APPENDIX 1 - EXISTING CONDITIONS SUMMARY

FOR 13 SOUTH FORK AND NORTH FORK NEWAUKUM RIVER REACHES

List of Existing Conditions Documentation Materials Developed For Each Reach:

1. Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description
2. Geomorphic Reach Description, Channel Migration and Erosion, Flooding Summary
3. Context and Vicinity Map
4. Existing Parcels Affected by Simulated 2009 Flood of Record Map
5. Existing Landcover Map
6. Relative Elevation Map (REM)
7. Geomorphic Landform Map
8. Existing Soils Map
9. Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change
10. Modern and Historical Floodplains
11. River Channel Changes From 1940 - 2017
12. Erosion Hazard Analysis

Introduction

In this appendix, we developed a series of reach-scale existing conditions summaries and maps for each reach, as follows:

Reach-scale Summaries (2 pgs per reach):

1. ***Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description***

   Describes the following landscape traits:

   - The valley bottom acreage, including the river channel, and the dominant landcover.
   - The dominant soil types and locations of hydric soils.
   - The number of river-crossings, and buildings in the reach.
   - The number of landowners in the valley bottom, with the largest landowner identified.

   This page also presents results from an analysis of the parcels and landowners affected by a simulation of the 2009 flood event, which is the current flood of record, in a table showing the parcels with greater than 75% area within the modeled flood area, and their respective land use description, acres flooded, and the largest landowner in each land use class.

2. ***Geomorphic Reach Description, Channel Migration and Erosion, Flooding Summary***

   The second summary page provides a description of the geomorphic landforms, historical channel migration, and flooding for each reach.

   Geomorphic landforms, such as relict channels, the active floodplain, and the historical floodplain were mapped throughout the valley bottom. Details of how these features were mapped is provided in a separate appendix document.

   These geomorphic features help scientists to understand how the river has changed over time and help to identify river restoration opportunities. These opportunities might include side-channel re-engagement, floodplain reconnection, and other restoration actions which increase overall river channel length and floodplain connectivity.

   The second summary sheet also presents a summary of extent and effects of large-scale floods, such as the 2009 event, with the mapped FEMA 100-year flood boundary, and a simulation of the 2009 event with an estimated 26% increase in peak flow due to climate change effects.

   All-together, these data show the area that was effected by the most recent flood of record, the inundated area that is currently covered by FEMA and the inundated area which is not covered by FEMA, and how big floods might change with climate change.

Maps (10 maps per reach):

1. Context and Vicinity Map
2. Existing Parcels Affected by Simulated 2009 Flood of Record Map
3. Existing Landcover Map
4. Relative Elevation Map (REM)
5. Geomorphic Landform Map
6. Existing Soils Map
7. Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change
8. Modern and Historical Floodplains
9. River Channel Changes From 1940 – 2017
10. Erosion Hazard Analysis

EXAMPLE RESULTS

The Restorative Flood Protection (RFP) treatment area, identified in the 2016 RFP feasibility analysis of the South Fork and North Fork Newaukum Rivers was divided into thirteen (13) geomorphically-distict river reaches, seven (7) for the South Fork Newaukum River, and six (6) for the North Fork River (Figure 2), see Index Map.

A geomorphic reconnaissance was completed in the fall of 2017 to gather data for hydraulic model development, to inform river reach characterization, and to identify opportunities and constraints for design elements for the RFP Feasibility Study. The NSD team walked approximately 12 miles of the South Fork Newaukum River (from Onalaska to the confluence with North Fork Newaukum River) and the lower section of the North Fork Newaukum River downstream from the Middle Fork Confluence. Field reconnaissance surveys included observations of channel substrate and streambank sediment, riparian vegetation types, existing wood accumulations, areas of erosion and deposition, and areas of bank armoring. Topographic survey data were collected at 18 road crossing locations. Surveys included topographic cross-sections both up- and downstream of the crossing and key elevations of the bridge structures and roadway.

North And South Fork Newaukum River Fact Sheet Highlights

The Restorative Flood Protection feasibility analysis area was comprised of about 21 miles of the lower South Fork Newaukum River (SFN), was divided up into 7 river reaches, and 12 miles of the lower North Fork Newaukum River (NFN), was divided up into 6 river reaches. The reaches were identified by river, NFN and SFN, respectively, and numbered from downstream to upstream.

Each of these 13 river reaches was studied for flood and erosion patterns under current landscape conditions, which were described below. Flood and erosion patterns were not only affected by the amount of water in the river, but also by landcover, such as pavement, pasture, or forest, the presence of bridge-crossings and adjacency of major roads. The variation in this landcover and land use, and examples of flood and erosional river responses are provided below.

Landcover Patterns

The lower-most 16 miles of the SF Newaukum River valley were dominated by pasture and then forest. This landcover pattern changes above river mile 16 to a dominant landcover of forest and then pasture, which correlated to the river valley becoming steeper and narrower further upstream. This transition happened in SFN Reach 6, about five river miles upstream of Onalaska, WA. Riparian and floodplain landcover and land use was important to analyze when researching river erosion and flooding. Forest provides a source of in-channel wood, and the tree roots stabilize river banks, whereas pasture is highly erodible with shallower root networks.

The landcover in NFN valley bottom was much more diverse. For example, NFN Reach 1 was pasture and forest, just like SFN Reach 1. However, the next reach upstream from NFN Reach 1, NFN Reach 2, switched to shrubs and forest and then to shrubs and pasture in NFN Reach 3. Landcover in NFN varied between pasture, shrubs and forest the rest of the way upstream.

Landowners Affected By Flooding

While the landcover patterns were relatively consistent within each reach, the assessed land use varied considerably. In order to understand the influence of the river on the most-effected landowners, parcels in the simulated 2009 flood event were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the greater the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel.

On average, within the SFN and NFN study reaches, about 50% to 60% of the valley bottom landowners had property that was inundated in the simulated 2009 flood. The relative percent of valley bottom land owners that were inundated in this simulation ranged from 23% in SFN Reach 4 to 95% in NFN Reach 6.

About 10% of the valley bottom land owners, or about 87 total landowners, 52 in the SFN study area and 35 in the NFN study area, had property that was mostly inundated, which was defined as a property with more than 75% parcel area within the simulated flooded area.

For example, twenty (20) of these 87 significantly affected landowners were in SFN Reach 2, owning 23 parcels of land between them:

- Fourteen (14) of these parcels were assessed as single-family residential, totaling 102 flooded acres of 112 total parcel acres;
- The other seven (7) parcels were undeveloped/vacant parcels, representing 25 flooded acres of 27 total parcel acres;
- The remaining 2 parcels were assessed as agriculture, with 25 flooded acres of 27 total parcel acres.

Another example from NFN Reach 1, illustrates the land use and ownership patterns of another 15 of these significantly affected landowners, who owned a total of 18 parcels:

- Four (4) were assessed as agricultural parcels, totaling 63 flooded acres of 70 total parcel acres;
- Two (2) were assessed as mining/forestry, totaling 15 flooded acres of 18 total parcel acres;
- Two (2) single family residential parcels, representing 6 flooded acres of 7 total parcel acres;
- Ten (10) undeveloped/vacant parcels, with 54 flooded acres of 57 total parcel acres.

SFN Reach 2 and 3, and NFN Reach 1 had the most landowners affected by the simulated 2009 flood, totaling 50 of the 87 affected landowners. These landowners use the land in a variety of ways, from residential and agricultural to forestry, and these uses were no different from those in less affected areas.

Incision

In general, incision depth in SFN increased from downstream to upstream. Incision was measured in terms of the difference between the current floodplain and the historical

floodplain. In the SF Newaukum River analysis area, the current floodplain is 4.2 ft to 7.8 ft below the historical floodplain surface. There is a strong transition point at SFN Reach 4, where the incision gets deeper. SFN Reaches 1 - 3 had an incised depth of 4.2 ft to 4.5 ft; and SFN Reaches 4 - 7 had incision depths that ranged from 6.0 ft to 7.8 ft. Conversely, NFN was more incised than SFN and ranged from 5.3 ft to 7.0 ft of incision. There was no pattern downstream to upstream, with NFN Reach 4 being the most incised and Reaches 1 and 6 the least.

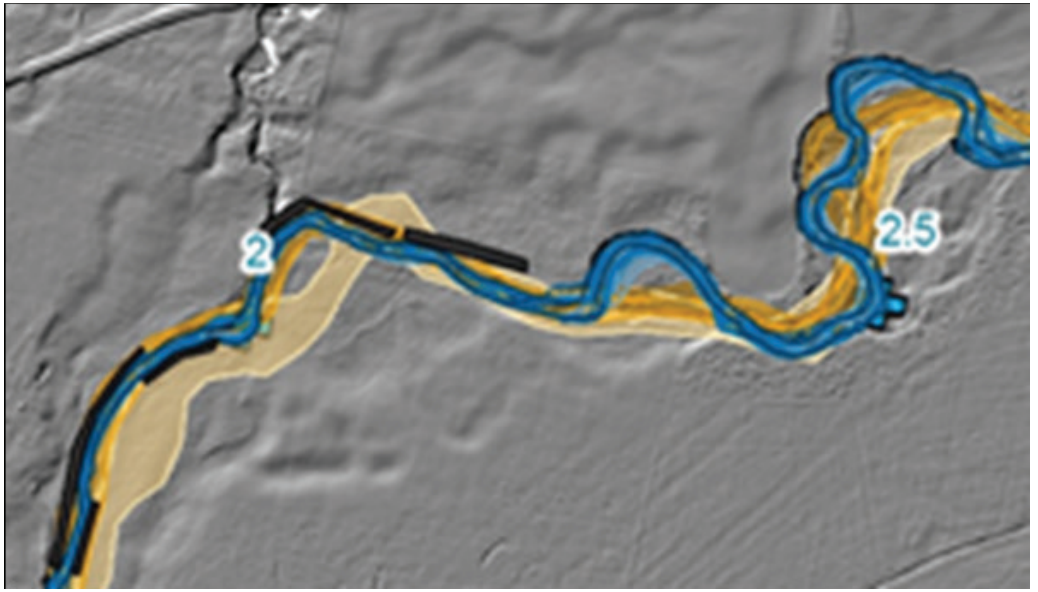
Slope

Like incision, channel slope increased from downstream to upstream, from 0.29% in SFN Reach 1 to 0.71% in SFN Reach 7, and from 0.08% in NFN Reach 1 to 0.41% in NFN Reach 6. Increases in slope lead to increases in water velocity, affecting incision rates, erosion, and other river processes.

Armoring

In general, the amount of bank armoring decreased from downstream to upstream in the three reaches where it was measured in the field. SFN Reach 1 had a mile of armoring, SFN Reach 2 had half of that, and SFN Reach 3 had about 1/3-mile of river bank armoring. Bank protection was not measured above SFN Reach 3 or NFN Reach 3 because these reaches were generally not accessible for field work.

Channel migration within NFN Reach 1 and 2 has been severely limited due to the large degree of bank armoring, roughly 98% and 44% of the banks, respectively. Because of this bank armoring, the channel has occupied the relative same location despite almost the entirety of the valley being capable of being eroded. For example, in NFN Reach 2, the lower portion of the reach between RM 1.5-2.25 is heavily armored along both banks and thus shows little evidence of channel migration besides a meander cutoff adjacent to the Middle Fork Confluence. The remainder of the channel is straight and enveloped by rip rap revetments. Upstream of the armored portion the channel has been actively migrating and widening the inset floodplain corridor into the surrounding historical floodplain surface (see Figure 4).



North Fork Newaukum River Reach 2, armored areas shown in black/dark gray, current channel is in blue, with historical channels in yellow/gold.

Channel migration and erosion

There has been localized recent channel migration within several of the study reaches. In addition to the NFN Reach 2 area shown in Figure 4, SNF Reach 3, particularly between RM 21-22 has also been meandering. In these locations, meanders have primarily eroded into pastured land with un-armored banks. This has widened the inset floodplain corridor within these locations. SFN Reach 3 is also dominated by pasture land and thus has a higher susceptibility to erosion, compared to shrub or forest land.

Despite having almost ½ mile of bank armoring, there has been recent and active channel migration within SFN Reach 2. Like most of the study area, the channel is in a widening phase, increasing the area of the inset-floodplain corridor. The channel is actively migrating by eroding banks comprised of historical floodplain material (i.e. highly erodible), avulsing into previously occupied channels, and cutting off meander bends. In SFN Reach 2, the channel migration is occurring into both forested and pastured lands (such as the pasture between RM 15.5-16).

There is also evidence of active channel migration within SFN Reach 6. At the downstream end of the reach there were two outward migrating meanders that are eroding into the historical floodplain surface on the left side of the valley between RM 28-29. Evidence of active widening of the inset floodplain corridor is found around RM 29.5 where the channel has been eroding into the right side of the valley which is underlaid by historical alluvium.

Bridges and Major Roads

There were nine (9) major bridge crossings in this 21-mile analysis area; five (5) of them are in the lower 8-miles of river, in SFN Reach 1 and 2. These bridges generally act as 'speed bumps' interrupting the flow of floodwaters down river, slowing water down and backing it up-river (see Figure 5). For example, Reach 1 of the South Fork Newaukum River, had three (3) major bridge crossings, the North Fork Road, Middle Fork Road, and SR 508. Like SFN, NFN had the most bridge crossings, three (3), in Reach 1. The rest of the NFN River Reaches all had one (1) bridge crossing.

For example, State Route 508 crossed SF Newaukum River in SFN Reach 1 about 3.5-miles upstream of the start of the analysis area, at the confluence of the SF and NF rivers. In this image, the hatched area illustrates the FEMA 100-year floodplain boundary, the cyan area shows the simulated 2009 flood event, and the gold area identifies the same 2009 event simulated with climate change effects. At the river, all of these boundaries shrink at the road crossing, and swell upstream from the bridge. This example not only shows the effect of a road on local flooding, and it illustrates the variation in flood boundaries in an inherently dynamic landscape.

The roads that follow the river, rather than cross it, like State Route 508 (SR 508), protect large areas of floodplain from flooding and concentrate flood waters (see Figure 5). These areas were exposed to high erosional forces. In SFN Reach 2, the river abuts the SR 508 road embankment six (6) times, all of which were armored with riprap which requires ongoing maintenance.

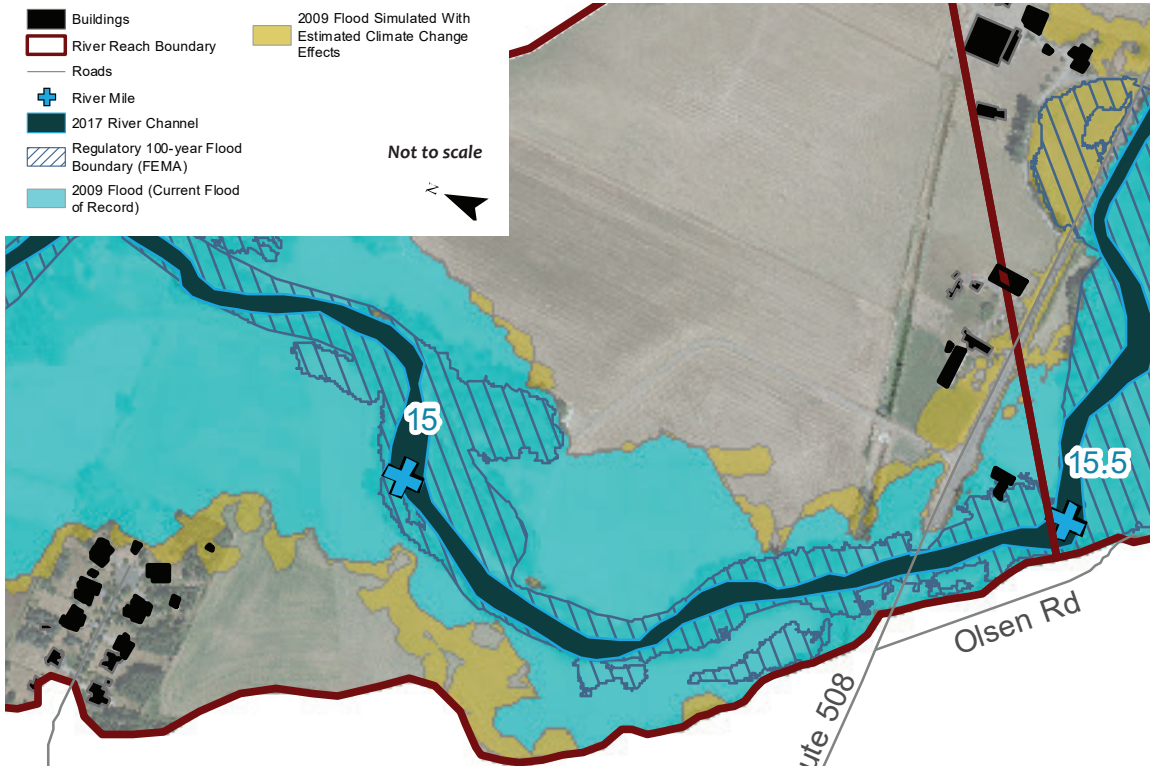
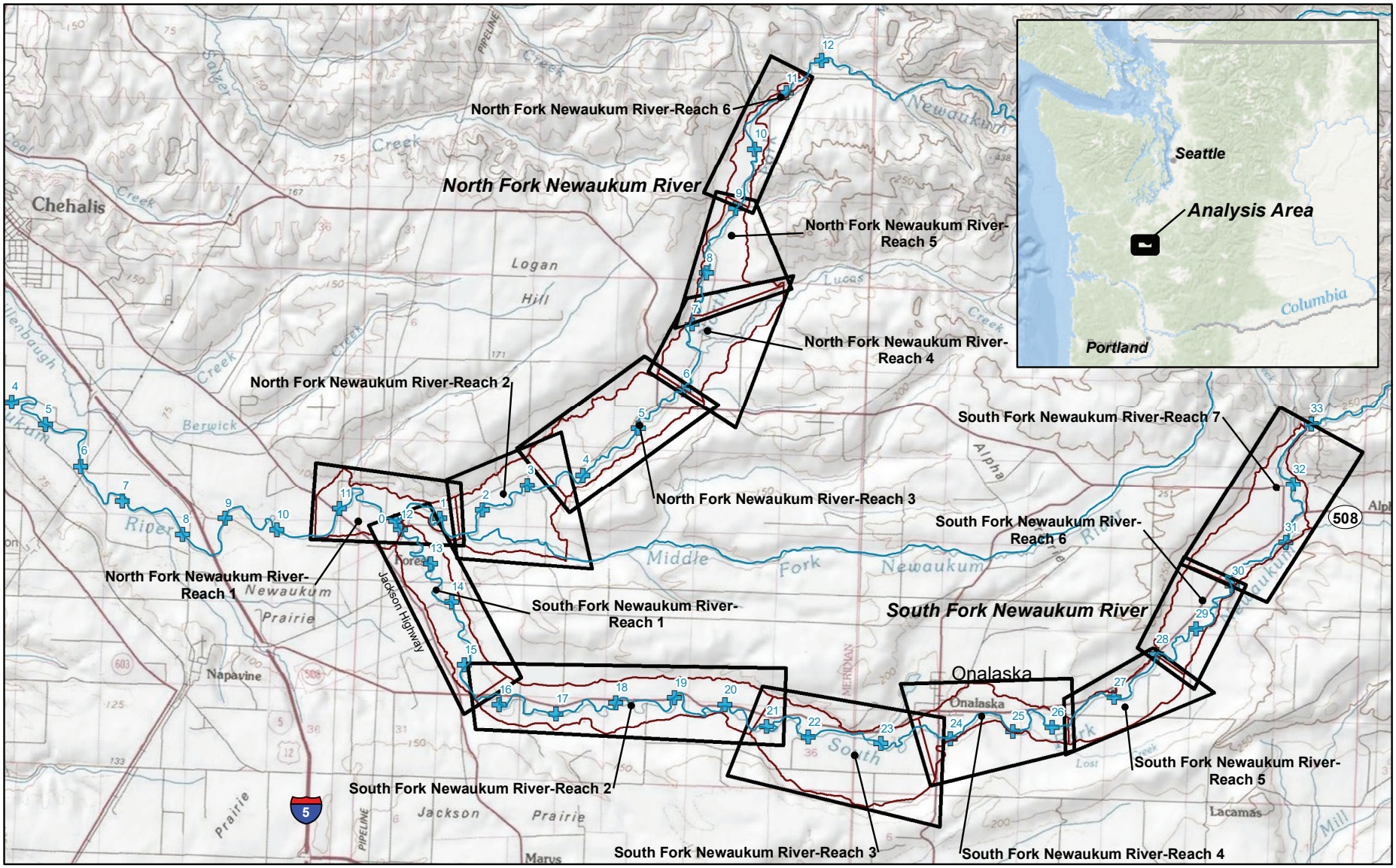


Figure 5 Bridges interrupt flood waters, creating upstream backwater effects in FEMA boundary, 2009 flood simulation, and 2009 flood with climate change simulation. Water flows from the right to the left of the image. The red line across the river valley is at the transition from South Fork Newaukum River Reach 1 (left half, downstream) and Reach 2 (right half, upstream).

Page Left Intentionally Blank

Index Map


North Fork Newaukum River-Reach 6
North Fork Newaukum River
North Fork Newaukum River-Reach 5
North Fork Newaukum River-Reach 4
North Fork Newaukum River-Reach 2
North Fork Newaukum River-Reach 3
South Fork Newaukum River-Reach 7
South Fork Newaukum River-Reach 6
South Fork Newaukum River-Reach 1
South Fork Newaukum River
North Fork Newaukum River-Reach 1
South Fork Newaukum River-Reach 2
South Fork Newaukum River-Reach 3
South Fork Newaukum River-Reach 4
South Fork Newaukum River-Reach 5
Seattle
Analysis Area
Portland
Columbia
Chehalis
Napavine
Onalaska
Jackson Highway
Middle Fork Newaukum
Newaukum Prairie
Jackson Prairie
Logan Hill
Berwick Creek
Alpha
Lacamas
508
5
Map Extents
River
River Reach Boundary (NSD 2017)
River Mile
N

Page Left Intentionally Blank

South Fork Newaukum River Reach 1

Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description

Vegetation, Soils and Wetlands

Reach 1 of the South Fork Newaukum River valley bottom occupies almost 600 acres, including the river channel. The floodplains and terraces of this river valley are currently dominated by 332 acres of pasture or mowed grass. The other half of the landcover is comprised of a mixture of forest, shrubs, roads, buildings, and river channels.

% Area	Acres	Landcover
56%	332	Pasture or Groundcover
32%	187	Forest
5%	32	Shrubs
4%	23	Water
2%	10	Road
1%	6	Gravel Bar
1%	5	Structure (Buildings)
0%	1	Vegetated Gravel Bar
0%	0	Log Jam
100%	**595**	**Total**

The soils of reach 1 of the South Fork Newaukum River valley bottom are comprised of ***Newberg fine sandy loam in the active channel area-- optimal conditions for cottonwood bottomland*** and Chehalis silty clay up on the floodplain, which lends itself to other types of forest (See Soils Map). As the valley topography increases in elevation from the river channel to the valley wall, hydric silty clay loam soils are found on the landscape. These hydric soils are an indicator of wetland soil formation processes.

Infrastructure, Buildings & Ownership

Reach 1 of the South Fork Newaukum River has ***three (3) major bridge crossings***, the North Fork Road, Middle Fork Road, and State Route 508 (SR 508).

There are numerous homes and farms in this reach, about ***91 structures*** total. From downstream to upstream, these neighborhoods and communities include:

- River Run, LLC
- Several small family farms, including sheep, small orchards, and outbuildings.
- Lewis County Central Shop
- Small cul-de-sac with several homes along Granite Lane.

The 83 parcels that comprise this valley bottom are ***almost entirely privately owned*** by 63 private landowners with the Lewis County Public Works Department only owning 1.1 ac (0.2%). The largest private landowner is River Run, LLC which owns about 16% (104 acres) of the total the valley bottom area. Another large landowner is Jake Lambert, who owns about 65 acres of valley bottom. This area calculation does not include the land outside of the valley bottom analysis area.

Description of Parcels in the Floodplain

In order to understand the influence of the river on landowners, parcels in the simulated 2009 flood event* were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the higher the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel. ***Of the 63 landowners in the valley bottom, 33 landowners had property that was inundated in the simulated 2009 flooded-area, and 8 land owners have property that are more than 75% within the approximated inundated area which represents about 65 parcel-acres*** (see table below). The dominant assessed land use for these parcels is agriculture, comprising 57 acres. 5 acres of single family residences are also predicted to be affected.

Landuse description of parcels with > 75% area in flooded area

Assessed Land Use Description	Number of Parcels	Acres Flooded*	Total Parcel Acres	Largest Landowner (Parcel Acres)
agriculture	10	52	57	L. Hanna (10.5 acres)
single-family residential	4	5	5	D.K. Davis (1 acre)
undeveloped/vacant	1	3	3	D.R. Roberts, Jr (3.5 acres)
TOTAL	**15**	**60**	**65**	**33 Landowners w/ > 75% land in flooded area**

Flooded buildings

The number of buildings in the simulated 2009 flooded area was ~21, including residences and outbuildings. (see inundation map for approximate location).

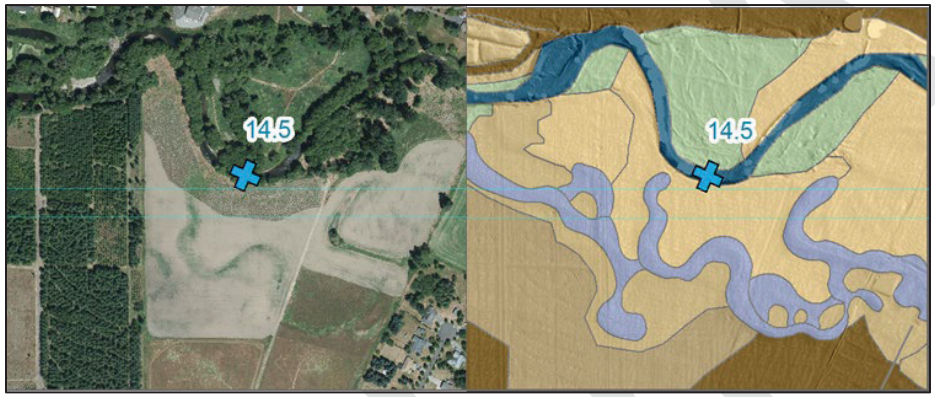
South Fork Newaukum River Reach 1

Geomorphic Reach Description

Reach 1 of the South Fork Newaukum River is located directly upstream from the confluence with the North Fork Newaukum River from the North Fork Rd. bridge (River Mile 12) to the Jackson Highway bridge (River Mile 15.5). The reach has an average slope of 0.0029 ft/ft (or 0.29%) and has a meandering pool-riffle morphology (Table 1, REM map) (Montgomery and Buffington, 1997). There are no major tributary junctions within this reach.

Geomorphic Landforms

The river is contained within an inset-floodplain corridor, which has incised an average of 4.2 ft below the historical floodplain. The active floodplain is currently widening into broader historical floodplain surfaces in locations without bank protection (see green area in the image to the right and Geomorphic Landform Map). ***A dense network of abandoned and relict channels*** is evident within the historical floodplain and can be seen in aerial photography (See abandoned channel features in example below). Some of these relict channel features are artificially-connected by ditches, presumably to aid in drainage of land. The ***modern active floodplain is ~5 times narrower than the historical floodplain***, which likely would have spanned the entirety of the river valley (Table 1). Relevant non-alluvial landforms include glacial outwash terraces along the left side of the valley between RM 14-15 and along the right side of the valley between RM 14.5-15.75.



Channel Migration and Erosion

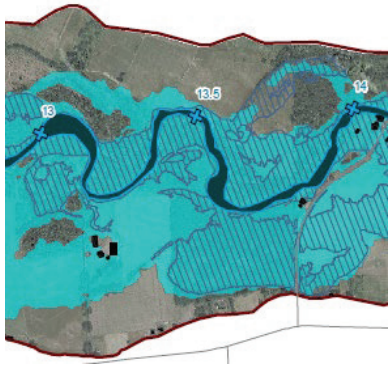
Channel migration within Reach 1 has been limited due to the ***large degree of bank armoring*** (See Channel Changes map and image to the right for an example of typical bank armoring). Roughly 28% of the banks contain some form of hardening and there is evidence of channel straightening (e.g. between RM 14-14.5). Because of this, the channel has occupied the relative same location since at least 1990 despite almost the entirety of the valley being capable of being eroded (See Erosion Susceptibility Map).

Table 1: Reach Statistics

Geomorphic Reach Description Statistics		Units
Slope	0.0029	ft/ft
Centerline Length	18,224	ft
Average Depth of Incision	4.2	ft
Historic Floodplain Average Width	1,087	ft
Active Floodplain Average Width	210	ft
Historic Floodplain: Active Floodplain	5	ft/ft
Flood Defense Length	5,118	ft
Flood Defense Length/Channel Length	0.28	ft/ft
Road Length	4,097	ft
Total Reach Area	596	acres

2009 Flooding & FEMA boundary

The ***FEMA 100-year flood boundary (hatched) is generally smaller*** than preliminary simulation results of the January 2009 flood (solid blue) within Reach 1 of the South Fork Newaukum (See Inundation map for details).



The flood simulation predicts 0.5-4 ft of flooding to occur within pastured areas along the left bank between RM 12.5-14 and RM 14.5-15 despite these areas not being mapped within the 100-yr flood boundary. The un-regulated flood inundation extends as much as ***1,700 feet away from the river*** in these locations. The FEMA map also delineates an area of historical floodplain (6-10') as within the 100-year flood boundary near RM 14.0 even though the food simulation does not predict inundation in this location.

Context and Vicinity Map

South Fork Newaukum River - Reach 1

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel

Notes:
1. Aerial Imagery and Digital Elevation Model (DEM) are based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. River reach breaks were done by Natural Systems Design (NSD) in 2017.

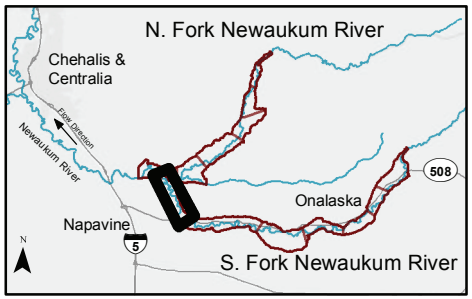
0 250 500 1,000 Feet

N

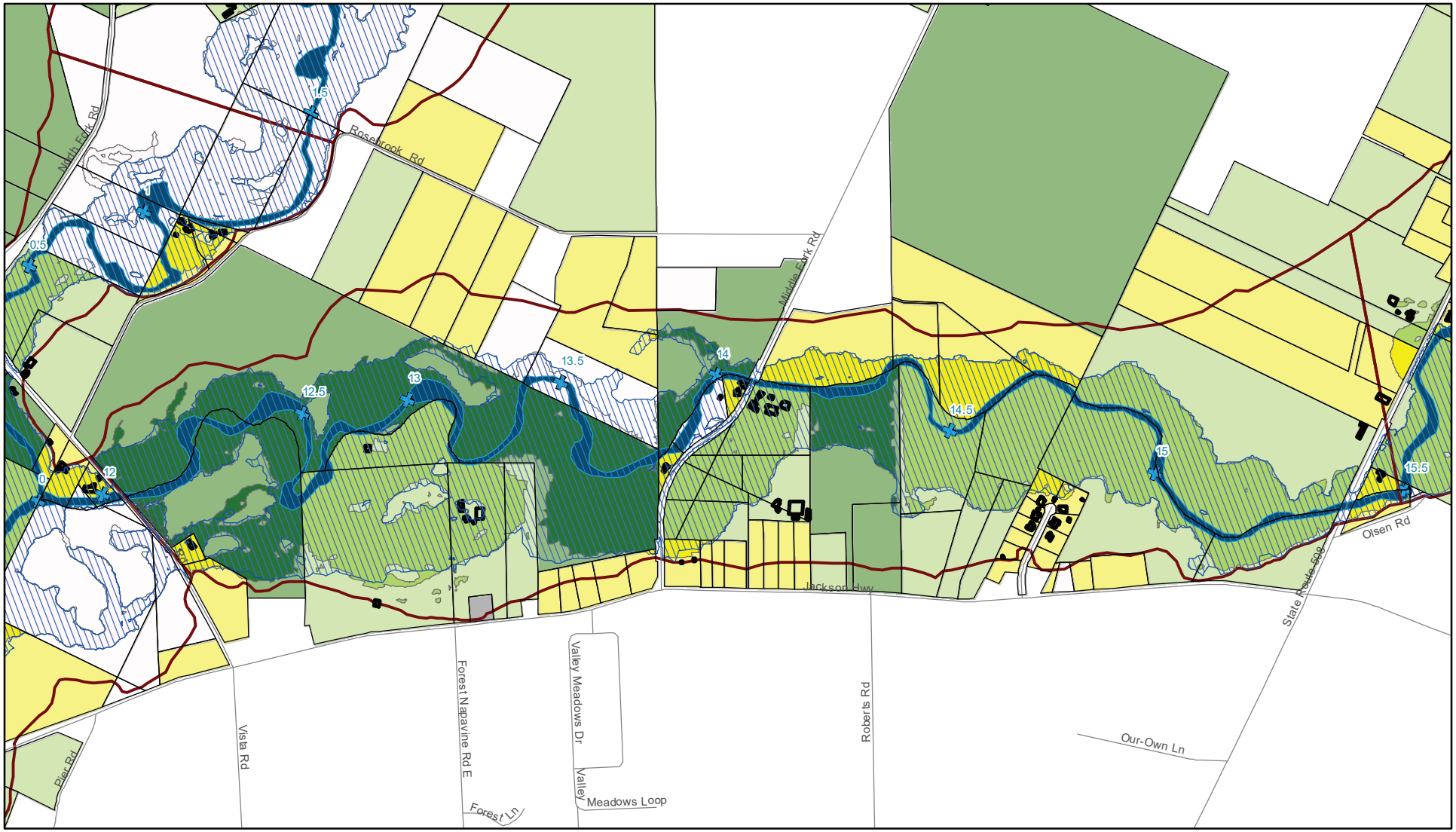
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Vicinity.mxd, Date Saved: 6/14/2018 2:26:17 PM



Existing Parcels Affected by Simulated 2009 Flood of Record

South Fork Newaukum River - Reach 1

Simulated 2009 Flood Extent

Affected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Undeveloped/Vacant

Unaffected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Trans/Util
- Undeveloped/Vacant

River Reach Boundary (NSD 2017)

Roads

River Mile

River Channel

Buildings

0 250 500 1,000 Feet

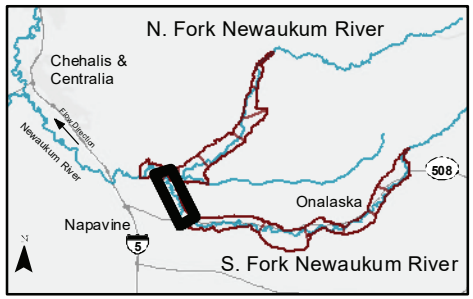
N

Notes:
1. Building/structures data from Lewis County,2013, additional buildings digitized by NSD, 2017.
2. Parcel data from Lewis County Assessor's Office. Accessed [8/18/2017].
3. The river channel delineated using 2017 LiDAR, represents low flow conditions for spring 2017.

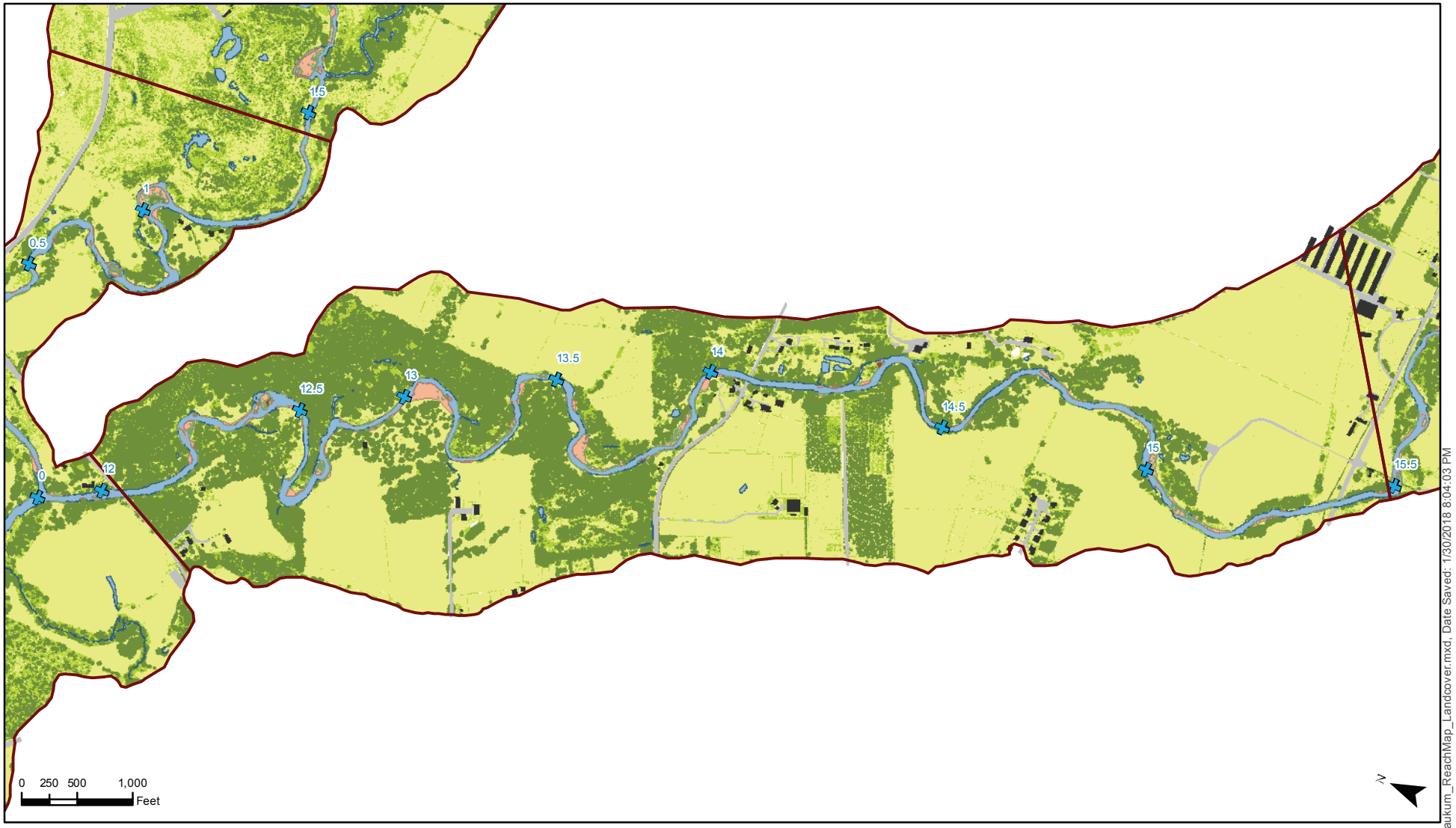
Vicinity Map

0 1 2 4 Miles

Location



\\NATUSYST-NAS1\Bellingham\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_UpdatedParcels.mxd, Date Saved: 6/14/2018 1:31:11 PM



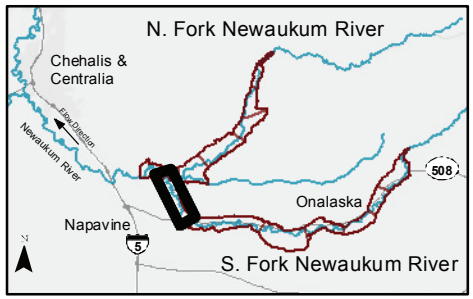
Existing Landcover Map

South Fork Newaukum River - Reach 1

River Reach (NSD, 2017)
River Mile
Landcover (NSD, 2017)
Pasture or Groundcover (< 3' tall)
Shrubs and Small Trees (3' to 20' tall)
Forest and Large Shrubs (> 20' tall)
Road
Structure (i.e. Building)
Gravel Bar
Vegetated Gravel Bar
Log Jam
Water

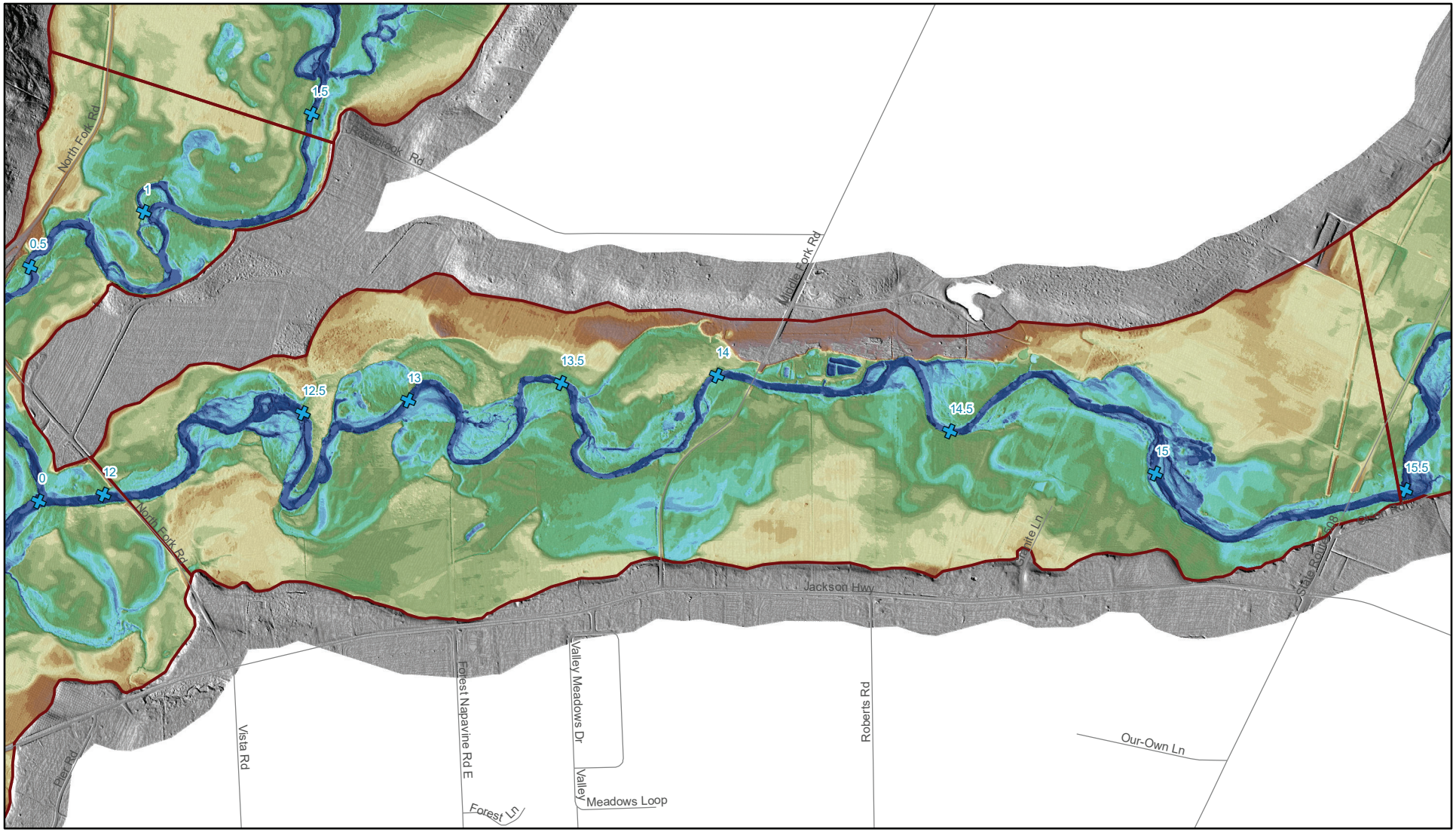
Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. There were statistically sigfnificant differences ($p<0.005$) between pasture and forest landcover types with erosion rates as follows:
a. Forest/shrubs: 6.0 +/- 3 ft/yr (n=20)
b. Pasture: 9.4+/- 5 ft/yr (n=24)
2.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
3.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
4. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Landcover.mxd, Date Saved: 1/30/2018 8:04:03 PM

Map 1 of 13



Relative Elevation Map (REM)

South Fork Newaukum River - Reach 1

River Reach Boundary (NSD 2017)
Roads
River Mile

Relative Elevation Above River Channel At Low Water (feet)

-4.6 - -1 | -1.1 - -2 | -2.1 - -3 | -3.1 - -4 | -4.1 - -5 | -5.1 - -6 | -6.1 - -7 | -7.1 - -8 | -8.1 - -9 | -9.1 - -10 | -10.1 - -11 | -11.1 - -12 | -12.1 - -13 | -13.1 - -14 | -14.1 - -15 | -15.1 - -16 | -16.1 - -17 | -17.1 - -18 | -18.1 - -19 | -19.1 - -20

0 250 500 1,000 Feet

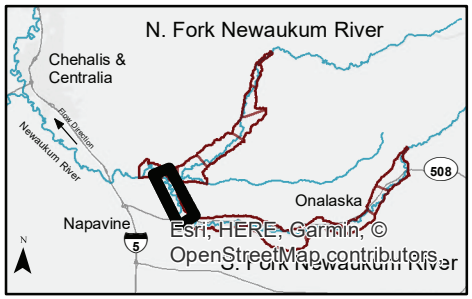
N

Notes:
1. Relative Elevation Model (REM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
3. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

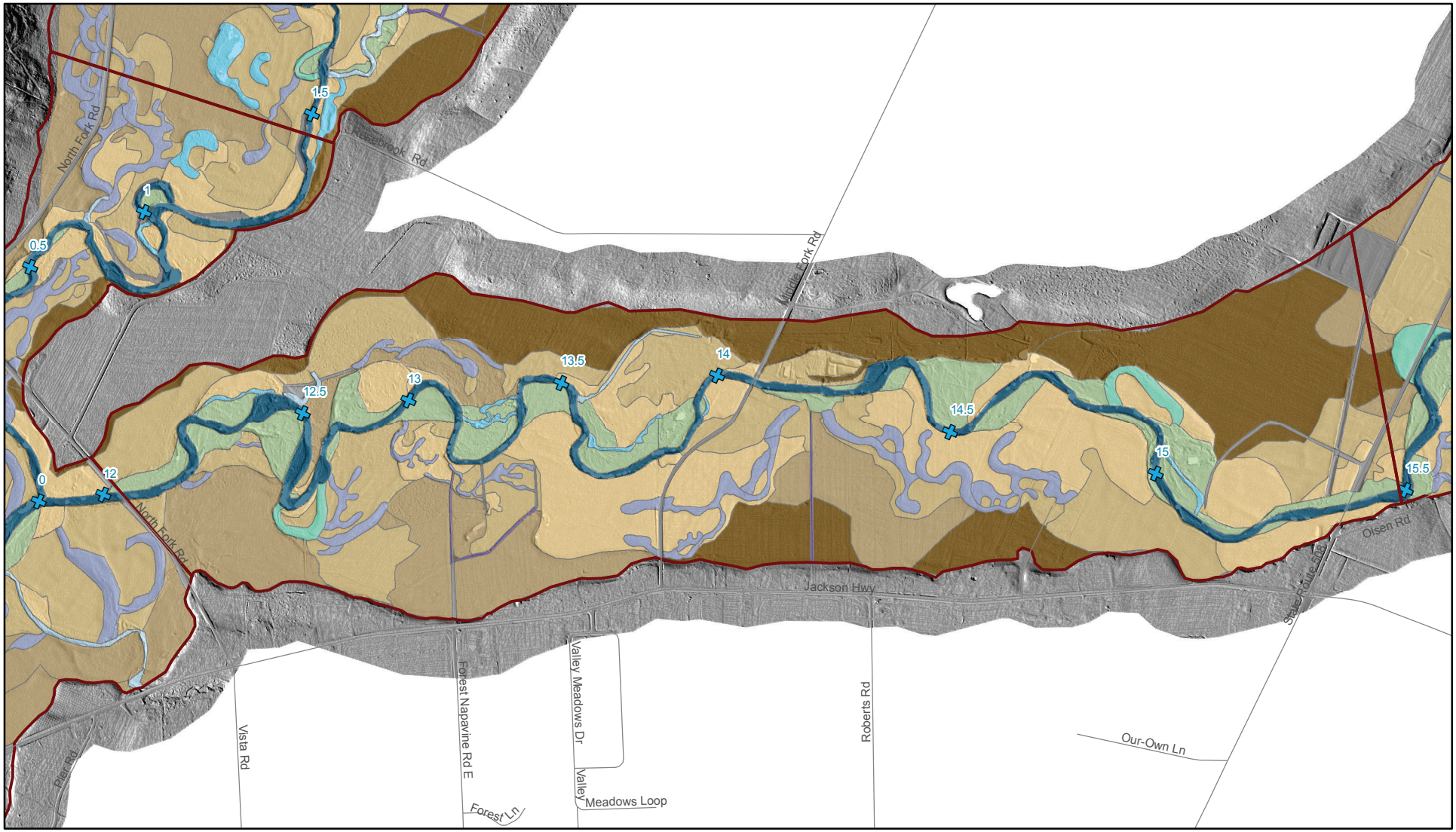
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_REM.mxd, Date Saved: 6/14/2018 1:12:00 PM



Geomorphic Landform Map

South Fork Newaukum River - Reach 1

River Reach Boundary (NSD 2017)
Roads
River Mile

Geomoprhic Landforms (NSD 2017)
- Main Channel
- Channel
- Abandoned Channel
- Oxbow
- Tributary
- Active Floodplain
- Historical Floodplain (4-6')
- Historical Floodplain (6-10')
- Historical Floodplain (10-15')
- High Terrace (>15')
- Infrastructure
- Road
- Ditch

0 250 500 1,000 Feet

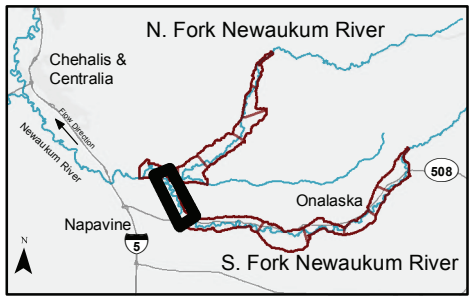
N

Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. The active and historical floodplain surfaces showed no statistically significant difference (p>0.1) and were determined to have the same erosion potential.
1.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
2.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4.Geomorphic landforms were delineated for the valley bottom which was defined where a slope break occured at the margin with the hillslope.

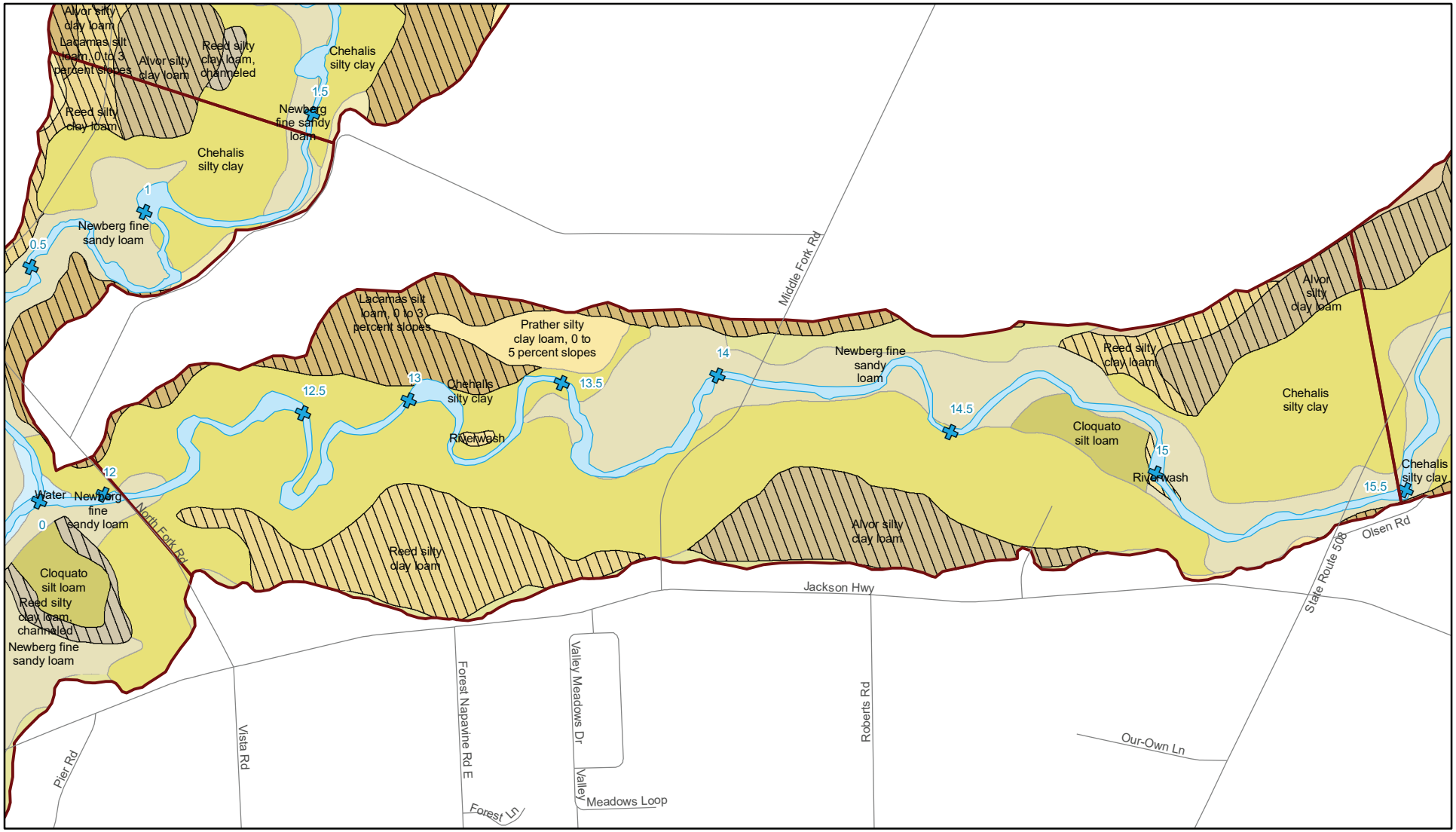
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Geomorph.mxd, Date Saved: 7/3/2018 12:35:06 PM



Existing Soils Map

South Fork Newaukum River - Reach 1

Notes:
1. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.
2. Soils data is from the USDA-SSURGO database.

0 250 500 1,000 Feet

N

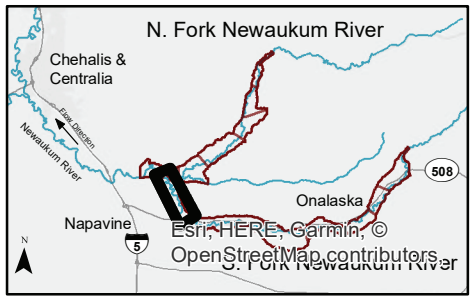
River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel
Hydric Soil

Soil Type
- Alvor silty clay loam
- Aquic Xerofluvents, overflow
- Chehalis silty clay
- Cloquato silt loam
- Lacamas silt loam, 0 to 3 percent slopes
- Lacamas silt loam, 3 to 8 percent slopes
- Newberg fine sandy loam
- Olequa silt loam, 0 to 5 percent slopes
- Prather silty clay loam, 0 to 5 percent slopes
- Prather silty clay loam, 5 to 15 percent slopes
- Reed silty clay loam
- Reed silty clay loam, channeled
- Riverwash
- Salkum silty clay loam, 0 to 5 percent slopes
- Salkum silty clay loam, 15 to 30 percent slopes
- Salkum silty clay loam, 5 to 15 percent slopes
- Scamman silty clay loam, 0 to 5 percent slopes
- Scamman silty clay loam, 5 to 15 percent slopes
- Water (From Soils Dataset)

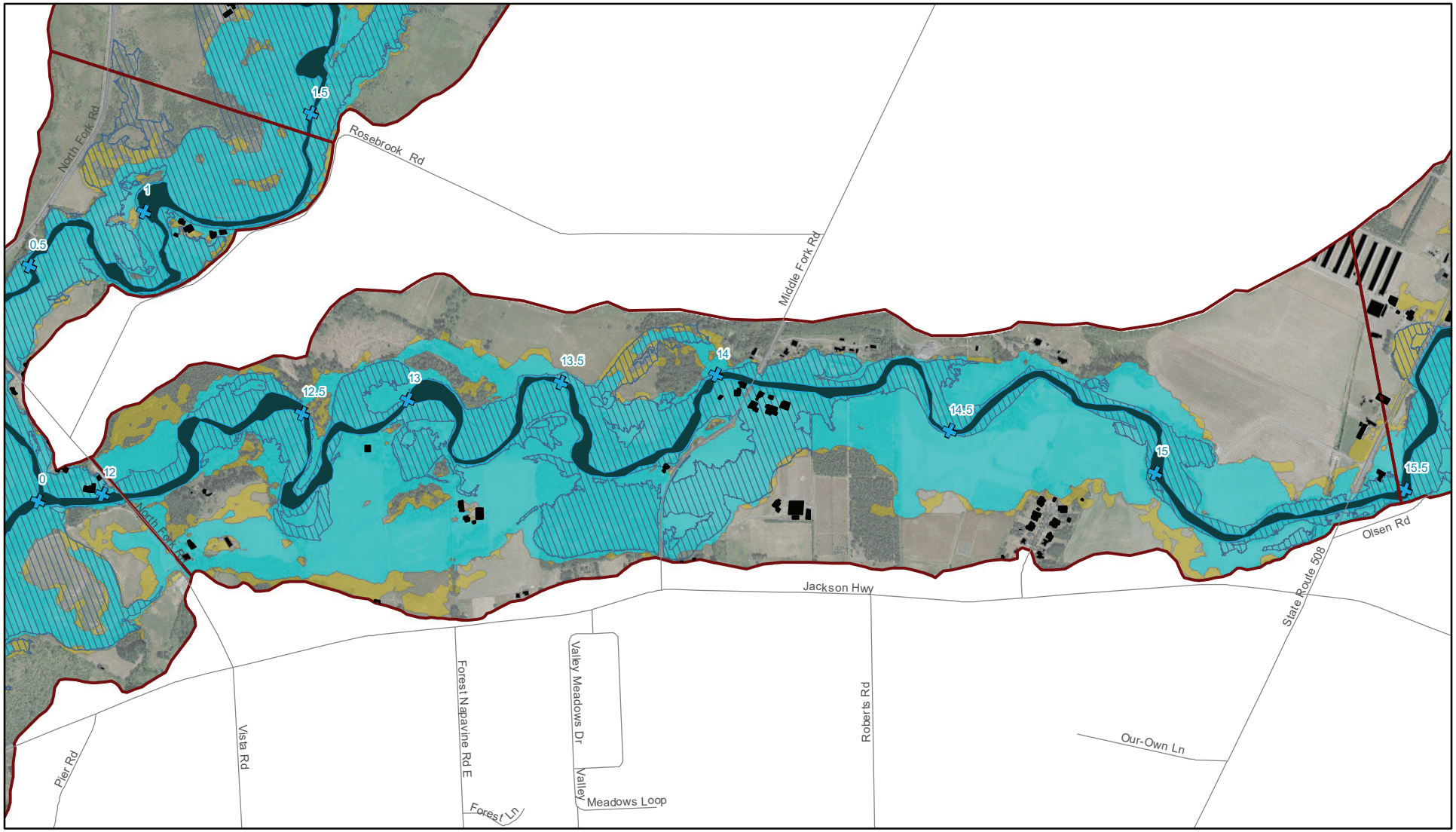
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Soils.mxd, Date Saved: 6/14/2018 1:17:11 PM



Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change

South Fork Newaukum River - Reach 1

- Buildings
- River Reach Boundary
- Roads
- River Mile
- 2017 River Channel
- Regulatory 100-year Flood Boundary (FEMA)
- 2009 Flood (Current Flood of Record)
- 2009 Flood Simulated With Estimated Climate Change Effects

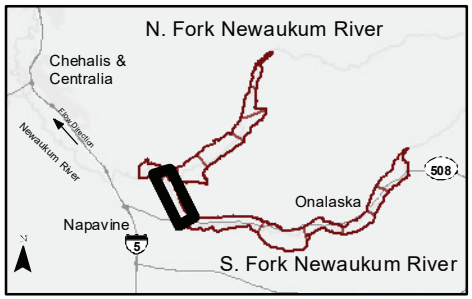
0 500 1,000 Feet

N

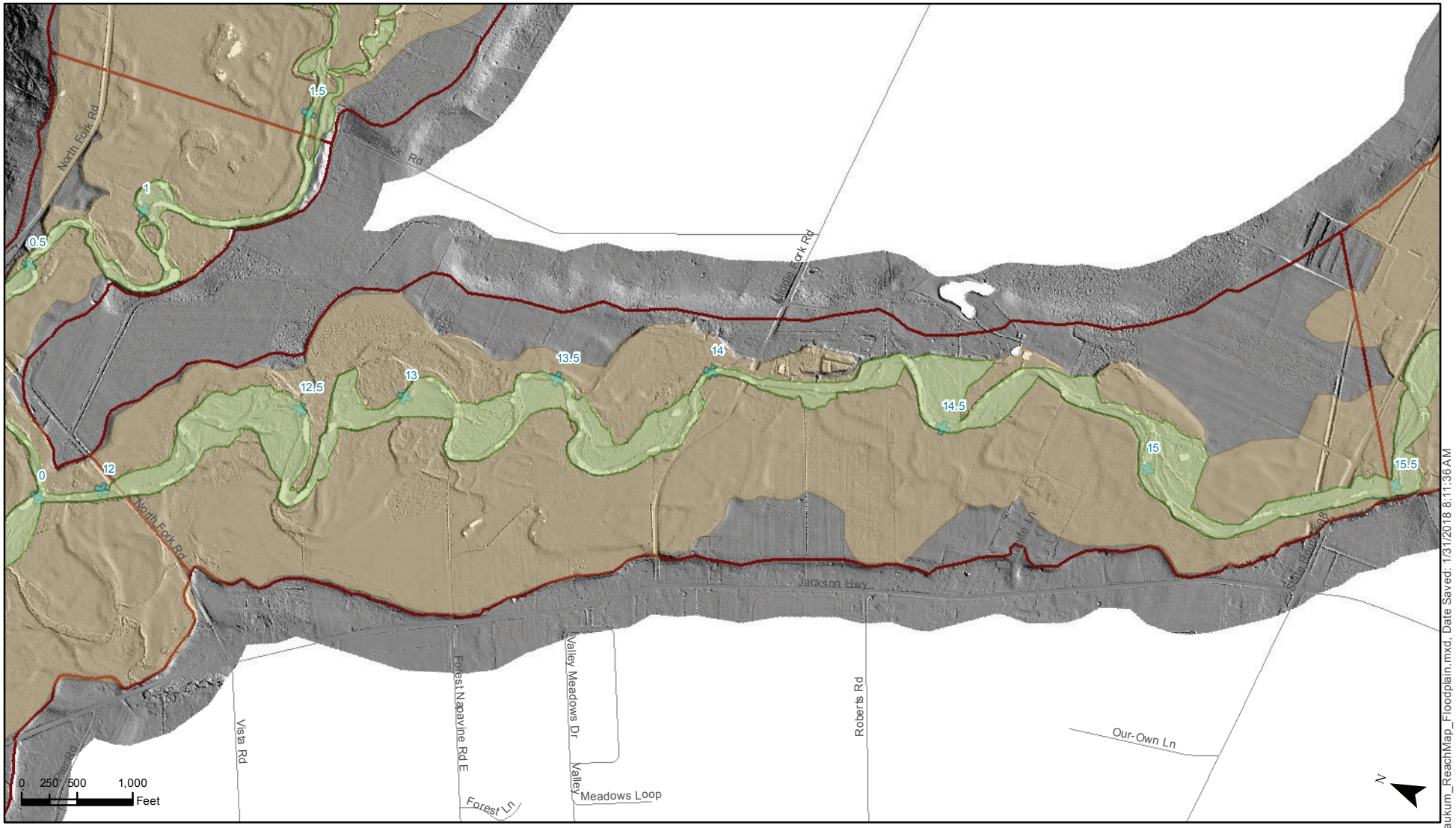
Notes:
1. Hydraulic simulation performed using RiverFlow2D - GPU. Simulation performed for the flood of record on the mainstem Newaukum Gage (USGS 12025000) which occurred from January 4 to Janaury 10th 2009. The estimated peak flow of 13,000 cfs occured on January 7th. Existing conditions 2009 flood simulation shows maximum simulated flood extent. Climate change flood simulation represents a 26% increase in 2009 flood water discharge.

2. Building (structures) dataset created by Lewis County, 2013. River reach boundary created by Natural Systems Design, 2017.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Inundation_ClimateChange.mxd, Date Saved: 10/10/2019 9:38:07 AM



Modern and Historical Floodplains

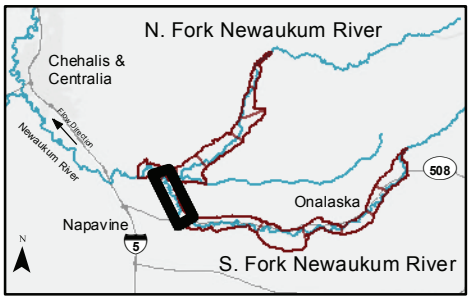
South Fork Newaukum River - Reach 1

Roads
River Reach (NSD, 2017)
River Mile
Modern Floodplain
Historical Floodplain

Notes:
1. The active and historical floodplain extents are based off of geomorphic landforms delineated by NSD.
2. The modern floodplain extent represents the current geomorphic surface within which moderate floods are contained. The modern floodplain was mapped as the active floodplain surface.
3. The historical floodplain includes terraces ranging from 4-15' and likely represent the extent of flood innundation during a moderate flood.
4. Digital Elevation Model (DEM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
5. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

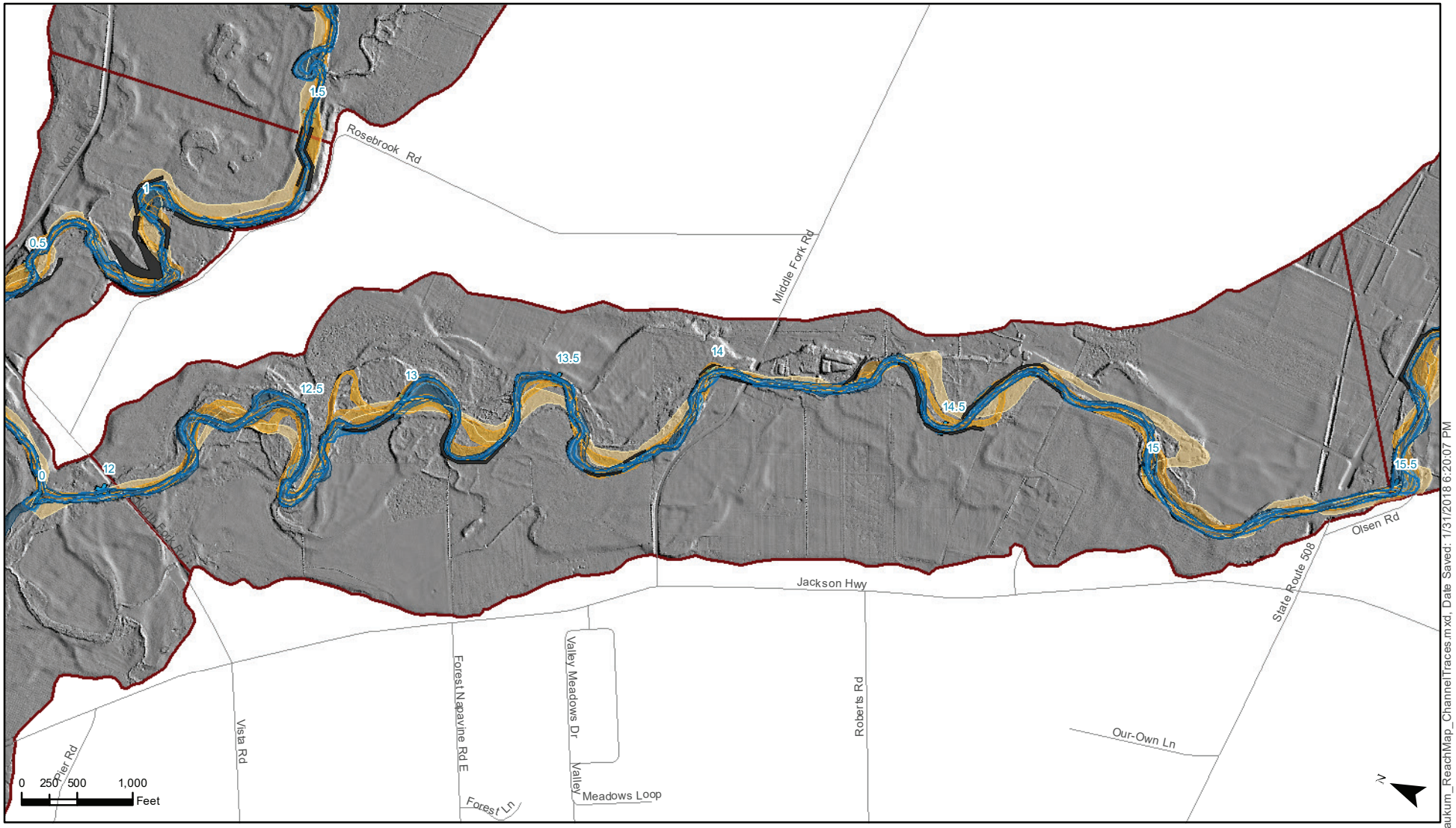
Vicinity Map

0 1 2 4 Miles
Location



Map 1 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Floodplain.mxd, Date Saved: 1/31/2018 8:11:36 AM



River Channel Changes from 1940 to 2017

South Fork Newaukum River - Reach 1

Bank Armoring (Incomplete Dataset*)
Roads
River Reach (NSD, 2017)
River Mile

River Channel Locations By Year
1940
1950
1980
1990
2006
2009
2011
2015
2017

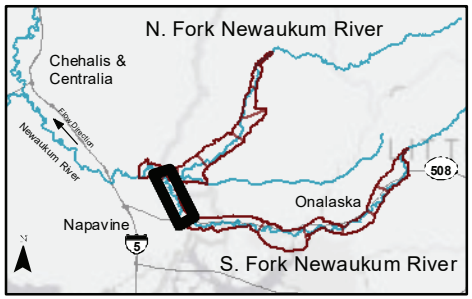
Notes:
*The bank armoring dataset only covers the lower reaches of the South and North Fork Newaukum Rivers (RM 12-22.5 on the South Fork and RM 0-2 on the North Fork. The data was generated during Fall 2017 field observations by NSD.

1. River Channel locations were digitally delineated as polygons surrounding the active un-vegetated channel from aerial photographs.
2. Digital Elevation Model (DEM) based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map

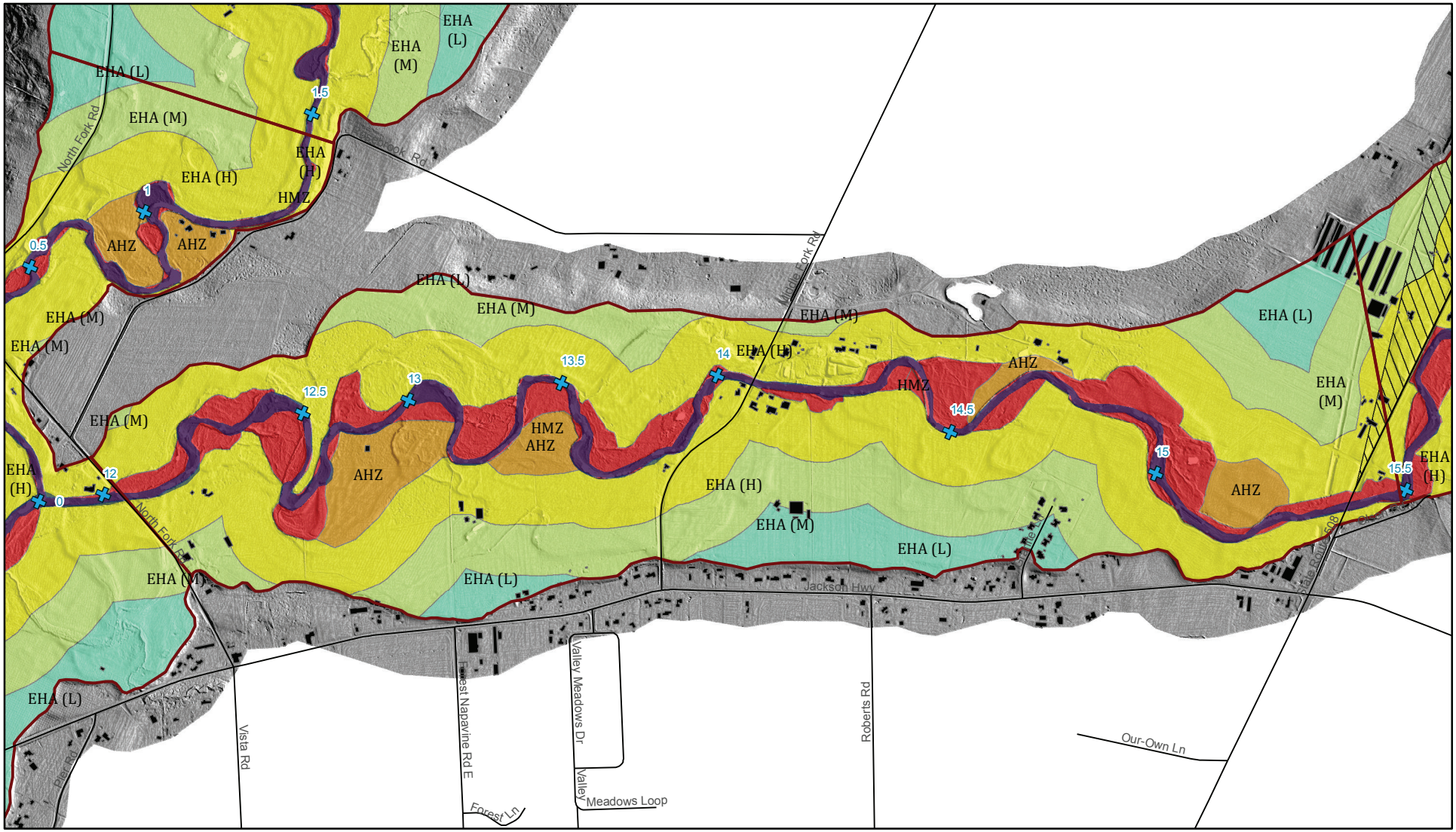
0 1 2 4 Miles

Location



Map 1 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_ChannelTraces.mxd, Date Saved: 1/31/2018 6:20:07 PM



Erosion Hazard Analysis

South Fork Newaukum River - Reach 1

River Reach Boundary (NSD 2017)
Roads
Buildings
River Mile
River Channel
Disconnected EHAs

Erosion Hazards
HMZ
AHZ
EHA (H)
EHA (M)
EHA (L)

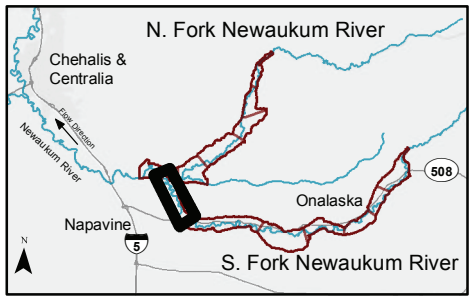
0 250 500 1,000 Feet

N

Notes:
1. Erosion hazard delineation is based on methods outlined in Rapp and Abbe (2003) "A Framework for Delineating Channel Migration Zones" WA Dept. of Ecology and Transportation.
2. Erosion hazards were delineated using the average historical channel migration rate between 1951-2017 (4.5 ft/yr). See Methods appendix for detailed description of delineation methodology.

HMZ - Historical Migration Zone
AHZ - Avulsion Hazard Zone
EHA (H) - Erosion Hazard Area High
EHA (M) - Erosion Hazard Area Medium
EHA (L) - Erosion Hazard Area Low
Disconnected EHAs - Areas on the non-river side of SR 508 and North Fork Rd.

Vicinity Map



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Erosion.mxd, Date Saved: 6/15/2018 10:37:25 AM

South Fork Newaukum River Reach 2

Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description

Vegetation, Soils and Wetlands

Reach 2 of the South Fork Newaukum River valley bottom occupies over 1,000 acres, including the river channel. The floodplains and terraces are currently co-dominated by 525 acres of pasture or mowed grass, and 327 acres of mixed forest (See Landcover Map in Appendix). Together, these landcover classes make up 81% of the floodplain landcover. The rest of the valley bottom, is a mixture of shrubs, roads and buildings, and river channels.

% Area	Acres	Landcover
50%	525	Pasture or Groundcover
31%	327	Forest
10%	105	Shrubs
4%	38	Road
3%	34	Water
1%	14	Gravel Bar
1%	12	Structure
1%	5	Vegetated Gravel Bar
0%	1	Log Jam
100%	**1,061**	**Total**

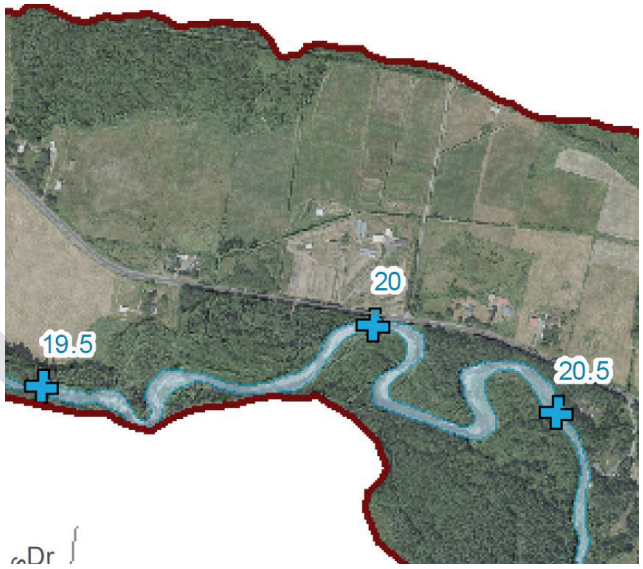
The soils of reach 2 of the South Fork Newaukum River valley bottom are comprised of Newberg fine sandy loam in the active channel area-- optimal conditions for cottonwood bottomland-- and Chehalis silty clay up on the floodplain, which lends itself to other types of forest (See Soils Map in Appendix). As the valley topography increases in elevation from the river channel to the valley wall, hydric silty clay loam soils appear on the landscape. These hydric soils are an indicator of wetland soil formation processes.

Infrastructure, Buildings & Ownership

Reach 2 of the South Fork Newaukum River has **two major bridge crossings**, at Guerrier Road and Gish Road. The **South Fork Newaukum River abuts the road embankment six (6) times in this reach, all of which are armored with riprap.**

There are numerous homes and farms in this reach, about 243 structures total, including Matthiesen Farm on the north side of SR 508, HDC Ranch, and numerous single-family homes and outbuildings with several structures on the riverbank.

The 176 parcels that comprise this valley bottom are almost entirely privately owned, by 126 landowners. There is one, 1.3 acre, parcel owned by Lewis County in this reach. The largest private landowners are Cascade Ranch, LLC, which owns about 8% (84 acres) of the total the valley bottom area and Flidais Forests, LLC, which owns about 5% (53 acres). This area calculation does not include the land outside of the valley bottom analysis area.



Description of Parcels in the Floodplain

In order to understand the influence of the river on landowners, parcels in the simulated 2009 flood event* were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the higher the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel. ***Of the 126 landowners in the valley bottom, 71 landowners had property that was inundated in the simulated 2009 flooded-area, and 20 land owners have property that is more than 75% within the approximated inundated area, or about 167 parcel-acres*** (see table below). The dominant assessed land use for these parcels is single family residential.

Landuse description of parcels with > 75% area in flooded area

Assessed Land Use Description	Number of Parcels	Acres Flooded *	Total Parcel Acres	Largest Landowner (Parcel Acres)
single-residential	14	102	112	R. & B. Roll (19 ac.)
undeveloped/vacant	7	27	28	B. & L. Jones (16 ac.)
agriculture	2	25	27	A. & M. Briggs (17 ac.)
TOTAL	**23**	**154**	**167**	**20 Landowners w/ > 75% land in flooded area**

Flooded buildings

The number of buildings in the simulated 2009 flooded area was ~45, including residences and outbuildings (see inundation map for approximate locations).

South Fork Newaukum River Reach 2

Geomorphic Reach Description

Reach 2 of the South Fork Newaukum River is located between the Jackson Highway bridge (RM 15.5) to RM 20.75 where there is a distinct widening in the valley as it progresses upstream. The reach has an average slope of 0.0032 ft/ft (or 0.32%) and has a meandering pool-riffle morphology (Table 1, REM map) (Montgomery and Buffington, 1997). There are no major tributary junctions within this reach, although there are several small streams that enter from both the north and south sides of the valley.

Geomorphic Landforms

The river is contained within an ***inset-floodplain corridor*** which has ***incised an average of 4.2 ft*** below the historical floodplain (See example of inset floodplain identified by orange arrow in figure and Geomorphic Landform Map). The corridor is currently widening into broader historical floodplain surfaces, especially in locations without bank protection. ***A dense network of abandoned and relict channels*** is evident within the historical floodplain and can be seen in aerial photography. Some of these relict channel features are artificially-connected by ditches, presumably to aid in drainage of land. The ***modern active floodplain is 4.7 times narrower than the historical floodplain***, which likely would have spanned the entirety of the river valley (Table 1). Relevant non-alluvial landforms include glacial outwash terraces along the left side of the valley between RM 16.5-19.5 and along the right side of the valley between RM 18-18.5. There is evidence of meander scalloping within the southern terrace (between RM 18.5-19) indicating that it is capable of being eroded.

Channel Migration and Erosion

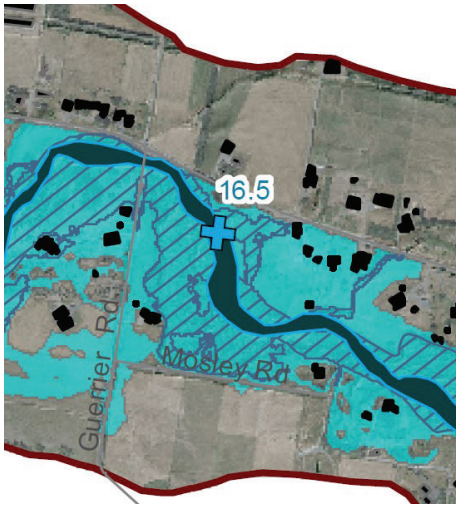
There has been recent and active channel migration within Reach 2 as the channel continues to widen the inset-floodplain corridor (See Channel Changes Map). Roughly 9% of the banks within this reach some form of hardening with the biggest structures residing on northward migrating meander bends that abut State Highway 508. In these locations, significant rip-rap and wooden revetments have been constructed to prevent erosion of the road prism. In the remainder of the reach the channel continues to actively migrate by eroding banks comprised of historical floodplain material (i.e. highly erodible), avulsing into previously occupied channels, and cutting off meander bends. The channel migration is occurring into both forested and pastured lands (such as the pasture between RM 15.5-16)

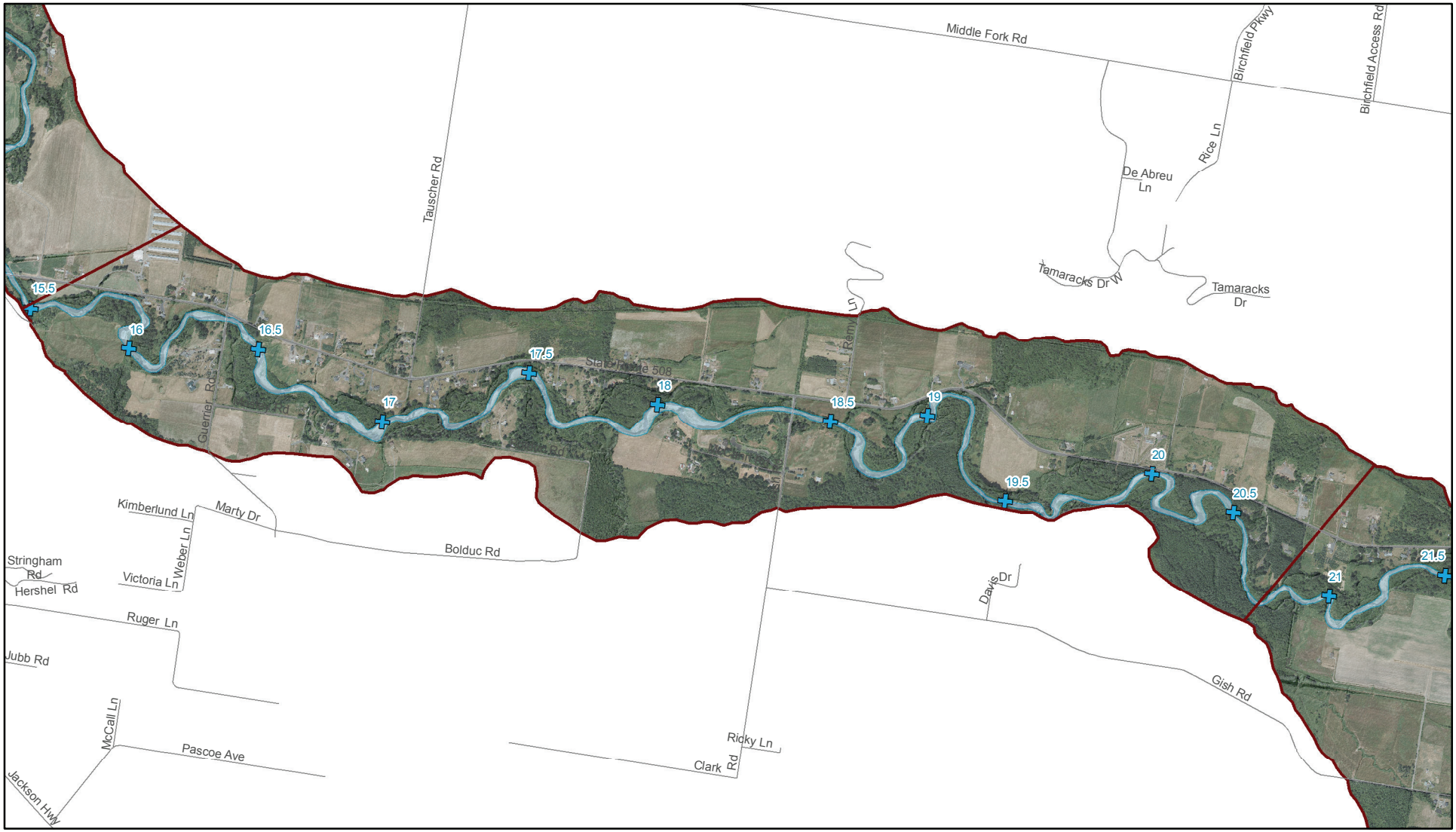
Table 1: Reach Statistics

Geomorphic Reach Description Statistics		Units
Slope	0.0032	ft/ft
Centerline Length	27,918	ft
Average Depth of Incision	4.2	ft
Historic Floodplain Average Width	1408	ft
Active Floodplain Average Width	299	ft
Historic Floodplain: Active Floodplain	5	ft/ft
Flood Defense Length	2,566	ft
Flood Defense Length/Channel Length	0	ft/ft
Road Length	29,177	ft
Total Reach Area	1067	acres
Slope	0.0032	ft/ft

2009 Flooding & FEMA boundary

The FEMA 100-year flood boundary is generally smaller (hatched) than preliminary simulation results of the January 2009 flood (solid blue) within Reach 2 of the South Fork Newaukum (See Inundation map). For example, the flood simulation predicts (and landowner accounts have confirmed) ~3 ft of flooding to occur over-top of Guerrier Rd. south of the bridge crossing despite these areas not being mapped within the 100-yr flood boundary. Other areas of difference include flooding along the left floodplain between RM 15.5-16 and RM 17.5-17.75, across Gish Rd., within the right floodplain between R M19-19.5 and along both left and right floodplains between RM 20-20.75. The un-regulated flood inundation extends as much as 1,200 feet away from the river in these locations and crosses two major roads.





Context and Vicinity Map

South Fork Newaukum River - Reach 2

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel

Notes:
1. Aerial Imagery and Digital Elevation Model (DEM) are based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. River reach breaks were done by Natural Systems Design (NSD) in 2017.

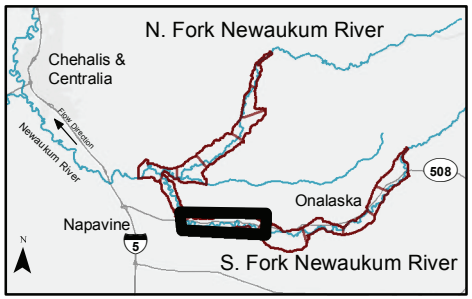
0 250 500 1,000 Feet

N

Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Vicinity.mxd, Date Saved: 6/14/2018 2:26:17 PM

Existing Parcels Affected by Simulated 2009 Flood of Record

South Fork Newaukum River - Reach 2

Simulated 2009 Flood Extent

Affected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Trans/Util
- Undeveloped/Vacant
- Water

Unaffected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Commercial Industrial; Commercial Retail
- Mining/Forestry
- Public/Quasi-Public
- Trans/Util
- Undeveloped/Vacant
- Water

- River Reach Boundary (NSD 2017)
- Roads
- River Mile
- River Channel
- Buildings

Notes:
1. Building/structures data from Lewis County,2013, additional buildings digitized by NSD, 2017.
2. Parcel data from Lewis County Assessor's Office. Accessed [8/18/2017].
3. The river channel delineated using 2017 LiDAR, represents low flow conditions for spring 2017.

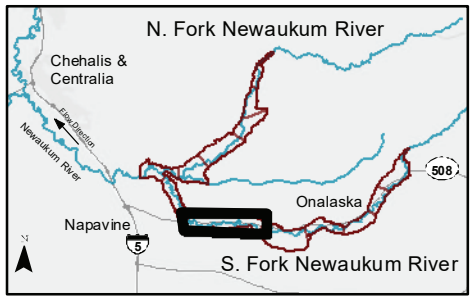
0 250500 1,000 Feet

N

Vicinity Map

0 1 2 4 Miles

Location



\\NATUSYST-NAS1\Bellingham\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_UpdatedParcels.mxd, Date Saved: 6/14/2018 1:31:11 PM

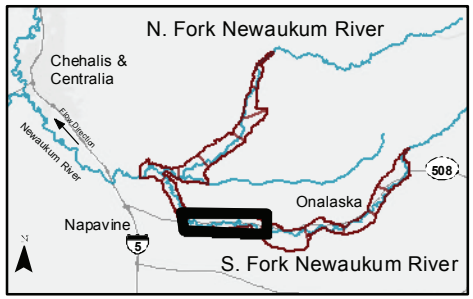
Existing Landcover Map

South Fork Newaukum River - Reach 2

River Reach (NSD, 2017)
River Mile
Landcover (NSD, 2017)
Pasture or Groundcover (< 3' tall)
Shrubs and Small Trees (3' to 20' tall)
Forest and Large Shrubs (> 20' tall)
Road
Structure (i.e. Building)
Gravel Bar
Vegetated Gravel Bar
Log Jam
Water

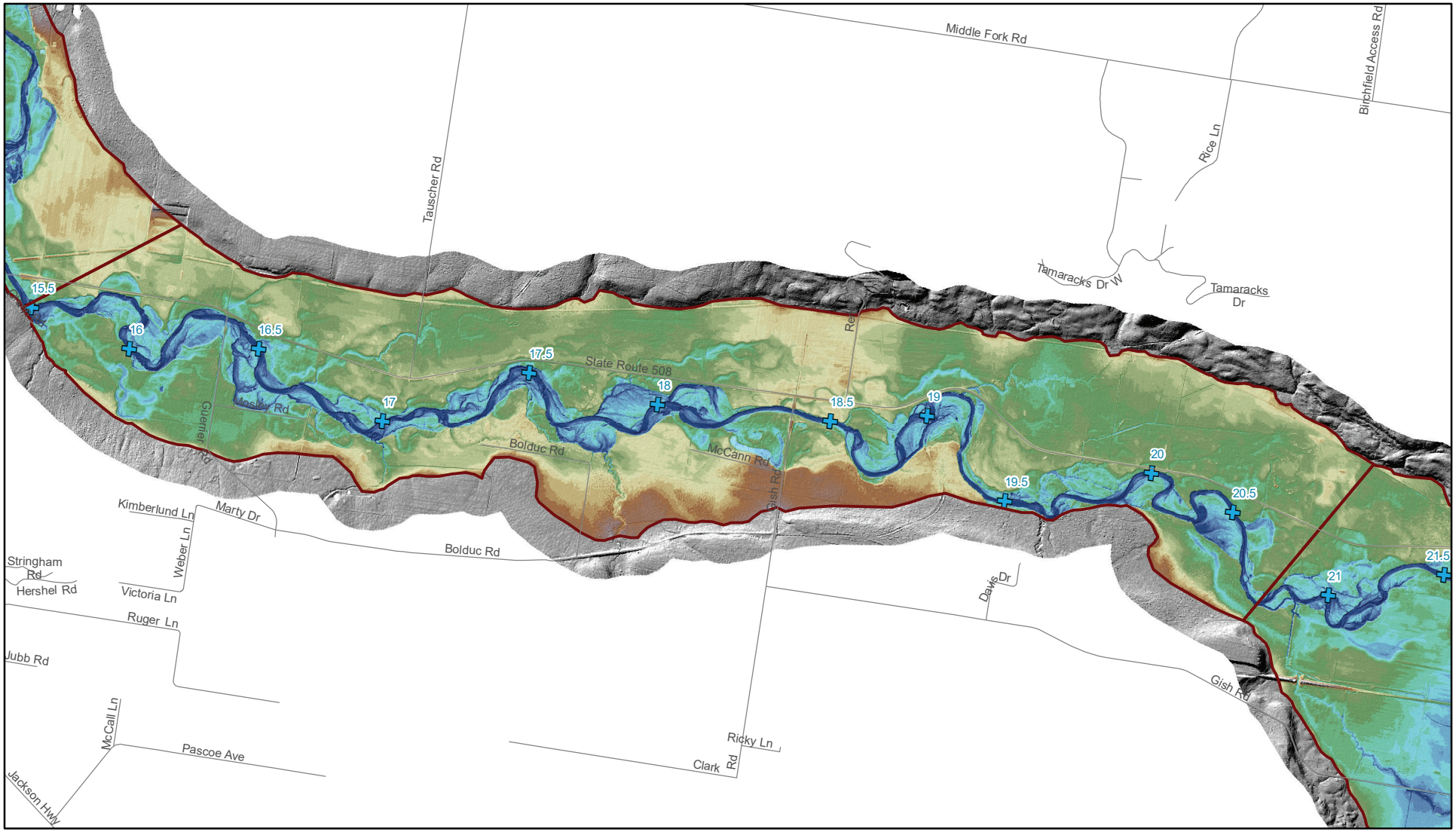
Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. There were statistically sigfnificant differences ($p<0.005$) between pasture and forest landcover types with erosion rates as follows:
a. Forest/shrubs: 6.0 +/- 3 ft/yr (n=20)
b. Pasture: 9.4+/- 5 ft/yr (n=24)
2.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
3.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
4. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Landcover.mxd, Date Saved: 1/30/2018 8:04:03 PM

Map 2 of 13



Relative Elevation Map (REM)

South Fork Newaukum River - Reach 2

River Reach Boundary (NSD 2017)
Roads
River Mile

Relative Elevation Above River Channel At Low Water (feet)

-4.6 - -1 -1.1 - -2 -2.1 - -3 -3.1 - -4 -4.1 - -5 -5.1 - -6 -6.1 - -7 -7.1 - -8 -8.1 - -9 -9.1 - -10 -10.1 - -11 -11.1 - -12 -12.1 - -13 -13.1 - -14 -14.1 - -15 -15.1 - -16 -16.1 - -17 -17.1 - -18 -18.1 - -19 -19.1 - -20

0 250 500 1,000 Feet

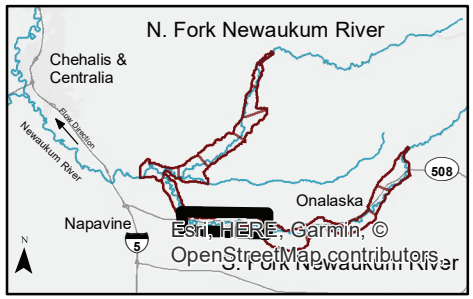
N

Notes:
1. Relative Elevation Model (REM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
3. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

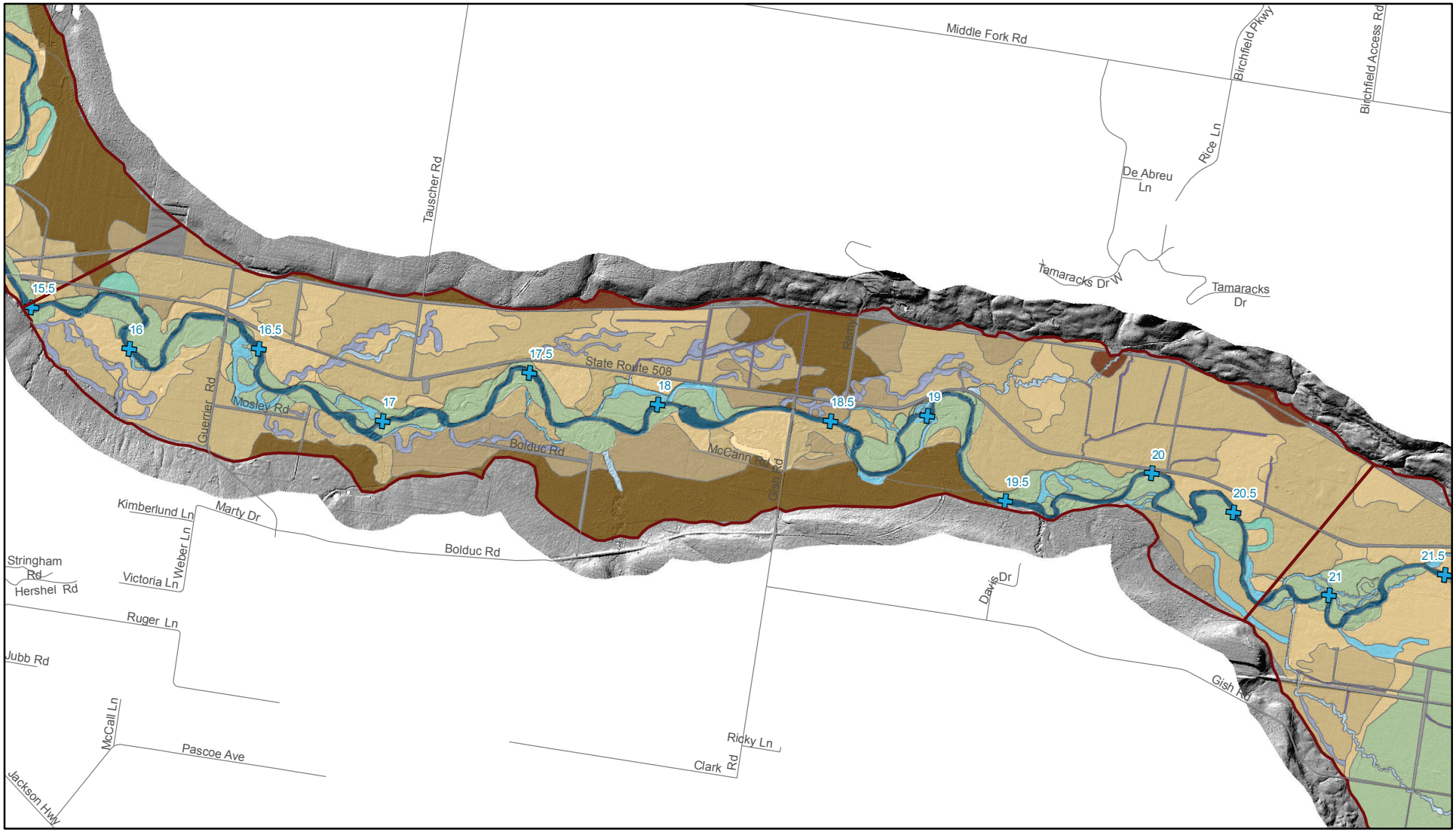
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_REM.mxd, Date Saved: 6/14/2018 1:12:00 PM



Geomorphic Landform Map

South Fork Newaukum River - Reach 2

River Reach Boundary (NSD 2017)
Roads
River Mile

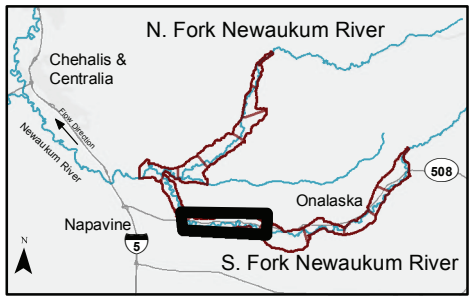
Geomoprhic Landforms (NSD 2017)
- Main Channel
- Channel
- Abandoned Channel
- Oxbow
- Tributary
- Active Floodplain
- Historical Floodplain (4-6')
- Historical Floodplain (6-10')
- Historical Floodplain (10-15')
- High Terrace (>15')
- Alluvial Fan
- Infrastructure
- Road
- Ditch

0 250 500 1,000 Feet

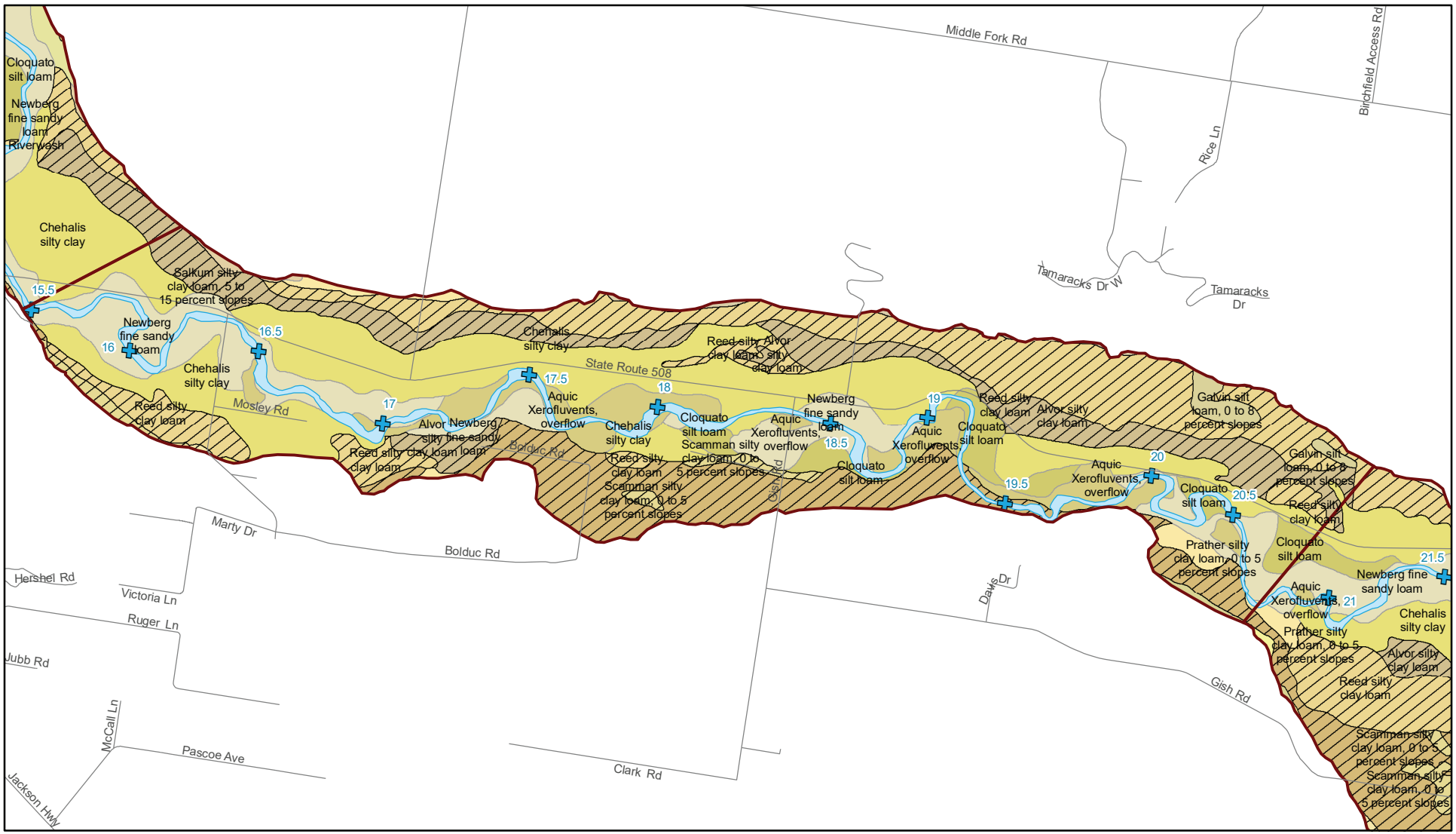
N

Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. The active and historical floodplain surfaces showed no statistically significant difference (p>0.1) and were determined to have the same erosion potential.
1.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
2.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4.Geomorphic landforms were delineated for the valley bottom which was defined where a slope break occured at the margin with the hillslope.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Geomorph.mxd, Date Saved: 7/3/2018 12:35:06 PM



Existing Soils Map

South Fork Newaukum River - Reach 2

Notes:
1. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.
2. Soils data is from the USDA-SSURGO database.

0 250500 1,000 Feet

N

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel
Hydric Soil

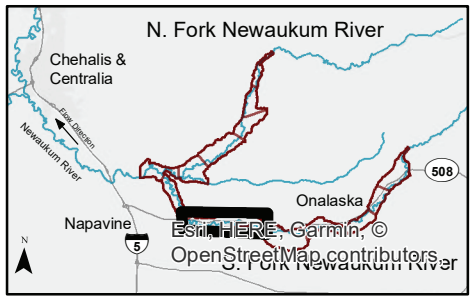
Soil Type

- Alvor silty clay loam
- Aquic Xerofluvents, overflow
- Chehalis silty clay
- Cinebar silt loam, 0 to 8 percent slopes
- Cloquato silt loam
- Galvin silt loam, 0 to 8 percent slopes
- Lacamas silt loam, 0 to 3 percent slopes
- Lacamas silt loam, 3 to 8 percent slopes
- Newberg fine sandy loam
- Prather silty clay loam, 0 to 5 percent slopes
- Prather silty clay loam, 5 to 15 percent slopes
- Reed silty clay loam
- Riverwash
- Salkum silty clay loam, 0 to 5 percent slopes
- Salkum silty clay loam, 15 to 30 percent slopes
- Salkum silty clay loam, 30 to 65 percent slopes
- Salkum silty clay loam, 5 to 15 percent slopes
- Scamman silty clay loam, 0 to 5 percent slopes
- Scamman silty clay loam, 5 to 15 percent slopes
- Xerorthents, steep

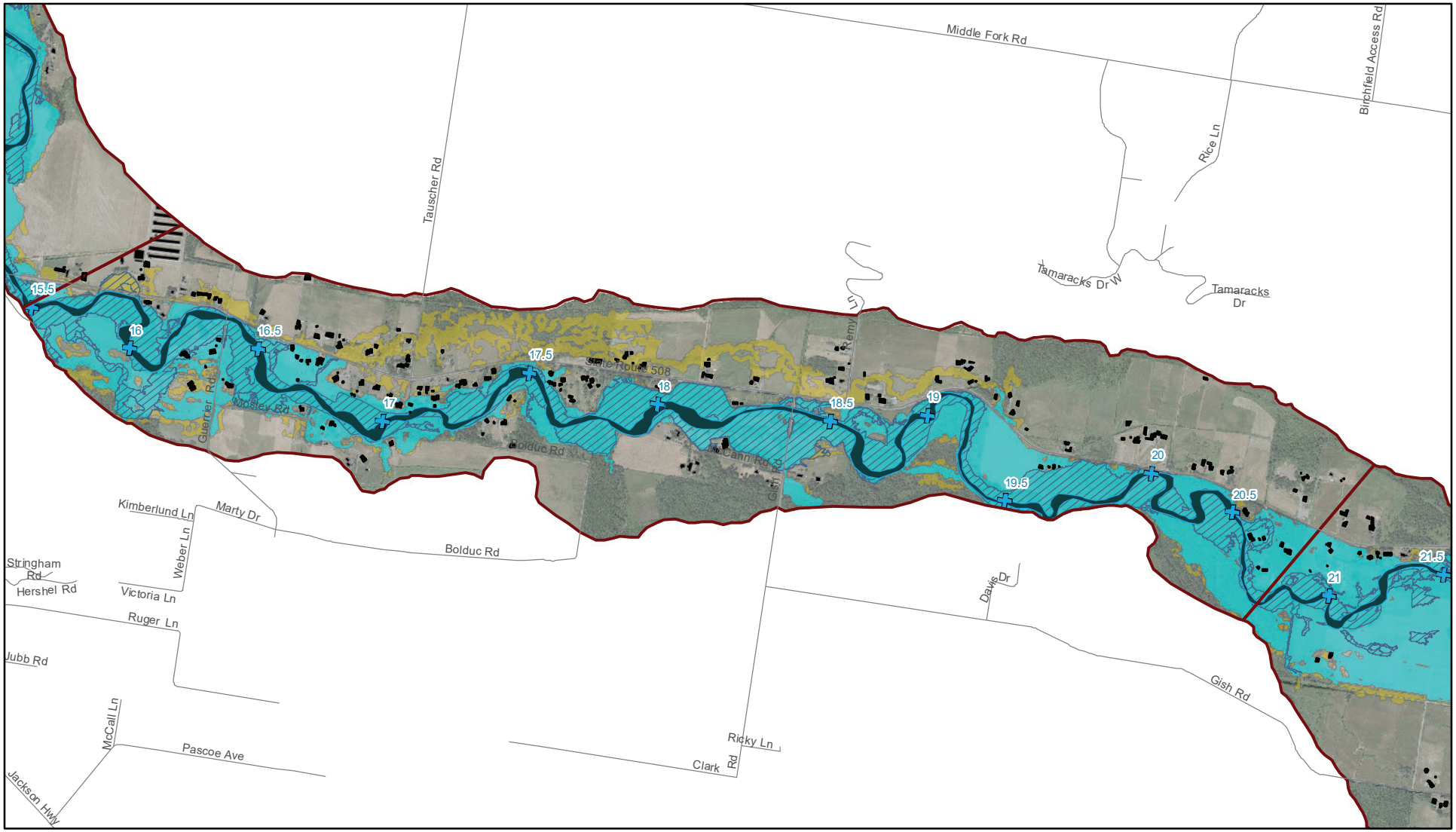
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Soils.mxd, Date Saved: 6/14/2018 1:17:11 PM



Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change

South Fork Newaukum River - Reach 2

- Buildings
- River Reach Boundary
- Roads
- River Mile
- 2017 River Channel
- Regulatory 100-year Flood Boundary (FEMA)
- 2009 Flood (Current Flood of Record)
- 2009 Flood Simulated With Estimated Climate Change Effects

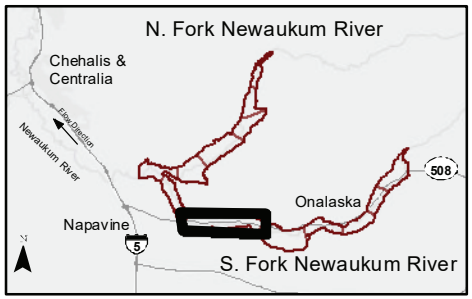
0 500 1,000 Feet

N

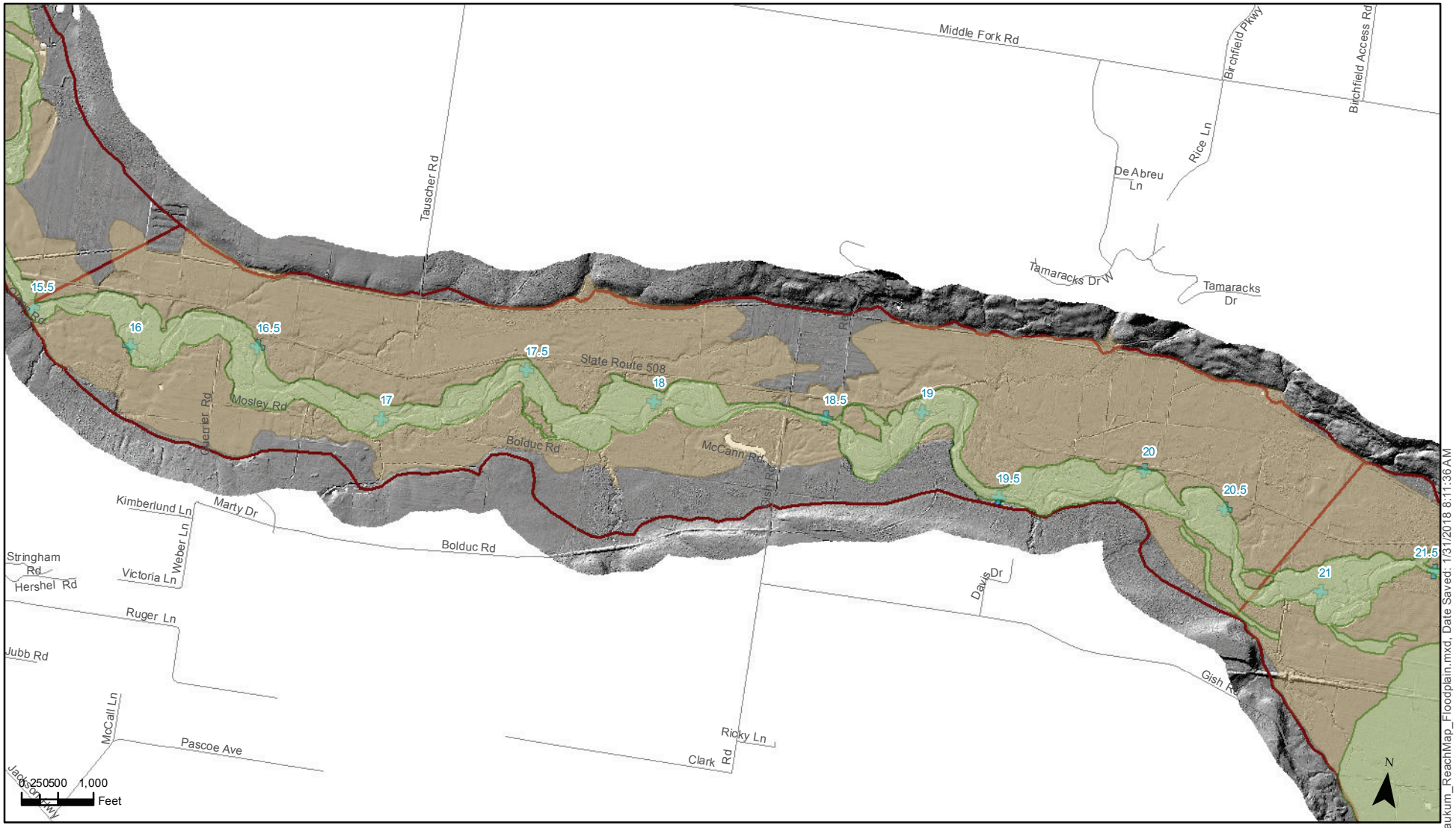
Notes:
1. Hydraulic simulation performed using RiverFlow2D - GPU. Simulation performed for the flood of record on the mainstem Newaukum Gage (USGS 12025000) which occurred from January 4 to Janaury 10th 2009. The estimated peak flow of 13,000 cfs occured on January 7th. Existing conditions 2009 flood simulation shows maximum simulated flood extent. Climate change flood simulation represents a 26% increase in 2009 flood water discharge.

2. Building (structures) dataset created by Lewis County, 2013. River reach boundary created by Natural Systems Design, 2017.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Inundation_ClimateChange.mxd, Date Saved: 10/10/2019 9:38:07 AM



Modern and Historical Floodplains

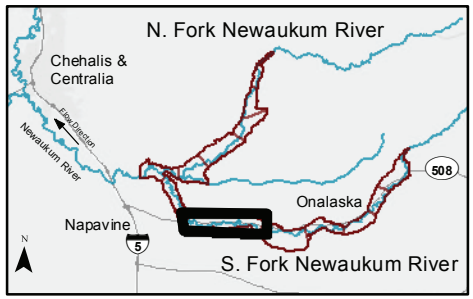
South Fork Newaukum River - Reach 2

- Roads
- River Reach (NSD, 2017)
- River Mile
- Modern Floodplain
- Historical Floodplain

Notes:
1. The active and historical floodplain extents are based off of geomorphic landforms delineated by NSD.
2. The modern floodplain extent represents the current geomorphic surface within which moderate floods are contained. The modern floodplain was mapped as the active floodplain surface.
3. The historical floodplain includes terraces ranging from 4-15' and likely represent the extent of flood innundation during a moderate flood.
4. Digital Elevation Model (DEM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
5. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

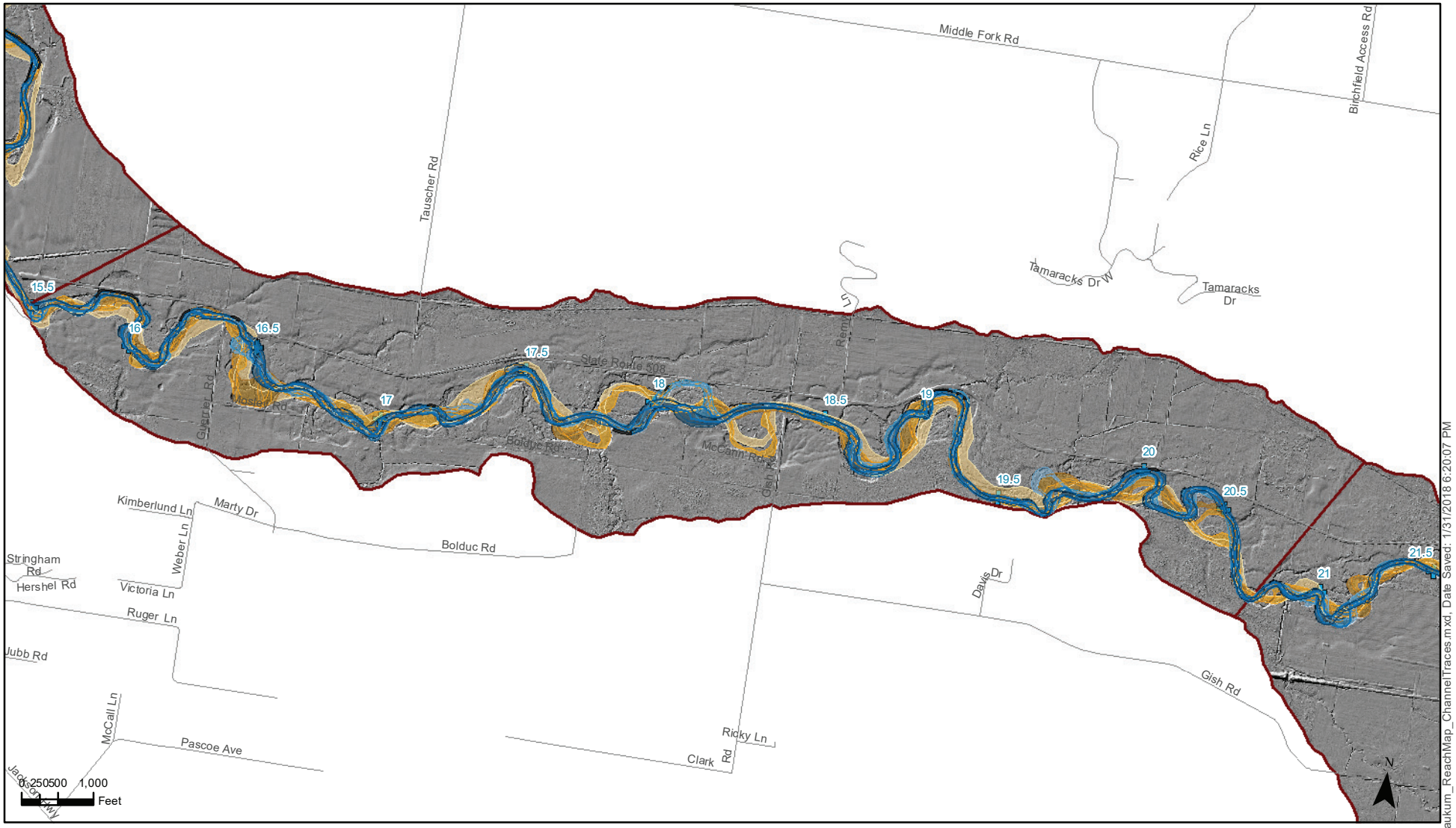
Vicinity Map

0 1 2 4 Miles — Location



Map 2 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Floodplain.mxd, Date Saved: 1/31/2018 8:11:36 AM



River Channel Changes from 1940 to 2017

South Fork Newaukum River - Reach 2

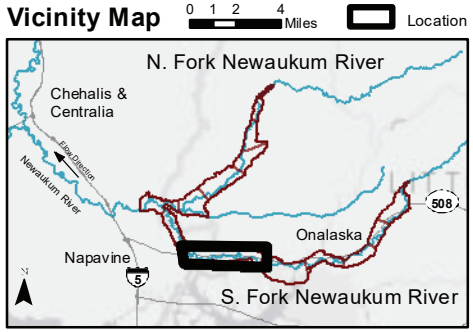
Bank Armoring (Incomplete Dataset*)
Roads
River Reach (NSD, 2017)
River Mile

River Channel Locations By Year
1940
1950
1980
1990
2006
2009
2011
2015
2017

Notes:
*The bank armoring dataset only covers the lower reaches of the South and North Fork Newaukum Rivers (RM 12-22.5 on the South Fork and RM 0-2 on the North Fork. The data was generated during Fall 2017 field observations by NSD.

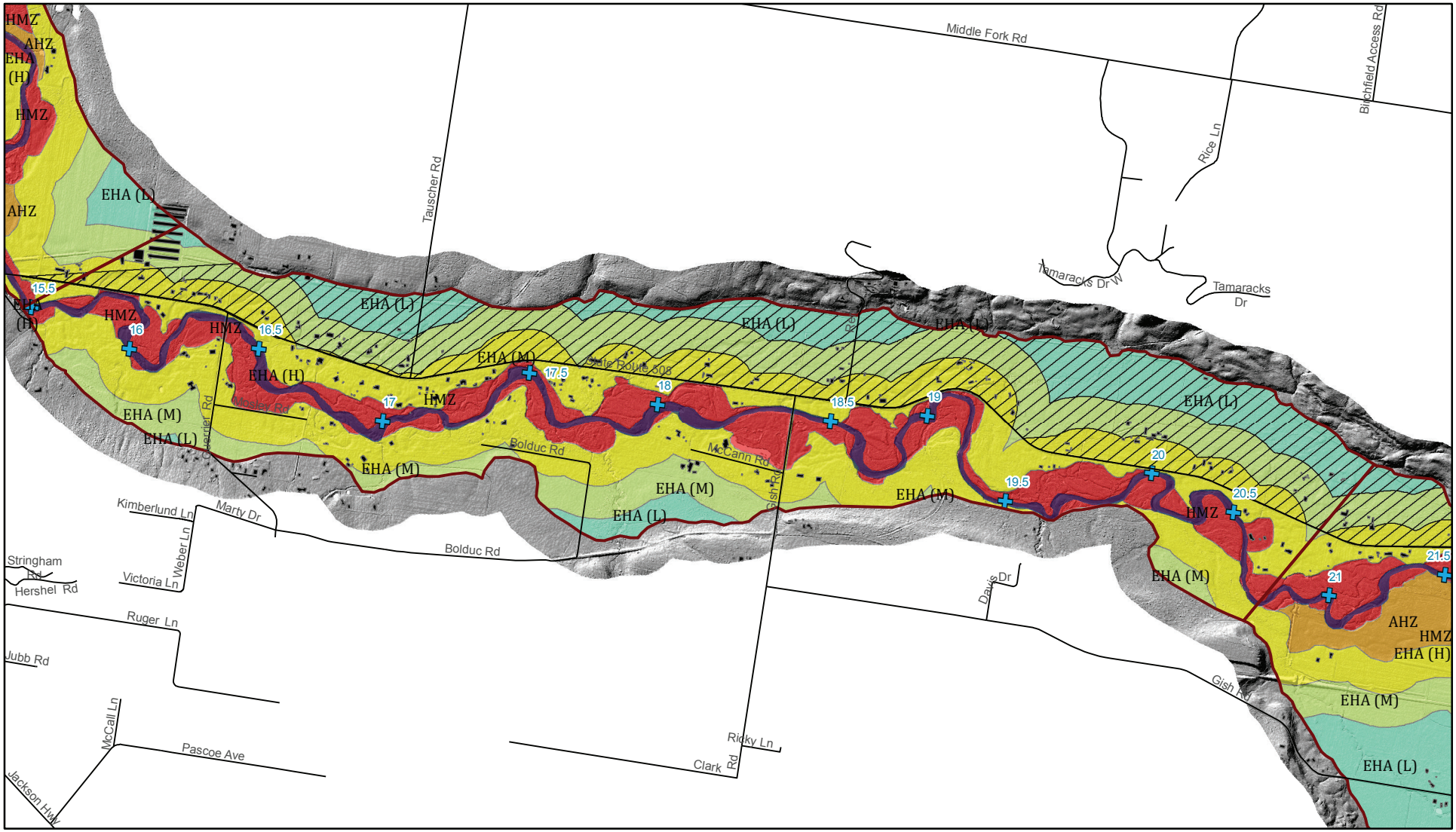
1. River Channel locations were digitally delineated as polygons surrounding the active un-vegetated channel from aerial photographs.
2. Digital Elevation Model (DEM) based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map



Map 2 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_ChannelTraces.mxd, Date Saved: 1/31/2018 6:20:07 PM



Erosion Hazard Analysis

South Fork Newaukum River - Reach 2

River Reach Boundary (NSD 2017)
Roads
Buildings
River Mile
River Channel

Disconnected EHAs

Erosion Hazards

HMZ
AHZ
EHA (H)
EHA (M)
EHA (L)

Notes:
1. Erosion hazard delineation is based on methods outlined in Rapp and Abbe (2003) "A Framework for Delineating Channel Migration Zones" WA Dept. of Ecology and Transportation.
2. Erosion hazards were delineated using the average historical channel migration rate between 1951-2017 (4.5 ft/yr). See Methods appendix for detailed description of delineation methodology.

HMZ - Historical Migration Zone
AHZ - Avulsion Hazard Zone
EHA (H) - Erosion Hazard Area High
EHA (M) - Erosion Hazard Area Medium
EHA (L) - Erosion Hazard Area Low
Disconnected EHAs - Areas on the non-river side of SR 508 and North Fork Rd.

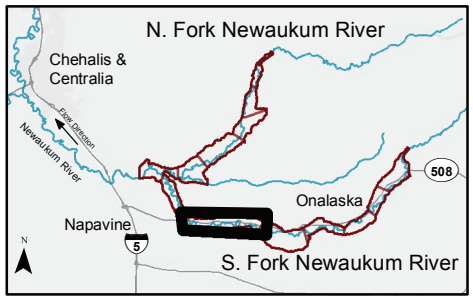
0 250 500 1,000 Feet

N

Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Erosion.mxd, Date Saved: 6/15/2018 10:37:25 AM

South Fork Newaukum River Reach 3

Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description

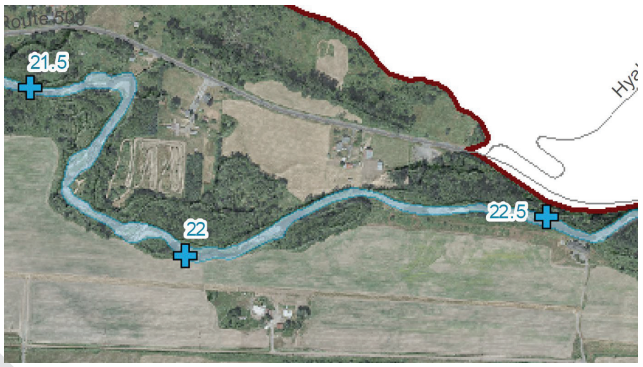
Vegetation, Soils and Wetlands

Reach 3 of the South Fork Newaukum River valley bottom occupies over 1,157 acres, including the river channel. The floodplains and terraces are currently co-dominated by 630 acres of pasture or mowed grass, and 333 acres of mixed forest (See Landcover Map in Appendix). Together, these landcover classes make up 84% of the floodplain landcover. The rest of the valley bottom, is a mixture of shrubs, roads and buildings, and river channels.

% Area	Acres	Landcover
55%	630	Pasture or Groundcover
29%	333	Forest
12%	134	Shrubs
1%	9	Structure
2%	23	Road
2%	20	Water
0%	0	Log Jam
0%	5	Gravel Bar
0%	2	Vegetated Gravel Bar
100%	**1,157**	**Total**

The soils of reach 3 of the South Fork Newaukum River valley bottom are comprised of Newberg fine sandy loam in the active channel area of the lower part of this reach--optimal conditions for cottonwood bottomland—transitioning to Aquic Xerofluvents, overflow (a glacial till) and Cloquato silt loam in the upper part of this reach. In both parts, these soils abut Chehalis silty clay up on the floodplain, which lends itself to other types of forest (See Soils Map in Appendix). As the valley topography increases in elevation from the river channel to the valley wall, hydric silty clay loam soils appear on the landscape. These hydric soils are an indicator of wetland soil formation processes.

Infrastructure, Buildings & Ownership



Reach 3 of the South Fork Newaukum River has no major bridge crossings.

There are numerous homes and farms in this reach, about 199 structures total. From downstream to upstream, these neighborhoods and communities include single family homes, farms and outbuildings with several structures on the riverbank.

The 137 parcels that comprise this valley bottom are almost entirely privately owned, by 92 landowners. There are four (4) publicly-owned parcels, which total about 5 acres. The largest private landowners are CF Ho'I Mai, LLC, which owns about 9% (105 acres) of the total the valley bottom. This area calculation does not include the land outside of the valley bottom analysis area.

Description of Parcels in the Floodplain

In order to understand the influence of the river on landowners, parcels in the simulated 2009 flood event* were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the higher the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel. ***Of the 137 landowners in the valley bottom, 41 landowners had property that was inundated in the simulated 2009 flooded-area, and 15 land owners have property that is more than 75% within the approximated inundated area, or about 198 parcel-acres*** (see table below). The dominant assessed land use for these parcels is agriculture.

Landuse description of parcels with > 75% area in flooded area

Assessed Land Use Description	Number of Parcels	Acres Flooded *	Total Parcel Acres	Largest Landowner (Parcel Acres)
agriculture	16	73	80	CF Ho'I Mai, LLC (37 ac.)
water	1	40	44	Water (44 ac.)
single-residential	6	36	38	C.A. & L.B. Freese (19 ac.)
undeveloped/vacant	6	35	36	CL & TD Gifford (13 ac.)
TOTAL	**29**	**184**	**198**	**15 Landowners w/ > 75% land in flooded area**

Flooded buildings

The number of buildings in the simulated 2009 flooded area was ~43, including residences and outbuildings (see inundation map for approximate locations.

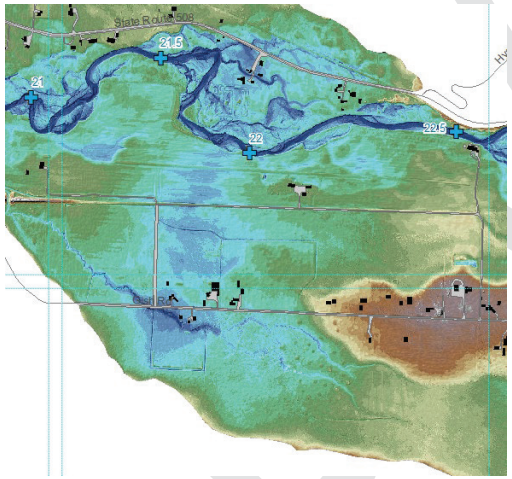
South Fork Newaukum River Reach 3

Geomorphic Reach Description

Reach 3 of the South Fork Newaukum River is located between RM 20.75 and the town of Onalaska at RM 23.5. The reach is contained within a broad section of the valley that is more than a mile wide. The reach has an average slope of 0.0039 ft/ft (or 0.3%) and has a meandering pool-riffle morphology (Table 1, REM map) (Montgomery and Buffington, 1997). There is a distinct slope break near RM 22.5 where the valley flattens and widens. There are two major tributary junctions within this reach, a perennial unnamed tributary at RM 20.75 and Gheer Creek at RM 22.75. The perennial unnamed tributary drains the southern half of the valley.

Geomorphic Landforms

The river within this reach has developed a wider active (modern) floodplain than the two reaches downstream, especially between RM 20.75-22.25. However, it appears that this surface is still incised an average of **4.5 ft** below the historical floodplain which is ~3.7 times wider than the modern surface. The historical floodplain would have likely spanned the entirety of the valley with the exception of a glacial outwash terrace that lies south of the river between RM 22-23 and is bisected by Gish Rd. There is ***a large topographic depression on both sides of the outwash terrace that were likely seasonally inundated wetlands before incision occurred*** (See broad blue/green location in REM figure at right and REM map). The upstream depression is currently drained by an unnamed perennial tributary. Similar glacial outwash terraces are impinging the width of the valley between RM 23-23.5 where a distinct break in slope and valley width occurs upstream.



Channel Migration and Erosion

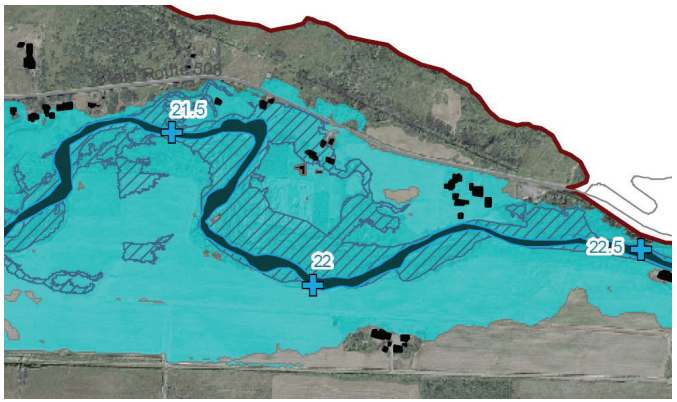
There has been localized recent channel migration within Reach 3, particularly between RM 21-22. In these locations, meanders have primarily eroded into pastured land with un-armored banks. This has widened the inset floodplain corridor within these locations (See Channel Changes Map). The remainder of the reach is heavily armored (Roughly 11% of the overall reach banks) which is restricting migration. There is also evidence of ***channel straightening*** between RM 22-22.5 where each meander bend is armored and the channel has not moved since 1940. Reach 3 is dominated by pastured land and thus has a high susceptibility to erosion (See Erosion Map).

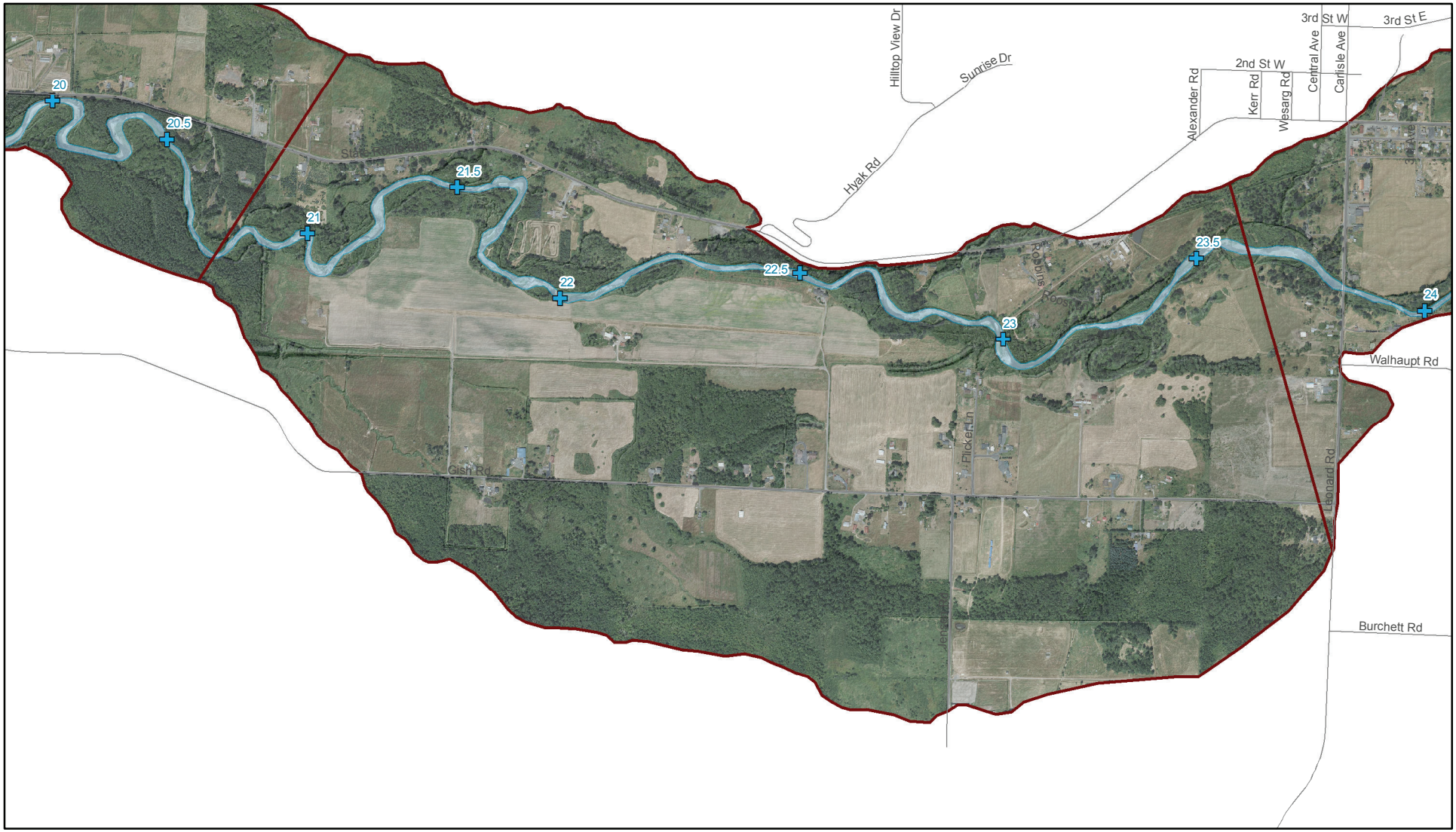
Table 1: Reach Statistics

Geomorphic Reach Description Statistics		Units
Slope	0.0039	ft/ft
Centerline Length	15078	ft
Average Depth of Incision	4.5	ft
Historic Floodplain Average Width	2619	ft
Active Floodplain Average Width	717	ft
Historic Floodplain: Active Floodplain	4	ft/ft
Flood Defense Length	1719	ft
Flood Defense Length/Channel Length	0.11	ft/ft
Road Length	20739	ft
Total Reach Area	1157	acres

2009 Flooding & FEMA boundary

The FEMA 100-year flood boundary (hatched) is ***much smaller*** than preliminary simulation results of the January 2009 flood (solid blue) within Reach 3 of the South Fork Newaukum (See Inundation map). The 2009 simulation predicts flood inundation to extend ***as much as 2,300 ft*** from the channel into areas that are ***not*** mapped by the FEMA boundary. This un-regulated area extends from RM 20.75-23 and depths are predicted to be ***as much as 2.5 ft*** in these locations. The FEMA boundary also does not map flooding that is predicted to occur adjacent to the SR-508 road prism.





Context and Vicinity Map

South Fork Newaukum River - Reach 3

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel

Notes:
1. Aerial Imagery and Digital Elevation Model (DEM) are based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. River reach breaks were done by Natural Systems Design (NSD) in 2017.

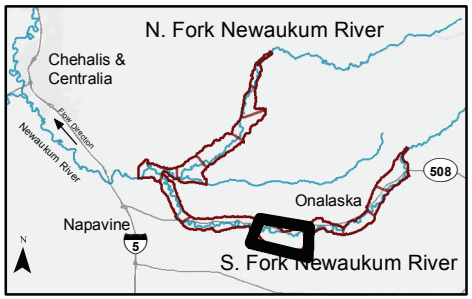
0 250 500 1,000 Feet

N

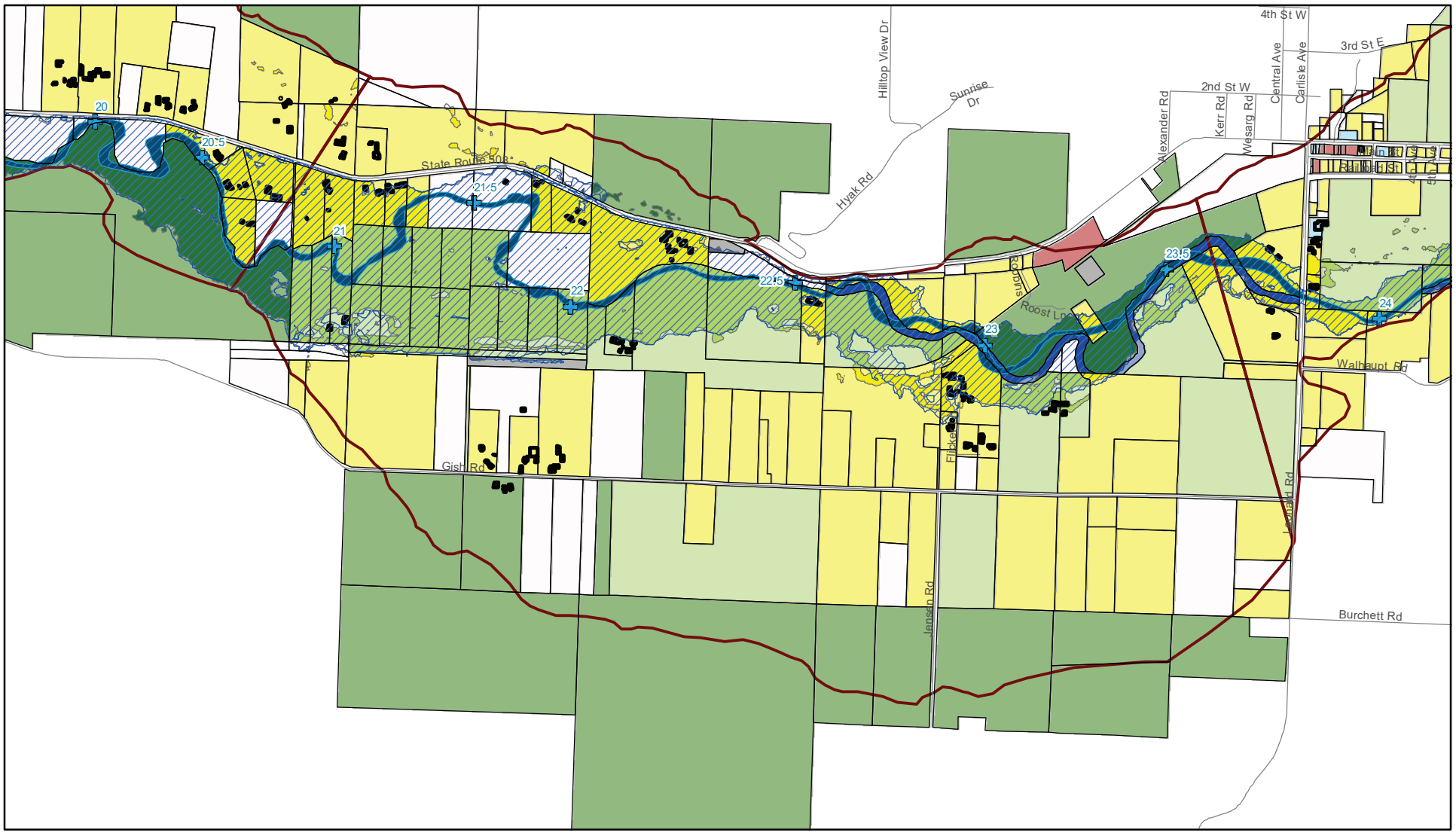
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Vicinity.mxd, Date Saved: 6/14/2018 2:26:17 PM



Existing Parcels Affected by Simulated 2009 Flood of Record

South Fork Newaukum River - Reach 3

Simulated 2009 Flood Extent

Affected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Trans/Util
- Undeveloped/Vacant
- Water

Unaffected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Commercial Industrial; Commercial Retail
- Mining/Forestry
- Public/Quasi-Public
- Trans/Util
- Undeveloped/Vacant
- Water

- River Reach Boundary (NSD 2017)
- Roads
- River Mile
- River Channel
- Buildings

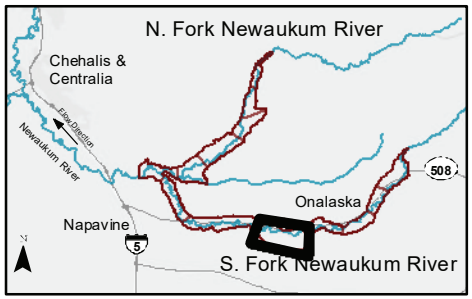
Notes:
1. Building/structures data from Lewis County,2013, additional buildings digitized by NSD, 2017.
2. Parcel data from Lewis County Assessor's Office. Accessed [8/18/2017].
3. The river channel delineated using 2017 LiDAR, represents low flow conditions for spring 2017.

0 250 500 1,000 Feet

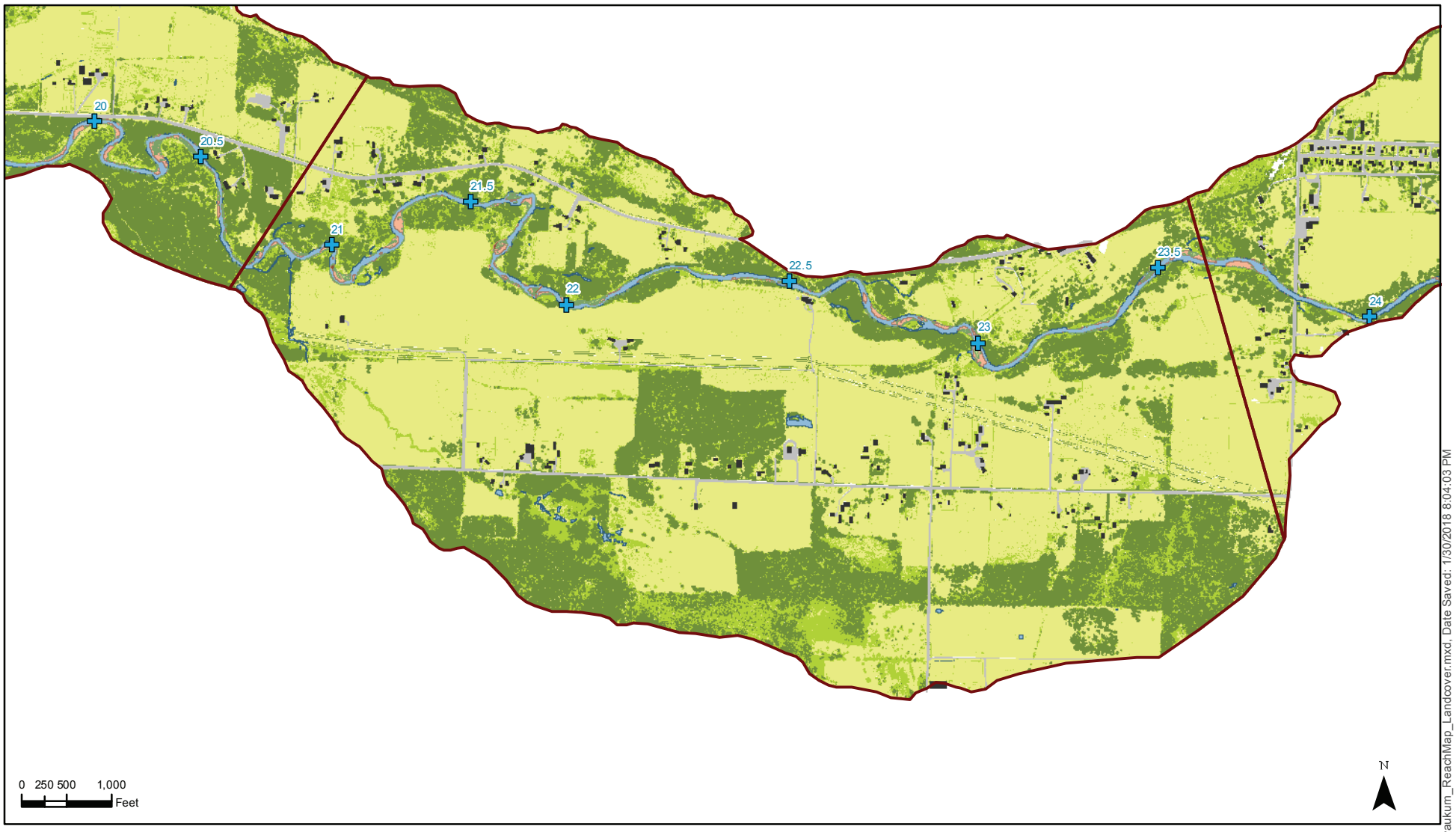
N

Vicinity Map 0 1 2 4 Miles

Location



\\NATUSYST-NAS1\Bellingham\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_UpdatedParcels.mxd, Date Saved: 6/14/2018 1:31:11 PM



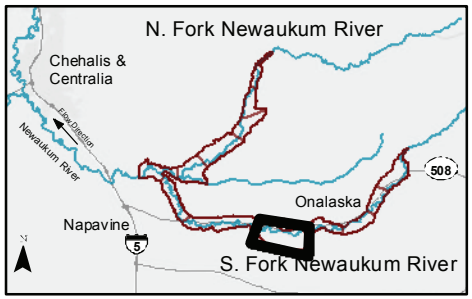
Existing Landcover Map

South Fork Newaukum River - Reach 3

River Reach (NSD, 2017)
River Mile
Landcover (NSD, 2017)
Pasture or Groundcover (< 3' tall)
Shrubs and Small Trees (3' to 20' tall)
Forest and Large Shrubs (> 20' tall)
Road
Structure (i.e. Building)
Gravel Bar
Vegetated Gravel Bar
Log Jam
Water

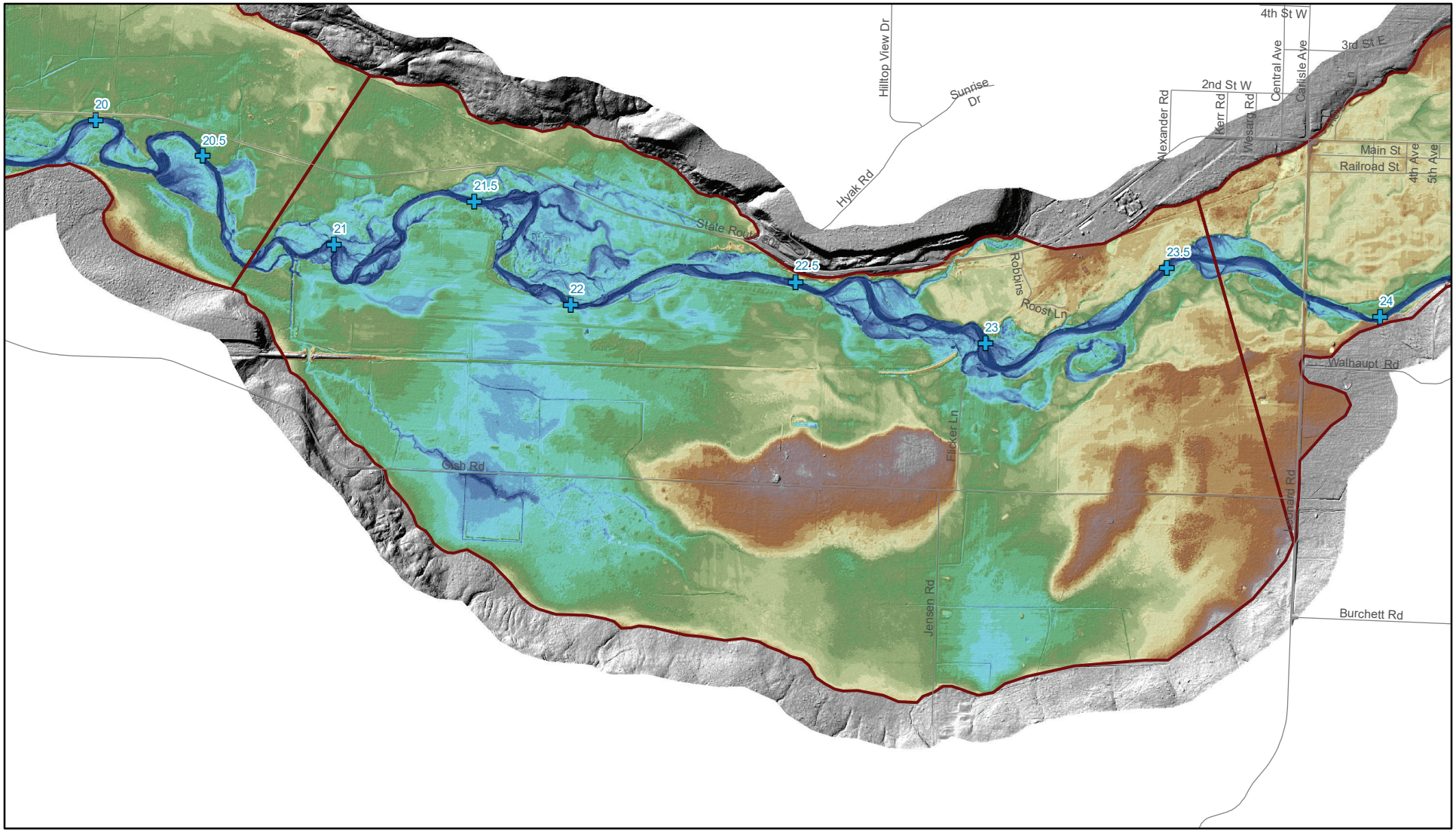
Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. There were statistically sigfnificant differences (p<0.005) between pasture and forest landcover types with erosion rates as follows:
a. Forest/shrubs: 6.0 +/- 3 ft/yr (n=20)
b. Pasture: 9.4+/- 5 ft/yr (n=24)
2.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
3.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
4. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map 0 1 2 4 Miles — Location



Map 3 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Landcover.mxd, Date Saved: 1/30/2018 8:04:03 PM



Relative Elevation Map (REM)

South Fork Newaukum River - Reach 3

River Reach Boundary (NSD 2017)

Roads

River Mile

Relative Elevation Above River Channel At Low Water (feet)

-4.6 - -1 -1.1 - -2 -2.1 - -3 -3.1 - -4 -4.1 - -5 -5.1 - -6 -6.1 - -7 -7.1 - -8 -8.1 - -9 -9.1 - -10 -10.1 - -11 -11.1 - -12 -12.1 - -13 -13.1 - -14 -14.1 - -15 -15.1 - -16 -16.1 - -17 -17.1 - -18 -18.1 - -19 -19.1 - -20

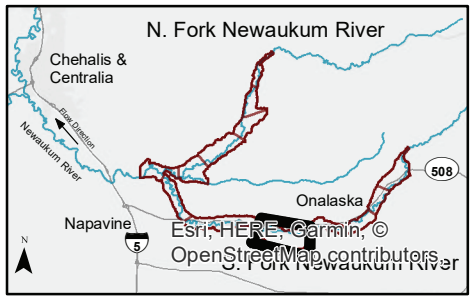
0 250 500 1,000 Feet

N

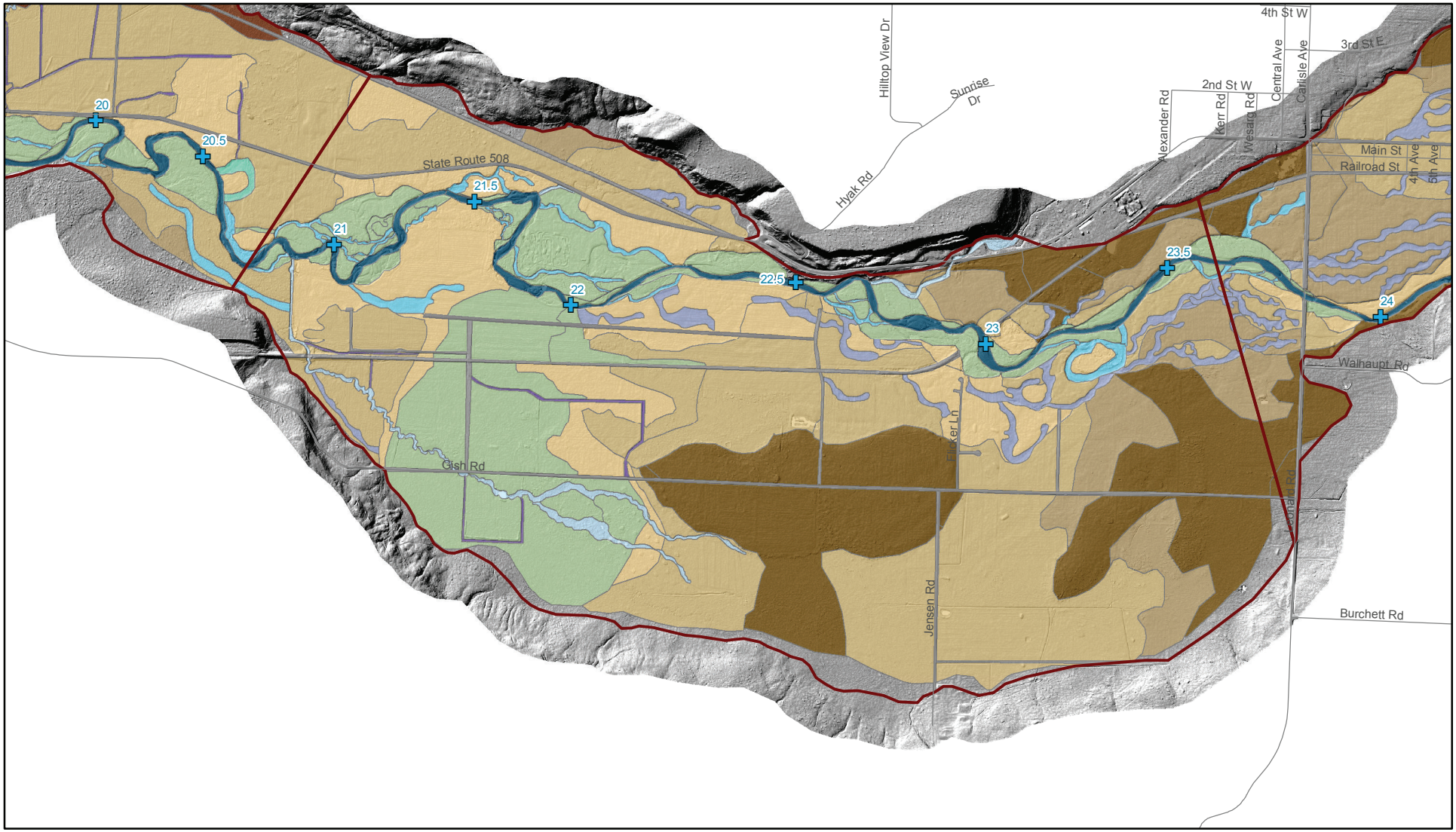
Notes:
1. Relative Elevation Model (REM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
3. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map 0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_REM.mxd, Date Saved: 6/14/2018 1:12:00 PM



Geomorphic Landform Map

South Fork Newaukum River - Reach 3

River Reach Boundary (NSD 2017)
Roads
River Mile

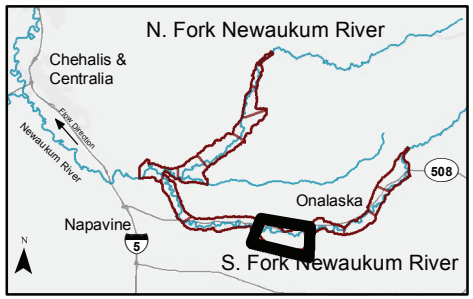
Geomoprhic Landforms (NSD 2017)
- Main Channel
- Channel
- Abandoned Channel
- Oxbow
- Tributary
- Active Floodplain
- Historical Floodplain (4-6')
- Historical Floodplain (6-10')
- Historical Floodplain (10-15')
- High Terrace (>15')
- Alluvial Fan
- Infrastructure
- Road
- Ditch

0 250 500 1,000 Feet

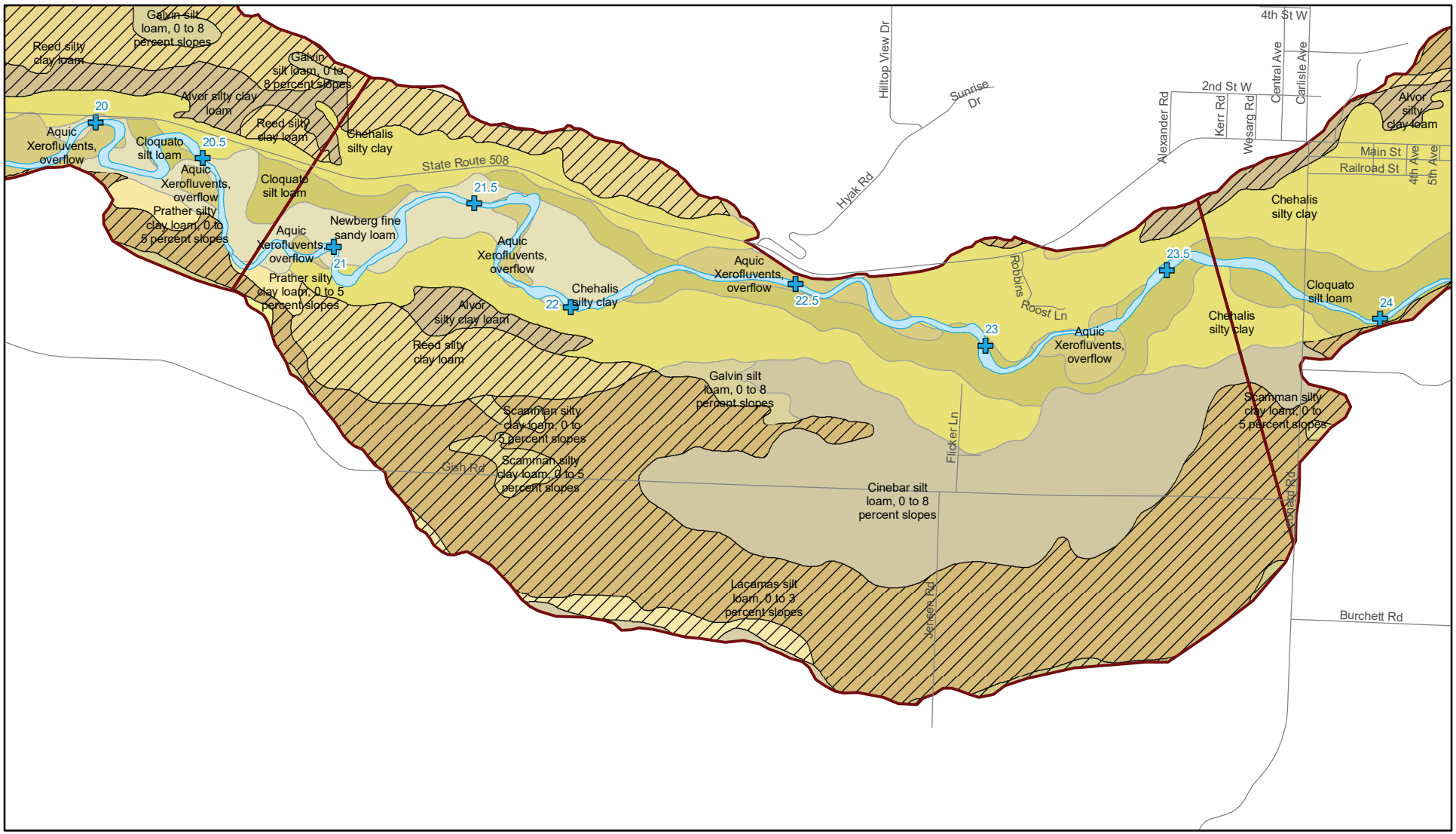
N

Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. The active and historical floodplain surfaces showed no statistically significant difference (p>0.1) and were determined to have the same erosion potential.
1.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
2.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4.Geomorphic landforms were delineated for the valley bottom which was defined where a slope break occured at the margin with the hillslope.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Geomorph.mxd, Date Saved: 7/3/2018 12:35:06 PM



Existing Soils Map

South Fork Newaukum River - Reach 3

Notes:
1. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.
2. Soils data is from the USDA-SSURGO database.

0 250 500 1,000 Feet

N

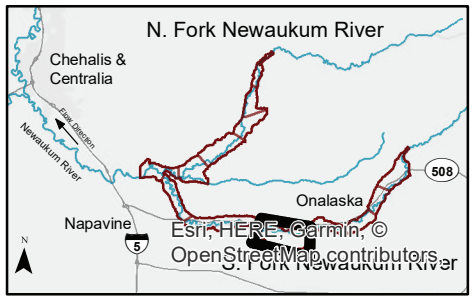
River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel
Hydric Soil

Soil Type
- Alvor silty clay loam
- Aquic Xerofluvents, overflow
- Chehalis silty clay
- Cinebar silt loam, 0 to 8 percent slopes
- Cinebar silt loam, 8 to 15 percent slopes
- Cloquato silt loam
- Galvin silt loam, 0 to 8 percent slopes
- Lacamas silt loam, 0 to 3 percent slopes
- Lacamas-Scamman complex, 0 to 15 percent slopes
- Newberg fine sandy loam
- Prather silty clay loam, 0 to 5 percent slopes
- Prather silty clay loam, 5 to 15 percent slopes
- Reed silty clay loam
- Salkum silty clay loam, 15 to 30 percent slopes
- Salkum silty clay loam, 30 to 65 percent slopes
- Scamman silty clay loam, 0 to 5 percent slopes
- Scamman silty clay loam, 5 to 15 percent slopes
- Xerorthents, spoils
- Xerorthents, steep

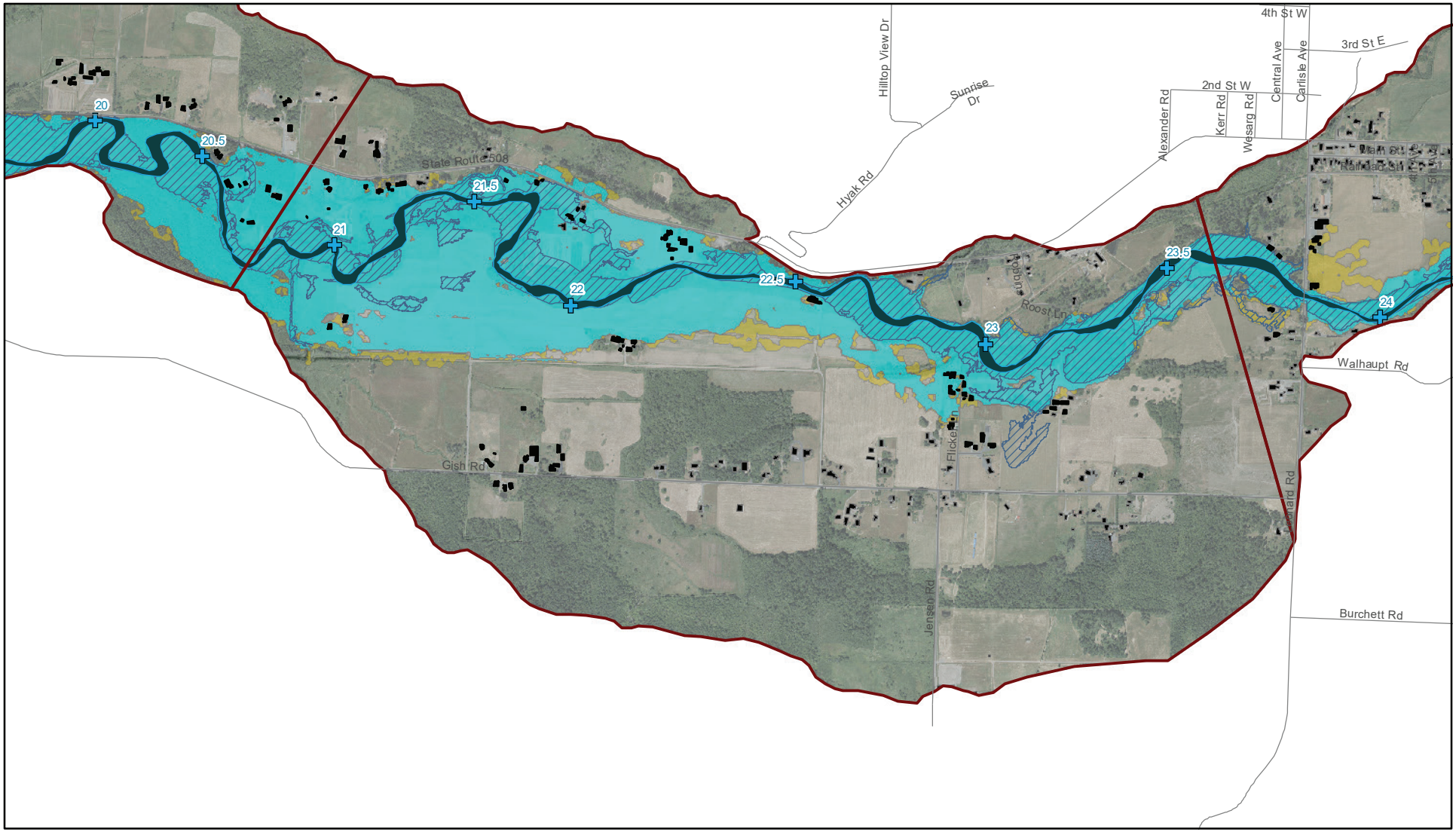
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Soils.mxd, Date Saved: 6/14/2018 1:17:11 PM



Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change

South Fork Newaukum River - Reach 3

- Buildings
- River Reach Boundary
- Roads
- River Mile
- 2017 River Channel
- Regulatory 100-year Flood Boundary (FEMA)
- 2009 Flood (Current Flood of Record)
- 2009 Flood Simulated With Estimated Climate Change Effects

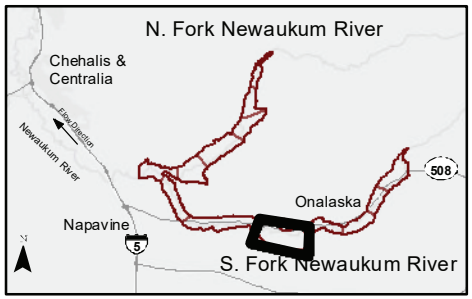
0 500 1,000 Feet

N

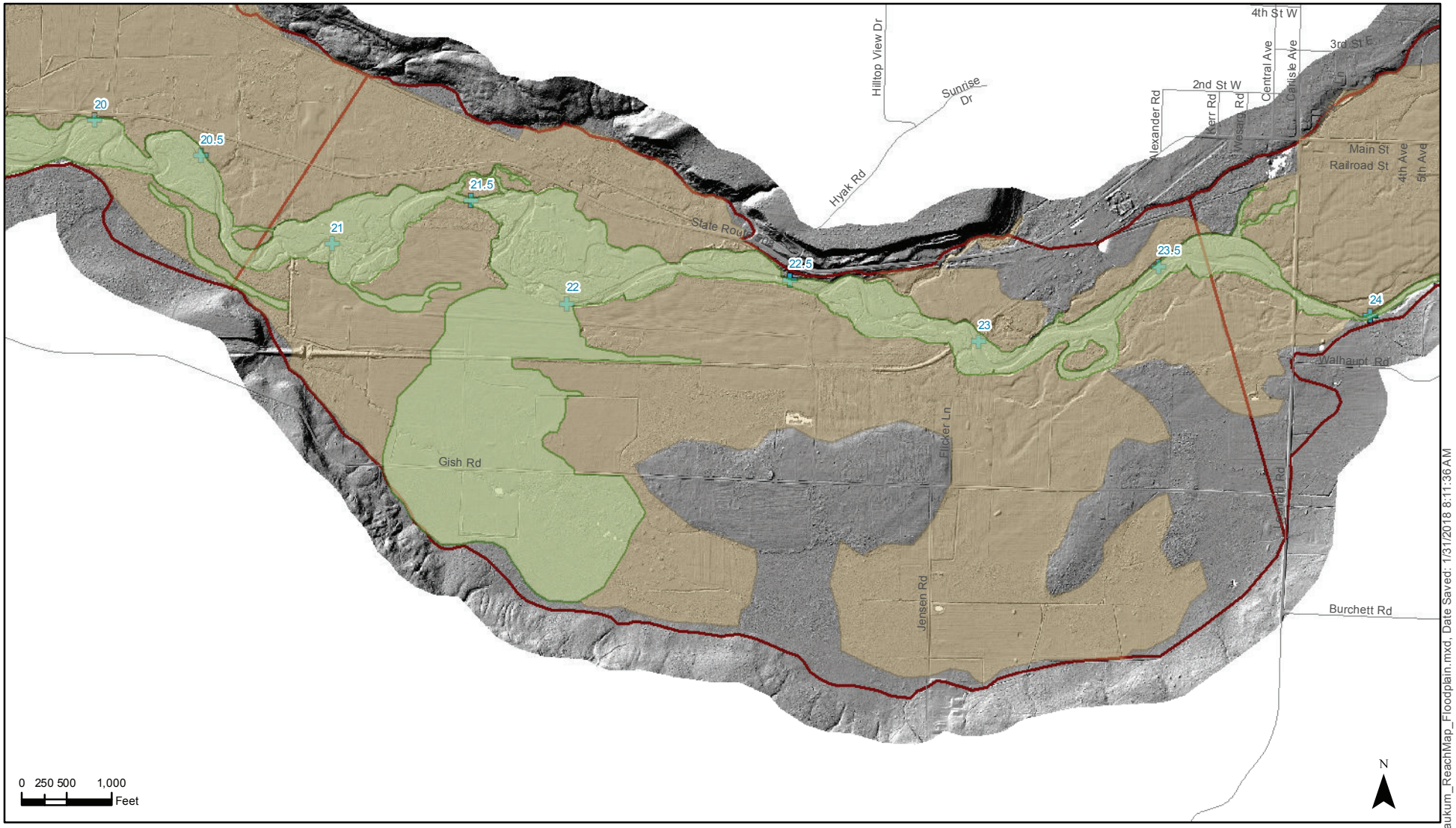
Notes:
1. Hydraulic simulation performed using RiverFlow2D - GPU. Simulation performed for the flood of record on the mainstem Newaukum Gage (USGS 12025000) which occurred from January 4 to Janaury 10th 2009. The estimated peak flow of 13,000 cfs occured on January 7th. Existing conditions 2009 flood simulation shows maximum simulated flood extent. Climate change flood simulation represents a 26% increase in 2009 flood water discharge.

2. Building (structures) dataset created by Lewis County, 2013. River reach boundary created by Natural Systems Design, 2017.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Inundation_ClimateChange.mxd, Date Saved: 10/10/2019 9:38:07 AM



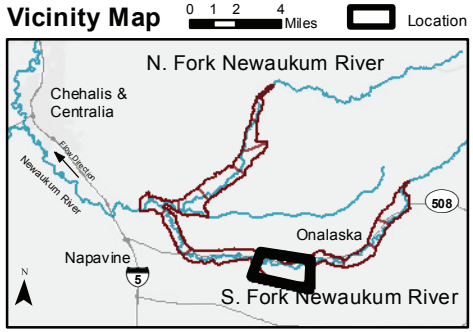
Modern and Historical Floodplains

South Fork Newaukum River - Reach 3

- Roads
- River Reach (NSD, 2017)
- River Mile
- Modern Floodplain
- Historical Floodplain

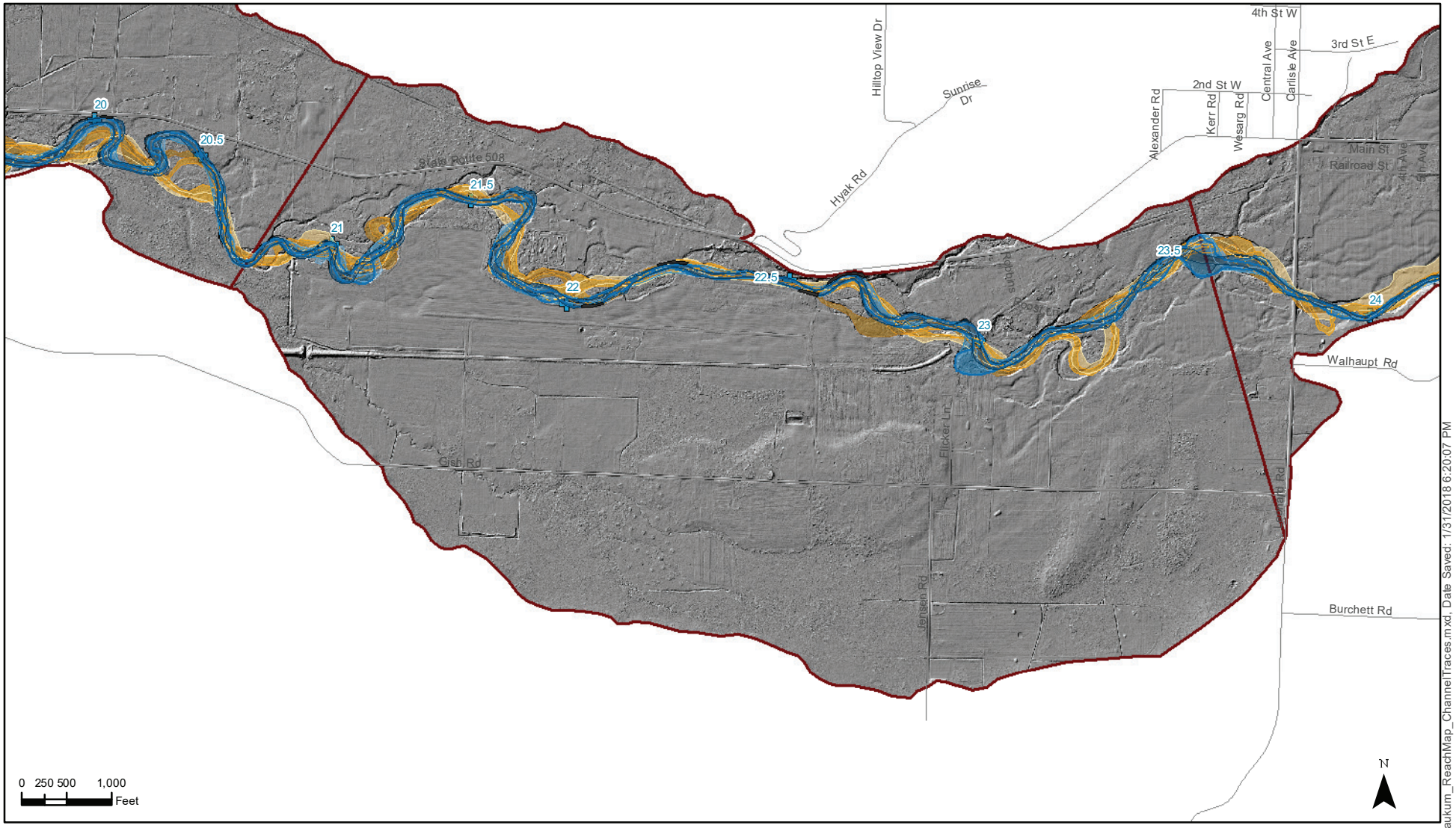
Notes:
1. The active and historical floodplain extents are based off of geomorphic landforms delineated by NSD.
2. The modern floodplain extent represents the current geomorphic surface within which moderate floods are contained. The modern floodplain was mapped as the active floodplain surface.
3. The historical floodplain includes terraces ranging from 4-15' and likely represent the extent of flood innundation during a moderate flood.
4. Digital Elevation Model (DEM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
5. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map



Map 3 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Floodplain.mxd, Date Saved: 1/31/2018 8:11:36 AM



River Channel Changes from 1940 to 2017

South Fork Newaukum River - Reach 3

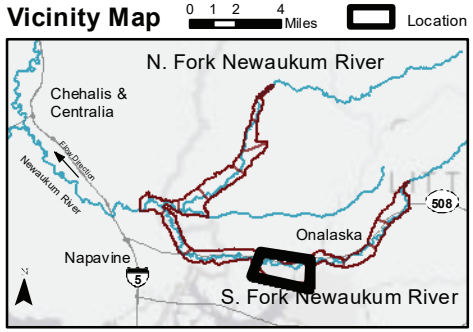
Bank Armoring (Incomplete Dataset*)
Roads
River Reach (NSD, 2017)
River Mile

River Channel Locations By Year
1940
1950
1980
1990
2006
2009
2011
2015
2017

Notes:
*The bank armoring dataset only covers the lower reaches of the South and North Fork Newaukum Rivers (RM 12-22.5 on the South Fork and RM 0-2 on the North Fork. The data was generated during Fall 2017 field observations by NSD.

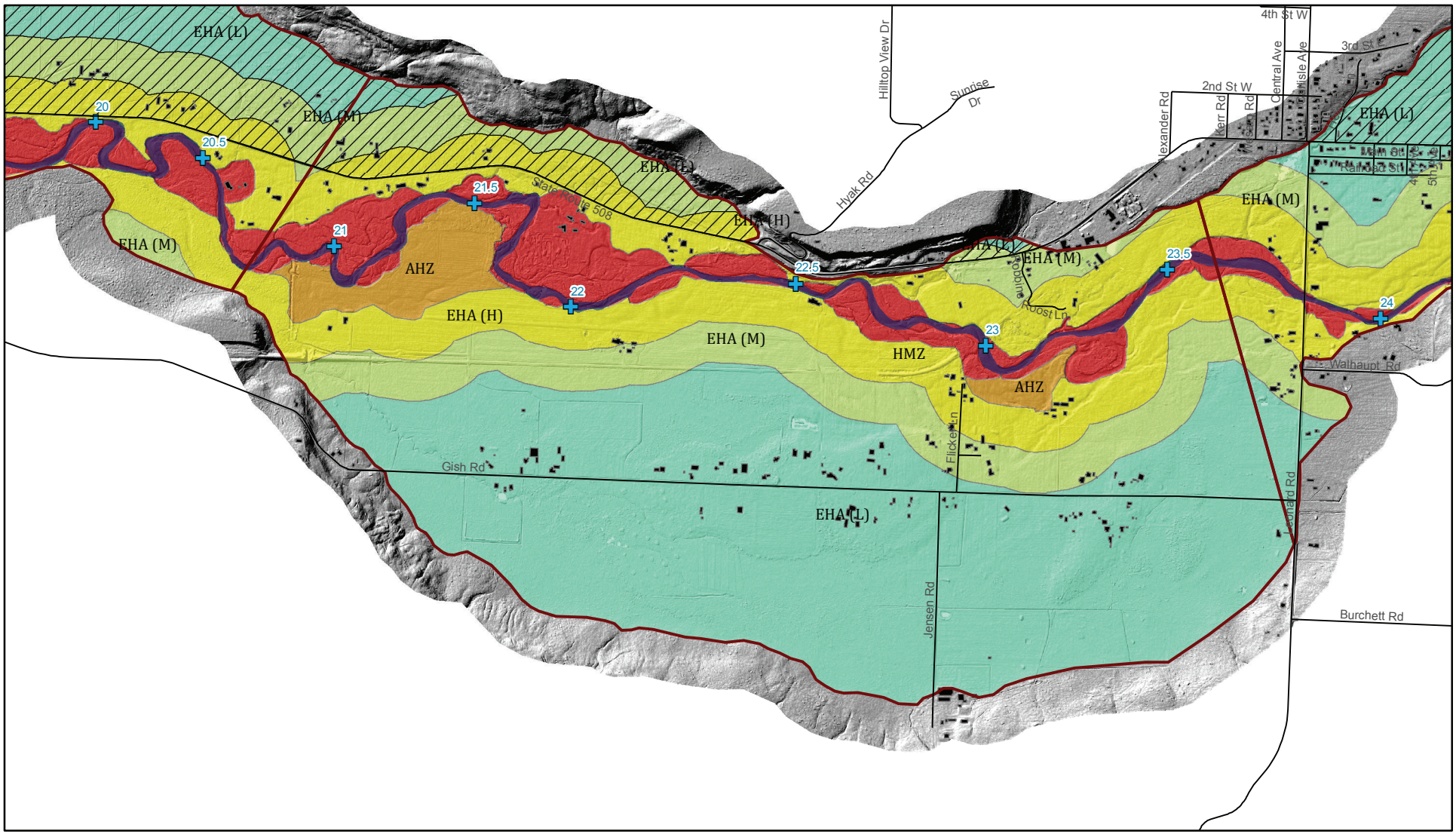
1. River Channel locations were digitally delineated as polygons surrounding the active un-vegetated channel from aerial photographs.
2. Digital Elevation Model (DEM) based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map



Map 3 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_ChannelTraces.mxd, Date Saved: 1/31/2018 6:20:07 PM



Erosion Hazard Analysis

South Fork Newaukum River - Reach 3

River Reach Boundary (NSD 2017)
Roads
Buildings
River Mile
River Channel

Disconnected EHAs

Erosion Hazards

HMZ
AHZ
EHA (H)
EHA (M)
EHA (L)

0 250 500 1,000 Feet

N

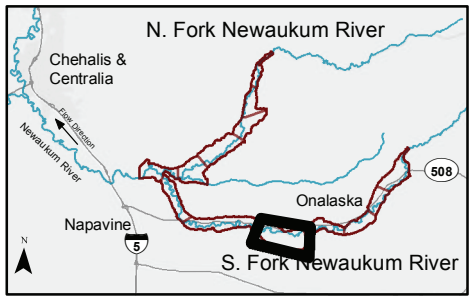
Notes:
1. Erosion hazard delineation is based on methods outlined in Rapp and Abbe (2003) "A Framework for Delineating Channel Migration Zones" WA Dept. of Ecology and Transportation.
2. Erosion hazards were delineated using the average historical channel migration rate between 1951-2017 (4.5 ft/yr). See Methods appendix for detailed description of delineation methodology.

HMZ - Historical Migration Zone
AHZ - Avulsion Hazard Zone
EHA (H) - Erosion Hazard Area High
EHA (M) - Erosion Hazard Area Medium
EHA (L) - Erosion Hazard Area Low
Disconnected EHAs - Areas on the non-river side of SR 508 and North Fork Rd.

Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Erosion.mxd, Date Saved: 6/15/2018 10:37:25 AM

South Fork Newaukum River Reach 4

Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description

Vegetation, Soils and Wetlands

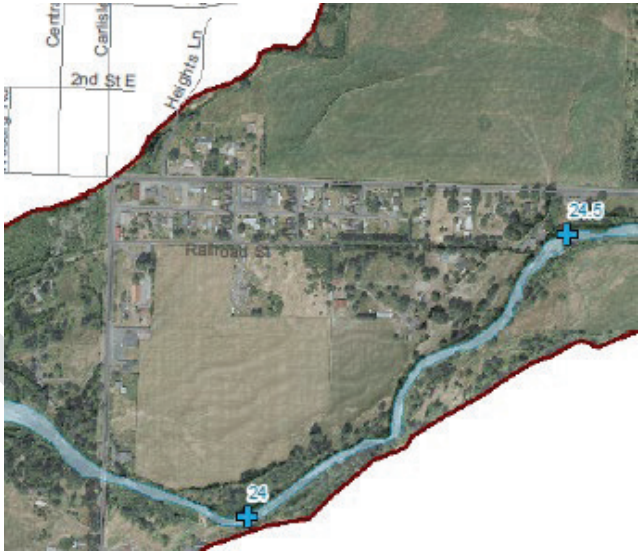
Reach 4 of the South Fork Newaukum River valley bottom occupies almost 500 acres, including the river channel. The floodplains and terraces are currently dominated by 238 acres of pasture or mowed grass. The next largest landcover class is mixed forest, 120 acres, and shrubs, 69 acres (See Landcover Map in Appendix). Together, these landcover classes make up 86% of the floodplain landcover. The rest of the valley bottom, is a mixture of small trees and shrubs, roads and buildings, and river channels.

% Area	Acres	Landcover
48%	238	Pasture or Groundcover
24%	120	Forest
14%	69	Shrubs
5%	25	Small Trees, Large Shrubs
3%	17	Road
3%	16	Water
1%	7	Buildings
1%	5	Gravel Bar
0%	0	Log Jam
100%	**497**	**Total**

The soils of reach 4 of the South Fork Newaukum River valley bottom are comprised of Cloquato silt loam and Chehalis silty clay in the active channel area of the lower part of this reach, transitioning to Newberg fine sandy loam and Aquic Xerofluvents, overflow (a glacial till) and in the upper part of this reach. In both parts, these soils are also present in the floodplain, which lends itself to other types of forest (See Soils Map in Appendix). As the valley topography increases in elevation from the river channel to the terraces adjacent to the valley wall, hydric silty clay loam soils are found on the landscape. These hydric soils are an indicator of wetland soil formation processes.

Infrastructure, Buildings & Ownership

Reach 4 of the South Fork Newaukum River has **two major bridge crossings**, at Leonard Road and Caughlin Road. **This reach includes a commercial/residential part of Onalaska, south of Main St.**



There are numerous homes and farms in this reach, about 187 structures total, including some businesses, numerous single-family homes, farms and outbuildings with several structures that are very close to the riverbank.

The 143 parcels that comprise this valley bottom are almost entirely privately owned, by 92 landowners. There are three (3) publicly-owned parcels, which total about 0.6 acres. The largest private landowners are the Larson family, who own about 50% (364 acres) of the total the valley bottom. This area calculation does not include the land outside of the valley bottom analysis area.

Description of Parcels in the Floodplain

In order to understand the influence of the river on landowners, parcels in the simulated 2009 flood event* were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the higher the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel. ***Of the 92 landowners in the valley bottom, 21 landowners had property that was inundated in the simulated 2009 flooded-area, and one (1) land owner has property that is more than 75% within the approximated inundated area, or about 1.8 parcel-acres*** (see table below). The dominant assessed land use for this parcel is agriculture.

Landuse description of parcels with > 75% area in flooded area

Assessed Land Use Description	Number of Parcels	Acres Flooded *	Total Parcel Acres	Largest Landowner (Parcel Acres)
agriculture	1	1.8	1.8	K.D. McGraw
TOTAL	**129**	**1.8**	**1.8**	**1 Landowner w/ > 75% land in flooded area**

Flooded buildings

The number of buildings in the simulated 2009 flooded area was ~10, including residences and outbuildings (see inundation map for approximate locations)

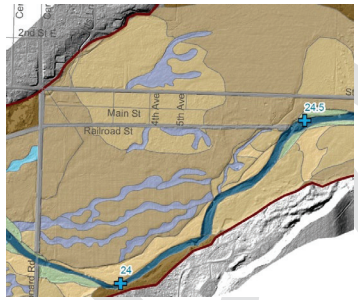
South Fork Newaukum River Reach 4

Geomorphic Reach Description

Reach 4 of the South Fork Newaukum River is located between RM 23.5 and RM 26.25 and incorporates the town of Onalaska. The reach is contained within a narrow section of the valley that is less than half a mile wide. The reach has an average slope of 0.0049 ft/ft (or 0.49%) and has a simple and straight morphology that is likely plane bedded (Table 1, REM map) (Montgomery and Buffington, 1997). There is one major tributary junction within this reach where Lost Creek enters the South Fork Newaukum around RM 25 on the left bank.

Geomorphic Landforms

The river within this reach is contained within a narrow (~200 ft wide) inset floodplain corridor that is primarily situated against the south side of the valley (with one exception being a northern meander around RM 25.5). The river is deeply incised below its historical location with the modern floodplain **7.9 feet** below the historical floodplain surface on average. **The town of Onalaska is located on top of a historical floodplain surface** where a dense relict channel network can be seen in the LiDAR DEM (See example of the Geomorphic Landforms map to the right with the historical channels symbolized in purple**).** This channel network extends to the north of SR 508 where abandoned wetland features were likely once present, based on the landform map. **As a result of the deep incision and narrow inset floodplain corridor, the active floodplain is 6 times narrower than the historical floodplain.**



Channel Migration and Erosion

The planform morphology of reach S4 has been relatively stable since 1950 (See the lack example of migration to the right). There has been no evidence of lateral channel migration through Onalaska between the Leonard Rd. bridge (RM 23.75) and RM 25.5. Upstream of the town, the channel has migrated during this period which is evident both in the channel traces and widened inset floodplain corridor morphology. Because field surveys were not conducted through this reach, the amount of flood defense is unknown. Because of the limited lateral migration, there has likely been little erosion through this reach.

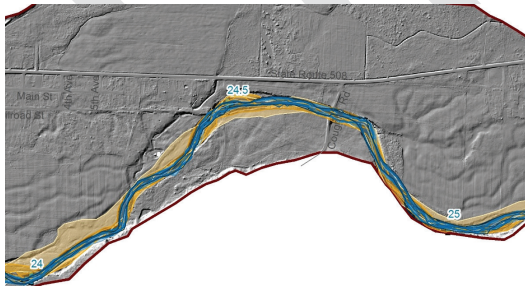
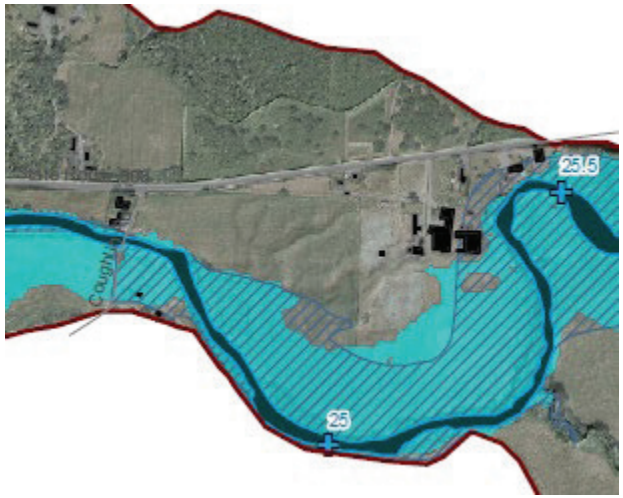


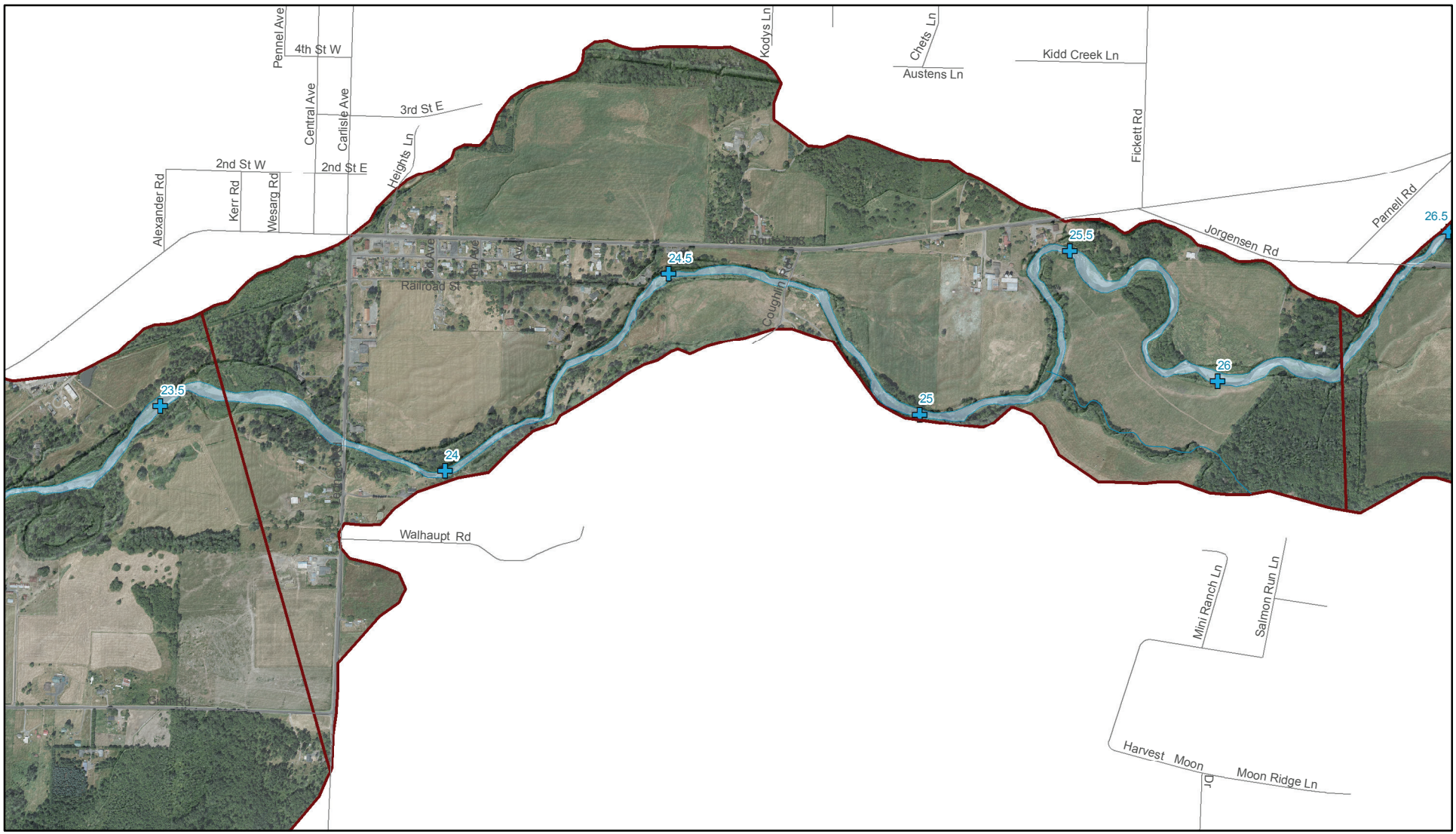
Table 1: Reach Statistics

Geomorphic Reach Description Statistics		Units
Slope	0.0049	ft/ft
Centerline Length	13799	ft
Average Depth of Incision	7.8	ft
Historic Floodplain Average Width	1072	ft
Active Floodplain Average Width	190	ft
Historic Floodplain: Active Floodplain	6	ft/ft
Flood Defense Length	N/A	ft
Flood Defense Length/Channel Length	N/A	ft/ft
Road Length	15314	ft
Total Reach Area	497	acres

2009 Flooding & FEMA boundary

The FEMA 100-year flood boundary (hatched) is generally smaller than preliminary simulation results of the January 2009 flood (solid blue) within Reach 4 of the South Fork Newaukum (See Inundation map). The difference is largest between RM 24-24.5 which is through the main population center of Onalaska. In this subreach, the January 2009 simulation predicts inundation to extend as much as 450 ft from the channel into areas that are not mapped by the FEMA boundary. These discrepancies occur on both the North and South sides of the river. Other discrepancies include the FEMA boundary extending 200 ft beyond the January 2009 simulation along a meander bend near RM 25.5.





Context and Vicinity Map

South Fork Newaukum River - Reach 4

- Stream
- River Reach Boundary (NSD 2017)
- Roads
- River Mile
- River Channel

Notes:
1. Aerial Imagery and Digital Elevation Model (DEM) are based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. River reach breaks were done by Natural Systems Design (NSD) in 2017.

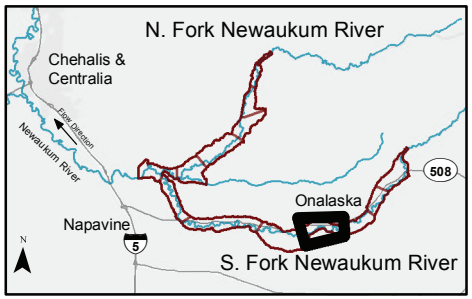
0 250 500 1,000 Feet

N

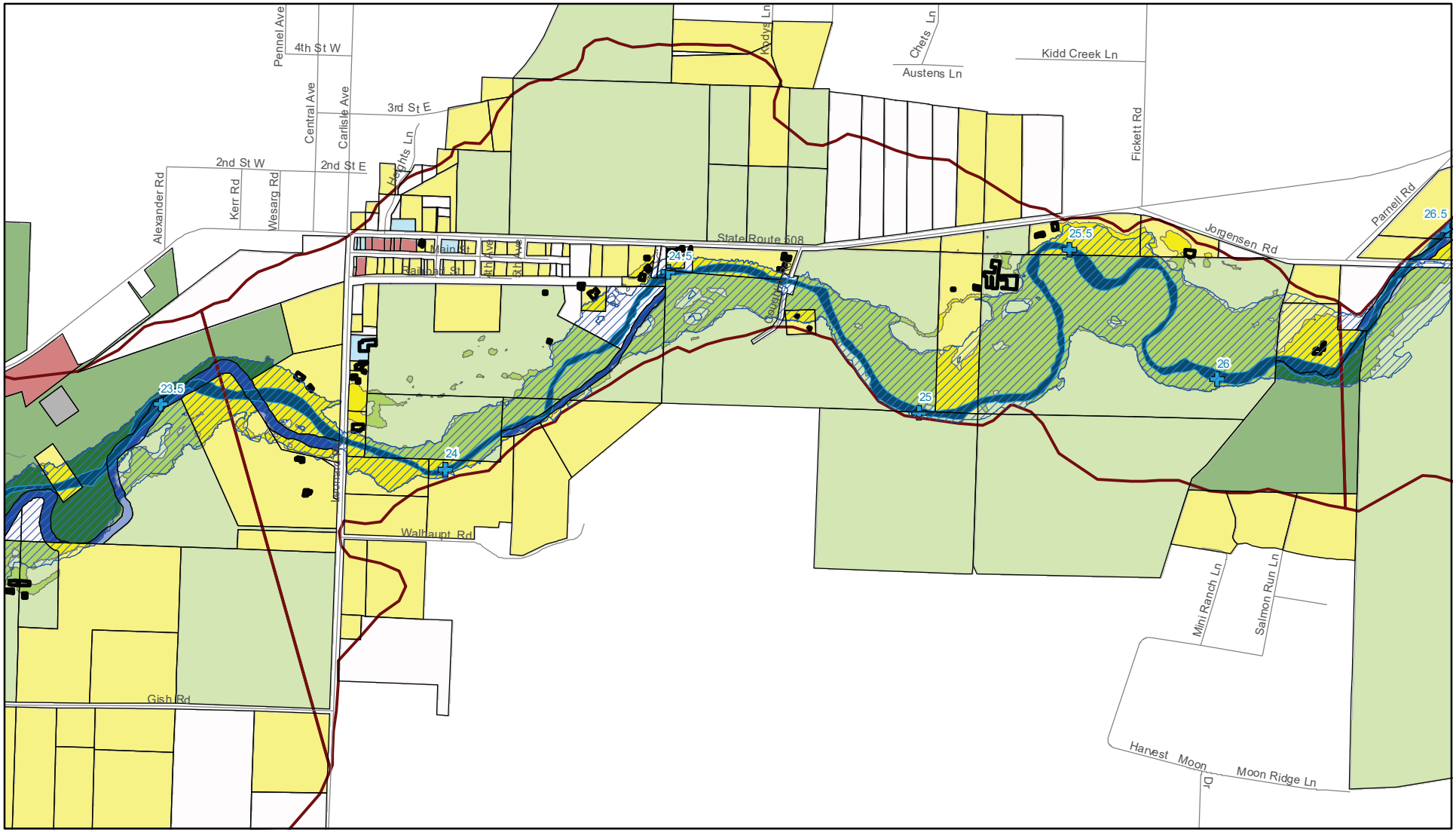
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Vicinity.mxd, Date Saved: 6/14/2018 2:26:17 PM



Existing Parcels Affected by Simulated 2009 Flood of Record

South Fork Newaukum River - Reach 4

Simulated 2009 Flood Extent

Affected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Undeveloped/Vacant
- Water

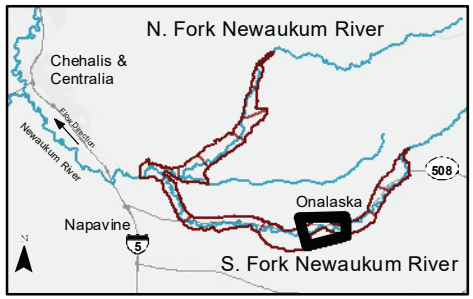
Unaffected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Commercial Industrial; Commercial Retail
- Mining/Forestry
- Public/Quasi-Public
- Trans/Util
- Undeveloped/Vacant
- Water
- River Reach Boundary (NSD 2017)
- Roads
- River Mile
- River Channel
- Buildings

0 250 500 1,000 Feet

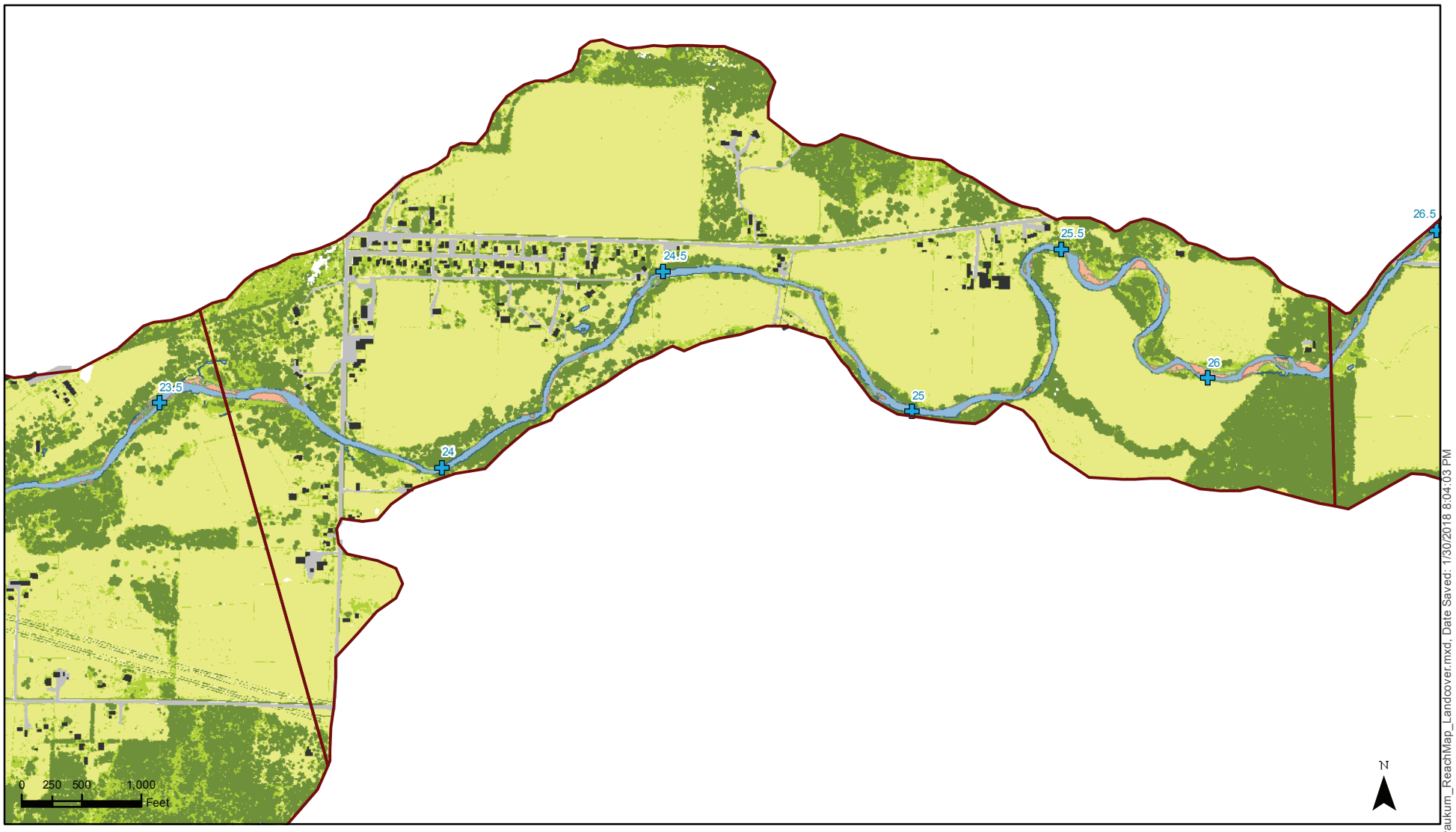
N

Notes:
1. Building/structures data from Lewis County,2013, additional buildings digitized by NSD, 2017.
2. Parcel data from Lewis County Assessor's Office. Accessed [8/18/2017].
3. The river channel delineated using 2017 LiDAR, represents low flow conditions for spring 2017.

Vicinity Map 0 1 2 4 Miles — Location



\\NATUSYST-NAS1\Bellingham\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_UpdatedParcels.mxd, Date Saved: 6/14/2018 1:31:11 PM



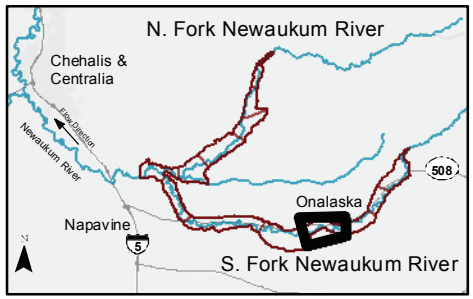
Existing Landcover Map

South Fork Newaukum River - Reach 4

River Reach (NSD, 2017)
River Mile
Landcover (NSD, 2017)
Pasture or Groundcover (< 3' tall)
Shrubs and Small Trees (3' to 20' tall)
Forest and Large Shrubs (> 20' tall)
Road
Structure (i.e. Building)
Gravel Bar
Vegetated Gravel Bar
Log Jam
Water

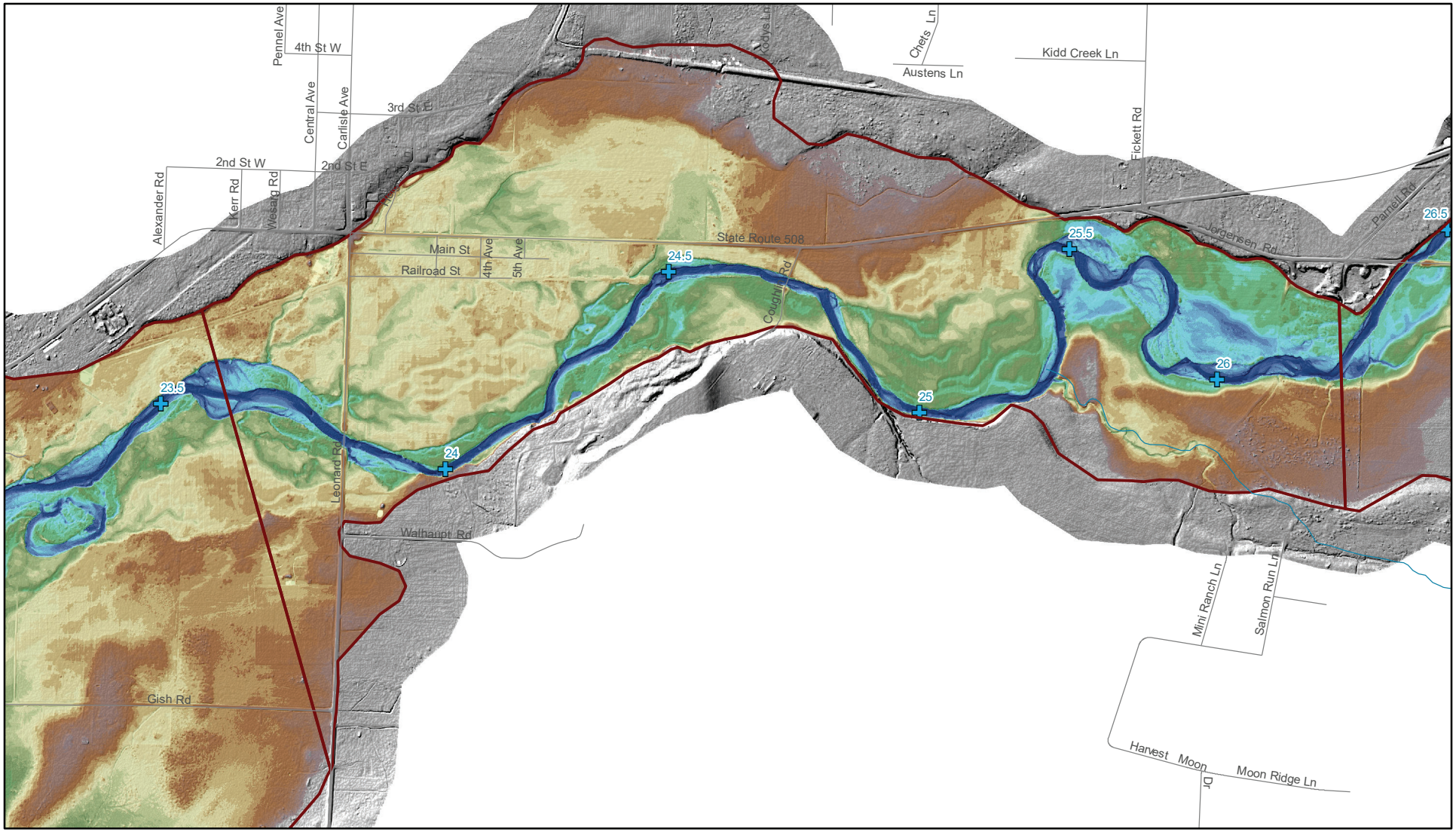
Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. There were statistically sigfnificant differences ($p<0.005$) between pasture and forest landcover types with erosion rates as follows:
a. Forest/shrubs: 6.0 +/- 3 ft/yr (n=20)
b. Pasture: 9.4+/- 5 ft/yr (n=24)
2.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
3.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
4. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map 0 1 2 4 Miles — Location



Map 4 of 13

P:\Projects\Chehalis\GIS\Newaukum\mxd\Newaukum_ReachMap_Landcover.mxd, Date Saved: 1/30/2018 8:04:03 PM



Relative Elevation Map (REM)

South Fork Newaukum River - Reach 4

Stream
River Reach Boundary (NSD 2017)
Roads
River Mile

Relative Elevation Above River Channel At Low Water (feet)

-4.6 - -1 | -1.1 - -2 | -2.1 - -3 | -3.1 - -4 | -4.1 - -5 | -5.1 - -6 | -6.1 - -7 | -7.1 - -8 | -8.1 - -9 | -9.1 - -10 | -10.1 - -11 | -11.1 - -12 | -12.1 - -13 | -13.1 - -14 | -14.1 - -15 | -15.1 - -16 | -16.1 - -17 | -17.1 - -18 | -18.1 - -19 | -19.1 - -20

Notes:
1. Relative Elevation Model (REM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
3. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

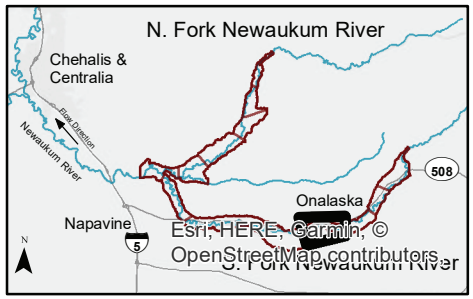
0 250 500 1,000 Feet

N

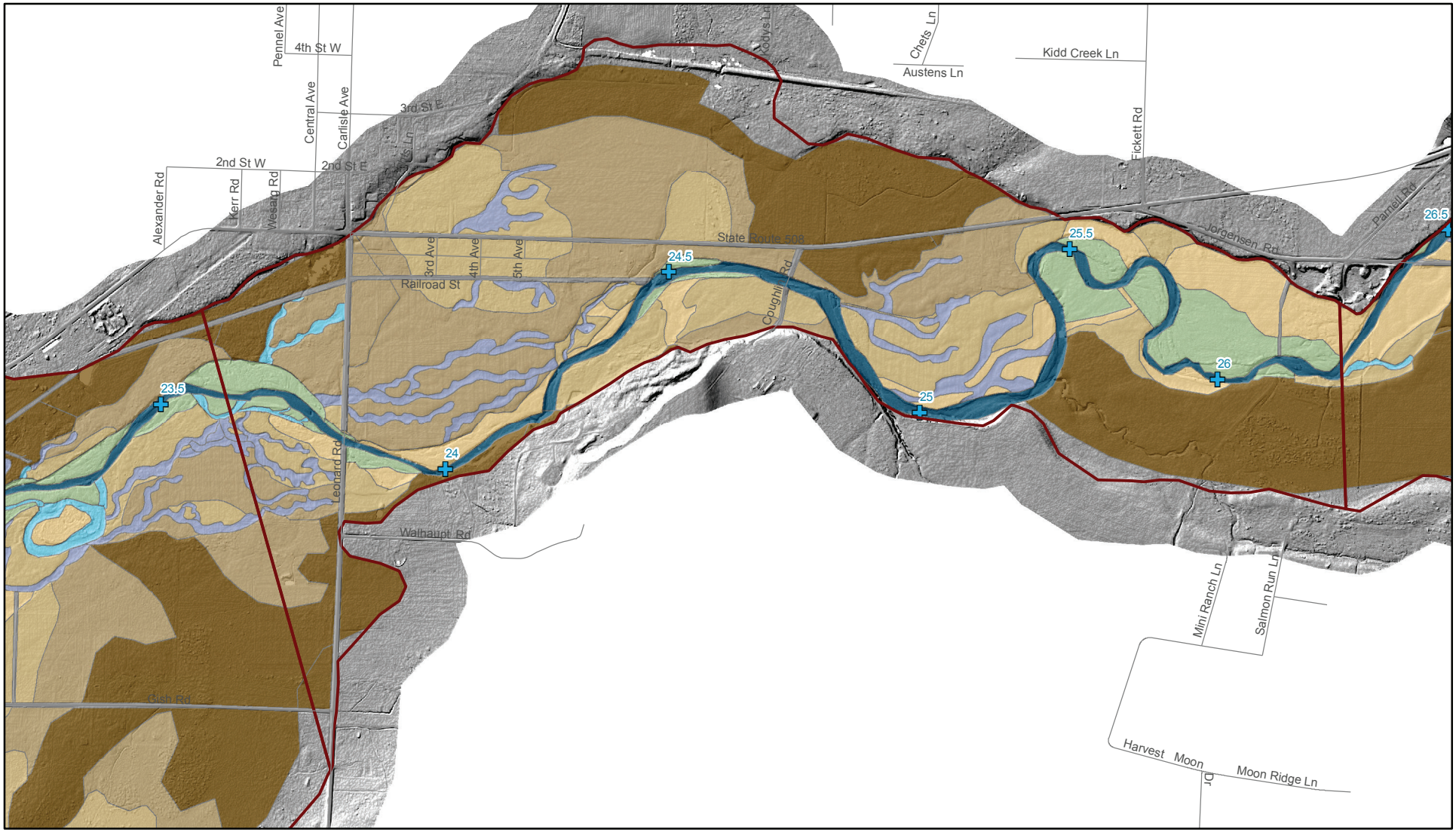
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_REM.mxd, Date Saved: 6/14/2018 1:12:00 PM



Geomorphic Landform Map

South Fork Newaukum River - Reach 4

River Reach Boundary (NSD 2017)
Roads
River Mile

Geomoprhic Landforms (NSD 2017)
- Main Channel
- Channel
- Abandoned Channel
- Active Floodplain
- Historical Floodplain (4-6')
- Historical Floodplain (6-10')
- Historical Floodplain (10-15')
- High Terrace (>15')
- Road

0 250 500 1,000 Feet

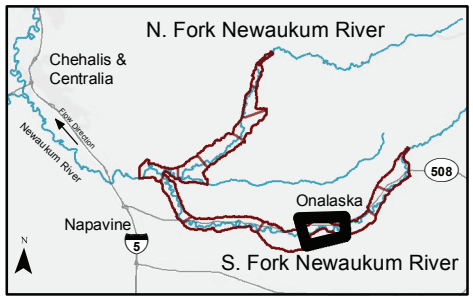
N

Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. The active and historical floodplain surfaces showed no statistically significant difference (p>0.1) and were determined to have the same erosion potential.
1.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
2.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4.Geomorphic landforms were delineated for the valley bottom which was defined where a slope break occured at the margin with the hillslope.

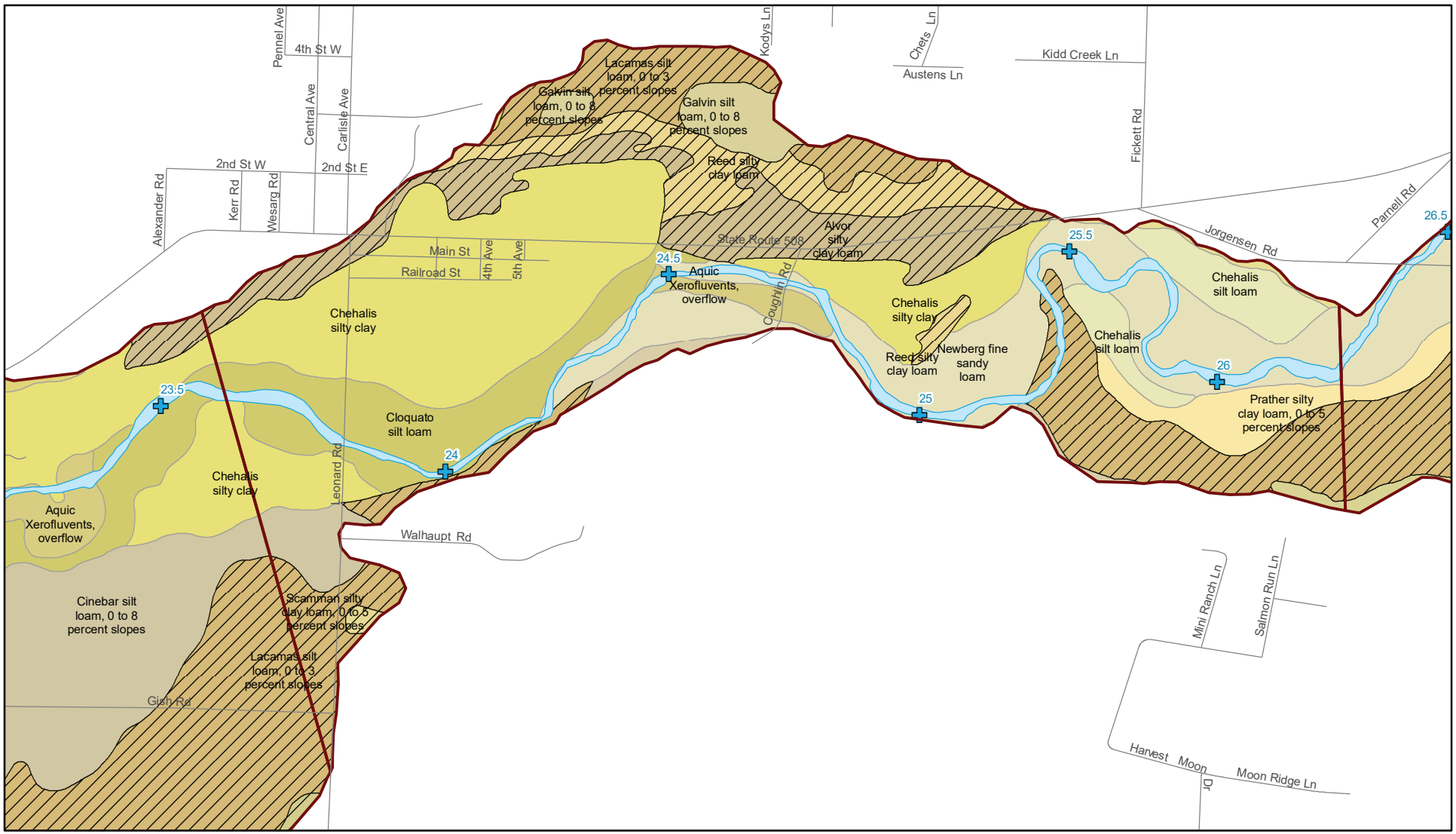
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Geomorph.mxd, Date Saved: 7/3/2018 12:35:06 PM



Existing Soils Map

South Fork Newaukum River - Reach 4

Notes:
1. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.
2. Soils data is from the USDA-SSURGO database.

0 250 500 1,000 Feet

N

- River Reach Boundary (NSD 2017)
- Roads
- River Mile
- River Channel
- Hydric Soil

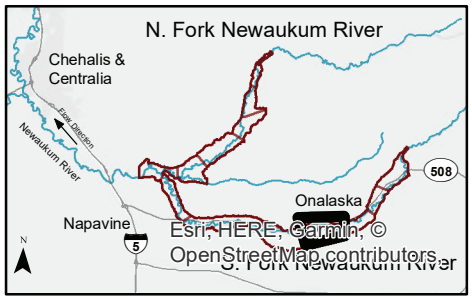
Soil Type

- Alvor silty clay loam
- Aquic Xerofluvents, overflow
- Chehalis silt loam
- Chehalis silty clay
- Cinebar silt loam, 0 to 8 percent slopes
- Cinebar silt loam, 15 to 30 percent slopes
- Cinebar silt loam, 8 to 15 percent slopes
- Cloquato silt loam
- Galvin silt loam, 0 to 8 percent slopes
- Lacamas silt loam, 0 to 3 percent slopes
- Lacamas-Scamman complex, 0 to 15 percent slopes
- Newberg fine sandy loam
- Prather silty clay loam, 0 to 5 percent slopes
- Prather silty clay loam, 5 to 15 percent slopes
- Reed silty clay loam
- Salkum silty clay loam, 0 to 5 percent slopes
- Salkum silty clay loam, 15 to 30 percent slopes
- Salkum silty clay loam, 30 to 65 percent slopes
- Scamman silty clay loam, 0 to 5 percent slopes
- Scamman silty clay loam, 5 to 15 percent slopes
- Xerorthents, spoils
- Xerorthents, steep

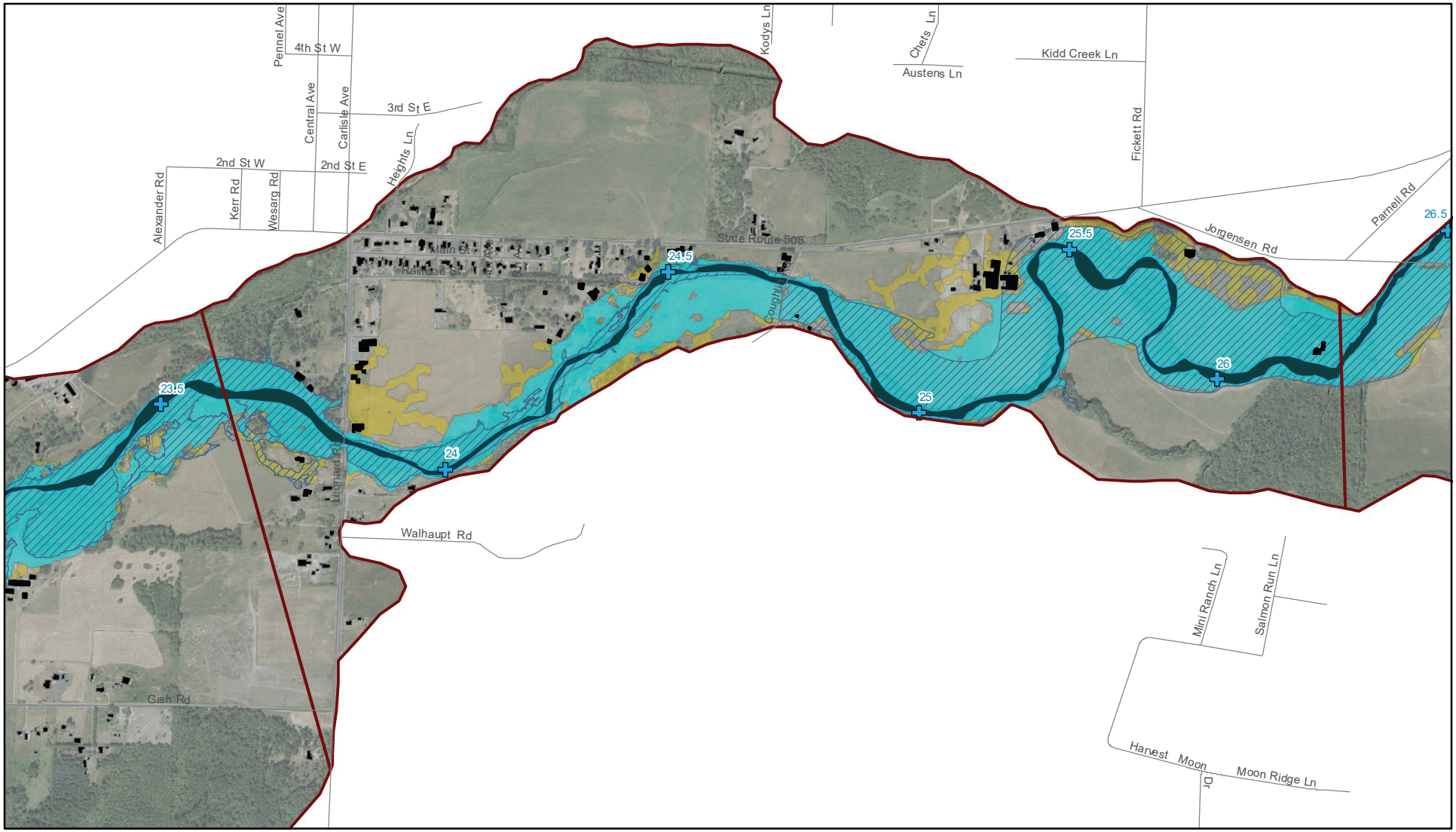
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Soils.mxd, Date Saved: 6/14/2018 1:17:11 PM



Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change

South Fork Newaukum River - Reach 4

- Buildings
- River Reach Boundary
- Roads
- River Mile
- 2017 River Channel
- Regulatory 100-year Flood Boundary (FEMA)
- 2009 Flood (Current Flood of Record)
- 2009 Flood Simulated With Estimated Climate Change Effects

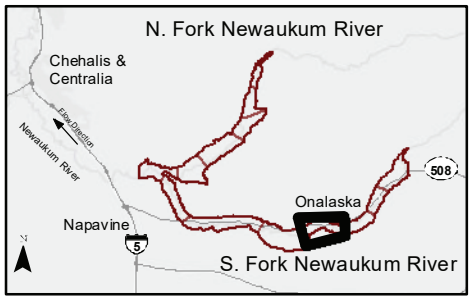
0 500 1,000 Feet

N

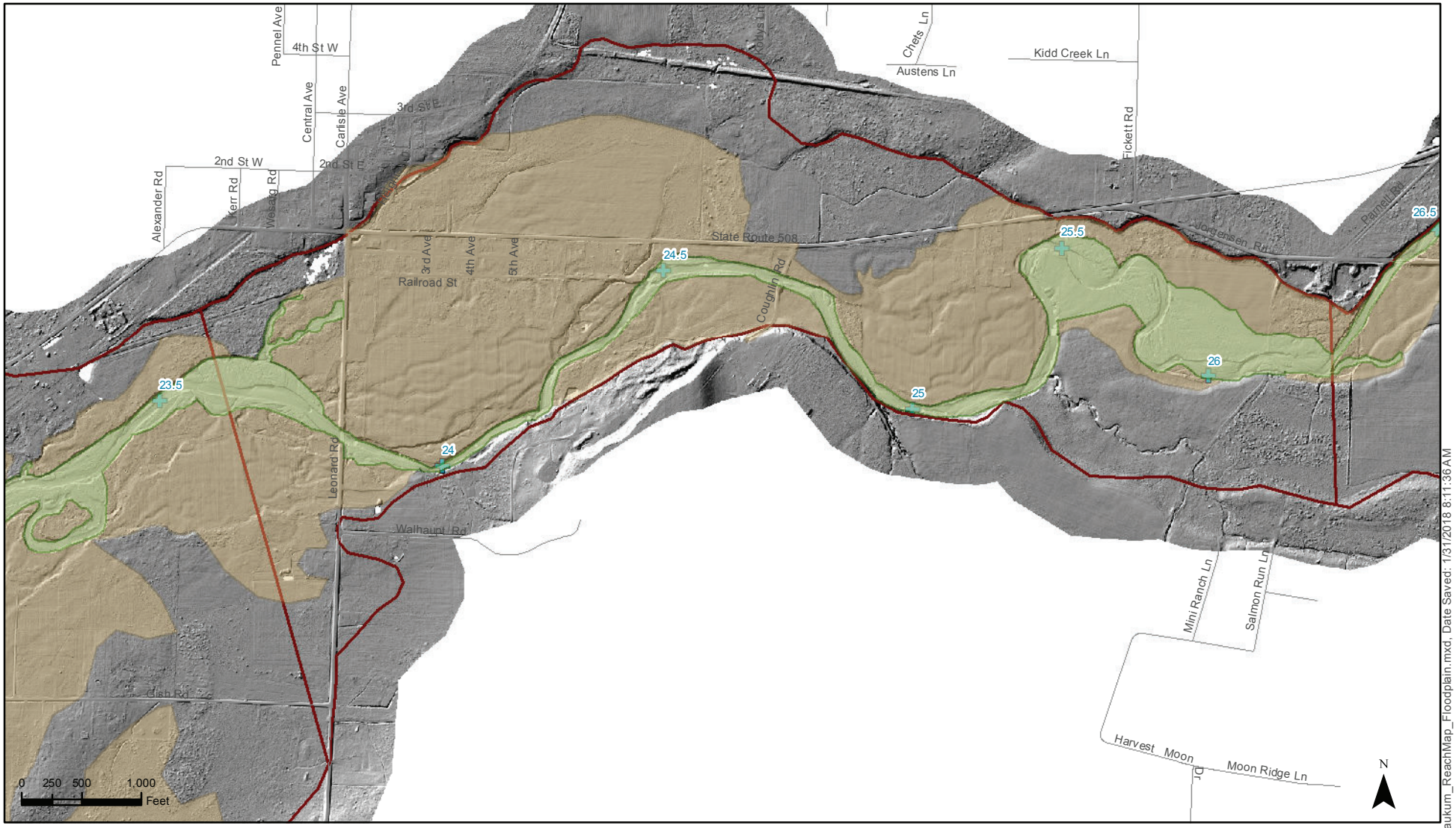
Notes:
1. Hydraulic simulation performed using RiverFlow2D - GPU. Simulation performed for the flood of record on the mainstem Newaukum Gage (USGS 12025000) which occurred from January 4 to Janaury 10th 2009. The estimated peak flow of 13,000 cfs occured on January 7th. Existing conditions 2009 flood simulation shows maximum simulated flood extent. Climate change flood simulation represents a 26% increase in 2009 flood water discharge.

2. Building (structures) dataset created by Lewis County, 2013. River reach boundary created by Natural Systems Design, 2017.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Inundation_ClimateChange.mxd, Date Saved: 10/10/2019 9:38:07 AM



Modern and Historical Floodplains

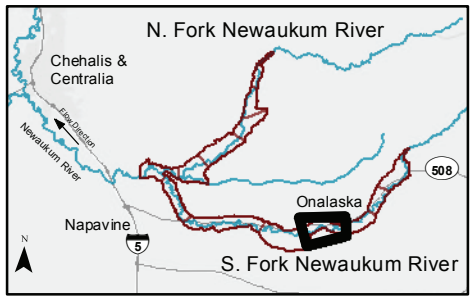
South Fork Newaukum River - Reach 4

- Roads
- River Reach (NSD, 2017)
- River Mile
- Modern Floodplain
- Historical Floodplain

Notes:
1. The active and historical floodplain extents are based off of geomorphic landforms delineated by NSD.
2. The modern floodplain extent represents the current geomorphic surface within which moderate floods are contained. The modern floodplain was mapped as the active floodplain surface.
3. The historical floodplain includes terraces ranging from 4-15' and likely represent the extent of flood innundation during a moderate flood.
4. Digital Elevation Model (DEM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
5. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

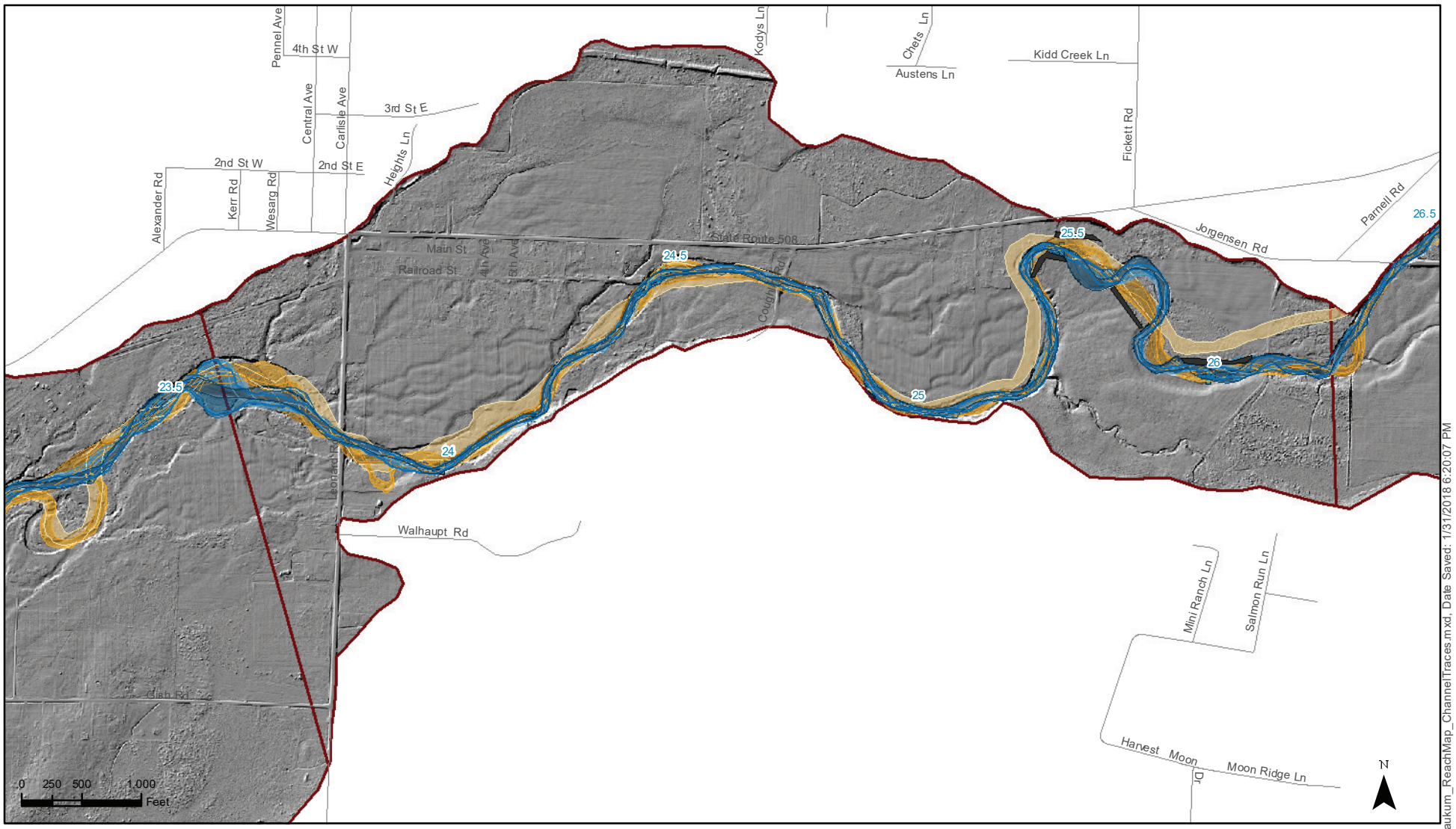
Vicinity Map

0 1 2 4 Miles — Location



Map 4 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Floodplain.mxd, Date Saved: 1/31/2018 8:11:36 AM



River Channel Changes from 1940 to 2017

South Fork Newaukum River - Reach 4

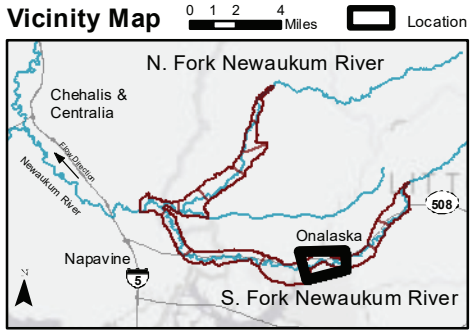
Bank Armoring (Incomplete Dataset*)
Roads
River Reach (NSD, 2017)
River Mile

River Channel Locations By Year
1940
1950
1980
1990
2006
2009
2011
2015
2017

Notes:
*The bank armoring dataset only covers the lower reaches of the South and North Fork Newaukum Rivers (RM 12-22.5 on the South Fork and RM 0-2 on the North Fork. The data was generated during Fall 2017 field observations by NSD.

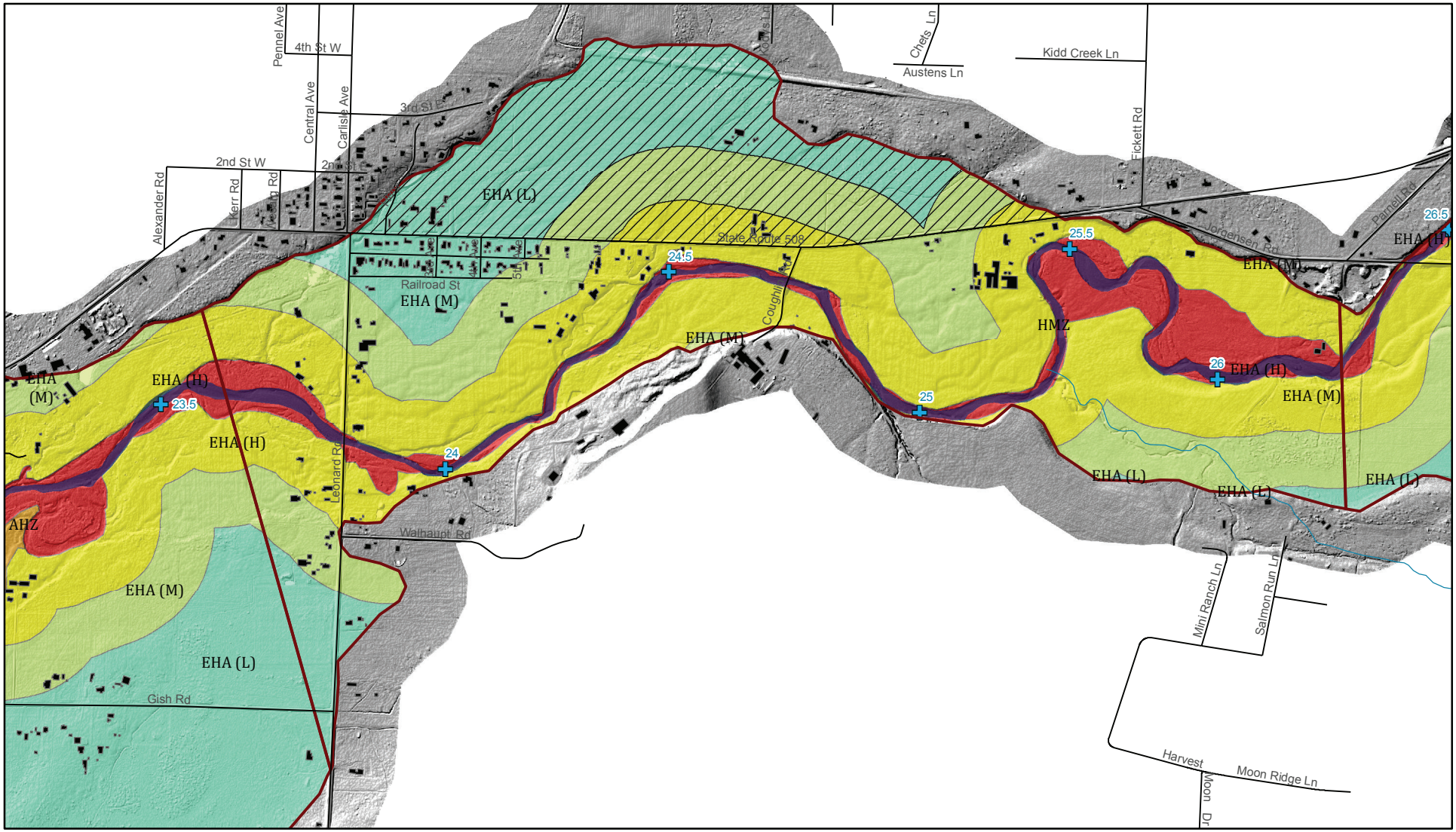
1. River Channel locations were digitally delineated as polygons surrounding the active un-vegetated channel from aerial photographs.
2. Digital Elevation Model (DEM) based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map



Map 4 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_ChannelTraces.mxd, Date Saved: 1/31/2018 6:20:07 PM



Erosion Hazard Analysis

South Fork Newaukum River - Reach 4

Stream
River Reach Boundary (NSD 2017)
Roads
Buildings
River Mile
River Channel
Disconnected EHAs

Erosion Hazards

HMZ
AHZ
EHA (H)
EHA (M)
EHA (L)

0 250 500 1,000 Feet

N

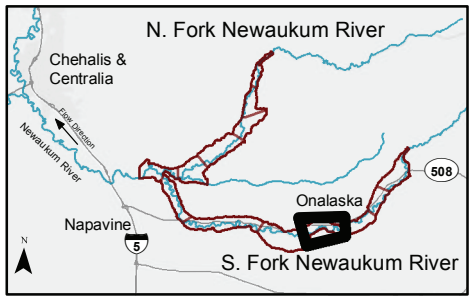
Notes:
1. Erosion hazard delineation is based on methods outlined in Rapp and Abbe (2003) "A Framework for Delineating Channel Migration Zones" WA Dept. of Ecology and Transportation.
2. Erosion hazards were delineated using the average historical channel migration rate between 1951-2017 (4.5 ft/yr). See Methods appendix for detailed description of delineation methodology.

HMZ - Historical Migration Zone
AHZ - Avulsion Hazard Zone
EHA (H) - Erosion Hazard Area High
EHA (M) - Erosion Hazard Area Medium
EHA (L) - Erosion Hazard Area Low
Disconnected EHAs - Areas on the non-river side of SR 508 and North Fork Rd.

Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Erosion.mxd, Date Saved: 6/15/2018 10:37:25 AM

South Fork Newaukum River Reach 5

Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description

Vegetation, Soils and Wetlands

Reach 5 of the South Fork Newaukum River valley bottom occupies over 430 acres, including the river channel. The floodplains and terraces are currently co-dominated by 175 acres of pasture or mowed grass, and 153 acres of mixed forest (See Landcover Map in Appendix). Together, these landcover classes make up 75% of the floodplain landcover. The rest of the valley bottom, is a mixture of shrubs, roads and buildings, and river channel.

% Area	Acres	Landcover
40%	175	Pasture or Groundcover
35%	153	Forest
13%	58	Shrubs
6%	25	Small Trees, Large Shrubs
3%	11	Water
2%	8	Road
1%	3	Buildings
1%	2	Gravel Bar
0%	0	Log Jam
100%	**436**	**Total**

The soils of reach 5 of the South Fork Newaukum River valley bottom are comprised of Newberg fine sandy loam in the active channel area of the lower part of this reach--perfect conditions for cottonwood bottomland—transitioning to Chehalis silt loam, Chehalis silty clay, and Cloquato silt loam (See Soils Map in Appendix). As the valley topography increases in elevation from the river channel to the valley wall, hydric silty loam soils are found on the landscape. These hydric soils are an indicator of wetland soil formation processes.

Infrastructure, Buildings & Ownership

Reach 5 of the South Fork Newaukum River has **one major bridge crossing**, at Jorgensen Road. **South Fork Newaukum River abuts the State Route 508 embankment about two (2) times in this reach, all of which are armored with riprap.**

There are numerous homes and farms in this reach, about 64 structures total, with several structures on the riverbank.

The 60 parcels that comprise this valley bottom are almost entirely privately owned, by 48 landowners. There are no publicly-owned parcels in this reach. The largest private landowner is Daryl Germann Farms, LLC, which owns about 18% (78 acres) of the total the valley bottom. This area calculation does not include the land outside of the valley bottom analysis area.

Description of Parcels in the Floodplain

In order to understand the influence of the river on landowners, parcels in the simulated 2009 flood event* were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the higher the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel. ***Of the 48 landowners in the valley bottom, 24 landowners had property that was inundated in the simulated 2009 flooded-area, and 1 land owner has property that is more than 75% within the approximated inundated area, or about 2.6 parcel-acres*** (see table below). The assessed land use for this parcel is mining/forestry.

Landuse description of parcels with > 75% area in flooded area

Assessed Land Use Description	Number of Parcels	Acres Flooded *	Total Parcel Acres	Largest Landowner (Parcel Acres)
Mining/forestry	1	2.6	2.8	CF Ho'I Mai, LLC (37 ac.)
TOTAL	**1**	**2.6**	**2.8**	**1 Landowner w/ > 75% land in flooded area**

Flooded buildings

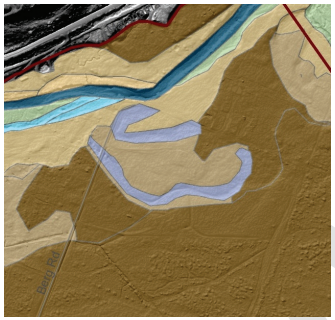
The number of buildings in the simulated 2009 flooded area was ~10, including residences and outbuildings (see inundation map for approximate locations).

South Fork Newaukum River Reach 5

Geomorphic Reach Description

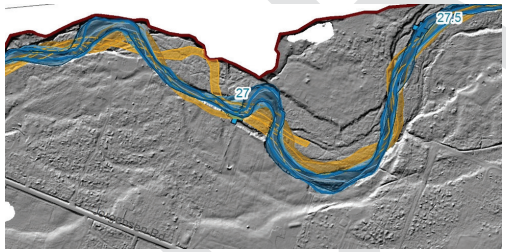
Reach 5 of the South Fork Newaukum River is located between RM 26.25 and RM 28 and is upstream of the town of Onalaska. The reach is contained within a narrow section of the valley that is less than half a mile wide. The reach has an average slope of 0.0042 ft/ft (or 0.42%) and has a simple and straight morphology that is likely plane bedded (Table 1, REM map) (Montgomery and Buffington, 1997). There are no major tributary junctions within this reach.

Geomorphic Landforms



The river within this reach is contained within a narrow (~170 ft wide) inset floodplain corridor. The river is incised below its historical location with the modern floodplain **6.0 feet** below the historical floodplain surface on average. The historical floodplain surface occupies the northern half of the valley and surrounds the current channel location. The remainder of the valley contains a non-fluvial terrace that is likely composed of glacial outwash deposits. The historical floodplain surface likely formed within this surface as there is evidence of scalloping adjacent to relict channel features (SEE FIGURE).

Channel Migration and Erosion



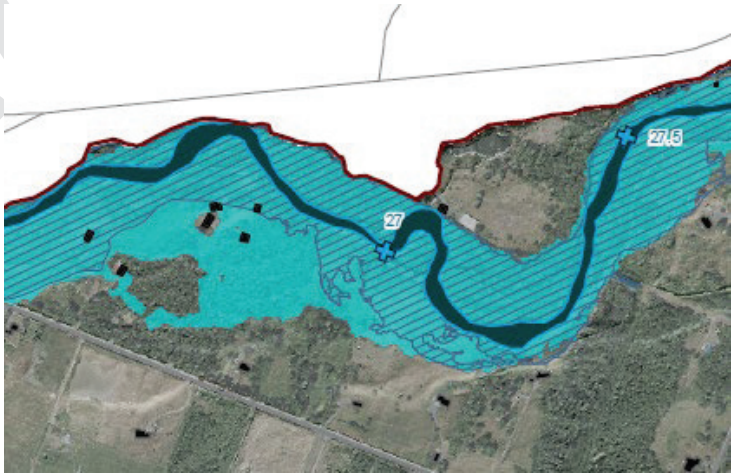
There has been active channel migration between RM 26.75-27.5 where the river has been widening its inset floodplain corridor as it erodes into historical alluvium (SEE FIGURE). The remainder of the reach has been relatively stable since 1950 with little evidence of channel migration. The lack of channel migration and the presence of the resistant non-fluvial terrace indicate that there has been minimal recent erosion within this reach.

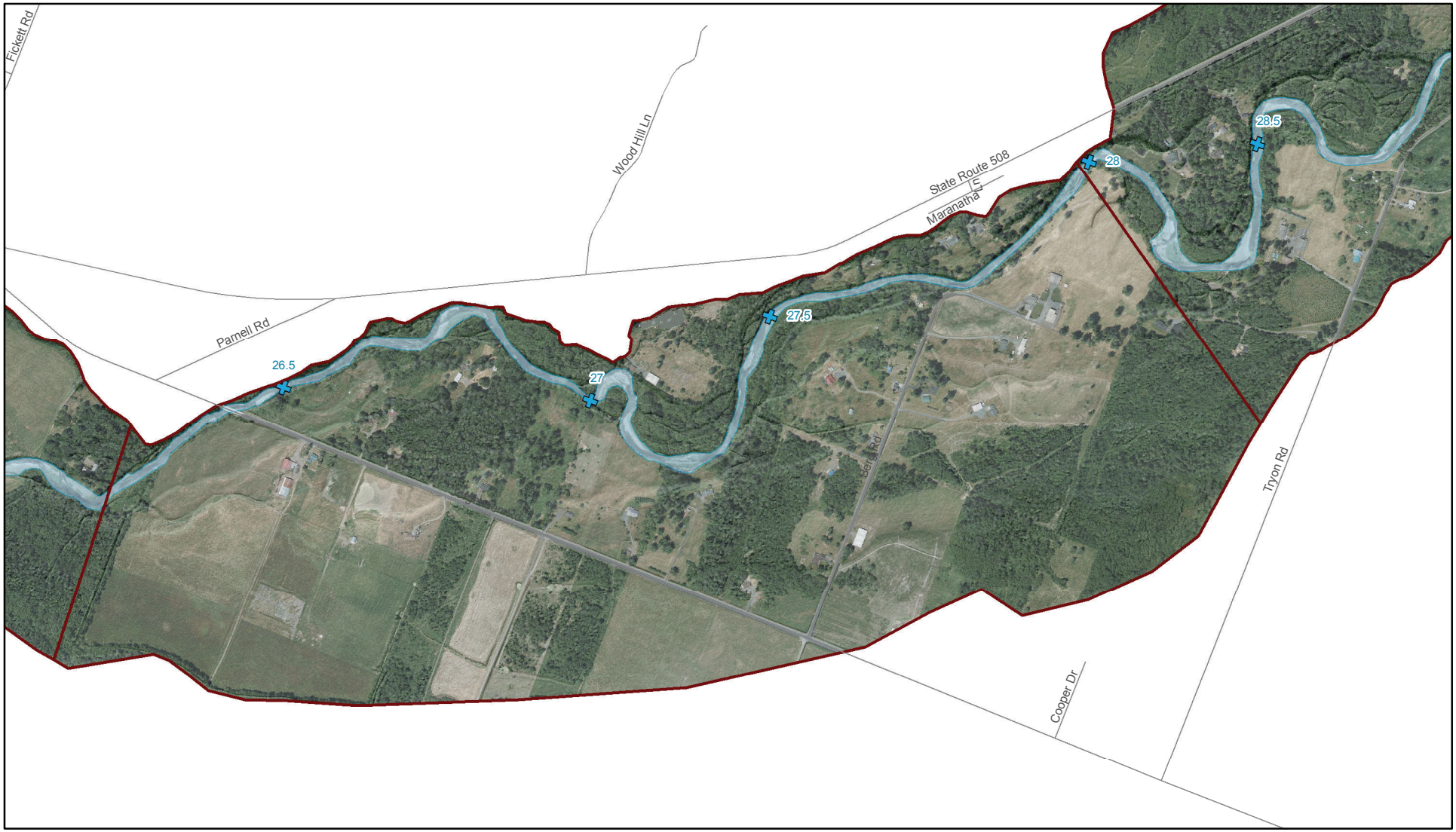
Table 1: Reach Statistics

Geomorphic Reach Description Statistics		Units
Slope	0.0042	ft/ft
Centerline Length	9297	ft
Average Depth of Incision	6.0	ft
Historic Floodplain Average Width	692	ft
Active Floodplain Average Width	169	ft
Historic Floodplain: Active Floodplain	4	ft/ft
Flood Defense Length	N/A	ft
Flood Defense Length/Channel Length	N/A	ft/ft
Road Length	7284	ft
Total Reach Area	436	acres

2009 Flooding & FEMA boundary

The FEMA 100-year flood boundary (hatched) is primarily similar to the preliminary simulation results of the January 2009 flood (solid blue) within Reach 5 of the South Fork Newaukum (See Inundation map). The only difference between the inundation boundaries occurs between RM 26.75-27.0 where the January 2009 simulation predicts inundation to occur ~650 ft away from the FEMA boundary. This location contains 4 structures.





Context and Vicinity Map

South Fork Newaukum River - Reach 5

Stream
River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel

0 250 500 1,000 Feet

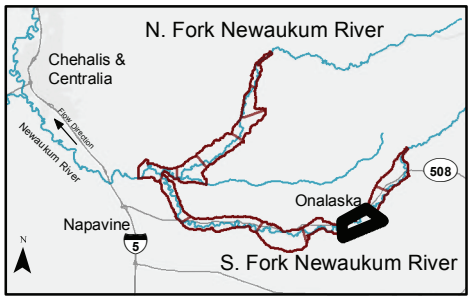
N

Notes:
1. Aerial Imagery and Digital Elevation Model (DEM) are based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. River reach breaks were done by Natural Systems Design (NSD) in 2017.

Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Vicinity.mxd, Date Saved: 6/14/2018 2:26:17 PM

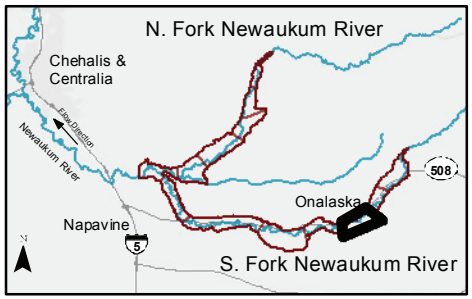
Existing Landcover Map

South Fork Newaukum River - Reach 5

River Reach (NSD, 2017)
River Mile
Landcover (NSD, 2017)
Pasture or Groundcover (< 3' tall)
Shrubs and Small Trees (3' to 20' tall)
Forest and Large Shrubs (> 20' tall)
Road
Structure (i.e. Building)
Gravel Bar
Vegetated Gravel Bar
Log Jam
Water

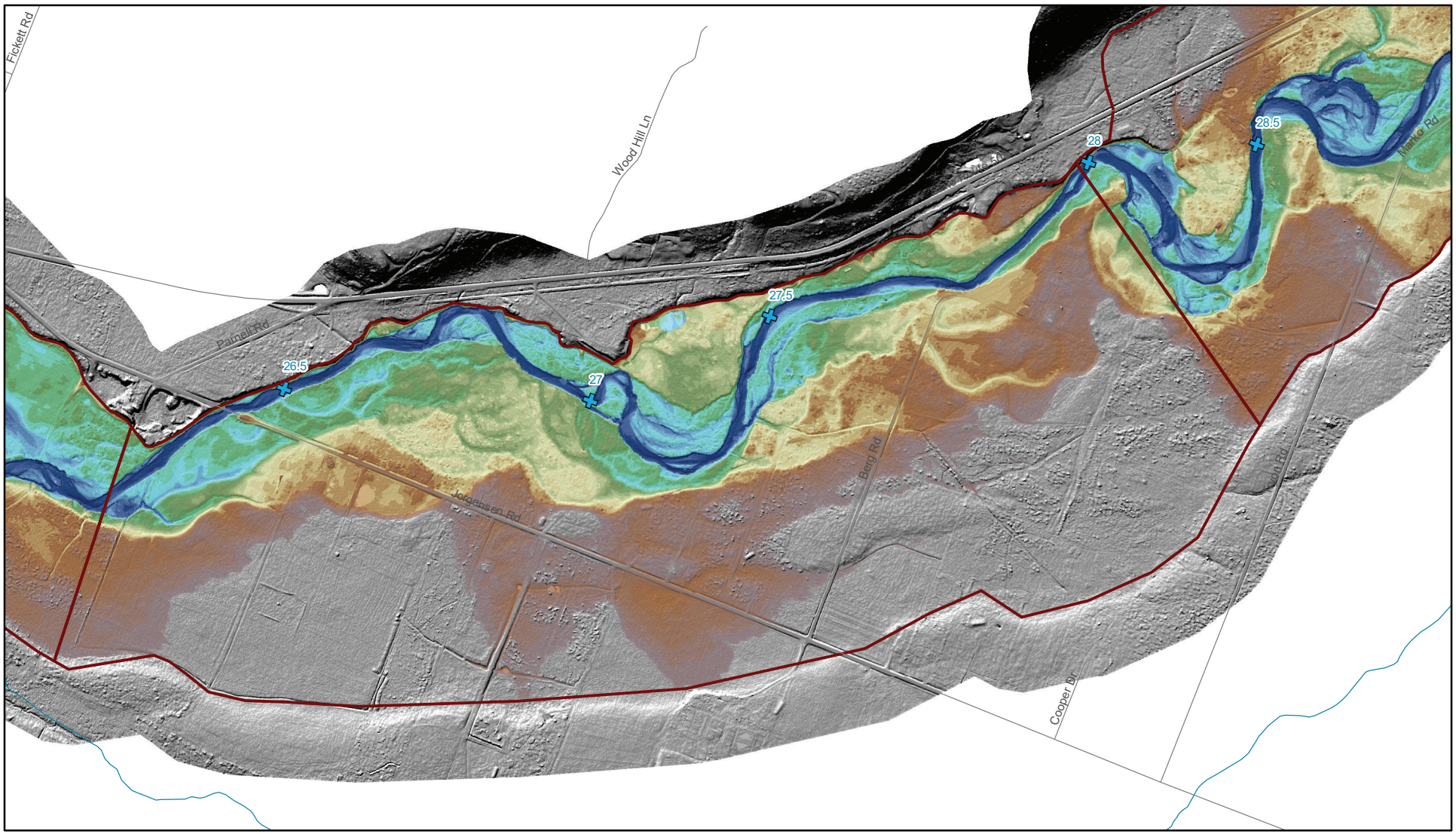
Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. There were statistically sigfnificant differences ($p<0.005$) between pasture and forest landcover types with erosion rates as follows:
a. Forest/shrubs: 6.0 +/- 3 ft/yr (n=20)
b. Pasture: 9.4+/- 5 ft/yr (n=24)
2.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
3.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
4. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map 0 1 2 4 Miles — Location



Map 5 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Landcover.mxd, Date Saved: 1/30/2018 8:04:03 PM



Relative Elevation Map (REM)

South Fork Newaukum River - Reach 5

Stream
River Reach Boundary (NSD 2017)
Roads
River Mile

Relative Elevation Above River Channel At Low Water (feet)

-4.6 - -1 | -1.1 - -2 | -2.1 - -3 | -3.1 - -4 | -4.1 - -5 | -5.1 - -6 | -6.1 - -7 | -7.1 - -8 | -8.1 - -9 | -9.1 - -10 | -10.1 - -11 | -11.1 - -12 | -12.1 - -13 | -13.1 - -14 | -14.1 - -15 | -15.1 - -16 | -16.1 - -17 | -17.1 - -18 | -18.1 - -19 | -19.1 - -20

0 250 500 1,000 Feet

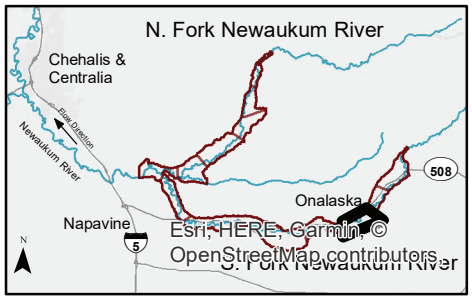
N

Notes:
1. Relative Elevation Model (REM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
3. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

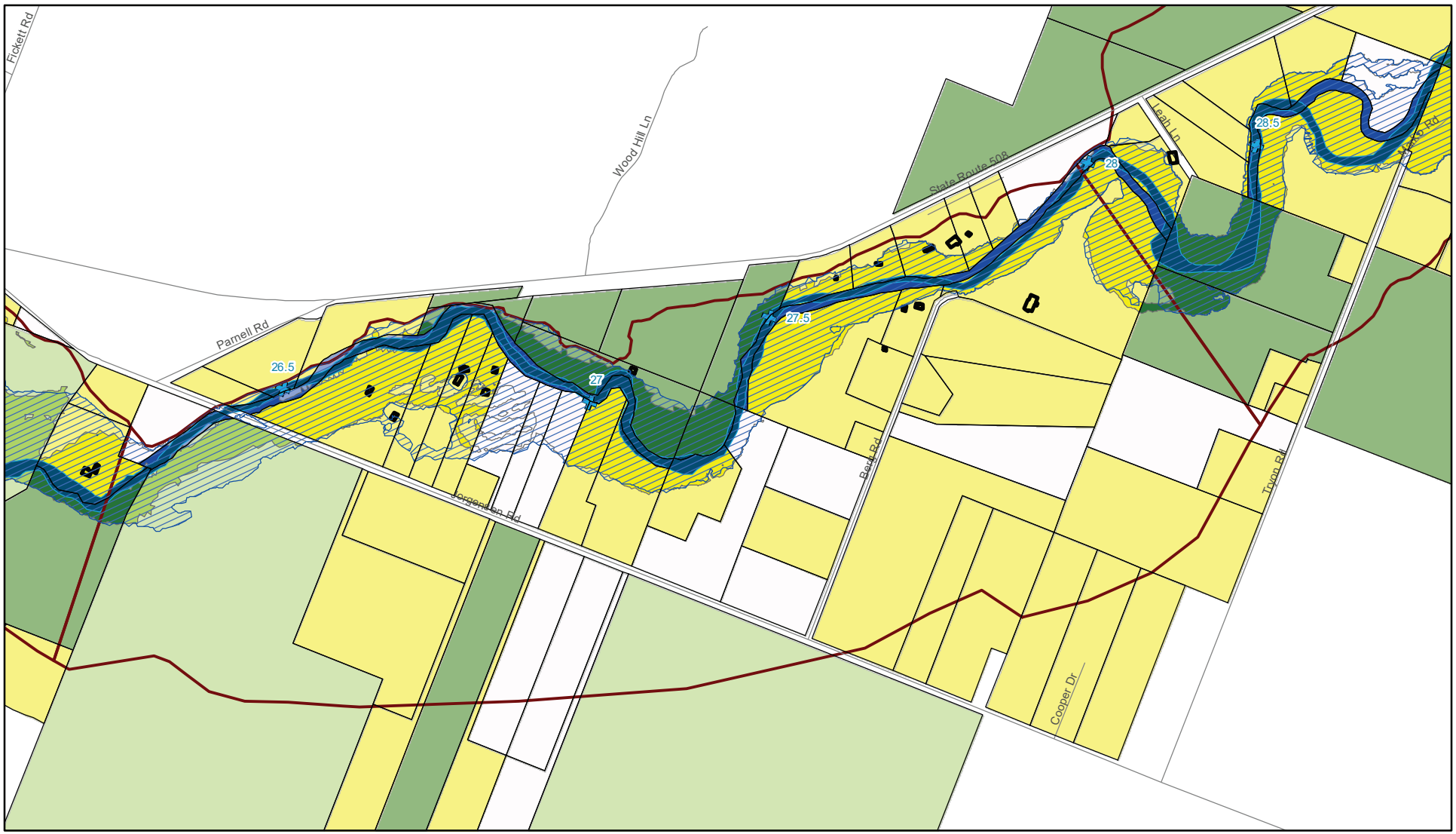
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_REM.mxd, Date Saved: 6/14/2018 1:12:00 PM



Existing Parcels Affected by Simulated 2009 Flood of Record

South Fork Newaukum River - Reach 5

Simulated 2009 Flood Extent

Affected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Undeveloped/Vacant
- Water

Unaffected Parcel Type
- Multi-Residential; Single-Residential
- Agriculture
- Mining/Forestry
- Undeveloped/Vacant
- Water

River Reach Boundary (NSD 2017)

Roads

River Mile

River Channel

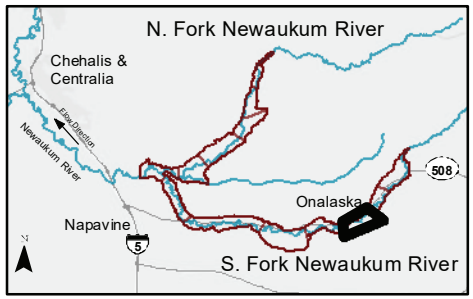
Buildings

0 250 500 1,000 Feet

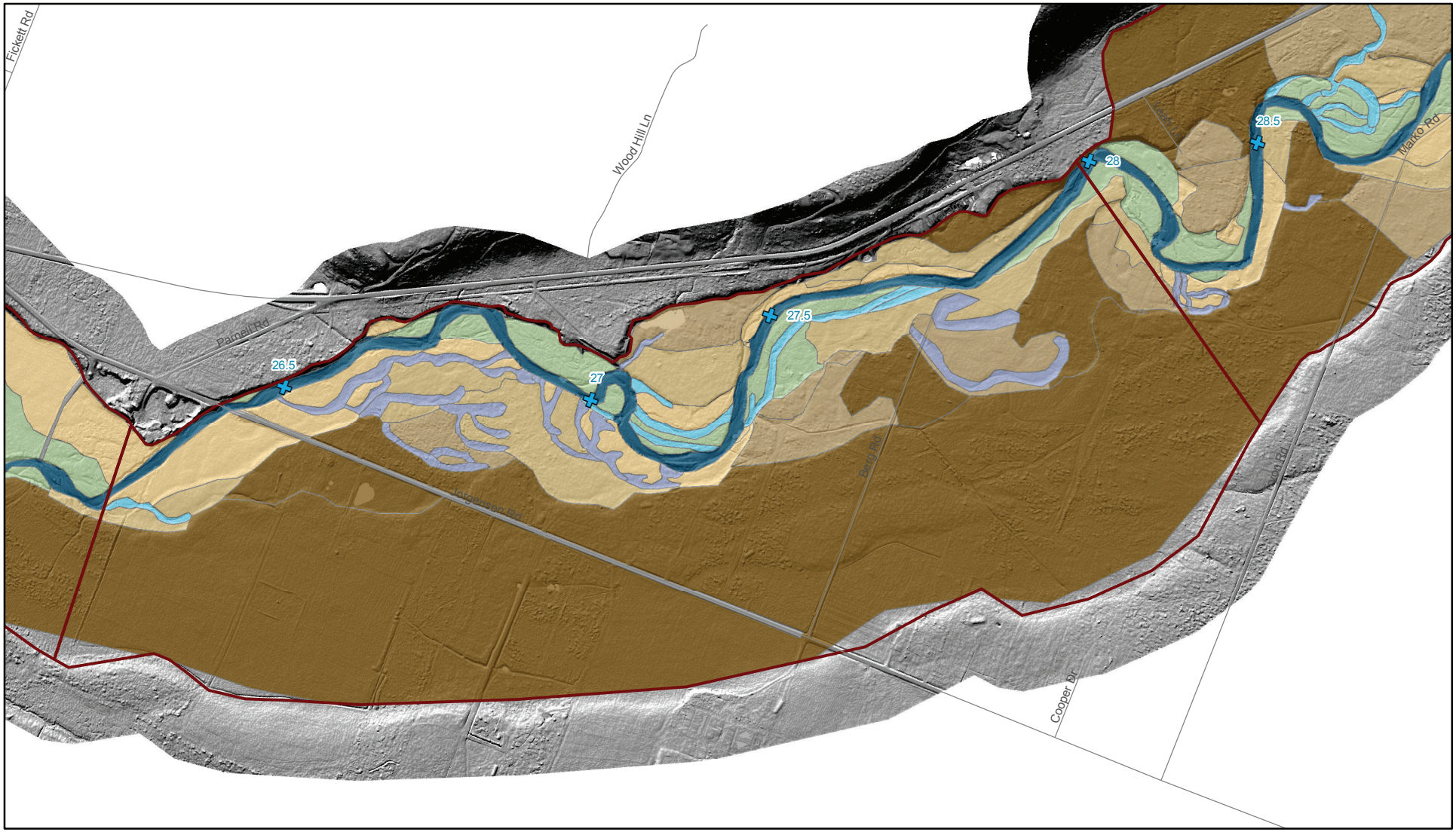
N

Notes:
1. Building/structures data from Lewis County,2013, additional buildings digitized by NSD, 2017.
2. Parcel data from Lewis County Assessor's Office. Accessed [8/18/2017].
3. The river channel delineated using 2017 LiDAR, represents low flow conditions for spring 2017.

Vicinity Map 0 1 2 4 Miles — Location



\\NATUSYST-NAS1\Bellingham\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_UpdatedParcels.mxd, Date Saved: 6/14/2018 1:31:11 PM



Geomorphic Landform Map

South Fork Newaukum River - Reach 5

0 250 500 1,000 Feet

N

River Reach Boundary (NSD 2017)
Roads
River Mile

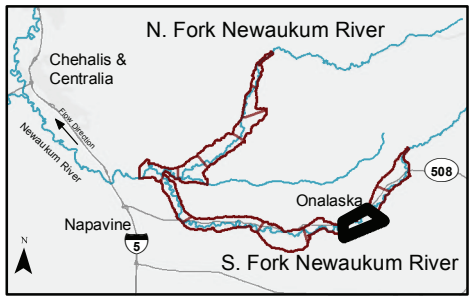
Geomoprhic Landforms (NSD 2017)
- Main Channel
- Channel
- Abandoned Channel
- Tributary
- Active Floodplain
- Historical Floodplain (4-6')
- Historical Floodplain (6-10')
- Historical Floodplain (10-15')
- High Terrace (>15')
- Road

Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. The active and historical floodplain surfaces showed no statistically significant difference (p>0.1) and were determined to have the same erosion potential.
1.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
2.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4.Geomorphic landforms were delineated for the valley bottom which was defined where a slope break occured at the margin with the hillslope.

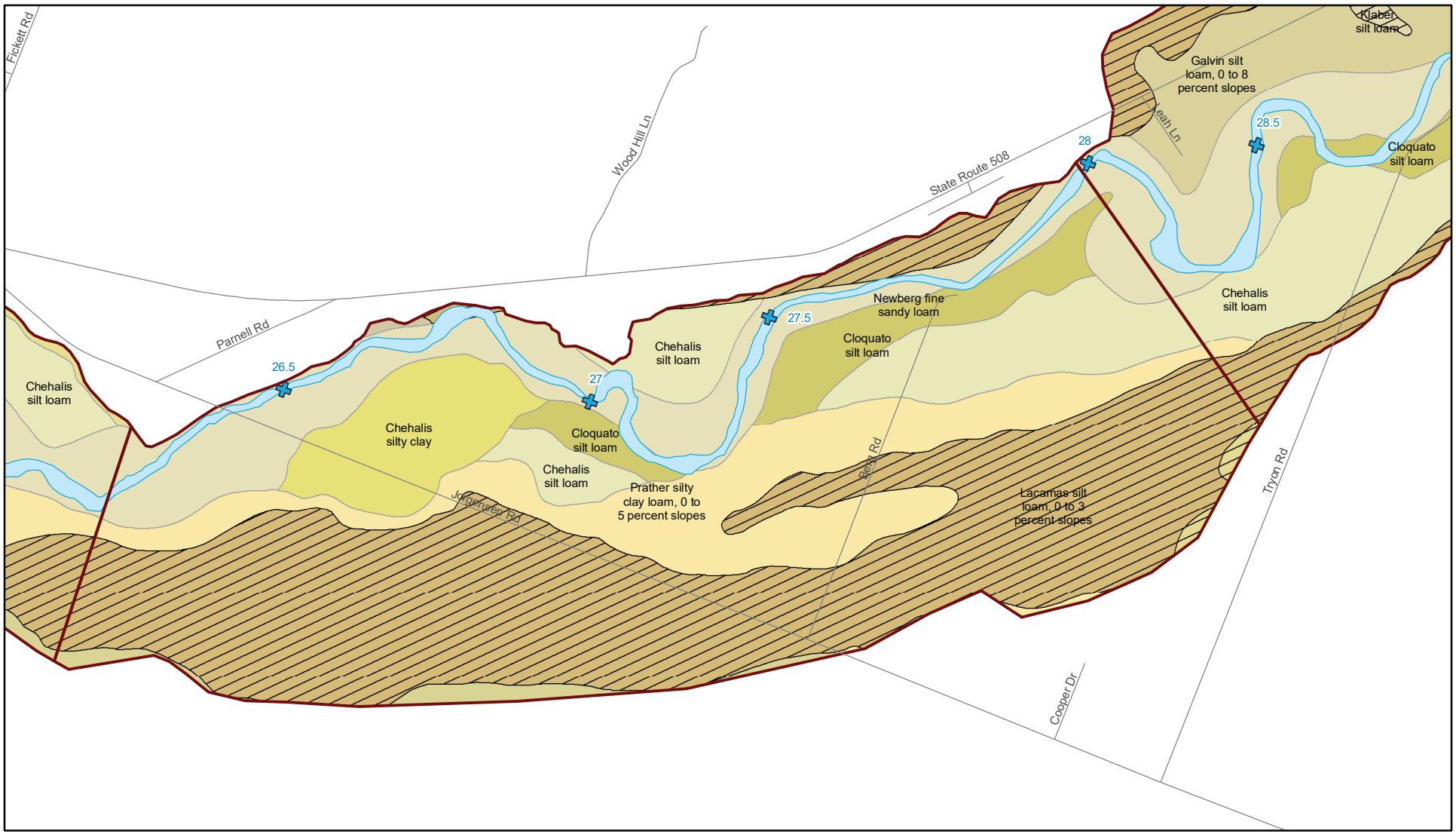
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Geomorph.mxd, Date Saved: 7/3/2018 12:35:06 PM



Existing Soils Map

South Fork Newaukum River - Reach 5

Notes:
1. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.
2. Soils data is from the USDA-SSURGO database.

0 250 500 1,000 Feet

N

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel
Hydric Soil

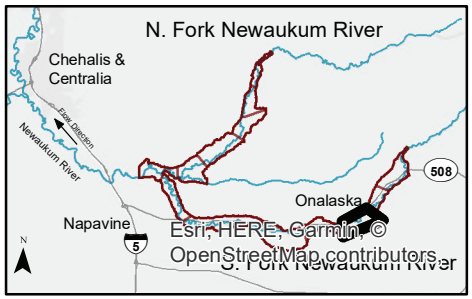
Soil Type

- Alvor silty clay loam
- Aquic Xerofluvents, overflow
- Chehalis silt loam
- Chehalis silty clay
- Cinebar silt loam, 0 to 8 percent slopes
- Cinebar silt loam, 15 to 30 percent slopes
- Cinebar silt loam, 30 to 65 percent slopes
- Cloquato silt loam
- Galvin silt loam, 0 to 8 percent slopes
- Klaber silt loam
- Lacamas silt loam, 0 to 3 percent slopes
- Lacamas-Scamman complex, 0 to 15 percent slopes
- Newberg fine sandy loam
- Olequa silt loam, 0 to 5 percent slopes
- Prather silty clay loam, 0 to 5 percent slopes
- Prather silty clay loam, 5 to 15 percent slopes
- Reed silty clay loam
- Salkum silty clay loam, 0 to 5 percent slopes
- Salkum silty clay loam, 15 to 30 percent slopes
- Scamman silty clay loam, 0 to 5 percent slopes

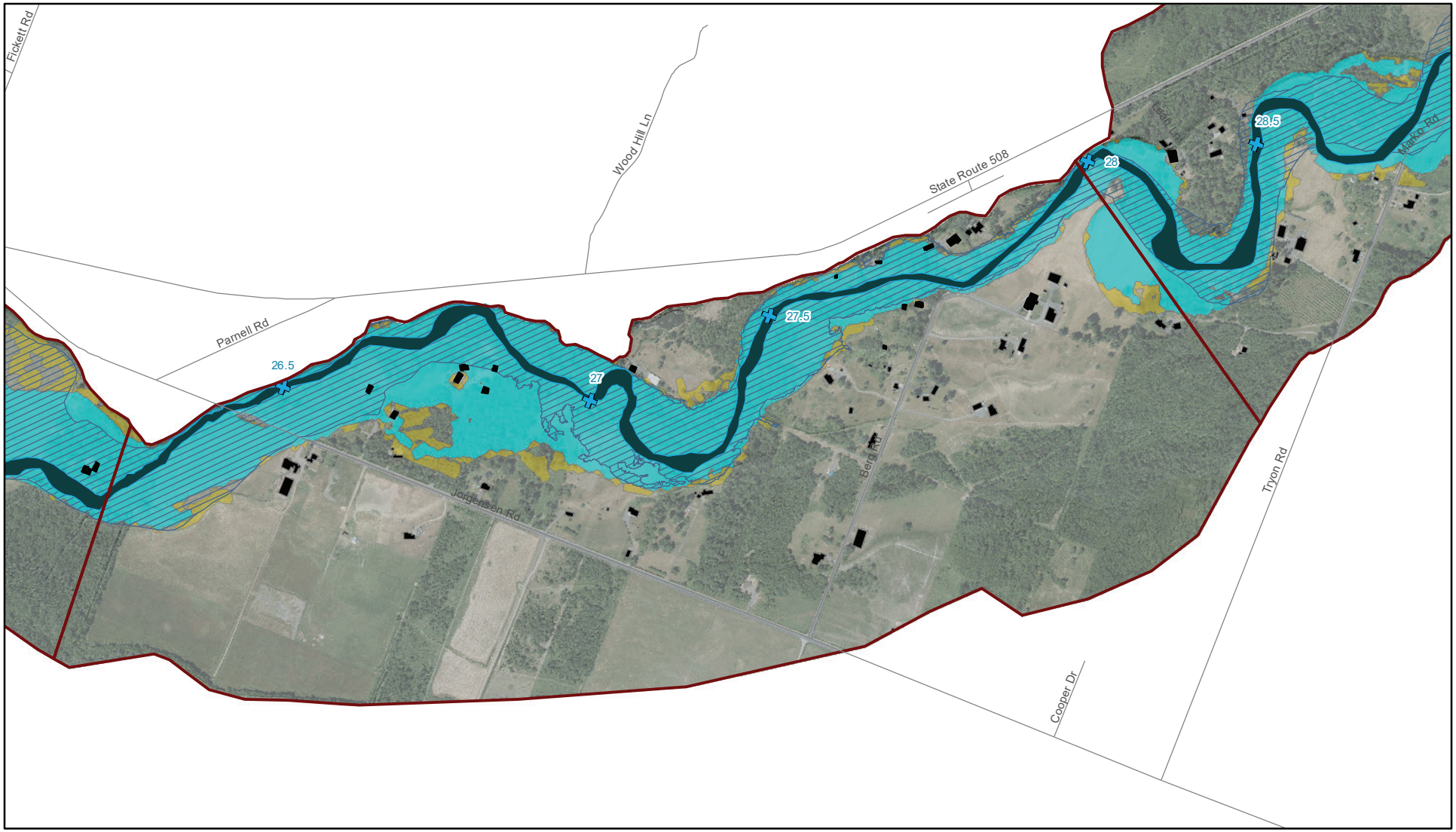
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Soils.mxd, Date Saved: 6/14/2018 1:17:11 PM



Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change

South Fork Newaukum River - Reach 5

- Buildings
- River Reach Boundary
- Roads
- River Mile
- 2017 River Channel
- Regulatory 100-year Flood Boundary (FEMA)
- 2009 Flood (Current Flood of Record)
- 2009 Flood Simulated With Estimated Climate Change Effects

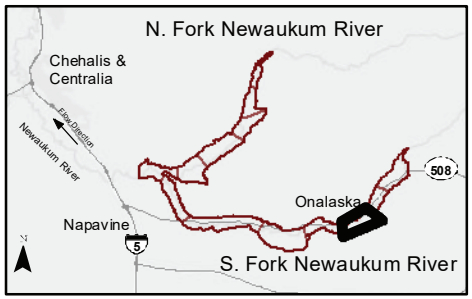
0 500 1,000 Feet

N

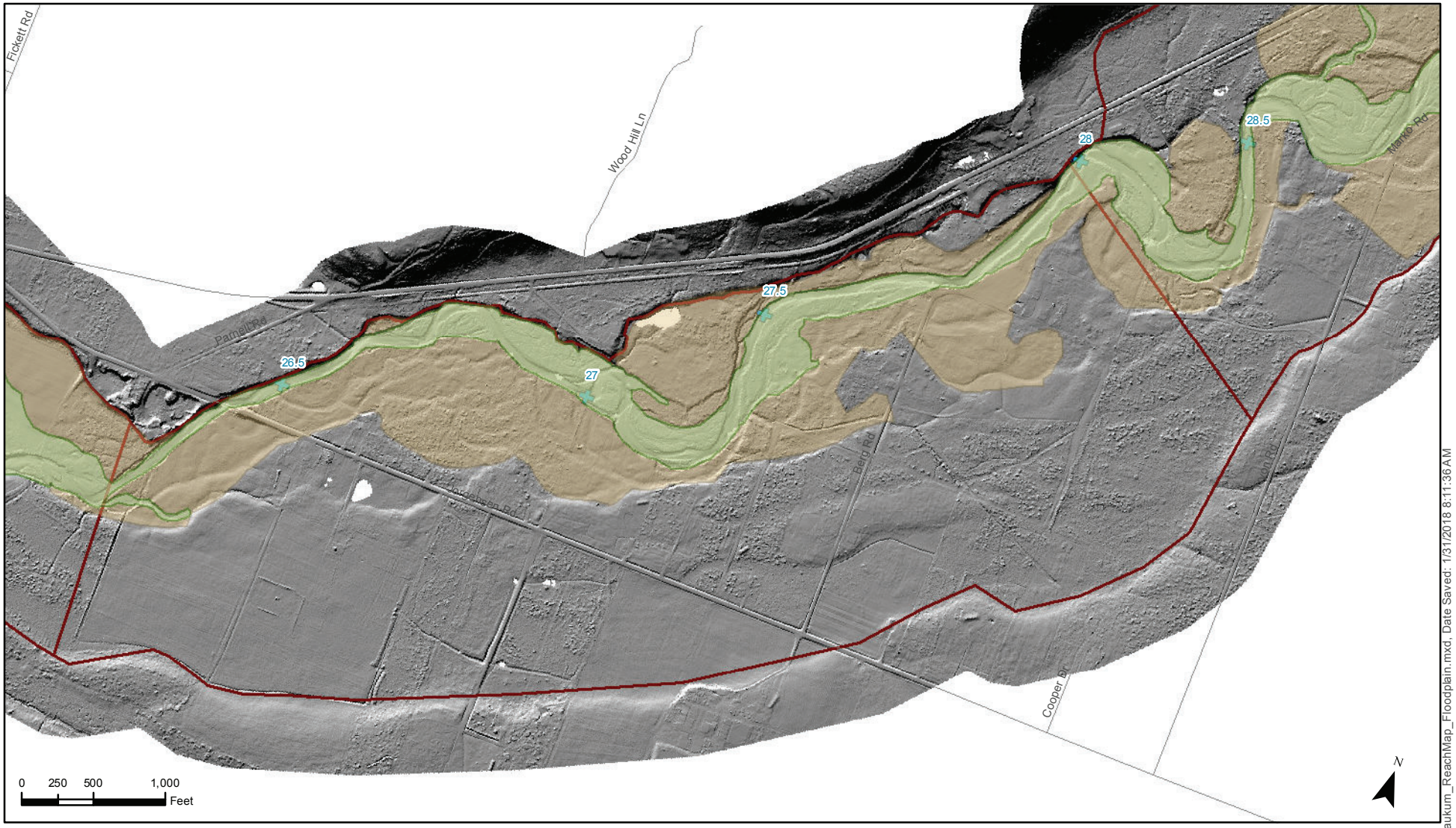
Notes:
1. Hydraulic simulation performed using RiverFlow2D - GPU. Simulation performed for the flood of record on the mainstem Newaukum Gage (USGS 12025000) which occurred from January 4 to Janaury 10th 2009. The estimated peak flow of 13,000 cfs occured on January 7th. Existing conditions 2009 flood simulation shows maximum simulated flood extent. Climate change flood simulation represents a 26% increase in 2009 flood water discharge.

2. Building (structures) dataset created by Lewis County, 2013. River reach boundary created by Natural Systems Design, 2017.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Inundation_ClimateChange.mxd, Date Saved: 10/10/2019 9:38:07 AM



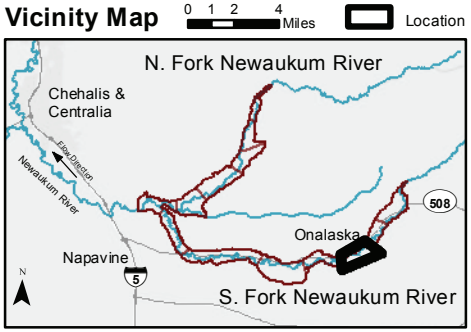
Modern and Historical Floodplains

South Fork Newaukum River - Reach 5

- Roads
- River Reach (NSD, 2017)
- River Mile
- Modern Floodplain
- Historical Floodplain

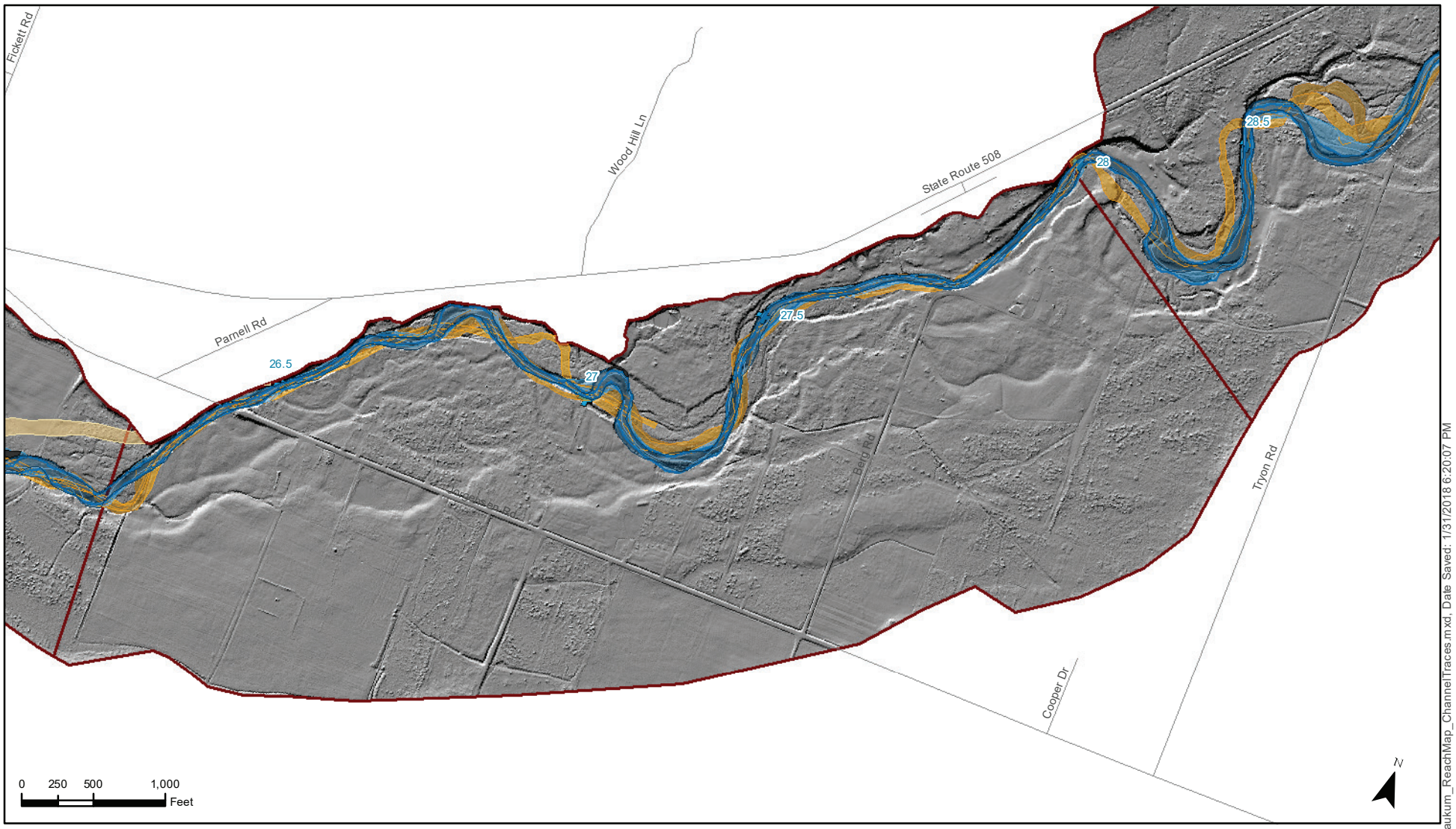
Notes:
1. The active and historical floodplain extents are based off of geomorphic landforms delineated by NSD.
2. The modern floodplain extent represents the current geomorphic surface within which moderate floods are contained. The modern floodplain was mapped as the active floodplain surface.
3. The historical floodplain includes terraces ranging from 4-15' and likely represent the extent of flood innundation during a moderate flood.
4. Digital Elevation Model (DEM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
5. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map



Map 5 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Floodplain.mxd, Date Saved: 1/31/2018 8:11:36 AM



River Channel Changes from 1940 to 2017

South Fork Newaukum River - Reach 5

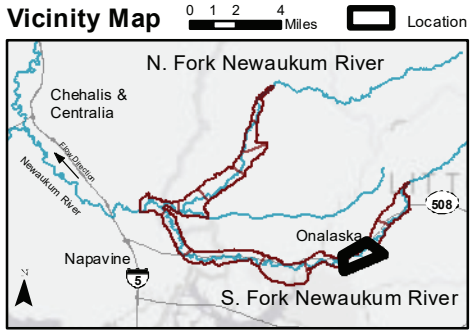
Bank Armoring (Incomplete Dataset*)
Roads
River Reach (NSD, 2017)
River Mile

River Channel Locations By Year
1940
1950
1980
1990
2006
2009
2011
2015
2017

Notes:
*The bank armoring dataset only covers the lower reaches of the South and North Fork Newaukum Rivers (RM 12-22.5 on the South Fork and RM 0-2 on the North Fork. The data was generated during Fall 2017 field observations by NSD.

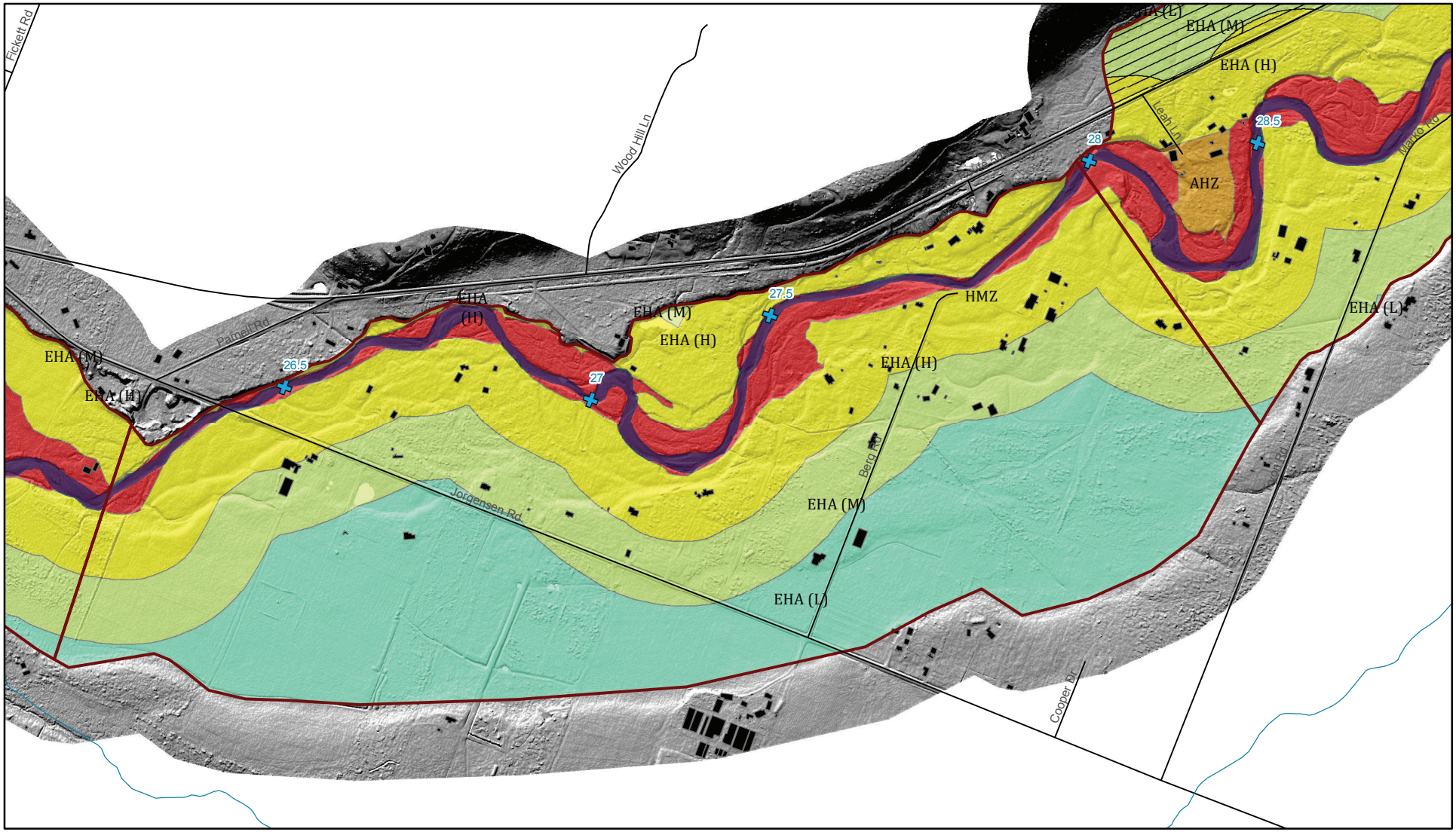
1. River Channel locations were digitally delineated as polygons surrounding the active un-vegetated channel from aerial photographs.
2. Digital Elevation Model (DEM) based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map



Map 5 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_ChannelTraces.mxd, Date Saved: 1/31/2018 6:20:07 PM



Erosion Hazard Analysis

South Fork Newaukum River - Reach 5

Stream
River Reach Boundary (NSD 2017)
Roads
Buildings
River Mile
River Channel
Disconnected EHAs

Erosion Hazards
HMZ
AHZ
EHA (H)
EHA (M)
EHA (L)

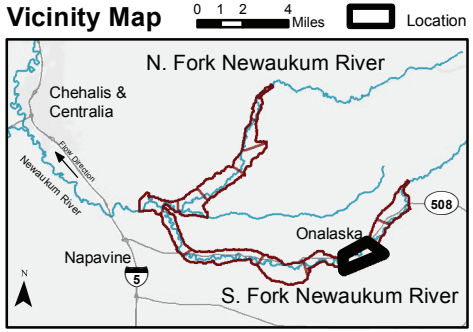
0 250 500 1,000 Feet

N

Notes:
1. Erosion hazard delineation is based on methods outlined in Rapp and Abbe (2003) "A Framework for Delineating Channel Migration Zones" WA Dept. of Ecology and Transportation.
2. Erosion hazards were delineated using the average historical channel migration rate between 1951-2017 (4.5 ft/yr). See Methods appendix for detailed description of delineation methodology.

HMZ - Historical Migration Zone
AHZ - Avulsion Hazard Zone
EHA (H) - Erosion Hazard Area High
EHA (M) - Erosion Hazard Area Medium
EHA (L) - Erosion Hazard Area Low
Disconnected EHAs - Areas on the non-river side of SR 508 and North Fork Rd.

Vicinity Map



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Erosion.mxd, Date Saved: 6/15/2018 10:37:25 AM

South Fork Newaukum River Reach 6

Summary of Land-Cover, Soils & Wetlands, Infrastructure, Buildings, Ownership, and Parcel Description

Vegetation, Soils and Wetlands

Reach 6 of the South Fork Newaukum River valley bottom occupies over 390 acres, including the river channel. The floodplains and terraces are currently dominated by 164 acres of mixed forest. One hundred one (101) acres of pasture or mowed grass, and 60 acres of large shrubs or small trees (See Landcover Map in Appendix) make up the other dominant landcover classes. Together, these landcover classes make up 83% of the floodplain landcover. The rest of the valley bottom, is a mixture of shrubs, roads and buildings, and river channels.

% Area	Acres	Landcover
42%	164	Forest
26%	101	Pasture or Groundcover
15%	60	Large Shrubs, Small Trees
8%	33	Shrubs
4%	14	Water
3%	10	Road
1%	5	Gravel Bar
1%	3	Buildings
0%	0	Log Jam
100%	**391**	**Total**

The soils of reach 6 of the South Fork Newaukum River valley bottom are comprised of Newberg fine sandy loam in the active channel area of the lower part of this reach--perfect conditions for cottonwood bottomland—transitioning to Cloquato silt loam, Galvin silt loam and Chehalis silt loam (See Soils Map in Appendix). As the valley topography increases in elevation from the river channel to the valley wall, hydric silt loam soils are found on the landscape. These hydric soils are an indicator of wetland soil formation processes.

Infrastructure, Buildings & Ownership

Reach 6 of the South Fork Newaukum River has no major bridge crossings. There are numerous homes and farms in this reach, about 72 structures total, including numerous single-family homes and some undeveloped land.

The 44 parcels that comprise this valley bottom are entirely privately owned, by 38 landowners. The largest private landowner is S&S Johnson, which owns about 17% (66 acres) of the total the valley bottom. This area calculation does not include the land outside of the valley bottom analysis area.

Description of Parcels in the Floodplain

In order to understand the influence of the river on landowners, parcels in the simulated 2009 flood event* were ranked by the relative percent of parcel area within the inundation area. In general, the closer a parcel is to the river, the higher the affected area. Since parcel boundaries do not follow topography, the degree to which a landowner or parcel is influenced by the river, varies from parcel to parcel. ***Of the 38 landowners in the valley bottom, 23 landowners had property that was inundated in the simulated 2009 flooded-area, and 4 land owners have property that is more than 75% within the approximated inundated area, or about 18 parcel-acres*** (see table below). The dominant assessed land use for these parcels is agriculture.

Landuse description of parcels with > 75% area in flooded area

Assessed Land Use Description	Number of Parcels	Acres Flooded *	Total Parcel Acres	Largest Landowner (Parcel Acres)
single-residential	3	11	13	R.C. & B.D Elliott (5 ac.)
undeveloped/vacant	1	4	5	Lambert Revocable Trust (5 ac.)
TOTAL	**4**	**15**	**18**	**4 Landowners w/ > 75% land in flooded area**

Flooded buildings

The number of buildings in the simulated 2009 flooded area was ~3, including residences and outbuildings (see inundation map for approximate locations).

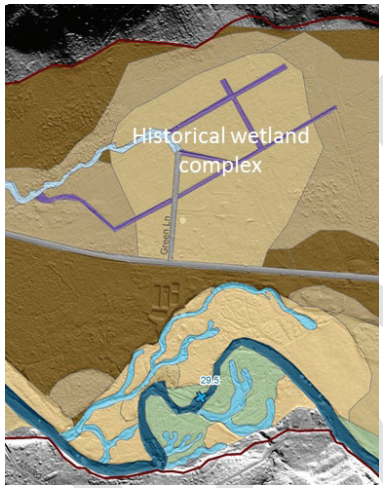
South Fork Newaukum River Reach 6

Geomorphic Reach Description

Reach 6 of the South Fork Newaukum River is located between RM 28 and RM 30. The reach is contained within a~ 3000 ft wide section of the valley. The reach has an average slope of 0.0051 ft/ft (or 0.51%) and has a meandering morphology (Table 1, REM map). There are no major tributary junctions within the reach. Highway 508 bisects the valley through the majority of reach 6.

Geomorphic Landforms

Reach 6 of the South Fork Newaukum contains an inset floodplain corridor that is incised an average of 7.8 feet below the historical floodplain surface. In this reach, the historical floodplain is ~5 times greater in width that the modern surface. The downstream half of the reach (RM 28-29.25) is confined by a non-fluvial terrace (likely glacial outwash) which constrains the width of the floodplain. Upstream of RM 29.25 however, the modern inset floodplain has widened into historical alluvial deposits on the right side of the valley. These alluvial deposits likely underlie a historical wetland complex that is currently disconnected from the river by SR 508 and currently drained by a series of ditches (See figure to right).



Channel Migration and Erosion

There is evidence of active channel migration within Reach 6. At the downstream end of the reach there are two outward migrating meanders that are eroding into the historical floodplain surface on the left side of the valley between RM 28-29 (See figure). There is no evidence of migration towards the right side of the valley into the non-fluvial terrace however. Evidence of active widening of the inset floodplain corridor is found around RM 29.5 where the channel has been eroding into the right side of the valley which is underlaid by historical alluvium. A straightened segment of the reach is contained between resistant surfaces along both banks.

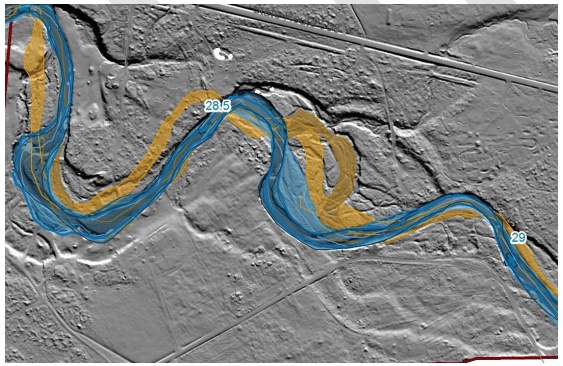
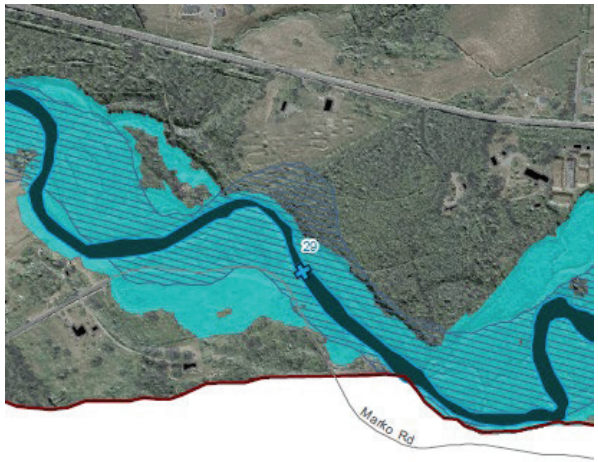


Table 1: Reach Statistics

Geomorphic Reach Description Statistics		Units
Slope	0.0051	ft/ft
Centerline Length	10908	ft
Average Depth of Incision	7.8	ft
Historic Floodplain Average Width	1015	ft
Active Floodplain Average Width	216	ft
Historic Floodplain: Active Floodplain	5	ft/ft
Flood Defense Length	N/A	ft
Flood Defense Length/Channel Length	N/A	ft/ft
Road Length	9456	ft
Total Reach Area	391	acres

2009 Flooding & FEMA boundary

The FEMA 100-year flood boundary (hatched) is similar to the preliminary simulation results of the January 2009 flood (solid blue) within Reach 6 of the South Fork Newaukum (See Inundation map). The only differences occur around RM 29.5 where the January 2009 simulation predicts flood inundation to extend as much as 380 ft beyond the FEMA boundary. The increased inundation area is located next to SR 508 and is likely in areas of inset floodplain widening.



Context and Vicinity Map

South Fork Newaukum River - Reach 6

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel

0 250 500 1,000 Feet

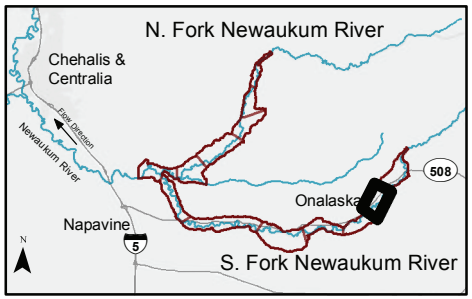
N

Notes:
1. Aerial Imagery and Digital Elevation Model (DEM) are based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. River reach breaks were done by Natural Systems Design (NSD) in 2017.

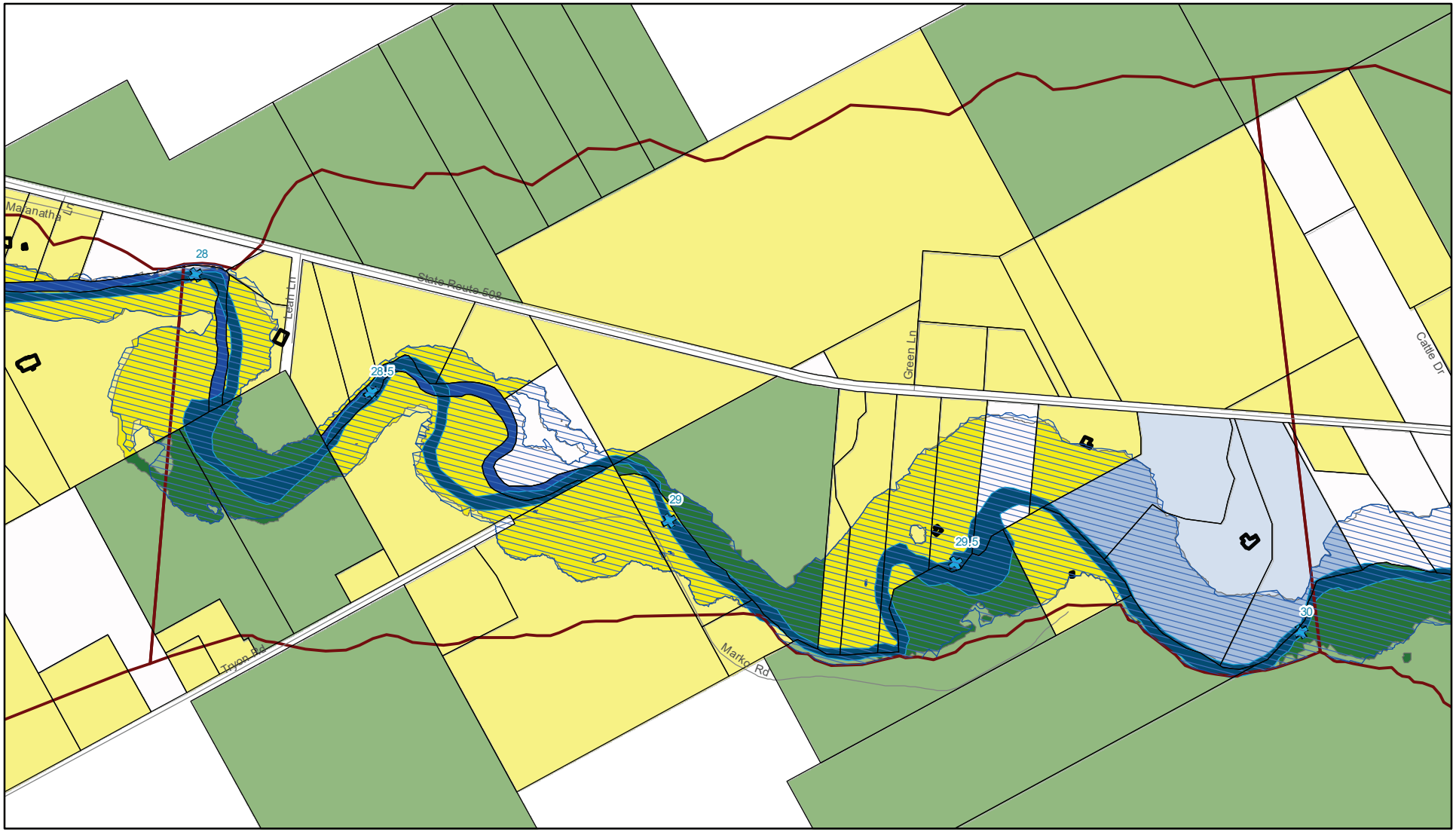
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Vicinity.mxd, Date Saved: 6/14/2018 2:26:17 PM



Existing Parcels Affected by Simulated 2009 Flood of Record

South Fork Newaukum River - Reach 6

Simulated 2009 Flood Extent

Affected Parcel Type
- Multi-Residential; Single-Residential
- Mining/Forestry
- Undeveloped/Vacant
- Water
- Unknown

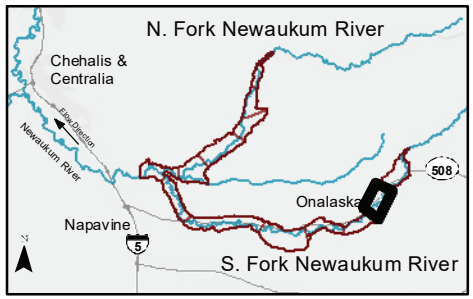
Unaffected Parcel Type
- Multi-Residential; Single-Residential
- Mining/Forestry
- Undeveloped/Vacant
- Water
- Unknown

River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel
Buildings

0 250 500 1,000 Feet

Notes:
1. Building/structures data from Lewis County,2013, additional buildings digitized by NSD, 2017.
2. Parcel data from Lewis County Assessor's Office. Accessed [8/18/2017].
3. The river channel delineated using 2017 LiDAR, represents low flow conditions for spring 2017.

Vicinity Map 0 1 2 4 Miles — Location



\\NATUSYST-NAS1\Bellingham\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_UpdatedParcels.mxd, Date Saved: 6/14/2018 1:31:11 PM

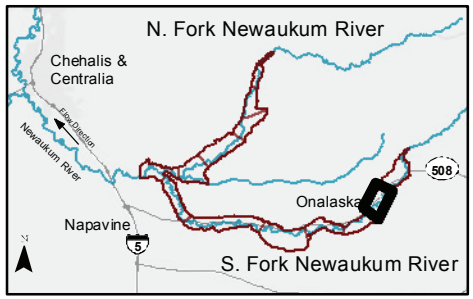
Existing Landcover Map

South Fork Newaukum River - Reach 6

River Reach (NSD, 2017)
River Mile
Landcover (NSD, 2017)
Pasture or Groundcover (< 3' tall)
Shrubs and Small Trees (3' to 20' tall)
Forest and Large Shrubs (> 20' tall)
Road
Structure (i.e. Building)
Gravel Bar
Vegetated Gravel Bar
Log Jam
Water

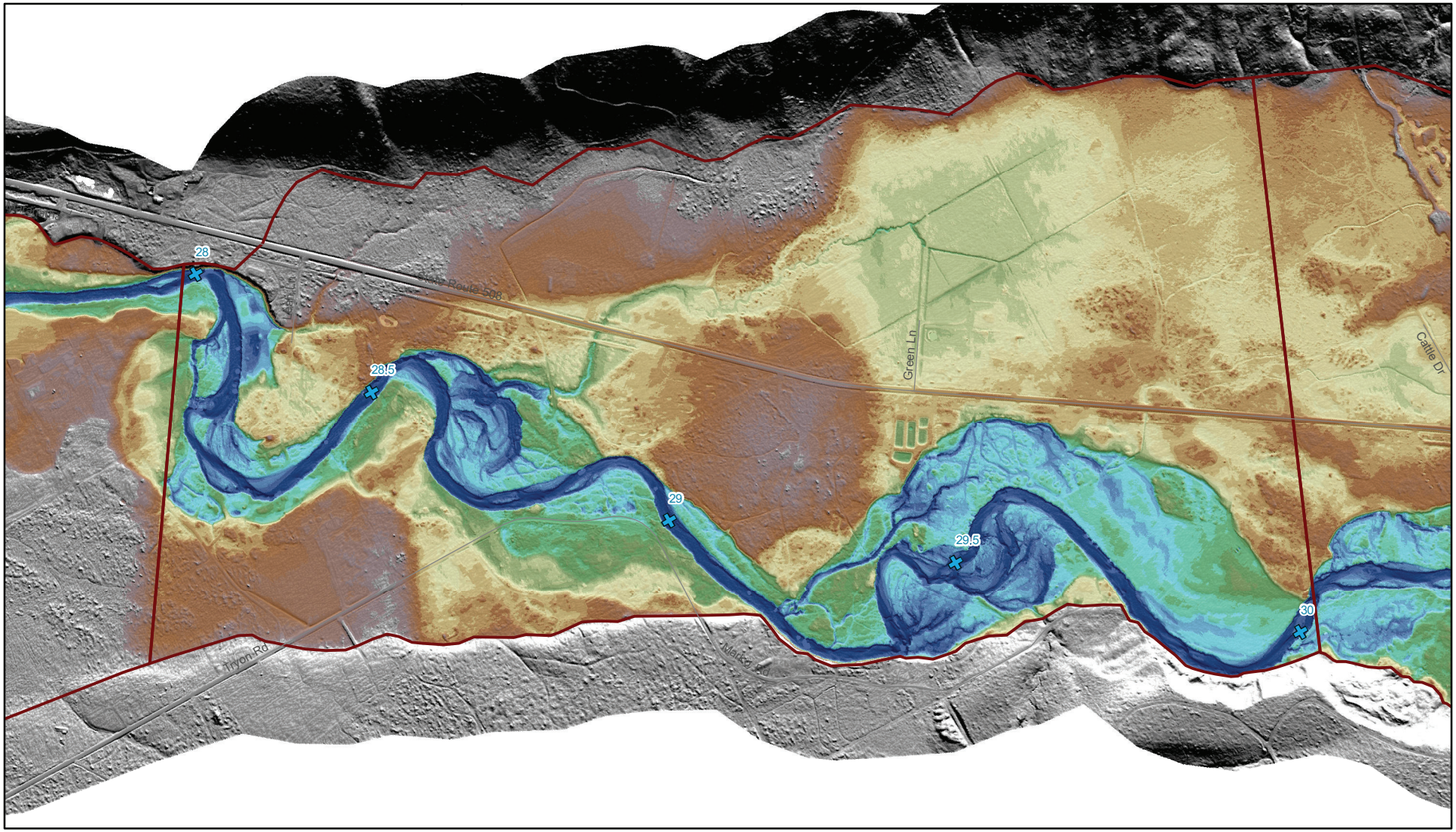
Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. There were statistically sigfnificant differences ($p<0.005$) between pasture and forest landcover types with erosion rates as follows:
a. Forest/shrubs: 6.0 +/- 3 ft/yr (n=20)
b. Pasture: 9.4+/- 5 ft/yr (n=24)
2.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
3.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
4. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

Vicinity Map 0 1 2 4 Miles — Location



Map 6 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Landcover.mxd, Date Saved: 1/30/2018 8:04:03 PM



Relative Elevation Map (REM)

South Fork Newaukum River - Reach 6

River Reach Boundary (NSD 2017)
Roads
River Mile

Relative Elevation Above River Channel At Low Water (feet)

-4.6 - -1 -1.1 - -2 -2.1 - -3 -3.1 - -4 -4.1 - -5 -5.1 - -6 -6.1 - -7 -7.1 - -8 -8.1 - -9 -9.1 - -10 -10.1 - -11 -11.1 - -12 -12.1 - -13 -13.1 - -14 -14.1 - -15 -15.1 - -16 -16.1 - -17 -17.1 - -18 -18.1 - -19 -19.1 - -20

0 250 500 1,000 Feet

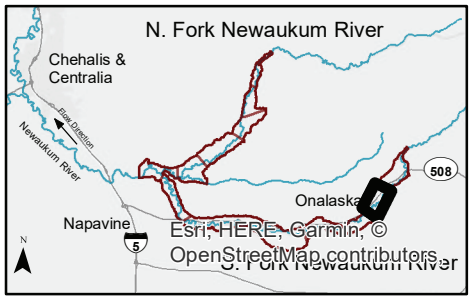
N

Notes:
1. Relative Elevation Model (REM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
2. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
3. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

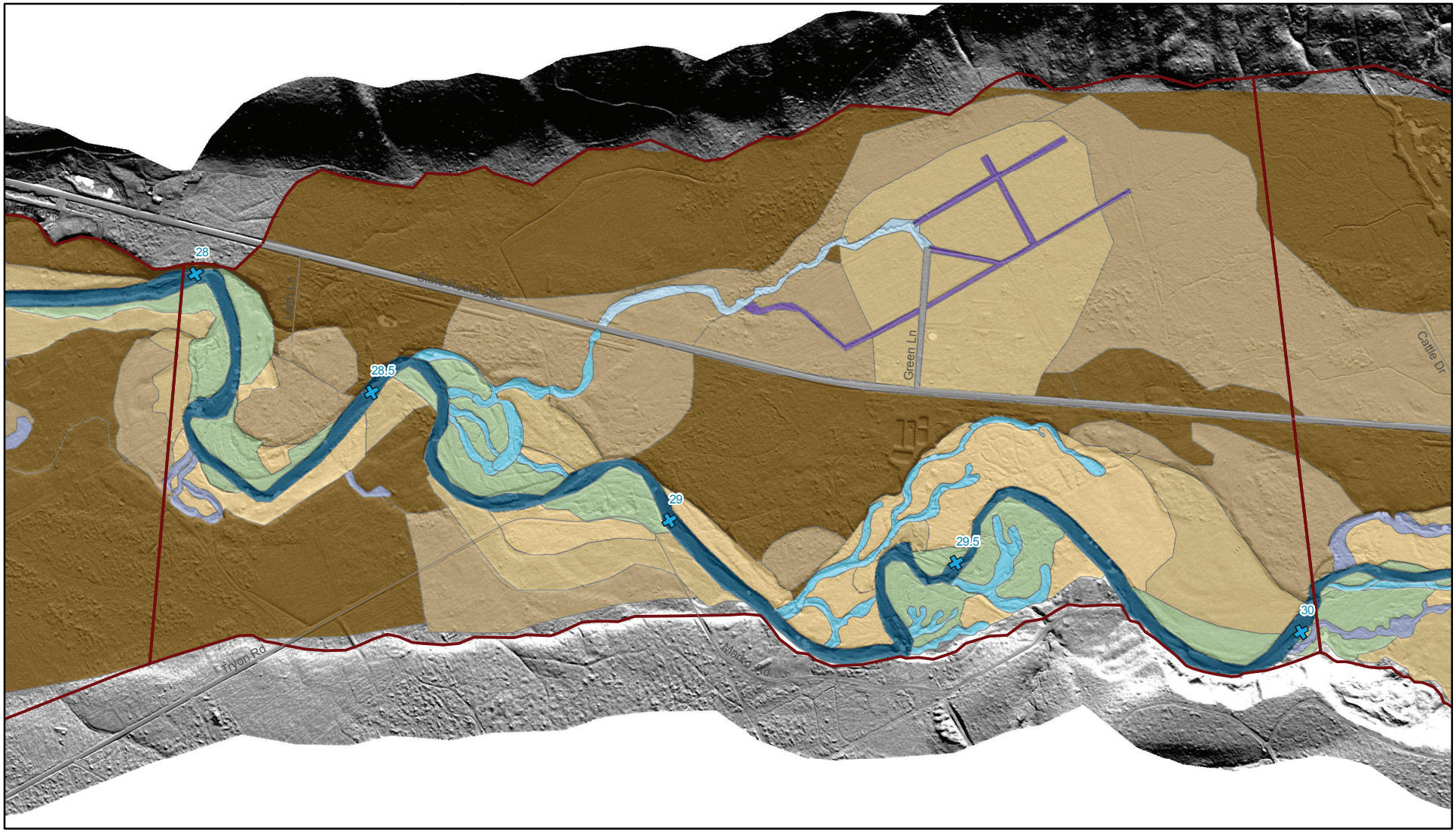
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_REM.mxd, Date Saved: 6/14/2018 1:12:00 PM



Geomorphic Landform Map

South Fork Newaukum River - Reach 6

0 250 500 1,000 Feet

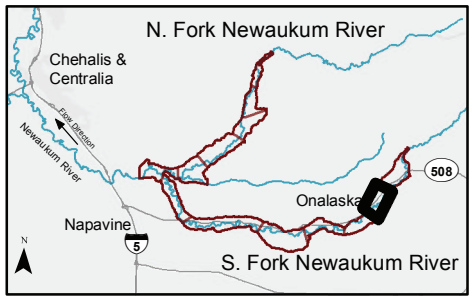
N

River Reach Boundary (NSD 2017)
Roads
River Mile

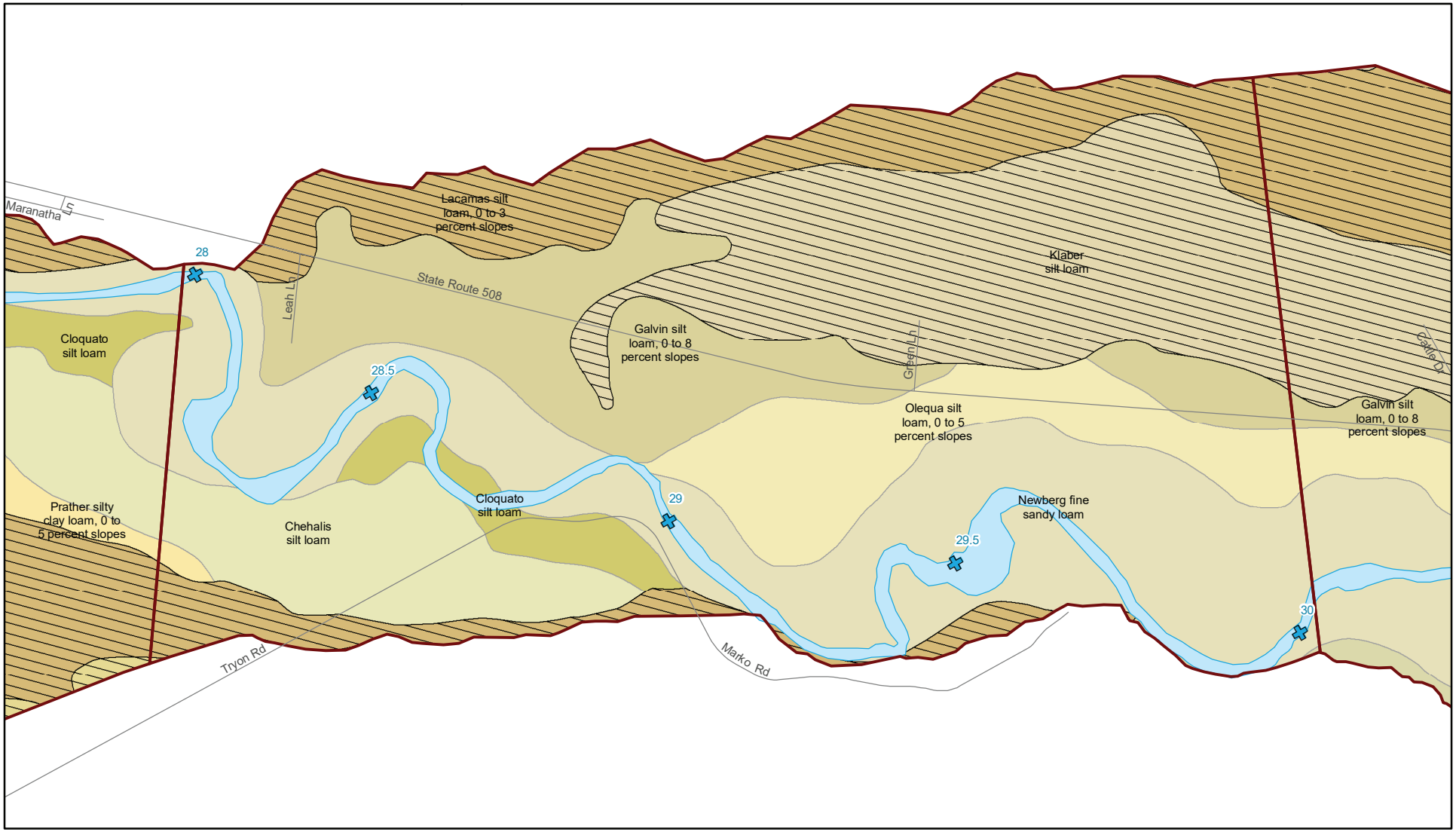
Geomoprhic Landforms (NSD 2017)
- Main Channel
- Channel
- Abandoned Channel
- Tributary
- Active Floodplain
- Historical Floodplain (4-6')
- Historical Floodplain (6-10')
- Historical Floodplain (10-15')
- High Terrace (>15')
- Road
- Ditch

Notes:
1.Erosion rates of the river through different landform types were calculated using historical aerial photography. The active and historical floodplain surfaces showed no statistically significant difference (p>0.1) and were determined to have the same erosion potential.
1.Geomorphic landform mapping, river reach breaks, and landcover analysis was done by Natural Systems Design (NSD) in 2017.
2.Digital Elevation Model (DEM),is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4.Geomorphic landforms were delineated for the valley bottom which was defined where a slope break occured at the margin with the hillslope.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Geomorph.mxd, Date Saved: 7/3/2018 12:35:06 PM



Existing Soils Map

South Fork Newaukum River - Reach 6

Notes:
1. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.
2. Soils data is from the USDA-SSURGO database.

0 250 500 1,000 Feet

N

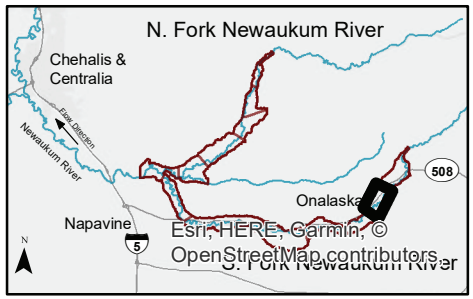
River Reach Boundary (NSD 2017)
Roads
River Mile
River Channel
Hydric Soil

Soil Type
- Chehalis silt loam
- Chehalis silty clay
- Cinebar silt loam, 30 to 65 percent slopes
- Cloquato silt loam
- Galvin silt loam, 0 to 8 percent slopes
- Klaber silt loam
- Lacamas silt loam, 0 to 3 percent slopes
- Newberg fine sandy loam
- Olequa silt loam, 0 to 5 percent slopes
- Prather silty clay loam, 0 to 5 percent slopes
- Salkum silty clay loam, 15 to 30 percent slopes
- Scamman silty clay loam, 0 to 5 percent slopes

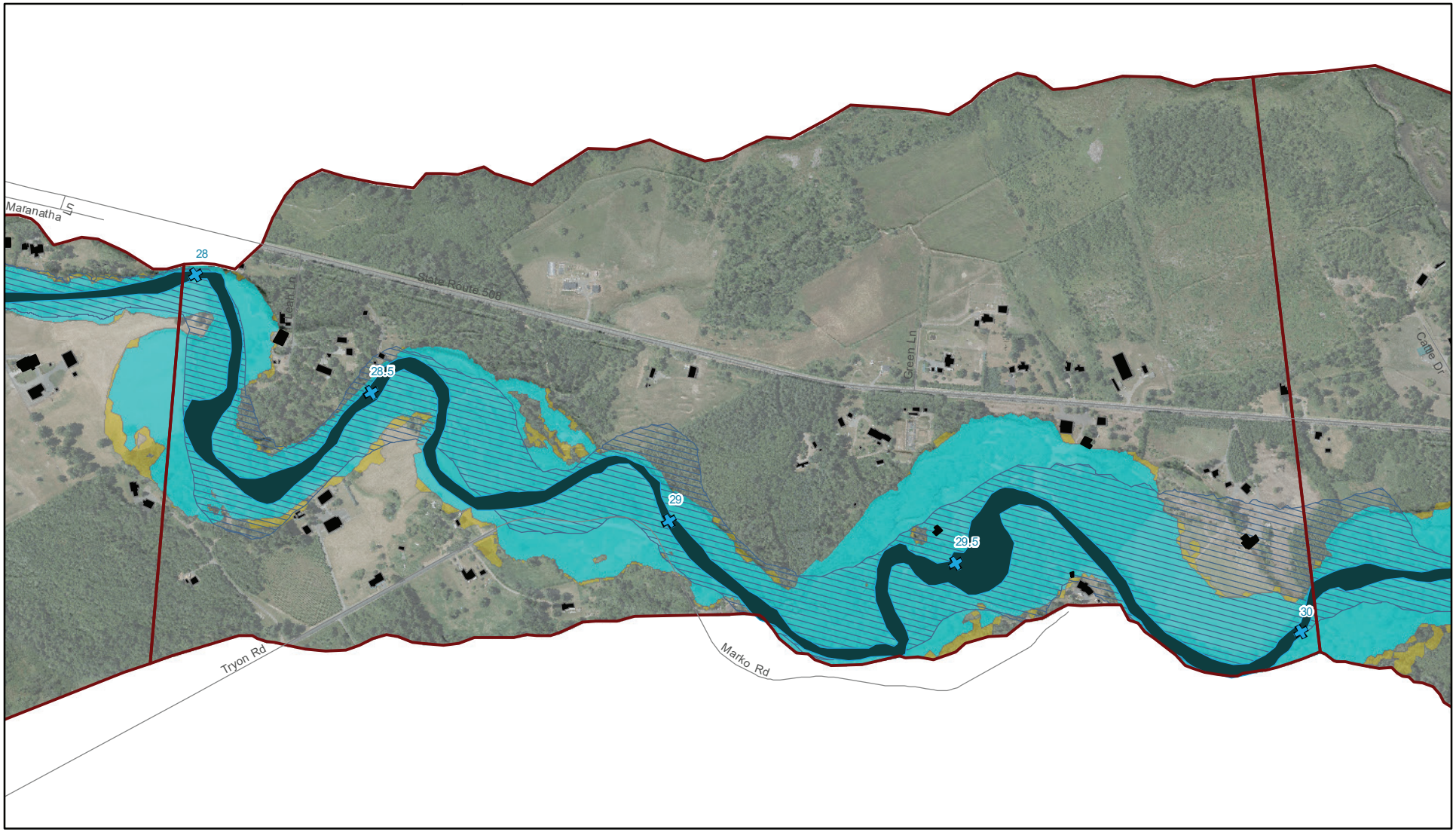
Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Soils.mxd, Date Saved: 6/14/2018 1:17:11 PM



Map of FEMA 100-year Flood Boundary, Simulated Flood-of-Record (2009), and Simulated 2009 Flood with Climate Change

South Fork Newaukum River - Reach 6

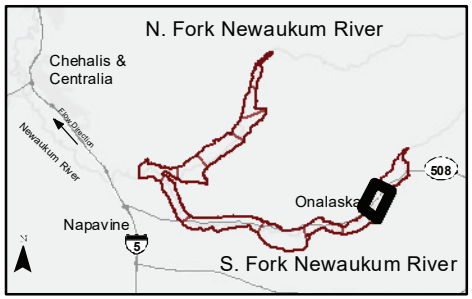
- Buildings
- River Reach Boundary
- Roads
- River Mile
- 2017 River Channel
- Regulatory 100-year Flood Boundary (FEMA)
- 2009 Flood (Current Flood of Record)
- 2009 Flood Simulated With Estimated Climate Change Effects

0 500 1,000 Feet

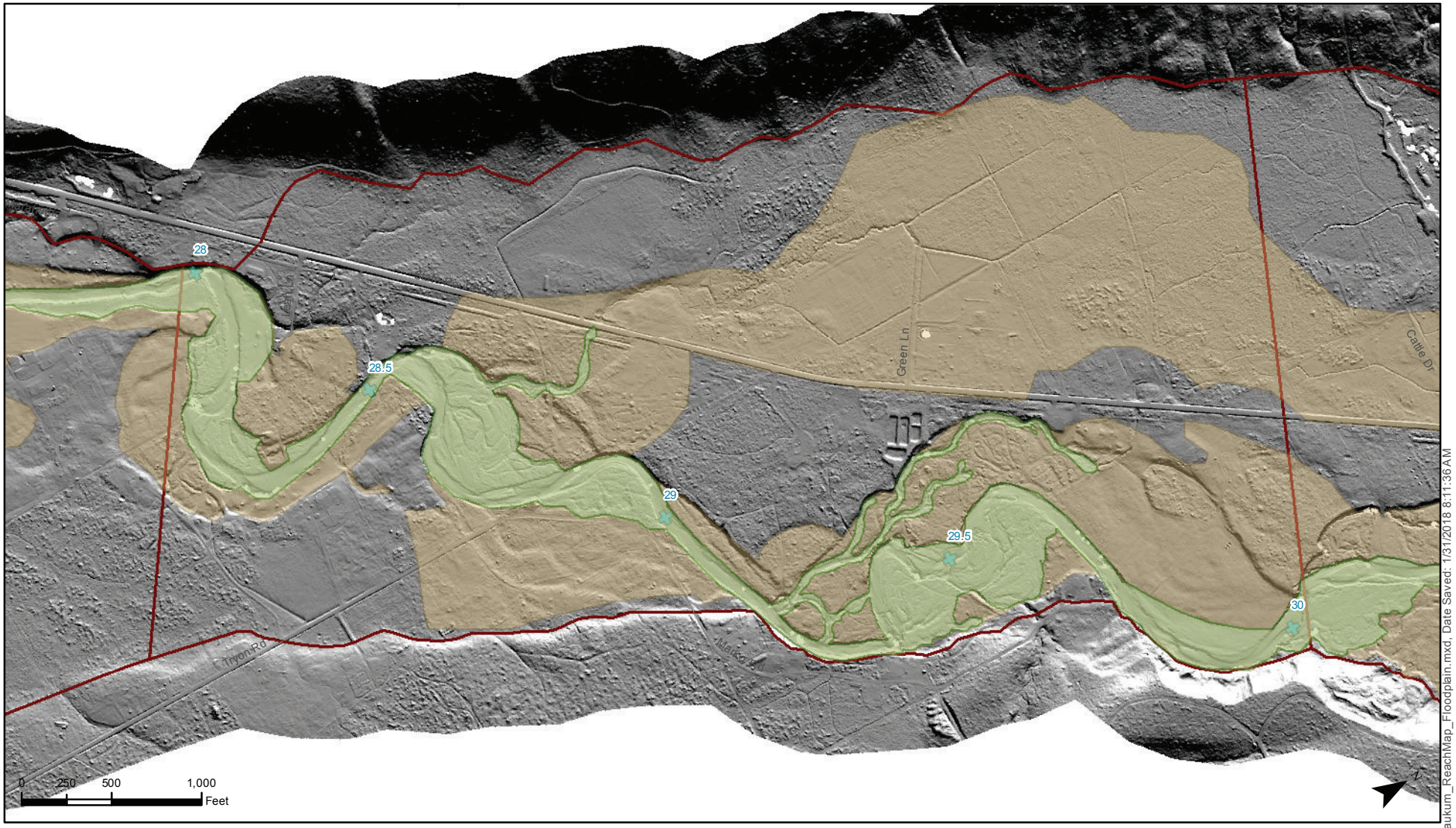
Notes:
1. Hydraulic simulation performed using RiverFlow2D - GPU. Simulation performed for the flood of record on the mainstem Newaukum Gage (USGS 12025000) which occurred from January 4 to Janaury 10th 2009. The estimated peak flow of 13,000 cfs occured on January 7th. Existing conditions 2009 flood simulation shows maximum simulated flood extent. Climate change flood simulation represents a 26% increase in 2009 flood water discharge.

2. Building (structures) dataset created by Lewis County, 2013. River reach boundary created by Natural Systems Design, 2017.

Vicinity Map 0 1 2 4 Miles — Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Inundation_ClimateChange.mxd, Date Saved: 10/10/2019 9:38:07 AM



Modern and Historical Floodplains

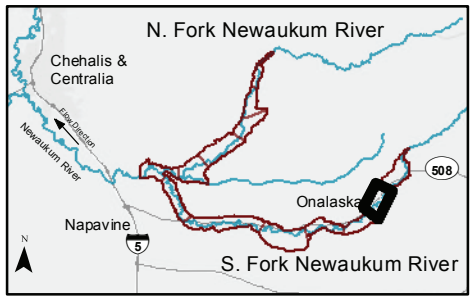
South Fork Newaukum River - Reach 6

- Roads
- River Reach (NSD, 2017)
- River Mile
- Modern Floodplain
- Historical Floodplain

Notes:
1. The active and historical floodplain extents are based off of geomorphic landforms delineated by NSD.
2. The modern floodplain extent represents the current geomorphic surface within which moderate floods are contained. The modern floodplain was mapped as the active floodplain surface.
3. The historical floodplain includes terraces ranging from 4-15' and likely represent the extent of flood innundation during a moderate flood.
4. Digital Elevation Model (DEM) is based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
5. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.

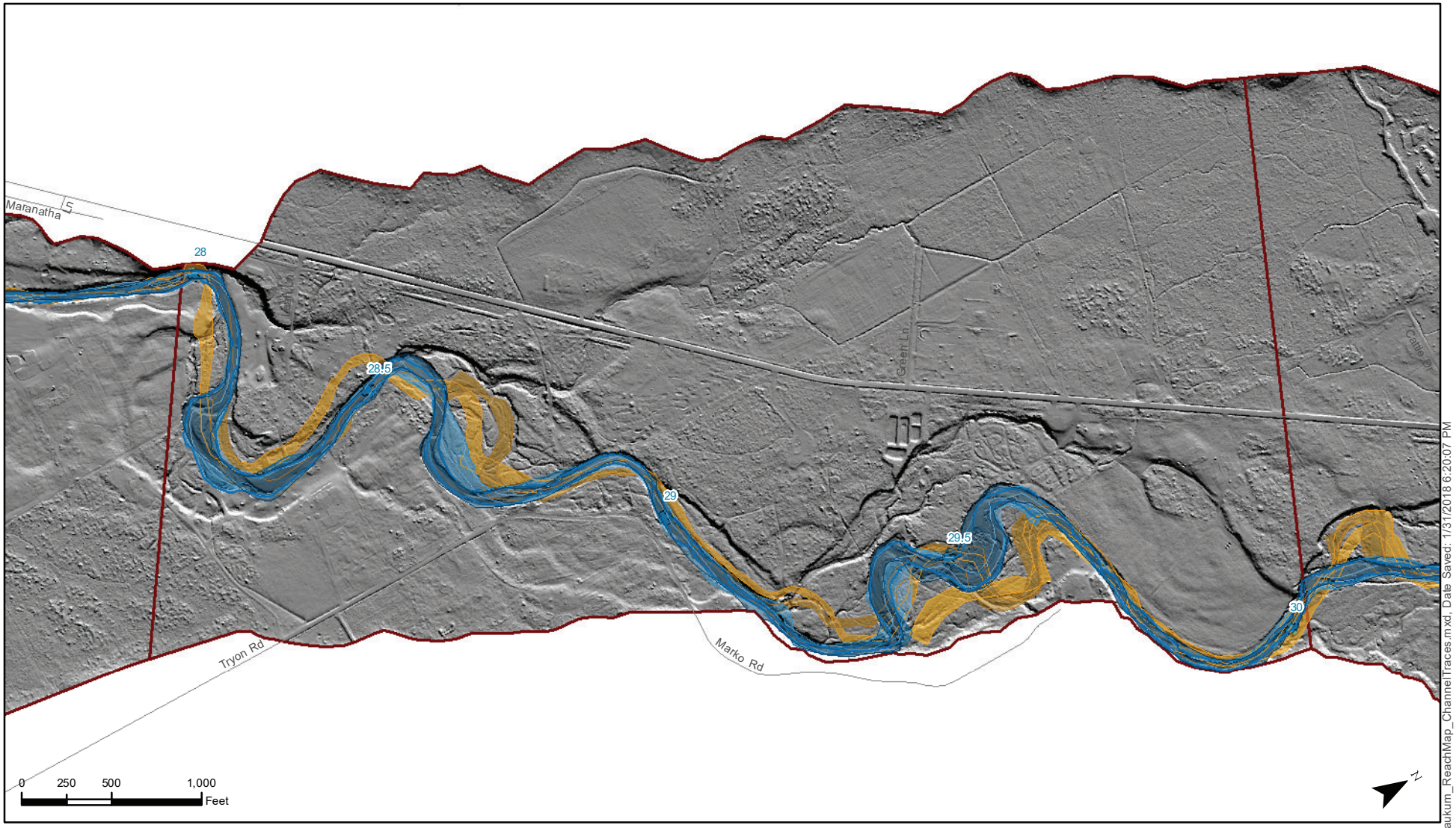
Vicinity Map

0 1 2 4 Miles — Location



Map 6 of 13

P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Floodplain.mxd, Date Saved: 1/31/2018 8:11:36 AM



River Channel Changes from 1940 to 2017

South Fork Newaukum River - Reach 6

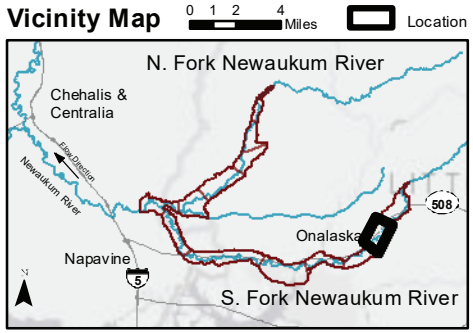
Roads
River Reach (NSD, 2017)
River Mile

River Channel Locations By Year
1950
1980
1990
2006
2009
2011
2015
2017

Notes:
*The bank armoring dataset only covers the lower reaches of the South and North Fork Newaukum Rivers (RM 12-22.5 on the South Fork and RM 0-2 on the North Fork. The data was generated during Fall 2017 field observations by NSD.

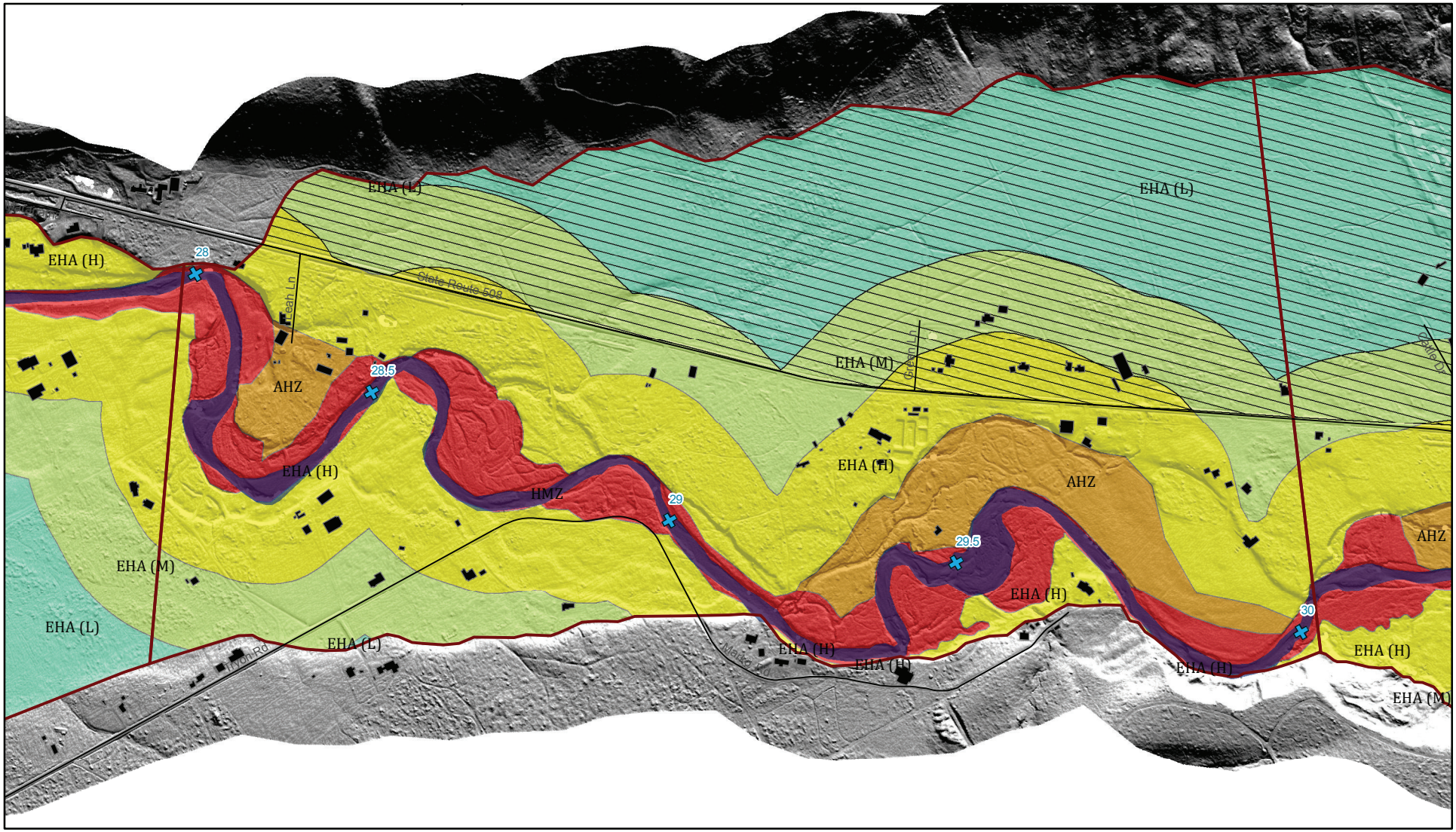
1. River Channel locations were digitally delineated as polygons surrounding the active un-vegetated channel from aerial photographs.
2. Digital Elevation Model (DEM) based off of 2017 LiDAR flight, which collected bathymetry, aerial imagery, and topographic data.
3. Vertical datum is NAVD 88 feet, Horizontal datum NAD 83 Washington State Plane South, feet.
4. Building/structures data is from Lewis County, with some additional buildings digitized by NSD, 2017.

Vicinity Map



Map 6 of 13

P:\Projects\Chehalis\GIS\Newaukum\mxd\Newaukum_ReachMap_ChannelTraces.mxd, Date Saved: 1/31/2018 6:20:07 PM



Erosion Hazard Analysis

South Fork Newaukum River - Reach 6

River Reach Boundary (NSD 2017)
Roads
Buildings
River Mile
River Channel
Disconnected EHAs

Erosion Hazards

HMZ
AHZ
EHA (H)
EHA (M)
EHA (L)

0 250 500 1,000 Feet

N

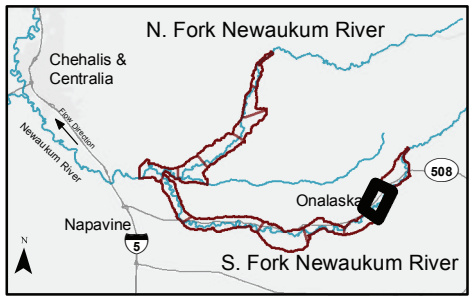
Notes:
1. Erosion hazard delineation is based on methods outlined in Rapp and Abbe (2003) "A Framework for Delineating Channel Migration Zones" WA Dept. of Ecology and Transportation.
2. Erosion hazards were delineated using the average historical channel migration rate between 1951-2017 (4.5 ft/yr). See Methods appendix for detailed description of delineation methodology.

HMZ - Historical Migration Zone
AHZ - Avulsion Hazard Zone
EHA (H) - Erosion Hazard Area High
EHA (M) - Erosion Hazard Area Medium
EHA (L) - Erosion Hazard Area Low
Disconnected EHAs - Areas on the non-river side of SR 508 and North Fork Rd.

Vicinity Map

0 1 2 4 Miles

Location



P:\Projects\Chehalis\GIS\Newaukum\maps\mxd\Newaukum_ReachMap_Erosion.mxd, Date Saved: 6/15/2018 10:37:25 AM