Boggy River Ecological Survey

9-10 September 2022

A Technical Report Prepared for:

A Rocha Manitoba and A Rocha Canada

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Acknowledgements

Thank you to Naomi Derksen, Tyler Fewings, Juniper Giesbrecht, Walker Giesbrecht, Lisa Greaves, Dave Guenther, Dr. Rachel Krause, Katrina Lengsavath, Ella Reimer-Epp, and Tyson Scott for helping with surveying the Boggy River.

Thank you to Catherine Roffey for additional support during the survey weekend.

Thank you to Dr. Rachel Krause and Dr. Paul Simonin for their consultation during the development of the report.

Photo credit to Walker Giesbrecht.

Revised: July 2023. Graham Peters

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Abstract

The Boggy River Ecological Survey was conducted as a follow-up to the initial Boggy River Baseline Survey (Derksen et al. 2018). By continuing to monitor the status of the river we can understand the health of the system and how it may be changing. Fieldwork was conducted in early September 2022. The morphology and habitability of the river were observed by taking bank measurements, channel measurements, water chemistry, and benthic macroinvertebrate samples. While the higher water level prevented us from taking all our channel measurements, we conclude that the Boggy River is a healthy system lacking evidence of pollution. Our benthic macroinvertebrate sampling highlighted that the river can support biodiversity and further supports the conclusion that the water quality is good.

The recommendations of the previous study were to continue to observe the stability of the banks. As noted, erosion is a normal part of a river ecosystem, but if an ecosystem is unstable the rate of erosion will be far greater. Such instabilities can threaten habitat integrity. Our findings show that for the most part bank status remained consistent from the previous study, and the right bank presented as falling most in line with OSAPs "eroding bank" classification. Observation of the bank should continue in order to monitor the stability of habitats in the Boggy River. This data should inform future management if changes in the river suggest that measures should be taken to prevent higher rates of erosion.

1. General Introduction

Rivers are vital and complex ecosystems. The impact that rivers have on other water bodies makes the health of the river system important on a much broader scale. Impacts that occur upstream will be felt downstream as the flow of water picks up materials, including nutrients and pollutants. These wide-reaching impacts that rivers have makes ensuring the health of these systems crucially important.

The Boggy River is found in East Braintree on Treaty 3 Territory and extends 40km through riparian forests. As it enters East Braintree the surrounding habitat becomes characterized by mixed deciduous and coniferous forests (Becker and Hamel 2017, Clarke 1998). East Braintree is located along the Trans-Canada Highway and Provincial Road 308, being first established in 1914 as a construction camp. Aqueduct construction was completed in 1919 and provided fresh water to Winnipeg, and the rich soil and abundance of natural resources (timber and wild game) attracted early settlers (Annell 2018). The Boggy River meanders westward as part of the Whitemouth River Watershed and the larger Winnipeg River basin. Water that flows through the Boggy River will make its way to the Birch River, Winnipeg River, and throughout the watershed therefore there is increased importance on maintaining the health of this system.

The Lake of the Woods ecoregion supports a large diversity of wildlife, including Gray Wolf (*Canis lupus*), North American River Otter (*Lontra canadensis*), and White-tailed Deer (*Odocoileus virginianus*). Birds observed in the area also include Belted Kingfisher (*Megaceryle alcyon*), Spotted Sandpiper (*Actitis macularius*), and Redwing Blackbird (*Agelaius phoeniceus*). These are not identified as species of special concern but are highlighted to provide some qualitative understanding of the biodiversity that the Boggy River and surrounding area are able to support. Past studies have also observed several species of fish in the Boggy River as shown in Table 1. While Carmine Shiner (*Notropis percobromus*), listed as endangered on the federal Species At Risk Act, has been observed further downstream in the Birch River, it has yet to be observed in the length of Boggy River surveyed here. This is likely due to its habitat requirements not being met in this section of river. Maintaining the health of the Boggy River is still important to the Carmine Shiner given that water for its habitat flows in from the Boggy River.

Figure 1. White-tailed Deer and River Otters at the Boggy River.

The most recent analysis of the river assessed aquatic habitats along 10.5km of the Boggy River in order to support plans to protect the infrastructure of the bridge that enters the Boreal Ecology Centre (Bulloch 2022). This involved depth measures along 41 transects and descriptions of substrata and fish habitat features. This work found that the deep hole identified beneath the bridge highlighted for its fish overwintering habitat potential was not unique to that site. These findings show that the river provides homogeneous habitat along the observed range with deep holes for overwintering habitat common. It also suggests that naturalization would be valuable for stabilization of these valuable habitats as part of the bridge restoration work.

Table 1. Fish species identified in the Boggy River (Bulloch 2022).

Family	Scientific name	Common name	Clarke (1998)	Derksen et al. (2018)
Esocidae	*Esox lucius*	Northern pike	✓	
Umbridae	*Umbra limi*	Central mudminnow	✓	
Cyprinidae	*Luxilus cornutus*	Common shiner	✓	✓
	Nocomis biguttatus	Horny head chub	✓	
	Notropis hudsonius	Spottail shiner	✓	
	Notropis vollucellus	Mimic shiner	✓	
	Phoxinus eos	Northern redbelly dace	✓	
	Pimephales promelas	Fathead minnow	✓	
	Rhinichthys cataractae	Longnise dace	✓	✓
Catostomidae	*Catostomus commersoni*	White sucker	✓	
	Moxostoma macrolepidotum	Shorthead redhorse	✓	✓
Gasterosteidae	*Culaea inconstans*	Brook stickleback	✓	✓
Centrarchidae	*Ambloplites rupestris*	Rock bass		✓
Percidae	*Etheostoma exile*	Iowa darter	✓	
	Etheostoma nigrum	Johnny darter	✓	✓
	Percina maculata	Blackside darter	✓	✓

Our study is meant to follow-up on Derksen et al. and provide a second data point in the ongoing monitoring of the Boggy River that can further our understanding of its overall health. This project provided a baseline understanding of the river's morphology, chemistry, and species diversity. With the base knowledge from this study that the Boggy River is a healthy, slow-moving river with minor erosion and no evidence of pollution, we have a benchmark to compare findings and observe changes in the river, reflecting on potential management and further observation that may be required. The continuation of this survey will allow us to observe fluctuations in these measures and overtime clarify the health of the system which could inform future recommendations regarding habitat stabilization and areas that should be focused on in future areas of study.

It should be clearly stated that maintaining the health of the river should not involve keeping the river in a fixed state. Erosion and changes in river morphology are normal and are contributors to the creation of habitat. Attempts to significantly reduce natural erosion may result in channel straightening and increased water velocity, thereby influencing plant and animal communities to establish themselves (Florsheim 2008). Any maintenance recommended should therefore not impede the dynamic nature of a river system but sustain the capabilities of the river to provide suitable habitat and clean water.

2. Overall Methods

2.1 Reach Choice and Transect Setup

This project is designed to follow and replicate the baseline Boggy River study conducted in 2018 (Derksen et al.) as continued health monitoring of the river. In order to best follow the recommendations of that study to continue to observe the health of the river we followed the same methodology. Details about the procedures that were put into place can be found in the CMU 2018/19 BIOL 3510 lab manual (Krause 2018).

The government of Manitoba reported that in 2022 between April 1 and June 19 Manitoba experienced “near-record precipitation that resulted in a prolonged spring flood period” (Hydrologic Forecast Centre Emergency Measures Organization). This history of flooding likely contributed to the loss of our original site marker, therefore a new one was placed in the same approximate location. Shortly after 2 kicknet samples were collected to prevent disturbing populations during transect setup. Ten transects were set up 10m apart extending to a total length of 100m. All samples and measurements were taken on September 9, 2022, in the evening until sunset and the following morning and afternoon, September 10.

3. Bank Measurements

3.1 Introduction

When observing the status of a riverbank it is important to measure bankfull and wetted widths, bank angle, undercut, sediment composition, and streamside vegetation. These factors provide a measure of the structural stability of the river and can be used to describe habitat characteristics for fishes and benthic macroinvertebrates. Table 2 highlights the effect that different bank conditions can have on erosion and the formation of habitats. This adds some dimension to our understanding of erosion on a river system, as it is important for creating fish and invertebrate habitats while also affecting the overall stability of the bank structure.

Table 2. Excerpts showing the effects of channel bank infrastructure to control bank erosion (Florsheim 2008).

Geomorphic and ecological attribute	Habitat or ecosystem service influenced	Examples of organisms affected
Loss of bank substrate		
Unconsolidated sediment	Vertical banks for wildlife burrowing and nesting Filter and retention of nutrients, pollutants, water quality	Bank swallow (*Riparia riparia*) Macroinvertebrates (eg. mayflies [Ephemeroptera], caddisflies [Trichoptera], and stoneflies [Plecoptera])
Natural biotic and abiotic components of land-water margin	Shoreline microhabitat: soft sediment or burrows, emergent vegetation to cling to; underwater plants, snags, roots protruding from bank	Shore-dwelling insects (eg. Neocurtilla); macroinvertebrates
Roughness and irregularity in land-water margin	Variation in near-bank flow velocity, refuge during storm flows	Overwintering fish, macroinvertebrates (see above)
Undercut banks	Protection from predators	Juvenile fish
Loss of riparian forest		
Stream-side riparian ecosystem Willow and cottonwood forests	Complex riparians vegetation, areas for wildlife: bird breeding, nesting, safety from predators; probing for insects under tree bark; wildlife: food, migration corridor, and/or dispersal route; plants: structure for vines	Birds (eg. willow flycatchers [*Empidonax traillii extimus*], semi aquatic mammals (eg. river otter [*Lontra canadensis*]), macroinvertebrates
Overhanging branches, leaves	Shade, organic material, fish food	Fish, macroinvertebrates (nymph and adult stages)
Large woody debris	Reduction in pool complexity and depth, loss of attachment sites	Fish, macroinvertebrates (see above)

Static banks are not normal or good for creating healthy habitats. A static bank is often the result of human stabilization of a river in order to protect land assets (Florsheim 2008). At the same time, if too much erosion occurs, habitat stability is threatened. Human activities in and around river systems can alter their biogeochemical processes resulting in impacts on five factors identified by Karr (1999): flow regime, physical habitat structure, water quality, energy source, and biological interactions. Impacts on these factors alter species richness and health as well as physical river conditions including erosion rate. This suggests that any recommendations for erosion control should be focused on promoting habitat stability.

Bank vegetation is important for maintaining bank stability. Higher density of vegetation and root structures increases the stability of bank structure (Florsheim 2008). It has been found in several agricultural settings that grasses, sedges, and reeds can be just as important as trees and shrubs for bank stabilization (Erskine 2011). This suggests that the type of vegetation we observe in riparian areas might have less impact on erosion control than the presence of vegetation generally though, certain benefits have been associated more with woody plants than smaller herbaceous groups. The role vegetation has on protecting against erosion will vary in quality based on the type of plant, but overall includes the restraint of soil particles, increasing surface roughness and therefore water velocity and water interception (Johnson 1993). Riparian forest also contributes to maintaining water quality in the Whiteshell region which is critical to many fish and benthic macroinvertebrates (Becker and Hammel 2017).

3.2 Methods

For monitoring each of the 10 transects along the river, collecting data for bank width, bank angle, undercuts, sediment composition, and streamside vegetation our methodology drew from OSAP (2017). Our observation of the river occurred in the fall; therefore, the river would likely be at its annual minimum and bankfull width had to be estimated based on the bank vegetation and morphology.

Figure 2a. Satellite image of the Boggy River taken in June 2020.

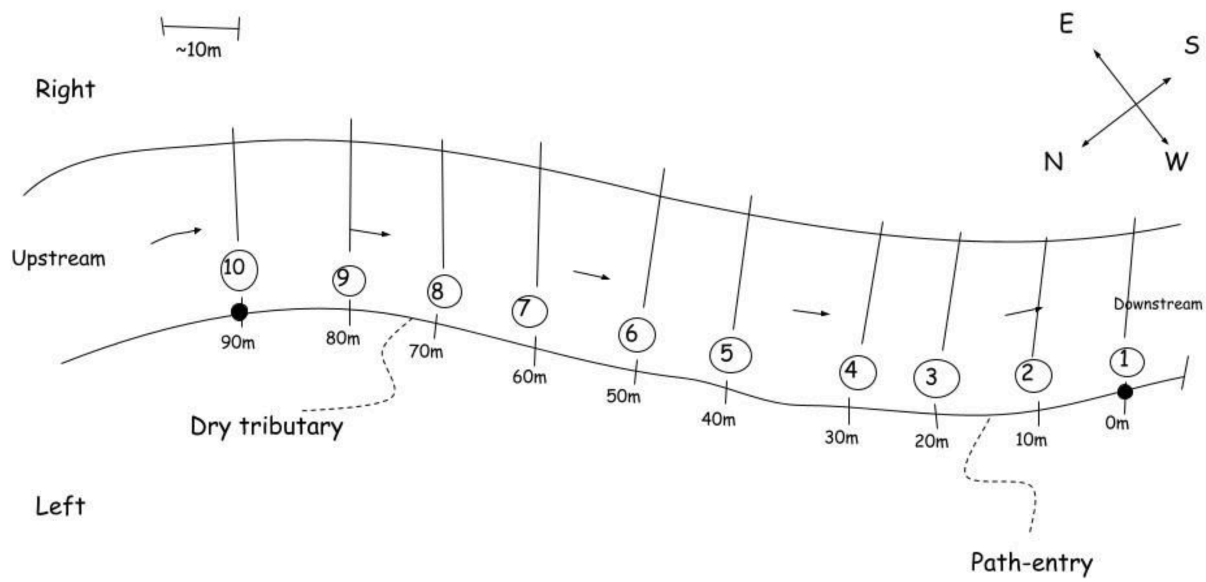

Figure 2b. Digital recreation of the site sketch of the survey transects.

For clarity, right and left banks are determined relative to the flow of the river, therefore when standing facing the upstream side of the river the right and left banks are to your right and left respectively.

Bank measurements were made using a bank profile tool (see concept in Figure 12 and the tool in practice in Figure 3) that was placed on the edge of the water, held at 90° angle.

Distances to the bank were recorded at intervals (0m, 0.25m, 0.75m, and 1.5m) 1.5m from the water's edge. The undercut was collected using a ruler held parallel to the bank's overhand and measuring inward to the deepest part of the undercut; all undercutting was recorded in each transect. Substrate at each transect at the base of the bank was classified as one of the following: unconsolidated clay, consolidated clay, silt, sand, bedrock, concrete, organic detritus, or large boulders. Vegetation at each transect was classified as one of the following: wetland, forest, scrubland, meadow, cropland, lawn, or no vegetation. All the bank data was gathered on the same day.

Figure 3. Use of the bank profile tool along the right bank of the Boggy River.

3.3 Results and Discussion

As was the case in the baseline study from 2018, the wetted width was consistently close to the average of 12.8 ± 0.3 (standard error; SE). The relatively homogenous width of the river suggests a uniform volume of water flowing through at any given point. The bankfull width was consistently close to the average of 14.9 ± 0.3. This indicates our water level observations likely represent an annual minimum. These measures lack the fluctuations noted in the previous study. These measures are helpful for understanding other bank measures. The space between the bankfull and wetted widths could have some impact on the vegetation and sediment types, due to seasonal fluctuations in water level carrying sediment deposits and limiting growth period for different riparian plants. These factors would also influence bank angle.

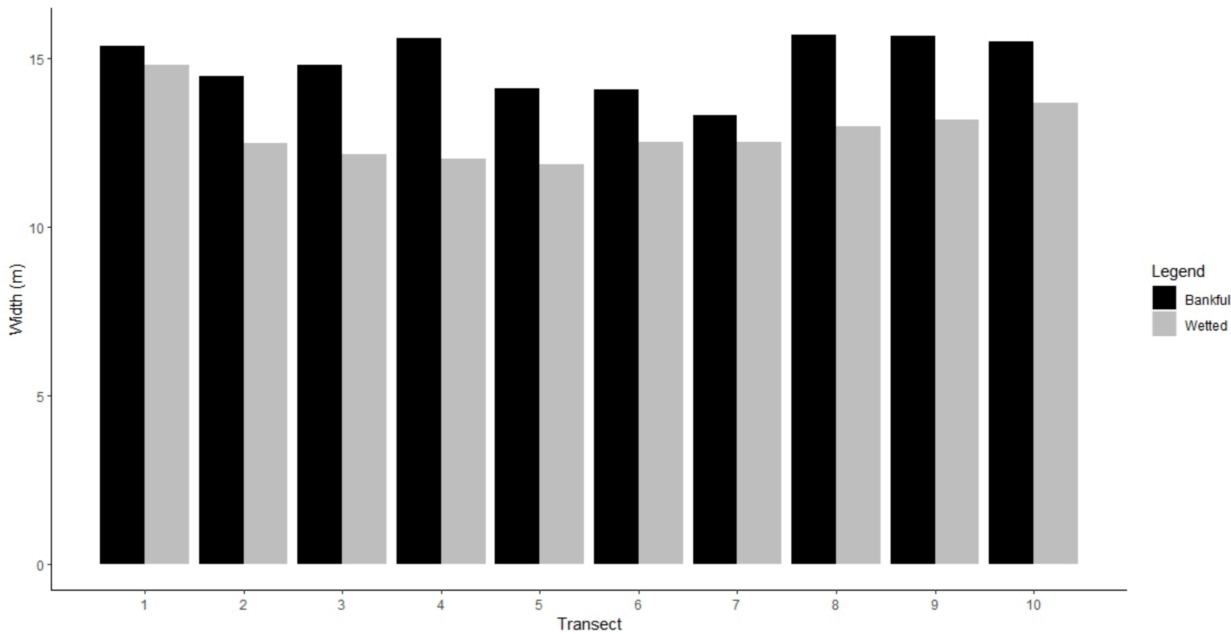

Figure 4. Bankfull and wetted widths of the river.

Bank angle is valuable for understanding bank erosion. Bank angles in Figure 5 were calculated from bank heights shown in Figure 10 of the appendix. In order to calculate the angle of the bank, distances to the top of the bank were taken at intervals along the width. Figure 5 shows the trends in the angles; both banks remain relatively consistent, the right bank (mean 52.54; standard deviation 5.24) observed with greater bank angles than the left bank (mean 19.91; standard deviation 5.31). The greatest bank angles occur on the right bank at transects 7, 8, 9. These values along with the minimum right bank angle at transect 4 are consistent with the inflection of the river at these transects.

The right bank is shown to be more susceptible to erosion due to its higher sloping, while the left does not exceed 45°, therefore according to OSAP would be considered a gradual incline. Larger bank angles were also observed on the right bank in the previous study and noted of particular concern. If bank angle continues to increase, this could be a sign of increased rate of fluvial erosion and could lead to bank collapse as it approaches the angle of repose (Newbury 1995).

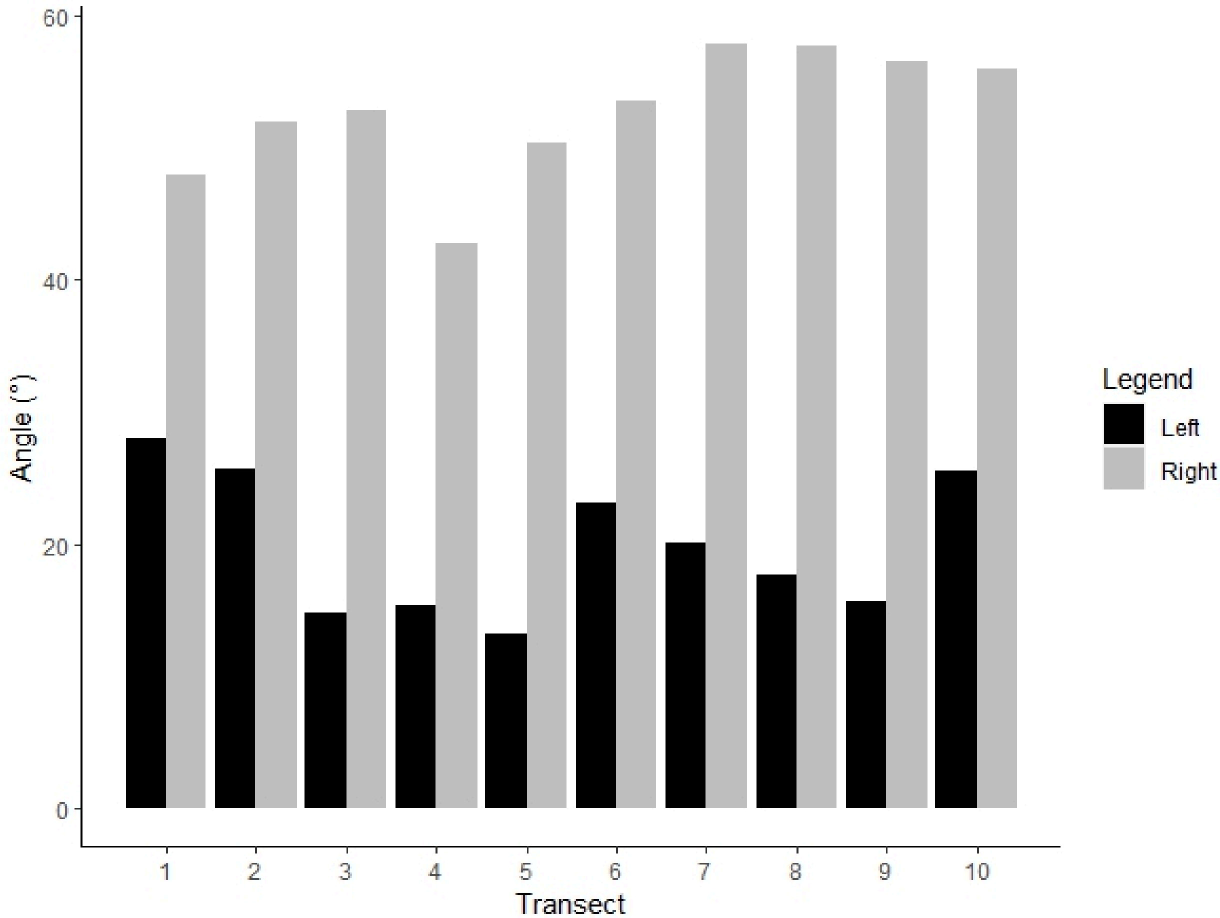

Figure 5. Bank angle for left and right sides of the river.

Undercut measurements are shown in Figure 6. As was the case in the previous study, undercut was greater on the right bank than left, where no undercut was observed. Transects 5 and 7 contained the most undercutting at 1450mm and 1040mm respectively. The undercutting was greater than those observed in the previous study which may suggest an increase in erosion. This may add to concern about the stability of this section of river. In Figure 6 when there is a second black bar present refers to a second undercut measure taken at a lower point on the bank at that same transect.

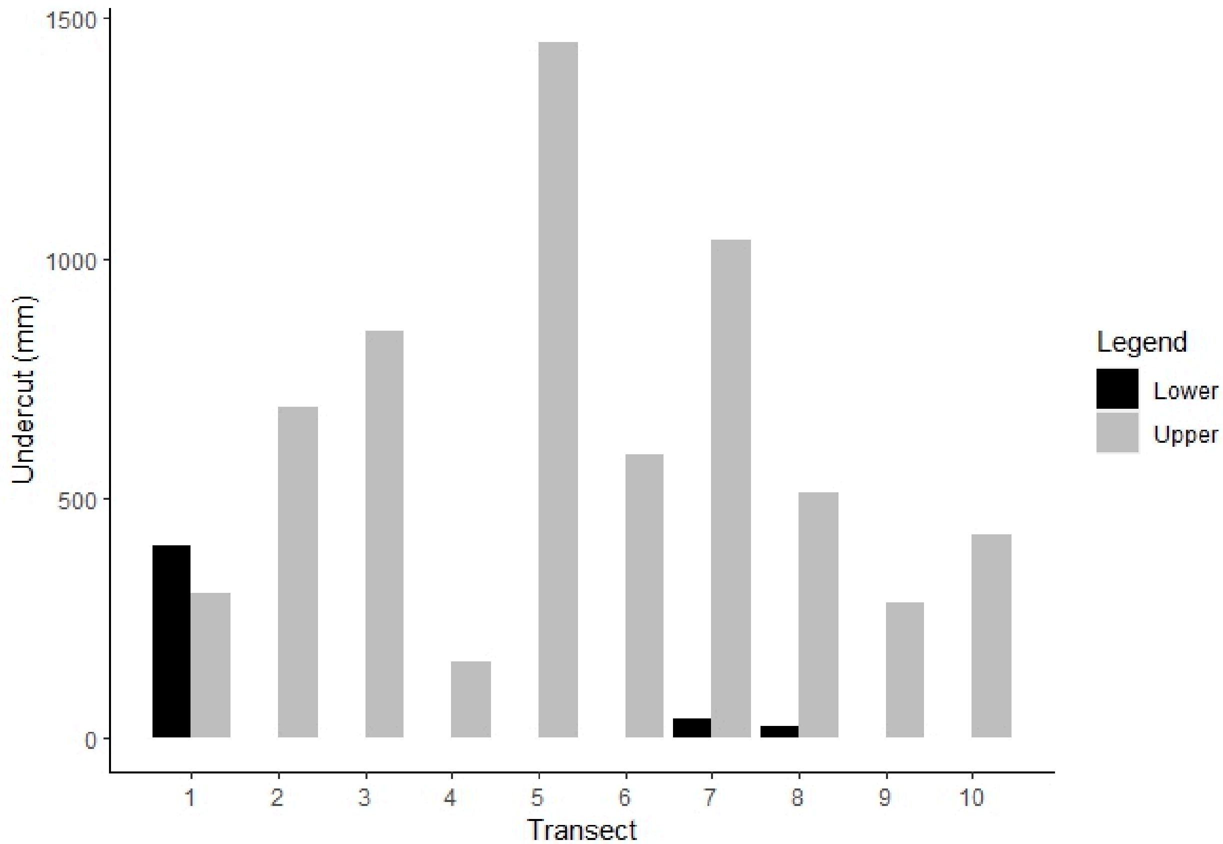

Figure 6. Bank undercutting for the right side of the river.

The higher water level may have impacted our vegetation observations. Previously the plant communities along the bank that were observed were grasslands that were not mowed. The higher water level could have submerged these communities therefore only those higher up on the bank could be observed. While individual species were not identified, the left bank was consistently identified as dominated by rushes and reeds and the right bank entirely dominated by trees. A few locations along the left bank were noted as void of vegetation, which may lend itself as a factor that could contribute to increased erosion on this side of the river overtime.

Table 3. Dominant vegetation observed along the left and right banks of the Boggy River[1].

Transects		1	2	3	4	5	6	7	8	9	10
Dominant Vegetation	Left	W	W	none	W	W	W	W	none	none	W
	Right	F	F	F	F	F	F	F	F	F	F

[1]F represents at least 1 tree with DBH >10cm (circumference 31.4cm) and W represents >50% area with water tolerant plants (eg. rushes, reeds)

Not noted in any of the tables is that the sediment type observed on the bank was exclusively silt. This uniformity of sediment type could have an impact on the presence of tolerant benthic macroinvertebrates (Cormier 2002).

4. Channel Measurements

4.1 Introduction

Macrophytes provide structural support to river systems. The presence of plants and other woody material can have an impact on the velocity of the river. An increase in channel complexity under water will cause a decrease in flow, therefore reducing the rate of erosion in smaller streams (Franklin 2008). However, the velocity of the river can affect the ability of macrophytes and woody debris to be established. If velocity is too high, it can push plant material downstream forming log jams and has the potential to erode substrates which itself has been observed promoting a marked increase in downstream log jams (Massé 2016).

Macrophyte presence also contributes to habitat quality, as greater physiological complexity provides shelter for benthic macroinvertebrates and fishes. During a flood, woody material can be pulled from banks and deposited in the river, again increasing the complexity of channel morphology and habitat (Florsheim 2008) and contributing to drag in the river which reduces the rate of erosion. While macrophytes can improve the physical conditions of the river, they are also impacted by conditions like water velocity, turbidity and presence of nutrients such that plant communities are as much a product of their environment as the environment is a product of the plant communities and their impacts (Franklin 2008).

Water velocity and channel depth also contribute to fish's ability to live in the river; slower shallower streams are occupied mostly by younger smaller fish and deeper waters are occupied by larger older fish (Bain 1988). While we were unable to take fish samples, knowing the effect that channel morphology has on fish habitat may allow us to speculate about how hospitable the river could be for fish, and prompt further study in the future.

4.2 Methods

In several areas along the river, it was not possible to take measurements due to the water exceeding the height of our hipwaders, therefore methods needed to be altered from the previous study. Depth was recorded at each transect at 50cm and 150cm from the left and right banks in order to maintain consistency and ensure that we were taking measurements from sections of the river we would be able to effectively survey. Measurements were taken using a meter stick. Due to this incomplete picture of the channel measure, we were not able to collect river flow data.

4.3 Results and Discussion

Due to the higher water level, we have an incomplete picture of the channel bottom. What we found was that the right side of the river was slightly deeper than the left (see Figure 7). This appears to relate to the shape of the river, as deeper channel measures relate to the outside of the stream at inflection points (see for example transects 1 and 2). The greater overall depth we observed is in line with predictions from Derksen et al. anticipating higher water flow and greater risk of flooding due to climate-driven precipitation events increasing overtime. However, we were unable to collect any discharge data due to the depth, therefore we can expect that discharge was higher than in 2018 because anecdotally the flow appeared similar and the wetted width was consistent with the 2018 wetted width, but the river was deeper.

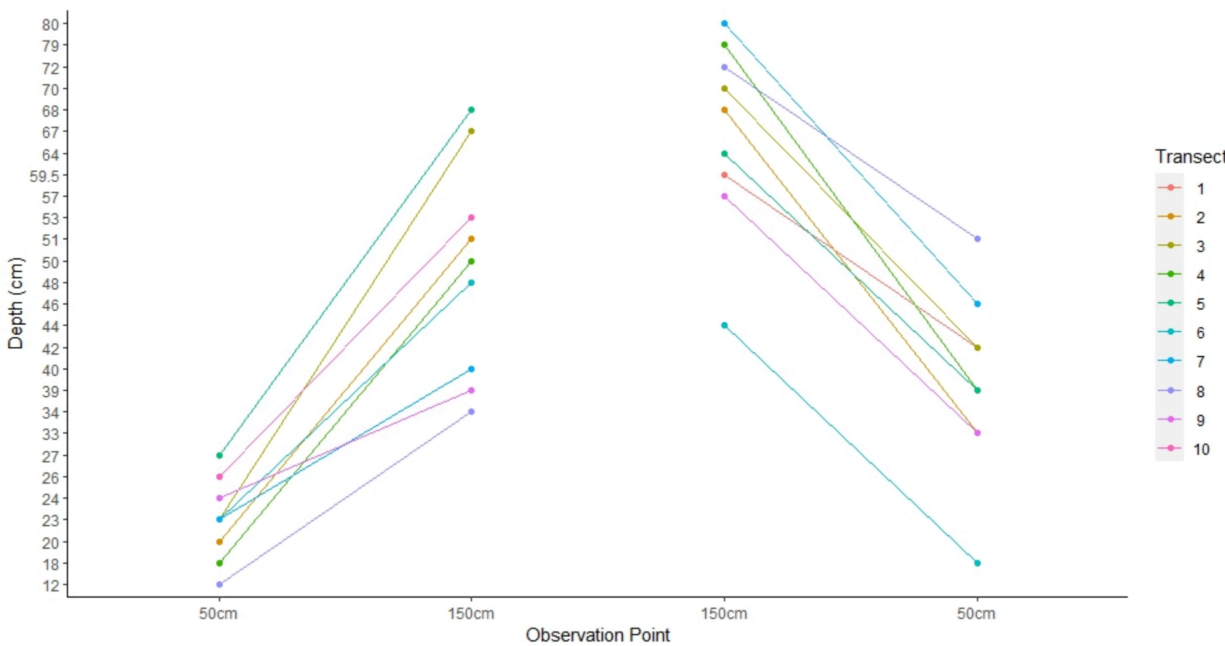

Figure 7. Channel measurements at 4 observations measured from left and right bank along the sampling reach.

In each transect the sediment type was characterized as silt with one exception. This was consistent with the findings from the previous study. Changes in land use, such as the clearing of woody material has been observed to lead to erosion and the movement towards a more homogenous silt bottom (Clarke 1998). The only location with any other categorization was on the left bank of transect 10, at measurement 50cm, classified as bedrock. OSAP categorizes these as finer substrates which are particularly vulnerable to erosion, which falls in line with the steep bank angle we observe here. This could promote instream vegetation if the velocity of the water is relatively low (Morrow and Fischenich 2000).

The absence of macrophytes on the right bank may also be attributed to sediment type. The predominantly silt sediment observed in tandem with the greater undercutting on the right bank might suggest that the bank is not stable enough for establishment of macrophytes. If sediments are being washed away by the river it will be more challenging for populations to establish themselves (Franklin 2008).

Our macrophyte data was also uniform, with no macrophytes observed on the right bank and macrophytes observed consistently on the left bank (with one exception at transect 3, 150cm from the bank). Recalling the riparian vegetation observed for each bank, this result could be affected by the forested right bank shading that side of the river. This has also been noted by Clarke (1998), suggesting thicker forest in riparian habitats may impact the ability of understory vegetation to grow. These complexities are valuable shelter for benthic macroinvertebrates and could also be contributing to the reduced erosion observed on the left bank because of macrophyte's contribution to slowing river velocity.

5. Water Chemistry

5.1 Introduction

Water chemistry is important for assessing the health of a river. The presence of chemicals such as nitrogen and phosphorus at different levels can affect the survival of benthic macroinvertebrates and fishes. Agricultural runoff also could run the risk of polluting the watershed, specifically nitrogen and phosphorus from fertilizers. Any areas along the river where woody vegetation identified within the riparian zone are removed would increase the risk of pollutants from farm chemicals and waste (Clarke 1998). Reports on land use have noted little agriculture occurring near the Boggy River, and agricultural activities within the watershed are restricted within 3km of the bank (Clarke 1998, Derksen et al. 2018). Upstream, the land surrounding the Boggy River is dominated by bog and marshland habitat which could also contribute to preservation of water quality.

Dissolved oxygen could also have some impact on the river's habitability. Mayflies as an indicator of good river water quality have particularly been noted to respond to changes in dissolved oxygen (Cormier 2002).

5.2 Methods

We used a handheld multimeter to collect the temperature, pH, total dissolved solids, and specific conductivity and a handheld dissolved oxygen meter for dissolved oxygen. Nitrates and phosphates were tested for by taking samples and using water testing kits. Samples were taken in the evening at sunset and morning around sunrise in order to observe the daily fluctuations of the river.

5.3 Results and Discussion

The results shown in Table 4 show that all the chemical measures remained consistent. The lower oxygen levels can likely be attributed to lower levels of photosynthesis having occurred in the early morning as well as any respiration occurring overnight. While it did not snow between sampling days as was the case in the previous study, we did observe a drop in air and water temperature between observation times. All phosphate and nitrate measures were too low to be detected apart from the phosphorus sample from September 10, 2022, which was recorded as 0.2ppm orthophosphate, a slight increase.

Table 4. Water chemistry measurements from the sample reach, measured at two times.

Date	Time	Air Temperature (°C)	Water Temperature (°C)	pH	Specific Conductance (μs/cm)	DO (mg/L)	TDS (ppm)
09/09/2022	20:12	12	17.9	7.66	158.2	8.6	112
09/10/2022	7:11	4	15.1	7.51	155.4	8	111

6. Benthic Macroinvertebrates

6.1 Introduction

While water chemistry data are important for determining if the water is free of pollutants, they can only determine if the water is clean at a specific location and time. The land use of surrounding areas as well as the presence of buffer riparian plants has been observed to correlate with macroinvertebrate diversity (Moore, 2005). Therefore, it is important to also take macroinvertebrate samples. By observing the families of invertebrates present in the water we can see if water conditions are livable for certain indicator groups. Presence of these individuals expands our understanding of the health of the river, suggesting that if the river has been able to support certain invertebrates, it needs to have been unpolluted for long enough to sustain a population. The presence of these invertebrates is also important to other organisms at higher trophic levels, as many fish and larger invertebrates will eat benthic macroinvertebrates in a linear food chain (Bowlby 1986).

Complexities in the river like woody debris, macrophytes, or large substrates are valuable for providing shelter for organisms in the river. The presence of benthic macroinvertebrates could contribute to the understanding that there is suitable habitat present to sustain any observed invertebrates. Macrophytes as well can provide food for invertebrates. Figure 8 highlights how there are many abiotic and biotic factors that impact the macroinvertebrate presence in the river.

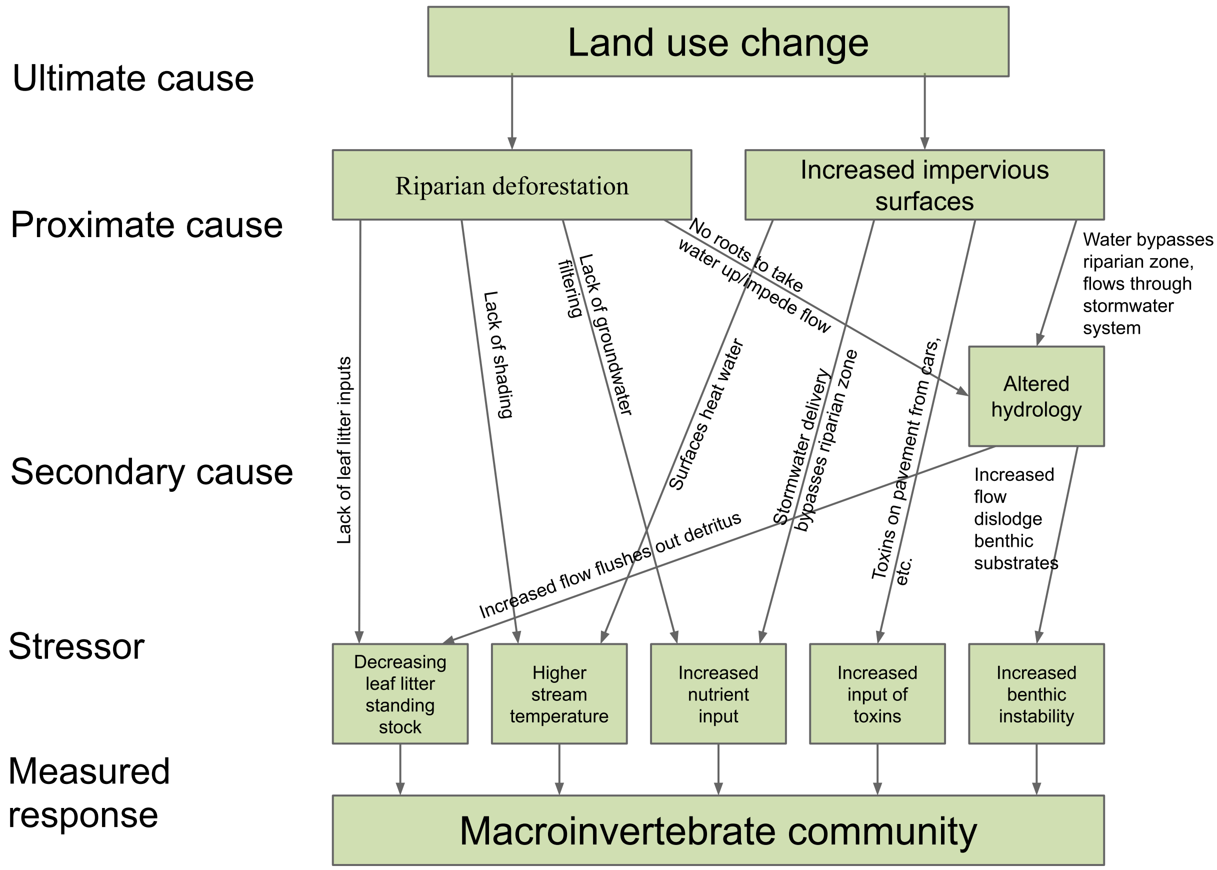

Figure 8. Diagram showing how various changes in land use and their potential impacts on macroinvertebrate communities in rivers (Kenney 2009).

The disturbances listed above highlight how the data observed in Sections 3 through 5 can have an impact on the presence of macroinvertebrates. Our observations of macrophytes and riparian plants, as well as chemical composition of the river therefore directly impact the ability of macroinvertebrate survival. Therefore, any concern about biodiversity should be addressed by reviewing bank and channel physiology and reviewing appropriate restoration techniques.

6.2 Methods

The procedure we used for sampling benthic macroinvertebrates follows that of the Canadian Aquatic Biomonitoring Network (CABIN 2017) protocol. This involved using a kicknet in a sample section of the river. The time of year we did this meant the sample we collected would be an effective representative of the diversity, given that most invertebrates are in the aquatic stage in the fall. Also worth noting is that kicknet samples were taken from the left bank which was observed in Section 4 to have more macrophyte presence, and therefore more habitat potential. Areas of river located between bank and midstream have been noted for their habitability for invertebrates, but not so clearly for fishes (Bain 1988).

Once samples were collected, invertebrates were sorted by order and individuals were counted. Due to time constraints, we were unable to sort the entire collection, therefore our findings represent a relative abundance. In order to clarify the relative abundance, volumes of water that were sorted through were recorded.

Figure 9. Sorting of benthic macroinvertebrates into distinct orders by volumes of sampled water.

6.3 Results and Discussion

The benthic macroinvertebrate sample found 490 individuals consisting of 21 different orders (Figure 10). These represent the individuals from a 9720mL of water. The most common invertebrates found were water mites (Acari), mayflies (Ephemeroptera), dragonflies (Anisoptera), and midges (Chironomidae). These 4 made up 84% of our findings. Water mites, mayflies, and midges also made up most of our findings in the previous study. Using this study as a benchmark for expected diversity, we could say that our findings show that the biodiversity is high. The presence specifically of Ephemeroptera and Trichoptera would suggest that the river is unpolluted. This abundance and diversity from our kicknet sample suggests that the Boggy River continues to be a healthy water system.

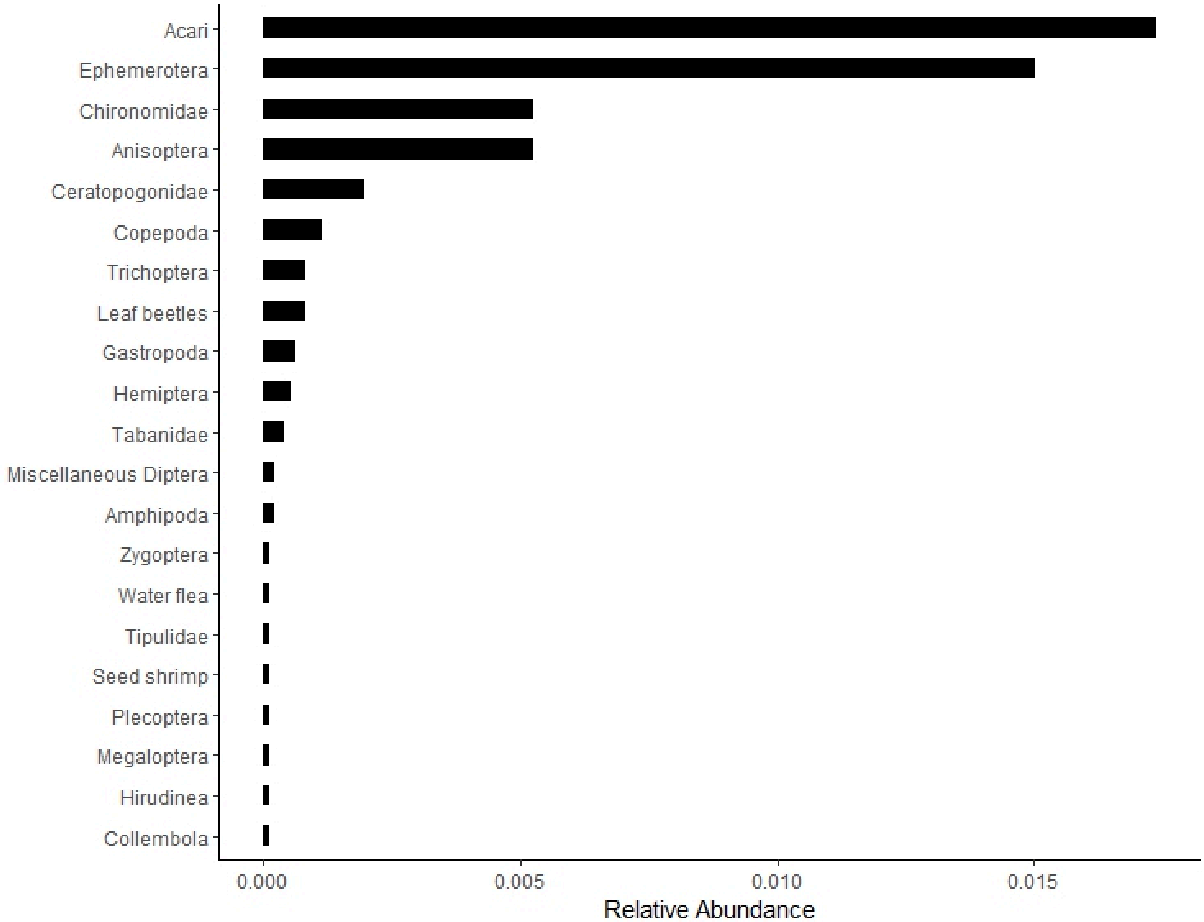

Figure 10. Benthic macroinvertebrates sampled using a kicknet, following methodology of the Canadian Aquatic Benthic Invertebrate Network.

Orders Ephemeroptera, Plecoptera, and Trichoptera have been identified as sensitive to pollution and other disturbances (Kenney 2009, Maloney 2008). While Ephemeroptera was clearly identified in greater abundance than the latter two species, the total percentage of these sensitive taxonomic groups found is 31.6%. This would again affirm the understanding that the Boggy River is free of pollutants.

8. Overall Discussion

8.1 Bank Stability

Our observations covered 100m meters of river which included a bend towards the right and the start of a bend toward the left. Capturing this variation along the river was critical for gaining as clear a picture as we could of the potential heterogeneity of the river. Surveying a full meander has more potential for seeing the variations that come with bends in either direction as well as in straight segments of river. While our substrate did not show much variability the bank status on either side were in line with our expectations given the curvature of the river at each transect (Krause 2018).

OSAP determines bank stability through a series of qualifications found in Table 5. According to the categories shown, the left bank would be considered entirely 'gentle' (<45°), and the right bank almost entirely 'steep' (>45°). We also find that our bank substrate was almost entirely erodible materials (silt), and our right bank shows large amounts of undercutting. Based on these qualifications for bank stability our findings would remain mostly consistent with the previous study, showing more erosion along the right bank, with some variability in classification along transects.

Table 5. Descriptions of Bank Stability Categories (OSAP).

Bank Stability Categories	Interface between Water and Bank	Bank Soil/Substrate	Characteristics of Bank
'Eroding Bank'	Steep, >45°	Erodible materials	Undercut (by at least 5cm) or shows signs of recent slumping (eg. no or little vegetation present)
'Vulnerable Bank'	Steep, >45°	Erodible materials	Shows no recent signs of erosion (eg. undercuts or slumping) and protected by a mat of living vegetation
'Protected Bank'	Steep, >45°	Non-erodible materials (eg. rock, boulders or hardened clay)	Vegetation may or may not be present, includes banks armored by humans
'Deposition Zone'	Gentle, <45°	Generally, materials which have been deposited by the river during its flood condition	Point bars inside bends of streams

While erosion along a river is normal and part of a healthy meandering river system, if we continue to observe increased erosion along the right bank action may be required to allow the system to maintain stability. Erosion could threaten the presence of macrophyte establishment and riparian forest. This would intern affect habitat quality overtime. Often erosion is viewed as a threat to human infrastructure (Bulloch 2022, Florsheim 2008, Massé 2016), therefore it is important that the needs identified around the bridge and the habitat needs are clearly understood before taking on stabilization to avoid oversimplification of the riverbank, therefore affecting habitat quality.

8.2 Benthic Macroinvertebrate Populations

Our findings would suggest that the Boggy River continues to be a valuable habitat for benthic macroinvertebrates. The water chemistry data presents negligible pollutants and a relatively large abundance of a diverse community of macroinvertebrates, including a variety of disturbance sensitive taxa. While we did not collect flow data, considering our findings were consistent with those of the high diversity identified in the previous study, it would suggest that the flow is consistent enough to provide adequate nutrients without washing away valuable instream habitat.

While we did not take fish samples, we expect that fish communities would be similar to 2018 due to habitat conditions in the river appearing to have remained consistent since measuring in 2018. The habitat complexities available in the river would also need to be suitable to support these populations, as higher percentage of silt has a negative impact on macroinvertebrates by reducing surface area to attach to (CABIN 2017). Given our substrate findings being dominated by silt, the presence of macrophytes and woody debris is likely fulfilling that role of channel complexity required for invertebrate habitats.

Depth also prevented us from taking channel measurements across the full width of the river, therefore leaving a lot of area in the river uncatalogued in terms of woody material and instream vegetation. This should be an area that is focused on in future study to verify the connection between biodiversity and available habitat in the form of river complexities.

9. Recommendations

9.1 Future Monitoring

Erosion is something that should continue to be monitored in the Boggy River. If we continue to see these large differences in channel and bank morphology it could suggest that erosion is occurring too rapidly. It is important that observation continues before any action is taken toward bank stabilization because erosion is still a natural phenomenon and can contribute to the stability of habitat formation. This can lead to natural stabilizing and shifting of sediments that helps improve habitat quality (Florsheim 2008). However, if it is observed that erosion is doing less for habitat stabilization and more for channel straightening it may be valuable to consider riparian planting to increase root systems holding together bank sediment and invest in future debris to create habitat complexities and reduce river flow rates. The critical thing to avoid is bank and channel homogeneity. Freeman et al. (2001) also suggested that regulated waterways were not as productive for fish populations as unregulated ones. Lower water levels during low rainfall periods were better for juvenile production, and this condition was not promoted by human alteration of flow regime (though it should be noted here that flow was regulated through damming rather than through bank alterations).

9.2 Future Studies

Due to the higher water level, we were not able to collect full channel measurements and velocity recordings were omitted. This was because without a full channel measure we could not extrapolate to approximate discharge. In future studies velocity should be observed based on the impacts that flow has on river morphology as well as overall habitability for macrophytes and aquatic organisms like fishes and invertebrates (Bain 1988, Florsheim 2008, Hart 1999). These data would also contribute to our understanding of the river's morphology, using them as indicators for bends in the river. It will be important in future studies to conduct a faithful follow-up to this and Derksen et al. (2018) in order to collect all of the valuable data for understanding river health.

Lately there has been an increase in large rain events and spring flooding has also become increasingly common due to climate change. The government of Manitoba anticipates precipitation variability will increase in the coming years, with extreme droughts, floods, and storms becoming more common. Continued monitoring should be done in anticipation of these effects continuing with changes in climate and how they impact the ecology of the river overall.

10. Conclusions

The second data point regarding the health of the Boggy River reveals the presence of key indicators of quality habitat, as highlighted in the previous study, but also maintains similar concerns about stability. The invertebrate biodiversity of the river included individuals from sensitive orders Ephemeroptera, Plecoptera, and Trichoptera. We did not find evidence of pollution. The changes in macrophytes and increased erosion may continue to be of concern and should continue to be monitored in future studies. If changes in bank angle increase at a higher rate it may indicate that disturbance is high and could be impacting habitat stability. Continued observation of the Boggy River should be done in order to ensure that these habitat features are maintained and keep watch for places that require restoration efforts, particularly in bank stabilization.

11. References

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12. Appendices

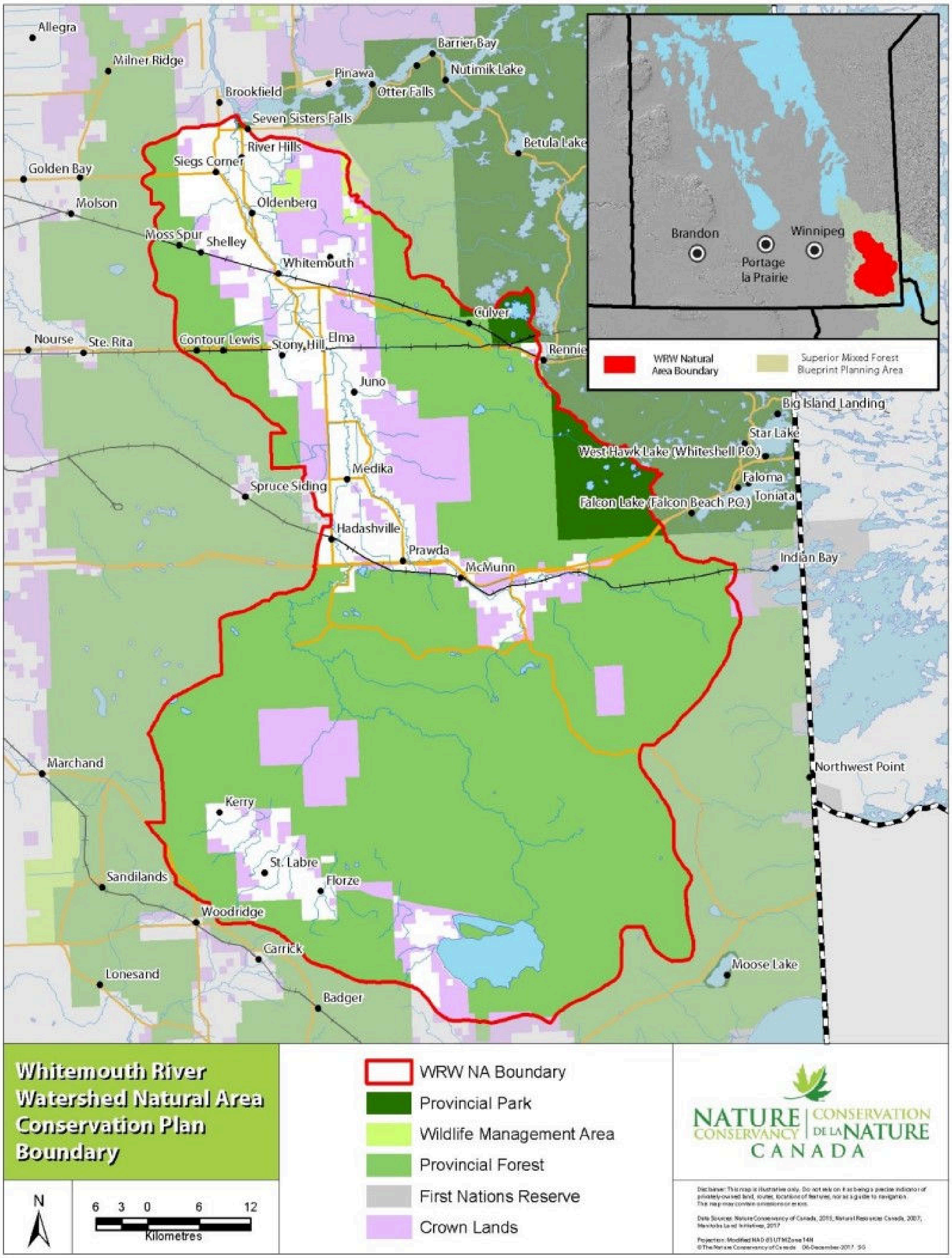

Figure 11. Whitemouth River Watershed Natural Area Boundary from Nature Conservancy Canada Natural Area Conservation Plan Summary 2017-2026.

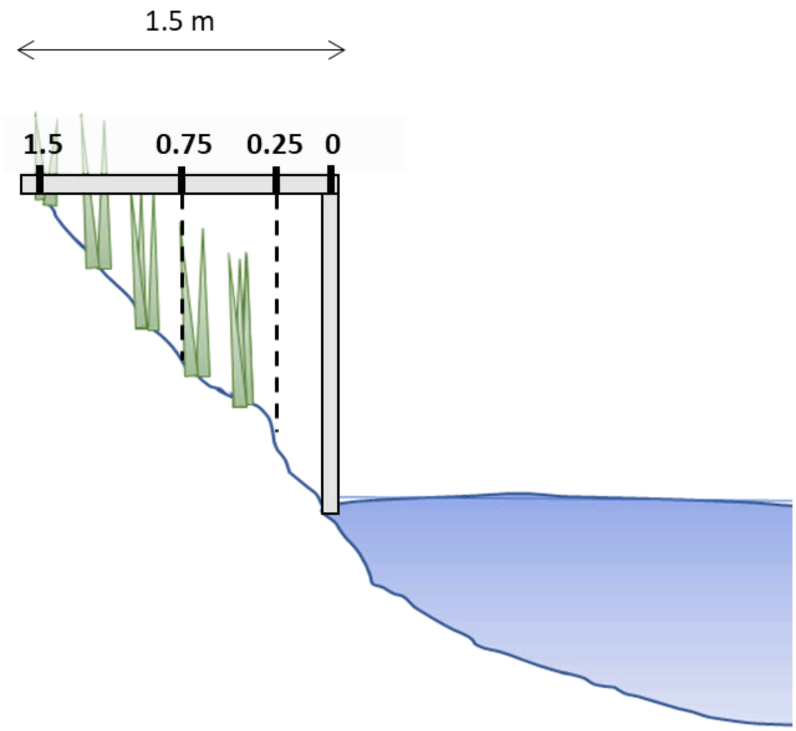

Figure 12. Spacing of measurement of bank angle (OSAP 2017).

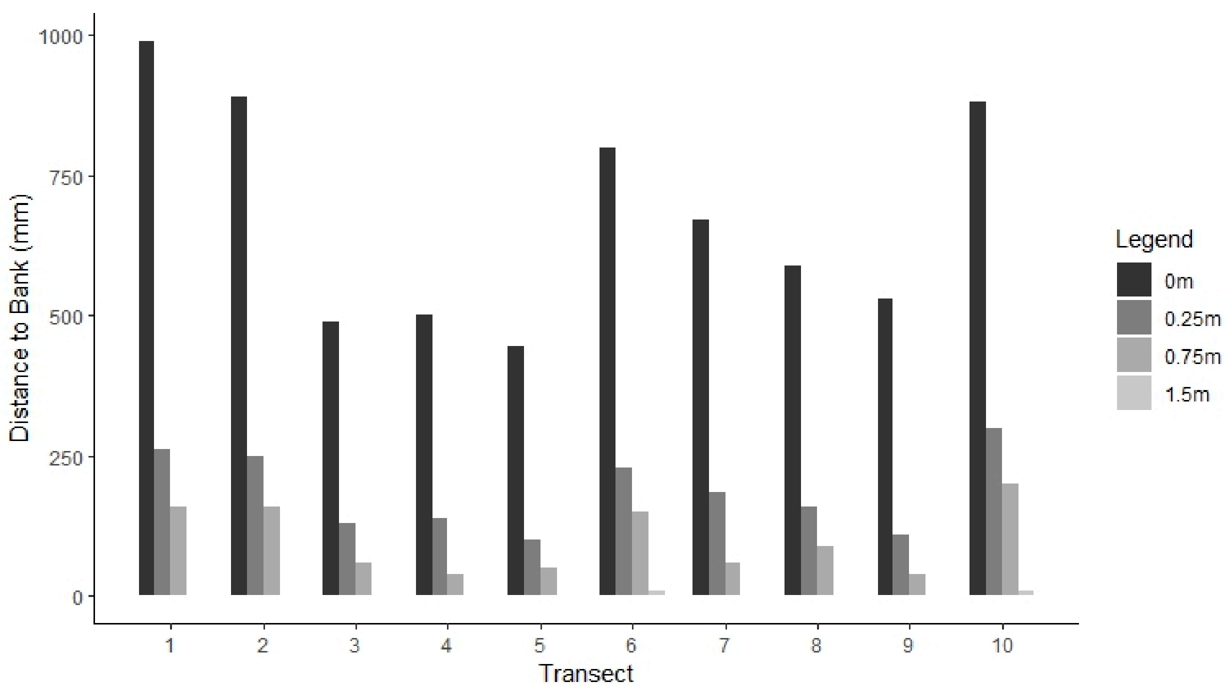

Figure 13a. Height measurements of bank angle for the left side of the river.

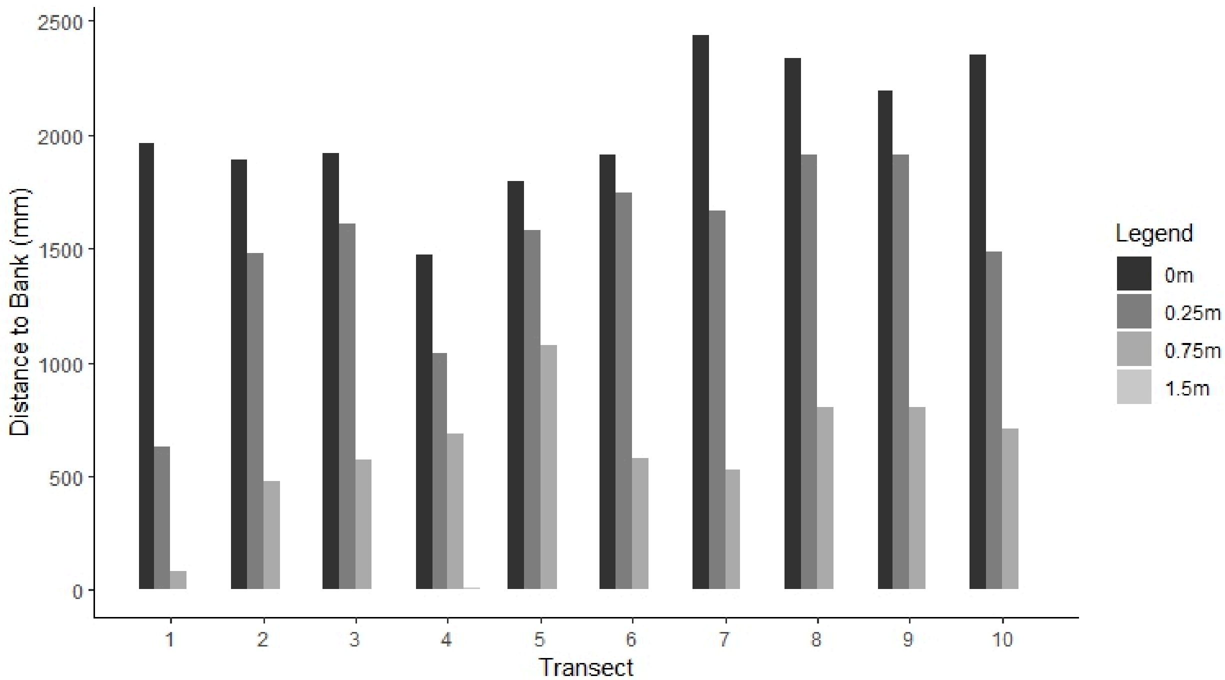

Figure 13b. Height measurements of bank angle for the right side of the river.

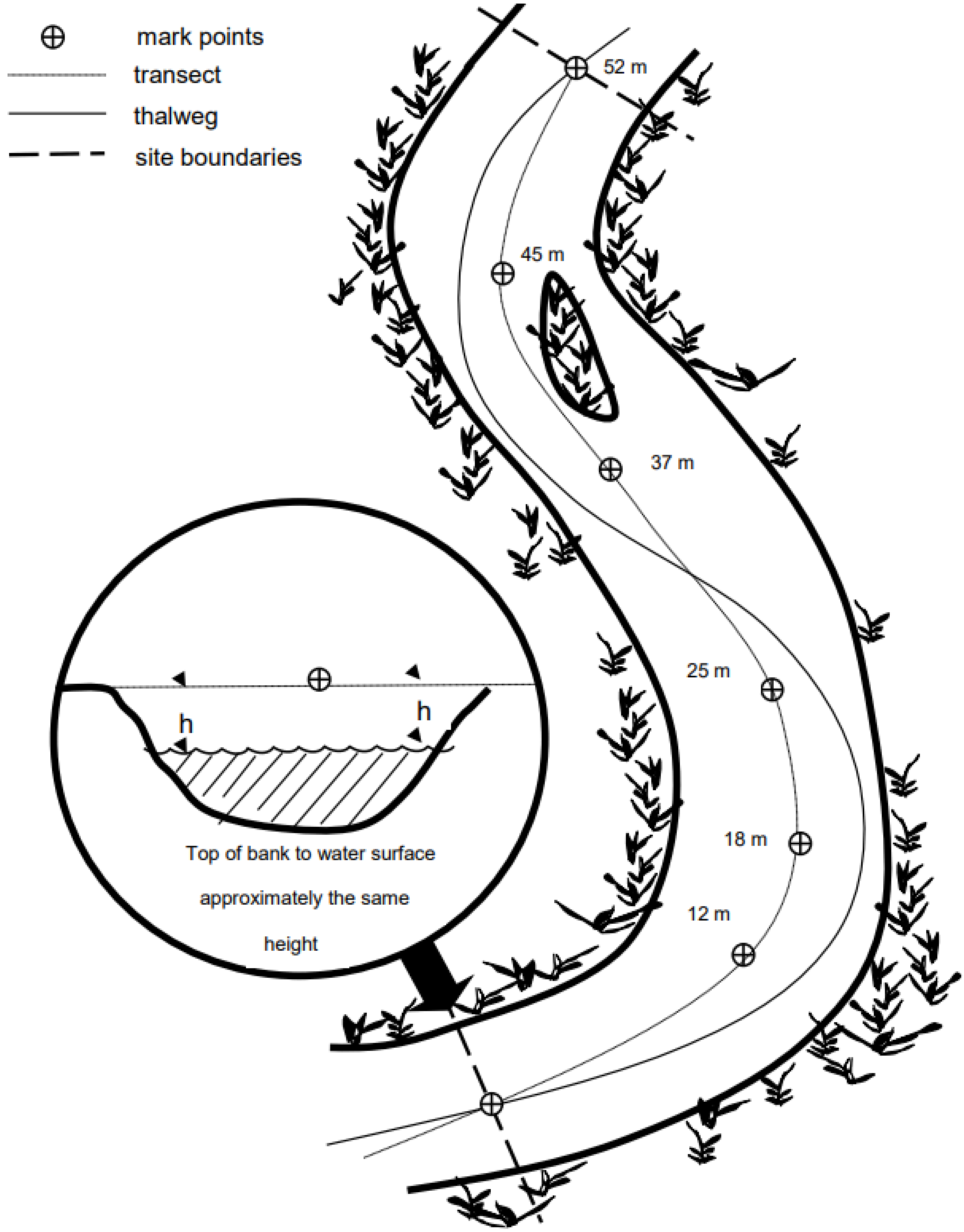

Figure 14. Site boundaries and length determination (OSAP 2017).

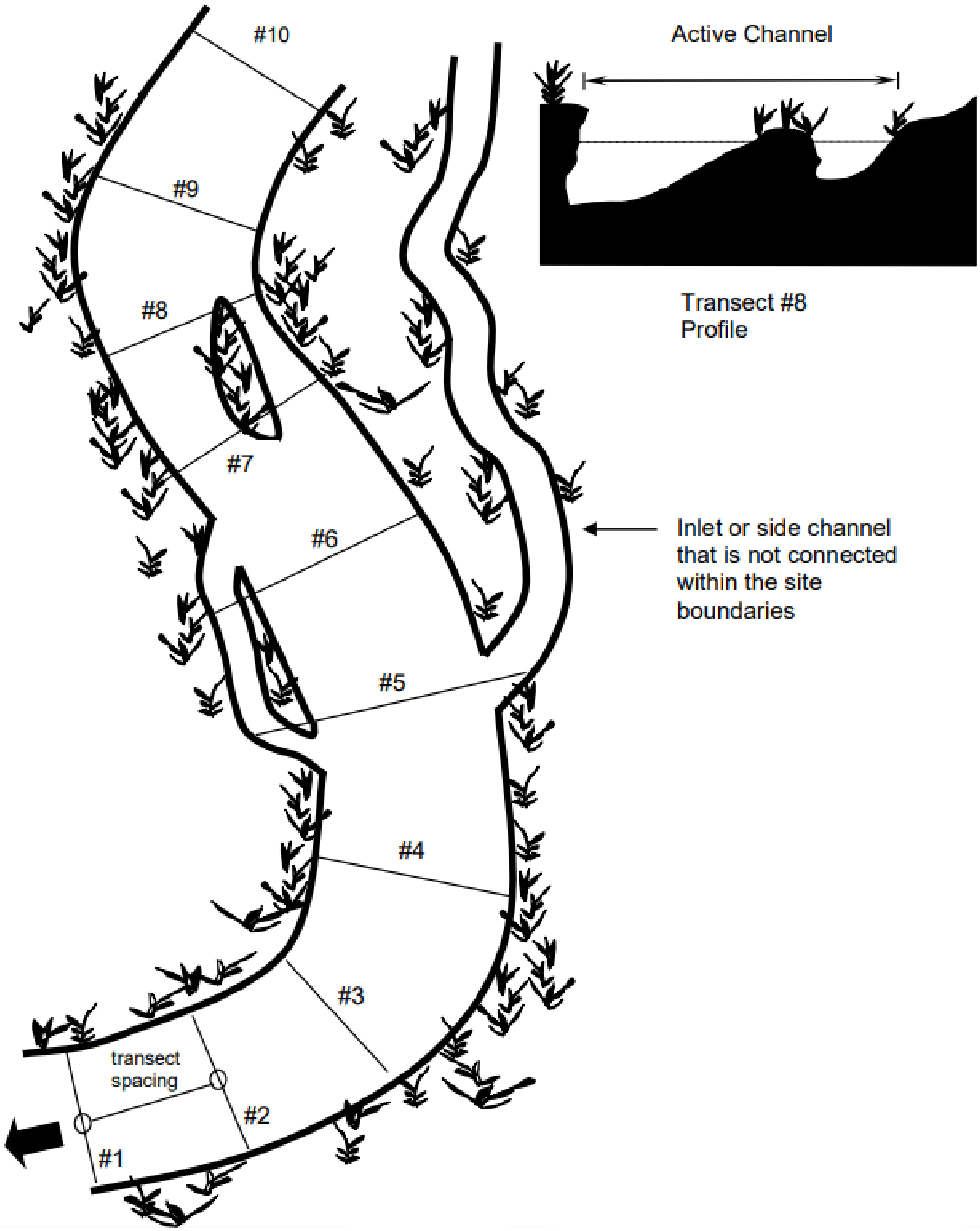

Figure 15. Setting up a transect sampling design (OSAP 2017).