Vancouver Lost Stream Restoration Assessment

GEOB 270: Introduction to GIS

L2B

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Abstract:

This paper attempts to analyze the differences between the historical distribution and the current distribution of rivers within the City of Vancouver, and strives to account for the differences. The main methodology applied in this study is the basic usage of ArcGIS 10, involving database creation, querying, spatial analysis and map production. In order to study the decline in streams comprehensively, we analyzed the distribution of both historical and current streams in regards to zoning practice and road network respectively. We found that most rivers deceased from its origins, as the land was mostly occupied by human and zoned as single family housing to accommodate for the rapidly growing housing demand in the last century. Rivers and streams that survived are mostly fragmented by roads and have gone partly underground, which is detrimental for the river ecosystem. We finally conducted a case study at Salish Stream to demonstrate the findings specifically and comprehensively.

1. Introduction

Rivers are part of the aquatic ecosystem that provide numerous ecological functions not only for aquatic creatures but for humans and the larger biosphere. However, the sharp decline of the number of rivers in the last a hundred years has indicated significant changes of many ecosystems. The industrialization accelerated in the 20th century brought up soaring population growth with rapid urbanization: DESA (2014) projects that the world's urban population is expected to increase by more than two thirds by 2050; more than half world population live in cities now. This huge population growth signaled further urbanization sprawl towards peripherals and land-use alteration for resource extraction and development. Considering the future severe conditions that may further undermine today's urban river ecosystem, more research of river ecology in and downstream of cities are in need. In order to achieve a comprehensive evaluation for future protection and restoration, we have to visualize and analysis the change in current urban streams, using the broad scope of geography to take advantage of all disciplines and different perspectives in an integrated method.

2. Study Area and Data

Considering the comprehensive change of the Vancouver land-use in the recent decades, we have looked at the change of the City of Vancouver's stream distributions from 1920 to 2017 according to an old hand-drawn stream map (1880-1920) digitized by UBC (2016) and the current stream map digitized by Dr. Christen (2017). Since urban streams, even small ones, provide a host of benefits such as fish habitat, riparian vegetation, storm runoff management, maintenance of water quality and quantity, etc., the decreasing number of functioning streams reduces the possibility of salmon reproduction and the number of salmon population, increases the risk of flooding, decreases the quality and storage of fresh water, etc. Considering that Vancouver is a primary salmon spawning site and salmon functions as a keystone species in respect of its ecological status, we suggest that the destruction of the salmon habitat may indicate considerable damaging effects on other species.

In order to reveal the specific reasons behind the disappearance of the majority of streams in Vancouver and initiate future rehabilitation and restoration for a more sustainable urban development, we also obtained the Vancouver roads data (CANMAP, 2017) and Zoning Labels (Vancouver Open Catalogue). In addition, in order to propose a practical solution for a more integrated river network in Vancouver, we conducted a detailed case study of one of the existing streams in Vancouver: we looked at the Salish Stream in the Pacific Spirit Park for its current states and functions, challenges and pressures, and future redesign possibilities.

3. Methodology of Analysis

Geographical Information Systems (GISs) are systems "designed to store, manipulate, analyze, and output map-based, or spatial, information." (Steinberg & Steinberg, 2006) They are commonly used in Environmental Geography fields, such as Hydrology, as well as Social Geography fields, such as Urban Planning and Cultural Studies. Various types of data like shapefiles (in the forms of point, line, and polygon), Digital Elevation Models (DEMs), and orthophotos are helpful with analysing the change of an area in each period time, such as changes in land use or degree of environmental degradation. In particular, GISs are used widely to "support water quantity and quality studies" (Hamdy et al., 2016). In this project, we applied basic ArcGIS analysis functions in order to uncover the reasons behind the disappearing streams of Vancouver in terms of the environmental, economical and social change. In our analysis, we compared the historical stream distribution of Vancouver in 1920 and the current streams in Vancouver.

The analysis was conducted in several steps. Firstly, the analysis aims to acquire and inform basic knowledge on the status of Vancouver streams. We determined the boundaries of roads and shorelines of Vancouver using "Clip" function in the ArcToolbox to constrain the necessary information within the study area. We then projected the current distribution and historical distribution of streams onto Vancouver's landscape.

Secondly, the analysis aims to investigate the patterns in the distribution of streams historically and currently in Vancouver and tries to reason for any declination in the amount and length of rivers that still exist within the City of Vancouver. Analyst tools from ArcToolbox such as select by attribute are used as querying methods to select certain features such as Vancouver's major roads. Using this tool, we are able to investigate the overlay between historical/current streams. Current streams that travel across roads are considered as underground streams; streams cross the wider major roads have a longer and deeper underground pipe, which are more risky with respect to the streams' survival. Shorelines are also highlighted by the applying of select by attributes; the retreat of shoreline are visualized clearly on the map. Zoning was analyzed in a similar manner in order to assess the impact of urban development on the streams.

Finally, we studied a specific area, Salish Stream, comprehensively as a case study. Orthophotos in the resolution of 7.5cm x 7.5cm cells of the University Endowment Lands are used in order to visualize the landscape of the study area and study with more details that vector data cannot show. (Vancouver Open Data Catalogue, 2015)

4. Discussion and Results

Our comparison map of the old and new streams reveals a startling reduction of the number of streams: the old stream map of 1920 has approximately a hundred streams in the City of Vancouver, while today only 6 of them are existed. Considering the City's rapid urban development in the past a hundred year such as the construction of the streetcar grid in 1912, the fill of the False Creek flats for business development in 1915, the transformation of pristine land to construction sites for numerous skyscrapers, the construction of the SkyTrain lines, etc., nearly all streams and creeks are filled for human urban activities. Even the few left existing ones are under severe pressures from current intensive urban development with respect to the vision of 1 million residents growth by 2041 (MVRD, 2011).

4.1. Zoning Features:

As seen from the Zoning District/ River Distribution map attached in the Appendix, we can see that most of Vancouver's centre landmass is dedicated to single family housing. The zoning pattern and its historical roots can trace back to the late 19th Century. Sitting on the South-West seaboard of Canada, Vancouver emerged from Dominion-resource economy. Initially, known as the Town of Granville (currently the Downtown Peninsula), Vancouver serves as a rail head and the terminal station of the CPR railway. (Liscombe, 2011, pg. 126) Even though a great fire in 1886 destroyed Vancouver's first attempt to regulate zoning, the city experienced rapid growth and expansion in the 1920s. Gridded streets sprawled onto the South of False Creeks and further South and West into the woods.

After the Great Depression and WWII, Vancouver experienced another rapid industrial and commercial growth due to the needs in reconstructions and the returning of veterans. During the post-1945 period, Vancouver "grew into a relatively large conurbation in an expanding metropolitan region spreading into the formerly forested and partially agricultural lands between the Burrard Inlet, Fraser Basin and English Bay." (Liscombe, 2011, pg. 126)

The excessive expansion in Vancouver has cried out for lands. The relatively young region faces great accommodation pressure from both its expanding population size and returning veterans. Many of these pressures are resolved through dedicating most of Vancouver's lands into suburban style single family housing. (For example, Shaughnessy's provincial legislation that protects single family zoning in the neighbourhood) This movement have resulted in the clear cut of most of the old growth forest in Vancouver South and Vancouver West.

Figure 1: City of Vancouver Panoramic View 1898, Photo Credits: City of Vancouver Archives

Considering the historical distribution of Streams in Vancouver projected onto the current zoning map, we can see that most of the streams' origins are located within single family zonings. The development of these single family neighbourhoods has caused many of the vegetation to be cleared. Consequently, many of the stream origins are exposed to sunlight and their temperature raises. Eventually, the streams to be either eliminated for construction or mitigated underground.

Industrial land expansion is another major concern for disappearing streams. During Vancouver's rapid growth, the demand for industry also increases. Most industrial developments took place alongside False Creek, where many streams go into the Georgia Straight. One significant example is the filling of False Creek Flats at the East of Main St. The landfill used to be an estuary for many of the streams, as seen from this historical map of Vancouver. However, the filling process have changed the shoreline and have consequently drained many of the streams.

4.2. Road Development

Vancouver is known for preserving its grid street system in North America due to its original streetcar development. Considering its relatively flat topography, Vancouver is suitable for developing straight, gridded streets that provide higher density to neighbourhoods and make communities more accessible. It also promotes commercial activities alongside the major arterials and encourage mixed use building.

However, a grid system is not a natural system. It is an artificial planned system that does not follow the natural landscape of Vancouver. Consequently, during the construction of such a system, natural systems such as vegetation or streams are

interrupted. Many streams were cut off by major corridors such as 16th Avenue, Broadway, and 4th Avenue.

Currently, most of the streams that still survive in Vancouver goes cross roads. This indicates that most of these streams have parts that are underground - "pipes, and have a few potential hazards to the stream ecosystem." (Mugade & Sapkale, 2015) High level of land use complexity in the region also brings various effects on crossing streams. Evidence have shown that the natural sediment supply, water quality, streams temperature and few other key factors that reflect the health of streams have been deteriorated by the expansion of residential and commercial area (LeBlanc, Brown & Fitzgibbon, 1996) For instance, the underground pipe rivers do not have the same riverbed roughness as the natural rivers. Therefore, not enough oxygen is dissolved into the stream water.

Compared with the historical streams in Vancouver in 1920, the current streams that survive from urban development only survive in fragments. Most of them have been cut up by roads and blocks, and have gone underground. In the Map 2: "Distribution of Historical Streams on Vancouver Zoning District, 2017", numerous old streams burying underground are cutting through multiple zoning districts. The case study below analyzes a specific case of how urban development have caused only part of this river to survive and change.

5. Case Study: Salish Stream

As we can see from the map 4, the old Salish Stream in 1920 flew from the region of today's University Golf Club to the sea. Considering that the golf club was established since 1929 (*universitygolf.com*), the development of this club may contribute to the retreat of the Salish Stream. According to PGL (2013), the development of the golf club results in increasing number of culverts and sewers to transport stormwater discharge into the Salish Stream, which is a significant fish habitat. That's to say, maintaining the quality and quantity of water in Salish Stream is substantial for the stream species and the ecosystem.

The current Salish Stream travels across the Chancellor Blvd: there is a portion of the stream redirected to the underground tube to cross the overlying road [Picture 1]. Based on our observation, this tube only helps to deliver water while blocking sediments behind (sediment aggradation near the tube). This aggradation pattern has a few indications: if deposition exceeds the equilibrium condition, the flow discharge may try to find its way and shift the channel location (Mugade & Sapkale, 2015), which makes the current drainage system useless and needs reconstruction; fish passages may be dissected and blocked by such an artificial tube; people may mistakenly recognize this stream as a surface runoff of sewage which drains off into some treatment facilities and therefore people may dump human waste into the stream. Meanwhile, the location of the stream (aside and downslope the residential street) indicates that dust, trash, and debris may be washed and blown into the channel, which may disturb the stream's ecosystem. Further considering the progressive retreatment of the stream towards the sea, we propose that the underground tube may hamper the streamflow due to the proximity of the

Picture 1: a stream-road crossing tube near the headwater of the stream

headwater.

Besides this stream's function of providing fish habitats, urban small channels also absorb significant amounts of rainwater, snowmelt, and runoff before flooding (Moser, 2003). With respect to Vancouver's recent abnormal weather with affluent precipitation, this natural stream channel's gravel bed, rocks, and dams of leaf litter and twigs slow storm water as it moves downstream [Picture 2]; slower moving water is more likely to seep into a stream's natural water storage system-its bed and banks-and to

Picture 2: The rough channel bed with logs and rocks

recharge groundwater. That's to say, this narrow channel surpasses artificial storm sewers

and conduits (which often increase storm frequencies downstream) regarding storm events: it has an indispensable function of providing natural flood control especially in the urban environment, which often has flushy events due to the high percentage of impervious surfaces and lack of vegetation. The ample riparian vegetation here provides not only a buffer for high discharge events but organic materials as food and shading for aquatic organisms; trees and shrubs near the stream are in return nourished by sediment loads and water in the stream; vegetation helps reduce the urban heat island effect and global climate change.

In addition, this stream as a part of the larger ecosystem of this region function as a wildlife corridor, which links isolated ecological communities together: fragmentation has a strongly negative effects for species' mobility. However, with respect to the various ecological services Salish Stream provides, we identify from the map that the existing riparian buffer is not wide enough: according to TPSF (2001), British Columbia's fish bearing streams should have at least 30m buffers measured from the top of the bank. However, Salish Stream, as a fish bearing stream (PGL, 2013), lack the streamside vegetation protection in many sections along the channel. Considering all the indispensable ecological services Salish Stream provided to not only human society but all other ecosystems, the conservation and restoration of this stream and enhancement of buffers should be considered.

6. Error and Uncertainty

Most of the previous studies were focusing on the land use changes derived from urban development, which does impose significant impacts on stream structure and nearby ecosystem. Although we analyzed the zoning distribution of the Vancouver urban basin. What specific effects do each type of land use is imposing on the underground streams are unknown. Also, since many buried streams are interfering with more than one zoning districts, is complicated to integrate the overall influences from above ground. Therefore, comprehensive research are stand in need for measuring the aggregate influence of various land uses acting on each watercourse.

In addition to the uncertain effects cause from multiple land uses, we also have trouble to get further information on the old streams. The layer does not provide the current conditions of the previous streams except stated them as underground. When earlier government dealt with the creeks, they might have managed them with different approaches. Some old watercourses might have replaced with culverts; some were transformed into city's sewage conduits; others may completely be filled up with earth. Hence, without the important information upon, is difficult to account how many old streams that actually exist underground today. Besides, the feasibility of streams rehabilitation in the urban context is another unsolved problem that must be addressed in future discussion.

Our research is primarily relying on the two datasets which are the old stream data in Vancouver area from 1880 to 1920 (UBC, 2016) and the digitized current streams map from Dr. Christen (2017). Our analysis and results are mainly generated from comparing the distribution of old streams with existing ones by overlapping two layers. However,

some errors may occur within both stream maps due to the technological difficulty given the limited time.

We noticed that the original map of Vancouver's old streams in 1920 was drawn by hand. The shapes and positions of streams may not be as accurate and precise as today's mapping, which is benefit from the advanced aerial photo collecting technology from satellites and airplanes. Without the support from orthophotos, researchers in the past might not be able to accurately locate the stream flows due to numerous uncertainties, such as the unevenness of the ground, changes in elevation, aspects and gradient of slopes etc. The current stream map is also digitized by Dr. Christen using Google Earth referring to an orthophoto: the precision of the physical location of the streams may be compromised.

7. Further Research

Our research has found the urbanization in Vancouver induced serial effects on the regional hydrological system primarily due to changes in land use such as housing development and infrastructure building. This invasion of urban development has generated detrimental influences on water quality, fish, especially salmon population, and riparian biodiversity of the existing streams. Visual results from our maps also revealed surprising evidence that most old streams have "disappeared" in the city, either being buried or directed by underground culverts; only a few streams' limited sections are running above ground. We propose that preservation and rehabilitation of the old stream will not only improve local ecosystem diversity and hydrological connectivity but also promote social benefits such as recreational and educational purposes.

However, the stream restorations in Vancouver have some foreseeable difficulties. Many former streams are in the dense built up area which is challenging especially for restoration due to the complicated infrastructure on site. It is easier to restore the exposed streams on the surface than to create a new water channel. In addition, the restoring projects would be economic and time consuming. People in the communities are unlikely to raise sufficient fund for the entire project; the government may consider the idea unattractive due to the long span of restoration process and the relatively quick change of politics and goals, which cannot sufficiently pursue these environmentally sustainable goals.

Therefore, different stakeholders' interests should be carefully considered to encourage the project start-up; ongoing maintenance is in need to sustain the revitalized streams. Further research is required to examine the feasibility of implement rehabilitation on the old stream. Researchers should carefully investigate on the variability of land cover and detail spatial analysis for a successful restoration of the urban ecosystem in Vancouver.

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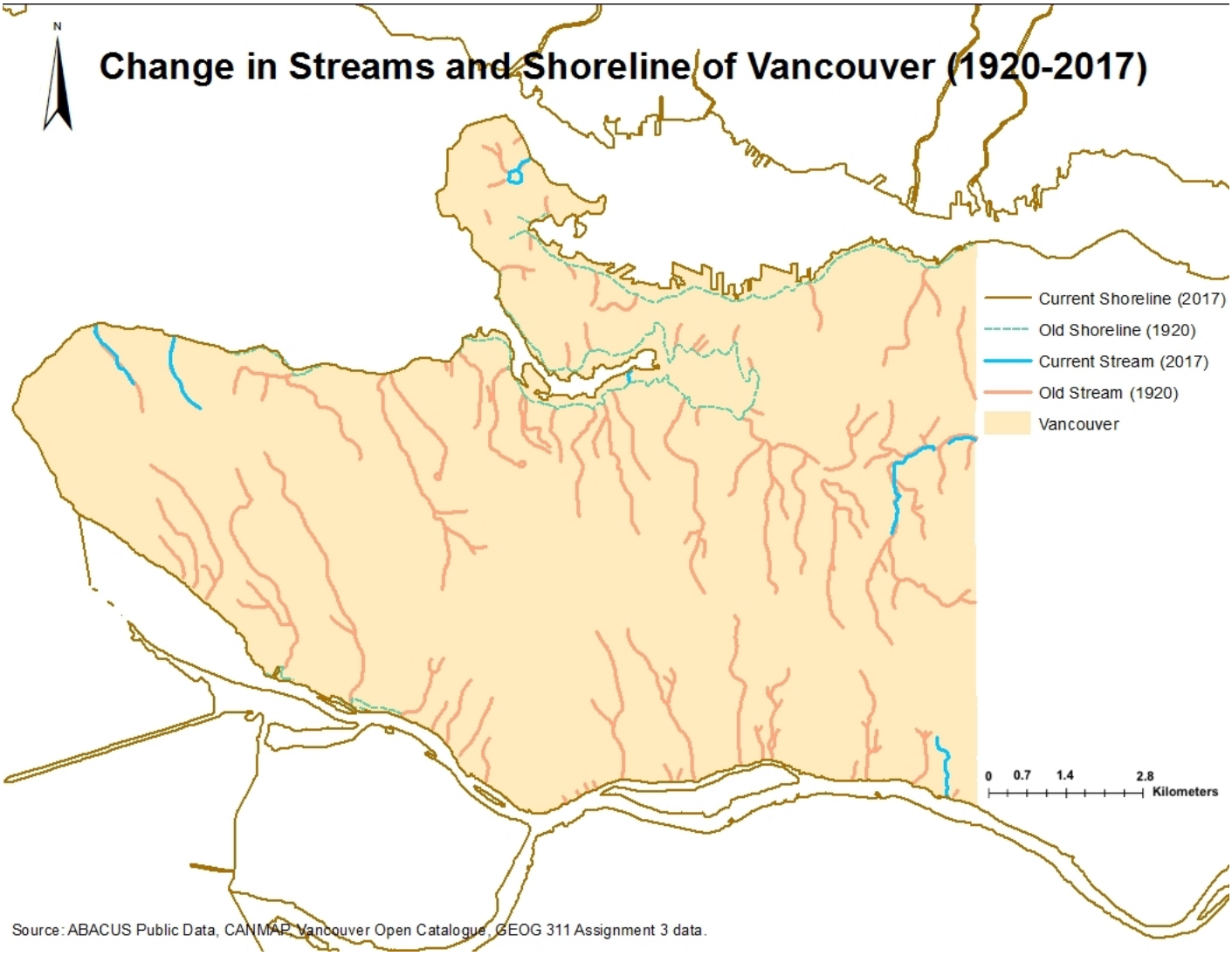
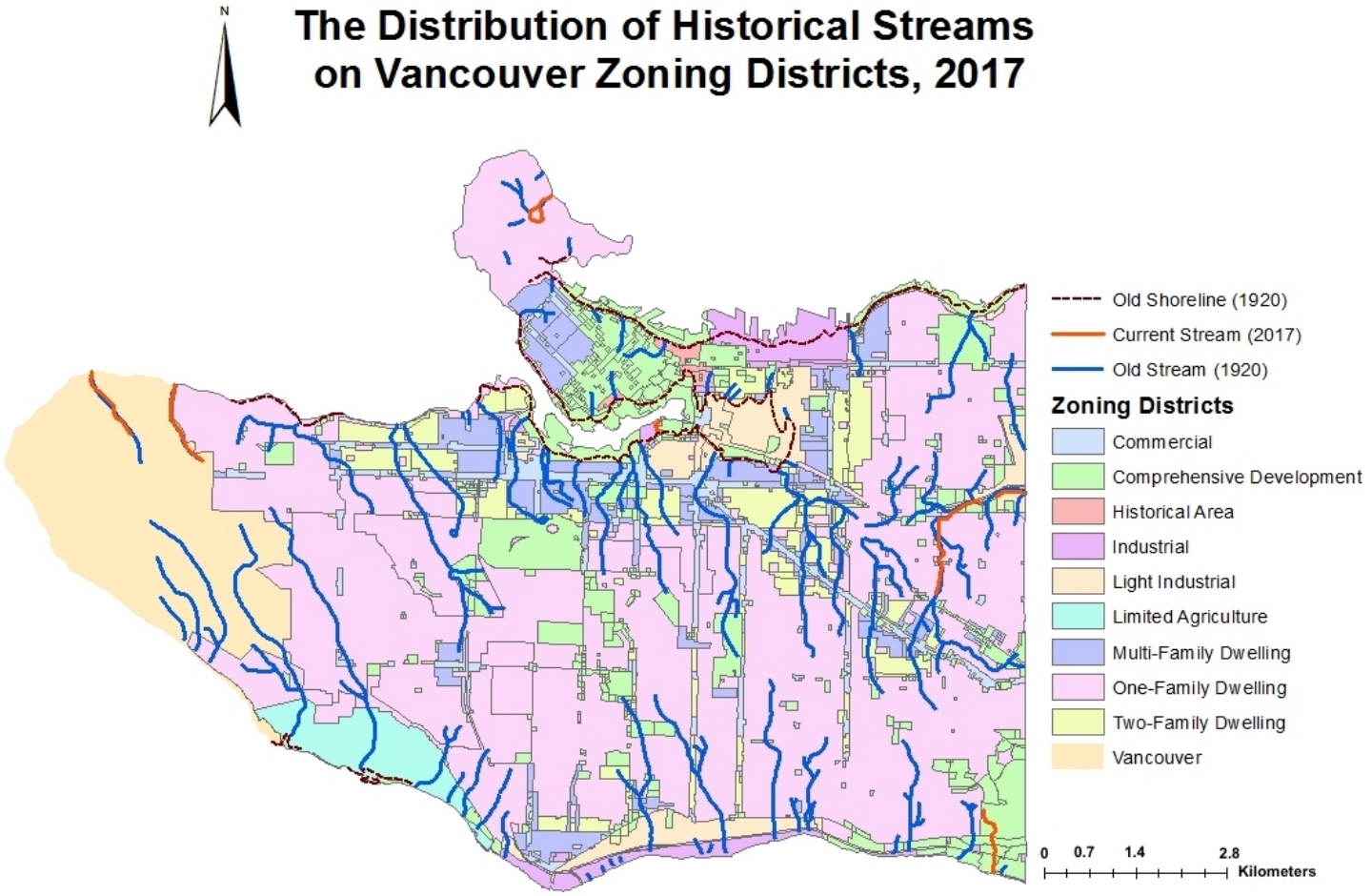
Map Appendixes:

Map 1: Change in Streams and Shoreline of Vancouver (1920-2017)

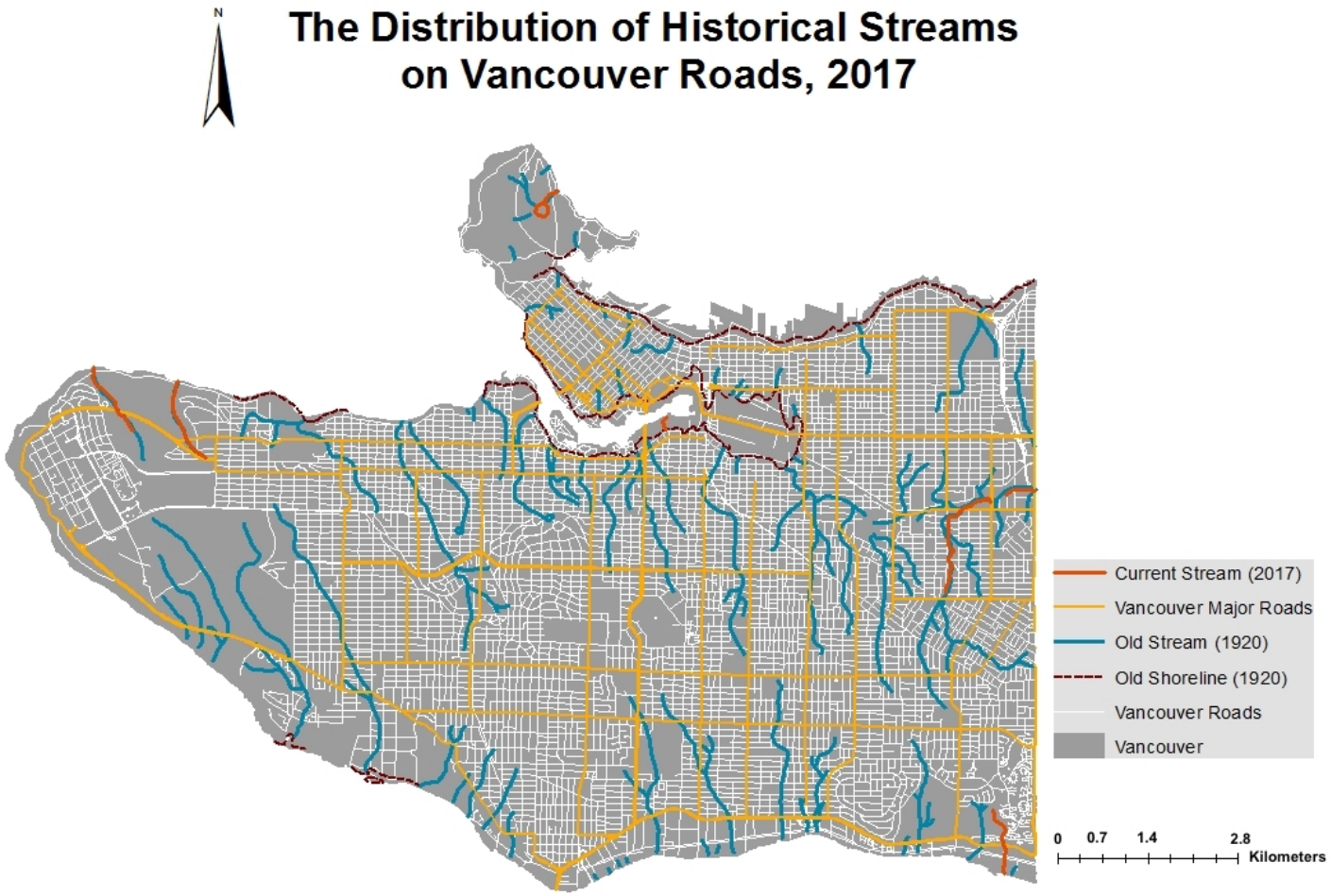


Map 2: The Distribution of Historical Streams on Vancouver Zoning District, 2017



Source: ABACUS Public Data, CANMAP, Vancouver Open Catalogue, GEOG 311 Assignment 3 data.

Map 3: The Distribution of Historical Streams on Vancouver Roads, 2017



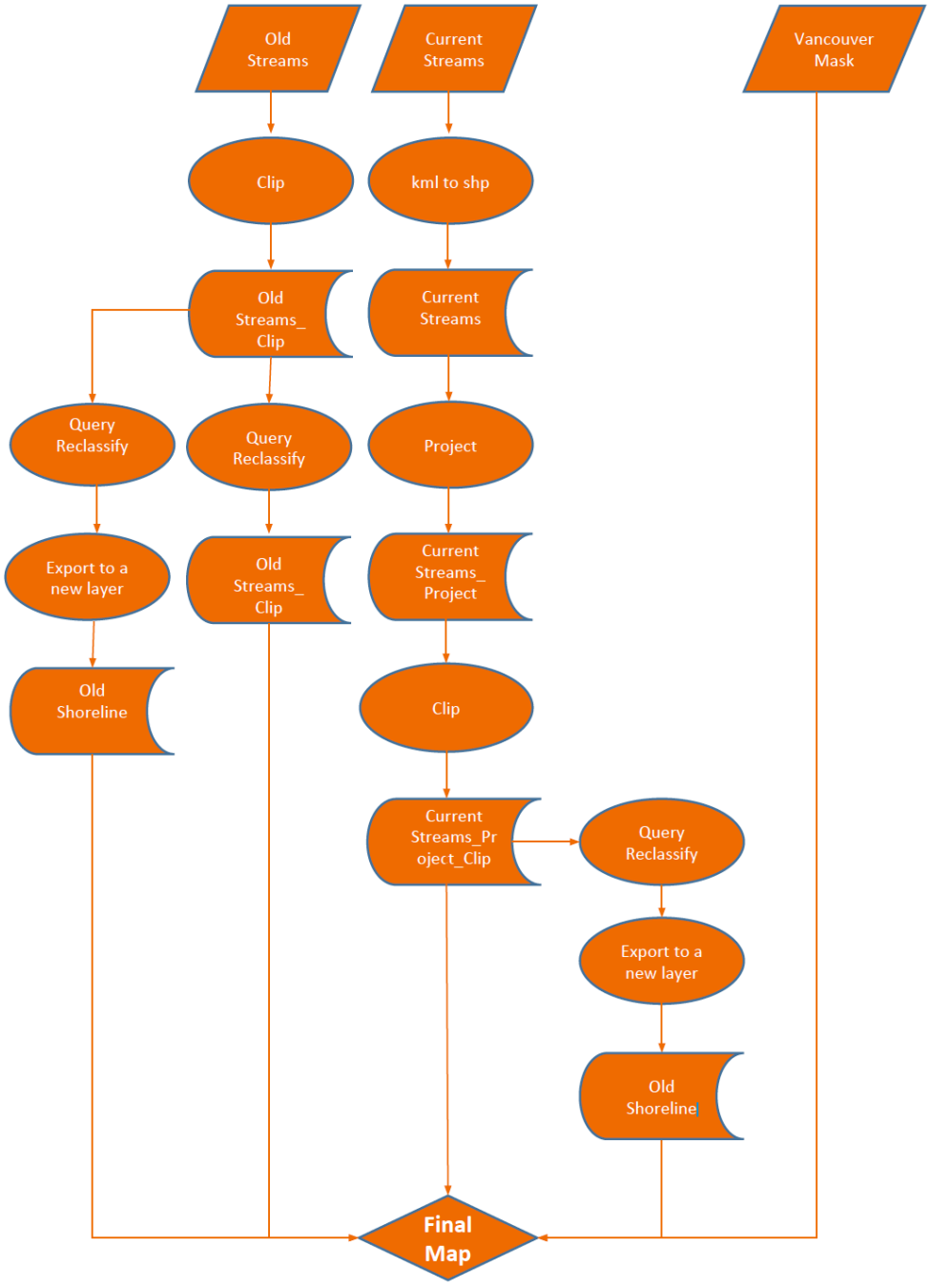
Source: ABACUS Public Data, CANMAP, Vancouver Open Catalogue, GEOG 311 Assignment 3 data.

Map 4: Salish Stream: 1920 vs. 2017

Source: ABACUS Public Data, CANMAP, Vancouver Open Catalogue, GEOG 311 Assignment 3 data.

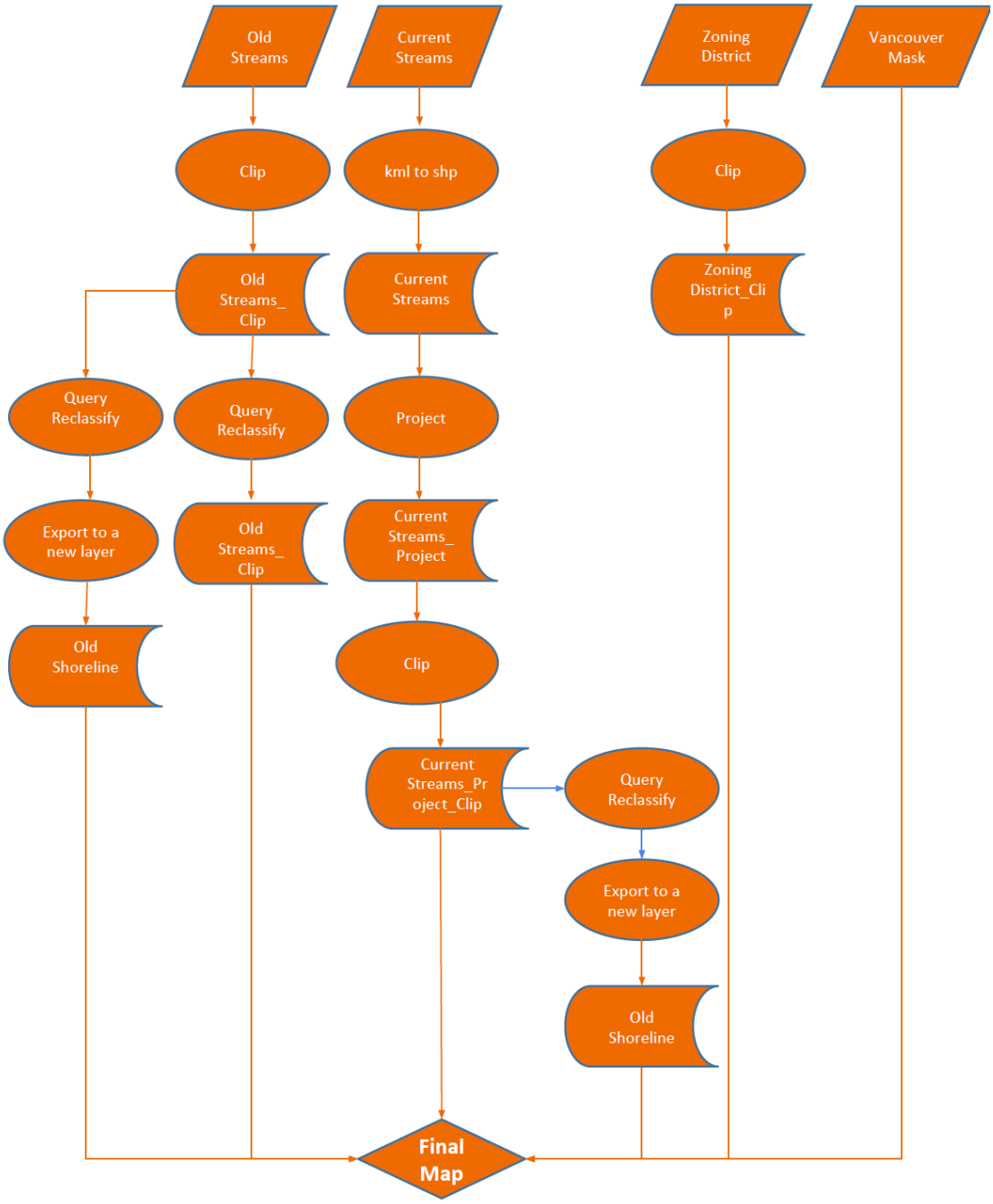
Flowchart 1

Map 1: Change in Streams and Shoreline of Vancouver (1920-2017)



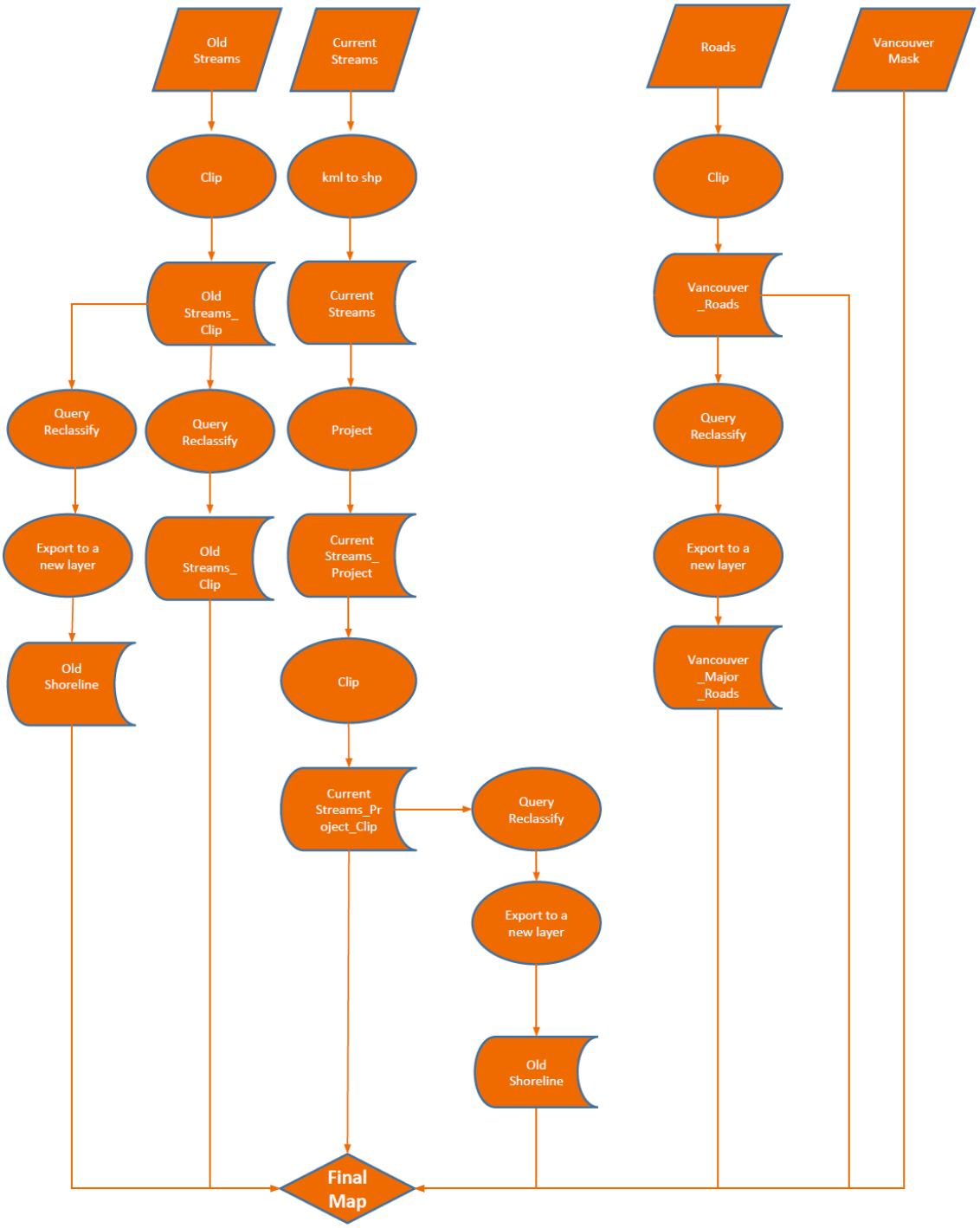
Flowchart 2

Map 2: The Distribution of Historical Streams on Vancouver Zoning District, 2017



Flowchart 3

Map 3: The Distribution of Historical Streams on Vancouver Roads, 2017



Flowchart 4

Map 4: Salish Stream: 1920 vs. 2017