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ENVS - 422
Aquila Flower
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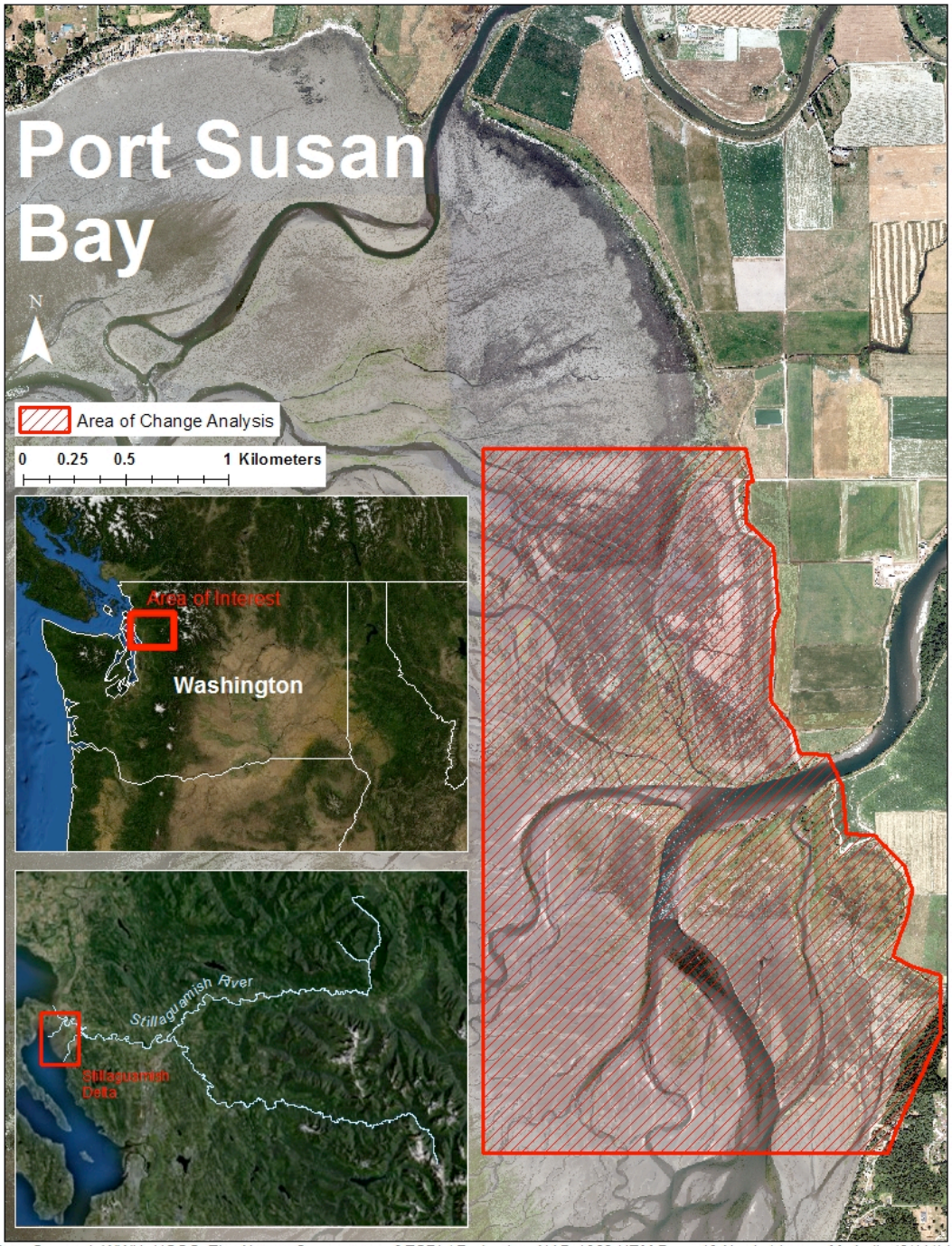
Port Susan Bay: A Change Analysis from 1947-2013

Temporal Habitat Classification and Channel Migration



Data Sourced: WWU, USGS, The Nature Consevancy, &ESRI / Projection: NAD 1983 UTM Zone 10 North / James McArdle (3/11/14)

Figure 1: The Stillaguamish Estuary at Port Susan Bay, the study site and its relative location.

Abstract

Migration of stream channels within a delta are imperative to the production and reduction of marsh habitat. Understanding the channels movements and its effect on the wetlands help maintain the health and well being of the estuary. In the Stillaguamish River Delta, irrigation and flood control infrastructure has impacted the area, however the extent of the impact and the severity of is unknown. In this research, channel location was determined and analyzed through the use digitization of present day and historical aerial images. Furthermore, a classification of tidal marsh in the delta was applied through the use of an ISODATA unsupervised classification. Channel migration, sinuosity, and marsh area were cross-referenced in order to better understand the impact channel geomorphology has on marsh habitat. Results indicate a relationship between channel geomorphology and marsh development. These methods could be refined and applied to a larger sample size and greater geographical extent to further understand the connection between delta stream channels and marsh habitat.

Introduction

The mixing of fresh and salt water to form estuaries is a coastal process that occurred on Washington's shores long before the arrival of our society. Protecting these areas and their unique qualities should be imperative in the years to come as our region experiences transformations due to climate change. Of the coastal areas in Washington State that once were estuaries, only one quarter remains. Many of these remaining estuaries have experienced shrinking tidal marshes due to man-made flood prevention infrastructure in order to protect agricultural and residential areas.

The necessity to protect these areas should have significant priority considering their potential impact on floods, food production, biodiversity of marine life, and the water quality of the Salish Sea. As many of the coastal areas where transformed for agricultural purposes, by the addition of levees and dykes, the area ceased its normal geomorphic processes that came with the changing of tides and the migrations of stream channels within the delta. As the sea level is expected to rise, it is critical that the channel migration patterns need to be observed and analyzed throughout the history of these flood control devices in order to discover which devices and channel locations best serve the estuary and those that live and work around it. As the delta channels flow into the sea, they bring rich sediment from the mountains and the foothills of the cascades; as a result, they alter the elevation and plant life of the bay. Seeing how these areas and habitats have changed in relation to the position of the stream channels will provide a blue print for how restoration work should be carried out. In addition, the mixing of the fresh and salt water serves as the foundation for marine life. Estuaries are rich in food and habitat for a wide array of marine life, many of which are crucial for the commercial fisheries of Washington State. It is for the reasons stated above that the task of looking to the Stillaguamish River Delta at Port Susan Bay and classified marsh habitat from both 1947 and 2013 was undertaken . In addition, the stream sinuosity was calculated, as was the migration of stream channel after the positions of 6 major stream channels in the delta from those specific years were authenticated. The sets of data were then combined in an effort to better define the relationship between channel migration, channel sinuosity, and marsh development.

Literature Review

When assessing the analyses to undertake such a project, prior research in similar studies can provide ideas and inspiration that can translate to the Stillaguamish Project. Some of literature on the topic deals with the mapping of future tidal marshes and evaluating certain aspects that are crucial to marsh development. Many articles focus in on the evaluation of areas of marsh lands, their respective distribution and their relationship to impediments to marsh growth, such as roads, shoreline hardening, and land slope. The marshes are frequently categorized with varying potential to protect nearby population. Other approaches have marsh categorized and classified in terms of viability such as one such study in which the marsh was assessed through an index based on marsh size, elevation and potential migration impediments. (The Nature Conservancy, 2010) The mapping of these features proved useful in the analysis performed in addition to retaining strong potential to be useful in future analysis.

Other examples of literature in related fields closely examined the links between the restoration of tidal marshes and channel hydrology. Current literature states the hydrological processes of marshes are imperative to the evolution, functional ability, variability, and transportation of material and organisms between marsh areas within the estuary. Scholars in the field, maintain that to accurately and appropriately restore the marsh areas within an estuary, the channel hydrological processes must first be fully understood in order to incorporate these processes into the restoration design. (Montalto & Steenhuis, 2004) Such studies were a valuable tool while analysis was performed, as one of the areas in the bay has already gone under restoration, and Snohomish County has further restoration plans for the rest of the region. When examining the state of the topic on a more localized level, literature on the Chehalis River in Washington confirmed the link between tidal channel formations and the ecological patterns and processes

in the marsh evolution. The reading suggested a link between the channel size and ebb tidal flow, and thus amount of detritus and sediment in the outflow. Both sediment and detritus are critical in the development of marsh areas. (Hood, 2002) To reinforce the issues on a local level, literature on the Skagit River, a river delta with similar conditions as the Stillaguamish, and found that the channels themselves were not processes of erosion but results of deposition. (Hood, 2006) The articles detailing the links between stream channel locations and marsh growth or reduction will proved to be valuable in determining how the locations of digitized stream channels influenced marsh areas.

Additional sources involved examining the state of GIS methods in the analysis of an estuary. Some methods suggest mapping the vegetation and habitat areas the estuaries as the studies of Padilla Bay in Skagit County, as well as the example found in the Puget Sound Nearshore Ecosystem Restoration Project report, and a study of geomorphic processes of the Skokomish River. These methods provided insight into the various re-sampling of images and mapping of shorelines and classification of vegetation and habitat. The methods used for the study in Padilla Bay were based off of methods for mapping eelgrass habitat in British Columbia. It also has an extensive section detailing a proper method for digitizing streams. (Shull and Bulthuis, 2002) Further methods for analysis were taken from an extensive report from PSNERP's comprehensive change analysis of Puget Sound. (PSNERP, 2009) More methods have been evaluated from a geomorphic analysis of the Skokomish River. These methods detail the digitizing of streams at a scale of 1:1000 and the use of segmentation and ISODATA unsupervised classification to determine specific habitat areas. Another method used was the classification of stream channels through determining channel width and depth. (Stellern, 2013)

Data Used

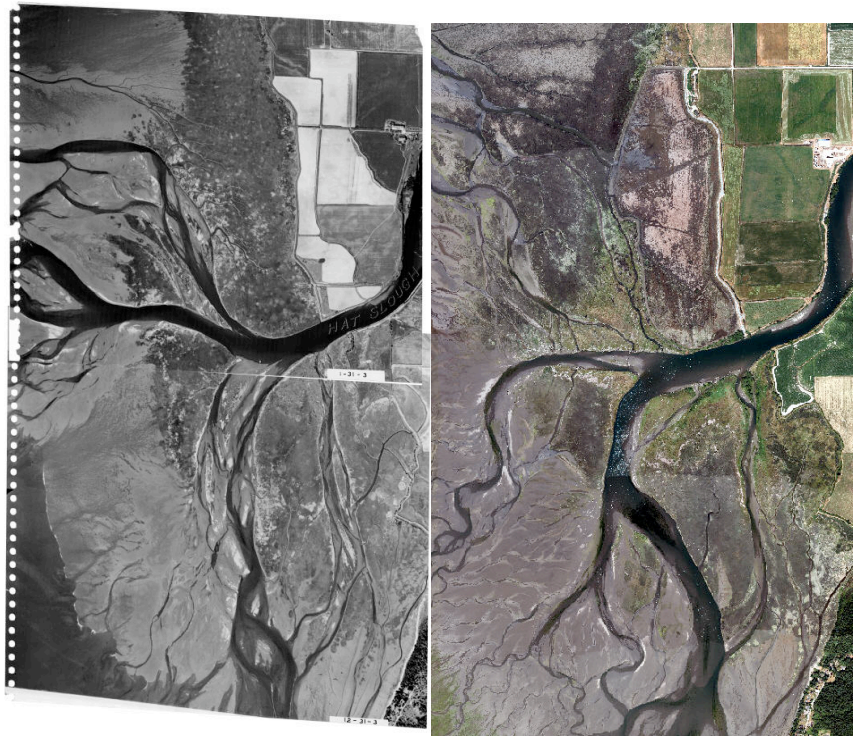


Figure 2. The 1947 and 2013 images respectively. Used for digitization of thalwegs and ISODATA unsupervised classification

Any data received and any analysis performed has been done in unison with the Nature Conservancy and United State Geological Service, and under the guidance of Roger Fuller. Aerial images of the Stillaguamish were acquired from the NAIP for 2013 and from the USGS for 1947. Additionally, vector files of the 5 study sites within the delta, and the estuary boundary were used. For elevation analysis, LIDAR data was acquired from 2013. Additional data acquired was vector data detailing the positions of man-made flood control structures. Other data used for analysis also includes a set of polygons form the Puget Sound Nearshore Ecosystem Restoration Project. This data from 2009 details the prior extent of the marsh and specific classification of the marsh area detailing specific type of marsh as either oligohaline mixed vegetation, estuarine mixing, euryhaline unvegetated, or tidal freshwater.

Methods

Analysis was performed on the images from 1947 and 2013. Six smaller aerial images from 2013 showing the estuary were put together through the use of the mosaic to new raster set tool. Feature Classes were created for the stream segments in the proper NAD 1983 UTM Zone 10 North, which will be used for all analysis. The resulting mosaiced image from 2013 was used as a reference for the digitization of thalwegs in the delta. Standard digitizing techniques were used to create the polyline file for thalwegs. All digitization was done at a scale of 1:1500. The resulting file created 100s of features that were then dissolved into one line based upon channel source. Once a file was created with one continuous polyline another editing technique, planarizing the lines, was applied to break the thalweg line into segments at every intersection. Six major thalwegs were then selected out of the file and sample points were placed every 200 meters. The above process was done for the areas of the delta in 1947 and 2013. Once major thalwegs files had been acquired with sample points for both years, a Point Distance tool was applied in order to calculate stream channel migration.

In addition, an unsupervised ISODATA classification was applied to the images for the above years. Using the PSNERP data as a reference, as well as the images loaded into true color and near-IR, 50 spectral classes were assigned in ENVI into one of the following 5 information classes: Channel or Water, Euryhaline Unvegetated, Estuarine Mixed Vegetation High Marsh, Estuarine Mixed Vegetation Low Marsh, and Deciduous Vegetation, which were then later renamed: water, tide flat, low marsh, high marsh, and decidiuos. After classifications had been acquired, specific parameters such as classes in certain elevations based off of LIDAR data, and classes of intersection with specific tidal zones were reassigned through a Con Nested tool in ArcGIS. In order to better improve the 1947 classification, which was lacking due to the

single band image and poor resolution, some digitizing of larger mash areas was done and then placed into a union with the classified image. (All classified images had been run through a raster to polygon tool and then dissolved in order to make the classifications easier to work with). In order to create specific zones for each of the 6 channels, a Thiessen Polygon tool was applied a file of all sample points for both 1947 and 2013. The resulting polygons were then dissolved based on Channel ID so that the study area was broken into 6 distinct areas. Since they are a combination of Thiessen polygons every point with in the polygon would be closer to one of the channels inside than any channel outside. Typically there would be a desire to ascertain the change within a specific watershed, but since the profile of the land was so low, the watersheds could change dramatically. This fact, combined with a lack of elevation data for the 1947 image resulted in the use of the Thiessen Polygons rather than attempting to define the watershed. The resulting areas of the classification for each zone for the 2 years were cross-referenced with the data achieved through stream channel migration in order to determine how the movement of the channel affected marsh habitat. To accomplish this, the data was placed on a scatter plot with marsh area percent change on one axis and average migration on another. In addition to channel migration, stream sinuosity was also calculated for each of the 6 channels. This was done by dividing the total stream length by the Euclidean (straight line or "as the crow flies") length from the start point to the end point of the stream. A stream with a value of 1 is considered straight, and a value of 1.5 is considered sinuous, and a value of 3 is considered meandering. The sinuosity of each stream channel was also cross referenced with marsh area change using the above cross referencing methods.

Results

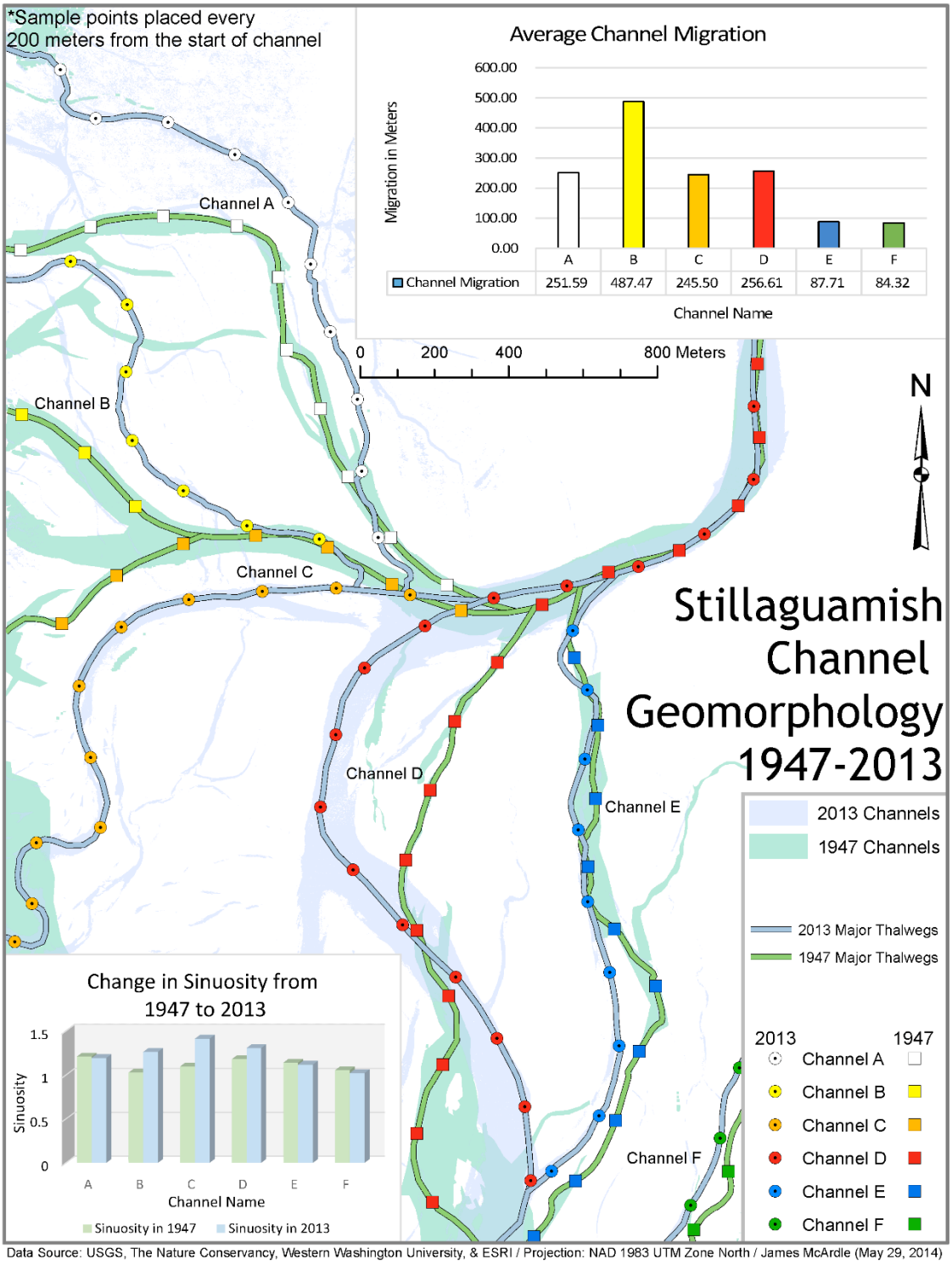


Figure 3. Stream Channel Migration and sinuosity of 6 major thalwegs in the Stillaguamish River Delta

When evaluating the channel migration, which can be seen in Figure 3, most channels experienced a significant amount movement over the time period. Channels E and F moved the least, migrating just over 80 meters during that time. Channel B saw the greatest change, moving nearly 487.5 meters over the same time period. The remaining channels experienced similar amounts of migration, all around 250 meters. Sinuosity change in the channels also varied. Three channels saw an increase in sinuosity while the other three experienced a decrease. The three channels that became more sinuous, however, saw greater rates of change than the channels that lost sinuosity. Lastly, all of the channels remained in 1 to 1.5 scale, meaning that the fall within the normal range of sinuosity and would neither be classified as straight nor meandering channels.

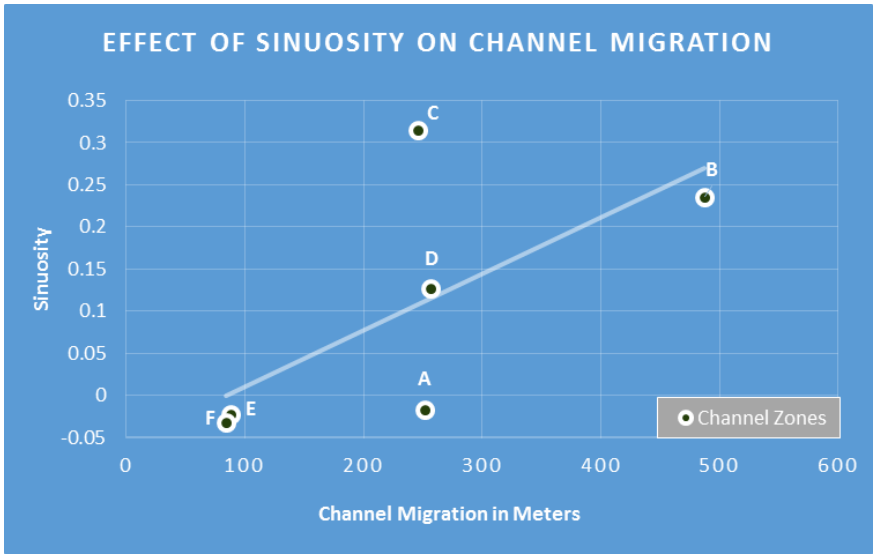


Figure 4. The relationship of sinuosity and channel migration

After the sinuosity and migration were calculated, the results were placed on a scatter plot to determine the relationship between the two fields of data. It can be seen in Figure 4 that while there is a positive correlation, it is a weak one, with the outcome dictated by outliers. Perhaps with more data the trend of "the greater the migration seen the larger the change in sinuosity" would continue.

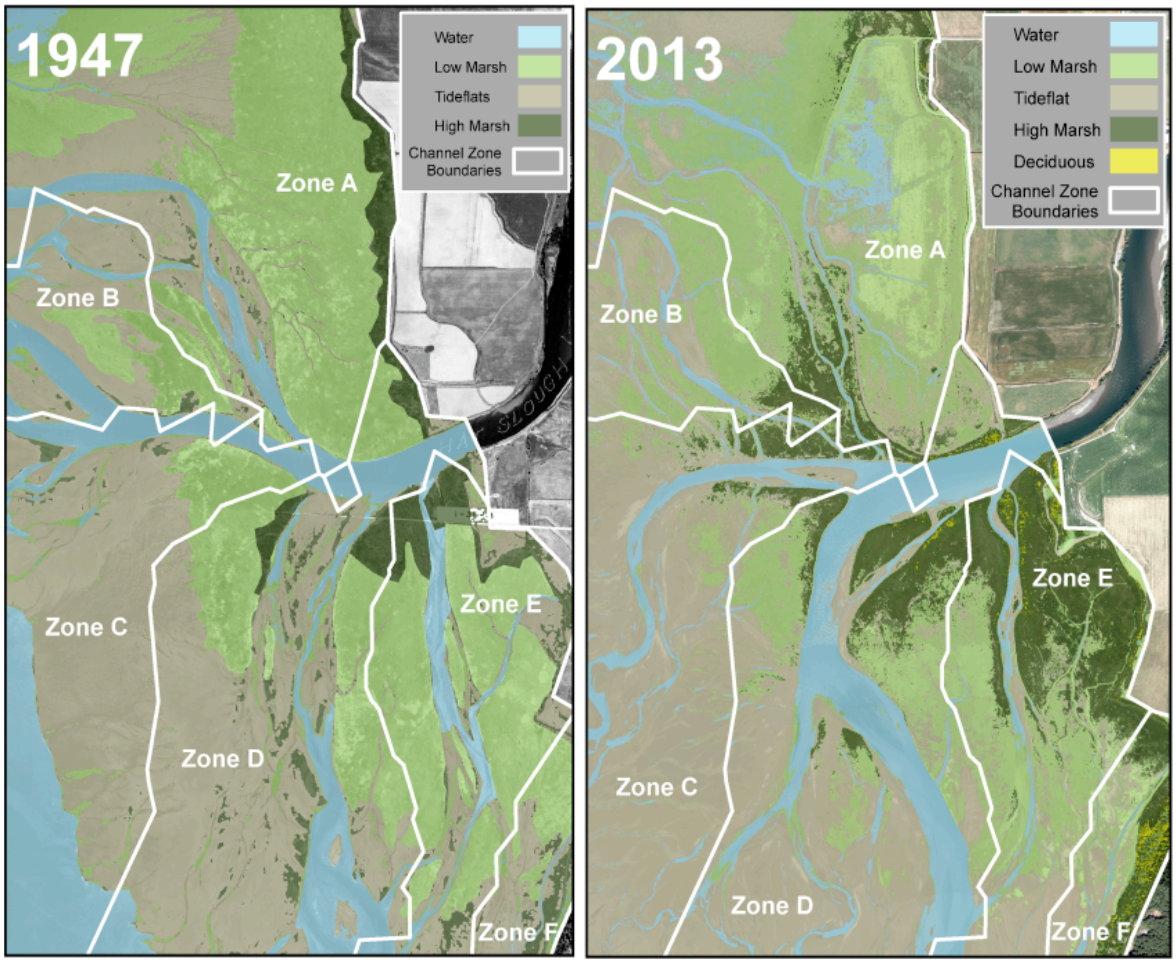


Figure 5. The resulting classifications for 1947 and 2013

The finished classifications, seen in Figure 5, show a significant growth in marsh, particularly high marsh. Much of the high marsh comes at the expense of low marsh around the areas near where hat slough (the main river channel) enters the estuary. The zones seen are the result of the dissolved Thiessen polygons. Any features within the designated zone are more closely related to the channel within the same zone, than any channel outside of the zone. Although the volume of water was not quantified in this research, the classifications above do provide a good visual indication of where the water went.

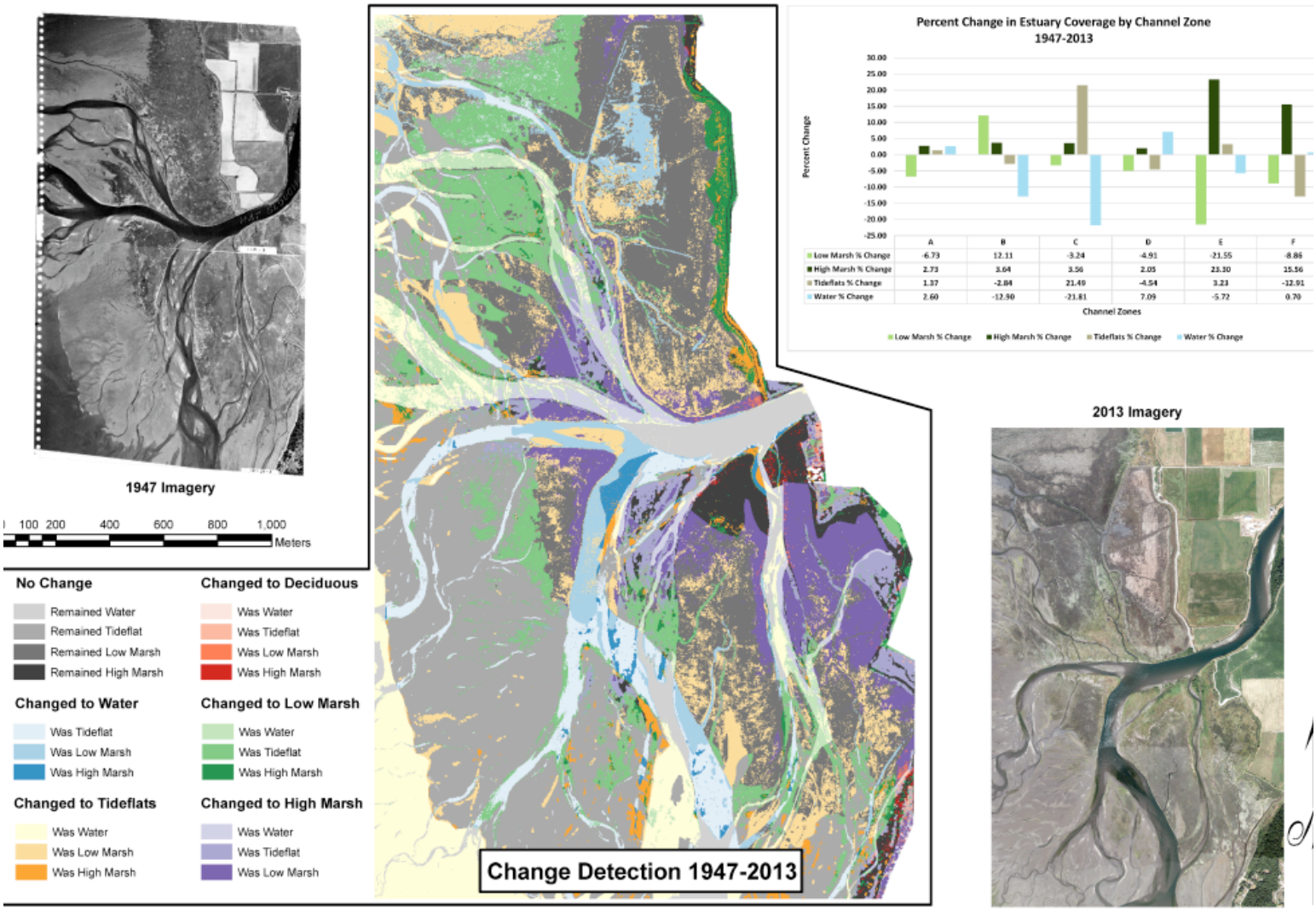


Figure 6. A change detection map of the study area, symbolized by the previous and present land cover

The resulting change over the years can be seen in Figure 6. Additionally the percent change for each channel zone can be viewed in the chart within Figure 6. Results were varied, but one constant was the addition of high marsh seen in all six zones. The high marsh typically replaced the low marsh or tidal flats. The largest addition of low marsh occurred in Zone B. In this case a large volume of water left the zone, leaving the low marsh to replace it. Additionally, Zone C saw a large increase in tidal flat that had once been water, however this is slightly misleading as the tide was higher at the time the picture was taken in 1947 than in 2013.

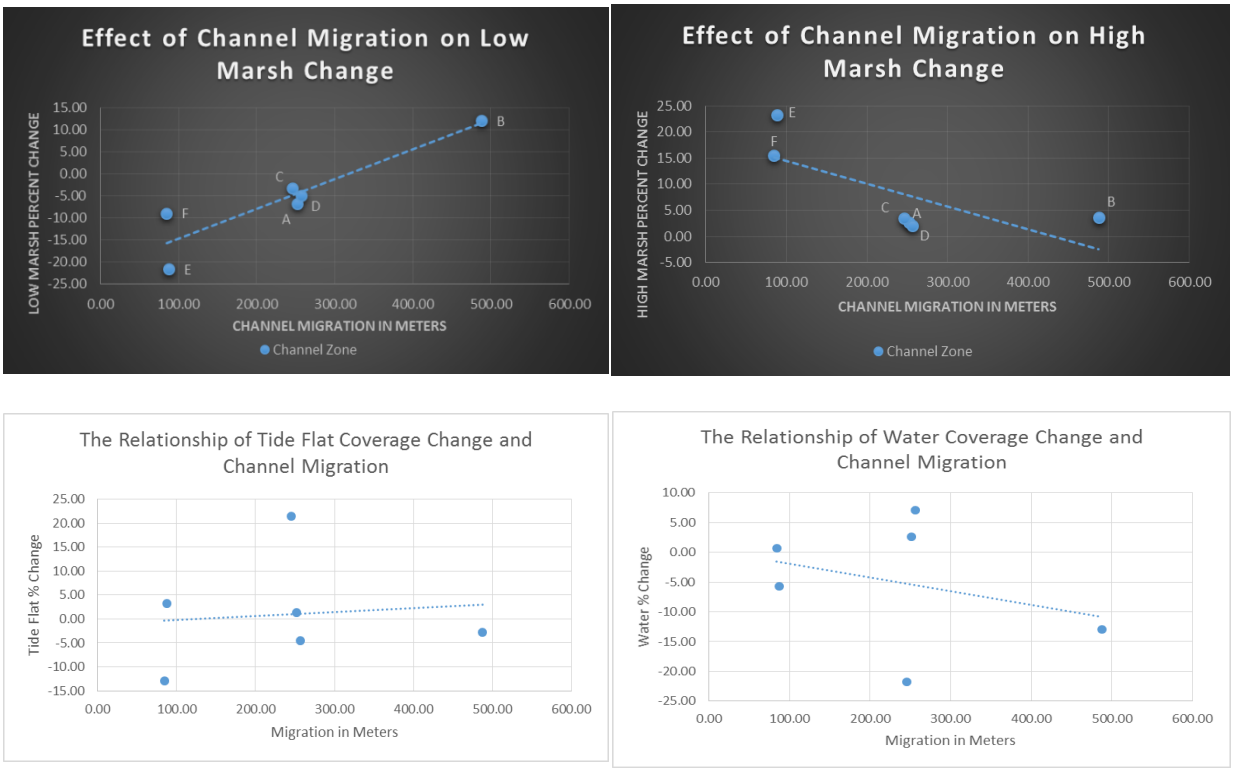


Figure 7. The relationships of Channel Migration and the 4 significant land cover changes.

When evaluating the relationship of channel migration on marsh coverage there does appear to be a correlation for both high and low marsh. The correlation is a weak one, but in the case of the relationship of low marsh and channel migration, there is evidence to suggest that when a channel has a large migration, more low marsh is seen. Conversely, the relationship between channel migration and high marsh is a negative correlation. When a lager migration distance occurs so does the erosion of high marsh. The relationship of migration on water and tide flat coverage was more nonexistent as the data points were clearly scattered. More sample points and a wider geographic extent are needed to state anything more definitively.

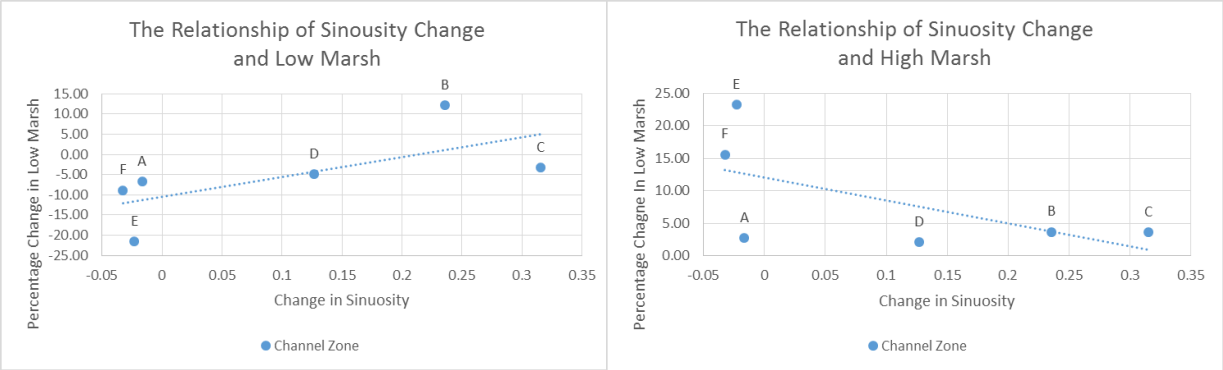


Figure 8. The relationship of Sinuosity and High and Low Marsh Change

When plotting the changes seen in high and low marsh against changes in sinuosity, similar trends are seen that were observed in evaluating the relationship between marsh and channel migration. Any correlation is even weaker than the relationship between the marsh and channel migration, but like with the previous relationship, as sinuosity increases so does low marsh growth, and once again conversely, as sinuosity increases, high marsh decreases. Also once again more data is needed to make any conclusive determinations

Discussion and Conclusion

When evaluating the results, a few factors made themselves evident. First, when analyzing the channel migration distances, it is evident that the largest migration occurred in Channel Zone B. Although the amount of water in a specific channel was not quantified, it does appear that this was the same channel zone which experience the most dramatic loss of volume of flow. Perhaps the larger the change in flow over time could influence the amount a channel migrates over the same period of time. Channel C also experienced a dramatic loss of water, and it was also the only channel not to migrate in a north or west direction. When evaluating the change in sinuosity, it is apparent that the three channels that experienced an increase in sinuosity all had a large association with dramatic changes in the volume of water in the

channels, while the three channels that saw a decrease appeared to shift in direction and distance, but stayed relatively similar in size.

Taking a closer look at the possible causes for the connection between large channel migration and an increase in low marsh development, one possible reason for the addition of low marsh would be sediment dispersal. As a channel moves more over the landscape, it deposits rich sediment over a wider region. The sediment from upstream may be more conducive for plant life that tidal flat areas and thus encourage the growth of marsh vegetation. Additionally this migration is more likely to occur in areas of low elevation and gentle to nonexistent slope, meaning that the elevations would remain low and not contribute to high marsh development. Conversely the erosional properties of channel geomorphology could decrease the elevation of a high marsh as the channel migrated across the landscape and thus changing the high marsh to either low marsh or tide flat

Further analysis needed would include an increased accuracy of classification, a greater sample size of stream channels and greater geographical extent is required to reach a more definite conclusion. With more time, the classifications could be improved through more editing techniques and overlays. Also an accuracy assessment could be applied if ground truth data was taken in the field to quantify the accuracy of the classifications. Moreover, if data was collected for multiple years, prior to and after 1947, the relationships may become clearer. In addition, a larger sample size, including more dispensary channels and also including blind channels, would be beneficial in determining just how channel migration, marsh development and sinuosity relate to one another. Other variables, such as quantifying the volume of water moving through a channel, or the elevation of specific areas could factor in as well to observe how a marsh is formed of erodes away.

Despite some stumbling blocks, and gaps in historical data, the process proved to be quite effective and are repeatable. With the previously mentioned additions to the methods, this research could be refined to show conclusive results in the relationship between stream channels and marsh development. The process was efficient and could become even more so as it is repeated. The results indicate that channel geomorphology greatly impacts the landscape of an estuary. The more discovered about the processes that occur, the greater the advantage when applying this knowledge to restoration work.

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