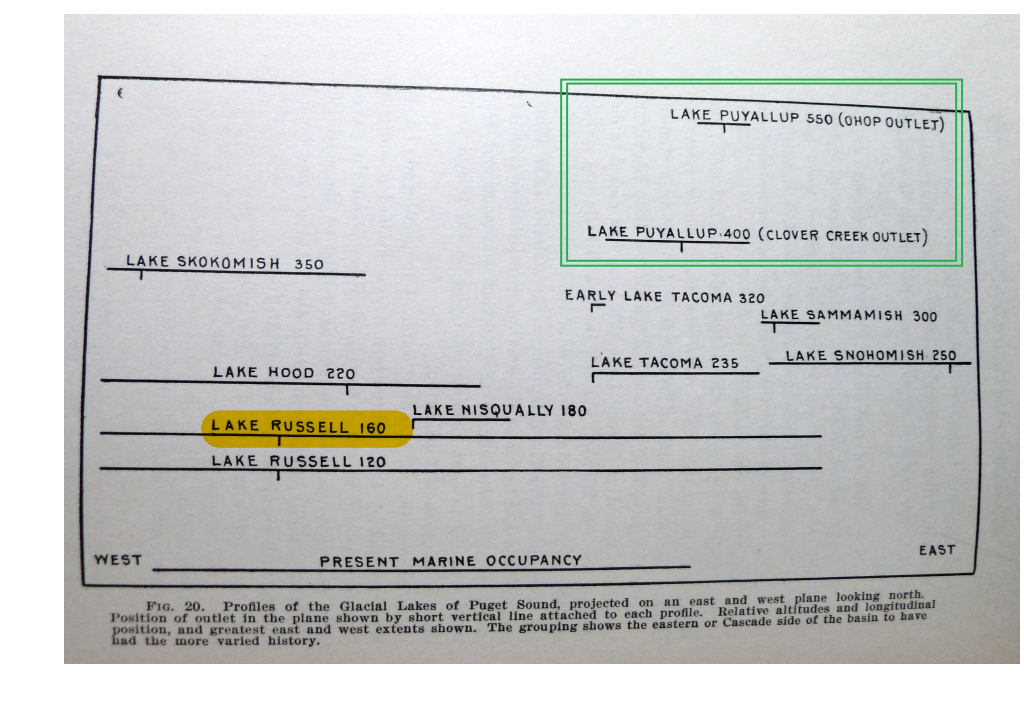
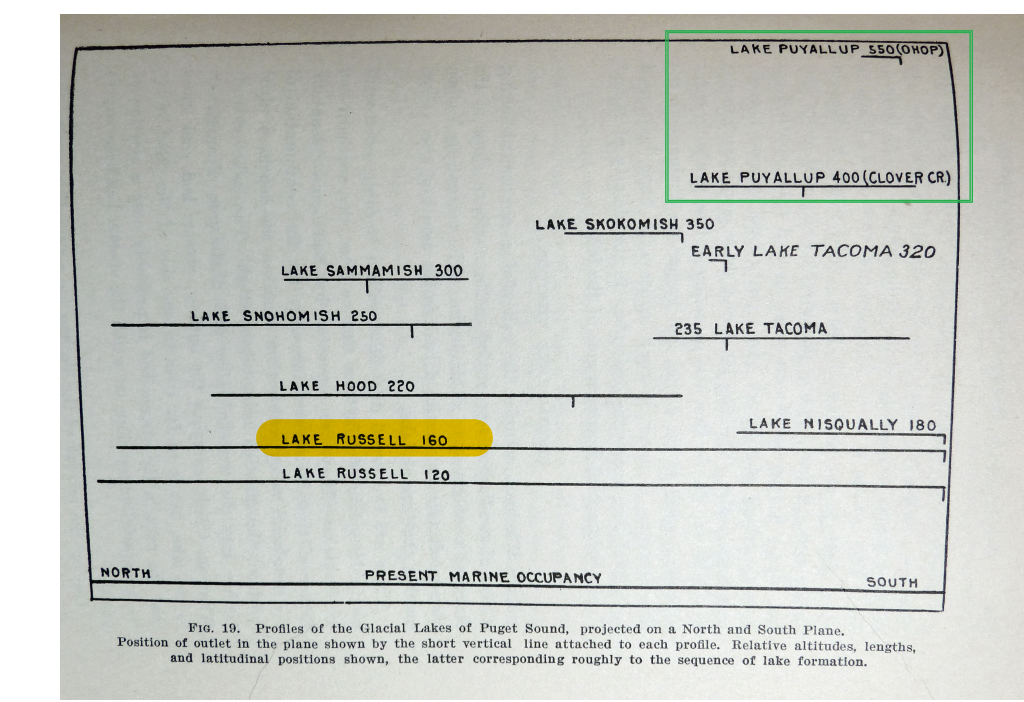
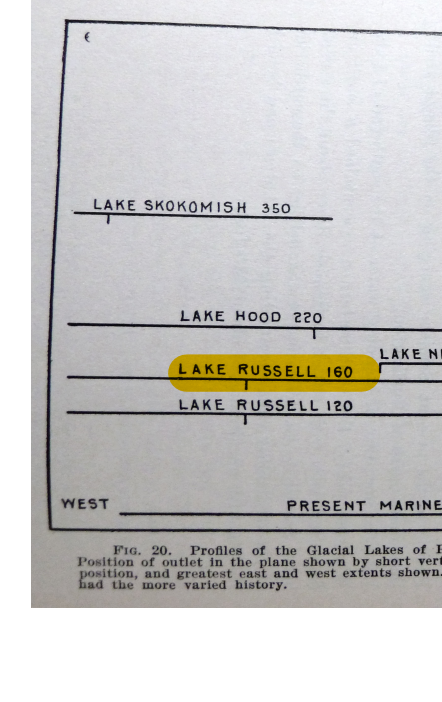
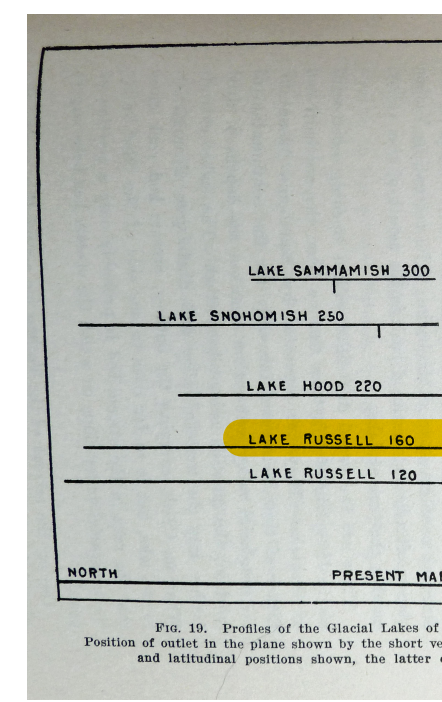
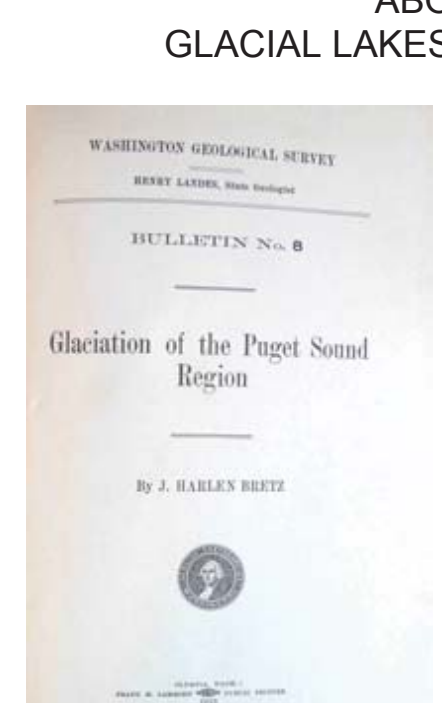


ABOUT THE GLACIAL LAKES OF PUGET SOUND

The Washington Geologic Survey published Bulletin No. 8 in 1913. "Glaciation of the Puget Sound Region" was written by J. Harlen Bretz and described the glacial features and the glacial lakes of Puget Sound.

Bretz located the outlets and elevations for each lake and summarized the information in two figures (below).

Glacial Lake Puyallup (two outlets) and Glacial Lake Russell are highlighted.



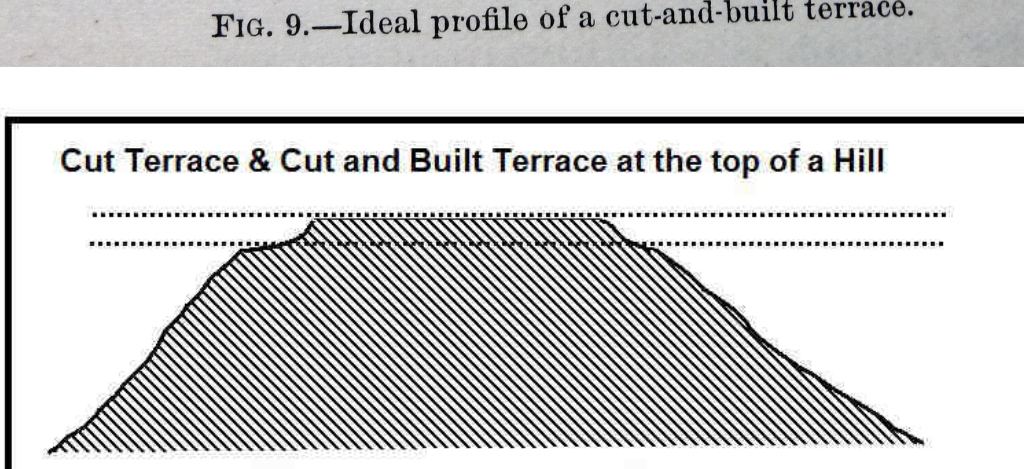
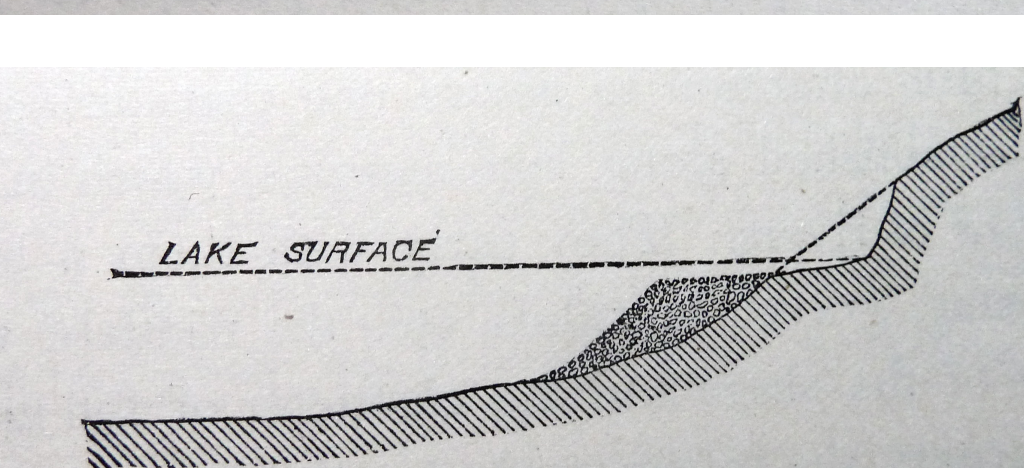
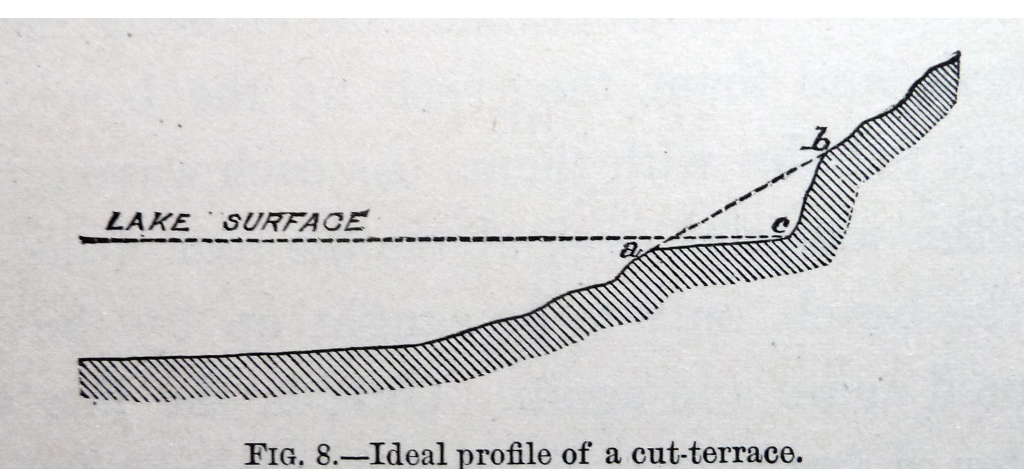
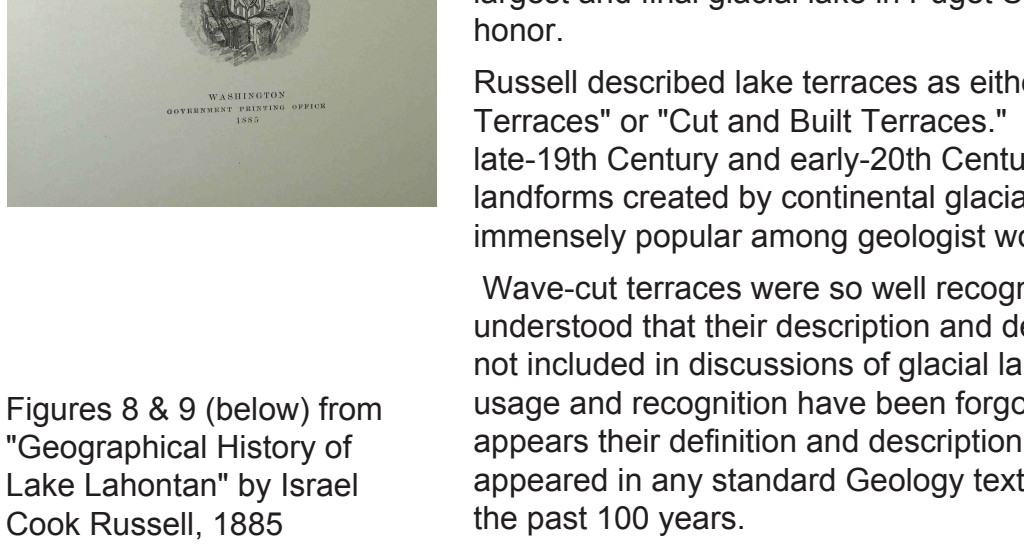
ISRAEL COOK RUSSELL'S INFLUENCE ON THE INTERPRETATION OF GLACIAL LAKES IN NORTH AMERICA DURING THE EARLY 20TH CENTURY

J. Harlen Bretz studied the Puget Sound Region to document the extent of the continental glaciation. He worked under Bailey Willis who was employed by the Washington (State) Geologic Survey. Willis was a second cousin to Israel Cook Russell, both having grown up in New York. Russell became a professor at the University of Michigan, but spent summers doing field work in the Pacific Northwest with Willis.

Russell was well known for his work in Alaska and the Great Basin. He died in 1906, age 53, from pneumonia. Bretz never met him, but named the largest and final glacial lake in Puget Sound in his honor.

Russell described lake terraces as either "Cut Terraces" or "Cut and Built Terraces." During the late-19th Century and early-20th Century, the study of landforms created by continental glaciation was immensely popular among geologists worldwide.

Wave-cut terraces were so well recognized and understood that their description and definition were not included in discussions of glacial lakes. Their usage and recognition have been forgotten and appears their definition and description has not appeared in any standard Geology textbooks during the past 100 years.



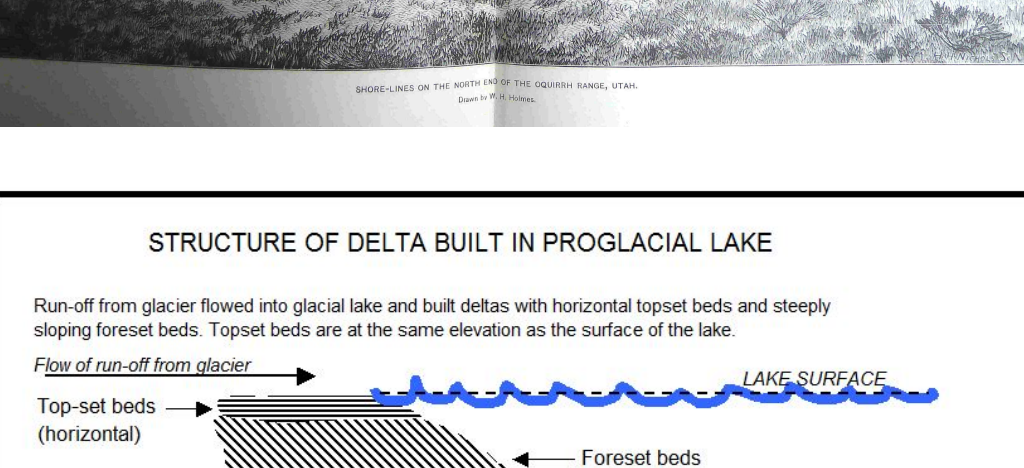
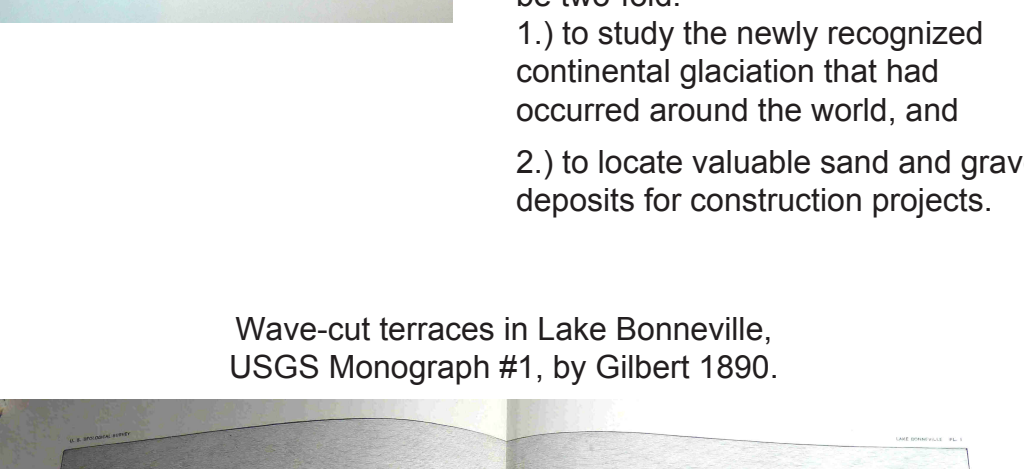
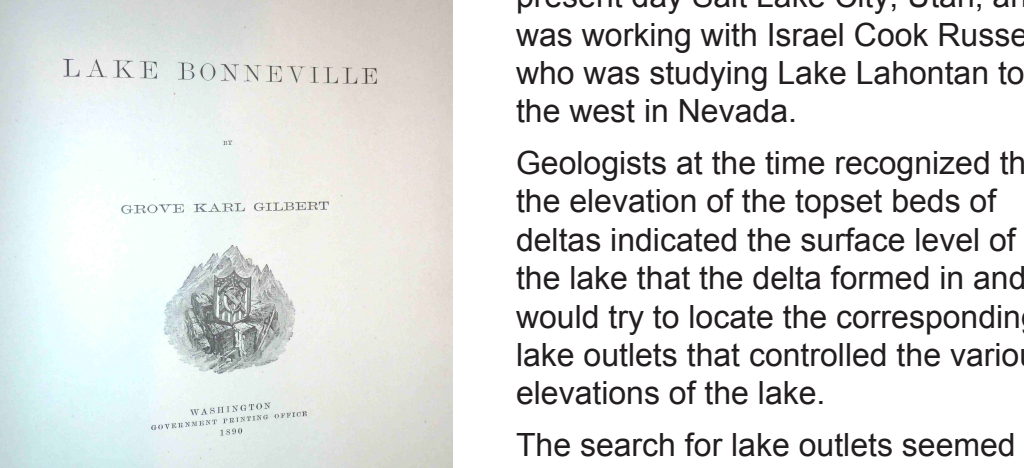
GROVE KARL GILBERT 4TH & 21ST PRESIDENT OF THE GEOLOGICAL SOCIETY OF AMERICA

From 1880 - 1890, G. K. Gilbert was documenting Lake Bonneville near present day Salt Lake City, Utah, and was working with Israel Cook Russell who was studying Lake Lahontan to the west in Nevada.

Geologists at the time recognized that the elevation of the topset beds of deltas indicated the surface level of the lake that the deltas formed in and would try to locate the corresponding lake outlets that controlled the various elevations of the lake.

The search for lake outlets seemed to be two-fold:

- 1) to study the newly recognized continental glaciation that had occurred around the world, and
- 2) to locate valuable sand and gravel deposits for construction projects.



GLACIAL LAKE PUYALLUP FROM THE VASHON GLACIATION FOUND IN THE BEAR CREEK VALLEY NEAR REDMOND, WASHINGTON & THEIR IMPLICATION IN SALMON MIGRATION AND DISTRIBUTION IN THE PUGET SOUND REGION

2017 Geological Society of America Annual Conference - Seattle, Washington

Susan Wilkins Session 383, Booth #324 Bellevue College, TELOS Program, 3000 Langerholm Circle, Bellevue, WA 98007 Susan@WaterTenders.org

In "Glaciation of the Puget Sound Region," (1913) J Harlen Bretz noted that glacial lakes had filled the Puget Sound Basin. His work focused on the outlets and elevations of the lakes, but his mapping and descriptions of the boundaries of the lakes were vague and imprecise.

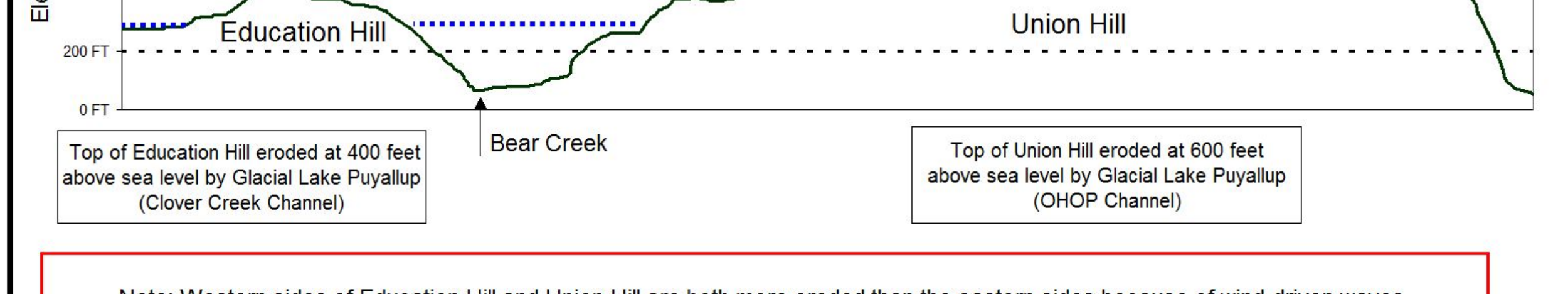
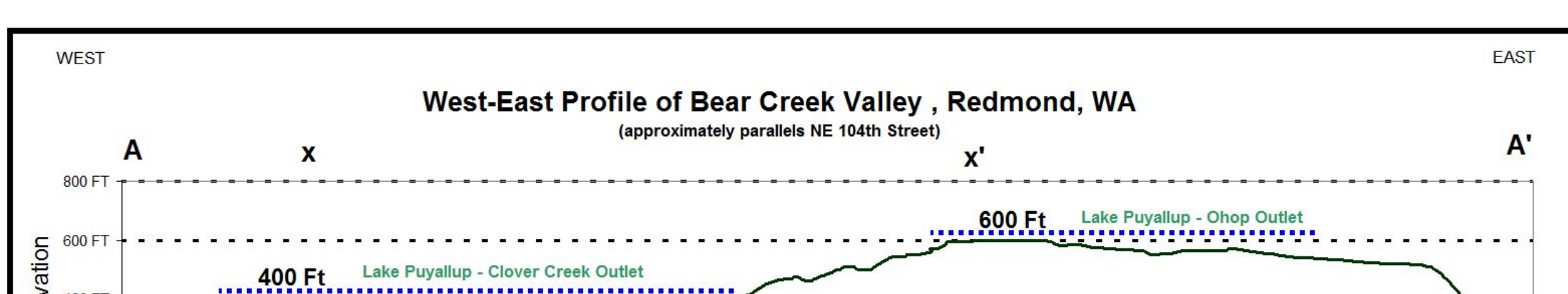
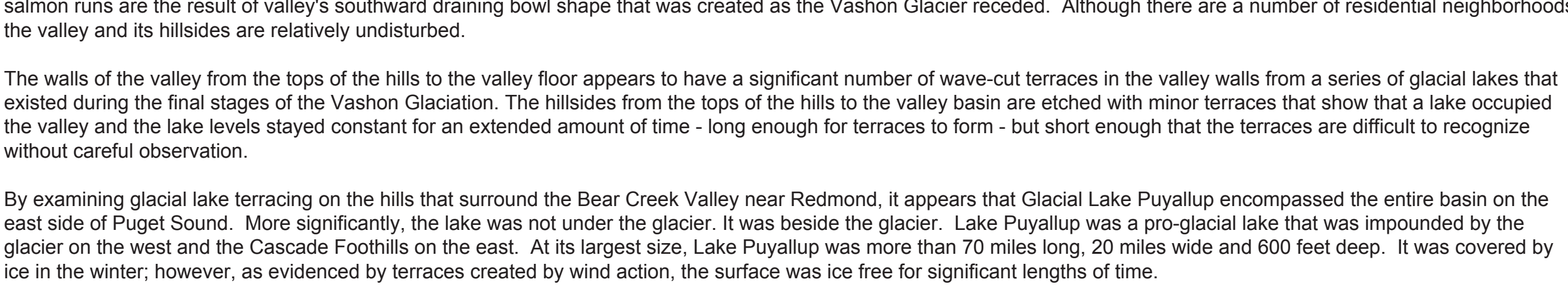
The lake that occurred at the highest elevation above sea level was Lake Puyallup. Bretz located two drainage channels for the lake, one at 550-600 feet above sea level in the Ohop Valley near present day Eatonville, and the other at 400 feet above sea level on Clover Creek near present day Tacoma. (Figures 19 & 20.) Both of these channels exist today and their size indicates that immense quantities of glacial melt water drained out of the lakes through the channels.

The Bear Creek Valley northeast of Redmond lies between two north-south trending hills, Education Hill on the west and Union Hill on the east. These hills were deposited during a pre-Vashon glaciation, but were subsequently overrun by the most recent Vashon glacial advance that left the hills scoured with steep hillsides and a central trough where Bear Creek and its tributaries flow southward through.

The entire Bear Creek Basin has such exceptional salmon runs that in 1990, King County designated the area for permanent environmental protection from development. The salmon runs are the result of valley's southward draining bowl shape that was created as the Vashon Glacier receded. Although there are a number of residential neighborhoods, the valley and its hillsides are relatively undisturbed.

The walls of the valley from the tops of the hills to the valley floor appears to have a significant number of wave-cut terraces in the valley walls from a series of glacial lakes that existed during the final stages of the Vashon Glaciation. The hillsides from the tops of the hills to the valley basin are etched with minor terraces that show that a lake occupied the valley and the lake levels stayed constant for an extended amount of time - long enough for terraces to form - but short enough that the terraces are difficult to recognize without careful observation.

By examining glacial lake terracing on the hills that surround the Bear Creek Valley near Redmond, it appears that Glacial Lake Puyallup encompassed the entire basin on the east side of Puget Sound. More significantly, the lake was not under the glacier. It was beside the glacier. Lake Puyallup was a pro-glacial lake that was impounded by the glacier on the west and the Cascade Foothills on the east. At its largest size, Lake Puyallup was more than 70 miles long, 20 miles wide and 600 feet deep. It was covered by ice in the winter; however, as evidenced by terraces created by wind action, the surface was ice free for significant lengths of time.



Using King County's MAP mapping program that has relatively precise contour lines at 5 foot intervals and accurate surface distances and measurements, it was possible to create a profile of Education Hill and Union Hill that parallels the main east-west road at the top of Education Hill (NE 104th Street) in Redmond and extends eastward into unincorporated King County.

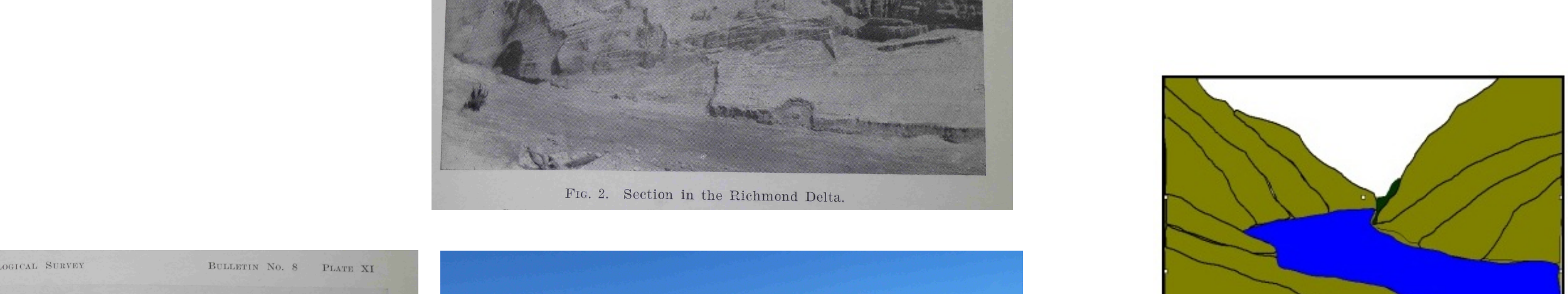
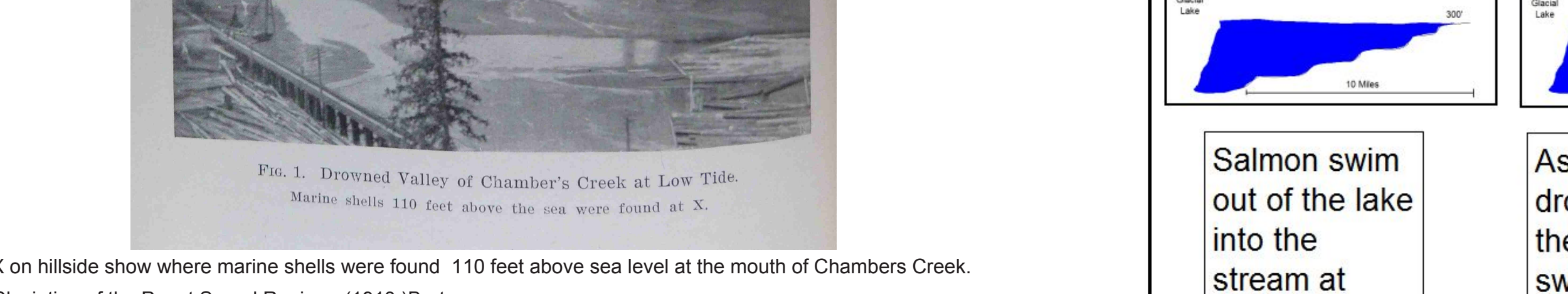
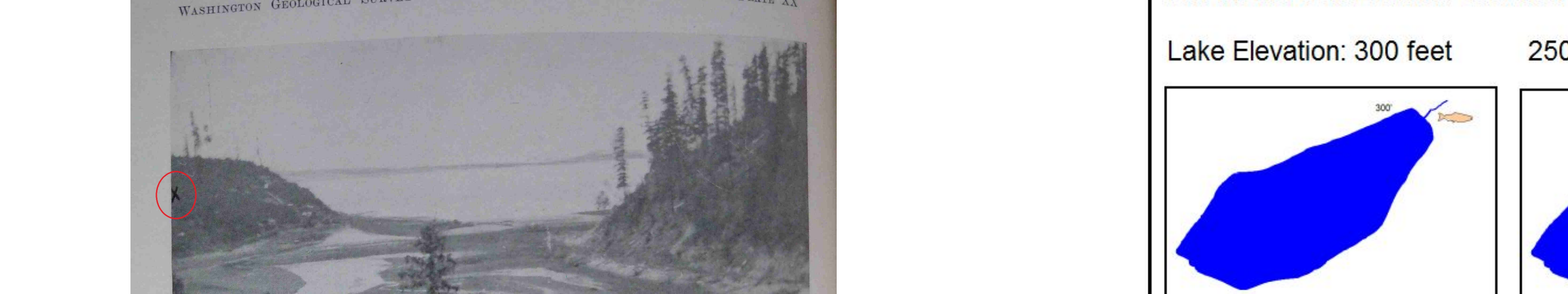
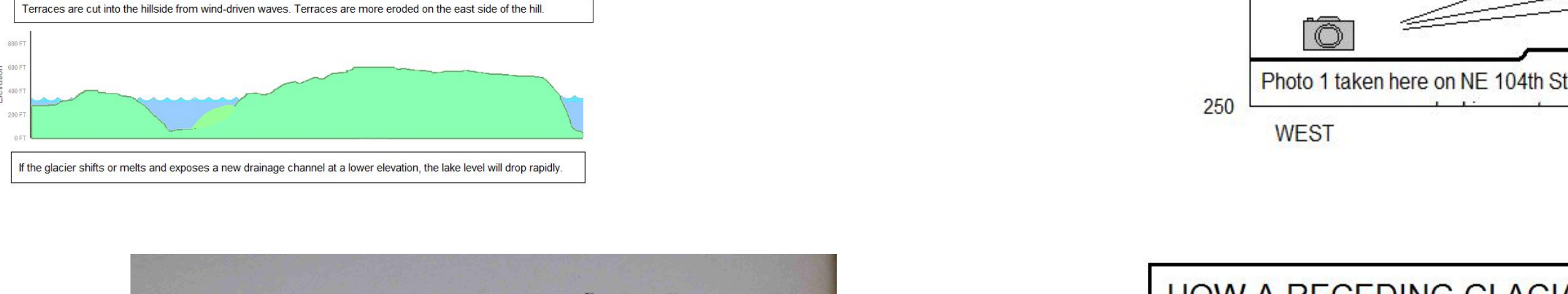
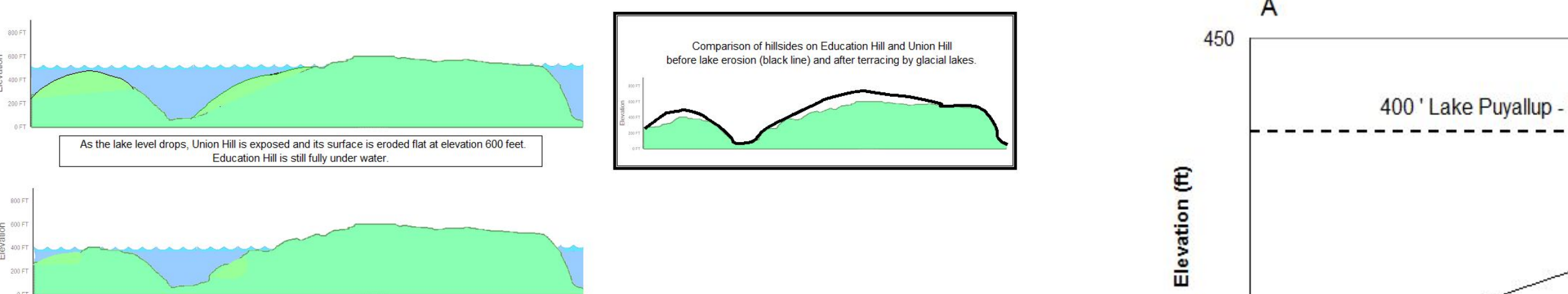
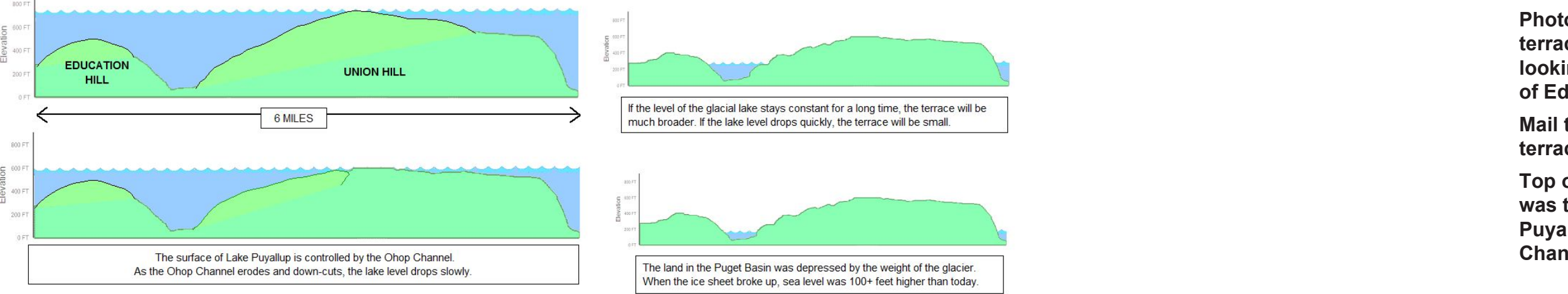
The tops of the hills on the east and west side of the Bear Creek Valley are flattened by lake terracing that corresponds to the major lake elevations for Glacial Lake Puyallup at both the Ohop and Clover Creek outlets. (At left see Figures 19 & 20 from "Glaciation of the Puget Sound Region" Bretz 1913).

Many terraces are only 2 to 5 feet tall so their existence is not evident on a USGS contour map. Between the valley floor and the tops of the hills nearly 60 ancient shorelines receded into the hillsides that were eroded by proglacial lakes that filled the Puget Sound Basin. The shorelines on the east and west sides of the basin match elevations, but the terracing is greater on the east side of the basin where winds would have been stronger, causing more wind action and shoreline erosion.

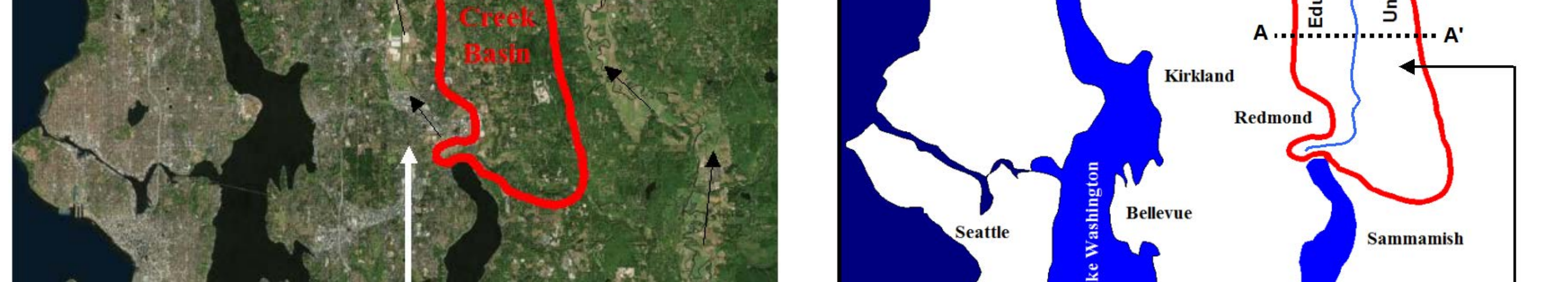
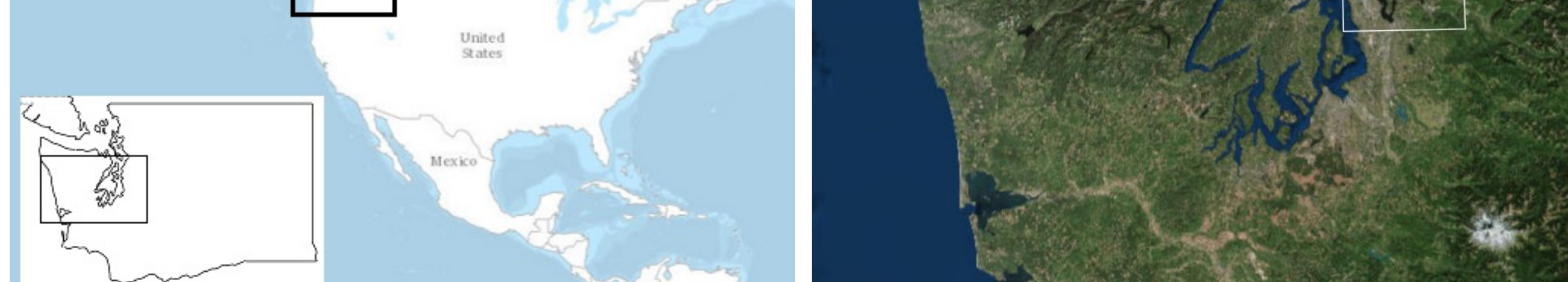



It must be noted that the terraces are found at the tops of the hills and also occur along the hillsides at intervals all the way to the bottom of the hills. Major terraces indicate that the lake level lasted for a significant amount of time and/or the hillsides sediments were poorly compacted and more easily eroded. There are also many smaller terraces at close intervals indicating that the lake level was constant for a short time before it dropped.

What is most important to note is that the lake basin was continuously filled with water and the lake drained slowly.



PUGET SOUND WESTERN WASHINGTON

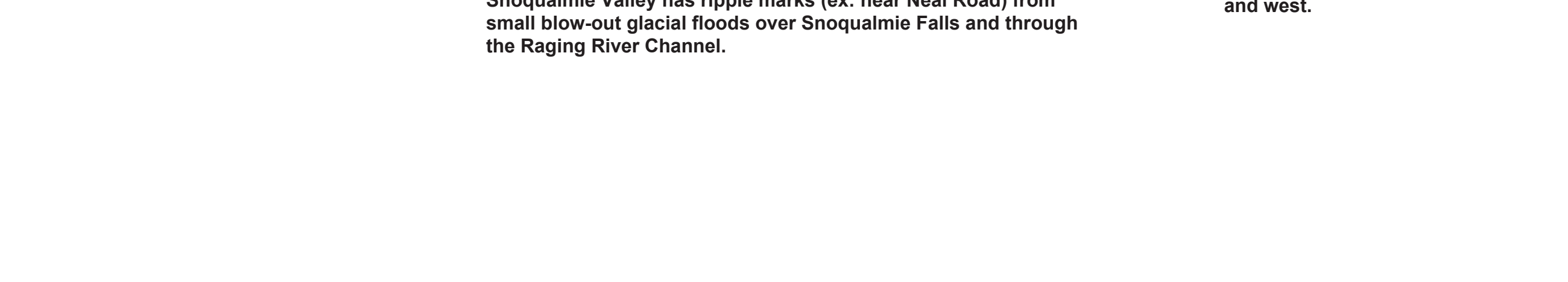


BEAR CREEK VALLEY NEAR REDMOND, WASHINGTON

Sammanish River Valley was a major glacial drainage channel flowing northward.

Snoqualmie River Valley was a major glacial drainage channel carrying an immense volume of melt water from the Cascades northward towards Everett and Puget Sound. Snoqualmie Valley has ripple marks (see near Neal Road) from small blow-out glacial floods over Snoqualmie Falls and through the Raging River Channel.

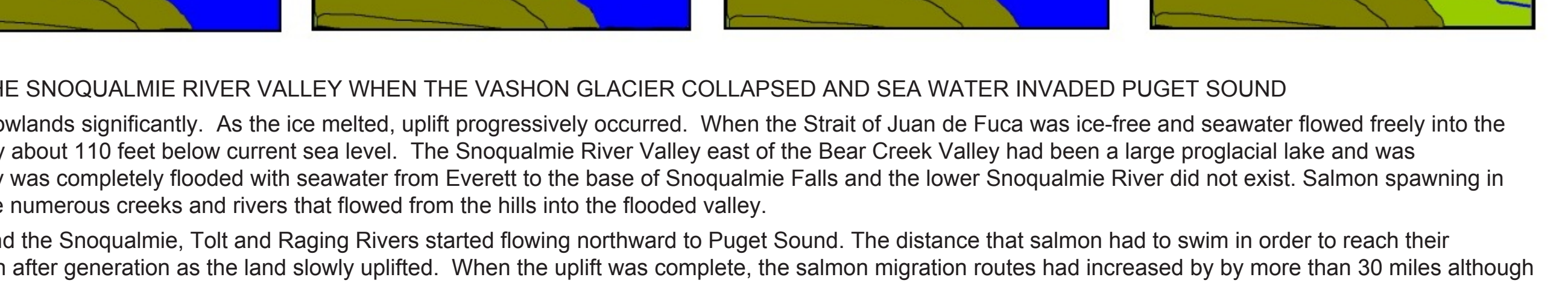
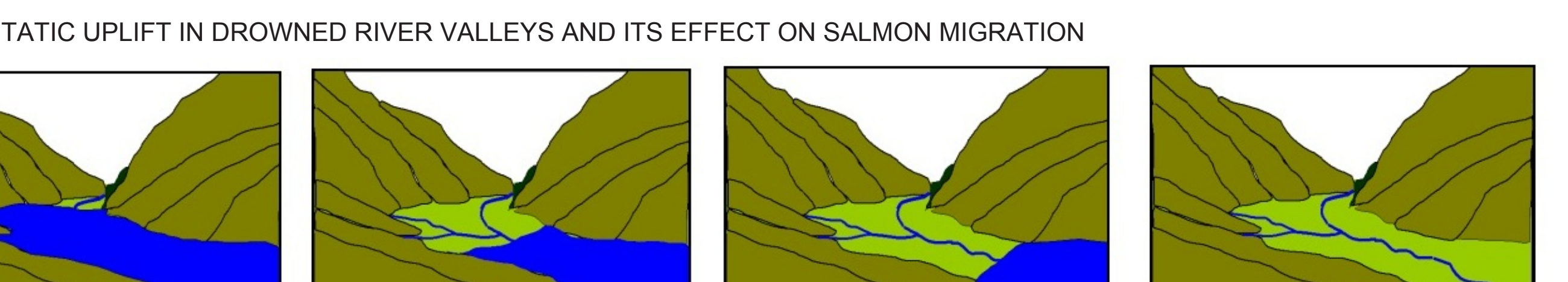
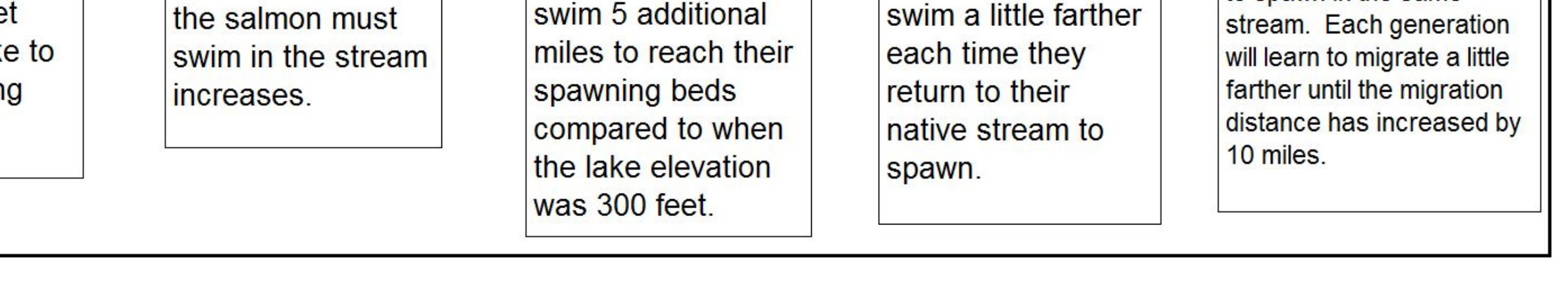
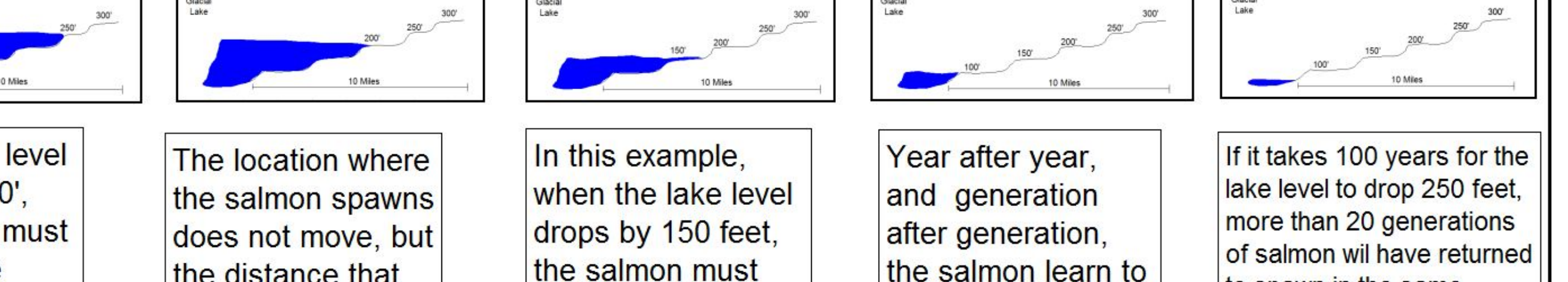
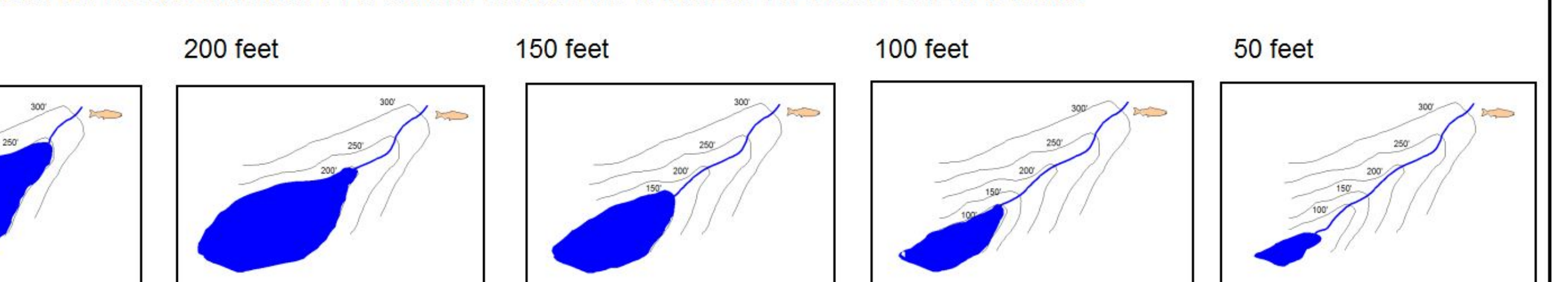
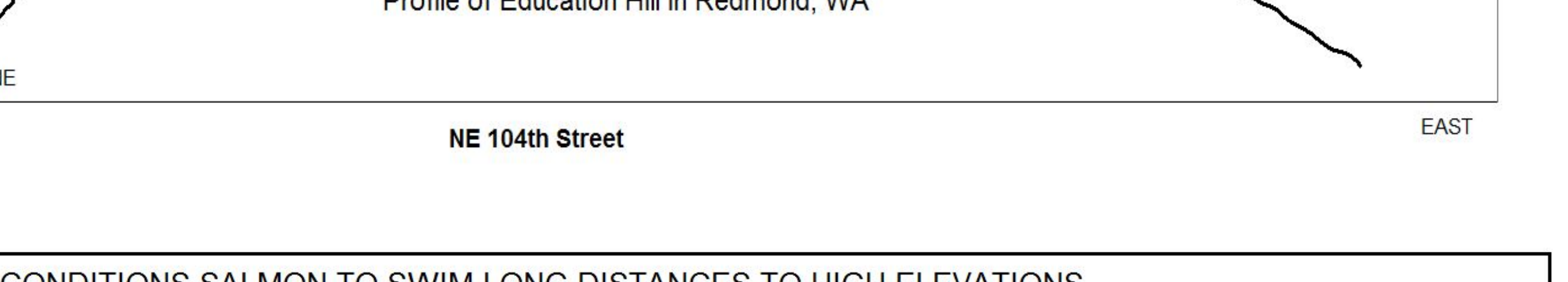
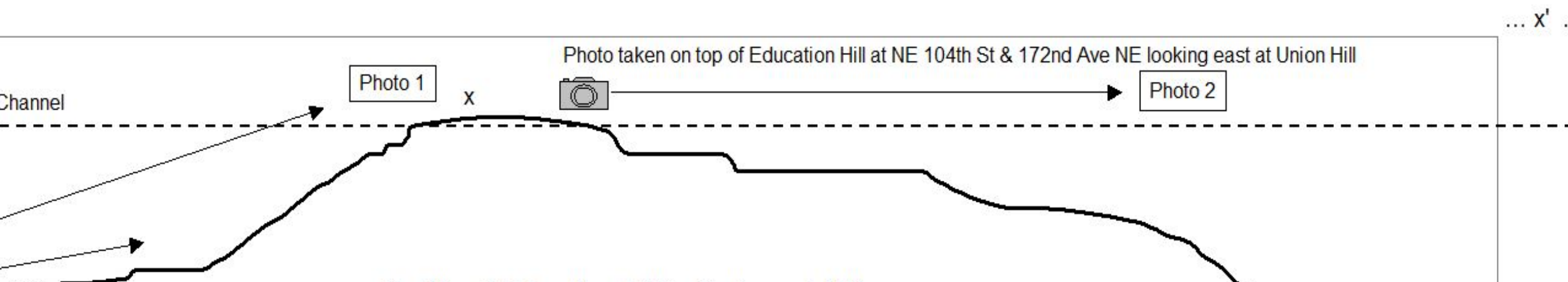
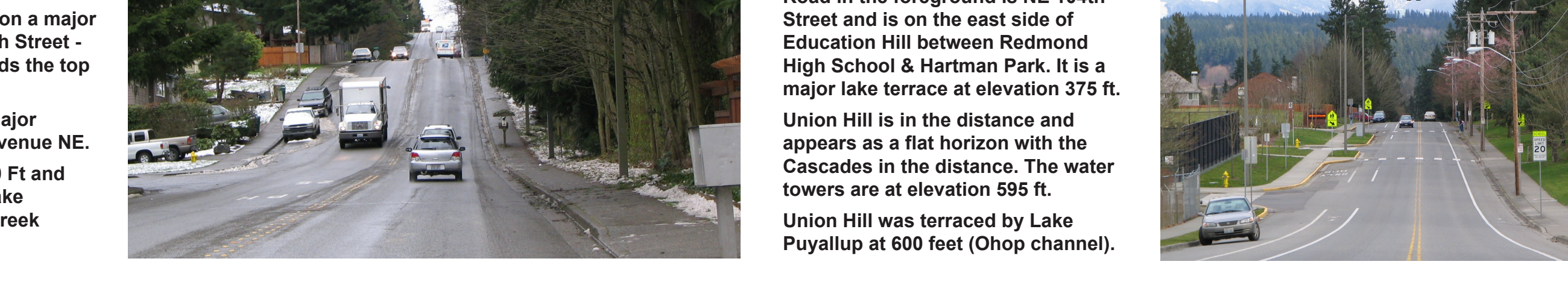
Bear Creek Basin was isolated between the two hills and was protected from outburst flooding that occurred in the valleys to the east and west.



MAJOR LAKE TERRACES AT THE TOP OF EDUCATION HILL AND UNION HILL

Photo 1: Standing on a major terrace on NE 104th Street - looking east towards the top of Education Hill. Mail truck is at a major terrace on 166th Avenue NE. Top of hill is at 400 ft and was terraced by Lake Puyallup (Clover Creek Channel).

Photo 2: Looking east from the top of Education Hill towards Union Hill. Road in the foreground is NE 104th Street and is on the east side of Education Hill between Redmond High School & Hartman Park. It is a major lake terrace at elevation 375 ft. Union Hill is in the distance and appears as a flat horizon with the Cascades in the distance. The water towers are at elevation 595 ft. Union Hill was terraced by Lake Puyallup at 600 feet (Ohop channel).



GLACIAL LAKE PUYALLUP - OHOP CHANNEL Surface Elevation of Lake - 600 Feet

Surface of Lake Puyallup is 600 feet above present day sea level, eroded to 500 before abandoned.

East side of Puget Sound Basin was flooded to 600 feet from the ridge of the glacier to the Cascade Foothills near North Bend.

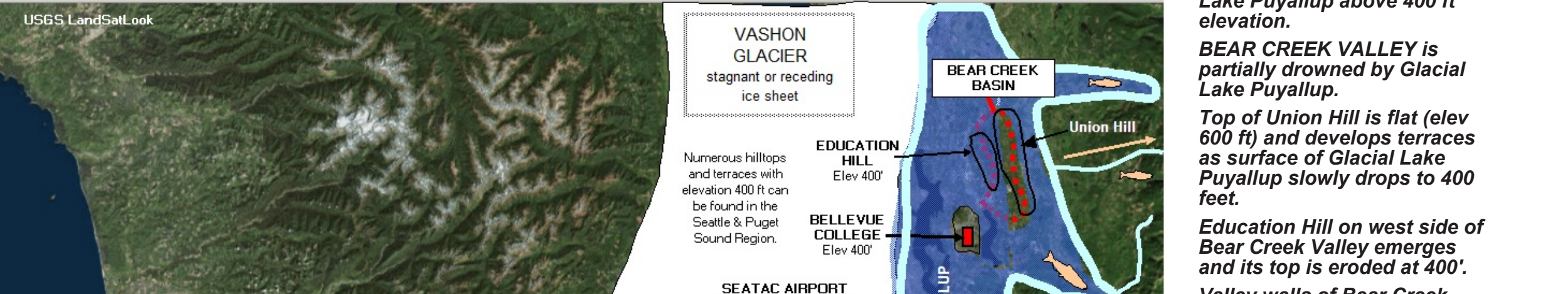
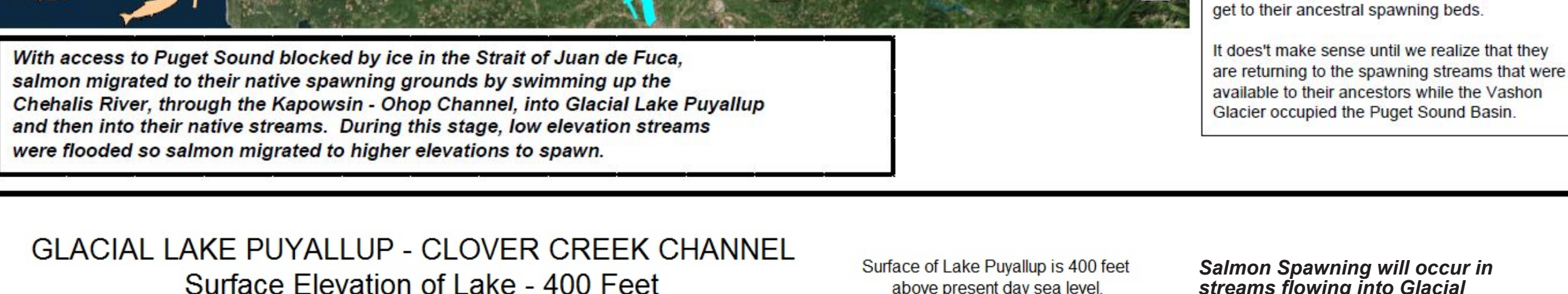
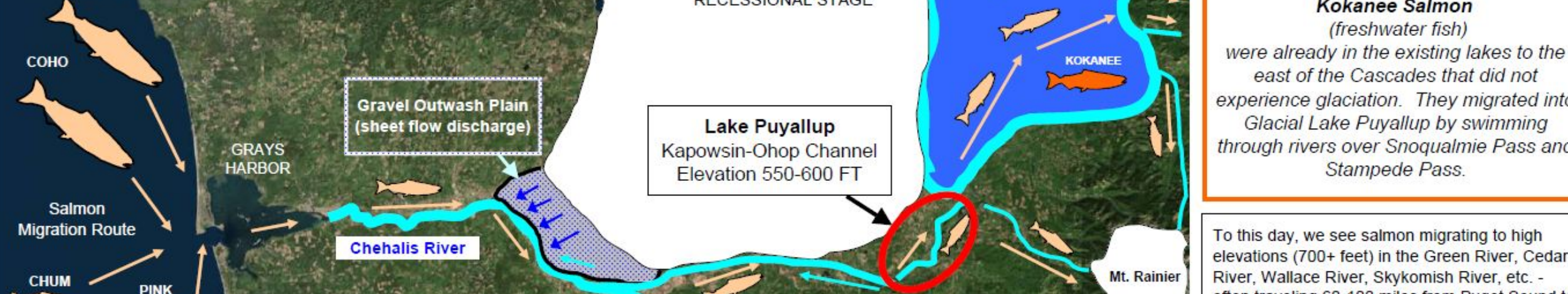
Salmon that hatch as the glacier is advancing will be forced to migrate to saltwater through the Chehalis River.

Salmon that return through the Chehalis River will spawn in high elevations (600+ ft) in streams flowing into Glacial Lake Puyallup.

Kokanee Salmon (freshwater fish) were already in the existing lakes to the east of the Cascades that did not experience glaciation. They migrated into Glacial Lake Puyallup by overwintering through rivers over Snoqualmie Pass and Stampede Pass.

To this day, we see salmon migrating to high elevations (700+ feet) in the Green River, Cedar River, Skagit River, Skayamish River, etc. often traveling 60-100 miles from Puget Sound to get to their ancestral spawning beds.

It doesn't make sense until we realize that they are returning to the spawning streams that were available to their ancestors while the Vashon Glacier occupied the Puget Sound Basin.



GLACIAL LAKE PUYALLUP - CLOVER CREEK CHANNEL Surface Elevation of Lake - 400 Feet

Surface of Lake Puyallup is 400 feet above present day sea level.

BEAR CREEK VALLEY is partially covered by Glacial Lake Puyallup.

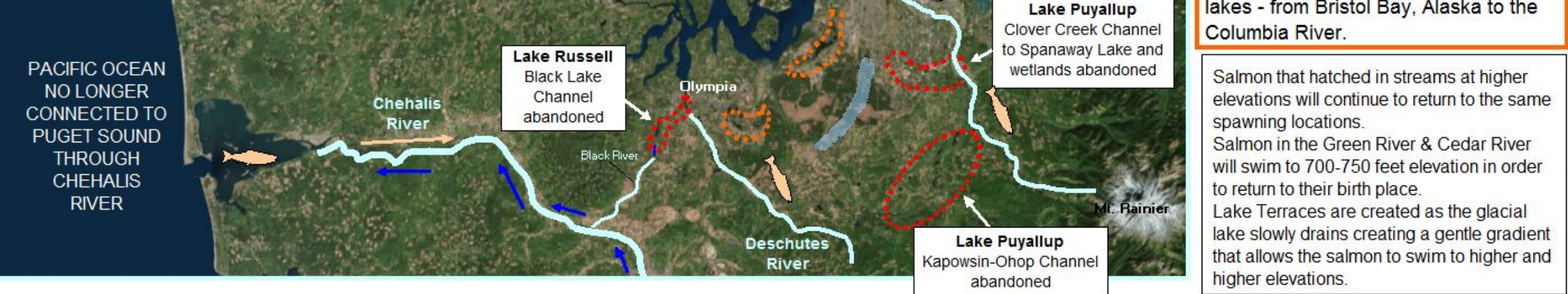
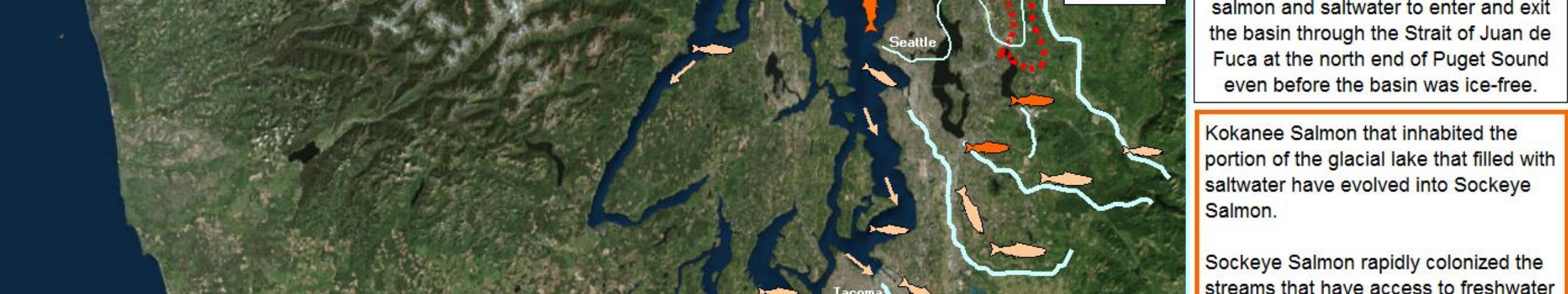
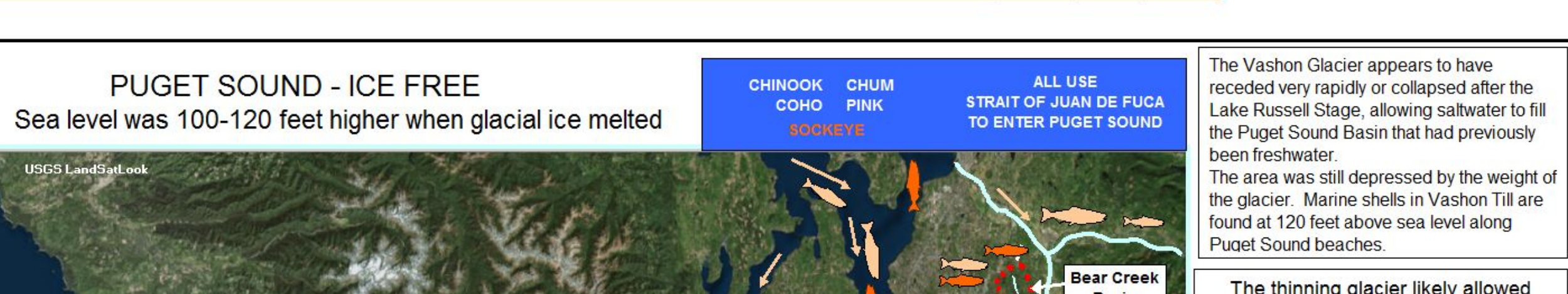
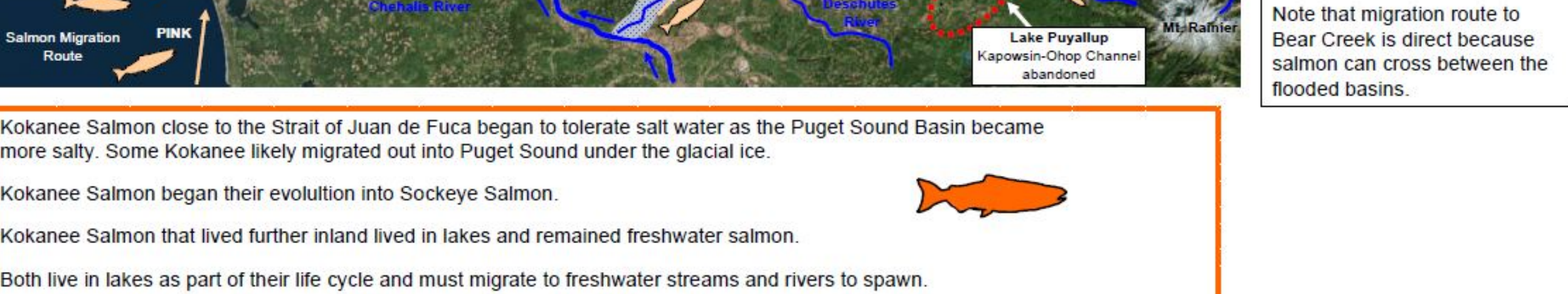
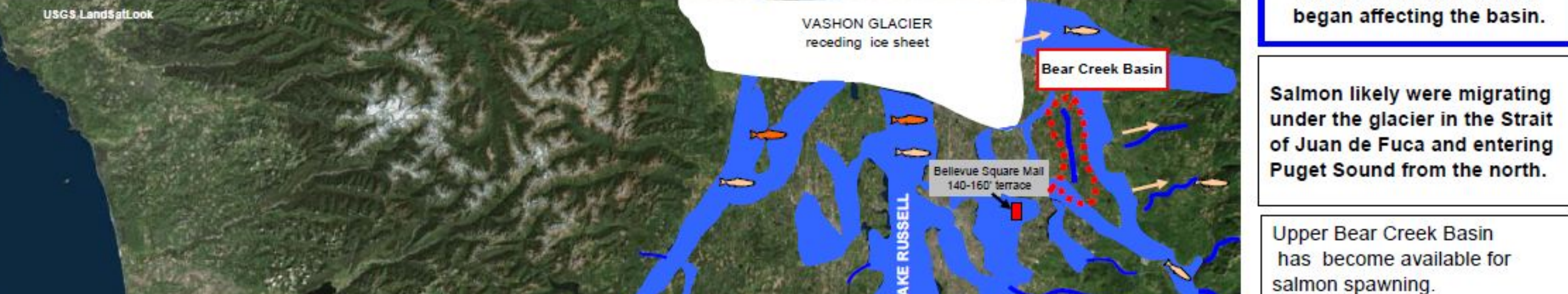
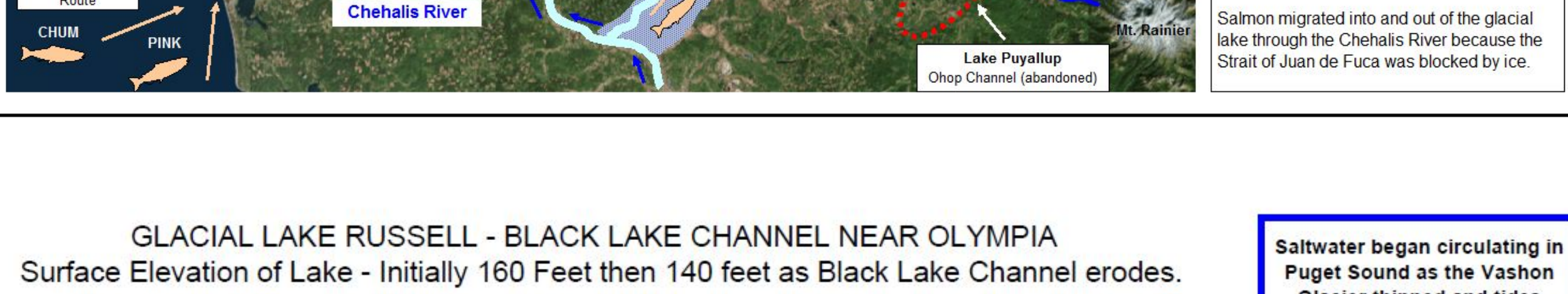
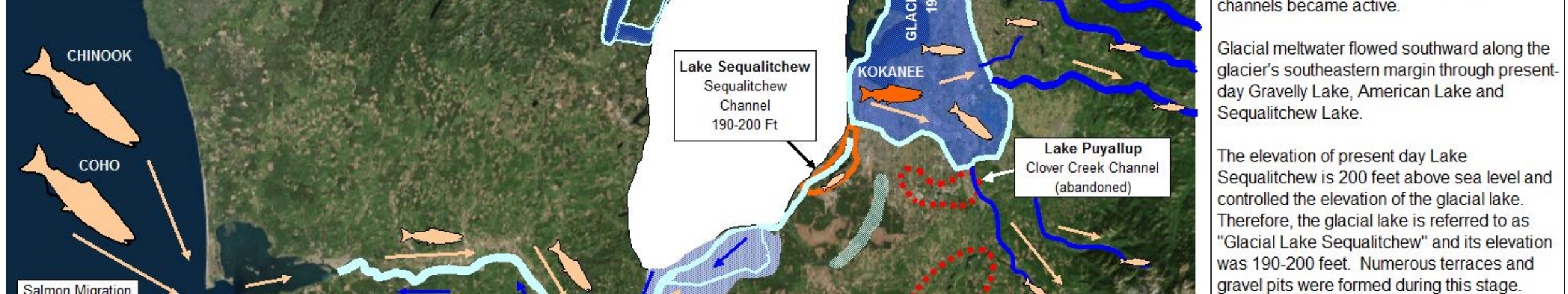
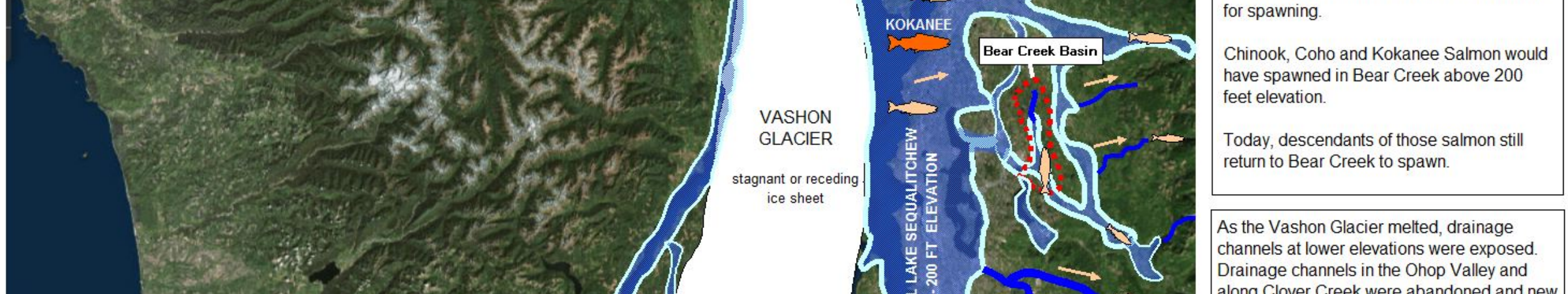
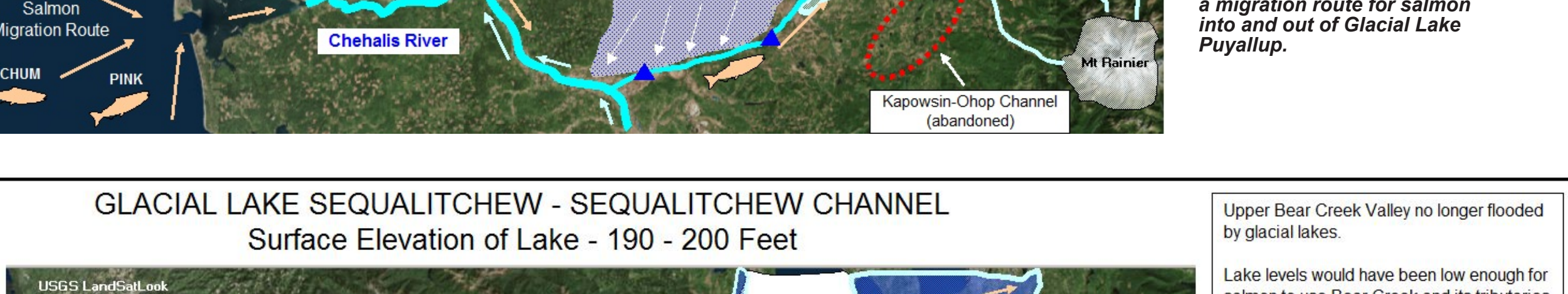
Top of Union Hill is flat (400 feet) and developed terraces as surface of Glacial Lake Puyallup slowly drops to its level.

Education Hill on west side of Bear Creek Valley emerges and its top is eroded at 400'.

Valley walls of Bear Creek Basin become terraced by wave action of lake.

Glacial Lake Puyallup drains through the Clover Creek Channel at elevation 400 ft.

Discharge of melt water along Clover Creek channel to Chehalis River is immense and continues during spring, summer and fall and provides a migration route for salmon into and out of Glacial Lake Puyallup.



OBSERVATIONS & CONCLUSIONS:

A series of immense glacial lakes once filled the Puget Lowlands. The lakes were formed when fresh water from the melting ice was impounded between the continental glacier that filled the Puget Sound Basin and the foothills of the Cascades to the east. The elevations and size of the glacial lakes were controlled by various drainage channels located at the south end of the Puget Lowlands.

At the end of the last ice age, the Bear Creek Valley was submerged under a glacial lake identified as Lake Puyallup by geologist J Harlen Bretz. The lake extended north-south more than 80 miles from Eatonville to Snohomish County (and possibly further north.). As the glacier melted and successively lower lake levels occurred, the Bear Creek Valley became a protected inlet between Education Hill and Union Hill.

The top of Union Hill was eroded off at 600 ft when the Ohop Channel was active. The top of Education Hill was eroded off at 400 ft when the ice receded enough for the Clover Creek Channel to be active. Minor lake terraces at intermittent elevations are found from the top of the hills to the valley floor.

The Bear Creek Valley is unique because it was not subjected to massive erosion and scouring from outburst floods that occurred in the Sammamish River Valley on the west and the Snoqualmie River Valley on the east. The hillsides of the Bear Creek Valley record more than 50 minor shoreline terraces and 6 major lake terraces.

The lake terraces provide significant evidence that the series of glacial lakes that occupied the basin were open water during warmer periods. We know this because the west sides of the hills are more eroded than the east sides, meaning that there were wind-driven waves. Also, the tops of all the hills in the region have been eroded flat - also evidence that the lakes were open water.

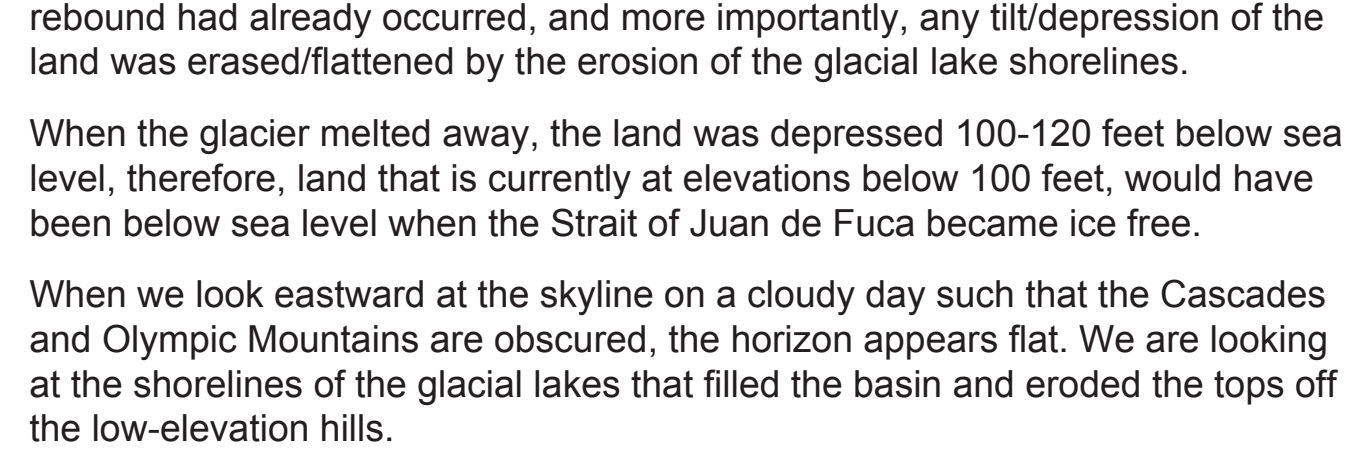
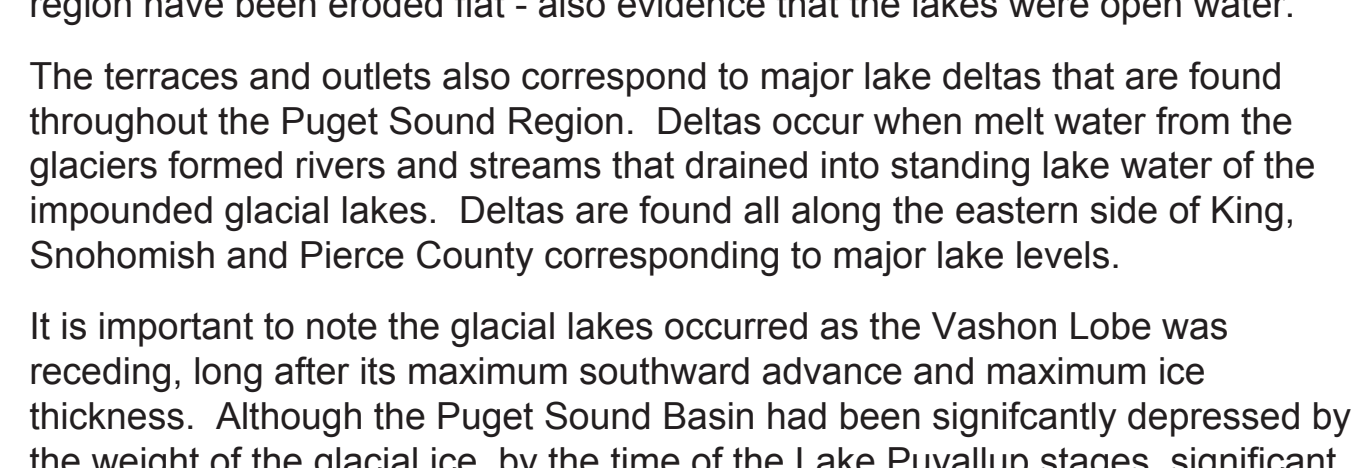
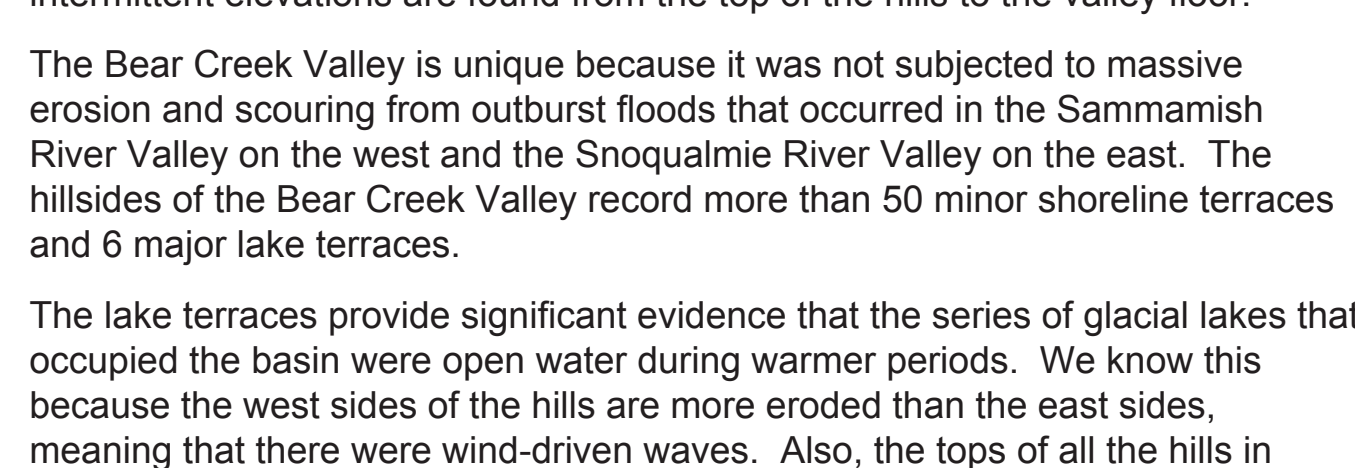
The terraces and outlets also correspond to major lake deltas that are found throughout the Puget Sound Region. Deltas occur when melt water from the glaciers formed rivers and streams that drained into standing lake water of the impounded glacial lakes. Deltas are found all along the eastern side of King, Snohomish and Pierce County corresponding to major lake levels.

It is important to note the glacial lakes occurred as the Vashon Lobe was receding, long after its maximum southward advance and maximum ice thickness. Although the Puget Sound Basin had been significantly depressed by the weight of the glacial ice, by the time of the Lake Puyallup stages, significant rebound had already occurred, and more importantly, any tilt/depression of the land was erased/flattened by the erosion of the glacial lake shorelines.

When the glacier melted away, the land was depressed 100-120 feet below sea level. Therefore, land that is currently at elevations below 100 feet, would have been below sea level when the Strait of Juan de Fuca became ice free.

When we look eastward at the skyline on a cloudy day such that the Cascades and Olympic Mountains are obscured, the horizon appears flat. We are looking at the shorelines of the glacial lakes that filled the basin and eroded the tops of the low-elevation hills.

ALL flat land at higher elevations in the Puget Sound Basin was probably terraced by glacial lakes (except downtown Seattle that was regressed in the early 1900s.). Historically, the large tracts of land on the major terraces were used for schools, sports fields, churches, shopping centers, factories and also for SeaTac Airport.



Looking east towards Cascades. Flat horizon of Union Hill foreground.



Salmon Life Cycle:

Salmon eggs are laid in the stream and the alevin quickly develop the ability to swim. Depending on the species, Chinook, Coho, Chum, Pink or Sockeye, the fish spend time in their native stream and then migrate downstream to the ocean.

Sockeye spend time in a lake before migrating to the ocean. Kokanee are freshwater salmon that are genetically identical to Sockeye Salmon (both are Oncorhynchus Nerka). Kokanee also inhabit freshwater lakes. Both migrate into streams in order to spawn.

Salmon runs are all unique because salmon return to the same stream at the same time of year after the same number of years in the ocean so that their genetic lineage is unique and preserved.

