EFFECTS OF STREAMBANK FENCING ON STREAM ECOSYSTEM INTEGRITY

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Division of Water Quality and Monitoring Programs
Susquehanna River Basin Commission

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ABSTRACT

Susquehanna River Basin Commission (SRBC) staff studied three streams in the Chesapeake Bay Watershed in Pennsylvania to document the response of riparian ecosystems to streambank fencing and to develop a protocol for assessing these streams. These three streams, located at the Veety, Epler, and Englart farms, were fenced to inhibit cattle from accessing the stream. A variety of sampling techniques was used at each site to determine the most effective tools in documenting changes after streambank fencing. At each site, improvements were found in the physical habitat and biological community one year after streambank fencing was in place.

To provide the most meaningful data, it is suggested that a sampling protocol should be based on time constraints and expertise of the collector, but should include both biological community and physical habitat analysis. Sites also should be sampled for more than one year to document future changes as the site becomes more stable.

INTRODUCTION

In 1995, the SRBC and the Pennsylvania Department of Environmental Protection (Pa. DEP) initiated a study to document the response of stream ecosystems to the implementation of streambank fencing and to develop a biomonitoring protocol for assessing these responses. This study was conducted on three streams in the Chesapeake Bay Watershed in Pennsylvania and involved the assessment of a variety of abiotic (nonliving) and biotic features of these streams and their riparian areas immediately before and approximately one year after fencing. As directed by Pa. DEP, SRBC staff used a variety of sampling methods at the three fencing sites to evaluate the utility of these methods for documenting the response of stream/riparian ecosystems to streambank fencing and to collect data from streambank fencing projects located in different geographic settings.

General Overview of Methods

Between October 1995 and June 1996, SRBC staff collected physical habitat, chemical water quality, riparian vegetative, and aquatic biological data at three streams flowing through pastured lands (study reaches) shortly before they were scheduled to be fenced. At each of the three farms included in this study, additional data were collected at a reference reach located upstream of the study reach outside of the fencing project area. Reference reach data were collected to obtain information that would be useful for discriminating between changes in study reach environmental conditions that were due to natural fluctuations in environmental conditions and/or activities occurring upstream of the study area versus changes that were in response to fencing. Approximately one year after pre-fencing data were collected, data collection efforts were repeated at the study and reference reaches at each of the three farms.

Fencing Project Site Descriptions

The streambank fencing projects included in this study were located in Lackawanna, Northumberland, and Fulton Counties, Pennsylvania (Figure 1). Physiographic,

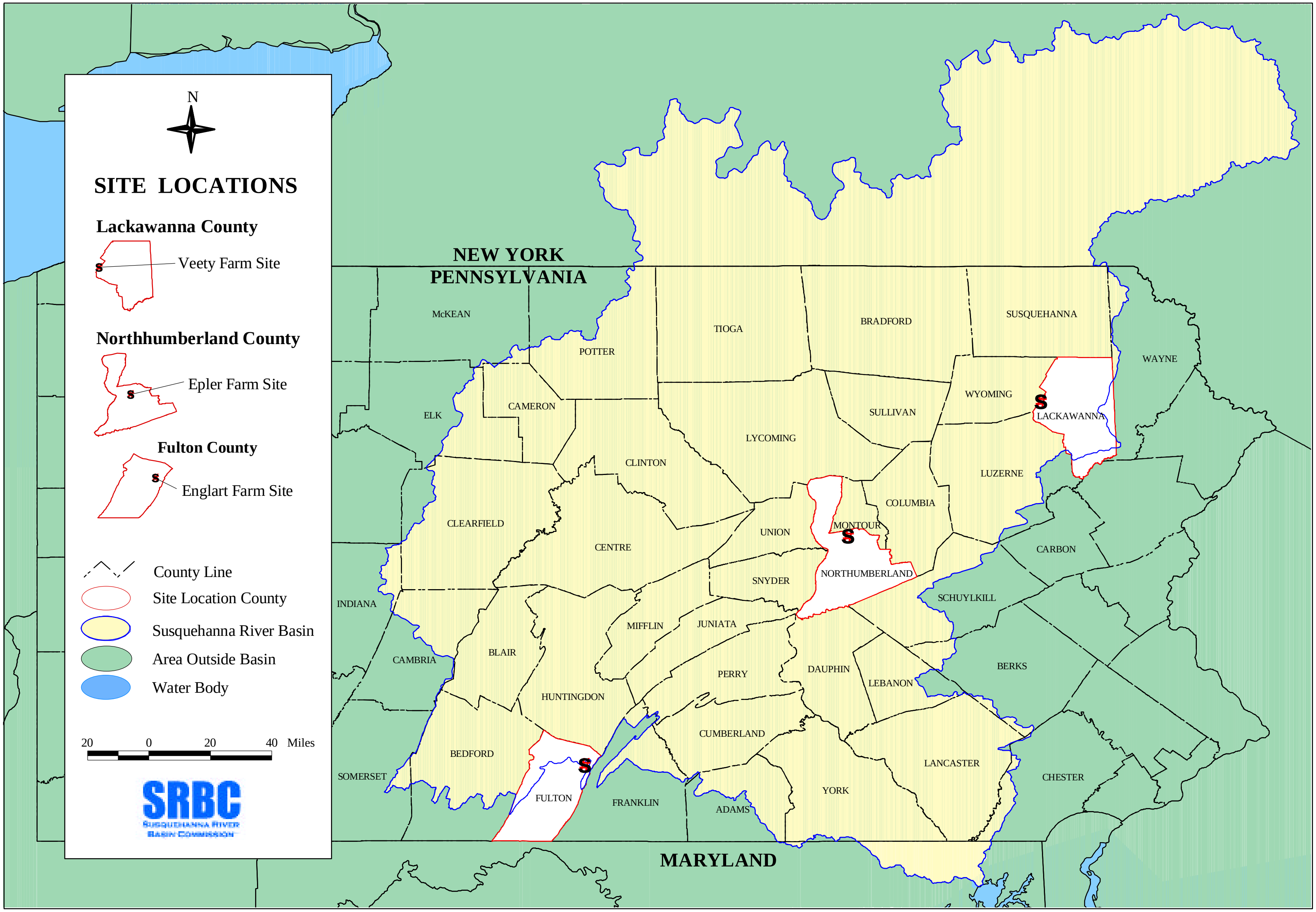

Figure 1. Streambank Fencing Project Locations

ecoregion, geological, and soil information pertaining to these projects is summarized in Table 1.

Veety Farm

During the first week of November 1995, 1,992 feet of fencing were installed on the Veety farm along an unnamed tributary to Falls Creek. This tributary originates approximately 1.5 miles upstream of the fencing project area as a swamp, and land use/land cover in its watershed consists primarily of rural residential areas, forest, swamp, and agriculture (Figure 2). Field data were collected during the last week of October and the first week of November in both 1995 and 1996.

The Veety farm reference reach is located immediately upstream of the study reach in an abandoned pasture. Prior to the 1995 installation of streambank fencing, cattle could gain access to the stream in the reference reach by entering the stream in the study reach and moving upstream in spite of existing fencing that had been in place along this reach since the early 1980s. Streambank and riparian vegetative conditions in the reference reach indicated that cattle impact to this reach was negligible before streambank fencing was installed in the study reach. The 1995 fencing project was designed such that cattle access to the reference reach would be eliminated. However, during the collection of post-fencing data, several cattle were observed in the Veety farm reference reach. Although these animals caused only minor damage to streambank and riparian vegetative conditions, their presence substantially influenced the ammonia concentrations observed in the reference reach in 1996.

Epler Farm

The unnamed tributary to the Susquehanna River that flows through the Epler farm was fenced May 30, 1996. The project included 5,566 feet of fencing. Land use/land cover in the watershed of this stream consists primarily of forest and agriculture with substantial agricultural activity occurring immediately upstream of the fencing project area (Figure 3). During the collection of post-fencing data, one heifer was observed in the study reach and had caused minor damage to streambank and riparian vegetative conditions. Additional signs such as hoofprints were observed throughout the study reach streambanks.

Englart Farm

Approximately 1.25 miles downstream of its source, Licking Creek flows through the Englart farm. Upstream of the Englart farm fencing project, land use/land cover in the Licking Creek watershed is predominantly forest with a few small areas of agricultural land (Figure 4). Approximately 4,700 feet of fencing were installed at the Englart farm on June 12, 1996. A fallow field that served as the reference reach was located immediately upstream of the fencing project. Although no cattle were observed in the reference reach during either pre- or post-fencing data collection, a few hoofprints were observed adjacent to the stream in this reach during the collection of post-fencing data. However, pre- and post-fencing streambank and riparian vegetative conditions in the reference reach indicated that cattle impact to this reach was negligible.

Table 1. Streambank Fencing Site Descriptions

	Fencing Project		
	Veety Farm	**Epler Farm**	**Englart Farm**
Stream Name (1)	Unnamed Tributary (UNT) to Falls Creek	UNT to Susquehanna River	Licking Creek
County (1)	Lackawanna	Northumberland	Fulton
Township (1)	Newton	Point	Todd
Latitude (1)	41° 28’ 03”	40° 56’ 07”	40° 01’ 33”
Longitude (1)	75° 47’ 52”	76° 42’ 25”	77° 56’ 41”
Physiographic Province (2)	Appalachian Plateaus	Ridge and Valley	Ridge and Valley
Physiographic Section (2)	Glaciated Low Plateau Section	Appalachian Mountain Section	Appalachian Mountain Section
Ecoregion (3)	Northern Appalachian Plateau and Uplands	Ridge and Valley	Ridge and Valley
Subecoregion (3)	Glaciated Low Plateau	Northern Shale Valleys	Northern Sandstone Ridges
Surface Geology (4)	Catskill Formation Undivided	Hamilton Group	Reedsville Formation
STATSGO Soil (4)	Volusia-Mardin-Lordstown/Wellsboro-Oquaga-Morris	Chenango-Pope-Holly	Hazelton-Dekalb-Buchanan

(1) U.S. Geological Survey 7.5 minute quadrangle map
(2) Sevon, W.D. (1995)
(3) Woods and others (1996)
(4) Pennsylvania GIS Compendium (1996)

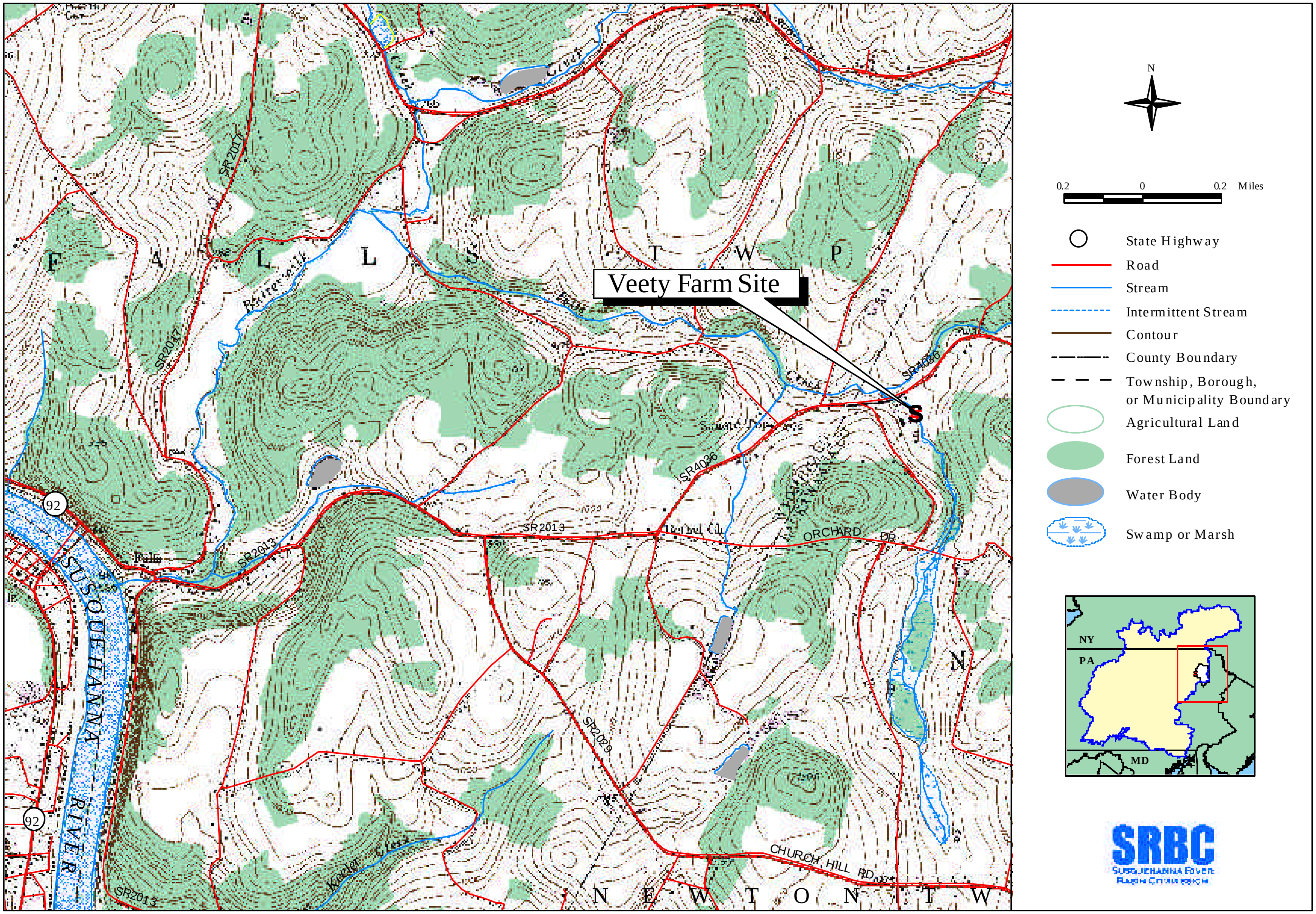

Figure 2. Land Use Surrounding the Veety Farm

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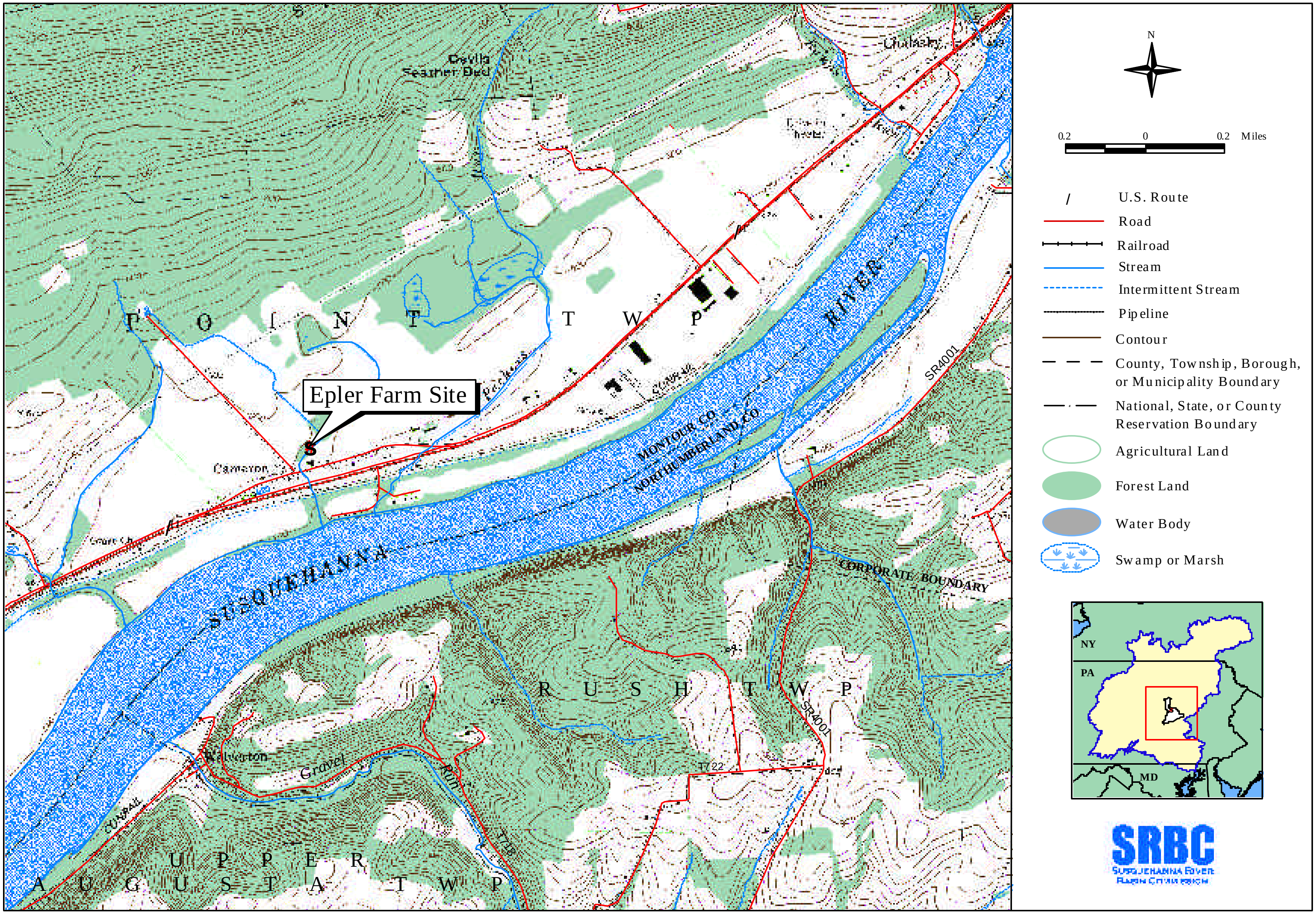

Figure 3. Land Use Surrounding the Epler Farm

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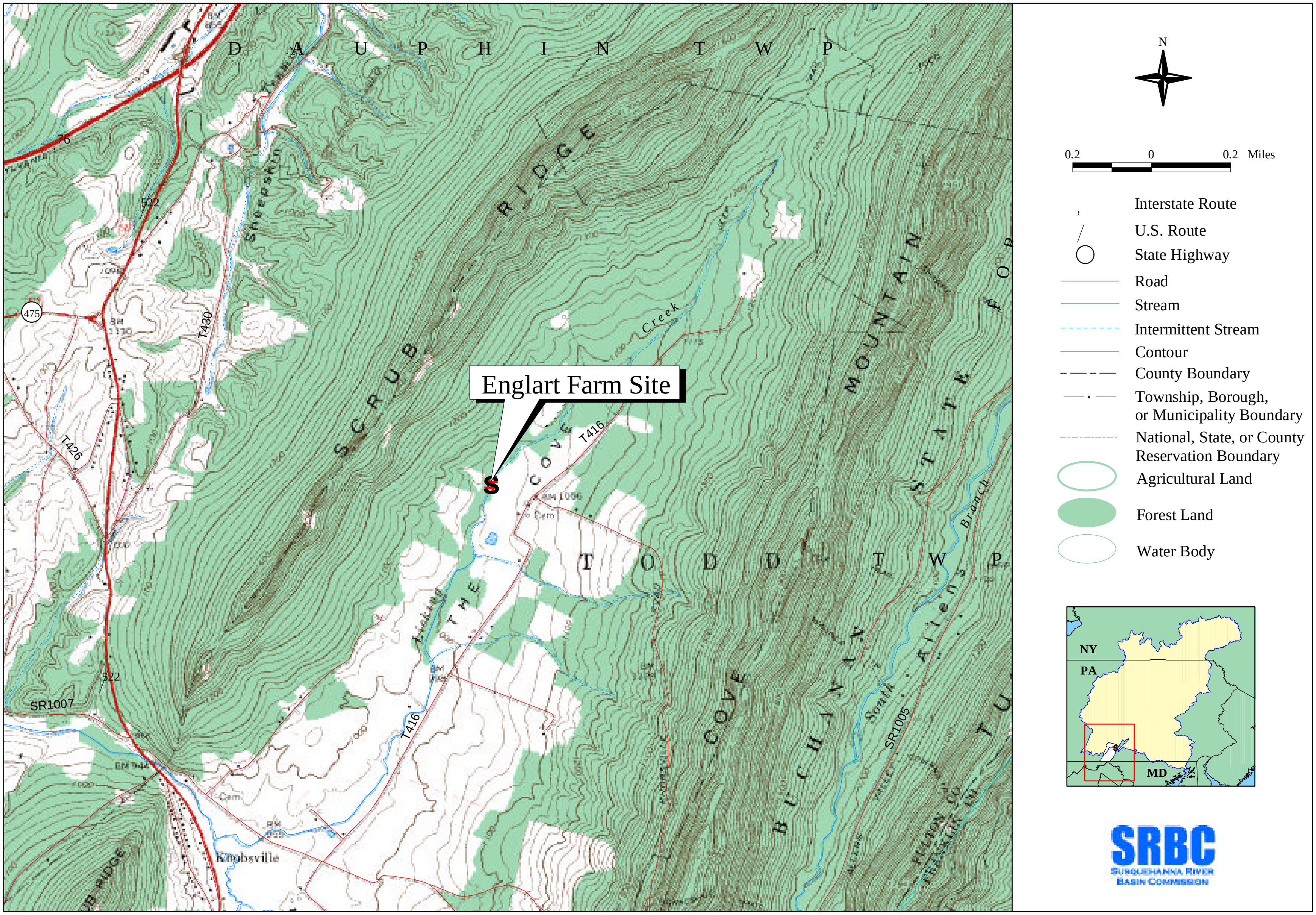


Figure 4. Land Use Surrounding the Englart Farm

RESPONSE OF STREAM AND RIPARIAN ECOSYSTEMS TO STREAMBANK FENCING

Riparian Vegetation

SRBC staff assessed study and reference reach riparian vegetative community composition using two line-intercept sampling methods at the Veety farm (U.S. Department of Agriculture, 1992). The first method, cross-sectional community composition, documented the riparian vegetative conditions along five transects oriented perpendicular to the stream channel. The second method, greenline community composition, assessed riparian vegetative community composition immediately adjacent to the stream along both banks. Both sampling methods involved the classification of riparian vegetation into one of the following vegetation community types: (1) moss; (2) shrub; (3) turf grass; (4) sedge/rush/grass; (5) herbaceous plant; (6) coniferous tree; or (7) deciduous tree. Cross-sectional and greenline sampling data were used to calculate vegetation community type composition based on the relative linear coverage of each of the vegetation community types.

Substantial changes in the riparian vegetative conditions of the Veety farm study reach were observed between 1995 and 1996 (Figure 5). These changes were most dramatic immediately adjacent to the stream channel, as evidenced by the greenline vegetation data. This technique indicated a shift from predominantly turf grass in 1995 to herbaceous plants and sedges/rushes/grasses in 1996. Study reach cross-sectional vegetation sampling also showed a decrease in relative coverage of turf grass and an increase in herbaceous plants. However, cross-sectional vegetation sample data did not reflect the increase in the relative coverage of the sedge/rush/grass community type immediately adjacent to the stream channel, as documented during greenline vegetation sampling. The changes observed in study reach cross-sectional vegetation and both the greenline and cross-sectional vegetative conditions of the reference reach were much less dramatic than those observed in the study reach greenline vegetation data (Figure 6).

Riparian vegetation sampling at the Epler and Englart farms was conducted using a third line-intercept sampling method similar to the greenline community composition method described above with some modification. Instead of assessing riparian vegetative community composition immediately adjacent to the stream channel, this modified greenline sampling method involved assessing study reach riparian vegetation along transects established between the rebar used to mark the end points of surveyed steam channel cross sections. Modified greenline vegetation data collected at the Epler farm showed a shift in study reach riparian vegetative conditions from predominantly turf grass to a community dominated by shrubs (multi-flora rose) one year after fencing (Figure 7). Riparian vegetation at the Englart farm indicated a shift from a predominantly turf grass community to a sedge/rush/grass community with an increase in the relative coverage of shrubs and herbaceous plants (Figure 8). Reference reach riparian conditions were not sampled at the Epler and Englart farms.

Chemical Water Quality

Chemical water quality was determined using the same sampling and analysis procedures at all three fencing sites. A total of 16 field and laboratory water quality parameters were assessed at study and reference reaches before and one year after fencing. Water samples used for field and laboratory analyses were collected at the downstream end of each reach to document changes in chemical water quality that occurred as water passed through fenced stream reaches.

Water quality parameters evaluated in the field included water temperature, dissolved oxygen, conductivity, pH, alkalinity, and acidity. Dissolved oxygen was measured using a YSI

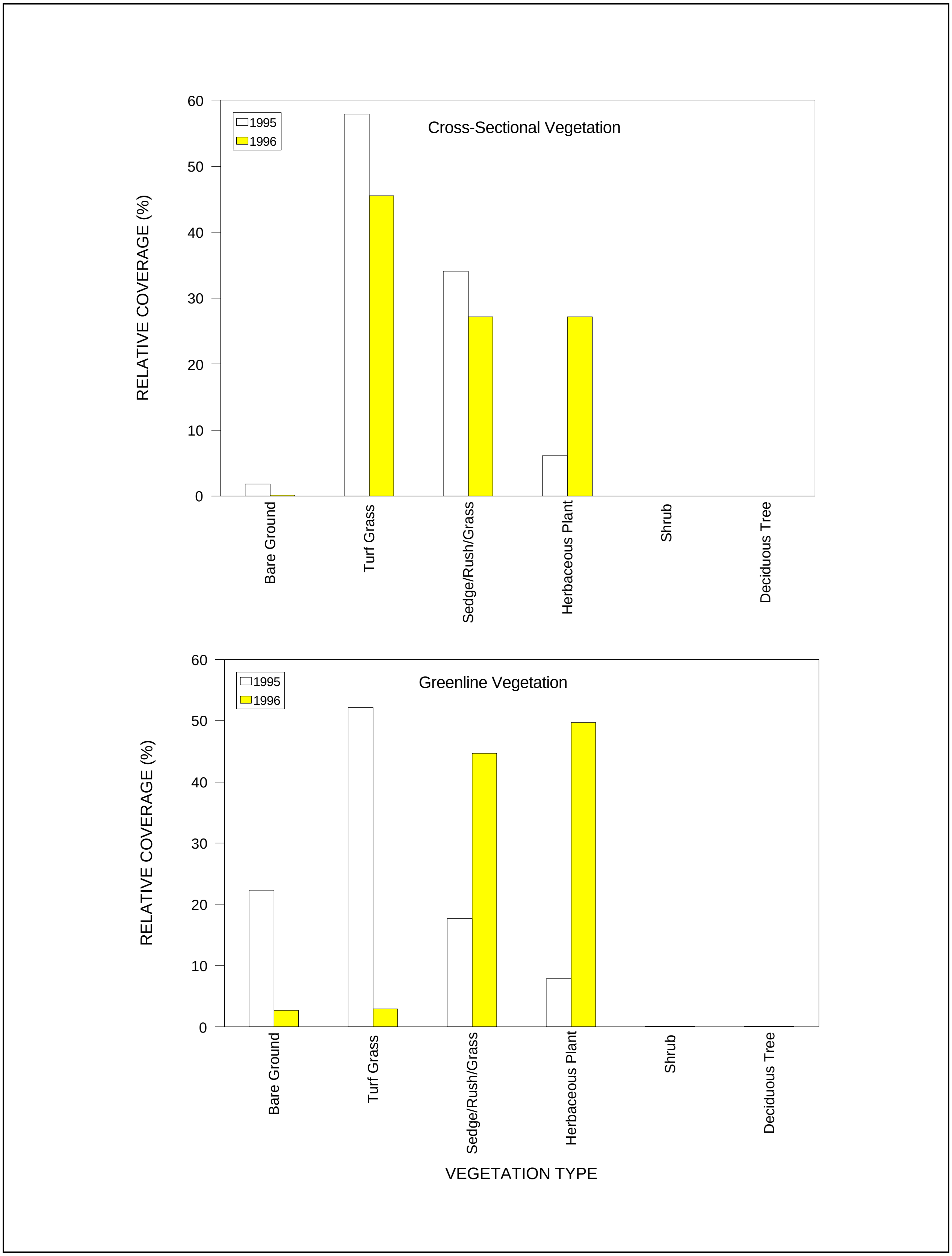


Figure 5. Summary of the Veety Farm Study Reach Vegetation Data, 1995 and 1996

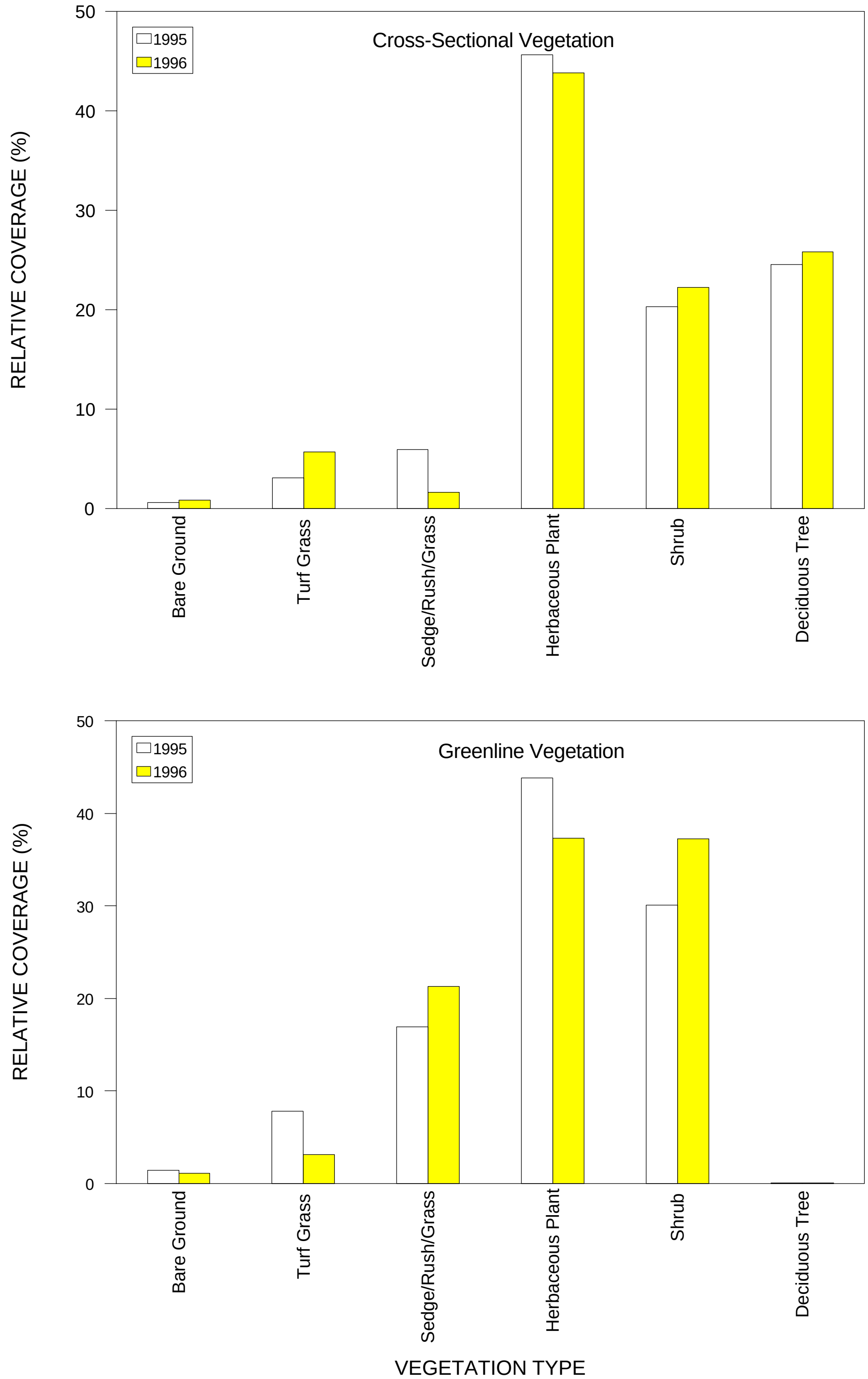


Figure 6. Summary of the Veety Farm Reference Reach Vegetation Data, 1995 and 1996

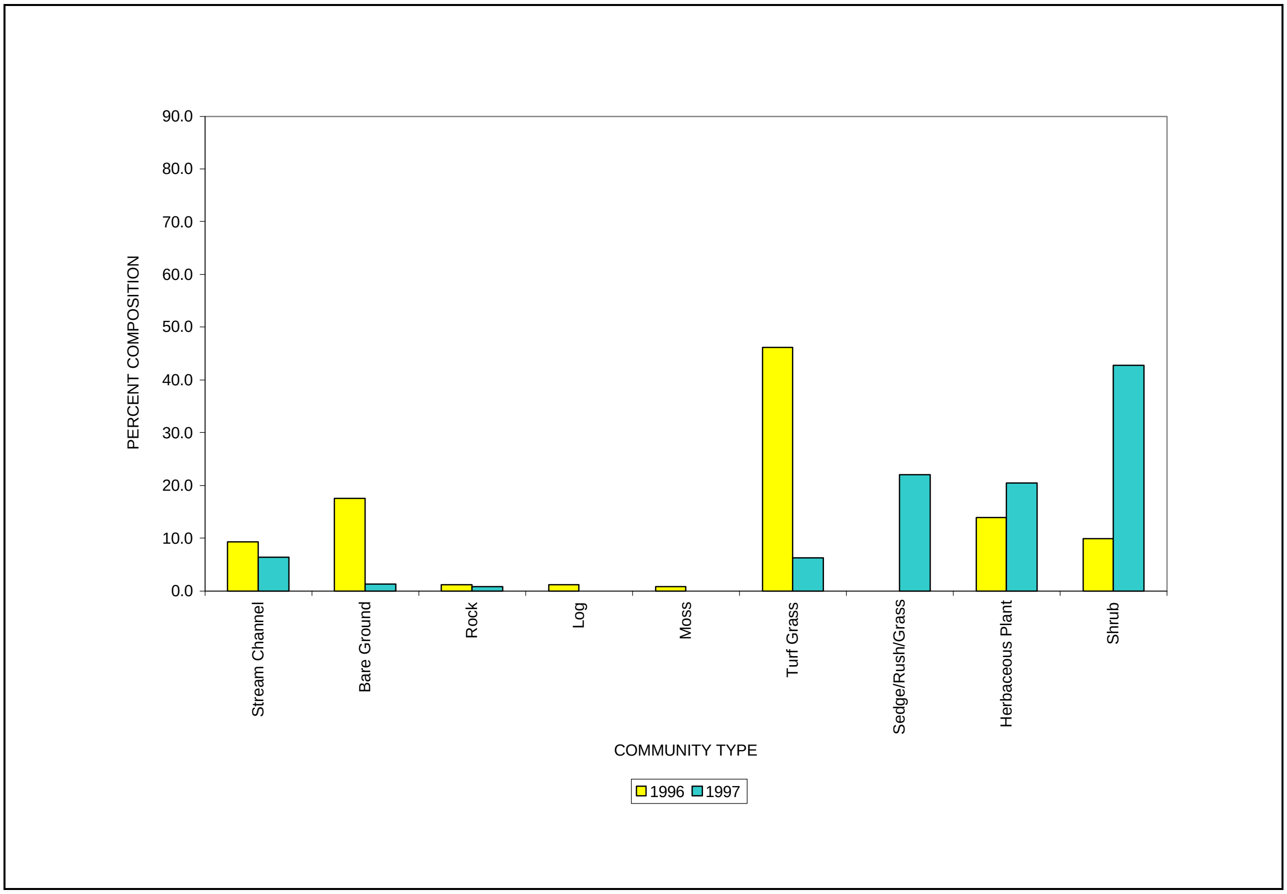


Figure 7. Summary of the Epler Farm Study Reach Vegetation Data, 1996 and 1997

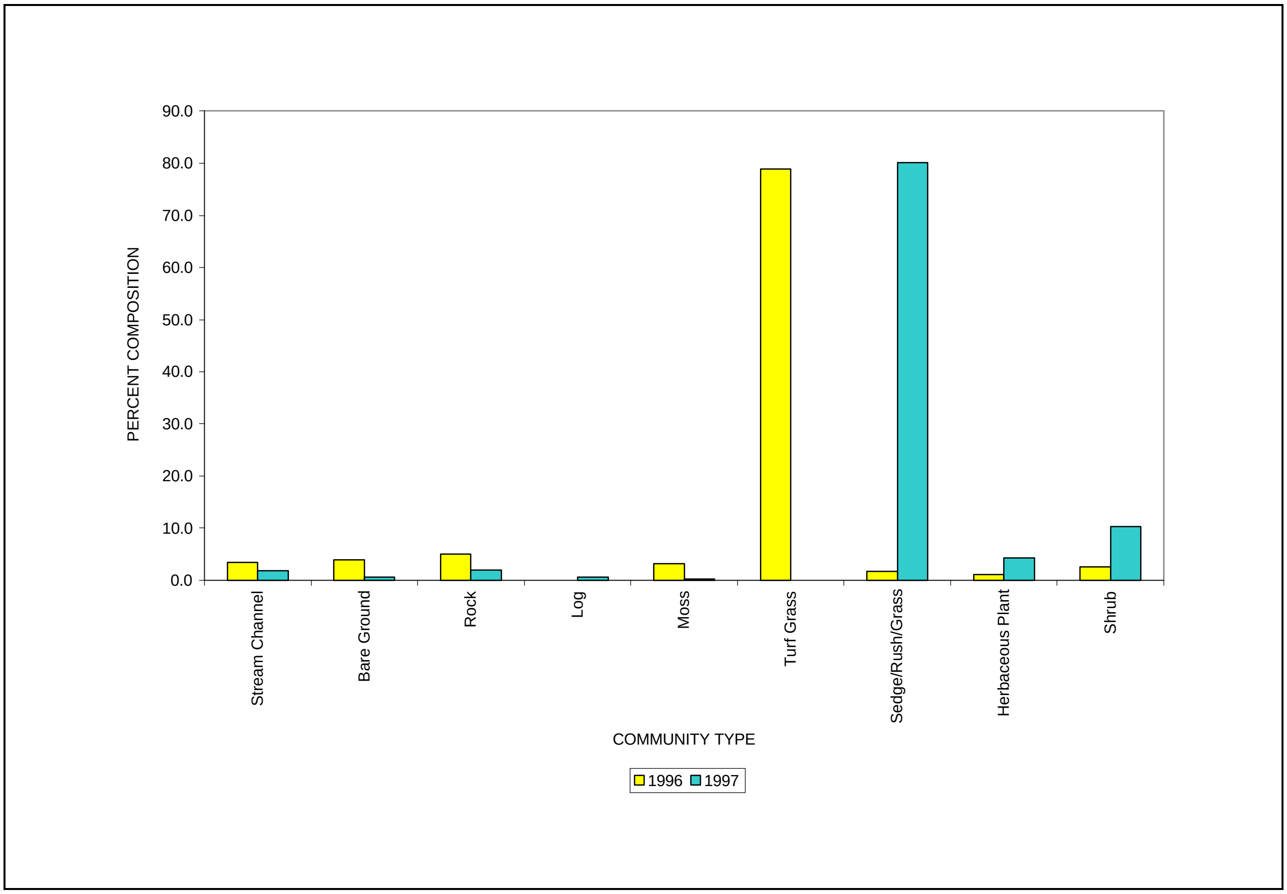


Figure 8. Summary of the Englart Farm Study Reach Vegetation Data, 1996 and 1997

Model 55 dissolved oxygen meter. Conductivity and pH were determined using Cole-Parmer Model 1481-61 and Model 5996-70 meters, respectively. Alkalinity was measured by titrating a known volume of sample water to pH 4.5 with 0.02N H_2SO_4. Acidity was measured by titrating a known volume of sample water to pH 8.3 with 0.02N NaOH. Stream discharge was measured at all study reaches using standard USGS procedures. Approximately one liter of water from each reach was collected for laboratory analysis. Laboratory samples consisted of two 500-ml bottles of water for nutrient analysis (one unfiltered and one filtered through a cellulose nitrate filter with a 0.45 µm pore size). The Pa. DEP, Bureau of Laboratories in Harrisburg, Pennsylvania, performed all laboratory analyses. The 95 percent confidence intervals of the concentrations reported by the laboratory were used to identify significant differences in water quality parameter concentrations. The 95 percent confidence intervals of nutrient water quality parameters were calculated as shown in Table 2.

Total organic nitrogen concentrations were calculated as:

Total Organic Nitrogen = Total Nitrogen – (Total Ammonia + Total Nitrite and Nitrate)

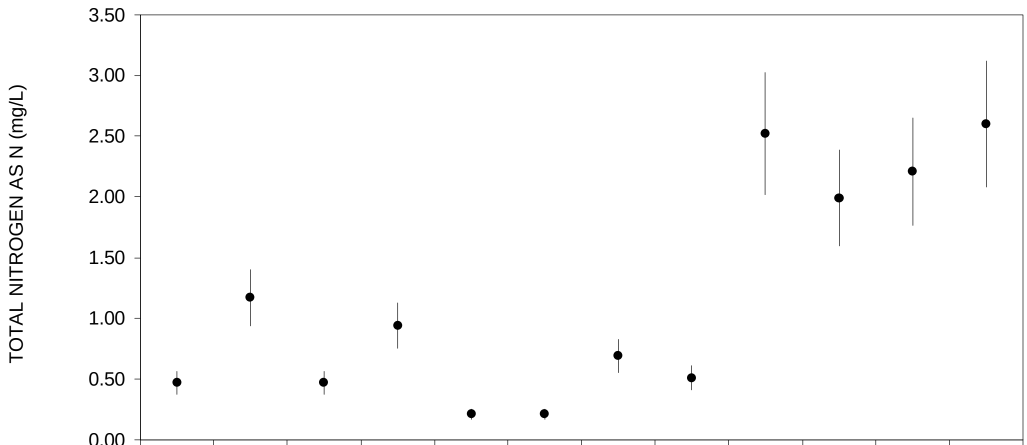
and were used to provide insight into the nitrogen species composition and the relative concentration of organic and inorganic nitrogen species at each stream reach. Chemical water quality and stream discharge data are summarized in Appendix A. Total nitrogen concentrations did not exceed Pennsylvania State water drinking standards of 10 mg/l at any sampling sites (Pa. DER, 1989).

Water quality data indicate that the water quality conditions, and the influence of streambank fencing on these conditions, are quite different among the three study streams. For example, total nitrogen concentrations observed at the Epler farm are significantly higher than concentrations at the Veety and Englart farms. Also, no significant change in total nitrogen concentration occurred as the stream flowed from the reference reach through the study reach at the Epler farm either before or after fencing (Figure 9). Additionally, nitrite/nitrate was the predominant nitrogen species in both the reference and study reaches at the Epler farm before and after fencing (Figure 10). Although total nitrogen concentrations at the Englart farm were significantly lower than those observed at the Epler farm, nitrite/nitrate also was the predominant nitrogen species in both the reference and study reach at the Englart farm before fencing (Figure 11). However, total nitrogen concentrations and the nitrogen species composition of both the study and reference reaches observed at the Englart farm one year after fencing were significantly different than those observed at this farm before it was fenced (Figures 9 and 11). Similar to the nutrient processes observed at the Epler farm, no

Table 2. Nutrient Water Quality Parameters

Parameter	Pa. DEP Analysis Code	95% Confidence Interval
Nitrogen Total as N	600 A	Reported value +/- 20%
Nitrogen Dissolved as N	602 A	Reported value +/- 20%
Ammonia Dissolved as N	608 A	Reported value +/- 15%
Ammonia Total as N	610 A	Reported value +/- 15%
Nitrite and Nitrate Total as N	630 A	Reported value +/- 10%
Nitrite and Nitrate Dissolved as N	631 A	Reported value +/- 10%
Phosphorus Total Wet Method	665 A	Reported value +/- 15%
Phosphorus Dissolved Wet Method	666 A	Reported value +/- 15%

Source: Pa. DEP, Bureau of Laboratories in Harrisburg, Pennsylvania.



	Veety Ref95	Veety Stdy95	Veety Ref96	Veety Stdy96	Englart Ref96	Englart Stdy96	Englart Ref97	Englart Stdy97	Epler Ref96	Epler Stdy96	Epler Ref97	Epler Stdy97
95% Conf. Int. Low	0.38	0.94	0.38	0.75	0.168	0.168	0.552	0.408	2.016	1.592	1.768	2.08
95% Conf. Int. High	0.56	1.40	0.56	1.13	0.252	0.252	0.828	0.612	3.024	2.388	2.652	3.12
Reported Value	0.47	1.17	0.47	0.94	0.21	0.21	0.69	0.51	2.52	1.99	2.21	2.6

Figure 9. Summary of Total Nitrogen Concentrations From the Veety, Englart, and Epler Farms

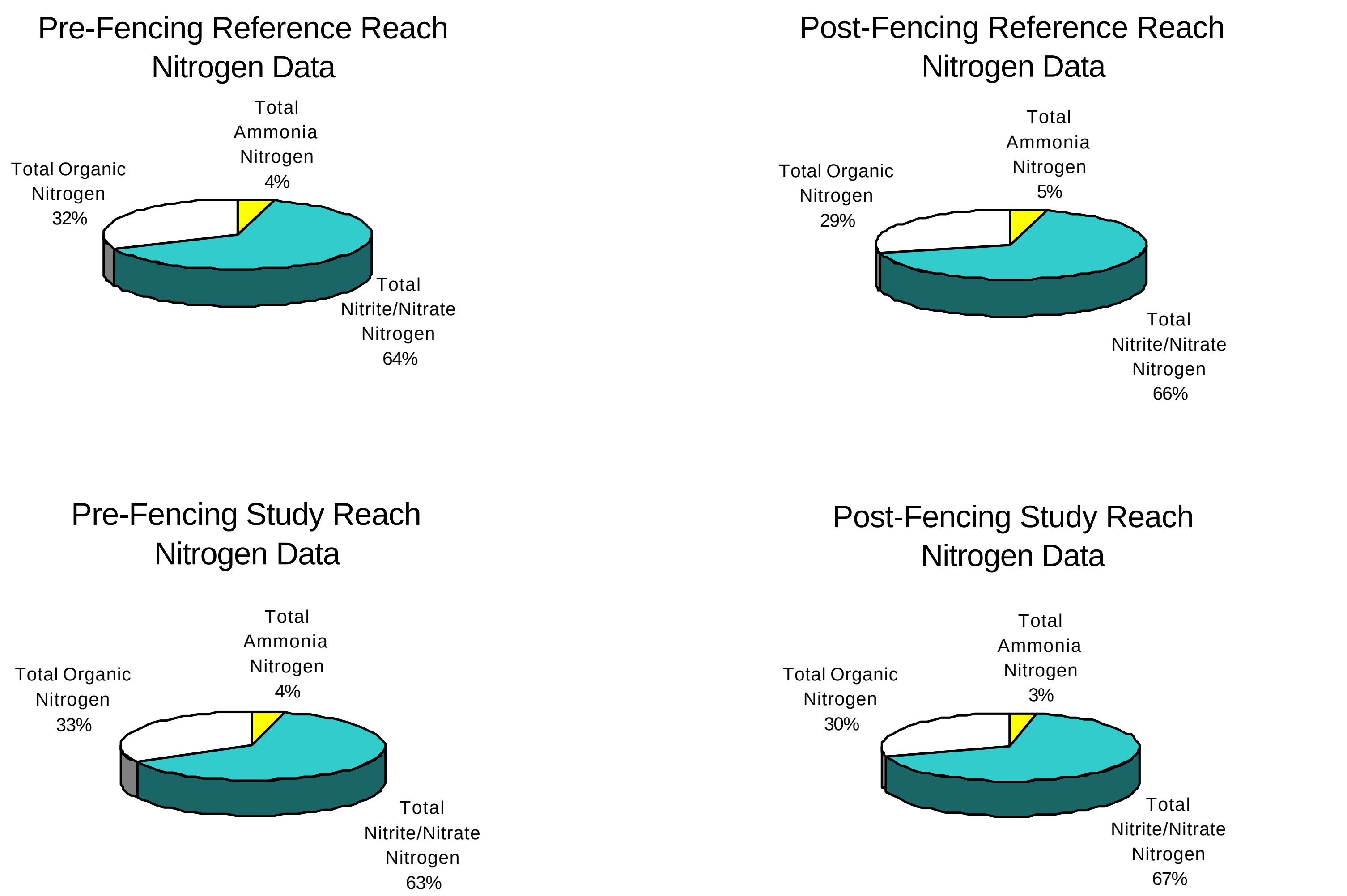


Figure 10. Summary of the Epler Farm Nitrogen Data

Figure 11. Summary of the Englart Farm Nitrogen Data

significant change in total nitrogen concentrations was observed at the Englart farm as stream water flowed from the reference reach through the study reach either before or after fencing. Furthermore, the total nitrogen concentration and nitrogen species composition of the streams flowing through the Epler and Englart fencing projects mirror those of the waters entering these projects.

In contrast to the Epler and Englart farms, the total nitrogen concentrations at the Veety farm increased as stream water flowed from the reference reach through the study reach, both before and one year after fencing (Figure 9). In addition, organic nitrogen tended to be the predominant nitrogen species at the Veety farm, as opposed to nitrite/nitrate, the predominant species at the Epler and Englart farms (Figure 12). However, ammonia was the predominant nitrogen species in the Veety farm reference reach one year after fencing due to several cattle gaining access to this reach at the time of post-fencing sampling.

Study and reference reach total ammonia and nitrite/nitrate concentrations observed at the three farms before and after fencing indicate that streambank fencing influences these nitrogen species differently at the various farms. For example, the highest total ammonia concentrations were observed at the Veety farm. Before fencing, the concentration of ammonia in the Veety farm reference reach was low (0.03 mg/l as N) and increased dramatically in the study reach (0.21 mg/l as N) where cattle had direct access to the stream (Figure 13). One year after fencing, cattle had obtained access to the reference reach, and the ammonia concentration of this reach was 0.22 mg/l as N. In spite of the elevated ammonia value of the reference reach one year after fencing, the ammonia concentration of the study reach was significantly lower than that of the reference reach, as well as that of the study reach before fencing. However, this dramatic reduction in concentration of ammonia was not observed at the Epler and Englart farms, perhaps due to the low levels associated with these sites.

Total nitrite/nitrate concentrations were highest at the Epler farm (ranged from 1.25 to 1.74 mg/l as N), and no significant reduction in this nitrogen species was observed at this site one year after fencing (Figure 14). Total nitrite/nitrate values at the Englart and Veety farms were relatively low and ranged between 0.11 and 0.40 mg/l as N (Figure 14). At the Englart farm, both study and reference reach total nitrite/nitrate concentrations were slightly higher one year after fencing, but no significant change in nitrite/nitrate concentration occurred as stream water flowed from the reference reach through the study reach, either before or after fencing. In contrast to the Epler and Englart farms, the Veety farm study reach total nitrite/nitrate concentrations were higher than those of the reference reach both before and after fencing. Furthermore, these concentrations were significantly lower one year after fencing than they were before fencing. However, a significant reduction in the Veety farm reference reach total nitrite/nitrate concentration also was observed after fencing, indicating a reduction in background nitrite/nitrate concentrations. Thus, the reduction in nitrite/nitrate nitrogen observed in the study reach after fencing cannot be solely attributed to the construction of the fence at this site.

A significant reduction in the concentration of total phosphorus was observed in the study reach of both the Veety and Epler farms after fencing (Figure 15). Although the total phosphorus concentration of the Veety farm reference reach also was significantly lower after fencing, the magnitude of change in study reach total phosphorus before and after fencing cannot be attributed entirely to the lower background phosphorus concentrations reflected in the post-fencing reference reach data. A similar reduction in the concentration of dissolved phosphorus was observed in the Veety farm study reach (Figure 16). A significant reduction in dissolved phosphorus also occurred in both the study and reference reaches at the Epler farm.

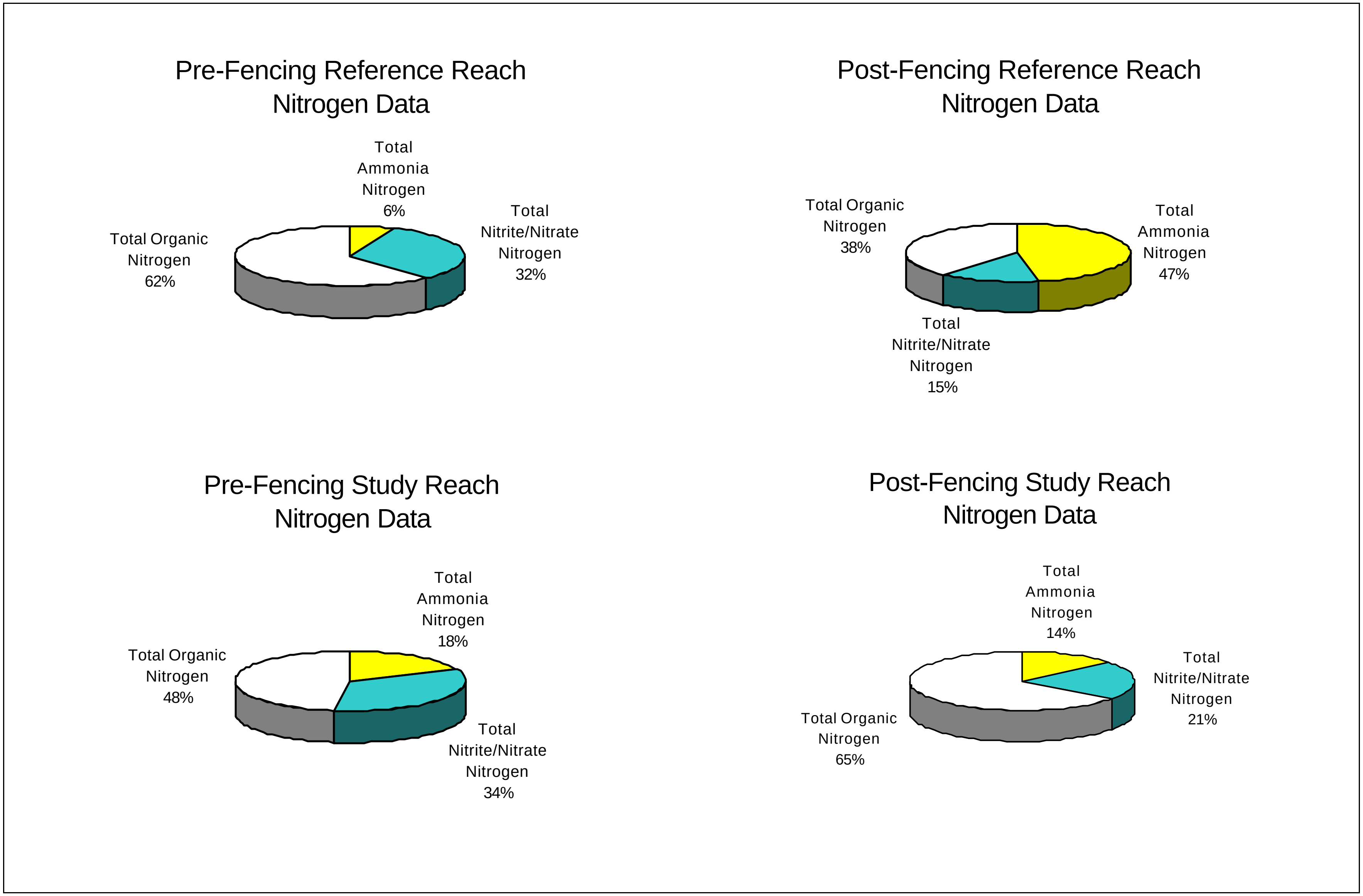
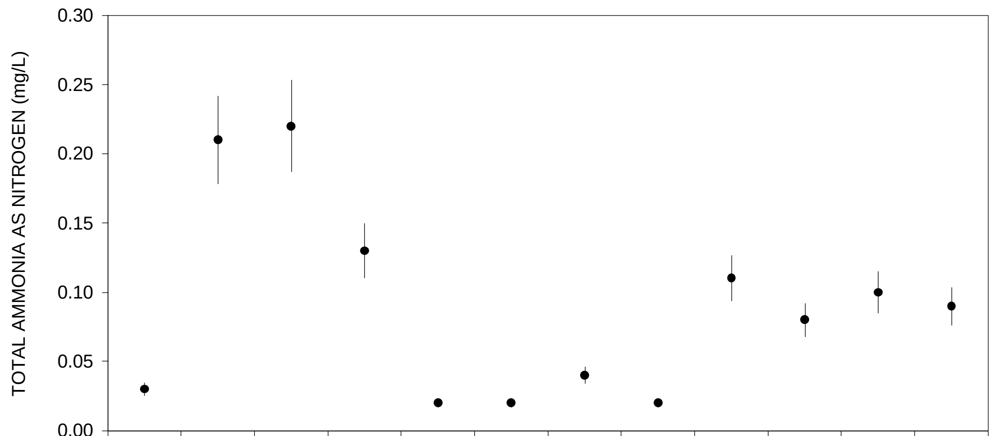
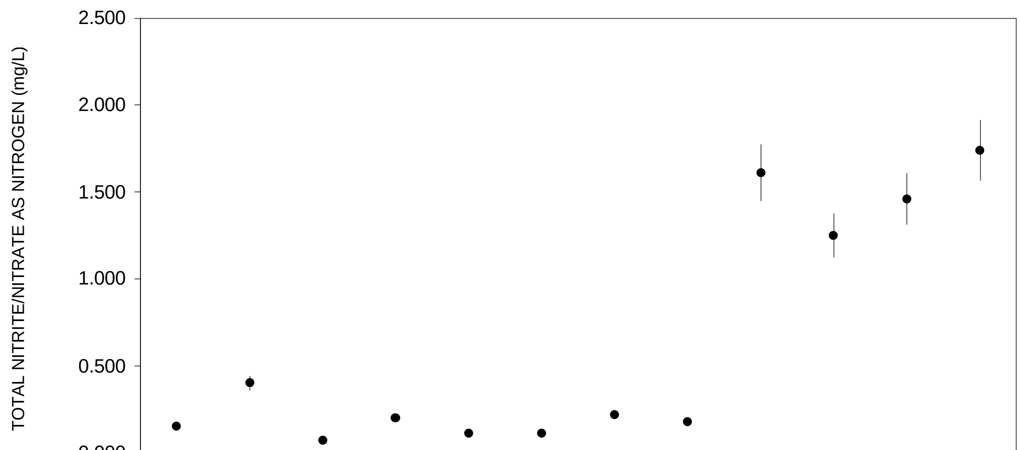


Figure 12. Summary of the Veety Farm Nitrogen Data



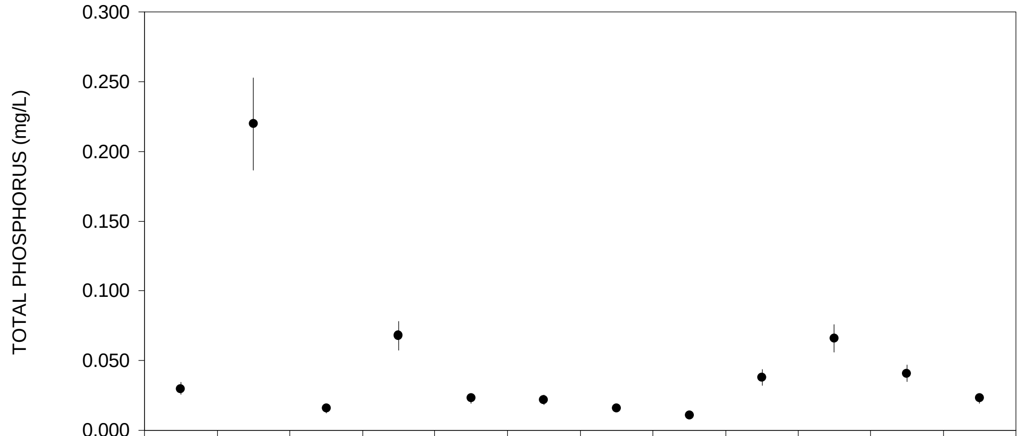
	Veety Ref95	Veety Stdy95	Veety Ref96	Veety Stdy96	Englart Ref96	Englart Stdy96	Englart Ref97	Englart Stdy97	Epler Ref96	Epler Stdy96	Epler Ref97	Epler Stdy97
95% Conf. Int. Low	0.0255	0.1785	0.187	0.1105	0.017	0.017	0.034	0.017	0.0935	0.068	0.085	0.0765
95% Conf. Int. High	0.0345	0.2415	0.253	0.1495	0.023	0.023	0.046	0.023	0.1265	0.092	0.115	0.1035
Reported Value	0.03	0.21	0.22	0.13	0.02	0.02	0.04	0.02	0.11	0.08	0.1	0.09

Figure 13. Summary of Total Ammonia Concentrations From the Veety, Englart, and Epler Farms



	Veety Ref95	Veety Stdy95	Veety Ref96	Veety Stdy96	Englart Ref96	Englart Stdy96	Englart Ref97	Englart Stdy97	Epler Ref96	Epler Stdy96	Epler Ref97	Epler Stdy97
95% Conf. Int. Low	0.135	0.360	0.063	0.18	0.099	0.099	0.198	0.162	1.449	1.125	1.314	1.566
95% Conf. Int. High	0.165	0.440	0.077	0.22	0.121	0.121	0.242	0.198	1.771	1.375	1.606	1.914
Reported Value	0.150	0.400	0.070	0.2	0.11	0.11	0.22	0.18	1.61	1.25	1.46	1.74

Figure 14. Summary of Total Nitrite/Nitrate Concentrations From the Veety, Englart, and Epler Farms



	Veety Ref95	Veety Stdy95	Veety Ref96	Veety Stdy96	Englart Ref96	Englart Stdy96	Englart Ref97	Englart Stdy97	Epler Ref96	Epler Stdy96	Epler Ref97	Epler Stdy97
95% Conf. Int. Low	0.026	0.187	0.0128	0.0578	0.0196	0.0187	0.0136	0.0094	0.0323	0.0561	0.0349	0.0196
95% Conf. Int. High	0.035	0.253	0.0173	0.0782	0.0265	0.0253	0.0184	0.0127	0.0437	0.0759	0.0472	0.0265
Reported Value	0.030	0.220	0.016	0.068	0.023	0.022	0.016	0.011	0.038	0.066	0.041	0.023

Figure 15. Summary of Total Phosphorus Concentrations From the Veety, Englart, and Epler Farms

Stream Channel Morphology

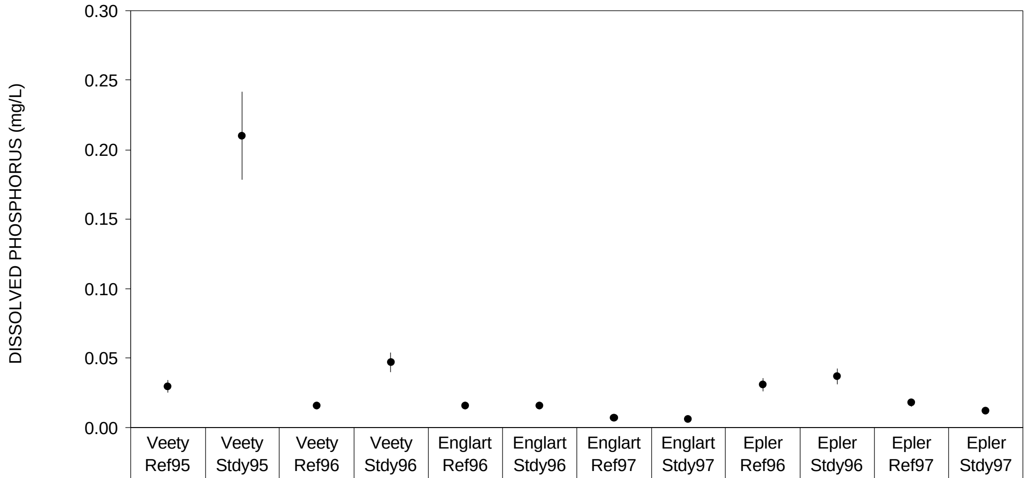
Study and reference reach stream channel morphology was characterized at the Veety farm using Rosgen Level II stream classification data (Rosgen, 1996). Rosgen Level II classification data also were collected in the study reaches of the Epler and Englart farms. These data consisted of field measurements of channel cross-sectional dimensions, sinuosity, slope, and the size of channel materials. Channel cross-sectional dimensions, sinuosity, and slope were determined using a surveying rod, level, and tape measure. Sinuosity, slope, and channel materials were assessed over the entire sample reach, the end-points of which were delineated such that reaches started and ended in the same type of channel unit (e.g., head-of-riffle to head-of-riffle). In each of the Veety farm stream reaches, stream channel cross-sectional geometry was surveyed at two locations (one riffle and one pool channel unit). Three study reach cross sections were surveyed at the Epler and Englart farms. Bankfull stage was identified using indicators such as those described by Dunne and Leopold (1978), Harrelson and others (1994), and Rosgen (1996). Some of these indicators included: floodplain elevations, the tops of depositional features such as point bars, breaks in streambank slope, changes in streambank particle size, and staining of rocks. Stream channel cross-sectional dimensions were calculated using XSPRO cross-sectional analysis software (Grant and others, 1992).

Entrenchment and width/depth ratios were derived from channel cross-sectional data. Entrenchment ratio describes the vertical containment of the stream channel (the degree to which it is incised in the valley floor). Entrenchment ratio was calculated as the following: the ratio of the width of the flood-prone area to the surface width of the bankfull channel. The flood-prone area width was measured at the elevation that corresponded to twice the maximum depth of the bankfull channel (Figure 17). Width/depth ratio was calculated as the ratio of the bankfull surface width to the mean depth of the bankfull channel.

Sinuosity was calculated as the ratio of stream channel length to valley length of the study reach. Stream length was determined in the field by measuring the length of each channel unit (riffle, run, or pool) in the study reach using a tape measure extended in alignment with the channel thalweg (the deepest part of the channel). Valley length was determined by measuring the straight-line distance between the upstream and downstream end-points of the reach, which were surveyed in the field and plotted in the office. Water surface slope was calculated as the change in surface water elevation per unit stream length. Surface water elevation at the upstream and downstream end-points of each study reach were surveyed in the field.

Dominant channel materials were determined based on the particle size distribution of bankfull channel materials using the modified Wolman "pebble-count" method, as described by Rosgen (1996). The intermediate axis diameter of approximately 100 randomly-selected substrate particles was measured and tabulated in the field. The number of particles selected from a given channel unit (riffle, run, or pool) was based on the channel unit configuration of the stream reach, such that channel units were sampled in proportion to their occurrence in the reach. The dominant particle size of the stream reach (d_{50}) was determined from a cumulative percent plot of the pebble count data.

At the Veety farm, the most noticeable changes in stream morphology were changes in channel cross-sectional geometry, substrate composition, and pool/riffle(run) composition. Study reach cross section 2, which was minimally impacted by cattle prior to the implementation of streambank fencing, showed little change between 1995 and 1996. However, at study reach cross section 3, which was located in the most severely degraded section of stream, the area, hydraulic radius, and average depth increased, while the perimeter and width decreased (Figure 18). Similar, but generally more substantial, changes in area, width, hydraulic



	Veety Ref95	Veety Stdy95	Veety Ref96	Veety Stdy96	Englart Ref96	Englart Stdy96	Englart Ref97	Englart Stdy97	Epler Ref96	Epler Stdy96	Epler Ref97	Epler Stdy97
95% Conf. Int. Low	0.0255	0.1785	0.0136	0.03995	0.0136	0.0136	0.00595	0.0051	0.02635	0.03145	0.0153	0.0102
95% Conf. Int. High	0.0345	0.2415	0.0184	0.05405	0.0184	0.0184	0.00805	0.0069	0.03565	0.04255	0.0207	0.0138
Reported Value	0.03	0.21	0.016	0.047	0.016	0.016	0.007	0.006	0.031	0.037	0.018	0.012

Figure 16. Summary of Dissolved Phosphorus Concentrations From the Veety, Englart, and Epler Farms

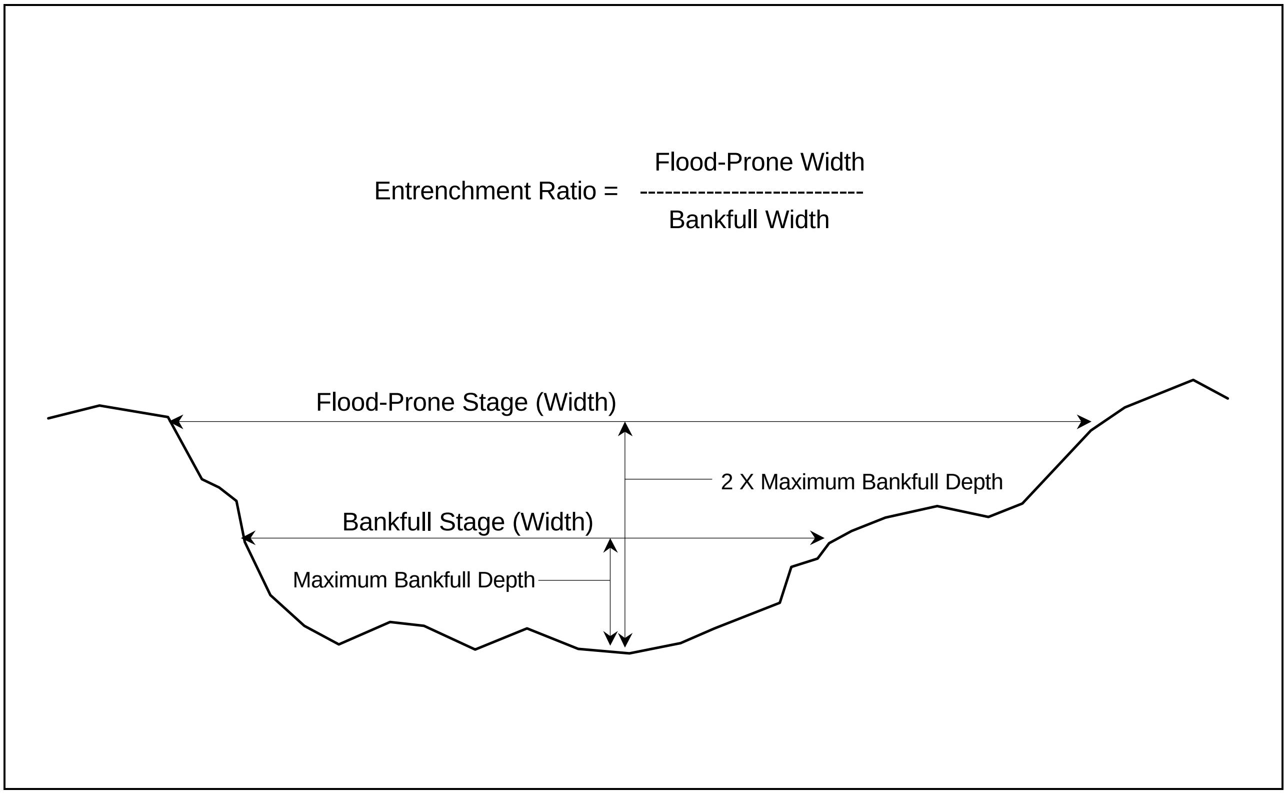


Figure 17. Illustration of Entrenchment Ratio Calculated From Bankfull and Flood-Prone Channel Width

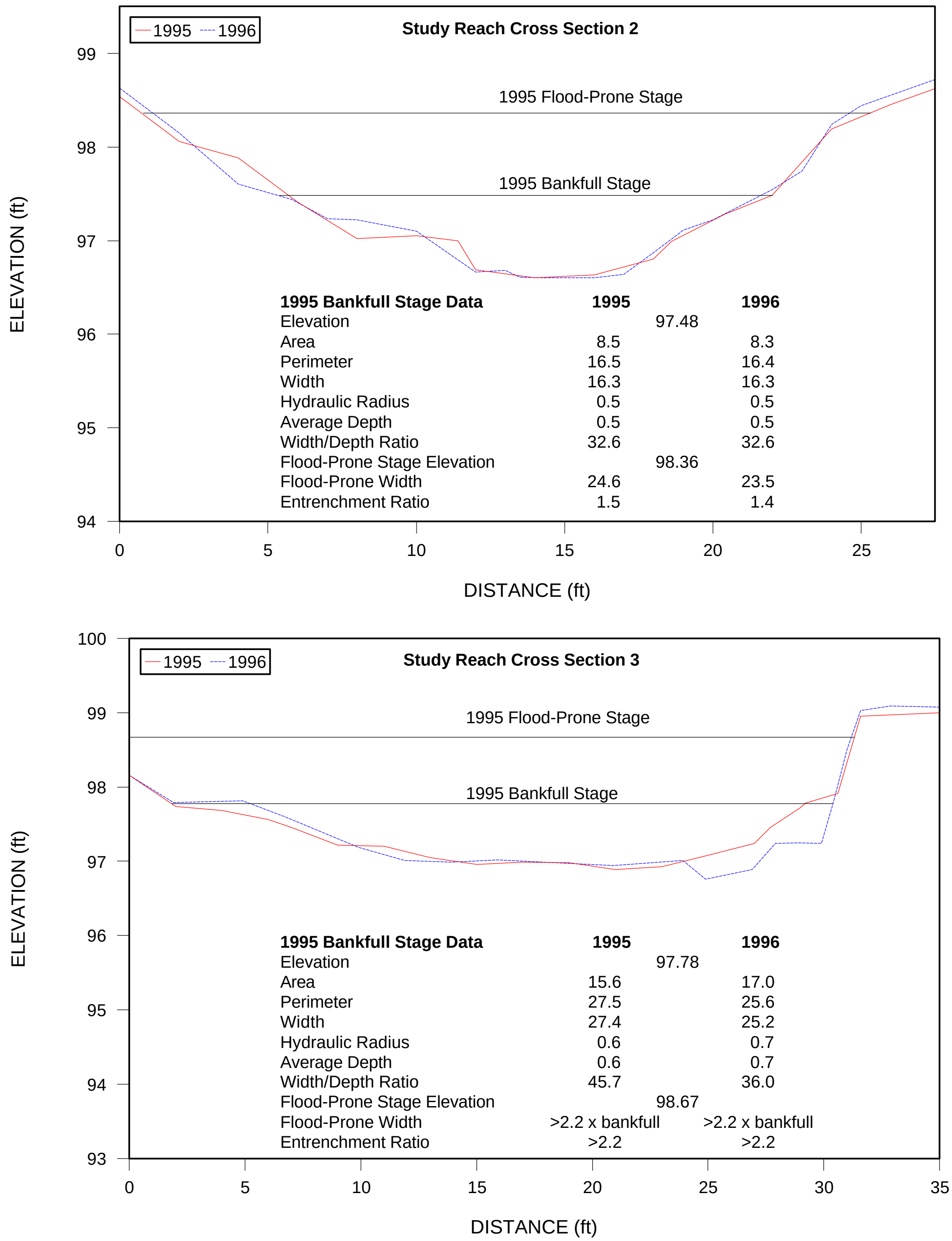


Figure 18. Veety Farm Study Reach Cross Sections 2 and 3, 1995 and 1996

radius, and average depth were observed at reference reach cross sections 2 and 3 (Figure 19). Changes in channel cross-sectional geometry of the Veety farm study and reference reach cross sections are summarized in Figure 20.

The most significant changes observed in stream reach morphology characteristics at the Veety farm included changes in substrate particle size and pool/riffle composition. Although the study reach d_{15} (the substrate particle size class that 15 percent of the sampled population is equal to or finer than) and d_{35} values were unchanged, the d_{50}, d_{84}, and d_{95} values increased between 1995 and 1996 (Figure 21). Thus, the amount of silt/clay and sand decreased, and gravel and cobble increased in the study reach between 1995 and 1996. Changes in the substrate composition of the reference reach were minor and consisted primarily of an increase in the amount of silt/clay and a reduction in small gravel (Figure 22).

Bedform morphologies of the Veety farm study and reference reaches are best described as pool/run and pool/riffle, respectively. Between 1995 and 1996, the amount of pool habitat decreased in the study reach, while it increased in the reference reach. Cross-sectional geometry and stream reach morphology data are summarized in Table 3.

Noticeable changes in channel geometry and substrate composition also occurred at the Epler farm study site. At study reach cross section 2, area, perimeter, and width increased, while in cross sections 3 and 4, these parameters decreased slightly (Figures 23 and 24). Additionally, hydraulic radius decreased at cross section 3 (Figure 23). Only study reaches were surveyed at this farm. Changes in channel cross-sectional geometry of study reaches are summarized in Figure 25.

One of the most significant changes in stream reach morphology at the Epler farm was the change in substrate particle size. Although the d_{15} value did not change between 1996 and 1997, the d_{35}, d_{50}, and d_{84} values increased (Figure 26). Thus, the amount of silt/clay and sand decreased, and gravel and cobble increased in the study reach over the sampling period. Particle sizes were not determined in the reference reach.

Although substantial changes in channel morphology and particle size occurred, the pool/riffle(run) ratio found at the Epler farm changed only slightly between 1996 and 1997. Between the two years, the percentage of pool decreased minimally from 51.5 percent to 50.3 percent with a reciprocal change in the amount of riffle(run). Cross-sectional and stream reach morphologies are summarized in Table 4.

Similar to the Veety and Epler farms, noticeable changes in channel cross-sectional geometry and substrate composition occurred at the Englart farm between 1996 and 1997. At cross section 2, area, perimeter, width, hydraulic radius, and width/depth ratio increased, in some cases substantially (Figure 27). Cross section 3 had a mixture of increasing and decreasing parameters: area, hydraulic radius, and average depth increased, while perimeter, width, and width/depth ratio decreased (Figure 27). At cross section 4, most parameters, including perimeter, width, and width/depth ratio, decreased (Figure 28). No measurements were taken at the reference reach at the Englart farm. Changes in channel cross-sectional geometry of study reaches are summarized in Figure 29.

Substrate particle size at the Englart farm also changed, though not as dramatically as at the Veety and Epler farms. Again, d_{15} values did not change; however, the values for d_{35} and d_{50} increased, while the d_{84} value decreased slightly (Figure 30). Thus, the amount of silt/clay and sand decreased, while the amount of gravel increased at this site. Particle sizes were not determined for the reference reach.

The pool/riffle(run) ratio at the Englart farm study reach also changed from 1996 to 1997. The percentage of pool increased substantially from 45.6 percent to 54.2 percent over the year, with a respective change in the amount of riffle.

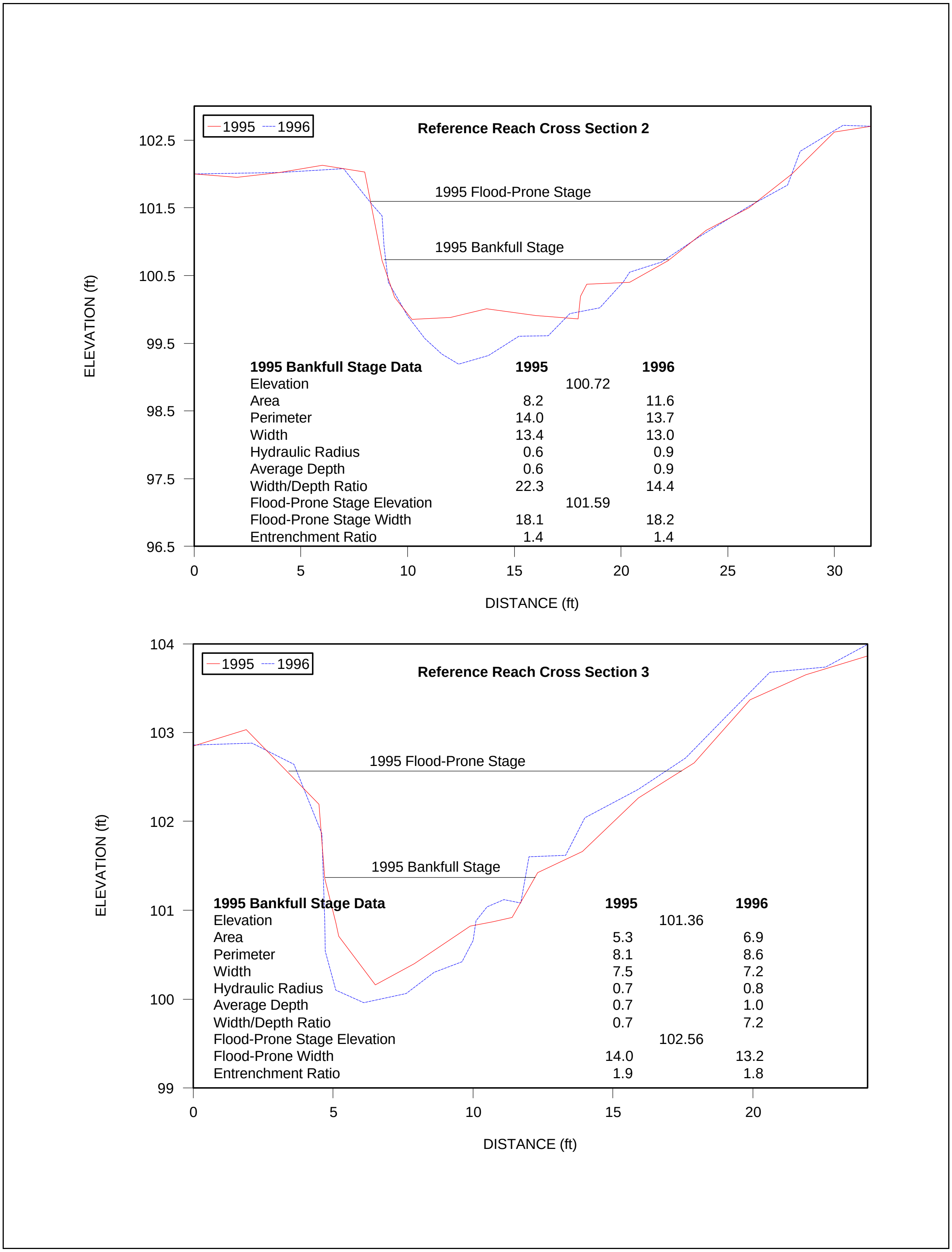


Figure 19. Veety Farm Reference Reach Cross Sections 2 and 3, 1995 and 1996

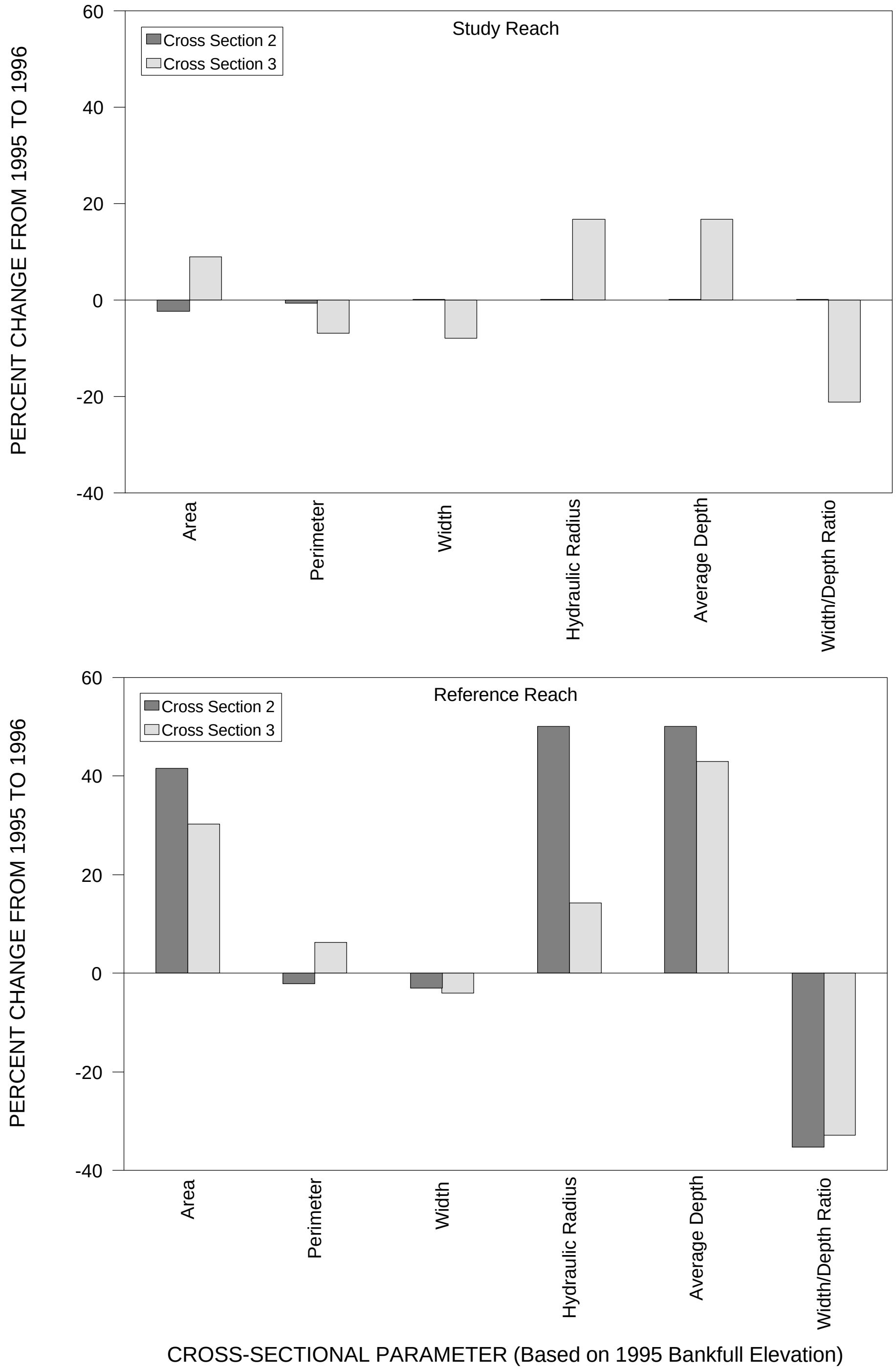


Figure 20. Summary of Changes in the Veety Farm Study and Reference Reach Channel Cross-Sectional Geometry Between 1995 and 1996

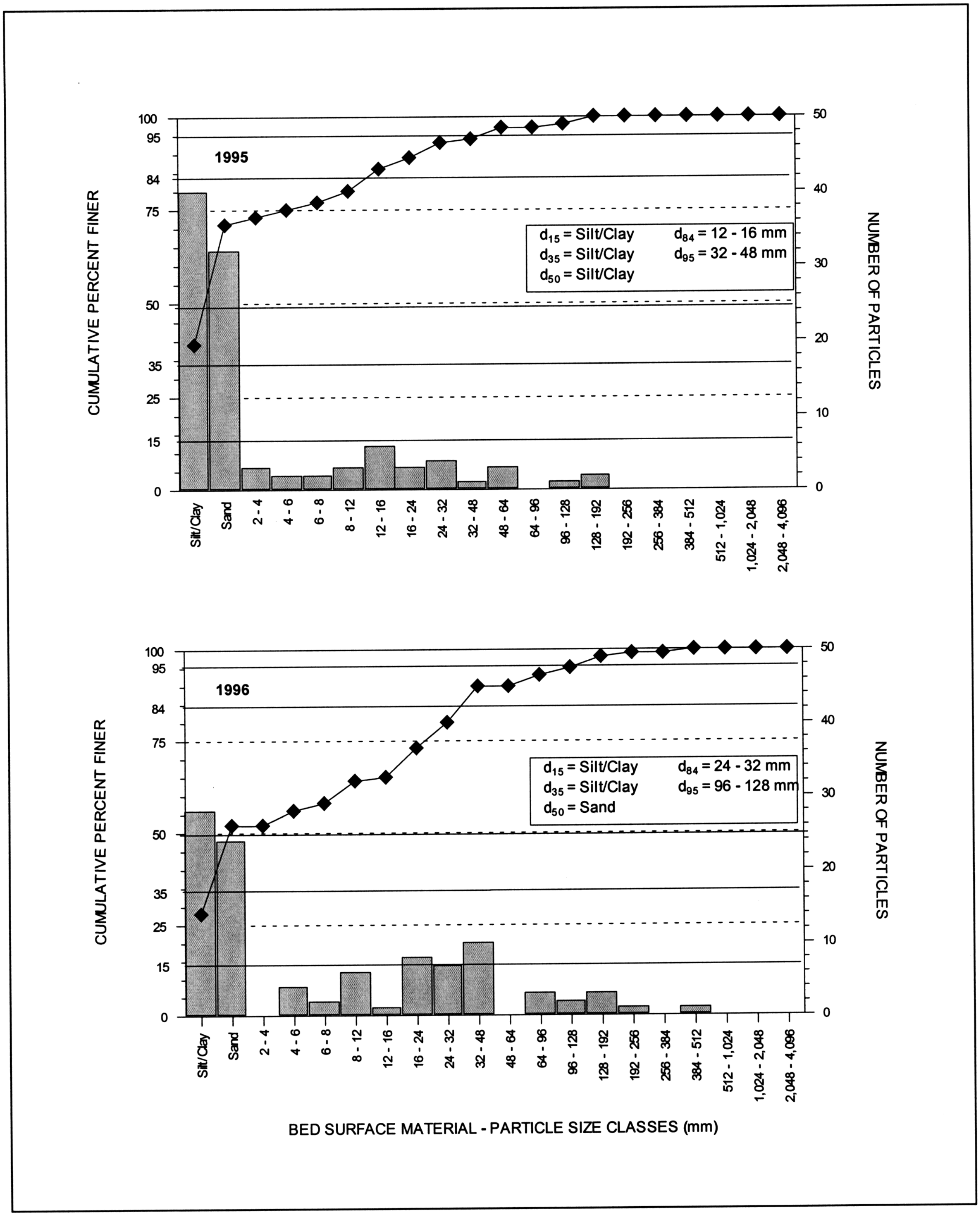


Figure 21. Veety Farm Study Reach Pebble-Count Data, 1995 and 1996

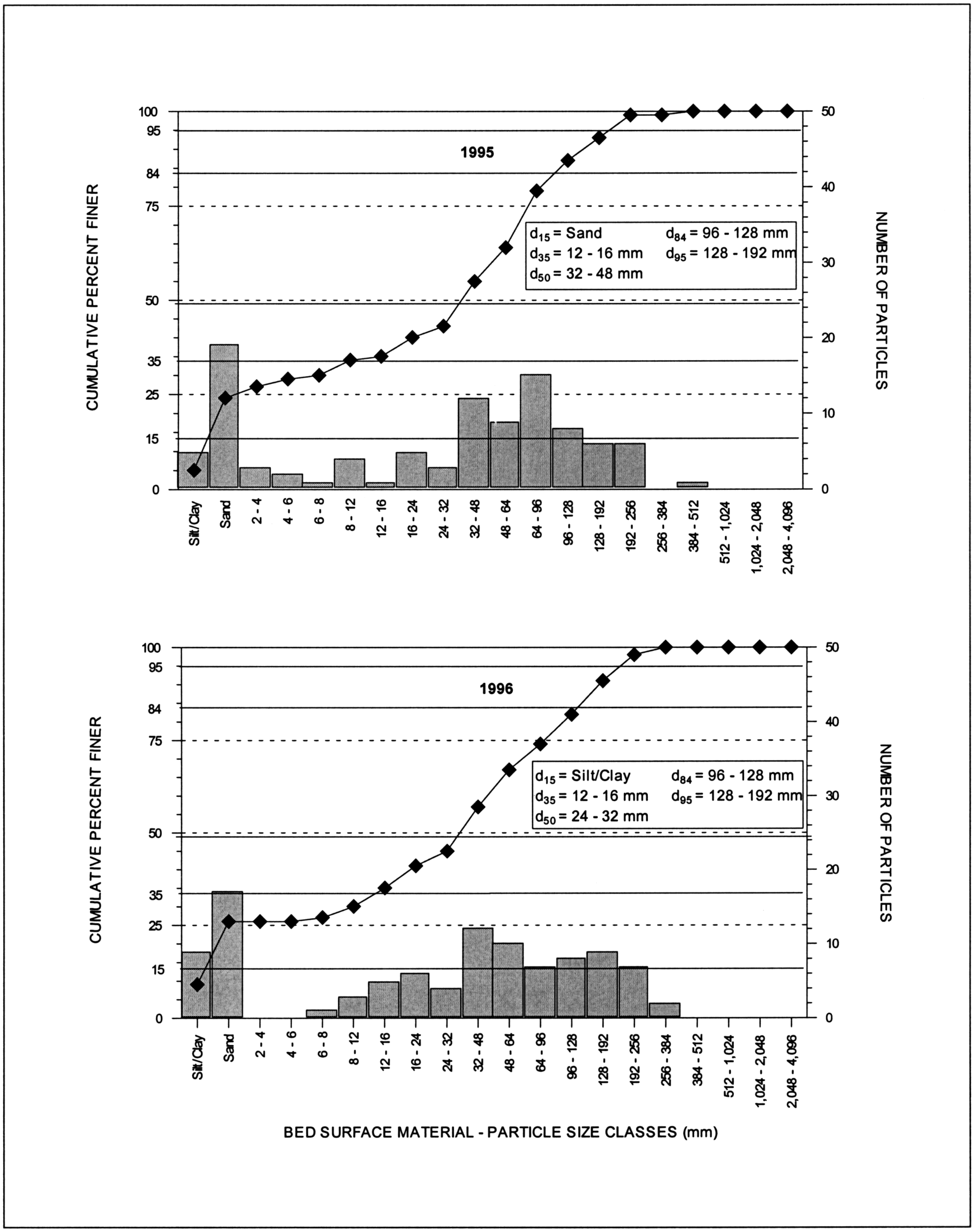
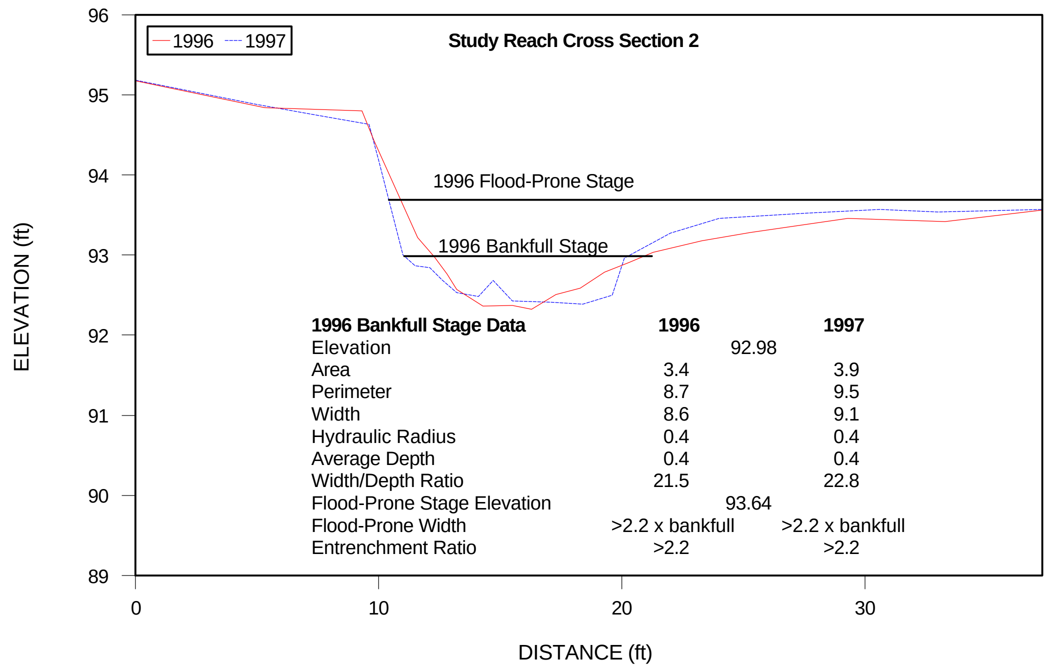


Figure 22. Veety Farm Reference Reach Pebble-Count Data, 1995 and 1996

Table 3. Summary of the Veety Farm Study Reach Morphology Data

Cross-Sectional Geometry	Study Reach Cross Section 2		Study Reach Cross Section 3		Reference Reach Cross Section 2		Reference Reach Cross Section 3	
	1995	**1996**	**1995**	**1996**	**1995**	**1996**	**1995**	**1996**
Bankfull Data								
1995 Bankfull Elevation	97.48		97.78		100.72		101.36	
Area	8.5	8.3	15.6	17.0	8.2	11.6	5.3	6.9
Perimeter	16.5	16.4	27.5	25.6	14.0	13.7	8.1	8.6
Width	16.3	16.3	27.4	25.2	13.4	13.0	7.5	7.2
Hydraulic Radius	0.5	0.5	0.6	0.7	0.6	0.9	0.7	0.8
Average Depth	0.5	0.5	0.6	0.7	0.6	0.9	0.7	1.0
BF Width/Depth Ratio	32.6	32.6	45.7	36.0	22.3	14.4	10.7	7.2
Flood-Prone Data								
1995 Flood-Prone Elevation	98.36		98.67		101.59		102.56	
Flood-Prone Width	24.6	23.5	>2.2 X bankfull	>2.2 X bankfull	18.1	18.2	14.0	13.2
Entrenchment	1.5	1.4	> 2.2	> 2.2	1.4	1.4	1.9	1.8

Stream Reach Morphology	**Study Reach**		**Reference Reach**	
	1995	**1996**	**1995**	**1996**
d_{15}	Silt/Clay	Silt/Clay	Sand	Silt/Clay
d_{35}	Silt/Clay	Silt/Clay	12 - 16 mm	12 - 16 mm
d_{50} - Median Particle Size	Silt/Clay	Sand	32 - 48 mm	24 - 32 mm
d_{84}	12 - 16 mm	24 - 32 mm	96 - 128 mm	96 - 128 mm
d_{95}	32 - 48 mm	96 - 128	128 - 192 mm	128 - 192 mm
Percent Pool (surface area)	78.1	62.2	36.6	52.1
Percent Riffle/Run (surface area)	21.9 (run)	37.8 (run)	63.4 (riffle)	47.9 (riffle)
Sinuosity	1.06	1.04	1.06	1.03
Surface Water Slope	0.003	0.004	0.013	0.013



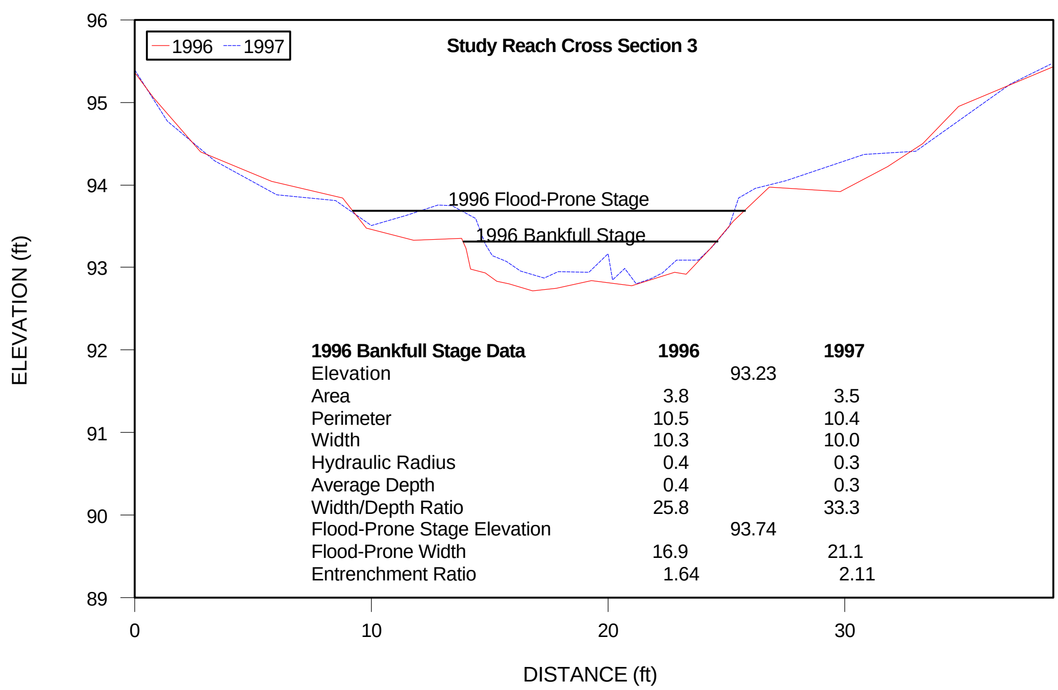


Figure 23. Epler Farm Study Reach Cross Sections 2 and 3, 1996 and 1997

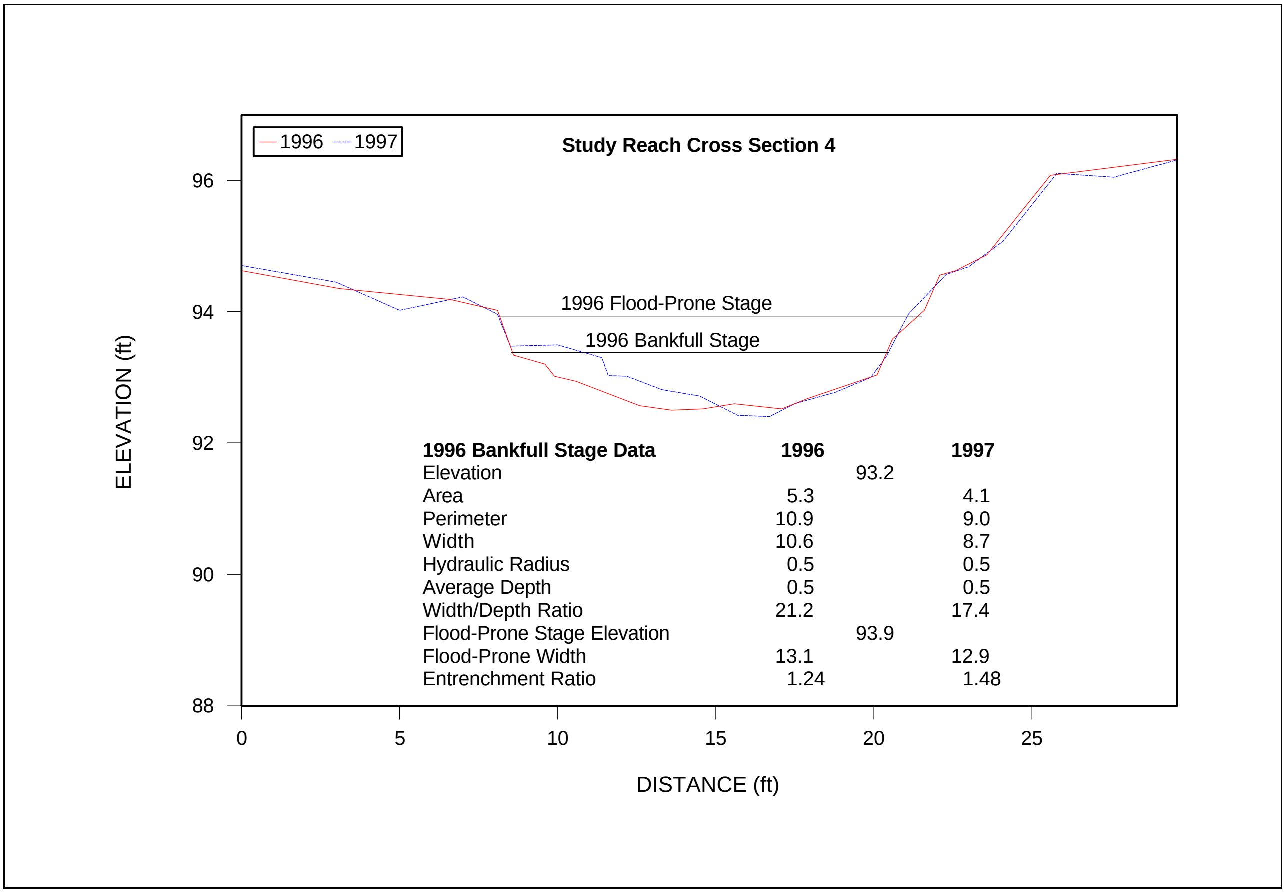


Figure 24. Epler Farm Study Reach Cross Section 4, 1996 and 1997

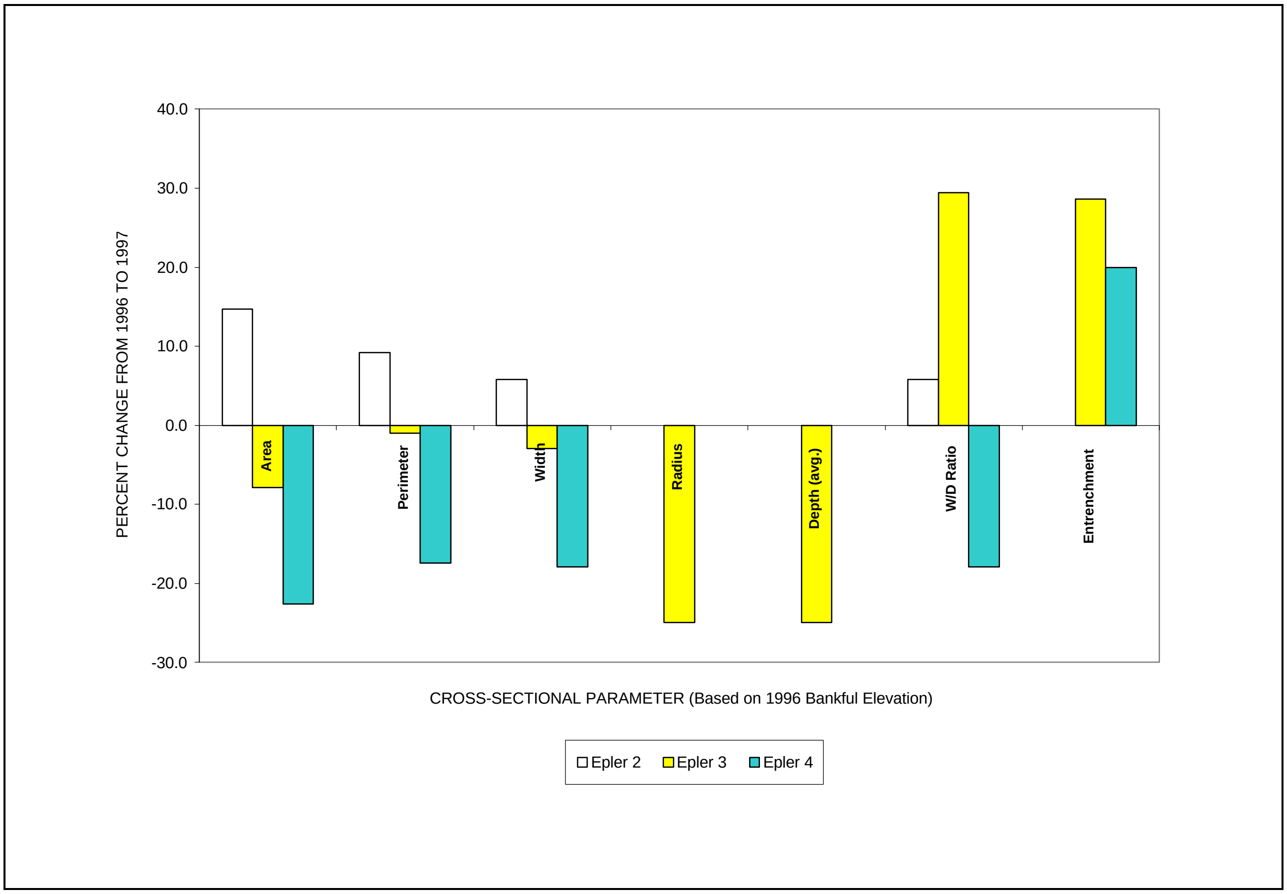


Figure 25. Summary of Changes in the Epler Farm Study Reach Cross-Sectional Geometry Between 1996 and 1997

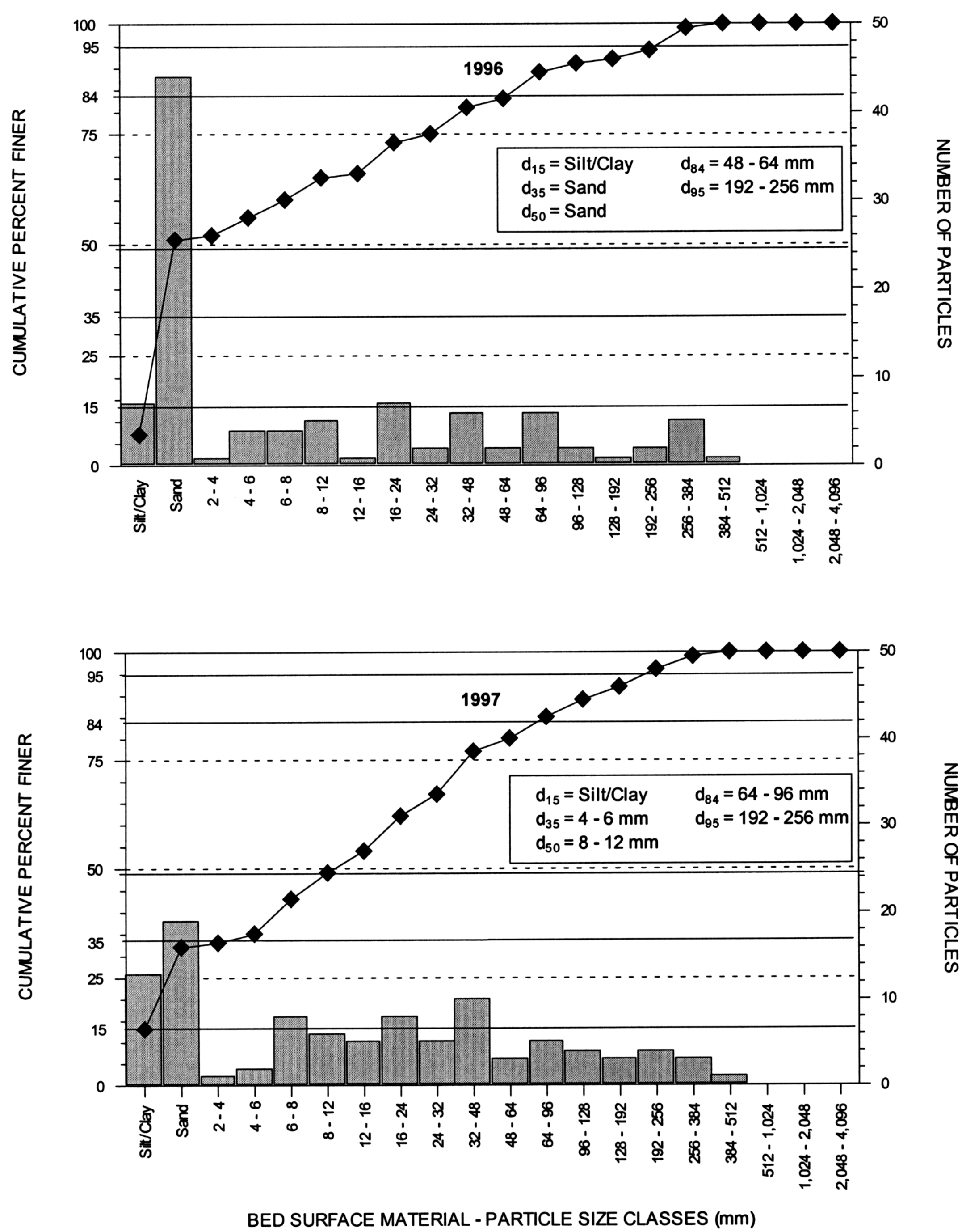


Figure 26. Epler Farm Study Reach Pebble-Count Data, 1996 and 1997

Table 4. Summary of the Epler Farm Study Reach Morphology Data

Cross-Sectional Geometry	Study Reach Cross Section 2		Study Reach Cross Section 3		Study Reach Cross Section 4	
	1996	1997	1996	1997	1995	1996
Bankfull Data						
1996 Bankfull Elevation	92.98		93.23		93.2	
Area	3.4	3.9	3.8	3.5	5.3	4.1
Perimeter	8.7	9.5	10.5	10.4	10.9	9.0
Width	8.6	9.1	10.3	10.0	10.6	8.7
Hydraulic Radius	0.4	0.4	0.4	0.3	0.5	0.5
Average Depth	0.4	0.4	0.4	0.3	0.5	0.5
BF Width/Depth Ratio	21.5	22.8	25.8	33.3	21.2	17.4
Flood-Prone Data						
1996 Flood-Prone Elevation	93.64		93.74		93.9	
Flood-Prone Width	>2.2 x bankfull	>2.2 x bankfull	16.9	21.1	13.1	12.9
Entrenchment	>2.2	>2.2	1.6	2.1	1.2	1.5

Stream Reach Morphology	Study Reach	
	1996	1997
d_{15}	Silt/Clay	Silt/Clay
d_{35}	Sand	4-6 mm
d_{50} - Median Particle Size	Sand	8-12 mm
d_{84}	48-64 mm	64-96 mm
d_{95}	192-256 mm	192-256 mm
Percent Pool (surface area)	51.5	50.3
Percent Riffle/Run (surface area)	48.5	49.7
Sinuosity	1.3	1.3

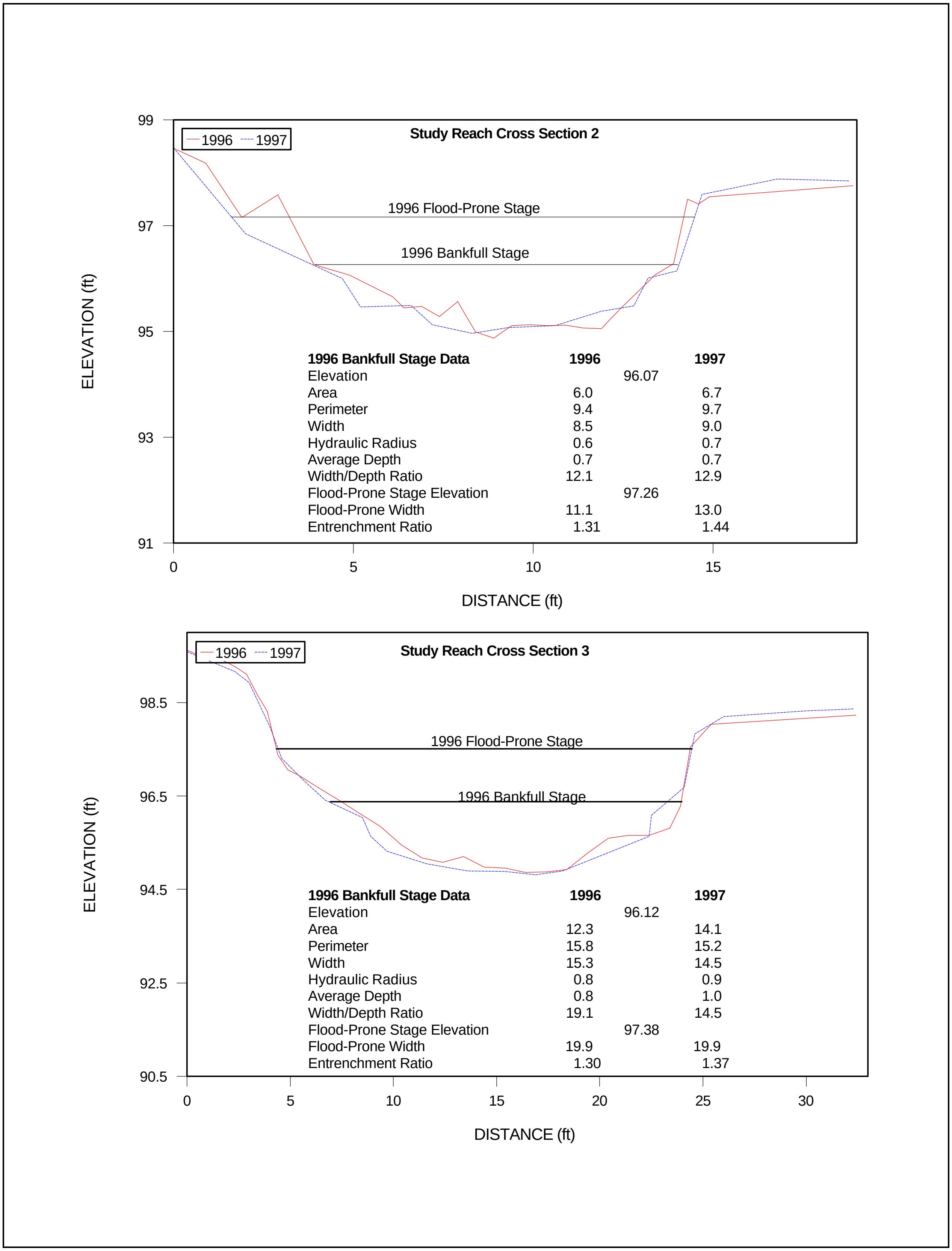


Figure 27. Englart Farm Study Reach Cross Sections 2 and 3, 1996 and 1997

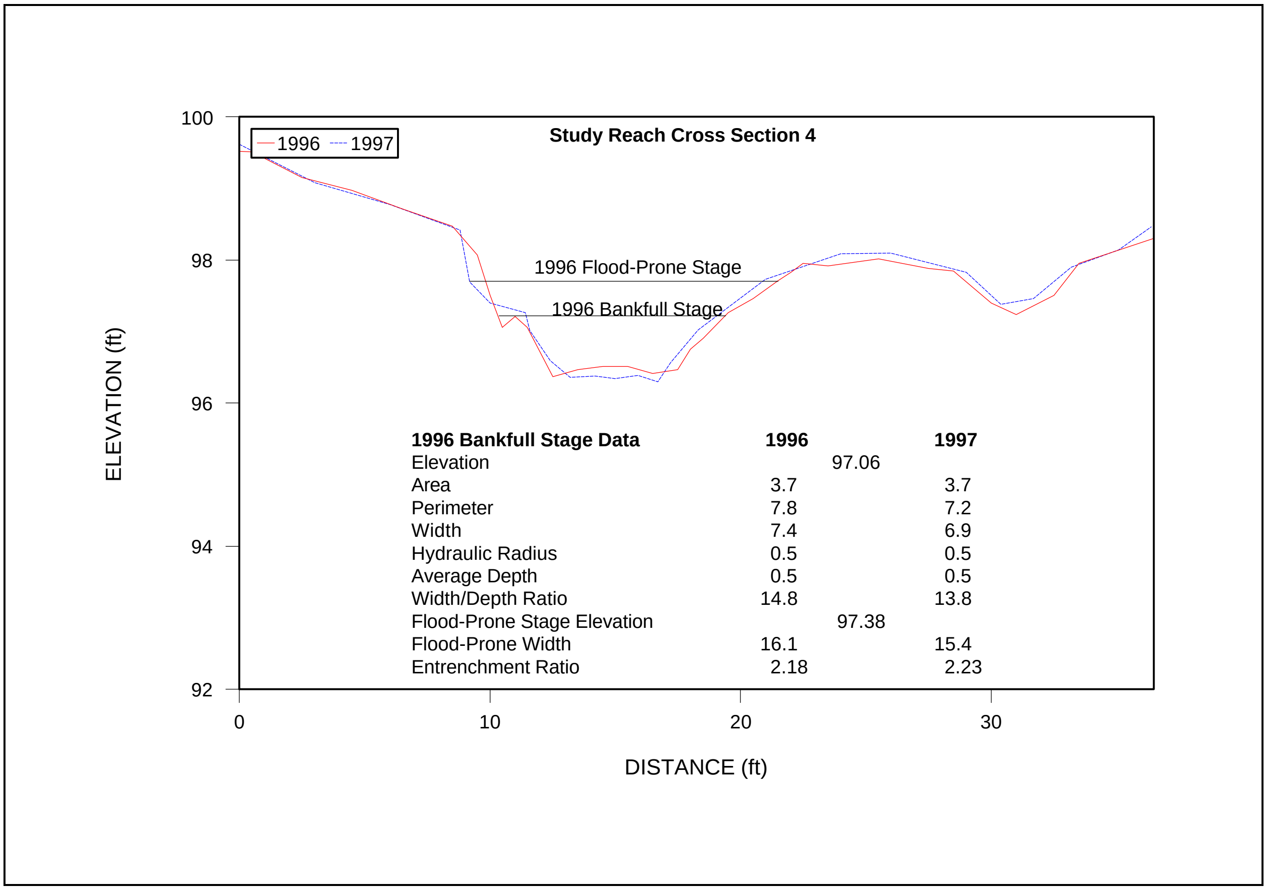


Figure 28. Englart Farm Study Reach Cross Section 4, 1996 and 1997

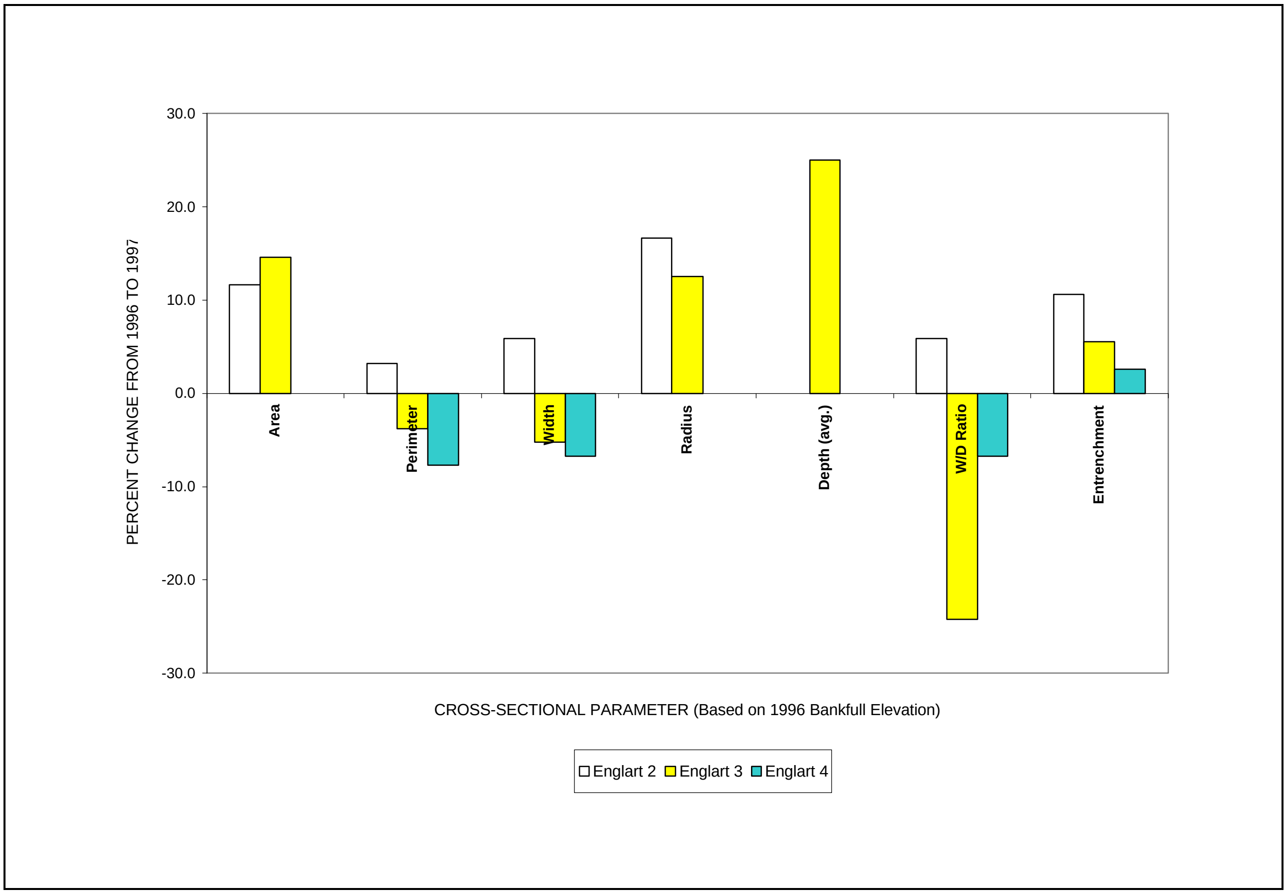


Figure 29. Summary of Changes in the Englart Farm Study Reach Cross-Sectional Geometry Between 1996 and 1997

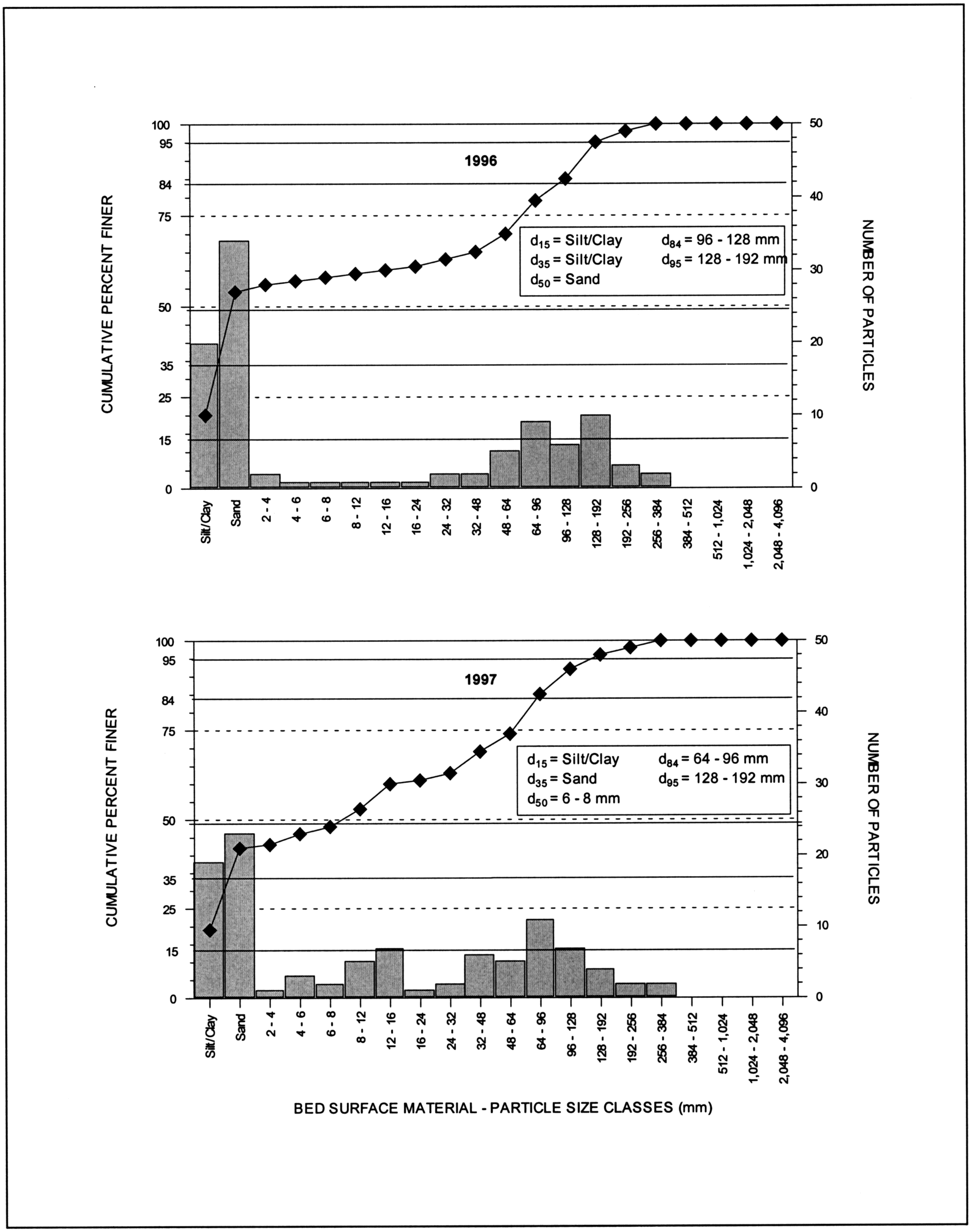


Figure 30. Englart Farm Study Reach Pebble-Count Data, 1996 and 1997

Measurements were not obtained from the reference reach at the Englart farm. Cross-sectional and steam reach morphologies are summarized in Table 5.

Stream Habitat

Stream habitat conditions of study and reference reaches were evaluated to assess the amount and quality of physical habitat available for stream biota. Habitat conditions were summarized using a Habitat Condition Index (HCI) that evaluated the following parameters: (1) pool/riffle ratio; (2) channel material; (3) pool structure; (4) streambank erosion; and (5) streamside vegetative cover. The reach's HCI value was calculated as the mean of the five parameters described above.

The 1996 HCI score of the Veety farm study reach was substantially higher than that recorded in 1995. All habitat parameters used to calculate the HCI score indicated improved habitat conditions one year after fencing. Although the habitat conditions also improved in the reference reach between 1995 and 1996, the improvement was not as dramatic as that observed in the study reach, and two of the five parameter scores recorded in 1996 were slightly lower than those observed in 1995 (Figure 31). An assessment of study reach habitat conditions relative to those of the reference reach indicated that pool/riffle(run) composition, channel material composition, and streambank erosion showed the most significant improvements (Figure 32).

Habitat conditions at the Englart and Epler farms also were assessed using HCI information. However, only study reach habitat conditions were evaluated at these two farms. At both the Englart and Epler farms, the 1997 HCI score was substantially higher than during 1996 sampling (Figure 33). All parameters increased during 1997 except the vegetative cover score at the Englart farm, which dropped slightly. In both cases, the most dramatic improvement was streambank erosion, which dropped to zero percent at both the Englart and Epler farms after fencing. Additionally, channel material showed significant improvement at both sites after streambank fencing.

Physical habitat conditions at the Englart and Epler farms also were assessed using a slightly modified version of the habitat assessment procedure outlined by Plafkin and others (1989). Eleven habitat parameters were field-evaluated at the two farms and were used to calculate a site-specific Habitat Assessment Score (HAS). Habitat parameters were identified as primary, secondary, or tertiary, based on their contribution to habitat quality. Primary parameters, stream habitat features that have the greatest direct influence on the structure of aquatic communities, were evaluated on a scale of 0 to 20 and included characterization of the stream bottom substrate, instream cover, embeddedness, and velocity/depth diversity. Secondary parameters included stream channel morphology characteristics such as pool/riffle ratio, pool quality, riffle/run quality, and channel alteration and were scored on a scale of 0 to 15. Tertiary parameters characterized riparian and bank conditions such as streambank erosion, streambank stability, vegetative cover, and forested riparian buffer zone width and were scored on a scale of 0 to 10. The criteria used to evaluate habitat parameters are summarized in Table 6. Habitat assessment scores of sample sites were compared to those of the reference sites to classify each sample site into a habitat condition category (Table 7).

Reference reach habitat conditions at the Epler and Englart farms changed very little between 1996 and 1997, falling slightly at both sites (Table 8**)**. The overall habitat score for the Epler farm study site also fell slightly in 1997. However, tertiary parameter values increased substantially, which was offset by a reduction in the values for the primary and secondary parameters. Thus, although the riparian conditions improved dramatically, instream conditions deteriorated. At the Englart farm study reach, however, there was a substantial improvement in habitat conditions, in both primary and tertiary parameters (Table 8). Values

Table 5. Summary of the Englart Farm Study Reach Morphology Data

Cross-Sectional Geometry	Study Reach Cross Section 2		Study Reach Cross Section 3		Study Reach Cross Section 4	
	1996	1997	1996	1997	1995	1996
Bankfull Data						
1996 Bankfull Elevation	96.07		96.12		97.06	
Area	6.0	6.7	12.3	14.1	3.7	3.7
Perimeter	9.4	9.7	15.8	15.2	7.8	7.2
Width	8.5	9.0	15.3	14.5	7.4	6.9
Hydraulic Radius	0.6	0.7	0.8	0.9	0.5	0.5
Average Depth	0.7	0.7	0.8	1.0	0.5	0.5
BF Width/Depth Ratio	12.1	12.9	19.1	14.5	14.8	13.8
Flood-Prone Data						
1996 Flood-Prone Elevation	97.26		97.38		97.38	
Flood-Prone Width	11.1	13.0	19.9	19.9	16.1	15.4
Entrenchment	1.3	1.4	1.3	1.4	2.2	2.2

Stream Reach Morphology	Study Reach	
	1996	1997
d_{15}	Silt/Clay	Silt/Clay
d_{35}	Silt/Clay	Sand
d_{50} - Median Particle Size	Sand	6-8 mm
d_{84}	96-128 mm	64-96 mm
d_{95}	128-192 mm	128-192 mm
Percent Pool (surface area)	45.6	54.2
Percent Riffle/Run (surface area)	54.4	45.8
Sinuosity	1.4	1.4

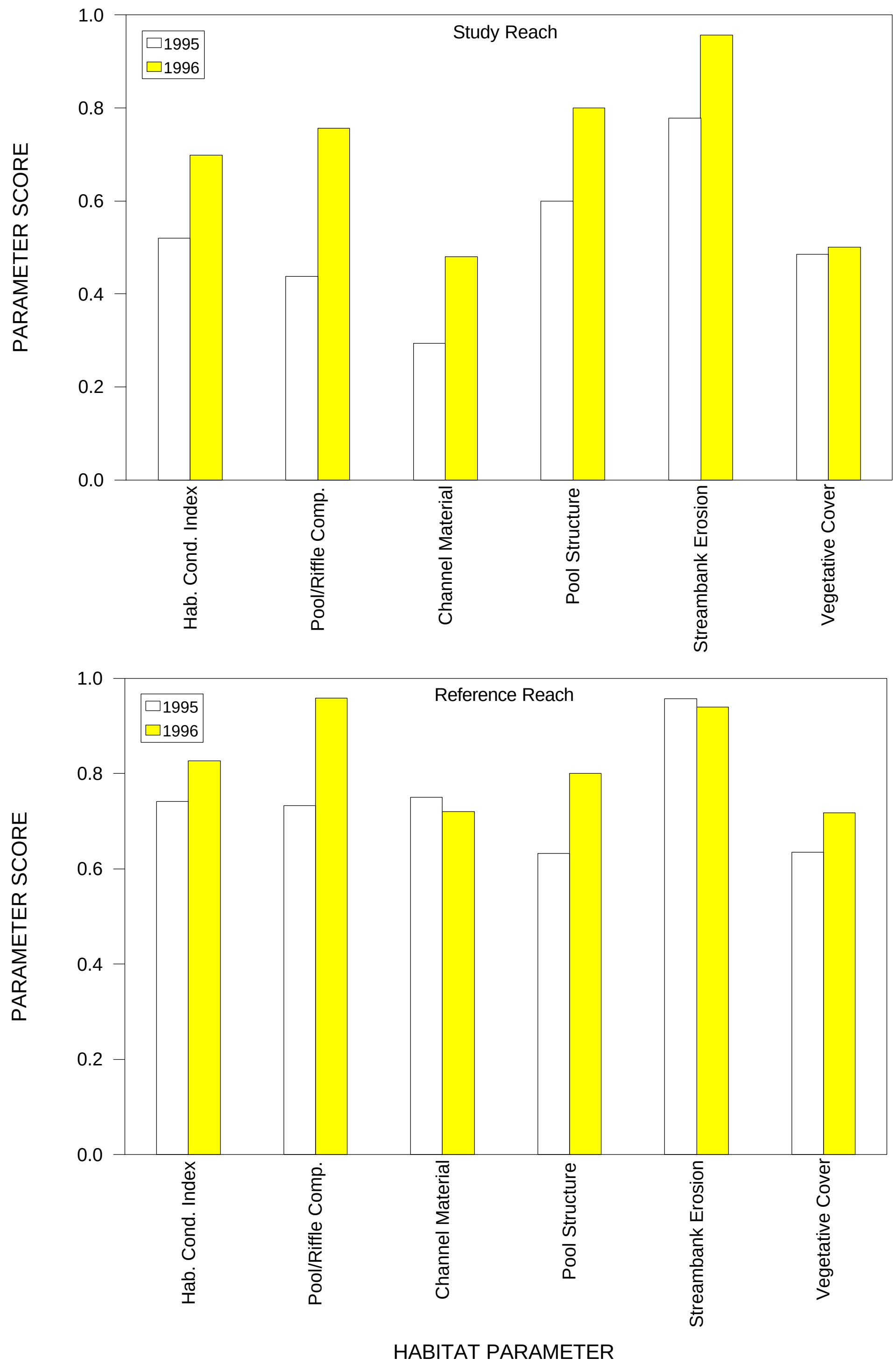


Figure 31. Veety Farm Study and Reference Reach Habitat Condition Index Data, 1995 and 1996

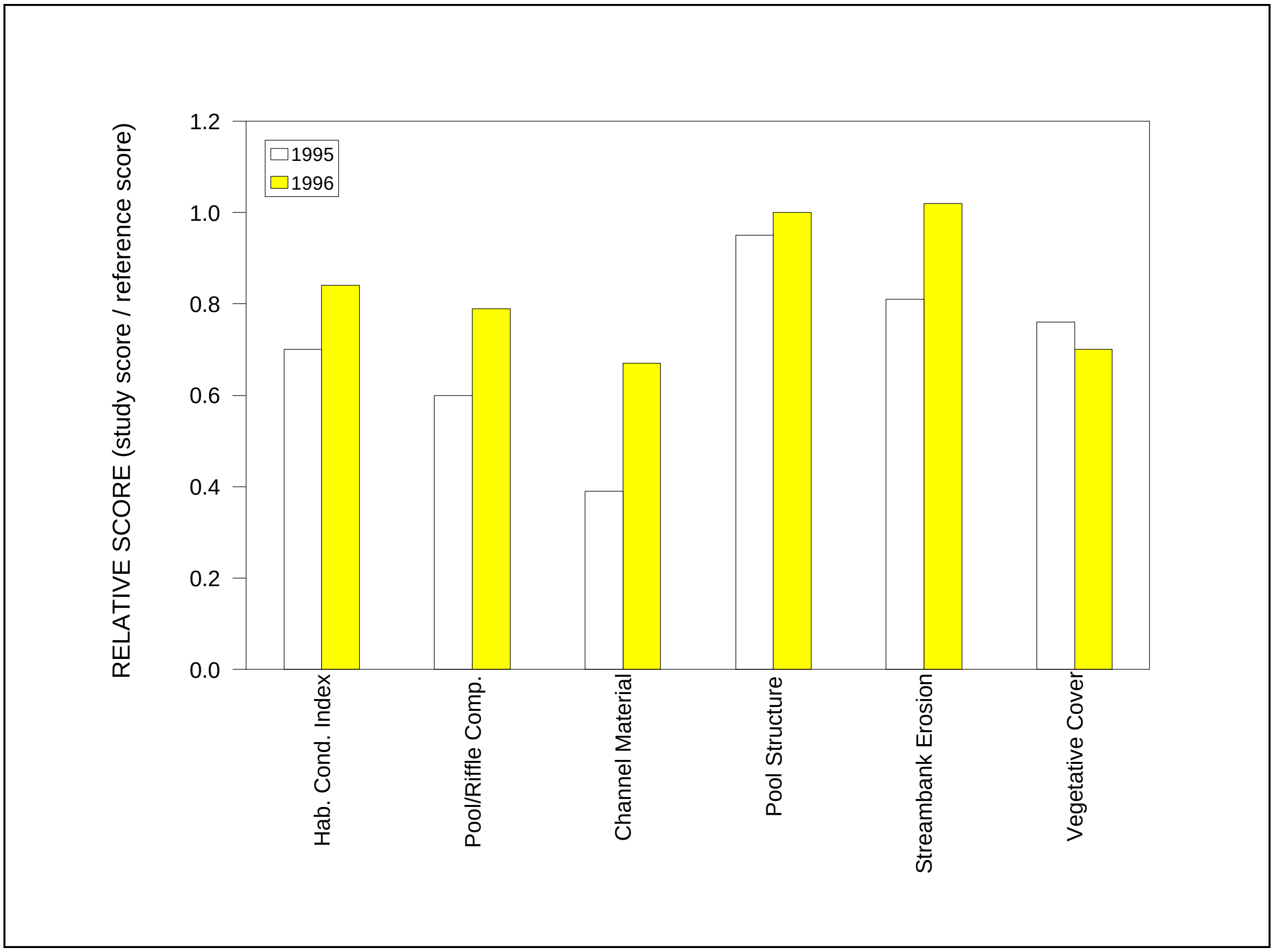


Figure 32. Veety Farm Study Reach Habitat Conditions Relative to Reference Reach Conditions, 1995 and 1996

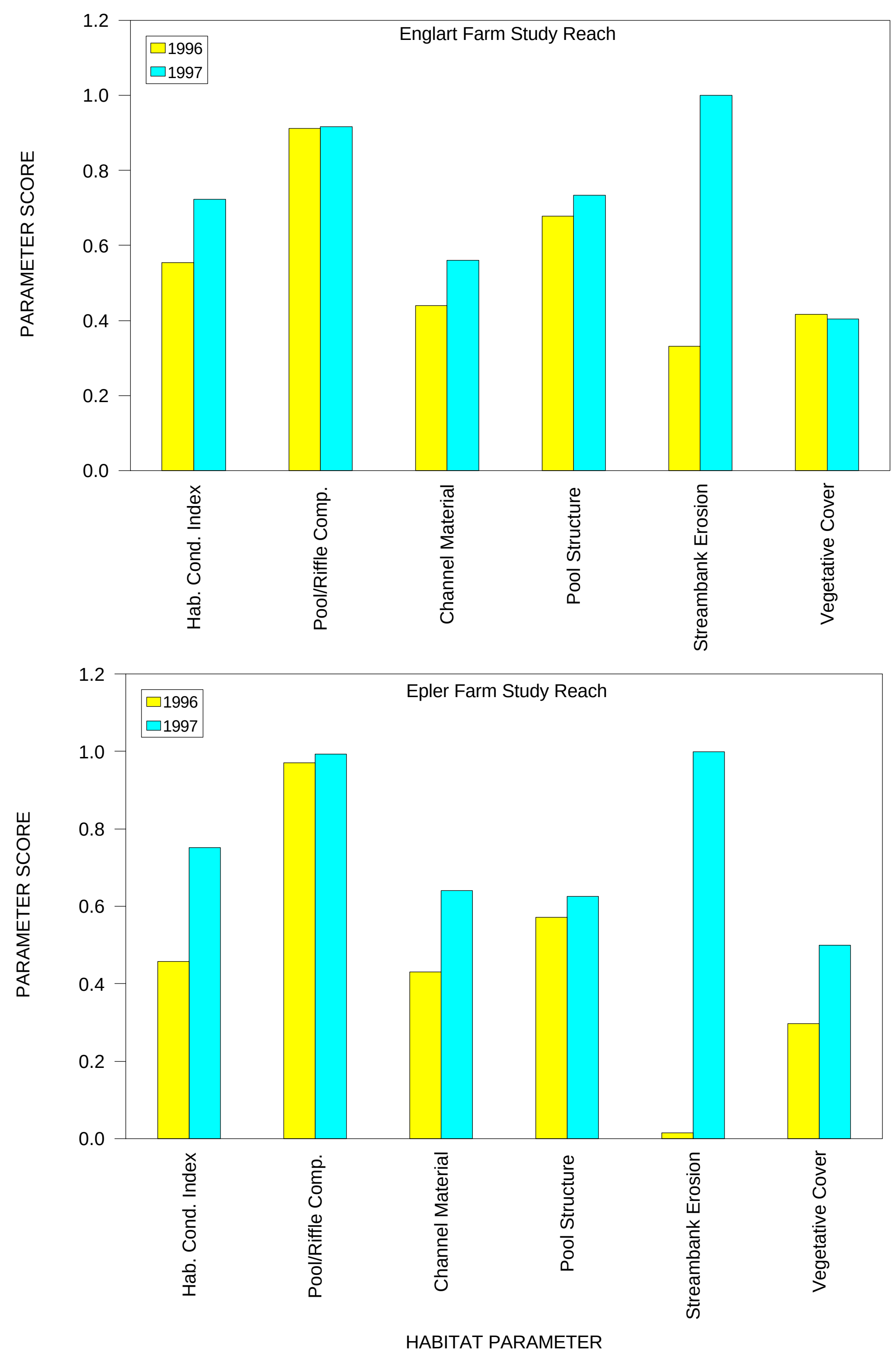


Figure 33. Summary of Study Reach Habitat Conditions From the Englart and Epler Farms, 1996 and 1997

Table 6. Criteria Used to Evaluate Physical Habitat

Habitat Parameter	Excellent	Good	Fair	Poor
1 Bottom Substrate	Greater than 50% cobble, gravel, submerged logs, undercut banks, or other stable habitat. **(16-20)**	30-50% cobble, gravel, or other stable habitat. Adequate habitat. **(11-15)**	10-30% cobble, gravel, or other stable habitat. Habitat availability is less than desirable. **(6-10)**	Less than 10% cobble, gravel, or other stable habitat. Lack of habitat is obvious. **(0-5)**
2 Embeddedness (a)	Larger substrate particles (e.g., gravel, cobble, boulders) are between 0 and 25% surrounded by fine sediment. **(16-20)**	Larger substrate particles (e.g., gravel, cobble, boulders) are between 25 and 50% surrounded by fine sediment. **(11-15)**	Larger substrate particles (e.g., gravel, cobble, boulders) are between 50 and 75% surrounded by fine sediment. **(6-10)**	Larger substrate particles (e.g., gravel, cobble, boulders) are over 75% surrounded by fine sediment. **(0-5)**
3 Velocity/Depth Diversity	Four habitat categories consisting of slow (<1.0 ft/s), deep (>1.5 ft); slow, shallow (<1.5 ft); fast (> 1.0 ft/s), deep; fast, shallow habitats are all present. **(16-20)**	Only three of the four habitat categories are present. **(11-15)**	Only two of the four habitat categories are present. **(6-10)**	Dominated by one velocity/depth category (usually pools). **(0-5)**
4 Pool/Riffle Ratio (or Run/Bend)	Distance between riffles divided by mean wetted width equals 5-7. Stream contains a variety of habitats including deep riffles and pools. **(12-15)**	Distance between riffles divided by mean wetted width equals 7-15. Adequate depth in pools and riffles. **(8-11)**	Distance between riffles divided by mean wetted width equals 15-25. Stream contains occasional riffles. **(4-7)**	Distance between riffles divided by mean wetted width >25. Stream is essentially straight with all flat water or shallow riffle. Poor habitat. **(0-3)**
5 Pool Quality (b)	Pool habitat contains both deep (>1.5 ft) and shallow areas (<1.5 ft) with complex cover and/or depth greater than 5 ft. **(12-15)**	Pool habitat contains both deep (>1.5 ft) and shallow (<1.5 ft) areas with some cover present. **(8-11)**	Pool habitat consists primarily of shallow (<1.5 ft) areas with little cover. **(4-7)**	Pool habitat rare with maximum depth <0.5 ft, or pool habitat absent completely. **(0-3)**
6 Riffle/Run Quality (c)	Riffle/run depth generally >8 in. and consisting of stable substrate materials and a variety of current velocities. **(12-15)**	Riffle/run depth generally 4-8 in. and with a variety of current velocities. **(8-11)**	Riffle/run depth generally 1-4 in.; primarily a single current velocity. **(4-7)**	Riffle/run depth <1 in.; or riffle/run substrates concreted. **(0-3)**
7 Channel Alteration (d)	Little or no enlargement of islands or point bars, and/or no channelization. **(12-15)**	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. **(8-11)**	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled with silt; and/or embankments on both banks. **(4-7)**	Heavy deposits of fine material, increased bar development; most pools filled with silt; and/or extensive channelization. **(0-3)**

Table 6. Criteria Used to Evaluate Physical Habitat—Continued

Habitat Parameter	Excellent	Good	Fair	Poor
8. Upper and Lower Streambank Erosion (e)	Stable. No evidence of erosion or of bank failure. Side slopes generally <30%. Little potential for future problems. **(9-10)**	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40% on one bank. Slight potential in extreme floods. **(6-8)**	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% in some areas. High erosion potential during extreme high flow. **(3-5)**	Unstable. Many eroded areas. Side slopes >60% common. "Raw" areas frequent along straight sections and bends. **(0-2)**
9. Upper and Lower Streambank Stability (e)	Over 80% of the streambank surface is covered by vegetation or boulders and cobble. **(9-10)**	50-79% of the streambank surface is covered by vegetation, gravel, or larger material. **(6-8)**	25-49% of the streambank surface is covered by vegetation, gravel, or larger material. **(3-5)**	Less than 25% of the streambank surface is covered by vegetation, gravel, or larger material. **(0-2)**
10. Streamside Vegetative Cover *(Both Banks)*	Dominant vegetation that provides stream-shading, escape cover, and/or refuge for fish within the bankfull stream channel is shrub. **(9-10)**	Dominant vegetation that provides stream-shading, escape cover, and/or refuge for fish within the bankfull stream channel is trees. **(6-8)**	Dominant vegetation that provides stream-shading, escape cover, and/or refuge for fish within the bankfull stream channel is forbs and grasses. **(3-5)**	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. **(0-2)**
11. Forested Riparian Buffer Zone Width (f) *(Least Forested Bank)*	Riparian area consists of all three zones of vegetation, Zones 1-3. (See zone descriptions (f). **(9-10)**	Riparian area consists of Zones 1 and 2. **(6-8)**	Riparian area is limited primarily to Zone 1. Zone 2 may be forested but is subject to disturbance (e.g. grazing, intensive forestry practices, roads). **(3-5)**	Riparian area lacks Zone 1 with or without Zones 2 and/or 3. **(0-2)**

(a) Embeddedness — The degree to which the substrate materials that serve as habitat for benthic macroinvertebrates and for fish spawning and egg incubation (predominantly cobble and/or gravel) are surrounded by fine sediment. Embeddedness is evaluated with respect to the suitability of these substrate materials as habitat for macroinvertebrates and fish by providing shelter from the current and predators, and by providing egg deposition and incubation sites.

(b) Pool Quality — Rated based on the variety and spatial complexity of slow- or still-water habitat within the sample segment. It should be noted that even in high- gradient segments, functionally important slow-water habitat may exist in the form of plunge-pools and/or larger eddies. Within a category, higher scores are assigned to segments that have undercut banks, woody debris, or other types of cover for fish.

(c) Riffle/Run Quality — Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

(d) Channel Alteration — A measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent sediment bar development. Sediment bars typically form on the inside of bends, below channel constrictions, and where stream gradient decreases. Bars tend to increase in depth and length with continued watershed disturbance. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of sediment bars, which indicate the degree of flow fluctuations and substrate stability.

(e) Upper and Lower Streambank Erosion and Stability — These parameters include the concurrent assessment of both the upper and lower banks. The upper bank is the land area from the break in the general slope of the surrounding land to the top of the bankfull channel. The lower bank is the intermittently submerged portion of the stream cross section from the top of the bankfull channel to the existing waterline.

(f) Forested Riparian Buffer Zone Width —
Zone 1: a 15 ft wide buffer of essentually undisturbed forest located immediately adjacent to the stream.
Zone 2: a 100-ft-wide buffer of forest, located adjacent to Zone 1, which may be subject to non-intensive forest management practices.
Zone 3: a 20-ft-wide buffer of vegetation, located adjacent to Zone 2, that provides sediment filtering and promotes the formation of sheet flow runoff into Zone 2. Zone 3 may be composed of trees, shrubs, and/or dense grasses and forbs, which are subject to haying and grazing, as of as long as vegetation is maintained in vigorous condition.

Source: Modified from Plafkin and others, 1989.

Table 7. Summary of Criteria Used to Classify the Habitat Conditions of Sample Sites

DETERMINATION OF HABITAT ASSESSMENT SCORES				
	Habitat Parameter Scoring Criteria			
Parameter	Excellent	Good	Fair	Poor
Bottom Substrate	20-16	15-11	10-6	5-0
Embeddedness	20-16	15-11	10-6	5-0
Velocity/Depth Diversity	20-16	15-11	10-6	5-0
Pool-Riffle (Run-Bend) Ratio	15-12	11-8	7-4	3-0
Pool Quality	15-12	11-8	7-4	3-0
Riffle/Run Quality	15-12	11-8	7-4	3-0
Channel Alteration	15-12	11-8	7-4	3-0
Upper and Lower Streambank Erosion	10-9	8-6	5-3	2-0
Upper and Lower Streambank Stability	10-9	8-6	5-3	2-0
Streamside Vegetative Cover	10-9	8-6	5-3	2-0
Forested Riparian Buffer Zone Width	10-9	8-6	5-3	2-0
Habitat Assessment Score (a)				

↓
↓
↓

HABITAT ASSESSMENT	
Percent Comparability of Study and Reference Site Habitat Assessment Scores	Habitat Condition Category
>90%	Excellent (comparable to reference)
89-75%	Supporting
74-60%	Partially Supporting
<60%	Nonsupporting

(a) Habitat Assessment Score = Sum of Habitat Parameter Scores

Table 8. Summary of RBP III Habitat Data From the Epler and Englart Farms

	Epler Farm				Englart Farm			
	1996		1997		1996		1997	
	Reference Reach	Study Reach	Reference Reach	Study Reach	Reference Reach	Study Reach	Reference Reach	Study Reach
Primary Parameters								
Bottom Substrate	9	10	6	12	19	12	18	15
Embeddedness	16	16	16	11	18	12	16	11
Velocity/Depth Diversity	6	8	5	7	15	12	14	13
Total	31	34	27	30	52	36	48	39
% of Reference	100	110	100	111	100	69	100	81
Secondary Parameters								
Pool/Riffle Ratio	4	14	3	8	15	13	15	13
Pool Quality	1	5	0	4	11	6	9	8
Riffle/Run Quality	5	7	4	5	8	8	8	7
Channel Alteration	3	7	3	4	15	9	12	8
Total	13	33	10	21	49	36	44	36
% of Reference	100	254	100	210	100	73	100	82
Tertiary Parameters								
U/L Streambank Erosion	6	2	6	6	8	3	8	5
U/L Streambank Stability	9	2	10	9	9	5	9	6
Vegetative Cover	9	3	10	5	5	3	5	5
FRB Zone Width	2	1	3	2	1	1	2	2
Total	26	8	29	22	23	12	24	18
% of Reference	100	31	100	76	100	52	100	75
Total Habitat Score								
Total Habitat Score	70	75	66	73	124	84	116	93
Habitat % of Reference	100	107	100	111	100	68	100	80

for bottom substrate, pool quality, streambank erosion, and vegetative cover increased after streambank fencing was erected.

One complication at the Epler farm study sites was the poor habitat quality at the reference reach as compared to typical reference conditions. Most primary and secondary parameters at the study reach scored higher than those of the reference reach during both years (Table 8). Degradation of the reference reach as well as the study reach may have been due partly to substantial agricultural activity in the watershed upstream of the Epler farm or to incomplete post-fencing exclusion of the cows from the steam.

Aquatic Living Resources

At the Veety farm site, biological sampling included surveys of benthic macroinvertebrate and fish communities in the study and reference reaches. Macroinvertebrate samples were collected using a Surber sampler to provide quantitative data pertaining to macroinvertebrate productivity (number of organisms/square foot). Fish community sampling included identifying and enumerating all fish collected during a single pass through each of the reaches using backpack electrofishing gear. Macroinvertebrates were identified to genus (except for Chironomidae, Simuliidae, and Tubificidae) in the laboratory using taxonomic keys by Pennak (1978) and Merritt and Cummins (1984). Each taxon was assigned an organic pollution tolerance value and a functional feeding category, as outlined in Appendix B. A macroinvertebrate taxa list can be found in Appendix C. Fish were identified to species in the field using taxonomic keys by Eddy and Underhill (1978) and Cooper (1983) and returned to the stream. A fish taxa list can be found in Appendix D.

The biological integrity of each study site was assessed using a modified version of U.S. Environmental Protection Agency's Rapid Bioassessment Protocol III (RBP III), as described by Plafkin and others (1989). This modification included the substitution of several of the indices ("metrics") used to evaluate the overall integrity of the site's benthic macroinvertebrate community. These substitutions included: (1) Shannon Diversity (log base 2) for the Percent Contribution of Dominant Taxa Metric; (2) Percent Taxonomic Similarity for the EPT/Chironomidae Abundances and Community Loss Metrics; and (3) Percent Trophic Similarity for the Scrapers/Filtering Collectors and Shredders/Total Metrics. The metrics used in this survey are summarized in Table 9. Fish community field data for the Veety farm sites also were reduced into a variety of metric scores, and these scores were compared to those of the reference reach. Each metric, for both benthic macroinvertebrates and fish, was assigned a biological condition score based on the criteria outlined in Table 10. The total biological condition score for the reach was calculated as the sum of the metric biological condition scores.

Macroinvertebrate and fish productivity increased in both the study and reference reaches between 1995 and 1996 at the Veety farm site. Although the total biological condition score of the study reach fish community improved substantially, the macroinvertebrate total biological score of the reach showed no change (Figure 34). The biological condition score for the EPT Index metric increased substantially between 1995 and 1996, indicating an improvement in the biological community; however, this increase was offset by lower Hilsenhoff Biotic Index (HBI) and percent taxonomic similarity scores indicative of a degraded condition (Figure 35). Substantial improvements to the reference reach macroinvertebrate community, rather than degradation of the study reach community, caused the lower study reach Hilsenhoff Biotic Index and taxonomic similarity scores observed in 1996 (Table 11).

The most noticeable change in the trophic structure of the Veety farm study reach macroinvertebrate community between 1995 and 1996 was a shift in the predominant collector-gatherer from pollution-tolerant Tubificidae to less tolerant Chironomidae. The most noticeable change in the reference reach macroinvertebrate

Table 9. Summary of Metrics Used to Evaluate the Overall Biological Integrity of Stream Benthic Macroinvertebrate Communities

Metric	Description
1. Taxonomic Richness (1)	The total number of taxa present in the 100-organism subsample.
2. Shannon Diversity Index (2)	A measure of biological community complexity based on the number of equally or nearly equally abundant taxa in the community.
3. Modified Hilsenhoff Biotic Index (1)	A measure of the overall pollution tolerance of a benthic macroinvertebrate community.
4. EPT Index (1)	The total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa present in the 100-organism subsample.
5. Percent Taxonomic Similarity (2)	A measure of the similarity between the taxonomic composition of the sample site and its appropriate reference community.
6. Percent Trophic Similarity (2)	A measure of the similarity between the functional feeding group composition of a sample site and its appropriate reference community.

Sources: (1) Plafkin and others (1989); and
(2) calculated using software developed by Kovach (1993).

Table 10. Macroinvertebrate and Fish Biological Condition Scoring Criteria

MACROINVERTEBRATE TOTAL BIOLOGICAL SCORE DETERMINATION				
	Metric Biological Condition Scoring Criteria (% of reference)			
Metric	6	4	2	0
1. Taxonomic Richness (a)	>80	79 - 60	59 - 40	<40
2. Shannon Diversity Index (a)	>75	74 - 50	49 - 25	<25
3. Modified Hilsenhoff Biotic Index (b)	>85	84 - 70	69 - 50	<50
4. EPT Index (a)	>90	89 - 80	79 - 70	<70
5. Percent Taxonomic Similarity (c)	>45	44 - 33	32 - 20	<20
6. Percent Trophic Similarity (c, d)	>75	74 - 50	49 - 25	<25

Total Biological Score = Sum of Metric Biological Condition Scores

FISH TOTAL BIOLOGICAL SCORE DETERMINATION				
	Metric Biological Condition Scoring Criteria (% of reference)			
Metric	6	4	2	0
1. Species Richness (a)	>80	79 - 60	59 - 40	<40
2. Shannon Diversity Index (a)	>75	74 - 50	49 - 25	<25
3. Pollution Tolerance Index (b)	>85	84 - 70	69 - 50	<50
4. Percent Taxonomic Similarity (c)	>45	44 - 33	32 - 20	<20
5. Percent Trophic Similarity (c, d)	>75	74 - 50	49 - 25	<25

Total Biological Score = Sum of Metric Biological Condition Scores

(a) Score is study site value/reference site value X 100.
(b) Score is reference site value/study site value X 100.
(c) Range of values obtained. A comparison to the reference site is incorporated in this metric.
(d) Macroinvertebrate functional feeding group and fish trophic level designations are summarized in Appendixes A and B, respectively.

Source: Modified from Plafkin and others (1989)

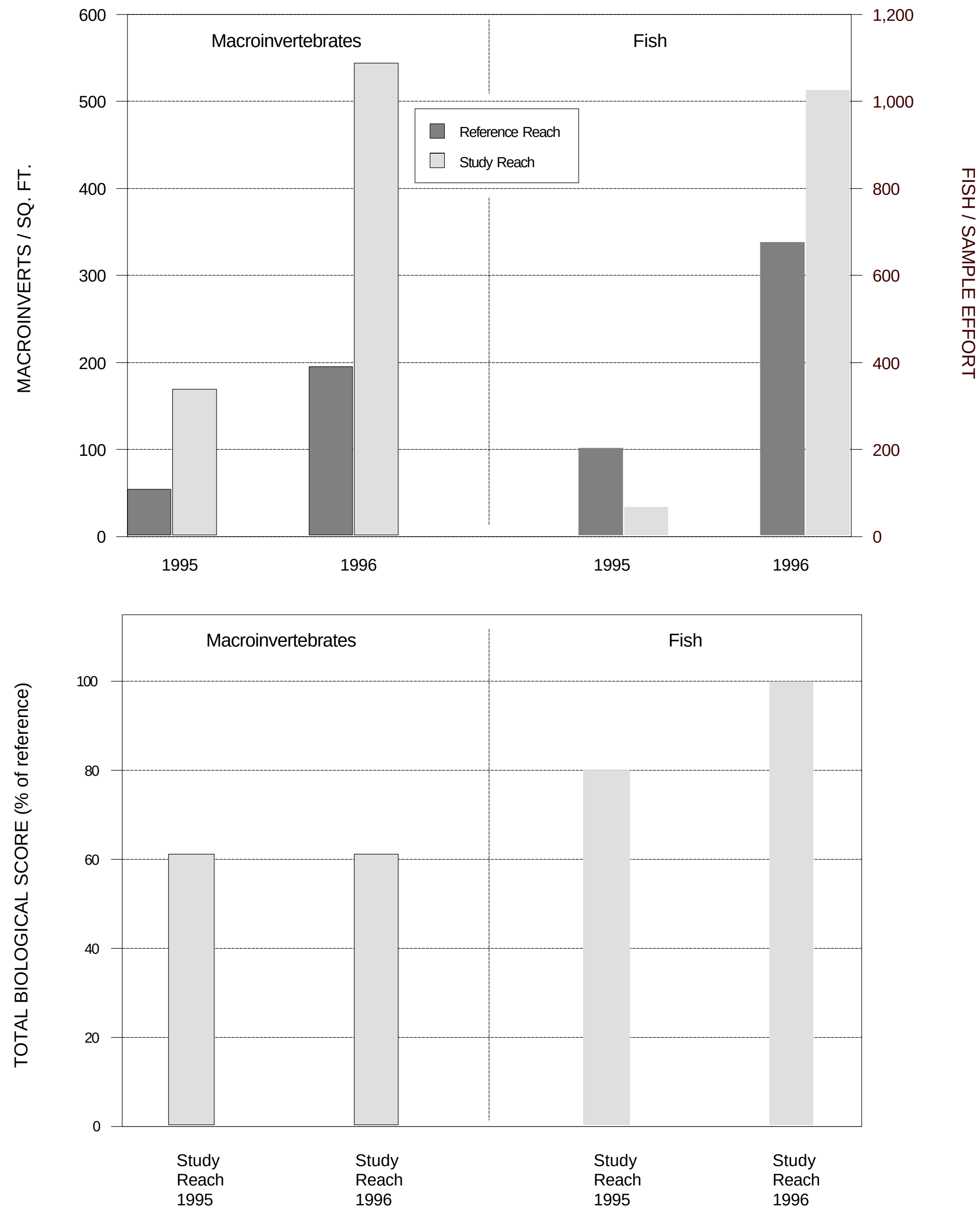


Figure 34. ***Summary of the Veety Farm Macroinvertebrate and Fish Productivity and Total Biological Condition Score Data, 1995 and 1996***

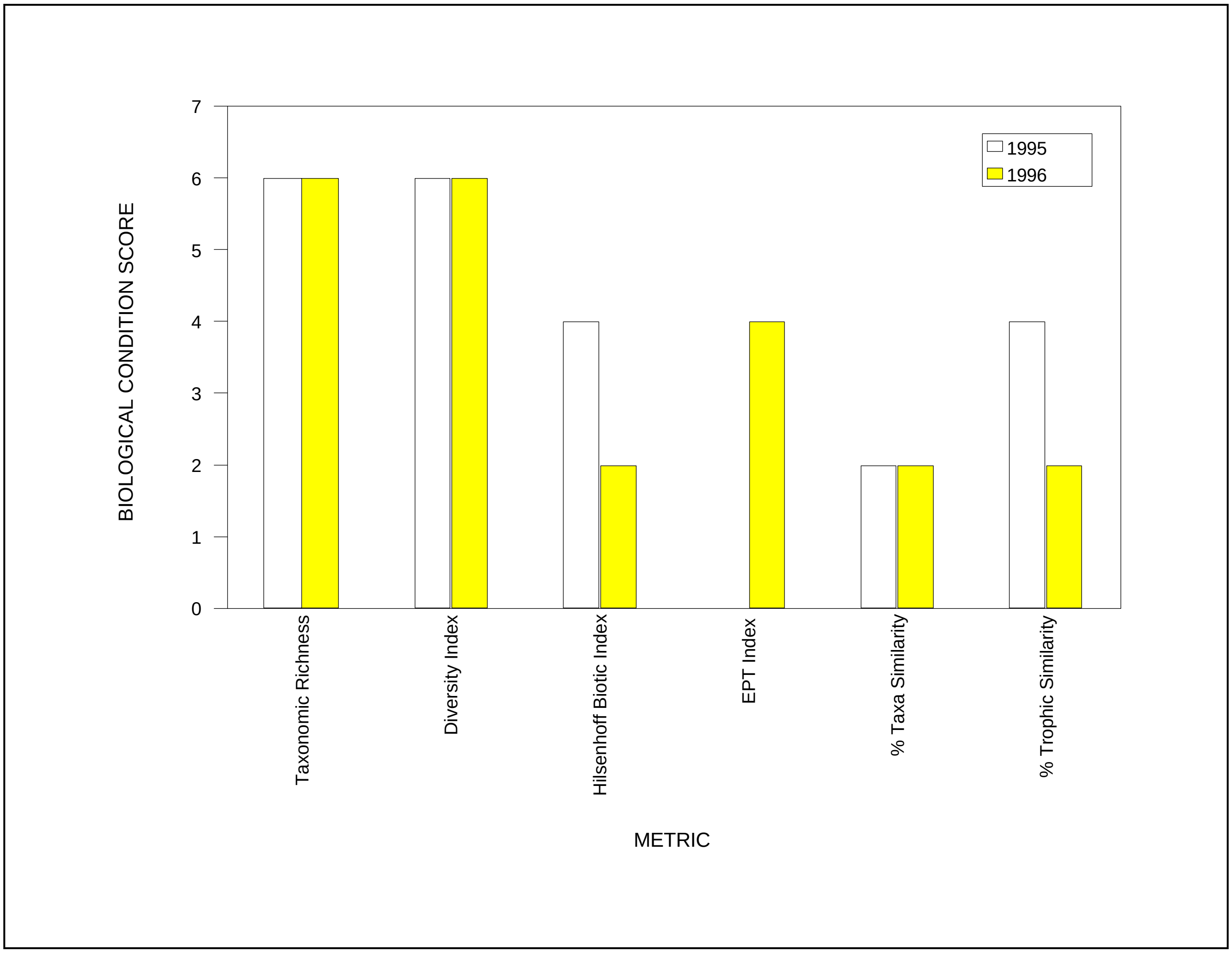


Figure 35. Veety Farm Macroinvertebrate Community Data, 1995 and 1996

Table 11. Summary of the Veety Farm Macroinvertebrate Community Data, 1995 and 1996 *(Metric scores for taxonomic richness, Shannon diversity, modified Hilsenhoff Biotic Index, and EPT Index represent the mean of individual metric scores calculated for each Surber sample. A single taxonomic and trophic similarity metric score was calculated for each reach based on a composite of the Surber sample data collected at each reach.)*

	1995		1996	
	Reference Reach	**Study Reach**	**Reference Reach**	**Study Reach**
Raw Data Summary				
Number of Individuals	55	170	194	544
% Shredders	39.0	51.9	10.7	52.7
% Collector-Gatherers	4.5	18.7	4.1	28.5
% Filterer-Collectors	30.6	20.0	74.2	16.4
% Scrapers	19.3	6.9	6.8	1.7
% Predators	6.7	2.5	4.2	0.7
Number of EPT Taxa	6.67	2.67	8.67	7.67
Metric Scores				
Taxonomic Richness	10	12	14	18
Shannon Diversity Index	2.30	2.25	2.69	2.30
Hilsenhoff Biotic Index	5.32	7.53	4.56	7.25
EPT Index	6.67	2.67	8.67	7.67
% Taxonomic Similarity	100.00	20.75	100.00	24.35
% Trophic Similarity	100.00	72.86	100.00	33.60
Percent of Reference				
Taxonomic Richness	100.0	120.0	100.0	128.6
Shannon Diversity Index	100.0	97.8	100.0	85.5
Hilsenhoff Biotic Index	100.0	70.7	100.0	62.9
EPT Index	100.0	40.0	100.0	88.5
% Taxonomic Similarity	100.0	20.8	100.0	24.4
% Trophic Similarity	100.0	72.9	100.0	33.6
Biological Condition Scores				
Taxonomic Richness	6	6	6	6
Shannon Diversity Index	6	6	6	6
Hilsenhoff Biotic Index	6	4	6	2
EPT Index	6	0	6	4
% Taxonomic Similarity	6	2	6	2
% Trophic Similarity	6	4	6	2
Total Biological Score	**36**	**22**	**36**	**22**
Biological % of Reference	**100**	**61**	**100**	**61**

community included a reduction in the abundance of the relatively pollution-tolerant shredder *Hyalella* (Amphipoda:Talitridae) and an increase in filter-feeding, hydropsychid and philopotamid caddisflies. Macroinvertebrate community trophic structure data are summarized in Figure 36.

In addition to increased productivity of the fish communities in both the Veety farm study and reference reaches between 1995 and 1996, both of these reaches supported white sucker (*Catostomus commersoni*) populations in 1996. No white suckers were collected in either reach in 1995. The changes in the study reach fish total biological scores between 1995 and 1996, illustrated in Figure 37, were primarily due to increased taxonomic and trophic structure similarity between the study and reference reaches in 1996 (Table 12 and Figure 37). In 1995, the fish community of the study reach consisted primarily of bluntnose minnow *(Pimephales notatus)*, creek chub *(Semotilus atromaculatus)*, and blacknose dace *(Rhinichthys atratulus)*, and the reference reach fish community consisted of blacknose dace, and to a lesser extent, creek chub, longnose dace *(Rhinichthys cataractae)*, and central stoneroller *(Campostoma anomalum)*. In 1996, both the study and reference reaches supported fish communities consisting primarily of blacknose dace, creek chub, and white sucker. Fish community taxonomic and trophic structure data are summarized in Figures 38 and 39, respectively. Unfortunately, no long-term biological data are available to determine if the 1995 conditions were representative of the site.

SRBC used a different sampling technique to assess the macroinvertebrate community at the Epler and Englart farms. Macroinvertebrates were collected and analyzed using field and laboratory methods described in Plafkin and others (1989). Benthic macroinvertebrate samples were taken using a 1-meter-square kick screen with size No. 30 mesh. The kick screen was stretched across the current to collect organisms dislodged from riffle areas by physical agitation of the stream substrate. Two kick screen samples were collected from a representative riffle at each station. The two samples were composited and preserved in a solution of glycerin and isopropyl alcohol for later laboratory analysis.

In the laboratory, composite samples were sorted into 100-organism subsamples using a gridded pan and a random numbers table. The organisms contained in the subsamples were identified to genus (except Chironomidae, Simuliidae, and Naididae) and enumerated. Each taxon was assigned an organic pollution tolerance value and a functional feeding category, as outlined in Appendix B. A taxa list for each station can be found in Appendix C. Fish community data were not collected at the Epler and Englart farms. Metrics for the Epler and Englart farms were calculated as described for the Veety farm.

At the Epler farm reference site in 1996, three taxa of stoneflies: *Leuctra* (Plecoptera: Leuctridae), *Amphinemura* (Plecoptera: Nemouridae), and *Isoperla* (Plecoptera: Perlodidae) dominated the macroinvertebrate community. However, during 1997, the situation was much different at the Epler farm reference reach. Instead of being dominated by the pollution-intolerant stoneflies, the macroinvertebrate community consisted largely of midges, which greatly increased the Hilsenhoff Biotic Index and decreased the number of EPT taxa and the diversity index. Table 13 summarizes the Epler farm macroinvertebrate community data.

Large numbers of stoneflies characterized both the reference and study sites at the Epler farm; however, the 1996 study site also contained a large number of *Baetis* (Ephemeroptera: Baetidae), which increased the Hilsenhoff Biotic Index. There was an increase in the taxa richness and diversity index of the study reach during the 1997 sampling season, indicating an improvement in the biological community. However, an increase in the number of midges and hydropsychid caddisflies and the absence of stoneflies in 1997 raised the Hilsenhoff Biotic Index over the 1996 level.

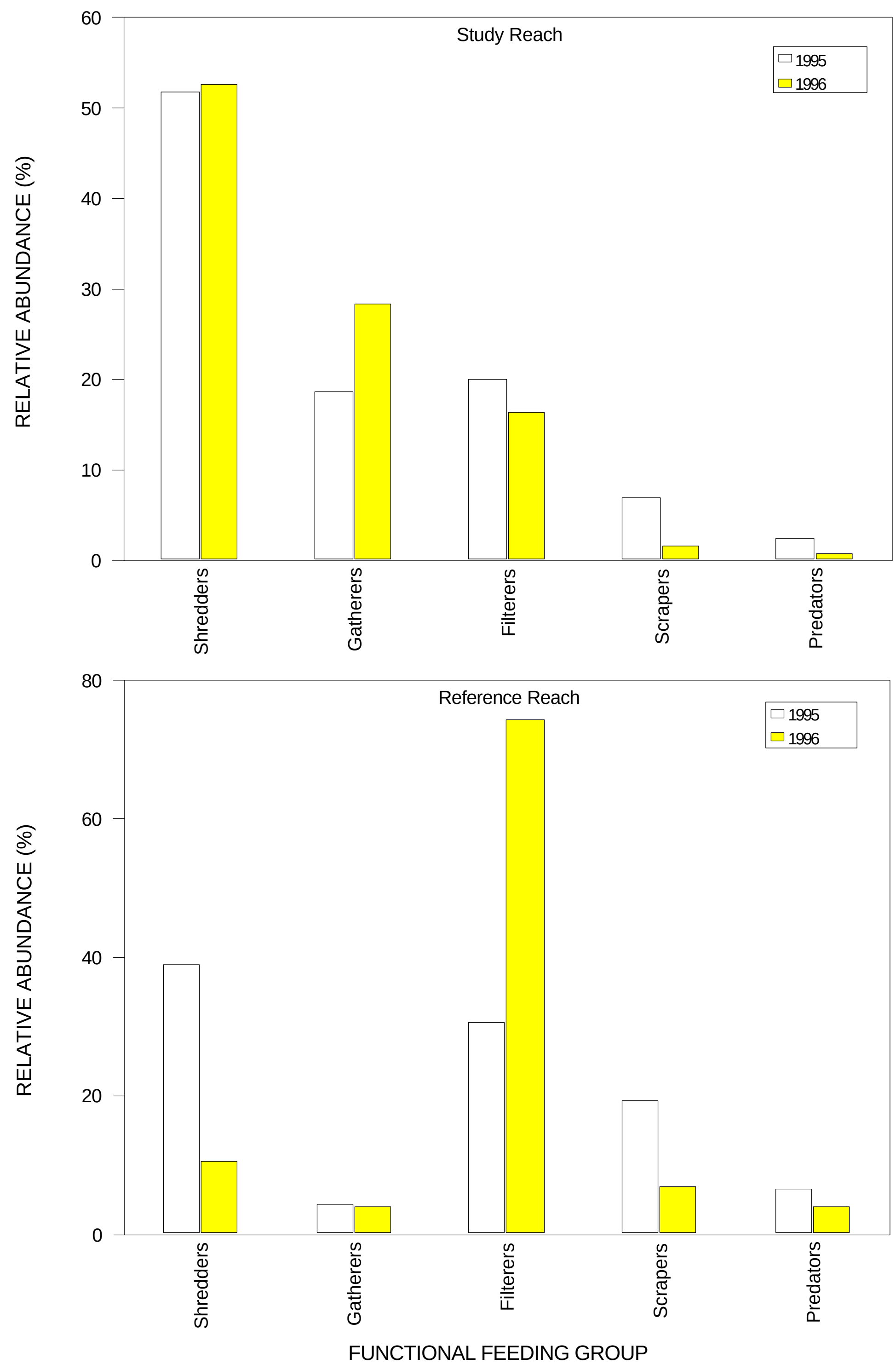


Figure 36. ***Veety Farm Macroinvertebrate Community Trophic Structure Data From the Study and Reference Reaches, 1995 and 1996***

Table 12. Summary of the Veety Farm Fish Community Data, 1995 and 1996

	1995		1996	
	Reference Reach	Study Reach	Reference Reach	Study Reach
Raw Summary				
Number of Individuals	200	65	677	1,024
% Omnivores		41.5	20.5	14.5
% Generalists	97.5	55.4	78.8	85.2
% Herbivores	1.0	1.5	0.7	0.2
% Insectivores	1.5	1.5	0.0	0.0
Metric Scores				
Species Richness	4	5	5	5
Shannon Diversity Index	0.50	1.73	1.56	1.55
Pollution Tolerance Index	2.96	2.97	2.99	3.00
% Taxonomic Similarity	100.00	20.38	100.00	79.25
% Trophic Similarity	100.00	57.93	100.00	93.55
Percent of Reference				
Species Richness	100.0	125.0	100.0	100.0
Shannon Diversity Index	100.0	346.0	100.0	99.4
Pollution Tolerance Index	100.0	99.7	100.0	99.7
% Taxonomic Similarity	100.0	20.4	100.0	79.3
% Trophic Similarity	100.0	57.9	100.0	93.6
Biological Condition Scores				
Species Richness	6	6	6	6
Shannon Diversity Index	6	6	6	6
Pollution Tolerance Index	6	6	6	6
% Taxonomic Similarity	6	2	6	6
% Trophic Similarity	6	4	6	6
Total Biological Score	**30**	**24**	**30**	**30**
Biological % of Reference	**100**	**80**	**100**	**100**

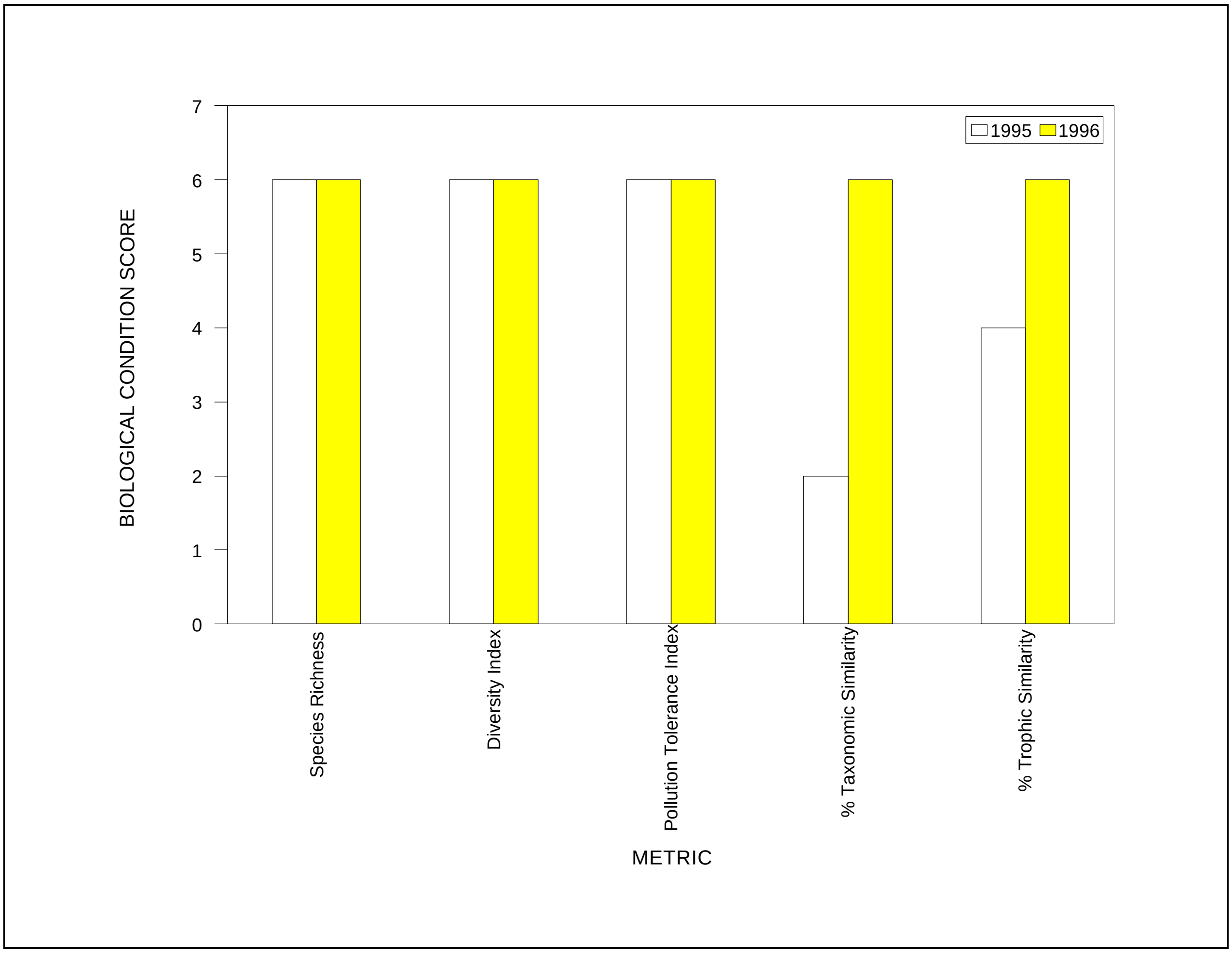


Figure 37. Veety Farm Fish Community Data, 1995 and 1996

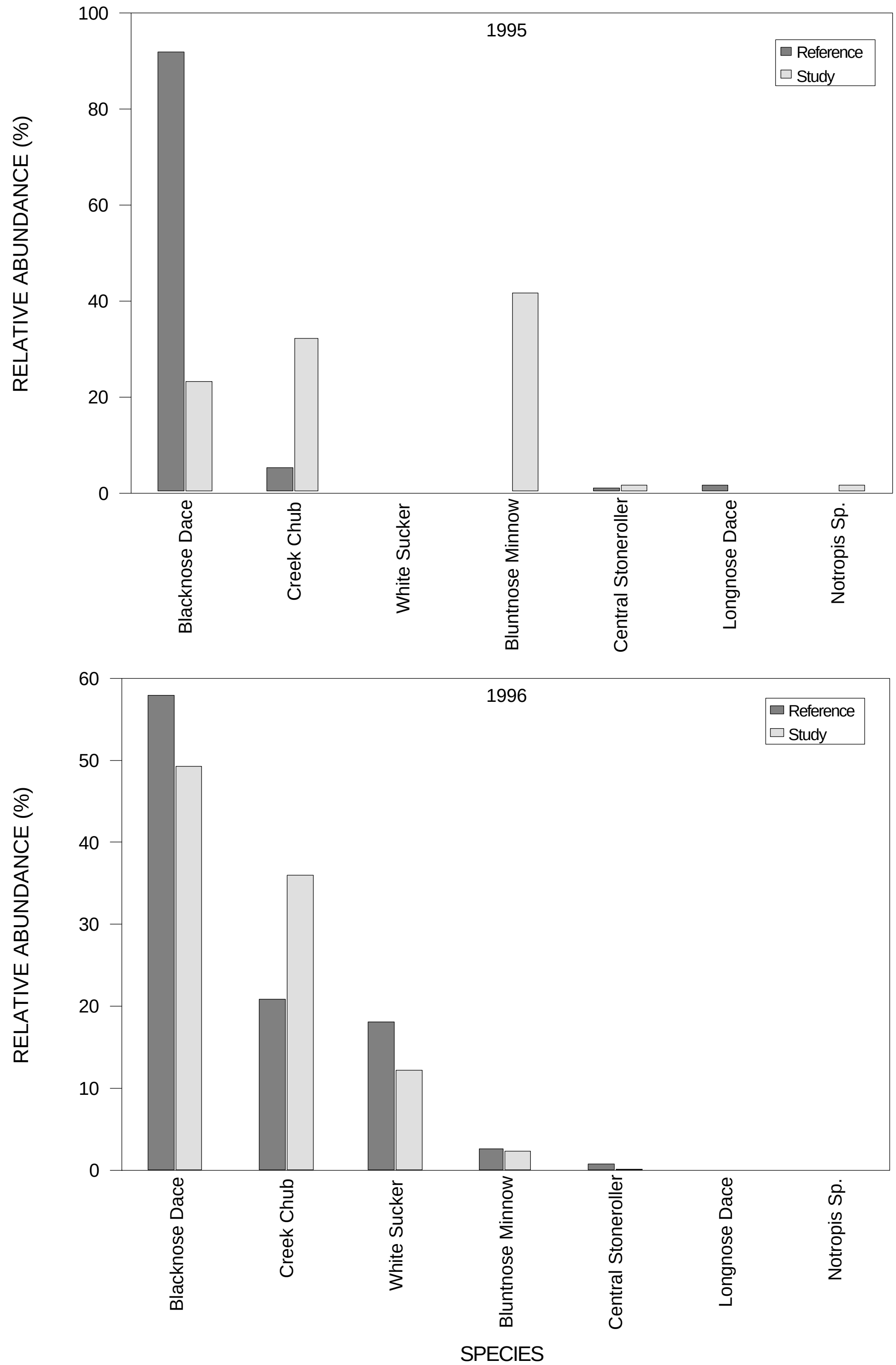


Figure 38. Veety Farm Fish Species Composition Data, 1995 and 1996

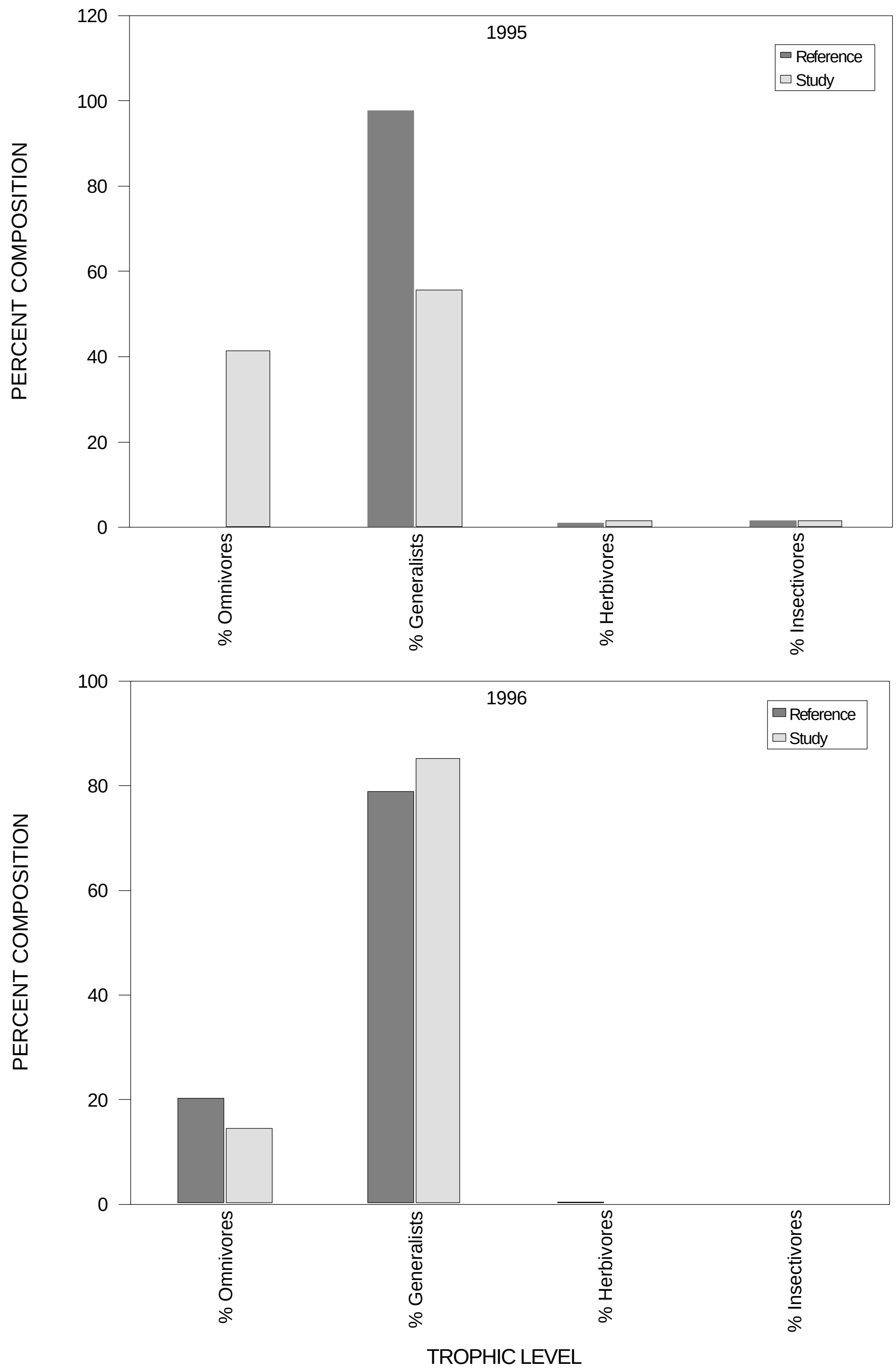


Figure 39. Veety Farm Fish Community Trophic Structure Data, 1995 and 1996

Table 13. Summary of the Epler Farm Macroinvertebrate Community Data, 1996 and 1997

	1996		1997	
	Reference Reach	**Study Reach**	**Reference Reach**	**Study Reach**
Raw Data Summary				
Number of Individuals	128	135	128	111
% Shredders	76.6	66.7	0.0	2.7
% Collector-Gatherers	6.3	20.7	78.1	37.8
% Filterer-Collectors	2.3	0.7	12.5	36.0
% Scrapers	2.3	2.2	3.1	19.8
% Predators	12.5	9.6	6.3	3.6
Number of EPT Taxa	7	6	6	5
Metric Scores				
Taxonomic Richness	13	12	13	16
Shannon Diversity Index	2.24	2.24	1.92	3.09
Hilsenhoff Biotic Index	1.62	2.97	5.66	5.53
EPT Index	7	6	6	5
% Taxonomic Similarity	100.00	52.60	100.00	39.20
% Trophic Similarity	100.00	90.48	100.00	78.30
Percent of Reference				
Taxonomic Richness	100.0	92.3	100.0	123.1
Shannon Diversity Index	100.0	99.8	100.0	161.2
Hilsenhoff Biotic Index	100.0	54.4	100.0	102.3
EPT Index	100.0	85.7	100.0	83.3
% Taxonomic Similarity	100.0	52.6	100.0	39.2
% Trophic Similarity	100.0	90.5	100.0	78.3
Biological Condition Scores				
Taxonomic Richness	6	6	6	6
Shannon Diversity Index	6	6	6	6
Hilsenhoff Biotic Index	6	2	6	6
EPT Index	6	4	6	4
% Taxonomic Similarity	6	6	6	4
% Trophic Similarity	6	6	6	6
Total Biological Score	**36**	**30**	**36**	**32**
Biological % of Reference	**100**	**83**	**100**	**89**

Although the total biological score for the 1997 study reach was comparable to the 1996 subsample, the macroinvertebrate community during the 1997 sampling season was degraded. The Hilsenhoff Biotic Index score was higher during 1997 (Figure 40) because the biological community of the reference reach was degraded, as well as that of the study reach. There also was a shift in the trophic structure of the community in both the reference reach and the study reach between the two years (Figure 41). During 1996, shredders (in the form of stoneflies) dominated the reference reach, while, during 1997, the dominant feeding group was collector-gatherers (midges). The study reach trophic structure also showed a shift from shredders (as stoneflies) to a co-dominance of collector-gatherers and filterer-collectors (midges, *Baetis*, and hydropsychid caddisflies) (Figure 41).

At the Englart farm reference reach in 1996, a relatively diverse macroinvertebrate community existed with significant numbers of Chironomidae, *Ephemerella* (Ephemeroptera: Ephemerellidae), *Isonychia* (Ephemeroptera: Isonychiidae), and *Isoperla*. However, the situation deteriorated slightly in 1997, when a large number of midges, and hydropsychid and philopotamid caddisflies increased the Hilsenhoff Biotic Index at the reference site. Additionally, at the reference reach in 1997, there were fewer EPT taxa, fewer EPT individuals, and a lower diversity index. A summary of the Englart farm macroinvertebrate community data can be found in Table 14.

The study site at the Englart farm in 1996 also contained a fairly diverse macroinvertebrate community with a large number of *Hexatoma* (Diptera: Tipulidae) and *Ephemerella*, but with a greater number of midges than found at the reference site. According to the metric scores, the study site improved greatly from 1996 to 1997. However, the increase in metric scores was due to deterioration in the quality of the macroinvertebrate community at the reference site in 1997, rather than to a true increase in the quality of the study site in 1997. The study site in 1997 showed a decrease in taxa richness and number of EPT taxa and an increase in the Hilsenhoff Biotic Index.

Similar to the situation at the Epler farm, the increase in metric scores at the Englart farm during the 1997 sampling season was not due to an improvement in the macroinvertebrate community at the study reach, but rather to deterioration in the condition of the reference reach community. Diversity and the EPT Index decreased, and the Hilsenhoff Biotic Index increased in the reference reach between 1996 and 1997. However, conditions in the study reach during 1997 were better than those in the reference reach, which was reflected in the metric scores (Figure 42). At both the study and reference reaches, there was an increase in the relative abundance of collector-gatherers during 1997 due to an increase in midges and *Paraleptophlebia* (Ephemeroptera: Leptophlebiidae) (Figure 43).

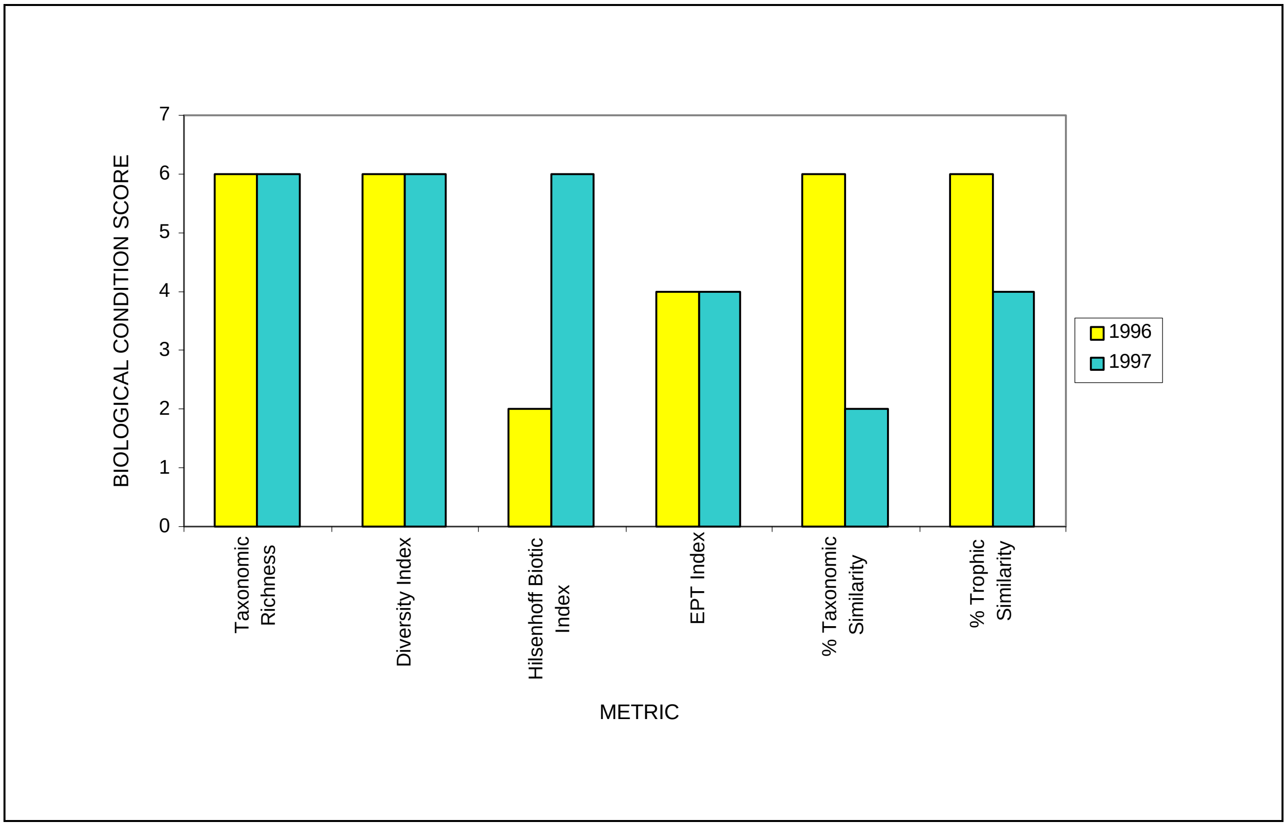


Figure 40. Epler Farm Macroinvertebrate Community Data, 1996 and 1997

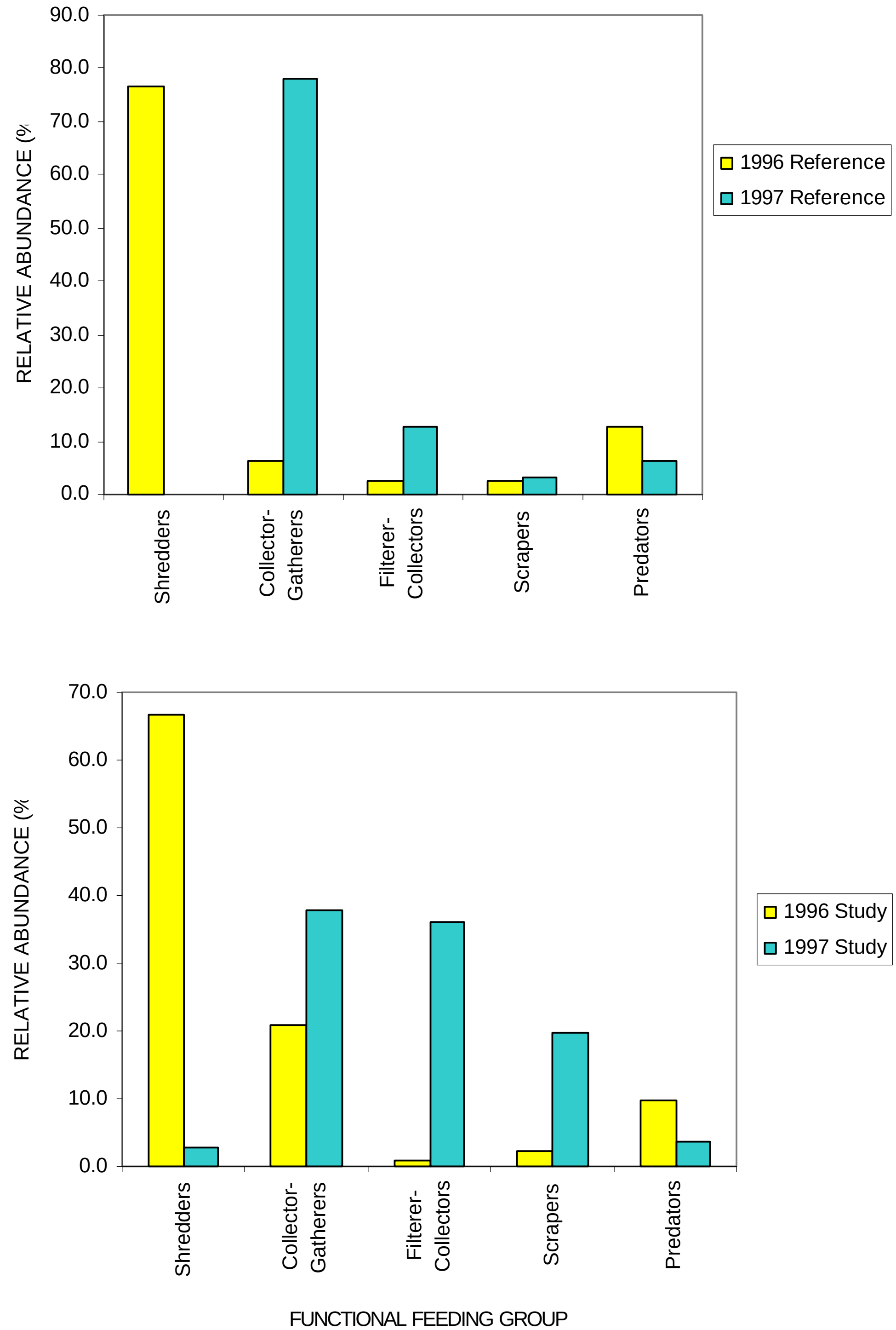


Figure 41. Epler Farm Macroinvertebrate Community Trophic Structure Data, 1996 and 1997

Table 14. Summary of the Englart Farm Macroinvertebrate Community Data, 1996 and 1997

	1996		1997	
	Reference Reach	**Study Reach**	**Reference Reach**	**Study Reach**
Raw Data Summary				
Number of Individuals	99	106	126	110
% Shredders	4.0	8.5	2.4	2.7
% Collector-Gatherers	27.3	29.2	50.8	39.1
% Filterer-Collectors	22.2	4.7	23.8	20.9
% Scrapers	32.3	28.3	15.1	19.1
% Predators	14.1	29.2	7.9	18.2
Number of EPT Taxa	14	11	10	10
Metric Scores				
Taxonomic Richness	21	21	21	20
Shannon Diversity Index	3.75	3.72	3.33	3.51
Hilsenhoff Biotic Index	2.81	3.75	4.47	3.99
EPT Index	14	11	10	10
% Taxonomic Similarity	100.00	51.30	100.00	80.30
% Trophic Similarity	100.00	89.75	100.00	94.65
Percent of Reference				
Taxonomic Richness	100.0	100.0	100.0	95.2
Shannon Diversity Index	100.0	99.2	100.0	105.5
Hilsenhoff Biotic Index	100.0	74.8	100.0	112.0
EPT Index	100.0	78.6	100.0	100.0
% Taxonomic Similarity	100.0	51.3	100.0	80.3
% Trophic Similarity	100.0	89.8	100.0	94.7
Biological Condition Scores				
Taxonomic Richness	6	6	6	6
Shannon Diversity Index	6	6	6	6
Hilsenhoff Biotic Index	6	4	6	6
EPT Index	6	2	6	6
% Taxonomic Similarity	6	6	6	6
% Trophic Similarity	6	6	6	6
Total Biological Score	**36**	**30**	**36**	**36**
Biological % of Reference	**100**	**83**	**100**	**100**

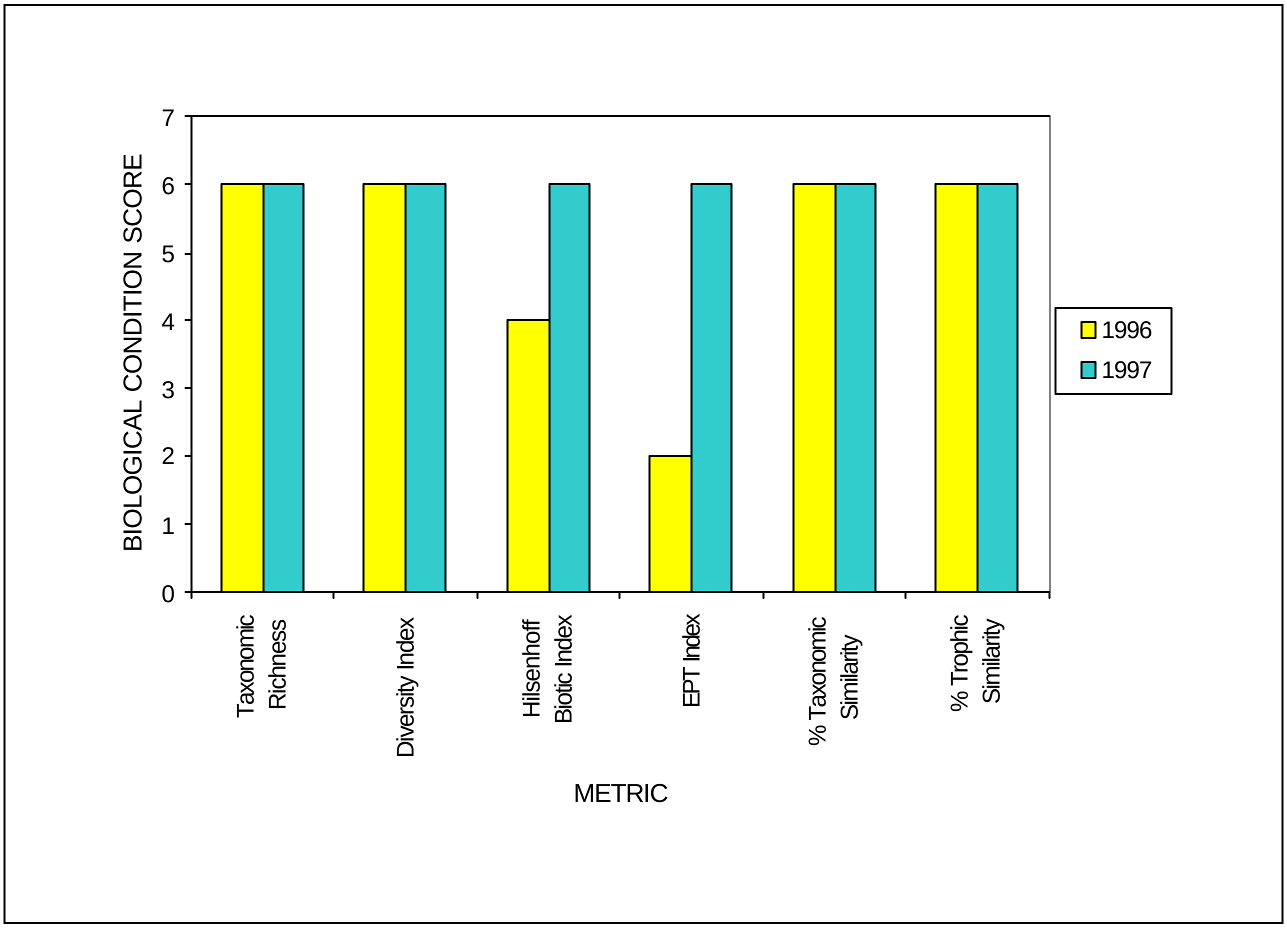


Figure 42. Englart Farm Macroinvertebrate Community Data, 1996 and 1997

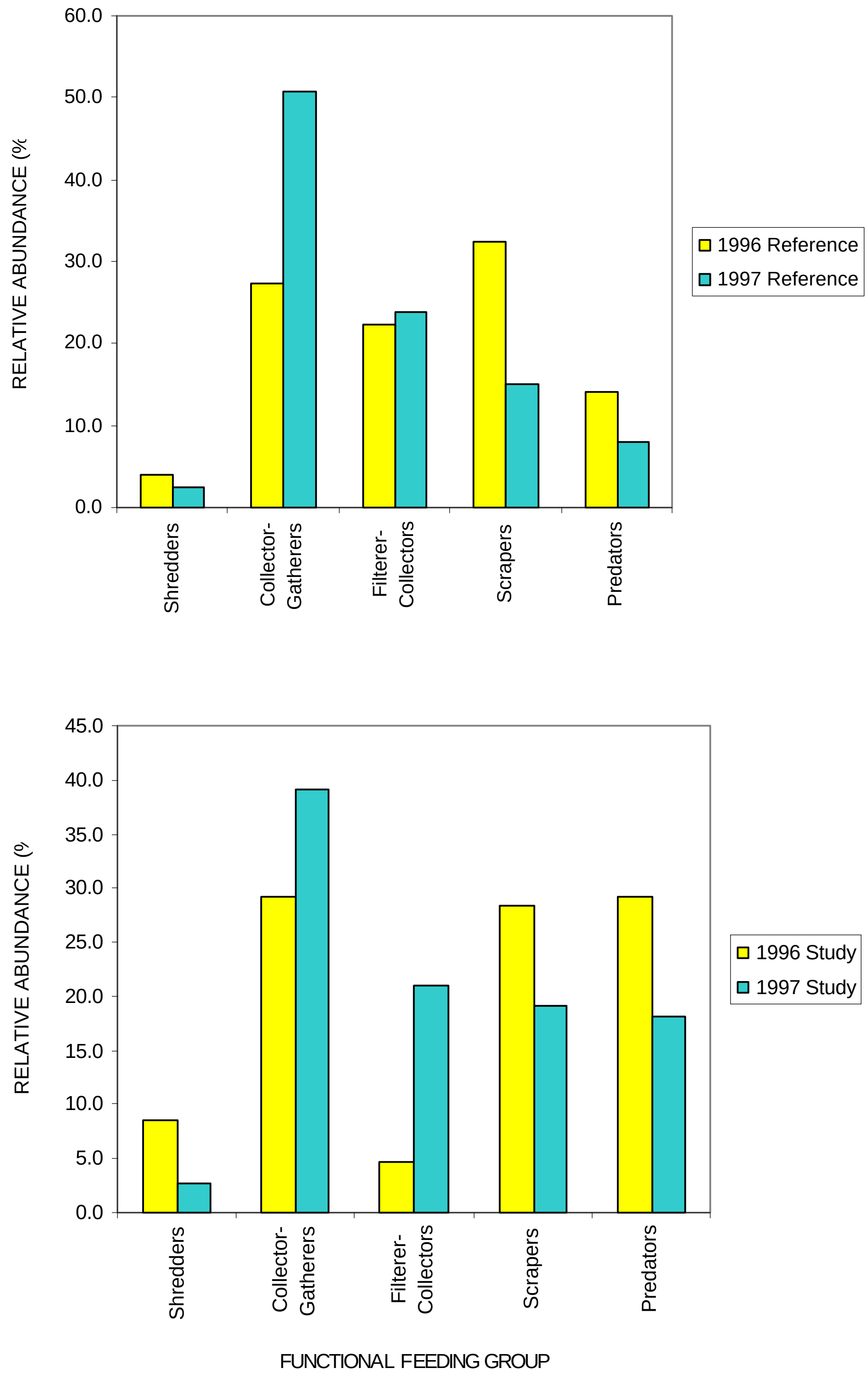


Figure 43. Englart Farm Macroinvertebrate Community Trophic Structure, 1996 and 1997

PROTOCOL FOR ASSESSING STREAM/RIPARIAN ECOSYSTEM RESPONSE TO STREAMBANK FENCING

Due to the differences in sampling method conducted at each site in this survey, a true protocol cannot be drafted. However, some suggestions for future sampling in riparian ecosystems undergoing streambank fencing can be introduced.

At all study sites, the quality of riparian vegetation improved from mostly turf grass to herbaceous plants and shrubs. However, the most dramatic improvements occurred closest to the stream channel due to exclusion of cattle from these sites. All methods for documenting vegetation response appeared to be effective; however, as riparian vegetation changes in response to streambank fencing were most dramatic immediately adjacent to the stream channel, it is recommended that the greenline method should be used. The greenline vegetation survey method was effective for documenting the change in streamside vegetation in the study reach from predominantly turf grass before fencing to herbaceous plants and sedges/rushes/grasses and shrubs one year after fencing.

Improvement in the chemical water quality of the study sites is not clear. Increasing the frequency of water quality sampling, and including storm-event data, would provide valuable information regarding the influence of streambank fencing on stream water quality and nutrient loading. Upstream conditions also should be considered when documenting water chemistry. In highly agricultural areas, the upstream conditions may have a substantial effect on the nutrient loads in the downstream portions. High nutrient levels at the Epler farm may have been due to substantial agricultural activity upstream in the watershed. These higher levels were not observed at the Veety and Englart farms, perhaps due to less agricultural activity in these watersheds.

Significant changes occurred at all study sites with regard to channel substrate. In each case, the amount of silt and sand decreased and gravel and cobble increased, indicating an improvement in instream habitat. Although very time-intensive, Rosgen Level II technology provided valuable information about stream channel morphology and its changes after streambank fencing. Pebble count data also were very effective in documenting substantial changes in the channel substrate composition during post-fencing sampling.

The overall habitat at all sites improved after streambank fencing. Both HCI and RBP III habitat assessments were effective in documenting changes in in-stream and riparian conditions at the streambank fencing sites. The HCI technique is much more time-intensive and quantitative than the RBP III stream assessment method and, thus, should be used when more in-depth studies are needed. The RBP III habitat assessment technique is a more subjective approach to habitat assessment but allows for an accurate description of the instream and riparian habitat conditions with a small amount of time and effort.

The macroinvertebrate communities of the Veety and Epler farms' study sites improved after streambank fencing, but the Englart farm showed a slight decrease in the health of the community. However, the reference reach at the Englart farm also was slightly depressed from conditions the previous year. Thus, this decline in the macroinvertebrate community may be due to background conditions in the watershed such as flooding and scouring the previous year or low flow conditions. The methods used to assess the response of the study reach macroinvertebrate and fish communities to streambank fencing appear to be quite effective, and, once the biological conditions of the control reach stabilize, the effectiveness of these methods will most likely improve. It is suggested that Surber samplers should be used to assess the benthic macroinvertebrate community to document changes in abundance of organisms after fencing. Additionally, as fish are good indicators of long-term biological community health, fish community data should be collected at all sites.

Another aspect that should be addressed is the level of identification of benthic macro-invertebrates. In this project, macroinvertebrates were identified to the genus level (with the exception of Chironomidae, Simuliidae, Naididae, and Tubificidae); but, identification also can be performed to the family level if time or experience level of the taxonomist does not permit genus-level identification. However, identification to the family level is not as accurate as genus-level identification and often results in different metric scores.

Control sites should be chosen carefully and represent the least impacted site in the watershed. These reference sites should be assessed when study sites are sampled to provide background information about the stream and its biological community. Agency staff and cooperating landowners should monitor the fencing sites regularly to ensure exclusion of farm animals from the stream. Additionally, sampling should be extended for several years to allow comparisons after habitat and biological communities have become more stable.

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Appendix A

Water Quality Data From the Veety, Epler, and Englart Farms

Table A1. Water Quality Data From the Veety Farm, 1995 and 1996

Parameter Symbol	Parameter Name	Pa. DEP Analysis Code	Units	Veety Farm			
				November 1, 1995		October 30, 1996	
				Study Site	Reference Site	Study Site	Reference Site
Flow	Stream Flow		cfs	0.824		1.413	
Temp.	Water Temperature	10	°C	9.0	11.0	8.7	8.7
pH	pH (field)	400	S.U.	6.80	6.90	6.90	6.95
D.O.	Dissolved Oxygen (field)	300	mg/l	9.20	9.50	7.98	8.06
Spec. Cond.	Specific Conductance (field)	94		242	229	143	132
Alk.	Alkalinity (field as $CaCO_3$)	410	mg/l	25	14	36	28
Acid.	Acidity (field as $CaCO_3$)	435	mg/l	20	7	2	4
TSS	Total Suspended Sediment		mg/l	3	5	7	2
N	Total Nitrogen	600	mg/l	1.17	0.47	0.94	0.47
N. Diss.	Dissolved Nitrogen	602	mg/l	1.17	0.44	0.82	0.44
NH_3 Diss.	Dissolved Ammonia Nitrogen	608	mg/l	0.21	0.02	0.09	0.11
NH_3	Total Ammonia Nitrogen	610	mg/l	0.21	0.03	0.13	0.22
NO_2	Total Nitrite/Nitrate Nitrogen	630	mg/l	0.40	0.15	0.20	0.07
NO_2 Diss.	Dissolved Nitrite/Nitrate Nitrogen	631	mg/l	0.40	0.15	0.15	0.02
P	Total Phosphorus	665	mg/l	0.220	0.030	0.068	0.016
P Diss.	Dissolved Phosphorus (wet meth.)	666	mg/l	0.210	0.030	0.047	0.016
P Diss. Ortho.	Dissolved Orthophosphorus	671	mg/l	0.100		0.090	0.016
TOC	Total Organic Carbon	680	mg/l	6.4	4.8	4.9	4.8
TON	Total Organic Nitrogen		mg/l	0.56	0.29	0.61	0.18

Table A2. Water Quality Data From the Epler Farm, 1996 and 1997

Parameter Symbol	Parameter Name	Pa. DEP Code Analysis	Units	Epler Farm			
				June 24, 1996		July 17, 1997	
				Study Site	Reference Site	Study Site	Reference Site
Flow	Stream Flow		cfs	0.204		0.188	
Temp.	Water Temperature	10	°C	20.5	18.8	21.2	26.0
pH	pH (field)	400	S.U.	6.90	6.20	6.90	5.85
D.O.	Dissolved Oxygen (field)	300	mg/l	7.80	7.94	6.86	6.5
Spec. Cond.	Specific Conductance (field)	94		73	55	75	56
Alk.	Alkalinity (field as $CaCO_3$)	410	mg/l	22	10	16	12
Acid.	Acidity (field as $CaCO_3$)	435	mg/l	8	10	6	16
TSS	Total Suspended Sediment		mg/l	17	7	13	19
N	Total Nitrogen	600	mg/l	1.99	2.52	2.60	2.21
N. Diss.	Dissolved Nitrogen	602	mg/l	1.94	2.52	2.28	2.15
NH_3 Diss.	Dissolved Ammonia Nitrogen	608	mg/l	0.08	0.11	0.08	0.09
NH_3	Total Ammonia Nitrogen	610	mg/l	0.08	0.11	0.09	0.10
NO_2	Total Nitrite/Nitrate Nitrogen	630	mg/l	1.25	1.61	1.74	1.46
NO_2 Diss.	Dissolved Nitrite/Nitrate Nitrogen	631	mg/l	1.25	1.61	1.73	1.46
P	Total Phosphorus	665	mg/l	0.066	0.038	0.023	0.041
P Diss.	Dissolved Phosphorus (wet meth.)	666	mg/l	0.037	0.031	0.012	0.018
P Diss. Ortho.	Dissolved Orthophosphorus	671	mg/l			0.005	0.018
TOC	Total Organic Carbon	680	mg/l	8.8	3.6	4.3	3.6
TON	Total Organic Nitrogen		mg/l	0.66	0.80	0.77	0.65

Table A3. Water Quality Data From the Englart Farm, 1996 and 1997

Parameter Symbol	Parameter Name	Pa. DEP Analysis Code	Units	Englart Farm			
				June 6, 1996		July 1, 1997	
				Study Site	Reference Site	Study Site	Reference Site
Flow	Stream Flow		cfs	1.212		1.048	
Temp.	Water Temperature	10	°C	13.5	13.2	19.8	18.3
pH	pH (field)	400	S.U.	7.00	7.05	6.50	6.65
D.O.	Dissolved Oxygen (field)	300	mg/l	8.80	9.20	8.2	7.61
Spec. Cond.	Specific Conductance (field)	94		44	45	50	52
Alk.	Alkalinity (field as $CaCO_3$)	410	mg/l	18	16	16	16
Acid.	Acidity (field as $CaCO_3$)	435	mg/l	4	4	4	6
TSS	Total Suspended Sediment		mg/l	4	7	12	23
N	Total Nitrogen	600	mg/l	0.21	0.21	0.51	0.69
N. Diss.	Dissolved Nitrogen	602	mg/l	0.21	0.21	0.51	0.69
NH_3 Diss.	Dissolved Ammonia Nitrogen	608	mg/l	0.02	0.02	0.02	0.04
NH_3	Total Ammonia Nitrogen	610	mg/l	0.02	0.02	0.02	0.04
NO_2	Total Nitrite/Nitrate Nitrogen	630	mg/l	0.11	0.11	0.18	0.22
NO_2 Diss.	Dissolved Nitrite/Nitrate Nitrogen	631	mg/l	0.11	0.11	0.18	0.21
P	Total Phosphorus	665	mg/l	0.022	0.023	0.011	0.016
P Diss.	Dissolved Phosphorus (wet meth.)	666	mg/l	0.016	0.016	0.006	0.007
P Diss. Ortho.	Dissolved Orthophosphorus	671	mg/l	0.01	0.01	0.002	0.006
TOC	Total Organic Carbon	680	mg/l	1.3	1.4	2.2	2.5
TON	Total Organic Nitrogen		mg/l	0.08	0.08	0.31	0.43

Appendix B

Organic Pollution-Tolerance Values and Functional Feeding Group Designations of Benthic Macroinvertebrate Taxa

Order	Family	Genus	Organic Pollution Tolerance Value	Functional Feeding Group Designation
Insecta: Coleoptera	**Dytiscidae**	*Agabus*	5	P
	Elmidae	*Ancyronyx variegata*	2	CG
		Optioservus	4	SC
		Stenelmis	5	SC
	Halipidae	*Peltodytes*	5	SH
	Hydrophilidae	*Enochrus*	5	CG
	Psephenidae	*Psephenus*	4	SC
Diptera	**Athericidae**	*Atherix*	2	P
	Ceratopogonidae	*Bezzia*	6	P
	Chironomidae	**Chironomidae**	7	CG
	Empididae	*Hemerodromia*	6	P
	Muscidae	*Limnophora*	6	P
	Simuliidae	**Simuliidae**	6	FC
	Tabanidae	*Tabanus*	5	P
	Tipulidae	*Antocha*	3	CG
		Dicranota	3	P
		Hexatoma	2	P
		Limonia	6	SH
		Tipula	4	SH
Ephemeroptera	**Baetidae**	*Acentrella*	4	CG
		Baetis	6	CG
	Caenidae	*Caenis*	7	CG
	Ephemerellidae	*Ephemerella*	1	SC
		Serratella	2	SC
	Ephemeridae	*Ephemera*	2	CG
	Heptageniidae	*Epeorus*	0	CG
		Heptagenia	4	SC
		Leucrocuta	1	SC
		Stenacron	4	SC
		Stenonema	3	SC
	Isonychiidae	*Isonychia*	2	FC
	Leptophlebiidae	*Paraleptophlebia*	1	CG
	Tricorythidae	*Tricorythodes*	4	CG
Hemiptera	**Vellidae**	*Microvelia*	8	P
Megaloptera	**Corydalidae**	*Nigronia*	2	P
	Sialidae	*Sialis*	4	P
Odonata	**Calopterygidae**	*Calopteryx*	6	P
		Hataerina	6	P
	Coenagrionidae	*Chromagrion*	4	P
	Cordulegastridae	*Cordulegaster*	3	P
	Gomphidae	*Stylogomphus albistylus*	4	P
	Libellulidae	*Erythemis*	5	P
Plecoptera	**Capniidae**	*Paracapnia*	1	SH
	Leuctridae	*Leuctra*	0	SH
	Nemouridae	*Amphinemura*	2	SH
	Perlidae	*Acroneuria*	0	P
		Agnetina	2	P
		Perlesta	4	P
	Perlodidae	*Isoperla*	2	P
	Taeniopterygidae	*Taeniopteryx*	2	SH
Trichoptera	**Hydropsychidae**	*Ceratopsyche*	4	FC
		Cheumatopsyche	5	FC
		Diplectrona	0	FC
		Hydropsyche	4	FC
		Potamyia flava	5	FC

Order	Family	Genus	Organic Pollution Tolerance Value	Functional Feeding Group Designation
	Odontoceridae	*Psilotreta*	0	SC
	Philopotamidae	*Chimarra*	4	FC
		Dolophilodes	0	FC
		Wormaldia	0	FC
	Phryganeidae	*Ptilostomis*	5	SH
	Polycentropodidae	*Polycentropus*	6	FC
Oligochaeta: Haplotaxida	**Naididae**	**Naididae**	8	CG
	Tubificidae	**Tubificidae**	10	CG
Hirudinea: Gnathobdellida	**Hirudinidae**	*Helobdella*	6	P
Crustacea: Amphipoda	**Talitridae**	*Hyalella*	8	SH
Decapoda	**Cambaridae**	*Cambarus*	6	CG
Isopoda	**Asellidae**	*Caecidotea*	8	SH
Gastropoda: Gastropoda	**Lymnaeidae**	*Fossaria*	7	SC
		Lymnaea stagnalis	7	SC
	Physidae	*Physa*	8	SC
	Planorbidae	**Planorbidae**	6	
Bivalvia: Pelecypoda	**Sphaeriidae**	*Pisidium*	8	FC
		Sphaerium	8	FC

Group: P Predator
CG Collector-Gatherer
SC Shredder-Collector
SH Shredder
FC Filterer-Collector

Appendix C

Benthic Macroinvertebrate Data From the Veety, Epler, and Englart Farms

Table C1. Macroinvertebrate Data From the Veety Farm Study Sites 1 and 2

Order	Family	Genus	Veety Farm Study Site 1 1995	Veety Farm Study Site 1 1996	Veety Farm Study Site 2 1995	Veety Farm Study Site 2 1996
Insecta: Coleoptera	**Dytiscidae**	*Agabus*				
	Elmidae	*Ancyronyx variegata*				
		Optioservus		1	1	
		Stenelmis		1		
	Haliplidae	*Peltodytes*			1	
	Hydrophilidae	*Enochrus*			1	
	Psephenidae	*Psephenus*				
Diptera	**Athericidae**	*Atherix*		3		
	Ceratopogonidae	*Bezzia*				
	Chironomidae	**Chironomidae**	7	154	6	49
	Empididae	*Hemerodromia*				
	Muscidae	*Limnophora*			3	
	Simuliidae	**Simuliidae**		11		6
	Tabanidae	*Tabanus*				
	Tipulidae	*Antocha*				
		Dicranota				
		Hexatoma				
		Limonia				
		Tipula	1			1
Ephemeroptera	**Baetidae**	*Acentrella*				
		Baetis				
	Caenidae	*Caenis*				2
	Ephemerellidae	*Ephemerella*				
		Serratella				
	Ephemeridae	*Ephemera*		2		2
	Heptageniidae	*Epeorus*				
		Heptagenia				
		Leucrocuta				
		Stenacron				
		Stenonema		7		1
	Isonychiidae	*Isonychia*				
	Leptophlebiidae	*Paraleptophlebia*				
	Tricorythidae	*Tricorythodes*				
Hemiptera	**Veliidae**	*Microvelia*				
Megaloptera	**Corydalidae**	*Nigronia*				
	Sialidae	*Sialis*				
Odonata	**Calopterygidae**	*Calopteryx*				1
		Hataerina				
	Coenagrionidae	*Chromagrion*			1	
	Cordulegastridae	*Cordulegaster*				
	Gomphidae	*Stylogomphus albistylus*				
	Libellulidae	*Erythemis*			1	
Plecoptera	**Capniidae**	*Paracapnia*				
	Leuctridae	*Leuctra*				
	Nemouridae	*Amphinemura*				
	Perlidae	*Acroneuria*				
		Agnetina			1	
		Perlesta				
	Perlodidae	*Isoperla*				
	Taeniopterygidae	*Taeniopteryx*				

Table C1. Macroinvertebrate Data From the Veety Farm Study Sites 1 and 2—Continued

Order	Family	Genus	Veety Farm			
			Study Site 1		Study Site 2	
			1995	1996	1995	1996
Insecta: Trichoptera	**Hydropsychidae**	*Ceratopsyche*		5		
		Cheumatopsyche	1	56	11	10
		Diplectrona				
		Hydropsyche		39	1	1
		Potamyia flava				
	Odontoceridae	*Psilotreta*		1		1
	Philopotamidae	*Chimarra*				
		Dolophilodes				
		Wormaldia				
	Phryganeidae	*Ptilostomis*				1
	Polycentropodidae	*Polycentropus*				
Oligochaeta: Haplotaxida	**Naididae**	**Naididae**				
	Tubificidae	**Tubificidae**	94	21	12	34
Hirudinea: Gnathobdellida	**Hirudinidae**	*Helobdella*	3	1		2
Crustacea: Amphipoda	**Talitridae**	*Hyalella*	11	5	22	74
Decapoda	**Cambaridae**	*Cambarus*				1
Isopoda	**Asellidae**	*Caecidotea*	148	392	36	205
Gastropoda: Gastropoda	**Lymnaeidae**	*Fossaria*				
		Lymnaea stagnalis		1		4
	Physidae	*Physa*	28		5	
Bivalvia: Pelecypoda	**Sphaeriidae**	*Pisidium*			3	
		Sphaerium			1	6

Table C2. Macroinvertebrate Data From the Veety Farm Study Site 3 and Reference Site 1

Order	Family	Genus	Veety Farm			
			Study Site 3		Reference Site 1	
			1995	1996	1995	1996
Insecta: Coleoptera	**Dytiscidae**	*Agabus*				
	Elmidae	*Ancyronyx variegata*		3		
		Optioservus		1		
		Stenelmis				
	Haliplidae	*Peltodytes*				
	Hydrophilidae	*Enochrus*				
	Psephenidae	*Psephenus*		1		
Diptera	**Athericidae**	*Atherix*				
	Ceratopogonidae	*Bezzia*				
	Chironomidae	**Chironomidae**	1	190		9
	Empididae	*Hemerodromia*				
	Muscidae	*Limnophora*				
	Simuliidae	**Simuliidae**		49		3
	Tabanidae	*Tabanus*				
	Tipulidae	*Antocha*				
		Dicranota				
		Hexatoma				
		Limonia				
		Tipula	1			
Ephemeroptera	**Baetidae**	*Acentrella*				
		Baetis				
	Caenidae	*Caenis*	1			
	Ephemerellidae	*Ephemerella*				3
		Serratella	3	2	4	7
	Ephemeridae	*Ephemera*		1	1	
	Heptageniidae	*Epeorus*				
		Heptagenia				
		Leucrocuta				
		Stenacron			2	
		Stenonema		1	2	
	Isonychiidae	*Isonychia*				
	Leptophlebiidae	*Paraleptophlebia*			1	
	Tricorythidae	*Tricorythodes*				
Hemiptera	**Veliidae**	*Microvelia*				
Megaloptera	**Corydalidae**	*Nigronia*			1	
	Sialidae	*Sialis*				
Odonata	**Calopterygidae**	*Calopteryx*				
		Hataerina				
	Coenagrionidae	*Chromagrion*				
	Cordulegastridae	*Cordulegaster*				
	Gomphidae	*Stylogomphus albistylus*				
	Libellulidae	*Erythemis*				
Plecoptera	**Capniidae**	*Paracapnia*				
	Leuctridae	*Leuctra*				
	Nemouridae	*Amphinemura*				
	Perlidae	*Acroneuria*		2		2
		Agnetina		2	3	16
		Perlesta				
	Perlodidae	*Isoperla*				
	Taeniopterygidae	*Taeniopteryx*		2		3

Table C2. Macroinvertebrate Data From the Veety Farm Study Site 3 and Reference Site 1—Continued

Order	Family	Genus	Veety Farm			
			Study Site 3		Reference Site 1	
			1995	1996	1995	1996
Insecta: Trichoptera	**Hydropsychidae**	*Ceratopsyche*		2		17
		Cheumatopsyche	48	55	18	57
		Diplectrona				
		Hydropsyche		33		75
		Potamyia flava				
	Odontoceridae	*Psilotreta*		2		
	Philopotamidae	*Chimarra*	1			12
		Dolophilodes				
		Wormaldia				
	Phryganeidae	*Ptilostomis*				
	Polycentropodidae	*Polycentropus*			1	
Oligochaeta: Haplotaxida	**Naididae**	**Naididae**				
	Tubificidae	**Tubificidae**	2	10		
Hirudinea: Gnathobdellida	**Hirudinidae**	*Helobdella*	1			
Crustacea: Amphipoda	**Talitridae**	*Hyalella*	6	15	14	2
Decapoda	**Cambaridae**	*Cambarus*				1
Isopoda	**Asellidae**	*Caecidotea*	44	149		4
Gastropoda: Gastropoda	**Lymnaeidae**	*Fossaria*				
		Lymnaea stagnalis		3		
	Physidae	*Physa*	3			
Bivalvia: Pelecypoda	**Sphaeriidae**	*Pisidium*	1			
		Sphaerium		8		

Table C3. Macroinvertebrate Data From the Veety Farm Reference Sites 2 and 3

Order	Family	Genus	Veety Farm			
			Reference Site 2		Reference Site 3	
			1995	1996	1995	1996
Insecta: Coleoptera	**Dytiscidae**	*Agabus*				
	Elmidae	*Ancyronyx variegata*				
		Optioservus	1			
		Stenelmis			1	
	Haliplidae	*Peltodytes*				
	Hydrophilidae	*Enochrus*				
	Psephenidae	*Psephenus*				
Diptera	**Athericidae**	*Atherix*			1	
	Ceratopogonidae	*Bezzia*				
	Chironomidae	**Chironomidae**				18
	Empididae	*Hemerodromia*				1
	Muscidae	*Limnophora*				
	Simuliidae	**Simuliidae**		1		5
	Tabanidae	*Tabanus*				
	Tipulidae	*Antocha*				4
		Dicranota				
		Hexatoma				
		Limonia				
		Tipula				
Ephemeroptera	**Baetidae**	*Acentrella*				
		Baetis				
	Caenidae	*Caenis*				
	Ephemerellidae	*Ephemerella*				10
		Serratella	13	4		4
	Ephemeridae	*Ephemera*				
	Heptageniidae	*Epeorus*				
		Heptagenia				
		Leucrocuta				
		Stenacron		2		
		Stenonema	1			1
	Isonychiidae	*Isonychia*			1	
	Leptophlebiidae	*Paraleptophlebia*	2			
	Tricorythidae	*Tricorythodes*				
Hemiptera	**Veliidae**	*Microvelia*				
Megaloptera	**Corydalidae**	*Nigronia*		1	1	2
	Sialidae	*Sialis*				
Odonata	**Calopterygidae**	*Calopteryx*				
		Hataerina				
	Coenagrionidae	*Chromagrion*				
	Cordulegastridae	*Cordulegaster*				
	Gomphidae	*Stylogomphus albistylus*				
	Libellulidae	*Erythemis*				
Plecoptera	**Capniidae**	*Paracapnia*				
	Leuctridae	*Leuctra*				
	Nemouridae	*Amphinemura*				
	Perlidae	*Acroneuria*				5
		Agnetina	2		1	
		Perlesta	1			
	Perlodidae	*Isoperla*				
	Taeniopterygidae	*Taeniopteryx*		1		

Table C3. Macroinvertebrate Data From the Veety Farm Reference Sites 2 and 3—Continued

Order	Family	Genus	Veety Farm Reference Site 2 1995	Veety Farm Reference Site 2 1996	Veety Farm Reference Site 3 1995	Veety Farm Reference Site 3 1996
Insecta: Trichoptera	**Hydropsychidae**	*Ceratopsyche*		1		5
		Cheumatopsyche	6	16	14	114
		Diplectrona				
		Hydropsyche	1	15	2	55
		Potamyia flava				
	Odontoceridae	*Psilotreta*		1		
	Philopotamidae	*Chimarra*		7	9	74
		Dolophilodes				1
		Wormaldia				
	Phryganeidae	*Ptilostomis*				
	Polycentropodidae	*Polycentropus*				
Oligochaeta: Haplotaxida	**Naididae**	**Naididae**				
	Tubificidae	**Tubificidae**				
Hirudinea: Gnathobdellida	**Hirudinidae**	*Helobdella*				
Crustacea: Amphipoda	**Talitridae**	*Hyalella*	10	16	48	5
Decapoda	**Cambaridae**	*Cambarus*	1		1	1
Isopoda	**Asellidae**	*Caecidotea*				
Gastropoda: Gastropoda	**Lymnaeidae**	*Fossaria*				
		Lymnaea stagnalis				
	Physidae	*Physa*				
Bivalvia: Pelecypoda	**Sphaeriidae**	*Pisidium*				
		Sphaerium				2

Table C4. Macroinvertebrate Data From the Epler Farm Sites

Order	Family	Genus	Epler Farm Reference Site 1996	Epler Farm Reference Site 1997	Epler Farm Study Site 1996	Epler Farm Study Site 1997
Insecta: Coleoptera	**Dytiscidae**	*Agabus*		1	4	
	Elmidae	*Ancyronyx variegata*				
		Optioservus				2
		Stenelmis			2	11
	Haliplidae	*Peltodytes*				
	Hydrophilidae	*Enochrus*				
	Psephenidae	*Psephenus*				2
Diptera	**Athericidae**	*Atherix*				
	Ceratopogonidae	*Bezzia*				1
	Chironomidae	**Chironomidae**	1	86	4	22
	Empididae	*Hemerodromia*				
	Muscidae	*Limnophora*				
	Simuliidae	**Simuliidae**	1			
	Tabanidae	*Tabanus*		1		
	Tipulidae	*Antocha*				
		Dicranota		3		
		Hexatoma				
		Limonia			1	
		Tipula	1		2	3
Ephemeroptera	**Baetidae**	*Acentrella*				
		Baetis		3	20	17
	Caenidae	*Caenis*				3
	Ephemerellidae	*Ephemerella*				
		Serratella				
	Ephemeridae	*Ephemera*				
	Heptageniidae	*Epeorus*				
		Heptagenia	3		1	
		Leucrocuta				
		Stenacron				
		Stenonema		4		3
	Isonychiidae	*Isonychia*				
	Leptophlebiidae	*Paraleptophlebia*		11		
	Tricorythidae	*Tricorythodes*				
Hemiptera	**Veliidae**	*Microvelia*				1
Megaloptera	**Corydalidae**	*Nigronia*	1	1		
	Sialidae	*Sialis*	1	1		
Odonata	**Calopterygidae**	*Calopteryx*				
		Hataerina				1
	Coenagrionidae	*Chromagrion*				
	Cordulegastridae	*Cordulegaster*		1		1
	Gomphidae	*Stylogomphus albistylus*				
	Libellulidae	*Erythemis*				
Plecoptera	**Capniidae**	*Paracapnia*	2			
	Leuctridae	*Leuctra*	47		12	
	Nemouridae	*Amphinemura*	48		75	
	Perlidae	*Acroneuria*				
		Agnetina				
		Perlesta				
	Perlodidae	*Isoperla*	14		9	
	Taeniopterygidae	*Taeniopteryx*				

Table C4. Macroinvertebrate Data From the Epler Farm Sites —Continued

Order	Family	Genus	Epler Farm Reference Site 1996	Epler Farm Reference Site 1997	Epler Farm Study Site 1996	Epler Farm Study Site 1997
Insecta: Trichoptera	**Hydropsychidae**	*Ceratopsyche*				
		Cheumatopsyche		9	1	31
		Diplectrona		5		
		Hydropsyche	1			9
		Potamyia flava				
	Odontoceridae	*Psilotreta*				
	Philopotamidae	*Chimarra*		2		
		Dolophilodes				
		Wormaldia	1			
	Phryganeidae	*Ptilostomis*				
	Polycentropodidae	*Polycentropus*				
Oligochaeta: Haplotaxida	**Naididae**	**Naididae**			4	
	Tubificidae	**Tubificidae**				
Hirudinea: Gnathobdellida	**Hirudinidae**	*Helobdella*				
Crustacea: Amphipoda	**Talitridae**	*Hyalella*				
Decapoda	**Cambaridae**	*Cambarus*	7			
Isopoda	**Asellidae**	*Caecidotea*				
Gastropoda: Gastropoda	**Lymnaeidae**	*Fossaria*				1
		Lymnaea stagnalis				
	Physidae	*Physa*				3
Bivalvia: Pelecypoda	**Sphaeriidae**	*Pisidium*				
		Sphaerium				

Table C5. Macroinvertebrate Data From the Englart Farm Sites

Order	Family	Genus	Englart Farm			
			Reference Site		Study Site	
			1996	1997	1996	1997
Insecta: Coleoptera	**Dytiscidae**	*Agabus*				
	Elmidae	*Ancyronyx variegata*	1			
		Optioservus	2	8	1	14
		Stenelmis	2	4	11	2
	Haliplidae	*Peltodytes*				
	Hydrophilidae	*Enochrus*				
	Psephenidae	*Psephenus*	3	5	1	4
Diptera	**Athericidae**	*Atherix*				
	Ceratopogonidae	*Bezzia*				
	Chironomidae	**Chironomidae**	14	38	20	22
	Empididae	*Hemerodromia*		1		
	Muscidae	*Limnophora*				
	Simuliidae	**Simuliidae**				
	Tabanidae	*Tabanus*				1
	Tipulidae	*Antocha*		1		
		Dicranota		3	2	7
		Hexatoma		2	12	2
		Limonia			3	
		Tipula		1	2	1
Ephemeroptera	**Baetidae**	*Acentrella*		1		
		Baetis		4	9	2
	Caenidae	*Caenis*				
	Ephemerellidae	*Ephemerella*	18		15	
		Serratella				
	Ephemeridae	*Ephemera*	1			
	Heptageniidae	*Epeorus*	1			
		Heptagenia				
		Leucrocuta		1		
		Stenacron		1		1
		Stenonema	7		2	
	Isonychiidae	*Isonychia*	12			1
	Leptophlebiidae	*Paraleptophlebia*	8	20	1	18
	Tricorythidae	*Tricorythodes*				1
Hemiptera	**Veliidae**	*Microvelia*				
Megaloptera	**Corydalidae**	*Nigronia*		1	5	7
	Sialidae	*Sialis*				
Odonata	**Calopterygidae**	*Calopteryx*				
		Hataerina				
	Coenagrionidae	*Chromagrion*				
	Cordulegastridae	*Cordulegaster*				
	Gomphidae	*Stylogomphus albistylus*	1	2		2
	Libellulidae	*Erythemis*				
Plecoptera	**Capniidae**	*Paracapnia*		2		2
	Leuctridae	*Leuctra*	4		4	
	Nemouridae	*Amphinemura*				
	Perlidae	*Acroneuria*	1	1		1
		Agnetina	1		8	
		Perlesta				
	Perlodidae	*Isoperla*	11		4	
	Taeniopterygidae	*Taeniopteryx*				

Table C5. Macroinvertebrate Data From the Englart Farm Sites—Continued

Order	Family	Genus	Englart Farm			
			Reference Site		Study Site	
			1996	1997	1996	1997
Insecta: Trichoptera	**Hydropsychidae**	*Ceratopsyche*			1	
		Cheumatopsyche	3	14	1	17
		Diplectrona				
		Hydropsyche	2	1	1	3
		Potamyia flava			2	
	Odontoceridae	*Psilotreta*				
	Philopotamidae	*Chimarra*	3	15		2
		Dolophilodes	2			
		Wormaldia				
	Phryganeidae	*Ptilostomis*				
	Polycentropodidae	*Polycentropus*				
Oligochaeta: Haplotaxida	**Naididae**	**Naididae**				
	Tubificidae	**Tubificidae**				
Hirudinea: Gnathobdellida	**Hirudinidae**	*Helobdella*				
Crustacea: Amphipoda	**Talitridae**	*Hyalella*				
Decapoda	**Cambaridae**	*Cambarus*	2		1	
Isopoda	**Asellidae**	*Caecidotea*				
Gastropoda: Gastropoda	**Lymnaeidae**	*Fossaria*				
		Lymnaea stagnalis				
	Physidae	*Physa*				
Bivalvia: Pelecypoda	**Sphaeriidae**	*Pisidium*				
		Sphaerium				

APPENDIX D

FISH DATA FROM THE VEETY FARM SITE

Table D1. Fish Data From the Veety Farm Site

Family	Scientific Name	Common Name	Pollution Tolerance Value	Trophic Level	Reference Reach 1995	Study Reach 1995	Reference Reach 1996	Study Reach 1996
Cyprinidae	*Campostoma anomalum*	Central stoneroller	2	Herbivore	2	1	5	2
	Notropis Sp.		2	Insectivore		1		
	Pimephales notatus	Bluntnose minnow	3	Omnivore		27	17	25
	Rhinichthys atratulus	Blacknose dace	3	Generalist	184	15	391	504
	Rhinichthys cataractae	Longnose dace	1	Insectivore	3			
	Semotilus atromaculatus	creek chub	3	Generalist	11	21	142	369
Catostomidae	*Catostomus commersoni*	White sucker	3	Omnivore			122	124
				TOTAL	**200**	**65**	**677**	**1,024**