Nutrient Concentrations and Distributions within the Lower Elwha River during Dam Removal

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Abstract

The objective of this research was to characterize nutrient concentrations and distributions throughout the Elwha River watershed, focusing on dissolved inorganic nitrogen (DIN), phosphorus and silicic acid. Previous research has indicated that the Elwha River is oligotrophic, however with the removal of the dams comes the subsequent discharge of a large fraction of the $1.9x10^6$ m^3 of sediment trapped behind the dams. Understanding the nutrient composition and distribution relative to grain size and suspended sediments will provide scientists with perspective as to how the ecosystem is going to react to dam removal. Sediments and their pore water were collected in the field and analyzed. Additional data was included from U.S. Geological Survey and the Department of Ecology. The culmination of this data demonstrates that the upper stretches of the Elwha River are nutrient poor but the recent removal of the two dams has led to an increase of nutrients within the nearshore environment, which is hypothesized to be related to the discharge of sediment based on this research. Implications for future studies can be made that refer to primary productivity, riparian health and the return of salmon.

1. Introduction

The Elwha River, located on the Olympic Peninsula of Washington State, was dammed ~100 years ago with the construction of the Elwha and Glines Canyon Dams. While they were run-of the-river dams, nether was built with fish passage. This once bountiful river lost its historic fish stock and mechanisms such as sedimentary processes were altered. Today, with the removal of the Elwha Dam and continuing demolition of the Glines Canyon Dam, there are uncertainties about the impact on the ecosystem. One of the concerns is the 1.9×10^6 m^3 of sediment estimated to be trapped behind the dams. Half of the fine sediment and 15% to 30% of the coarse sediment is estimated to erode (Duda, 2011). Due to the influx of sediment downstream there is an opportunity to study how the pore water of the accumulated sediments will influence the potential productivity of the river, and the near shore environments.

The Elwha River is a small and mountainous. Large cobbles and boulders are found in the upper river which are slowly moved down stream and accumulate over long periods of time, the lower reaches of the river are characterized by smaller particles (i.e., silts and clays) that are held in suspension and moved with relative ease. Since these materials have been trapped for such a long period, it is possible that the composition of the nutrients retained by pore water has been altered. If the nutrient content fluctuates throughout the watershed, then the effects to the riparian environment and near-shore environment will vary. The nutrients significant to this study include nitrate [NO_3], nitrite [NO_2], ammonia [NH_4], phosphate [PO_4], and silicic acid $Si(OH)_4$. This paper will focus on how concentrations of nutrients will increase as one moves from the upper reaches of the river and heads to the nearshore. The near shore environment might have higher concentrations of nutrients due to influences of suspended sediments and sorption to fine grained material. Finding a relation between turbidity and therefore suspended sediment in the river could show correlations with nutrient concentrations.

2. Background

2.1 Regional Setting

The Elwha River is located on the Olympic Peninsula in the Olympic National Park of, Washington State. The peninsula is bordered by the Pacific Ocean to the west, the Strait of Juan de Fuca to the North and the Hood Canal in the east. It runs 45 miles north from the top of the

Olympic Mountains and drains into the Strait of Juan de Fuca. The climate of the peninsula is influenced by precipitation from the Pacific Ocean; some areas receive precipitation rates of 350-500 cm a year. As a result the peninsula is heavily forested and contains patches of temperate, coastal, montane, lowland and subalpine forest (http://www.nps.gov/). Until recently there were two hydroelectric dams. One was the Elwha Dam, built in 1913; located 7.9 km upstream from the ocean. The other was the Glines Canyon Dam, built in 1927, 21.6 km from the ocean. Peak discharge of the river occurs during winter storms (Nov-Feb), and early summer (May-July), (Fig 1). The construction of the two dams greatly reduced the amount of sediments being deposited to the near shore environment. However, with the removal of the dams nearly complete, there has been a large release of sediment into the marine environment and there are studies being conducted by USGS and others that focus on the rate of deposition, nutrient content and accumulation of these sediments.

2.2 Topical background

The Elwha River basin is known to be oligotrophic (nutrient poor), which is characteristic of many rivers in the Pacific Northwest (Duda, 2011). Before the dams were constructed, the salmon were a critical source of nutrients to the aquatic environment (pbs.org). Their decomposing carcasses would bring marine-derived nutrients back into the watershed. After the construction of the dams this critical source of nutrients was lost. With the demolition nearly complete, there is a chance to study how the nutrient composition has or will change. USGS and the Department of Ecology have historic data related to nutrient content and this data consistently shows oligotrophic concentrations. USGS Investigations Report 98-4223, found that many of the tributaries are critical to supplying sediment, woody debris and nutrients into the main stem. They also concluded that the quantity of nutrients being brought into the Elwha River basin from salmon restoration will increase substantially. This increase in nutrients would improve primary and secondary production within the river and help to restore the system to its previous productivity levels (Munn, 1999). Using historic and current data will establish a baseline for how the system will respond to dam removal. Analyzing the distribution of sediment grain-size, and suspended sediments in the river and nearshore will display how the concentration or abundance of nutrients relates to particle size. Silts, clays, and other fine particles, (4 to 2 phi) are expected to retain most of the nutrients and coarser material, (-1 to 2 phi) material should have less abundance.

3. Methods

3.1 Attainment of Pore-water Samples

Seven sediment samples were collected for analysis and gathered along the Elwha River and within the recently drained Lake Aldwell. Water and sediment samples in the marine environment were obtained from the research vessel R/V Barnes and an inflatable, metal-hulled boat both in the near shore. Sediment samples were collected by scraping off the surface of exposed sediment, using an improvised corer out of a plastic bottle, using a Van Veen for river bottom samples and a niskin bottle for surface water. Each sample was placed in a plastic sampling bag and the GPS coordinate of each sample was recorded. The samples collected were analyzed for pH and grain size, and also centrifuged to extract pore water.

3.2 Measuring pH

To gage the pH level of the sediment a 5-6 g sub-sample from each site was placed into a beaker, and 5mL of DI water was added and the sample was stirred vigorously. The samples then stood for 30 min to reach equilibrium with the DI water. After each 30 min interval the pH was measured. For the water samples, the procedure required a simple measure with the pH meter, just as was done for samples saturated with water.

3.3 Separation of pore-water from sediment

A centrifuge was used to obtain the pore water from the sediment samples. Once the pore water was separated from the sediment a pipet was used to extract the water, then placed into a new 50 mL tube. After all the pore water was obtained, a 0.45 µm filter was attached to the bottom of a 60 mL syringe to separate the pore water from any suspended sediment. The completed samples were then sent to the University of Washington, Marine Chemical Lab to be analyzed by a CHN scanner, which was used to detect [PO_4], [$Si(OH)_4$], [NO_3], [NO_2], and [NH_4]. Analysis and calibration follow the protocols of the WOCE Hydrographic Program using a Technicon AA11 system.

3.4 Grain-size Analysis

The first step of grain size analysis was to remove the pebbles and cobbles larger than 1.6 cm. Each of the larger grains was measured on a, b, and c axes and weighed. A jar was weighed, and a 35-45 g sub-sample was added to a tin, and the wet weight was recorded. Dispersant was added to the jar, which was shaken vigorously for 2 min. The next step was to place a sieve over a funnel, above the pre-weighed jar. The sample bag with the sediment was then poured over the sieve, which was rinsed with dispersant until all the ≤ 4-phi material passed through. The jar with the ≤ 4-phi material was set aside for pipette analysis and the tin was put in the oven to dry. After the grain larger than 4-phi was dry, additional analysis using sieves ranging in size from 16-1/16 mm were used to obtain the abundance.

4. **Results Section**

4.1 River discharge during sampling

River discharge during our sampling period of April 3- 5, 2012 was ~ 31. m^3/s. This discharge rate was relatively low to average in the annual cycle (Fig. 1-2). For example, in other months such as December, the river can reach a magnitude of 283 m^3/s and in June peak discharge can be as high as 240 m^3/s (Fig.2).

4.2 Nutrient concentrations

The nutrients that were relevant to this study included nitrate [NO_3], nitrite [NO_2], ammonia [NH_4], phosphorus [PO_4], and silicic acid $Si(OH)_4$ and their concentrations varied among sample location. Sample locations are denoted as ME for middle Elwha, LE for lower Elwha, NS for nearshore, and sample types are denoted as GS for grab sample and SW for surface water. The following concentrations for nitrate, nitrite and ammonia were calculated in terms of N_2 (meaning NO_3, NO_2 and NH_4 were converted using nitrogen to nutrient ratio).

A ME sample, wpt. 180 had the second highest concentration of nitrate, at 8.13 µM. The highest level of nitrate was detected at wpt. 170 a LE sample with a concentration of 32.75 µM. Wpt. 24, located near the mouth of river contained concentrations of 4.19 µM for the GS and 0.682 µM for SW. Wpt. 22, also near the mouth of the river had a concentration of 3.65 µM. The last nitrate sample located in the NS, had a SW concentration of 0 µM and GS value of 1.16 µM. Nitrite levels, were some of the lowest among the five nutrients sampled. Wpt. 180 had the lowest concentration at 0.03 µM, wpt. 170 had the third highest concentration at 0.185 µM, wpt. 24 SW was measured at 0.036 µM and GS at 0.383 µM. Wpt. 22 had the second highest concentration at 0.03 µM/L and wpt. 146 SW and GS had 0.082 and 0.57 µM respectively.

The ammonia level at wpt. 180, was 4.64 µM, wpt. 170 was 0.512 µM, wpt. 24 SW was 0.838 and GS 0.977 µM. Wpt. 22 ammonia concentration was 5.28 µM the last site at wpt.146 had a SW concentration of 0.054 µM and a GS value that was considered to be unreliable for this paper due to its concentrations being in the thousands. Phosphorus was only detected at two sites. Wpt. 24 GS had a concentration of 0.46 µM and wpt. 146 SW had 0.02 µM/L and the GS at the same site was 48.6 µM (Fig. 4-6).

Silicic acid $Si(OH)_4$ had the highest concentrations of all nutrients. Wpt. 180 had a value of 121 µM. Wpt. 170 measured highest at 154. µM, wpt. 24 SW was 124 µM which was similar to its grab sample at 129 µM. Wpt. 22 had the second highest level at 137 µM. The last site, wpt. 124 had a SW concentration of 20.5 µM and a GS value of 619.9 µM (Table 1).

4.3 Grain size analysis

Some of the samples analyzed for grain size corresponded to the nutrient samples as well as a few sites that do not correspond directly with nutrient samples but are included to better characterize grain-size distribution throughout the river. Grain size samples at wpts. 172 and 173 which are not related to nutrient samples characterized grains upstream from Lake Mills. Wpt. 172, showed 95.0% sand and only 4.7% mud, wpt. 173, found nearby had similar characteristics of grains that were 96.3% sand and 3.7% mud. Wpt. 180 corresponded to a nutrient sample and characterized Lake Aldwell bed sediments. Here the sediment sizes were bimodal and very poorly sorted. Percent gravel was 2.9%, sand 69.3% and mud 27.8%. Wpt. 170 also relates to a nutrient sample and was taken next to the river below Lake Aldwell. Like wpt. 180, it was bimodal and poorly sorted, at 38.9% mud, 57.1% sand and 4.0% gravel. The last two samples that corresponded to nutrient samples are wpt. 24 and wpt. 146. Both samples characterized the lower reaches of the river and the nearshore. Wpt. 24, located in the river mouth, consisted of 55.2% mud, 44.7% sand and only 0.1% gravel. It was bimodal, and poorly sorted, with fine silt, sand and gravel. Lastly, wpt. 124 located just offshore was bimodal with coarse gravel and silty sand. The contents were 70.5% gravel, 25.7% sand and 3.8% mud. The findings from this grain-size analysis showed a trend of coarse sandy material which transitioned to finer sand and muds closer to the river if mouth. In the nearshore there was little mud and a high amounts of gravel (Fig. 7-8).

4.4 pH results

pH analysis was conducted on each nutrient sample, all which were all in the range of 6.82 to 7.89. Wpt. 170 located on the river below Lake Aldwell was found to be 7.59. In the river mouth wpt. 24 and wpt. 22 were found to have a pH of 7.89 and 7.36, respectively. The ocean surface water and grab sample at wpt. 146 were found to have a pH of 7.69 to 7.45 respectively. Wpt. 180, located in Lake Aldwell was determined to have the lowest pH at 6.82.

4.5 Suspended sediments

Suspended-sediment concentrations in the Elwha River basin were shown to vary by location. Data showed that suspended sediment values were low in the upper reaches of the river and increased towards the mouth. However, suspended sediment decreased again when heading farther into the ocean. Wpt. 171, taken in upper Lake Mills had the lowest concentration of suspended sediment with a measurement of 0.005 g/L. Wpt. 169 taken in the river below Lake Aldwell of the lower river has a concentration of 0.845 g/l, which is the highest of the samples in relation to where the nutrient samples were taken. Wpts. 22 and 21 at the river mouth had values of 0.5074 g/l and .2998 g/l respectively. Wpt. 24 also near the river mouth had 0.57 g/l and from here the concentrations dropped within the plume. Plume sample one, had a concentration of 0.0252 mg/l and wpt. 146 had one of the lowest at 0.0014 mg/l. These numbers show that the concentration of suspended sediments increase towards the nearshore but then drop once introduced to the marine environment (Fig. 8).

5. Discussion

5.1 Nutrient transportation and retention within rivers

There are many factors that affect the retention and distribution of nutrients throughout a watershed; these factors include physical, chemical and biological processes. Cycles such as the "nutrient spiraling concept," which involves geomorphic influences on nutrients, serve as additional explanations for nutrient retention (Ensign et al, 2006). While there are many dynamics involved in nutrient transport and distribution, this paper will focus on nutrient composition, concentration and distribution in correlation with grain size, and suspended sediments.

There has been much research related to sediments and uptake of nitrogen and phosphorus. These two nutrients play a critical role in the aquatic environment and are both utilized for primary productivity. Sediments that are composed of coarse gravel have a lower potential for denitrification than those with finer sediments. The anaerobic conditions within fine grained material can lead to the processes of denitrification and the production of nitrite and ammonia. Therefore nitrogen retention in streams is partially dependent on the degree to which nitrogen rich water encounters areas where oxygen is depleted. To contrast, phosphorus transport is manipulated by the movement of particles in rivers, large impoundments such as the Elwha and Glines Canyon dams could have served as retention zones for phosphorus. Aggradation and widening of the river could cause future retention of phosphorus due to aggradation (Stanley and Doyle, 2002). Understanding the connections that phosphors and nitrogen have with sediment, allows for correlations to be drawn in relation to the grain size and suspended sediment concentrations found in this study. The following sections will reveal the relations found between nutrients and the interaction between analyzed grain-size and suspended sediments.

5.2 *Spatial variations in nutrient concentrations*

This research revealed that the concentration in nutrients generally increased when traveling from upstream above the dams and to the nearshore (Fig. 3-4). Additional data from USGS research conducted in 1997 gave the water quality data from various tributaries located upstream from the Glines Canyon Dam and other sites in parts of the lower river. The data collected in 1997 showed that nutrient levels were either just below or at detection limits, with the median at (<0.05 mg/L). One of the highest concentrations of DIN (dissolved inorganic nitrogen), in the in 1997 was 16.64 µM, detected at LIL 1 (pg. 16, Munn et al., 1999). This sample taken outside of the Olympic National Park was likely subjected to anthropogenic processes, such as logging and agriculture, activities which lead to nutrient runoff (Fig. 8). The concentration from 1997 matches some of the higher concentrations calculated at locations downstream for this study. For example, in the former sediment beds of Lake Aldwell, wpt. 180, the concentration of DIN was 12.49 µM. At wpt. 170 the next location heading down river, DIN was 33.45 µM. In the mouth of the river at wpts. 22 and 24 concentrations for DIN were 9.13 and 5.50 µM respectively. All of these samples were located where high concentrations of suspended sediment and fine muds were measured (Fig. 7)

Due to higher trends of nutrients observed in the lower reaches of the river, one must understand the changing physical state that the Elwha River has and will continue to experience. One of these changes is the resuspension of fine sediments from the former lake beds of Lake Mills and Lake Aldwell. These sediments are significant to nutrient concentrations for various reasons. Sediments act as nitrogen sinks over the geologic lifespan of lakes, and over shorter periods of time they act as resources to the overlaying waters. Nitrogen can also be lost to sediments by deposition of particulate matter, i.e., detritus and silt, and by sorption of ammonia to clays that are in the sediments. Nitrogen can also be released from sediments by activities of burrowing animals, decomposition of organic nitrogen to ammonia, and desorption of ammonia from clays (Herbert et al., 1972). It is possible that sediments exposed to the atmosphere wpts. 180, 170, and 22 are undergoing nitrification, which would explain their higher levels of DIN, relative to the USGS water DIN. These relationships between nitrogen and sediments could explain some of the higher concentrations of nitrate found in lower river samples, where high concentrations of mud and suspended sediments were measured.

5.3 Nutrients, grain-size and suspended sediments

The trend of grain-size in the Elwha River is generally understood to range from large cobbles and pebbles in the upper stretches of the river and transitions to finer sands, and muds closer to the ocean (National Park Service, 1996). Based off the samples collected suspended-sediments increase from the former Lake Mills down to the mouth of the river and as mentioned above it is likely that increasing nutrient levels can occur with reworked sediment. For example, wpt. 170 below Lake Aldwell contained one of the highest concentrations of DIN and was located in an area with high concentrations of suspended sediment as well as relatively higher levels of fine grained material. Here a large percentage of grains were fine silt at 37.3%, medium sand equaled 10.9%, fine sand was 28.0% and very fine sand was 16.7%. Suspended sediment was also high below at wpt. 169, located near nutrient sample wpt. 170, with a concentration of 0.885 g/l. While there is no suspended- sediment concentration for wpt. 180, the major components of the grain-size were 30.5% fine sand, 32.1% very fine sand and 26.5% fine silt. These two samples indicate a possible correlation between fine sediments and high nutrient concentrations.

In contrast to the above samples that had high DIN concentrations, wpt. 146 found within the reaches of the plume had the lowest level of DIN, 0.136 µM. When analyzing this site multiple factors can explain why this might be so. Stratification may be responsible for reducing the amount of water mixing and nutrient dispersal in the water column (Mackas et al, 1994). So while wpt. 146 had a high level of PO_4 at 48.6 µM and high amounts of $Si(OH)_4$ for the grab sample, layering prevents an even distribution of nutrients. In addition grain size and suspended-sediment concentrations were different from the nutrient rich sites found in the lower river. At wpt. 146, gravel percentage was high, 70.5%, sand 25.7% and mud only represented 3.8%. The suspended sediment concentration was only 0.0014 g/L. These significant differences between the nutrient rich sites and the ocean sample serve as an explanation for nutrient variability.

5.4 $Si(OH)_4$ and the lower river

Silicic acid, $Si(OH_4)$ was in high concentrations throughout all samples (Fig. 5). Silicate mineral materials are known to be of igneous origin and are represented by potassium, feldspar and mica. The rock composition of the Olympic Mountains is known to be composed of basalts, sandstones and feldspar (nps.gov). Basalts are known to contain high levels of $Si(OH)_4$ and because rivers are one the most important mechanisms for the delivery of dissolved major ions and elements to the ocean (Emerson, 2008), it is likely that most of the measured silicate comes from the Olympic Mountains. Silicic acid concentrations were highest on the seabed of the sub-aqueous delta at wpt. 146, it is possible that high productivity and fallout of diatoms in this region has led to the accumulation of silicic acid on the ocean floor sediments, but more research needs to be conducted to verify. This proposed condition of stratification would result in low silicic acid content of the surface water of wpt. 146 and high concentrations at the seabed. Within the Elwha River variation was limited and values ranged from 121 µM at wpt. 180 to 154 µM at wpt. 170. The consistency of these concentrations suggests that similar patterns can be found upstream and that the steady source may indeed be the Olympic Mountains.

5.5 Implications

While the Elwha River has been characterized to be nutrient poor in multiple studies, i.e., (Munn et. al, 1991), (Duda et al, 2011) this study indicated that the initial stages in dam removal has had subsequent effects on the lower Elwha River nutrient concentrations. Sediment stored in Lake Mills was estimated to be composed of 48% silt and clay, 37% sand, and 15% cobbles and boulders. Suspended sediments after dam removal were expected to reach levels of 200 and 1,000 mg/L (Czuba et al, 2011). According to data from this study these predicted concentrations correlate to the numbers obtained by this research.

Suspended sediments and grain size are relevant because they have a direct influence on nutrient transport and concentration. While previous studies of lake sediments have shown that levels of phosphorus within sediments are limited (Fig. 6), (Cacaliere, 2010) and will not harm water quality, sediments from reservoirs can change nutrient status downstream (Stanely and Doyle, 2002). With dam removal nearly complete it is clear that the ecosystem has and will continue to experience significant change in nutrient composition, suspended sediment concentrations and grain-size distribution. With the expected time to flush out sediments being 5-7 years, significant changes to nutrient concentrations will continue to manifest. Future study will need to be conducted to observe how an increase in nutrients will change primary productivity, abundance of salmon and health of riparian environment.

Conclusions

This study found that nutrient concentrations found within river bank, river bottom and surface water samples vary in nutrient concentrations. The sediment samples collected along the river banks and with the Van Veen showed the highest levels of nutrients. Surface water samples collected with the niskin bottle showed lower levels of nutrients. These lower levels of nutrient concentrations found in the water samples correlates with the low levels of DIN found within the water samples collected by USGS in 1997. Due to this disparity between water sample concentrations and sediment samples, understanding the physical characteristics of the sediments helped to explain why there were higher concentrations of nutrients within the pore waters. Most of the sediments were characterized with high levels of silts and muds. In addition their residence time within the reservoirs has probably led to a buildup of organic material. It is likely that processes such as de-nitrification within these sediments is contributing to the higher levels of DIN. With these higher concentrations it is clear that as the river meanders through the former lake beds aggregation and re-suspension will continue to influence the distribution and concentrations of sediment within the lower reaches of the watershed. In the future it will be necessary to study the role that the sediments will continue to play in this historic restoration project.

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Figures

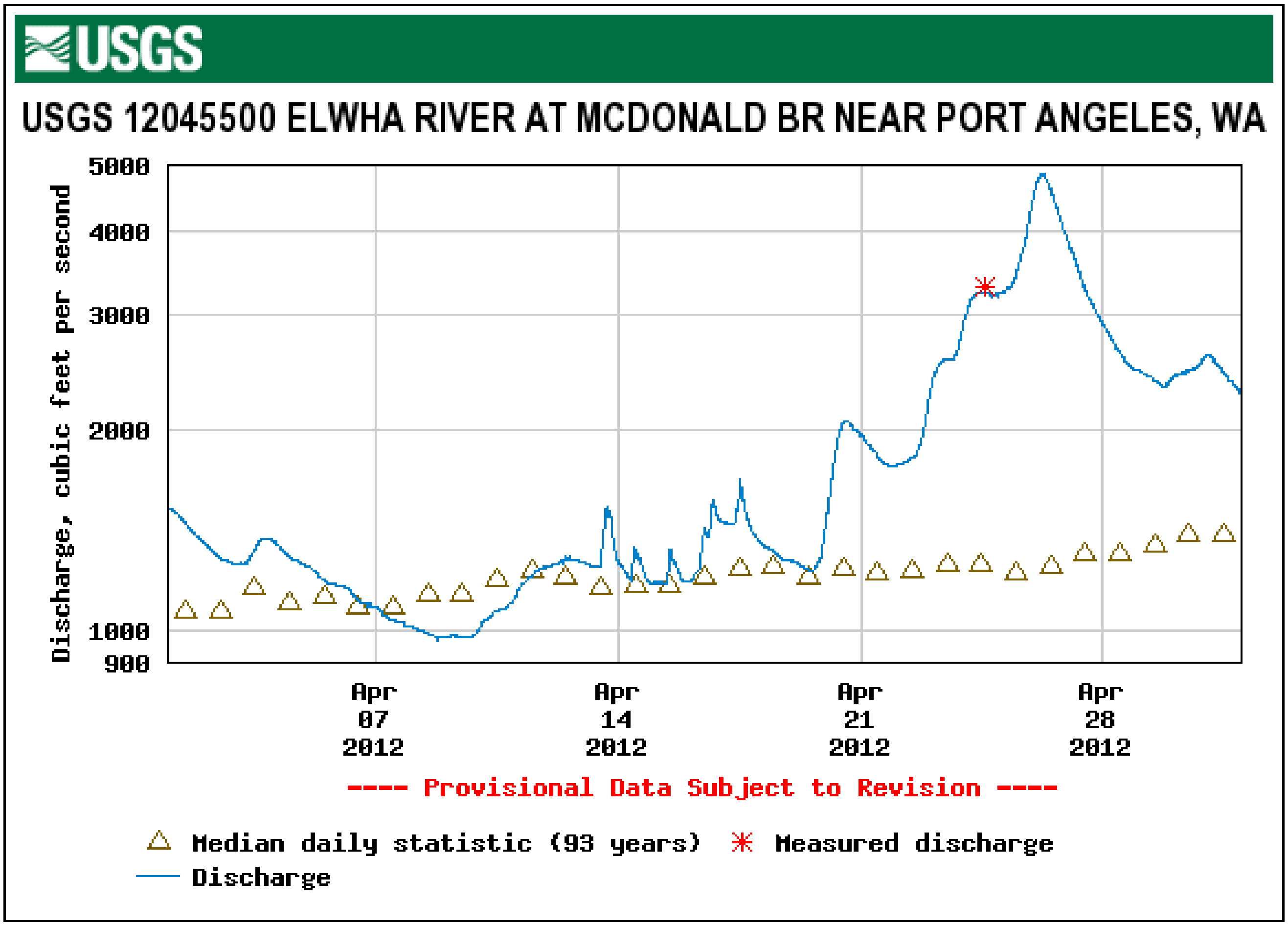

Figure 1. Elwha River discharge during the month of April. The triangles depict the median for ~100 yr and the blue line shows the measured discharge in (cfs). During our sampling period from 3-5 April, the river was at a relative low flow. Figure courtesy of USGS, found at: http://wa.water.usgs.gov/projects/elwhasediment/webcams.htm.

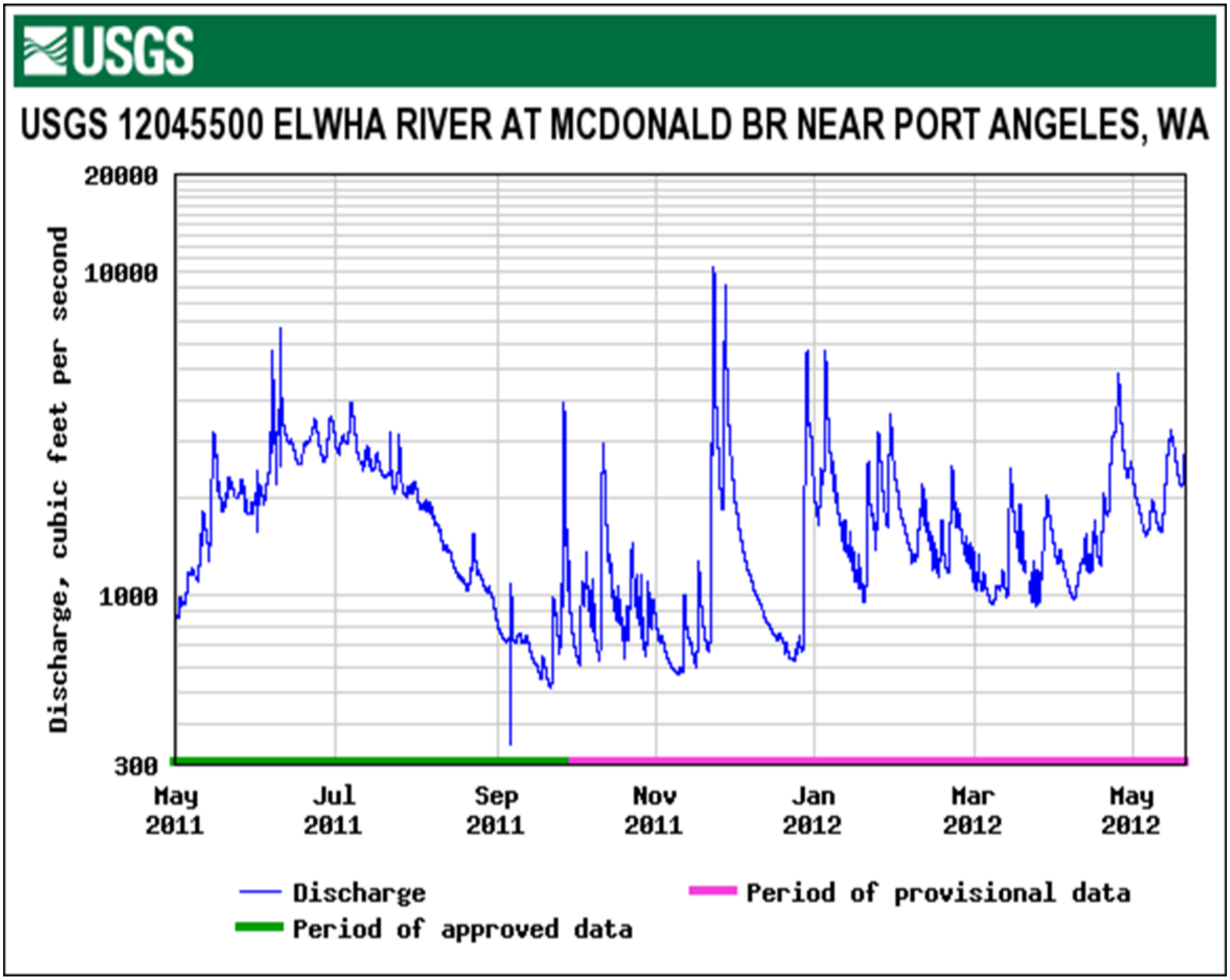

Figure. 2 Elwha River discharge in (cfs), from May 2011-May 2012. Peak discharge can be seen in June and December. Figure is courtesy of USGS, found at: http://wa.water.usgs.gov/projects/elwhasediment/webcams.htm.

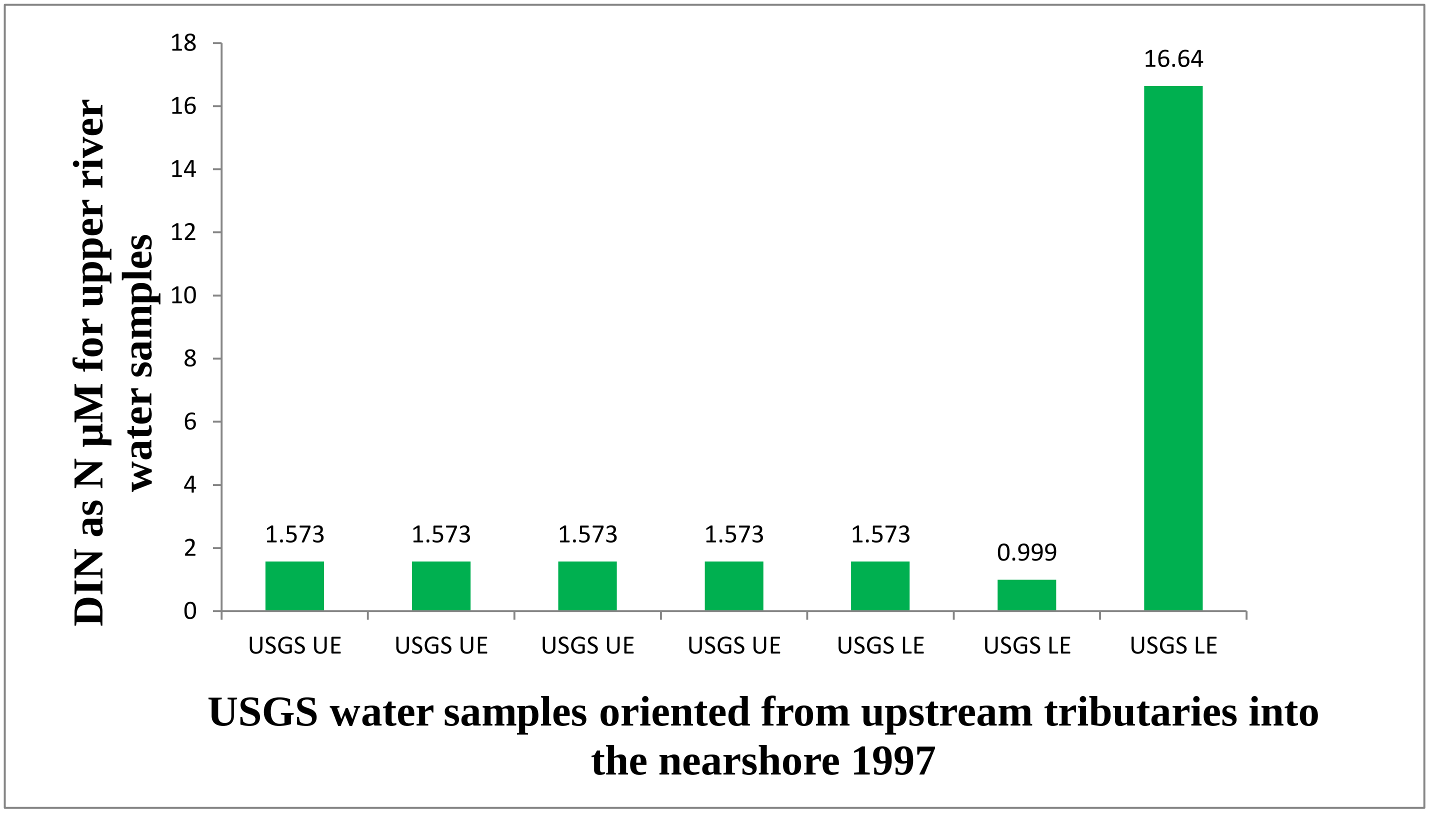

Figure 3. Sample label UE stands for upper Elwha, LE designates lower Elwha. Concentration of DIN were calculated in terms of N for USGS samples taken in 1997. Most of the upstream samples are oligotrophic. The exception to this trend is a sample taken in a tributary outside of the national park which has a concentration of 16.64 µM. This higher concentration can be attributable to anthropogenic processes such as logging and agriculture.

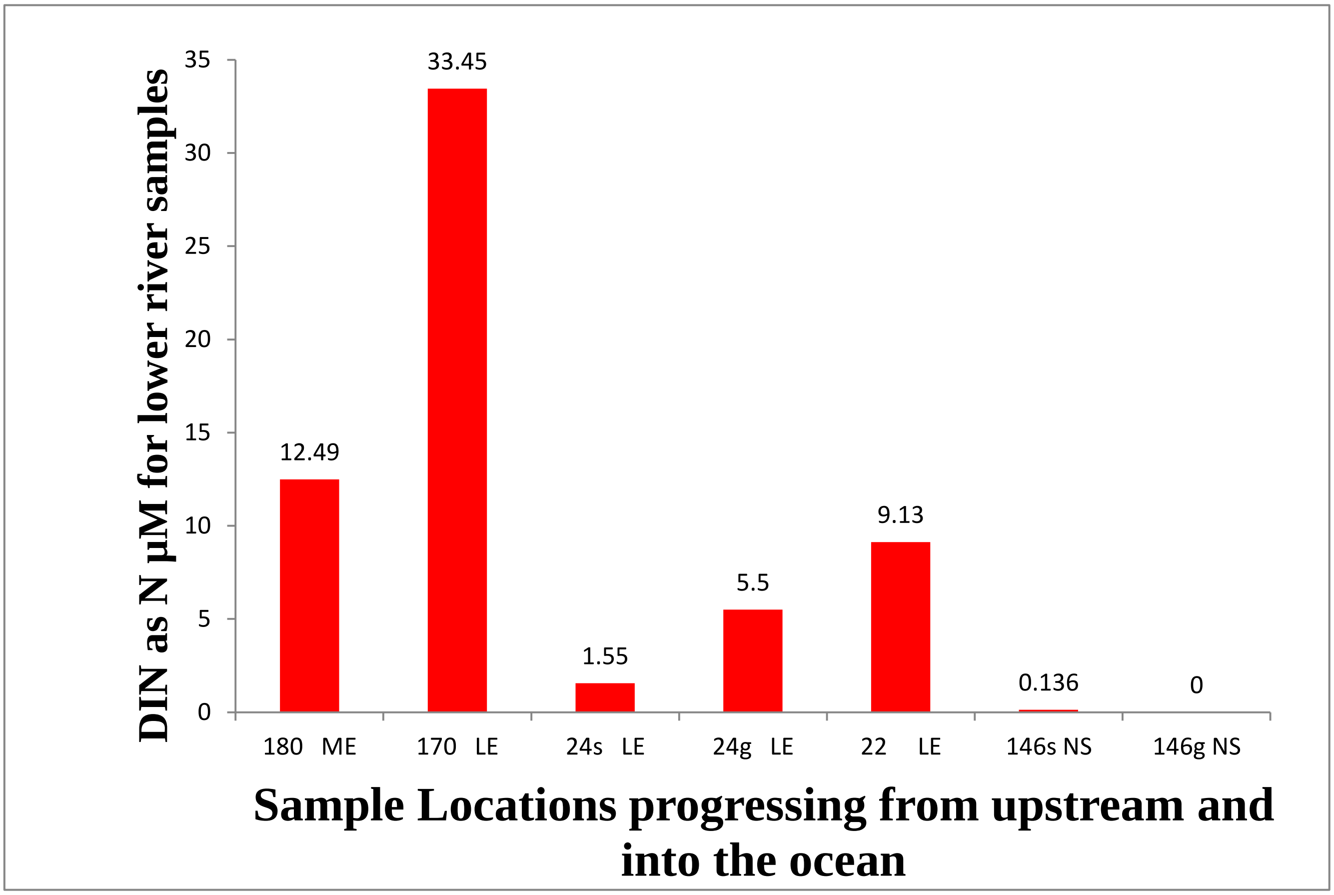

Figure 4. Graphs shows concentrations of DIN as N in µM/L as you head from former Lake Aldwell into the nearshore. ME indicates middle Elwha, LE stands for Lower Elwha, The levels of DIN in this graph show values that are both oligotrophic and mesotrophic, with some higher concentrations. These higher values can be attributable to de-nitrification which leads to the release of high amounts of NO3 within the sediments.

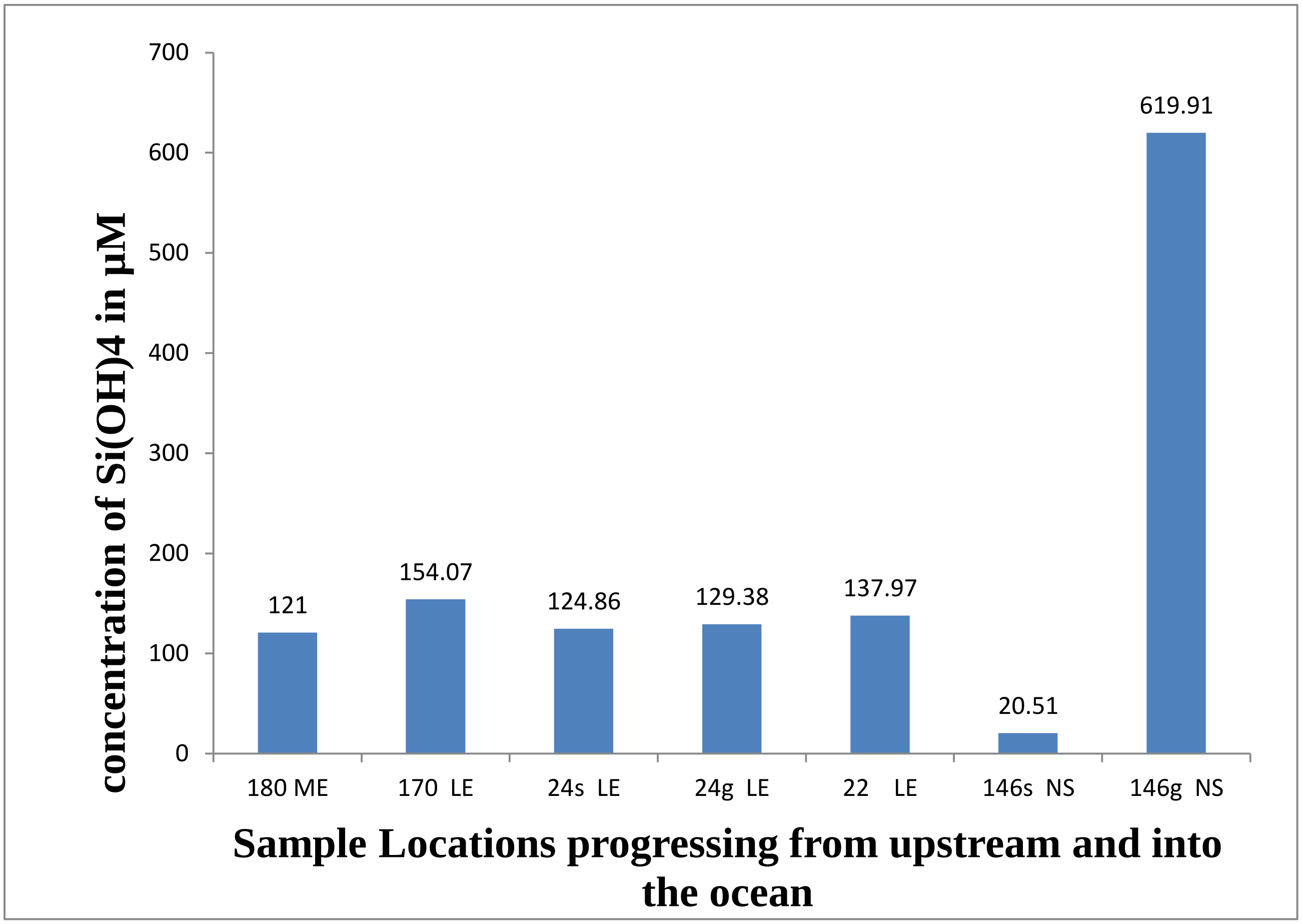

Figure 5. Concentrations of $Si(OH)_4$ heading downstream. There is a relatively even distribution compared to other nutrients in this study that had higher variations between each sampling sites. Wpt. 146 with the highest value is a grab sample taken from 29.5 m water depth.

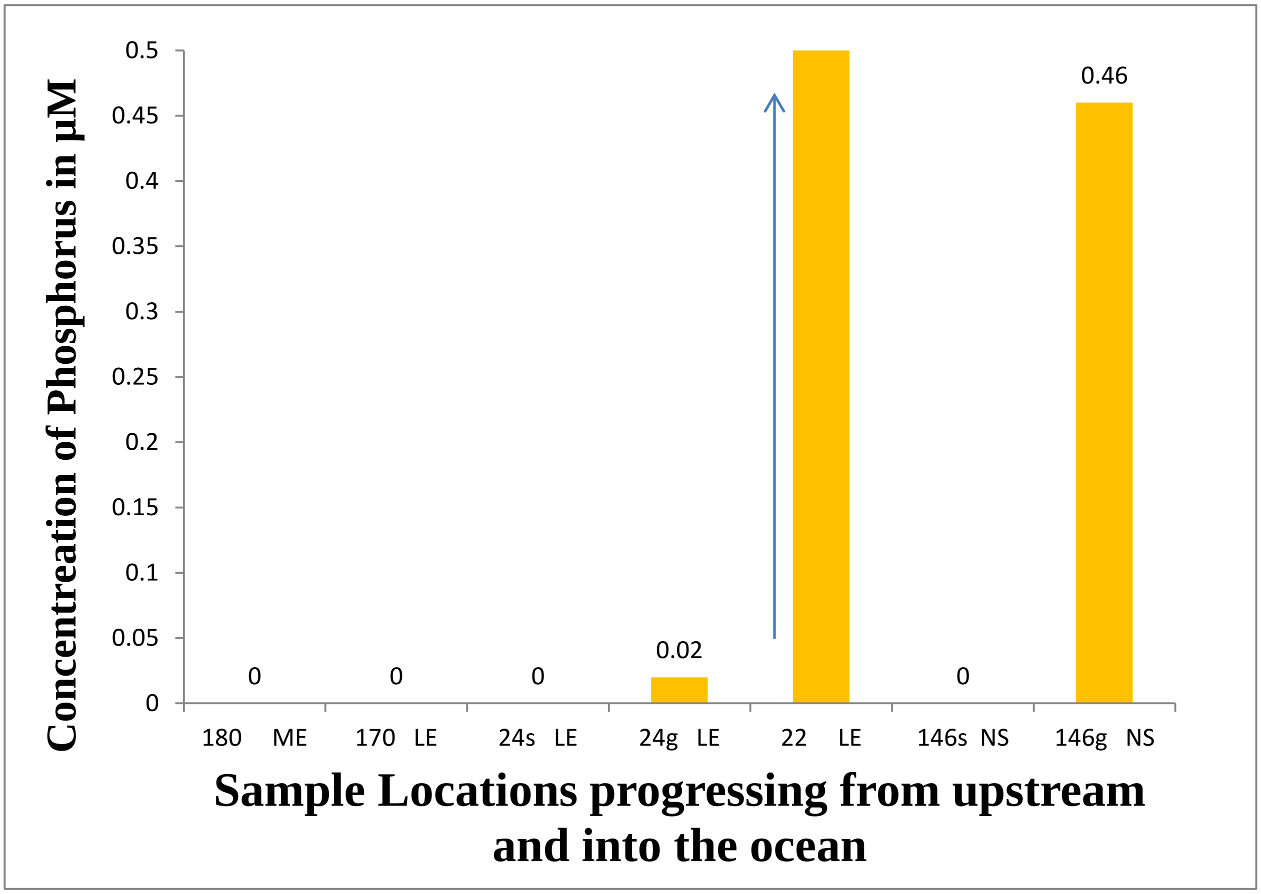

Figure 6. The concentrations of phosphorus heading downstream from lower Lake Aldwell. Here we can see that phosphorus concentrations are negligible. This trend is consistent with research in the past that indicated low levels of phosphorus within the reservoirs. Notice that this graph ranges from 0-0.5 µM/L which causes wpt. 146 to have a highly inflated look.

Figure 7. GIS map showing the concentrations of gravel, sand and mud, relative to locations where nutrient samples were taken. Suspended sediments are also depicted in g/l.

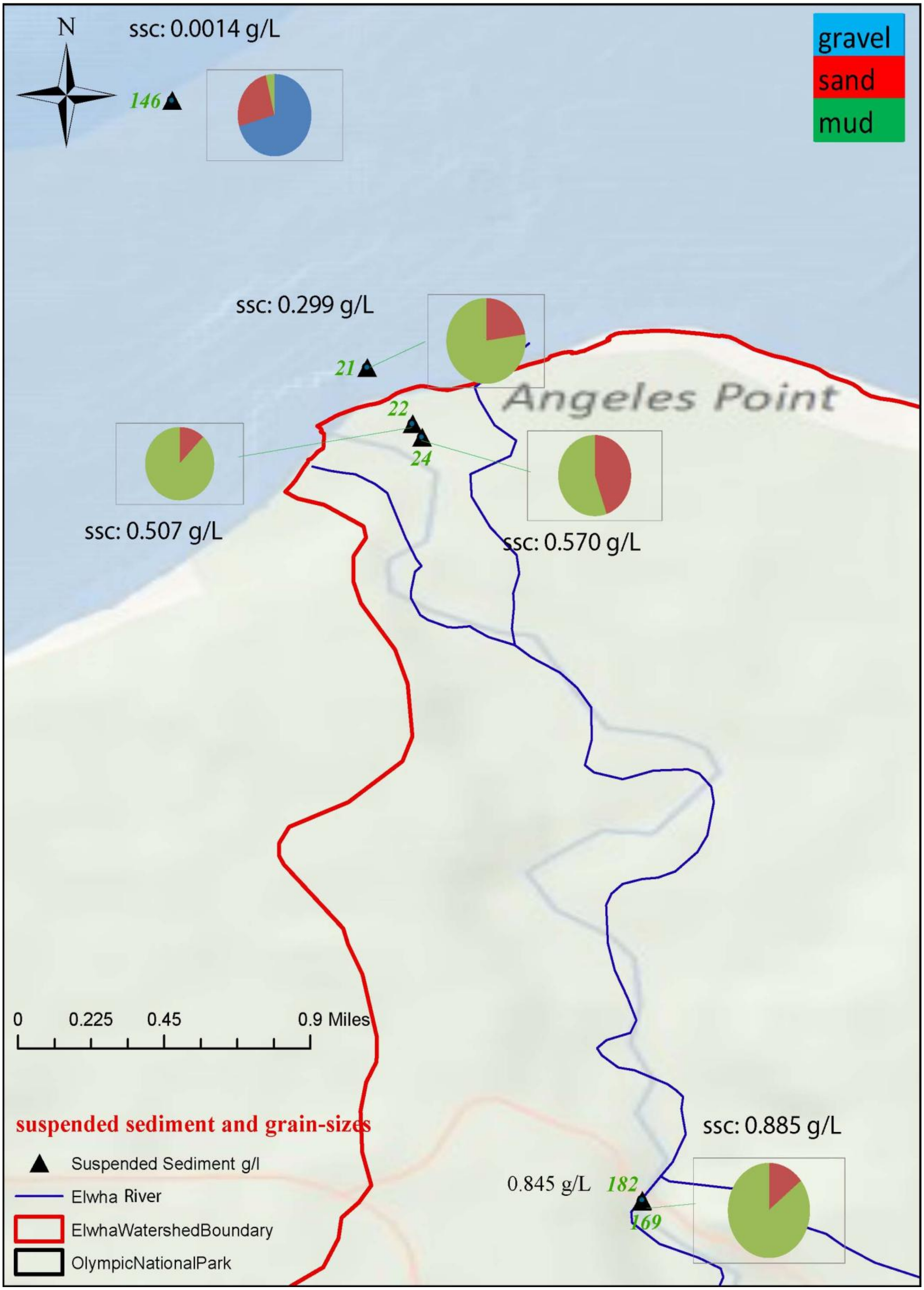

Figure 8. Elwha water shed with nutrient concentrations of DIN as N for both 1997 USGS samples and 2012 samples.

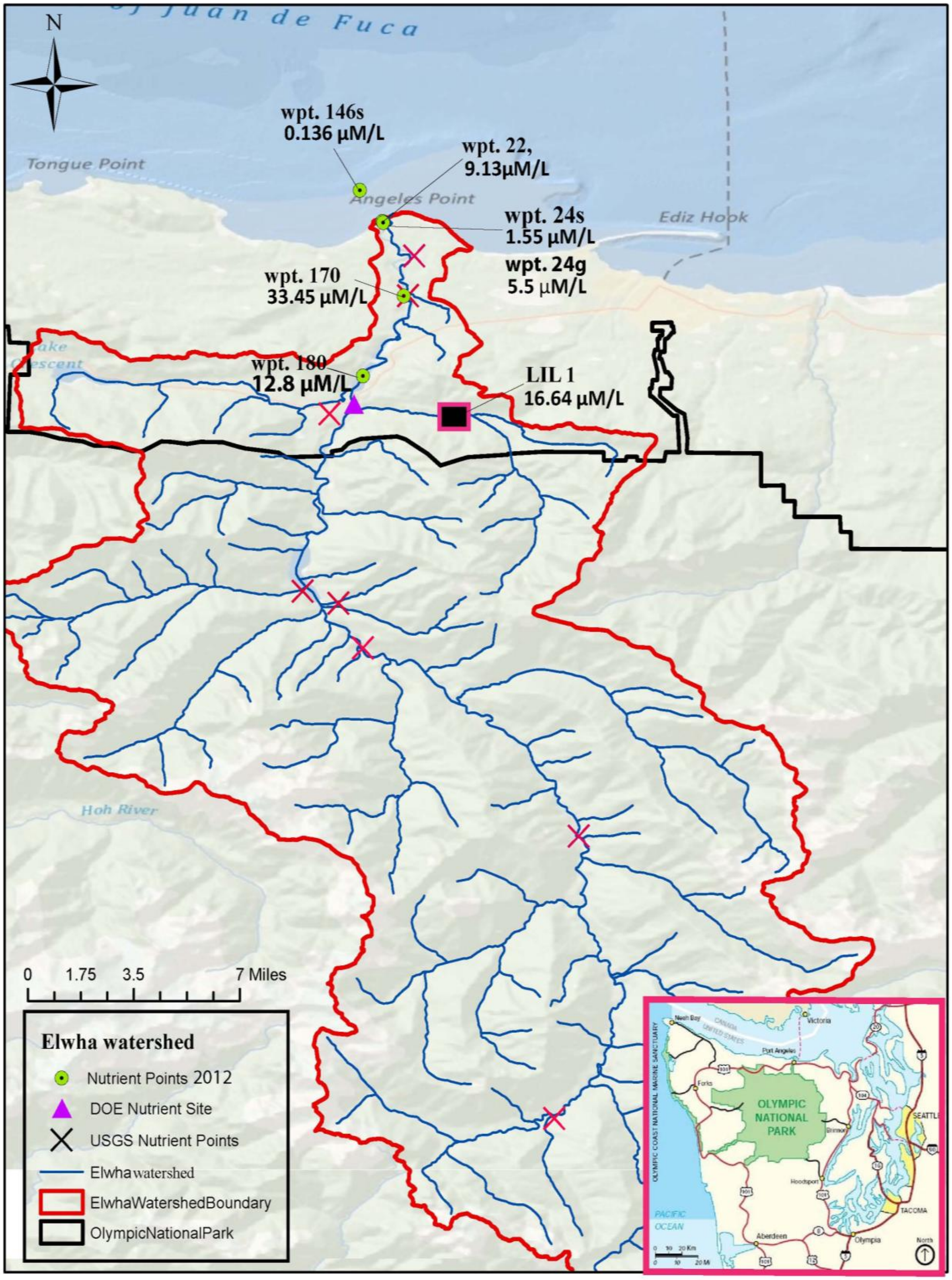

Table 1. Has the concentrations of nutrients for 2012 samples. Table progresses from the upper collection sites into the lower river. Nitrate, nitrite and ammonia were calculated in terms of N_2. Values that are N/A were considered unreliable.

Date	LAT	LONG	NO_3 (Nitrate) as N, µM/L	NO_2 (Nitrite) as N, µM/L	NH_4 (Ammonia) as N, µM/L	DIN as N µM/L	Discription of Site
4/3/2012	48.077816	-123.573383	8.128	0.03	4.64	12.8	wpt. 180 Expoed Lake Bed Aldwell
4/3/2012	48.113683	-123.553816	32.75	0.185	0.512	33.45	Pedestrian Foot Bridge, wpt. 170, Niskin surface
4/5/2012	48.14656	-123.56374	0.682	0.036	0.838	1.55	RM5, Niskin Surface Water
4/5/2012	48.14656	-123.56374	4.19	0.383	0.977	5.5	RM5, grab sample, wpt. 24
4/5/2012	48.14713	-123.56416	3.65	0.24	5.28	9.13	RM3 River Mouth, Bank Sediment, wpt. 22
4/4/2012	48.160983	-123.574883	0	0.082	0.054	0.136	CAB 970, Stat. 124, surface, ocean water, wpt. 146
4/4/2012	48.160983	-123.574883	1.16	0.57	N/A	N/A	CAB 970, stat. 124, 29.5m, grab sample, ocean water, wpt. 146

Table 2. USGS DIN water samples as N_2 1997, sample locations are oriented from lower river to the headwaters. Samples with N/A did not contain values for individual species of nutrient.

Nitrate NO_3 as N, µM/L	Nitrite NO_2 as N, µM/L	Ammonia NH_4 as N, µM/L	DIN as N, µM/L	Location Description
N/A	N/A	0.015	16.64	LIL 1
0.806	0.217	0.55	1.573	Hays River
0.806	0.217	0.55	1.573	Elwha River AB, Slate Creek
0.806	0.217	0.55	1.57	Elwha River, Goblins Gate
0.806	0.217	0.55	1.57	Boulder Creek
0.806	0.217	0.55	1.57	Elwha River, Old HWY 122
0.177	0.434	0.388	0.999	Elwha River, Stration RD