Changing Waterways

Pre- and Post-Removal Analysis of the Elwha Dam: Impacts to Fluvial Geomorphology & Ecology

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Abstract

Dam removal has various associated short-term environmental impacts, such as increased sedimentation and turbidity. The study of the impacts of dam removal is a relatively new field and still requires extensive investigation. Dam removal has been found to have long-term environmental benefits but also to be a disturbance to river ecology in terms of immediate impacts and as such requires further investigation. Did the removal of the Elwha River Dam improve the geomorphology and ecology of the ecosystem when compared to that of pre-removal even when considering the short-term effects? After two decades of planning, the removal of the Glines Canyon and Elwha River Dams in Clallam County, Washington, from mid-2011 to early-2012, was the largest dam removal operation in history along with the added benefit in that it provided an interesting example of how dam removals can be conducted with the environment in mind. Although more research is recommended, this reports results indicated that despite short-term disruption to the ecosystem, with increased temperatures and pH, already salmonid and other local species are returning in higher numbers.

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Introduction

With the growing awareness and understanding of the deleterious impacts of anthropogenic activity on the environment, dams have been scrutinized for degrading riverine ecosystems and depleting fish stocks due to adverse impacts to hydrology and water quality as well as disrupting the cultural practices of people dependent upon these resources (Brown, P., *et al.*, 2008). Dam removal has been found to have long-term environmental benefits but also to be disruptive to river ecology in terms of immediate impacts and as such require further investigation (Stanley, E. & Doyle, M., 2003). After two decades of planning, the removal of the Glines Canyon and Elwha River Dams in Clallam County, Washington, from mid-2011 to early-2012, was the largest dam removal operation in history (Elwha River Restoration, n.d.). The removal was planned to take place over a period of two years in order to minimize the harmful impacts to the river ecosystem. This operation served the needs of our project in its recency and scope, along with the added benefit in that it provided an interesting example of how dam removals can be conducted with the environment in mind. Therefore, we endeavored to use Geographic Information Systems (GIS) analysis to answer the spatial question: Did the removal of the Elwha River Dam improve the geomorphology and ecology of the ecosystem when compared to that of pre-removal even when considering the short-term effects?

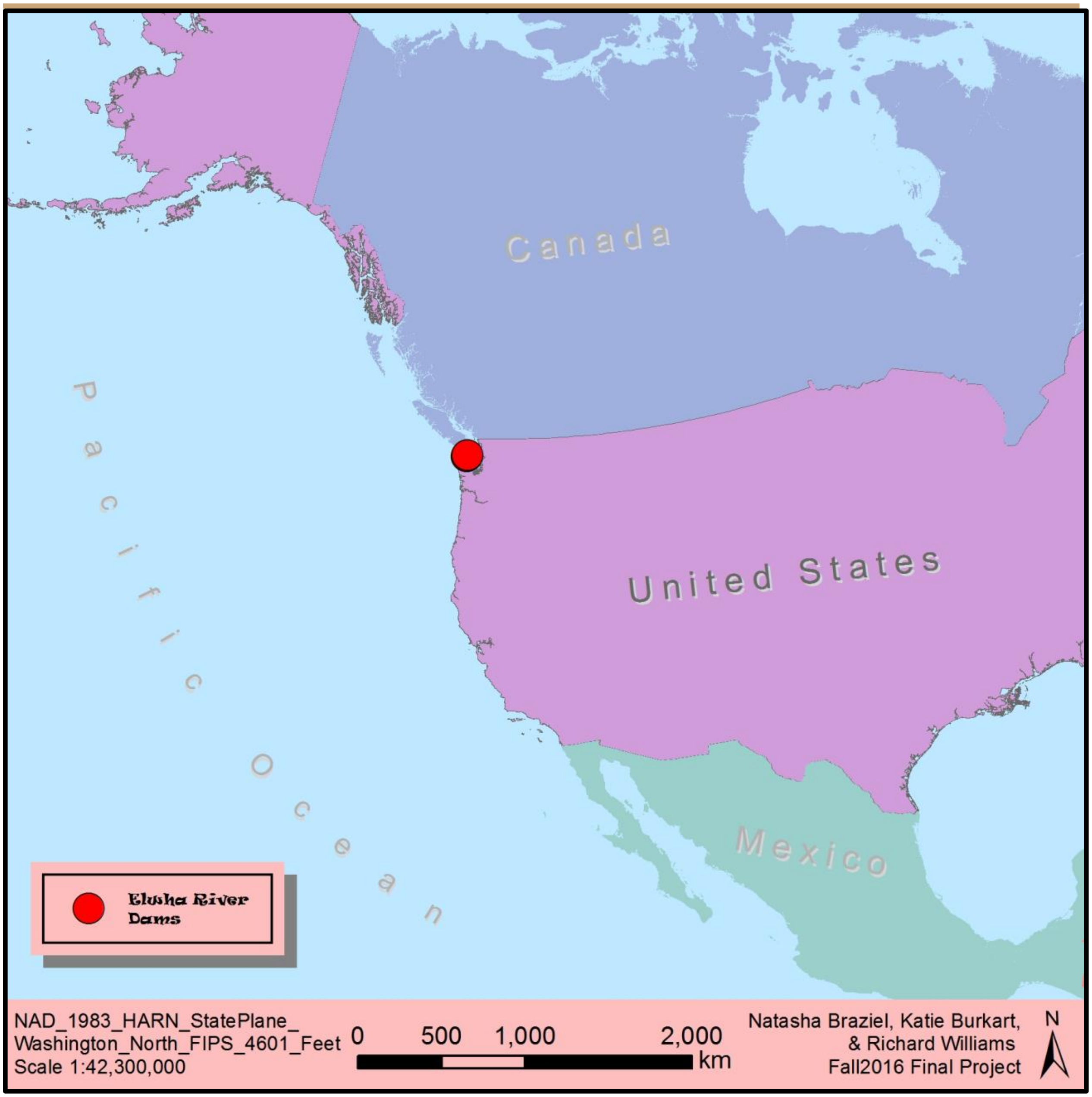


Figure 1: Elwha River Dam, Clallam County, Washington

Methods

Data Collection

A small scale, area of interest, GIS related, investigation of a particular geographic question potential topics were narrowed down to an analysis of dam removal projects in the United States. Research into various removal operations when compared with the project criteria led to the selection of a small scale dam removal on the Elwha River Dam in Clallam County, Washington State.

Waterbody and dam shapefiles were obtained from the Clallam County website (Clallam.net). National Agricultural Imagery Program (NAIP) files from 2006 and 2013 along with Washington Water Quality Assessment (WWQA) data from 2008 and 2012 (pre-and-post removal) were acquired from The State of Washington Department of Ecology Website (ecy.wa.gov). The US County Boundaries shapefile was downloaded from the US Census Data Website (census.gov).

All datasets were loaded into ArcMap 10.3.1 and projected into the North American Datum (NAD) 1983 High Accuracy Reference Network (HARN) Stateplane Washington North Federal Information Processing Standard (FIPS) 4601 (US Feet) spatial reference system (SRS).

Firstly, the dam data set file was selected to only the Glines Canyon and Elwha River Dams. Secondly, the streams and waterbody files as well as 2008 and 2012 WWQA's data were narrowed to the Elwha River Watershed (Table 2). Lastyly, the NAIP files (6 for each of the two years analyzed) were combined to generate a distinct image for both years. A complete list of all the data sets obtained and utilized in this analysis can be seen in Table 2.

Table 1: WWQA standards

Category Number	Description
1	Meets tested standards. Placement in this category means that the waterbody segment meets the criteria it was tested for. It does not necessarily mean that a water body is free of all pollutants. Most water quality monitoring is designed to detect a specific array of pollutants, so placement in this category means that the water body met standards for all the pollutants for which it was tested. Specific information about the monitoring results may be found in the individual listings.
2	Waters of concern. This category lists waterbody segments where there is some evidence of a water quality problem, but not enough to require production of a TMDL. There are several reasons why a water body would be placed in this category. A water body might have pollution levels that are not quite high enough to violate the water quality standards, or there may not have been enough violations to categorize it as impaired according to Ecology's listing policy. There might be data showing water quality violations, but the data were not collected using proper scientific methods. In all of these situations, these are waters that we will want to continue to test.
3	Insufficient or No data. This category houses those listings where the assessed data was insufficient to determine a proper categorization of the water.
4	Polluted waters that do not require a TMDL. This category is for waterbody segments that have pollution problems that are being solved in one of three ways.*
*4a	waterbody segments that have an approved TMDL in place and are actively being implemented.
*4b	waterbody segments that have a pollution control plan in place that is expected to solve the pollution problems. While pollution control plans are not TMDLs, they must have many of the same features and there must be some legal or financial guarantee that they will be implemented.
*4c	waterbody segments impaired by causes that cannot be addressed through a TMDL (not due to a pollutant). These impairments include low water flow, stream channelization, and dams. These problems require complex solutions to help restore streams to more natural conditions.
5	Polluted waters that require a TMDL. Placement in this category means that Ecology has data showing that the water quality standards have been violated for one or more pollutants, and there is no TMDL or pollution control plan.

Data Analysis

The change in total river surface area was determined by creating two shapefiles to reflect the surface areas of the pre- and post-dam removal pertaining to the years 2006 and 2013, respectively. Using the attribute tables for both shapefiles, the calculate geometry tool was employed to approximate the surface area of the river for both years. The difference between the two values of surface area for the rivers was then obtained and a percent change was calculated using the following equation:

$$\%\ \square\square\square\square\square\square\square\square\square\ \square\square\square\square_{\ \square\square\square h\square\ \square\square\square\square\square} = \frac{\square\square\square h\square\ \square\square\square\square\square\ \square\square\square\square\square\square\square\square\ \square\square\square\square_{\ 2006} - \square\square\square h\square\ \square\square\square\square\square\ \square\square\square\square\square\square\square\square\ \square\square\square\square_{\ 2013}}{\square\square\square h\square\ \square\square\square\square\square\ \square\square\square\square\square\square\square\square\ \square\square\square\square_{\ 2006}} \times 100 \qquad (1)$$

The same analysis was utilized to determine the approximate change in surface area of the river downstream of the Elwha dam for pre- and post dam removal states (Table 3).

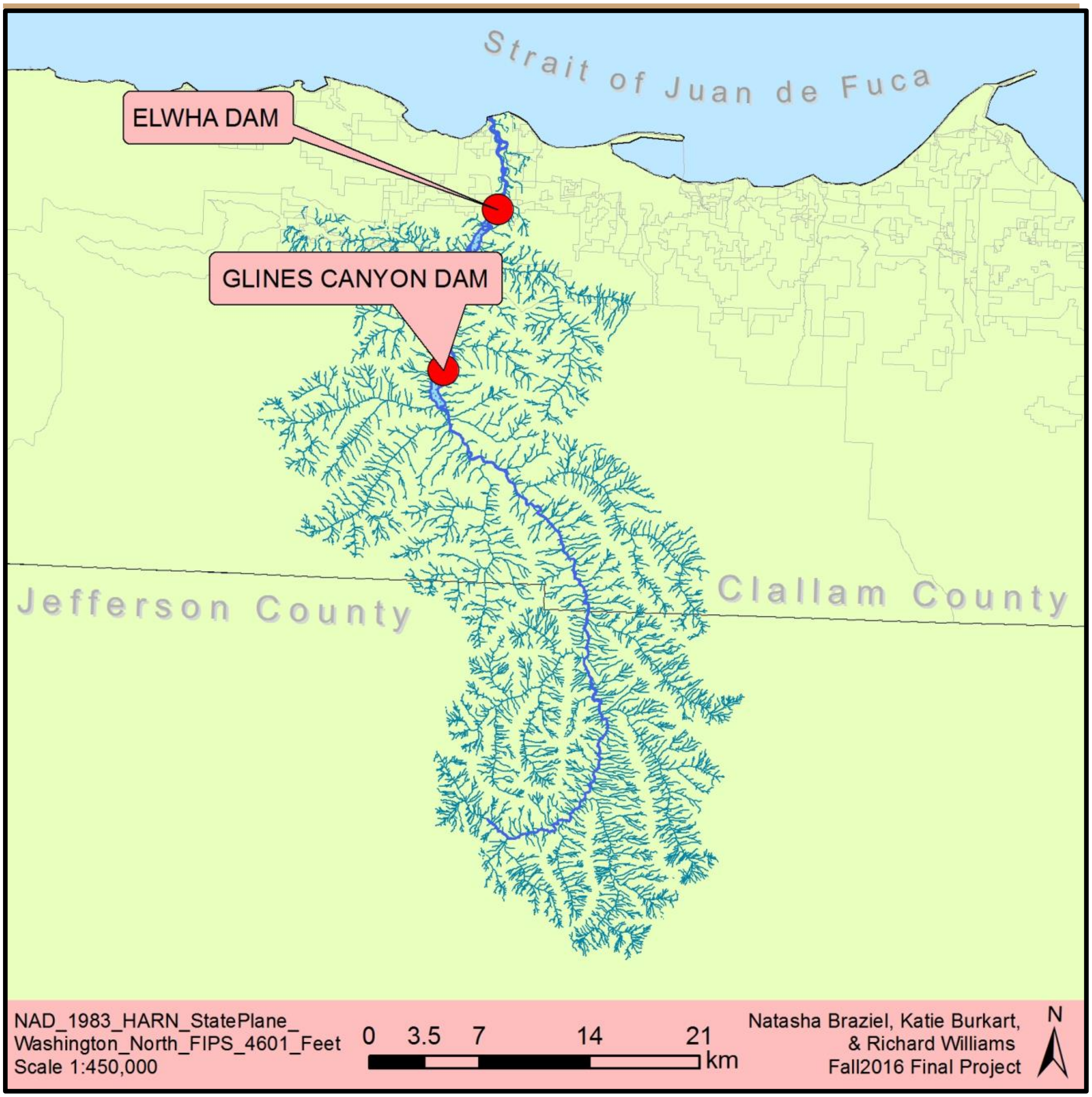
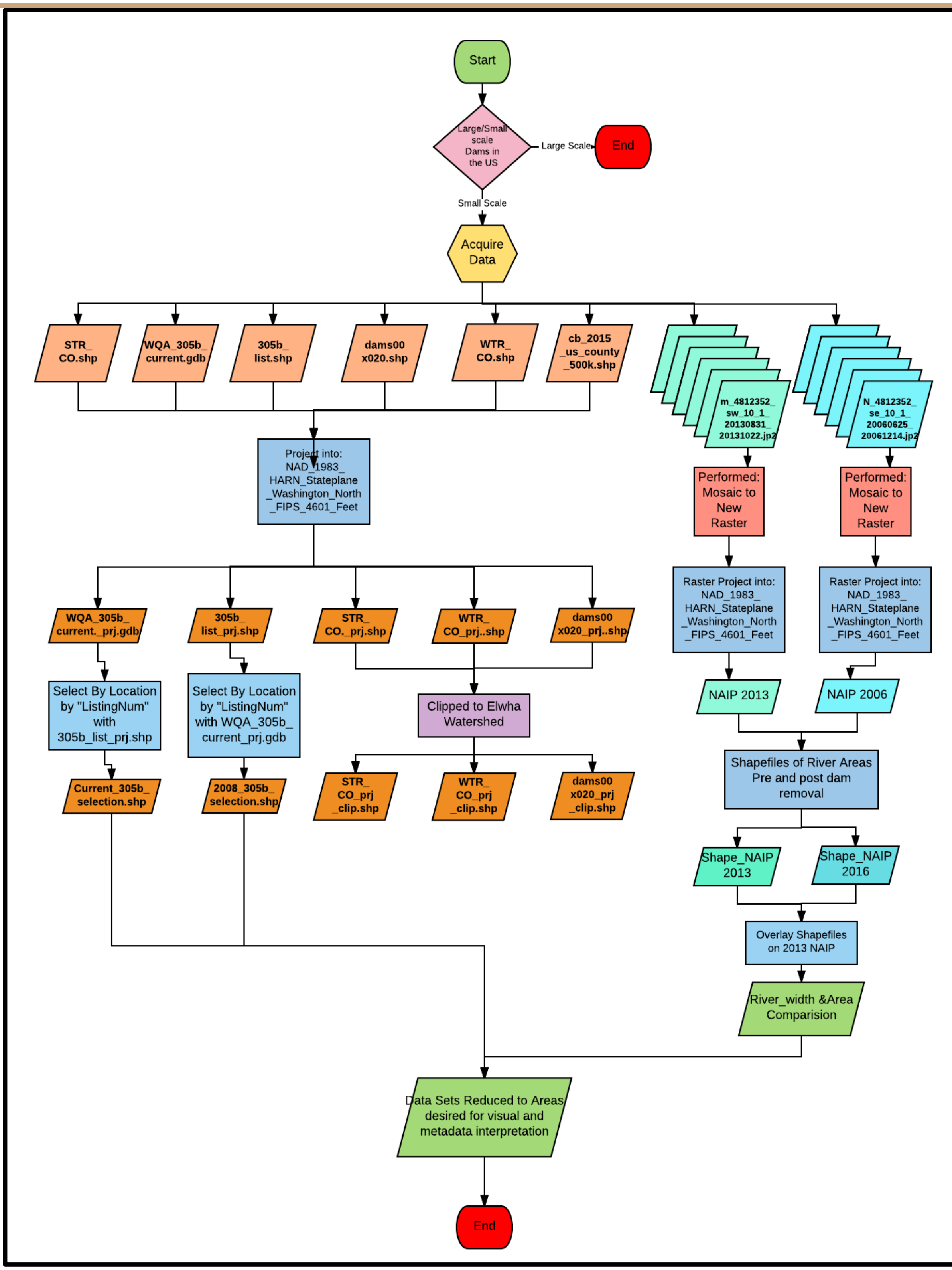


Figure 2: Elwha River watershed that runs through Clallam County and Jefferson County, Washington.

Table 2: Summary of data sets utilized in the analysis

Dataset Name	Description	Original SRS	Data Source	Link to Data Source
cb_2015_us_county_500k.shp	US County Boundaries	GCS_North_American_1983	U S Census Bureau	https://www.census.gov/geo/maps-data/data/cbf/cbf_counties.html
dams00x020.shp	Dams	GCS_North_American_1983	USGS	https://catalog.data.gov/dataset/usgs-small-scale-dataset-major-dams-of-the-united-states-200603-shapefile
N_4812352_se_10_1_20060625_20061214.jp2	2006 NAIP (1)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
N_4812352_sw_10_1_20060625_20061214.jp2	2006 NAIP (2)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
N_4812360_ne_10_1_20060625_20061214.jp2	2006 NAIP (3)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
N_4812360_nw_10_1_20060625_20061214.jp2	2006 NAIP (4)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
N_4812360_se_10_1_20060625_20061214.jp2	2006 NAIP (5)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
N_4812360_sw_10_1_20060625_20061214.jp2	2006 NAIP (6)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
m_4812352_se_10_1_20130831_20131022.jp2	2013 NAIP (1)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
m_4812352_sw_10_1_20130831_20131022.jp2	2013 NAIP (2)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
m_4812360_ne_10_1_20130831	2013 NAIP (3)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/

_20131022.jp2				
m_4812360_nw_10_1_20130831_20131022.jp2	2013 NAIP (4)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
m_4812360_se_10_1_20130831_20131022.jp2	2013 NAIP (5)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
m_4812360_sw_10_1_20130831_20131022.jp2	2013 NAIP (6)	NAD_1983_UTM_zone_10N	USGS Earth Explorer	http://earthexplorer.usgs.gov/
305b_list.shp	2008 WWQA	NAD_1983_HARN_Stateplane_Washington_South_FIPS_4602_Feet	Department of Ecology - State of Washington	http://www.ecy.wa.gov/services/gis/data/data.htm
WQA_305b_current.gdb	2012 WWQA	NAD_1983_HARN_Stateplane_Washington_South_FIPS_4602_Feet	Department of Ecology - State of Washington	http://www.ecy.wa.gov/services/gis/data/data.htm
STR_CO.shp	Streams	NAD_1983_HARN_Stateplane_Washington_North_FIPS_4601_Feet	Clallam County Map Data	http://www.clallam.net/maps/mapdata.html
WTR_CO.shp	Waterbodies	NAD_1983_HARN_Stateplane_Washington_North_FIPS_4601_Feet	Clallam County Map Data	http://www.clallam.net/maps/mapdata.html


Start
Large/Small scale Dams in the US
Large Scale
End
Small Scale
Acquire Data
STR_ CO.shp
WQA_305b_ current.gdb
305b_ list.shp
dams00 x020.shp
WTR_ CO.shp
cb_2015 _us_county _500k.shp
m_4812352_ sw_10_1_ 20130831_ 20131022.jp2
N_4812352_ se_10_1_ 20060625_ 20061214.jp2
Project into: NAD_1983_ HARN_Stateplane _Washington_North _FIPS_4601_Feet
Performed: Mosaic to New Raster
Performed: Mosaic to New Raster
Raster Project into: NAD_1983_ HARN_Stateplane _Washington_North _FIPS_4601_Feet
Raster Project into: NAD_1983_ HARN_Stateplane _Washington_North _FIPS_4601_Feet
WQA_305b_ current._prj.gdb
305b_ list_prj.shp
STR_ CO._prj.shp
WTR_ CO_prj..shp
dams00 x020_prj..shp
Select By Location by "ListingNum" with 305b_list_prj.shp
Select By Location by "ListingNum" with WQA_305b_ current_prj.gdb
Clipped to Elwha Watershed
NAIP 2013
NAIP 2006
Shapefiles of River Areas Pre and post dam removal
Current_305b_ selection.shp
2008_305b_ selection.shp
STR_ CO_prj _clip.shp
WTR_ CO_prj _clip.shp
dams00 x020_prj _clip.shp
Shape_NAIP 2013
Shape_NAIP 2016
Overlay Shapefiles on 2013 NAIP
River_width &Area Comparision
Data Sets Reduced to Areas desired for visual and metadata interpretation
End

Flowchart 1: Project Process

Results

The overall difference in total surface area of the Elwha River from 2006 to 2013, reflecting the pre- and post-dam removal conditions was approximately 235 acres. This decrease in surface area translated to a percent change in river surface area of approximately 79%. The change in surface area of the river downstream of the Elwha dam was approximated to be 25 acres. This decrease in surface area reflected a percent change in downstream river surface area of approximately 44% from the year 2006 to 2013. The finding of the river health analysis from the Washington Water Quality Assessment (WWQA) data revealed a decrease the upstream acidity (pH) levels from category 1 to category 2 from 2008 to 2012. An additional decrease in downstream river temperatures were also identified from the analysis results, which showed the temperature criteria moving from a category 2 to category 5. The temperature decrease was the largest reduction in river health observed from this analysis.

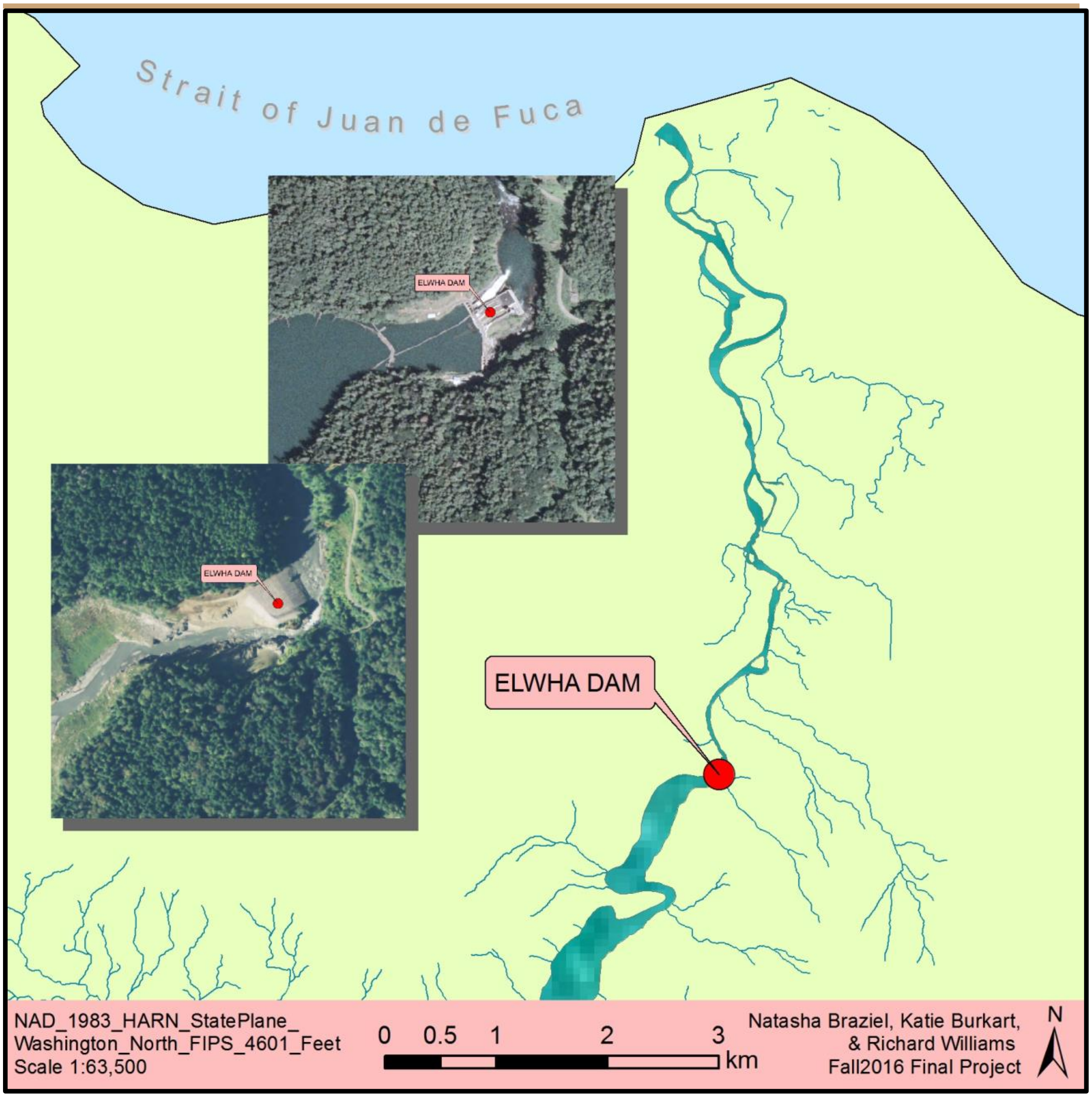


Figure 3: Area that is affected by the removal of the 2 Elwha River dams.

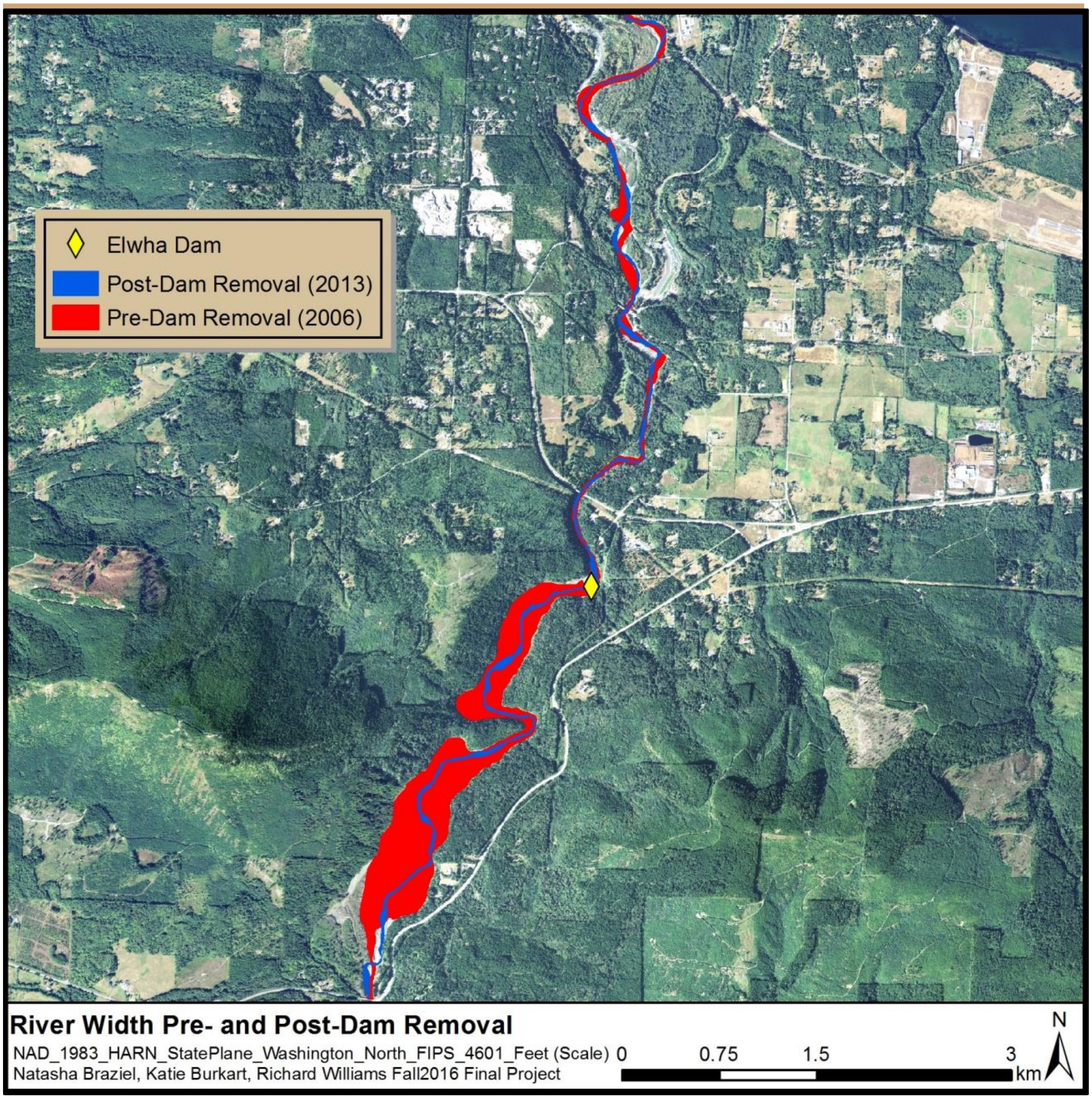


Figure 4: Elwha River Dam, Clallam County, Washington pre- and post-dam removal river width comparison. Note: NAIP image reflects 2013 conditions.

Table 3: Difference in surface area of Elwha River pre- and post-dam removal.

Dam Status	**Surface Area of River (acres)**
Pre-Removal	300
Post-Removal	64
Difference	**235**

Table 3: Difference in downstream surface area of Elwha River pre- and post dam removal.

River Surface Area Downstream of Elwha dam (acres)	
Pre-Removal	58
Post-Removal	33
Difference	**25**

Conclusion

As shown and discussed, the removal of the Elwha River Dam has had a significant impact to the geomorphology of the Elwha River by reducing the total surface area over time. By removing the impediments to the river's historical flow rates and paths, hydrological and water quality conditions have begun improving and will hopefully restabilize to temperature and turbidity levels that are conducive to salmonid spawning as well as allow for the regeneration of other riverine organism populations of cultural significance to the Lower Elwha Klallam Tribe.

The decrease in surface area of the river resulted in higher river temperatures, displayed in the WWQA analysis, which likely created less dissolved oxygen in the water composition. Though, decreased dissolved oxygen in the river is not always helpful for fish population in the rivers, the removal of the Elwha dam allowed for 90% more river access for salmon species to their spawning grounds (Elwha in the News, 2016). This new access allows for a much larger area for salmon species to reproduce and increase their populations in the future, which will stimulate the ecosystem of the river and surely contribute to an increase in overall river health. An influential factor fostering the kickstart of the ecological improvement is the effects of the mass sediment transport that resulted just after the Elwha dam was removed (Draut, et al, 2008).

The removal of the dam allowed for an estimated 9 million cubic meters of finely accumulated sediments to be released and deposited at the river mouth, just before the Strait of Juan De Fuca (Draut, et al, 2008). Initially, the mass sediment transport created highly turbid waters, but as the river regained equilibrium, the deposited sediments at the river mouth created a new habitat for smaller ecosystems to foster. This ecosystem produced new populations of smaller fish like anchovies, sardines, herring, and other forage fish that larger prey could then feed off (Draut, et al, 2008). In conjunction with the reclaimed salmon habitat, the outcome of the dam removal fostered an increase in the populations of not only salmon, but all of the smaller organisms that pave the foundation for the river's ecological food pyramid (Draut, et al, 2008). A study from

USGS, observing salmonid populations, suggested the populations of Chinook, Steelhead, Chum, Coho, and Pink salmon populations had all increased from their prior populations recorded pre-dam removal. This increase in population has been welcomed by the local tribes neighboring the river and will likely better their micro-economies, as well as their deep connections to the river and the fish that reside in it (Draut, et al, 2008). The dam removal was well received by most of the neighboring communities and has allowed for scientific studies on river restoration and recovery that have never been observed on a scale so large (Draut, et al, 2008).

The restoration of this river ecosystem will eventually stimulate the local economy with increases in recreational opportunities such as fishing and kayaking. Currently the USGS, the Olympic National Park, the Lower Elwha Klallam Tribe, the Bureau of Reclamation, Washington Department of Fish and Wildlife, U.S. Fish and Wildlife Service, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and other local and state entities are working on extensive research into the large scale ecosystem restoration and its benefits to all aspects of life in the area. As the removal process was only completed in 2012, further research into the long and short term ecological impacts is required but this collaborative effort will hopefully yield promising results for future dam removal projects on other rivers around the country.

Acknowledgements

We would like to thank the Clallam County website for providing the majority of the GIS data used in this analysis.

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