MEMORANDUM

Date: March 31, 2021
To: Andrea McNamara Doyle, Office of Chehalis Basin
From: Mike Curran, Mike Gieschen, PE, Erik Pipkin, Tracy Drury, PE, and Merri Martz; Anchor QEA, LLC
cc: Chrissy Bailey, Office of Chehalis Basin; Lynn Schmidt, Ecology; Jim Kramer and Ken Ghalambor, Office of Chehalis Basin consultant staff; Bob Montgomery and Heather Page, Anchor QEA, LLC; Larry Karpack, Watershed Science and Engineering
Re: Initial Historical Channel Mapping and Floodplain Topography in Priority Erosion Hazard Areas

Executive Summary

This memorandum summarizes the results of an initial focused mapping exercise of approximately 100 miles of priority erosion hazard river segments within the Chehalis Basin. For this analysis, historical channel location maps and relative elevation maps were developed to identify where river channels have migrated over the past approximately 70 years. Low-lying areas of the floodplain that could be prone to future channel migration and avulsion were also identified. The purpose of this memorandum is to inform the Chehalis Basin Board on options for additional analyses that could further support an erosion management strategy and local jurisdiction management of critical areas to reduce future erosion damages.

Table 1 summarizes the number of structures, parcels, and length of roads within selected buffers around the 70-year historical channel migration area and within the entire low-lying valley segments. The Wynoochee River and South Fork Newaukum River segments have the most structures in proximity to the historical channel migration area, whereas the Chehalis River segments have the most roads in proximity to the historical channel migration area.

Next steps that could be considered for further mapping and quantification of erosion risks include the following:

- Conduct outreach to conservation districts and local jurisdictions on their priorities for further detailed mapping.
- Conduct detailed mapping and/or modeling of more frequent flood events that affect erosion processes within areas identified by the conservation districts and local jurisdictions as high priorities.

Overview

This memorandum summarizes the results of an initial focused mapping exercise of priority erosion hazard areas within the Chehalis Basin. This analysis was a refinement of the original Option 1: Focused Modern Valley Bottom and Avulsion Hazard Mapping identified in the *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Potential Options for Delineating Erosion Hazards*

Mapping memorandum (Anchor QEA 2020). For this analysis, historical channel location maps and relative elevation maps were developed to identify where river channels have migrated over the past approximately 70 years. Low-lying areas of the floodplain that could be prone to future channel migration and avulsion were also identified. In addition, parcels and structures have been overlain on the maps to identify parcels where historical and recent channel migration is continuing to occur, and the number of structures and lengths of roads within a migration buffer based on locally averaged historical migration distances (Table 1). Historical channel locations, which are relatively recent in a geologic context, are not a predictor of risk for future channel occupation. The purpose of this memorandum is to inform the Chehalis Basin Board on options for additional analyses that could support an erosion management strategy and local jurisdiction management of critical areas to reduce future erosion damages.

Table 1
Summary of Structures, Parcels, and Roads Present in the River Segments

		Number Within Historical Channel Location Buffer			Number Within Low-Lying Valley		
River Segment	Buffer (feet)	Roads (feet)	Structures	Parcels	Roads (feet)	Structures	Parcels
Humptulips	500	3,054	19	68	11,479	61	114
Wynoochee	400	43,305	205	274	113,258	351	487
Satsop	700	27,820	95	117	96,346	368	347
EF Satsop	500	13,847	106	215	43,614	193	309
WF Satsop	600	26,934	90	124	11,529	71	121
Chehalis 13-25	500	48,830	107	243	442,634	1,872	1,608
Chehalis 33-55	400	51,465	53	301	496,867	2,185	1,835
Newaukum	300	21,389	105	210	76,805	422	392
SF Newaukum	300	34,357	327	237	82,871	624	639

Note: This analysis identifies all structures and does not distinguish "valuable" structures separately. Valuable structures include homes, barns, commercial buildings as opposed to small sheds, picnic shelters, and other low-value structures.
EF: East Fork
SF: South Fork
WF: West Fork

All of these initially mapped river segments are also included in the Aquatic Species Restoration Plan (ASRP) for habitat protection and restoration and provide good opportunities for combined erosion management and habitat restoration projects.

The Chehalis Basin Board has agreed upon several outcome measures for a Local Actions Program, with the following being the most directly relevant to erosion and channel migration hazards:

- The number of locations where migrating river channels and bank erosion pose a high risk of near-term damage to valuable structures or loss of economically productive land uses would be reduced by an average of X per year over up to 30 years, while protecting ecological processes (Outcome 4A: Farmland and Rural Structures Protected).
- No new structures would be developed that are vulnerable to channel erosion or mainstem or tributary flooding from 2080 predicted 100-year flood levels, because all basin local governments have adopted model floodplain management ordinances that exceed the State and National Flood Insurance Programs' minimum requirements; all local government construction and building code standards support flood damage risk reduction through measures such as subdivision set-asides, filling restrictions, freeboard height of new buildings, critical facility placement and protection, and non-conversion agreements; and incentives direct future development out of harm's way (Outcome 8: Prevent New At-Risk Development).

This memorandum and the attached maps are provided for Chehalis Basin Board and local jurisdiction consideration on potential additional steps that would be required to support reducing erosion hazards as part of the Chehalis Basin Strategy. Future delineation of the channel migration zone or erosion hazard areas could be used by local jurisdictions and tribes to reduce near-term and long-term risks and economic damages from channel migration through actions such as reach-scale erosion management projects, removal or relocation of at-risk structures and infrastructure, or through additional management of new development within erosion hazard areas.

Background

Riverbank erosion occurs in many areas of the Chehalis Basin and can affect property and infrastructure adjacent to the rivers and streams, within the valley bottom, or on adjacent hillslopes. Depending on the rate of erosion, or during an avulsion or major channel shift, a river could move rapidly outside of its current channel into a new or historical channel. Areas of easily erodible soils, such as sand and gravel deposits from alluvial processes or from past glacial deposition, or loamy soils, are particularly susceptible to bank erosion and channel migration. Areas with limited vegetation cover can also be more susceptible to erosion.

Channel migration is a natural process and the movement of a channel though its floodplain creates new habitats, stores or recruits sediment and wood, and creates bare alluvial surfaces for the regeneration of cottonwoods and other important native riparian plant species. Even though channel migration is a natural process and has ecological benefits, human activity can affect where erosion occurs and can also dramatically increase the rate of erosion causing a destabilization of the river system, negatively impacting aquatic species and human investments. Identifying areas where erosion is occurring at high

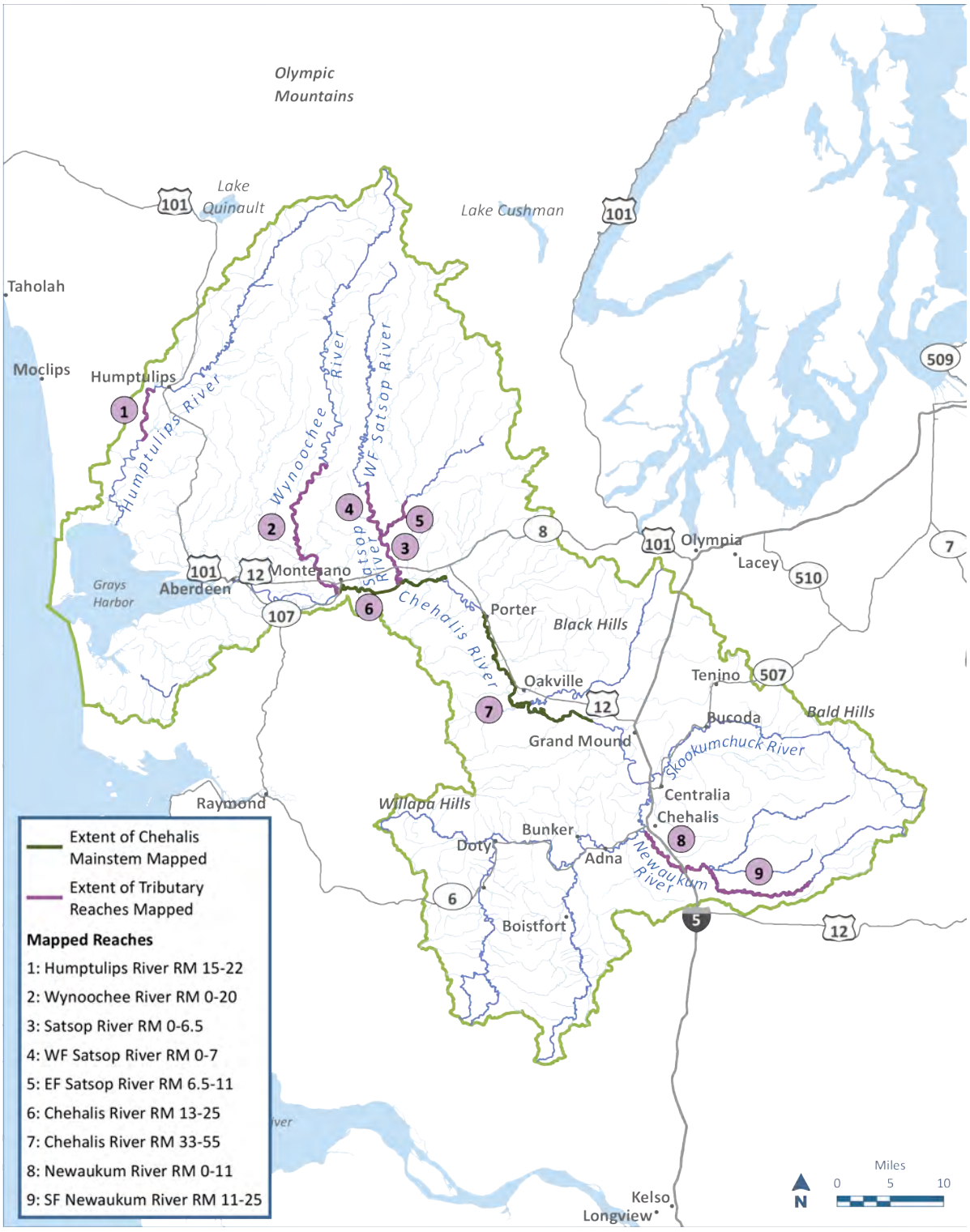
rates or threatens human investments will allow for the development of a more holistic and comprehensive strategy to address the problem.

Several options for delineating erosion and channel migration hazard areas were outlined in the *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Potential Options for Delineating Erosion Hazards* memorandum (Anchor QEA 2020). Based on input received from the Local Actions Program Technical Advisory Group and discussions with the Chehalis Basin Board, near-term mapping was completed to provide historical channel tracing maps and relative elevation mapping for approximately 100 miles of rivers that have been identified by advisory group members as areas of concern for erosion.

The following river segments have been mapped and are shown in overview in Figure 1. The detailed maps are attached at the end of this memorandum.

- Humptulips River, river mile (RM) 15 to 22
- Wynoochee River, RM 0 to 20
- Satsop River, RM 0 to 11
- West Fork Satsop River, RM 0 to 7
- Chehalis River, RM 13 to 25 and RM 33 to 55
- Newaukum River, RM 0 to 11
- South Fork Newaukum River, RM 11 to 25

Figure 1
River Reaches Included for Initial Focused Historical Channel and Avulsion Hazard Mapping



Methods

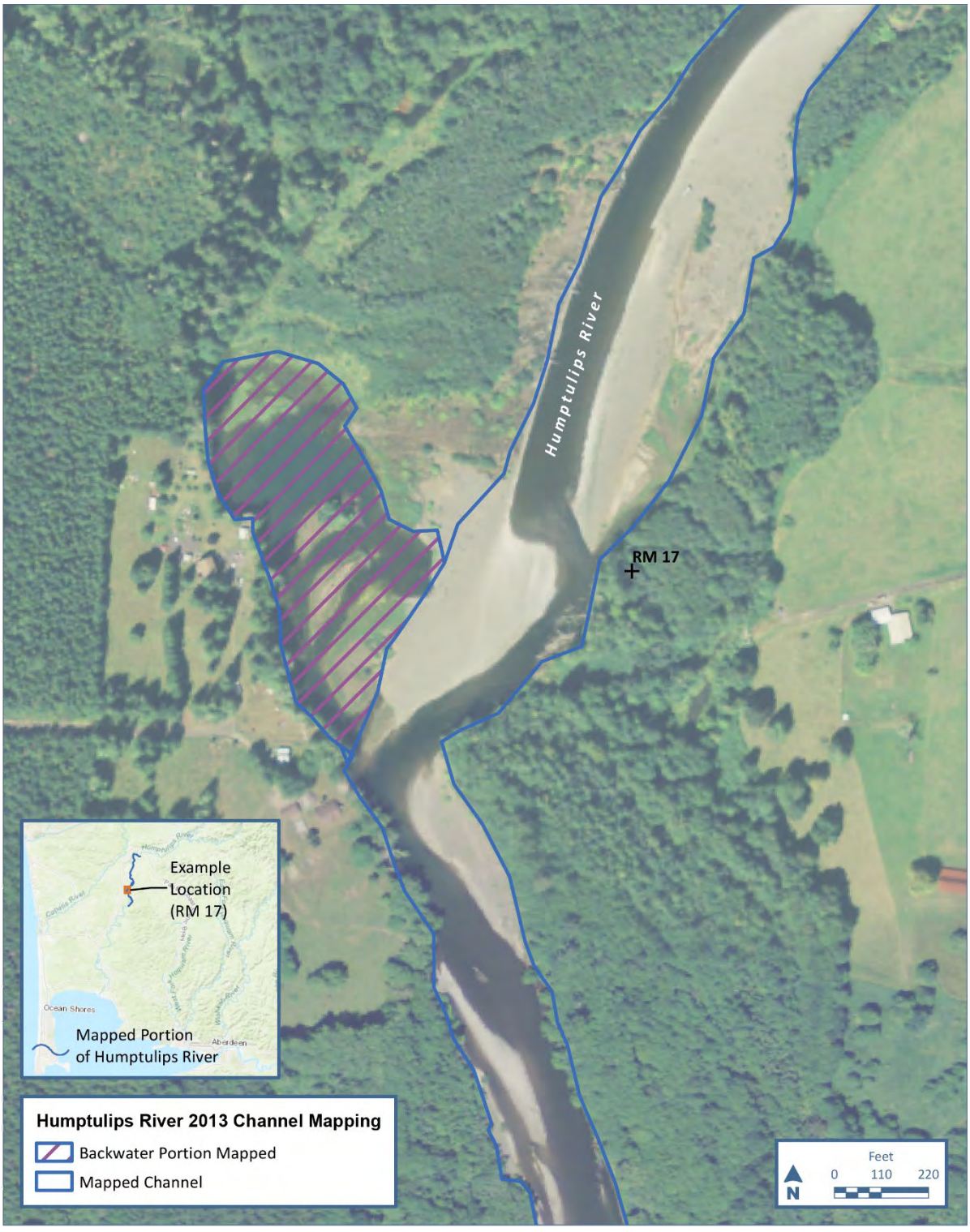
Channel Digitization

To identify patterns and trends of channel migration and potential erosion risk areas, historical aerial photography was used to perform heads-up digitizing of the selected river segment channels for various time points over the last approximately 70 years. The aerial photographs were obtained from the United States Geological Survey (USGS) and the Washington State Department of Natural Resources (DNR). Table 2 presents a summary of the aerial photographs used in the digitization process. Prior to digitization, the aerial photographs were georeferenced to their spatial location using the United States Department of Agriculture's (USDA) National Agricultural Imagery Program (NAIP) aerial photographs from 2013 for Grays Harbor County, Lewis County, and Thurston County. Common anthropogenic features visible in both the 2013 and historical aerials were used to locate control points and shift the historical imagery to their geographic position using ArcMap Desktop 10.8.

Digitization was achieved by locating the approximate bank line from the aerial photograph and creating a polygon extent of the channel for each reach using ArcMap. The estimated bank line was identified using best professional judgment and considered to be the lateral extent of river where water could reach at bankfull flow. Because much of the aerial photography used was collected during the lower flow periods of hydrographs typical for this area (July through September), the extent of flow was estimated based on geomorphic indicators of bankfull flow. The most common indicator used was the interface between open channel and mature vegetation (trees, shrubs, etc.) where the river would be at approximately annual flood flows. Therefore, transient planform features seen in the aerial imagery such as lateral bars and point bars were included in the digitization despite not always being inundated in the aerial photography used.

Areas in the floodplain that were inundated and connected to the main channel, but that would not have active flow with significant velocity and were not connected at that upstream end, were digitized but were also classified separately as "backwater" areas. Figure 2 shows an example of an area classified as a backwater area on the Chehalis River. Inundated oxbows, floodplain lakes, wetland areas, and other areas that appeared as inundated in the aerial imagery but are not connected to the main channel flow were not included in the digitization. Split flows and side channels that appeared would carry a significant proportion of the flow at a bankfull flow event were also included in the digitized channel areas.

Figure 2
Backwater Area Example



The historical channel tracing maps (Attachment 1 of this memorandum) show the location of the channel in each of the time steps, a migration buffer based on reach-averaged migration rates added to the cumulative historical channel migration area (Table 3), and callouts and migration vectors showing the more significant areas of channel migration or avulsion—all overlaid on 2017 to 2019 aerial photography. The buffer is intended to illustrate the averaged distances that the channels have migrated over the period from which historical imagery were examined. The buffer widths were determined individually for each river segment by measuring the distances of channel migration in locations deemed to be typical of the potential magnitude of migration for that segment. It was calculated as the average of the distances between the outside edges of the oldest and youngest channels in locations where migration was generally consistent in one direction. Areas of channel avulsion were not considered in the selection of representative locations. Buffers extend beyond the edge of the valley in some locations. This buffer is not intended to represent a quantified risk zone for erosion or avulsion hazard, but highlights structures and infrastructure in closest proximity to historical and recent migration. Quantification of risks by near-term or long-term should be based on more detailed analysis of erosion rates and avulsion hazards within individual reaches for each segment.

Table 2
Summary of Aerial Photographs Used for Historical Channel Tracing

RIVER	YEARS	SOURCE
Humptulips	1953	USGS
	1977 2003	DNR
	2013	USDA (NAIP)
Wynoochee	1951 1953	USGS
	1977 2003	DNR
	2013	USDA (NAIP)
Satsop	1951 1953	USGS
	1977 2003	DNR
	2013	USDA (NAIP)
Newaukum	1952	USGS
	1974 1999	DNR
	2013	USDA (NAIP)
Chehalis[1]	1938 1975 1999	USACE
Chehalis	2003	DNR
Chehalis	2013	USDA (NAIP)

Note:
1. Chehalis River channel digitization was provided by the Washington Department of Fish and Wildlife (WDFW) for the full extent of analysis area for the years 1938, 1975, and 2013. Channels were also provided for a portion of the Chehalis River for 1999. Additional digitization was completed for this study by Anchor QEA using 2003 imagery in portions of the Chehalis River where 1999 channel traces were not available from WDFW.

Table 3
Summary of Typical Migration Buffers Based on Historical Channel Tracing

RIVER SEGMENT	BUFFER WIDTH (FEET)
Humptulips River	500
Wynoochee River	400
West Fork Satsop River	600
East Fork Satsop River	500
Lower Satsop River	700
Chehalis River RM 12-25	500
Chehalis River RM 33-55	400
South Fork Newaukum River	300
Newaukum River	300

Relative Elevation Mapping

To assist in identifying potential erosion and avulsion risk areas, a relative elevation map for each reach in the analysis was created. A relative elevation map visually represents elevations of the floodplain relative to the adjacent stream's water surface elevation using a GIS model that adjusts/accounts for the channel gradient moving downstream (Olson et al. 2014). The resulting mapping provides a clear visualization of lower and higher areas of the floodplain and a given location's proximity to risk factors for flooding and erosion, including current and historical side channels, meander scars, oxbows, and terraces.

Existing relative elevation maps were provided to Anchor QEA by DNR for the mainstem Chehalis River, and from a previous study of the Newaukum River by Natural Systems Design (Abbe et al. 2020); these were not modified and are shown for those segments on the attached maps. New relative elevation maps were created for the Humptulips, Wynoochee, and Satsop rivers. Topographic Light Detection and Ranging (LiDAR) from DNR was used for the input elevation data and relative elevation maps were processed in ArcGIS Desktop 10.8 using the kernel density method outlined by Ecology's 2014 document, *A Methodology for Delineating Planning-Level Channel Migration Zones (*Olson et al. 2014). A summary of the GIS input parameters is provided in Table 4.

Table 4
Relative Elevation Mapping GIS Parameters Summary

RIVER	PARAMETER	VALUE
Humptulips	Topography	Olympic Peninsula, Washington 3DEP LiDAR Area 1 (2019)
	Point Spacing	175 feet
	Search Radius	4,500 feet
Wynoochee	Topography	Olympic Peninsula, Washington 3DEP LiDAR Area 1 (2019) Olympic Peninsula, Washington 3DEP LiDAR Area 2 (2019) Western Washington 3DEP LiDAR (2017)
	Point Spacing	150 feet
	Search Radius	3,800 feet
Satsop	Topography	Olympic Peninsula, Washington 3DEP LiDAR Area 1 (2019) Western Washington 3DEP LiDAR (2017)
	Point Spacing	100 feet (East and West Forks); 200 feet for remaining portion of Lower Satsop
	Search Radius	1,800 feet (West Fork); 4,000 feet for remaining portion

The relative elevation maps (Attachment 2 of this memorandum) show the buffer from the historical channel area, parcels, structures and roads, and callouts highlighting low-lying channel scars and other features in the valley bottom that could be avulsion and migration risks.

Results for Mapped River Segments

The attached maps show historical channel tracing and relative elevations for each of the river segments.

Humptulips River, RM 15 to 22

This segment of the Humptulips River extends for 7 miles downstream of the town of Humptulips and Highway 101. Figures 3 through 8 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley is a mix of timberland, agricultural (hay and pasture), and rural residential. There are several public or conservation properties as well.

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 1,700 feet to 6,000 feet in width over this segment. Over the past 70 years, the channel has migrated only a few feet in some locations or up to 850 feet in another location. At least five meander cutoffs (avulsions) have occurred during the past 70 years. Much of the riparian area is forested with deciduous trees in relatively wide patches (200 to 800 feet). In a few locations, the river is immediately adjacent to fields.

Beyond the 70-year historical channel location area, the relative elevation maps show numerous low-lying channel meander scars, which present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull.

A total of 19 structures, 68 parcels, and 3,054 feet of roads are present within the 500-foot buffer around the historical channel location area, and the total within the low-lying valley includes 61 structures, 114 parcels, and 11,479 feet (2.2 miles) of roads. Avulsions and meander cutoffs can cause much more dramatic and rapid movements of the channel (e.g., over 1,500 feet in one location in this segment); hence, roads and structures much further distant from the historical channel location could be at future risk and a detailed delineation of erosion hazards could quantify that risk. Several smaller parcels exist in the low-lying valley that could be subject to future residential development that could be subject to erosion risks.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is included in the ASRP and is proposed as a near-term priority for habitat protection and restoration within the first 10 years of the ASRP (Middle Humptulips, RM 9 to 32).

Wynoochee River, RM 0 to 20

This segment of the Wynoochee River extends for 20 miles upstream of Montesano. For this draft memorandum, not all time periods for RM 11 to 20 are currently shown due to a delay in receiving all historical aerial photography. Figures 9 through 24 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley is predominantly agricultural (hay and pasture) and rural residential with gravel mined ponds present in several areas. An ASRP Early Action Reach is located in this river segment (Wynoochee River Early Action Reach Project, RM 14 to 16).

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 1,500 feet to over 3,200 feet in width over this segment and then enters the much larger Chehalis River floodplain at Highway 12. Over the past 70 years, the channel has migrated from approximately 100 feet to 770 feet, depending on location. At least four meander cutoffs (avulsions) have occurred during the past 70 years. Much of the riparian area is very narrow or immediately adjacent to fields over the majority of this segment, although there are wider deciduous forested riparian patches in some locations. Downstream of Highway 12, the riparian area is wider and dominated by deciduous forest.

Beyond the 70-year historical channel location area, the relative elevation maps show numerous low-lying channel meander scars, which present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull. Essentially the entire low-lying valley bottom between RM 7 and 11 shows former channel meanders.

A total of 205 structures, 274 parcels, and 43,305 feet (8.3 miles) of roads are present within the 400-foot buffer of the historical channel location area, and the total within the low-lying valley includes 351 structures, 487 parcels, and 113,528 feet (21.5 miles) of roads. Considering that meander cutoffs have moved the channel rapidly (over 700 feet in one location), roads and structures much further

distant from the historical channel location could be at future risk. Some smaller parcels exist in the low-lying valley that could be subject to future residential development.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is a mid-term priority in the ASRP and is proposed for habitat protection and restoration in the second 10-year increment of the ASRP (Lower Wynoochee River, RM 0 to 20).

Satsop River, RM 0 to 6.3

This segment of the Satsop River extends for 6.3 miles upstream to the confluence with the West Fork Satsop River. Figures 25 through 30 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley includes agricultural (hay and pasture) and rural residential with gravel mined ponds that are currently being restored. A combined erosion management and habitat enhancement project that has been funded by the Flood Authority is in progress in the lower 2 miles of the Satsop River (Lower Satsop Restoration and Protection Program, RM 0 to 2).

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 3,000 feet to over 4,700 feet in width and then enters the Chehalis River floodplain at Highway 12. Over the past 70 years, the channel has migrated from approximately 50 feet to over 1,000 feet, depending on location. At least three meander cutoffs (avulsions) have occurred during the past 70 years. The riparian area is highly variable in width, ranging from very narrow or immediately adjacent to fields to larger patches of deciduous forest. Downstream of Highway 12, the riparian area is wider and dominated by deciduous forest.

Beyond the 70-year historical channel location area and its 700-foot buffer, the relative elevation maps show numerous low-lying channel meander scars, which occupy essentially the entire valley width and present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull.

A total of 95 structures, 117 parcels, and 27,820 feet (5.3 miles) of roads are present within the 700-foot buffer of the historical channel location area, and the total within the low-lying valley includes 368 structures, 347 parcels, and 96,346 feet (18.2 miles) of roads. Considering that meander cutoffs have moved the channel rapidly, roads and structures much further distant from the historical channel location could be at future risk. There are numerous smaller parcels in the low-lying valley with existing homes that could potentially be at future risk of erosion damage.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is included in the ASRP and is proposed as a near-term priority for habitat protection and restoration within the first 10-year increment of the ASRP (Lower Satsop River, RM 0 to 6.3).

East Fork Satsop River, RM 6.3 to 11

This segment of the East Fork Satsop River extends from the confluence of the West Fork Satsop River upstream for approximately 5 miles to the confluence with the Middle Fork Satsop River. Figures 31 through 36 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley includes agricultural (hay and pasture) and rural residential with some gravel removal ponds. An ASRP Early Action Reach project (East Fork Satsop River Early Action Reach, RM 7.8 to 10.8) is located in this river segment.

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 700 feet to over 3,500 feet in width. Over the past 70 years, the channel has had little to no migration in some stretches to approximately 500 feet, depending on location. At least four meander cutoffs (avulsions) have occurred during the past 70 years. The riparian area is highly variable in width ranging from very narrow or immediately adjacent to fields to larger patches of deciduous forest.

Beyond the 70-year historical channel location area and its 500-foot buffer, the relative elevation maps show numerous low-lying channel meander scars, which occupy essentially the entire valley width and present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull.

A total of 106 structures, 215 parcels, and 13,847 feet (2.6 miles) of roads are present within the 500-foot buffer of the historical channel location area, and the total within the low-lying valley includes 193 structures, 309 parcels, and 43,614 feet (8.3 miles) of roads. Considering that meander cutoffs have moved the channel rapidly, roads and structures much further distant from the historical channel location could be at future risk. There are numerous smaller parcels in the low-lying valley that could potentially be at future risk of development and erosion damage.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is included in the ASRP and is proposed as a near-term priority for habitat protection and restoration within the first 10-year increment of the ASRP (Lower East Fork Satsop River, RM 6.3 to 18).

West Fork Satsop River, RM 0 to 7

This segment of the West Fork Satsop River extends for 7 miles upstream from the confluence with the East Fork Satsop River. Figures 37 through 42 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley includes timber, agriculture (hay and pasture), and rural residential.

The low-lying valley bottom shown in the relative elevation maps ranges from confined sections only 150 to 200 feet in width to over 2,300 feet in width over this segment. Over the past 70 years, the channel has migrated from only a few feet in more confined areas to over 600 feet, depending on

location. At least three meander cutoffs (avulsions) have occurred during the past 70 years. Much of the riparian area has deciduous forest, although in some locations it is narrow or adjacent to fields.

Beyond the 70-year historical channel location area and its 600-foot buffer, the relative elevation maps show numerous low-lying channel meander scars wherever the valley is less confined, which present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull.

A total of 90 structures, 124 parcels, and 26,934 feet (5.1 miles) of roads are present within the 600-foot buffer of the historical channel location area (most of these road segments are located on higher ground but are immediately adjacent to the channel), and the total within the low-lying valley includes 71 structures, 121 parcels, and 11,529 feet (2.2 miles) of roads. Considering that meander cutoffs have moved the channel rapidly over large distances, roads and structures much further distant from the historical channel location could be at future risk. There are numerous smaller parcels in the low-lying valley that either have existing homes or could be subject to future residential development.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is a mid-term priority in the ASRP and is proposed for habitat restoration and protection in the second 10-year increment of the ASRP (Lower West Fork Satsop River, RM 0 to 18.6).

Chehalis River, RM 13 to 25

This segment of the Chehalis River extends for 12 miles from the confluence of the Wynoochee River up to Elma. Figures 43 through 54 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley is predominantly agricultural (vegetable crops, hay, and pasture) and rural residential with protected wildlife area lands as well.

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 3,300 feet to over 10,000 feet in width over this segment. Over the past 70 years, the channel has migrated from only a few feet to over 800 feet, depending on location. At least three meander cutoffs (avulsions) have occurred during the past 70 years. The riparian area is highly variable with some areas that are narrow or adjacent to fields as well as larger patches of deciduous forest in some locations.

Beyond the 70-year historical channel location area and its 500-foot buffer, the relative elevation maps show numerous low-lying channel meander scars, which essentially occupy the entire low-lying valley width and present erosion and avulsion hazard risks because the river could occupy these areas during frequent flood events above bankfull.

A total of 107 structures, 243 parcels, and 48,830 feet (9.2 miles) of roads are present within the 500-foot buffer of the historical channel location area, and the total within low-lying valley includes 1,872 structures, 1,608 parcels, and 442,634 feet (83.8 miles) of roads. Considering that meander cutoffs

have moved the channel rapidly over large distances, roads and structures much further distant from the historical channel location could be at future risk. Some smaller parcels exist in the low-lying valley that could be subject to future residential development.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is a near-term priority in the ASRP for habitat protection and restoration in the first 10 years (Estuary).

Chehalis River, RM 33 to 55

This segment of the Chehalis River extends for 22 miles from Porter to Scatter Creek. Figures 55 through 72 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley is predominantly agricultural (vegetable crops, nursery, hay, and pasture) and rural residential and includes the Confederated Tribes of the Chehalis Reservation.

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 2,600 feet to over 9,700 feet in width over this segment. Over the past 70 years, the channel has migrated from a few feet to over 900 feet, depending on location. At least 10 meander cutoffs (avulsions) have occurred during the past 70 years. The riparian area is highly variable with some areas that are narrow or adjacent to fields as well as larger patches of deciduous forest in some locations, particularly on the Chehalis Reservation.

Beyond the 70-year historical channel location area and its 400-foot buffer, the relative elevation maps show numerous low-lying channel meander scars essentially occupying the entire valley width, even past higher terraces in the valley, which present erosion and avulsion hazard risks because the river could occupy these areas during frequent flood events above bankfull.

A total of 53 structures, 301 parcels, and 51,465 feet (9.8 miles) of roads are present within the 400-foot buffer of the historical channel location area, and the total within the low-lying valley includes 2,185 structures, 1,835 parcels, and 496,867 feet (94.1 miles) of roads. Considering that meander cutoffs have moved the channel rapidly over large distances, roads and structures much further distant from the historical channel location could be at future risk. Several smaller parcels exist in the low-lying valley that could be subject to future residential development.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide in-channel structure to slow down erosion. This river segment is a long-term priority in the ASRP and is proposed for habitat restoration primarily as nodes that incorporate off-channel habitats during the third 10-year increment of the ASRP (Lower Chehalis River, RM 20 to 67).

Newaukum River, RM 0 to 11

This is the mainstem segment of the Newaukum River that extends for 11 miles from the confluence with the Chehalis River up to the North Fork and South Fork Newaukum rivers confluence. Figures 73 through 80 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley includes agriculture (hay and pasture), residential, commercial, transportation corridors, and parks.

The low-lying valley bottom shown in the relative elevation maps ranges from approximately 2,600 feet to over 5,500 feet in width over this segment. Over the past 70 years, the channel has migrated from a few feet to over 450 feet, depending on location. At least four meander cutoffs (avulsions) have occurred during the past 70 years. Much of the riparian area is very narrow in this segment and immediately adjacent to fields.

Beyond the 70-year historical channel location area and its 300-foot buffer, the relative elevation maps show numerous low-lying channel meander scars occupying the majority of the valley, which present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull.

A total of 105 structures, 210 parcels, and 21,389 feet (4.1 miles) of roads are present within the 300-foot buffer of the historical channel location area, and the total within the low-lying valley includes 422 structures, 392 parcels, and 76,805 feet (14.5 miles) of roads. Considering that meander cutoffs have moved the channel rapidly over a large distance, roads and structures much further distant from the historical channel location could be at future risk.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is included in the ASRP and is proposed as a near-term priority for habitat protection and restoration within the first 10 years of the ASRP (Lower Newaukum, RM 0 to 10.5).

South Fork Newaukum River, RM 11 to 25

This segment of the South Fork Newaukum River extends for 14 miles upstream of the confluence with the North Fork Newaukum. Figures 81 through 92 in Attachment 1 show the historical channel locations and relative elevations. The land use in the valley includes agricultural (hay and pasture) and rural to more dense residential development. An ASRP Early Action Reach is located in this river segment (South Fork Newaukum River Early Action Reach Project, RM 10.9 to 13.7).

The low-lying valley bottom as shown in the relative elevation maps ranges from approximately 380 feet to over 3,500 feet in width over this segment. Over the past 70 years, the channel has migrated from a few feet to over 300 feet, depending on location. At least 12 meander cutoffs (avulsions) have occurred

during the past 70 years. The riparian area is highly variable in this reach ranging from narrow to larger deciduous forested patches.

Beyond the 70-year historical channel location area and its 300-foot buffer, the relative elevation maps show numerous low-lying channel meander scars that occupy the majority of the valley, which present erosion and avulsion hazard risks because the river could easily occupy these areas during frequent flood events above bankfull.

A total of 327 structures, 237 parcels, and 34,357 feet (6.5 miles) of roads are present within the 300-foot buffer of the historical channel location area, and the total within the low-lying valley includes 624 structures, 639 parcels, and 82,871 feet (15.7 miles) of roads. Considering that meander cutoffs have moved the channel over large distances, roads and structures much further distant from the historical channel location could be at future risk. This river segment has a large number of smaller parcels in the low-lying valley that either have existing homes or could be subject to future residential development.

This river segment presents good opportunities for combined erosion management and restoration projects that could diversify the habitats and provide structure to slow down erosion. This river segment is included in the ASRP and is proposed as a near-term priority for habitat protection and restoration within the first 10-year increment of the ASRP (RM 10.5 to 32.5).

Summary

The attached maps provide a first step in the channel migration or erosion hazard delineation process and highlight areas where future study is warranted. Table 5 summarizes the number of structures, parcels, and length of roads within the selected buffers around the 70-year historical channel migration area and within the entire low-lying valley segments. The Wynoochee River and South Fork Newaukum River segments have the most structures in proximity to the historical channel migration area, whereas the Chehalis River segments have the most roads in proximity to the historical channel migration area.

More detailed quantification of erosion rates and avulsion hazard areas is necessary for local jurisdictions and tribes to manage erosion hazards as part of their Shoreline Master Programs and Critical Area Ordinances. Defining erosion hazard zones (e.g., 30-, 50-, and 100-year boundaries) could be used to assess risk to existing structures and infrastructure. Erosion hazard zones have already been preliminarily delineated by Abbe et al. (2020) for the Newaukum River and the North Fork and South Fork Newaukum rivers within the *Chehalis Basin Strategy Restorative Flood Protection Advanced Feasibility Evaluation for the North and South Forks of the Newaukum River.* This example could be used as the basis for further erosion hazard delineations in high-priority areas of the basin.

Table 5
Summary of Structures, Parcels, and Roads Present in the River Segments

River Segment	Number Within Historical Channel Location Buffer				Number Within Low-Lying Valley		
	Buffer (feet)	Roads (feet)	Structures	Parcels	Roads (feet)	Structures	Parcels
Humptulips	500	3,054	19	68	11,479	61	114
Wynoochee	400	43,305	205	274	113,258	351	487
Satsop	700	27,820	95	117	96,346	368	347
EF Satsop	500	13,847	106	215	43,614	193	309
WF Satsop	600	26,934	90	124	11,529	71	121
Chehalis 13-25	500	48,830	107	243	442,634	1,872	1,608
Chehalis 33-55	400	51,465	53	301	496,867	2,185	1,835
Newaukum	300	21,389	105	210	76,805	422	392
SF Newaukum	300	34,357	327	237	82,871	624	639

Note: This analysis identifies all structures and does not distinguish "valuable" structures separately. Valuable structures include homes, barns, commercial buildings as opposed to small sheds, picnic shelters, and other low-value structures.
EF: East Fork
SF: South Fork
WF: West Fork

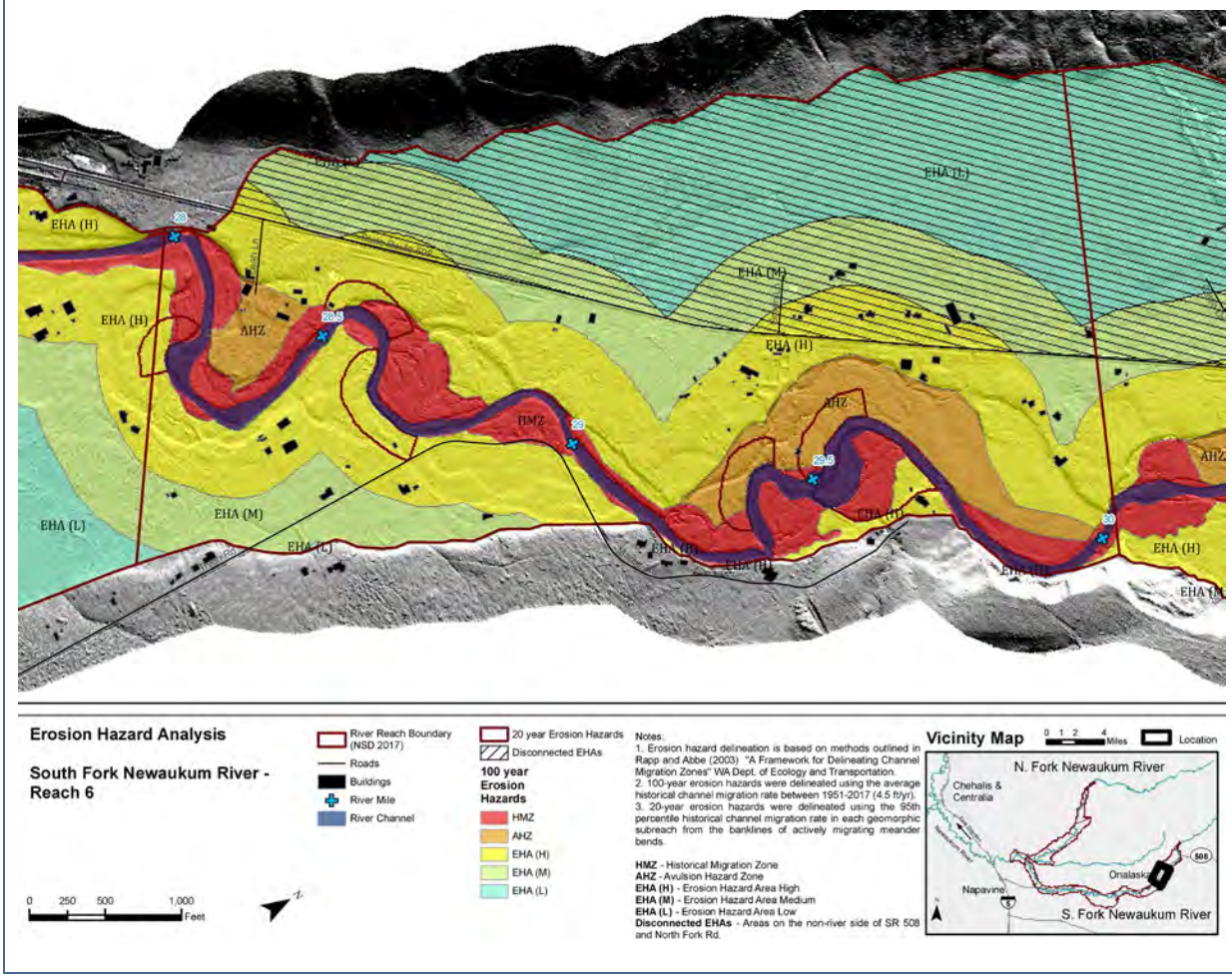
Next steps that could be considered for further mapping and quantification of erosion risks include the following:

Outreach to Conservation Districts and Local Jurisdictions on Priorities for Further Detailed Mapping. Present and discuss these maps with conservation districts, local jurisdictions, and tribes to identify their interest in more detailed analyses in the highest priority river segments initially mapped herein or expanding mapping to additional priority areas.

Conduct Additional Analyses or Mapping. Additional options identified in the *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Potential Options for Delineating Erosion Hazards* memorandum (Anchor QEA 2020) and consideration of modeling more frequent flood events that affect erosion processes as recommended by the Technical Advisory Committee could be pursued. Additional data that could be evaluated in order to quantify erosion hazards would include identifying geomorphic features; measuring erosion rates on a reach scale; evaluating geology, soils, and vegetation mapping; and field ground-truthing as appropriate to detail erosion hazard areas (low, medium, or high risks). Further analysis to identify "valuable" structures as a subset of all structures identified in this analysis could also be considered to prioritize potential erosion management actions.

An example of erosion hazard mapping for consideration is shown in the following map, which is from the analysis conducted for the *Chehalis Basin Strategy Restorative Flood Protection Advanced Feasibility Evaluation for the North and South Forks of the Newaukum River, Washington* (Abbe et al. 2020).

Example of Erosion Hazard Mapping



Source: Abbe et al. 2020

References

Abbe, T., C. Carlstad, D.L. Devier, S. Dickerson-Lange, J. Jay, M. Nelson, L. Embertson, S. Higgins, S. Katz, B. Keller, and K. Fetherston, 2020. *Chehalis Basin Strategy Restorative Flood Protection Advanced Feasibility Evaluation for the North and South Forks of the Newaukum River, Washington*. Prepared for Washington State Department of Ecology. Prepared by Natural Systems Design. January 2020.

Anchor QEA, 2020. *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Potential Options for Delineating Erosion Hazards*. Memorandum prepared for the Office of Chehalis Basin, October 22, 2020.

Olson, P.L., N.T. Legg, T.B. Abbe, M.A. Reinhart, and J.K. Radloff, 2014. *A Methodology for Delineation Planning-Level Channel Migration Zones*. Washington Department of Ecology Publication Number: 14-06-025. Available at: https://fortress.wa.gov/ecy/publications/SummaryPages/1406025.html

Attachment 1
Maps for Historical Channel Tracing and Relative Elevation

Figure 3
Historical Channel Mapping: Humptulips River

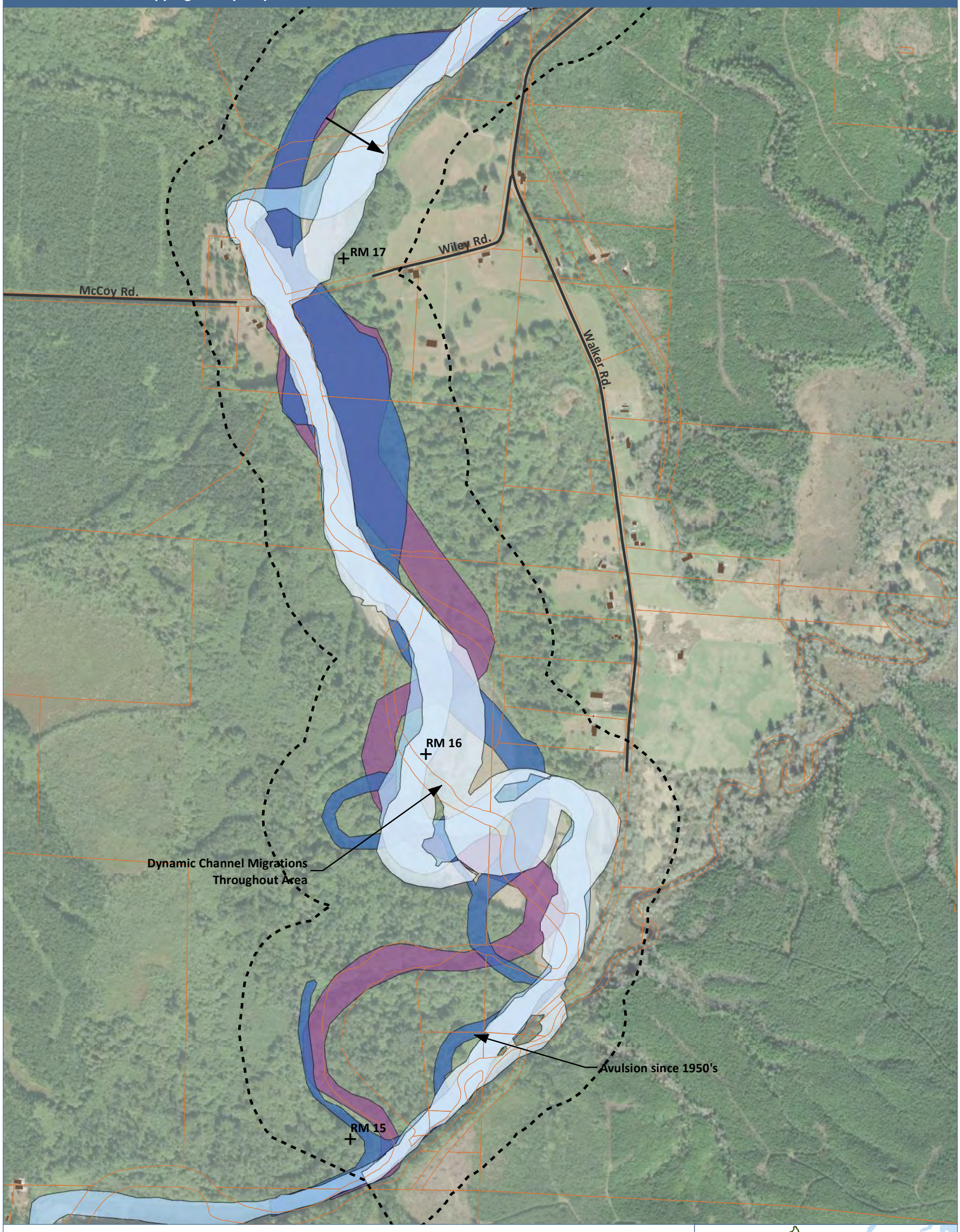
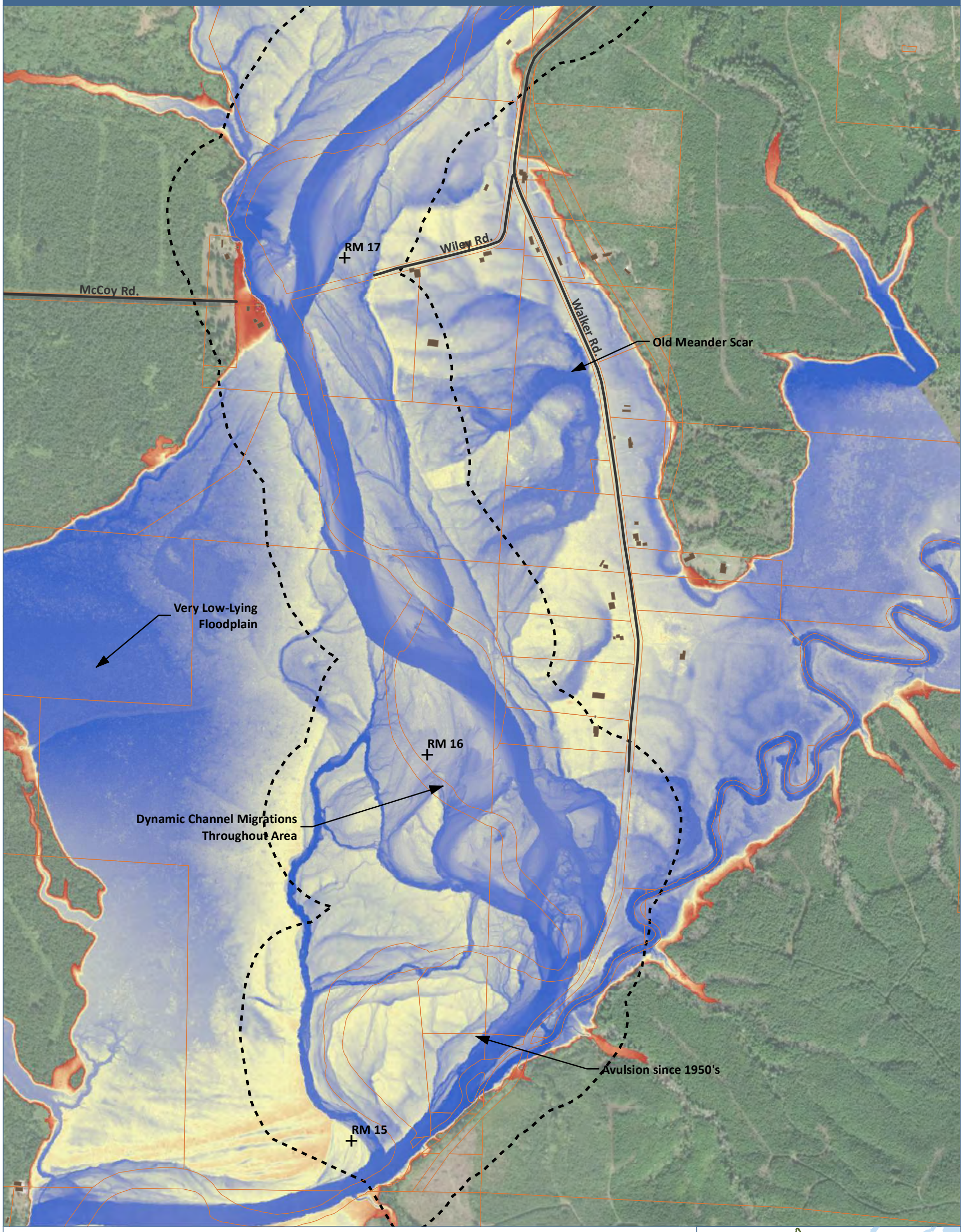


Figure 4
Relative Elevation Mapping: Humptulips River



River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer

Elevation Relative to Water Surface (ft)
25
-7

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 5
Historical Channel Mapping: Humptulips River

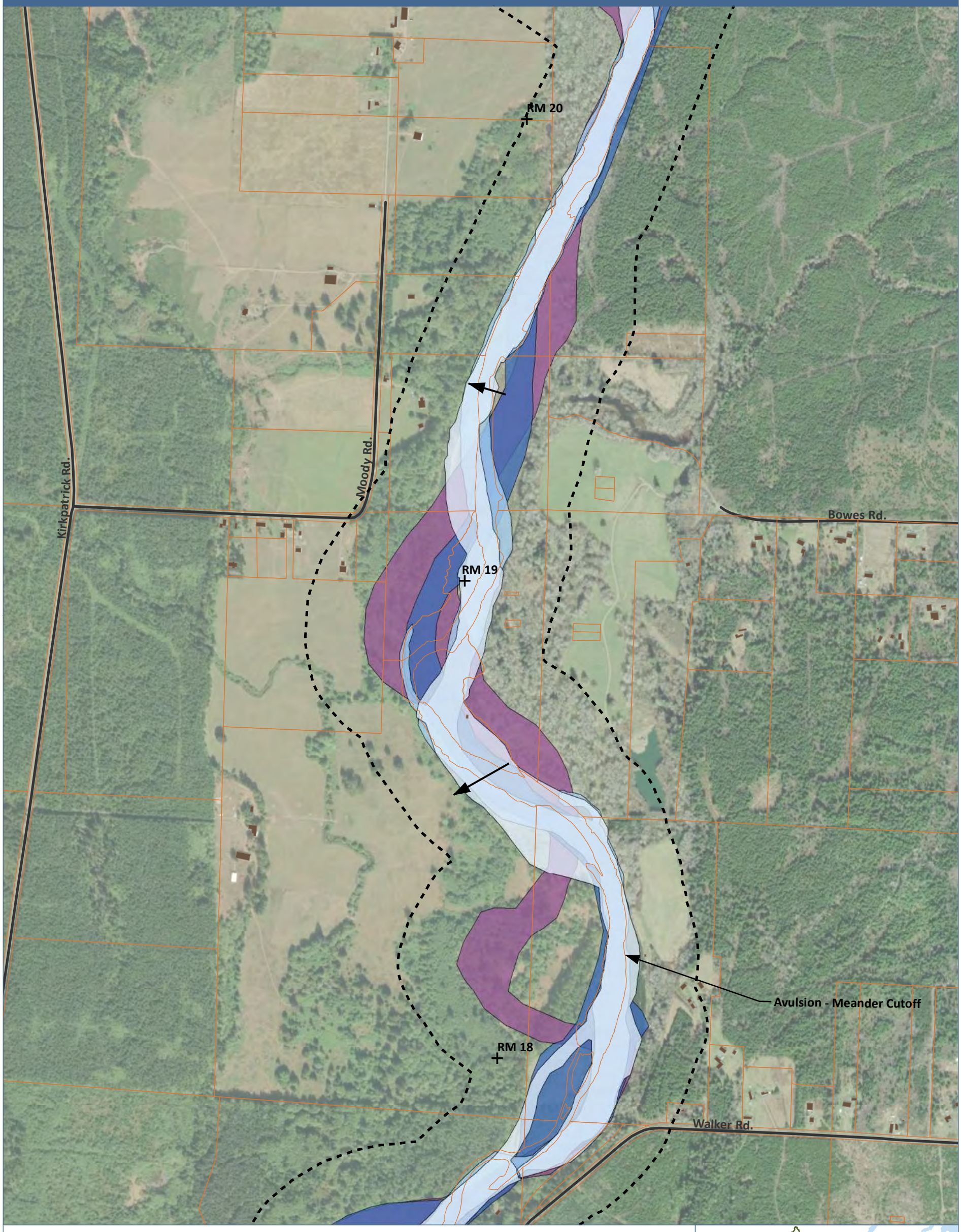


Figure 6
Relative Elevation Mapping: Humptulips River

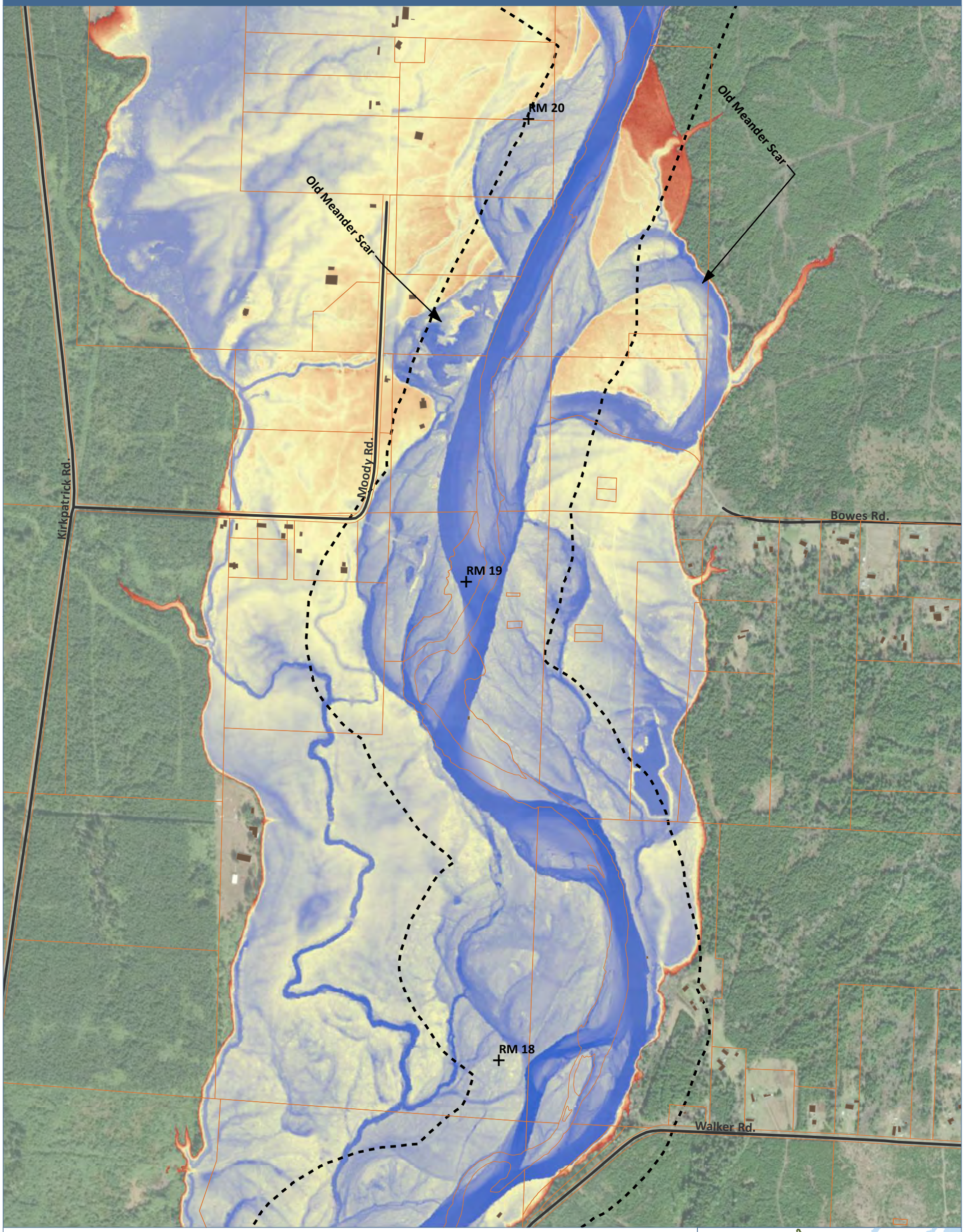


Figure 7
Historical Channel Mapping: Humptulips River

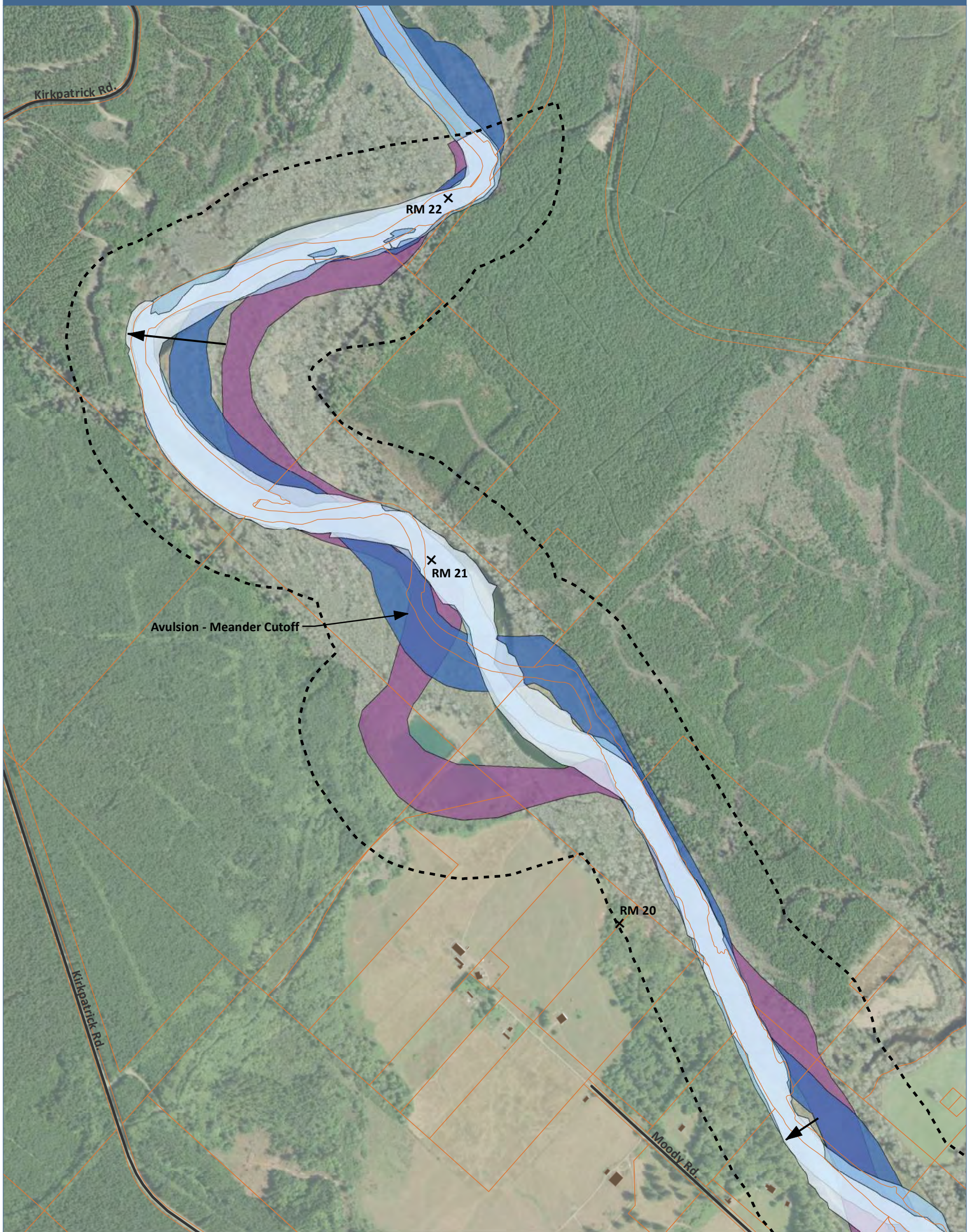


Figure 8
Relative Elevation Mapping: Humptulips River

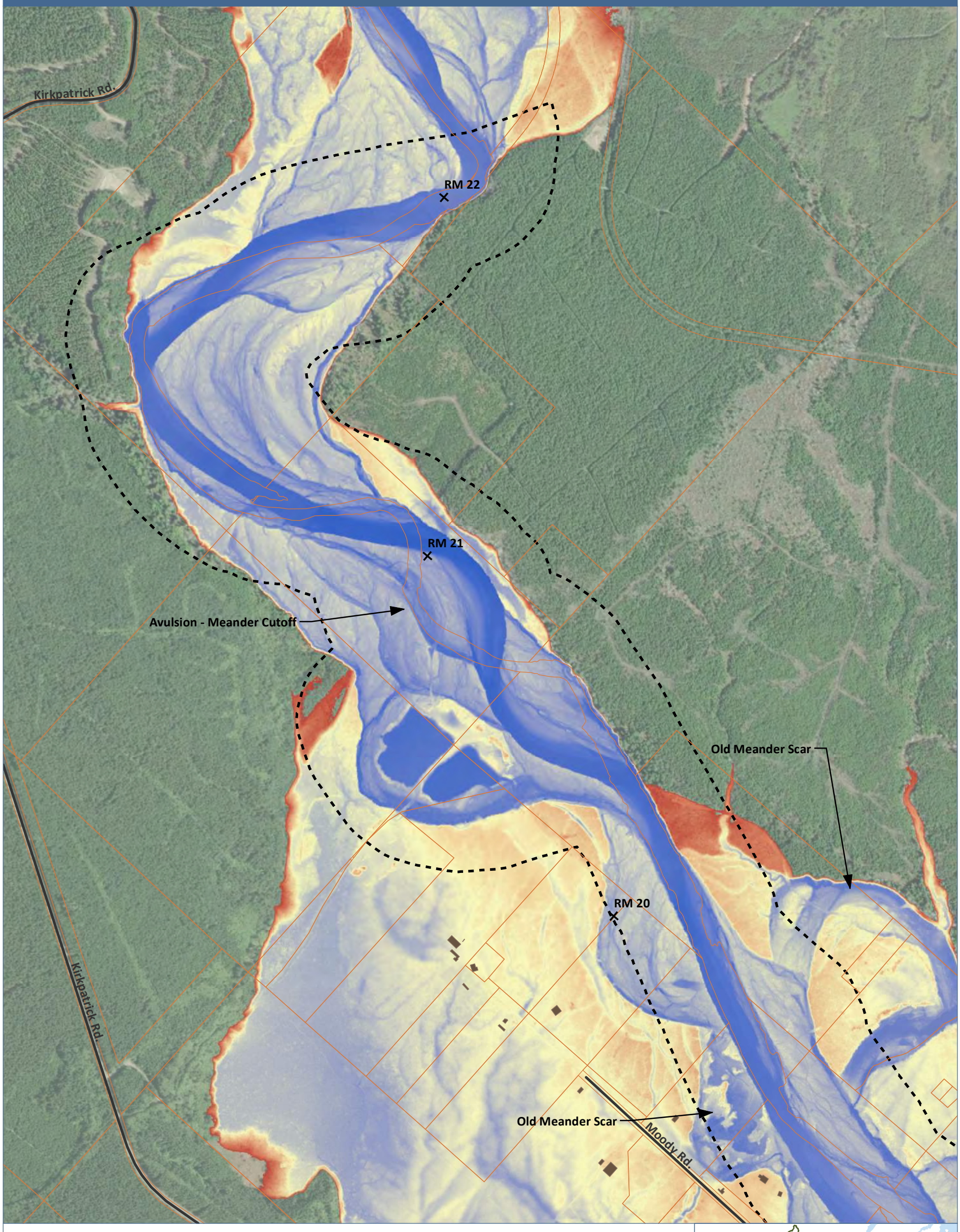


Figure 9
Historical Channel Mapping: Wynoochee River

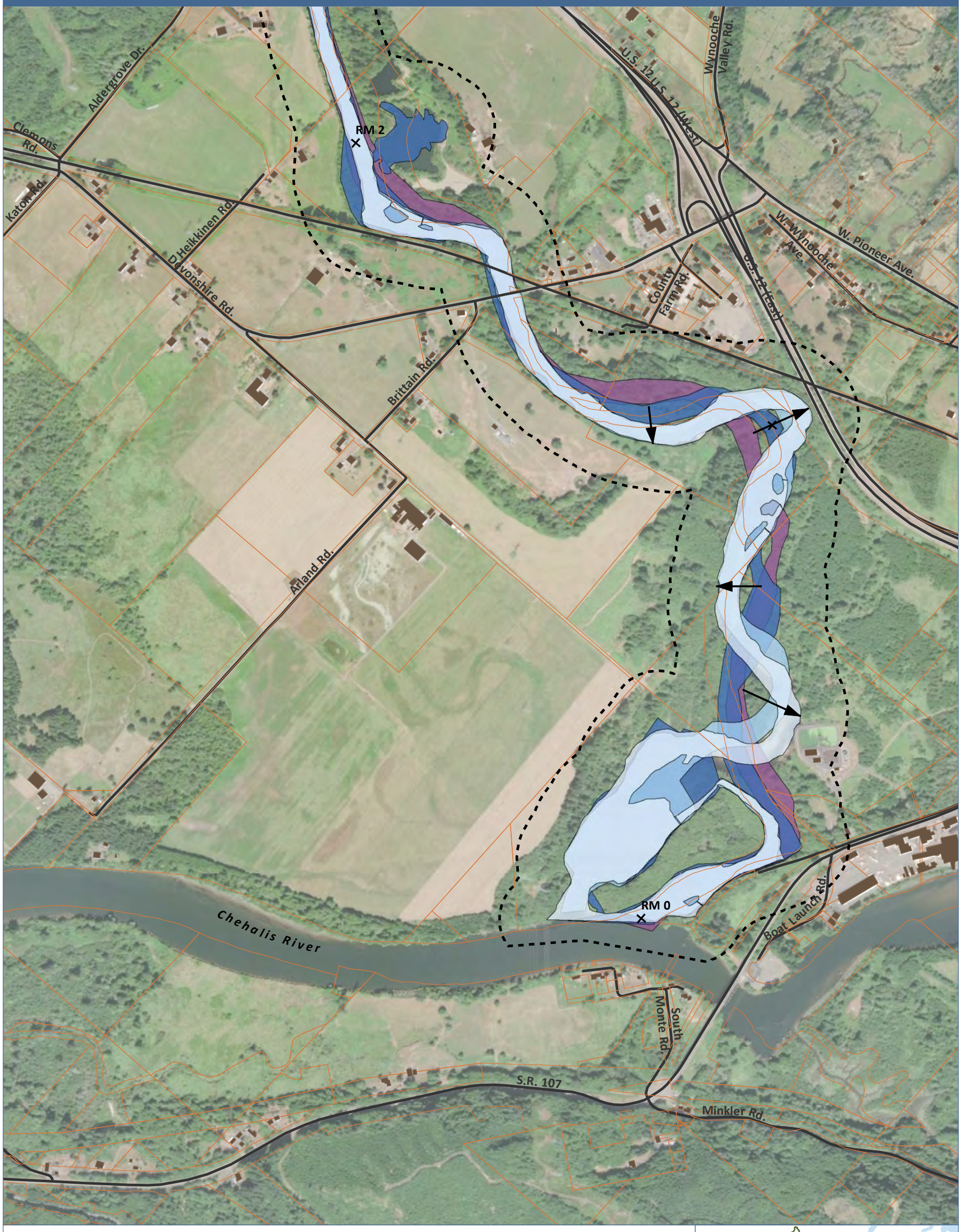
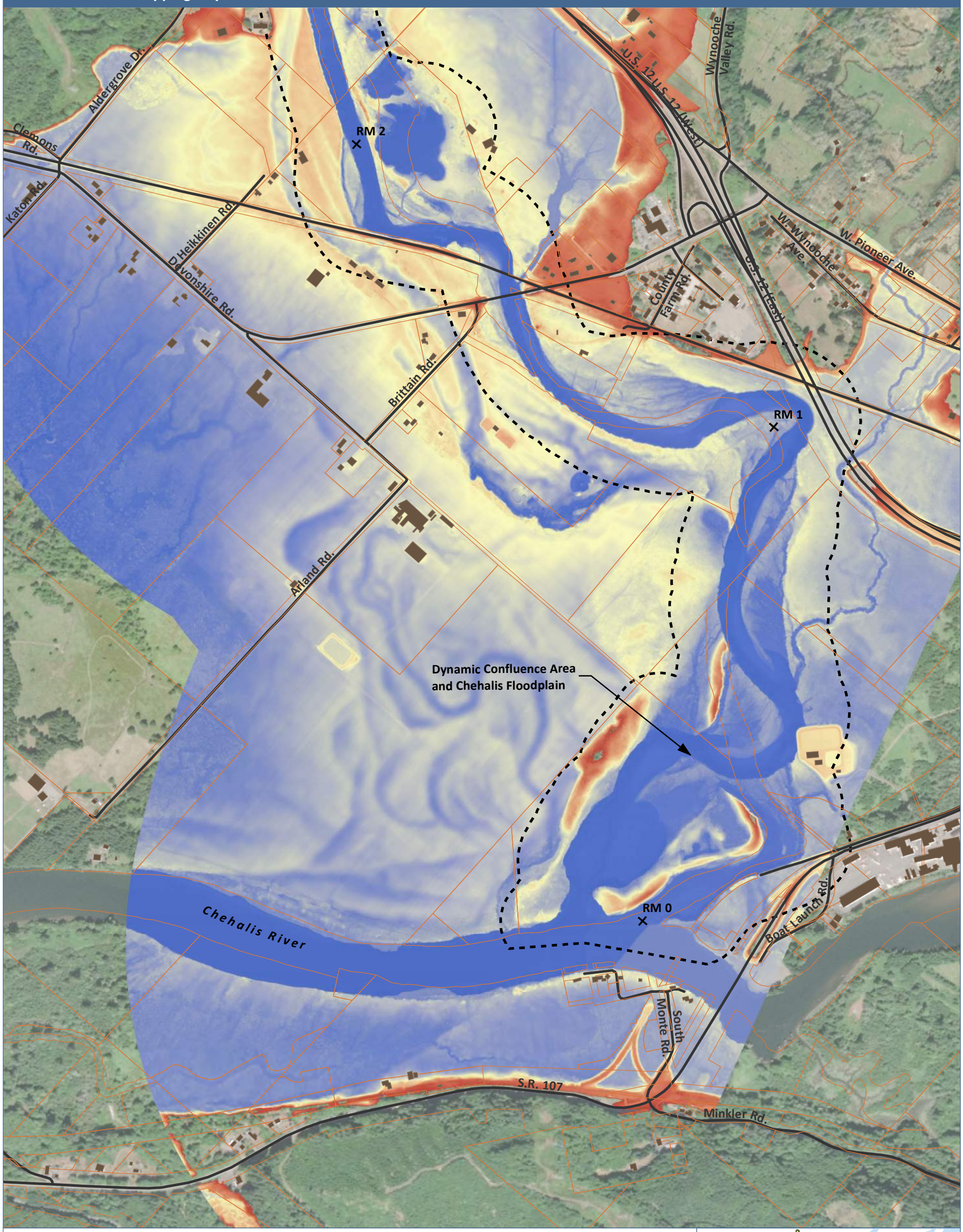


Figure 10
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 11
Historical Channel Mapping: Wynoochee River

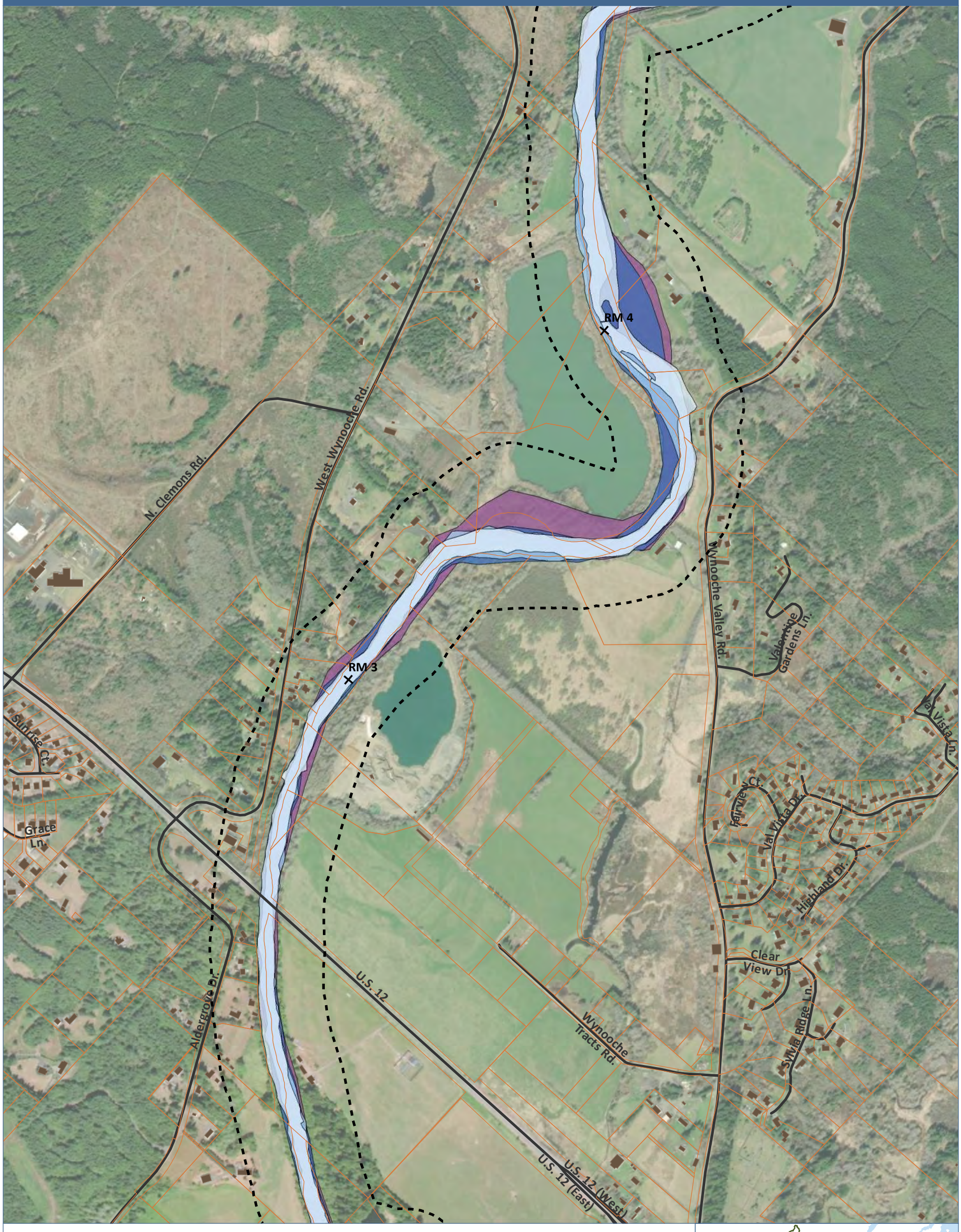
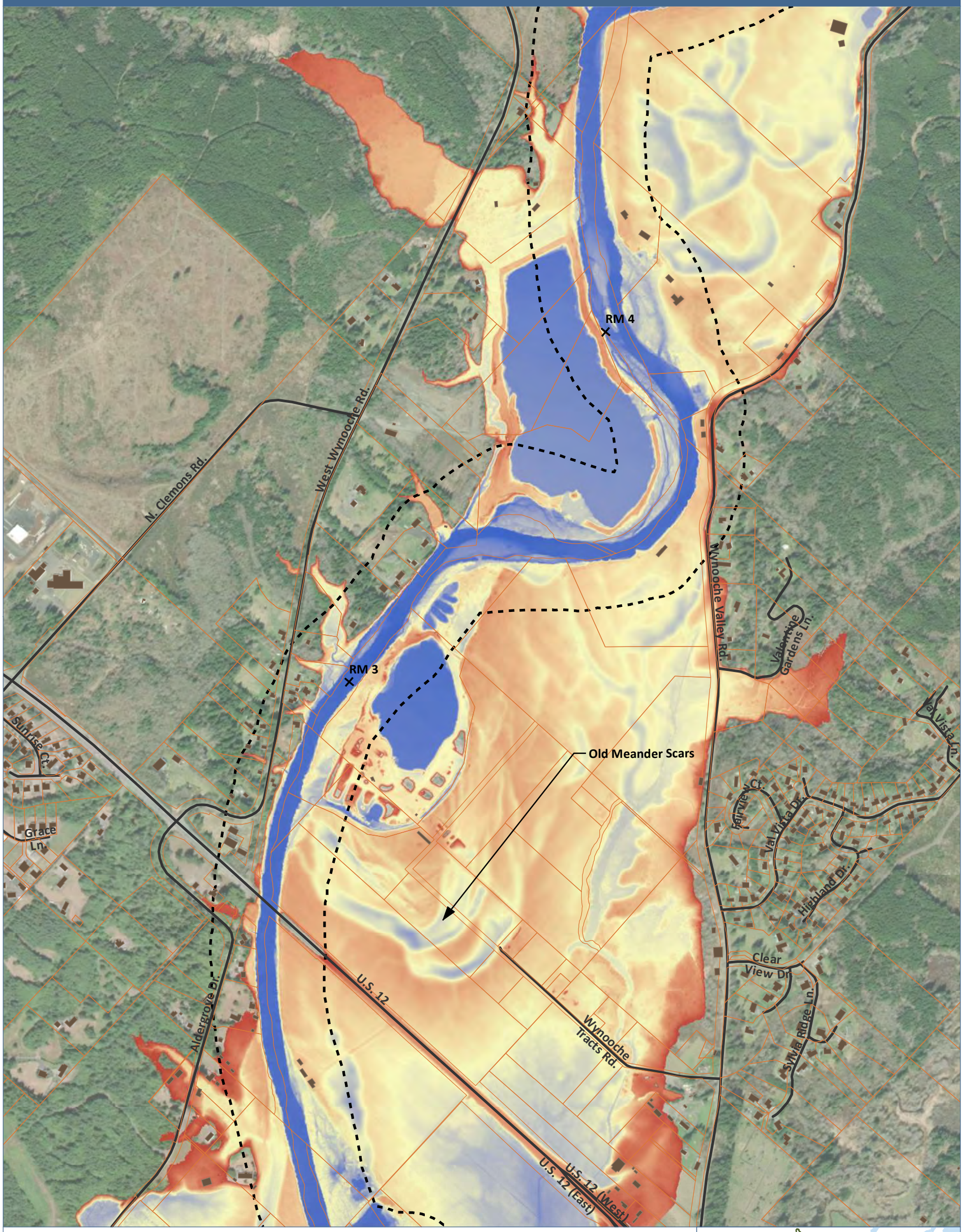
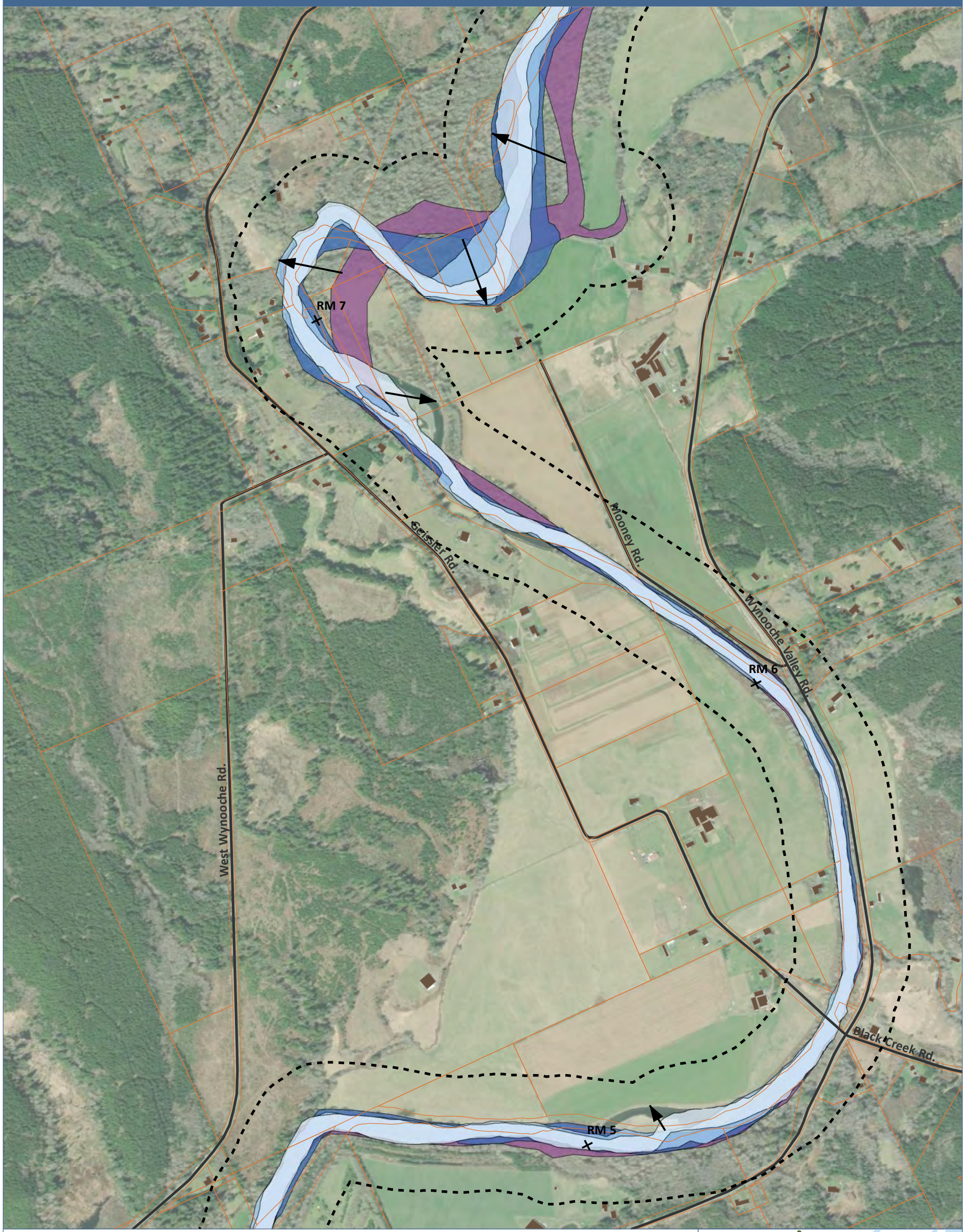


Figure 12
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 13
Historical Channel Mapping: Wynoochee River



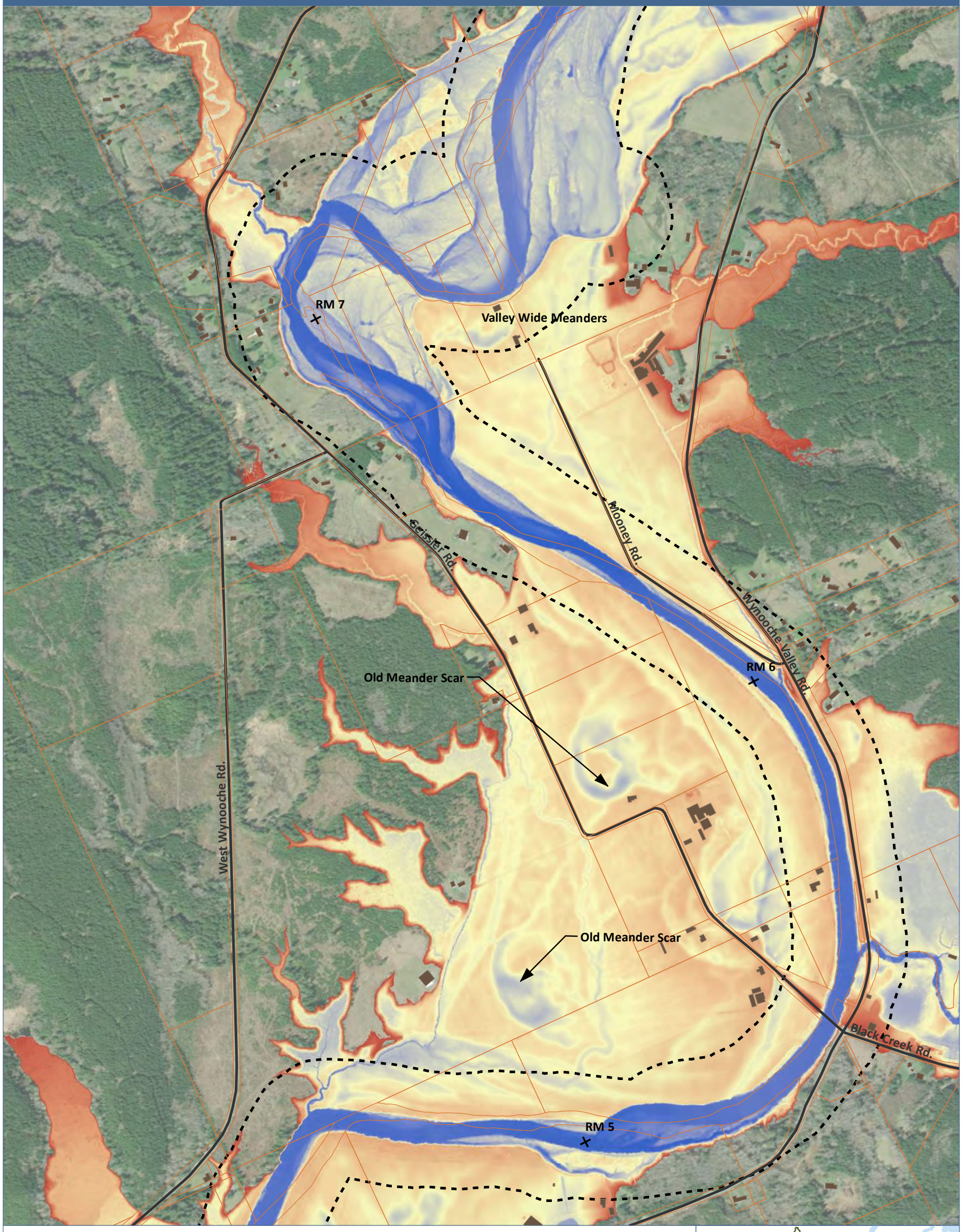
River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer
2013 Channel
2003 Channel
1977 Channel
1950s Channel
Migration Direction Indicator Arrow

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

Figure 14
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 15
Historical Channel Mapping: Wynoochee River

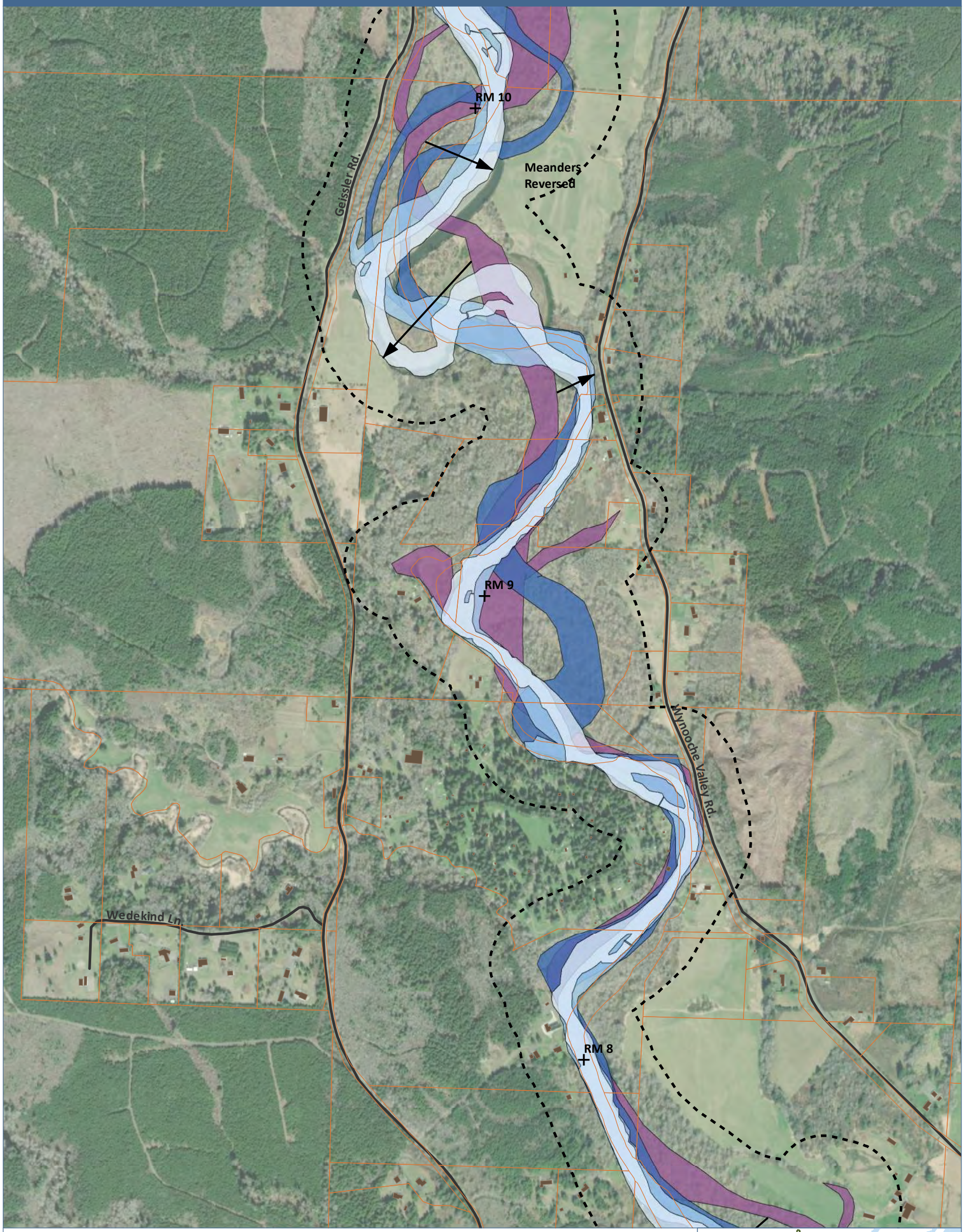
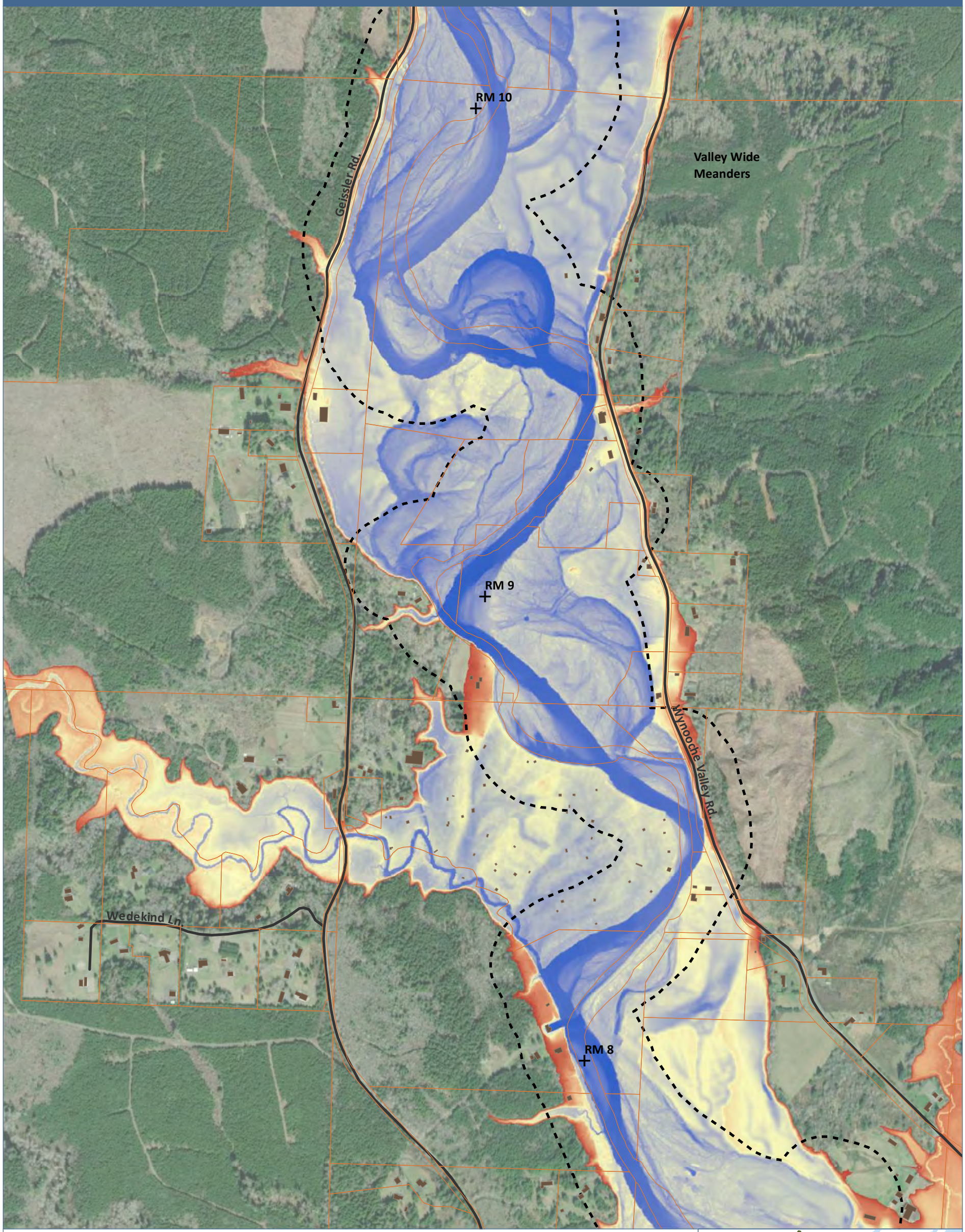


Figure 16
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 17
Historical Channel Mapping: Wynoochee River

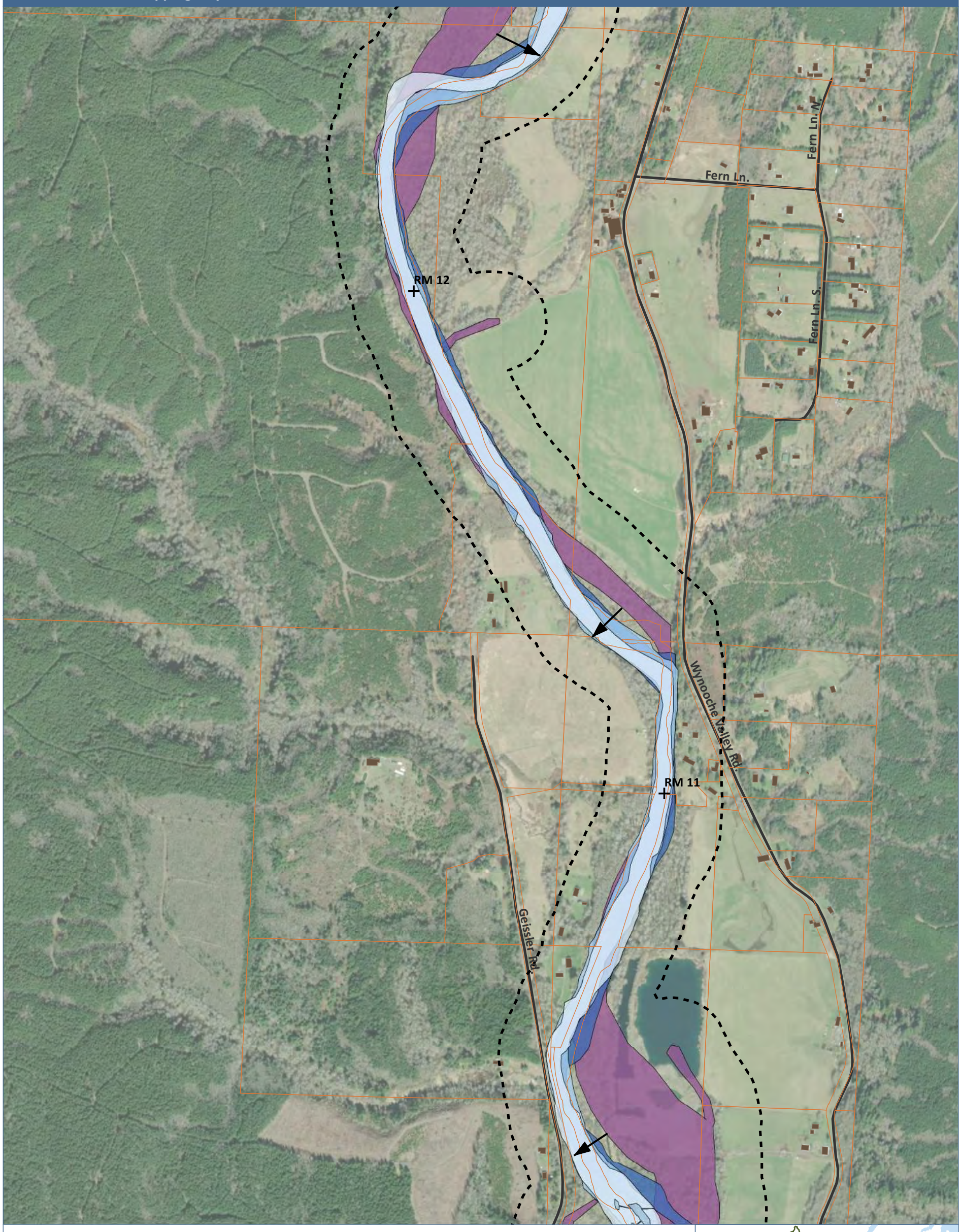
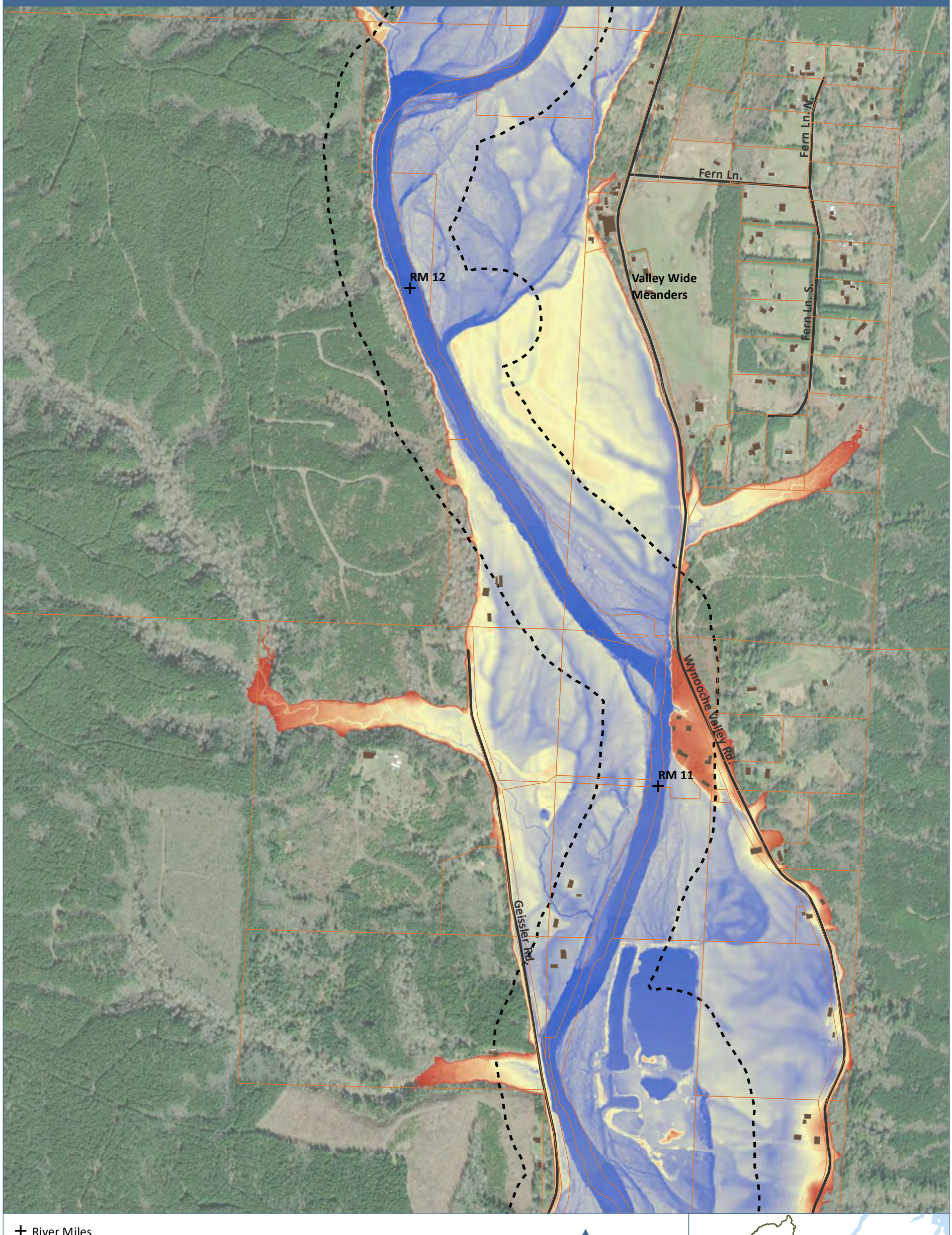


Figure 18
Relative Elevation Mapping: Wynoochee River

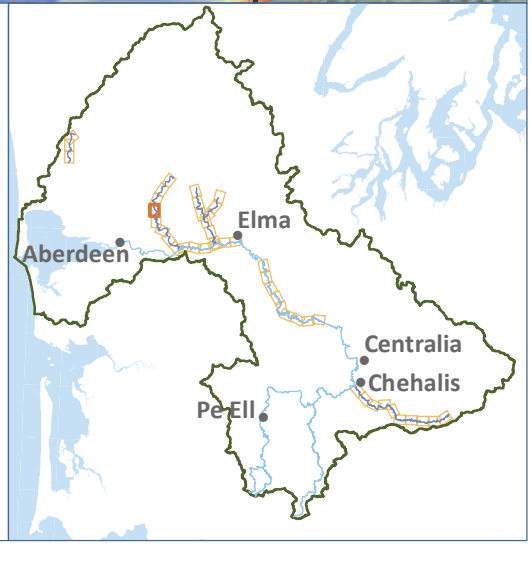


River Miles
Roads
Buildings
Parcels
400' Historical Channel Migration Buffer
Early Action Reach Extents

Elevation Relative to Water Surface (ft)
25
-3.5

N

Feet
0 500 1,000



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 19
Historical Channel Mapping: Wynoochee River

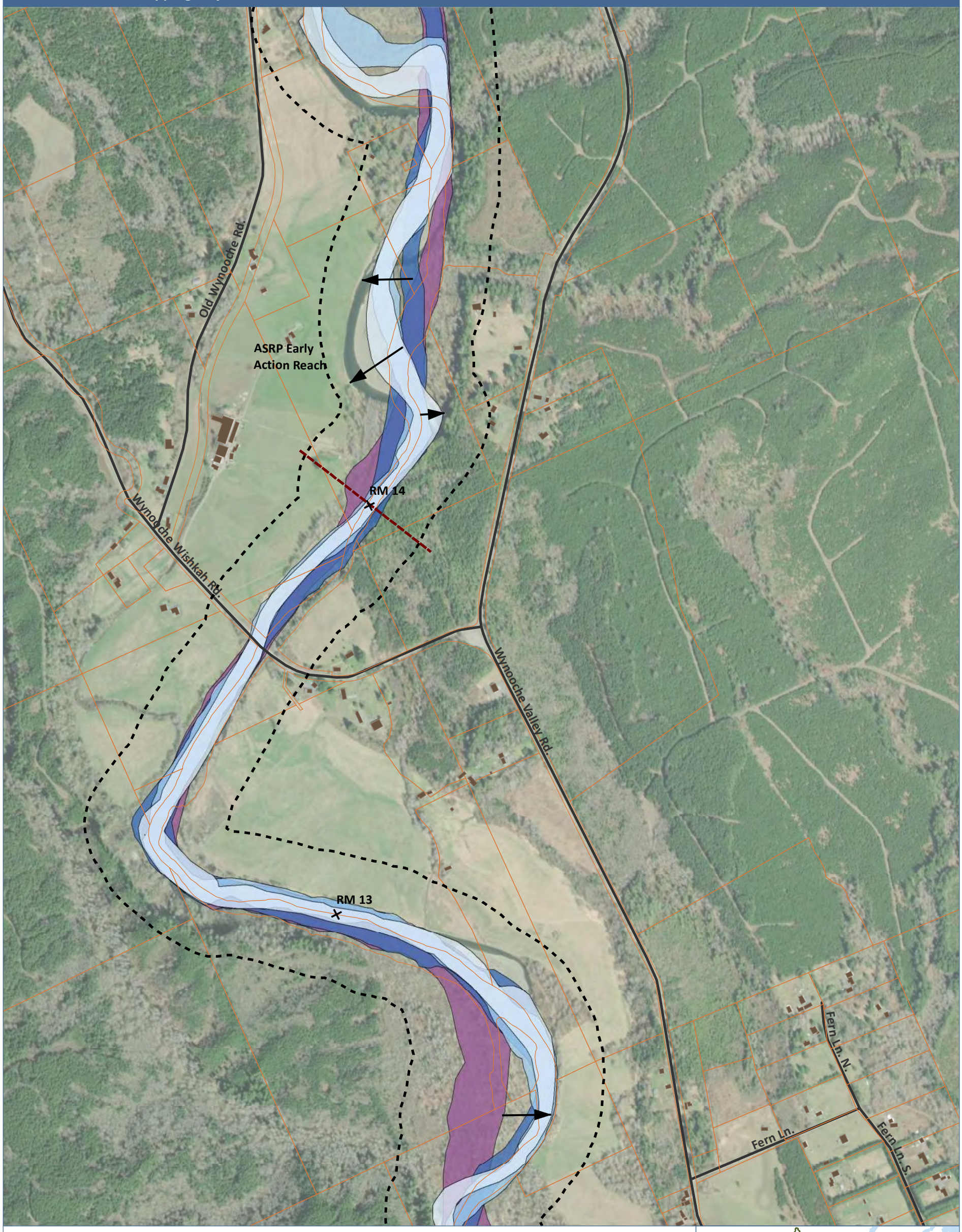
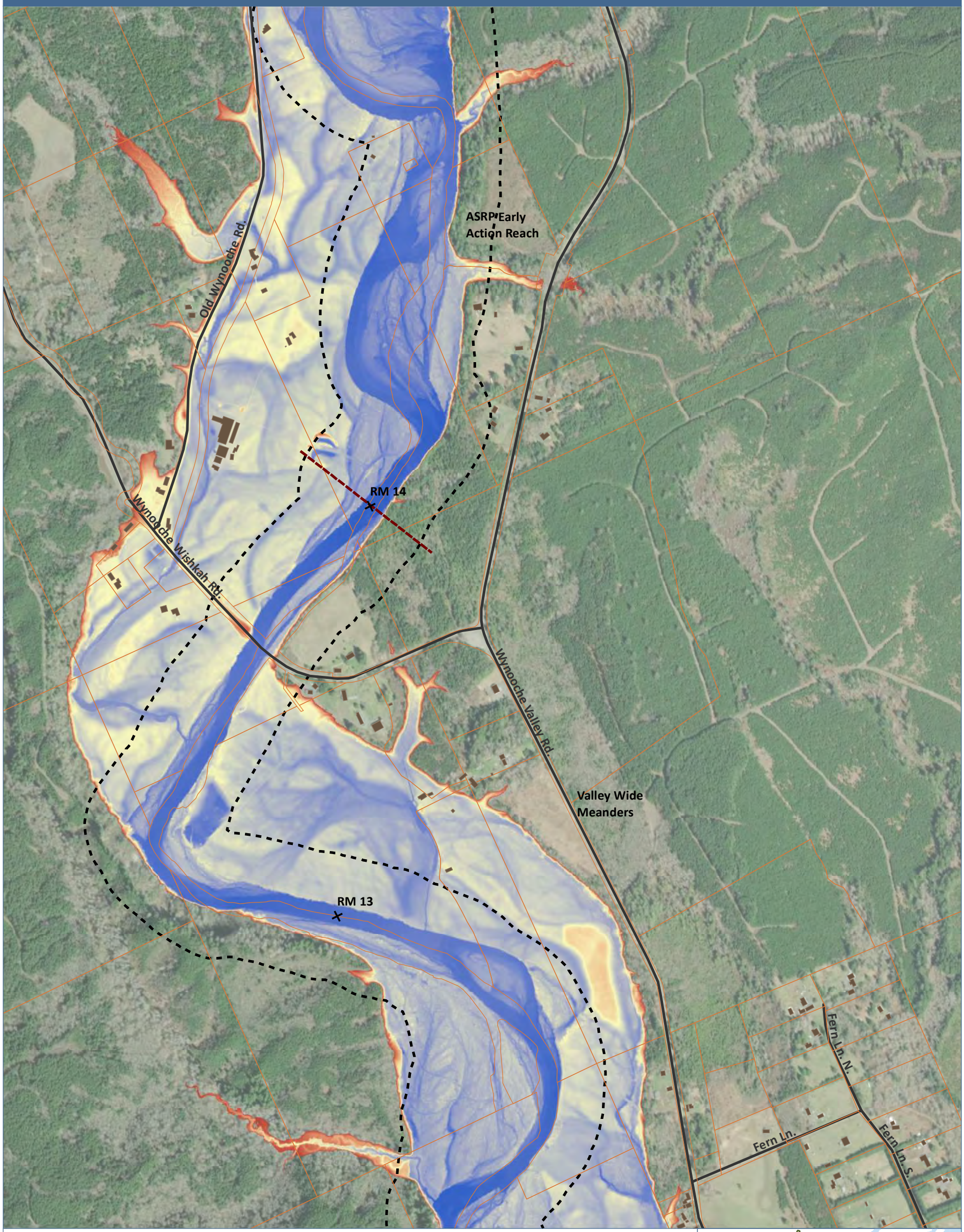


Figure 20
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 21
Historical Channel Mapping: Wynoochee River

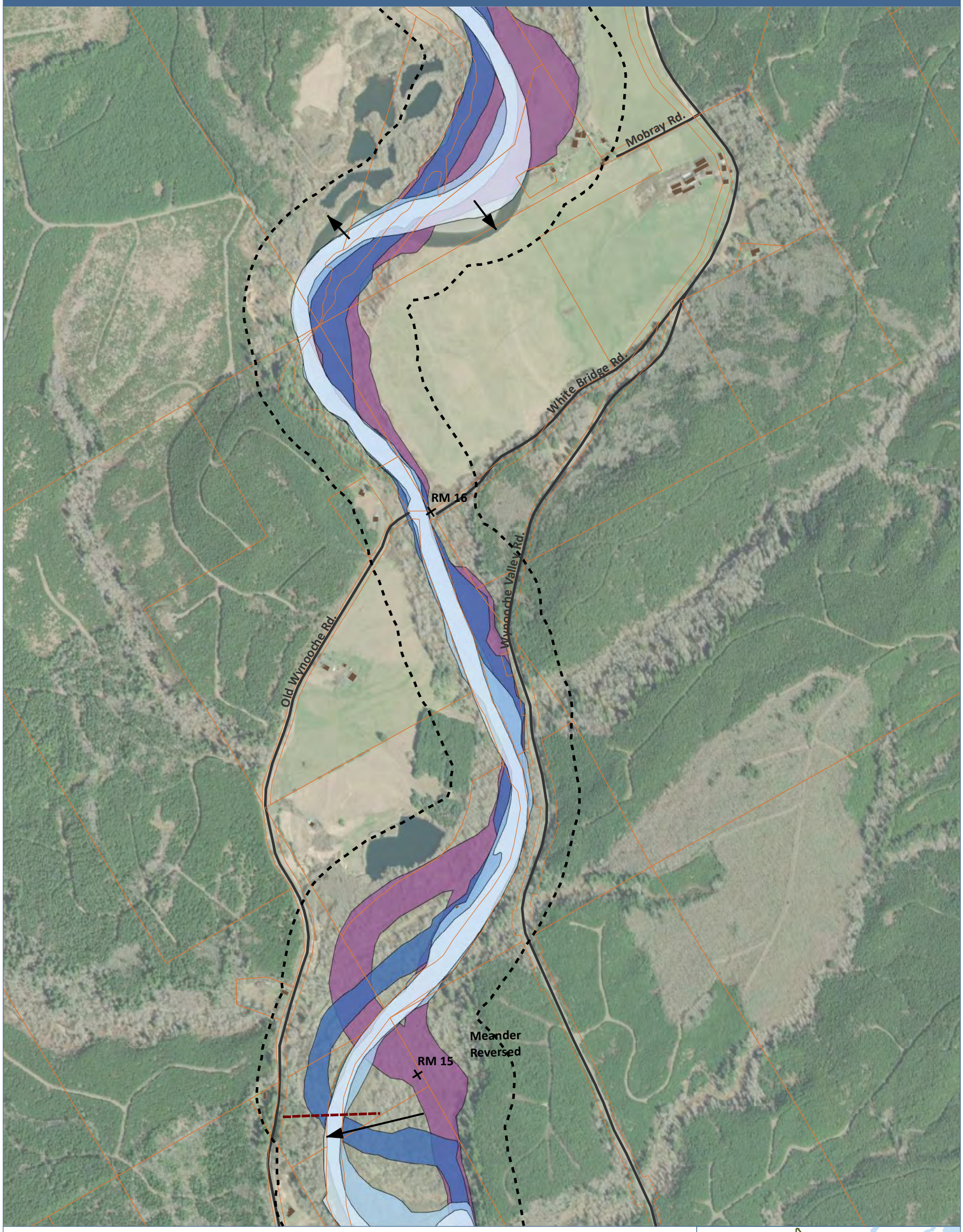
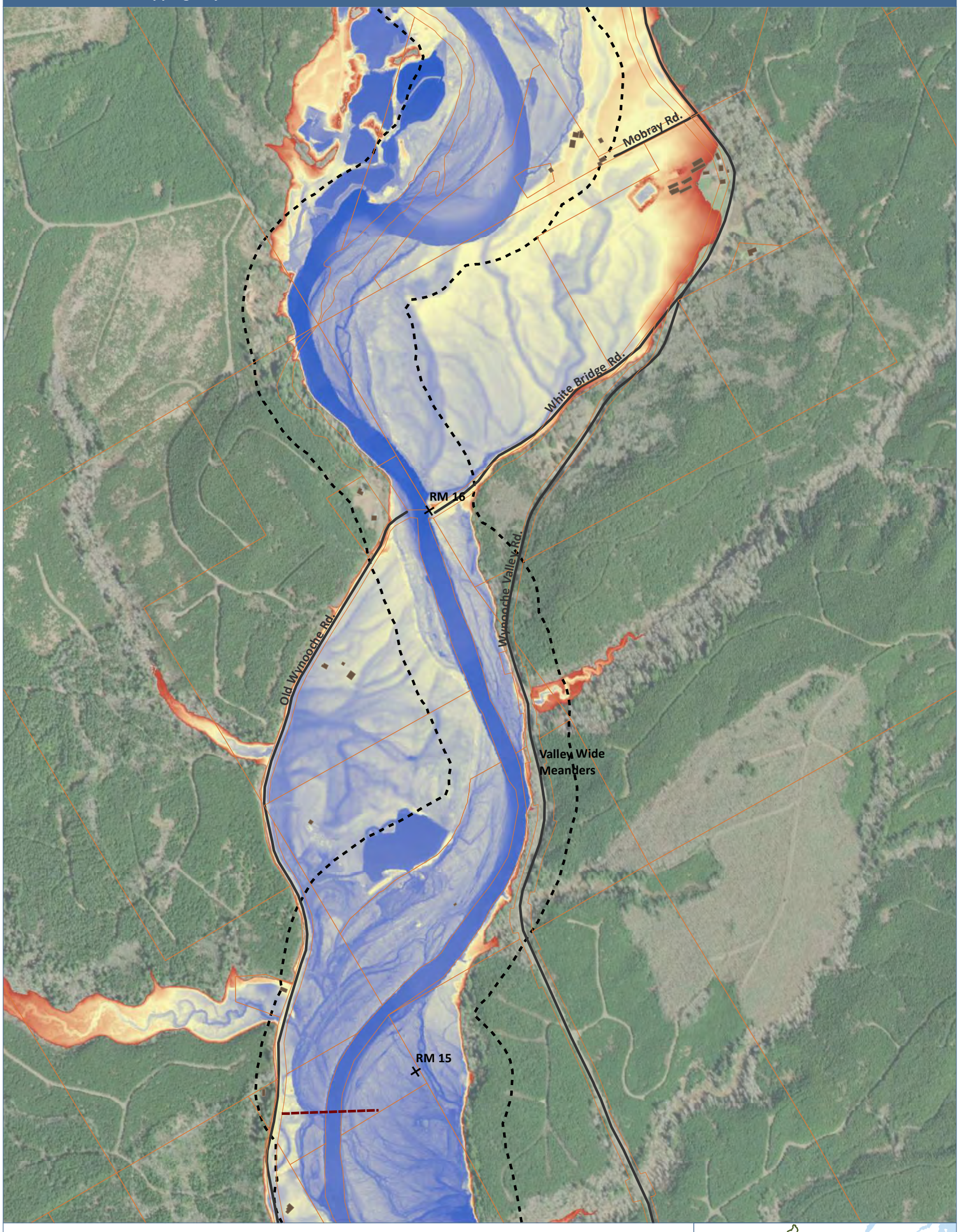
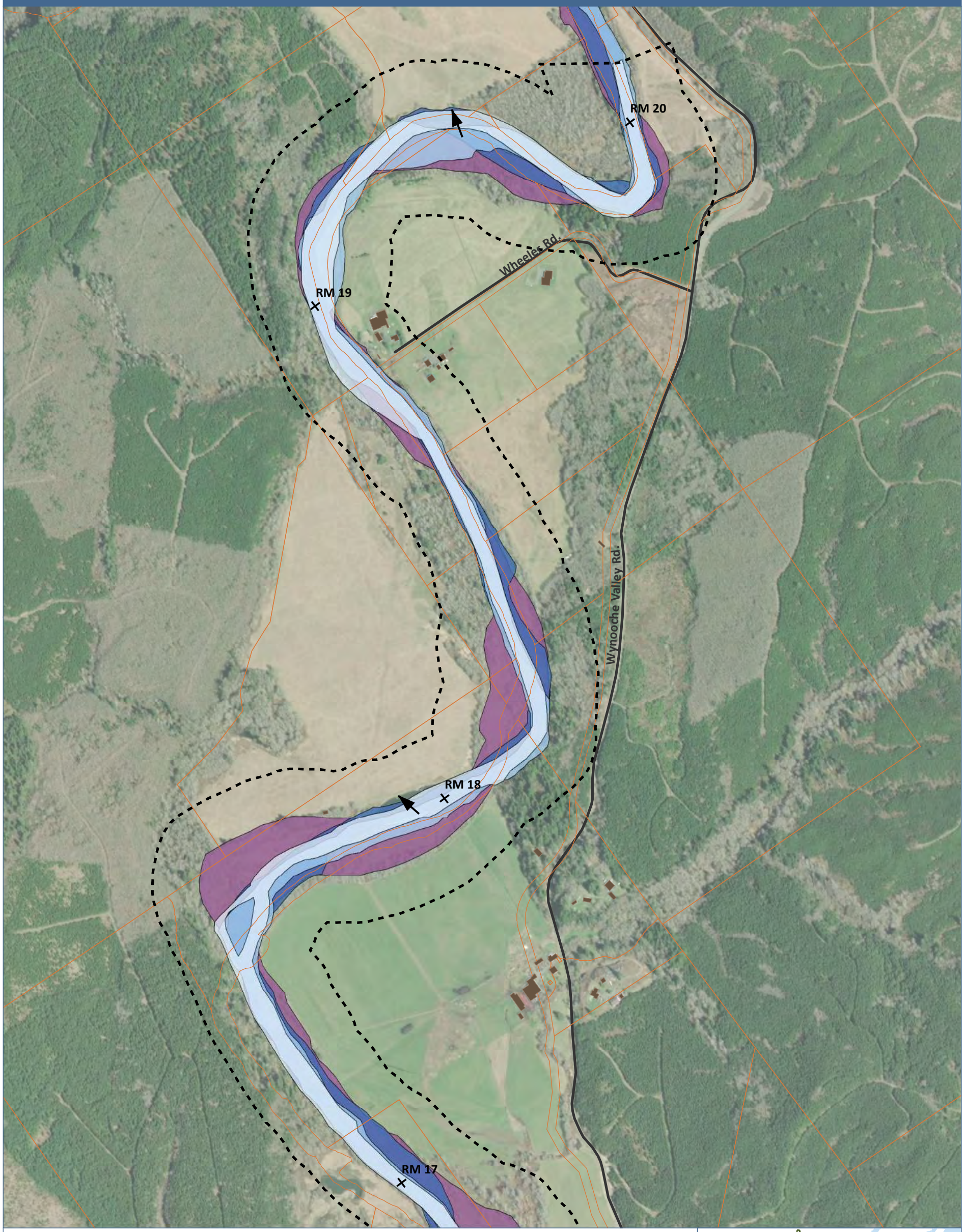


Figure 22
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 23
Historical Channel Mapping: Wynoochee River



River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer
2013 Channel
2003 Channel
1977 Channel
1950s Channel

Migration Direction Indicator Arrow

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

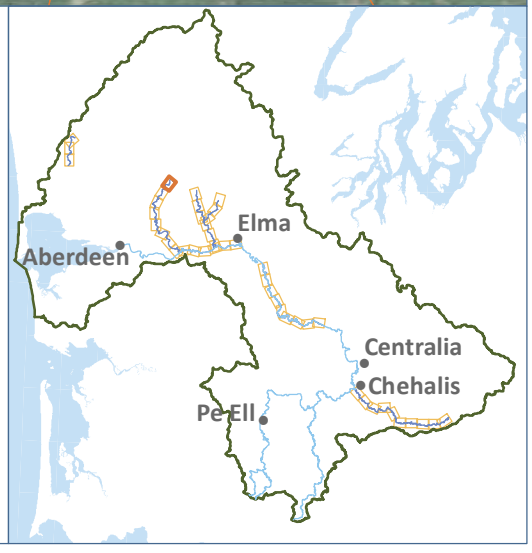
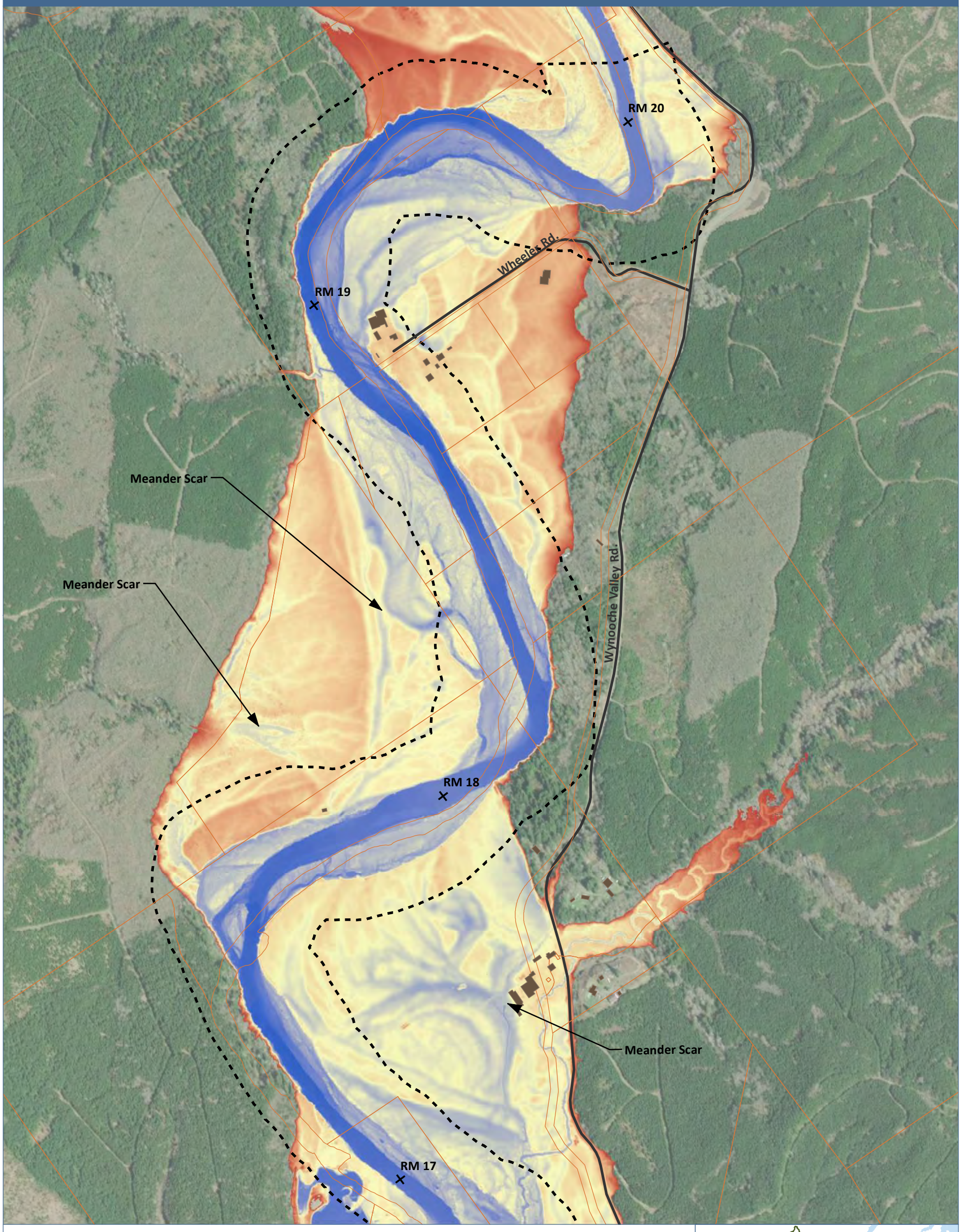


Figure 24
Relative Elevation Mapping: Wynoochee River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 25
Historical Channel Mapping: Satsop River

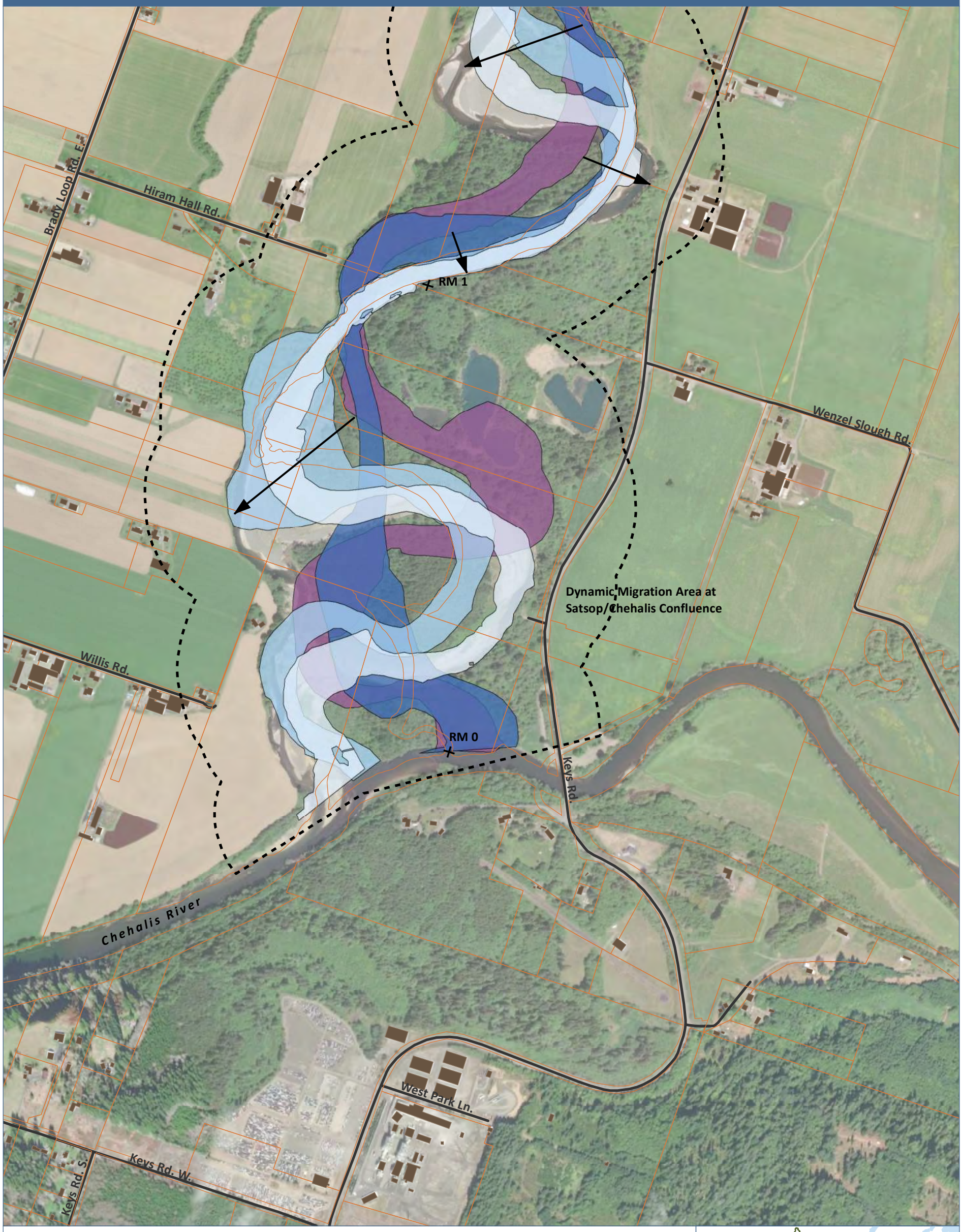
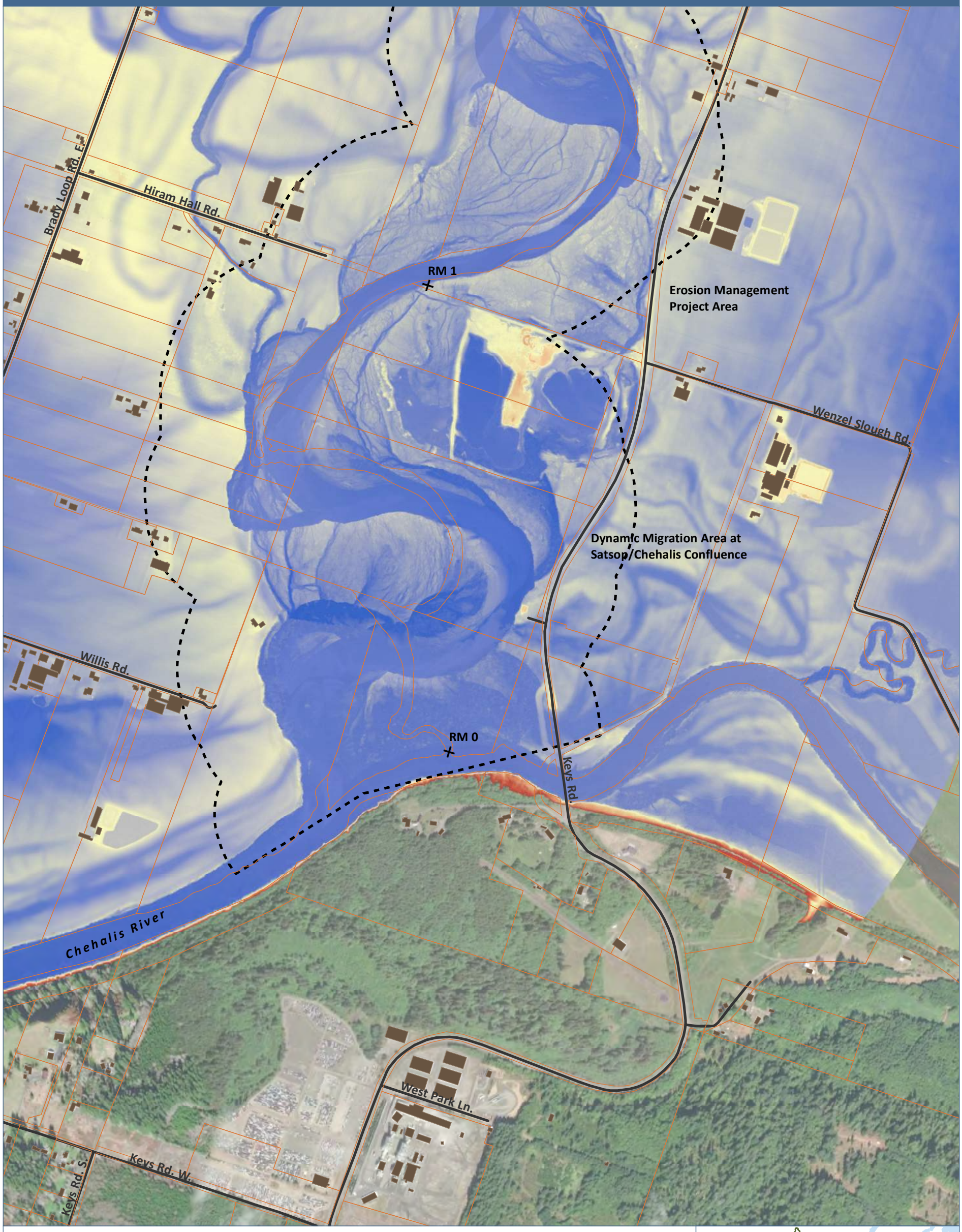


Figure 26
Relative Elevation Mapping: Satsop River

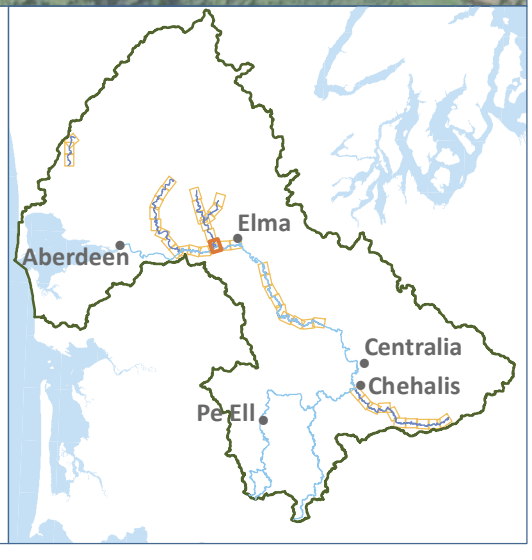


River Miles
Roads
Buildings
Parcels
700' Historical Channel Migration Buffer

Elevation Relative to Water Surface (ft)
25
-5

N

Feet
0 500 1,000



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 27
Historical Channel Mapping: Satsop River

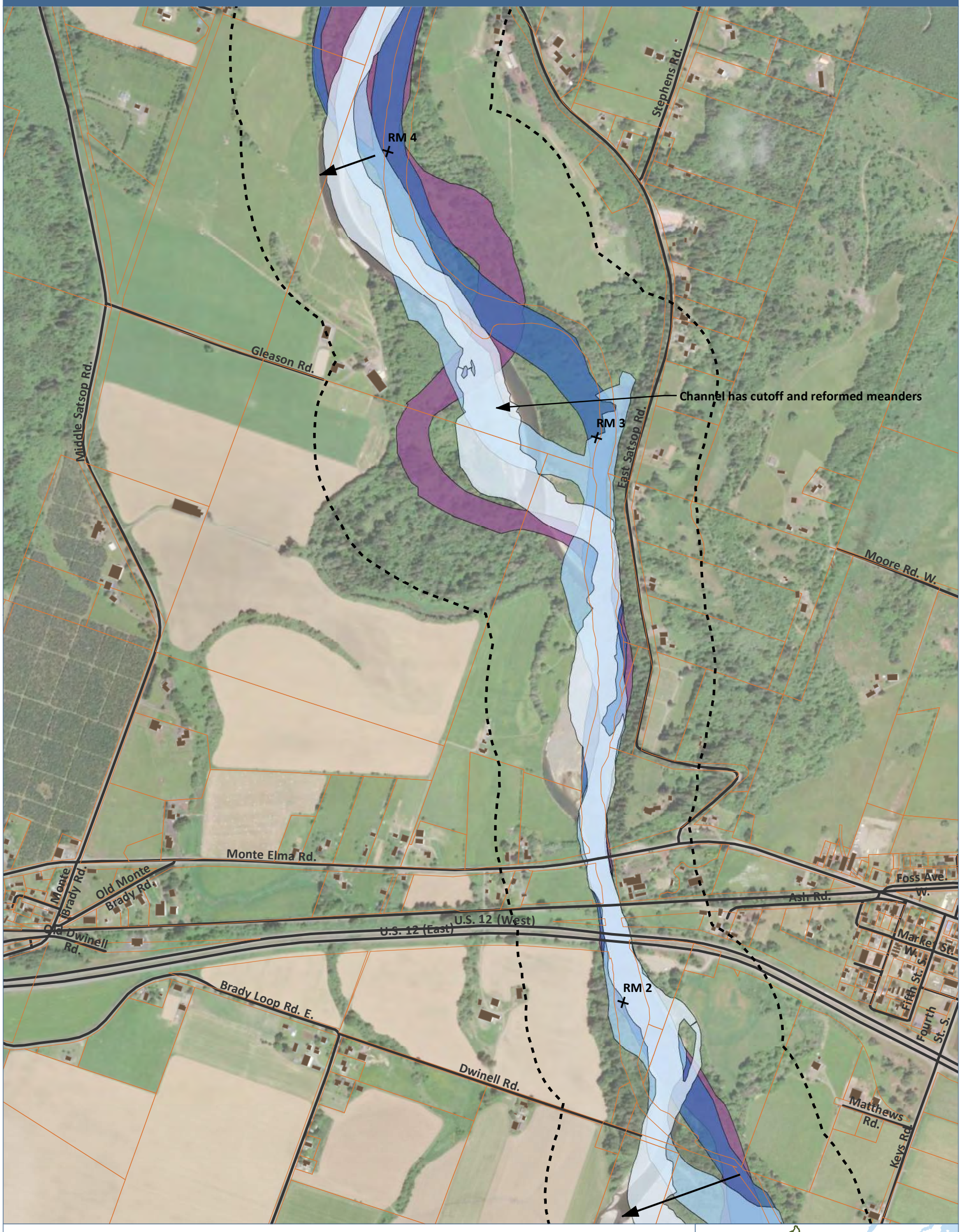
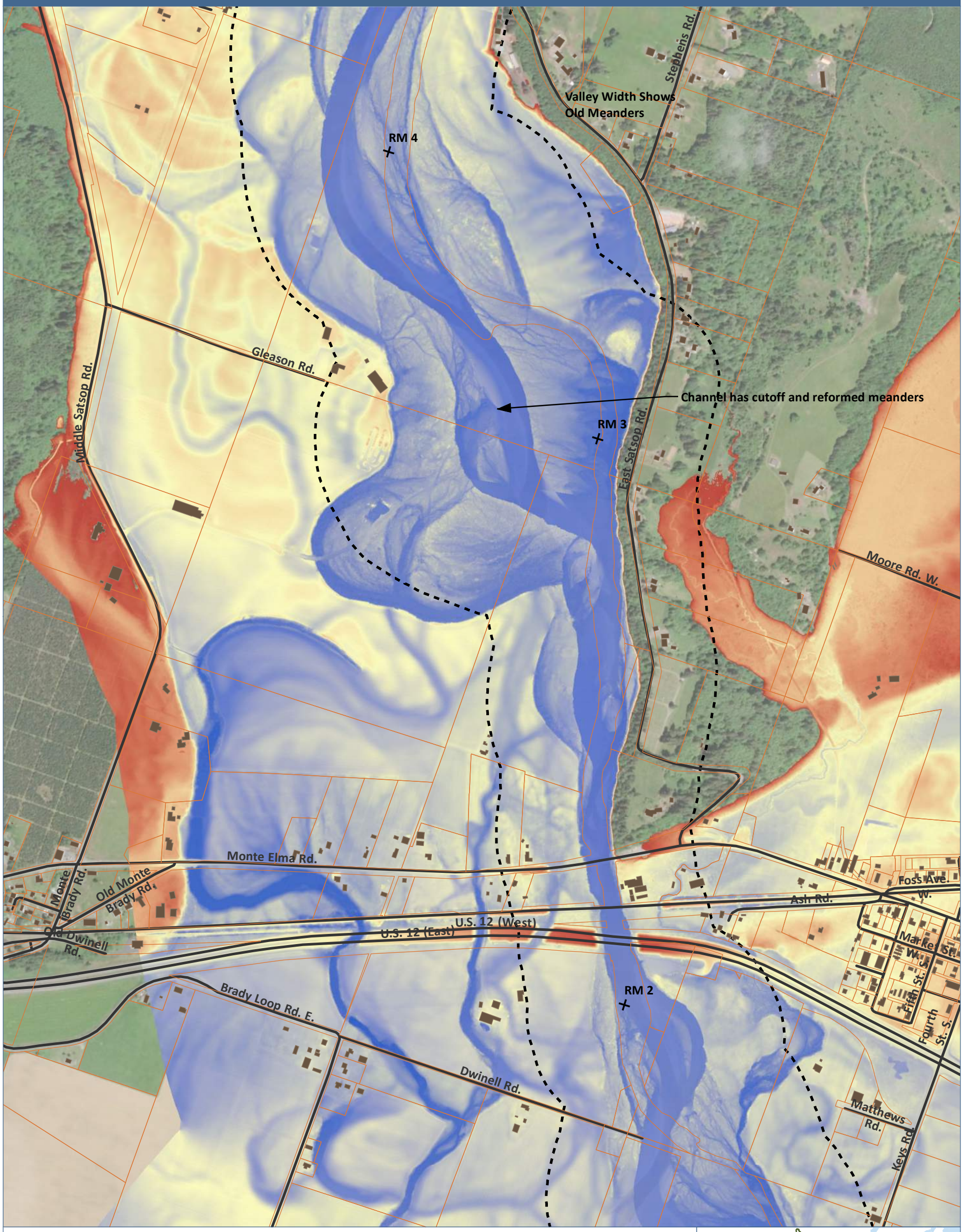


Figure 28
Relative Elevation Mapping: Satsop River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 29
Historical Channel Mapping: Satsop River

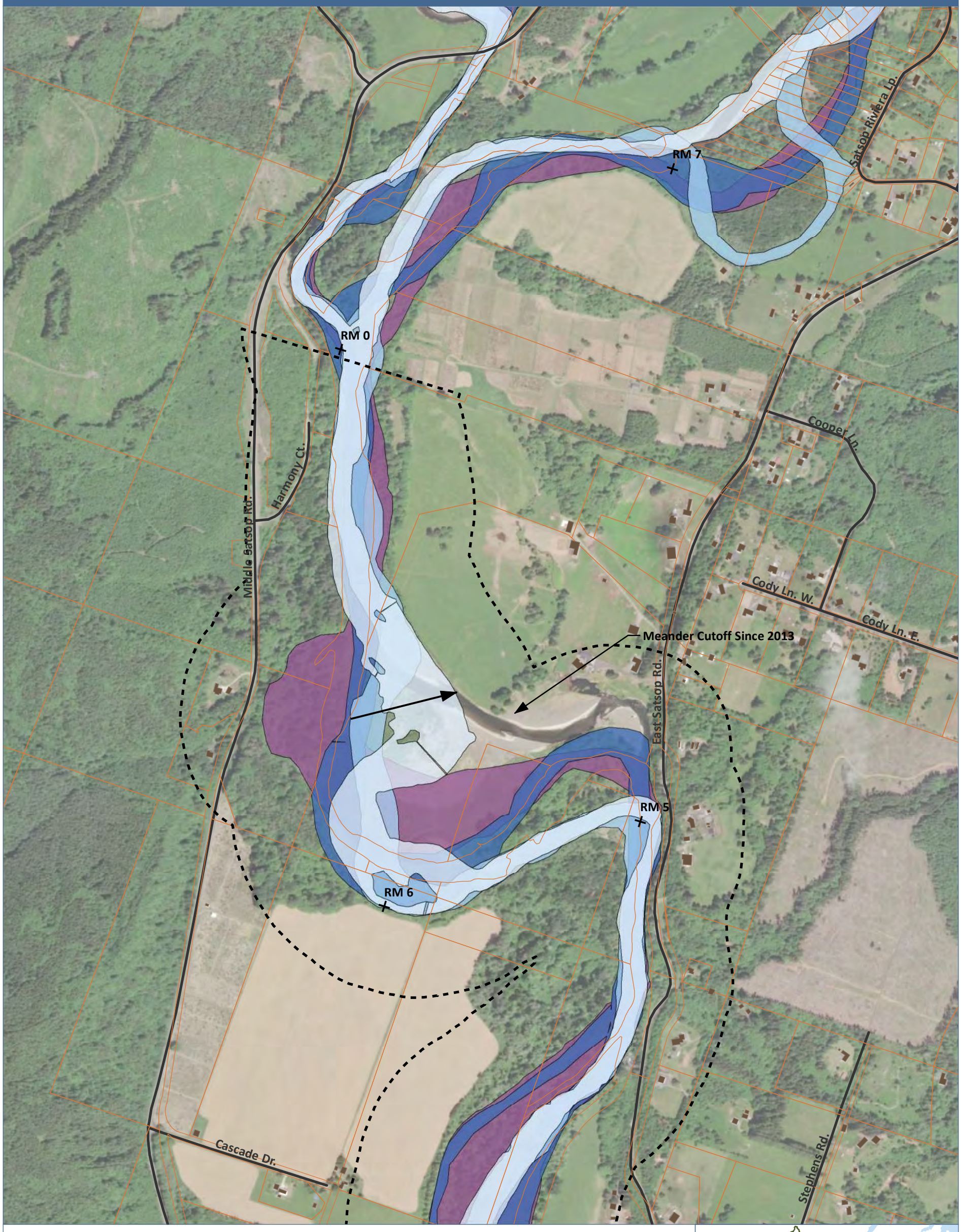
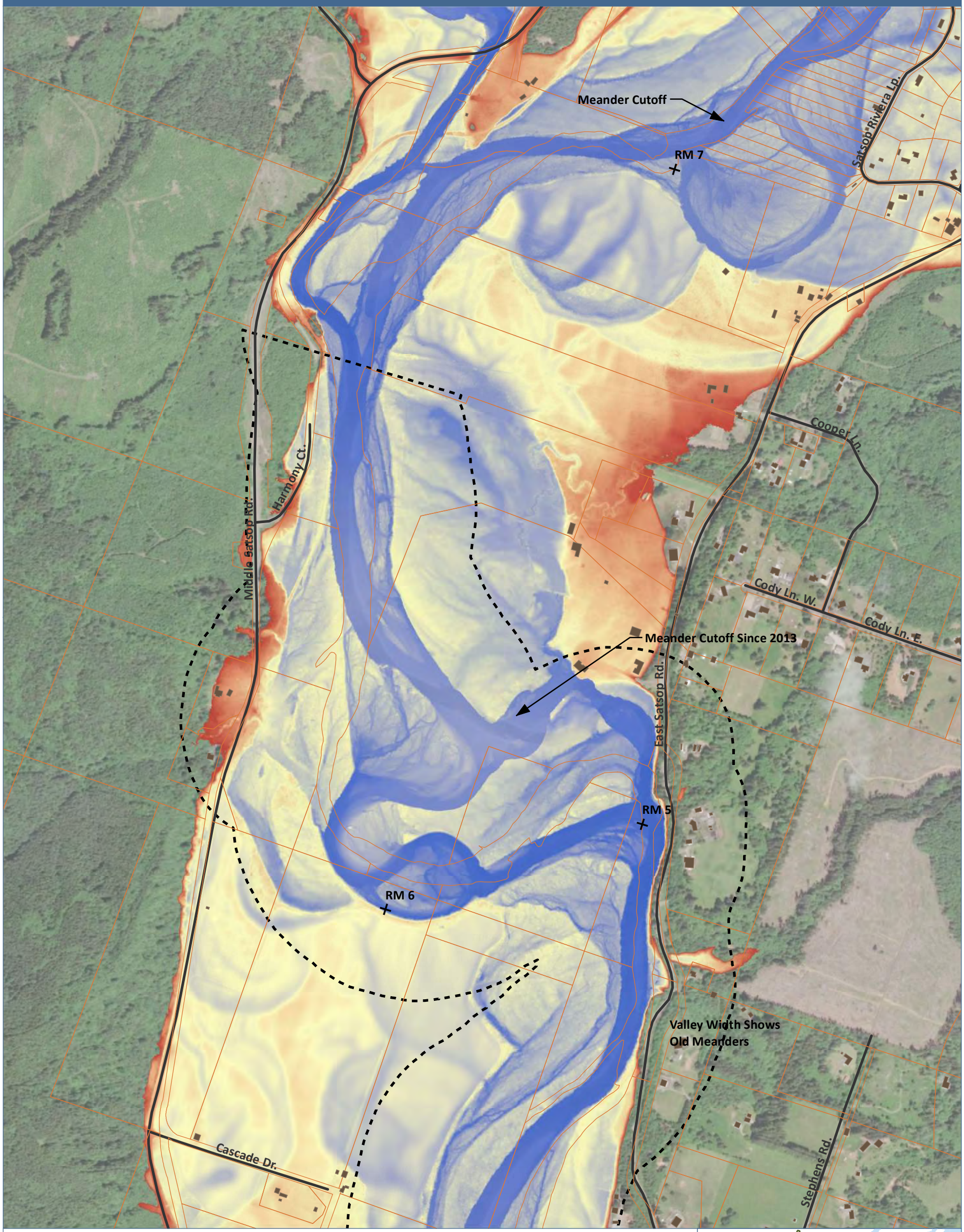


Figure 30
Relative Elevation Mapping: Satsop River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 31
Historical Channel Mapping: EF Satsop River

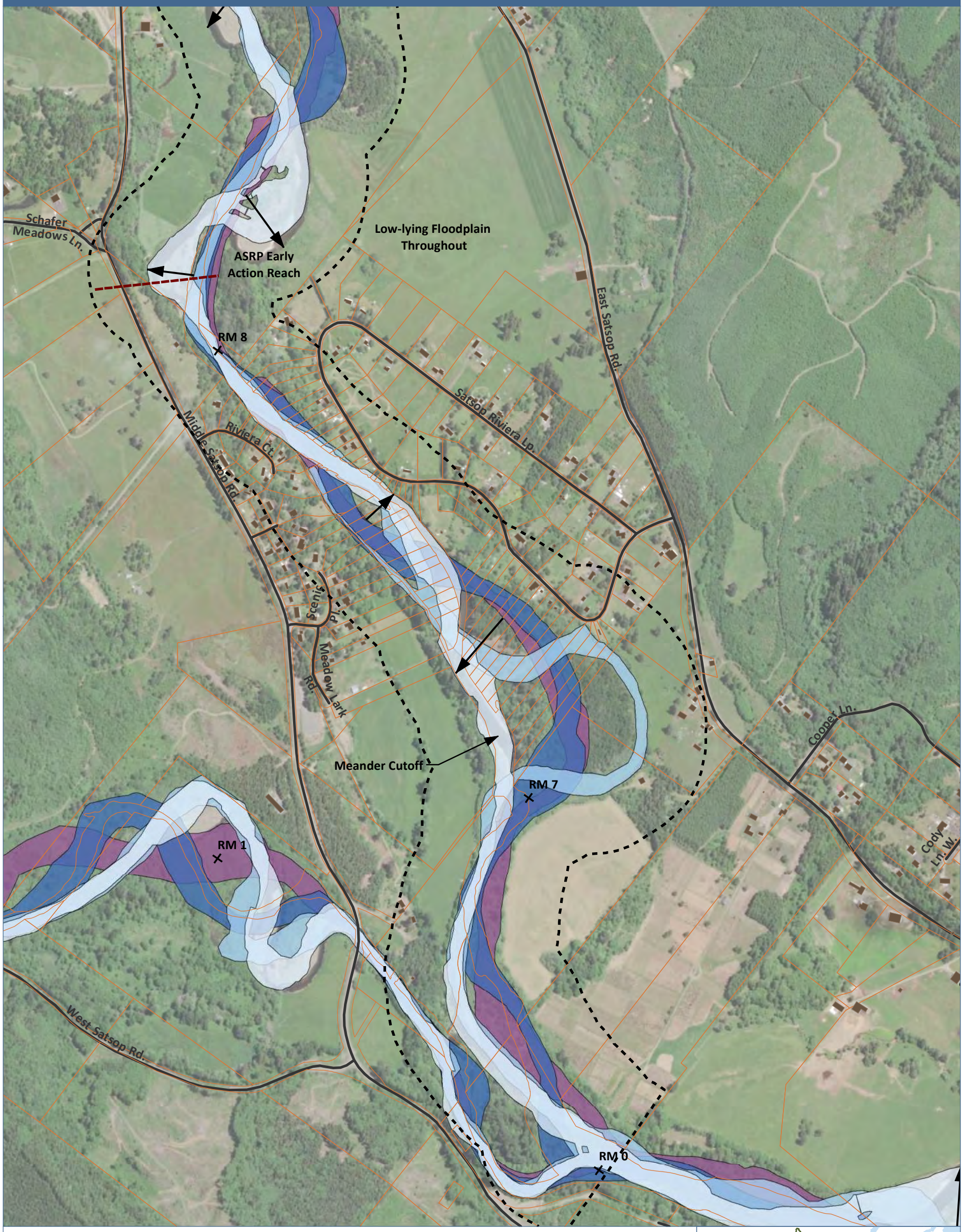
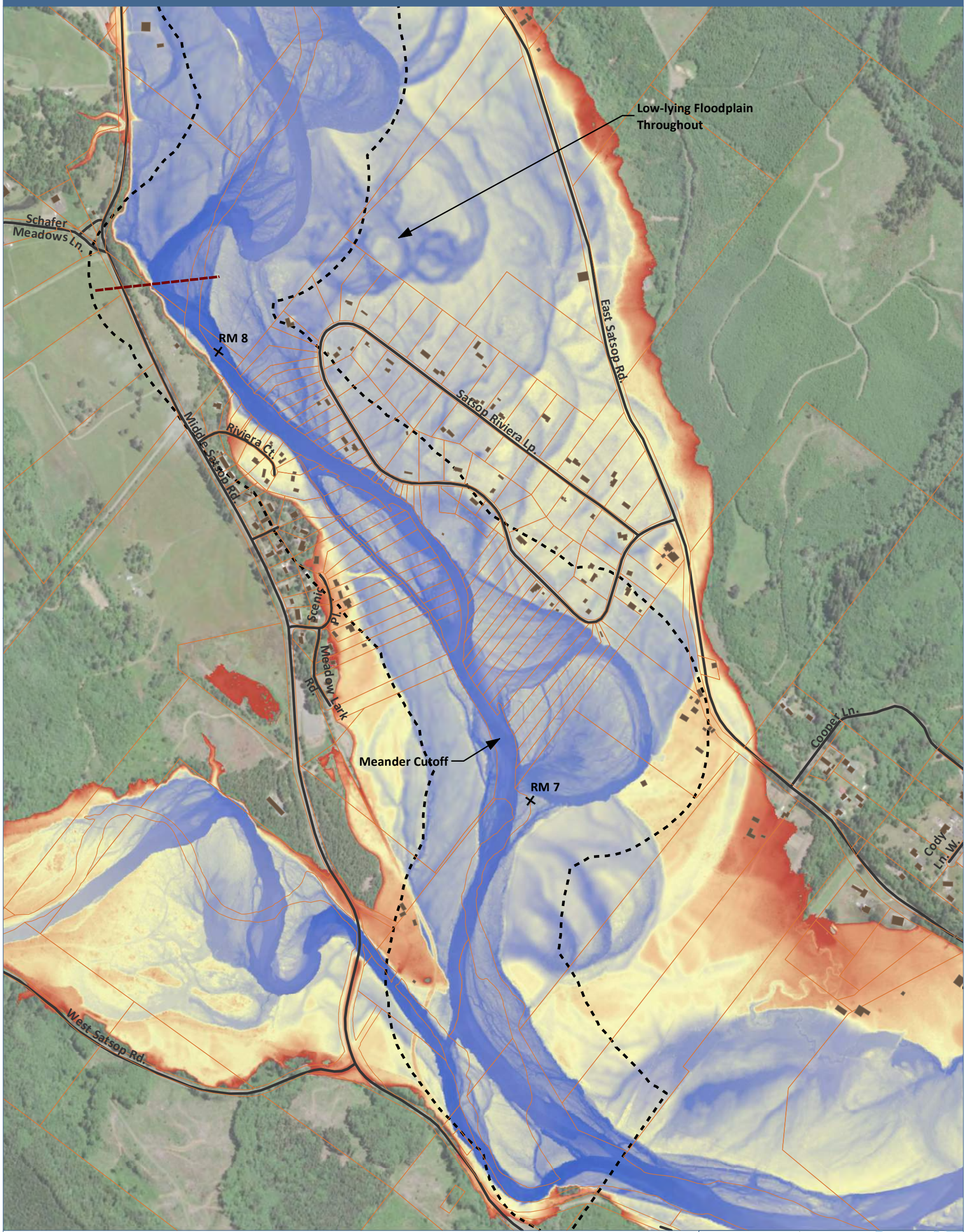


Figure 32
Relative Elevation Mapping: EF Satsop River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 33
Historical Channel Mapping: EF Satsop River

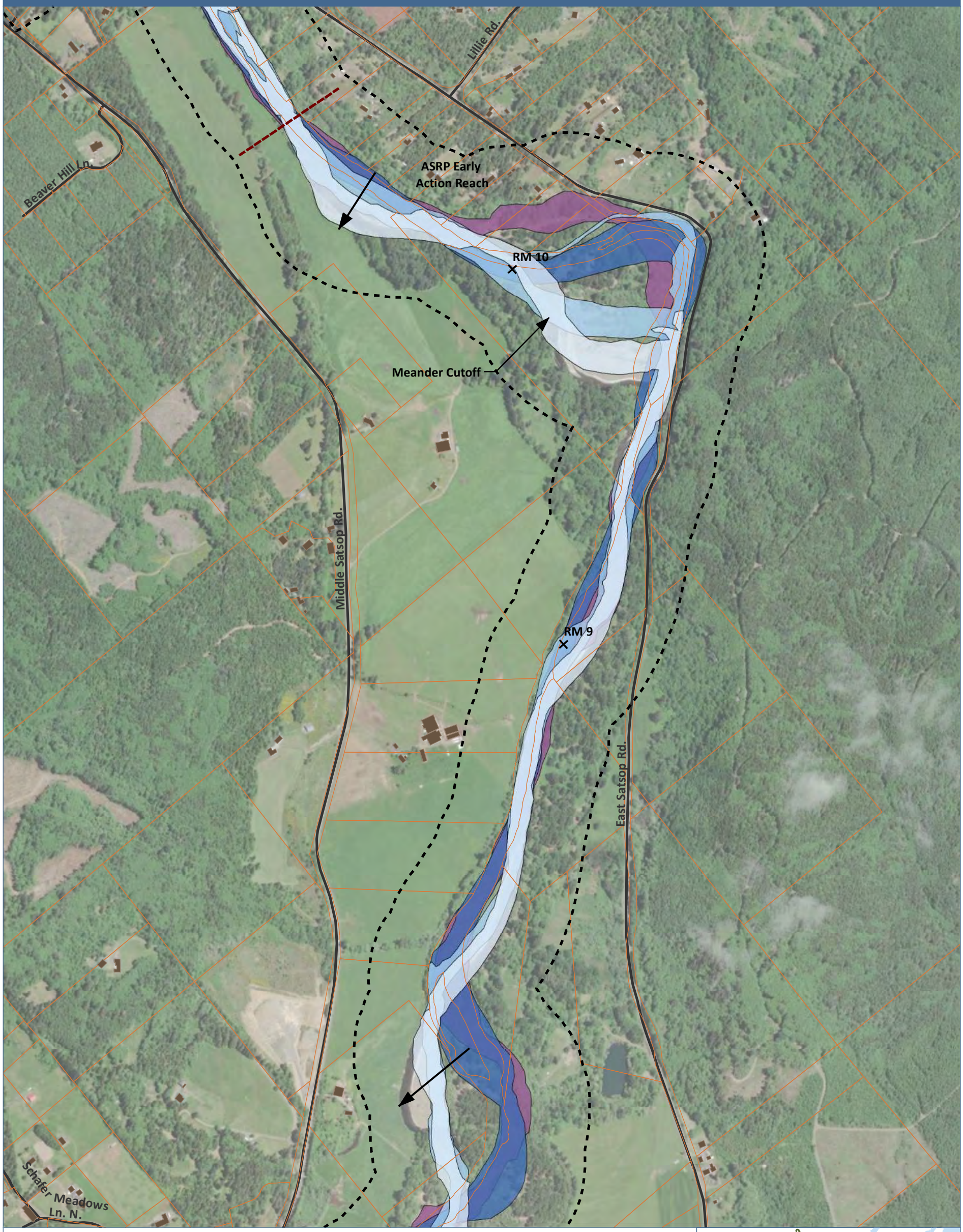
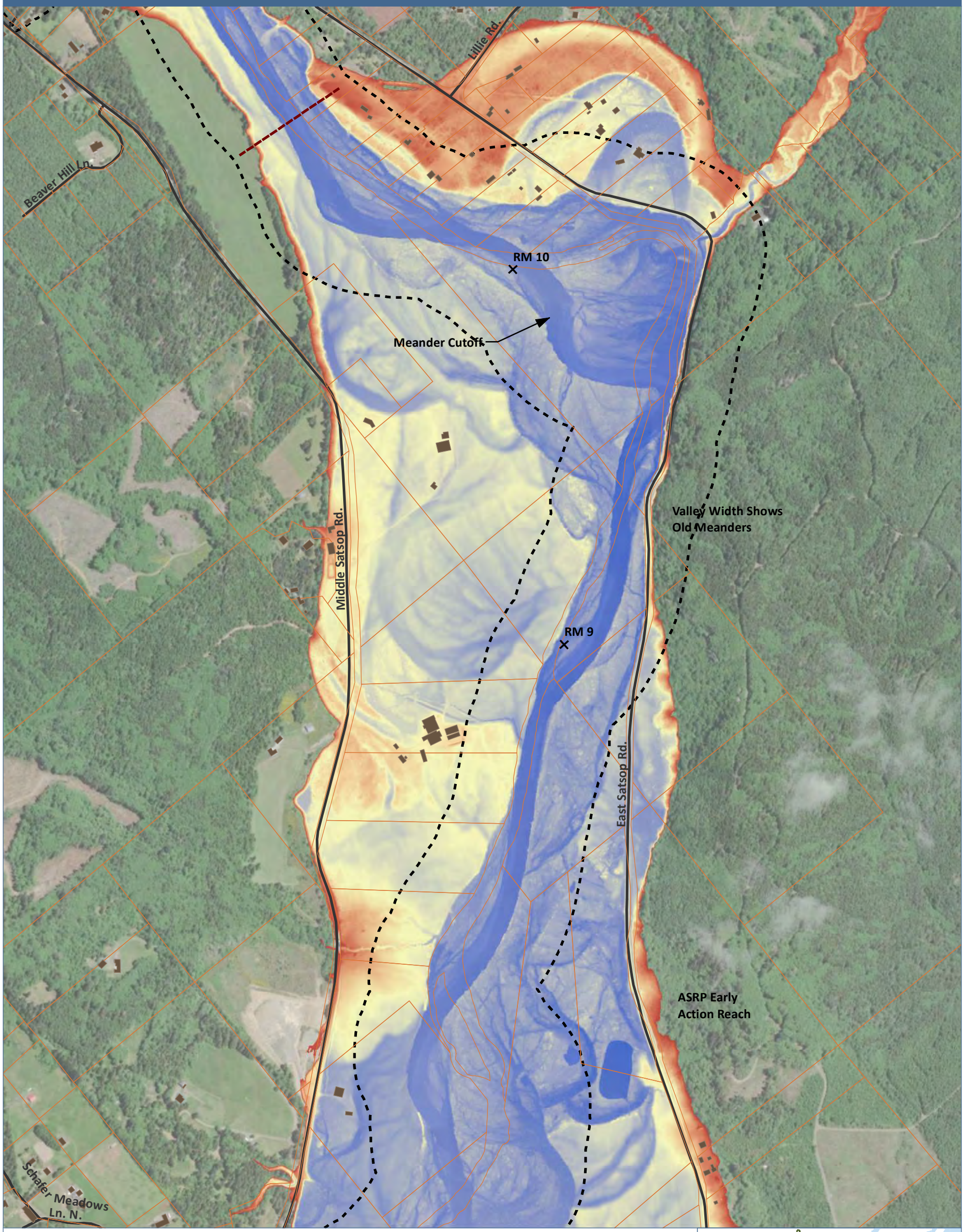


Figure 34
Relative Elevation Mapping: EF Satsop River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 35
Historical Channel Mapping: EF Satsop River

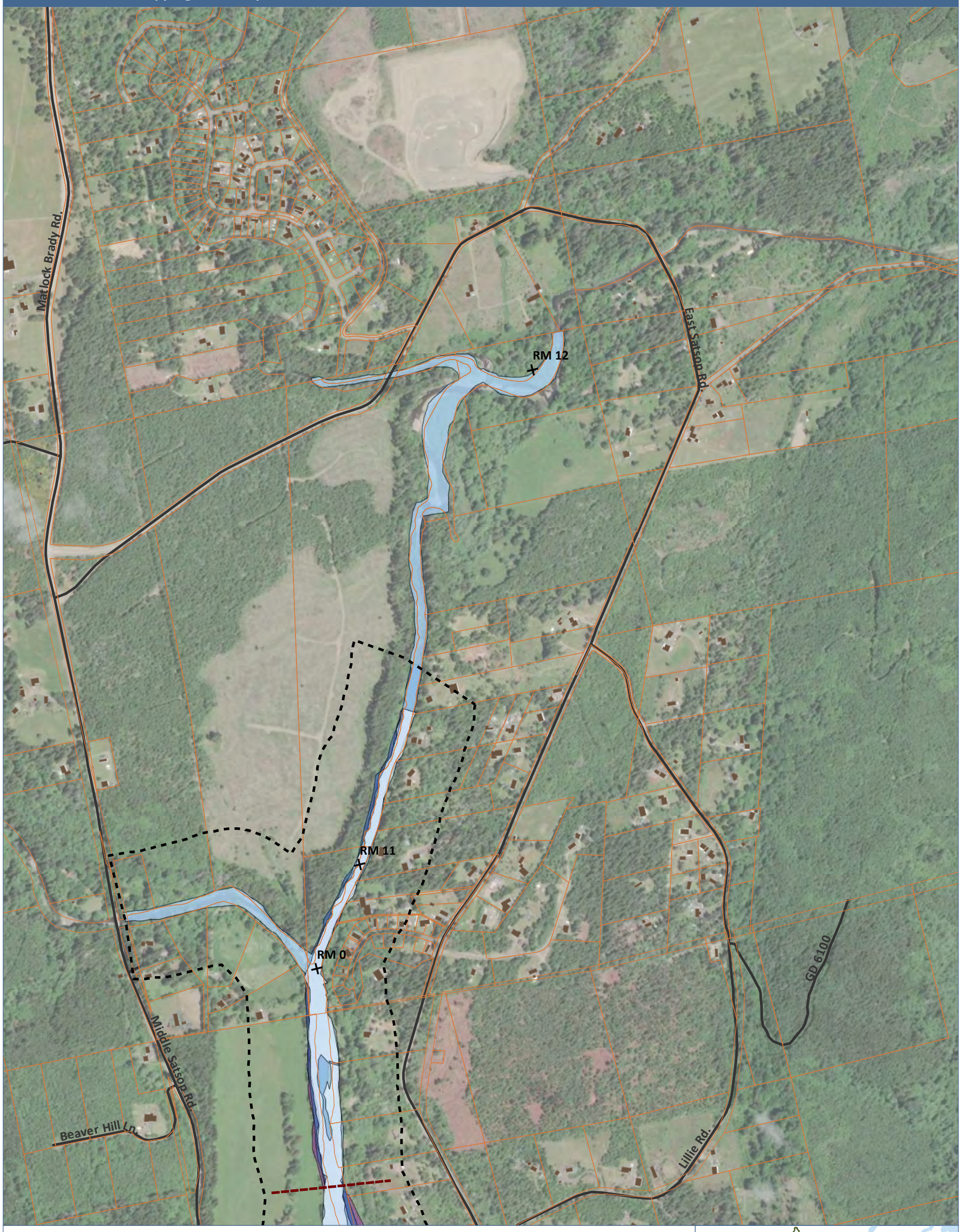
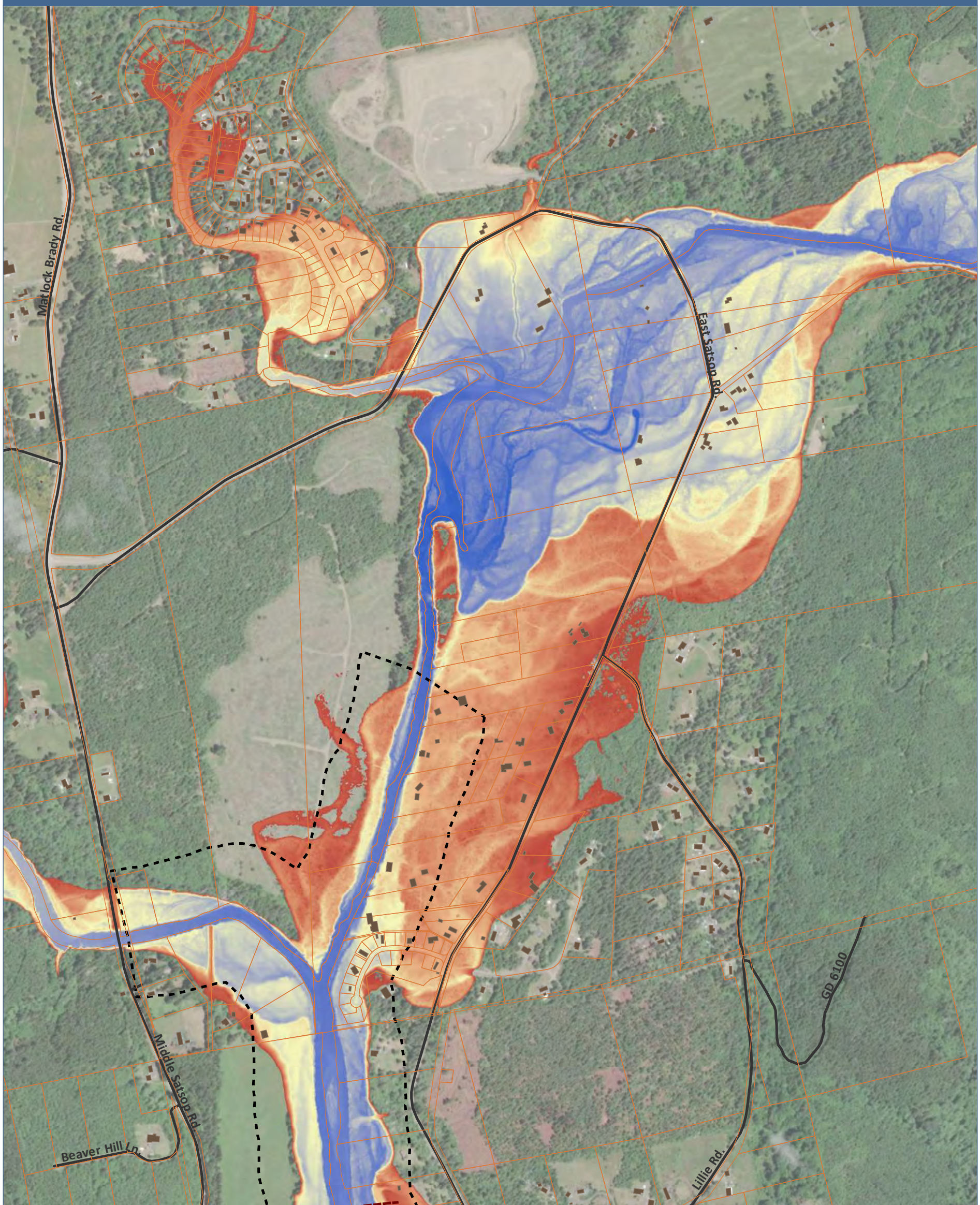


Figure 36
Relative Elevation Mapping: EF Satsop River



River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer
Early Action Reach Extents

Elevation Relative to Water Surface (ft)
25
-5

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

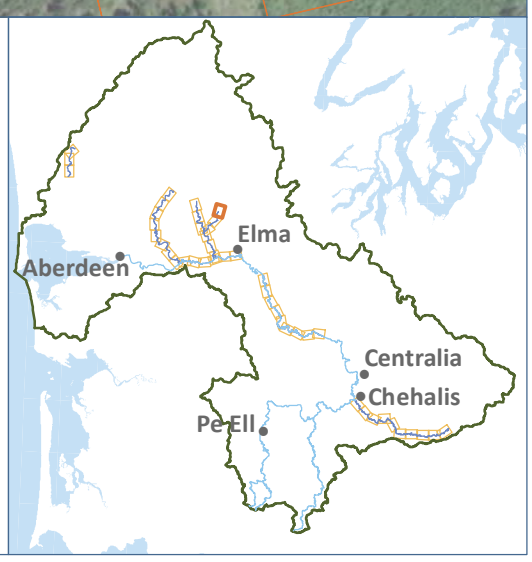


Figure 37
Historical Channel Mapping: WF Satsop River

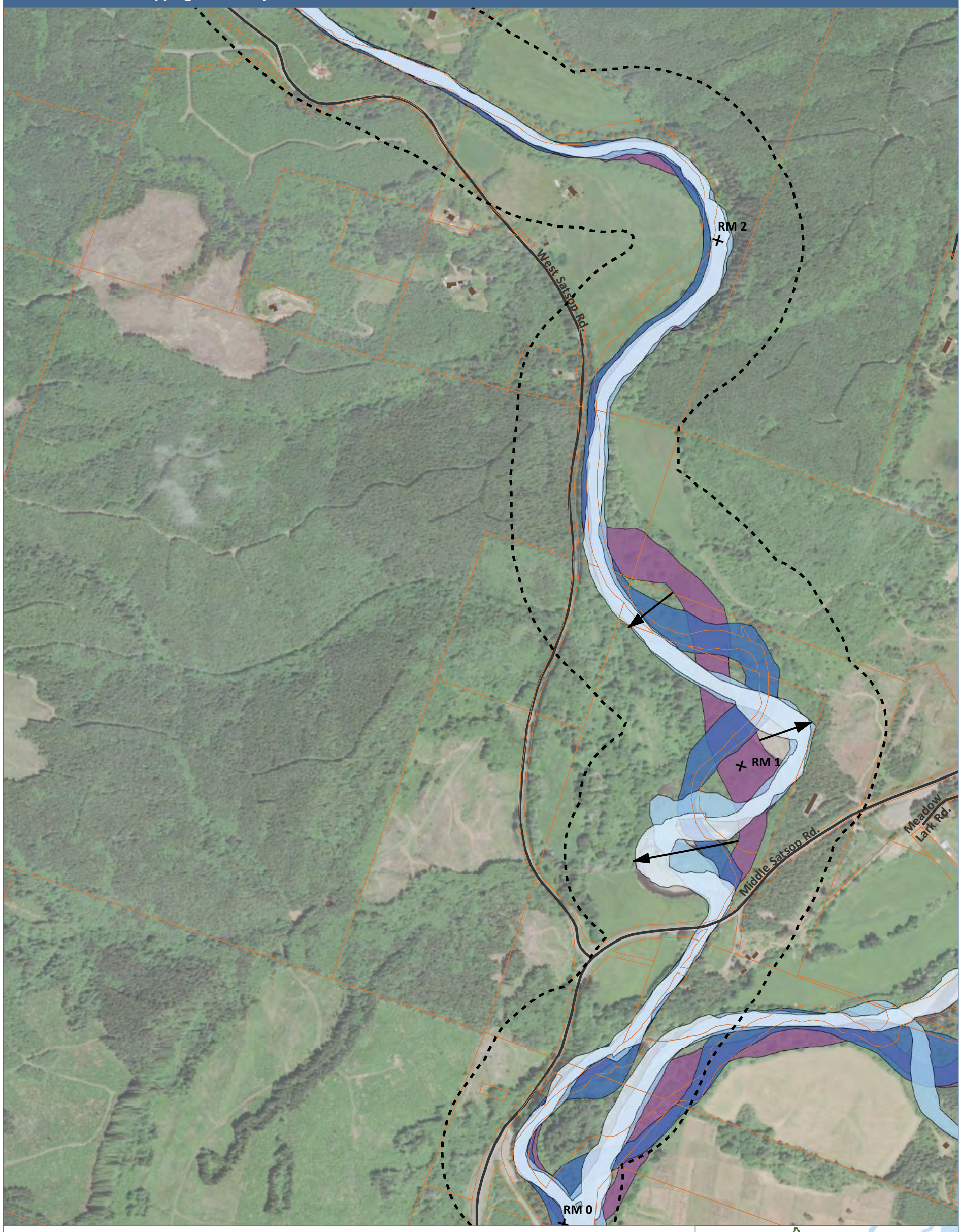
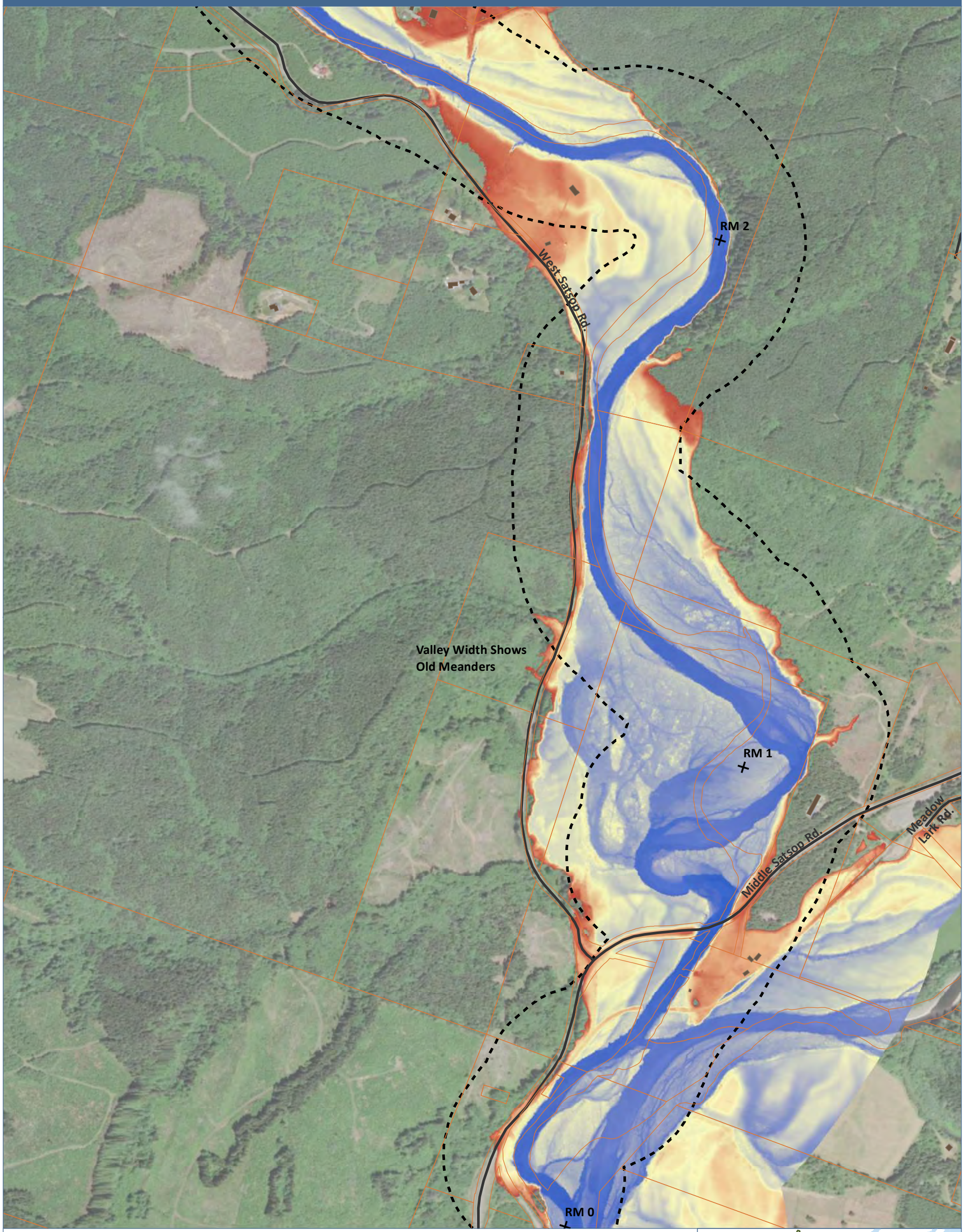


Figure 38
Relative Elevation Mapping: WF Satsop River



River Miles
Roads
Buildings
Parcels
600' Historical Channel Migration Buffer

Elevation Relative to Water Surface (ft)
25
-2

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 39
Historical Channel Mapping: WF Satsop River

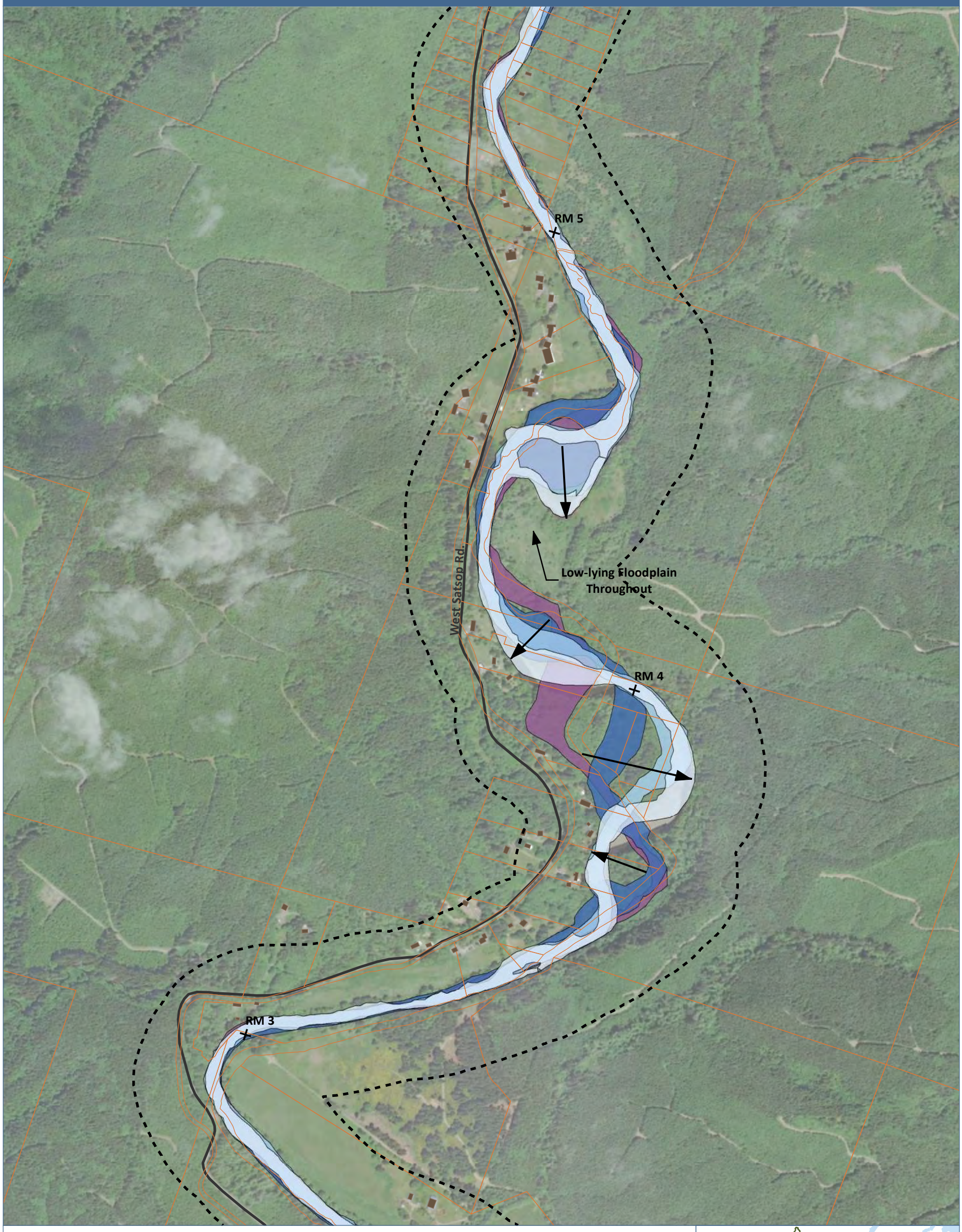


Figure 40
Relative Elevation Mapping: WF Satsop River

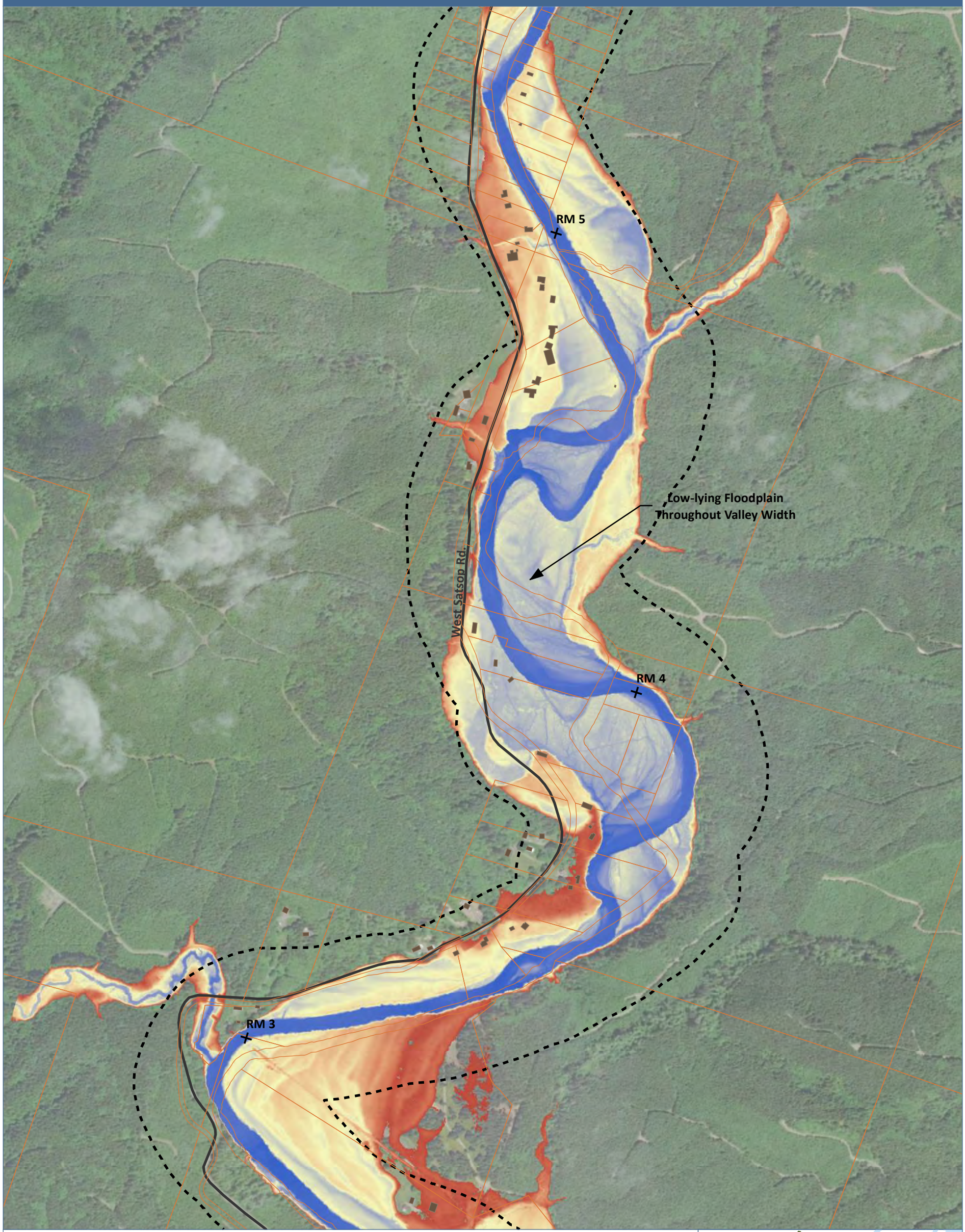


Figure 41
Historical Channel Mapping: WF Satsop River

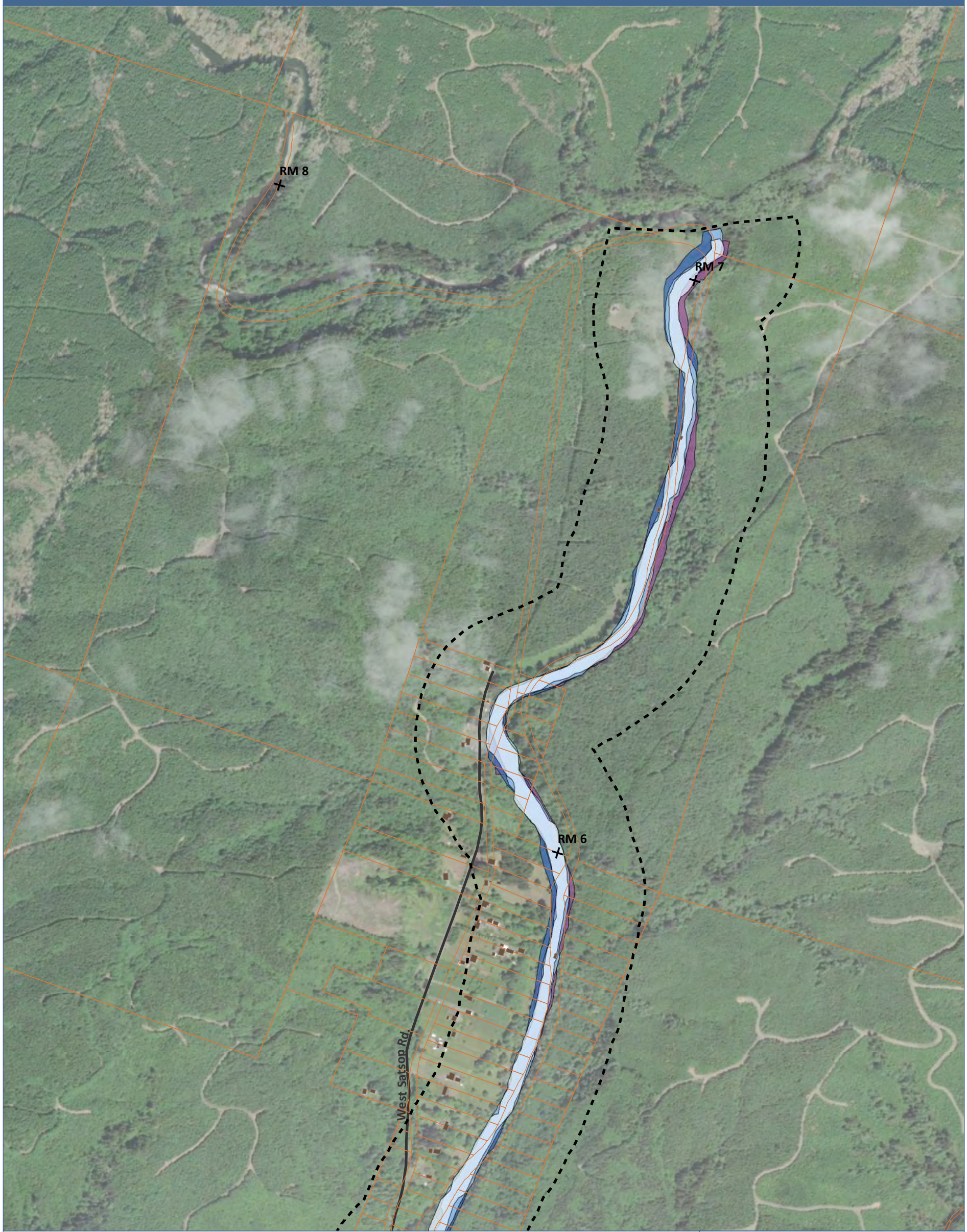
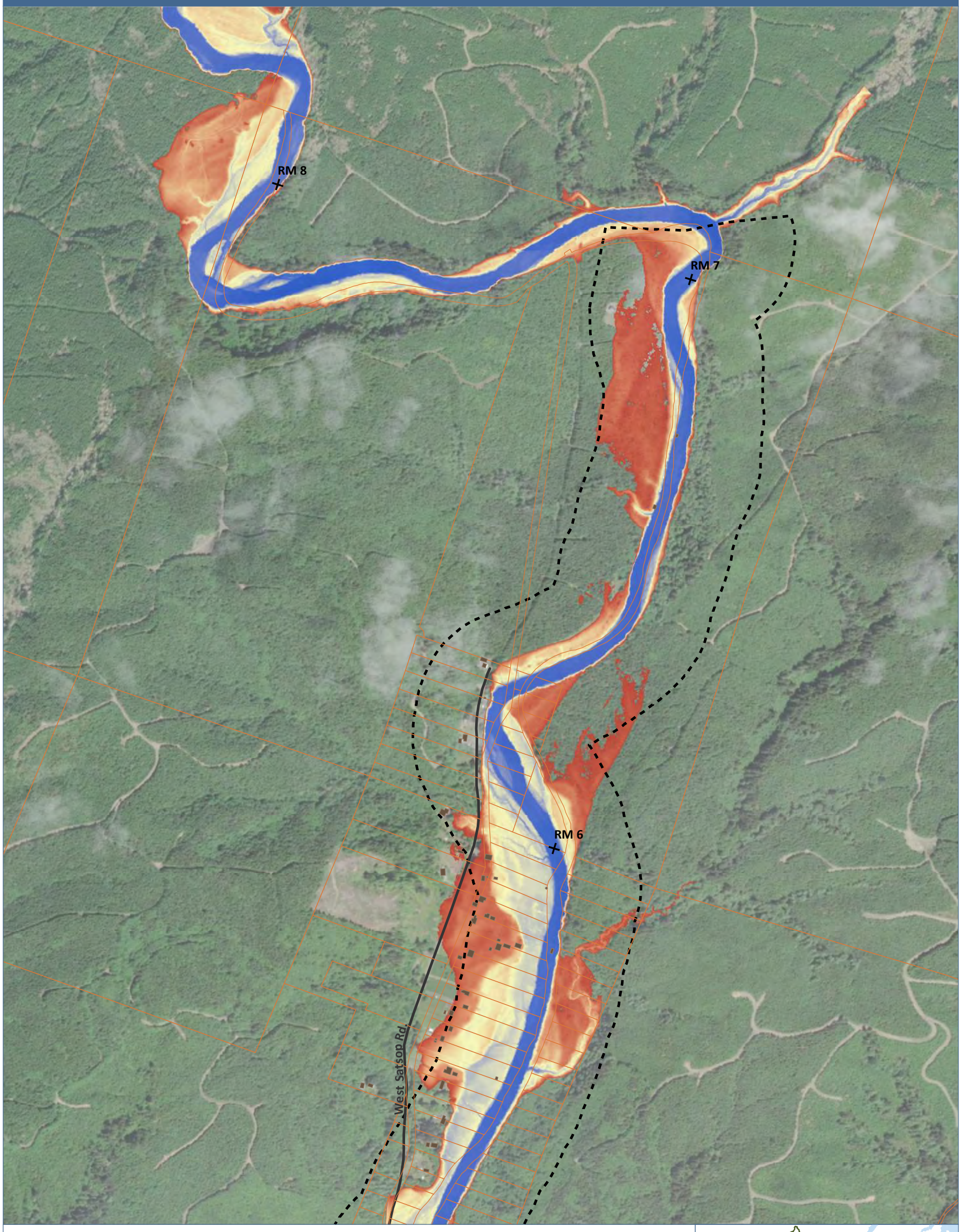


Figure 42
Relative Elevation Mapping: WF Satsop River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 43
Historical Channel Mapping: Chehalis River RM 13-25

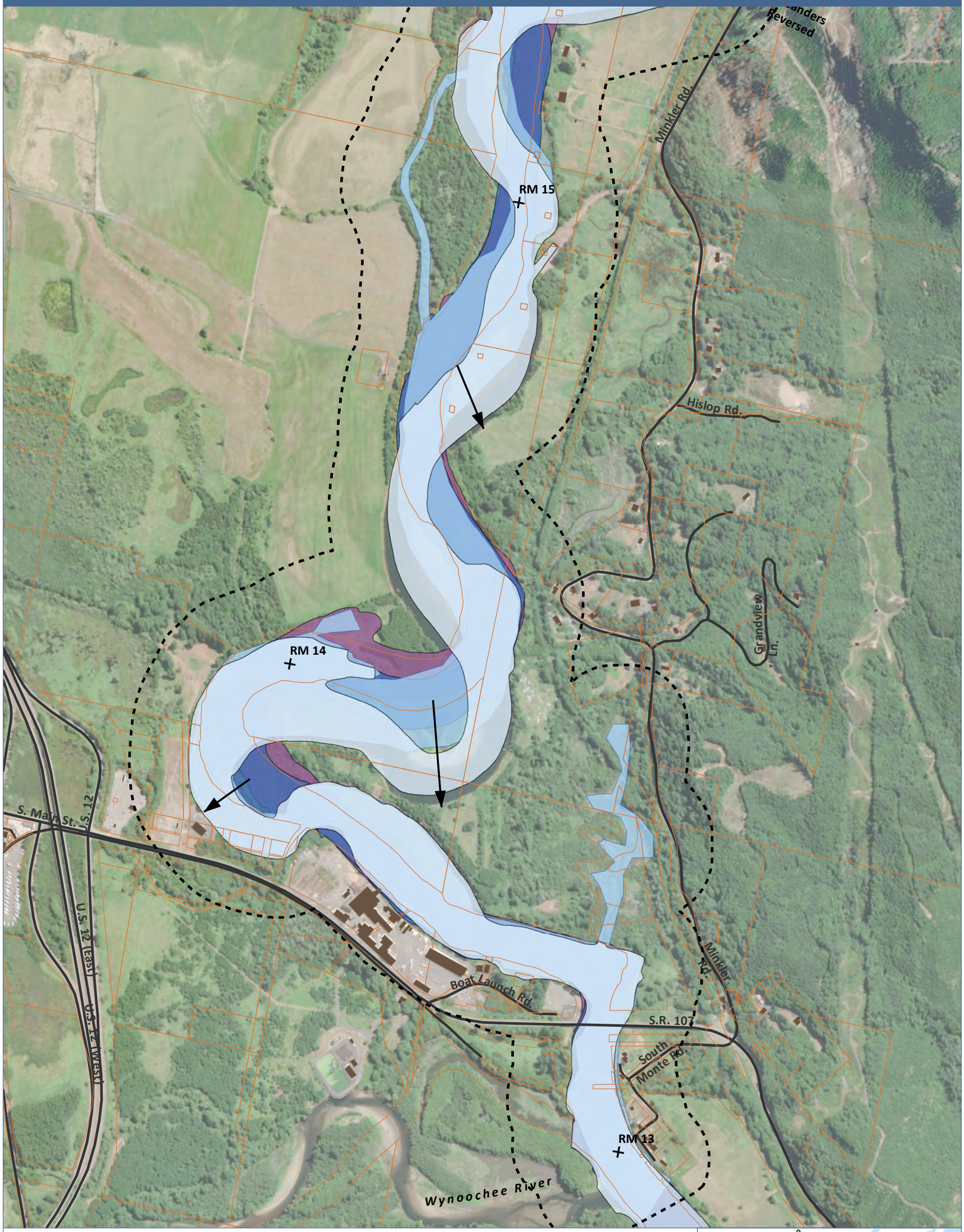
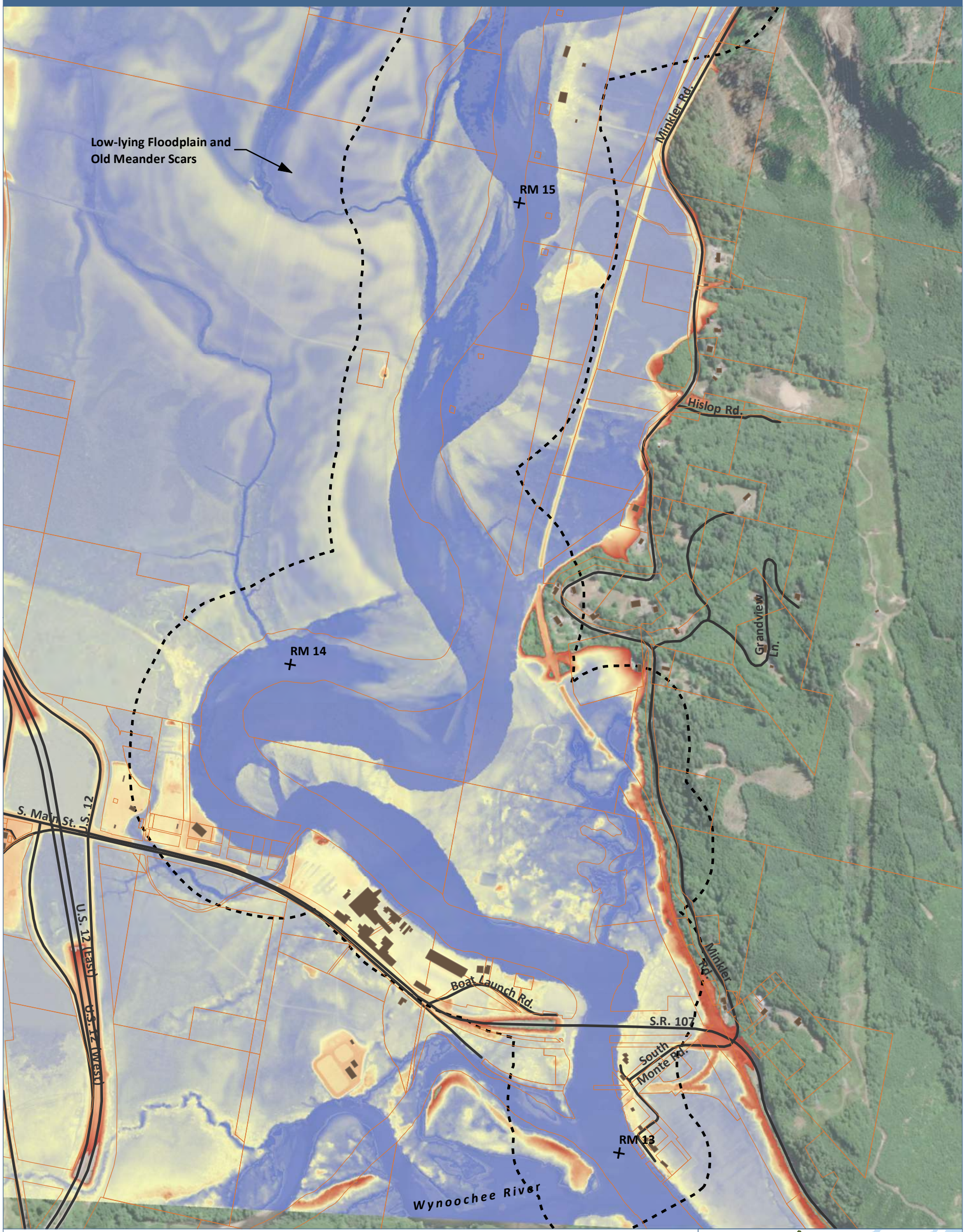
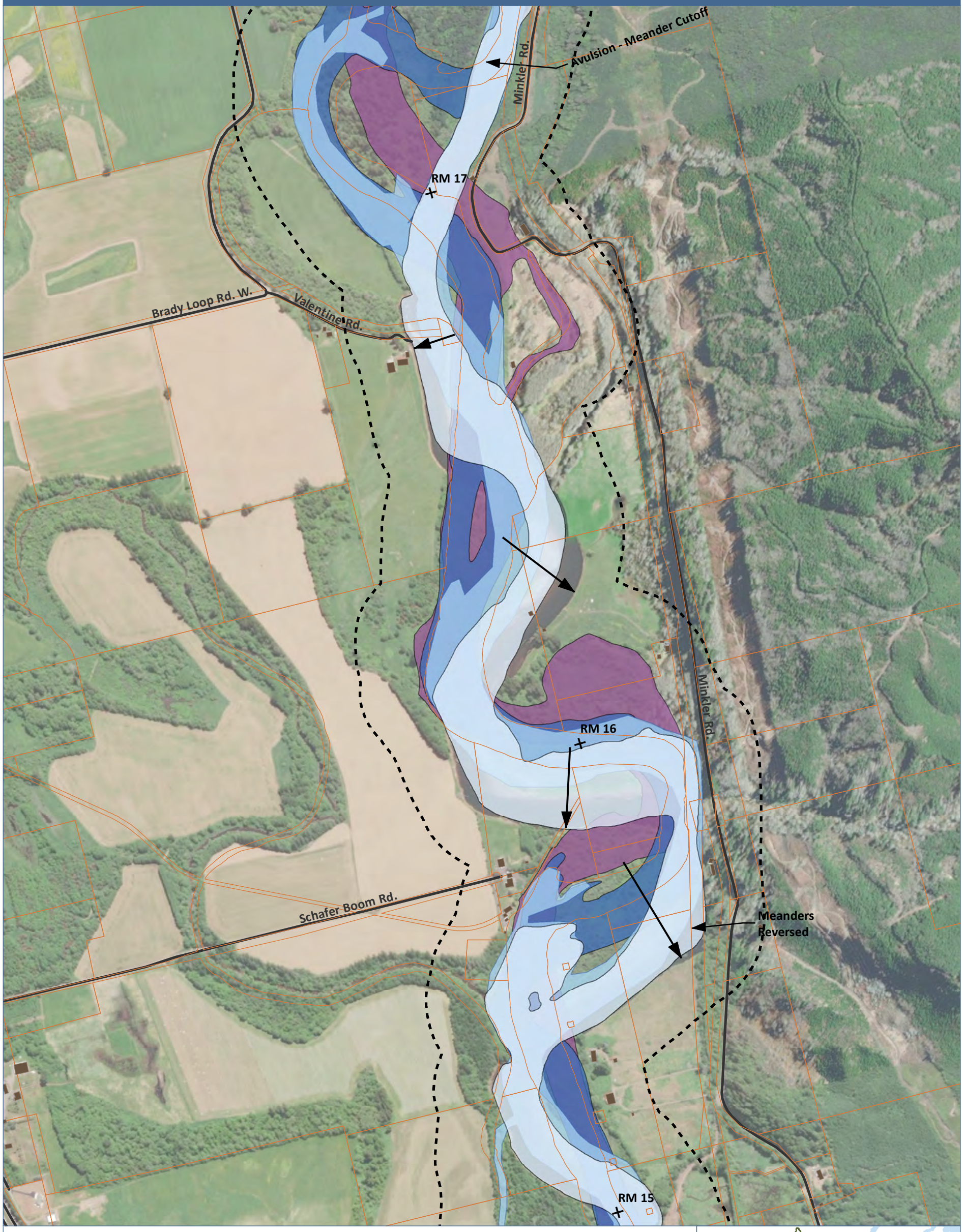


Figure 44
Relative Elevation Mapping: Chehalis River RM 13-25



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 45
Historical Channel Mapping: Chehalis River RM 13-25



River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer
2013 Channel
2003 Channel (In lieu of 1999)
1975 Channel
1938 Channel

Migration Direction Indicator Arrow

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

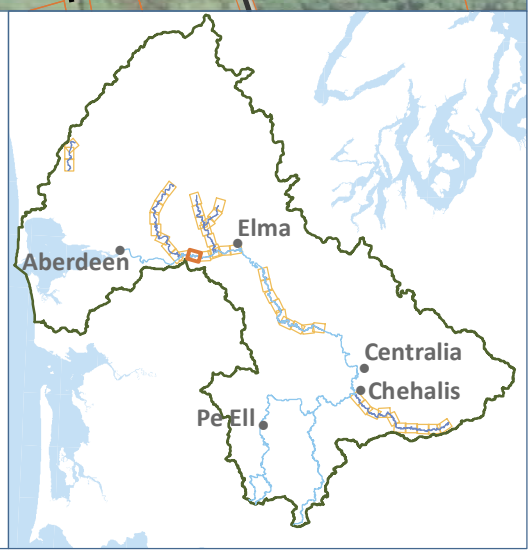
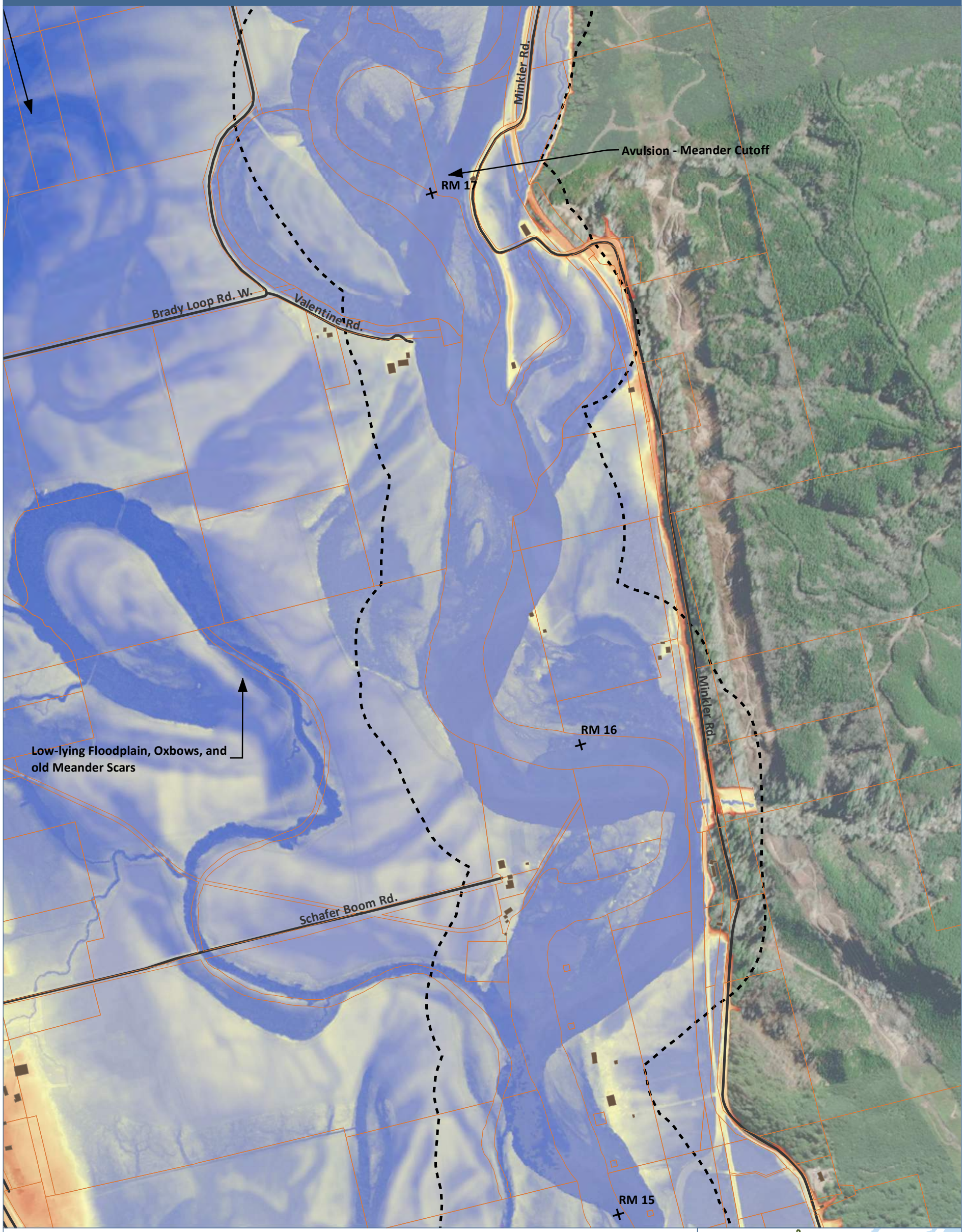
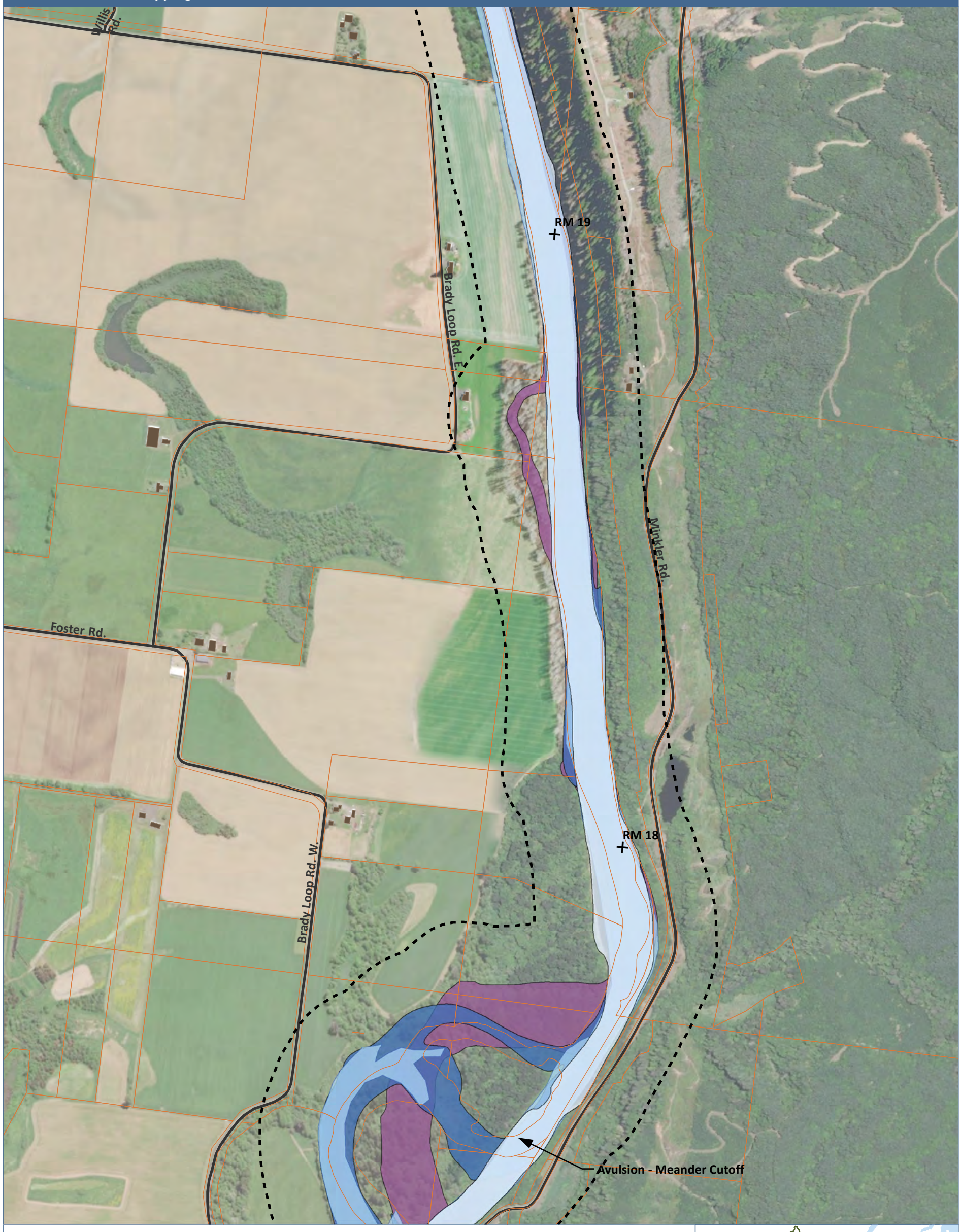


Figure 46
Relative Elevation Mapping: Chehalis River RM 13-25



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 47
Historical Channel Mapping: Chehalis River RM 13-25



River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer
2013 Channel
2003 Channel (In lieu of 1999)
1975 Channel
1938 Channel

Migration Direction Indicator Arrow

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

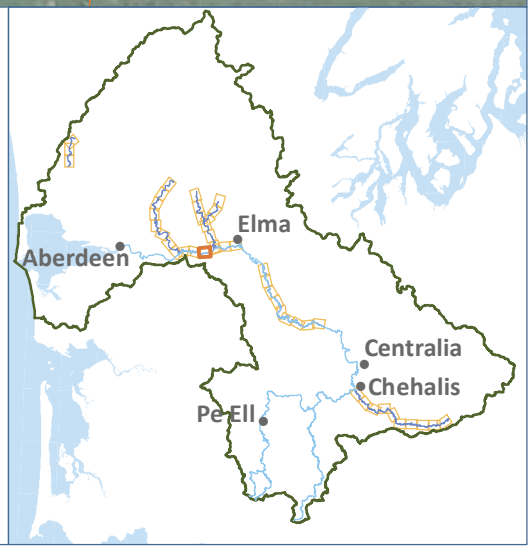
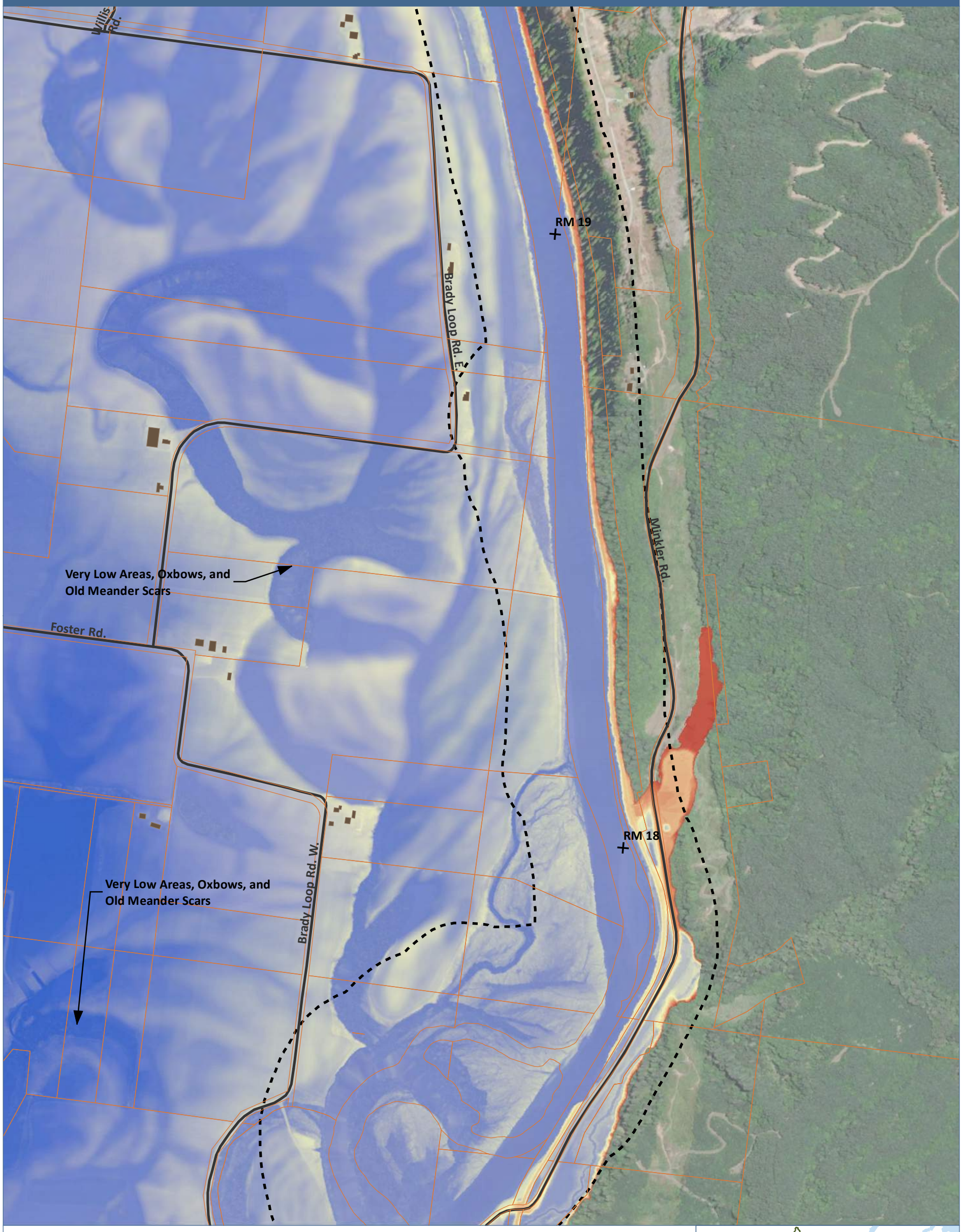


Figure 48
Relative Elevation Mapping: Chehalis River RM 13-25



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 49
Historical Channel Mapping: Chehalis River RM 13-25

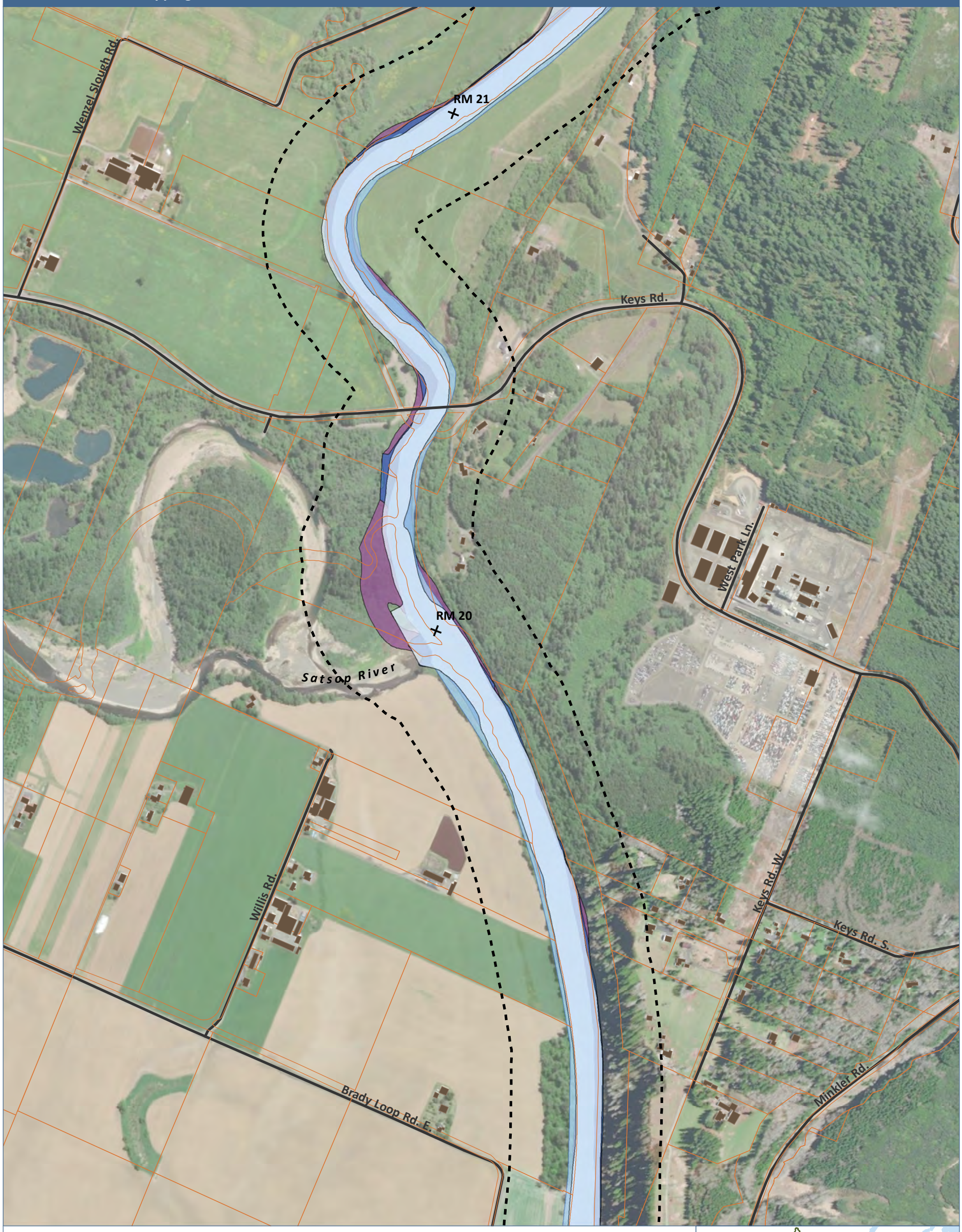
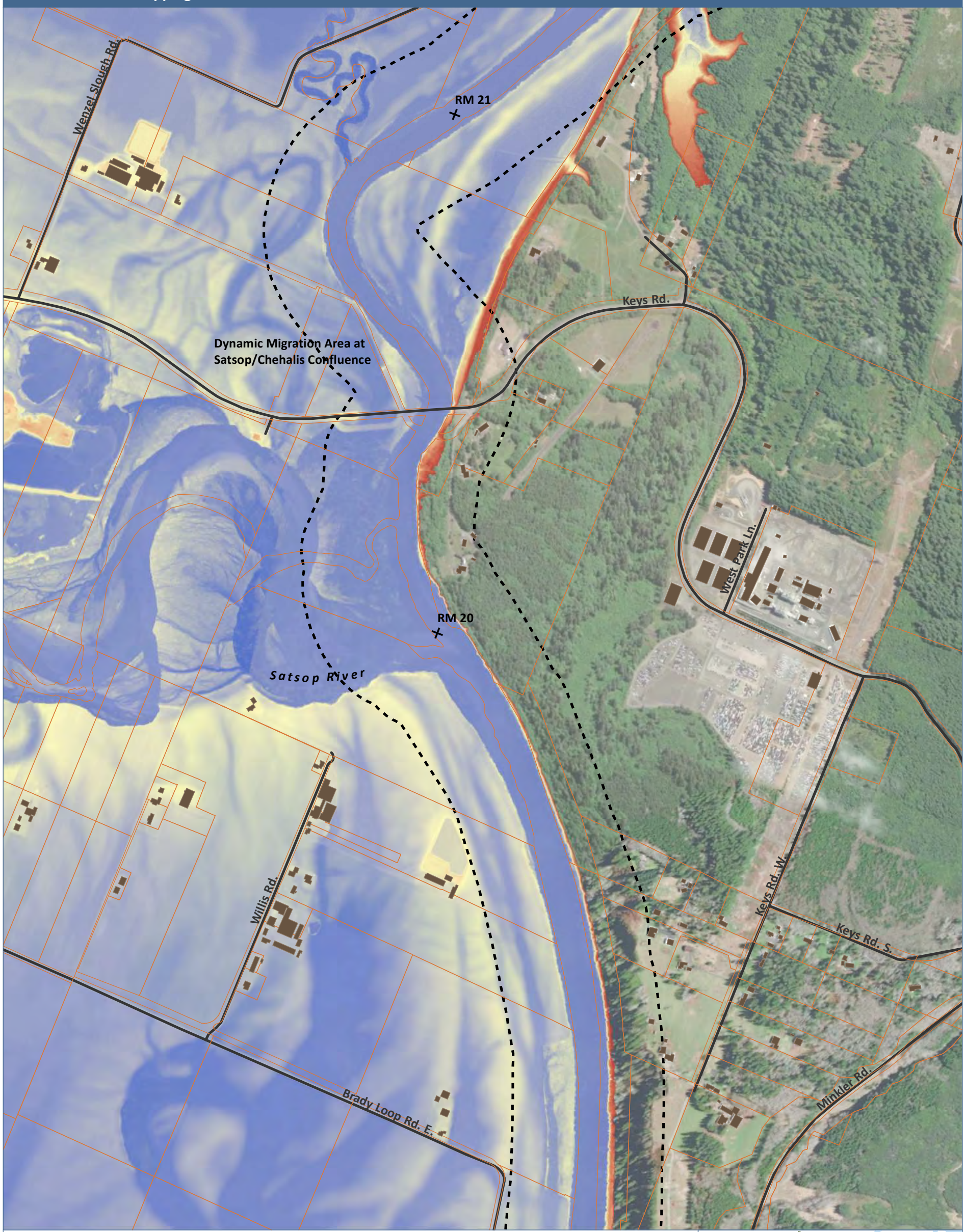
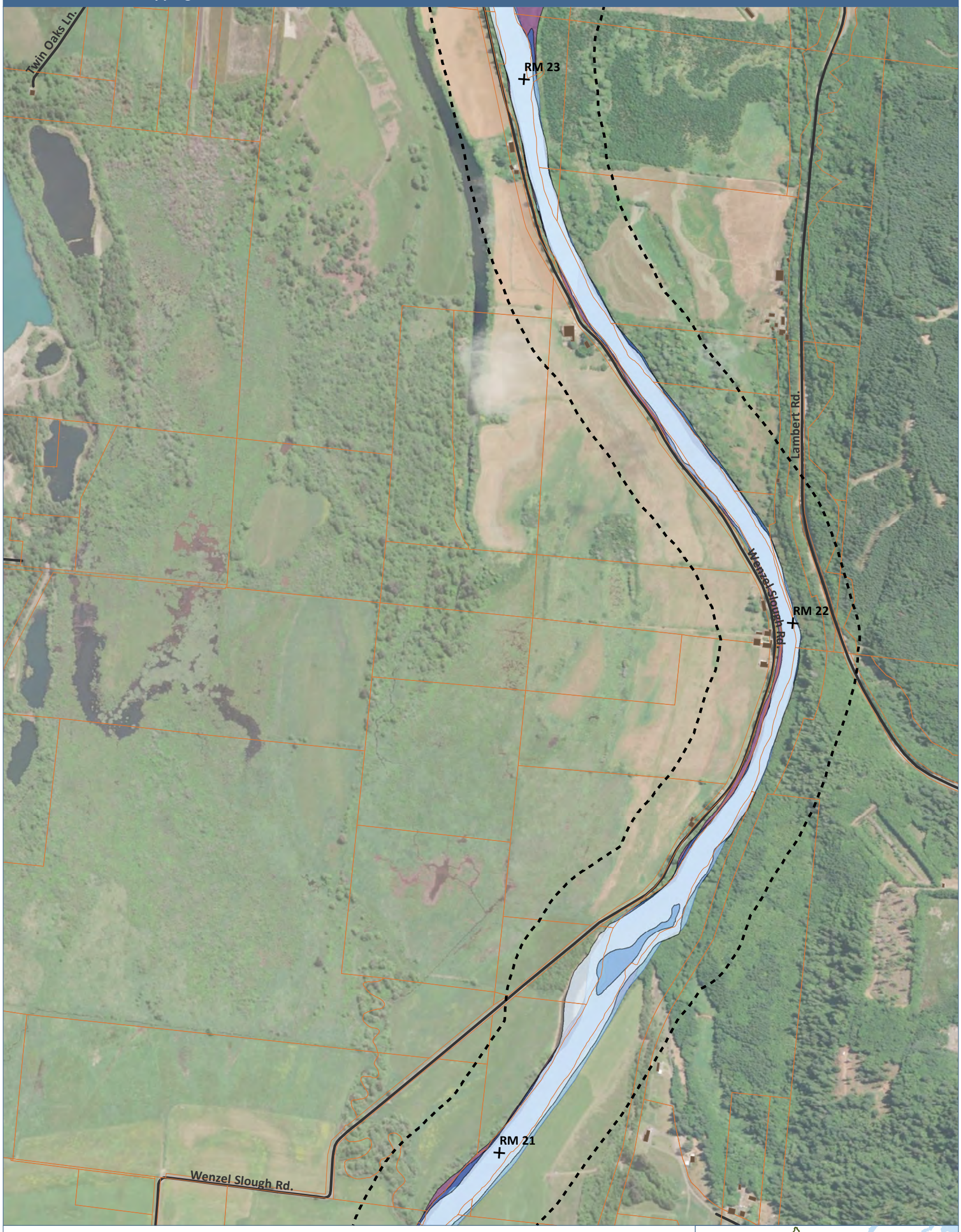


Figure 50
Relative Elevation Mapping: Chehalis River RM 13-25



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 51
Historical Channel Mapping: Chehalis River RM 13-25



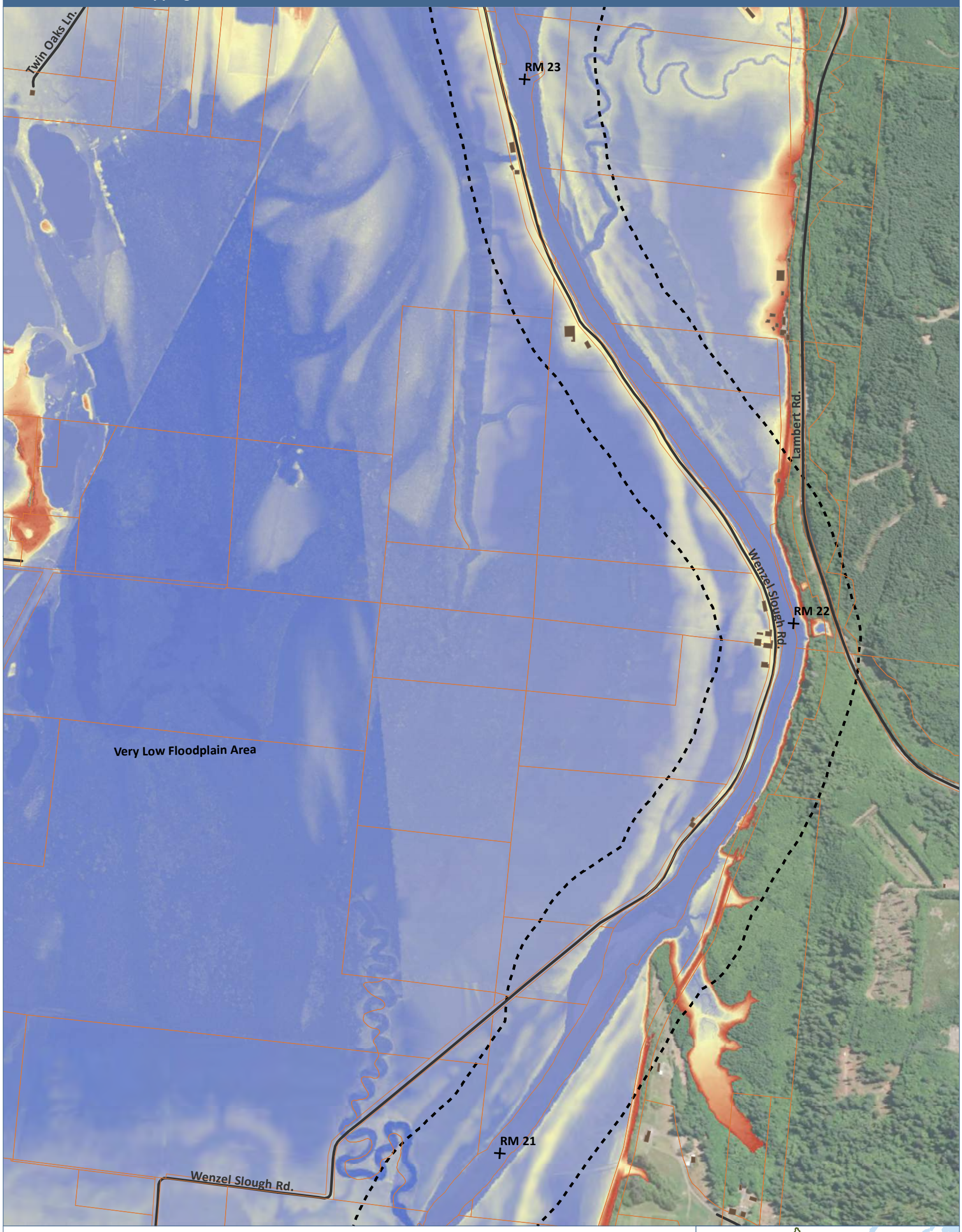
River Miles
Roads
Buildings
Parcels
500' Historical Channel Migration Buffer
2013 Channel
2003 Channel (In lieu of 1999)
1999 Channel
1975 Channel
1938 Channel
Migration Direction Indicator Arrow

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

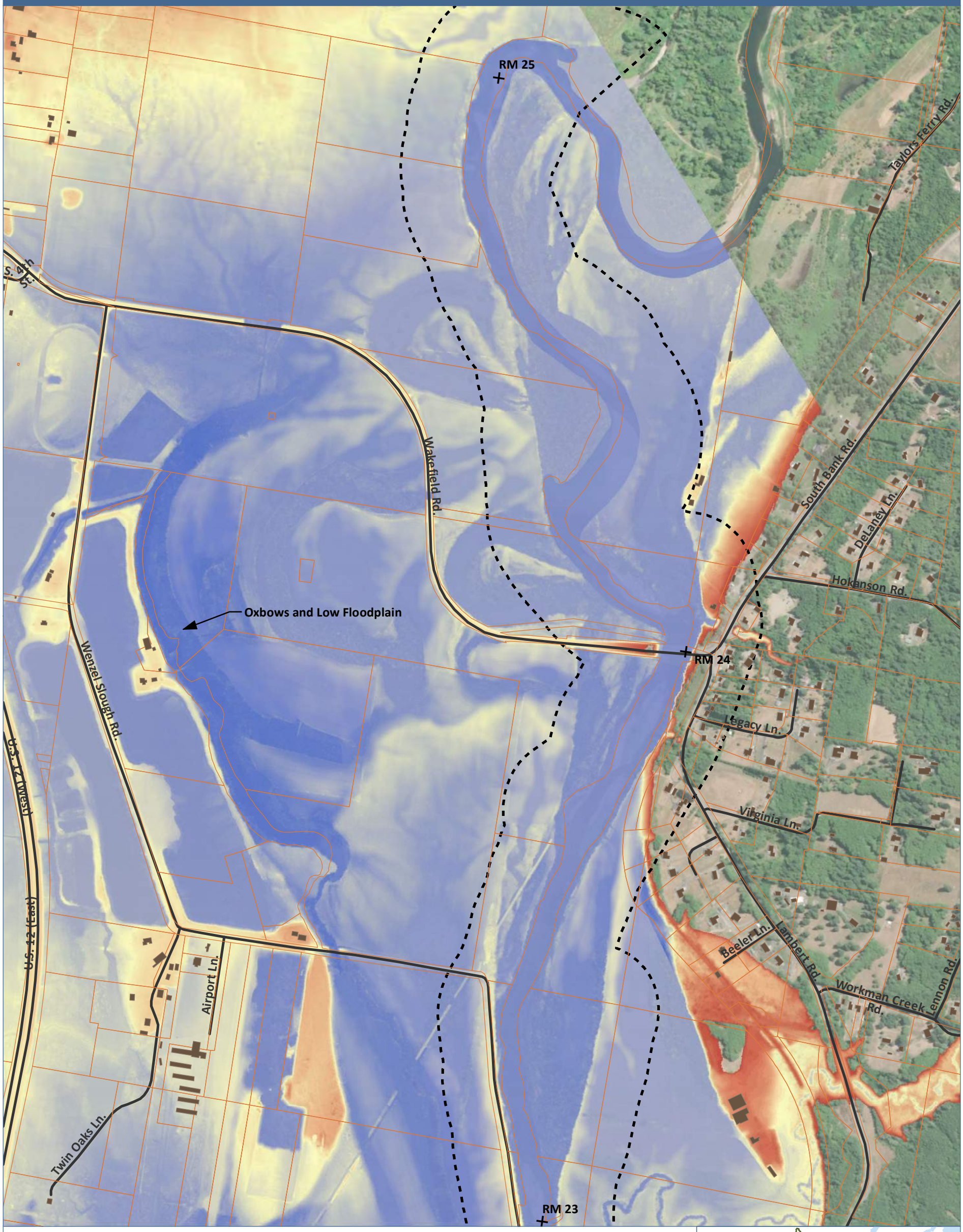
Figure 52
Relative Elevation Mapping: Chehalis River RM 13-25



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 53
Historical Channel Mapping: Chehalis River RM 13-25

Figure 54
Relative Elevation Mapping: Chehalis River RM 13-25



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 55
Historical Channel Mapping: Chehalis River RM 33-55

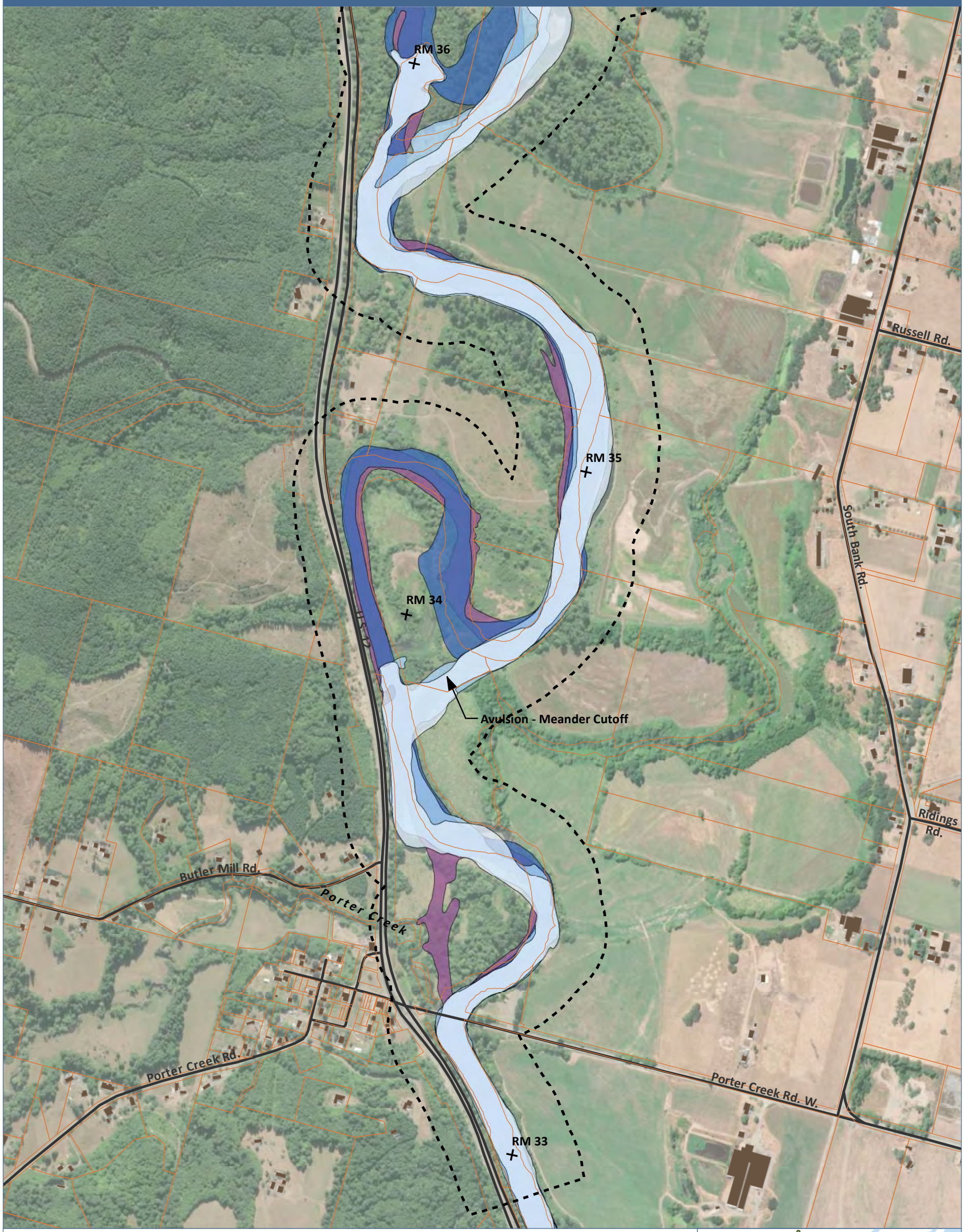
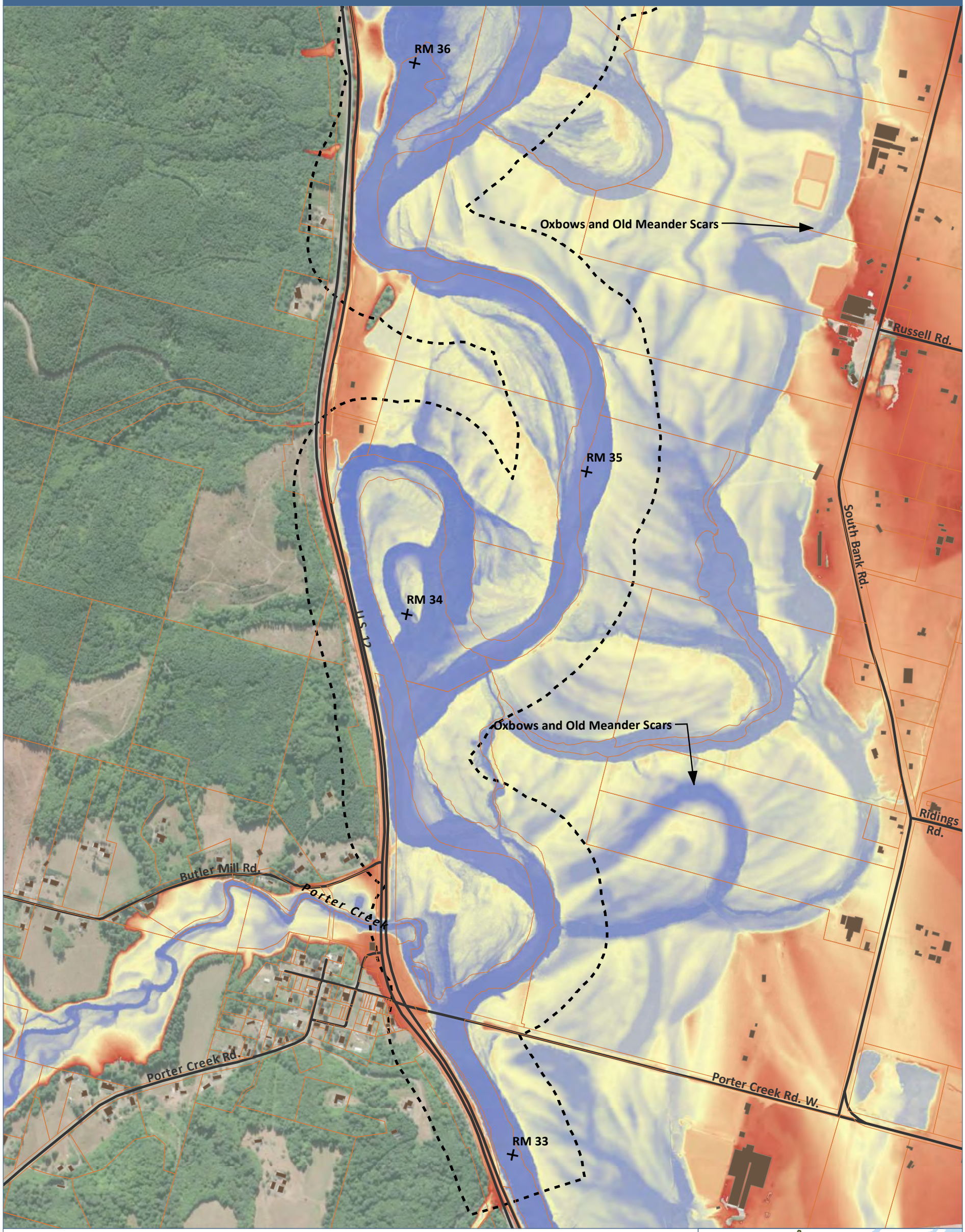
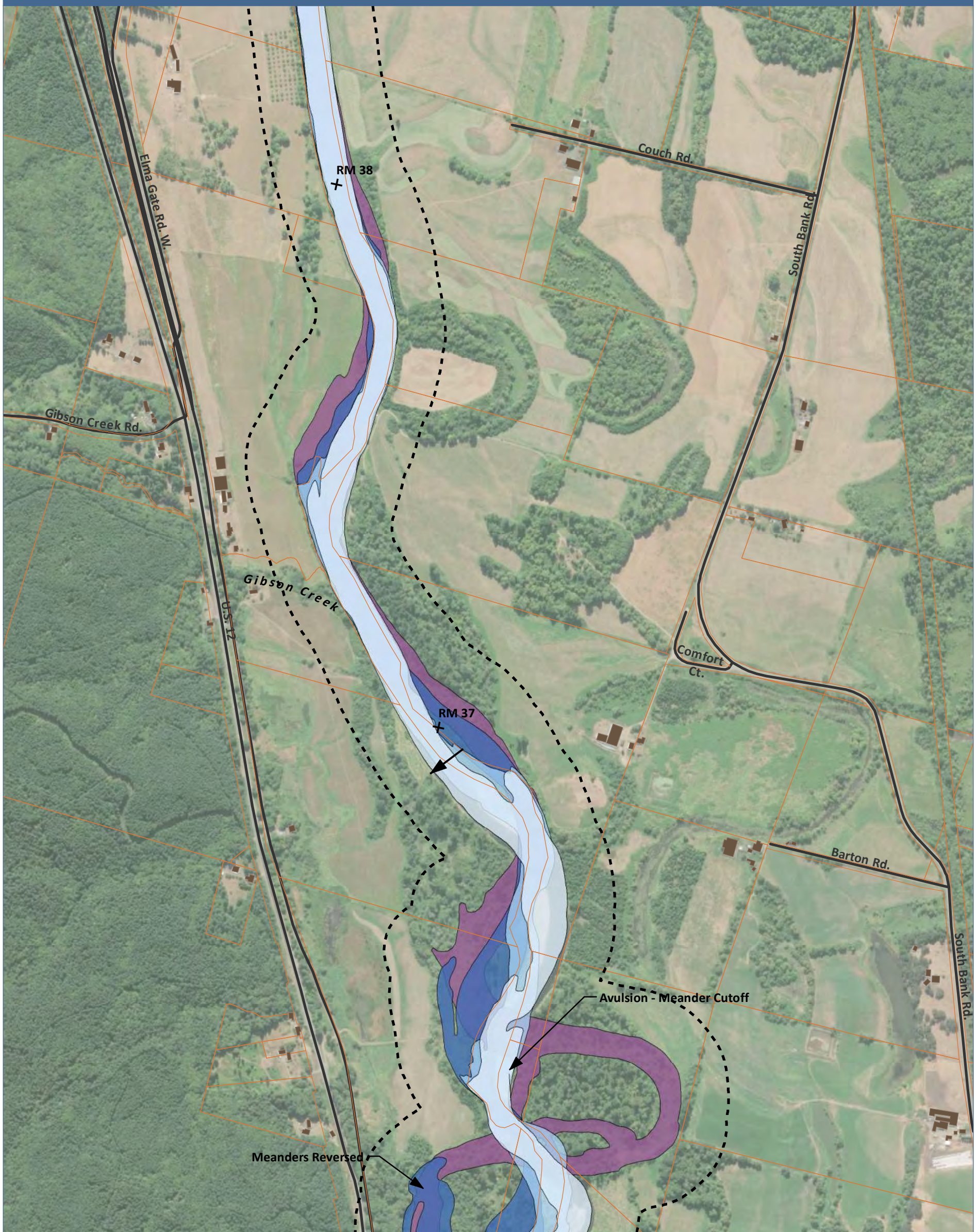


Figure 56
Relative Elevation Mapping: Chehalis River RM 33-55



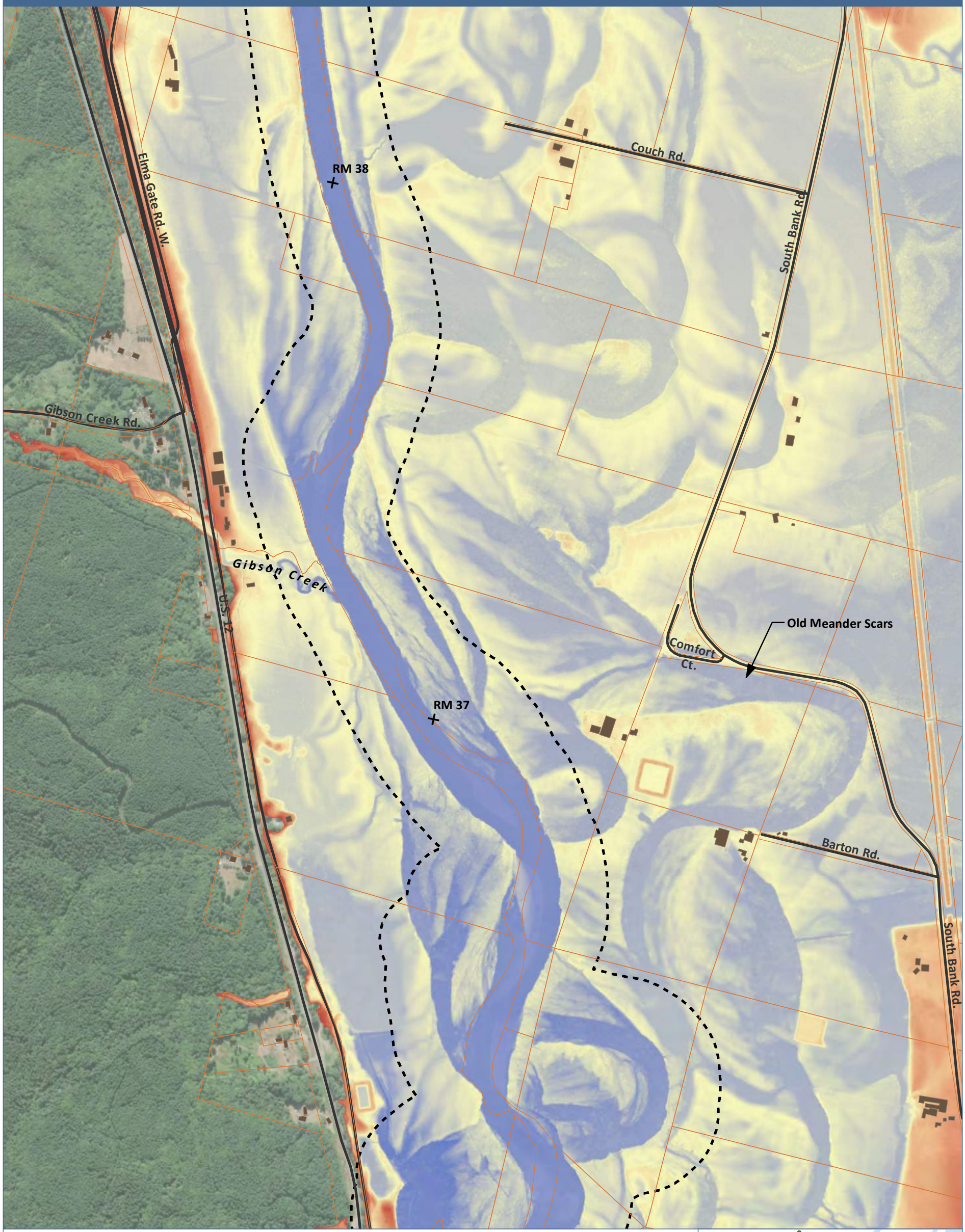
Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 57
Historical Channel Mapping: Chehalis River RM 33-55



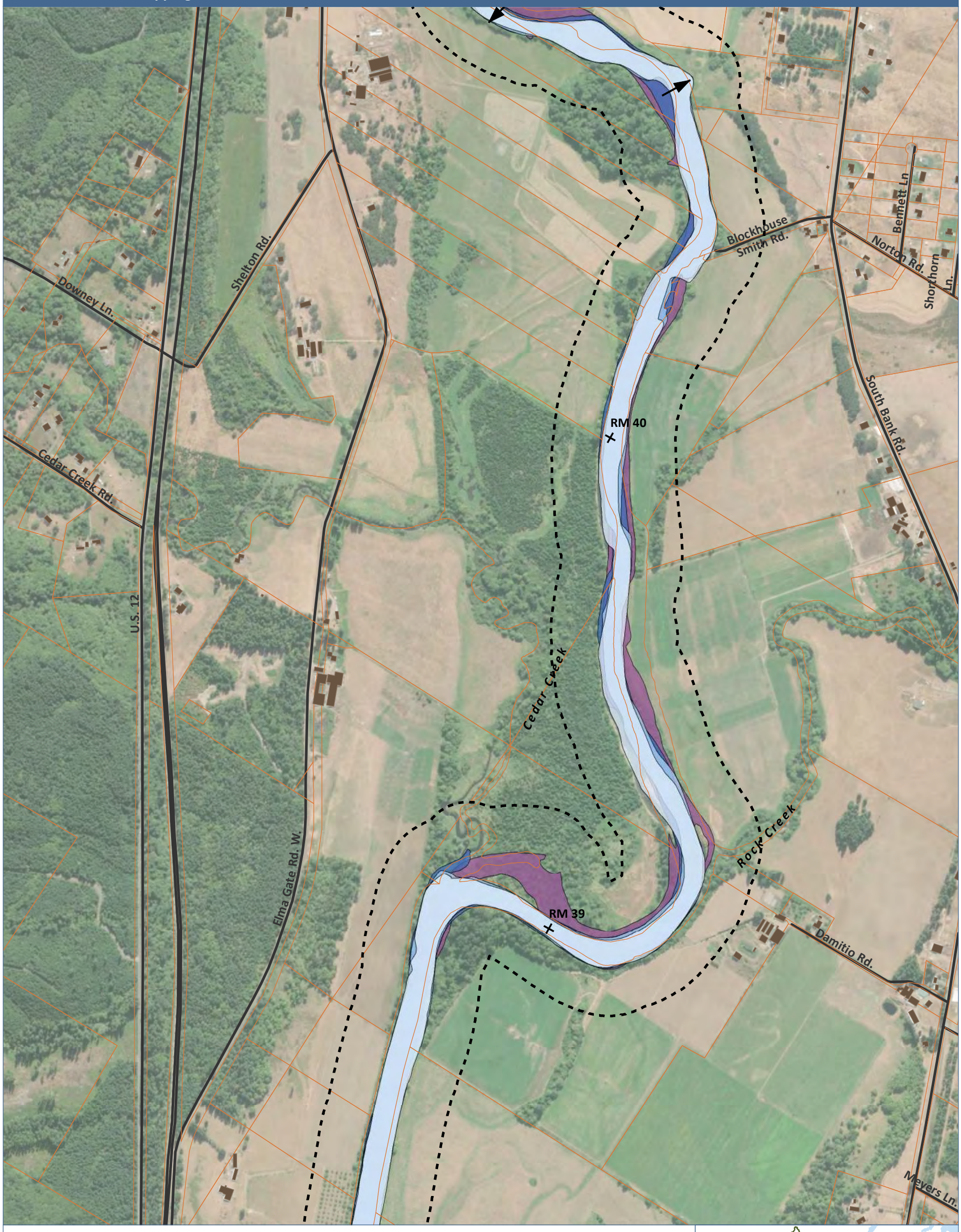
Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

Figure 58
Relative Elevation Mapping: Chehalis River RM 33-55



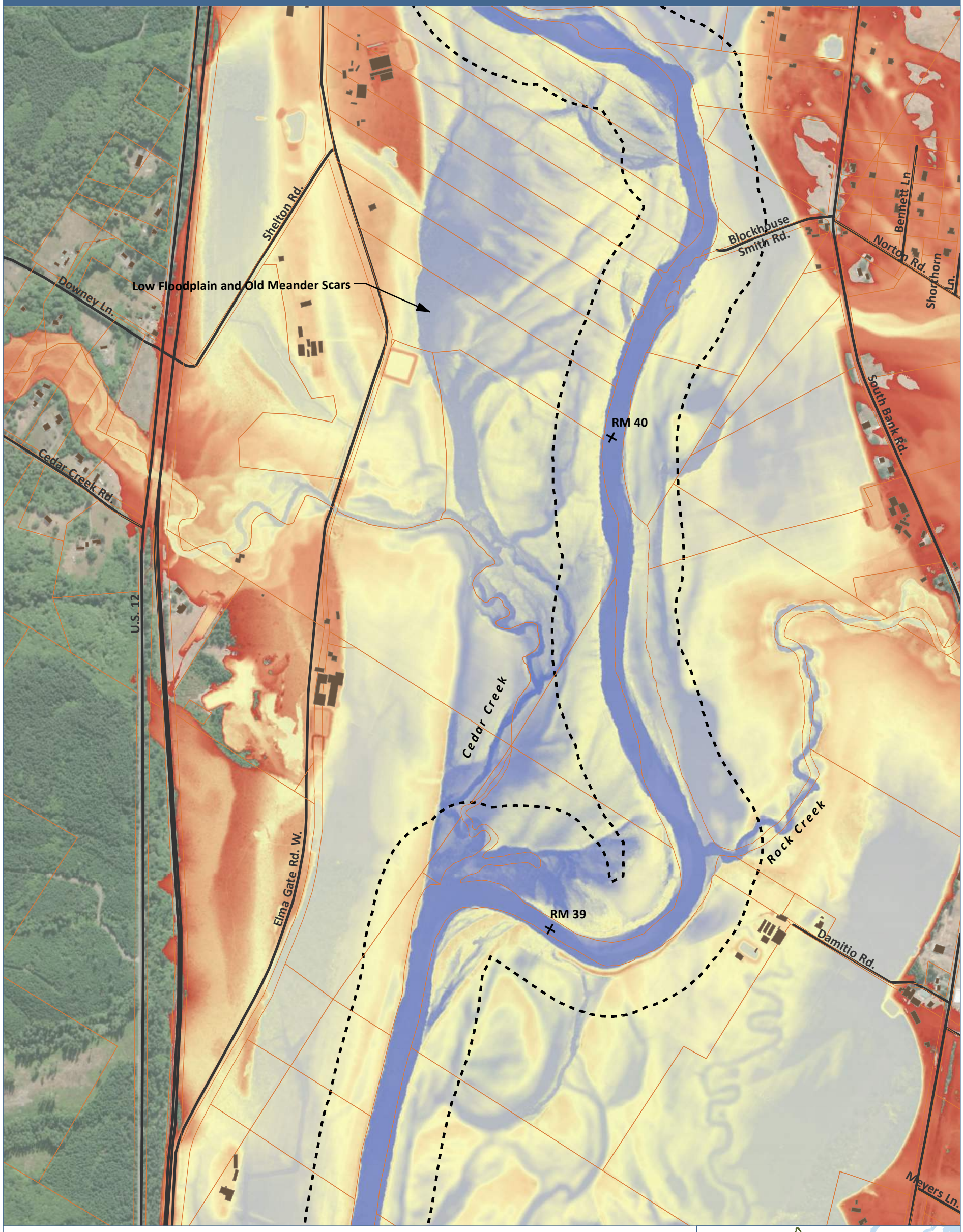
Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 59
Historical Channel Mapping: Chehalis River RM 33-55



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

Figure 60
Relative Elevation Mapping: Chehalis River RM 33-55



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 61
Historical Channel Mapping: Chehalis River RM 33-55

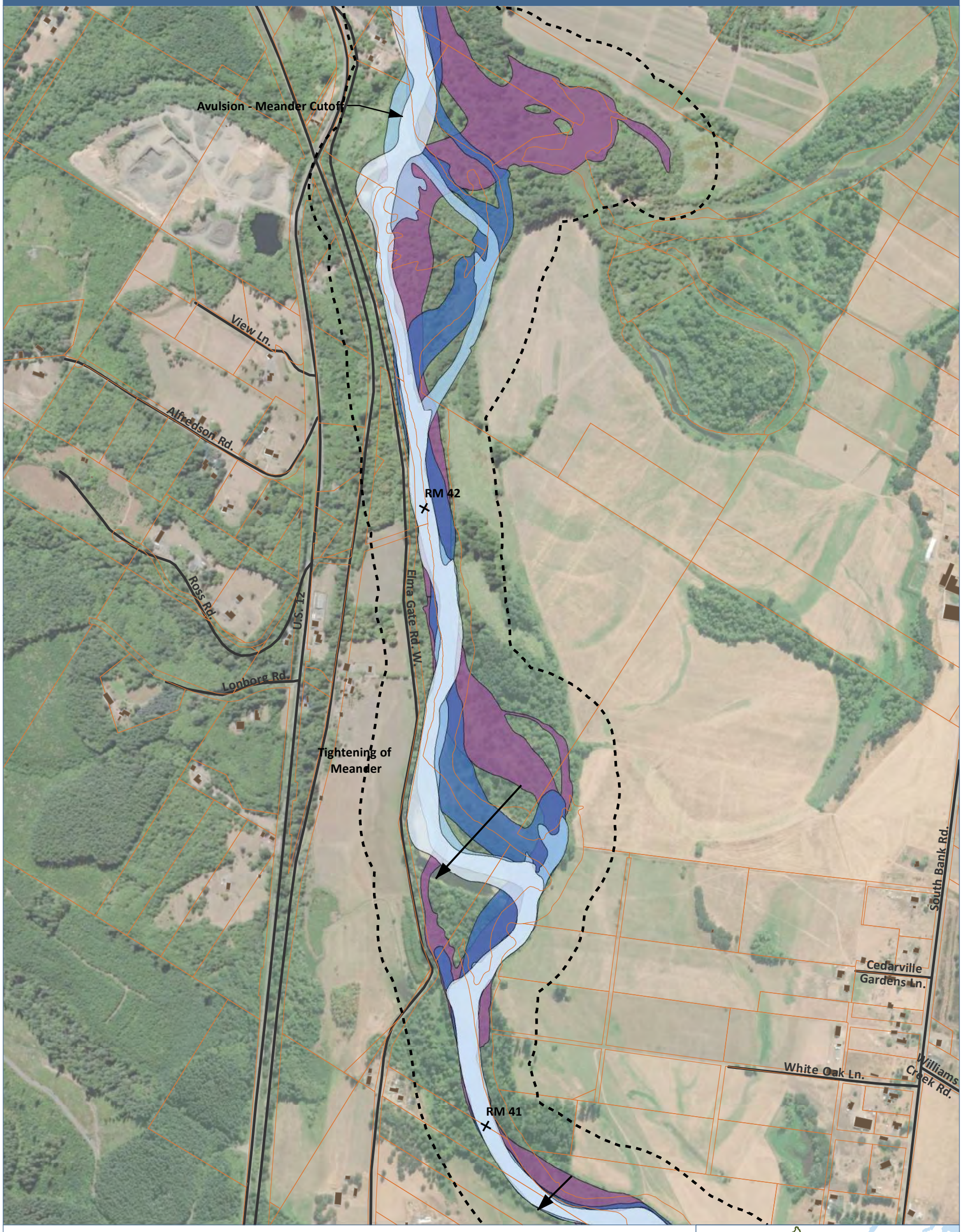
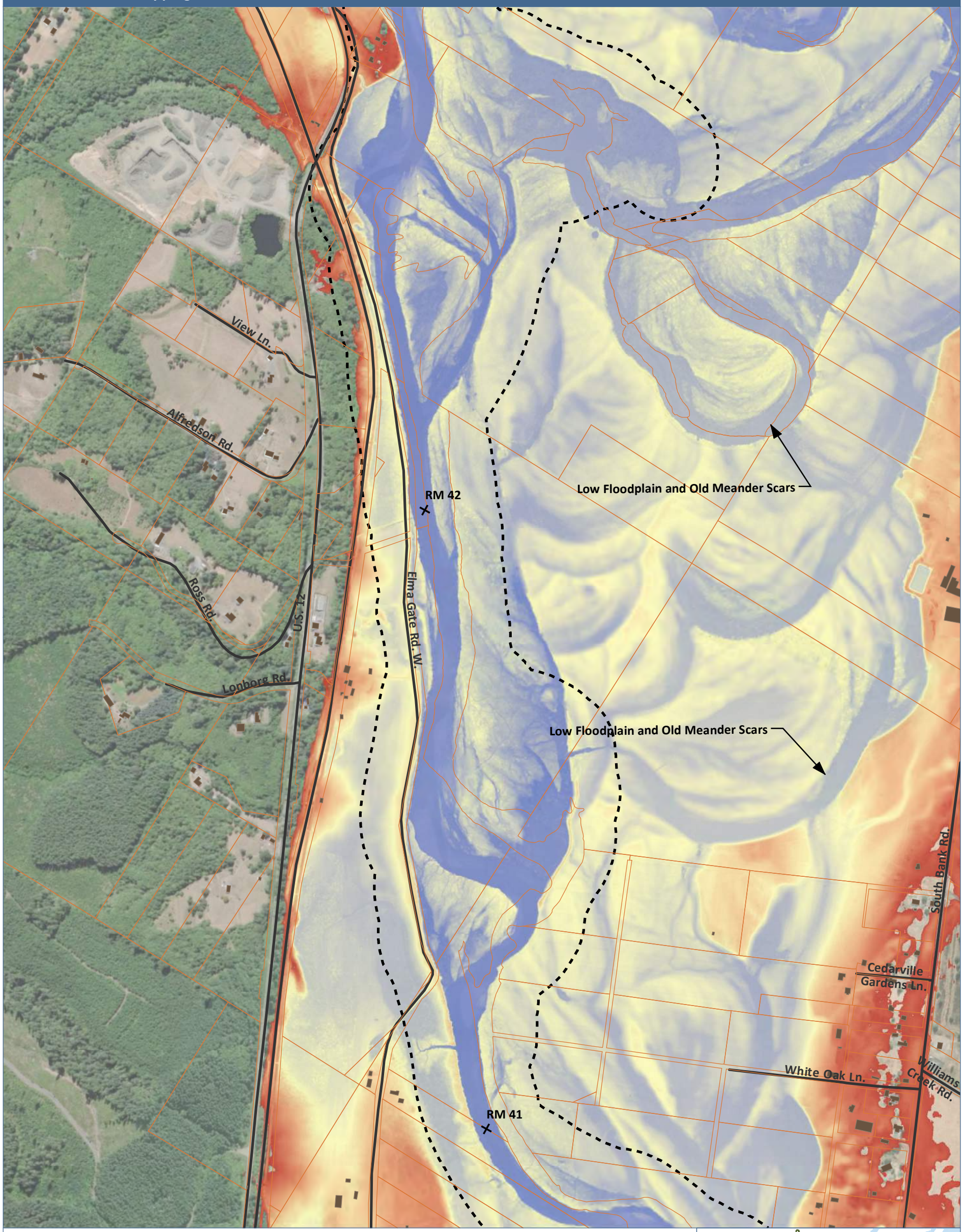


Figure 62
Relative Elevation Mapping: Chehalis River RM 33-55



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 63
Historical Channel Mapping: Chehalis River RM 33-55

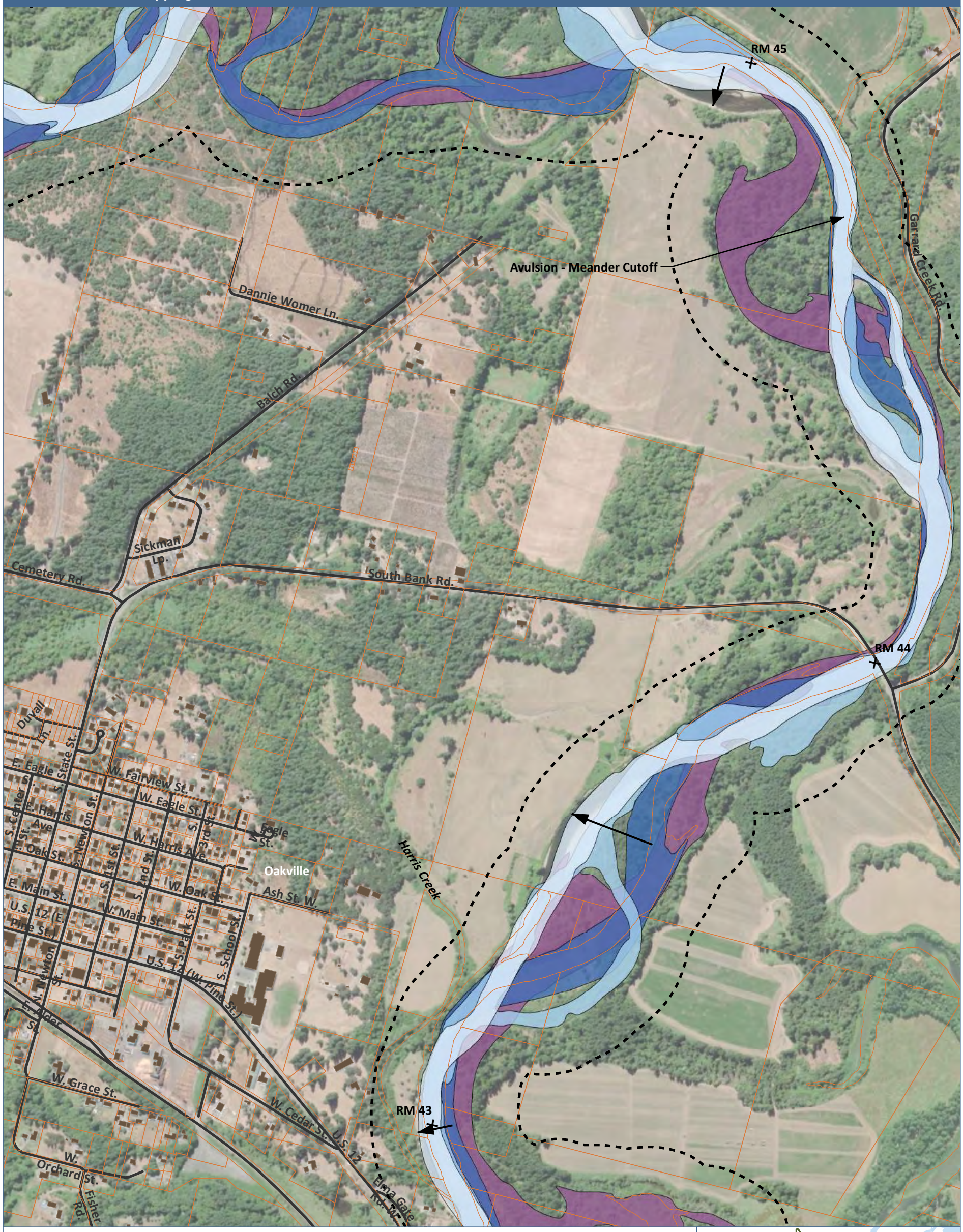
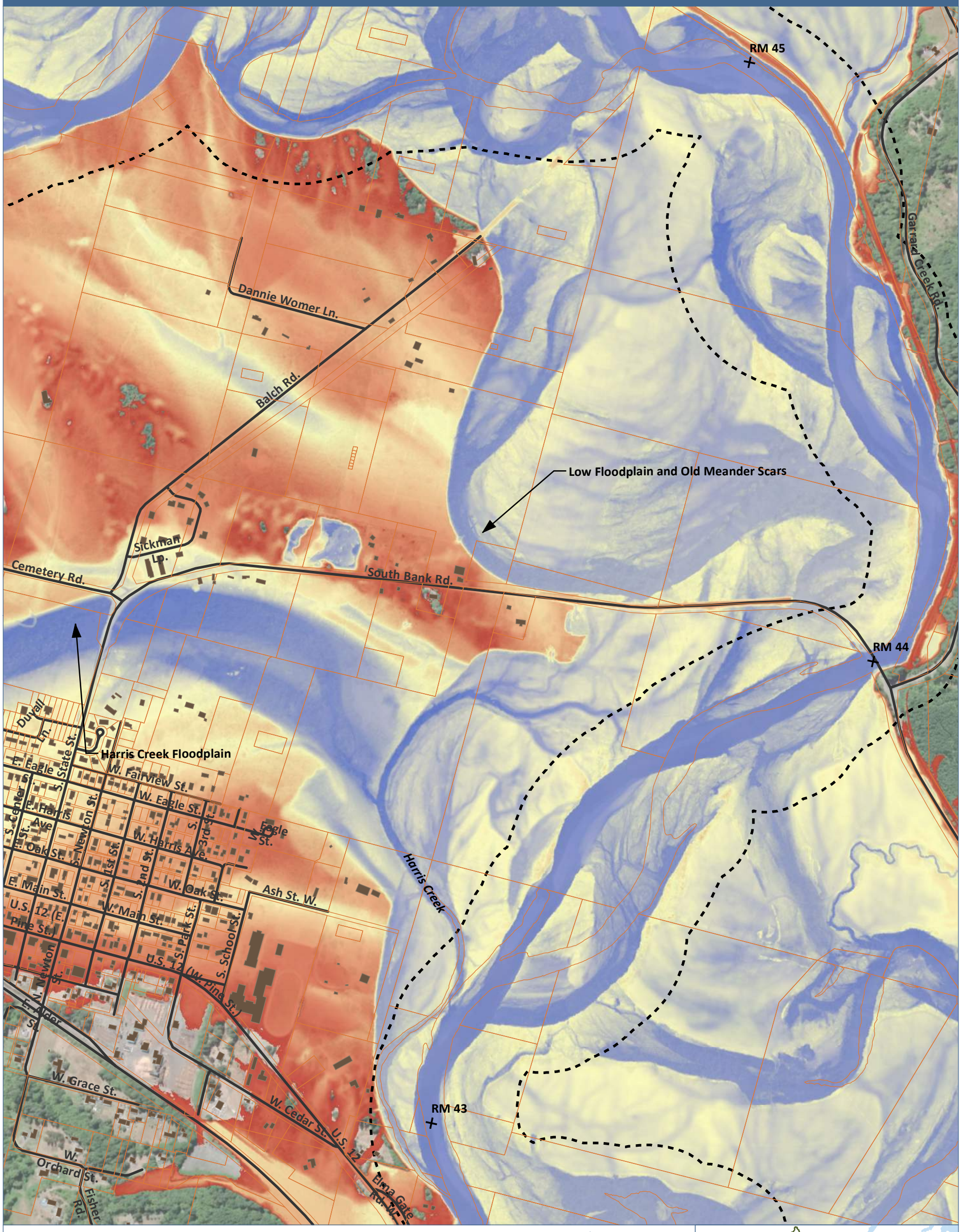


Figure 64
Relative Elevation Mapping: Chehalis River RM 33-55



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 65
Historical Channel Mapping: Chehalis River RM 33-55

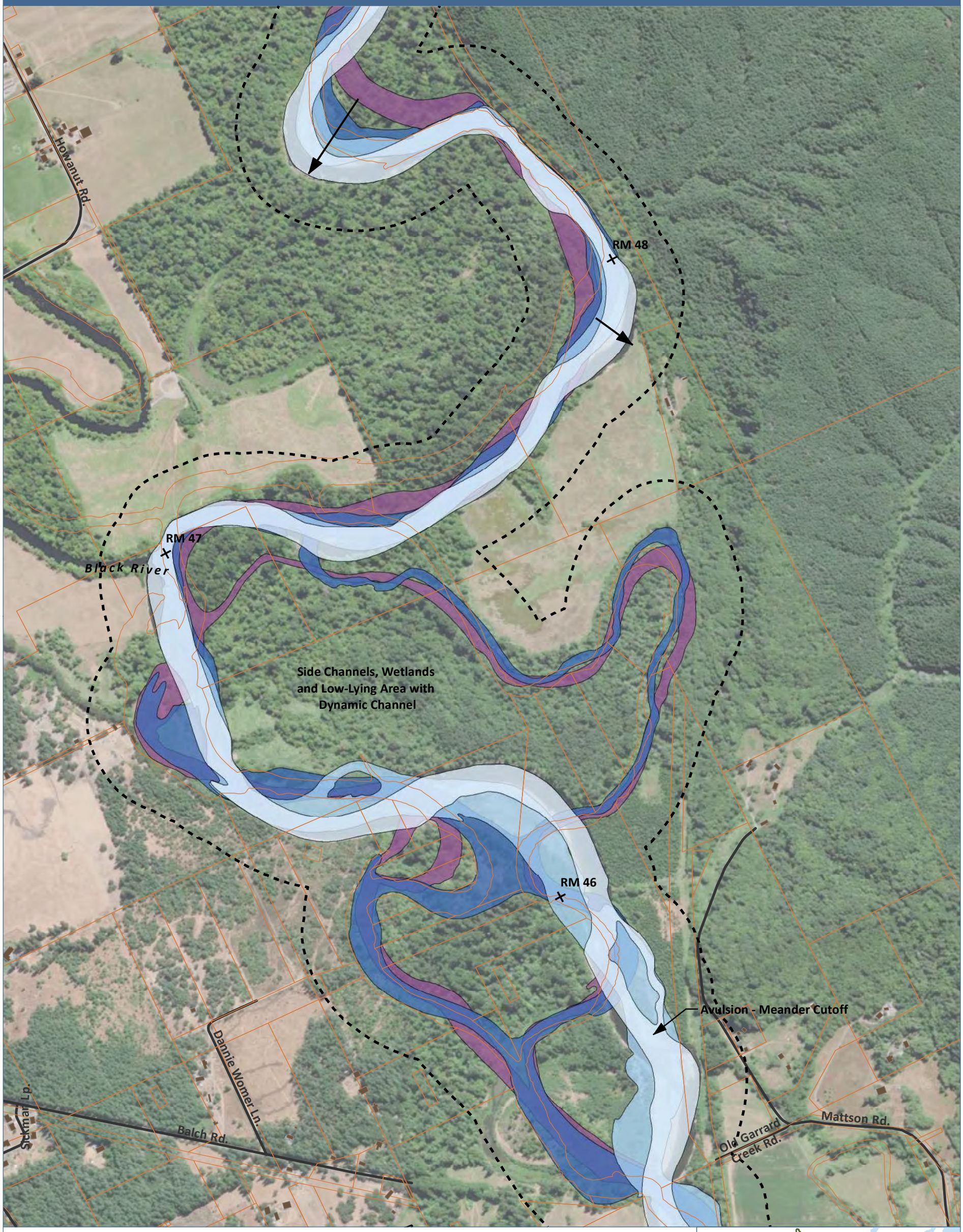
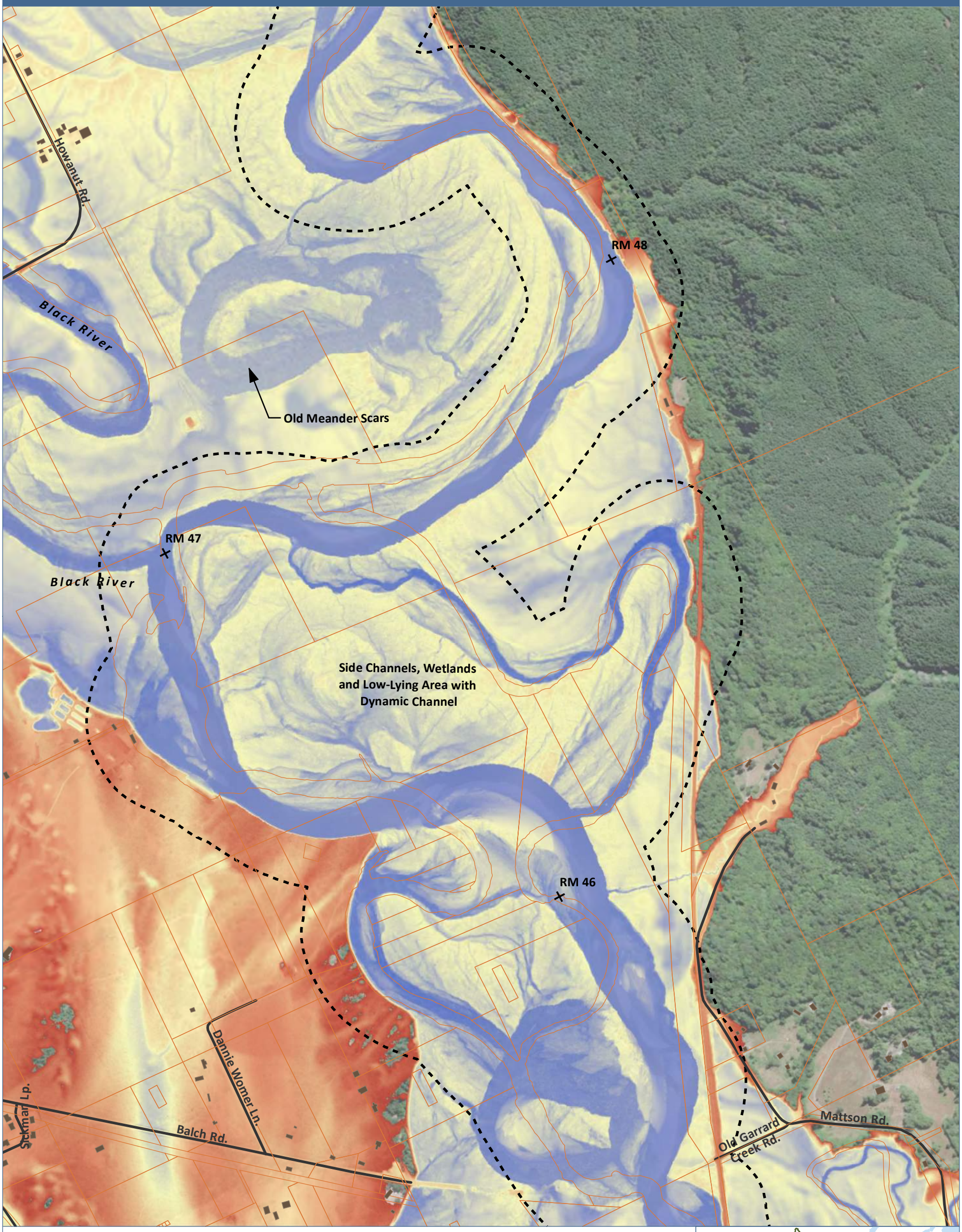


Figure 66
Relative Elevation Mapping: Chehalis River RM 33-55



River Miles
Roads
Buildings
Parcels
400' Historical Channel Migration Buffer

Elevation Relative to Water Surface (ft)
25
-8

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 67
Historical Channel Mapping: Chehalis River RM 33-55

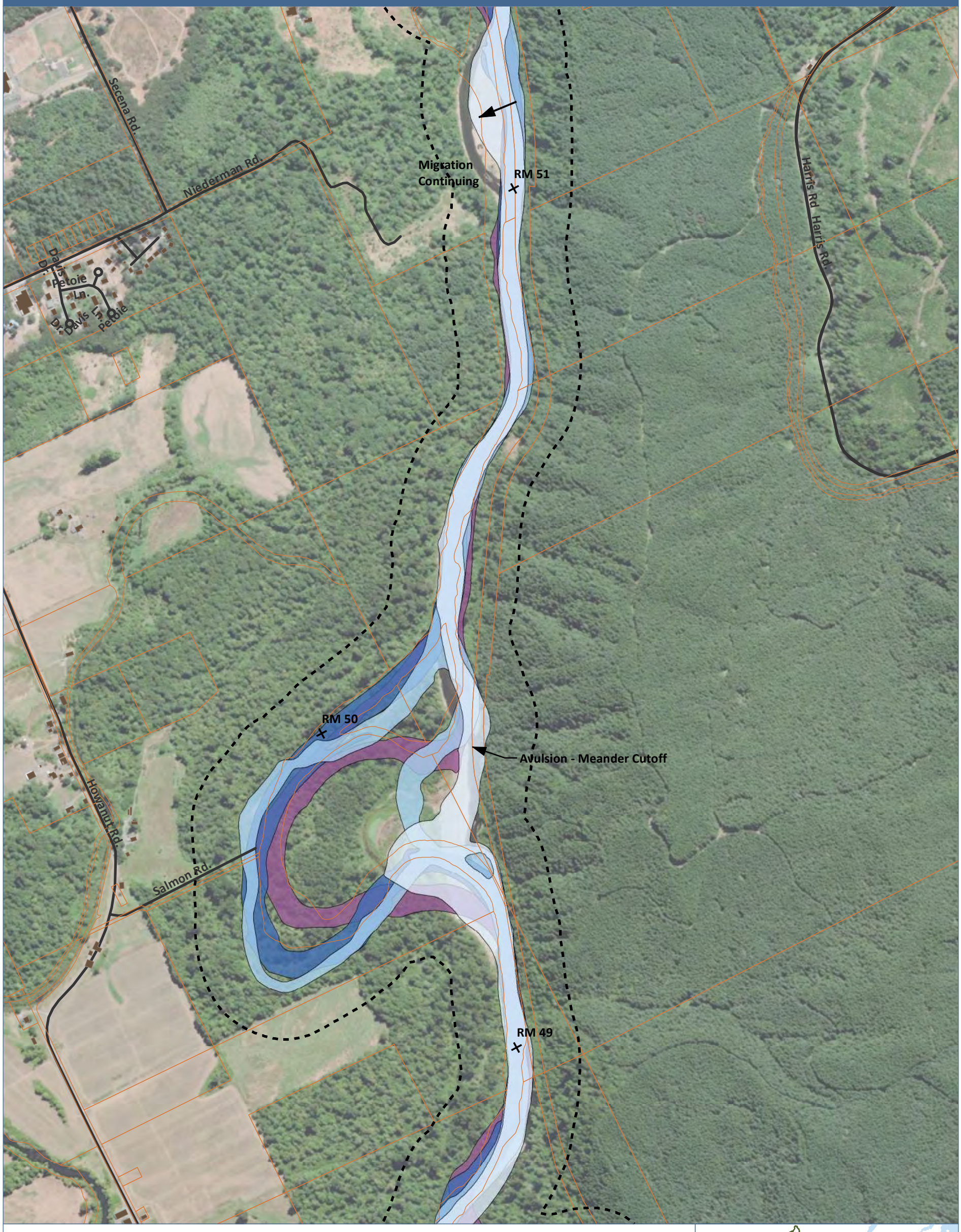
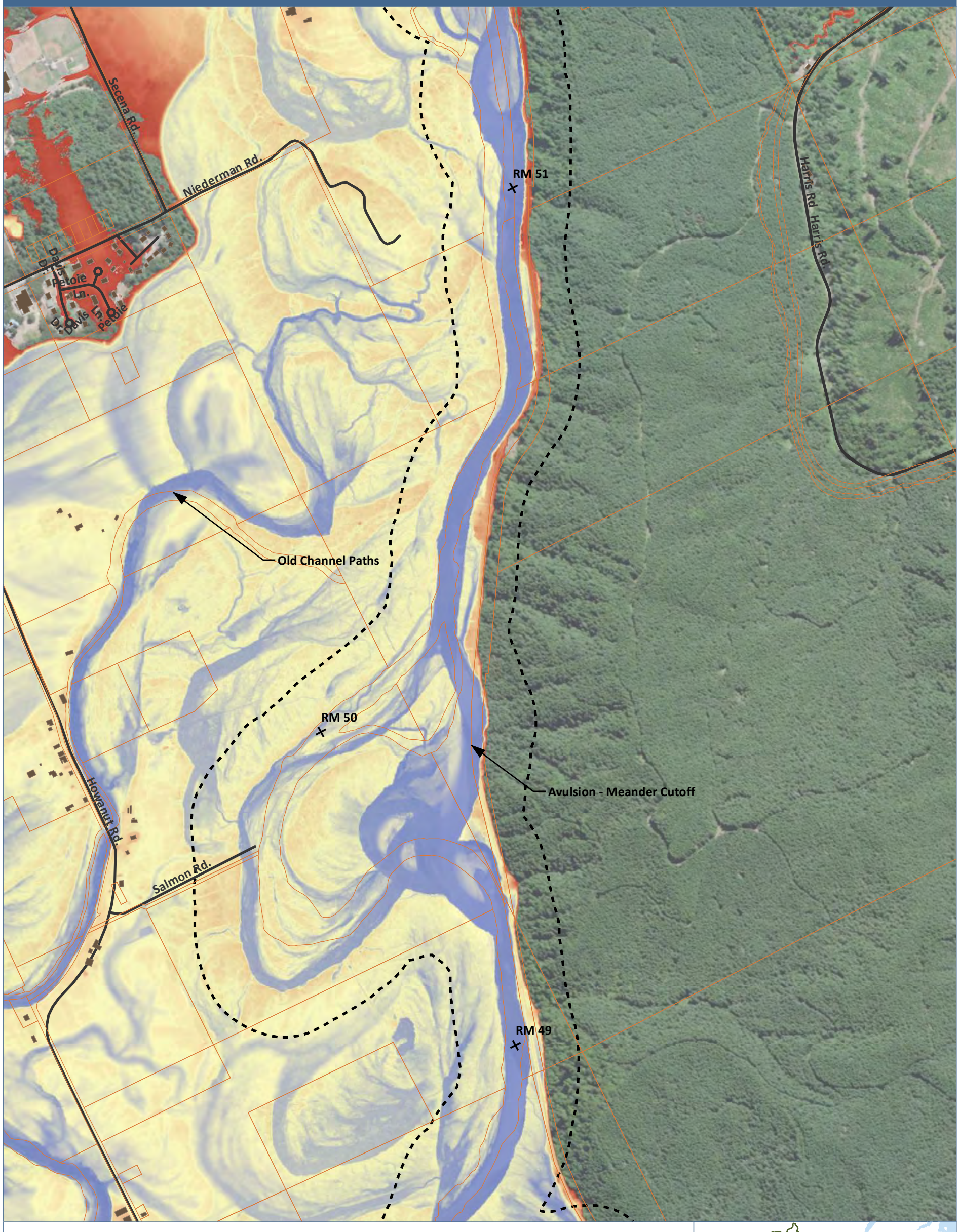


Figure 68
Relative Elevation Mapping: Chehalis River RM 33-55



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 69
Historical Channel Mapping: Chehalis River RM 33-55

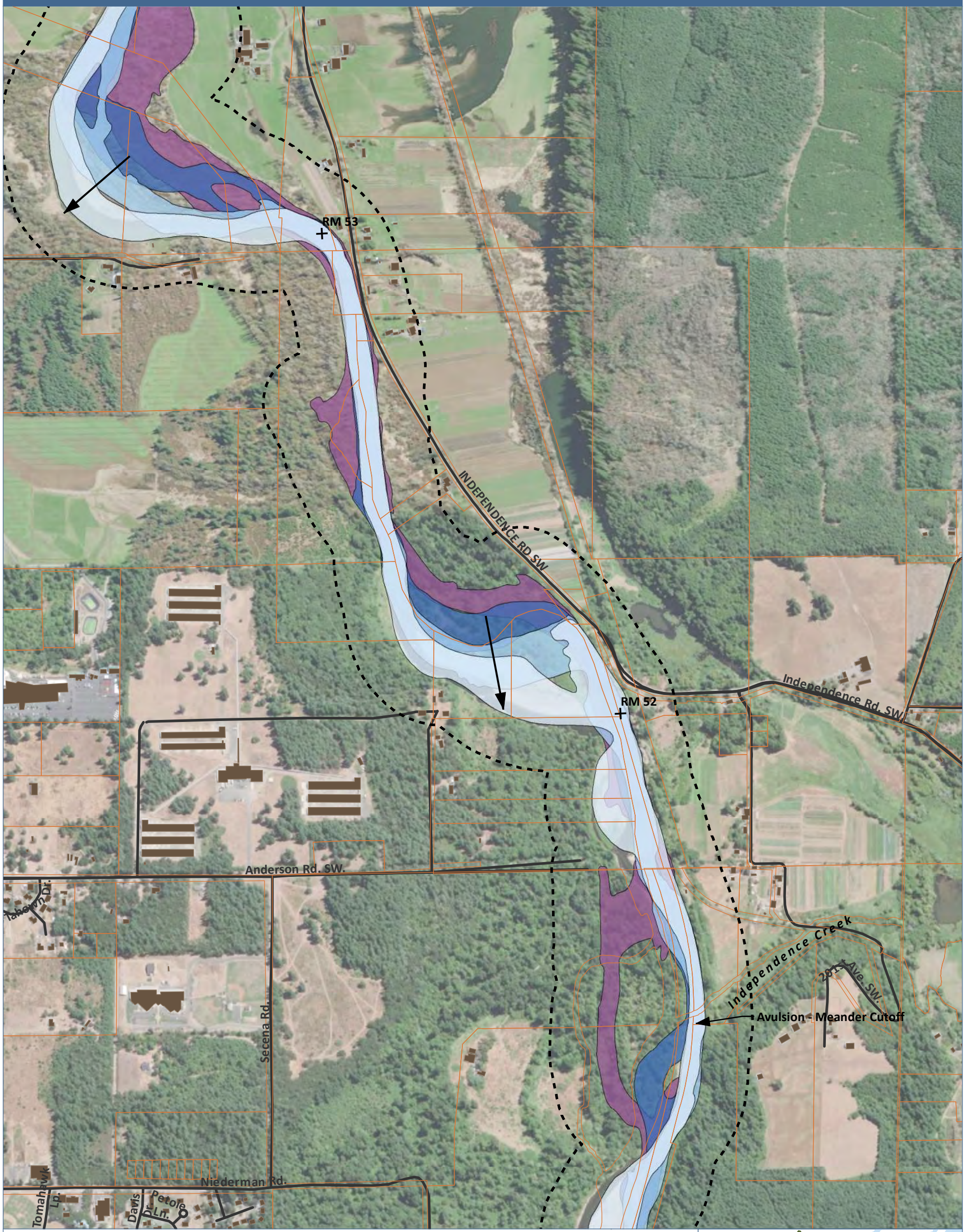
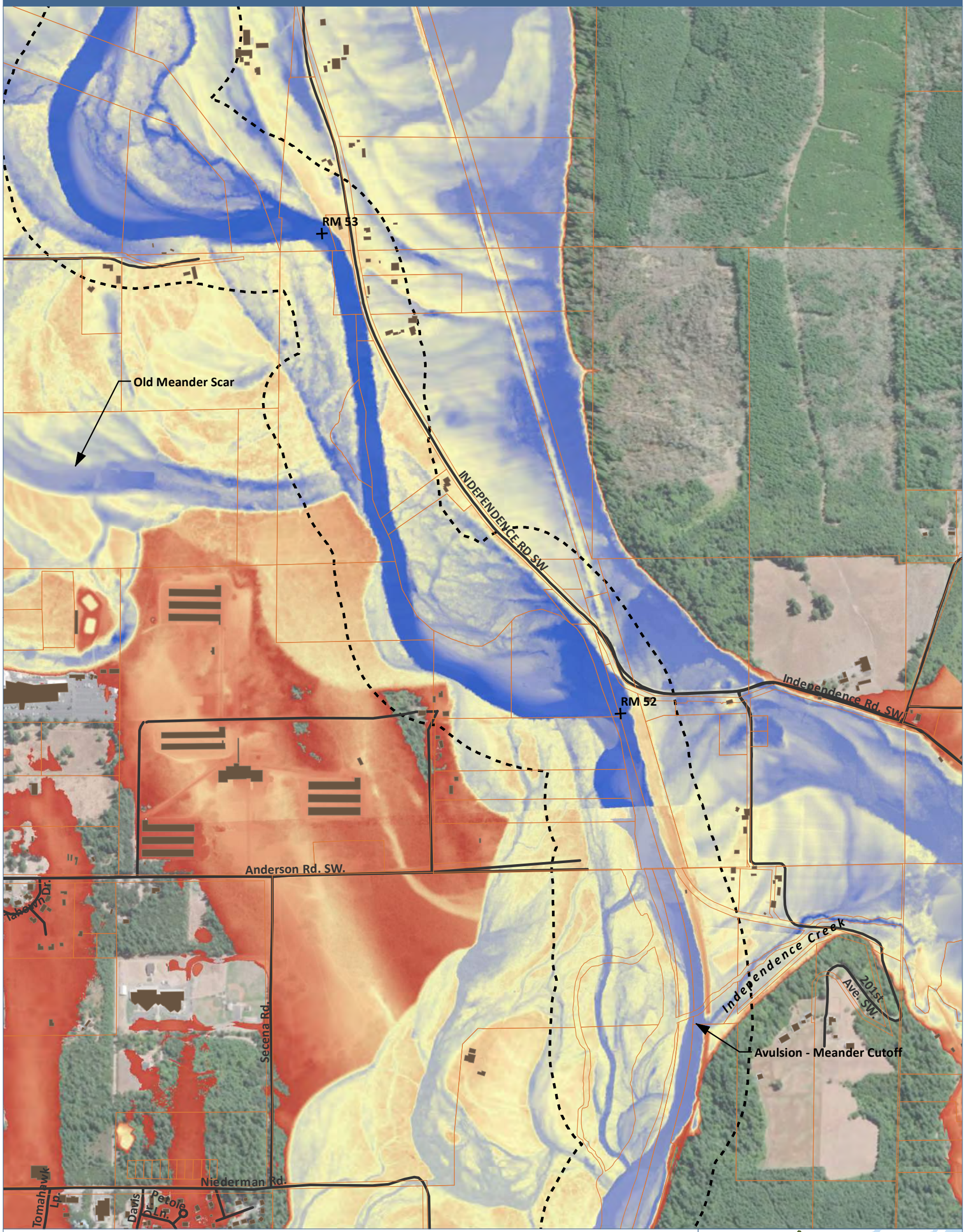


Figure 70
Relative Elevation Mapping: Chehalis River RM 33-55



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 71
Historical Channel Mapping: Chehalis River RM 33-55

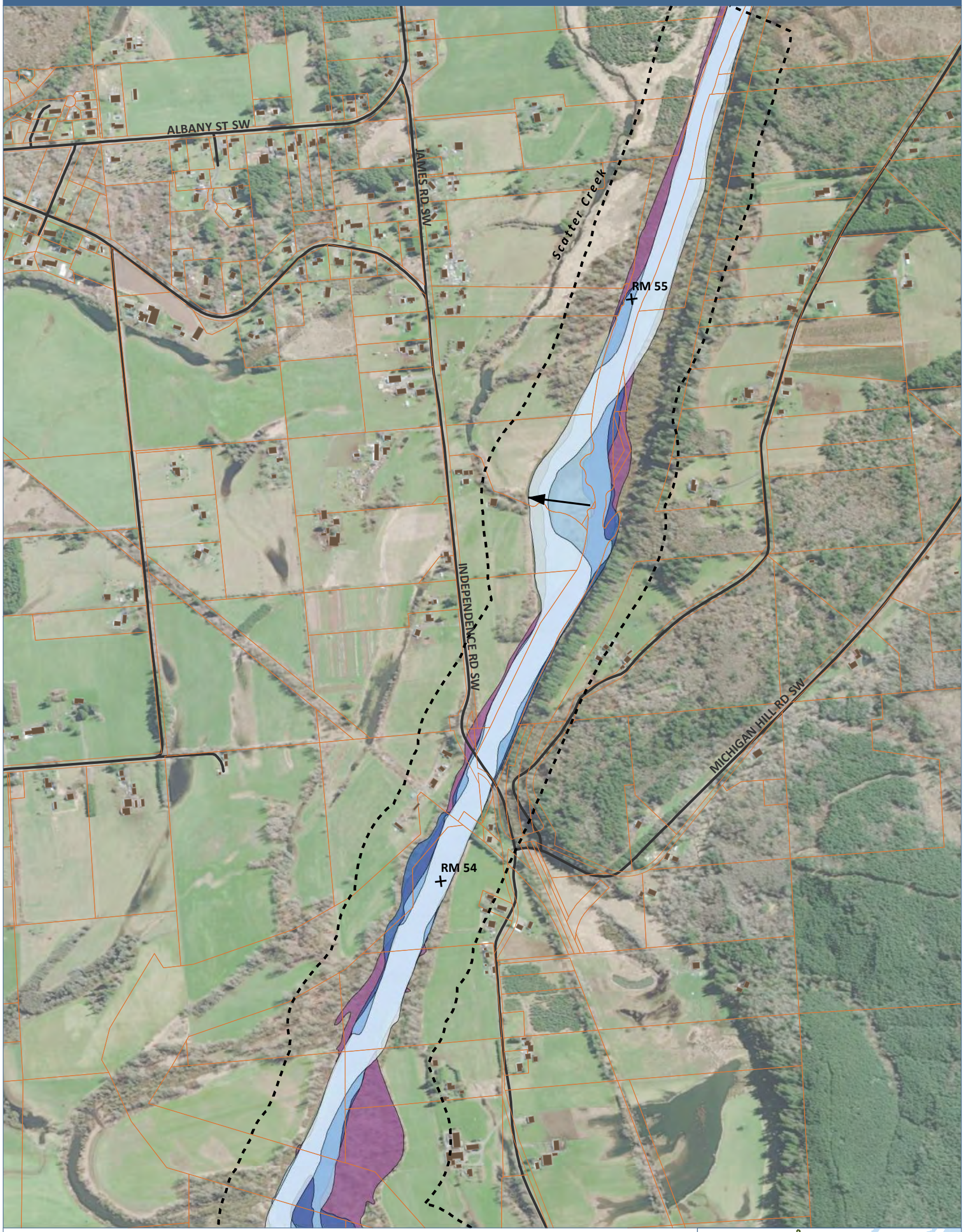
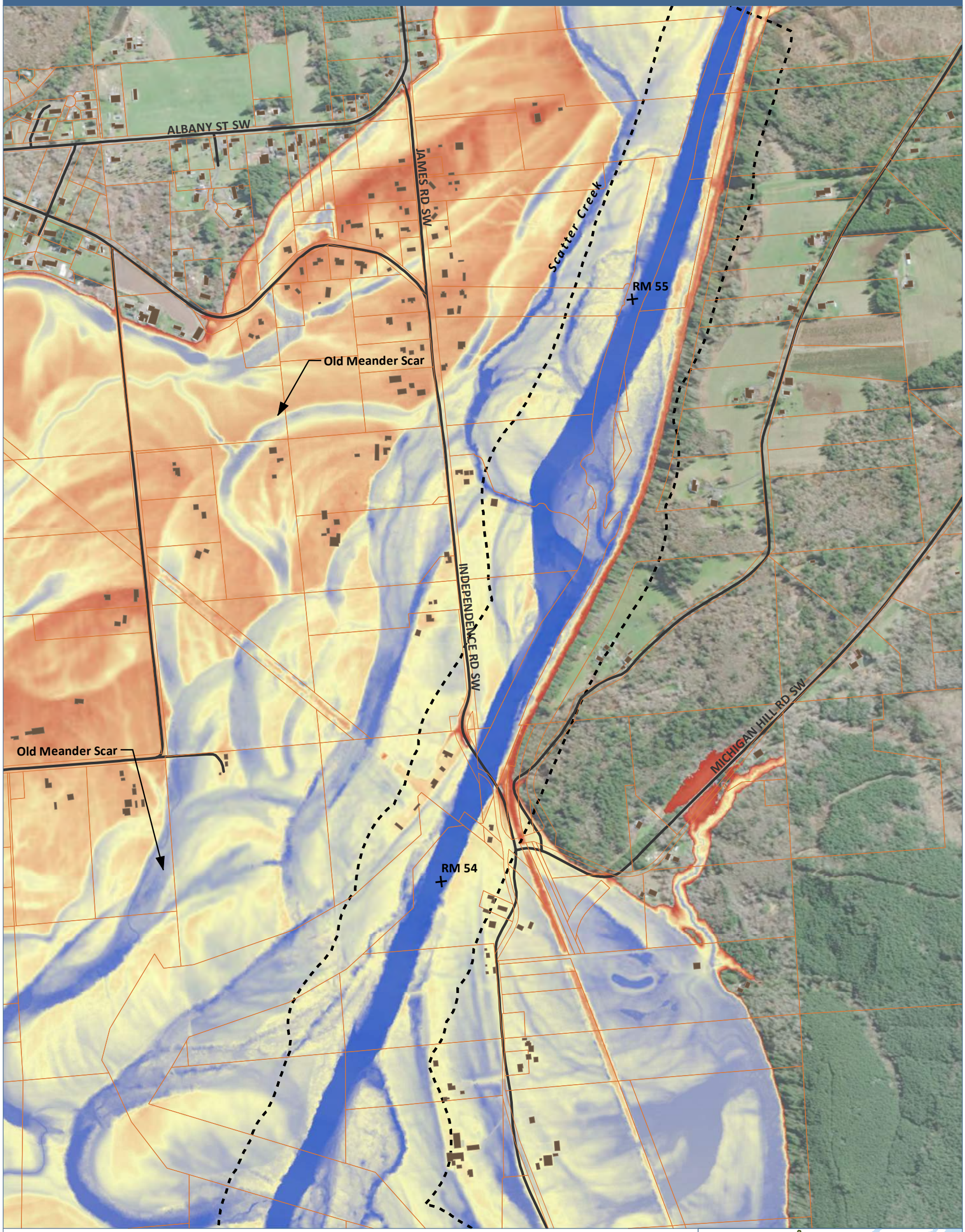


Figure 72
Relative Elevation Mapping: Chehalis River RM 33-55



River Miles
Roads
Buildings
Parcels
400' Historical Channel Migration Buffer

Elevation Relative to Water Surface (ft)
25
-8

N

Feet
0 500 1,000

Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

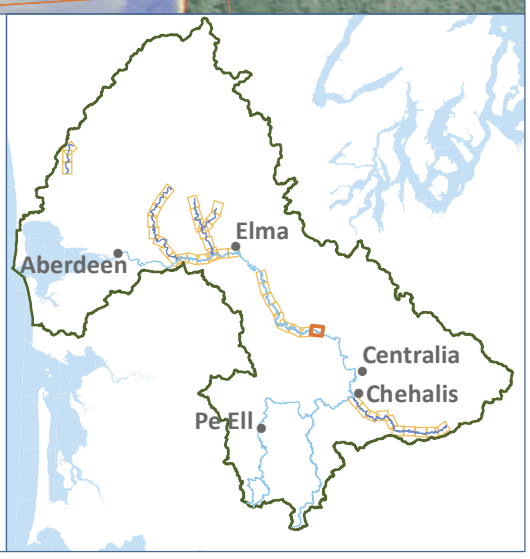
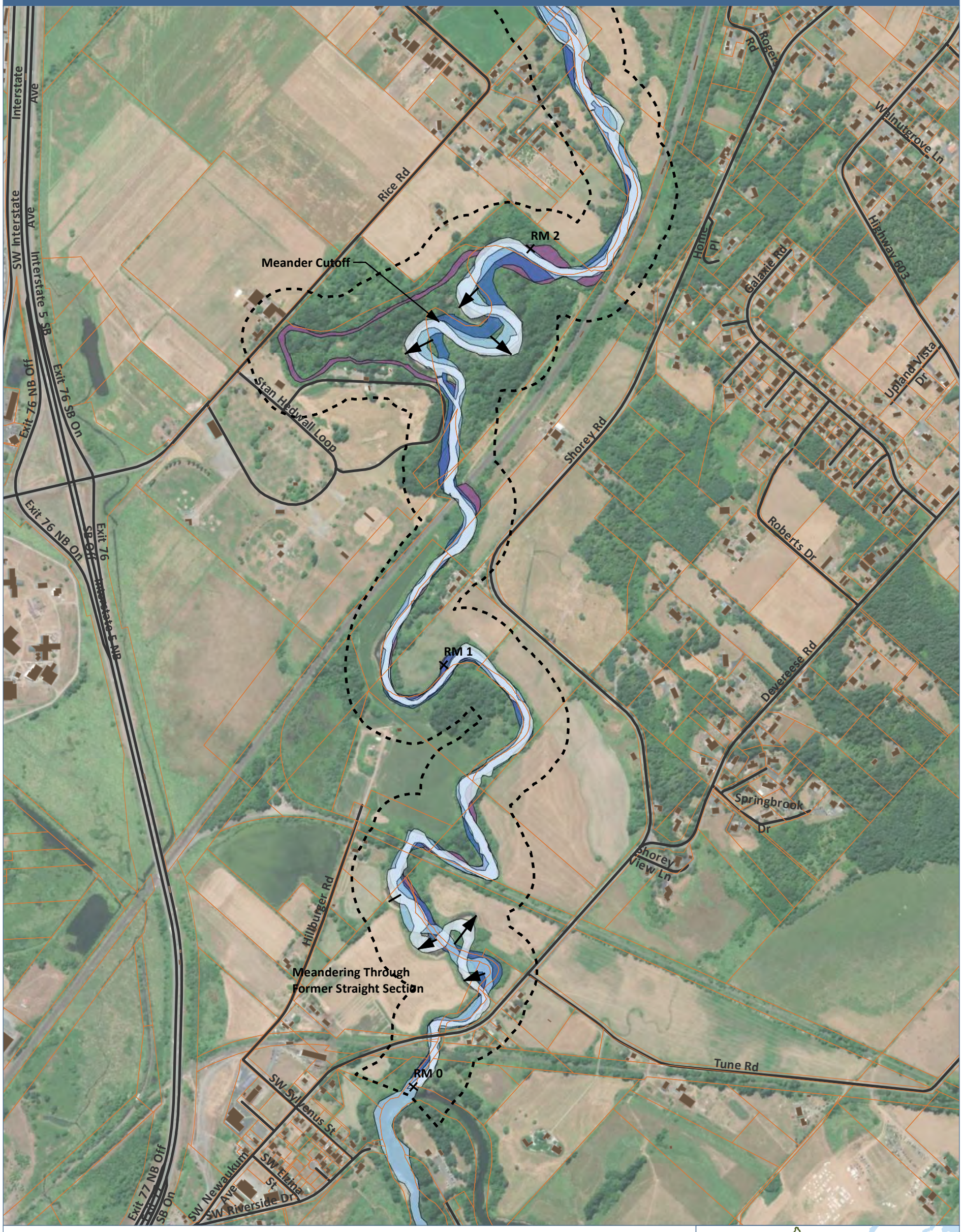
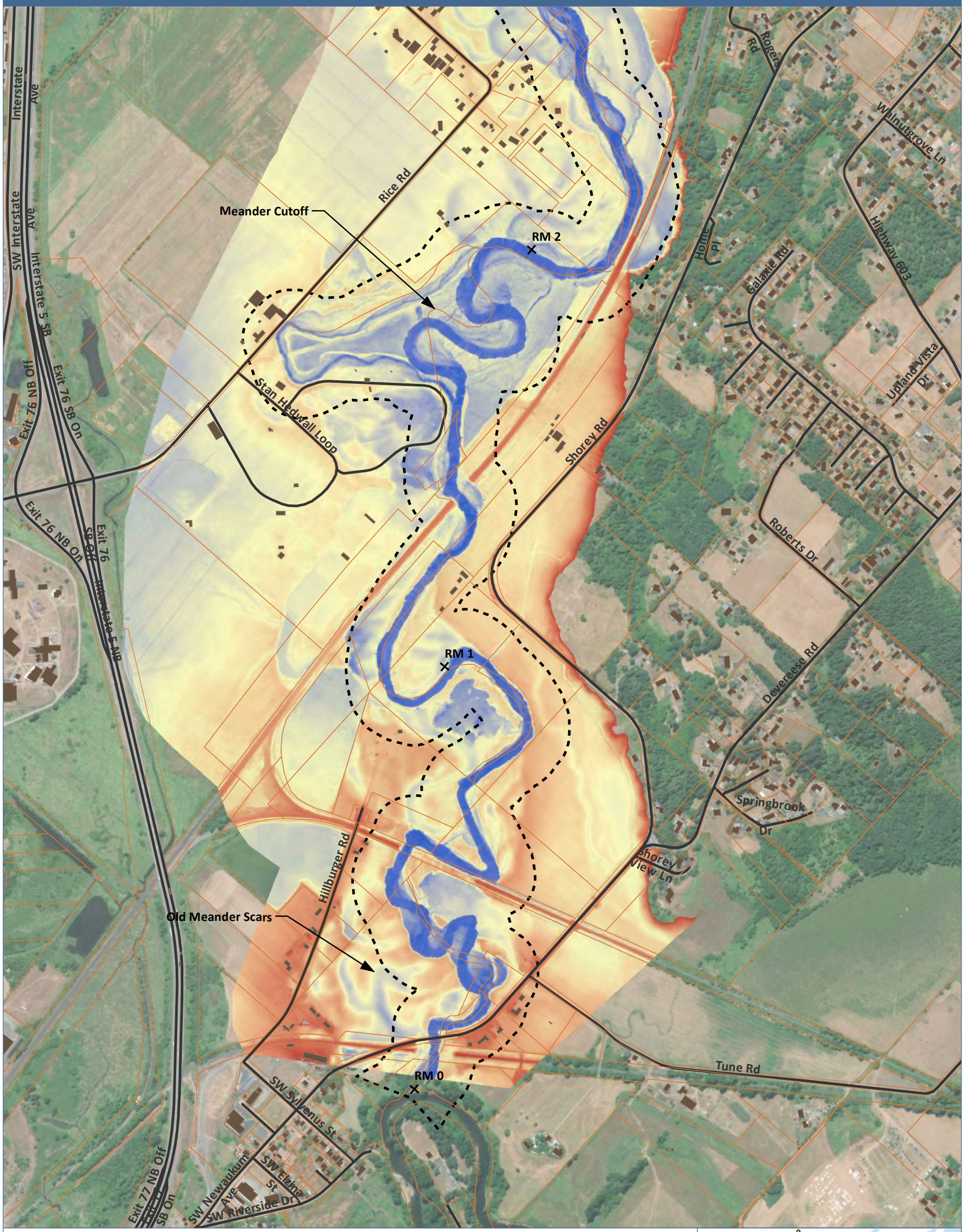


Figure 73
Historical Channel Mapping: Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

Figure 74
Relative Elevation Mapping: Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 75
Historical Channel Mapping: Newaukum River

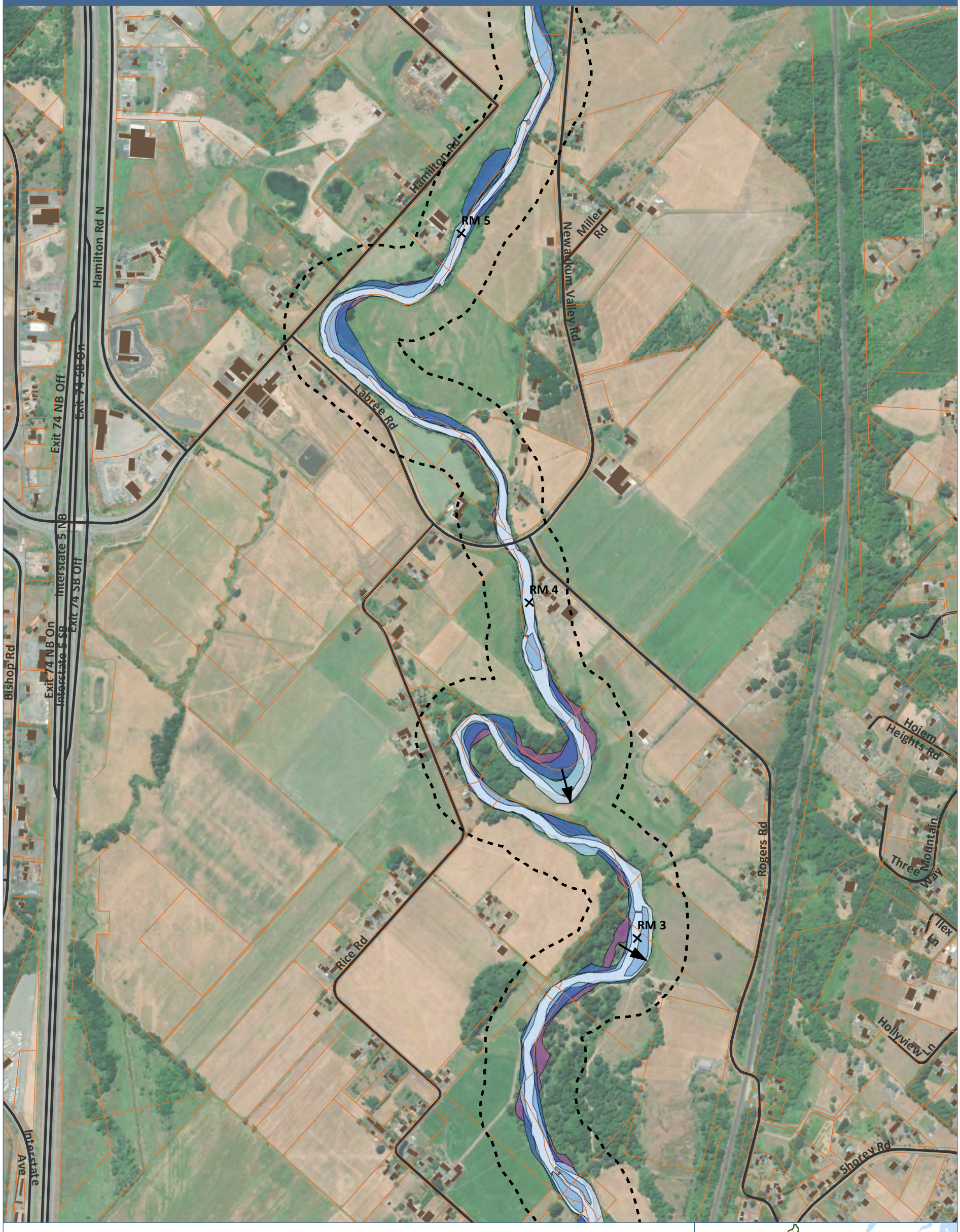
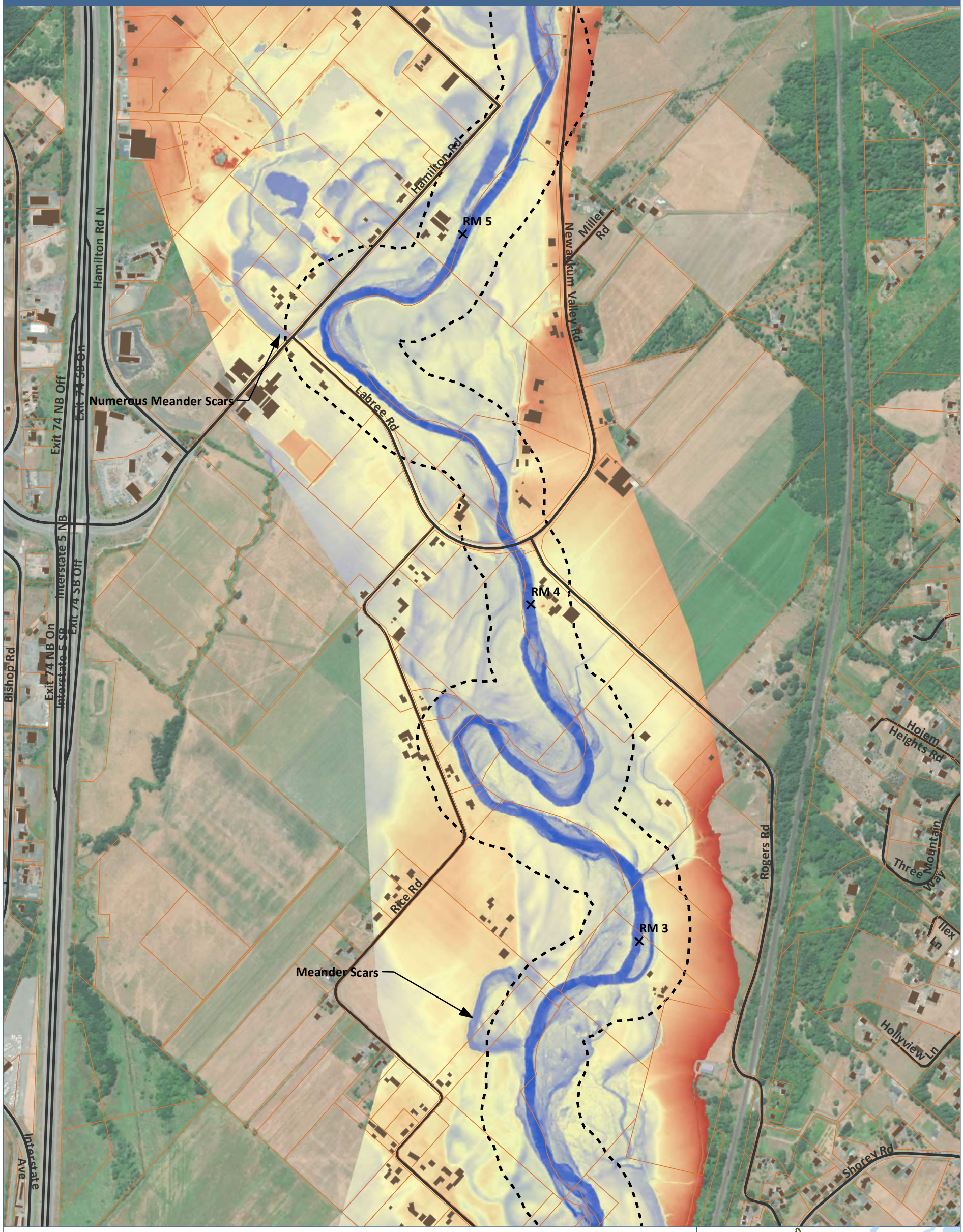


Figure 76
Relative Elevation Mapping: Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 77
Historical Channel Mapping: Newaukum River

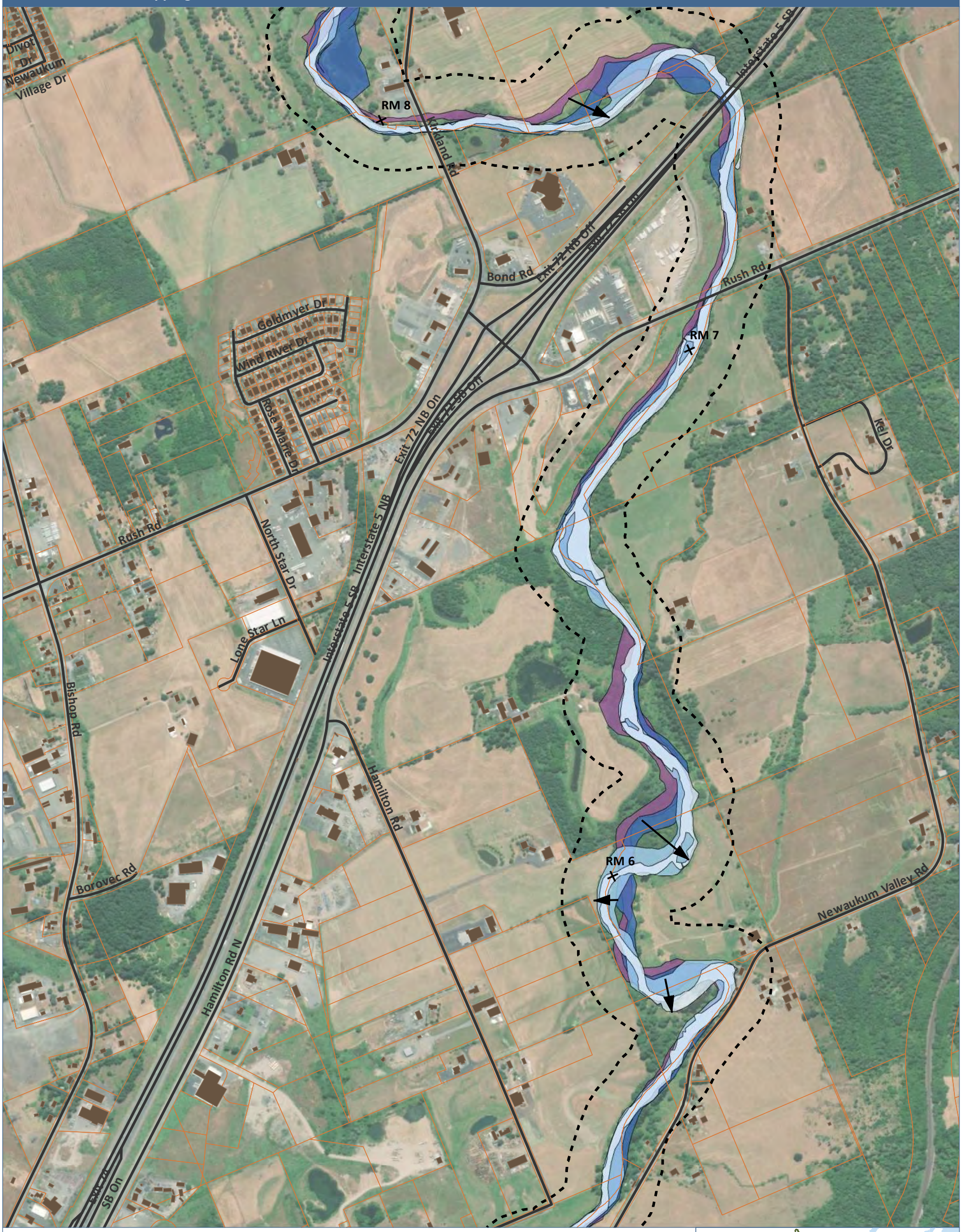
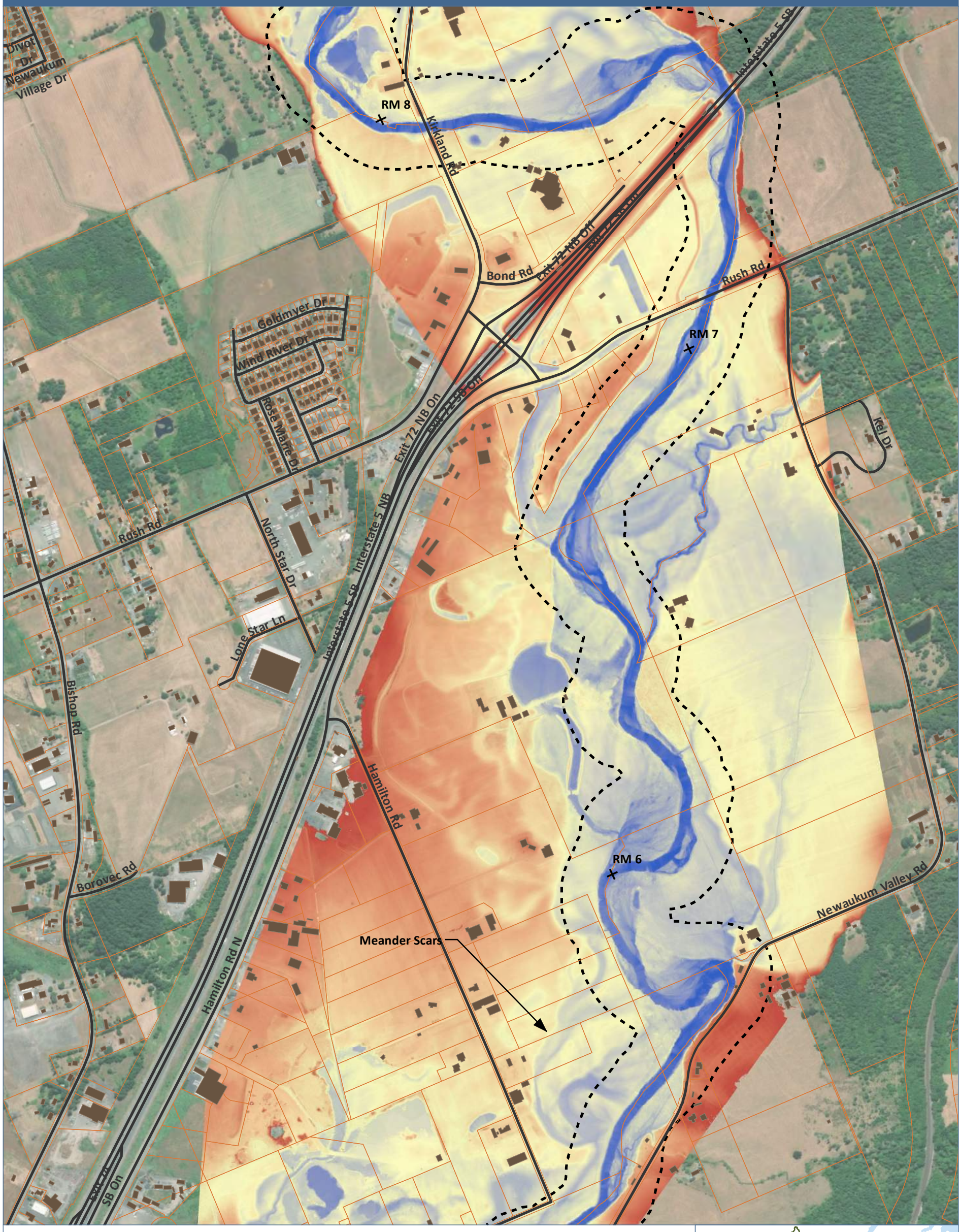


Figure 78
Relative Elevation Mapping: Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 79
Historical Channel Mapping: Newaukum River

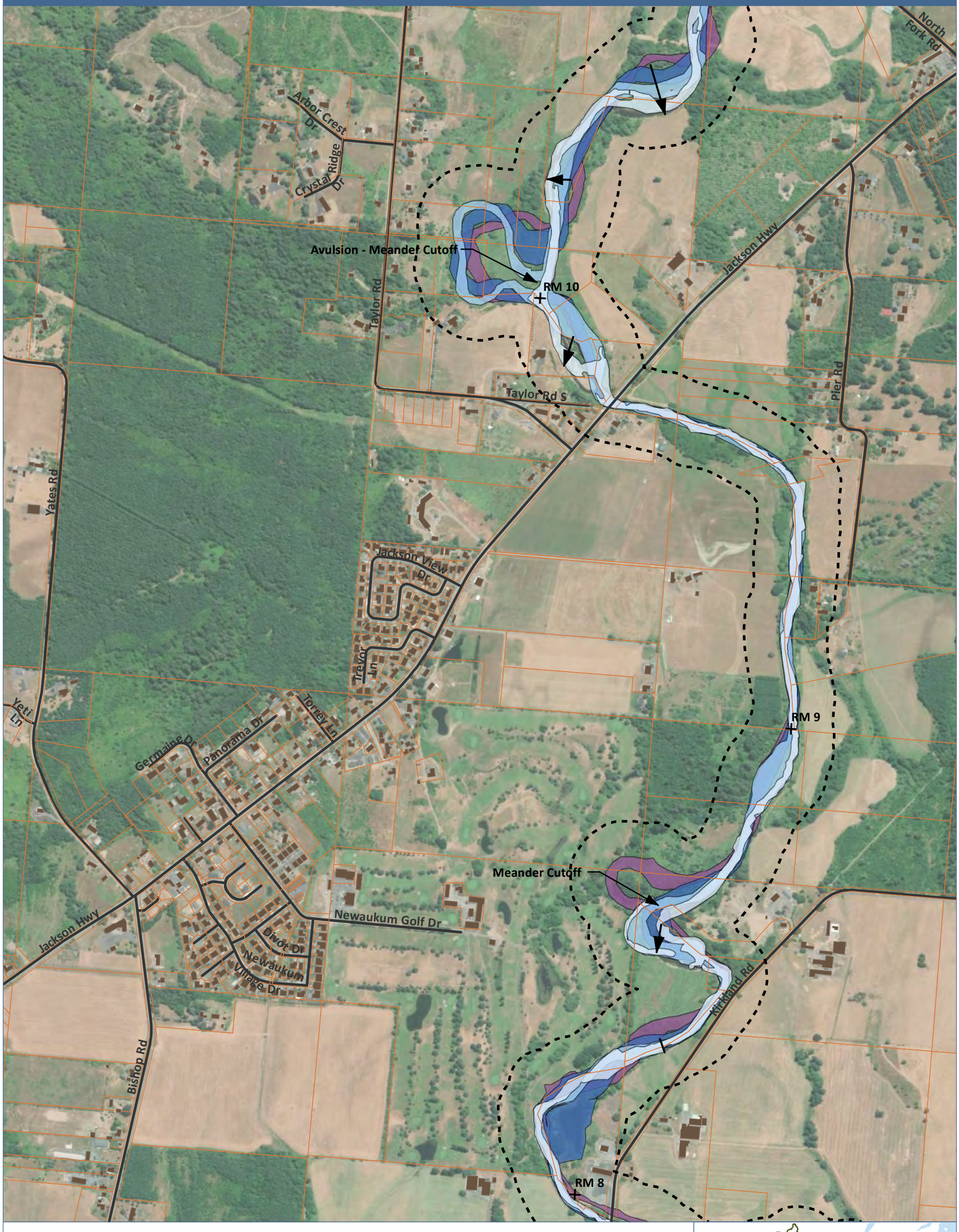
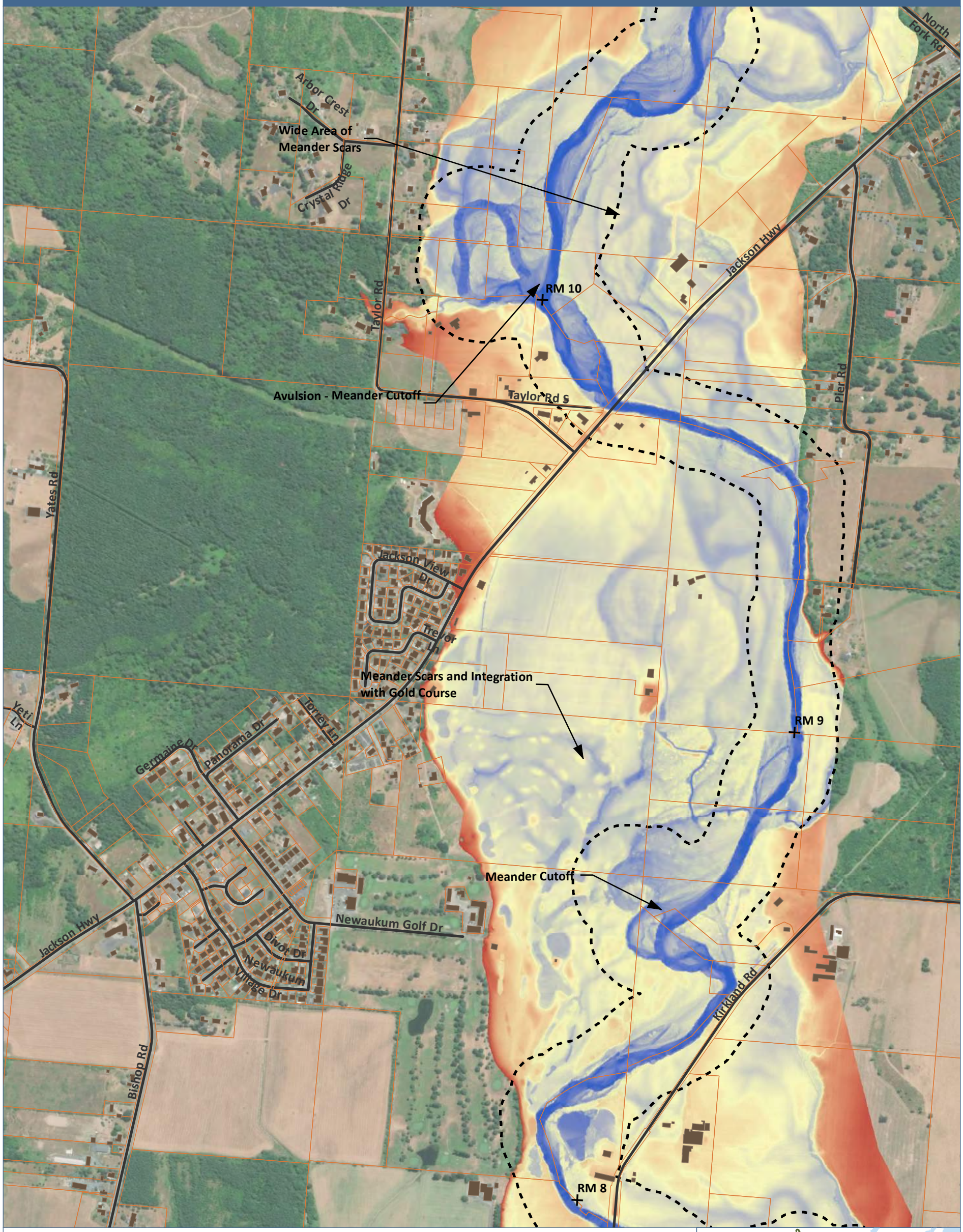


Figure 80
Relative Elevation Mapping: Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 81
Historical Channel Mapping: SF Newaukum River

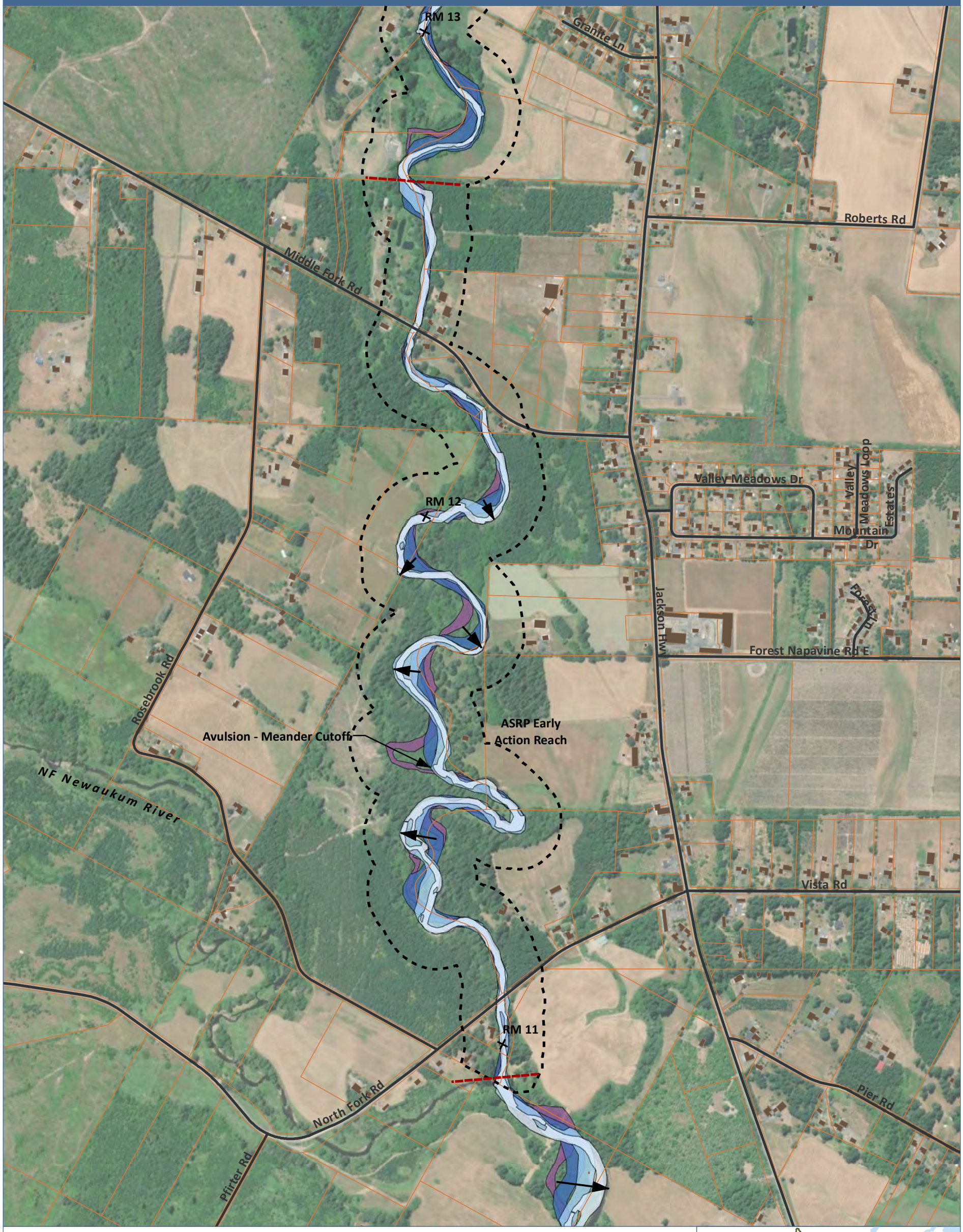
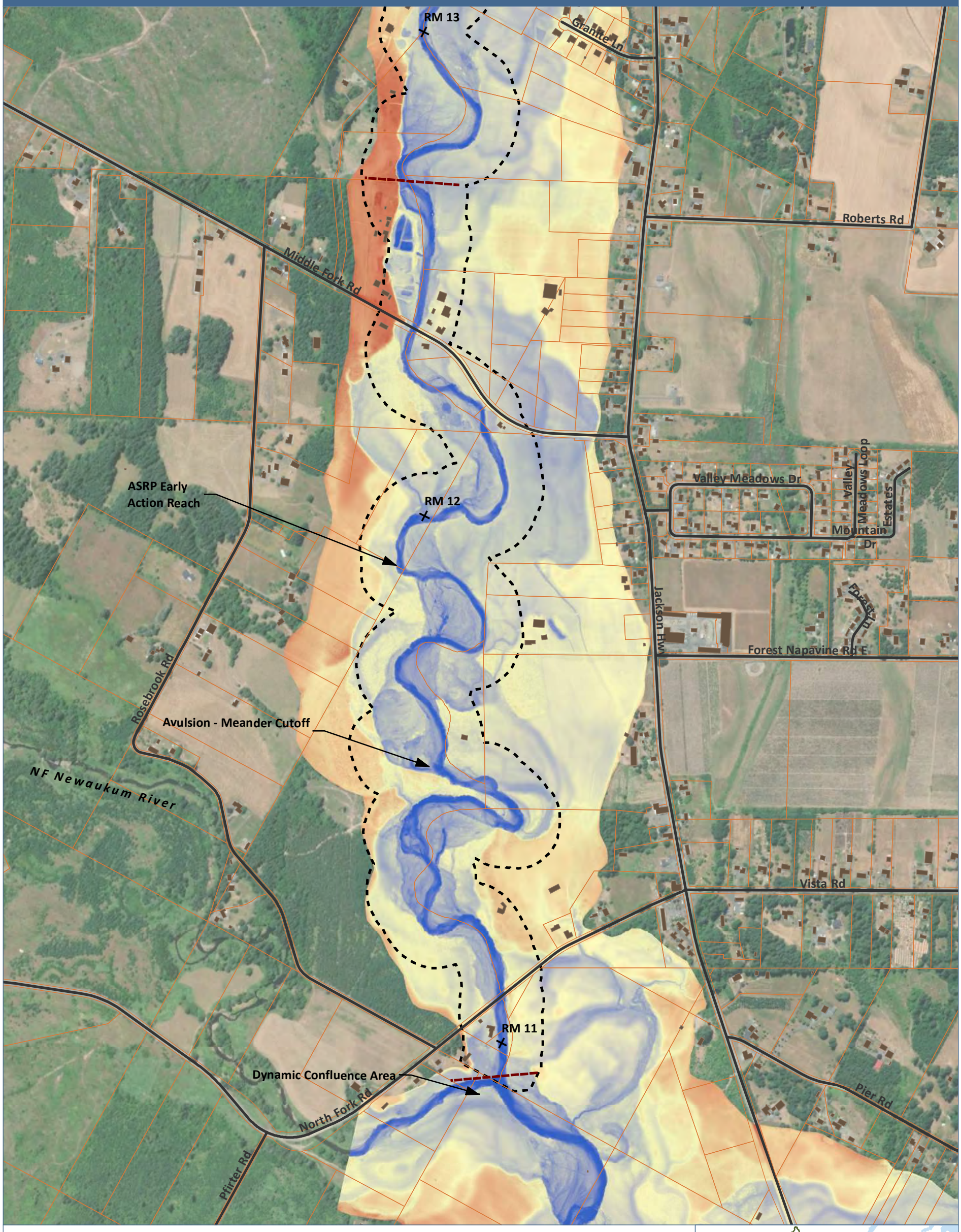


Figure 82
Relative Elevation Mapping: SF Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 83
Historical Channel Mapping: SF Newaukum River

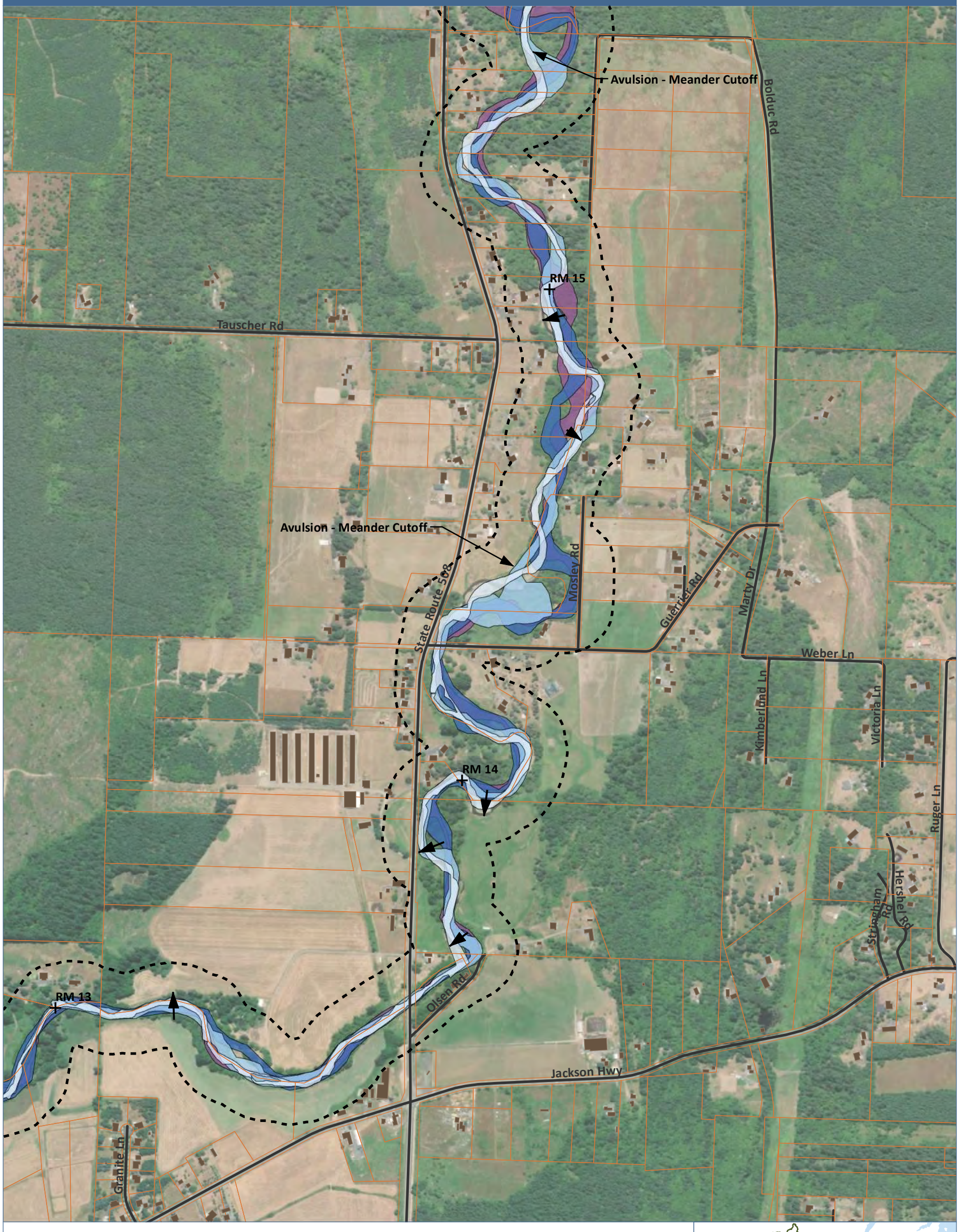


Figure 84
Relative Elevation Mapping: SF Newaukum River

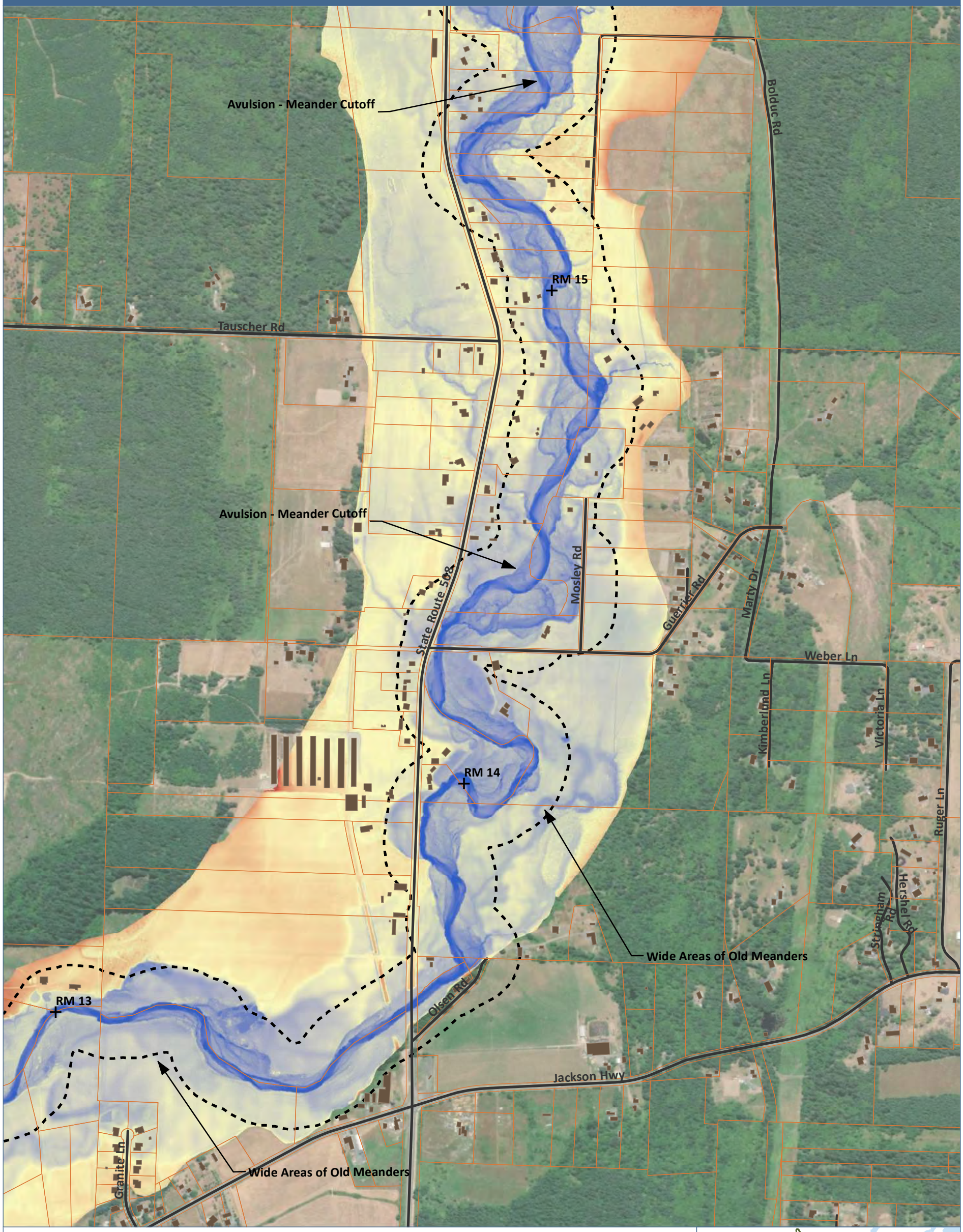


Figure 85
Historical Channel Mapping: SF Newaukum River

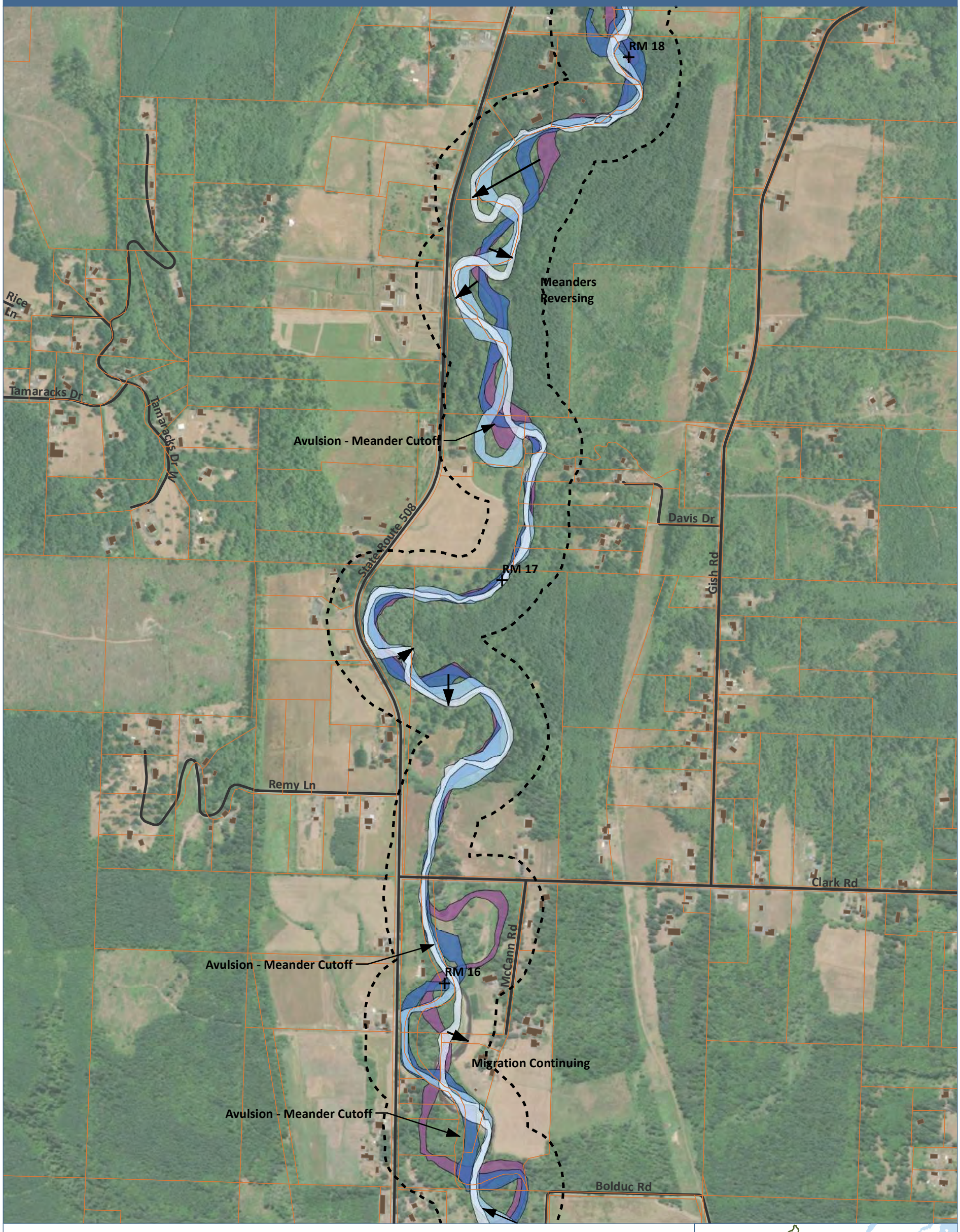
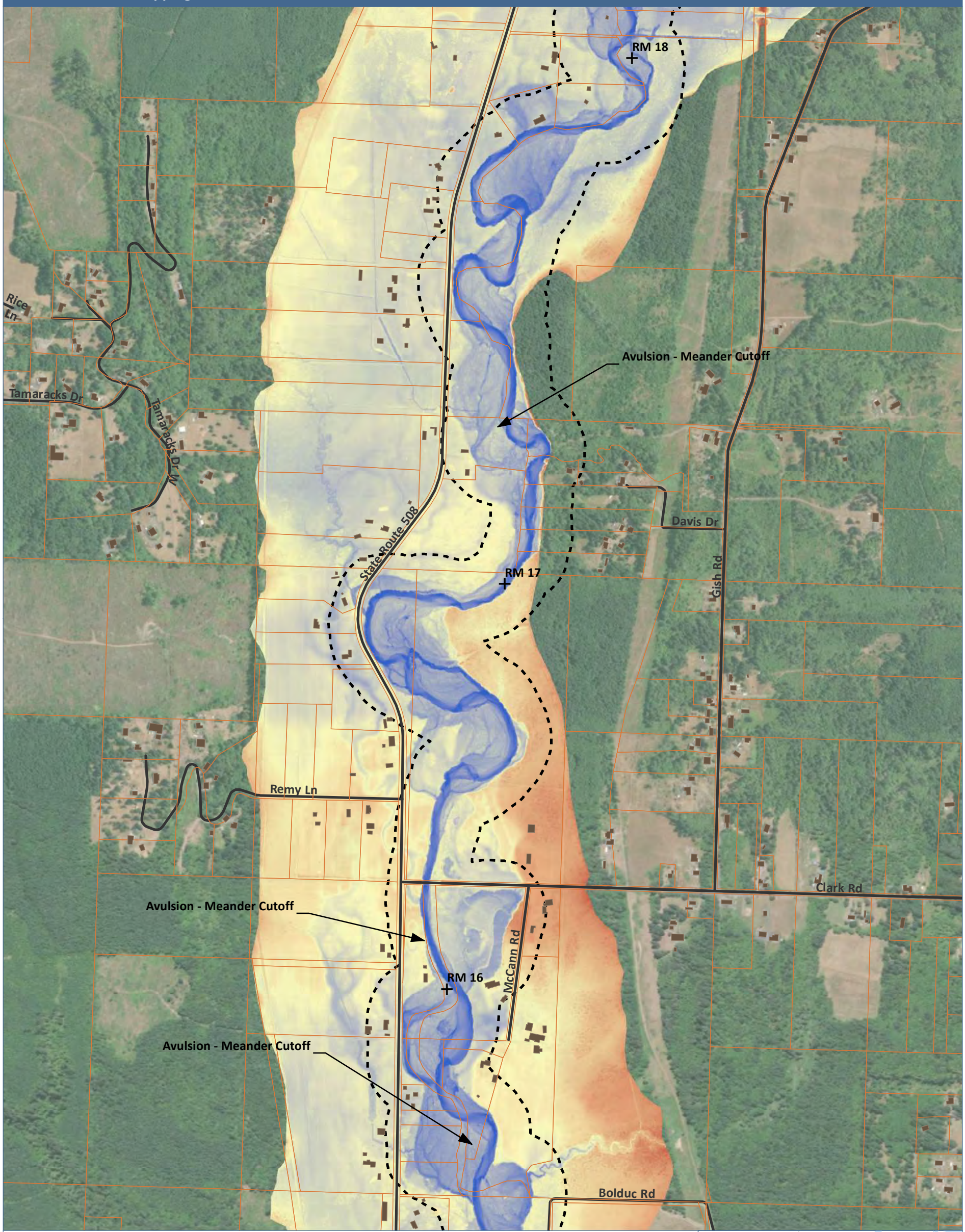


Figure 86
Relative Elevation Mapping: SF Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 87
Historical Channel Mapping: SF Newaukum River

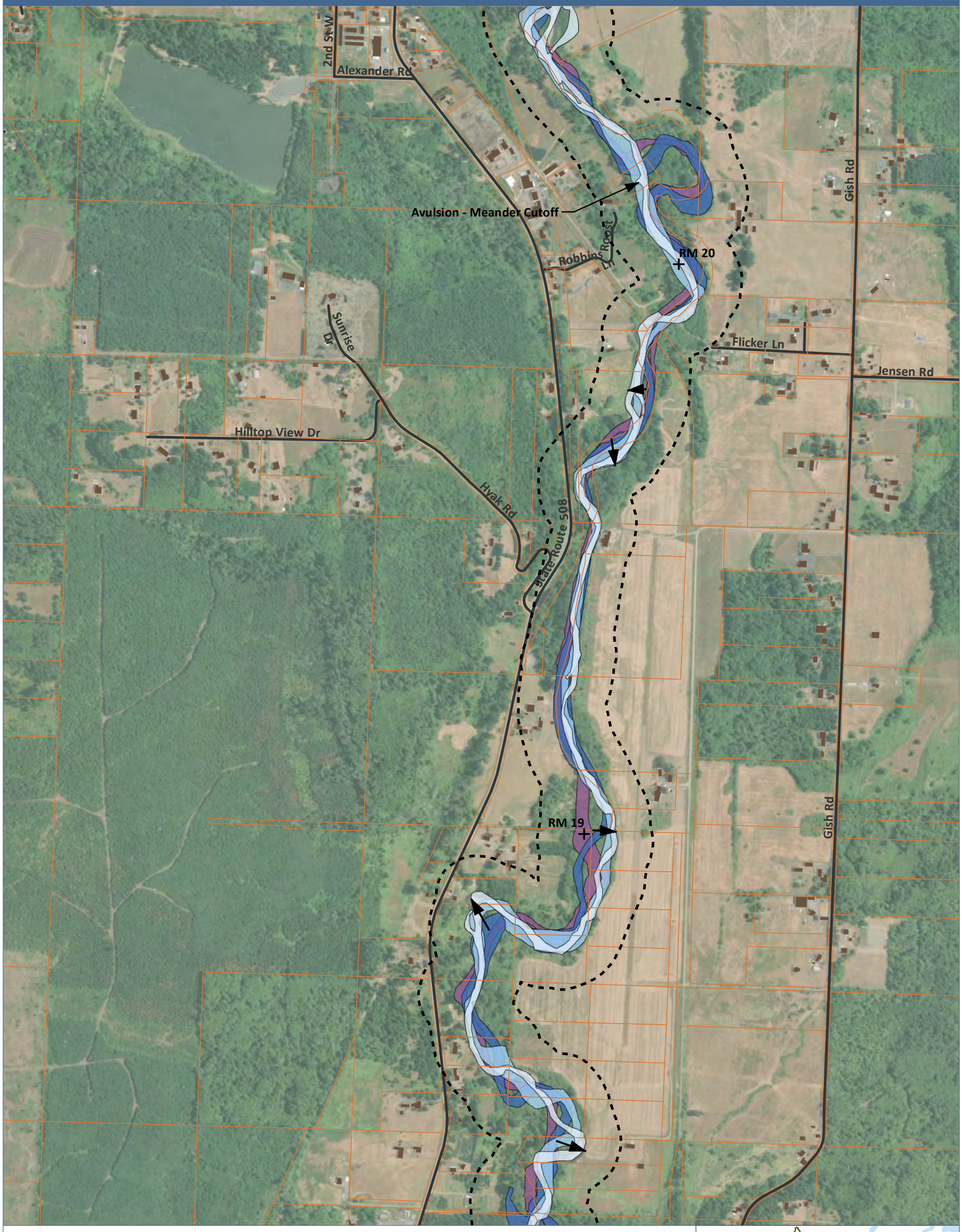
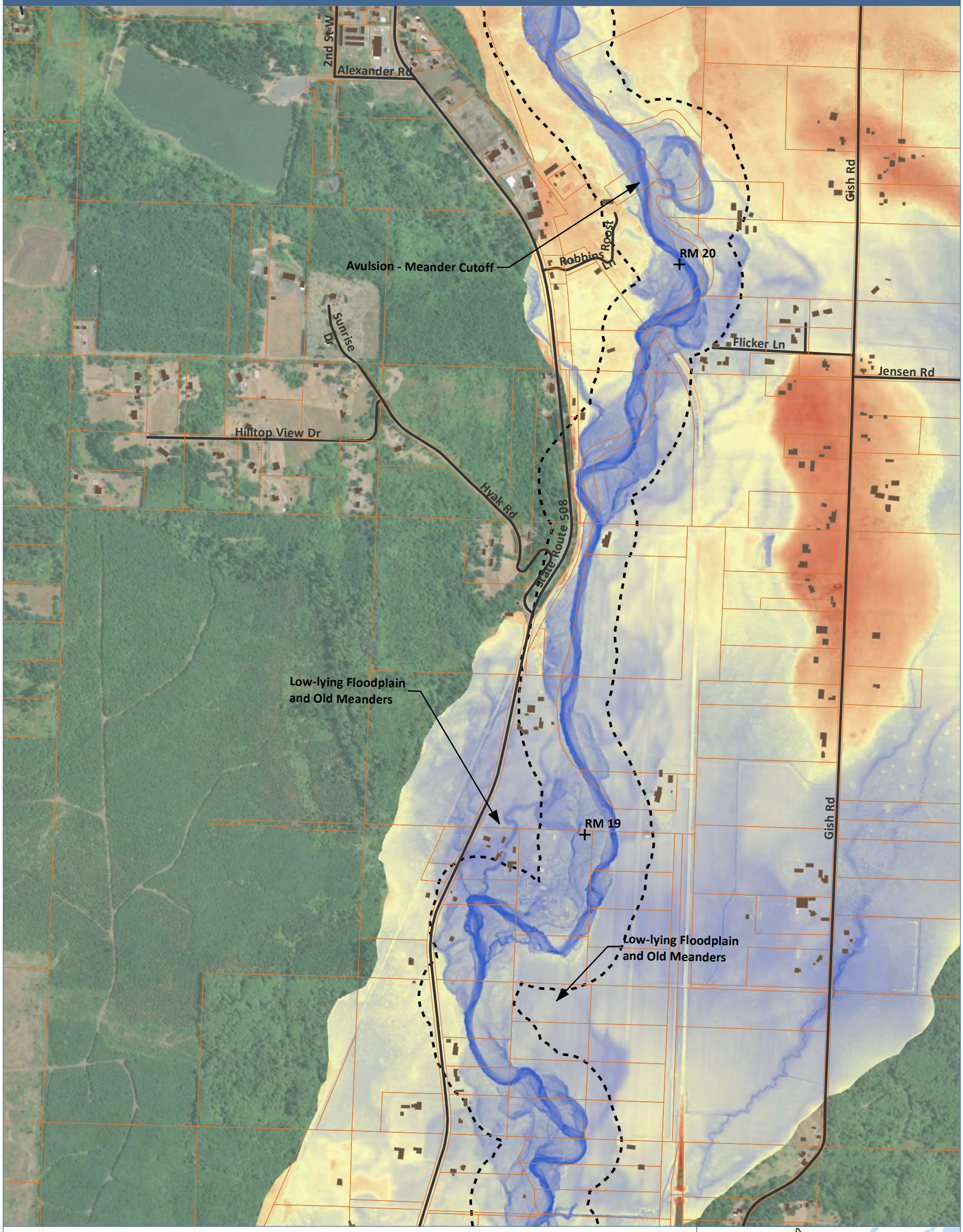
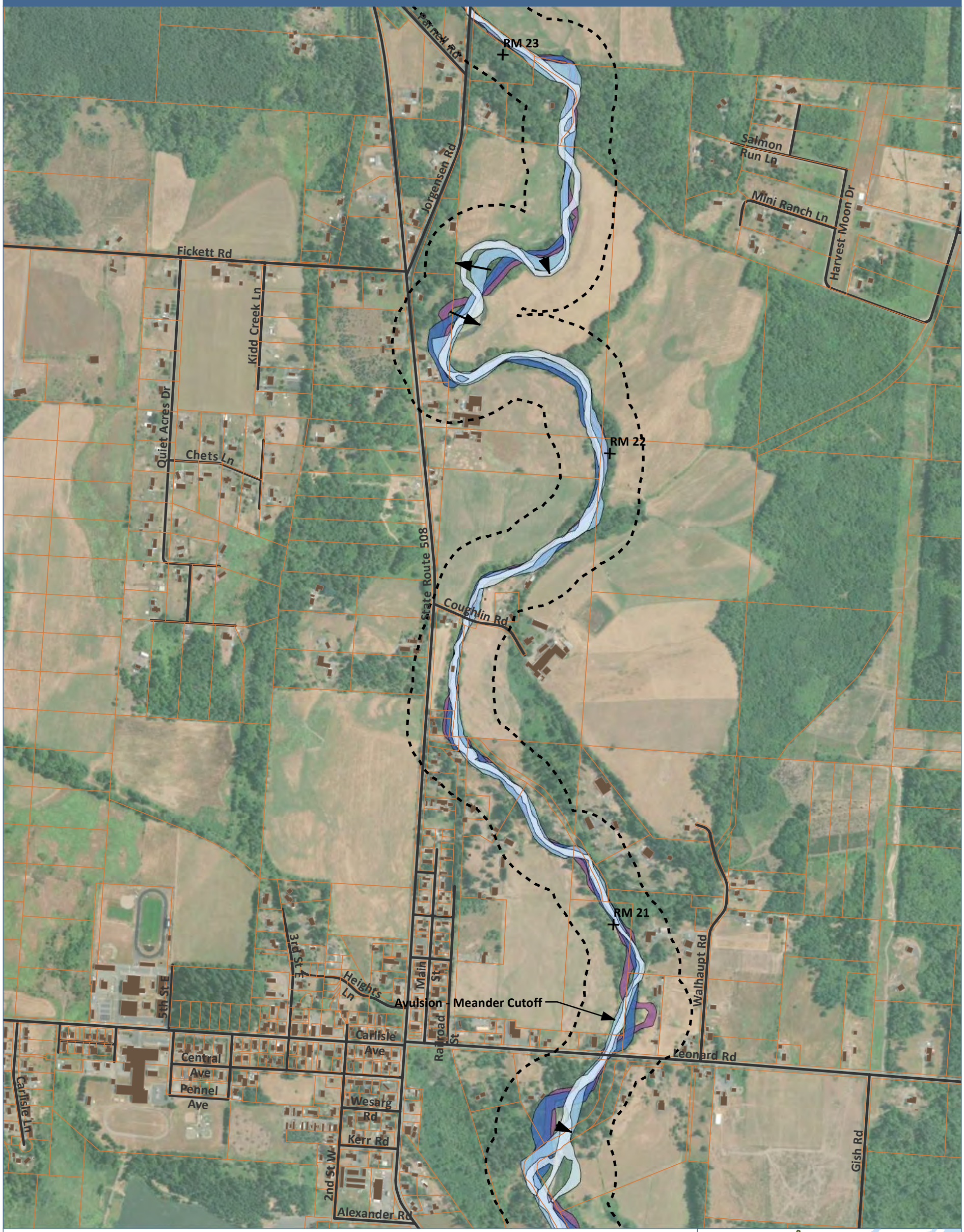


Figure 88
Relative Elevation Mapping: SF Newaukum River



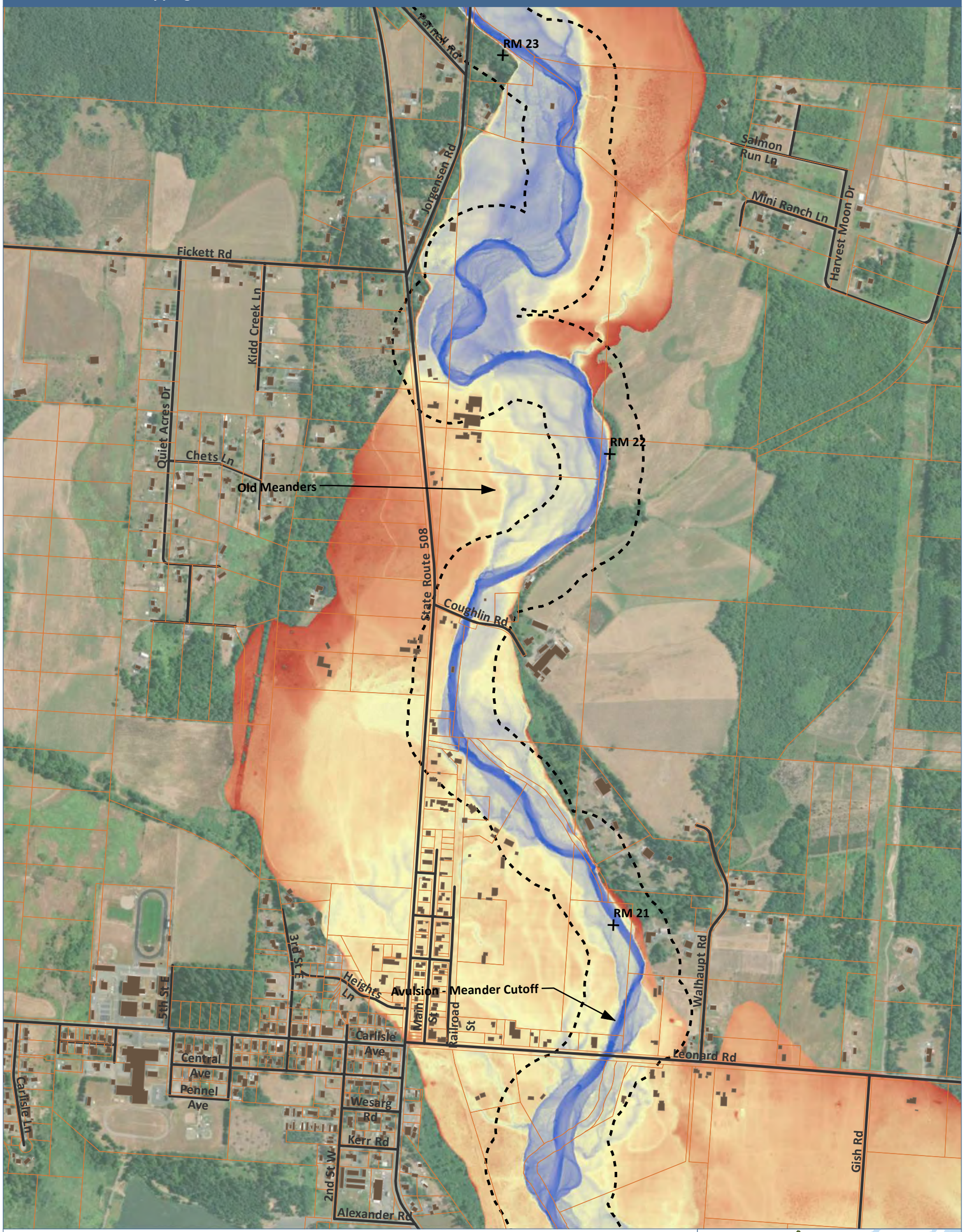
Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 89
Historical Channel Mapping: SF Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.

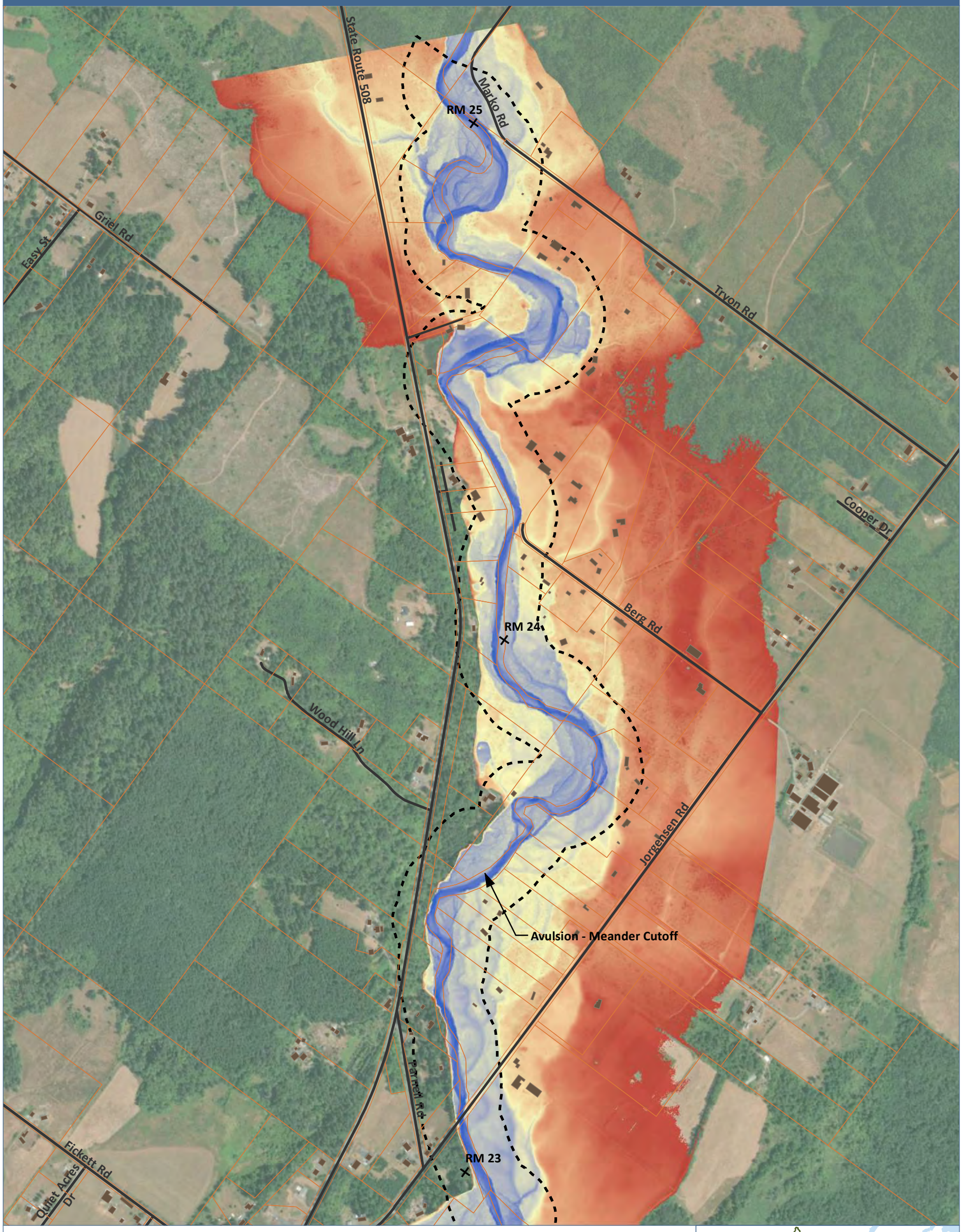
Figure 90
Relative Elevation Mapping: SF Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.

Figure 91
Historical Channel Mapping: SF Newaukum River

Figure 92
Relative Elevation Mapping: SF Newaukum River



Notes:
1. Aerial photo is provided by Esri.
2. Parcel and road data provided by Grays Harbor, Mason, Thurston, and Lewis Counties.
3. Buildings provided by Microsoft. No structure type information provided.
4. Relative elevation mapping based on LiDAR data provided by DNR.