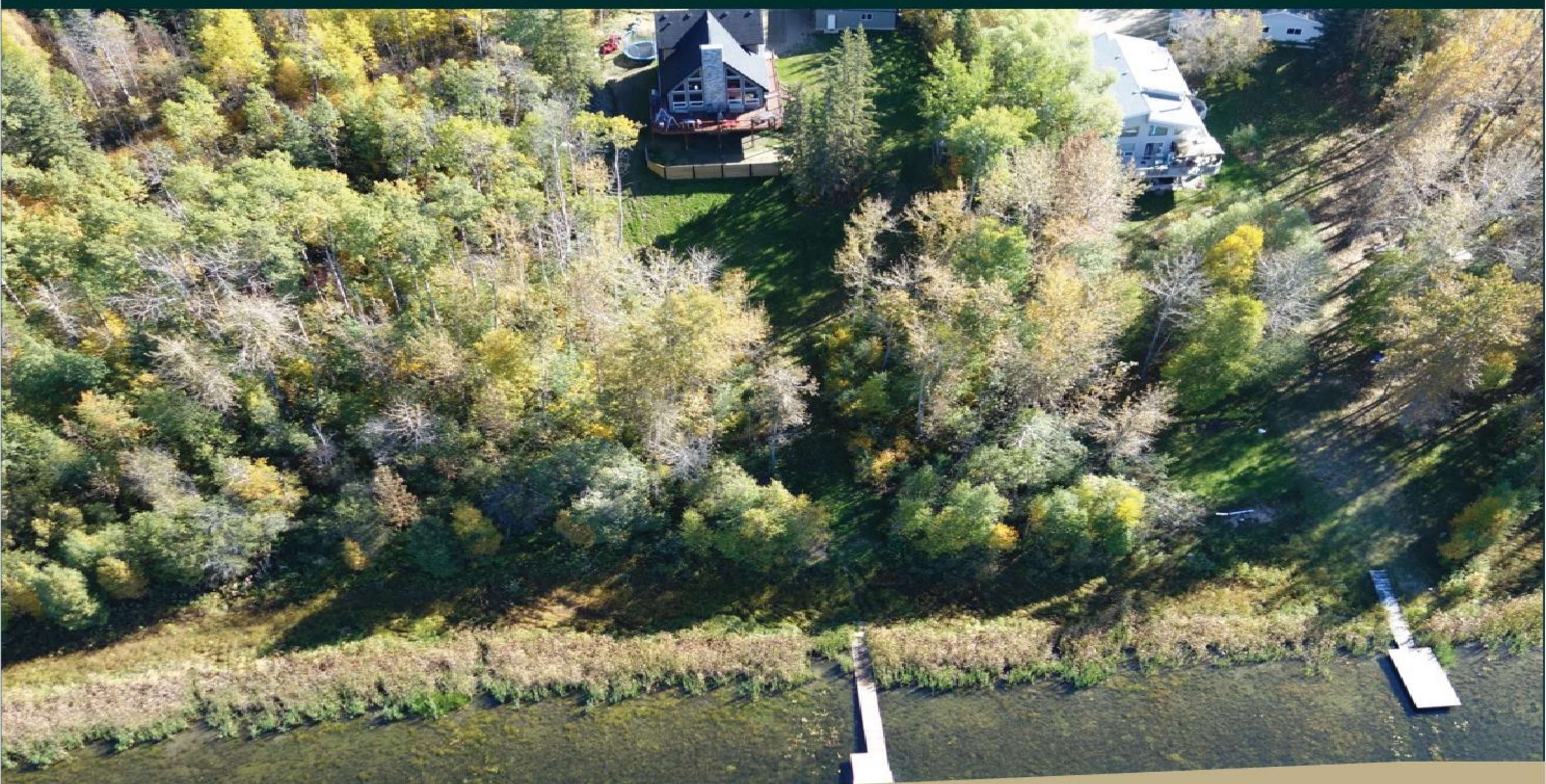
Riparian Assessment Validation for North Saskatchewan Region Lakes

FINAL REPORT



Prepared for:
Alberta Environment and Parks
Policy and Planning Division, Planning Branch

January 2019

Project 1853

FIERA
Biological Consulting

Front Cover Photo:
Aerial view of a riparian area in the North Saskatchewan River basin, captured from an unmanned aerial vehicle. Credit: Fiera Biological Consulting Ltd.

Suggested Citation:

Fiera Biological Consulting Ltd. 2019. Riparian Assessment Validation for North Saskatchewan Region Lakes. Fiera Biological Consulting Report #1853. Prepared for the Alberta Environment and Parks, Policy and Planning Division, Edmonton, Alberta. Pp. 45.

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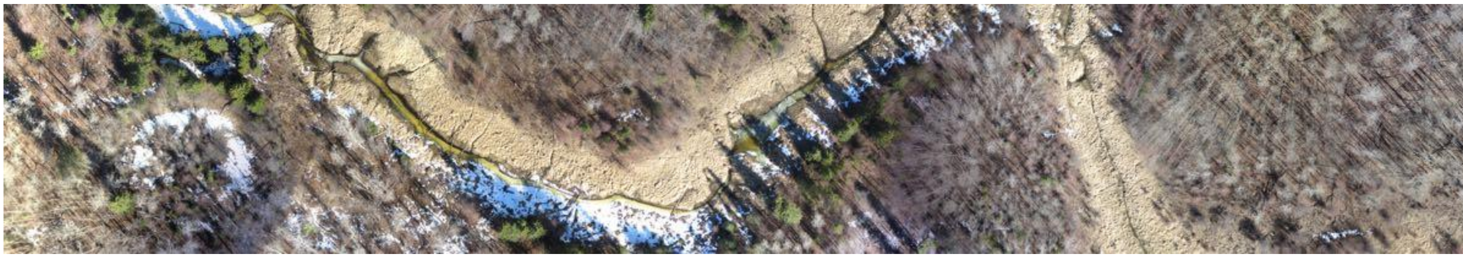

List of Terms

Abbreviations

AEP: Alberta Environment and Parks

GIS: Geographic Information System

GOA: Government of Alberta

RMA: Riparian Management Area

Glossary

Aerial Videography: Video captured from a low flying aerial platform, such as helicopter.

Intactness: In reference to the condition of natural habitat, intactness refers to the extent to which habitat has been altered or impaired by human activity, with areas where there is no human development being classified as high intactness.

Metric: A qualitative or quantitative variable that can be measured (quantified) or described (qualitatively) and demonstrates either a trend in an indicator or whether or not a specific threshold was met.

Riparian Area, Riparian Habitat, Riparian Land, or Riparian Zone: Transitional areas between upland and aquatic ecosystems that have variable width and extent both above and below ground. These lands are influenced by and/or exert an influence on associated water bodies, which includes alluvial aquifers and floodplains, when present. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and/or hydrological processes.

Riparian Management Area: As per Teichreb and Walker (2008), and for the purpose of this report, a Riparian Management Area is defined as an area along the shoreline of a waterbody that includes near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone.

Waterbody: Any location where water flows or is present, whether or not the flow or the presence of water is continuous, intermittent, or occurs only during a flood. This includes, but is not limited to lakes, wetlands, aquifers, streams, creeks, and rivers.

Watercourse: A natural or artificial channel through which water flows, such as in creeks, streams, or rivers.

Watershed: An area that, on the basis of topography, contributes all water to a common outlet or drainage point. Watersheds can be defined and delineated at multiple scales, from very large (e.g., thousands of square kilometers, such as the North Saskatchewan River watershed) to very small local watersheds (e.g., square metres, such as a small prairie wetland).

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1.0 Introduction

1.1. Project Background & Context

Riparian areas provide a multitude of ecosystem functions, including water quality improvement, sediment removal, nutrient cycling, bank stabilization, and flood reduction. While these habitats provide a wide range of benefits to human communities, the loss and impairment of riparian lands in Alberta has been significant, and recent watershed management efforts throughout the province have been focused on identifying priority areas for riparian restoration and habitat management. In order to efficiently target restoration efforts and resources, however, there first needs to be reliable information about the location, condition, and function of riparian habitats.

At present, there is little information about the location and extent of riparian habitat in Alberta, and the condition of these habitats is typically assessed at a site-specific or reach-scale using either ground-based surveys, airborne videography, or stereo air photo interpretation methods. These approaches tend to be labour intensive and costly, and often rely on subjective and qualitative metrics to assess the condition of riparian vegetation. While these methods are useful for gathering information about the general condition of riparian habitat at small spatial extents, there is a need for a more rigorous and objective approach to riparian condition assessments. Further, developing reliable and cost-effective methods that allow for the standardized assessment of riparian condition at different spatial resolutions (e.g., very detailed and fine-scale versus general and coarse-scale), and that can be tailored to the type and quality of available data (e.g., expensive and high resolution versus freely available and lower resolution) is an important step in improving riparian management outcomes across the province.

Given the large area of riparian habitat within Alberta, Fiera Biological responded to the pressing need to develop a riparian condition assessment method that is rapid, reliable, repeatable, comparable, and objective. This GIS-based assessment method allows for a general assessment of riparian condition for stream and lake shorelines using land cover layers derived from satellite data, thereby allowing for the mapping and assessment of riparian habitats over large spatial extents. The approach provides an overview of the status of riparian health at the watershed scale, which allows land managers to direct restoration activities, management efforts, and financial resources towards the areas where there is the greatest need.

In the spring of 2018, this GIS riparian assessment method was used to assess nearly 900 km of stream and lake shoreline in the Pigeon, Gull, Sylvan, and Buffalo lake watersheds (Fiera Biological 2018a), using land cover data derived from the most recent SPOT satellite imagery available (2016 for Gull and Sylvan and 2017 for Buffalo and Pigeon). When initially developed, this GIS-based approach was validated against videography-based assessments and performed well (Fiera Biological 2018b); however, for AEP to have confidence in the results of this work, and extend the method to other regions of the province, further validation of both the land cover inputs into the model and the intactness scores provided by the model is required. Because of known issues discerning particular land classes (e.g., pasture versus open/natural ground cover) and limitations associated with using satellite imagery to assess condition on the ground (e.g., image resolution, features obscured by tree cover) it is important to assess both the land cover and intactness scores critically so that the results from future assessments can be trusted and the purpose of the GIS-based approach fully understood and appreciated.

1.2. Study Goal and Objectives

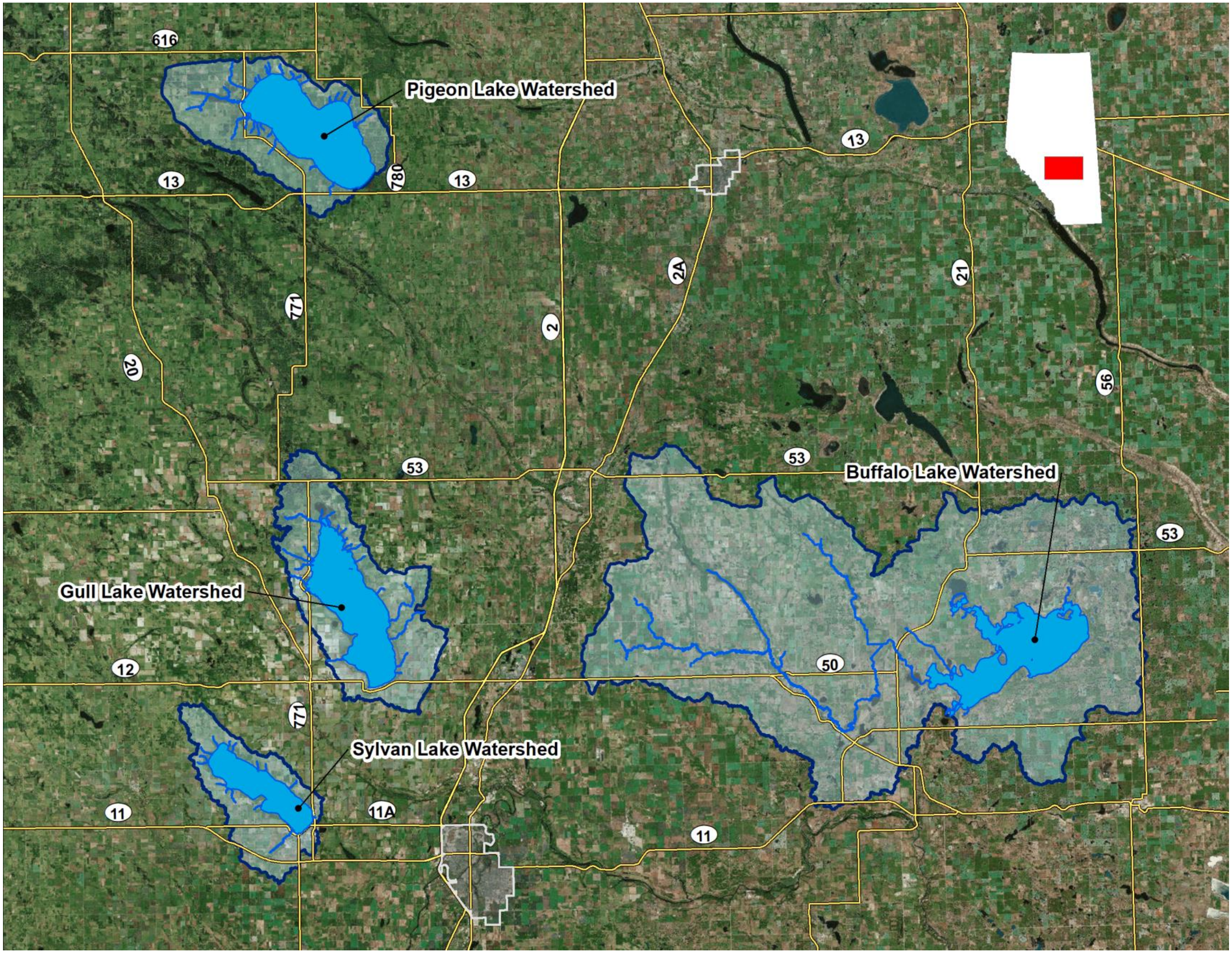
The overall goal of this project was to assess the performance of the GIS-based method used to evaluate the intactness of riparian habitats along the shorelines of Pigeon, Gull, Sylvan, and Buffalo lakes and their associated tributaries. This involved both desktop and field approaches to validation. In order to accomplish the project goal, the following major objectives were defined for this project:

1) Perform a desktop accuracy assessment of the land cover layers that were created for each watershed;
2) Perform an accuracy assessment of GIS-derived intactness scores using validation data collected in the field and during a desktop-based validation assessment;
3) Test of ability of the GIS assessment approach to capture relative differences in intactness locally and regionally.

The results of this validation work provide the Government of Alberta with information about the accuracy and suitability of the GIS-based method to characterize riparian intactness along lake shorelines in central Alberta. Additionally, this report outlines issues that should be considered in the creation and development of land cover layers that are used to assess riparian condition, as well as considerations for how to modify the GIS method to improve the accuracy and reliability of the tool.

1.3. Study Areas

This study included the watersheds of four lakes: Pigeon, Gull, Sylvan, and Buffalo (Map 1). These large lakes are located in the Parkland Natural region, have various degrees of shoreline development, and are considered important recreational lakes in central Alberta.



Map 1. Location of the four lakes and the associated tributaries that were assessed within each lake watershed included in this study.

2.0 Methods

2.1. Accuracy Assessment of Land Cover

The land cover classifications that were created to conduct the riparian assessment of the Pigeon, Sylvan, Gull, and Buffalo lake watersheds are foundational to the quantification of the riparian intactness scores. The land cover layers are used to identify the start and end of each RMA polygon, as well as to quantify the metrics that are used to derive the overall intactness score within each riparian polygon. Thus, having a land cover layer that meets an acceptable standard for overall and within-class accuracy is essential to ensuring a reliable prediction of riparian management area intactness. In particular, for land cover classes that are known to have a large influence on intactness scores, and for which there is common confusion between classes (e.g., low open natural and agricultural pasture), it is essential to ensure an acceptable level of classification accuracy. Further, because the land cover classification is derived using imagery taken from a nadir (overhead) angle, certain vegetation classes (e.g., forest) may obscure human footprint; therefore, understanding the degree to which this may be an issue in the assessment of riparian intactness using the GIS tool is important.

Given that the land cover layers used for this riparian assessment were derived using imagery from 2016 (for Gull and Sylvan lakes) and 2017 (for Pigeon and Buffalo lakes), the validation and accuracy assessment of the land cover was primarily a desktop exercise that included validation of randomly selected points, as well as randomly selected polygon objects. For each watershed, a limited number of randomly generated points were also visited in the field. A detailed description of each of these validation methods is provided below.

2.1.1. Point-based Validation

While a wall-to-wall land cover was created for each lake watershed, for the purpose of the riparian assessment, the accuracy of the land cover is most important within the 50 m riparian management area buffer because it is this area that is used to calculate the intactness metrics. Consequently, we restricted the land cover accuracy assessment to the 50 m buffer along the shorelines of the waterbodies that were included in the study. A stratified sample of 1001 random points was generated within ArcGIS to perform the desktop land cover validation. The random points were stratified by watershed and based on the proportional coverage of each land cover class; therefore, the largest watershed and the land cover classes with the greatest coverage were allotted a greater number of validation points. A minimum distance between random points was set to 50 m. The number of points allotted to each watershed and land cover class is summarized in Table 1. Definitions for each of the land cover classes included in this classification are provided in Table 2.

Table 1. Land cover class coverage within the 50 m riparian management areas that were associated with the shorelines included in this study for each lake watershed. The proportional coverage of each class by watershed was used to stratify and allot random points for land cover validation.

Watershed	**Land Cover Class**	**Area in hectares (proportion)**	**Number of Validation Points**
Buffalo	Crops	190.5 (4.8%)	48
	Disturbed vegetation	94.0 (2.3%)	23
	Exposed developed	26.5 (0.7%)	7
	Forest/woody cover	396.1 (9.9%)	99
	Natural exposed	2.9 (0.1%)	1
	Natural open	831.9 (20.8%)	208
	Open water	49.9 (1.2%)	12
	Open water other	5.0 (0.1%)	1
	Pasture	478.2 (12.0%)	120
	Road verge	34.6 (0.9%)	9
	Road	19.9 (0.5%)	5
Gull	Crops	102.0 (2.6%)	26
	Disturbed vegetation	25.2 (0.6%)	6
	Exposed developed	35.8 (0.9%)	9
	Forest/woody cover	150.6 (3.8%)	38
	Natural exposed	28.8 (0.7%)	7
	Natural open	282.1 (7%)	70
	Open water	6.0 (0.1%)	1
	Open water other	2.5 (0.1%)	1
	Pasture	97.2 (2.4%)	24
	Road verge	19.3 (0.5%)	5
	Road	10.6 (0.3%)	3
Pigeon	Crops	22.9 (0.6%)	6
	Disturbed vegetation	44.9 (1.1%)	11
	Exposed developed	55.9 (1.4%)	14
	Forest/woody cover	380.4 (9.5%)	95
	Natural exposed	0 (0%)	0
	Natural open	145.3 (3.6%)	36
	Open water	8.6 (0.2%)	2
	Open water other	1.3 (0%)	0
	Pasture	26.2 (0.7%)	7
	Road verge	34.1 (0.9%)	9
	Road	24.3 (0.6%)	6
Sylvan	Crops	37.1 (0.9%)	9
	Disturbed vegetation	25.0 (0.6%)	6
	Exposed developed	26.4 (0.7%)	7
	Forest/woody cover	182.1 (4.6%)	46
	Natural exposed	0.3 (0%)	0
	Natural open	44.1 (1.1%)	11
	Open water	4.7 (0.1%)	1
	Open water other	0.2 (0%)	0
	Pasture	23.6 (0.6%)	6
	Road verge	15.3 (0.4%)	4
	Road	9.6 (0.2%)	2
	Total	**4,001.5 (100%)**	**1001**

Table 2. Cover classes that were included in the land cover classification that was created using SPOT imagery and used to assess riparian area intactness for Pigeon, Gull, Sylvan, and Buffalo Lakes.

Class Name	Description
Crops	Agricultural land primarily used for cultivated crops
Disturbed vegetation	Vegetation that has been disturbed by human activity, such as farm yards, residential lawns, or other manicured vegetation
Exposed developed	Bare ground that is human-caused or caused because of human-related activities (e.g., bare soil on river banks where livestock are highly active and have caused bare soil)
Forest/woody cover	Upland and lowland areas dominated by deciduous or coniferous trees typically >2 m in height, or areas dominated by other woody vegetation (e.g., shrubs or immature trees) between 1 and 2 m in height
Natural exposed	Naturally occurring areas of bare rock or mineral soil (e.g., exposed banks), or naturally occurring sandy areas
Natural open	Upland areas dominated by low (non-woody) vegetation, such as grasses and forbs, and non-treed wetlands
Open water	Deep open water habitat
Open water other	Open water that is not naturally occurring (e.g., lagoons or marinas), and manmade features associated with water bodies such as docks that extend out into the water body
Pasture	Agricultural land primarily used as pasture; includes lands grazed at many different intensities and frequencies (e.g., rough pasture, tame pasture, range lands)
Road verge	Disturbed vegetation directly adjacent to roads, typically associated with the road ditch
Road	Gravel and paved road surfaces

Personnel who were highly experienced in image interpretation manually performed the validation exercise for each lake watershed using the same 6 m SPOT imagery that was used to create the land cover layers. In order to assess accuracy, the class associated with the point location derived using the imagery was assumed to be the ‘ground-truth’ or ‘reference’ condition, and the land cover class that was associated with each validation point was extracted and compared to the class that was derived from the image interpretation.

Confusion matrices were used to compare the class from the land cover layer to the class in the reference datasets. All four watersheds were evaluated together and individually, and tests were performed comparing the original 11 land cover classes, as well as by using a compiled class approach, in which the 11 classes were grouped into 5 metric-relevant classes. This second approach was used because confusion between some classes does not affect the calculation of the intactness metrics. For example, if crops are misclassified as pasture, this would not affect the calculation of the human cover metric because both classes are considered equally when calculating the human footprint metric. Combining classes resulted in a 5-class land cover with the following metric-relevant classes: Human footprint (Crops, Disturbed vegetation, Exposed developed, Open water other, Pasture, Road verge, Roads); Natural exposed; Natural open; Forest; and Open water.

2.1.2. Object-based Validation

In addition to the point validation exercise, an additional validation exercise based on polygon objects was performed. This second validation exercise was conducted because we used an object-based classification method to create the land cover layers, and there are theoretical and practical differences in how classes are assigned in an object-based classification compared to a traditional pixel-based classification. In a pixel-based classification, each pixel is classified individually, while in an object-based classification, pixels are first grouped into meaningful polygon objects, and then each object is classified into a land cover class. Object-based classifications tend to create smoother, more eye-pleasing classifications compared to pixel-based classifications; however, some fine-scale detail can be lost, since an object, especially when large, may include a small number of pixels that may be a different class than what was assigned to the larger object (e.g., a forest object with small gaps of open natural cover is classified as all forest). Because of the differences in the pixel-based and object-based approaches, there could be an unintended bias associated with using only points to test the accuracy of the land cover classification. Consequently, we thought it was important to also validate the land cover using photointerpretation of the polygon objects in the classification. The debate over the pixel-based versus object-based method for creating land cover classifications has received a lot of attention within the literature; however, rather than there being one “best” approach, each approach may be better or worse suited to a project depending on the end use of the classification and the type of imagery being used.

The random point locations were used to select a set of random objects for photointerpretation. Because some of the classification objects are large, more than one random point could exist in a polygon object when the point locations and the objects were overlaid. To eliminate double- and triple-counting of a validation object, objects associated with more than one sample point were considered only once. Thus, the object validation data set contained fewer total samples compared to the point dataset and had a total of 668 polygon samples. This number of samples was still judged to be sufficient to test the land cover classification since the total areal coverage of the selected polygons was just over half of the total land cover within the RMA buffers (2,046.9 ha out of a total of 4,001.5 ha).

The ground-truth or reference objects were assigned classes via photointerpretation using a combination of 1.5 m SPOT imagery and high resolution basemap imagery available within ArcGIS 10.6. The land cover class for the object and the reference class were then compared at the level of the entire classification (all watersheds combined) and for each individual watershed for both the 11-class and the aggregated 5-class land cover classification using confusion matrices.

2.1.3. Field Validation

A number of field validation points by land cover class were selected within each of the lake watersheds, and these points were visited between August 17 and 24, 2018. Because land cover validation points were selected such that they could be accessed and observed from a publically accessible road, a representative sample of all classes could not be created. Instead, classes known to have created confusion in previous land classifications and classes that are central to calculating the intactness metrics were selected for visitation. These classes included: Forest, Natural open vegetation, Crops, Pasture, Disturbed vegetation, and Exposed developed. For each point visited, observers recorded the land cover class that was present and made notes on land use or other activities that may have been relevant at the time of assessment.

2.2. Accuracy Assessment of RMA Intactness Scores & Categories

The intactness of riparian management areas is calculated using three different metrics that are combined together to derive a single score. These scores are then used to assign an RMA into one of four intactness categories based on percentile break thresholds. When the GIS assessment method was developed, the thresholds that were selected were generally based upon thresholds defined by the existing videography method. While the videography thresholds served as a good basis upon which to derive the GIS category threshold values, and there was generally good agreement between the videography and GIS condition categories, the methods used to derive the videography thresholds is unknown, nor is there any information available regarding how appropriate these thresholds are for assigning RMAs into High, Moderate, Low, or Very Low intactness categories. Thus, visiting a selection of RMAs in the field that were assigned to each intactness category and comparing these areas both within watersheds and between watersheds allows for a general assessment of whether the threshold values between intactness categories are appropriate.

Further, this field evaluation allowed for the identification of land cover features, such as low natural vegetation, naturally sandy or rocky areas, and human footprint (e.g., trails, sheds, embankments, etc.) that may be missed in the land cover classification because they are obscured by vegetation cover, or because the features are too small to be resolved by the 6 m SPOT imagery. Field validation also allows for the opportunity to generally confirm the accuracy of the land cover classification. Combined, this validation step allows for an evaluation of whether the scores assigned to each RMA are appropriate given what was documented in the field by the observer.

2.2.1. Field Validation

Given the challenges associated with accessing private lands to collect validation data, the field campaign focused entirely on assessing RMA scores along lake shorelines, where field data was collected via boat for Gull, Sylvan, and Buffalo lakes, and by truck for Pigeon lake. All field sampling occurred between August 17 and 24, 2018.

For each lake, there was a sampling target of 46 RMAs: with a target of 8 RMAs selected from the High and Very Low categories and 15 RMAs from each of the Moderate and Low categories (Table 3). We targeted a larger number of RMAs in the Moderate and Low categories because we felt that these were the categories where there was likely to be the greatest confusion or misclassification between categories. While 46 was the target sample number for each lake, we were only able to identify 34 RMAs along the shoreline of Gull lake that were suitable for sampling due to issues related to the number and character of RMAs for Gull lake (i.e., fewer total RMAs and RMAs that were either too short or too long to practically assess in the field) and shallow water depths that limited access to the shoreline. In total, 172 RMAs were identified for validation in the field.

Table 3. Number of RMAs by lake watershed and intactness category that were identified for assessment as part of the field validation.

Watershed	High	Moderate	Low	Very Low	Total
Buffalo	8	15	15	8	**46**
Gull	7	10	9	8	**34**
Pigeon	8	15	15	8	**46**
Sylvan	8	15	15	8	**46**
Total	**31**	**55**	**54**	**32**	**172**

At each RMA validation location, observers collected the following information:

- Dominant vegetation type;
- The type and extent of human disturbance, including shoreline modifications, structures, and land use;
- The extent to which vegetation cover obscured human footprint or other natural vegetation types;
- The extent to which human disturbance was missed in the land cover due to image resolution;
- The approximate distance from the observation point into the RMA;
- A subjective assessment of whether each of the RMA score and intactness category was appropriate given what the observer could see from their vantage point;

Observers also made notes regarding land use and activities that were relevant to assessing RMA intactness, as well as notes related to the accuracy of shoreline and RMA delineation. A photo was also taken at each validation location to document conditions. A copy of the field data sheet is provided in Appendix A.

2.2.2. Desktop & Field Comparison

While field ground-truthing is generally seen as the hypothetical ideal for validation, an important consideration and caveat is that the land cover created to assess intactness within each watershed was derived using imagery from either 2016 or 2017. Thus, there is a strong assumption that any field data collected in 2018 accurately represents the vegetation cover, lake water levels, and condition of the shoreline at the time the satellite imagery was captured. Further, because the RMAs extend 50 m from the shoreline of the lake or stream, in many cases, field personnel are not able to observe conditions within the entire riparian assessment area from the lake shoreline or roadway. As a result, for RMAs where the field data suggested that the intactness score and/or category was not appropriate, the field data was compared against the land cover layer, SPOT imagery, and high resolution imagery to determine why there was disagreement between the field-derived scores and the GIS-derived scores.

3.0 Results

3.1. Accuracy Assessment of Land Cover

3.1.1. Desktop Assessment Results

Overall, the accuracies of the land cover layers that were created for this assessment were considered reasonable for quantifying RMA intactness; however, results varied depending upon which accuracy assessment method was used (point- versus object-based), and whether accuracy was assessed using an 11-class or 5-class land cover (Table 4).

When using a point-based assessment and SPOT 6 m imagery as the reference, the overall accuracy of the 11-class land cover was 65%, while accuracy for the 5-class land cover was 75% (Table 4). Specific to lake watersheds, land cover accuracy ranged between 62% and 72% for the 11-class land cover, and between 71% and 81% for the 5-class land cover. For both land covers, accuracy in the Pigeon lake watershed was the highest, while accuracy in the Buffalo lake watershed was the lowest. Accuracy of the land cover for individual watersheds also improved using the object-based assessment, ranging between 81% and 89% for the 11-class land cover, and between 89% and 96% for the 5-class land cover.

Table 4. Accuracy scores for the various validation assessments performed as part of the land cover validation.

Watershed	Point-based Assessment		Object-based Assessment		Field Assessment
	11 Class	5 Class	11 Class	5 Class	11 Class*
All	65%	75%	86%	93%	85%
Buffalo	62%	71%	87%	92%	84%
Gull	70%	79%	81%	89%	90%
Pigeon	72%	81%	89%	96%	83%
Sylvan	60%	77%	84%	96%	89%

*The majority of the lands within the lake watersheds are private and were accessed via truck on public roads; therefore, access to field validation sites was limited and field validation data could only be collected for six of the eleven land cover classes, including: Crops, Disturbed vegetation, Exposed developed, Forest, Natural open, and Pasture.

For both the 11- and 5-class land covers, within-class accuracy was generally very good for classes that are spectrally distinct, such as Open water, Road, and Exposed developed (Table 5 and Table 6). Conversely, there was much more confusion between classes that are difficult to separate based on spectral reflectance alone. In particular, for the 11-class land cover, there was a large amount of within-class confusion in the Pasture, Natural open, Forest, and Disturbed vegetation classes (Table 5). Confusion between Pasture and Natural open was expected, as these classes were identified as being an issue early in the development of the GIS method because they are very similar spectrally and structurally (e.g., short vegetation), particularly in spring and mid-summer imagery. This class confusion is important in the context of the riparian assessment method because human footprint (including pasture) is treated differently from natural vegetation, and so confusion between these two classes can have a large influence on intactness scores. As a result, the Pasture and Open natural classes received considerable attention during the QA/QC and manual clean-up of the land cover layers.

Unexpectedly, when using the point-based validation we found a fairly high degree of class confusion for the Forest class; however, this was markedly reduced when we used an object-based validation approach (Table 6). This result can likely be explained by the “segmentation level” that is selected for an object-based classification. The segmentation level sets the lower threshold for the size of polygons that are created in an object-based classification, and often, if the segmentation level does not extract small features within a larger feature, such as a small open areas in a forest patch or a small stand of trees within a large pasture, then the small features are classified along with the larger feature (Figure 1). In the case of the land cover created for this assessment, it appears that the segmentation level may have been too coarse, which likely explains the class confusion we see within the Forest class, and to some degree, within the Natural open class.

While there was a substantial amount of class confusion in the 11-class land cover, much of the confusion was between classes that were similar in terms of how the riparian intactness metrics treats larger land cover types (e.g., natural vegetation versus human footprint). For example, Pasture and Crops can be classified separately in a land cover with high thematic resolution, but can also be classed together as “Agriculture”, or can be further lumped together with other classes into a “Human footprint” class. When classified separately, there is a much greater chance that the overall accuracy of the land cover will be lower, due to misclassification of each individual class. Generally speaking, when thematic resolution is high, there is a much greater likelihood of misclassification and a lower land cover accuracy. When we grouped the 11 land cover classes into a smaller number of classes, which are still relevant in the context of assessing RMA intactness in a GIS environment, the overall accuracy of the land cover increased substantially (Table 4), as did the class accuracy (Table 7 and Table 8). This highlights the trade-offs that exist between creating a land cover with high thematic resolution, versus one with less resolution, but higher overall accuracy.

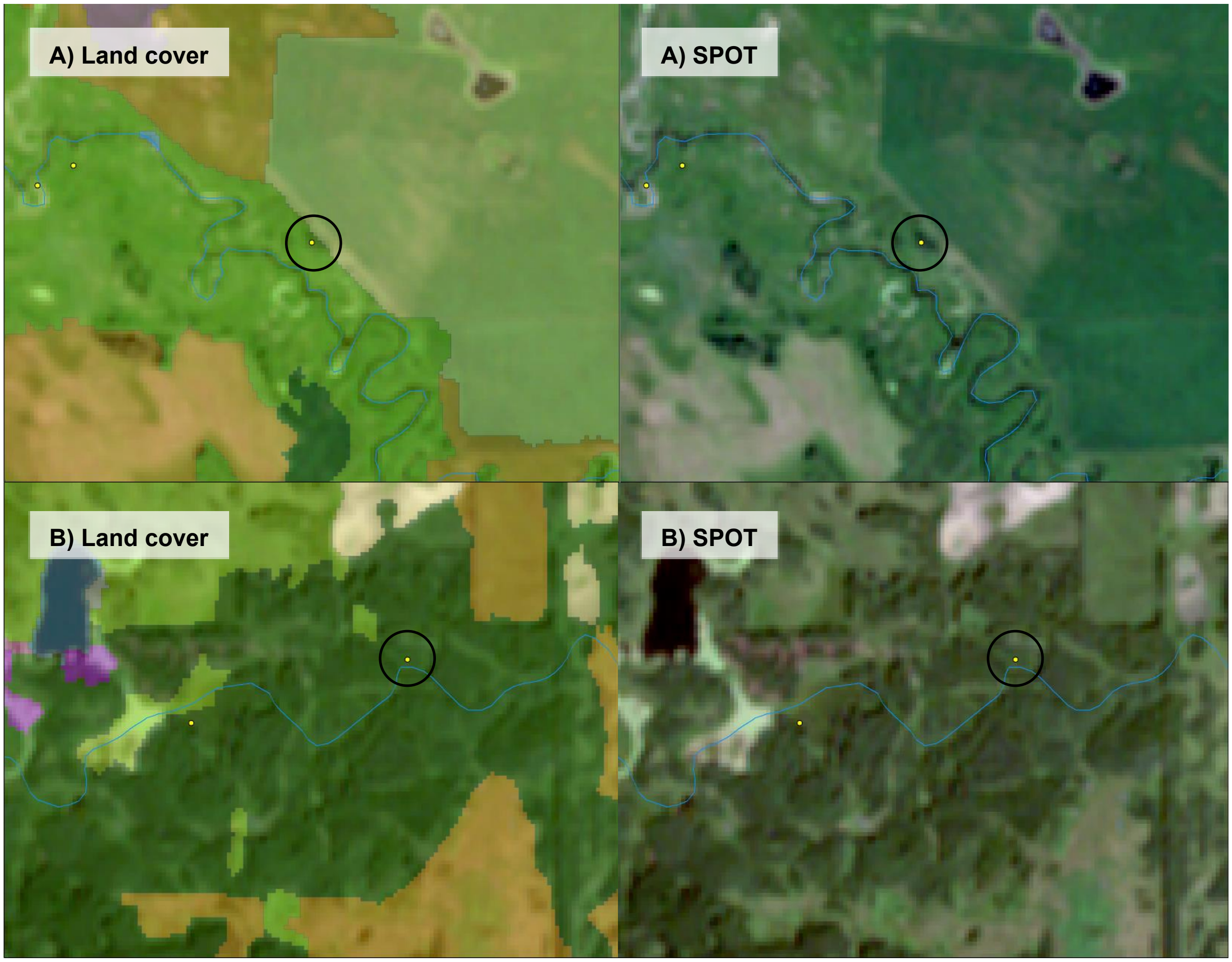


Figure 1. Examples of cases in which the segmentation level set for the object-based classification missed small features that were detected in the point-based accuracy assessment. In example A, a small patch of trees (circled in black) was classified as part of a larger natural open polygon. In example B, a small natural open area (circled in black) was included as part of the larger forest polygon. In both cases, the thematic class of the polygon is correct, but the class associated with the yellow validation point does not agree with the polygon class.

Table 5. Accuracy results comparing the 11-class land cover to the point-based validation classes derived from SPOT 6 m imagery. The class accuracy is the proportion of points that were correctly identified, out of total points validated from that class. Total accuracy is reported in the bottom right-hand corner.

Land Cover Class	Point-based Validation Class: Crops	Disturbed vegetation	Exposed developed	Forest	Natural exposed	Natural open	Open water	Open water other	Pasture	Road verge	Road	Class Accuracy (%)
Crops	**52**	3	0	4	0	9	0	0	21	1	0	57.8
Disturbed vegetation	3	**19**	6	3	0	2	1	0	11	1	0	41.3
Exposed developed	0	3	**27**	2	0	2	0	0	0	3	0	73.0
Forest	4	20	2	**186**	0	63	1	0	3	0	0	66.7
Natural exposed	0	2	0	0	**2**	3	0	0	1	0	0	25.0
Natural open	3	8	1	17	3	**246**	16	0	27	2	1	75.9
Open water	0	1	1	0	0	4	**6**	2	0	0	0	42.9
Open water other	0	0	0	0	0	0	0	**3**	0	0	0	100
Pasture	14	6	3	3	0	35	0	1	**95**	0	0	60.5
Road verge	0	1	7	4	0	0	0	0	1	**8**	6	29.6
Road	0	3	3	0	0	0	0	0	0	3	**7**	43.8
											Total Accuracy	**65.0**

Table 6.Accuracy results comparing the 11-class land cover to the object-based validation classes derived from high resolution imagery. The class accuracy is the proportion of points that were correctly identified, out of total points validated from that class. Total accuracy is reported in the bottom right-hand corner.

Land Cover Class	Object-based Validation Class: Crops	Disturbed vegetation	Exposed developed	Forest	Natural exposed	Natural open	Open water	Open water other	Pasture	Road verge	Road	Class Accuracy (%)
Crops	**50**	1	0	0	0	1	0	0	11	0	0	79.4
Disturbed vegetation	0	**20**	0	1	0	1	0	0	16	0	0	52.6
Exposed developed	0	5	**27**	0	0	2	0	0	0	0	1	77.1
Forest	0	3	0	**197**	0	3	0	0	0	0	0	97.0
Natural exposed	0	1	0	0	**2**	3	0	0	1	0	0	28.6
Natural open	0	0	0	5	0	**165**	0	0	12	0	0	90.7
Open water	0	0	0	0	0	2	**6**	0	0	0	0	75.0
Open water other	0	0	0	0	0	0	0	**3**	0	0	0	100
Pasture	1	0	0	0	0	7	0	0	**84**	0	0	91.3
Road verge	0	6	4	5	0	1	0	0	0	**10**	0	38.5
Road	0	0	0	0	0	0	0	0	0	0	**11**	100
											Total Accuracy	**86.1**

Table 7. Within-class accuracy results comparing the 5-class land cover to the point-based validation classes derived from SPOT imagery. The class accuracy is the proportion of points that were correctly identified, out of total points validated from that class. Total accuracy is reported in the bottom right-hand corner.

Land Cover Class	Point-based Validation Class: Human footprint	Natural exposed	Natural open	Open water	Forest	Class Accuracy (%)
Human footprint	**311**	0	48	1	16	82.7
Natural exposed	3	**2**	3	0	0	25
Natural open	42	3	**246**	16	17	75.9
Open water	4	0	4	**6**	0	42.9
Forest	29	0	63	1	**186**	66.7
					Total Accuracy	**75.0**

Table 8. Within-class accuracy results comparing the 5-class land cover to the object-based validation classes derived from high resolution imagery. The class accuracy is the proportion of points that were correctly identified, out of total points validated from that class. Total accuracy is reported in the bottom right-hand corner.

Land Cover Class	Object-based Class: Human footprint	Natural exposed	Natural open	Open water	Forest	Class Accuracy (%)
Human footprint	**250**	0	12	0	6	93.3
Natural exposed	2	**2**	3	0	0	28.6
Natural open	12	0	**165**	0	5	90.7
Open water	0	0	2	**6**	0	75.0
Forest	3	0	3	0	**197**	97.0
					Total Accuracy	**92.8**

3.1.2. Field Assessment Results

The overall accuracy for land cover classes that could be assessed from road locations (Crops, Disturbed vegetation, Exposed developed, Forest, Natural open, Pasture) was 85% (Table 9), with the accuracy for individual watersheds ranging between 83% for Pigeon and 90% for Gull (Table 4). In contrast to the desktop validation results, the accuracy of the Natural open and Forest classes was high. Interestingly, field validation results revealed that much of the confusion between Pasture and Natural open occurred in areas where the pasture could be considered "rough" pasture (i.e. non-intensive grazing pasture, typically associated with poor soils), which is spectrally and visually similar to natural open areas in the SPOT 6 m imagery. We also found more confusion between these classes in areas where there was a patchy, complex mixture of pasture, forest, and natural open vegetation that was difficult to distinguish in the SPOT 6 m imagery.

Field notes from the validation provided additional information with regards to the issue related to segmentation level of the object-based classification. In many cases, it was noted that the size of the land cover polygon object was too big, and captured smaller areas of distinct land cover classes that were being lumped together into a single land cover object. In these cases, the dominant land cover was correctly identified; however, smaller patches that could have been classified as distinct land cover units (e.g., a small forest stand in an agricultural field) were not being distinguished in the classification. As well, the majority of the "Natural open" polygons were identified as being wetlands in the field, many of which were shrubby fen or swamp wetlands with tall shrubs or trees.

Table 9. Within-class accuracy results for the 6 land cover classes that could be assessed in the field from road locations. The class accuracy is the proportion of points that were correctly identified, out of total points validated from that class. Total accuracy is reported in the bottom right-hand corner.

		Field Class						Class Accuracy (%)
		Crop	**Disturbed vegetation**	**Exposed developed**	**Forest**	**Natural open**	**Pasture**	
Land Cover Class	**Crop**	**15**	0	1	0	0	2	83.3
	Disturbed vegetation	0	**17**	1	2	2	3	68
	Exposed developed	0	0	**7**	1	0	0	87.5
	Forest	0	0	0	**35**	0	0	100
	Natural open	0	3	0	2	**49**	5	83.1
	Pasture	1	2	0	0	2	**33**	86.8
							Total Accuracy	**85.2**

3.2. Accuracy Assessment of RMA Intactness Scores & Categories

3.2.1. Field Validation

Of the 172 RMAs that were targeted for validation, a total of 161 were visited in the field (Table 10). Eleven RMAs, all located in the Pigeon Lake watershed, could not be assessed due to access issues or other restrictions.

Table 10. Total number of RMAs that were assessed in the field, summarized by lake and intactness category.

Watershed	High	Moderate	Low	Very Low	Total
Buffalo	8	15	15	8	**46**
Gull	7	9	9	8	**34**
Pigeon	6	11	10	8	**35**
Sylvan	8	15	15	8	**46**
Total	**29**	**50**	**49**	**32**	**161**

A primary objective of the field validation was to evaluate whether the GIS-derived intactness scores and corresponding categories were appropriate given the conditions that were observed in the field. For 54% of the RMAs that were assessed in the field, the view of the 50 m buffer was obstructed by vegetation, steep banks, or other features, and for approximately 13% of the RMAs, the observer estimated that less than 10 m of the buffer could be seen. Consequently, for the majority of RMAs assessed in the field as part of this validation project, intactness was evaluated based only upon what could been seen by the observer, and not on the condition of the entire 50 m buffer. Further, RMAs were either viewed from a boat or truck, and in many instances, the observer was limited by how close to the shore or property line they could get, and often had to view the RMA from a distance of 50 m or more. Finally, given that the observer was typically some distance away from the RMA, precisely determining the start and end point of the RMA in the field was difficult; thus, accurately determining the extent of the RMA that was to be evaluated in the field was challenging. All of these limitations of the field validation should be kept in mind when reviewing the results below.

For each RMA that was visited, the observer made a subjective assessment of whether the GIS-based score and category was appropriate based upon the type, extent, and density of human disturbance that could be observed, along with the amount and type of natural vegetation present. Typical examples of each RMA intactness category are presented in Figure 2. These examples also illustrate the limited extent to which the entire RMA could be viewed and assessed while in the field.

High Intactness Category

Moderate Intactness Category

Low Intactness Category

Very Low Intactness Category

Figure 2. Photos illustrating typical examples of RMAs within each intactness category.

Initially, 62 of the 161 RMAs that were assessed in the field were judged by the observer to have been assigned the wrong category and/or score. While field validation of RMA categories and scores provides important information on, and insights into, how to improve the GIS model, there are also limitations associated with conducting RMA validation in the field. Perhaps most significantly, field validation is limited in the extent to which the observer can see the entirety of the RMA, and in most cases, it is difficult for the observer to perceive the shape and extent of the RMA that defines the unit of assessment. Further, while the field validation was performed by a very experienced biologist, the determination of whether the RMA was correctly scored and classified into an intactness category was largely subjective. Given these limitations, we carefully examined the RMAs for which there was a disagreement between the field observer and the GIS method, to determine whether the field assessment misclassified the RMA due to issues of subjectivity or limited field of observation. Based on this assessment, the GIS-derived scores and categories for 16 of the 62 RMAs examined in detail (26%) were determined to be accurate, despite what the observer had indicated in their field notes.

The overall agreement between the field and GIS when considering the intactness category was 77% (Table 11). The highest level of agreement between the field observer and the GIS model was in the Very Low category (88%), followed by the Low (82%), High (72%), and Moderate (69%) categories (Figure 3 – All Lakes). When agreement is examined for each individual lake, the subjective assessment of the observer agreed with the GIS-based categories for 83% of the RMAs assessed at Buffalo Lake, 80% at Sylvan Lake, and 71% of the RMAs assessed at Gull and Pigeon Lakes (Table 11). When agreement for each lake is examined by intactness category, there was 100% agreement in the High and Very Low categories at Buffalo Lake, 80% agreement in the Moderate category, but only 67% agreement in the Low category (Figure 3 – Buffalo Lake). At Gull Lake, the level of agreement for the High (86%), Moderate (70%), and Low (78%) categories was very good; however, there was a only 50% agreement in the Very Low category (Figure 3 – Gull Lake). At Pigeon Lake, the agreement in the Low and Very Low categories was very good (100%); however, agreement in the Moderate (36%) and High (50%) categories being quite low (Figure 3 – Pigeon Lake). Finally, agreement in the Very Low (100%), Low (87%), and Moderate (80%) categories at Sylvan Lake was very good, with the agreement in the High category being only 50%; Figure 3 – Sylvan Lake).

Table 11. Number of RMAs where there was disagreement between the observer and GIS category.

Lake	Agree	Disagree	Total
Buffalo	38 (83%)	8 (17%)	46
Gull	24 (71%)	10 (29%)	34
Pigeon	25 (71%)	10 (29%)	35
Sylvan	37 (80%)	9 (20%)	46
Total	124 (77%)	37 (23%)	161

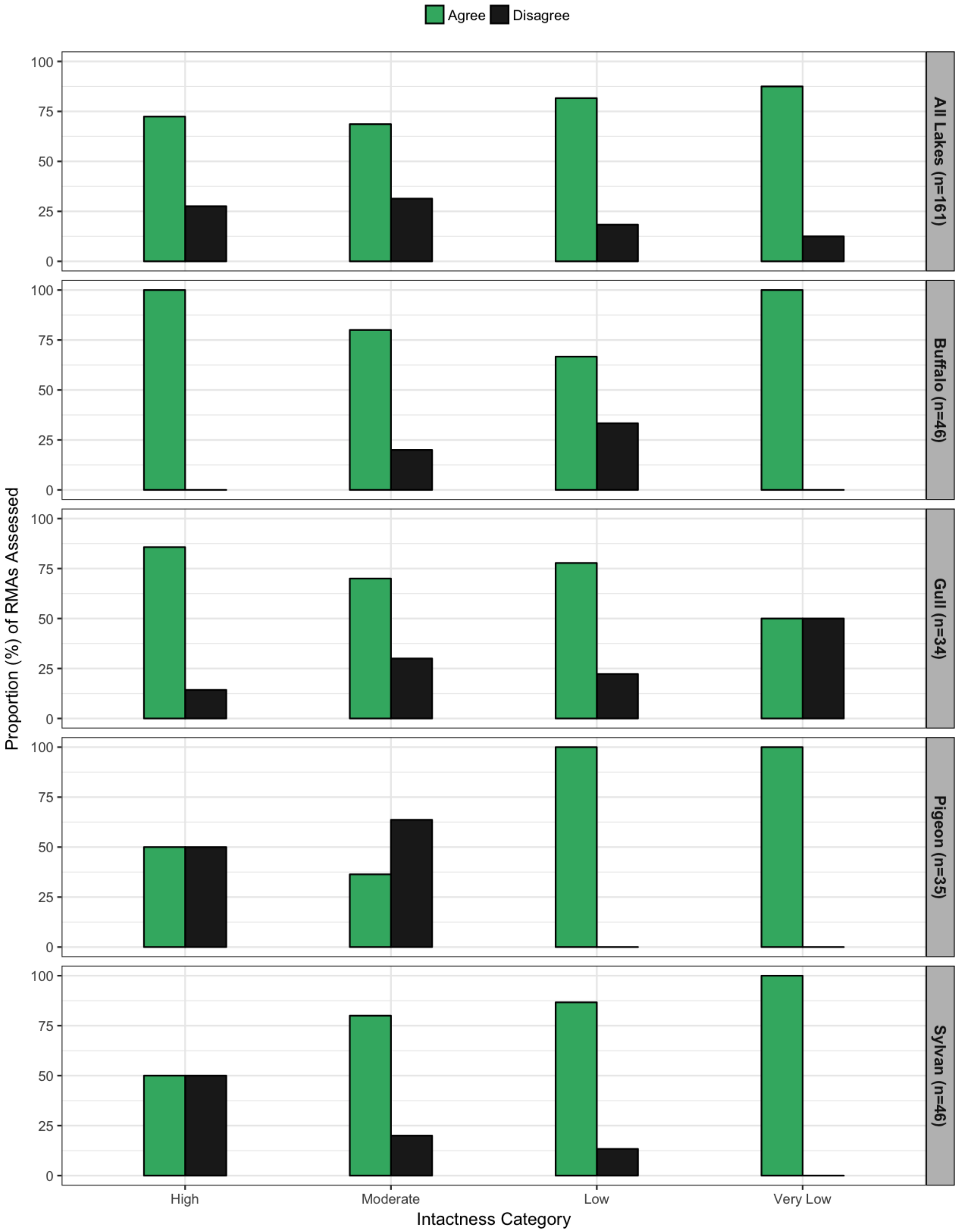


Figure 3. Level of agreement for the Intactness category derived using the GIS-based assessment method versus the subjective assessment made by the field observer, summarized by lake and by intactness category.

For the RMAs that the observer felt had been assigned to the wrong intactness category, a subjective decision was made in the field regarding which intactness category was more appropriate, based upon the type, amount, and intensity of human disturbance and natural vegetation that was observed. For RMAs assigned to the High or Moderate category by the GIS tool, there was generally a reassignment by one category (Table 12). In three instances, the observer felt that the length of the RMA was not appropriate, and should be split to be more representative of the conditions in the field. For example, RMAs where there was an obvious change between natural vegetation and human disturbance that did not appear to have been captured by the GIS tool through the creation of a new RMA were flagged as being an instance where the RMA should have been split into multiple units that would have been more representative of condition. For RMAs that were assigned to the Low and Very Low categories there was slightly more variation in what the observer felt was an appropriate alternative, with three instances of the observer feeling that the RMA would have been more appropriately placed in the High Category.

Table 12. Comparison of the intactness category that was assigned using the GIS tool, versus the intactness category that the observer felt was more appropriate for the 48 RMAs where there was disagreement between the field and GIS category assignment.

		Field Validated Category							
		H	**H or M**	**M**	**M or L**	**L**	**L or VL**	**VL**	**Split RMA**
GIS Category	**H**	---	0	7	0	0	0	0	1
	M	2	0	---	0	10	1	1	2
	L	1	2	4	0	---	0	2	0
	VL	2	0	0	2	0	0	---	0

In addition to validating the intactness categories, field observers subjectively assessed intactness scores for each RMA that was visited in the field. This is because in some cases, the intactness category may have been considered to be appropriate, but the score of the RMA within the intactness category was considered by the observer to be either too high or too low. Generally, the pattern of agreement with intactness scores was similar to the pattern observed for the intactness categories, with an overall agreement of 69%. When scores were examined by intactness category for all lakes combined, agreement was relatively good for the Very Low (84%), Low (78%), and High (72%) categories, while agreement was only 49% for the Moderate category.

In the instances where the observer decided that the GIS-derived RMA score was not appropriate, they made a determination regarding whether the GIS score was too high or too low (Table 13). Generally speaking, RMA scores at Buffalo and Gull Lakes were more frequently considered to be too low, while scores at Pigeon and Sylvan were more frequently considered to be too high.

Table 13. Number of RMAs where there was disagreement between the observer and GIS score.

Lake	**Too High**	**Too Low**	**Total**
Buffalo	4 (31%)	9 (69%)	13
Gull	4(33%)	8 (67%)	12
Pigeon	10 (100%)	--	10
Sylvan	14 (100%)	--	14
Total	32 (65%)	17 (35%)	49

3.2.2. Desktop & Field Comparison

For the 46 RMAs that were assessed in the field, and for which the initial desktop and field comparison confirmed that the GIS category or score was incorrect, we reviewed high resolution imagery, SPOT imagery, and the land cover layer to diagnose the issue (or issues) that may be causing the error. This review resulted in the identification of the following issues:

- **RMA buffer delineation**: Instances where the shape of the RMA buffer that is automatically generated in ArcGIS based upon the shoreline delineation creates a buffer shape that does not appropriately capture condition in the RMA.
- **Shoreline delineation**: Instances where the delineation of the shoreline is not accurate, resulting in calculation of intactness that is not representative of the riparian management area.
- **Classification of land use versus land cover**: Instances where the land cover (e.g., sand) can have multiple land uses (e.g., a public beach or sandy area with little or no human use), and the land cover class assigned to the area can either be a natural land cover class (e.g., Natural exposed) or a land cover class associated with human disturbance (e.g., Exposed developed). The classification as a natural cover class versus one associated with human footprint has implications for the final score of the RMA.
- **Misclassification of land cover**: Instances where there is an error in the land cover class assigned to a feature. For example, the class label “Forest” is applied to a feature that should have been labelled “Road”.
- **Image resolution**: Instances where there is a misclassification of land cover because the SPOT image resolution is too coarse to capture the feature(s) of interest.
- **Land cover issue related to roads**: The land cover created for this assessment included a “Road verge” class, which was a static buffer that was applied to all roads to classify the disturbed vegetation that occurs alongside roads and within road ditches. This road verge results in a fairly large area that is treated as human footprint in the riparian assessment, and in some cases, the effect that the road and its associated road verge has on the RMA score may not be appropriate.
- **Land cover issue related to woody vegetation**: One of the intactness metrics is the proportion of the RMA that is covered by land cover classes that contain woody vegetation. Depending on the thematic resolution of the land cover, there may be a “shrub” class, but because this is a difficult class to accurately classify, land cover classifications may not have such a class and instead, woody vegetation such as tall shrubs are often classified together with trees. The land cover created for this assessment did not include a “shrub” category, and we chose to classify shrubs into the Forest class to create a single woody cover class. In many cases, however, we found that shrubby areas, especially wetlands with shrub cover, were classified into the “Open natural” class, rather than the “Forest” class, which affected the woody vegetation metric score.
- **Tree canopy obstructing human footprint**: Instances where human footprint is present, but cannot be detected in the satellite image because of the presence of overhead tree cover.
- **Sensitivity of the moving window to detect change**: RMAs are created using a moving window that quantifies the amount of vegetation cover within 10 m of the shoreline. When the GIS method was first developed, this distance was tested against a number of other distances to select the value that was considered to be most sensitive to meaningful changes in the amount of shoreline vegetation present; however, this value may not be appropriate in all instances.

The results of this review, including notes describing what was observed in the field, along with the notes recorded as part of the desktop validation of the RMA categories and scores, is provided in Table 14.

Table 14. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Buffalo	U31	No	Too high	No	58.4	M	L	Shoreline delineation is not correct in this location; RMA is in Provincial park and included public beach area	**Shoreline delineation issue** - Beach looks like built structure in images & was treated like docks in shoreline delineation
Buffalo	U60	No	Too low	No	30.5	L	M	From boat this RMA looks more intact than it was scored, but perhaps can't see disturbance beyond the trees on the shoreline - airphoto suggests human disturbance in RMA, but I can't see this from the boat	**Land cover (road and woody) issue** - trees classified as Open natural and road verge is large so lack of woody vegetation and road verge pulling score down
Buffalo	U63	No	Too low	No	64.8	M	H	From the boat this RMA looks highly intact and score seems too low	**Land cover (road and woody) issue** - road verge pulling score down; also Open natural cover and lack of woody vegetation reduces score
Buffalo	U64	No	Too high	No	44.6	L	VL	Large emergent zone along shore - all vegetation on shore has been completely removed - very large houses with landscaped lawns - score is way too high for this RMA. Shoreline delineation in this location is not correct	**Shoreline delineation issue** - shoreline does not follow open water
Buffalo	U88	No	Too low	No	55.5	M	H	RMA has minimal disturbance - natural vegetation is intact. RMA should score higher	**GIS score is representative of what is within RMA buffer** - front of RMA appears disturbed/manicured in SPOT and high resolution imagery
Buffalo	U104	No	Too low	No	48.4	L	Split	10 m moving window might not capture variability here because of wide sandy area - RMA should be split because there is large variation in condition - some lots have extensive clearing and manicured areas and others have no shoreline clearing. Because of this, the Low category seems too low, but if the RMA was split, there would be a Low and a High condition RMA	**Sensitivity of moving window to detect differences along shoreline too low** - Exposed clearing/sand goes back 20m, so out of range of moving window for change
Buffalo	U108	No	Too high	No	27.9	L	VL	Marina with extensive disturbance and very little natural vegetation. Score seems high for amount of disturbance. Weeds evident on shoreline	**GIS score is representative of what is within RMA buffer** - Forest in SE portion of RMA increases score - score only 2 points higher than a Very Low classification

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Buffalo	U123	No	Too low	No	65.1	M	H	Weeds apparent along shoreline - this RMA is in good condition - trees are dense and understorey relatively healthy. Should be in High category. Houses set back	**Land cover/land use issue -** beach classified as Exposed developed, not as a Natural exposed. Front of RMA classed as developed/disturbed ("Beach" covers front 1/3)
Buffalo	U127	No	Too low	No	45.7	L	M or H	Natural sand bar with natural grassy/open areas? Difficult to determine whether the low vegetation is a natural condition or whether this area has been cleared. If natural, should score higher. If cleared, score is appropriate	**GIS score is representative of what is within RMA buffer** - Area looks cleared/manicured in SPOT and high resolution imagery, particularly in relation to adjacent parcels
Buffalo	U149	No	Too high	No	39.5	L	VL	Score for this RMA is too high - should not outscore RMA U151	**GIS score is representative of what is within RMA buffer** - RMA buffer shape captures forest cover in the back corner of the RMA, increasing overall score
Buffalo	U151	No	Too low	No	34.1	L	M	From the boat this RMA looks highly intact but because of emergent zone we are >100m from shore, so what is being observed might not be representative of shoreline intactness	**GIS score is representative of what is within RMA buffer** - RMA is small and includes an area that appears cleared/manicured in SPOT and high resolution imagery
Buffalo	U153	No	Too low	No	43.8	L	M or H	Cant get very close to RMA because of very large emergent zone - big littoral wetland in this location - All natural in this location other than road, don't know why this RMA scored so low	**Shoreline delineation issue** - does not include wetland area to east of road. Road verge bringing down score, also wetland is classified as Open natural, so lack of woody vegetation also bringing down score
Buffalo	U155	No	Too low	No	26.7	L	M or H	Road runs through lake/wetland (with culvert) - road verge might be too large for this road - score is very low for this RMA	**Land cover (road) issue** - road verge bringing down score, also wetland is classified as open water so lack of woody vegetation bringing down score
Gull	U3	No	Too low	Yes	78.0	H	H	Category (H) good; score (78) seems too low - this is a good RMA	**Land cover (woody) issue -** Most of RMA is classified as Natural open, which brings down score because of the woody vegetation metric
Gull	U5	Yes	N/A	No	77.5	H	M	South end of RMA is provincial park and in good shape; docks and other disturbance located in northern portion of RMA, but still in good shape - no veg clearing that we could see. Score seems appropriate by category seems too high - should be a highly scoring Moderate RMA	**Land cover (misclassification) issue** - Small areas of disturbance misclassified as natural. RMA score is only over the Moderate/High threshold by 2 points

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Gull	U31	No	Too low	Yes	64.4	M	M	Thick emergent zone - from boat RMA looks as good as U32, not sure why it receives a lower score. Score is too low, but Moderate category is appropriate.	**Land cover (woody) issue** - Dominant land cover is Open natural and Natural exposed, so woody metric score is zero. Need a shrub land cover category for Gull Lake
Gull	U33	Don't know	N/A	Don't know	72.8	M	Don't know	Emergent veg too thick and dense to see shoreline - but think this may be scored too high - think it is a continuation of park based on imagery brought into field	**Land cover (misclassification) issue** - misclassification of Disturbed vegetation as Natural open
Gull	U35	No	Too high	No	70.4	M	VL	Disturbed area adjacent to road	**Land cover (misclassification) issue** - Looks natural open in SPOT imagery but should have been classified as disturbed vegetation
Gull	U37	No	Too high	No	69.3	M	L	Recent development? There is a marina here that is not on the high-res image - location of shoreline delineation also looks wrong	**Land cover (misclassification) issue** - misclassification of Disturbed vegetation as Natural open
Gull	U39	No	Too low	No	18.6	VL	H	This is a mostly natural shoreline (open natural) -> wetland area that was misclassified	**Land cover (misclassification) issue** - misclassification of trail/boardwalk as road and road verge
Gull	U46	No	Too low	Yes	30.2	L	L	Might be scored slightly too low, but category appropriate for amount and intensity of use	**GIS score is representative of what is within RMA buffer** - RMA is very small and road dominates, which may have been hard to perceive in the field. Road verge may be bringing down score, but overall the GIS score seems appropriate
Gull	U50	No	Too low	No	23.0	VL	H	From the boat, this looks H to me, but can't see onto the shore and can't get very close to shore because of emergent vegetation - map suggests there is HF on shore that we can't see from boat	**Land cover (misclassification) issue** - Natural exposed and shrubby areas misclassified as disturbed
Gull	U53	No	Too low	No	7.0	VL	L or M	The score seems too low - the sandy area appears natural and is surrounded by intact shrubby/treed areas - there is human disturbance but fairly low intensity - low or moderate score more appropriate	**Land cover (road) issue** - Road and road verge dominate in RMA. Sandy area looks cleared in high resolution area and was classified as developed. Some shrubby areas misclassified as road.

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Gull	U60	No	Too low	No	14.4	VL	L or M	Very low score - not appropriate - south end of RMA mostly natural shrubland, human disturbance small and low intensity	**Land cover (road, woody) issue** - Road and road verge take up large area and natural shrubby areas misclassified as disturbed
Gull	U63	No	Too low	Yes	50.7	M	M	There is human disturbance here, but the riparian vegetation is intact and there are no permanent human structures, only temporary things like chairs/umbrellas. Moderate category is OK, but score (50.7) seems too low	**GIS score is representative of what is within RMA buffer** - classification is accurate; disturbance covers ~half of RMA
Gull	U65	No	Too low	No	34.1	L	H	Thick emergent zone along shoreline, can't get to RMA north coordinate; shoreline looks like giant wetland from boat. Score is way too low - this RMA is all natural vegetation and no human footprint is present for some distance	**Land cover (misclassification) issue** - Natural land cover (shrubby and natural exposed) misclassified as Disturbed
Gull	U71	No	Too high	Yes	22.4	VL	VL	Score seems high for amount of disturbance	**RMA buffer issue** -Shoreline has sharp angle that creates a strange RMA shape that picks up natural cover at south end; score is appropriate for the RMA buffer that is delineated in GIS
Pigeon	U04	No	Too high	No	56.4	M	L	Moderate score seems too high for this RMA - should be low - either need to adjust cutoff or the land cover not capturing extent of disturbance	**Image resolution issue** - Disturbed vegetation (lawns) classified as Forest, difficult to distinguish disturbed vegetation in SPOT
Pigeon	U11	No	Too high	No	64.1	M	L	Dominated by manicured lawn - seems likely this RMA was overscored - perhaps land cover does not capture full extent of human disturbance in this location?	**Image resolution issue** - Disturbed vegetation (lawns) classified as Forest, difficult to distinguish disturbed vegetation in SPOT
Pigeon	U15	No	Too high	No	66.1	M	Split	This RMA should be split in half, (see map) because west end and trees brings up overall score	**Sensitivity of moving window to detect differences along shoreline too low** - Lots are very narrow and front of RMA has high vegetation cover; break in cover not wide enough to create new RMA
Pigeon	U17	No	Too high	No	56.6	M	L	Quite a lot of mature conifer that likely drive the moderate score (56.55) -> this is a segment that is borderline for a low score	**Image resolution issue** - fine scale human footprint not being detected in SPOT

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Pigeon	U18	No	See comment	No	68.8	M	Split	East end of RMA much more intact than west end. Maybe this should have been more than one RMA? West end Low and East end Mod/High? Feels like this should have been multiple RMAs - split where stand of trees ends and development starts as marked on map.	**Image resolution issue** - Disturbance towards shoreline misclassified as natural cover, likely a SPOT resolution issue
Pigeon	U20	No	Too high	Yes	73.9	M	M	Score might be high relative to amount of human footprint - but trees are mature and quite dense in some spots	**Image resolution issue** - manicured lawn areas not detectable in SPOT
Pigeon	U29	No	Too high	No	85.0	H	M	RMA mostly treed but trees obstruct human disturbance including small playground and picnic shelter; numerous trees recently cut down. High score might be a bit high, but relative to other spots, this RMA is much more intact, especially with respect to trees.	**Tree canopy obstructing human footprint** - almost full tree cover in SPOT and hi res imagery, recent disturbance not reflected in 2017 image
Pigeon	U32	No	Too high	No	94.0	H	M	Classified as high - this is over-scored based on what we can see under the canopy - maybe some misclassification in land cover?	**Image resolution issue** - Human footprint not detected in SPOT image
Pigeon	U48	No	Too high	No	56.7	M	L	This was classified as M (56.68); think this should have been classified as L because not a lot of natural or tree cover	**Image resolution issue** - manicured lawn and some structures with dark roofs not detectable in SPOT. RMA score close to Low/Moderate threshold
Pigeon	U79	No	Too high	No	84.5	H	M	This RMA score seems too high based on what we can see, although human disturbance in this location is less dense than other locations - road set back from RMA	**Image resolution issue** - manicured lawn and some structures with dark roofs not detectable in SPOT
Pigeon	U110	No	Too high	No	53.5	M	L	This RMA scored 2x higher than U244, but looked very similar from the road. This RMA score seems too high - should be low - cut-off too high?	**GIS score is representative of what is within RMA buffer** - High forest cover in middle of RMA
Pigeon	U121	No	Too high	No	62.5	M	L	Better condition than U256, but seems to be too highly scored (62) - tree canopy could be obstructing development should not be M -> L is more appropriate	**Tree canopy obstructing human footprint** - Many trees and shadows in SPOT and high resolution image

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Pigeon	U175	No	Too low	No	23.0	VL	L	VL model score seems a bit low from what we can see; but looked like more impacts towards shore that we could not see - score of 22.9 might be borderline between VL and L	**GIS score is representative of what is within RMA buffer** - Only a few trees in imagery; manicured up to shore
Pigeon	U252	No	Too high	No	50.4	M	L	Moderate category too high - this should be a "low" RMA	**GIS score is representative of what is within RMA buffer** - Thick strip of trees in SPOT and high resolution images (~50% of RMA classified as forest). RMA score is only 0.4 points over the Low/Moderate threshold, so score is very close to being a low classification
Sylvan	U7	No	Too high	Yes	69.2	M	M	Houses are set back and mature trees have been retained with some removal. Score (69) might be a bit high but category is appropriate	**Land cover (misclassification) issue** - some misclassification of houses as Forest, but score is mostly representative of what is in the RMA
Sylvan	U12	No	Too high	Yes	63.2	M	M	More veg along shoreline than U107, but still manicured vegetation in some spots - Moderate category is OK, but score (63) seems high	**Land cover (misclassification) issue** - Human footprint (houses) being misclassified as Forest
Sylvan	U27	No	Too high	No	53.6	M	L	Houses are large and quite dense, extensive lawn and modified vegetation/shoreline. Houses quite close to shore	**GIS score is representative of what is within RMA buffer** -small amount of misclassification of human footprint as trees. Score only 3 points above Low/Moderate threshold
Sylvan	U31	No	Too high	No	76.7	H	Split	Houses are very close to shoreline on west end, includes undeveloped lot on east end that is likely bringing up RMA score. This vacant lot should be separate RMA (H) and west should be another L scoring RMA	**Land cover (misclassification) issue** - misclassification of houses (dark roofs) as Forest
Sylvan	U36	No	Too high	No	86.7	H	M	Lots of tall trees that obstruct human footprint. Score too high - should be moderate category	**Land cover (misclassification) issue** - misclassification of houses as Forest
Sylvan	U41	No	Too high	No	85.4	H	M	Disturbed and manicured vegetation is obscured by tall, mature trees - high category and score of 85 too high - should be moderate category	**Image resolution issue** - some human footprint in RMA not detectable in SPOT
Sylvan	U42	No	Too high	Yes	74.3	M	M	RMA shape is strange - includes a lot of manicured area to the south, If the RMA went straight back from shore, then score is appropriate, but RMA score seems high for the shape of RMA	**Land cover (misclassification) issue** - misclassification of houses as Forest

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Sylvan	U55	No	Too high	No	71.8	M	L	Extensive bank reinforcement structures, east end more disturbed than west end - score seems way too high for this RMA, should be lower score and Low category	**Image resolution issue** - fine scale human disturbance not detected in SPOT
Sylvan	U81	No	Too high	No	78.8	H	M	More veg than U177 - east end of RMA more vegetated than west end - score is close despite the disturbance, which is set back, but this RMA would be more appropriate as a high-scoring Moderate, rather than a low-scoring High	**Land cover (misclassification) issue** - misclassification of houses (dark roof) as Forest
Sylvan	U86	No	Too high	Yes	64.2	M	M	Score a bit too high, but moderate category is OK	**Land cover (misclassification) issue** - some misclassification of houses as Forest, but score is mostly representative of what is in the RMA
Sylvan	U111	No	Too high	Yes	39.6	L	L	Emergent veg in front of lots has been removed; scores seems high for amount of cleared vegetation and manicured lawn, category is OK	**Image resolution issue** - some portions of the manicured lawns not detectable in SPOT
Sylvan	U113	No	Too high	Yes	12.7	VL	VL	Score seems high - this RMA has NO natural vegetation. Category is appropriate	**GIS score is representative of what is within RMA buffer** - Small tree patches in SPOT and high resolution imagery
Sylvan	U115	No	Too high	No	39.4	L	VL	Extensive development and modification, should be VL category	**Image resolution issue** - manicured lawn misclassified as Forest
Sylvan	U123	No	Too high	Yes	34.4	L	L	Has gigantic house and some scattered trees. Score might be slightly too high but Low category is appropriate	**GIS score is representative of what is within RMA buffer** - Large patch of trees in middle of RMA
Sylvan	U135	No	Too low	No	27.9	L	M	Based on what I can see from boat, RMA is quite intact, but bank is steep and human footprint is on top of bank where it can't be seen. I think this is scored too low based on what can be see from the boat	**GIS score is representative of what is within RMA buffer** - Campsites and road at top of RMA start 30 m from shoreline; there also appears to be some misclassification of natural exposed as disturbed right along shoreline
Sylvan	U142	No	Too high	No	27.1	L	VL	Huge massive house: extensive landscaping. Score too high and should be Very Low category - should score lower than U141	**GIS score is representative of what is within RMA buffer** - Strip of trees running from front to back of RMA bringing score up; score only two points above Very Low/Low cutoff

Continued …

Table 14 *continued*. Results of the RMA validation that included a comprehensive review of high resolution and SPOT imagery, as well as the land cover layer created for the riparian assessment for each of the 63 RMAs that were identified by the field observer as having been assigned the wrong intactness category and/or score.

Watershed	RMA	Is Score appropriate?	Score high or low?	Is Category Appropriate	GIS Score	GIS Category	Observer Category	Field Notes	GIS Notes
Sylvan	U144	No	Too high	No	47.5	L	M	Summer camp boat launch - surrounded by mature trees. Score seems too low considering the low density and area of disturbance - moderate category is more appropriate - should score higher than U42. Shoreline delineation not correct in this location	**Land cover (road) issue** - Road verge bringing down score - score only 2.5 points below Low/Moderate cut-off
Sylvan	U152	No	Too high	No	50.6	M	L	Quite extensive disturbance in this RMA. Houses quite close to shore, also quite dense - should not be Moderate, score is close	**Image resolution issue** - Some minor misclassification of developed areas (manicured) but RMA classification is generally good. Score is only 0.6 over the Low/Moderate threshold
Sylvan	U154	No	Too low	No	22.5	VL	L	Road is narrow and is only disturbance - should be Low rather than Very Low	**GIS score is representative of what is within RMA buffer** - RMA is quite narrow, observer may have been considering larger area in field evaluation of RMA
Sylvan	U158	No	Too high	No	64.6	M	L	Human disturbance under the canopy quite extensive - should not score so high - should be in Low category - houses close to shore, bank not as steep here, houses more dense	**Tree canopy obstructing human footprint** - RMA also contains large amount of tree cover upslope of shore

The largest source of error, affecting 33% of the RMAs for which there was disagreement between the field and GIS assessment, was misclassification in the land cover (Table 15). For example, RMA U39 at Gull Lake was assigned to the “Very Low” intactness category by the GIS, and the observer felt that this RMA should have been assigned to the “High” category (Table 14). When the high resolution and SPOT imagery was examined, it was clear that a trail/boardwalk associated with the provincial park had been misclassified as a road with a road verge, and that there was also some misclassification of natural exposed areas as developed, which was driving the score of this RMA down (Figure 4).

The second greatest source of error, affecting 28% of the RMAs, was attributed to the resolution of the SPOT image (Table 15). At 6 m resolution, small features cannot be resolved in the imagery, and in some cases it can be difficult to distinguish human footprint from natural cover based on spectral properties alone. For example, houses or structures with dark roofs can be hard to distinguish from shadow that is often associated with and classified as forest cover, and small patches of manicured vegetation are not spectrally distinct from other green vegetation, such as forest or low open vegetation classes (Figure 5). Because of this difficulty differentiating human footprint from natural cover in the SPOT imagery, some RMAs were over-scored because human footprint was being missed in the land cover classification, particularly in locations where residential lots were narrow and human disturbance occurred together with tall trees.

The way in which roads and road verges are treated in the land cover was the third largest source of error, affecting 13% of the RMAs that we assessed. In these cases, the total area of the RMA covered by the road and the associated verge had a disproportionately negative influence on the intactness scores. The result was often a RMA score that was too low, relative to the conditions that were observed in the field (Figure 6).

The influence of the “woody” metric on the overall score was the forth largest source of error, affecting 11% of RMAs (Table 15). The lack of a shrub category in the land cover meant that shrubby areas were either classified as “Forest” or misclassified as “Natural open”. In most cases, shrubby areas were classified into the “Natural open” class, which meant that the woody metric scored zero, or a value close to zero. For the lakes that were assessed in this study, and for Gull Lake in particular, shrubby areas are quite prevalent along the shoreline, and so this misclassification coupled with a model that specifically quantifies woody vegetation resulted in the underscoring of many RMAs. Additionally, if forest cover was misclassified as open natural cover, as in the case of RMA U60 at Buffalo Lake (Figure 7), the score would be affected (reduced) because of a lack of woody vegetation within the RMA.

All other types of error identified during this validation step were relatively minor, affecting between 2% and 7% of the RMAs we examined.

Table 15. Summary of the issues related to the GIS tool that could explain the difference between the field validated score/category and the GIS score/category. Note that a single RMA could be affected by more than one issue, and thus, the total number of RMAs affected does not sum to 46, nor does the percentage sum to 100.

Issue	Number of RMAs affected	Percentage of RMAs affected
Land cover misclassification	15	33%
Image resolution	13	28%
Land cover - road & road verge	6	13%
Woody metric	5	11%
Shoreline delineation	3	7%
Tree canopy obstruction	3	7%
Moving window sensitivity	2	4%
Buffer shape	1	2%
Land cover/land use	1	2%

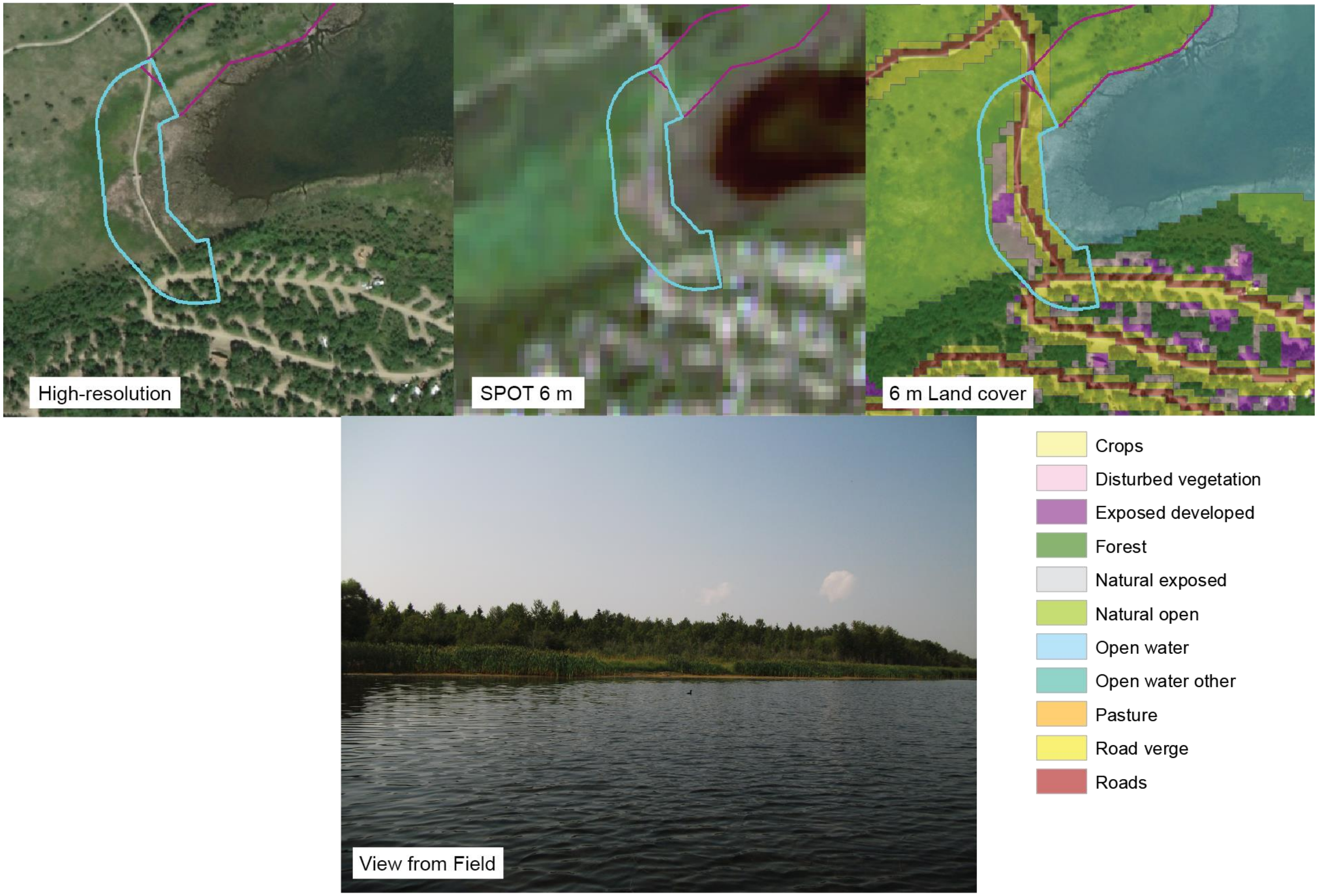


Figure 4. RMA U39 at Gull Lake. This RMA was assigned to the Very Low category by the GIS tool, but was assigned to the High category during the field assessment. In this instance, the low score could be attributed to a land cover error, in which the trail and surrounding area was misclassified as Road, Road verge, Disturbed vegetation, and Exposed developed, which had a large influence on the final RMA score.

Figure 5. RMA U79 at Pigeon Lake. This RMA was assigned to the High category by the GIS tool, but was assigned to the Moderate category during the field assessment. In this instance, the error could be attributed to the SPOT image resolution, which resulted in the misclassification of human footprint as Forest.

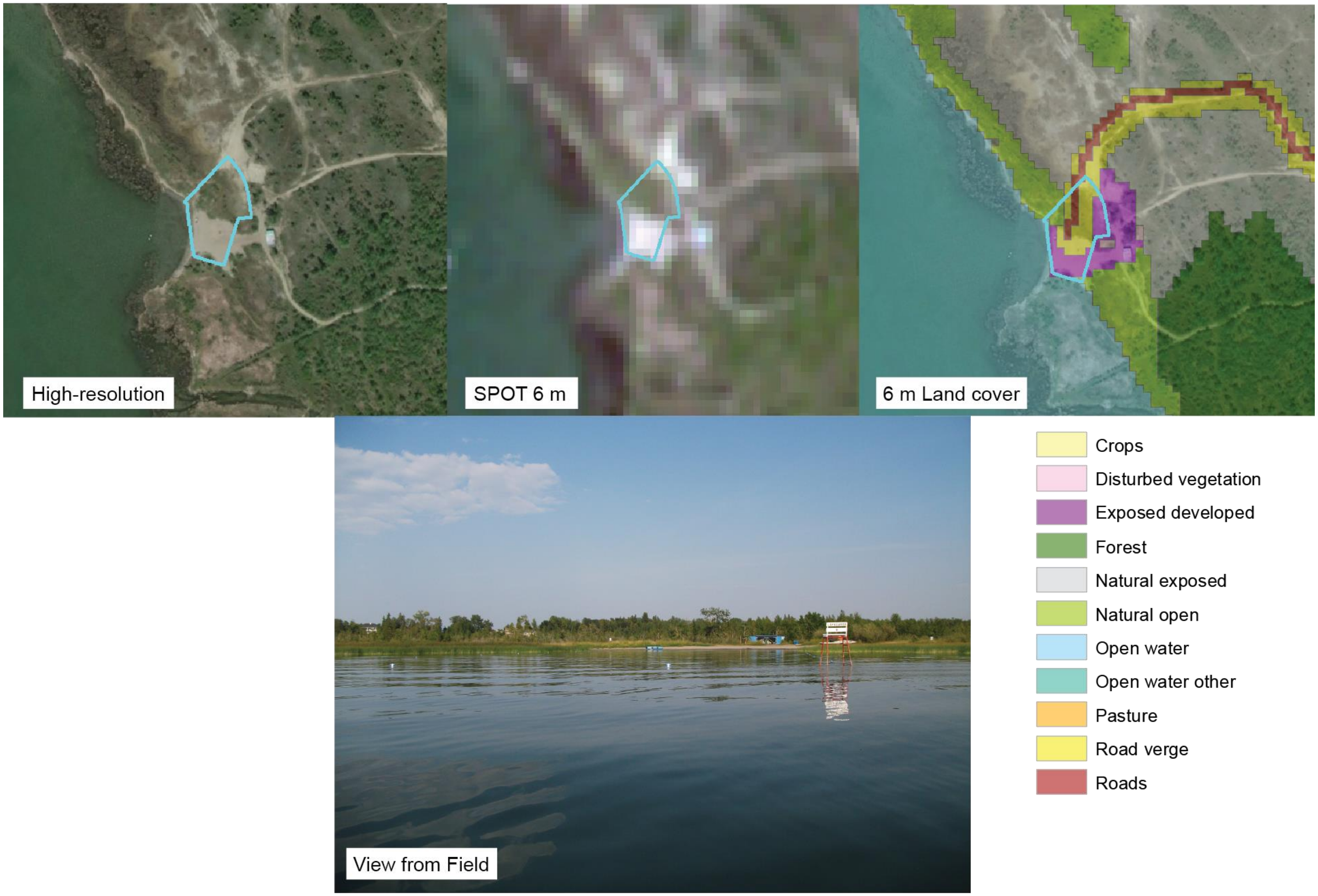


Figure 6. RMA U53 at Gull Lake. This RMA was assigned to the Very Low category by the GIS tool, but was assigned to the Low or Moderate category during the field assessment. In this instance, the error could be attributed to the presence of a road and associated road verge, which covered a large are of the RMA, bringing down the overall score.

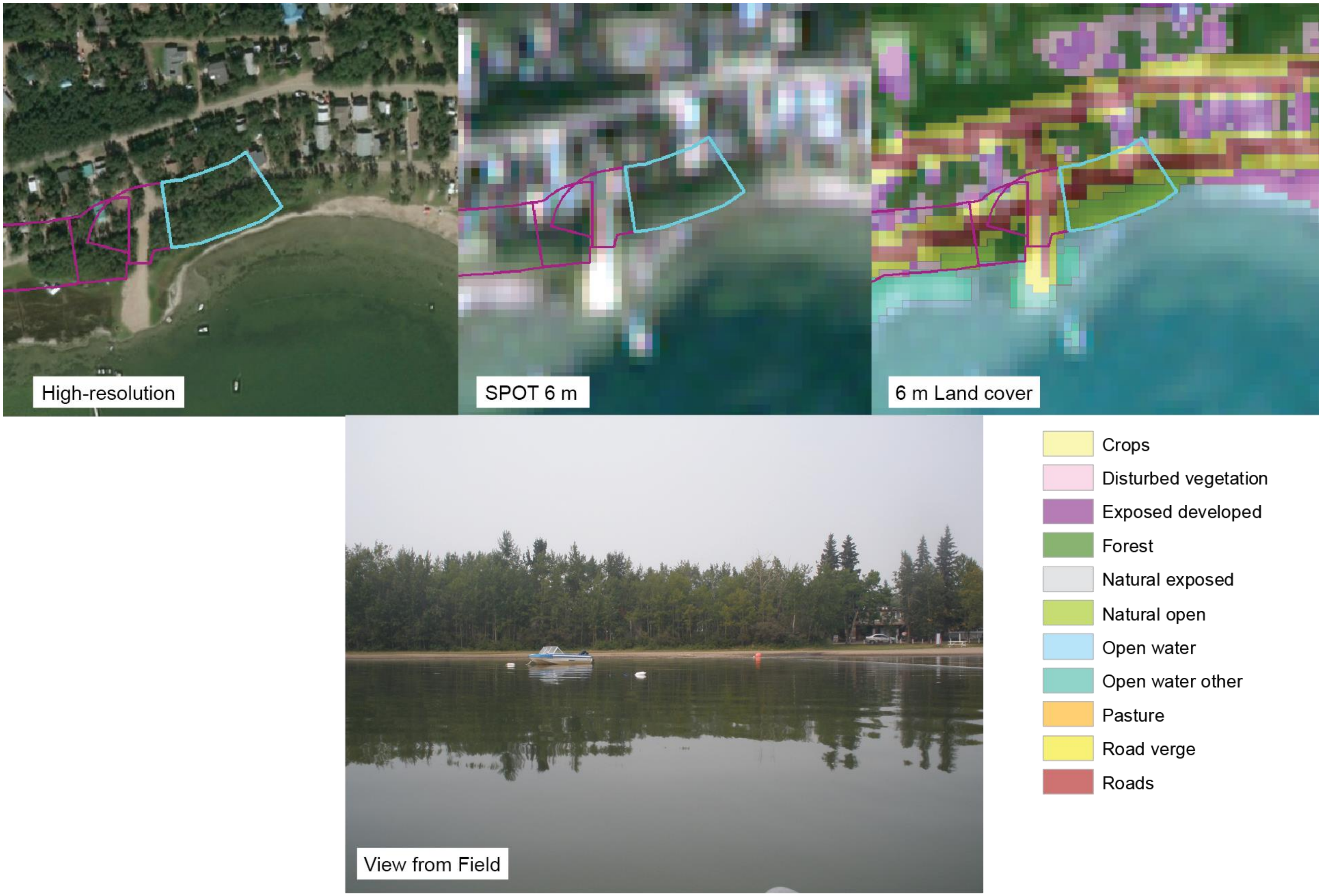


Figure 7. RMA U60 at Buffalo Lake. This RMA was assigned to the Low category by the GIS tool, but was assigned to the Moderate category during the field assessment. In this instance, the error could be attributed to multiple issues, including misclassification of the trees to the Open natural category, which resulted in a zero score for the “woody” metric. In addition, this RMA had a road and road verge that covered a large portion of the RMA, further reducing the score of the RMA.

4.0 Discussion

4.1. Land Cover

The land cover is the foundation of a GIS-based riparian assessment, given that it is the primary source of information used to quantify the intactness metrics; therefore, the accuracy of the riparian assessment is directly related to the quality and accuracy of the land cover. The validation work revealed a number of important considerations related to the creation of land cover layers for the purpose of conducting riparian assessments, which we discuss in more detail below.

4.1.1. Pixel- versus Object-based Classification

For this assessment, we chose to create the land cover using an object-based classification method, and the accuracy of the 11-class land cover was assessed using both a point- and object-based validation approach. The results from the point-based validation suggest that the accuracy of the land cover was lower than desired (ranging between 62 and 72%); however, when accuracy was assessed at the scale of the object, rather than at the pixel-level, the results were much better and within an acceptable range of accuracy. Similarly, the results from the field validation assessment suggest that the accuracy of the land cover is generally very good across all watersheds.

These validation results highlight an important consideration when creating an object-based classification, which is that the segmentation level for an object-based classification must be set to a value where objects of a meaningful resolution (to the assessment tool) can be captured. While object-based classifications can segment very small objects, this can result in a very large number of objects, which can be very time consuming to QA/QC properly and can pose computer processing challenges when creating land covers over large areas, particularly when using higher resolution imagery. Given what we have learned through this validation exercise, it is our feeling that a pixel-based classification may be better suited for creating land covers for the purpose of conducting riparian assessments. This is because the minimum resolution of any feature mapped in the land cover is equal to the size of the pixel (in the case of a SPOT image, 6 m), and when applying metrics that are based upon the proportion of an area classified by land cover class, omission of small areas from the calculation can have a significant influence on the final score. While pixel-based classifications have their own issues (e.g., salt and pepper effects due to misclassification of individual pixels), we feel that these classifications may be better suited to quantify riparian intactness using this model.

4.1.2. Thematic Resolution

We created a 5-class land cover from the original 11-class land cover by grouping a smaller number of broad cover types that were still meaningful in the context of assessing riparian intactness. The accuracy of this 5-class land cover was then evaluated, and relative to the 11-class land cover, the 5-class land cover had a higher accuracy for both the point- and object-based validation. Creating a land cover with high thematic resolution is time consuming, both in terms of the level of effort that is required to select training data and in the manual editing and quality checking of the resulting land cover layer. While a land cover with higher thematic resolution may be desirable because it can be used for other applications or analysis, there is a trade-off between thematic resolution and the associated cost and accuracy (both overall and within-class) of the land cover.

This validation particularly highlighted important issues related to the classification of areas dominated by shrubby vegetation. The lakeshores included in this study, and in particular, Gull Lake, had very large areas where both sparse and dense shrubs were the dominate land cover. Because the riparian assessment tool has a metric that quantifies the proportion of “woody” land cover classes within an RMA, it is important to accurately capture shrub cover in the land cover classification. This can be done by grouping forest and shrub categories together, or by creating a separate shrub class. Either approach is suitable for the purpose of quantifying riparian intactness, with the most important consideration being that shrub cover should not be classified together into a cover class that represents open, short vegetation classes, such as areas dominated by graminoid species, and this will result in a woody metric score of zero, and will result in underscoring of the RMA.

Given our experience creating land cover layers for the GIS-based assessment of intactness, combined with what we have learned from this validation exercise, we feel that creating a land cover layer with fewer but meaningful classes will result in more accurate riparian intactness scores. As such, we suggest the following classes, at a minimum, be included in a land cover layer that is created for the purpose of conducting a riparian assessment:

- **Woody cover**: including upland forest, upland shrub, treed wetlands, and shrubby wetlands
- **Natural open vegetation**: including natural grasslands and graminoid/emergent wetlands
- **Open water**: including shallow and deep open water
- **Natural exposed**: areas naturally devoid of vegetation such as sand or rock, or soils that are bare due to the action of wind or water (e.g., floodplains)
- **Human disturbance/human footprint**: lands that have been modified due to human activities, such as agricultural fields, developed and built up areas, roads, marinas, disturbed vegetation, and human-caused exposed/bare areas

4.1.3. Land Use versus Land Cover

For several of the land cover classes in our classification, there are questions regarding whether to classify an area based on its land cover or its land use. For example, naturally sandy areas along shorelines are often utilized as beach areas, with associated impacts. Classifying such an area as natural cover (e.g., sand) versus human footprint (e.g., disturbed or developed) has implications for the score of the RMA. A second example of this issue is wetland habitat that has been impacted by agricultural activity, such as cultivation. In these instances, a wetland could be classified as its land cover (e.g., open water, open natural) or as its land use (e.g., agricultural crop), with either decision having impacts on the final RMA score. A final example includes single or small clusters of trees located within a pasture, which could be classified as forest or as pasture. Making a decision in advance of creating the land cover with respect to how to deal with these types of ambiguous land cover classes is important to evaluating the accuracy of the results, as well as communicating those results to the public.

4.1.4. Image Resolution

SPOT satellite images are utilized to create a land cover for this assessment because provincial government departments, and partners of the government such as Watershed Planning and Advisory Councils, have access to this imagery. Satellite imagery is well-suited for riparian assessments because a single scene covers a large area, the multispectral resolution of the imagery allows for the creation of more accurate supervised or unsupervised classifications of land cover, and the frequent acquisition times of satellites allows for assessment through time. The multispectral SPOT imagery that can be accessed through the GOA is 4-band and 6 m resolution, which is a reasonably high spectral and spatial resolution; however, at this resolution, there limitations related to the size of object that can be resolved and the type of land cover that can be automatically differentiated. Because of this, there will inevitably be misclassification error in the land cover that is driven by both the spatial and spectral resolution of the imagery. While this issue can be overcome by using higher resolution imagery, purchasing higher resolution satellite imagery or using 4-band air photos for very large areas is cost prohibitive, as well as being more time consuming because many more images have to be processed to allow for classification of imagery over large areas.

In this validation, image resolution influenced the scores of 13 of the 161 RMAs that we assessed in the field, and the majority (8) of these RMAS were in the Moderate category. Based on our review of the RMAs with disagreement between field and GIS scores, image resolution appeared to be the biggest issue in areas where residential lots were narrow and development density was high (e.g., particular areas along the shorelines of Pigeon and Sylvan lakes). In these cases, it was difficult to resolve human footprint such as manicured lawns and structures with dark roofs. Further, the 6 m imagery is too course to identify small features such as rip rap or other small-scale bank modifications.

While the 6 m imagery is limiting and there is some error that is associated with this resolution of imagery, overall, the riparian intactness tool performs well, and does a very good job of differentiating between areas of high intactness and areas of low intactness. We would argue that areas where the image resolution creates the highest amount of error, which are those areas assessed as Moderate, are good candidates for other field-based assessments that would help to differentiate and identify areas with more or less human development and impacts to riparian areas. With time, higher resolution imagery may become more affordable, and with that will come higher land cover classification accuracy. Further, if other spatial data such as building footprints or impermeable surfaces are available from project partners (e.g., municipalities), this ancillary data can be used to more accurately map and measure human footprint in RMAs. If available, high resolution LiDAR point-cloud data could also be used to more accurately quantify human footprint and vegetation structure within RMAs, but this data is rare because of the expense associated with acquisition and the technical expertise required to process the data.

4.1.5. Road and Road Verge

Roads have well-documented direct and indirect effects on ecosystems and water quality, and in an effort to account for the full suite of road effects, we chose to apply a 10 m “road verge” buffer on each side of all roads in our land cover classification. The result of this is that in the case of narrow roads, the road and road verge accounted for a very large area of many RMAs that were assessed, thereby substantially reducing the overall score of the RMA. The practice of applying a single road verge to all roads in the land cover classification should be revised, and consideration should be given to only applying the road verge to larger roads (e.g., major paved roads or highways). We provide recommendations for road verge widths in Table 16.

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Table 16. Recommendations for road verge buffer widths for each road type defined in the GOA base features road layer. Recommendations are based on an assumption that the land cover will be created from SPOT satellite imagery with a 6 m resolution.

Road Type	Recommended Road Verge Width**	Comment
Truck-Trail	None	Typically very narrow laneway or narrow roads with no associated ditch
Road-Unimproved	None	
Road-Unclassified	None	
Road-Paved-Undiv-1L	1 pixel	Generally local roads in subdivisions that may or may not have ditch. Should be QA/QC checked to ensure verge does not over classify disturbance
Road-Gravel-1L	1 pixel	Generally township or range roads with well established ditches on either side of road, but occasionally local access roads with no ditch. Should be QA/QC checked to ensure verge does not over classify disturbance
Road-Gravel-2L	1 pixel	Generally larger gravel roads with well established road ditches on both sides of the road
Road-Paved-Undiv-2L	2 pixels	Typically secondary highways with well established ditches on both sides of road
Road-Paved-Div	2 pixels	Major divided highways with well established ditches on either side of each 2-lane road
Interchange-ramp	2 pixels	On and off-ramps associated with major highways

**Assumes a pixel-based land cover classification where the road layer and associated verge will be rasterized and burned into the land cover layer.

4.2. Intactness Metrics

This riparian assessment tool was initially developed as an alternative to the aerial videography method, and was validated using aerial videography data. As a result, the GIS tool was developed to replicate videography results, which required selection of metrics that are comparable to those used in a videography assessment. One of the metrics included in the videography assessment is the presence of woody vegetation and evidence of woody vegetation recruitment. In a GIS environment, this metric is replicated by quantifying the amount of the RMA covered by land cover classes that contain woody vegetation of any kind (e.g., trees and shrubs). While this approach validated well with videography results, the inclusion of a metric that assesses woody vegetation in a model that only includes three metrics gives considerable weight to the presence or absence of this land cover type. As a result, accurate classification of shrubby areas, which is difficult using imagery with a limited number of spectral bands, is important to achieving RMA scores that are representative of conditions on the ground.

In this validation exercise, we found that the woody metric influenced RMA scores, mostly because the shrubby areas were being misclassified as open natural, rather than as forest (our classification did not have a shrub class). These results highlight the importance of ensuring that shrubby vegetation is classified into a separate class, or is classified together with forest to create a more inclusive "woody" land cover class. The choice of whether to include a separate shrub class, or a more inclusive woody cover class (including trees and shrubs, as defined in Table 2), will largely be up to the discretion of those responsible for creating the land cover, and will depend upon both the spectral and spatial resolution of the imagery. For classifications being creating from SPOT 6 m imagery, we recommend using a single “Woody Cover” class, which includes both upland and lowland trees and shrubs.

The influence of the woody metric can also be modified by changing the weighting of this metric in the overall calculation of intactness. In this study, the woody metric received 25% of the weight in the overall score, and this was based upon previous testing of weightings that was conducted in the Strawberry watershed (Fiera Biological 2018d). The choice of weightings is largely subjective, but can be based upon more objective criteria. For example, the weighting for the woody metric could be based upon Natural Region or Subregion, and informed by a literature review as to the prevalence of woody vegetation in a given area. Alternatively, weightings could be based upon some other characteristic that could be reliably assessed in a GIS environment, such as soil and moisture regime. In order to do this, however, some work would need to be done to compile this information, select weightings, and validate the weighting values if they are to be used as standard values across the province.

4.3. RMA Generation

This validation exercise highlights the importance of an accurate shoreline delineation, as this drives the generation of the RMAs, and the resulting intactness scores. One challenge of this assessment is delineating the shoreline of waterbodies with highly variable water levels that fluctuate due to the presence of control structures or other water management activities. In these cases, a choice needs to be made whether to delineate the shoreline to match the location of water in the image that is being used to create the land cover, or to use some “average” or other historical shoreline delineation. This choice is not an insignificant one, as choosing a historical shoreline in a year with high water levels will give a vastly different assessment result than delineating the shoreline based on the location of the water. This choice will also potentially affect field validation if the shoreline conditions are different between the assessment and validation time steps.

Shoreline delineation is made difficult when there is an abundance of emergent vegetation within the littoral zone of lakes. In a satellite image, these dense mats of aquatic vegetation can be difficult to differentiate from terrestrial vegetation, leading to errors in shoreline delineation. Further, delineating the shoreline in areas where there is a littoral wetland can also be difficult, and depending upon the water levels, there is no clear answer as to whether to include the wetland as part of the lake boundary, or as separate from the lake. As part of this riparian assessment project, we experimented with a variety of techniques for more objectively delineating the shoreline (e.g., wetness indices created from the satellite image, LiDAR terrain analysis), but ultimately, there will always be some subjective interpretation that is required to delineate the shoreline of large waterbodies such as lakes. Creating standards for how to make such decisions would help to create consistency in how RMAs are being generated.

Related to the shoreline delineation is the issue of RMA shape, as the start and end segments of each RMA is generated perpendicular to this line. When shorelines are complex and highly sinuous, the RMA segments can take on odd shapes that are not representative of the riparian area, but are artefacts of how the RMA buffer is created in the GIS. In some cases, we felt that the disagreement in our field and GIS score could be explained by the odd RMA shape that was automatically generated in the GIS. Because of this, it is important to perform a quality control check of the RMA segments once generated, to correct or clean up and segments that may result in erroneous results.

In a small number of cases, the field validation highlighted that the size of the moving window used to generate the start and end of the RMAs may be too large. As part of the development of this assessment tool, we tested a number of different moving window sizes and intervals at which to calculate change in vegetation cover, and we have also tested the moving window using higher resolution imagery (2 m) as part of a separate riparian assessment of the Blindman River (Fiera

Biological 2018e). After all of the testing, we feel that our method of calculating the cover of natural vegetation using a 25 m moving window (i.e., 12.5 m radius) at 10 m intervals, and 10 m from the shoreline performs the best and is the most accurate representation of change in condition on the ground for 6 m satellite imagery. For higher resolution imagery (2 m), we found that the best results were achieved by adjusting the moving widow to 20 m in size (i.e., 10 m radius), while maintaining the same 10 m intervals located 10 m from the shoreline (Fiera Biological 2018e). Most critical to the issue of accurately generating the RMAs is an accurate shoreline delineation and correct classification of vegetation versus human footprint in the land cover, since the moving window calculates the proportion of vegetation in the window and creates RMA segments when there are major changes in the amount quantified. Thus, we feel that focusing efforts on ensuring an accurate land cover is the most important element to determining the start and end of RMAs.

4.4. Intactness Category Thresholds

In general, this validation exercise confirmed that the threshold values selected to differentiate between intactness categories are representative of what was observed in the field. In the majority of cases where the field observer noted that the RMA should be assigned to a different category, there was some corresponding error that if corrected, would change the RMA score and result in a reassignment of the category to match the one suggested by the observer. The thresholds between intactness categories also seemed to perform well across lake watersheds with different shoreline development conditions.

4.5. Prioritizing RMAs for Restoration & Management

One of the primary objectives of this riparian assessment tool is to provide land managers with information that can be used to prioritize areas for restoration or for special management. While the intactness scores on their own can be used to prioritize areas, previous riparian assessments that have been completed in the North Saskatchewan River (NSR) basin (see Fiera Biological 2018b, 2018c, and 2018d) combined RMA intactness scores with a local catchment “pressure” score to derive a separate priority ranking. The pressure score was calculated based upon an adapted “Watershed Integrity” scoring methodology (Flotemersch et al. 2016) that quantified natural resilience and human impacts within local catchment areas. This approach to prioritizing RMAs for management was developed and adopted based upon requests from various stakeholders, who were interested in considering development pressure along with riparian intactness.

It should be noted that prioritization of RMAs for restoration or other management action can be done in a multitude of different ways, and there is no one single or “correct” approach. How areas are prioritized for management should largely be informed by the needs and objective of the user of the information. For example, a single landowner of a small parcel of land may only require intactness scores to target areas for restoration, while a local watershed stewardship group may be interested in targeting riparian areas in the headwaters to improve source water protection. In either case, the approach to determining how to prioritize areas for management may be unique. As such, the question of how to prioritize RMAs for management should be informed by the needs and requirements of the primary users of the data.

5.0 Conclusions

In order to assess the accuracy and performance of a newly developed GIS tool for quantifying the intactness of riparian management areas, we performed a number of desktop- and field-based validation exercises for the Pigeon, Gull, Sylvan, and Buffalo Lakes watersheds. This validation work focused on assessing the accuracy of the land cover layers that were created to quantify riparian intactness, as well as examining agreement between a field-based intactness assessment and the GIS-based intactness assessment.

When results from the field-based assessment of riparian intactness was compared against the GIS categories, the overall agreement (77%) was very good; however, this assessment also revealed important issues related to the creation of the land cover layer, as well the metrics that are included in the assessment model. The primarily findings from this validation work highlight the critical importance of creating an accurate land cover layer, and the need to ensure that the classes included in the land cover meaningfully capture the cover types that are most relevant to the metrics that are used to quantify riparian intactness. In particular, this validation project clearly illustrates the sensitivity of the tool to the presence or absence of woody vegetation, and the need to accurately capture this land cover type in a way that allows for the quantification of cover classes that contain shrubs and/or trees. The validation also highlights limitations of using 6 m satellite imagery as it relates to both spectral and spatial resolution, and the difficulty accurately and consistently classifying certain land cover types (e.g., manicured vegetation) and detecting small human footprint features, particularly in areas where human footprint is more dense. The field validation also uncovered issues related to how the lands adjacent to roads are being over classified as “road verge” in areas where the road is narrow, such as local roads in residential subdivisions, and confirmed the importance of accurately delineating the shoreline boundary prior to creating the RMA segments that are then used to quantify intactness.

Overall, we feel that the riparian assessment method is a reliable method for assessing and comparing the intactness of riparian management areas across a variety of different landscapes. With careful attention to how the land cover layer is created, including adjustments to the road verge class and with rigorous quality control checks of problematic land cover classes, this tool provides Alberta Environment and Parks with information that can be used to consistently and objectively assess riparian areas over time and across large geographic extents.

5.1. Closure

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Appendix A: Field Data Sheet

RMA Intactness Validation - 2018

Lake Watershed: ☐Pigeon ☐Gull ☐Sylvan ☐Buffalo

Date: ________________ **Observer:** ____________________

RMA #: ________________ **Photos:** ____

1. On average, how far can you seen upslope from the lake onto the bank (or downslope from road to lake)?

☐<1 m ☐<10 m ☐>10 m ☐At least 50 m

2. What land cover(s) is present in the RMA? (as seen from above, check all that apply)

☐Deciduous forest	☐Natural grassland/graminoid	☐Cultivated crops	☐Exposed developed
☐Coniferous forest	☐Natural exposed (bare, sand, rock)	☐Pasture	☐Disturbed vegetation
☐Shrubland	☐Open water	☐Road or road verge	☐Other (describe)

Describe the land cover you see (height, density, type of pasture, etc.):

3. Is the ground cover obstructed by canopy cover? ☐No (skip to 4) ☐Yes ☐Partially

3a. If **yes**, what ground cover(s) are present in the RMA? (check all that apply)

☐Shrubland	☐Open Water	☐Human caused bare ground	☐Manicured or disturbed vegetation
☐Natural grassland/graminoid	☐Cultivated Crops	☐Building or structures	☐Other (describe)
☐Natural exposed (bare, sand, rock)	☐Pasture	☐Road or road verge	

Describe the land cover and reason for obstruction:

4. Is human disturbance present in this RMA? ☐No (skip to 7) ☐Yes

For example, structures, trails, evidence of livestock, etc.

If **yes**, describe the type of disturbance:

5. Is the disturbance large enough to have been detected in the land cover? ☐No ☐Yes ☐Partially

6. Is the disturbance obscured by overhead vegetation? ☐No ☐Yes ☐Partially

7. Are there docks present along the shoreline of this RMA? ☐No ☐Yes

8. How would you characterize the intactness of the RMA from overhead (e.g., satellite perspective)?

☐High (>90% cover by trees, shrubs, or open natural)	☐Moderate (70-90% cover by trees, shrubs, or open natural)	☐Low (50-70% cover by trees, shrubs, or open natural)	☐Very Low (<50% cover by trees, shrubs, or open natural)

9. How would you characterize the intactness of the RMA from the boat/road?

☐High (>90% cover by trees, shrubs, or open natural)	☐Moderate (70-90% cover by trees, shrubs, or open natural)	☐Low (50-70% cover by trees, shrubs, or open natural)	☐Very Low (<50% cover by trees, shrubs, or open natural)

10. Is the RMA score appropriate? ☐No ☐Too high ☐Too low ☐Yes

NOTES: