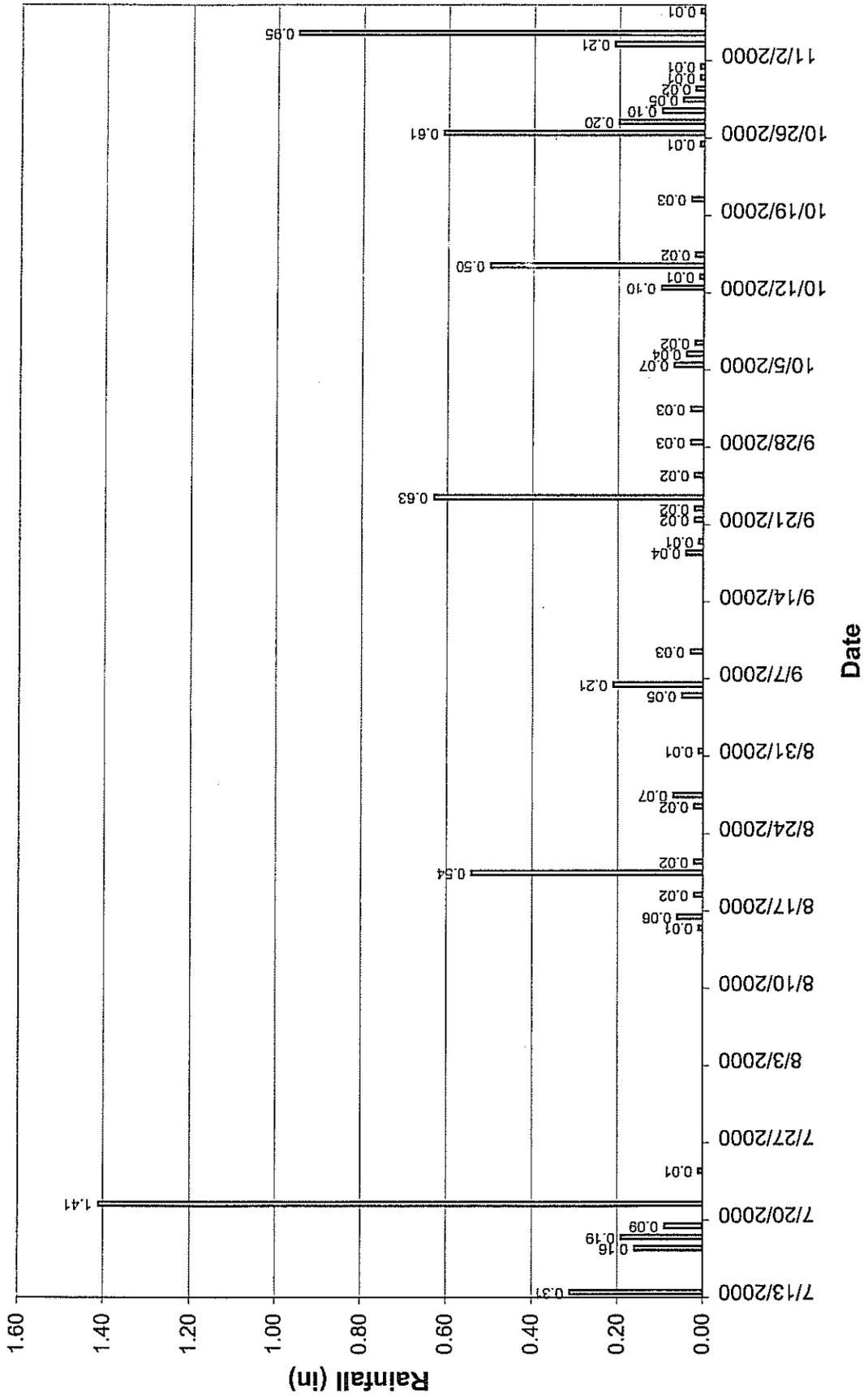
# Middle School Daily Rainfall Totals 2000



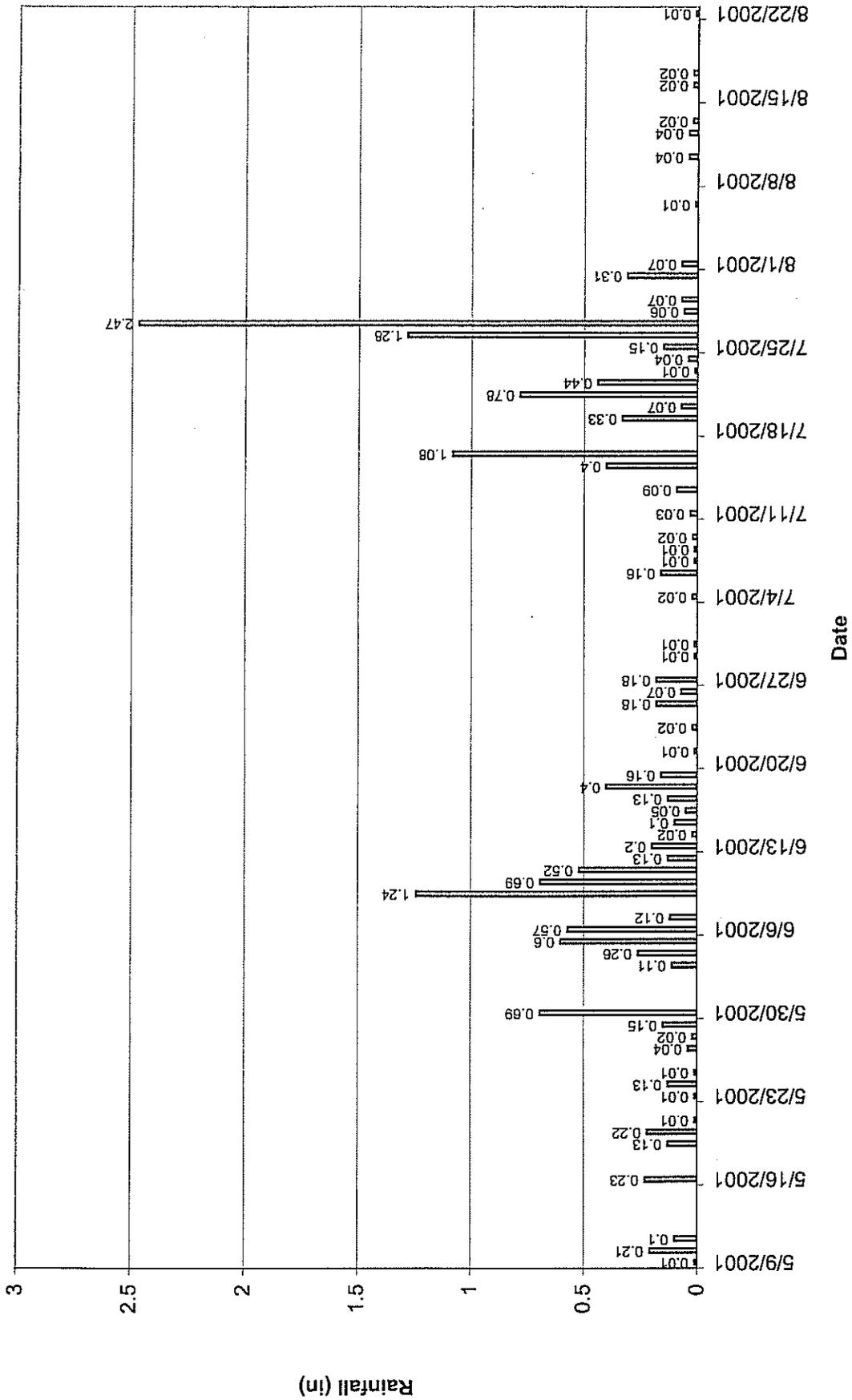
# Middle School Daily Rainfall Totals 2001



# Valley Drive Daily Rainfall Totals 2000



# Valley Drive Daily Rainfall Totals 2001



## **APPENDIX B**

### **Description of Water Quality Parameters**

## **Solids**

### Total Suspended Solids (TSS)

Total Suspended Solids (TSS) represent the amount of particulate matter (regardless of size) filtered from the water column. In essence, TSS is comprised of all suspended particulate matter that is not dissolved. The problems caused by suspended solids in transit and after settling includes turbidity, aquatic biota habitat destruction, transport of adsorbed pollutants, benthic accumulation, and direct adverse impact on aquatic organisms. Greater concentrations of TSS are expected from sampling sites with developing drainage areas.

### Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) represent the amount of organic and inorganic material that is dissolved solution in water. A direct relationship exists between measured conductivity and TDS. High TDS generally indicated high turbidity and poor water clarity.

## **Nutrients**

Nutrients of particular importance are phosphorus and nitrogen. These nutrients accelerate eutrophication in quiescent waters, exert toxic effects on aquatic organisms (ammonia), produce highly organic sediments, affect dissolved oxygen concentration, aid in the shift toward less desirable aquatic organisms and impact groundwater (nitrate).

### Total Phosphorus (TP) and Dissolved Phosphorus (DP)

Total Phosphorus represents the amount of orthophosphates, polyphosphates, and organic phosphate in solution. Phosphorus stimulates the growth of plankton and aquatic plants. If excess of phosphorus enters the waterway, algae and aquatic plants can grow rapidly, cause excessive plant growth and upon death, use up large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. The rapid growth of aquatic vegetation can cause the death and decay of vegetation and aquatic life because of the decrease in dissolved oxygen levels. Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could

occur from extremely high levels of phosphate. Orthophosphates are available for immediate biological uptake.

#### Total Nitrogen (TN), Total Kjeldahl Nitrogen (TKN), Nitrate, Nitrite and Ammonia (NH<sub>3</sub>)

Total Nitrogen (Total N) is comprised of organic nitrogen, ammonia, nitrite and nitrate. Total N is the sum of Total Kjeldahl Nitrogen (organic nitrogen and ammonia) and nitrite plus nitrate. Nitrate reactions (NO<sub>3</sub><sup>-</sup>) in fresh water can cause oxygen depletion. Thus, aquatic organisms depending on the supply of oxygen in the stream will die. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feedlot discharges, animal wastes (including birds and fish) and discharges from car exhausts. Bacteria in water quickly convert nitrites (NO<sub>2</sub><sup>-</sup>) to nitrates (NO<sub>3</sub><sup>-</sup>).

Nitrites can produce a serious condition in fish called "brown blood disease." Nitrites also react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0 mg/l should not be used for feeding babies. Nitrite/nitrogen levels below 90 mg/l and nitrate levels below 0.5 mg/l seem to have no effect on warm water fish.

Ammonia (NH<sub>3</sub>) represents a form of nitrogen that is readily utilized for biological uptake. In addition, the presence of ammonia is an indicator of anthropogenic influences on a watershed. Water quality monitoring sites with drainage areas classified as "developing" tend to have higher mean NH<sub>3</sub> concentrations than those classified as "mostly undeveloped" or are developed to a lesser degree.

#### **Physical Characteristics**

##### Dissolved Oxygen (DO)

Dissolved Oxygen (DO) represents the total amount of oxygen in solution. The concentration of DO in any water is governed by its temperature and organic matter

content. In addition, DO concentrations are influenced by hydraulic structures that promote aeration. The health of any aquatic ecosystem, at its most fundamental level, is dependent upon the presence of DO. Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the concentration of dissolved oxygen, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills.

### pH

pH represents a standard measure of acidity in water. Acidity, the concentration of hydrogen ion, drives many chemical reactions in living organisms. Many biological processes, such as reproduction, cannot function in acidic or alkaline waters. Acidic conditions also aggravate toxic contamination problems because sediments release toxins such as metals in acidic waters. The most significant environmental impact of pH involves synergistic effects. Synergy involves the combination of two or more substances, which produce effects greater than their sum. This process is important in surface waters. Runoff from agricultural, domestic, and industrial areas may contain iron, aluminum, ammonia, mercury or other elements. The pH of the water will determine the toxic effects, if any, of these substances. For example, 4 mg/l of iron would not present a toxic effect at a pH of 4.8. However, as little as 0.9 mg/l of iron at a pH of 5.5 can cause fish to die.

### **Trace Metals**

#### Zinc (Zn)

Zinc is used as an indicator parameter for the trace metal category. Zinc (Zn) represents the amount of the trace metal found in solution. Although Zn occurs naturally in the environment, high concentrations generally can be attributed to human activities such as industrial processes and mining.

## **Biological**

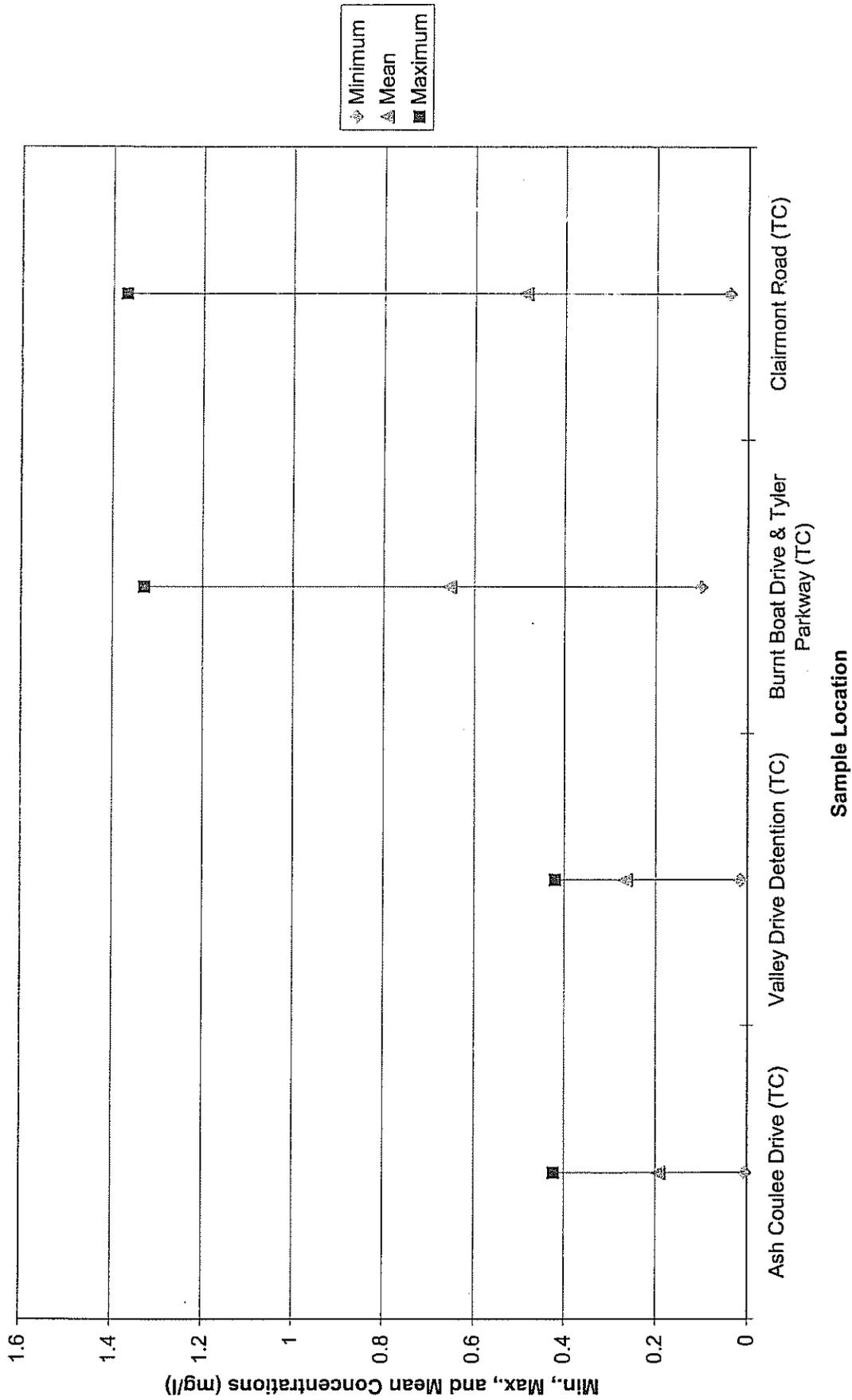
### Fecal Coliform Bacteria

The presence of Fecal Coliform (FC) bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water might have been contaminated by pathogens or disease producing bacteria or viruses, which can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. FC bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste.

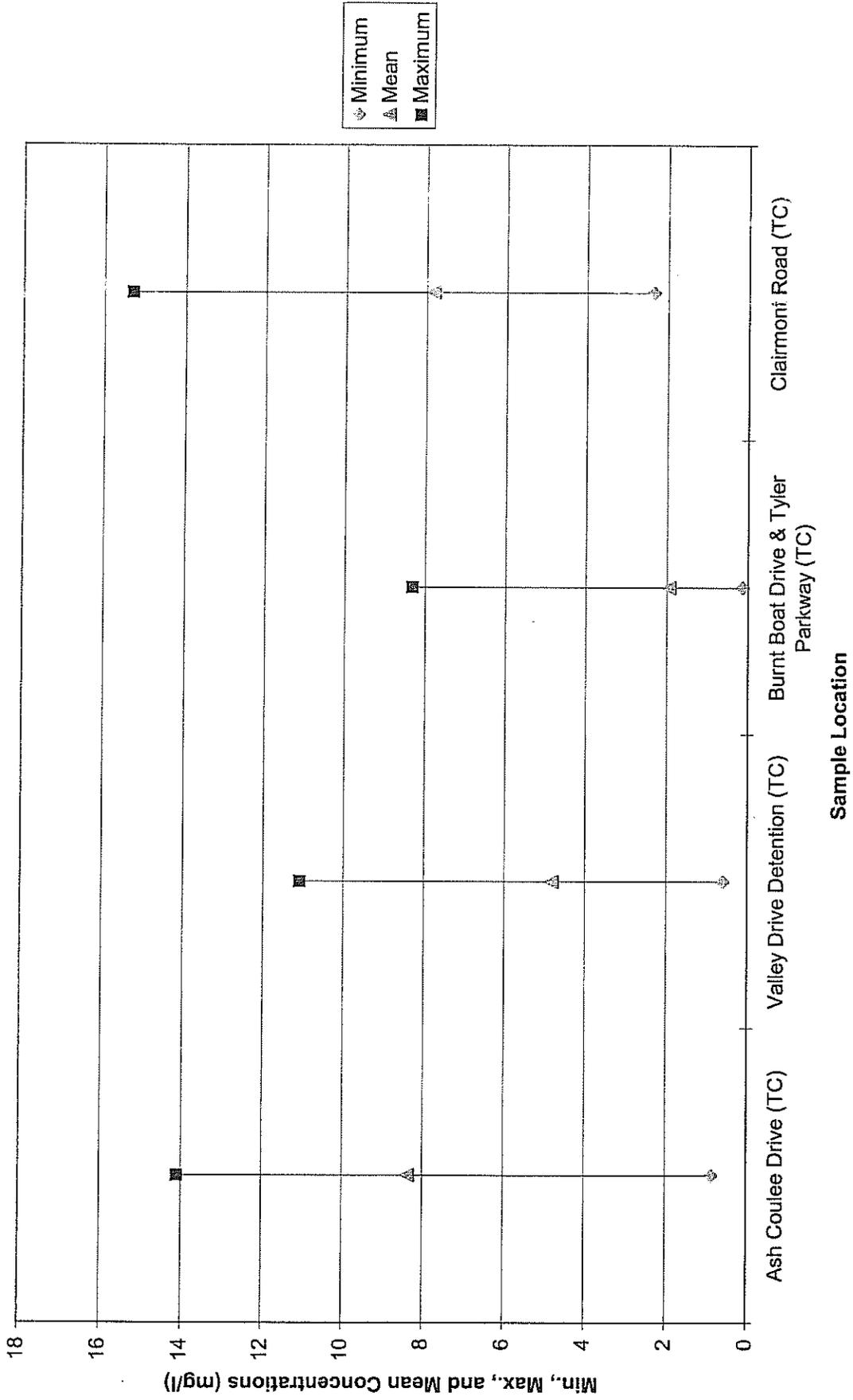
## **APPENDIX C**

### **Tyler Coulee and Hay Creek Water Quality Comparison**

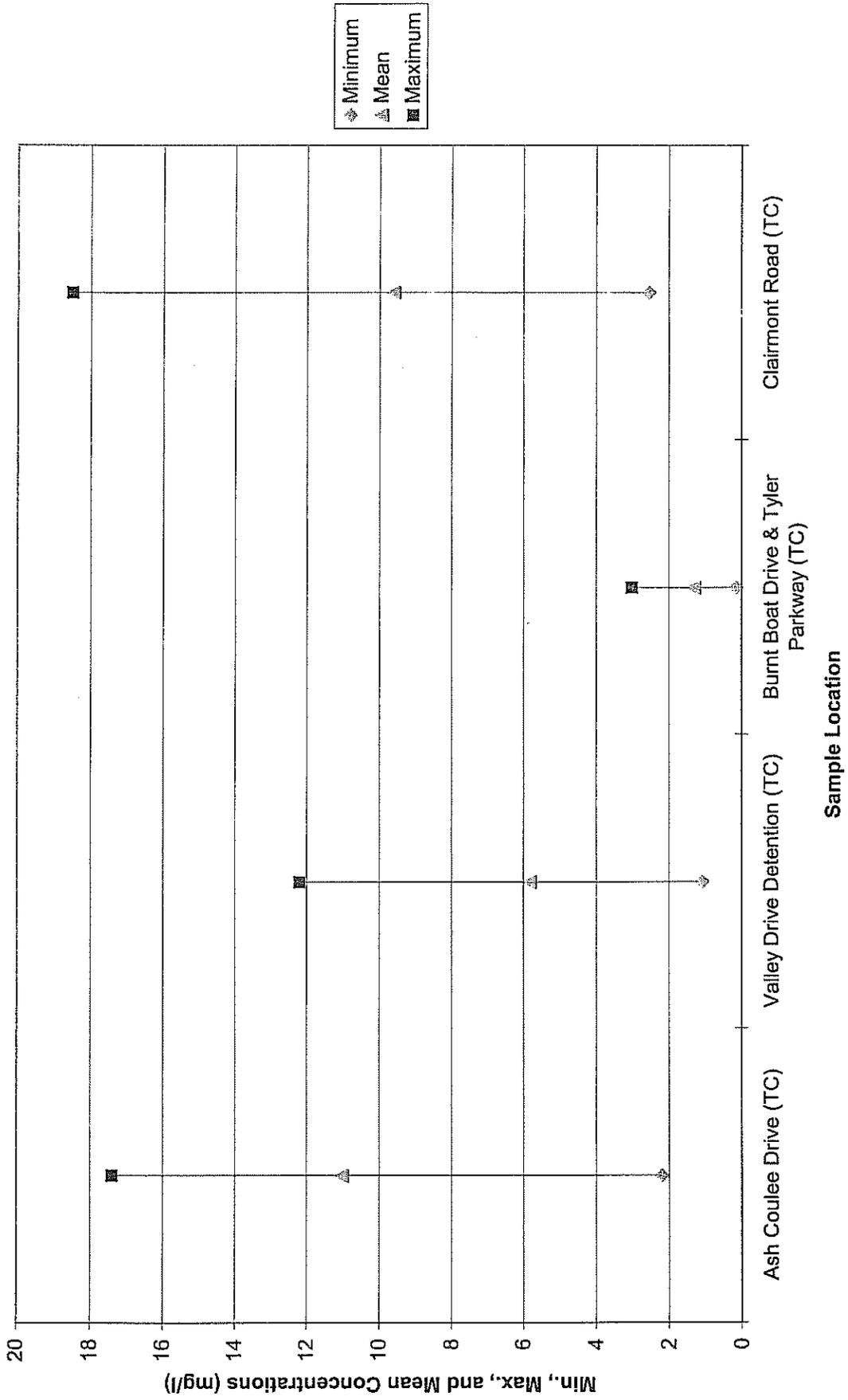
# Ammonia Nitrogen



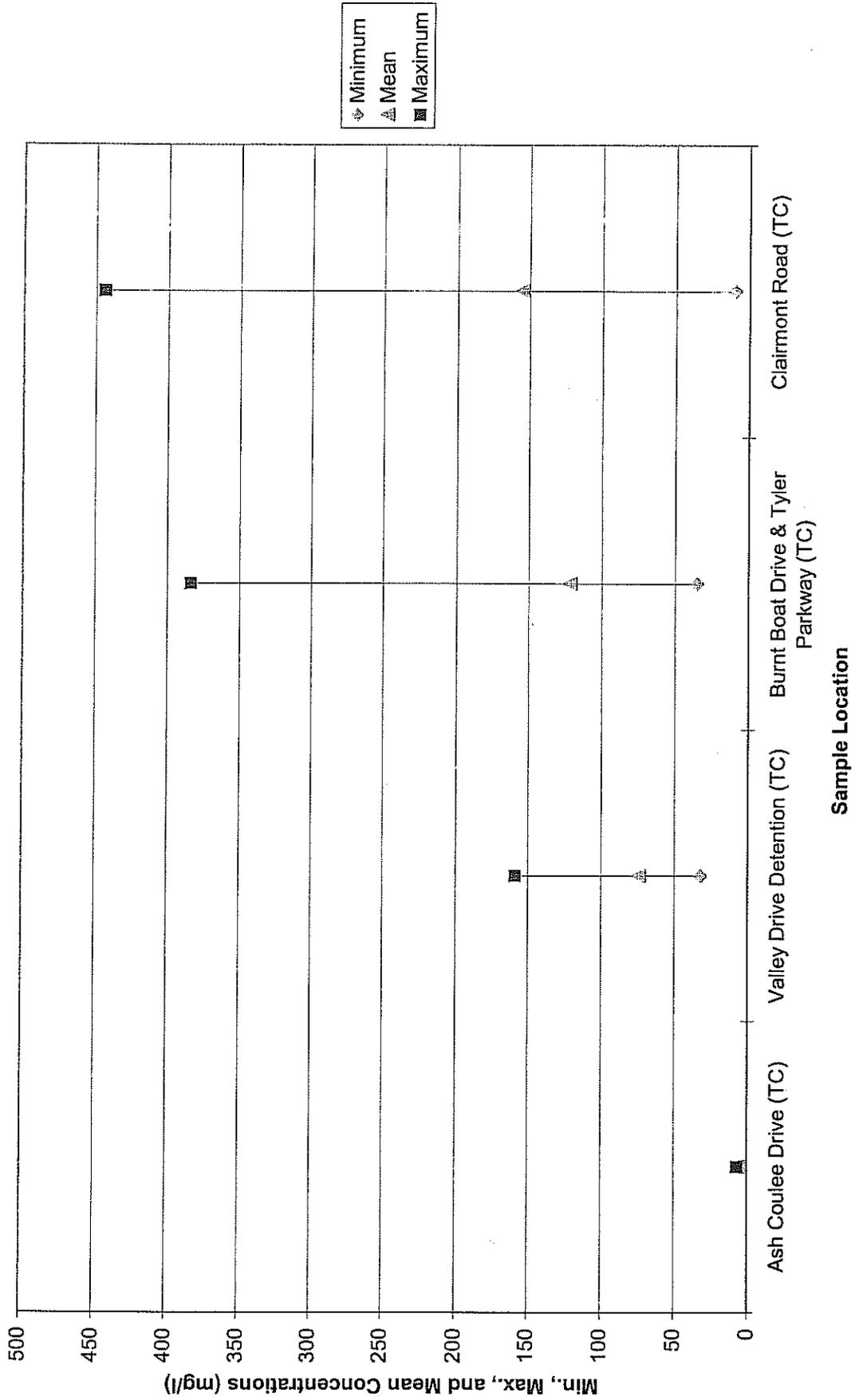
# Nitrate + Nitrite Nitrogen



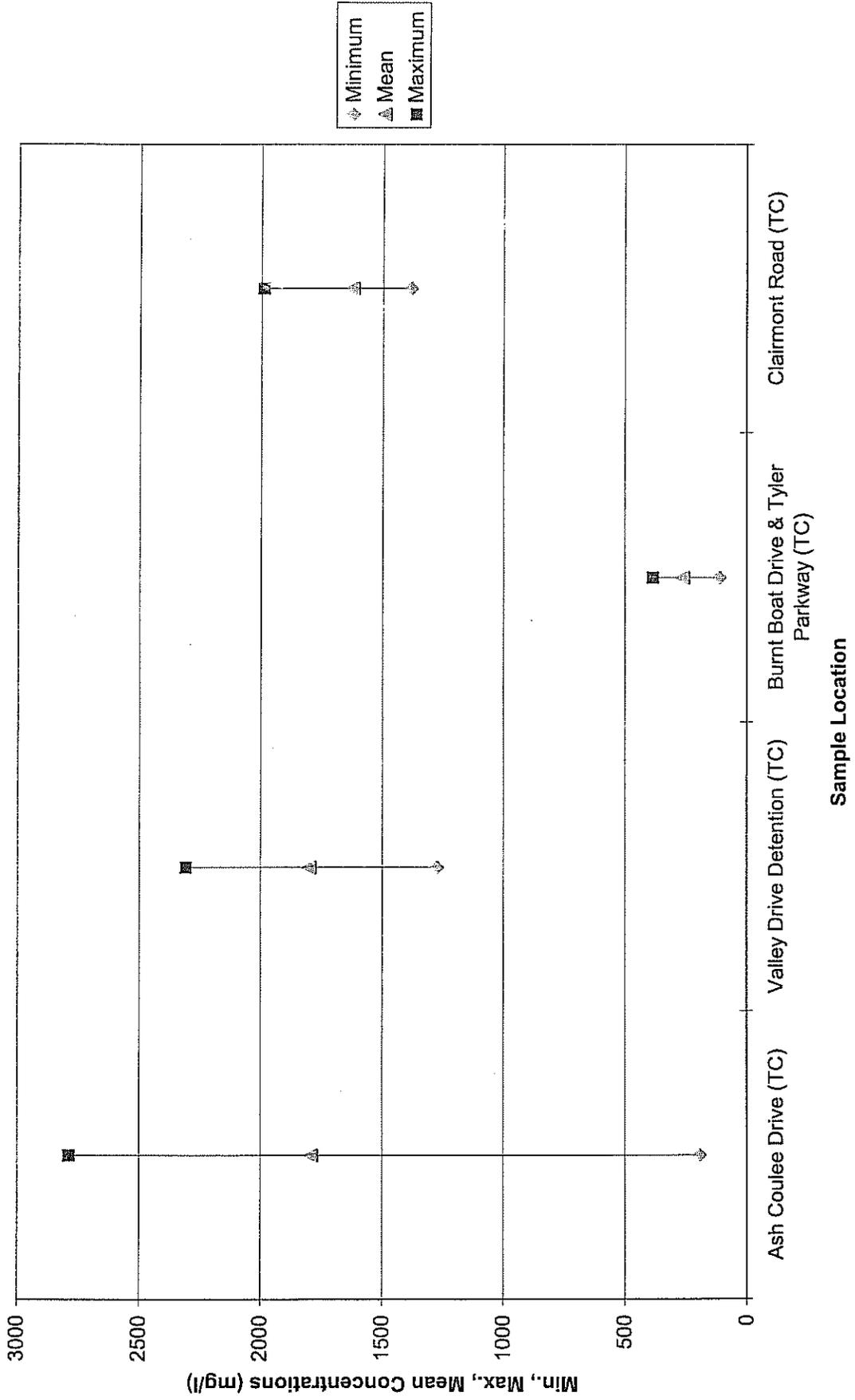
# Total Nitrogen



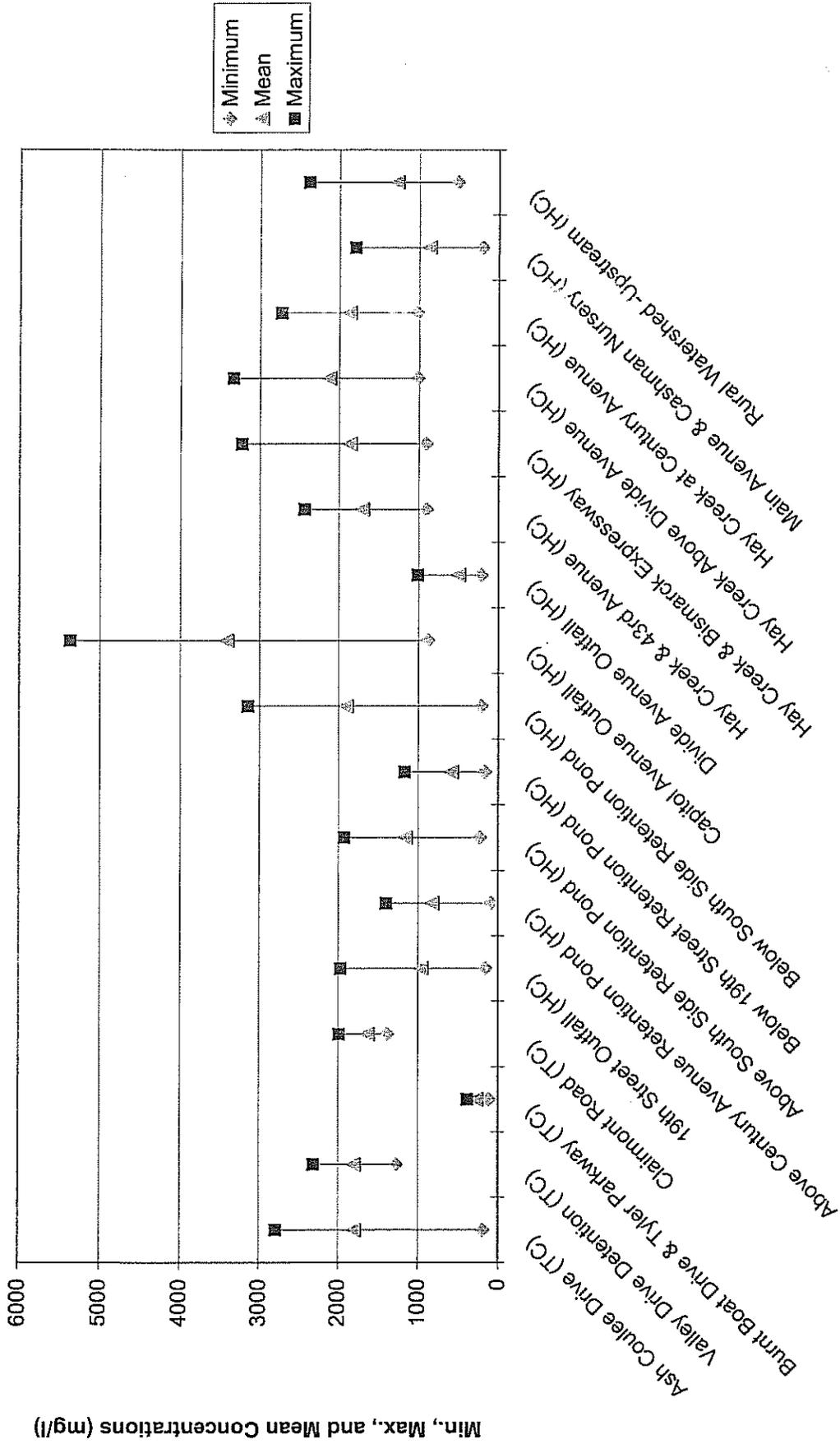
# Total Suspended Solids



# Total Dissolved Solids



# Tyler Coulee (TC) vs. Hay Creek (HC) - Total Dissolved Solids

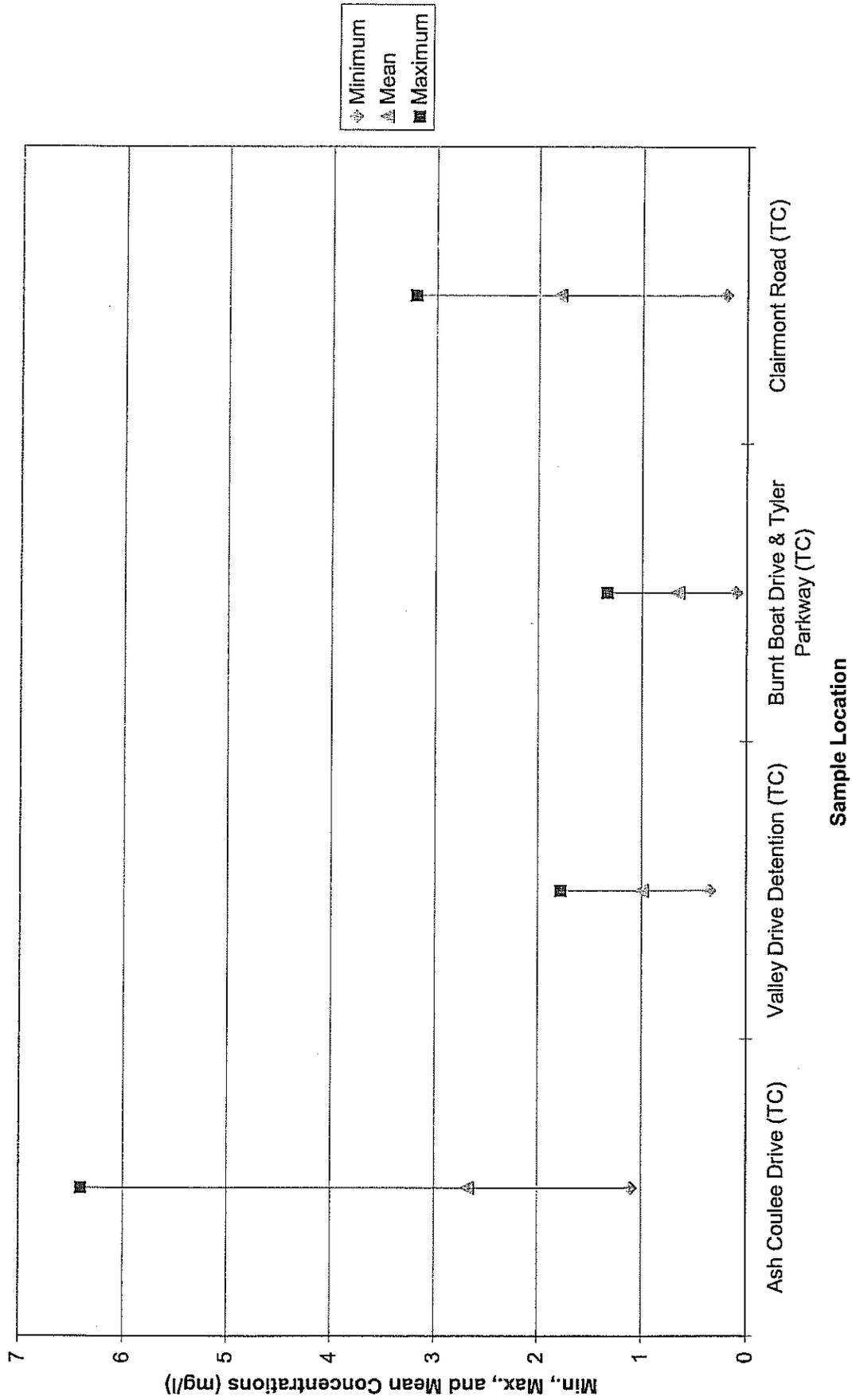


Sample Location

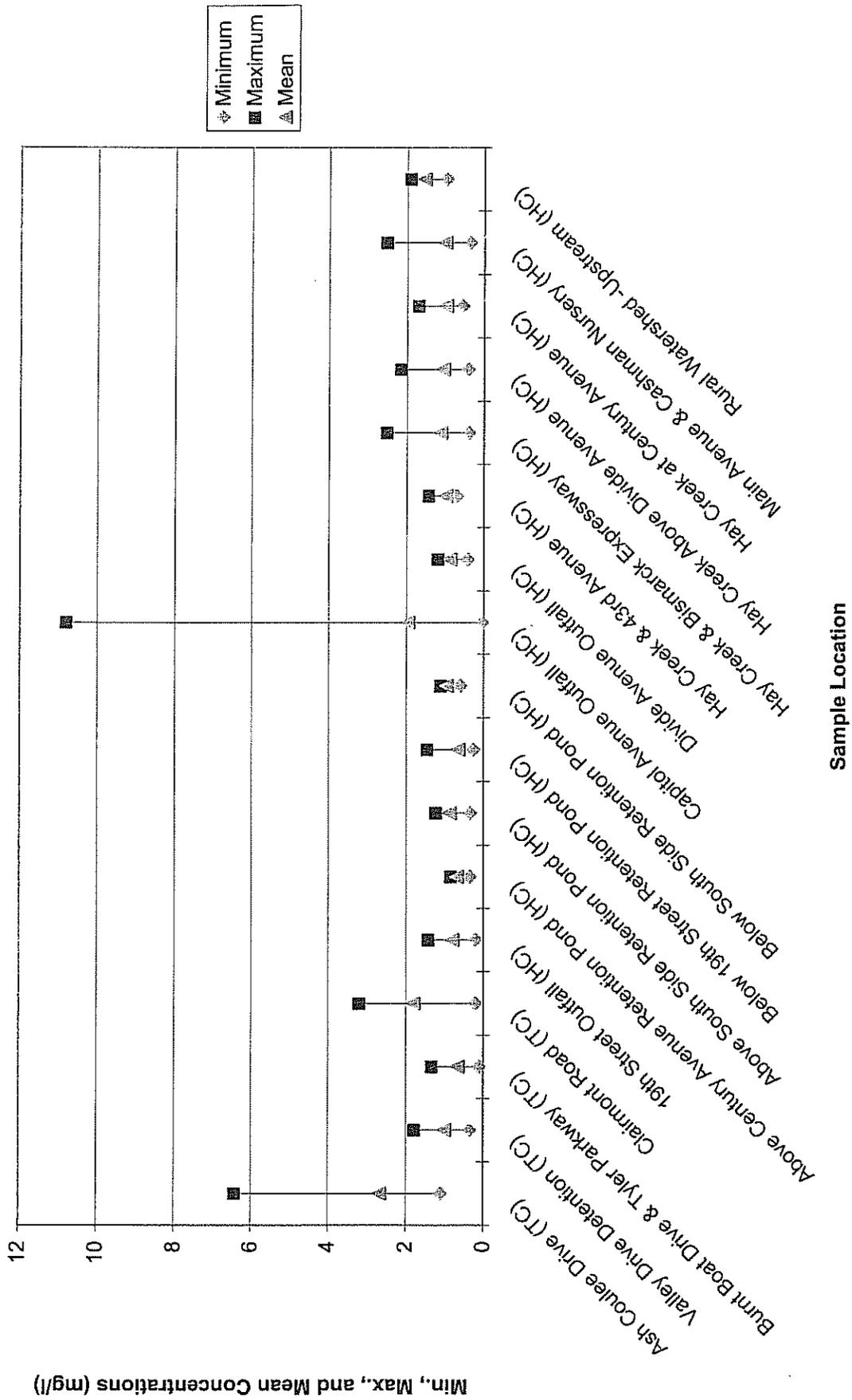
Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.



# Total Kjeldahl Nitrogen

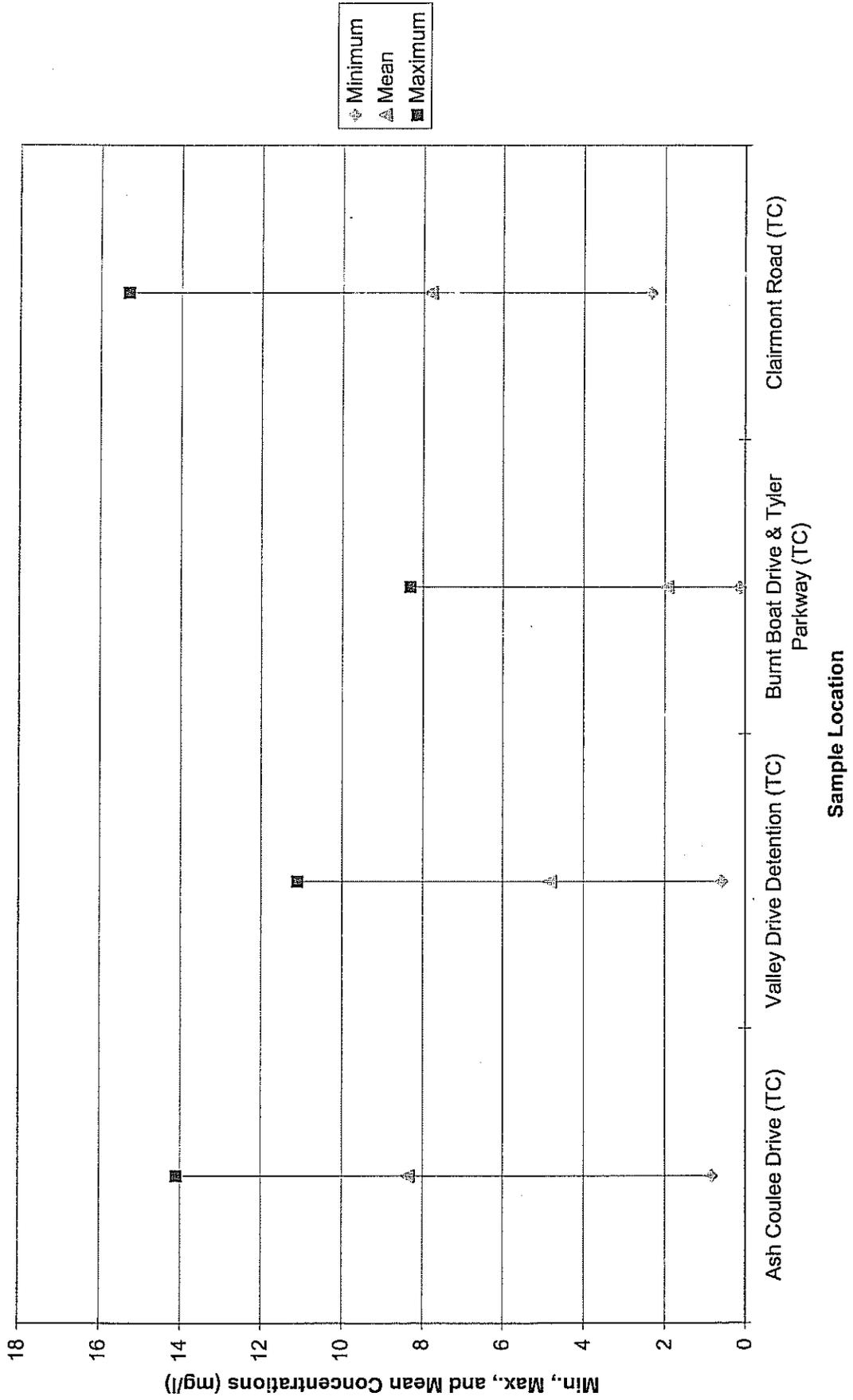


# Tyler Coulee (TC) vs. Hay Creek (HC) - Total Kjeldahl Nitrogen



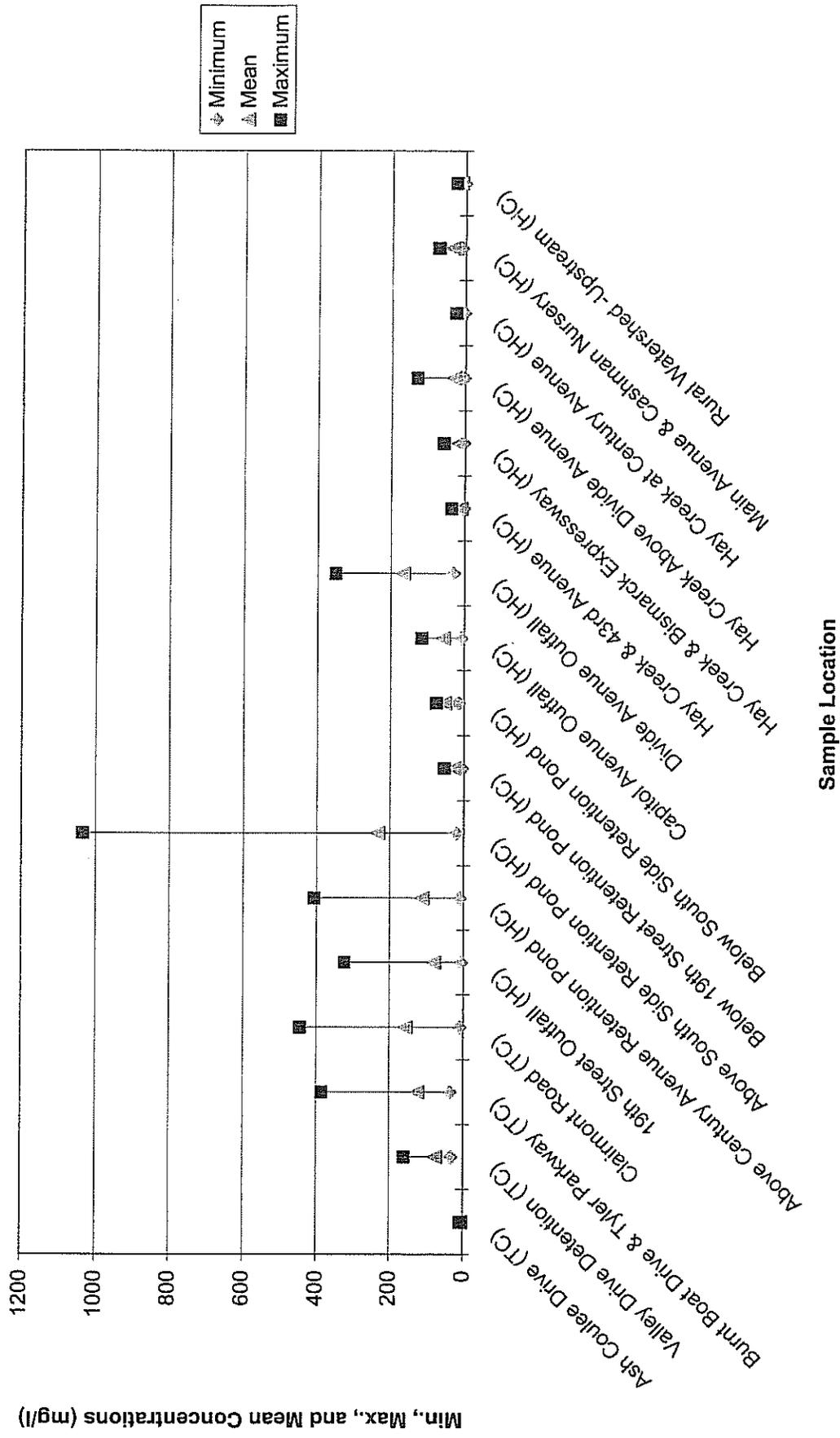
Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

# Nitrate + Nitrite Nitrogen



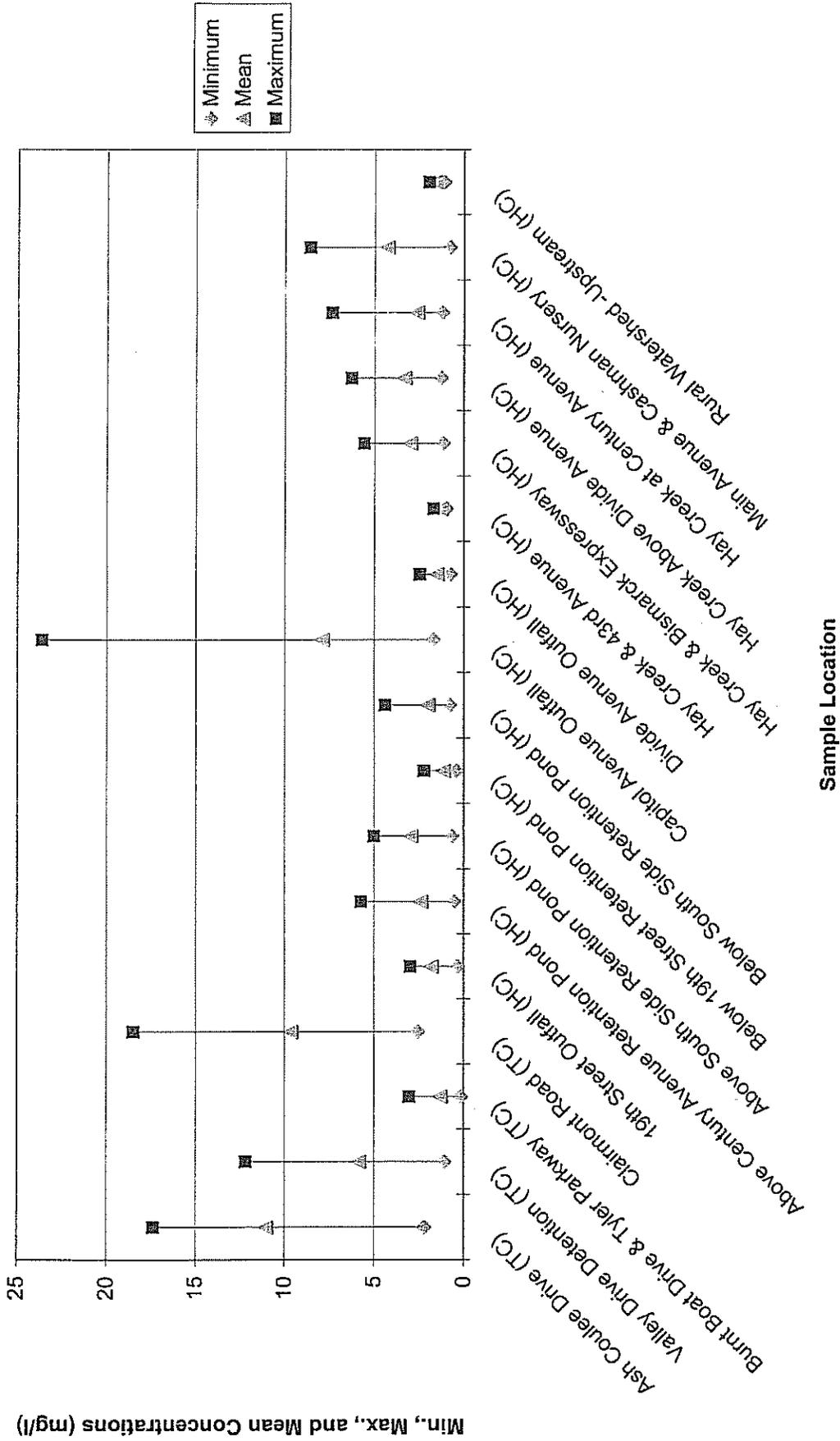


### Tyler Coulee (TC) vs. Hay Creek (HC) - Total Suspended Solids



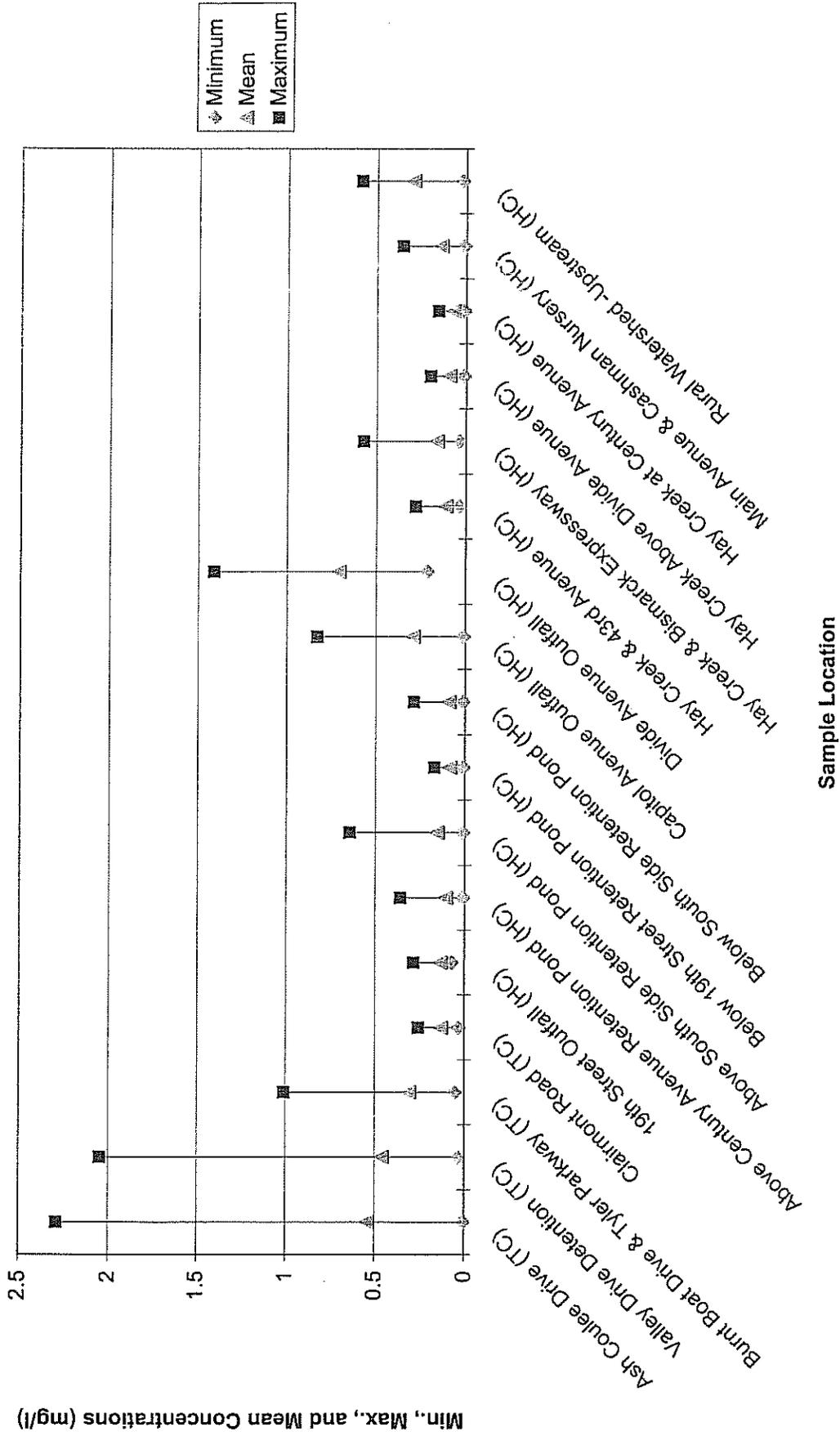
Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

### Tyler Coulee (TC) vs. Hay Creek (HC) - Total Nitrogen



Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

# Tyler Coulee (TC) vs. Hay Creek - Total Phosphorus

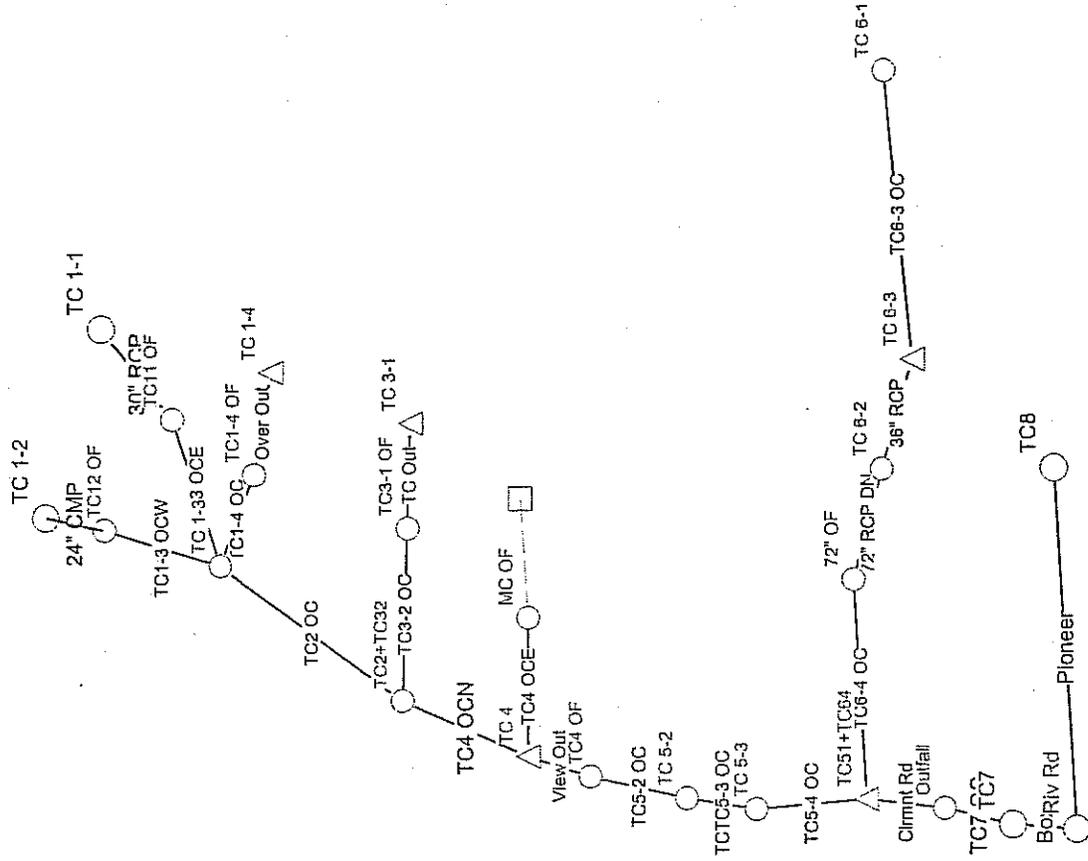


Tyler Coulee data collected late fall of 2000 and spring of 2001. Hay Creek data collected fall of 1999 and spring, summer and fall of 2000.

## **APPENDIX D**

### **Hydrologic Model Parameters and Data**





Tyler Coulee-Proposed

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SWMM2000

Version 8.05

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Tyler Coulee

by RGL 6/18/02

Subwatershed	Total Area (acres)	B Soils (%)	D Soils (%)	B Area (acres)	D Area (acres)	Existing Development (%)	Undeveloped CN	Existing Development CN	Fully Developed CN
TC 1-1	48	48.5%	51.5%	23.3	24.7	0.0%	77	77	81
TC 1-2	56	58.7%	41.3%	32.9	23.1	0.0%	75	75	80
TC 1-3	44	27.7%	72.3%	12.2	31.8	0.0%	80	80	84
TC 1-4	136	37.6%	62.4%	51.1	84.9	70.5%	78	80	82
TC 2	325	55.3%	44.7%	179.7	145.3	0.0%	76	76	80
TC 3-1	130	16.3%	83.7%	21.2	108.8	14.9%	82	82	85
TC 3-2	43	11.3%	88.7%	4.9	38.1	0.0%	82	82	86
TC 3-3	95	44.1%	55.9%	41.9	53.1	85.2%	77	80	82
TC 4	266	58.4%	41.6%	155.3	110.7	0.0%	75	75	80
TC 5-1	83	50.2%	49.8%	41.7	41.3	0.0%	76	76	81
TC 5-2	12	0.0%	100.0%	0.0	12.0	8.3%	84	84	87
TC 5-3	101	58.2%	41.8%	58.8	42.2	61.2%	75	77	80
TC 5-4	35	4.6%	95.4%	1.6	33.4	13.6%	83	83	86
TC 6-1	154	62.1%	37.9%	95.6	58.4	60.3%	75	77	80
TC 6-2	77	68.7%	31.3%	52.9	24.1	51.5%	74	76	79
TC 6-3	71	97.5%	2.5%	69.2	1.8	8.7%	69	71	79
TC 6-4	137	41.8%	58.2%	57.3	79.7	54.8%	78	81	82
TC 7	62	40.8%	59.2%	25.3	36.7	0.0%	78	78	82
TC 8	25	100.0%	0.0%	25.0	0.0	0.0%	69	69	75

Commercial

B Soil

Proposed

General

Table E1 - Conduit Data

Inp Num	Conduit Name	Length (ft)	Conduit Class	Area (ft <sup>2</sup> )	Manning Coef.	Max Width (ft)	Depth (ft)	Trapezoid Side Slopes	
1	TC2 OC	6175.0000	Trapezoid	400.0000	0.0300	20.0000	10.0000	2.0000	2.0000
2	View Out	200.0000	Circular	3.1416	0.0120	2.0000	2.0000		
3	TC5-2 OC	1460.0000	Trapezoid	250.0000	0.0300	5.0000	10.0000	2.0000	2.0000
4	Clrmnt Rd	200.0000	Circular	33.1831	0.0130	6.5000	6.5000		
5	TC6-3 OC	2800.0000	Trapezoid	182.0000	0.0300	5.0000	7.0000	3.0000	3.0000
6	TC4 OCE	1235.0000	Trapezoid	450.0000	0.0300	15.0000	10.0000	3.0000	3.0000
7	TCTC5-3 OC	560.0000	Trapezoid	250.0000	0.0300	5.0000	10.0000	2.0000	2.0000
8	TC5-4 OC	1940.0000	Trapezoid	250.0000	0.0300	5.0000	10.0000	2.0000	2.0000
9	TC3-2 OC	1965.0000	Trapezoid	350.0000	0.0300	15.0000	10.0000	2.0000	2.0000
10	TC Out	262.0000	Circular	7.0686	0.0120	3.0000	3.0000		
11	TC1-3 OCW	1675.0000	Trapezoid	450.0000	0.0300	15.0000	10.0000	3.0000	3.0000
12	TC1-3 OCE	1800.0000	Trapezoid	450.0000	0.0300	15.0000	10.0000	3.0000	3.0000
13	72" RCP DN	300.0000	Circular	28.2743	0.0120	6.0000	6.0000		
14	TC1-4 OC	775.0000	Trapezoid	350.0000	0.0300	5.0000	10.0000	3.0000	3.0000
15	TC6-4 OC	3000.0000	Trapezoid	250.0000	0.0500	5.0000	10.0000	2.0000	2.0000
16	36" RCP	300.0000	Circular	7.0686	0.0120	3.0000	3.0000		
17	TC4 OCN	3225.0000	Trapezoid	1625.0000	0.0300	15.0000	25.0000	2.0000	2.0000
18	TC7 OC	600.0000	Trapezoid	182.0000	0.0500	5.0000	7.0000	3.0000	3.0000
19	Box	75.0000	Rectangle	60.0000	0.0120	10.0000	6.0000		
20	Pioneer	1500.0000	Trapezoid	287.0000	0.0300	20.0000	7.0000	3.0000	3.0000
21	24" CMP	121.0000	Circular	3.1416	0.0240	2.0000	2.0000		
22	30" RCP	98.0000	Circular	4.9087	0.0120	2.5000	2.5000		
23	Low	200.0000	Circular	0.5411	0.0120	0.8300	0.8300		
24	primary	200.0000	Circular	3.1416	0.0120	2.0000	2.0000		

proposed - 100yr, 6hr

Conduit Name	Flow (cfs)	Time	Velocity (ft/s)	Time	WS Upstream (ft)	WS Dwnstrm (ft)
TC2 OC	252.5980	3 13	5.4788	3 11	1801.528	1713.403
View Out	69.2998	8 8	21.3741	8 8	1704.167	1680.334
TC5-2 OC	69.2998	8 11	4.5770	8 11	1680.334	1669.822
Clmnt Rd	543.6142	3 37	18.5574	3 37	1658.780	1648.277
TC6-3 OC	589.8630	3 24	8.3053	3 24	1807.153	1781.800
TC4 OCE	947.8248	5 21	5.9251	3 10	1731.076	1704.167
TCTC5-3 OC	98.3218	3 10	5.4079	3 7	1669.822	1664.596
TC5-4 OC	291.2785	3 25	4.4708	11 52	1664.596	1658.780
TC3-2 OC	97.2436	3 50	3.7248	3 5	1761.868	1713.403
TC Out	97.2499	3 48	21.0341	6 12	1792.625	1761.868
TC1-3 OCW	15.6678	4 15	3.3617	10 2	1848.124	1801.528
TC1-3 OCE	39.9057	3 33	3.2471	3 2	1859.584	1801.528
72" RCP DN	403.2158	3 15	28.3524	3 16	1774.919	1755.605
TC1-4 OC	57.6488	5 43	6.7772	5 41	1824.225	1801.528
TC6-4 OC	370.2224	3 18	4.6323	1 14	<u>1755.605</u>	<u>1658.780</u>
36" RCP	74.5331	4 9	14.6142	4 12	1781.800	1774.919
TC4 OCN	620.1431	4 8	5.6081	3 10	1713.403	1704.167
TC7 OC	543.5742	3 38	4.2708	3 38	1648.277	1642.338
Box	608.8666	3 26	11.4416	3 26	1642.338	1639.052
Pioneer	608.6342	3 29	5.6561	3 29	1639.052	1632.040
24" CMP	15.6679	4 12	10.4563	1 46	1864.223	1848.124
30" RCP	39.9073	3 30	13.0604	3 30	1875.839	1859.584
Low	7.8077	3 42	13.3040	3 43	1845.502	1824.225
primary	50.4280	5 41	19.0330	4 21	1845.502	1824.225

16

1639.052  
 1632.040  
 -----  
 7.0121

TC 6-2 to TC 6-4

.4790

# Proposed

## Detention Area Design

\*=====\*

| Variable storage data for node |TC 4

\*=====\*

Data Point	Elevation ft	Depth ft	Area ft <sup>2</sup>	Volume ft <sup>3</sup>
1	1682.3000	0.0000	435.6000	0.0000
2	1683.2300	0.9300	32452.2000	11360.7594
3	1685.2300	2.9300	41338.4400	84972.3937
4	1687.2300	4.9300	57978.3600	183821.2336
5	1689.2300	6.9300	81718.5600	322840.8229
6	1695.2300	12.9300	242759.8800	1.253492E+06
7	1699.2300	16.9300	359500.6800	2.450398E+06
8	1709.2300	26.9300	664420.6800	7.492579E+06

*VD Detention West*

\*=====\*

| Variable storage data for node |TC51+TC64

\*=====\*

Data Point	Elevation ft	Depth ft	Area ft <sup>2</sup>	Volume ft <sup>3</sup>
1	1647.8500	0.0000	14374.8000	0.0000
2	1649.9500	2.1000	19841.5800	35773.3603
3	1659.9500	12.1000	141787.8000	751339.6061
4	1669.9500	22.1000	442482.4800	3.533830E+06

*Clairmont*

\*=====\*

| Variable storage data for node |TC 6-3

\*=====\*

Data Point	Elevation ft	Depth ft	Area ft <sup>2</sup>	Volume ft <sup>3</sup>
1	1775.0000	0.0000	435.6000	0.0000
2	1776.0000	1.0000	113256.0000	40238.4797
3	1777.0000	2.0000	117612.0000	155665.6300
4	1778.0000	3.0000	121968.0000	275449.0294
5	1779.0000	4.0000	126324.0000	399588.6605
6	1780.0000	5.0000	130680.0000	528084.5075
7	1781.0000	6.0000	135036.0000	660936.5563
8	1782.0000	7.0000	139392.0000	798144.7941

\* ( This is only one where area changed from existing to proposed

\*=====\*

| Variable storage data for node |TC 3-1

\*=====\*

Data Point	Elevation ft	Depth ft	Area ft <sup>2</sup>	Volume ft <sup>3</sup>
1	1784.0000	0.0000	435.6000	0.0000
2	1788.0000	4.0000	2178.0000	4783.5083
3	1790.0000	6.0000	47480.4000	44668.5645
4	1792.0000	8.0000	199504.8000	274210.1092
5	1796.0000	12.0000	748360.8000	2.053225E+06
6	1800.0000	16.0000	1498464.0000	6.460935E+06

VD East

*4.2570775 x 10<sup>6</sup>*  
*97.7 a-f @ 1798*

\*=====\*

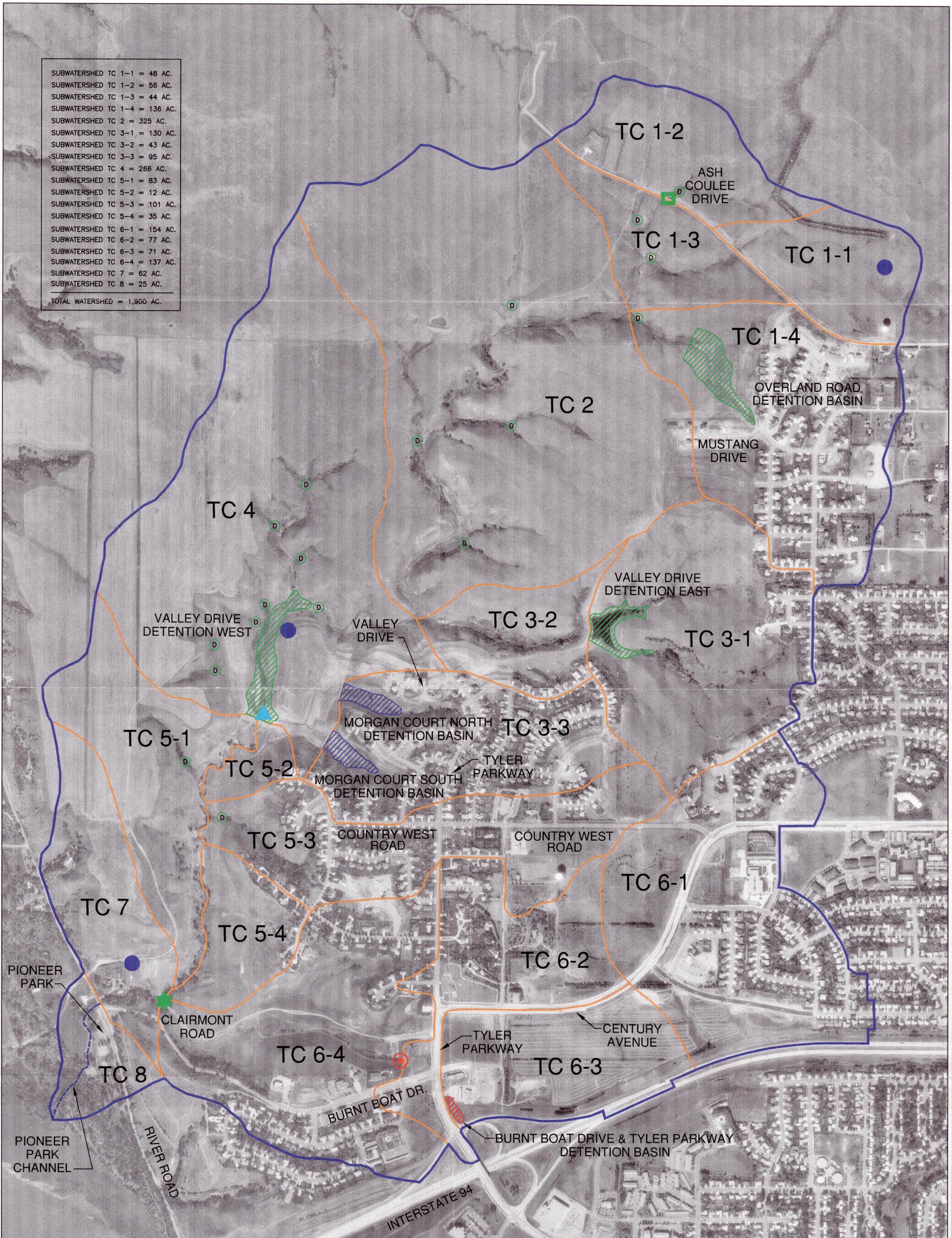
| Variable storage data for node |TC 1-4

\*=====\*

Data Point	Elevation ft	Depth ft	Area ft <sup>2</sup>	Volume ft <sup>3</sup>
1	1827.0000	0.0000	435.6000	0.0000
2	1830.0000	3.0000	3001.2840	4580.2821
3	1840.0000	13.0000	42619.1040	194347.6431
4	1850.0000	23.0000	118034.5320	966280.4333
5	1860.0000	33.0000	220195.8000	2.631103E+06

*Overland  
Drive*

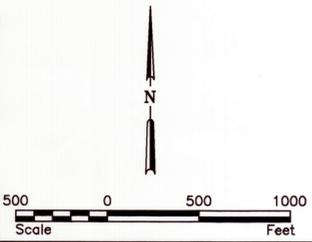
SUBWATERSHED TC 1-1 = 48 AC.
SUBWATERSHED TC 1-2 = 56 AC.
SUBWATERSHED TC 1-3 = 44 AC.
SUBWATERSHED TC 1-4 = 136 AC.
SUBWATERSHED TC 2 = 325 AC.
SUBWATERSHED TC 3-1 = 130 AC.
SUBWATERSHED TC 3-2 = 43 AC.
SUBWATERSHED TC 3-3 = 95 AC.
SUBWATERSHED TC 4 = 266 AC.
SUBWATERSHED TC 5-1 = 83 AC.
SUBWATERSHED TC 5-2 = 12 AC.
SUBWATERSHED TC 5-3 = 101 AC.
SUBWATERSHED TC 5-4 = 35 AC.
SUBWATERSHED TC 6-1 = 154 AC.
SUBWATERSHED TC 6-2 = 77 AC.
SUBWATERSHED TC 6-3 = 71 AC.
SUBWATERSHED TC 6-4 = 137 AC.
SUBWATERSHED TC 7 = 62 AC.
SUBWATERSHED TC 8 = 25 AC.
TOTAL WATERSHED = 1,900 AC.



LEGEND

- = TYLER COULEE WATERSHED BOUNDARY
- = TYLER COULEE SUBWATERSHED BOUNDARY
- ★ = LOCATION OF ISCO FLOW METER AND AUTOMATIC SAMPLER
- = LOCATION OF STARLOG FLOW METER AND GRAB SAMPLE
- ▲ = LOCATION OF TELEG STAGE RECORDER AND GRAB SAMPLE
- = LOCATION OF STAFF GAGE AND GRAB SAMPLE
- = LOCATION OF RECORDING RAIN GAGE
- TC X = SUBWATERSHED DESIGNATION
- = POTENTIAL EXTENDED DETENTION POND SITES
- ▨ = EXISTING DETENTION BASIN
- ▨ = EXISTING DETENTION BASIN WITH MINOR STORAGE (FUTURE POTENTIAL STORAGE)
- ▨ = PROPOSED DETENTION BASIN

NOTE:  
 POTENTIAL EXTENDED DETENTION LOCATIONS ARE SHOWN ONLY TO ILLUSTRATE THE TYPE OF SUITABLE TOPOGRAPHIC FEATURES. ADDITIONAL LOCATIONS ARE LIKELY. SPECIFIC LOCATIONS WILL BE DETERMINED DURING PLAT REVIEW BASED UPON A SPECIFIC DEVELOPMENT PROPOSAL.



HYDROLOGIC ELEMENTS

TYLER COULEE  
 STORM WATER QUALITY AND MASTER PLAN  
 CITY OF BISMARCK, NORTH DAKOTA

Scale AS SHOWN	Drawn by B.G.J.	Checked by MRD	Project No. 1012-600	Date 6-11-02	Fig. 2
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PREPARED BY



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PHOTO SOURCE:  
 U.S. DEPARTMENT OF THE INTERIOR  
 U.S. GEOLOGICAL SURVEY  
 DIGITAL ORTHOPHO QUADRANGLE DATA

**ESTIMATED STREET DEVELOPMENT SCHEDULE**

- 2002: Platted Area of Golf Drive and Part of CWV.
- 2002: Area east of Ducks Unlimited and west of Clairmont Road.
- 2002: Extend Valley Drive from the west side of Country West XVII to the dam.
- 2002: Extend Valley Drive from the south side of Country West XXII to first lot on south side of Overland Road.
- 2003-2004: Extend Valley Drive from the dam to top of hill.
- 2004: Start at intersection of Valley Drive and Overland Road and complete Overland Road.
- 2006: Complete Longhorn Drive and its intersection with Valley Drive.
- 2008: Extend High Creek Road 750' west from Valley Drive.
- 2010: Extend High Creek Road to a point 300' south of future Mustang Drive.



**LEGEND**

- = TYLER COULEE WATERSHED BOUNDARY
- = TYLER COULEE SUBWATERSHED BOUNDARY
- ▨ = LOT DEVELOPED IN 1999-2000
- = SANITARY SEWER TRUNKLINE - SUMMER 2000
- = 24" WATERMAIN - SUMMER 2000
- = EXISTING ROAD AND STREET DEVELOPMENT
- = PROPOSED BIKE/HIKE PATH
- = WATERLINE CORRIDOR
- ▨ = PROPOSED PARK

**DEVELOPMENT SCHEDULE**

TYLER COULEE  
STORM WATER QUALITY AND MASTER PLAN  
CITY OF BISMARCK, NORTH DAKOTA

Scale AS SHOWN	Drawn by BGJ	Checked by MRD	Project No. 1012-600	Date 8-11-02	Fig. 4
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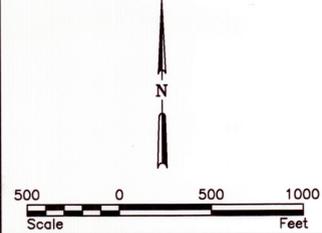


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