Lab 3 Report

1. Result

1.1 Flow Direction and Flow Accumulation

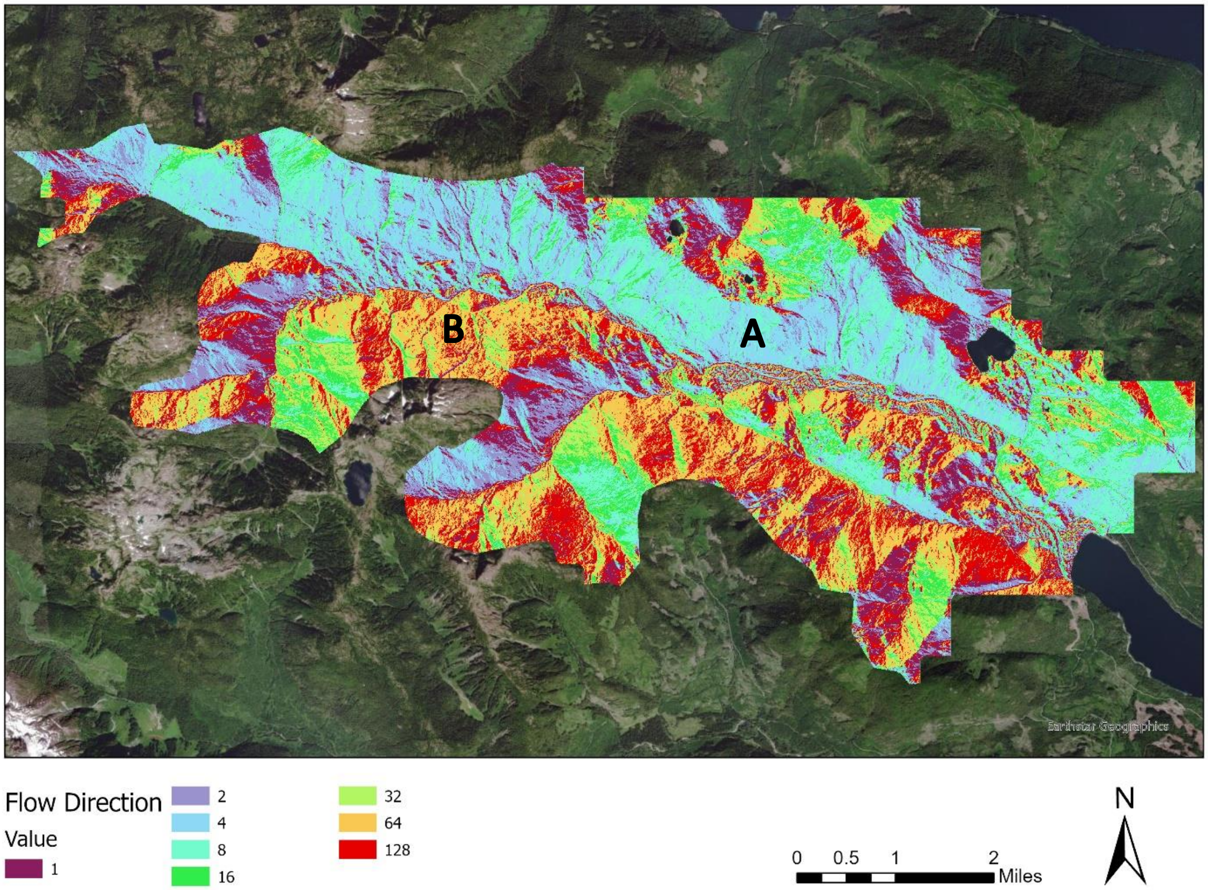

Figure 1 D8 Flow Direction Map of the Nahmint Watershed indicating the terrain-influenced water flow paths, with color-coded directions ranging from east (1) to northeast (128).

In Figure 1, the D8 flow direction map for the Nahmint watershed assigns values from 1 to 128, indicating the primary flow directions based on the terrain. These values, 1 for east, 2 for southeast, 4 for south, 8 for southwest, 16 for west, 32 for northwest, 64 for north, and 128 for northeast, reveal the nuanced patterns of water movement. For instance, at point A, the color of this area appears to be a mix of blue shades correlated with value of 2, 4 and 8, suggesting that water is flowing towards the southeast, south and southwest. At point B, the color appears to be orange and red, indicating that water is flowing towards the north and northeast.

In addition, I chose flow accumulation threshold value of 300 to create the raster-based stream network, keeping a balance between representing actual stream channels and minimizing the inclusion of transient or minor flow paths. This threshold was instrumental in identifying a stream network that corresponds closely with the streams depicted on the ArcGIS basemap, ensuring that the primary hydrological features of the watershed are accurately captured for subsequent analysis.

1.2 Stream Order and Characteristics

According to Figure 2, by utilizing the Strahler method for stream ordering, the streams within the Nahmint watershed were classified into five orders ranging from 1 to 5. Higher order streams represent the main channels that receive water from multiple tributaries, whereas lower order streams are smaller and more numerous.

Table 1 summarizes the characteristics of each stream order, revealing a pattern where the number of stream links and the average gradient decrease as the stream order increases, while the average width tends to increase. Order 5 streams, representing the largest channels, are characterized by the greatest width and the lowest gradient, indicating their capacity to transport larger volumes of water and sediment compared with the higher-gradient, narrower streams of lower orders.

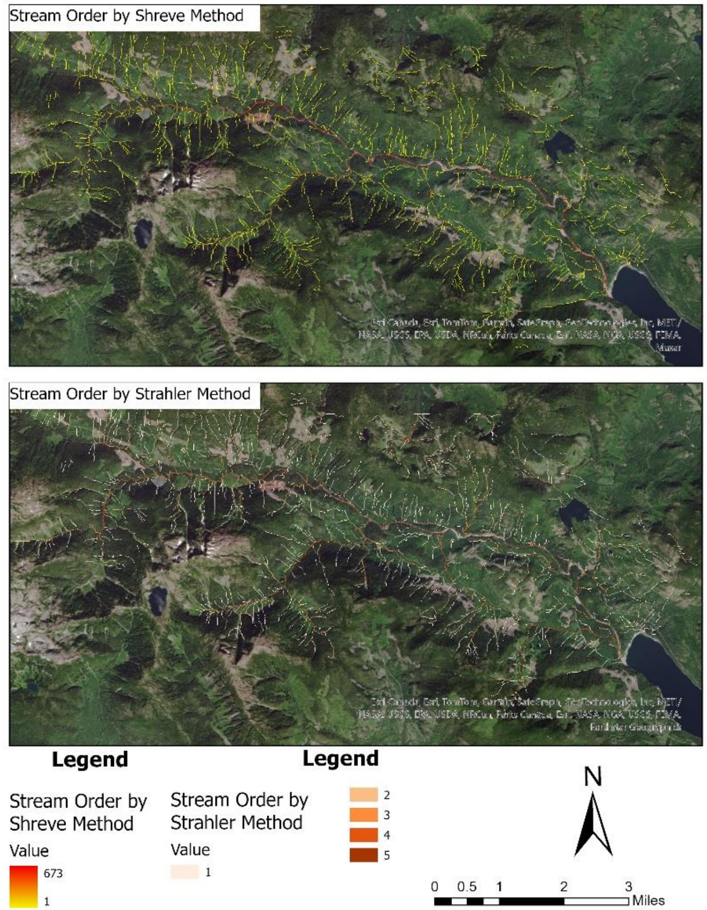

Figure 2 Comparative Stream Order Visualization in the Nahmint Watershed using Strahler (bottom) and Shreve (top) Methods.

Table 1 Summary of Nahmint Watershed Stream Characteristics by Stream Order, depicting the relationship between stream order and its physical attributes such as number of stream links, length, width, and gradient.

Stream Order \ Variables	Number of Stream Links	Average Stream Length (Meters)	Average Width (Meters)	Average Percent Gradient (%)
Order 1	20145	269.84	1.00	34.65
Order 2	7654	207.55	5.49	24.95
Order 3	2780	174.27	9.19	11.46
Order 4	1789	140.01	16.59	3.26
Order 5	931	278.41	60.71	0.12

1.3 Stream Class and Riparian Management Areas

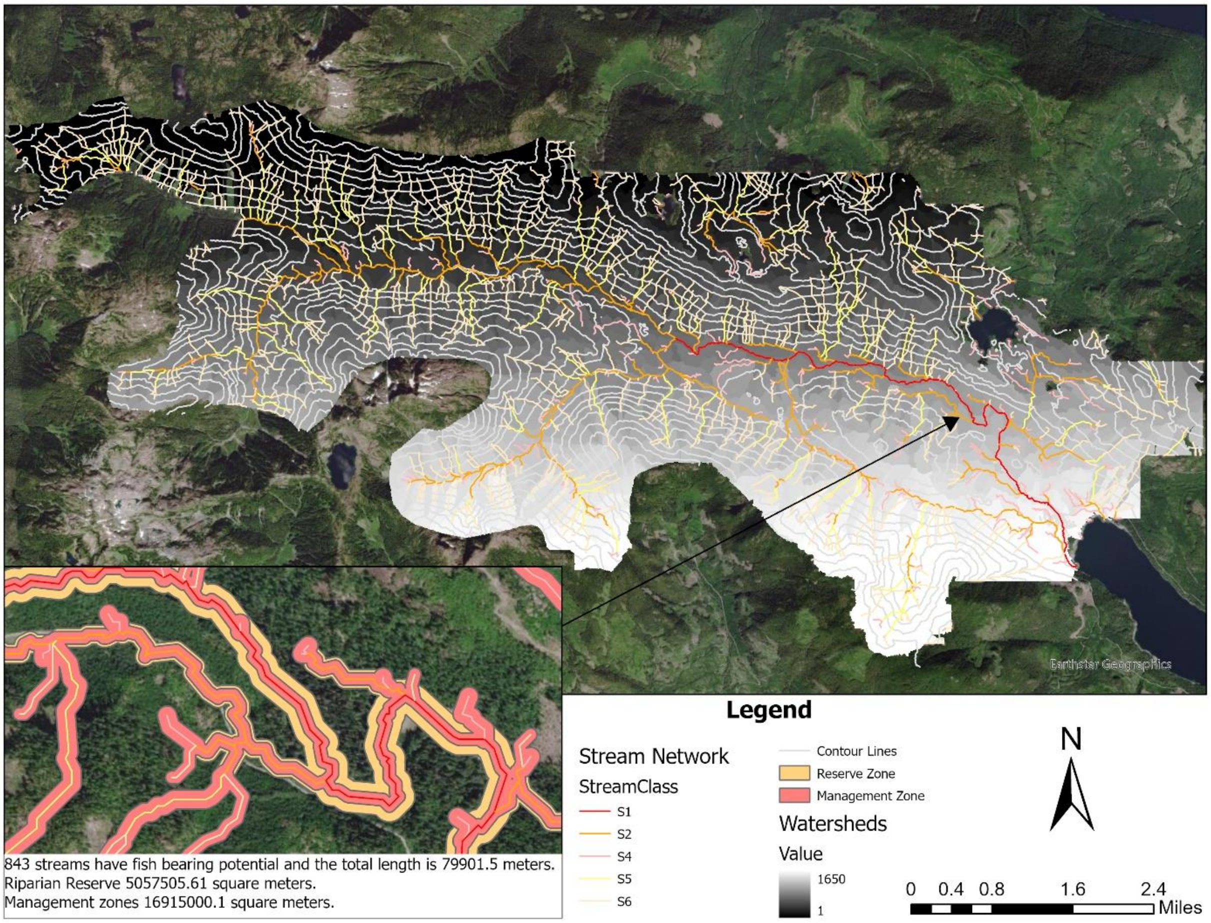

Figure 3 Stream Classification and Riparian Management Areas in Nahmint Watershed, depicting fish-bearing streams (Classes S1, S2, S4) and non-fish-bearing streams (Classes S5, S6), with the Reserve Zones (no harvest) and Management Zones (limited harvest) outlined.

In the Nahmint watershed region, stream classification based on fish-bearing potential has been conducted, with 843 streams (Stream Class: S1, S2, S4) identified as fish-bearing, and the total length is 79,901.5 meters. Conversely, 807 streams are classified as non-fish-bearing (Stream Class: S5, S6) with a total length of 122,439.6 meters.

Riparian Management Areas (RMAs) have been delineated according to the BC government's stream classification system. As depicted in the inset of Figure 3, the Reserve Zones, marked in red, are areas where no harvest activities are allowed, encompassing a total of 5,057,505.6 square meters. The Management Zones, colored in orange, allow for limited harvesting and cover a larger area of 16,915,000.1 square meters. Furthermore, the average area of the 1,600 watersheds within the study area is calculated to be 49,920.3 square meters.

2. Discussion

2.1 Riparian Management Areas in British Columbia

Riparian Management Areas (RMAs) in British Columbia are established as a fundamental part of environmental conservation, as outlined by the Forest Practices Code of British Columbia Act. These areas, critical for maintaining ecological balance, consist of both the riparian management zone and the reserve zone (*Riparian Management Area Guidebook - Province of British Columbia*, 2024). The former is a space where forestry operations are conducted with special considerations for ecological preservation, while the latter is a more protected zone with stringent restrictions to safeguard natural habitats.

The primary objectives of RMAs include the protection of stream channel dynamics, aquatic ecosystems, and water quality. They also aim to conserve the biodiversity and productivity of wildlife habitats adjacent to water bodies. Specifically, the RMAs are designed to minimize the adverse effects of forestry and range uses by maintaining key habitat attributes such as wildlife trees, large trees, and structural diversity, ensuring these practices are consistent with the conservation of natural riparian ecosystems.

2.2 Accuracy of Stream Networks

In the stream network I created from the DEMs, I observed some overrepresentations of minor streams which were not visible on the basemap. This discrepancy suggests the chosen flow accumulation threshold of 300 was potentially too sensitive, leading to minor landscape features being misinterpreted as stream channels. Conversely, the stream network I created from the DEMs also exhibited limitations in capturing the entirety of certain streams visible on the basemap, likely because parts of these streams presented flow accumulation values below the set threshold. This contrasting issues of overrepresentation and underrepresentation highlights the challenges in setting a flow accumulation threshold that accurately reflects the true extent and character of stream networks in varied terrain and vegetation cover.

Potential Sources of Error:

Data Resolution: A lower-resolution DEM may fail to capture finer details, leading to the exclusion of small stream features.

Flow Accumulation Threshold: Setting this threshold too high could result in the exclusion of valid streams, whereas a too low threshold might incorporate inconsequential drainage paths.

Improvements:

Enhanced DEM Resolution: A higher-resolution DEM would enable a more precise delineation of streams, including the finer topographical variations.

Field Verification: Validating the stream network created in ArcGIS against on-site observations would refine the flow accumulation threshold, ensuring a more accurate depiction of the actual streams.

2.3 Stream Ordering Method: Strahler and Shreve

According to Figure 2, the Strahler and Shreve methods for stream ordering offer distinct approaches to understanding river networks. The Strahler method presents a simple, clear and hierarchical structure of the stream network, with orders ranging from 1 to 5, emphasizing the main river channels. An advantage of the Strahler method is its ability to simplify complex networks for easier understanding and analysis, while a disadvantage is its limitation in capturing the full complexity of stream networks compared to more comprehensive methods (Antonson, 2018). In contrast, the Shreve method results in a more complex web, with significantly higher stream orders, reflecting the cumulative nature of the system where every tributary contributes to the order of the stream. The advantage of the Shreve method is its more integrated and comprehensive understanding of the stream network, while a disadvantage involves potential oversimplifications and the challenges of managing complex, integrated processes (Albuquerque et al., 2015). In summary, the Strahler method offers a simplified framework for hierarchical stream classification, ideal for general hydrological applications, whereas the Shreve method offers a detailed approach, better suited for complex ecological and environmental analyses.

2.4 Interpretation of Stream Characteristics by Stream Order

Referring to Table 1, in the Nahmint watershed, stream characteristics exhibit both anticipated and unexpected trends across different stream orders. As stream order increases from 1 to 5, there's a marked decrease in the number of stream links from 20145 to 931, which aligns with the hierarchical nature of stream systems that numerous small tributaries merge into fewer large rivers. Average stream width expands significantly from 1 meter for first-order streams to 60.71 meters for fifth-order streams, reflecting the progressive widening of channels as they collect water from upstream. Gradient patterns also adhere to geomorphological principles, with a steep average gradient of 34.65% for first-order streams tapering to a gentle 0.12% for fifth-order streams. This suggests a smoothing of the stream path as it matures and expands.

Unexpectedly, average stream length fluctuates, diminishing from 269.84 meters for first-order to 140 meters for fourth-order streams before escalating to 278.41 meters for fifth-order streams. This irregularity might be due to local topographical factors or different measurement methods and threshold selection in this study.

2.5 Impact of Runoff from Harvesting Areas

According to Figure 1 and Figure 3, runoff is more likely to happen in areas where contour lines get densified and flow directions get converged, which might significantly impact stream networks within the Nahmint watershed. For instance, central watershed areas where most major streams of Order 5 and Class S1 are located, are particularly vulnerable to runoff. These streams are crucial for ecosystem integrity and subject to increasing sedimentation from harvesting runoff. Runoff will potentially degrade water quality and affect aquatic habitats of these streams.

The Riparian Management Areas (RMAs) serve to protect these stream networks by providing buffer zones where harvest activities are either limited or prohibited. The effectiveness of these RMAs depends on their size and the harvesting practices employed within and around them.

According to the inset of the Figure 3 which shows the RMAs around the stream classified as S1, the largest RMAs are implemented here and offer adequate protection in these streams and the adjacent areas. However, in steeper regions where runoff is more rapid, but smaller RMAs are implemented due to lower riparian class, the RMAs need to be expanded or supplemented with additional conservation measures, such as creating retaining ground cover to slow water movement and reduce erosion.

2.6 Limitation and Future Improvement

The workflow for determining riparian reserve and management zones within the Nahmint watershed exhibits both strengths and limitations:

Workflow Strengths:

The workflow for delineating riparian zones in the Nahmint watershed effectively combines topographical data with stream classifications to establish protective areas. The strengths of the workflow lie in its integration and precision. The workflow effectively integrates various datasets, such as DEMs, flow direction, and stream classification, to create a comprehensive view of the watershed's hydrological characteristics. In addition, by using ArcGIS tools like contour lines and flow direction layers allows, I am able to implement more criteria for more precise spatial analyses, enabling the identification of critical areas that require protection.

Workflow Limitations:

While the workflow for delineating riparian zones in the Nahmint watershed demonstrates efficacy in mapping and protection, it also presents certain limitations that need to be addressed. As discussed in 2.2, a significant limitation is the potential for misclassification of stream networks due to a fixed threshold for flow accumulation, such as the utilized value of 300, which may not reflect the variable hydrological conditions throughout different seasons or under the impact of climate change. Moreover, the lack of field verification within this workflow could result in a gap between the modelled RMAs and the actual field conditions, which is critical for the accurate and effective management of these ecologically sensitive areas. The workflow could be enhanced by incorporating adaptive thresholds that account for the dynamic nature of hydrological processes and by integrating ground-truthing to align the modelled data with real-world conditions.

Reference

Albuquerque, A. E. C., Primo, M. A. de M., & Pereira, F. A. (2015). Advantages, disadvantages and risks in the adoption of design-build contracting method in the Brazilian public sector. *Review of Business Management*, *17*(54), 822–838. https://doi.org/10.7819/rbgn.v17i54.1757

Antonson, H. (2018). *Revisiting the "Reading Landscape Backwards" Approach: Advantages, Disadvantages, and Use of the Retrogressive Method* (1). *5*(1), Article 1. https://doi.org/10.16993/rl.47

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