LENTIC AND LOTIC MAPPING OF THE ELK RIVER WATERSHED

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ABSTRACT

The Elk Valley Selenium Task Force (EVSTF) through Teck Coal Ltd. (Teck Coal) retained Interior Reforestation Co. Ltd. (Interior) to determine the relative proportion of lentic (standing) and lotic (moving) waters in the Elk River Valley downstream of the mines. Data was gathered from a helicopter using Red Hen geo-spatial video technology in the fall of 2007. Following video analysis and field reconnaissance, lentic and lotic areas were delineated on orthophoto maps using GIS. Lotic areas were in the active channel where water had a short retention time (seconds to minutes), while lentic areas had a longer retention time (hours to weeks). Lentic areas were distinguished as either:

- Lentic 1 areas - standing water apparent at base stream flow conditions; or
- Lentic 2 areas - not wetted at base flows, but likely wetted under mid to high flows and included standing water when it was not visible because of vegetation or the area was too small to delineate accurately.

The study area was comprised of approximately 139 ha lentic and 976 ha lotic habitat, respectively representing 12% and 84% of the aquatic area assessed. The Elk River subbasin had the greatest extent of aquatic habitat assessed (838 ha) and the greatest extent of lentic area (94 ha). The Fording River had the second largest area assessed (180 ha) and lentic habitat (33 ha).

KEY WORDS: lentic, lotic, stream, mapping

INTRODUCTION

There are ongoing studies to identify the role of anthropogenic selenium on biotic systems. Monitoring of selenium concentrations in water, sediment and biota near and away from coal mines indicates that the mines are the primary source of elevated selenium. Although flowing water (lotic) areas are most common in the Elk River Valley, areas of still or standing water (lentic) pose particular concerns because of the greater likelihood of inorganic selenium being converted into the much more toxic organic form. In order to assist the mines in understanding the overall relative distribution of each type of area downstream of the mines and assist in focusing future selenium research and assessments, Interior was retained by the EVSTF through Teck Coal to determine the amount of lotic versus lentic areas in the Elk River Valley, especially within and below the mines.

The new technology provided by the Red Hen Geospatial Video (geo-video) product was chosen as a cost effective tool to collect video data on the Elk River Valley along the major rivers and creeks. The Red Hen is mounted in a helicopter and collects video coverage along a geo-referenced tagged path. The product facilitates the identification of 'spatial and temporal parameters as well as feature characteristics' along the video path and permits the transfer of geo-referenced data to a GIS data base.

METHODS

The study area for this project encompassed the mainstem and tributary areas of the Elk River watershed located downstream of the coal mines and within the mines' boundaries. The area was videotaped from a Bell 206 helicopter operated by Bighorn Helicopters (Cranbrook BC). A Canon HV20 high-definition video camera was used for image capture. An initial test flight was conducted over Michel Creek, on September 14, 2007. The second flight to collect geo-video data for the whole of the project area was conducted on October 18, 2007. Image capture improvements were instituted between the flights and included: changing the configuration of the geo-video; switching the camera mounting from outside to inside the helicopter bubble window, surrounding the camera within a foam containment unit in order to reduce vibration; and reducing the helicopter altitude and velocity. The stream corridor for each of the sub-basins in the study area was videotaped according to the following flight paths:

1. Elk River – from Koocanusa Lake upstream to the Fording River confluence, above the Greenhills Mine;
2. Erickson Creek – from the confluence with Michel Creek, upstream to the Elkview Mine;
3. Line Creek – from the Fording River confluence upstream to the Line Creek Mine;
4. Lower Fording River – from the Greenhills Mine downstream to the Elk River confluence;
5. Upper Fording River –from the Greenhills Mine upstream to the headwaters;
6. Henretta Creek – from the Henretta Creek headwaters downstream to the Fording River confluence;
7. Michel Creek – from the headwaters above Coal Mountain, downstream to the Elk River confluence. The lower section of Corbin Creek, which flows into Michel Creek near the north side of the Coal Mountain Mine, was also included in this flight.

Lentic and Lotic Definitions

To distinguish habitats within the watershed, clear definitions of "lentic" and "lotic" areas were required. For this study, the definitions of lentic and lotic habitats provided by Adams et al. (2000) were modified slightly in order to reflect a mountainous environment. Lotic sites were defined as flowing water with short hydraulic retention times (i.e., seconds to minutes). Lentic areas were defined as very slow flowing water to standing water with longer hydraulic retention times (i.e., hours to weeks or longer). Water features were delineated as one of the following: anthropogenic, lotic, lentic 1, lentic 1a, lentic 2 or beaver dam/end**.** A description for each of these features is provided below and Figure 1 portrays delineation examples of lotic, lentic 1, lentic 1a and lentic 2 areas.

Anthropogenic features were man-made wetted areas. These were evidenced mainly as regularly shaped pools near the mine sites. Generally only anthropogenic ponds that were evident on the flight path were delineated. The flight path covered a distance that was, on average, 10 times the width of the channel and thus included all ponds with the potential to be associated with the mainstem. However, in the immediate vicinity of the mine sites some anthropogenic ponds may have been excluded, since the mine sites themselves were not the focus of this study and were thus not extensively video taped.

Lotic areas comprised the active channel, which included the river and active channel that would be inundated at normal spring flood flows (i.e., those with an average return interval of one to two years) (Gregory 2000). Lotic features incorporated the outermost active channel boundary including the mobile channel (at low-flow) and the non-vegetated gravel bars.

Lentic 1 areas were comprised of standing water apparent at base flow conditions. This included ponds, backwater areas, relict channels and open water in the wetland, and beaver dams which caused flooding along the banks of lotic areas. Lentic 1 polygons were delineated along the bank edge of the standing water.

Lentic 2 areas comprised outlying wetland areas that may not have been wetted at base flows, and/or may have had shallow water areas masked from view by vegetation, as well as areas expected to be wetted and/or exhibit increased water depths during mid to high flow periods for a significant portion of the year. The outlying boundaries for these lentic areas were defined by vegetation, soils and topography visible in the 2007 aerial images and field review.

Lentic 1a areas were identified solely for GIS data sorting and area calculation purposes. They represent the lentic 1 areas that were embedded in lentic 2 areas. An example of which, would be a clearly defined open water area surrounded by shallow water or muddy wetland area that was expected to exhibit increased depth at higher flows. Lentic 1a areas were distinguished so that duplication of areas did not occur during the calculation process.

Beaver Dam and End delineation designated the location of both the beaver dam structure and the uppermost ‘end’ point of the wetland created by the beaver dam. The ‘end’ point indicates the end of the wetland influence on the lotic waters.

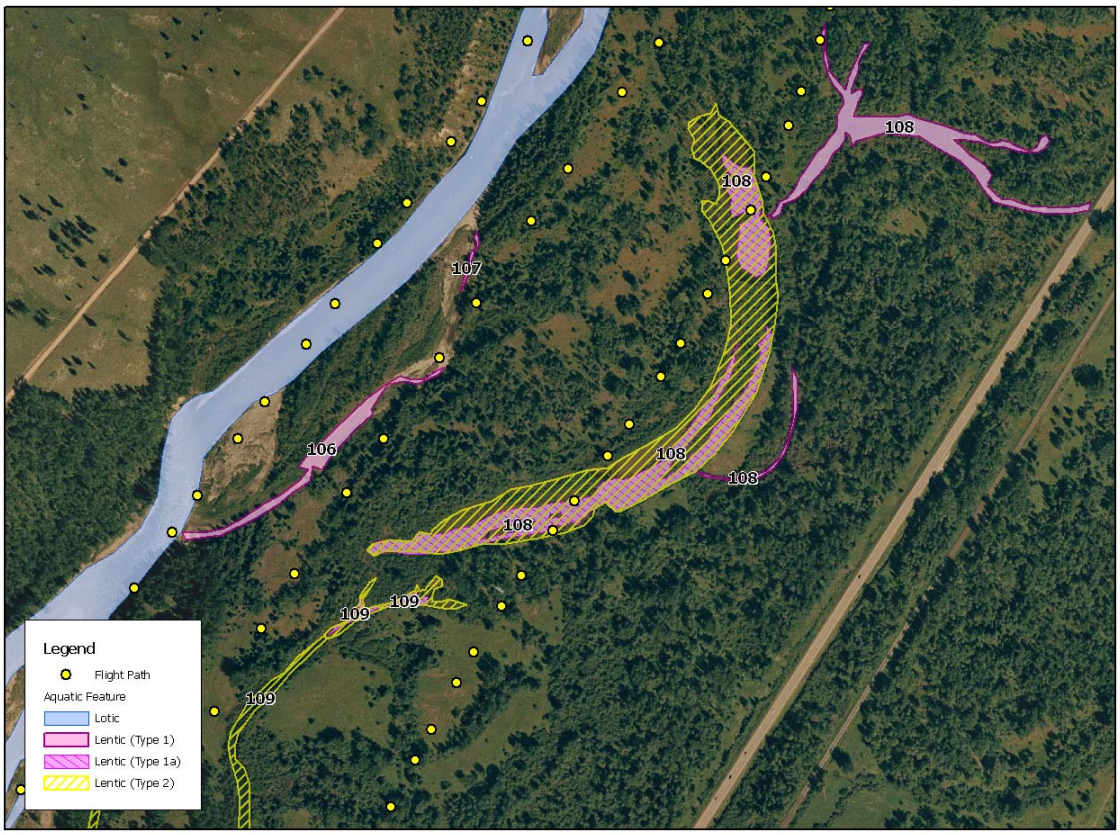

Figure 1. Representative site along the Elk River showing delineation of discrete wetted ponds (lentic 1), embedded wetted ponds (lentic 1a), and lentic 2 areas (the whole wetland complex).

Field Review

The geo-video for each of the basins was reviewed and annotations were made for areas considered to be lentic. Areas that were questionable in terms of their boundaries or classification were designated as requiring further analysis through ground-truthing. Each area requiring further study had a still photo created from the geo-video frame. The still photos were merged to create composites covering the areas of interest. The still photos were used as an aid in the field for ground-truthing and for delineation in the office. Ground-truthing was conducted on October 26, 2007 (Upper Fording River), November 1, 2007 (Lower Fording River), November 8, 2007 (Michel Creek) and November 15 (Elk River). A Trimble GPS unit was used to map actual channel dimensions in order to assist with geo-video analysis.

Mapping and Analysis

Michel Creek was first analysed as a test subbasin. The results were evaluated by the EVSTF and requested adaptations were included in this analysis of the whole project area. Lentic and lotic areas were digitized as polygons onto TRIM orthophotos while viewing the geo-video as a reference on a second monitor. Additional delineation tools utilized included: air photo interpretation at 1:20,000 scale or less; government mapping; local forestry mapping; and mine air photo interpretation.

The TRIM orthophotos and geo-video flight path were linked using Arc GIS so that the exact locations would be known. The likelihood for error during data transfer and polygon delineation was limited as much as possible (e.g., by linking the two maps spatially and by viewing the two maps at the same scale). All maps were created using orthophoto and TRIM/DEM files as a base and were provided in standard government UTM (NAD 83) coordinate system format. The following maps were created to display the lentic/lotic findings from this study:

- 1:175,000 Project Area Key Map, displaying the spatial extent for each of the associated subbasins within the whole of the project area. Subbasin name, mine locations, roads and other features of interest were identified.
- 1:10,000 Detailed Subbasin Site Maps, depicting the lentic and lotic polygons in relation to the base TRIM data along the length of each subbasin.

Attribute Table

An attribute table was prepared which contained data for each of the seven subbasins. Key information summarized in the attribute table included:

1) Site Number (for all lentic polygons);
2) Aquatic Feature Type (e.g., anthropogenic, lotic; lentic, beaver dam/end point);
3) Wetland Classification for Lentic Areas (i.e., Forest Practices Code or Canadian Wetland Classification);
4) Channel Type for Lotic Areas (e.g., mainstem, anastomizing, braided, headwater);
5) Potential Fish Accessibility (during fall/spring);
6) Polygon Area (hectares and m^2); and
7) Characteristics (general description of the wetlands, lakes, ponds, side channels, etc).

The Aquatic Feature Type parameter was defined earlier, and additional details on the remaining parameters are as follows.

Wetland classification for lentic areas: All wetlands (lentic areas) other than anthropogenic ponds were reviewed and classified using current standard methods provided in the Forest Practices Code (FPC 1995) and the Canadian Wetland Classification System (Shallow Water Wetland Class) (Warner and Rubec 1997). Lentic wetlands were classified by the area which included open water and the associated wetland (Lentic 2). If wetlands were not large enough to be classified as W1 to W5 according to the FPC Guidelines, they were designated as either: 1) Riparian Stream Water Wetlands (Stream Water) or 2) Riparian Floodplain Waters (Floodplain Water) under the Shallow Water Wetland forms (Warner and Rubec 1997).

Stream Water Wetlands were characterized as follows:

- situated in riparian zones of freshwater rivers and streams;
- the source of water and the water level are largely controlled by water in the adjacent river or stream;
- water is usually persistent and continuously flowing;
- situated along streams;

- and some sediment deposition zones may occur.

Floodplain Water Wetlands were characterized as follows:

- situated in riparian zones of freshwater rivers and streams;
- the source of water and the water level are largely controlled by water in the adjacent river or stream;
- "intermittent flow" usually restricted to overbank flow;
- high water table;
- additionally, may receive water from run-off or groundwater sources;
- and occupy abandoned channels, oxbows or river meanders on river floodplains.

Channel type for lotic areas: The lotic or flowing water areas were classified according to their channel pattern type observed on the video. The key channel type characterizations considered were: mainstem, braided channel, side channel, anastomizing channel and head water channel. These patterns typically gradually merge into another and often develop in response to sediment transport (Leopold and Wolman 1957). Channel morphology characteristics were from Leopold and Wolman (1957), Schumm (1981) and Rosgen (1994).

Fish accessibility (during fall/spring): Lentic areas were labelled according to potential connection with the mainstem during both the high flow (spring) and low flow (fall) periods. This was a qualitative assessment based on photo interpretation (lentic site distance from the river and channel morphology at or near the site) and generally did not involve field confirmation.

Polygon area (hectares and m^2): Polygon areas identified the size of the respective lentic or lotic polygon. Lotic areas were divided into polygons mainly as a result of the mechanics of digitizing, which required that the polygon be closed on each frame/screen. Therefore, they were summed at the end of the delineation as they were a continuous feature.

RESULTS AND DISCUSSION

When the geo-video footage of the study area was compared to the TRIM orthophotos, differences attributed to temporal variation were evident. The river morphology, for example, had changed between the time that the 2004/2005 orthophotos were obtained and the 2007 study period. This was evidenced by new channel alignment and new wetlands. Rivers are dynamic landscapes, so this was expected and demonstrated the ability of geo-referenced video to record change over time. Some of the differences between the 2004/2005 orthophotos and the geo-referenced video were from the difference in the time of year they occurred. Orthophotos were taken during the summer months while the geo-referenced video reflected late fall conditions when the majority of the deciduous trees and shrubs had dropped their leaves. Differences in the time of year and different years also influenced stream stage levels. Figure 2 illustrates the variability of peak monthly discharge throughout the summer and fall months and between years on the Elk River. A true comparison of discharge, however, between the orthophotos and the 2007 sampling period is very difficult to make, because the orthophotos cover a wide range of time that varies within and throughout the subbasins.

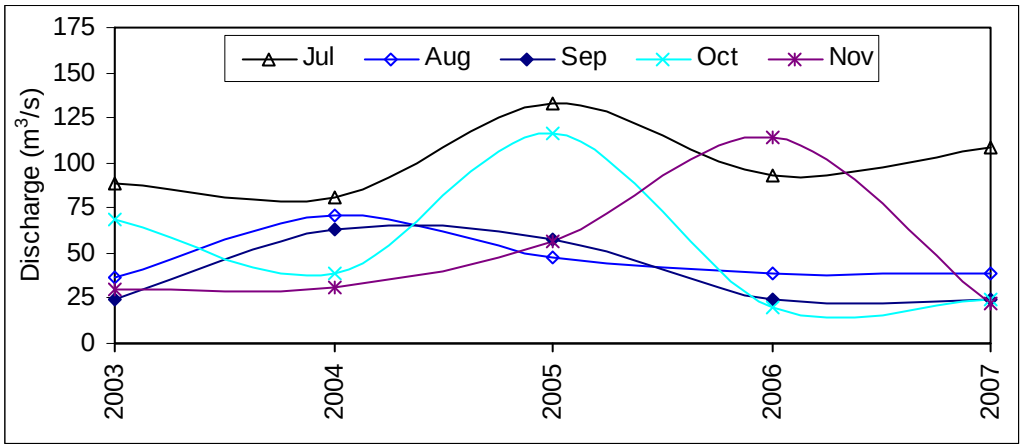

Figure 2. Peak monthly discharge at the Elk River (at Fernie), during the months of July, August, September, October and November from 2003 to 2007 (Water Survey of Canada 2008).

An integral component to accurately identify lentic and lotic areas was the timing of geo-video data collection. Initially we thought the optimal time to collect field information would be during mid flow conditions, which is July for the study area, when wetland (lentic) features would be most evident and readily defined using wetted area and vegetation indications. However, as a result of project administration circumstances, geo-video data collection did not proceed until September and October, 2007 and field reconnaissance activities ensued in November, 2007. During this period, flows were near base flow levels. Although the full extent of the open water evident was likely lower during the study period, visual identification of features was actually better than expected. The aquatic environment and surface substrates were more discernable in the aerial video, since the trees and shrubs had lost their leaves.

A summary of the calculated lentic and lotic areas (ha) and percentages (%) for the study area is provided in Tables 1 and 2, respectively. These tables reveal that the project area as a whole is made up of approximately 139 ha (12%) lentic and 976 ha (84%) lotic habitat. The Elk River subbasin had the greatest extent of aquatic habitat (838 ha) overall, including the greatest area of lentic habitat (93 ha). The Fording River had the second largest aquatic habitat area (180 ha) and lentic area (33 ha). Note that standing water wetland areas (lentic 1) were often surrounded by lentic 2 areas. These were identified in the attribute tables as lentic 1a habitats and their areas were summated in with the lentic 2 areas. Anthropogenic areas were not part of the lentic area calculation; however, the results revealed that they made up a large percentage of the aquatic area in the Fording River (17%), Henretta Creek (38%) and Line Creek (30%) subbasins.

Table 1. Summary of aquatic feature type areas (hectares) by subbasin.

Watershed	Area (ha)					
	Anthro-pogenic	Lentic 1	Lentic 2	Lentic Total	Lotic	Grand Total
Elk River	5	20	74	94	740	839
Erickson Creek	0	0	0	0	1	1
Fording River (Lower)	0	<1 (0.35)	3	4	51	55
Fording River (Upper)	30	3	26	29	67	126
Fording River (Total)	30	3	29	33	118	181
Henretta Creek	3	<1 (0.03)	<1 (0.14)	<1 (0.17)	5	8
Line Creek	5	<1 (0.08)	<1 (0.34)	<1 (0.42)	11	16
Michel Creek	6	<1 (0.35)	12	13	101	120
Grand Total	49	23	115	140	976	1165

Note: For values <1, the actual area calculated is provided in brackets, for reference purposes. Only values that could be rounded to whole numbers were included in the grand total calculations, to reflect levels of uncertainty.

Table 2. Summary of aquatic feature types as a percentage of the subbasin and watershed.

Watershed	Percentage (%)			
	Anthropogenic	Lentic	Lotic	Total
Elk River	1	11	88	100
Erickson Creek	0	0	100	100
Fording (Lower)	0	7	93	100
Fording (Upper)	24	23	53	100
Fording (Total)	17	18	65	100
Henretta Creek	38	2	60	100
Line Creek	30	3	67	100
Michel Creek	5	11	84	100
Project Area Totals	4	12	84	100

Lentic Classification

In the project area, 31 of the lentic areas were large enough to be classified under the FPC. Most (29) were between 1 and 5 ha in size and were classified as W3 wetlands. The Elk River subbasin had the majority (18) of W3 wetlands as well as the only W1 wetlands (2) and the only W5 wetland complex in the subbasin.

As a result of the location relative to the river, almost all of the lentic areas assessed were classified as *Floodplain Water* W*etland.* The *Stream Water Wetland* designation was imparted on wetlands created in the mainstem itself as a result of depositional processes backing up and restricting flow. There were only a few of these *Stream Water Wetlands* identified, which included: six on the Elk River, resulting from depositional processes upstream of the Elko dam; and five on Michel Creek resulting from beaver dams.

Fish Accessibility

There was variation amongst wetlands in terms of their potential fall and spring accessibility for fish. Generally, it appeared that many of the wetlands would not be accessible to fish in the fall, under low flow conditions. However, in the spring under higher flows the fish accessibility to most of the wetlands was expected to improve. Field review would be necessary to confirm the fish accessibility results.

Elk River

The Elk River subbasin had approximately 838 ha of aquatic habitat, representing 72% of the aquatic habitat assessed in the whole study area. Eighty eight percent (88%) of the aquatic area reviewed in the Elk River subbasin was classified as lotic habitat. There were numerous channel types and varied characteristics evident throughout the mainstem's length including: canyon sections, delta-like channel sections resulting from the Elko dam, braiding around islands, sidechannels and anastomizing areas. The Elk River had seven anthropogenic pools, which appeared to be associated with either industrial (4 pools), golf course (2 pools) or mining activities (1 pool).

The Elk River subbasin contained 93 ha or 11% lentic habitat. A large proportion of this area was typed as lentic 2 habitat, which typically included the presence of wetland vegetation and/or soils around a wetted pool. This subbasin had the greatest number of wetlands that would be classified under the FPC. Two W1 wetlands (>5 ha), eighteen W3 wetlands (1-5 ha) and one W5 (wetland complex) were identified. The largest W1 wetland was approximately 13 ha and included a pond and a wetted area in an old channel and associated wetland features. The other W1 wetland totalled approximately 5 ha and was comprised of 6 pools connected by water throughout an old channel. The W5 wetland, totalled approximately 5 ha and was made up of pools in an old oxbow channel. The remaining wetlands in this drainage were too small to be classified under the FPC and were determined to be mostly *Floodplain Water* wetlands. The *Stream* Water designation was limited to six lentic areas created by backwatering effects and sedimentation associated with the Elko Dam.

Erickson Creek

The Erickson Creek subbasin was comprised of approximately 1 ha of aquatic habitat, representing <1% of the aquatic habitat assessed in the whole study area. No lentic habitat was identified in this small subbasin. The lotic habitat all appeared to be single channel, narrowing near the headwaters.

Fording River

The Fording River subbasin had approximately 181 ha of aquatic habitat, representing 15% of the aquatic habitat assessed in the whole study area. Lotic waters made up approximately 118 ha or 65% of this subbasin. The lotic environment was comprised of a variety of channel types, including single channel with some braiding and anastomizing areas near the headwaters, a canyon section, and mostly single meandering channel from approximately midway along the river, down to the confluence with the Elk River. The Fording River contained approximately 30 ha (or 17% of the aquatic area) of

anthropogenic wetlands. These were mainly located in the upper sections of the river near the Fording River Mine.

The Fording River was calculated to contain 33 ha of lentic habitat, equating to 18% of its aquatic habitat. Most of the lentic areas had some outlying extent of wetland area, which although may not have been wetted during this assessment, would be expected to be wetted under higher flow conditions (lentic 2 areas). Although the characteristics of the wetlands varied, it appeared that the river contained numerous pools in old river sections. Other evident wetlands included: adjacent wetlands, backwater channels and clearly defined ponds. Eight of the lentic areas in the Fording River subbasin were large enough to be classified under the FPC as W3 wetlands, with the largest being just over 3 ha. All but one of these wetlands were located above the Greenhills Mine. The remaining wetlands were less than 1 ha in size each and were classified as *Riparian Floodplain Water Wetlands*.

Henretta Creek

The Henretta Creek subbasin had approximately 8 ha of aquatic habitat, representing 1% of the aquatic habitat area assessed in the whole study area. Approximately 5 ha or 62% of the Henretta Creek's aquatic area was determined to be lotic habitat. This was comprised of a single channel originating from under the mine near the headwaters. Lower in the system, the river anastomosed into multiple channels for a stretch and braided around mid channel bars. Anthropogenic pools made up a large portion (38%) of this subbasin's aquatic area. These included five pools, which appeared to be associated with the Fording River mine.

The lentic area covered only a small portion (2%) of the aquatic habitat in the Henretta Creek subbasin and was comprised of small pool areas; some of which were wetted during the assessment. Since the wetlands were assessed to all be less than 1 ha in this subbasin, none were classified as FPC wetlands. The lentic areas were all classified as *Riparian Floodplain Water Wetlands*.

Line Creek

The Line Creek subbasin was assessed to have approximately 16 ha of aquatic habitat, representing 1% of the aquatic habitat assessed in the whole study area. Approximately 11 ha or 69% of the aquatic area was determined to be lotic habitat in the Line Creek subbasin. The flowing waters were composed mainly of single channel, with some braided and anastomized sections around islands. Most of the wetland areas in the Line Creek subbasin appeared to be anthropogenic pools. There were 21 anthropogenic pools, which comprised approximately 5 ha or 30% of the aquatic area in the subbasin. All of the anthropogenic areas appeared to be associated with mine activities.

The lentic area only comprised a small area (<1 ha or 3%) of the Line Creek subbasin. This included, for example: old channel pools, ponds, a sidechannel and drainage channels from the anthropogenic ponds. All of the lentic areas were smaller than 1 ha, and thus were not large enough to be classified under the FPC. They were all classified as *Riparian Floodplain Water Wetlands* as a result of their proximity to the mainstem.

Michel Creek

The Michel Creek subbasin had approximately 120 ha of aquatic habitat, representing 10% of the aquatic habitat assessed in the whole project area. Eighty four percent (101 ha) of the aquatic habitat in the Michel Creek subbasin was classified as lotic habitat. The lotic area had a variety of features. Near its headwaters, the creek was generally single channel with some beaver activity. Further downstream, mid channel gravel bars were evident with some braiding. Downstream of this, single channel characteristics resumed; and in the lowermost section, near the confluence with the Elk River, braiding was prevalent again. A few side channels were also observed that were expected to flow during higher water levels. Michel Creek had 22 small anthropogenic pools totalling approximately 6 ha or 5% of the assessed aquatic area for the subbasin. These pools appeared to be associated with mine activities. Subsequently, most were located in the upper sections of the Michel drainage including the Corbin Creek area.

Michel Creek contained approximately 11% lentic habitat. Lentic 1 habitat added up to less than 1 ha and almost all standing water areas (lentic 1) observed had outlying wetland areas (lentic 2). Although there were a variety of wetlands evident, many of the lentic areas were shallow backwater type channels connected to the mainstream at their downstream end/outlet having no inlet. Four beaver dams were observed. Three of the dams were constructed on the mainstem in the upper parts of the basin. Michel Creek was the only subbasin of those reviewed that had this type of beaver activity on the mainstem. The fourth beaver dam was constructed in a wetland area alongside the mainstem lower in the subbasin. Only two wetland complexes in the Michel Creek drainage met the FPC classification. These were classified as W3 wetlands based on their size (approximately 3 and 2 ha). The remaining wetlands in this drainage were too small to be classified and were determined to be mostly *Floodplain Water* wetlands. The *Stream* Water designation was limited to three lentic areas located in the sedimentation zone behind the beaver dams built on the mainstem.

CONCLUSIONS

This lentic and lotic information for the Elk River watershed should be a useful tool to guide future assessments on fish and wildlife and selenium influences. The Red Hen Video approach allowed for a cost effective and accurate spatial distribution and estimation of lentic and lotic areas, over a large drainage area, while supplying a long term monitoring tool to track lentic and lotic spatial changes.

RECOMMENDED ACTIONS

An integral component to accurately identifying lentic and lotic areas is the timing of data collection or videotaping the stream. It may be best to collect field information during mid flow conditions (optimally July to mid August) in order to have a summer and fall video for comparison. Although the September and October flight results appeared to be better than anticipated, a summer flight would allow for a comparison of results. This would be particularly valuable for key basins, such as those with the greatest potential for selenium concerns.

A next step may be to classify and conduct a detailed analysis of lentic areas identified in this study, which are deemed to be a priority (e.g., for subbasins of significance). This could involve using attributes such as relative depth, size, wetland type and fish accessibility to develop a classification system that ranks the relative importance (e.g., rating of 1 - 5) of the lentic areas.

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