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**REPORT
ON
AUTOMATED STREAM
CLASSIFICATION PROJECT**

Submitted to:

**Weldwood of Canada Ltd.
(Hinton Division)**

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1. INTRODUCTION

1.1 Background

The Automated Stream Classification project is a component of the Watershed Management Tools being developed for the Weldwood FMA. The objective of the overall project is to address Weldwood's need for estimating peak flows and sediment yield due to logging activities. The automated morphologic classification of streams throughout the FMA was undertaken for assessment of stream sensitivity to disturbance.

1.2 Goals of the Project

The main goal of the automated stream classification project was to develop an automated GIS-based procedure to classify all stream reaches within the Weldwood FMA. Stream morphologic classes were based on modified Level I and Level II Rosgen classifications (Rosgen, 1994; FMF, 2001).

The first phase of the approach was the development of classification procedures for the McLeod River watershed based on the available Digital Elevation Model (DEM) and single-line hydrography. The procedures and classification rules were validated and refined using field data from previous Rosgen assessments. In Phase II, the classification procedures and rules were applied to the 3 remaining watersheds within the Weldwood FMA, namely the Berland, Athabasca, and Pembina River watersheds.

Deliverables for the project include all codes and documentation for the procedures, as well as digital maps with attributes for each reach. Final reporting is also presented as a research report (Facet Decision Systems, 2001) describing the development of process methodology, and findings as a basis for future applications.

2. GIS-BASED CLASSIFICATION PROCEDURES

The following sections provide a description of the steps followed in the automated stream classification procedures. Further details are provided in the code documentation and the Facet Final Research Report (Facet Decision Systems, 2001).

2.1 Automated creation of reach breaks

Reach breaks in the single-line hydrography were created where the channel gradient of a 100 m length changed by over:

- 1% for streams with channel slope <4%
- 2% for streams with channel slope 4-10%
- 3% for streams with channel slope >10%

Reach breaks were maintained at stream confluences, and also inserted at waterfall points and at lake boundaries.

2.2 Drainage area calculations

The available DEM was used to calculate the local drainage area of each reach up to its downstream point. Total drainage area was then determined by summing all the local drainage areas from upstream reaches. (Drainage area was used to estimate peak flows and channel characteristics based on morphologic relationships. See attributes below.)

2.3 Reach attributes

Stream reach characteristics such as channel length, channel slope, and sinuosity were determined using the stream hydrography and watershed DEM. In conjunction with the drainage area calculations, other characteristics were estimated based on morphologic relationships and regime equations. Table 1 shows a complete list of the 26 reach attributes derived, along with their definitions or data sources where applicable.

Table 1 – Hydrography Reach Attributes

Attribute Name	Abbr.	Unit	Description	Definition
ID		n/a	Unique reach number	from the procedures
RISE	dH	m	Vertical elevation change from start to end of reach	from the DEM
ST_LN_DIST	Lv	M	Straight-line distance from start to end of reach	from the hydrography
VAL_SLOPE	Sv	m/m	Valley slope	= dH/Lv
CH_LENGTH	Lc	M	Channel (reach) length	from the hydrography
CH_SLOPE	Sc	m/m	Channel slope	= Sv / P
SINUOSITY	P	n/a	Sinuosity	= Lc / Lv
LOC_DRNG_A	A _L	Km ²	Local drainage area to downstream end of reach	from the DEM
TOT_DRNG_A	A _T	Km ²	Total drainage area to downstream end of reach	from the DEM
Q2	Q ₂	m ³ /s	2-year return period flow	= 0.248*A _T ^{0.843}
Q5	Q ₅	m ³ /s	5-year return period flow	= 0.554*A _T ^{0.808}
Q10	Q ₁₀	m ³ /s	10-year return period flow	= 0.774*A _T ^{0.804}
Q25	Q ₂₅	m ³ /s	25-year return period flow	= 1.073*A _T ^{0.803}
Q50	Q ₅₀	m ³ /s	50-year return period flow	= 1.371*A _T ^{0.803}
Q100	Q ₁₀₀	m ³ /s	100-year return period flow	= 1.690*A _T ^{0.802}
WIDTH	W	m	Channel width estimated from regime equations	= 0.375*4.746*Q ₂ ^{0.527}
DEPTH	D	m	Channel depth estimated from regime equations	= 1.185*0.266*Q ₂ ^{0.333}
WD_RATIO		n/a	Width to depth ratio	= W/D
D50	D50	mm	Dominant bed size material from regime equations	= 304.8*12300*D ^{3.53} *Sc ^{1.82}
ELEV_STR	Zs	m	Average elevation of the stream	from the DEM
ELEV_20L	Z20L	m	Average elevation at 20 m to the left of the channel	from the DEM
ELEV_40L	Z40L	m	Average elevation at 40 m to the left of the channel	from the DEM
ELEV_20R	Z20R	m	Average elevation at 20 m to the right of the channel	from the DEM
ELEV_40R	Z40R	m	Average elevation at 40 m to the right of the channel	from the DEM
CLASSI		n/a	Level I classification	from the procedures
CLASSII		n/a	Level II classification	from the procedures

Note: DEM= Digital Elevation Model;
hydrography = provincial single-line hydrography;
regime equations = predictive equations for channel form and substrate based on dominant flow; and
procedures = automated GIS-based classification procedures developed by Golder and Facet.

2.4 Level I Classification Procedures

The Level I classification of each reach was determined using the following steps:

2.4.1 Step 1

If channel sinuosity > 2.2 and channel slope $< 0.5\%$ then Class E

If channel slope $\geq 8\%$ then Class A

If channel slope $\geq 2\%$ and $< 8\%$ then Class B

If channel slope $< 2\%$ then C

2.4.2 Step 2

If stream reach is Class B after Step 1, and average channel gradient is between 2% and 6%, and:

- $|Z_{20R} - Z_S| < 4$, and
- $|Z_{20L} - Z_S| < 4$, and
- $|Z_{40R} - Z_{20R}| < 4$ or $|Z_{40L} - Z_{20L}| < 4$, then
- reclassify as Class E

Refer to Table 1 for definitions of each term.

If stream reach is Class C after Step 1 and:

- Width-depth ratio < 6.4 then reclassify as E

2.4.3 Lakes

Reaches falling within a lake polygon are classified as "lake".

2.5 Level II Classification Procedure

The Level II classification for each reach was determined based on the predicted dominant bed size material. The regime equation used to predict bed size material assumes alluvial material and as such cannot predict bedrock (Class 1), silt/clay fines (Class 6), or organic materials (also assumed to be Class 6). The regime equations are based on research conducted by Dale Bray (1972) and are representative of gravel-bed rivers in Alberta. Substrate classes used in this project are shown in Table 2.

Table 2 – Bed Material Size Ranges for Level II Classification

Level II Class	Description	Size Range for D ₅₀
2	Boulder	>300 mm
3	Cobbles	45-300 mm
4	Gravel	10-45 mm
5/6	Sand/Fines/Organic	≤10 mm

The size ranges for each class, as shown above, were determined during the validation stage of the procedure development. Note that the upper end of Class 5/6 is higher than would be expected for sand/fines/organic type substrate, however this range provided the best results when automated classifications were compared with validation data. No substrate type is estimated for lake reaches.

2.6 Limitations of the procedures

There are always limitations in terms of accuracy when dealing with digital data. The main concerns in this application involve the resolution of the elevation data, as well as the accuracy of the stream hydrography. As a result, channel gradient calculations are highly sensitive to DEM accuracy and the length of reach over which the slope is calculated.

The procedures outlined above do not take into account D, F, and G-type streams. D-type streams are wide braided channels which cannot be predicted by geomorphic relationships. Although they often appear as 2-line streams on topographic maps, they cannot be determined explicitly based on single-line hydrography where all streams, regardless of size and width, are

represented as single lines. This, however, is not a significant concern within the Weldwood FMA as there are relatively few D-type streams, and most can be identified using available orthophotos.

In the Weldwood FMA, F and G streams are often associated with high erosion and significant downcutting. Occurrence of these stream types is limited and generally occurs in alluvial outwash areas where steeper streams enter a larger valley. They are also found in areas where significant disturbance has occurred within the watershed. Maps and orthophotos can be used to delineate areas prone to these downcutting stream types. A good example of a G-type (gully) stream is Seabolt Creek upstream of the bridge that has been washed out. At the bridge site itself the creek starts to meander, and an F-type channel begins to form on the downstream side of the crossing.

Morphologic/regime equations relate substrate size with the channel-forming flow of an alluvial stream. The equations are most applicable to gravel-bed rivers and as such, extrapolation for coarser or finer materials results in some error. The majority of streams within the Weldwood FMA are characterized by cobble and gravel, however all substrate types have been observed. Bedrock outcrops cannot be identified by these relationships, and there is some difficulty in differentiating fines from sand substrate. In addition, the equations cannot predict organic substrates since they are not alluvial materials and they are highly influenced by the presence/absence of local vegetation.

3. STREAMS WITHIN THE WELDWOOD FMA

The Weldwood FMA lies in generally low-lying foothills topography. The four main watersheds are the Athabasca, the Berland, the McLeod, and the Pembina River watersheds. The following sections describe the types of streams commonly found within the FMA, as well as the extent and quality of existing field data related to previous Rosgen assessments.

3.1 Observed Stream characteristics

Streams within the Weldwood FMA are predominantly E-type channels characterized by a high entrenchment ratio (floodprone width divided by bankfull width) and well-developed floodplains. There are also a fair number of B and C-type channels which occur in similar topography but these have a larger width to depth ratio than E-type streams.

The automated classification procedures indicate numerous A-type channels in the Upper Foothills region. These classifications are based solely on gradient and it is likely the streams are either ephemeral or intermittent with flow only occurring during snowmelt periods.

B channels are often observed in transition zones between the steeper slopes and flatter valleys. In the Weldwood FMA these streams are also observed within valleys and can appear as steeper E-channels. The main difference between the two is that for B-type streams flood flows are contained within the developed channel.

C streams are very common along the main valleys of the Weldwood FMA. They typically have a high width to depth ratio and a moderate sinuosity. Erosion is often observed along the outside of bends, and depositional features such as point bars can be found along the insides. Depending on the topography and vegetation of the immediate area (affects bank stability and erosional characteristics), the channel may vary from C to B, C to E, and B to E (and vice versa).

E-type streams are by far the most dominant within the FMA. Three sub-types have been identified: forested, non-forested wetland, and black spruce wetland. The E-type streams occurring in non-forested wetlands and black spruce wetlands are highly sinuous and are generally characterized by a mild slope. The same is true for forested E-channels, however

steeper gradients have also been observed. These are similar to B-type channels, however flood waters appear to overtop the banks and extend over the developed floodplain.

F and G (gully) channels occur in areas of alluvial deposition where there is a significant erosion potential. Although bank instability and degradation are often associated with F and G-type streams, vegetation usually re-establishes itself over time and significantly reduces erosion rates. When G-type streams (gullies) occur after a major disturbance in the watershed, they tend to start meandering after initial downcutting and eventually an F-type channel may develop.

3.2 Available Field Data

An inventory was conducted of the field data and Rosgen classifications available for streams in the Weldwood FMA. During the summers of 1999 and 2000, Foothills Model Forest conducted numerous Rosgen assessments at their fish inventory sites (FMF, 2000). In addition to this, field data was available from the Fall of 1997 (Golder, 1998) and the Fall of 2000 from assessments completed by Golder.

3.2.1 Quality of Field Data

A full review of the available field data was conducted to determine which sites could be used as representative test sites for validating the classification procedures. In many cases, field data were incomplete or obtained with a low degree of accuracy. Where possible, photographs from each site were also used to assess the original classification; however, numerous classifications could not be confirmed.

It was noted that the dominant bed material size, D50, was generally overestimated for large gravel substrates during visual assessments. These reaches were often classified as having a cobble substrate. This is common with visual assessments as larger particles appear to outnumber smaller materials, despite the actual percentage occurrence of each type.

3.2.2 Extent of Field Test Sites

A subset of test sites was chosen based on the degree of confidence in the available field data and the field classification obtained. Seventy-four (74) test sites in the McLeod watershed pilot area were chosen, along with a further 61 sites in the Athabasca, Berland, and Pembina watersheds.

The McLeod test sites are dominated by E-type streams with a mix of cobble, gravel, fines, and organic substrates.

3.2.3 Locations of Field Test Sites

A number of the available field sites were located within 50 m of a stream confluence. This has little impact on the field classification if both the upstream and downstream reaches are of similar types, but there may be consequences if stream types differ. For sites located in this type of transitional zone, it may be difficult to distinguish between two possible stream types and observed characteristics may be indicative of more than one class.

4. RESULTS: AUTOMATED CLASSIFICATIONS VS. FIELD DATA (TEST SITES)

The McLeod River watershed was chosen as the pilot area for developing the automated stream classification procedures based on the available watershed data and the range of terrain covered. In addition, the McLeod watershed makes up approximately 1/3 of the Weldwood FMA, and the majority of field test sites are located within this region. Once tested and refined, the procedures were applied to the remaining three watersheds in the FMA. Results from the automated procedures comprise a hydrography layer with the attributes shown in Table 1.

4.1 McLeod River Watershed Pilot Area

Level I automated classification results (major stream type) for the McLeod watershed are illustrated in Figure 1. A close-up is also provided in Figure 2. Level II results (substrate type) are included in the digital coverages as attributes of each reach.

4.1.1 Level I Stream Type

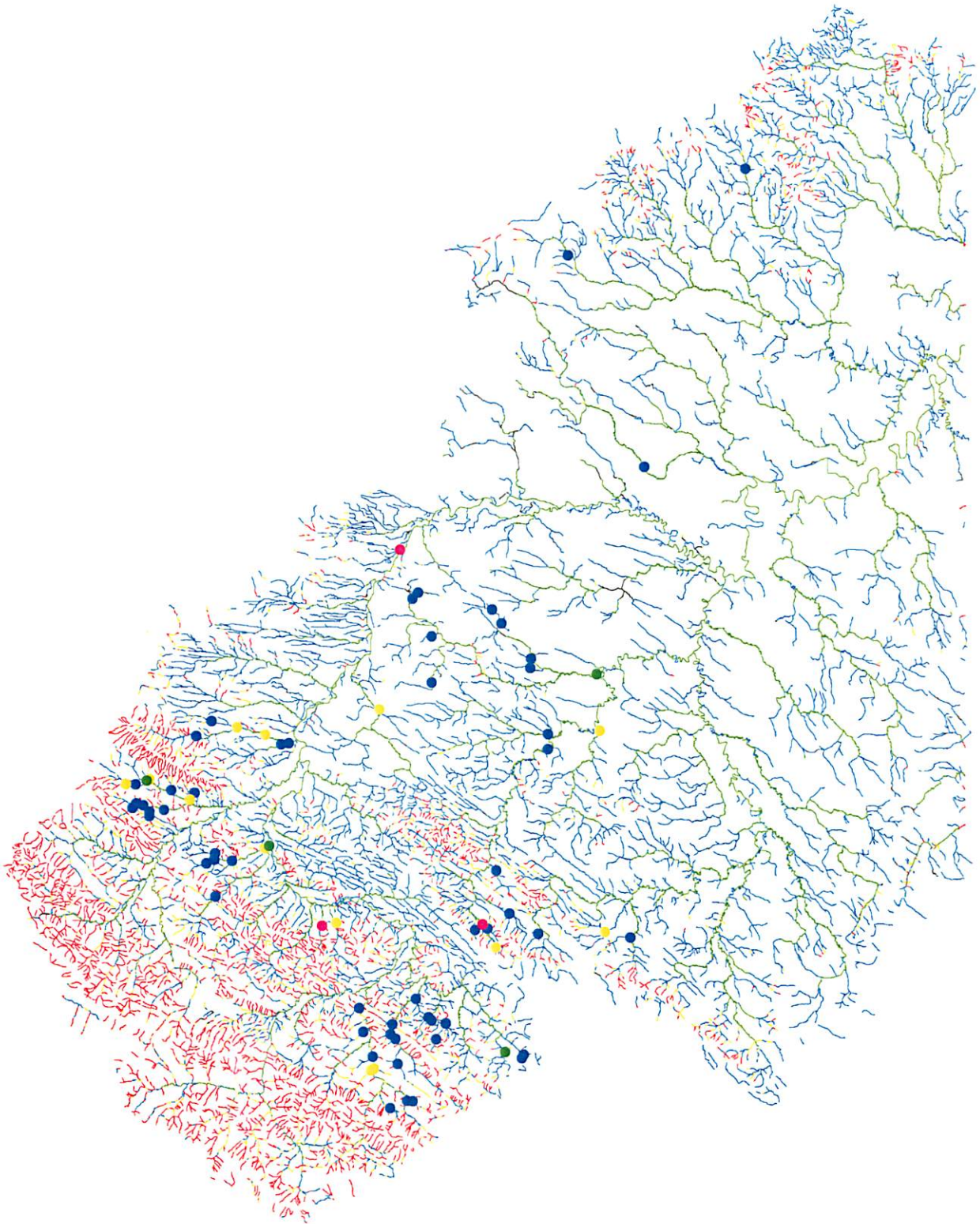
Table 3 shows the results of the Level I classifications (modified Rosgen) for the McLeod watershed. Of the 74 test sites, 55 (74%) were E-type streams and the remaining were B and C-type reaches.

Table 3 – Level I Automated Classification Results for the McLeod Watershed

Stream Type	# of Test Sites from Field	# of Sites Correct by GIS	% of Total Correct	# of Sites in Each Category by GIS			
				A	B	C	E
B	12	2	17%	0	2	5	5
C	4	2	50%	0	0	2	2
E	55	41	75%	4	2	8	41
Other	3	0	n/a				

Total 74 45 61%

Note: There were no A channels in the test data set, and too few C channels from which to derive meaningful results. "Other" stream types represent D, F, or G type streams which cannot be predicted by the automated procedures.



10 5 0 10 Kilometers

LEGEND

TEST SITES

- A
- B
- C
- D
- E
- F
- G

Level I Stream Type by GIS Procedures

- A
- B
- C
- D
- E
- Lake

PROJECT

Weldwood of Canada Ltd.
Stream Classification Project

TITLE

McLeod Watershed Pilot Area - Level I Classification



PROJECT No.	002-2619-3000
DESIGN	DCY 04 Aug 2001
GIS	DCY 15 Jan 2002
CHECK	DCY 15 Jan 2002
REVIEW	AB 15 Jan 2002

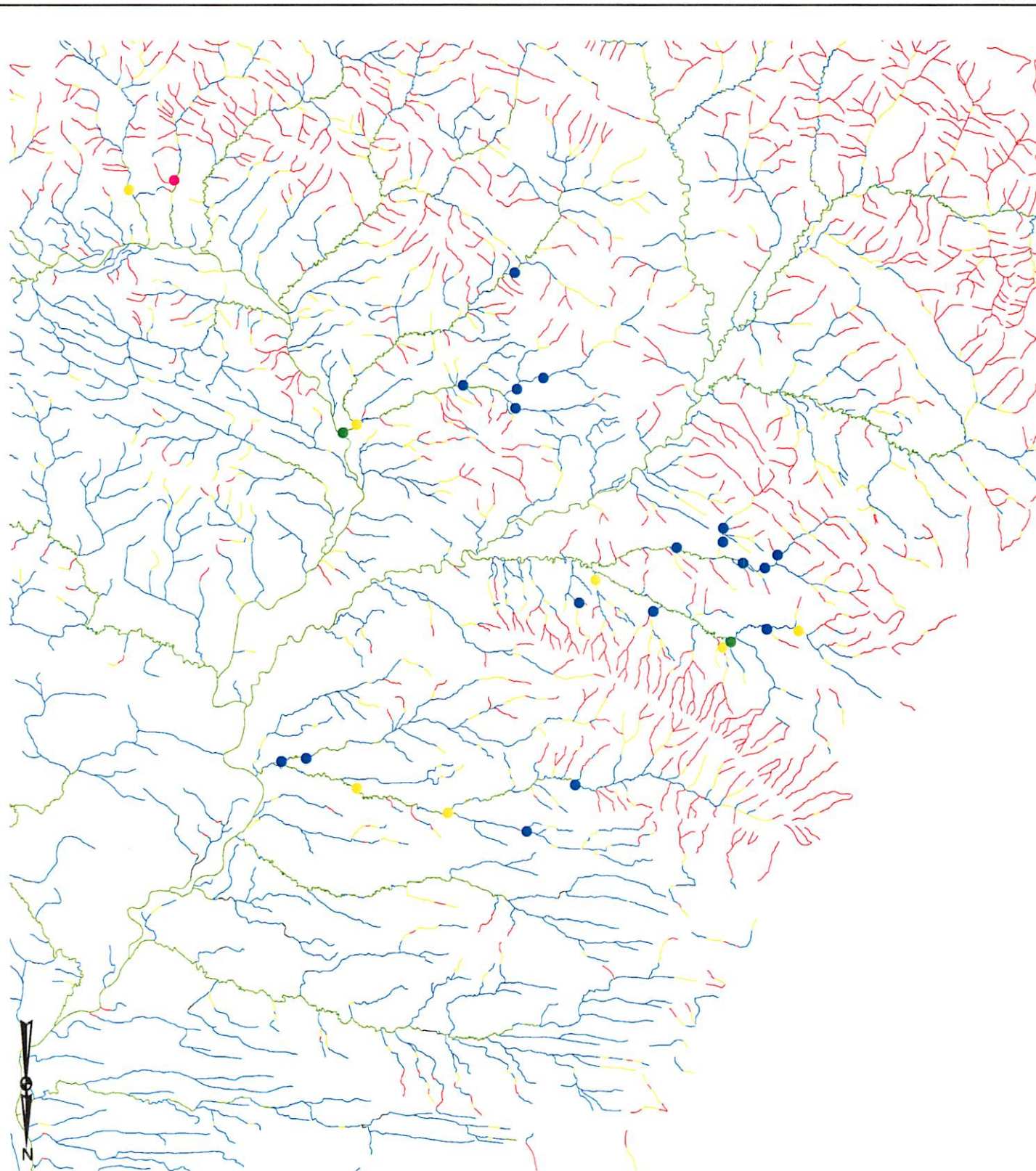
SCALE AS SHOWN REV 0

FIGURE 1

- TEST SITES**
- A ●
 - B ●
 - C ●
 - D ●
 - E ●
 - F ●
 - G ●

- Level I Stream Type by GIS Procedures**
- A —
 - B —
 - C —
 - D —
 - E —
 - Lake —

LEGEND



Weldwood of Canada Ltd.
Stream Classification Project

PROJECT

TITLE

McLeod Watershed Close-Up of Test Sites

PROJECT No. 002-2619-3000 SCALE AS SHOWN REV. 0

DESIGN DCY 04 Aug 2001

GIS DCY 15 Jan 2002

CHECK DCY 15 Jan 2002

REVIEW AB 15 Jan 2002



FIGURE 2

Of the 12 B-type streams, only 2 were correctly identified. However, a closer look at the results and associated field data showed the following:

- The calculated slopes for 3 reaches were lower than expected for typical B streams. This could be due to these streams being slightly atypical with lower gradients, or the resolution of the DEM or length of stream reach affecting slope calculations;
- 2 of the test sites which were classified as C-type streams by the automatic procedures appear to be borderline B-C reaches (i.e, field data and photos indicate characteristics consistent with both classes);
- 1 test site, which was classified as an E stream by the procedures, appears to be borderline B-E;
- 1 site was located on an intermittent stream with no flow at the time of assessment; and
- 1 was affected by local geology.

A reasonably high percentage of E channels were classified correctly (75%). Of the 4 streams mis-classified as A channels, 3 of them were located within 40 m of an E channel. It is likely that these test sites were located within a transition zone between short steeper tributaries and the main E-type channel. The 2 streams which were mis-classified as B channels are associated with channel gradients steeper than typical. As noted previously, however, it is not unusual to find steep E channels within the Weldwood FMA. Of the 8 reaches which were mis-classified as C channels, the following was noted:

- 4 sites were within 100 m of an E channel
- 2 sites were borderline E-C channels (field data and photos indicate characteristics of both stream types); and
- 1 site had no field data, although visually the stream did appear to be an E channel.

4.1.2 Level II Substrate Type

Table 4 shows the results of the Level II classifications for the McLeod watershed. There were no field sites with a Type 2 dominant bed material size (boulder), however the numbers of test sites within Classes 2, 3, and 5/6 were nearly equal.

Table 4 - Level II Automated Classification Results for the McLeod Watershed

Substrate Type	# of Test Sites from Field	# of Sites Correct by GIS	% of Total Correct	# of Sites in Each Category by GIS			
				2	3	4	5/6
2	0	0	n/a	0	0	0	0
3	27	4	15%	0	4	18	5
4	26	23	85%	0	1	23	2
5/6	21	11	52%	0	3	7	11
<i>Total</i>	<i>74</i>	<i>38</i>	<i>51%</i>				

As shown in the table above, only 4 of the 27 Class 3 Cobble streams (15%) were correctly classified. The dominant bed material sizes for the remaining 23 sites were underestimated and resulted in Level II classifications of gravels and fines. The low percentage of correct classifications can be attributed to a number of issues including:

- Extrapolation of the regime equations. The morphologic relationships used are based on gravel-bed rivers and extrapolation to cobble substrate is beyond the regression extremes;
- A tendency for dominant substrate to be visually overestimated in the field resulting in gravel streams being classified as cobble streams (i.e., some test sites were classified as Type 3 cobble substrate on a visual basis, but the dominant bed material size may actually be gravel if a complete pebble count were conducted.)
- The occurrence of large cobbles along with finer materials in slow flowing reaches. These systems are poorly-graded and although the larger substrate may be present, it may not be transported in significant quantities. If the large cobbles are considered "imposed", the regime equations would not be applicable.

Level II classifications are sensitive to the substrate size ranges shown in Table 2. As a results, the three mis-classified sites in Class 4 Gravel (23 correct out of 26) can be attributed to:

- 1 site where the predicted D50 of 10 mm is exactly at the divide between gravels and fines;
- 1 site where the drainage area is very small (0.2 km²) and hence the predicted D50 is small; and
- 1 site where the predicted D50 is 55 mm (gravel range is 10 to 45 mm).

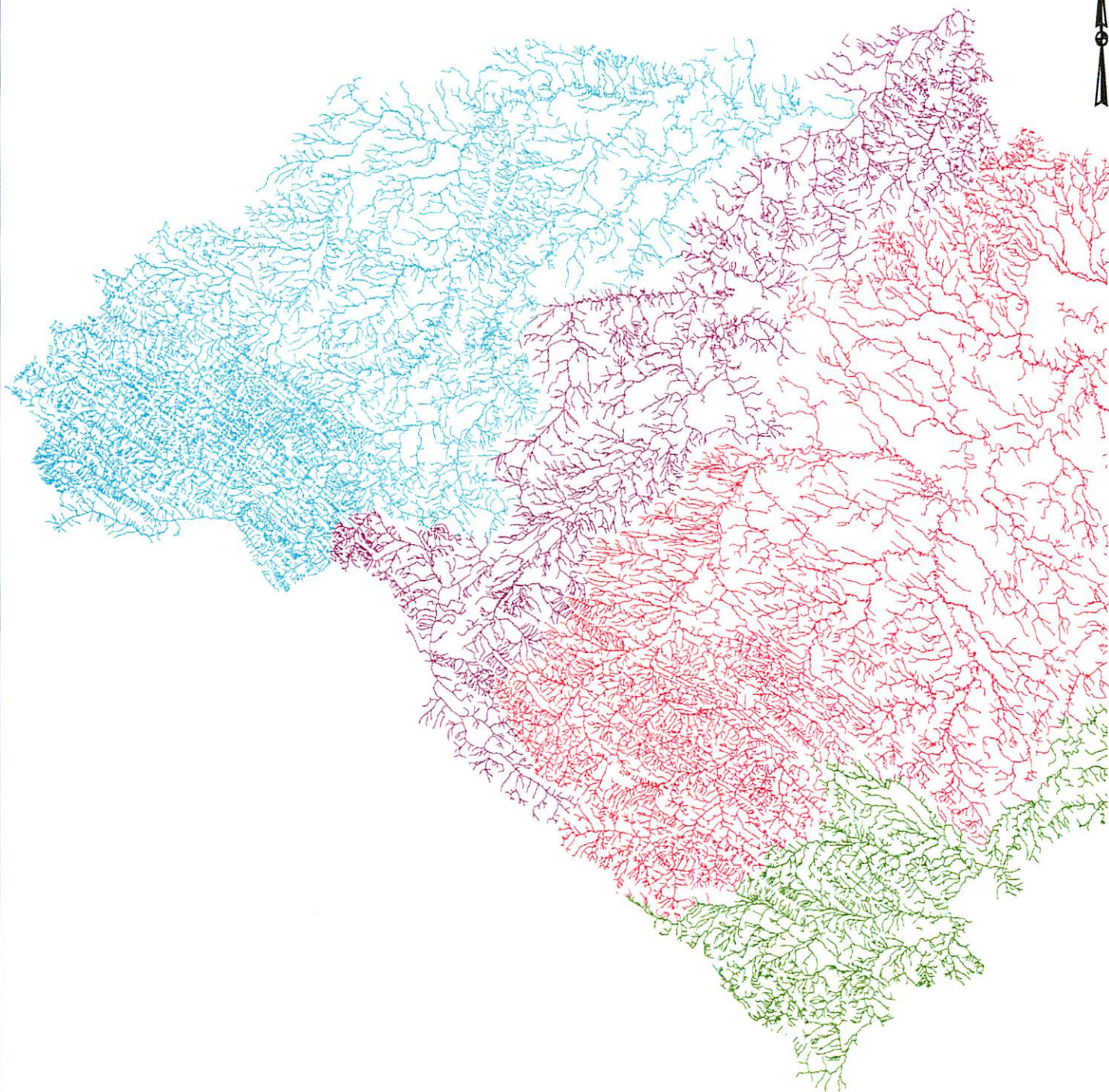
All 10 mis-classified sites in Class 5/6 (11 correct out of 21) can be attributed to the presence of organic materials as the dominant substrate. Organic materials cannot be predicted using regime or morphologic equations, and their presence is largely influenced by local vegetation.

4.2 The Berland, Athabasca, and Pembina Watersheds

Figure 3 illustrates the major watersheds within the Weldwood FMA, including the McLeod watershed pilot area. After refining the classification procedures using the McLeod pilot area, they were applied to the remaining watersheds (Berland, Athabasca, and Pembina). Level I and Level II classification results for the entire Weldwood FMA are shown in Figure 4 and Figure 5. These figures also show the test site locations and their associated field classifications.

4.2.1 Level I Stream Type

Level I classification results for the Berland, Athabasca, and Pembina watersheds were comparable and slightly better than observed in the McLeod pilot area. The percentage of field sites with correct classifications increased for all stream types; however overall results are still highly affected by the small sample sizes. The small number of test sites in each category preclude any definitive conclusions.



LEGEND

Watershed

- Berland
- Athabasca
- McLeod
- Pembina

10 0 10 20 Kilometers



PROJECT

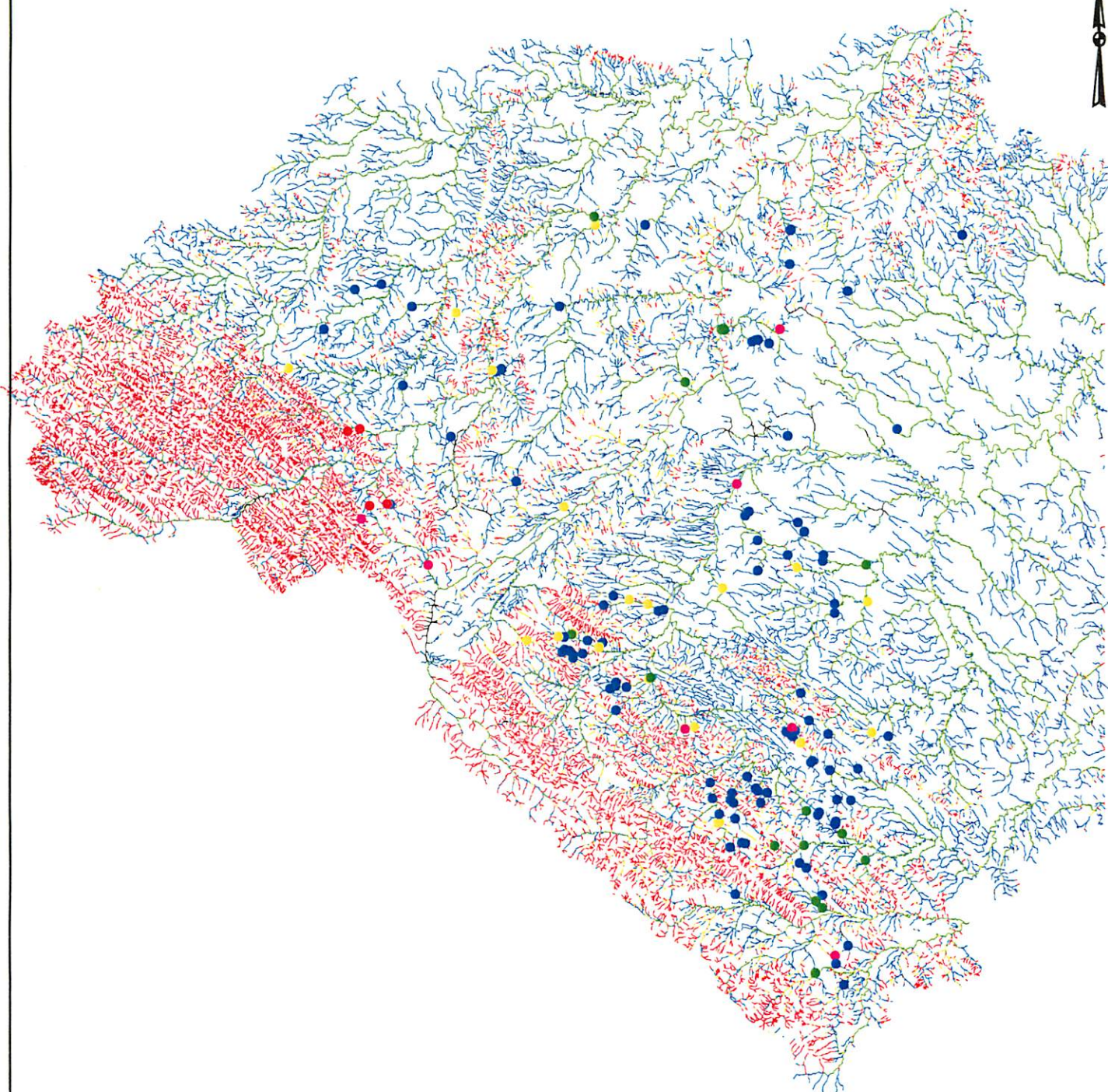
Weldwood of Canada Ltd.
Stream Classification Project

TITLE

Major Watersheds within the Weldwood FMA



PROJECT No. 002-2619.3000			SCALE AS SHOWN	REV 0
DESIGN	DCY	04 Aug 2001	FIGURE 3	
GIS	DCY	15 Jan 2002		
CHECK	DCY	15 Jan 2002		
REVIEW	XXX	15 Jan 2002		



LEGEND

TEST SITES

- A
- B
- C
- D
- E
- F
- G

Level I Stream Type by GIS Procedures

- A
- B
- C
- D
- E
- Lake

10 0 10 20 Kilometers



PROJECT

Weldwood of Canada Ltd.
Stream Classification Project

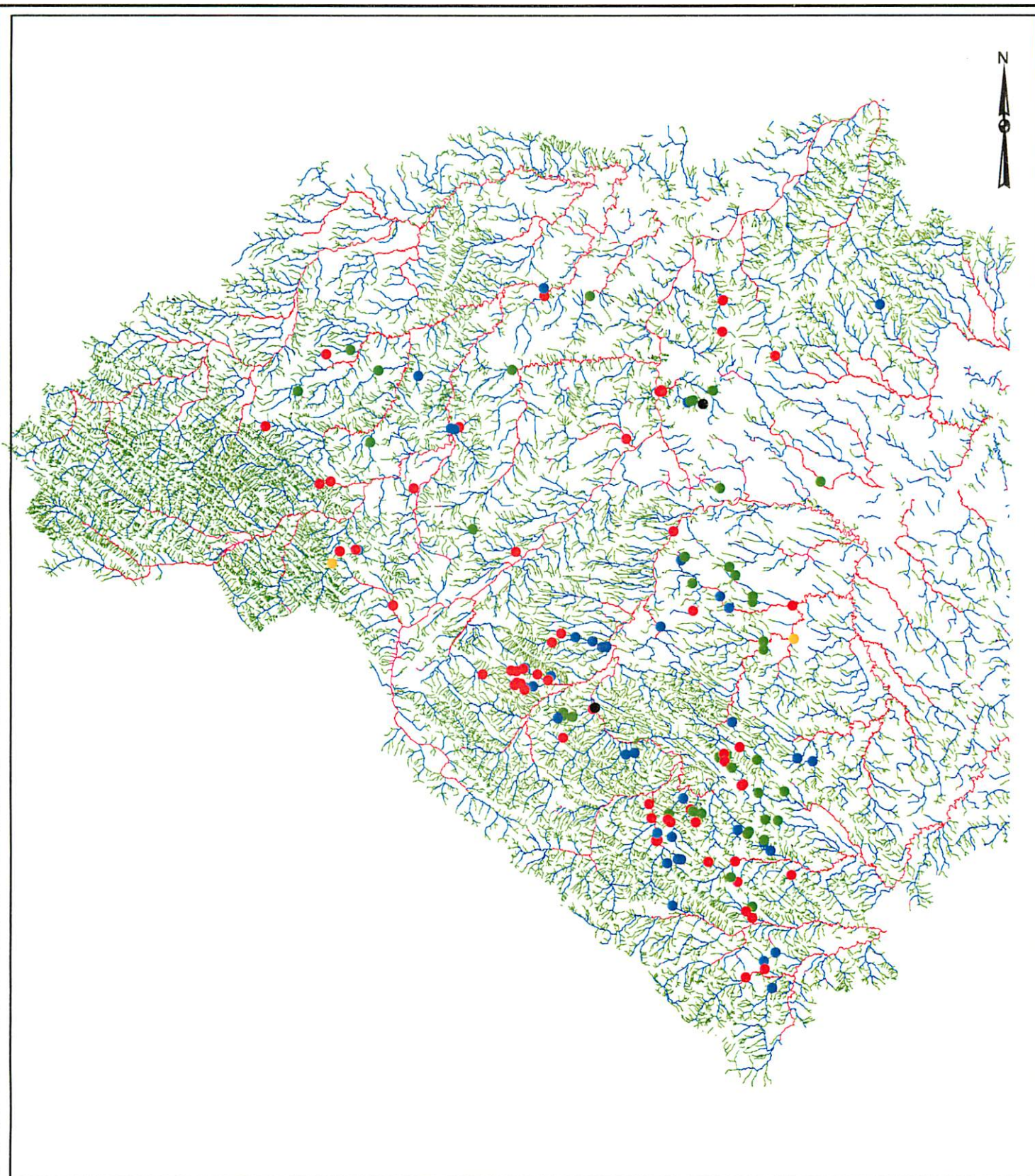
TITLE

Weldwood FMA Channel Classification



PROJECT No.	002-2619.3000	SCALE AS SHOWN	REV. 0
DESIGN	DCY 04 Aug 2001		
GIS	DCY 15 Jan 2002		
CHECK	DCY 15 Jan 2002		
REVIEW	XXX 15 Jan 2002		

FIGURE 4



LEGEND

TEST SITES

- 0
- 2
- 3
- 4
- 5
- 6

Level II Stream Type by GIS Procedures

- 3
- 4
- 5/6
- lake
- none

10 0 10 20 Kilometers

PROJECT

Weldwood of Canada Ltd.
Stream Classification Project

TITLE

Weldwood FMA Level II Classification



PROJECT No.	002-2619.3000	SCALE AS SHOWN	REV. 0
DESIGN	DCY 04 Aug 2001		
GIS	DCY 15 Jan 2002		
CHECK	DCY 15 Jan 2002		
REVIEW	XXX 15 Jan 2002		

FIGURE 5

Table 5 - Level I Automated Classification Results for the Berland, Athabasca, and Pembina Watersheds

Stream Type	# of Test Sites from Field	# of Sites Correct from GIS	% of Total Correct	# of Sites in each category by GIS			
				A	B	C	E
A	4	2	50%	2	0	1	1
B	6	2	33%	0	2	0	4
C	12	7	58%	1	0	7	4
E	35	28	80%	0	1	6	28
Other	4	n/a	n/a	0	0	1	3
Total	57	39	68%				

Two of the four A test sites were classified correctly. The other two sites were classified as a C-type and an E-type stream. A-type streams are much steeper than C and E streams which are defined in the procedures as having channel gradients less than 2%. Two possible reasons for the mis-classifications are that the calculated slopes are inaccurate due to the DEM resolution or a short reach length, or that the original test site data is incorrect.

The B-type streams that were classified as E-type streams are likely the borderline B-E streams that have been observed within the Weldwood FMA. They are B-type streams due to their higher channel gradient and flood levels that do not extend beyond the immediate channel section. However, the topography is very flat, similar to an E-type stream, and the valley entrenchment is quite low (also typical of an E-type stream).

As mentioned above, C and E-type streams are generally characterized by channel gradients less than 2%. The automated procedures differentiate between these two types based on an estimated width to depth ratio. Because these width and depth characteristics are based on regression equations, there is an inherent amount of error associated with the predicted relations.

4.2.2 Level II Substrate Type

In terms of Level II classification, results of the automated procedures for the Berland, Athabasca, and Pembina watersheds were not as successful as for the McLeod pilot area. The main reason for this is the higher number of field test sites classified as Type 3

(cobbles), and the underestimation of bed material size based on the gravel-bed morphologic equations.

Table 6 - Level II Automated Classification Results for the Berland, Athabasca, and Pembina Watersheds

Substrate Type	# of Test Sites from Field	# of Sites Correct from GIS	% of Total Correct	# of Sites in each category by GIS			
				2	3	4	5/6
2	1	0	0%	0	0	0	1
3	28	7	25%	0	7	16	5
4	14	12	86%	0	1	12	1
5	18	4	22%	0	1	13	4
<i>Total</i>	<i>61</i>	<i>23</i>	<i>38%</i>				

As with results from the McLeod pilot area, substrate size was underestimated for the cobble sites. Again, this is likely attributed to the use of gravel-bed morphologic equations, and possibly to a tendency to overestimate dominant bed material size when evaluated visually.

Gravel substrates were predicted correctly for the majority of sites, and the poor classification of fines may be attributed to the presence of organic matter in the stream beds.

5. DISCUSSION

The project was successful in automating a stream classification procedure for the entire Weldwood FMA. The classification system was based on a modified Rosgen system, as well as on observed stream characteristics within the FMA. The procedure has been automated, however further refinement of the classification rules is required to improve the accuracy of the classifications for both Level I (stream type) and Level II (substrate type) evaluations. The results achieved to date represent preliminary classifications that may be improved in the future based on additional field data and on further refinement of the classification rules.

Although preliminary Level I and Level II results have been evaluated, the sensitivity of the classification system to slope break point locations and to values of width-to-depth ratio has not been tested. Reach breaks were created based on change in slope over a 100 m length (see Section 2.1), and resulted in an average reach length of 584 m. Similarly, the values of width and depth, and hence the width-to-depth ratio, are based on generalized morphologic relationships and have not been explicitly tested using field data.

A number of streams that occur within the FMA do not fall within typical Rosgen classes. For example, steep E-type channels are found in certain areas at gradients approaching 4% (more typical of B-type channels), but are classified as E channels based on their cross-section shape and evidence of a floodplain. Sinuosity remains high and channel banks are heavily vegetated (with grasses and shrubs) and are generally considered stable. On the other hand, highly sinuous B channels with low gradients have also been observed. In these channels, the gradient is lower than would typically be expected, and flood levels appear to remain within the immediate channel. Just beyond the banks, however, the topography is flat and similar to that found with typical E-channels. It is important to realize that while the Rosgen classification system presents discrete stream classes, actual stream characteristics fall within a continuum of stream types. As a result, streams may exhibit characteristics of one class as well as characteristics of another. Although the classification system provides a tool to describe streams and their management implications, some reaches may require site-specific consideration if they do not clearly fall within a single stream type category.

In addition to the hybrid B-E and E-B streams discussed above, it is useful to differentiate between the three common types of E-streams found in the FMA: forested, non-forested wetland, and black-spruce wetland. Each has a different significance to logging practices from both a harvesting and operational point of view. A forested E-channel would fall within an area with commercially valuable timber, however one in a non-forested wetland could pose a problem for stream crossings and road building over unstable or organic soil.

For Level II classifications, Type 4 substrate (gravel) was successfully predicted by the morphologic regression equations. These equations are based on data from gravel-bed rivers and do not extrapolate well to much smaller and larger substrate sizes. Results from the automated classification indicate that cobble sizes are generally underestimated. The equations also do not have the ability to predict organic substrates that are often found within the FMA. It may be possible to use vegetation overlays to predict the presence of organics in stream channels, however the fact that organic materials can be easily transported downstream may limit the effectiveness of this approach.

The Rosgen classification system is designed for alluvial systems where Level II classification is based on the dominant bed size material (D50, the size of particle exceeded 50% of the time). It is not always easy to determine the dominant bed size material without rigorous time-consuming field sampling. For example, numerous streams within the FMA have a substrate of cobbles or boulders mixed with sand. These substrates are poorly-graded and determining substrate class based on dominant size (as size exceeded 50% of the time) the Rosgen classification is not always a straight forward exercise.

6. RECOMMENDATIONS

In order to refine the classification rules, accurate field data should be collected for sites across the FMA, and for the entire range of stream types and substrate types observed. Good quality data includes an accurate slope measurement, good estimation of bankfull stage, and a confident estimation of the dominant bed size material (refer to FMF classification guide, 2001, *work in progress*). Assessments should concentrate on the main stream types in the FMA so that a quality database can be developed. It is recommended that a sampling program be designed based on an appropriate number of test sites in each category. Alternatively, a sub-sample of the available field data may be used. These data should be selected based on sampling design principles, and it would not be necessary to include the entire available set. The same comments apply to Level II classifications and for application to the entire Weldwood FMA.

More detailed information from C and B-type streams should also be gathered so that the automated procedures can be refined to differentiate these streams from similar E-type streams. A number of sites currently designated as A-type channels should also be visited to determine whether they are ephemeral, intermittent, or permanent drainages. They are generally short steep reaches which likely only carry flow during peak runoff periods.

In the future, it will be useful to attach an attribute to the dominant E-type streams identifying them as either forested, non-forested wetland, or black-spruce wetland streams. This can be done by using available vegetation information, and creating reach breaks where vegetation polygons change. Similar information would also be available for the other channel types.

7. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

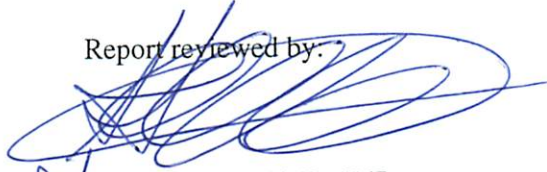
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REFERENCES

Bray, D. I. 1972. Generalized Regime-Type Analysis of Alberta Rivers. Ph.D. Thesis, Department of Civil Engineering, University of Alberta. 232 pp., Appendix A-L.

Facet Decision Systems, 2001. Final Research Report: Weldwood Automated Stream Classification Project.

Golder Associates Ltd., 1998. Hydrologic Resource Issues Review and Recommendations. Report submitted to Weldwood of Canada Ltd. May 1998

Foothills Model Forest, 2000. Photo Report Level 2 Stream Classification Project (2000 Field Season).

Foothills Model Forest, 2001. DRAFT Stream Classification Field Guide. Prepared for Foothills Model Forest Partners including Weldwood of Canada (Hinton Division) and Alberta Sustainable Resource Development.

Rosgen, D. 1994. A classification of natural rivers. Catena. Vol 22; 16-199. Elsevier Science, B.V. Amsterdam.