MODEL FOREST NETWORK
RÉSEAU DE FORÊTS MODÈLES

foothills model forest
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Report 2.4.2

Level II Stream Classification Project 1999 - 2002

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Foothills Model Forest
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Acknowledgements

Rick Bonar, Chief Biologist of Weldwood of Canada – Hinton Division originally expressed the need for a stream classification system that would be useful to guide forest management activities. As a result, we initiated work on this field classification project in 1999. The project was completed with support from partners including Weldwood of Canada Ltd. (Hinton Division) Forest Resources Improvement Program, the Canadian Forest Service, Alberta Sustainable Resource Development, the Alberta Conservation Association and Jasper National Park.

Deborah Chan-Yan, Water Resources Engineer with Golder Associates Ltd. provided a review of the results from the 1999 - 2001 field classification. Karen Halwas and James Power of ARC-Inc. provided a review of the draft version of the report. Fran Hanington provided an editorial review.

Abstract

This report describes the trial application of an existing field-based stream classification system to an area managed for timber harvest and other resource uses. The field classification was intended to serve a number of purposes including: facilitating communication between stakeholders from a variety of backgrounds; increasing our knowledge of regional streams and riparian ecosystem structure and function; and improving our ability to predict and measure stream and riparian ecosystem response to management activities. The Classification of Natural Rivers was selected because it provides descriptors of the stream channel and floodplain. A total of 286 sites representing the range of physiographic conditions within the study area were classified. Findings relating to channel structure, floodplain structure, and key riparian management applications are presented.

In the area of channel structure, in most upper foothills and all lower foothills basins, vegetation exerted a strong influence on streambank form and channel shape. In the highest relief upper foothills watersheds, vegetation was less important in determining streambank and channel form. As a result of highly active erosion processes in Solomon Creek, a steep upper foothills basin, various stream channels displayed disturbed or disequilibrium characteristics.

In regards to floodplain structure, a number of processes were identified that contribute to floodplain development. In addition to floods that result from events greater than the 1:2 year or bankfull event, beaver damming, channel obstruction, and spring runoff events that occur prior to ice-out, also result in frequent inundation of the lands adjacent to the stream channel. As a result, a combination of the existing stream classification system and the provincial ecosite classification was used to determine extent of the floodplain.

Key applications of our findings include production of maps illustrating small and large permanent streams within the study area. Potential applications requiring additional work include development of alternative riparian management strategies based on ecological boundaries as an alternative to the current rule-based watercourse class system. In addition, parameters that may be well suited for monitoring regional stream and floodplain structure were identified. These include stream width, width/depth ratio, and bank stability.

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1 Introduction

This report describes the trial application of an existing field-based stream classification system to an area managed for timber harvest and other resource uses. The field classification was intended to serve a number of purposes including: facilitating communication between stakeholders from a variety of backgrounds; increasing our knowledge of regional streams and riparian ecosystem structure and function; and improving our ability to predict and measure stream and riparian ecosystem response to management activities.

The Level II classification of Natural Rivers (Rosgen and Silvey 1996) was selected because it provides descriptors of both the stream channel and the floodplain portion of the adjacent terrestrial environment. This system was also selected for use in the field assessment of the Cows and Fish Alberta Riparian Habitat Management Program (Fitch et al. 2001).

The Level II classification procedure was integrated into the Foothills Model Forest fish and fish habitat inventory procedure and for the sake of efficiency, some modifications of the Level II classification methodology (Rosgen and Silvey 1996) were made. In this report we detailed the original methodology and our modifications. We provided results of the classification exercise and summarized the management implications of the most commonly occurring stream types. It is our intention to develop a more concise classification guidebook that would be used to assist foresters as they plan road crossings and forest harvest activities.

2 Methods

The methods we selected for Level II stream classification were consistent with Rosgen and Silvey (1996). Between 1999 and 2002, some modifications to these methods were made in order to adapt the systems to our needs. The original methods and the changes we made are described below.

Level II Classification was based on field measurements of seven attributes, including:

1. Bank-full width
2. Average bank-full depth
3. Maximum bank-full depth
4. Width of flood-prone area
5. Channel slope
6. Channel sinuosity, and

7. Dominant bed material.

Several of these attributes were then used to calculate two important descriptors:

1. Width / depth ratio, and
2. Entrenchment ratio.

These two descriptors and four of the field attributes were then used to determine channel type using the key to Rosgen Classification of Natural Rivers (Rosgen and Silvey 1996).

2.1 Field Methods

Six of the seven stream attributes were measured at a representative channel cross-section. Before choosing a representative cross-section to complete the classification exercise, the crew backpack electrofished or walked a section of stream, usually 300 meters in length. The cross-section was located in a riffle section along a relatively straight portion of the stream, in between meander bends in an area representative of the entire reach (Rosgen and Silvey 1996). Isolated bedrock outcroppings, areas of recent beaver activity, or areas of local anthropogenic disturbance such as road crossings and right-of-way clearings were avoided. Areas with extensive bank erosion and slumping undercut banks were avoided where possible. The importance of choosing an adequate location was emphasized and field staff received training and had opportunities for questions during periodic field reviews.

2.1.1 Bank-full Width

Bank-full width was defined as the stage at which water starts to flow onto the floodplain (Rosgen and Silvey 1996). At the representative location, a measuring tape was stretched across the stream channel at bank-full width. Field crews searched for signs of high water including breaks in slope of the streambank, the elevation of the highest depositional features, and changes in vegetation including rooted woody vegetation in closest proximity to the stream channel. The bank-full width was recorded to the nearest 0.1 meter.

2.1.2 Average Bank-full Depth

The average bank-full depth was defined as the average depth of water measured from the surface to the channel bottom when the water surface is even with the top of the streambank (Rosgen and Silvey 1996). Three depth measurements to the bank-full width were taken - one at left, center, and right, representing the channel cross-section. The average of the three measurements was calculated and recorded. All depths were recorded to the nearest centimeter.

2.1.3 Maximum Bank-full Depth

The maximum bank-full depth was defined as the maximum depth of water measured from the surface to the channel bottom when the water surface is even with the top of the streambank (Rosgen and Silvey 1996). The maximum bank-full depth was recorded to the nearest centimeter.

2.1.4 Width of the Flood-Prone Area

The width of the flood-prone area was defined as the area that would be inundated during the 50-year flood event (Rosgen and Silvey 1996). During 1999 and 2000, the width of the flood-prone area was measured by calculating two times the maximum depth measurement. This was accomplished by stretching the tape horizontally across the floodplain at that height (Figure 1). Width of the flood-prone area was recorded to the nearest 0.1 meter.

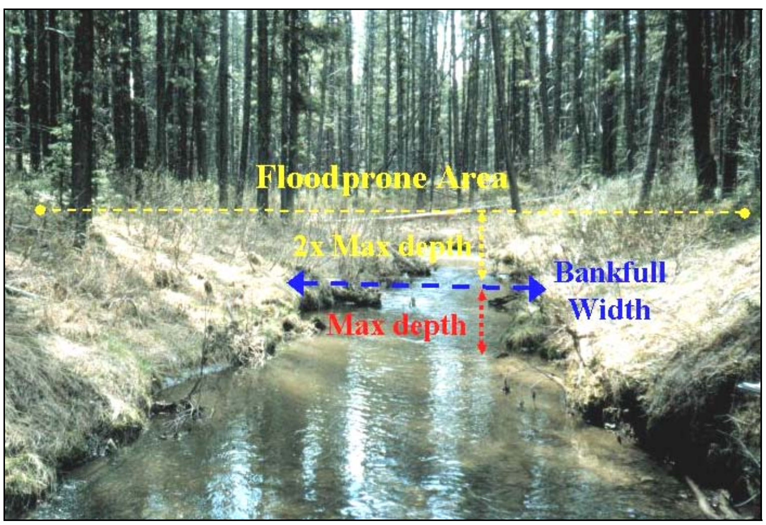


Figure 1. Determining floodplain width.

During 1999 and 2000, technicians occasionally underestimated the floodplain width. During this period, three additional natural processes besides major flood events were observed to cause inundation of streamside areas. These processes included flooding due to beaver activity, formation on debris jams that obstructed the bank-full channel, and spring runoff events that occurred prior to ice-out. As a result, we adopted the channel migration zone concept as synonymous with the floodplain. The channel migration zone constitutes the area that a stream has a likelihood of moving around on over a period of decades of forest management cycles (O'Connor and Watson 1999).

As a result, during 2001 the criteria for determining the active floodplain were expanded to include other ecological variables including soil texture and drainage class (Beckingham et. al 1996), as well as terrain characteristics.

Soil textural characteristics, including incorporation of recently deposited silt and sand within the surface organic layer were indicative of recent flood events. Terrain characteristics such as presence of relic channels were also used to identify the channel migration zone.

2.1.5 Channel Slope

The methods for estimating channel slope class evolved over the four year period between 1999 and 2002 (Appendix 1). In 2002, we utilized a visual key to confirm the slope class for each sample site. (Table 1 and Table 2).

Table 1. Slope class definitions

Slope Class	Range (in percent)
1	0 – 1 %
2	1 – 2 %
3	2 – 3 %
4	3 – 4 %
5	4 – 6 %
6	6 – 10 %
7	> 10 %

Table 2. Photographic key for channel slope classes

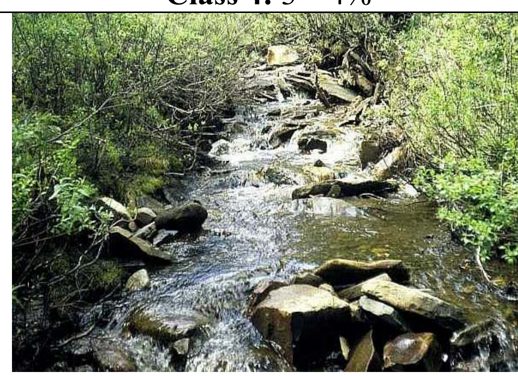
Class 1: 0 – 1 %

Class 2: 1 – 2 %

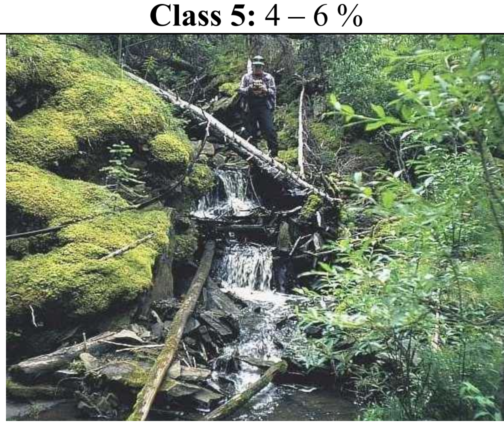
Class 3: 2 – 3 %

Class 4: 3 – 4%

Class 5: 4 – 6 %



Class 6: 6 – 10 %

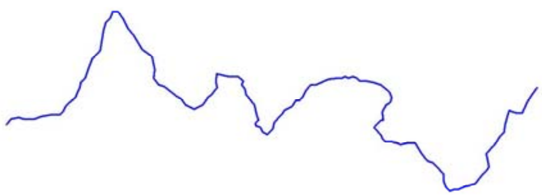
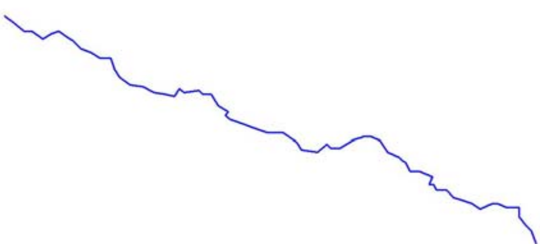


Class 7: > 10 %

2.1.6 Channel Sinuosity

Channel sinuosity was defined as the stream length divided by the valley length (Rosgen and Silvey 1996). The sinuosity of the stream channel was estimated. A visual guide was used to determine the sinuosity for the site (Table 3). Sinuosity was grouped into one of three categories; low (1 - 1.35), moderate (1.35 – 1.7), or high (greater than 1.7).

Table 3. Photographic key for channel sinuosity classes

 **High: > 1.7**	
 **Moderate: 1.35 – 1.70**	
 **Low: 1.0 – 1.35**	

2.1.7 Dominant Bed Material

Dominant bed material was defined as the grain size that is surpassed fifty percent of the time (Rosgen and Silvey 1996). Unlike the other six attributes, dominant bed material was not determined using the procedures recommended by Rosgen and Silvey (1996) at the representative cross-section. Instead, it was visually estimated at a number of transects along the reach. Using the standard visual substrate size estimation procedure, which is part of the FMF fish and fish habitat inventory procedure (McCleary et. al 2001), transects were measured every 50m, from the beginning of the site to the end. There were typically five transects at each site. At each transect, streambed cover composition for each of the six size categories was estimated in five percent increments (Table 4).

Table 4. Substrate classes

Substrate Type / D50 rating	Size Range (mm)	Rosgen Level II
Silt/Clay, Organic	< 2	6
Sand	< 2	5
Gravel (includes small and large)	2 – 64	4
Cobble (includes small and large)	65 - 256	3
Boulder	257 – 2000	2
Bedrock	> 2000	1

To determine the D50, the total cover for each substrate category was calculated and the median substrate category was identified (Table 5).

Table 5. Determining D50 from visual estimates of percent cover by substrate size class

Transect	Fines	Small Gravel	Large Gravel	Small Cobble	Large Cobble	Boulder	Bedrock	Total (%)
1	15	50	10	10	10	5	0	100
2	5	20	15	20	25	15	0	100
3	50	5	10	5	20	5	5	100
4	10	10	20	30	20	10	0	100
5	5	10	20	30	30	5	0	100
Total (by size)	85	95	75	95	105	40	5	500
Cumulative Total	85	180	**255**	350	455	495	500	
D50 = Gravel								

Once the D50 was determined, the corresponding Rosgen Level II number was assigned (Table 4). During a review of the Level II classification that we assigned for all 1999 – 2001 sites, Deborah Chan-Yan, Water Resources Engineer, Golder Associates Ltd., expressed a concern over the potential consistent under-estimation of D50 based on visual estimates. In 2002, a small pilot study was undertaken to compare the findings between pebble count and visual estimates procedures for determining D50 (Appendix 2).

2.1.8 Channel and Floodplain Descriptors

After the reach characteristics were resolved and all measurements were taken, two ratios were calculated. These were the entrenchment ratio and width to depth ratio, respectively. The first was calculated by dividing the bank-full width by the width of the flood-prone area while the second involved dividing the mean bank-full depth by the bank-full width. All ratios were rounded to one decimal place.

2.1.9 Site Photographs

Photographs were taken and a description of each was recorded on the data sheet. In general, a minimum of two photographs was required for each site. One picture showed the downstream view of the tape stretched across the channel at bank-full width, the other showed the upstream view of the same. Field technicians were included within the photographs to provide a scale reference. If there were any other significant features worth noting, such as signs of previous flood events, additional photographs were taken and recorded.

2.1.10 Determination of Channel Type

In the field, all of the above factors were passed through the Rosgen flow chart and stream type was determined (Figure 2). The Rosgen Level II classification is a letter and number combination; the letter represents the type of stream (ranging from A – G) while the number represents the dominant bed material or substrate (ranging from 1-6).

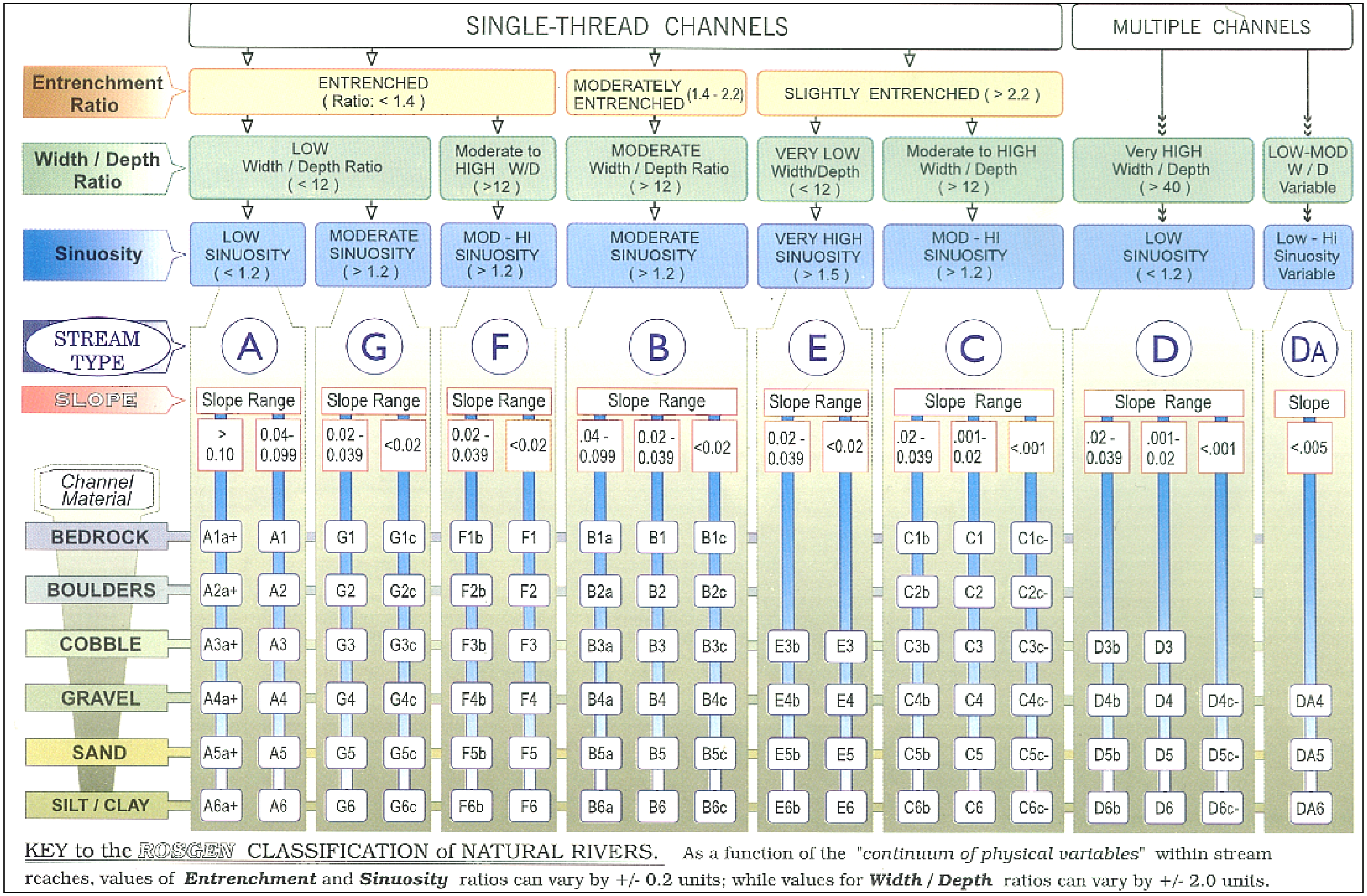


Figure 2. Key to the Rosgen classification of natural rivers (Rosgen and Silvey 1996).

2.2 Office Methods

The data were entered into a Microsoft Access database. All data were checked with the original data sheets for quality control. All ratios, averages, and maximum depths were re-calculated in Access to ensure data integrity. Any questionable data was referred back to the data recorder for further clarification.

All photographs taken at each site were developed as slides. Each slide was labeled with a Site ID, date of visit, stream name, and brief description. The slides were stored in slide pages, catalogued by year, and placed into binders. Each binder holds one year of data. All slides were then scanned, saved on a compact disc, and put on a hard drive belonging to the Foothills Model Forest.

A "Photo Report" was established for each field season. Due to the late start date in 1999 and subsequent amount of data collected, the 1999 and 2000 reports were combined into one. A representative photograph was chosen for each site that was classified and saved in a Microsoft Word document. The corresponding data for each site was queried out of Access and mail merged in with the photos. This data included Site ID, stream name, bank-full width, mean bank-full depth, width of flood-prone area, slope class, entrenchment ratio, width to depth ratio, D50, stream type, and any relevant comments. All sites were checked for accuracy. The 1999 – 2001 photo reports were supplied to Deborah Chan-Yan, Water Resources Engineer, Golder Associates Ltd., for review of the channel classification. Any questionable data was again referred back to the original field data recorder for further clarification. In cases where this was not possible, due to summer staff leaving, another visit to the site was planned. If this wasn't feasible, the data was removed from the database and no longer considered.

3 Results

3.1 Description of Findings by Watershed

3.1.1 Anderson Creek Watershed

Nine sites were classified between 1999 and 2002 in the Anderson Creek watershed (Figure 3).

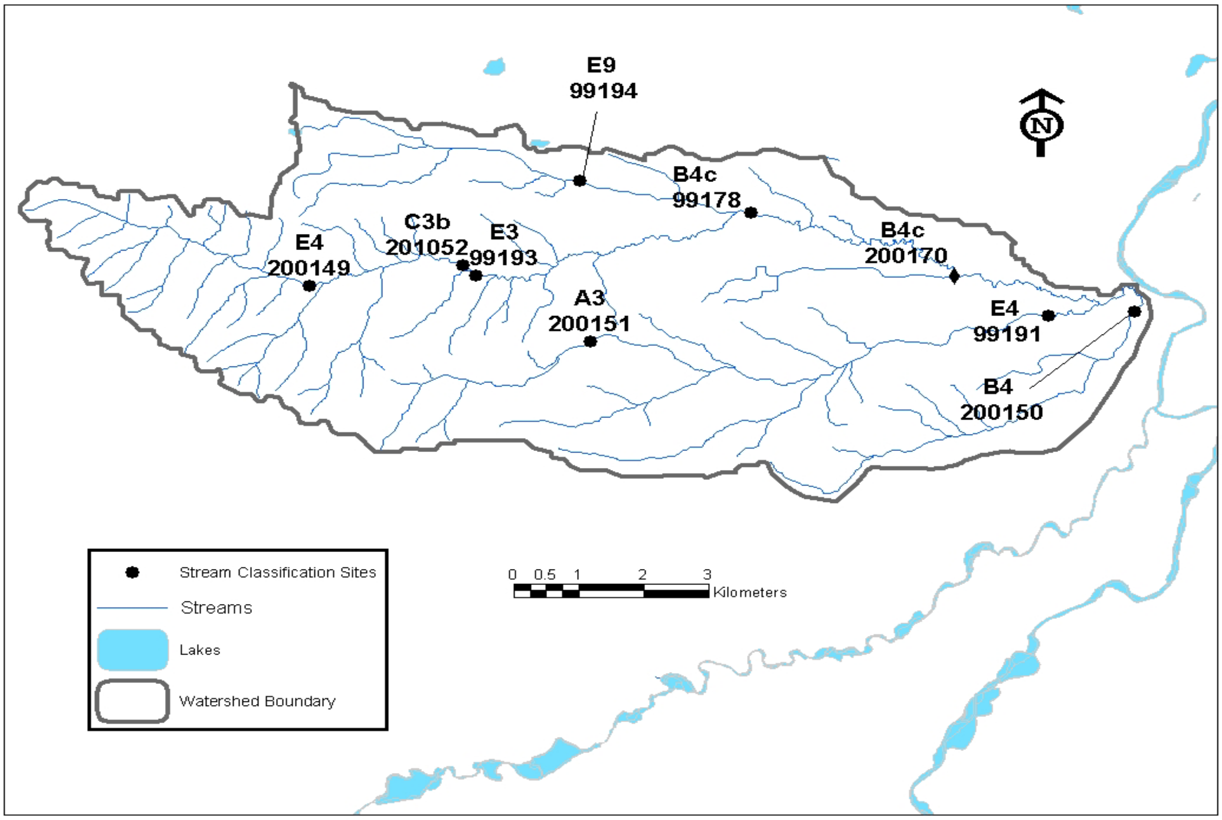


Figure 3. Stream classification sites and their corresponding stream types within the Anderson Creek watershed.

Of the nine sites in Anderson Creek watershed, four were classified as "E" type channels (Figure 4).

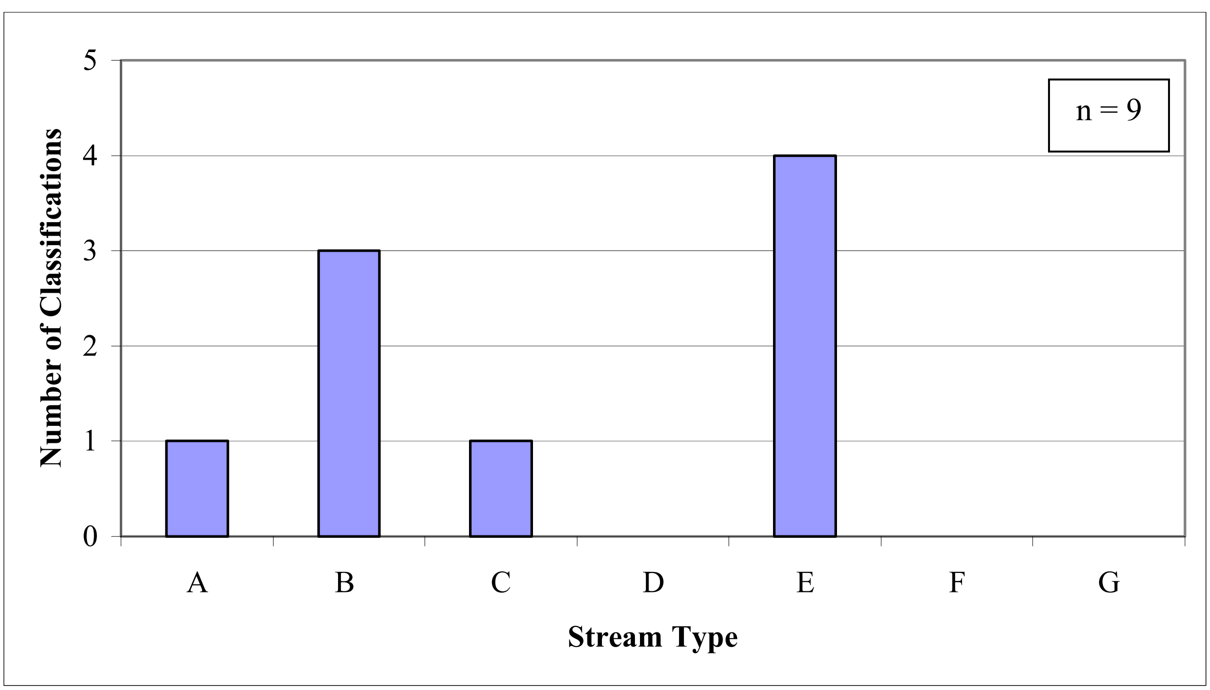


Figure 4. Number of classifications by stream type between 1999 and 2002 for the Anderson Creek watershed.

3.1.2 Antler Creek Watershed

Twelve sites were classified in the Antler Creek watershed over the four-year period (Figure 5).

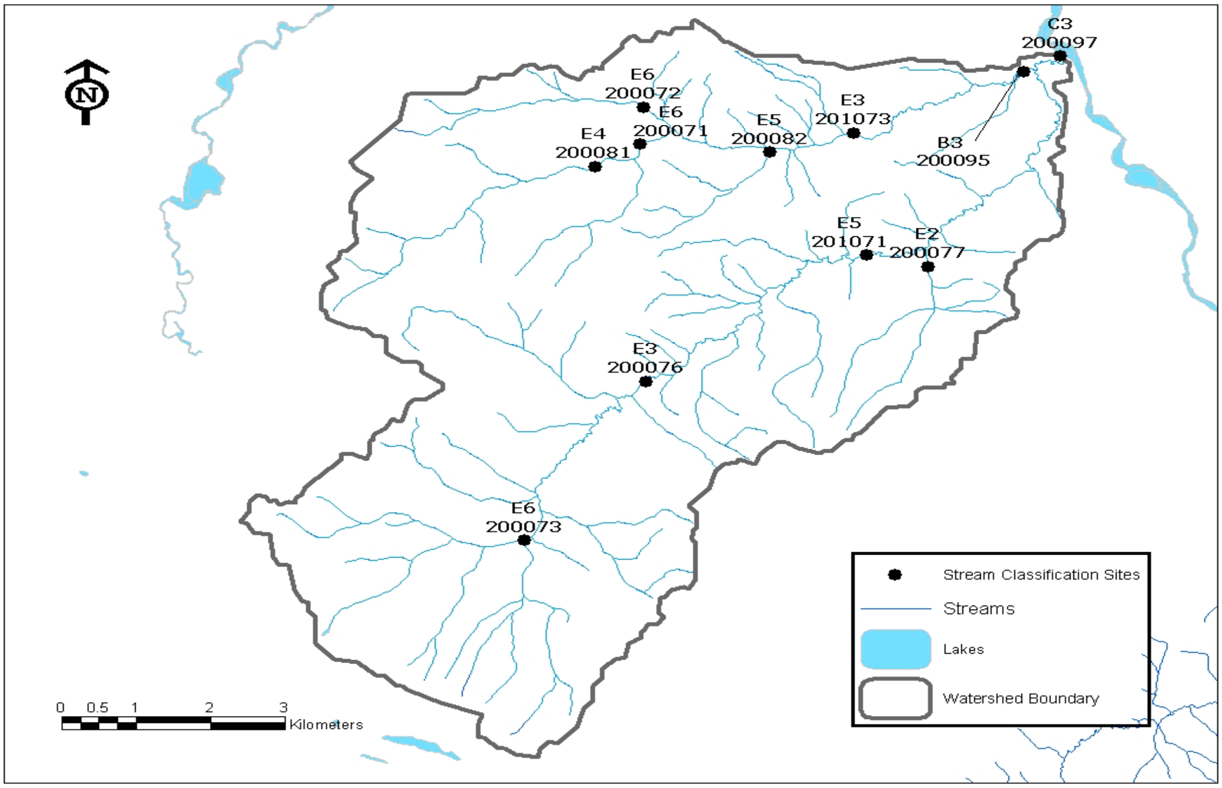


Figure 5. Stream classification sites and their corresponding stream types within the Antler Creek watershed.

Of the twelve sites in Antler Creek watershed, ten were "E" type channels (Figure 6).

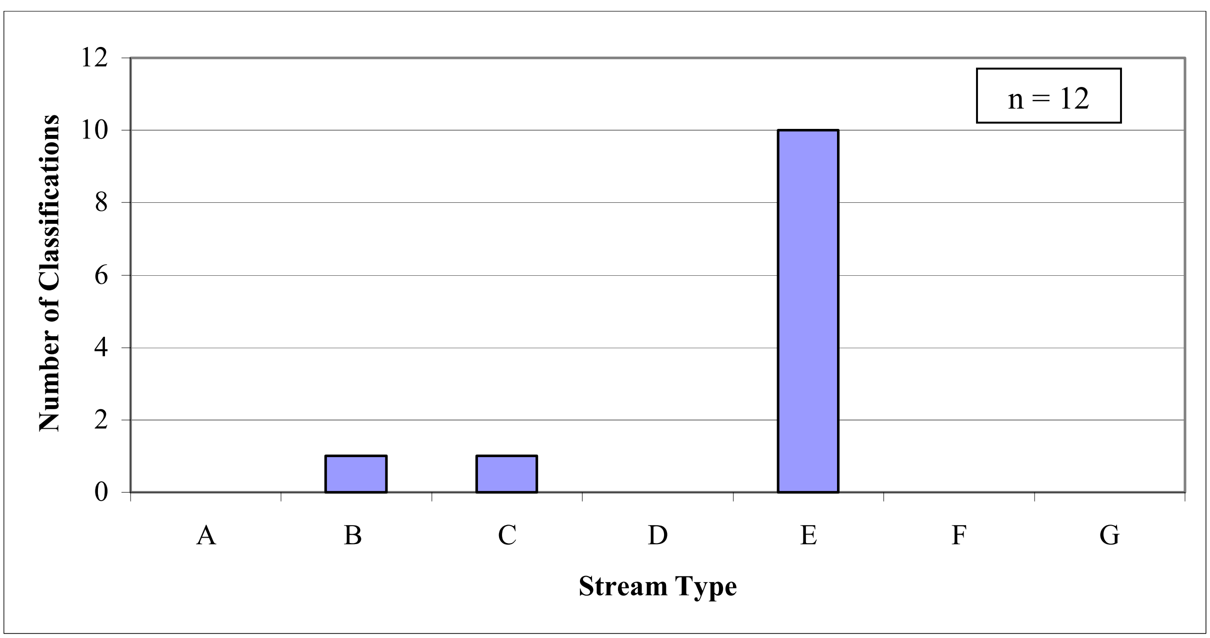


Figure 6. Number of classifications by stream type between 1999 and 2002 in the Antler Creek watershed.

3.1.3 Emerson Creek Watershed

Fourteen sites were classified in the Emerson Creek watershed from 1999 to 2002 (Figure 7).

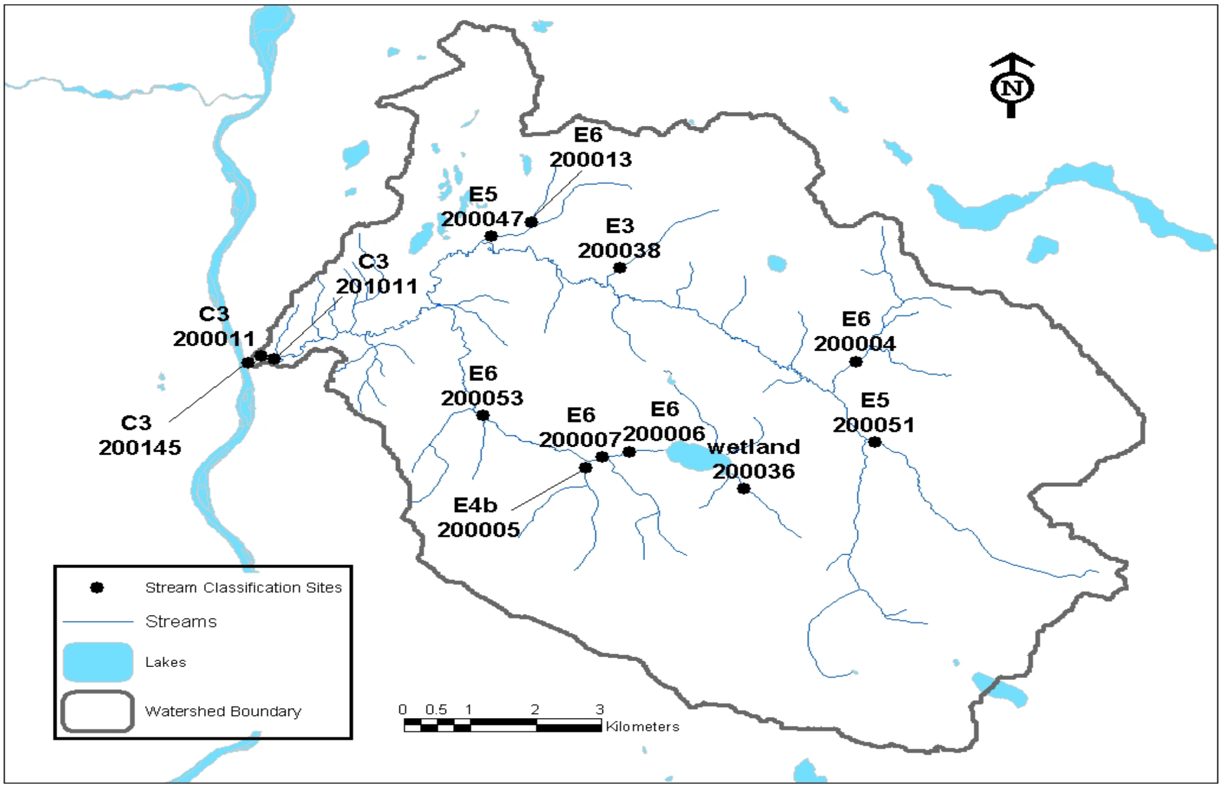


Figure 7. Stream classification sites and their corresponding stream types within the Emerson Creek watershed.

Of the fourteen sites in Emerson Creek watershed, nine were "E" type channels.

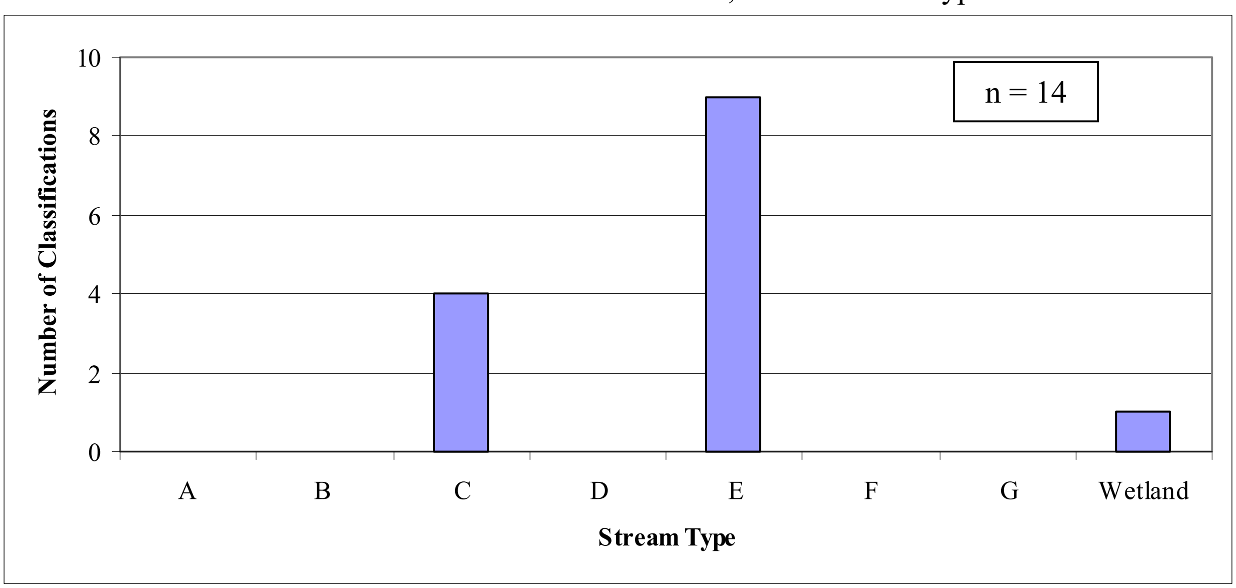


Figure 8. Number of classifications by stream type between 1999 and 2002 in the Emerson Creek watershed.

3.1.4 Fish Creek Watershed

Only three sites have been classified in the Fish Creek watershed in the last four years (Figure 9).

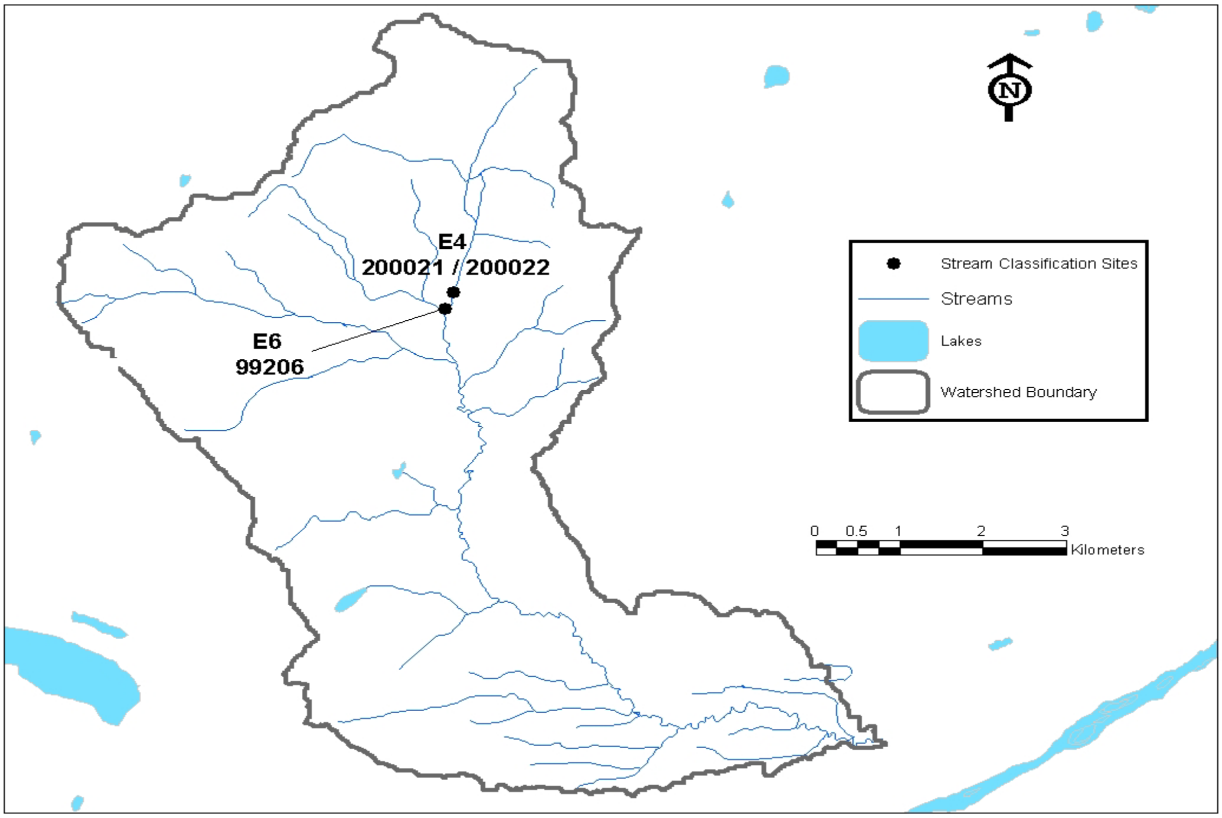


Figure 9. Stream classification sites and their corresponding stream types within the Fish Creek watershed.

All the sites in Fish Creek watershed were "E" type channels (Figure 10).

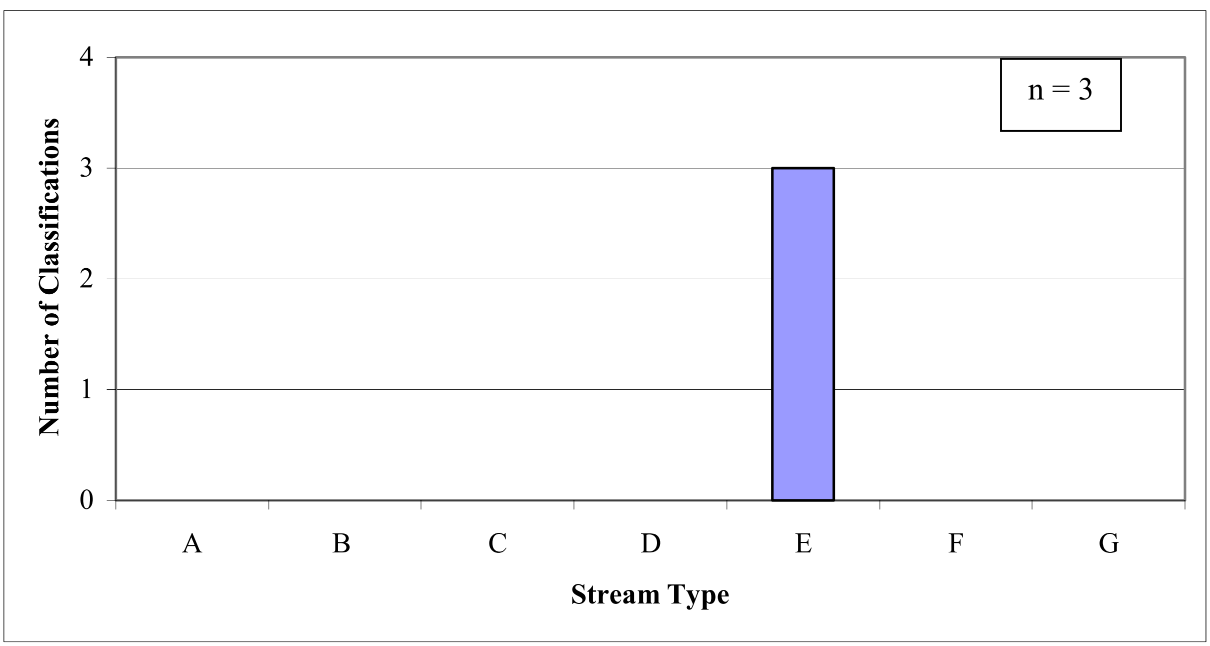


Figure 10. Number of classifications by stream type between 1999 and 2002 in the Fish Creek watershed.

3.1.5 Lambert Creek Watershed

Of the seventeen sites classified between 1999 and 2002 in the Lambert Creek watershed, only “B” and “E” type streams were encountered (Figure 11).

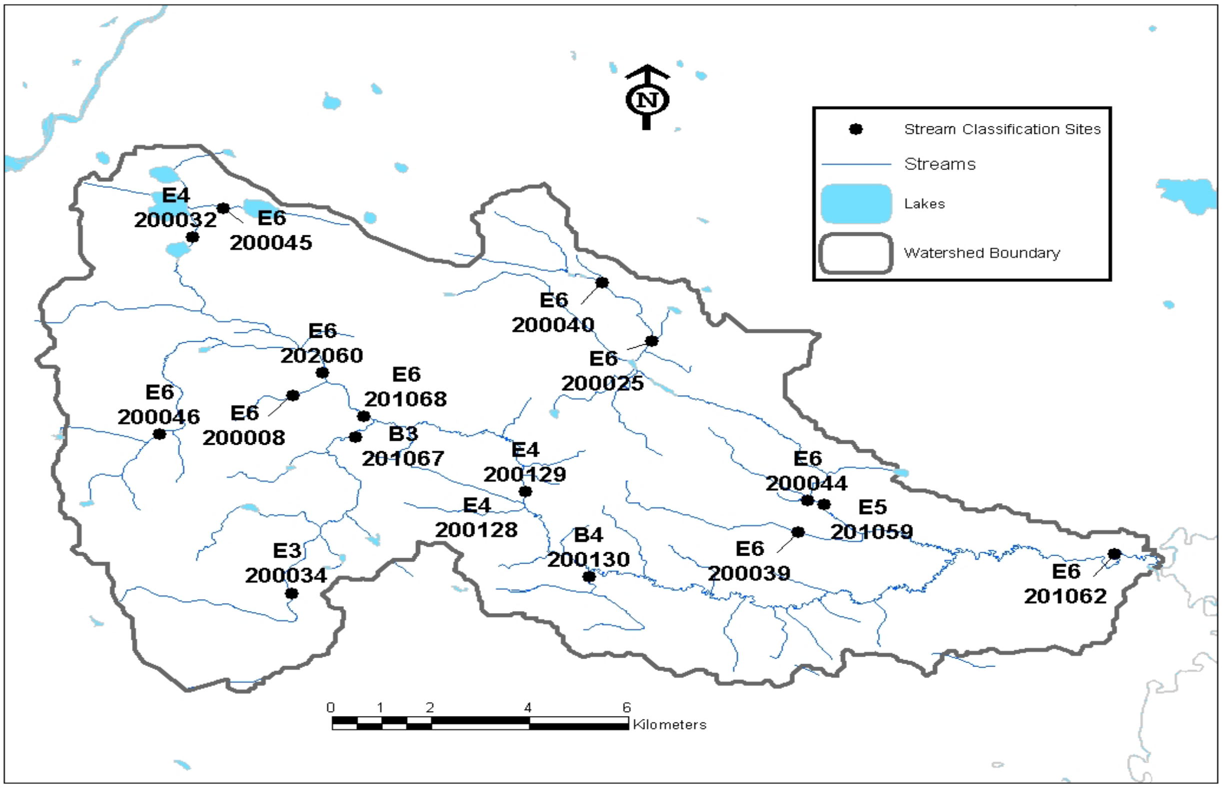


Figure 11. Stream classification sites and their corresponding stream types within the Lambert Creek watershed.

Of the seventeen sites in Lambert Creek watershed, fifteen were “E” type streams (Figure 12).

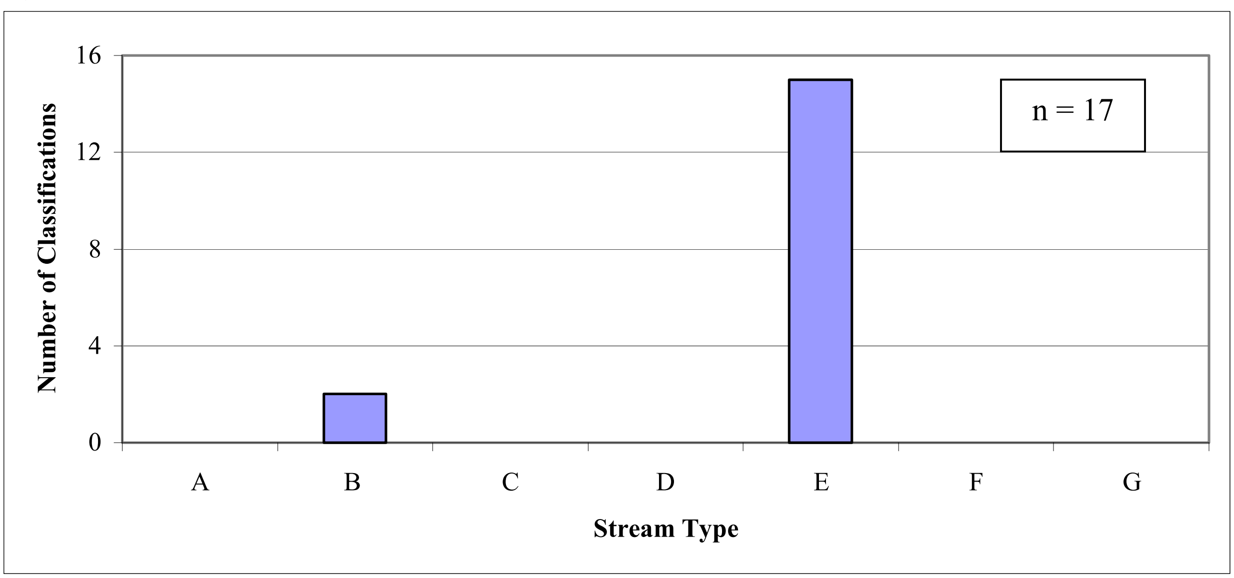


Figure 12. Number of classifications by stream type between 1999 and 2002 in the Lambert Creek watershed.

3.1.6 Lynx Creek Watershed

To date, five sites have been classified in the Lynx Creek watershed (Figure 13).

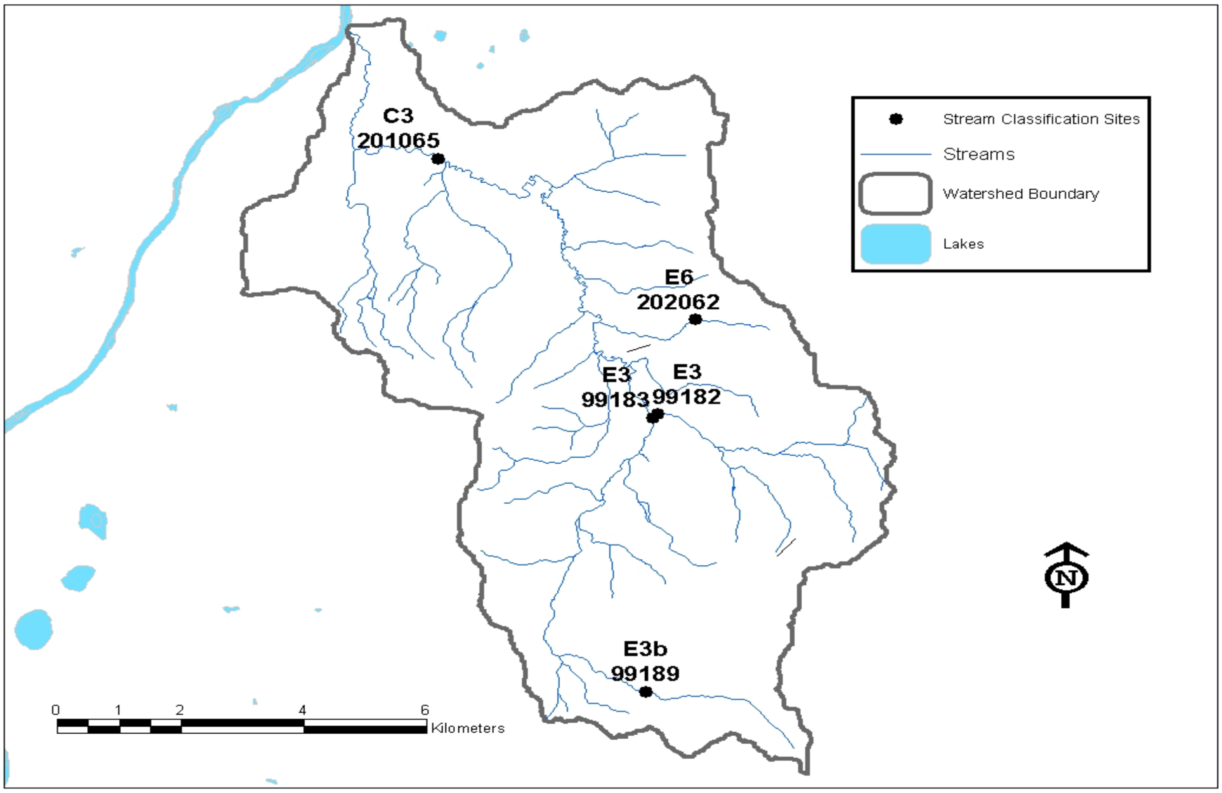


Figure 13. Stream classification sites and their corresponding stream types within the Lynx Creek watershed.

Four of the five sites in Lynx Creek watershed were "E" type streams (Figure 14).

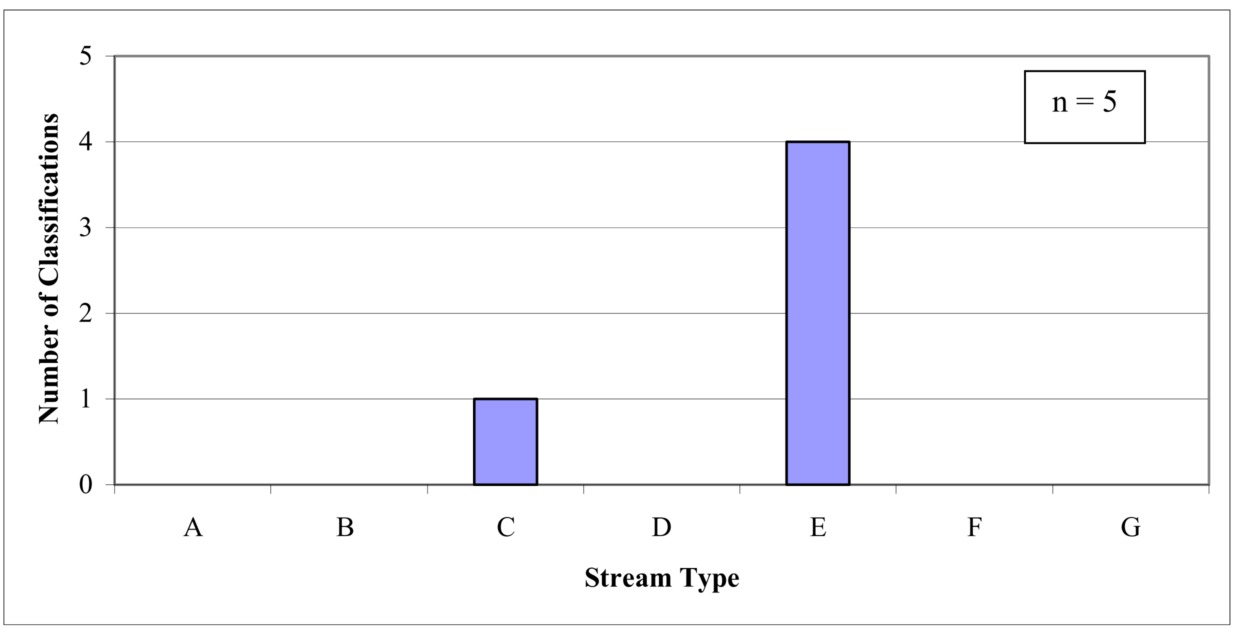


Figure 14. Number of classifications by stream type between 1999 and 2002 in the Lynx Creek watershed.

3.1.7 MacKenzie Creek Watershed

Thirteen sites have been classified in the MacKenzie Creek watershed (Figure 15).

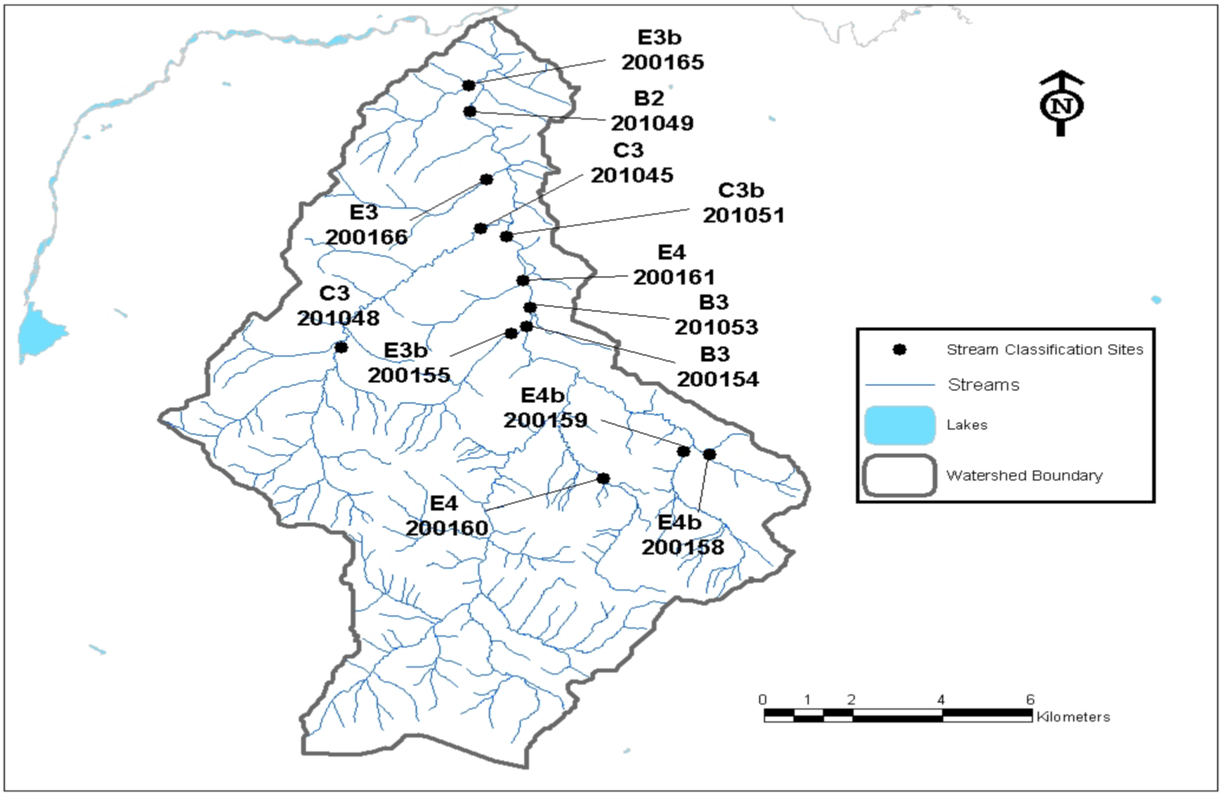


Figure 15. Stream classification sites and their corresponding stream types within the MacKenzie Creek watershed.

Within MacKenzie Creek, seven sites were "E" type streams and "B" and "C" type streams were found in equal numbers at the other six sites (Figure 16).

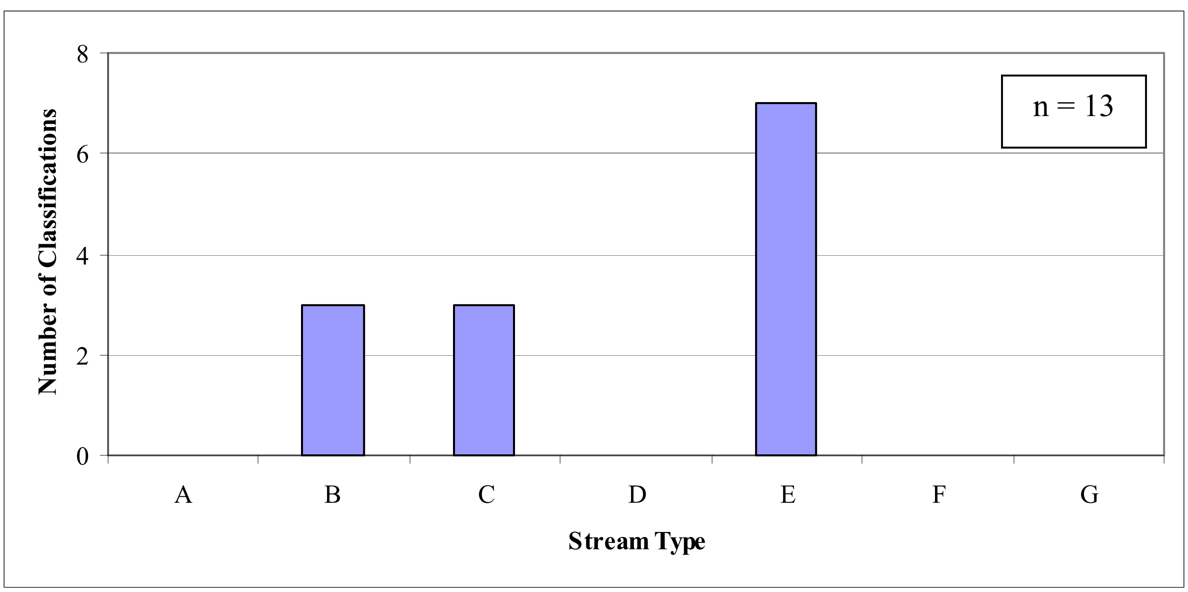


Figure 16. Number of classifications by stream type between 1999 and 2002 in the MacKenzie Creek watershed.

3.1.8 Moon Creek Watershed

To date, only four sites in the Moon Creek watershed have been classified (Figure 17).

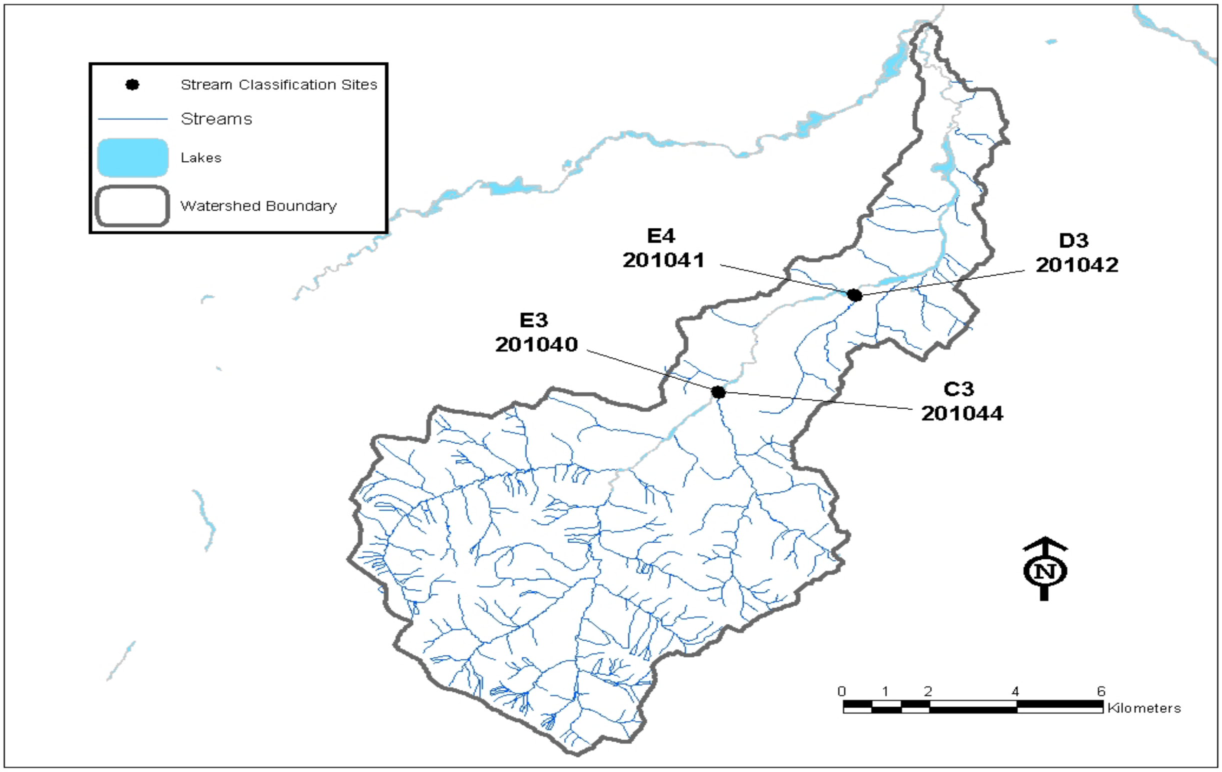


Figure 17. Stream classification sites and their corresponding stream types within the Moon Creek watershed.

A "D" type stream, characterized by a braided channel was noted at one of the sites in Moon Creek watershed (Figure 18).

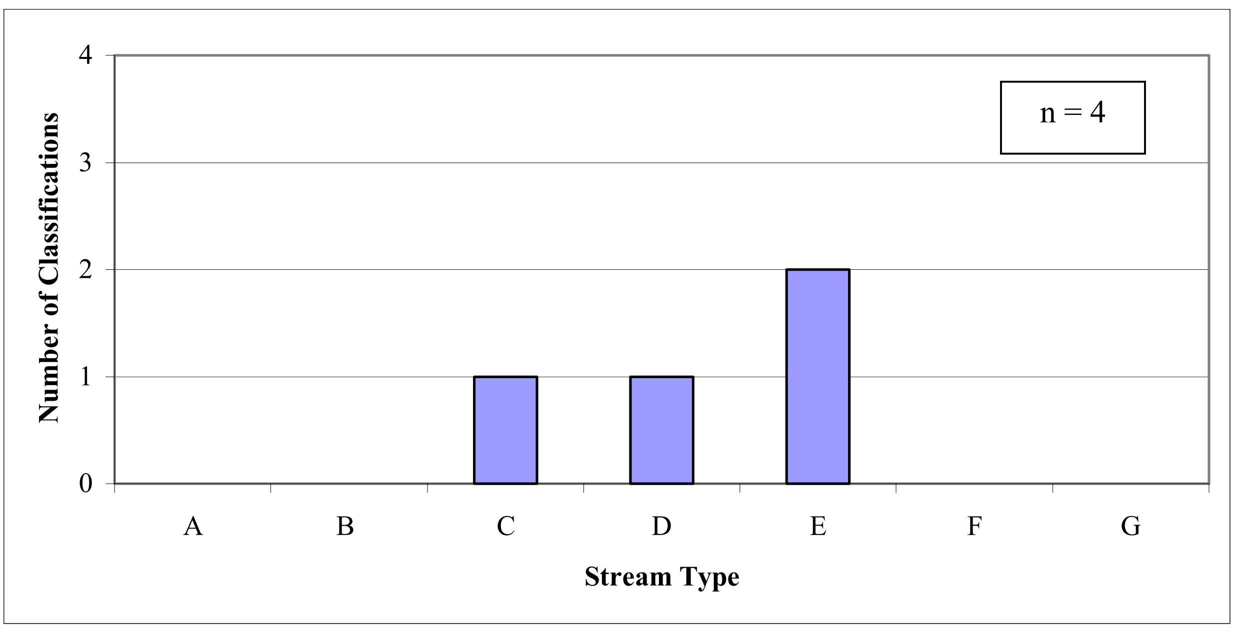


Figure 18. Number of classifications by stream type between 1999 and 2002 in the Moon Creek watershed.

3.1.9 Pinto Creek Watershed

Twelve sites have been classified in the Pinto Creek watershed (Figure 19).

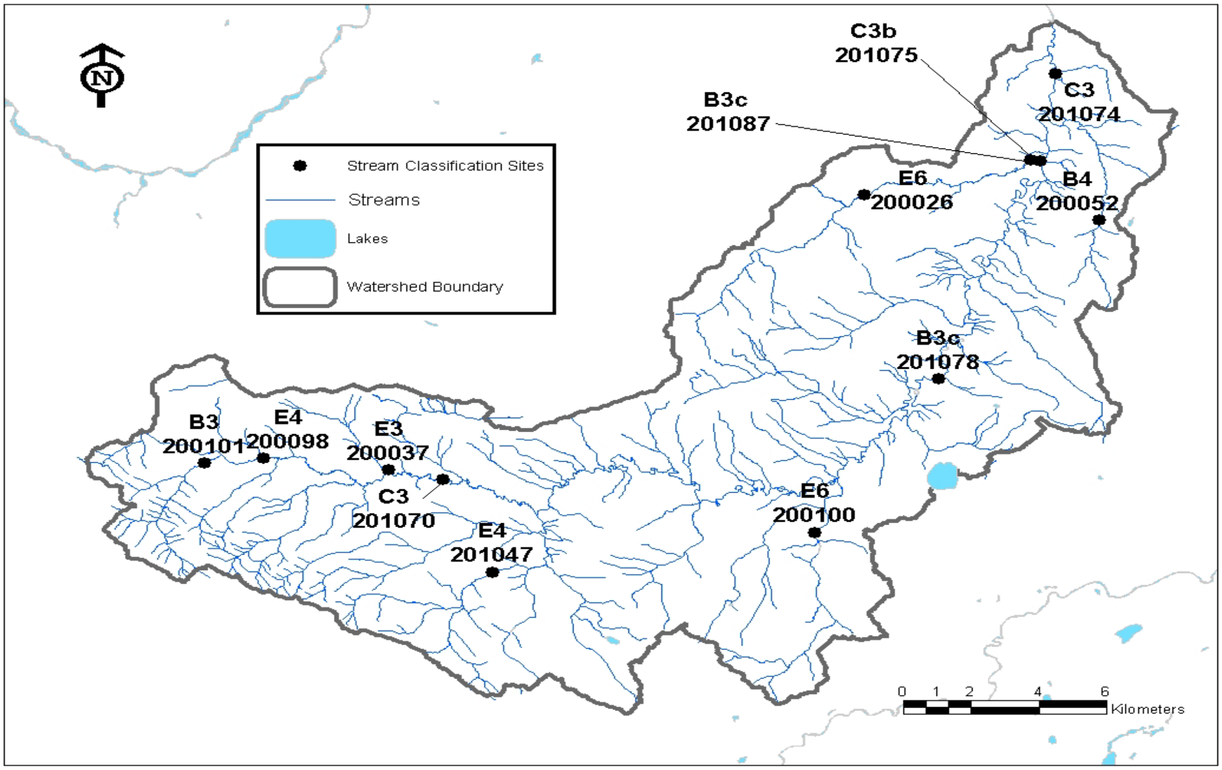


Figure 19. Stream classification sites and their corresponding stream types within the Pinto Creek watershed.

"B", "C", and "E" types streams were well represented in Pinto Creek watershed (Figure 20).

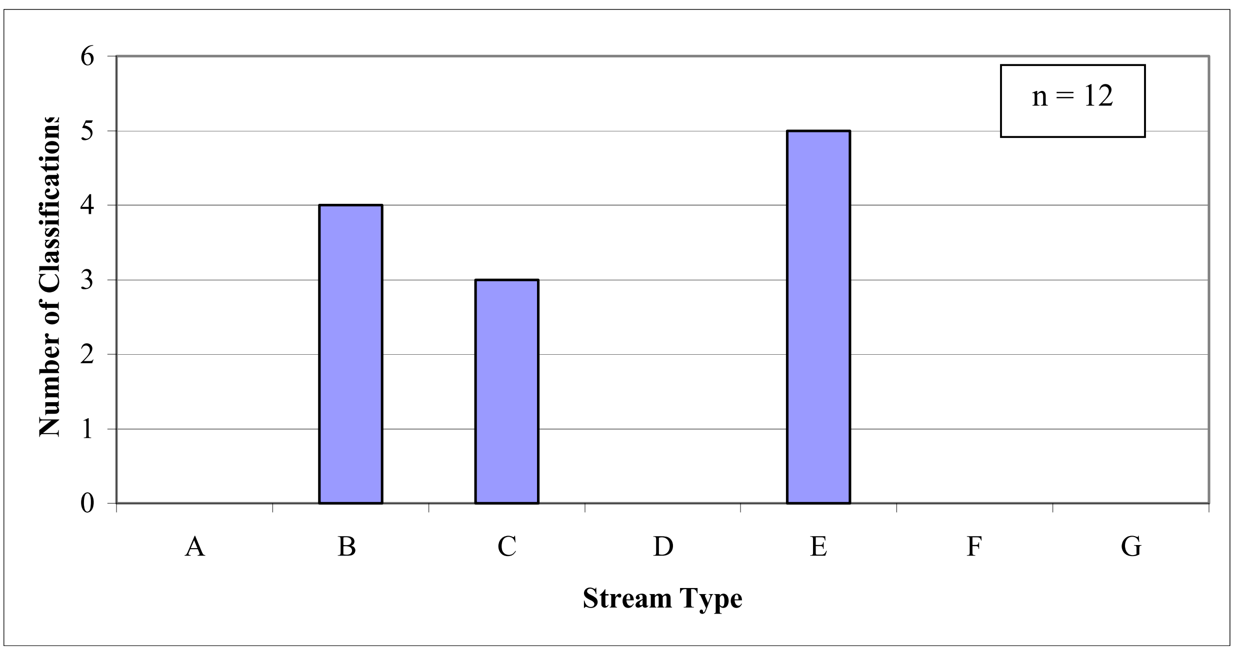


Figure 20. Number of classifications by stream type between 1999 and 2002 in the Pinto Creek watershed.

3.1.10 Solomon Creek Watershed

To date, only 3 sites have been classified in the Solomon Creek watershed (Figure 21).

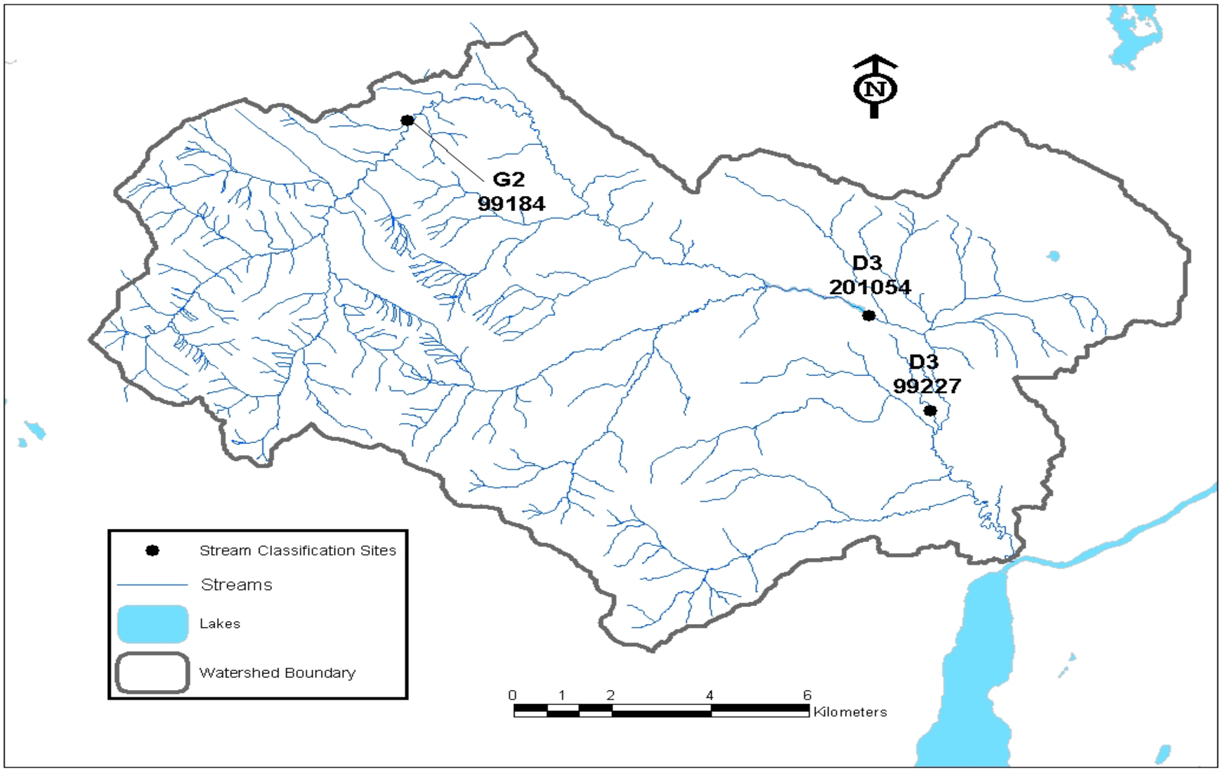


Figure 21. Stream classification sites and their corresponding stream types within the Solomon Creek watershed.

A "G" type stream, characterized by recent channel widening was observed in Solomon Creek watershed (Figure 22).

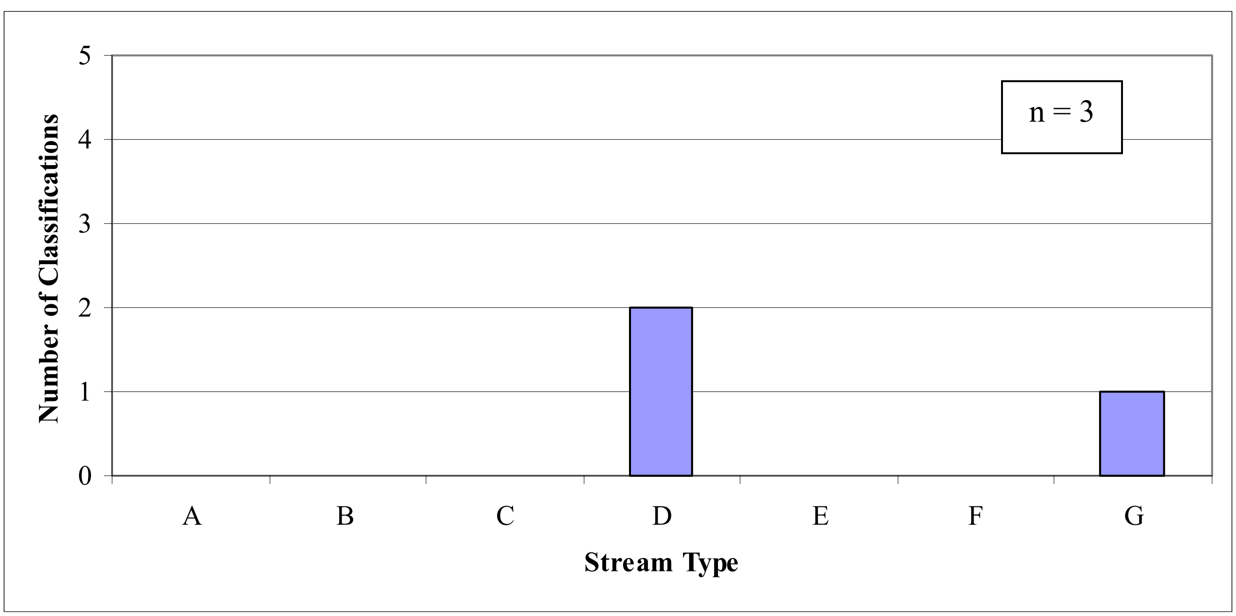


Figure 22. Number of classifications by stream type between 1999 and 2002 in the Solomon Creek watershed.

3.1.11 Teepee Creek Watershed

A total of 17 sites were classified in the Teepee Creek watershed (Figure 23).

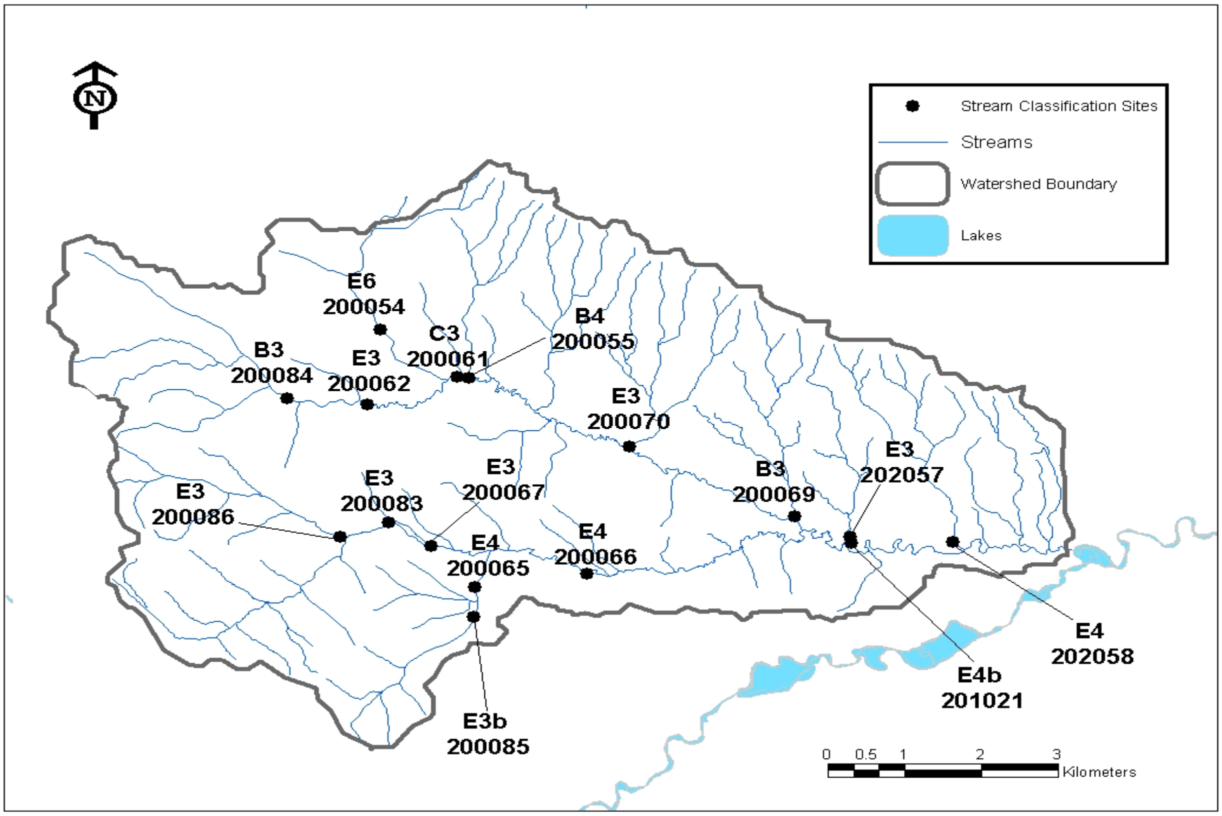


Figure 23. Stream classification sites and their corresponding stream types within the Teepee Creek watershed.

An "E" type stream was observed at thirteen of the seventeen sites in Teepee Creek watershed (Figure 24).

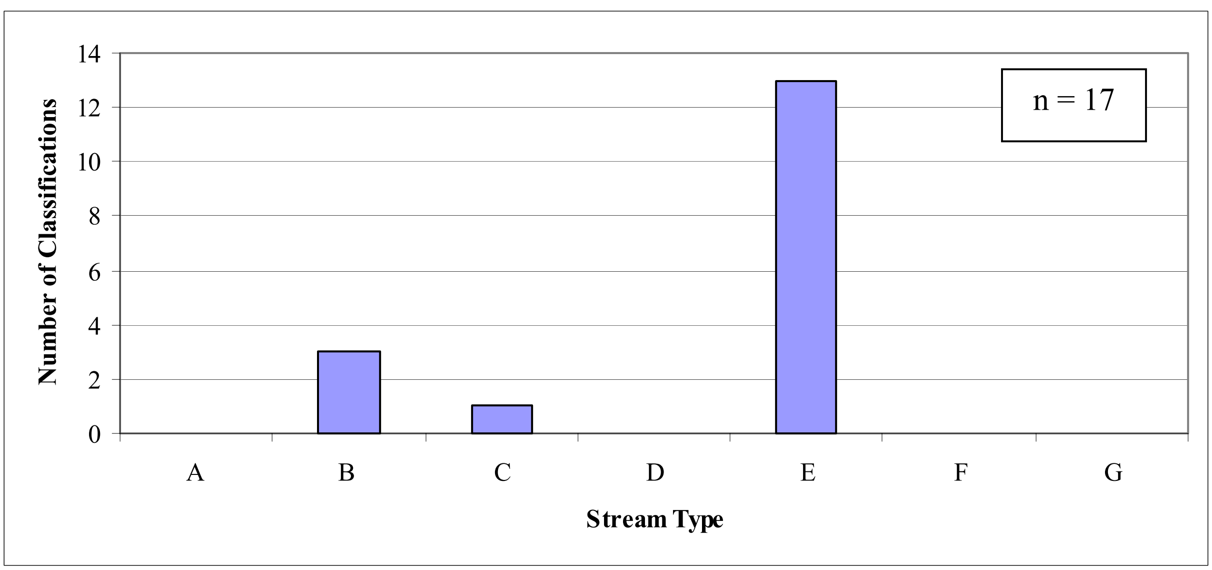


Figure 24. Number of classifications by stream type between 1999 and 2002 in the Teepee Creek watershed.

3.1.12 Tri-Creeks Watershed

The Tri-Creeks watershed is composed of the Wampus, Deerlick, and Eunice Creek watersheds. During the fish inventories, no sites were classified in the Wampus Creek watershed during (Figure 25). One site was classified in the Deerlick Creek watershed.

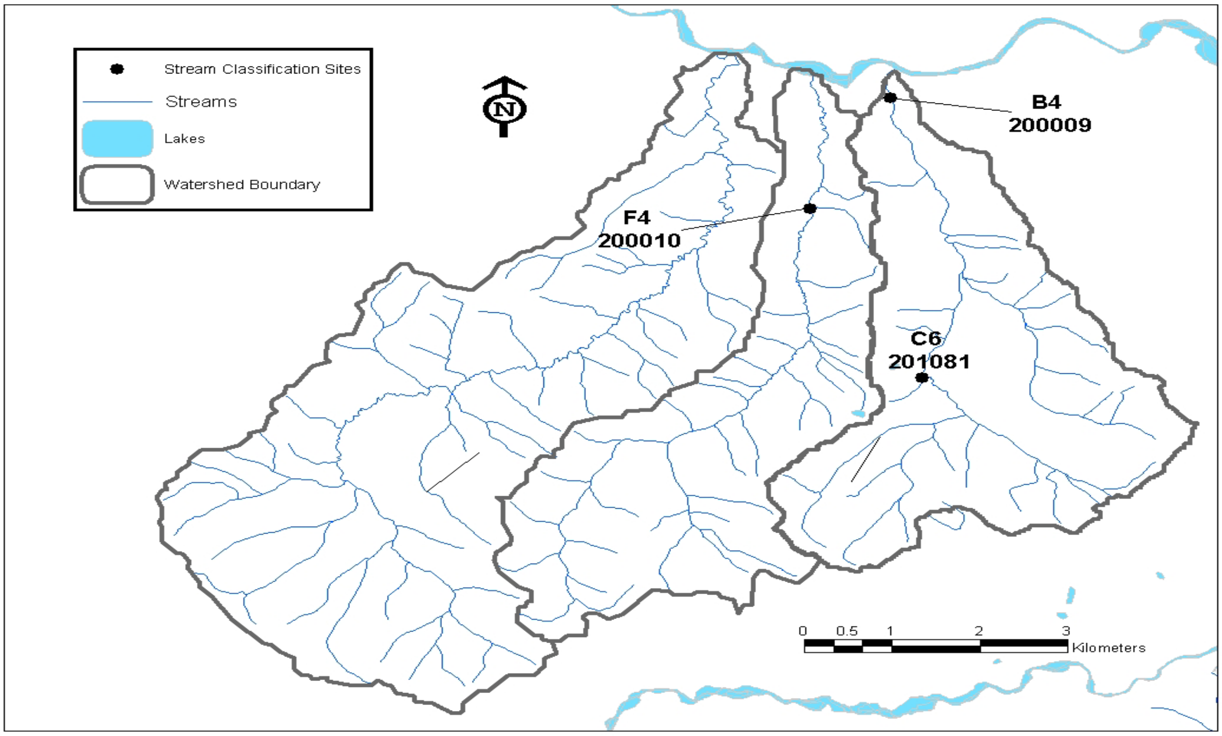


Figure 25. Stream classification sites and their corresponding stream types within the Tri-Creeks watershed.

The single "F" type stream observed in Deerlick Creek watershed is an indication of recent channel down-cutting (Figure 26).

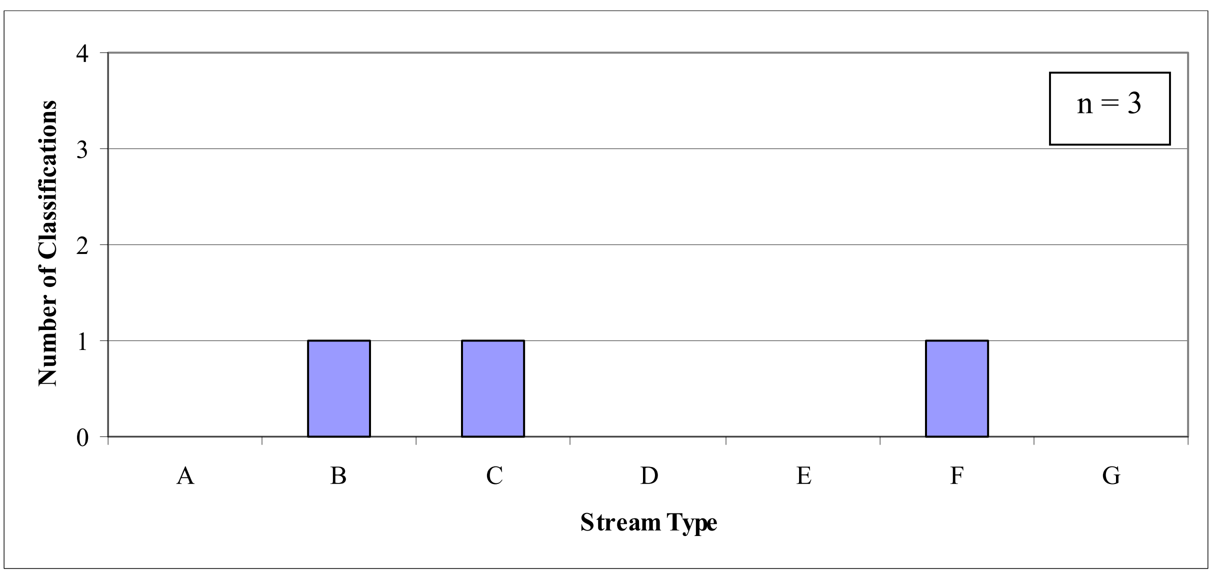


Figure 26. Number of classifications by stream type between 1999 and 2002 in the Eunice and Deerlick Creek watersheds.

3.1.13 Upper Erith River Watershed

A total of nine sites were classified in the Upper Erith River watershed between 1999 and 2002 (Figure 27).

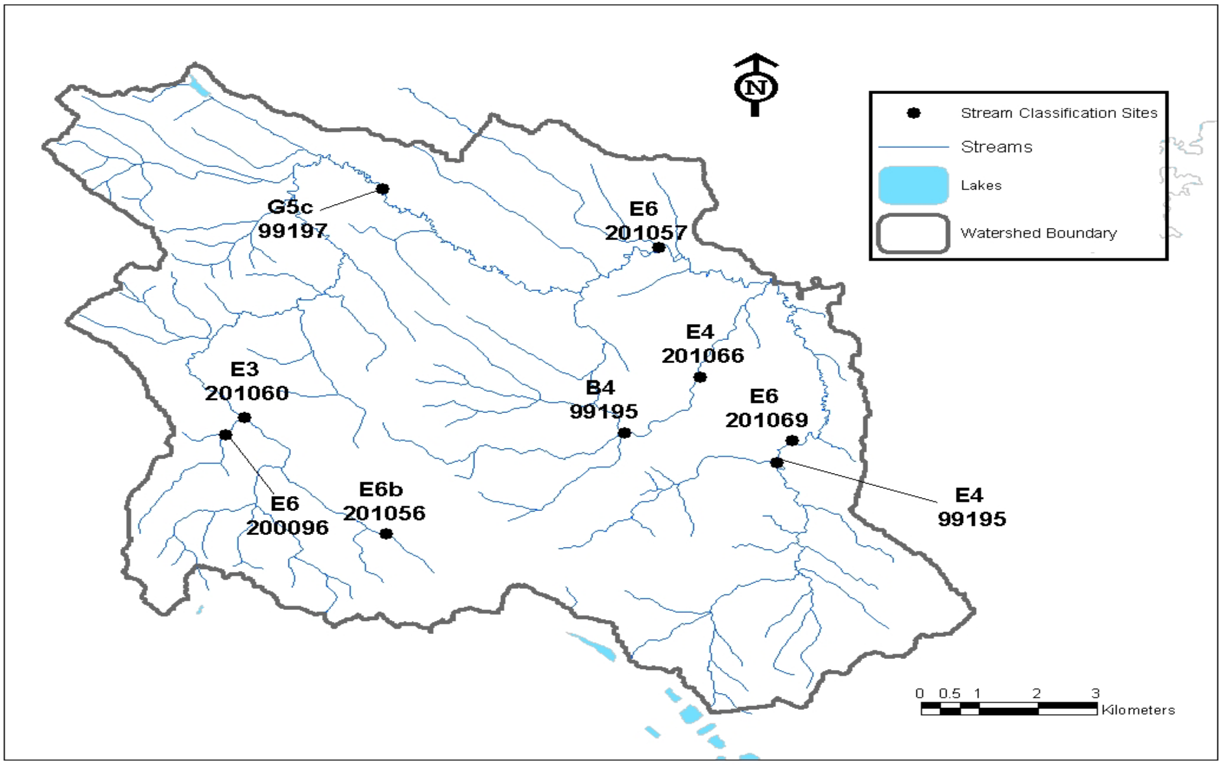


Figure 27. Stream classification sites and their corresponding stream types within the Upper Erith River watershed.

A total of seven sites out of nine in the Upper Erith watershed supported "E" type streams (Figure 28).

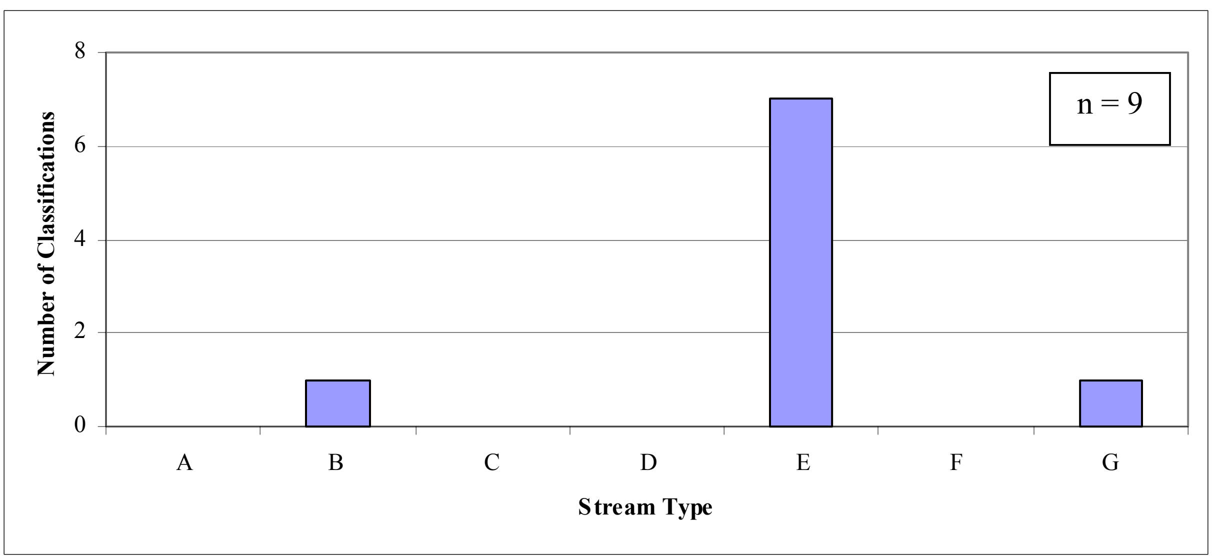


Figure 28. Number of classifications by stream type between 1999 and 2002 in the Upper Erith River watershed.

3.2 Summary for all Selected Monitoring Watersheds

The Foothills Model Forest initiated stream classification within its fish and fish habitat inventory program in September of 1999. Between 1999 and 2002, 286 sites were classified (Figure 29).

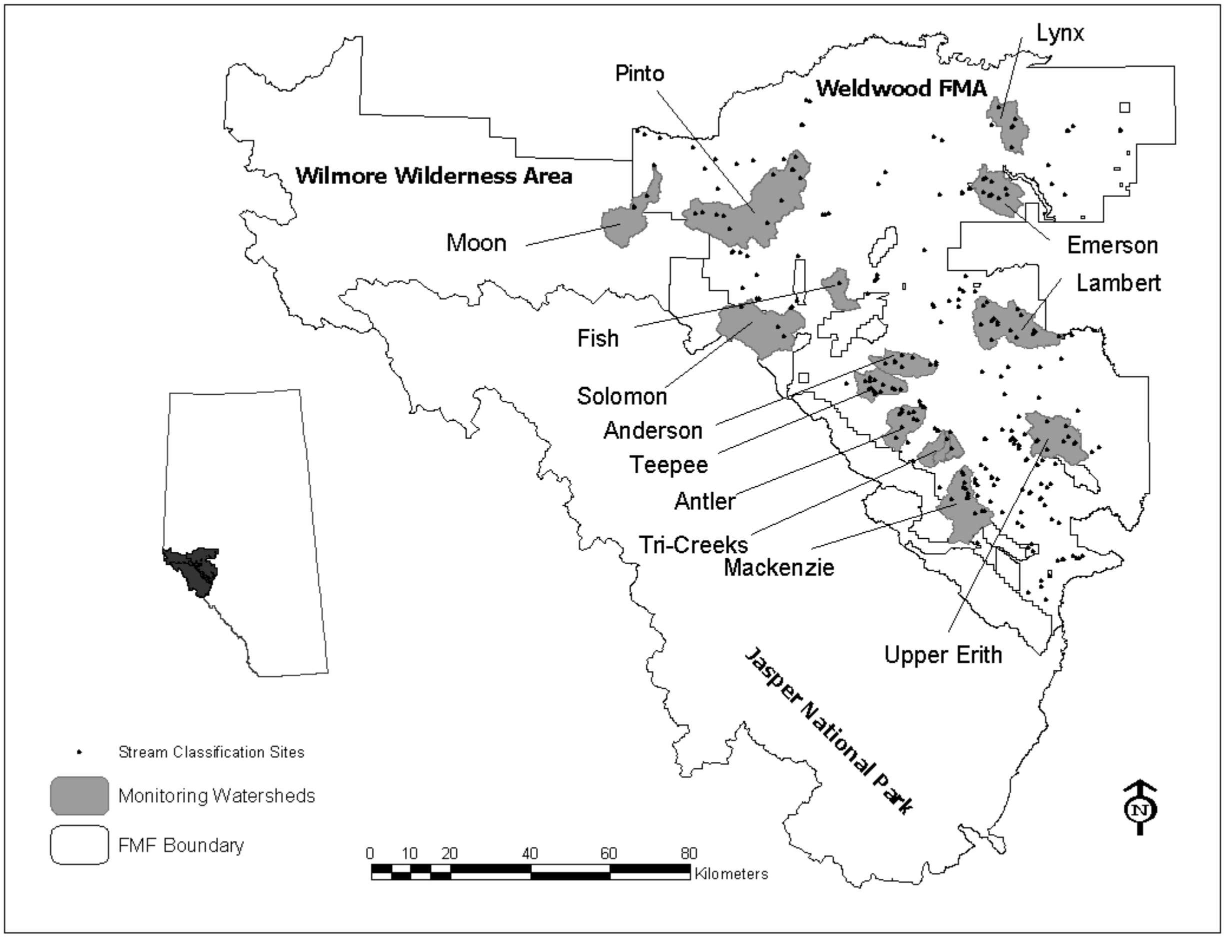


Figure 29. Stream classification sites within the Foothills Model Forest.

Of these 286 sites, 206 were classified as "E" type streams (Figure 30).

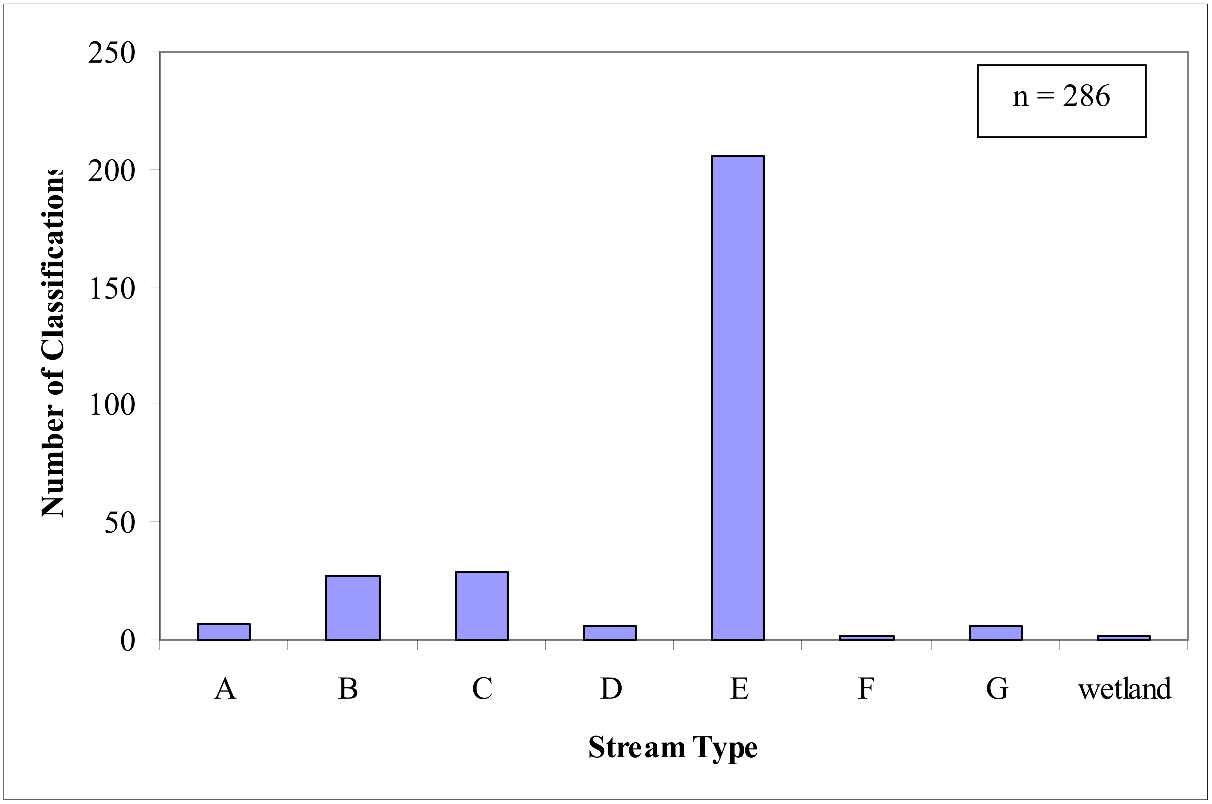


Figure 30. Number of classifications by stream type from 1999 to 2002 in the Foothills Model Forest.

4 Key Applications

4.1 Generating Maps of Small and Large Permanent Streams

Drainage area was a reasonable predictor of bankfull stream width (Figure 31 and Appendix 6). Therefore, maps that distinguish small and large permanent streams could be generated for the entire Weldwood FMA using the information from the automated classification (Golder Associates Ltd. 2001).

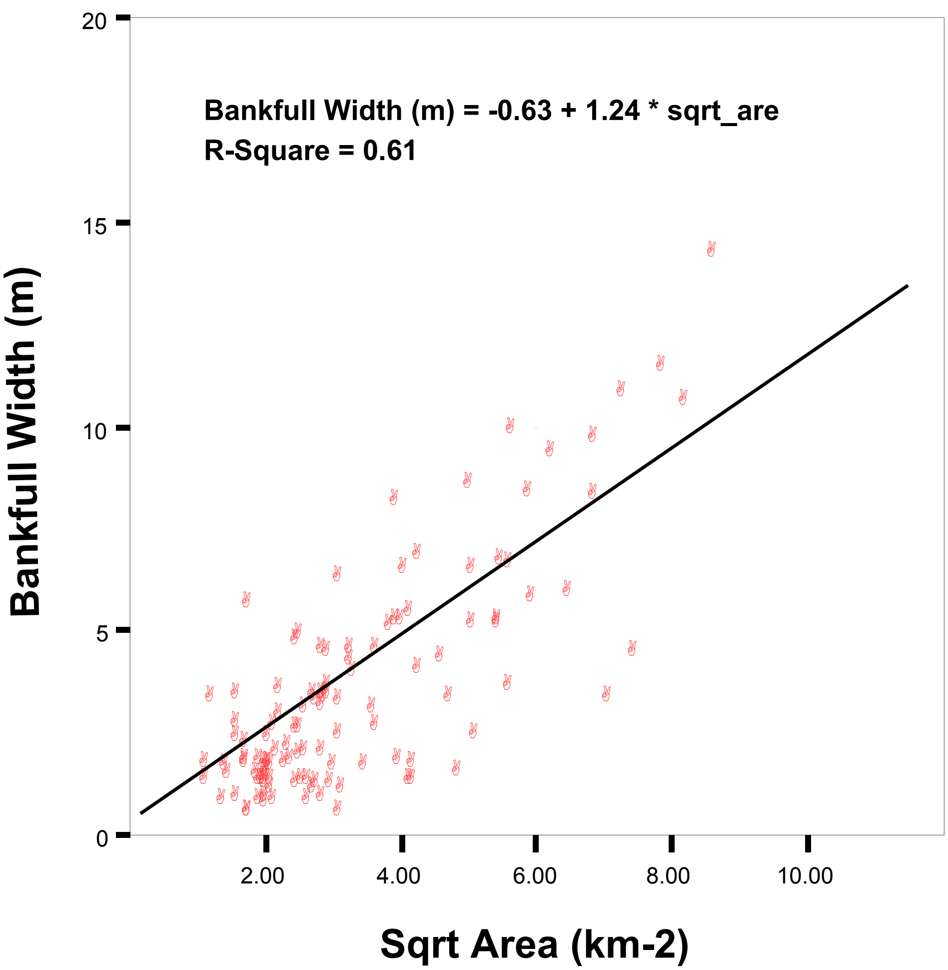


Figure 31. Predictive model of the bankfull width from upstream drainage area.

4.2 Generating Maps of Riparian Area Width

Although drainage area served as a reasonable predictor of bankfull width, this single parameter was a poor predictor of floodplain width (Figure 32). Future modeling exercises attempting to facilitate mapping riparian area width could include additional parameters such as relief, stream slope or vegetation type.

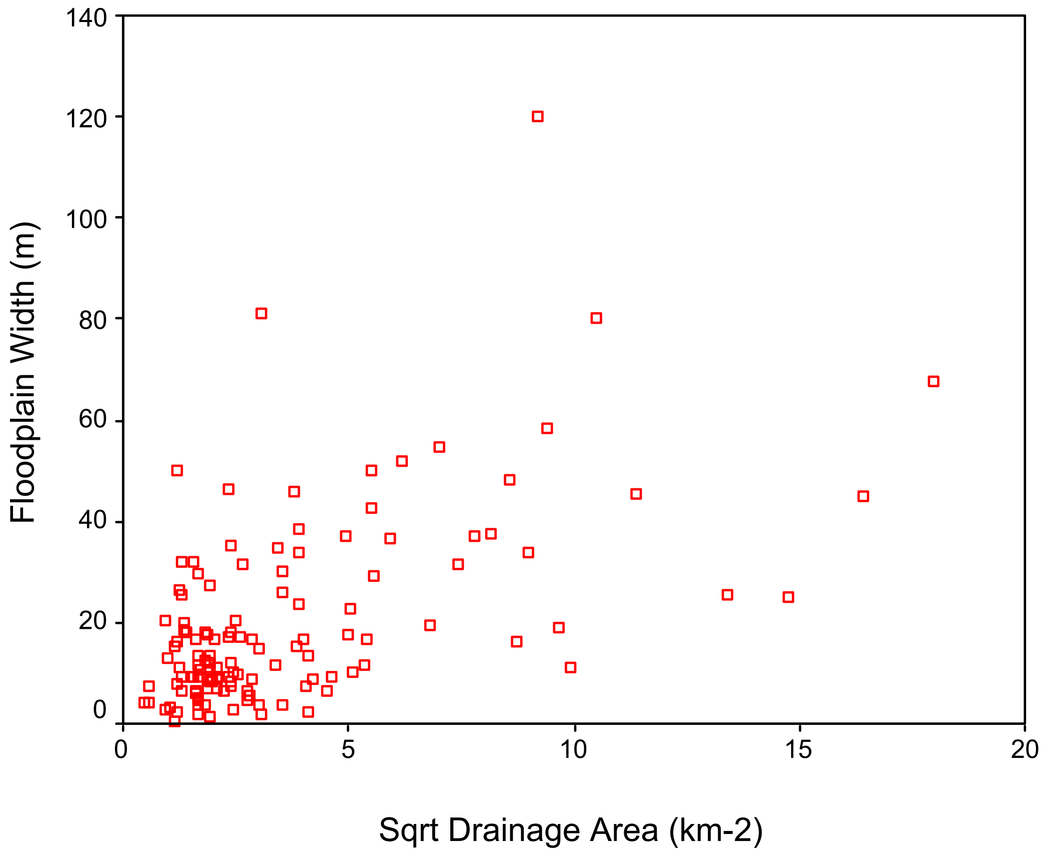


Figure 32. Floodplain width versus drainage area from 2001 and 2002 surveys.

4.3 Riparian Area Management

Key forestry applications of the Rosgen Classification of Natural Rivers are tied to the determination of the floodplain boundary. Riparian functions that are linked to conservation of aquatic resources are focused within this portion of the landscape. These functions include flood attentuation, carbon contribution and streambank maintenance. The mean distance from the streambank to the outer floodplain boundary averaged 6.6 meters for small permanent streams and 11.0 meters for large permanent streams (Table 6).

Table 6. Floodplain width summary statistics for small and large permanent streams from 2001 and 2002 sample sites.

Watercourse Class	Sample Size	Mean Distance from Streambank to Outer Floodplain Boundary (m)	Standard Deviation (m)
Small permanent (bankfull width < 5m)	95	6.6	6.6
Large permanent (bankfull width >5m)	32	11.0	7.3

The 30 meter and 60 meter buffer strips, recommended by current timber harvest ground rules for small and large permanent streams (Alberta Environmental Protection 1994), encompassed the vast majority of the floodplains for these two stream classes (Figure 33). The single extreme outlier was a small permanent stream (Site ID 202006, FMF 2002) that flowed through a broad non-forested wetland. These ground rules provide a very effective catch-all strategy for protecting riparian area functions associated with the floodplains of small and large permanent streams.

Establishing riparian management strategies to conserve aquatic values could be tied to floodplain width rather than watercourse classification. This shift would require training of forestry technicians and regulators to the level where both partners could consistently identify the floodplain boundary. Although forestry technicians are familiar with the ecological classification methodology recommended in this report, regulators with a fish biology or water quality background may not be. Development of a training manual or further simplification of the system could be explored if an ecologically - based system is desired.

Under the current ground rules, intermittent streams (which also have an associated floodplain) are afforded a much lower degree of protection than permanent streams. This policy could be reviewed if an ecological approach is selected.

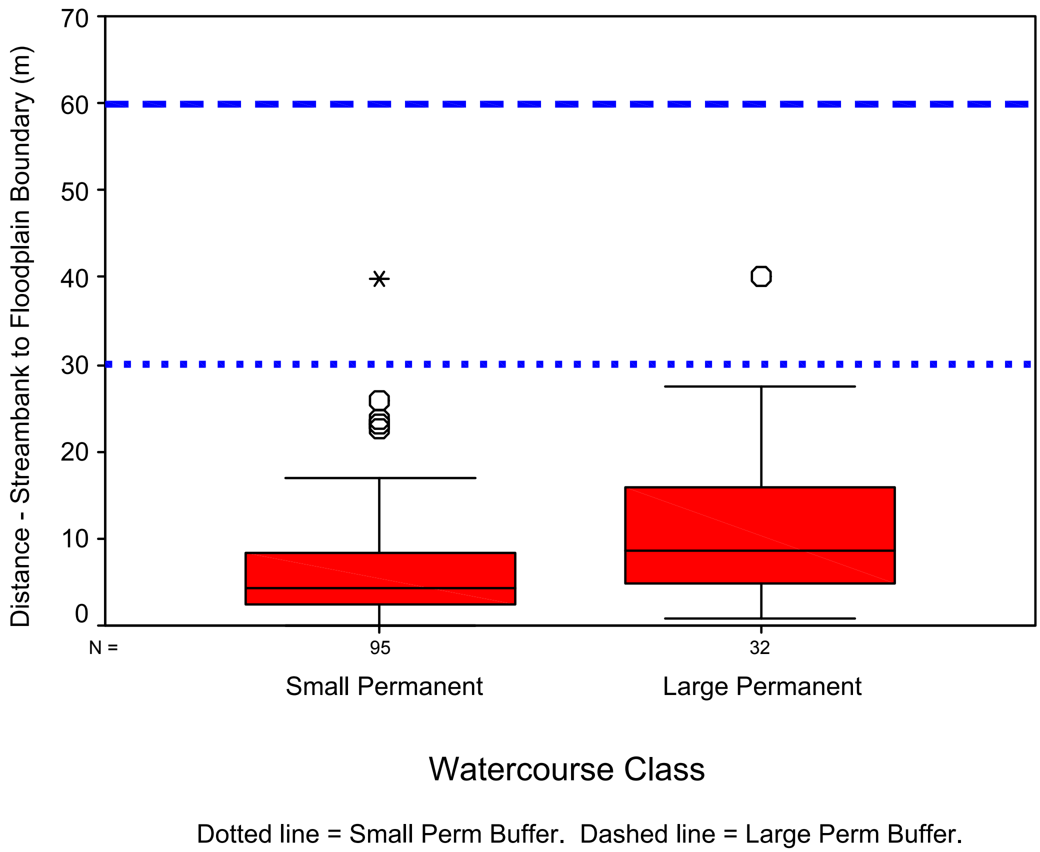


Figure 33. Box-plots of distance from streambank to floodplain boundary for small and large permanent streams from 2001 and 2002 sample sites. Edges of box represent 25th and 75th percentile and horizontal line represents sample median. Vertical lines extending up and down from each box represent 1.5 times the interquartile range. Open circles represent outliers and astericks represent extreme outliers.

Rosgen and Silvey (1996) found that the mean width/depth ratios for "E" type channels averaged between 5.8 and 9.5. Within our study area, the width/depth ratio for all small and large permanent streams (regardless of stream type) averaged 4.2 and 13.8, respectively (Table 7).

Table 7. Width/depth ratio summary statistics for small and large permanent streams from 1999-2002 sample sites.

Watercourse Class	Sample Size	Mean Width/Depth Ratio	Standard Deviation
Small permanent (bankfull width < 5m)	181	4.2	3.3
Large permanent (bankfull width >5m)	51	13.8	8.6

This very low width/depth ratio in small permanent streams represents another distinguishing characteristic of our study area streams (Figure 34). Within these small permanent streams, the roots of streamside shrubs and trees function to maintaining the very steep banks. Management activities that occur adjacent to these small permanent streams are currently limited to stream crossings. Maintaining as much of the streambank vegetation as possible within cleared areas upstream and downstream of the crossing structure would serve to prevent the mobilization of the sediment stored within the streambanks and adjacent floodplain.

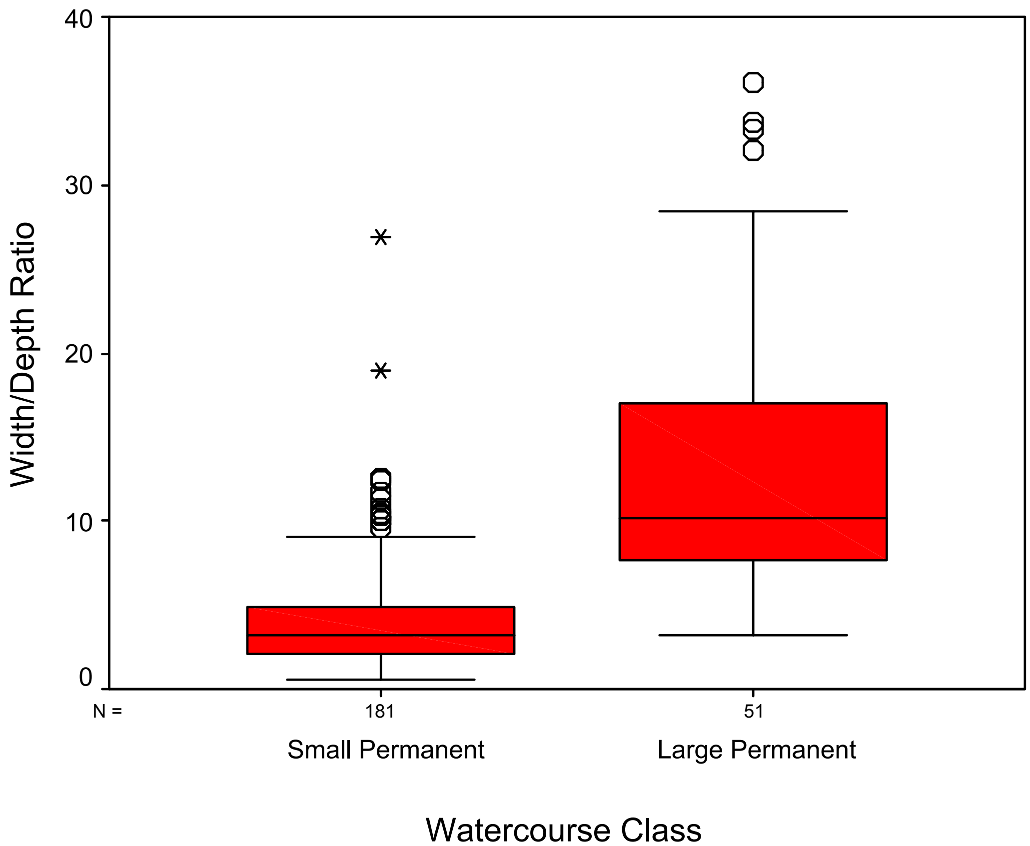


Figure 34. Box-plots of width/depth ratios for small and large permanent streams. Edges of box represent 25th and 75th percentile and horizontal line represents sample median. Vertical lines extending up and down from each box represent 1.5 times the interquartile range. Open circles represent outliers and astericks represent extreme outliers.

4.4 Channel Sensitivity to Disturbance

Stream channels have varying sensitivities to disturbance. The Classification of Natural Rivers includes information on the sensitivity to disturbance for each of the stream types (Rosgen and Silvey 1996). This is important when viewing the most common channel types found across the study area and also when considering the differences in channel types between watersheds.

In many geographic regions, “A” and “B” stream types are the dominant type when stream channels have gradients greater than two percent slope. However, across the study area “E” type streams were the dominant type regardless of gradient (Figure 35).

Figure 35. “E” class channel; width/depth ratio = 4.5

The nature of the streambanks is an important characteristic that distinguishes these two types of channels. In “E” stream types, deep-rooted vegetation functions to maintain the integrity of the steep banks that typically occur along both sides of the channel (Figure 36). In comparison, the banks of “A” and “B” stream types are typically armoured by substrate similar in size or larger than the stream bed material (Figure 37, Figure 38).

Figure 36. "E" class channel; width/depth ratio = 3.2

Figure 37. "A" class channel; width/depth ratio = 4.39

Figure 38. "B" class channel; width/depth ratio = 3.06

There are five different management implications for "A" and "B" stream types verses "E" stream types (Table 8). First, the sensitivity of the stream type to disturbances (increases in stream-flow magnitude and frequency, increases in sediment load) varies between these three channel types. For example, for the cobble substrate category for these stream types (3 = cobble), sensitivity to disturbance is very low for "A", low for "B" and high for "E" type streams. Second, the recovery potential for the cobble substrate category is very poor for "A", excellent for "B" and good for "E" type streams. Third, the sediment supply for the cobble substrate category is very high for "A", low for "B" and low for "E". Fourth, the streambank erosion potential for the cobble substrate category is very high for "A", low for "B" and moderate for "E". Fifth, the importance of vegetation as a factor in controlling the width/depth ratio for the cobble substrate category is negligible for "A", moderate for "B" and very high for "E" stream types.

Table 8. Management interpretations of various stream types (Adapted from Rosgen and Silvey 1996).

Stream Type	Count	Sensitivity to disturbance	Recovery potential	Sediment supply	Streambank erosion potential	Vegetation controlling influence
A1	1	Very low	Excellent	Very low	Very low	Negligible
A3	6	Very low	Very poor	Very high	Very high	Negligible
B2	3	Very low	Excellent	Very low	Very low	Negligible
B3	15	Low	Excellent	Low	Low	Moderate
B4	9	Moderate	Excellent	Moderate	Low	Moderate
B5	1	Moderate	Excellent	Moderate	Moderate	Moderate
C3	25	Moderate	Good	Moderate	Moderate	Very high
C4	4	Very high	Good	High	Very high	Very high
C6	1	Very high	Good	High	High	Very high
D3	6	Very high	Poor	Very high	Very high	Moderate
E2	1	N/A	N/A	N/A	N/A	N/A
E3	68	High	Good	Low	Moderate	Very high
E4	38	Very high	Good	Moderate	High	Very high
E5	18	Very high	Good	Moderate	High	Very high
E6	82	Very high	Good	Low	Moderate	Very high
F2	1	Low	Fair	Moderate	Moderate	Low
F4	1	Extreme	Poor	Very high	Very high	Moderate
G2	1	Moderate	Fair	Moderate	Moderate	Low
G3	2	Very high	Poor	Very high	Very high	High
G4	2	Extreme	Very poor	Very high	Very high	High
G5	1	Extreme	Very poor	Very high	Very high	High

When viewing the stream types and their management interpretations within individual basins, the differences in sediment supply become apparent. The steepest watershed, Solomon Creek was dominated by “D” and “G” stream types, which for the cobble substrate category are all characterized by very high sediment supply (Table 8). In contrast is MacKenzie Creek, which although it has less relief, is another relatively high relief basin. MacKenzie Creek supports “B”, “C” and “E” stream types, which, for the cobble substrate category, have a low, moderate and low sediment supply, respectively. Most of the lower relief watersheds were dominated by “E” type streams, which for the cobble substrate category have a low sediment supply.

4.5 Measuring Channel Disturbance Associated with Land-use Activities – Deerlick Creek Case Study

Several methodologies have been established to provide a measure of the relative level of channel disturbance that may be associated with land-use (Pfankuch 1978 and Hogan et al. 1996). These methodologies consider a number of channel attributes including stream bed, large woody debris and streambanks.

The most frequently occurring stream channels within the actively managed portion of the Foothills Model Forest have two distinguishing characteristics: well-developed floodplains and steep streambanks that are maintained by deep-rooted woody vegetation. Given the nature of most stream channels within the study area and the long-term changes to bank stability that were detected in Deerlick Creek (McCleary et al. 2003 & Figure 39), a focus on streambank integrity and channel width/depth ratios seems appropriate.

Figure 39. Bank erosion in Deerlick Creek twenty years after experimental riparian harvest.

Channel width/depth ratios and bank stability have been rated as “moderately affected and highly sensitive” to road building and maintenance (MacDonald et al. 1990). These two monitoring parameters require low sampling frequency and have low equipment and analysis costs (MacDonald et al. 1990).

5 Discussion

Dominant stream type varied between the basins. The stream types have different sensitivities to disturbance and therefore setting management objectives based on individual basin and stream reach characteristics may be appropriate.

This level II classification system may have applications for resource management planning at the basin and reach scales. At the basin scale, the dominant stream type varied between each watershed. Solomon Creek, the highest relief watershed, was characterized by stream type indicative of unstable channels. In contrast, a low relief basin such as Lambert Creek was characterized by stable stream type with low sediment loads where vegetation exerted a strong controlling influence. With the different stream channel disturbance sensitivities among the watersheds, it may be useful to identify those watersheds with higher sensitivities to peak flow increases.

At the site scale, the classification system may have two applications for resource managers:

1) First, the system can be used by forestry technicians to consistently define the land adjacent to a stream that experiences regular inundation. Planning activities in order to minimize floodplain impacts, such as soil compaction and vegetation removal, should conserve many of the riparian functions associated with these areas.
2) A stream identified as “F” or “G” stream type, is not in a stable state and any structures, roads or crossings in the immediate vicinity may be at risk. Therefore, crossings over “F” or “G” channels should either be temporary in nature or other crossing location options should be identified.

Regardless of gradient, a vast majority of streams within the study area were “E” type streams. These types of streams have the most well developed floodplains over all other stream types. Type “E” streams are characterized by a low sediment supply and steep streambanks that are maintained by deep-rooted vegetation. Riparian vegetation exerts a very high controlling influence for maintaining width/depth ratios of these streams. Therefore, management activities that promote the vigor of deep-rooted vegetation along watercourses are important within the study area. Activities such as ATV/four-wheel drive fords and cattle grazing would have to be carefully managed in order to maintain channel and floodplain structure and function. Natural disturbance, such as flooding and wildfire, promote the vigor of riparian vegetation and may be of particular importance for maintaining the function in these systems.

6 Literature Cited

Alberta Environmental Protection, Land and Forest Services. 1994. Alberta timber harvest planning and operating ground rules. Alberta Environmental Protection, Land and Forest Services, Edmonton.

BC Fisheries Information Services Branch. 2001. Fish and fish habitat inventory standards and procedures. Resource Inventory Committee Publication, British Columbia.

Beckingham, J.D., I.G.W. Corns and J.H. Archibald. 1996. Field guide to ecosites of west-central Alberta. University of British Columbia Press, Vancouver, British Columbia.

Fitch, L., B.W. Adams and G. Hale, Eds. 2001. Riparian Health Assessment for Streams and Small Rivers – Field Workbook. Lethbridge, Alberta: Cows and Fish Program. 86 pages, adapted from Riparian and Wetland Research Program, School of Forestry. 2001. Lotic health assessments: Riparian Health Assessment for Streams and Small Rivers (Survey) User Guide. University of Montana, Missoula, Montana, January, 2001.

FMF (Foothills Model Forest). 2002. 2002 Fish and stream inventory-site summaries. Prepared for the ACA, Weldwood of Canada (Hinton Division), and ASRD. FMF, Hinton, Alberta.

Golder Associates Ltd. 2001. Automated Stream Classification Project. Project completed for Weldwood of Canada Ltd. – Hinton Division.

Hogan, D.L., S.A. Bird, and D.J. Wilford. 1996. Channel Conditions and Prescriptions Assessment (Interim Methods). Ministry of Environment, Lands, and Parks and Ministry of Forests, British Columbia.

MacDonald, L., A.W. Smart, and R.C. Wissmar. 1990. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. U.S. Department of Commerce, Springfield, Virginia.

McCleary, R., C. Sherburne, S. Wilson and C. Bambrick. 2003. Level IV Channel Classification. Foothills Model Forest, Hinton, Alberta.

McCleary, R., C. Weik and J. Blackburn. 2002. Comparison between field surveyed and GIS derived descriptors of small streams within the west-central foothills of Alberta. Foothills Model Forest, Alberta.

McCleary, R., C. Johnson, and C. Nelin. 2001. 2000 ACA Annual Report: An Evaluation of the Effects of Human-Use on Fish - a Description of Fish Populations and Habitats in Selected Watersheds within the Foothills Model Forest. Report completed for the Fisheries Habitat Development Program of the Alberta Conservation Association.

O'Connor, M. and G. Watson. 1998. Geography of channel migration zones and implications for riparian forest management. Appendix A *in* Light, J., M. Holmes, M. O'Connor, E.S.

Toth, D. Berg, D. McGreer and K. Doug'hty. 1999. Design of effective riparian management strategies for stream resource protection in Montana, Idaho and Washington. Native Fish Habitat Conservation Plan Technical Report No. 7. Plum Creek Timber Company, Seattle, Washington.

Pfankuch, D. 1978. Stream Reach Inventory and Channel Stability Evaluation. USDA For. Serv., Northern Region. Missoula, Montana.

Rosgen, D. and H.L. Silvey. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Appendix 1.

Evolution of the Methodology for Estimating Slope Class

Although use of a rod and level was the recommended method for determining channel slope (Rosgen and Silvey 1996), the channel classification exercise was just one component of the fish and fish habitat inventory procedure and it was not practical for each crew to obtain and transport the additional equipment to each inventory site. As a result, a portable hand level (Abney level), which was the recommended tool for fish habitat inventories in the province of BC (BC Fisheries Information Services Branch 2001), was selected as the best tool.

During 1999 and 2000, three slope measurements were taken along the line of sight within a sample reach. The Abney level provided a precise slope value in degrees and minutes, which was converted to percent slope and averaged for the three measurements. However, many of the streams had moderate and high sinuosity values and the line of sight approach may have over-estimated slope of the meandering channel.

Therefore, in 2001, the methodology was modified and the channel was broken down into a number of relatively straight sections. For each section the chainage and elevation change was determined and percent slope was calculated from the distance and elevation change over a length of stream at least 100 meters in length. This method, however, was found to be very time consuming and the Abney levels required regular calibration. In 2001, we also completed an evaluation of GIS-based measures of stream gradient and a methodology was developed that resulted in 58 % accuracy in prediction of slope class (McCleary et al. 2002). Therefore in 2002 we utilized a visual key to confirm the map generated slope class for each sample site.

Appendix 2.

Pilot Study Comparison Between Pebble Count and Visual Estimation Procedures for Determining Median Substrate Size

1. Introduction

Although hydrologists and fish biologists routinely describe similar stream characteristics during their respective surveys, field methodologies are often different. The Foothills Model Forest advocates the use of methodologies that allow for the greatest interpretation and application from field surveys. Therefore, a pilot study was undertaken to compare a substrate analysis procedure developed by fish biologists with a standard substrate survey technique used by hydrologists.

2. Methods

2.1 Pebble count

A pebble count, based on Rosgen and Silvey (1996) was completed as follows. Locate a reach for sampling through two meander wavelengths or cycles of a channel reach. The channel reach should be approximately 20 to 30 "channel widths" in length. Determine the percentage of the reach length configured as riffles and pools, and adjust the pebble-count transects or sampling locations so that riffles and pools are sampled on a proportional basis. For example, if 70% of the reach is in a riffle area, then seven of the ten samples should be taken in riffles. At least five pebbles should be tallied at each transect location. Record all substrate sizes in a tally chart (Table 1).

Table 1. Example tally chart for substrate sizes from pebble count transects.

Fines <2mm	Gravel 2-64mm	Cobble 65-256mm	Boulder >256mm	Bedrock
13	16	18	3	0

2.2 Visual estimation

Substrate composition was estimated as the percentages of each substrate type present at each transect (Table 2), in 5% increments. Substrate sizes are fines (clay, sand, silt <2mm);

small gravel (2-6mm); large gravel (17-64mm); small cobble (65-128mm); large cobble (129-256mm); boulder (>256mm); and bedrock (McCleary et al. 2001).

Table 2. Substrate (%) by visual estimation, for five transects

	Fines	SmGr	LgGr	SmCo	LgCo	Bo	R	Total
T1								
T2								
T3								
T4								
T5								

3. Results

For this pilot study, the D50 was determined at eight different locations during 2001 (Table 3).

Table 3. Locations and tallies of pebble counts in 2001.

Location	**Site**	Total	**Tally**					
ID	**ID**[1]	**Count**	**Fines**	**Gravels**	**Cobble**	**Boulder**	**Bedrock**	**D50**
913	201511	74	11	29	33	1	-	gravel
193	201513	50	14	12	21	3	-	gravel
915	201514	50	-	9	30	11	-	cobble
597	201515	50	21	-	13	16	-	cobble
723	201516	55	15	30	10	-	-	gravel
916	201517	51	5	14	32	-	-	cobble
808	201519	50	17	20	13	-	-	gravel
919	201524	50	20	18	12	-	-	gravel

Technicians had completed visual estimates of substrate composition while completing fish and fish habitat inventories at four of the eight locations during previous years (Table 4).

Table 4. Visual estimation of substrate sizes, in percent.

Location	**Site**	**% Composition**					
ID	**ID**[1]	**Fines**	**Gravels**	**Cobble**	**Boulder**	**Bedrock**	**D50**
913	201511	-	-	-	-	-	-
193	99091	59	8	-	34	-	fines
915	201514	-	-	-	-	-	-
597	200004	73	14	12	1	-	fines
723	99138	13	42	43	2	-	cobble
916	201517	-	-	-	-	-	-
808	99146	71	16	13	-	-	fines
919	201524	-	-	-	-	-	-

[1]Site ID's starting with 99, 200 and 201 were surveyed in 1999, 2000 and 2001, respectively.

At three of the four sites where both pebble counts and visual estimations were completed, the visual estimates provide a smaller substrate size class for the D50 (Table 5).

Table 5. Comparison of D50 for pebble count and visual estimation at eight locations.

Stream	Location ID	D50	
		Pebble count	**Visual estimation**
Unnamed creek	913	gravel	-
Fish creek	193	gravel	fines
Neat creek	915	cobble	-
Emerson creek	597	cobble	fines
Trib. to Erith creek	723	gravel	cobble
Trib. to Erith creek	916	cobble	-
Trib. to Erith creek	808	gravel	fines
Trib. to Upper Erith creek	919	gravel	-

4. Discussion

Ideally, both of the surveys would have been completed on the same day. This would have reduced the likelihood that changes in substrate composition could have occurred due to a natural event. Nonetheless, the underestimation of the D50 based on visual estimates was a concern expressed by Deborah Chan-Yan following the review of the 1999-2001 results.

The standard fish and fish habitat inventory procedure developed for use in the FMF utilizes the visual estimation methodology. Time constraints do not permit two separate surveys to be completed. However, the time required to complete either one of the surveys would likely be similar.

5. Recommendations

The Rosgen Level II classification is based on a pebble count to determine D50. A number of management interpretations have been developed based on the Level II classification. If the end users of the information generated in the Foothills Model Forest Fish and Fish Habitat inventory are interested in using the existing management interpretations, a more detailed analysis of the results from pebble count vs. visual estimate would be warranted. If a bias towards underestimation is confirmed, previous visual estimates could be calibrated to the true D50 as identified in a pebble count.

Appendix 3.

1999 - 2000 Photo Report

Please use CD provided to view

Appendix 4.

2001 Photo Report

Please use CD provided to view

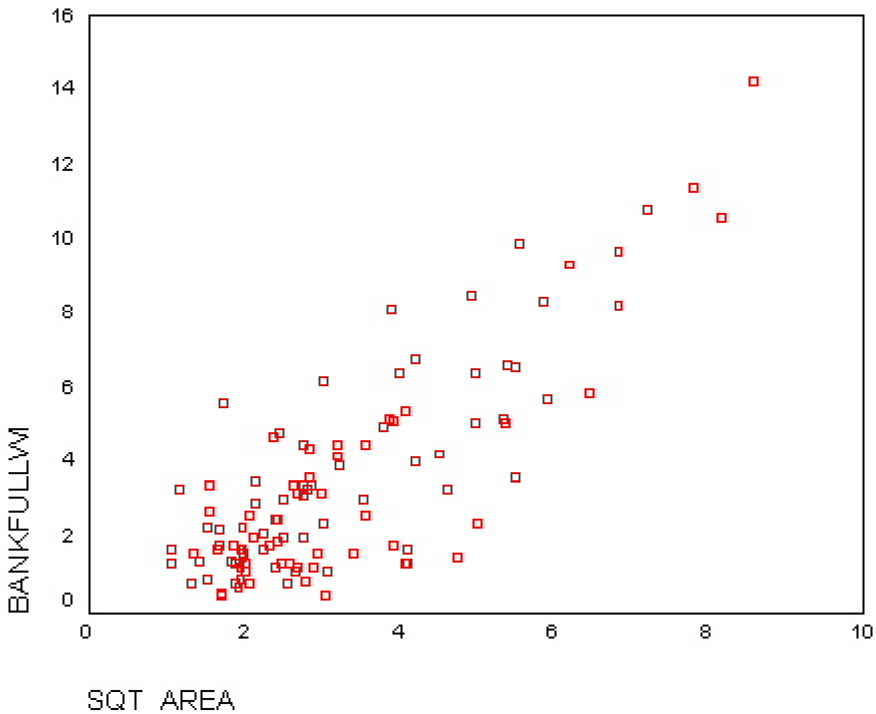
Appendix 5.

2002 Photo Report

Please use CD provided to view

Appendix 6.

Stream Width Model



Regression

Descriptive Statistics			
	Mean	**Std. Deviation**	**N**
BANKFULLWI	3.41626087	2.71581543	115
SQT_AREA	3.1972	1.6323	115

Correlations			
		BANKFULLWI	SQT_AREA
Pearson Correlation	BANKFULLWI	1.000	.817
	SQT_AREA	.817	1.000
Sig. (1-tailed)	BANKFULLWI	.	.000
	SQT_AREA	.000	.
N	BANKFULLWI	115	115
	SQT_AREA	115	115

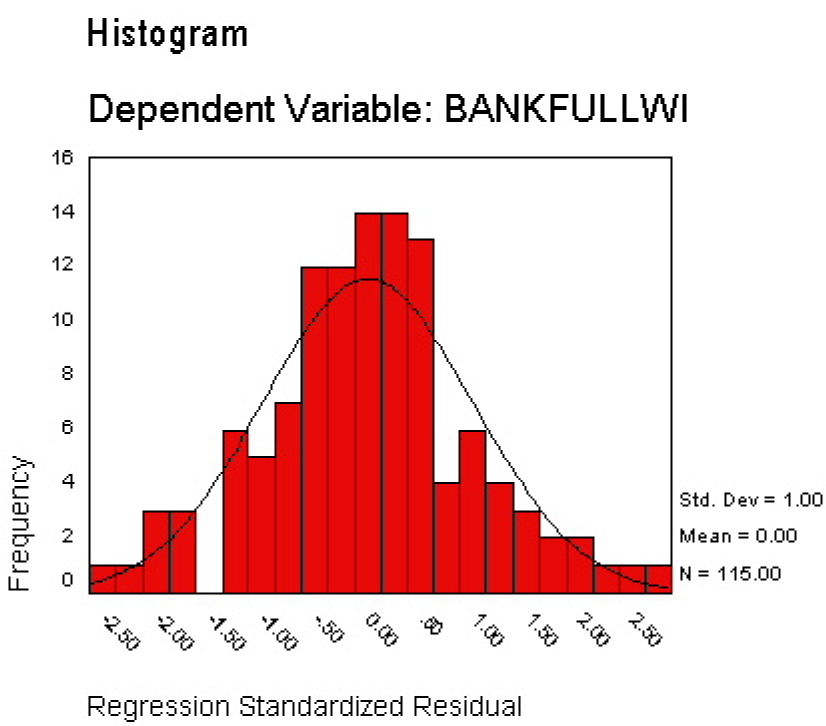
Model Summary(b)				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.817(a)	.668	.665	1.57128560
a Predictors: (Constant), SQT_AREA				
b Dependent Variable: BANKFULLWI				

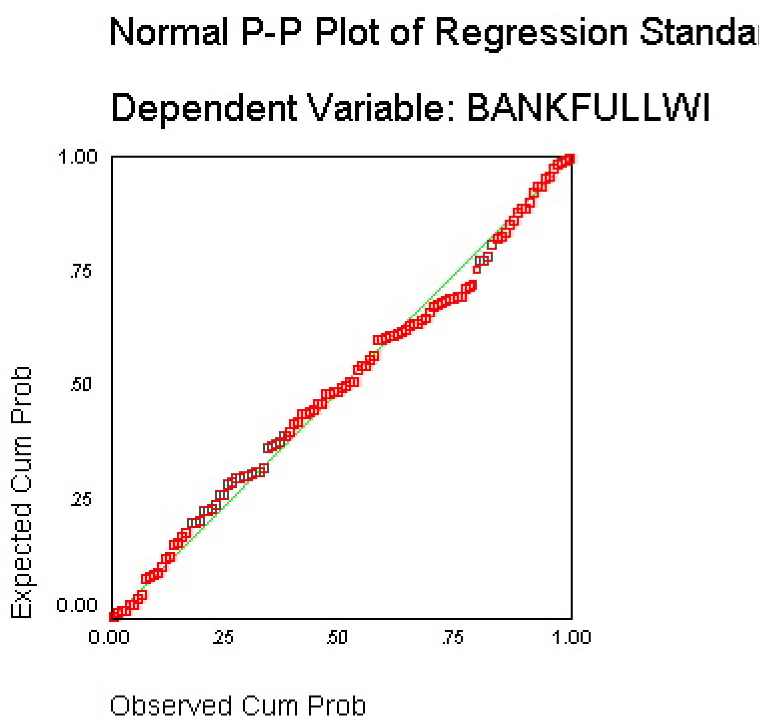
ANOVA(b)						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	561.834	1	561.834	227.561	.000(a)
	Residual	278.990	113	2.469		
	Total	840.824	114			
a Predictors: (Constant), SQT_AREA						
b Dependent Variable: BANKFULLWI						

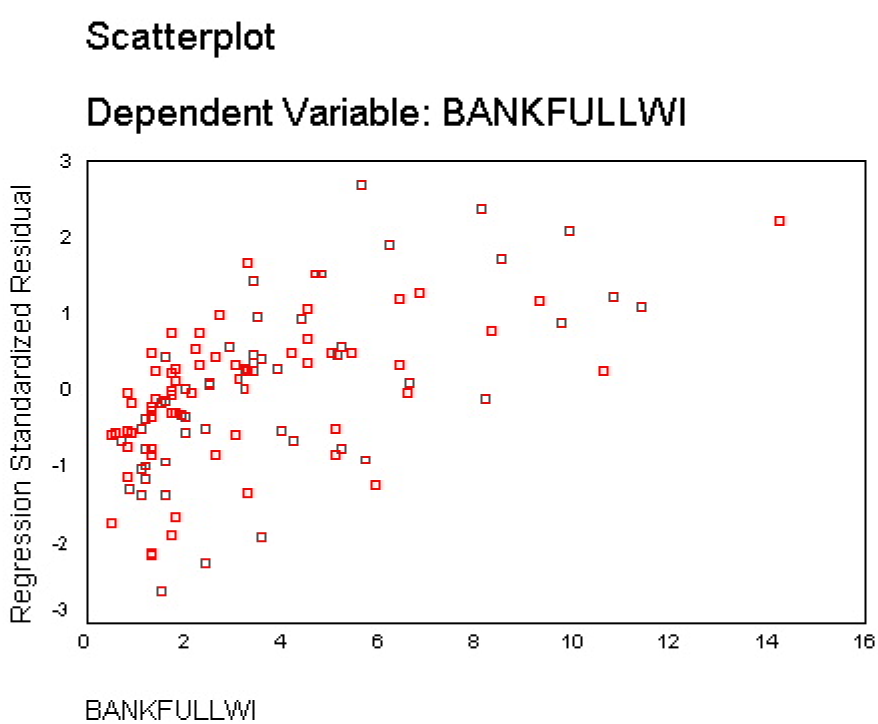
Coefficients(a)						
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	-.932	.323		-2.883	.005

	SQT_AREA	1.360	.090	.817	15.085	.000
a Dependent Variable: BANKFULLWI						

Residuals Statistics(a)					
	Minimum	**Maximum**	**Mean**	**Std. Deviation**	**N**
Predicted Value	.50072491	10.71070576	3.41626087	2.21999378	115
Residual	-4.05294466	4.21647835	-1.34771421E-15	1.56437882	115
Std. Predicted Value	-1.313	3.286	.000	1.000	115
Std. Residual	-2.579	2.683	.000	.996	115
a Dependent Variable: BANKFULLWI					




Normal P-P Plot of Regression Standa
Dependent Variable: BANKFULLWI
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob


Scatterplot
Dependent Variable: BANKFULLWI
3
2
1
0
-1
-2
-3
Regression Standardized Residual
0
2
4
6
8
10
12
14
16
BANKFULLWI