Delineation of the Dungeness River Channel Migration Zone

River Mouth to Canyon Creek



Byron Rot
Pam Edens

Jamestown S'Klallam Tribe

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Cover: Roof of house from Kinkade Island in January 2002 flood (Reach 6), large CMZ between Hwy 101 and RR Bridge (Reach 4, April 2007), and Dungeness River Channel Migration Zone map, Reach 6.

Table of Contents

Introduction

The Dungeness River flows north 30 miles and drops 3800 feet from the Olympic Mountains to the Strait of Juan de Fuca. The upper watershed south of river mile (RM) 10 lies entirely within private and state timberlands, federal national forests, and the Olympic National Park. Development is concentrated along the lower 10 miles, where the river flows through relatively steep (i.e. gradients up to 1%), glacial and glaciomarine deposits (Drost 1983, BOR 2002). The most productive salmonid habitat in the watershed lies within the lower 10 miles (Hirschi and Reed 1998, Mobrand Biometrics 2004).

This delineation of the Dungeness River Channel Migration Zone provides maps of the Dungeness River channel migration zone (CMZ), and the rationale behind those boundaries. The CMZ includes the outer extent of known historic channels, plus potential future migration over the next 100 years. It is the hope of Jamestown S'Klallam Tribe that this product will provide the basis to make informed decisions in terms of planning for riverside development, protecting the public welfare, and providing for resource protection.

How we manage a channel migration zone in a given place has an immediate effect on landowners and salmon habitat in the area. When the Dungeness naturally migrates during a flood, a great deal of flood (erosive) energy is expended as sediment is transported and deposited forming the floodplain. As the river migrates, salmon habitat is created and destroyed. Diking within the CMZ disconnects the river from its floodplain and greatly reduces the creation of salmon habitat. The result of diking is the potential for rapid lateral bank erosion and vertical movement of the riverbed, both across the river from the dikes and down-river. The aerial photo record gives us an excellent record of channel migration and provides clues to how channels have responded to manipulation.

In the Clallam County Critical Areas Ordinance, the channel migration zone is described as the Channel Meander Hazard Zone (CMHZ). The CMHZ was mapped in 1999 by County staff, prior to the availability of Lidar (2002, 2008), prior to significant geomorphic research on the Dungeness (BOR 2002, 2003, 2007 a,b, Collins 2005, Herrera Environmental 2006, 2008), and prior to guidance on CMZ delineation from the Department of Ecology (Rapp and Abbe 2003, Bona and Reinhart 2005). The existing Clallam County Channel Meander Hazard Zone map roughly estimates CMZ boundaries; this report provides a much more accurate update.

Legal requirement for CMZ's

In addition to using this CMZ delineation to update the Clallam County Critical Areas Ordinance (CAO), the State Shorelines Management Act states that "*applicable shoreline master programs should include provisions to limit development and shoreline modification that would result in interference with the process of channel migration that may cause significant adverse impacts to property or public improvements and or result* *in a net loss of ecological functions associated with the rivers and streams." In addition "the channel migration zone would be established to identify those areas with a high probability of being subject to channel movement based on historic record, geologic character, and evidence of past migration. It should also be recognized that past action is not a perfect indicator of the future and that human and natural changes may alter migration patterns. Consideration should be given to such changes that may have occurred and their effect on future migration patterns* (Chapter 173-26, WAC 58). Delineation of Channel Migration Zones is required under the State Shoreline Master Program. Clallam County is planning to update their Shoreline Master Program in the near future.

Further to reduce Flood Hazards (Chapter 173-26-221 (3)), *nonstructural measures should be preferred over structural measures. Land use and related regulations and zoning should reflect the natural constraints of the Dungeness River flood plain, meander zone and riparian habitat zone. Changes in land use should try to restore the natural character of the river to the pre-degradation state whenever possible.*

Finally, the WAC further defines which dikes are considered to large enough to truncate the CMZ (WAC 173-26-221(3)(b). *Outside incorporated municipalities and urban growth areas, channel constraints and flood control structures built below the one hundred-year flood elevation do not necessarily restrict migration and should not be considered to limit the channel migration zone unless demonstrated otherwise using scientific and technical information.*

Terminology used in this report

Most of these terms were originally defined in Rapp and Abbe (2003); some are further described by the author and others.

Active channel: is the portion of a channel that is largely unvegetated at least for some portion of the year, and inundated at times of high discharge (Rapp and Abbe 2003 from Montgomery and MacDonald 2002).

Avulsion Hazard Zone (AHZ): is the area at risk of rapid channel occupation. While channel avulsions also occur within the Historic Migration Zone (HMZ), the AHZ is mapped landward to the HMZ and includes such portions of the river landscape as relic channels and swales. We focus on these features because steep rivers prone to avulsion (like the Dungeness) commonly avulse down these low places in the floodplain. In this case, a new channel initiates at the downstream end and migrates (headcuts) up until it intersects with the river. The magnitude (depth) and duration of the flood are important factors in whether the headcut fully migrates to the mainstem.

Not all relic channels or swales are part of the AHZ because some of these features were apparently relic channels from earlier hydrologic eras. In this report, the AHZ is shown on maps as a hatched area or with arrows indicating likely migration pathways.

Channel Migration Zone (CMZ): is the area where the river channel has occupied in the past and other areas it is likely to occupy in the future. For this report, our planning horizon is 100 years, roughly the amount of accurate historical channel information. The CMZ is the sum of the AHZ, HMZ, and EHA.

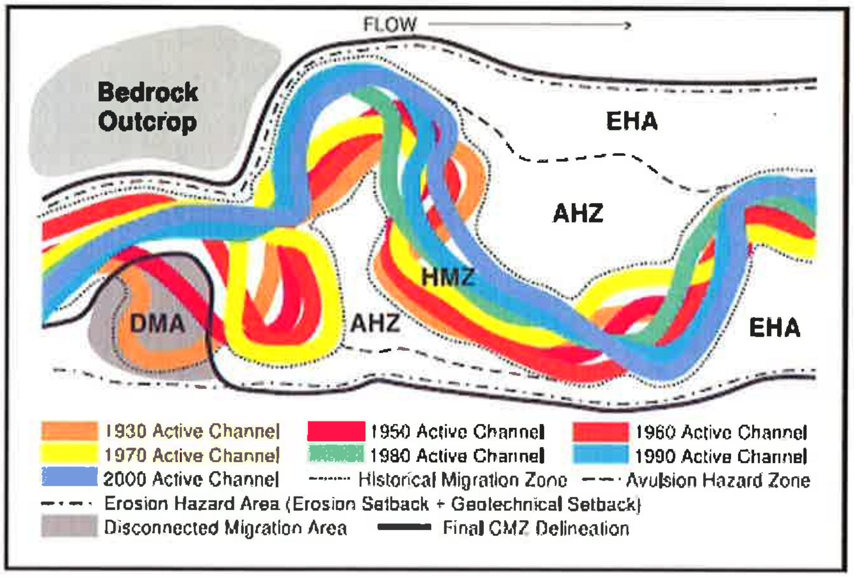

Figure 1. An example of the CMZ as the cumulative product of the Historical Migration Zone (HMZ), the Avulsion Hazard Zone (AHZ), the Erosion Hazard Area (EHA), and the Disconnected Migration Area (DMA) based on historical and field analysis and interpretation

Figure 1. An example of the CMZ, mathematically the CMZ = HMZ + AHZ + EHA (figure from Abbe and Rapp 2003, used with permission from the Department of Ecology).

Where dikes and other bank armoring meet the Shorelines legal definitions, the CMZ becomes: CMZ=HMZ+AHZ+EHA-DMA.

***Disconnected Migration Area (DMA)*:** are areas physically disconnected from the CMZ by man-made constraints that meet Shoreline Management Plan criteria: "*a legally existing artificial structure that is likely to restrain channel migration, including transportation facilities, built above or constructed to remain intact through the 100 year flood.*" (WAC 173-26-221(3)(b)). In general, these are revetments that are designed, installed and maintained by a public agency such as the Army Corps of Engineers or Clallam County. The floodplain behind dikes that do not comply with the above requirements are not to be included in the DMA. Thus the criteria for a DMA are that the structure is legal, prevents the 100-year flood event, and has demonstrated maintenance.

***Erosion Hazard Areas (EHA)*:** is the area susceptible to bank erosion. It is part of the CMZ unaccounted for in the AHZ and HMZ. The EHA consists of the Erosion setback (ES) and the geologic setback (GS). The ES is the amount of erosion outside of both the HMZ and AHZ that is expected to occur over the 100 year planning period. The GS is the erosion that will occur on bluffs. The GS is added to the ES to form the EHA.

Floodplain vs. channel migration zone: the geomorphic floodplain is a landform that is created by the river through the transport and deposition of sediment. Floodplains come at varying heights above the riverbed and can be described by flood return intervals; for example the 100-year floodplain is flooded during a 100-year event (and not a smaller flood). The geomorphic floodplain is bounded by valley walls, bluffs, or other confining features.

In contrast, the Channel Migration Zone describes historic channels and areas that have potential for future channel movement. The CMZ can extend outside of the geomorphic floodplain, for example when the river is eroding against a bluff (GS). More commonly the CMZ is contained within the geomorphic floodplain, however often extends beyond the federally (FEMA) designated 100-year floodplain (Patricia Olson, personal communication). The CMZ delimits an area where river channels may be located in the future, the 100-year floodplain describes an area that will flood during a 100-year flood event.

Historical Migration Zone (HMZ): the area the channel has occupied over the course of the historical record and is delineated by the outermost extent of these channels plotted over that time. The HMZ includes active side channels.

Wandering Channel: includes meandering, straight, braided and anabranching (multiple, interconnected, coexisting channels generally separated by stable vegetated alluvial floodplain islands) channels. Braided channels also have multiple channel patterns, they often change position abruptly both vertically and laterally, and contain islands not necessarily forested or stable.

Geologic setting

Sedimentary rock, glacial deposits, and marine basaltic lava flows underlay the river in the upper watershed (BOR 2002, Schasse 2003). Roughly 17,000 years ago, continental glaciers advanced to their maximum extent into the upper Dungeness watershed to an approximate elevation of 3200 ft in both the Dungeness and Gray Wolf Rivers. The glacial ice dammed the river and formed lakes that trapped relatively deep layers of fine sand, silt, and clay. Larger gravel to boulders was also pushed into the upper watershed by the glaciers (BOR 2002).

In the lower watershed (below RM 10), the valley widens and encompasses the present day river floodplain and paleo-floodplain. As the continental glaciers receded north, the lower Dungeness River successively incised into and abandoned three paleochannels north of Hwy 101 (moving from east to west across Dungeness valley) in present day Bell Creek, Gierin Creek, and Casselary Creek (Collins 2005). There is some evidence that the Dungeness River has occupied its current delta for as little as 400 years (Collins 2005).

Channel gradient through the anadromous reach (up to RM 18.7) exceed 1%, with gradients dropping below 1% only from approximately RM 3.0 to the mouth. Geology of the lower 10 miles is Holocene alluvium (Schasse 2003). Development and the most productive salmonid habitat are concentrated along the lower 10 miles of the river.

The Bureau of Reclamation (BOR 2002) identified the following sources of coarse sediment that could affect channel morphology in the lower watershed. Approximately 15% of the basin's surface area is ***steep alpine*** with extensive talus fans forming at the mountains base. An undefined, but substantial amount of coarse sediment exists in these fans. However, beneath and downriver of the fans the channels are generally narrow and do not exhibit braiding patterns indicative of high sediment loads (BOR 2002). Basin-wide natural ***forest wildfires*** occurred in A.D. 1308, 1508, 1701, and seven human-caused forest fires occurred from 1860-1925 (Dungeness Watershed Analysis Team 1995). Each fire could result in a significant sediment pulse in the years following those events. The five fires occurring between 1860 and 1902 (with 1890 as the most severe) may have contributed to the 1914 channel showing remarkably different form than from the 1940's to present. ***Older alluvial*** deposits are reactivated by the river through bank erosion and bed degradation. The river has down-cut through older alluvium two to three times in the past 500 years leaving distinct terraces. This potentially is a large sediment source to the lower river (BOR 2002). The Bureau disagreed with a published study that attributed a high ***glacial*** sediment load to the Dungeness (Golder Associates 1993), stating that the watershed glaciers are small and observed background turbidity due to glacial flour is low. Finally several large ***landslides*** (Silver Creek, Gold Creek, Forest Service Road 2650) caused by failing culverts or road prisms have locally been considered important sources of sediment. Since the majority of these landslides are in fine-grained glacial and lacustrine sediments, the Bureau did not consider landslides a major source of coarse sediment. The most consistent coarse sediment sources are alpine deposits, and older alluvial deposits. Forest fires could provide episodic sediment pulses.

Dungeness flooding history

The Dungeness River basin has a fall rain/spring snowmelt (bi-modal) hydrology. Peak flows occur with fall rains, winter rain on snow, and less frequently spring runoff. In the Dungeness River, overbank flooding occurs above 3000 cfs (England 1999, updated 2006). The flood of record was roughly a 45 year flood event (Table 1), with the 100 year flood estimated at 9080 cfs (England 2006). Please note that the flood return interval is a probability estimate, the 100-year flood has a 1% probability of occurring each year, the 5 year flood has a 20% probability of occurring each year. Scientists believe that as the climate changes, floods will become more frequent and that the historic record will not be accurate to predict future flooding.

Table 1. Top ten Dungeness River annual peak flows, USGS gauge (RM 11.8)

Date	Discharge (cfs)	Approximate return interval (yrs)
January 7, 2002[1]	7610	25-50
November 24, 1990	7120	10-25
November 27, 1949	6820	10-25
November 3, 1955	6750	10-25
January 18, 1986	6560	10-25
February 11, 1924	6340	10-25
March 19, 1997	5990	10-25
October 20, 2003	5920	10-25
January 15, 1961	5900	10-25
November 15, 1983	5510	5-10

[1] Flood of record

Data Sources

Historical aerial photos from 1942-2005 were utilized to map the Historical Migration Zone (HMZ, Table 2, Figure 2), along with active side channels mapped from field investigation in 2005. An 1855 map was also used to help map the HMZ near the river mouth. To map the Avulsion Hazard Zone, we used the 1914 Clallam County Tax Assessors map, a current Tribal map of inactive side channels, and LiDar (Table 2). The 1914 map was not used for the HMZ due to questions regarding survey accuracy. There were substantial border inconsistencies between individual survey maps near the present RR Bridge and Powerlines. The 1914 channel through the Powerlines reach especially did not fit the current landscape. Where the 1914 map followed swales displayed in LiDar, it was deemed accurate enough to use for the AHZ; however we needed higher standards for the HMZ in order to use that data to calculate the Erosion Hazard Areas. Despite its shortcomings, the 1914 map provides an fascinating record of the extent of the 1914 active mainstem, side channels, and flood channels (e.g. Figure 3).

Jamestown S'Klallam Tribe has flown the Dungeness River corridor (1:6000) every year since 1994. The Bureau of Reclamation used the 1994 and 2000 photo sets for their Dungeness geomorphic study (BOR 2002); the 2005 orthophoto set was added to help identify channel movement resulting from the 2002 flood of record. All aerial photos were orthorectified, either by the U.S. Bureau of Reclamation (BOR 2002, 2003), University of Washington (Collins 2005), or by Jamestown S'Klallam Tribe (JKT). The 1914 tax map was rectified by the University of Washington using map section lines, roads, and other identifiable features (Collins 2005).

Table 2. Historical aerial photos, LiDar and maps

Year of flight	Vendor	Scale	Type	Channel delineated by
2008	JKT	--	LiDar	--
2005	WDNR	Orthophoto 1:12,000	Color	JKT
2001	Clallam County	--	LiDar	--
2000	JKT	1:6,000	Color	BOR
1994	JKT	1:6,000	Color	BOR
1985	WDNR	1:12,000	B/W	JKT
1965	WDNR	1:12,000	B/W	BOR
1942	Dept of War	1:20,000	B/W	BOR/JKT
1914	Clallam County	--	Survey drawings	UW
1870	UW	--	U.S. Coast and Geodetic Survey T-sheets	UW
1855	UW	--	U.S. Coast and Geodetic Survey T-sheets	UW

Dept of War — Army Corps of Engineers
JKT — Jamestown S'Klallam Tribe
UW — University of Washington Puget Sound River History Project
WDNR — Washington Department of Natural Resources

Sources of error and report limitations

There are several sources of error in this delineation of the channel migration zone. Aerial photos are distorted at the photo edge. Combining many aerial photos into a master photo can introduce error. Aligning these photos so they accurately represent ground distances can introduce error (rectification), as can the interpretation of where a channel edge is located (digitizing). Using similar strategies, an analyst for a study of basins in Hood Canal, concluded remaining error on the order of 100 ft. (Klawon 2004). The primary author has a good knowledge of this watershed; he has walked the entire anadromous reach of the river (18 miles on the Dungeness) at least once a year for the past 8 years. Our strategies to maintain high quality and accuracy of this report are discussed in the next section.

Any omissions or errors are those of the primary author. Neither authors are licensed geologists; this report is intended solely to update the Clallam County Critical Areas Ordinance and the Shoreline Management Plan, and to provide general information to the public. The report is not intended for site-specific design purposes, for example a landowner attempting to find a safe place to build a house near the Dungeness River should consult with a licensed geologist or engineer that specializes in river geomorphology.

Geomorphic reach delineation

The project area extends from the mouth of the Dungeness River to Canyon Creek (RM 10.5), just upriver of the Dungeness Hatchery. This area encompasses all of the non-federal floodplain development in the Dungeness River. Six reaches were delineated. Reaches were broken at major infrastructure and/or geomorphic boundaries (Table 3).

Table 3. Dungeness River CMZ reaches.

Reach	Reach description	River mile	Geomorphic Type	Sediment regime	Comments
1	Mouth to Schoolhouse Bridge	0 to 0.7	Delta-Alluvial fan	depositional	Modern delta (Collins 2005)
2	Schoolhouse Bridge to upstream end of ACOE dike	0.7 to 2.7	Wandering River	depositional	Historic delta (Collins 2005, BOR 2002). Fully diked on the east bank and diked or confined by a resistant clay terrace on the west bank.
3	ACOE dike to Burlingame Bridge	2.7 to 4.0	Wandering river	depositional	The relatively steeper upriver channel gradient flattens near Burlingame Bridge (BOR 2002).
4	Burlingame Bridge to lower end of Dungeness Meadows dike	4.0 to 7.5	Wandering river	Transport-depositional	Mostly undiked (one small dike at RR Bridge) and minimal bank armoring. Lower ½ of reach is good remnant salmon habitat.
5	Lower Dungeness Meadows dike to May Rd	7.5 to 9.2	Straight and Entrenched	Transport-depositional	Historic Wandering River Reach. Reach approximately 25% diked or bank armored (BOR 2003).
6	May Rd to Canyon Ck	9.2 to 10.5	Wandering river	Transport-depositional	An alluvial fan at the south end of Dungeness valley as it exits the more confined mountain valley. It has some diking and many side channels.

CMZ delineation methods and results

Historical Migration Zone (HMZ)

The Historic Migration Zone (HMZ) was a map/aerial photo office interpretation exercise plus field visits to map active side channels (Figure 2). The active channels were mapped for all the photo and map sets in Arcview GIS. The Bureau of Reclamation mapped the active channel for 1942, 1965, 1994, and 2000. Jamestown S'Klallam Tribe mapped active channels for 1914, 1985, 2005, and 2005 active side channels. University of Washington mapped 1855 and 1870 channels at the mouth.

Avulsion Hazard Zone (AHZ)

After defining the HMZ, then the Avulsion Hazard Zone (AHZ) was delineated (Figure 2). Utilizing the 2005 aerial photos and the Clallam County 2001 LiDar, we located relic channels and swales located outside of the HMZ. Abandoned flood channels and swales were identified as potential avulsion pathways. Potential avulsion zones were first identified in the office, and then field checked by examining local topography and soils. We also utilized data collected following the 2002 flood of record flood for flow patterns across the floodplain (Hagen 2002a). All these sites were visually checked in the field. A final check utilized the high definition LiDar flown in 2008.

Avulsion hazard zones were divided into two types; one was mapped as a hatched area, (avulsion hazard) and the second by avulsion pathways (Figure 2). The hatched areas were generally smaller in size or with limited exposure to infrastructure or development. While no level of risk was established, these areas could potentially be occupied by the river during any of the flood events listed in Table 1 and should be considered Moderate to High Avulsion risk. Avulsion pathways are also within the AHZ, but are swales with exposure to infrastructure or development. These pathways are further defined to the relative avulsion risk.

Avulsion pathways with **High** avulsion risk are those areas that have frequently flooded in the recent past, or in one case is a side channel that is expanding. These are also identified as high risk in other geomorphic studies. The pathways with High avulsion risk are Kinkade side channel (Figure 2, Reach 6), Independent ditch outtake (Figure 2, Reach 5), near Hurd Creek Hatchery (Figure 2, Reach 3), and Rivers End (Figure 2, Reach 1). The one side channel identified as High risk (Kinkade Creek) is within the HMZ, but is included here to highlight public risk. These are avulsions that can be expected with any large flood event, such as those on Table 1.

Avulsion pathways with **Moderate** avulsion risk are those areas that appeared to be side channels or flood channels during the photo record of 1942-1965. None of the moderate avulsion risk pathways flooded in the 2002 flood of record (Hagen 2002a), and we do not have 100-year flood modeling data for the moderate pathways. The Moderate avulsion risks are through Dungeness Hatchery (Figure 2, Reach 6), Upper Haller dike (Figure 2, Reach 6), just below Powerlines (Figure 2, Reach 5), the downstream end of Dungeness Meadows dike (Figure 2, Reach 4), and Woodcock Rd. (Figure 2, Reach 3). These avulsions can be expected only with the largest floods, at floods of record or higher.

Avulsion pathways with a **Low** risk were identified in the 1914 Tax Assessor map as either active side channels or dry flood channels, but since then the photo record showed no signs of flooding. Additionally the Low-risk surfaces are not flooded during 100-year flood modeling by Herrera (2006). The Low avulsion risks are the channel east of the RR Bridge (Figure 2, Reach 4), and the west bank below RR Bridge (Figure 2, Reach 4). It is important to note that flood modeling is based on current bed elevations, in reality the river bed continuously moves up and down as waves of sediment move through the channel network (see Geologic Setting). All the avulsion pathways are discussed in the "CMZ by Geomorphic Reach" section.

Erosion Hazard Areas (EHA)

The erosion setback (ES) was calculated by geomorphic reach using the maximum observed erosion in that reach between two consecutive photo sets (Table 4, see GeoEngineers 2007). For each reach, a unique ES was calculated for the east and west bank. River channels generally shift only during large flood events, and our assumption is future erosion should not exceed previously observed HMZ maximum movements. In other words, if the river is at the edge of the HMZ or AHZ, we do not expect erosion to extend beyond previously observed maximum movements. Excluded from ES analyses were dikes actively maintained and built to contain the 100 year flood, and the CMZ directly upstream and downstream of bridges. No ES was calculated for reach 1 because this is a river delta with markedly different channel movement mechanisms (i.e. tidally influenced) than in the river channel proper. A geotechnical setback (GS) was established for the bluff over Rivers End on Reach 1, however, the EHA is likely underestimated here. In Reach 2, the ES was mapped as the small amount of remaining floodplain between the HMZ or AHZ and the dikes. A geotechnical setback (GS) was established for a portion of Reach 2.

Table 4. Erosion setback (ES) calculation

Reach	West bank maximum erosion (ft)	East bank maximum erosion (ft)
1	N/A	N/A
2	N/A	N/A
3	209	216
4	325	227
5	287	245
6	360	245

The lower Dungeness River primarily flows through recent alluvium deposited at heights no more than 10 ft above the active channel; there are just a few areas with different geology. A Geotechnical setback (GS) is calculated as the bluff angle of repose to maintain a stable slope. The GS was calculated along the bluff at the south edge of Rivers End on Reach 1, the west bank downstream of the Beebe dike of Reach 2, the high bluff locally known as the "Powerlines" on the east bank in Reach 5, and the Fish Hatchery road in Reach 6. The GS was simply considered the 1:1 slope, or the height of the bluff (e.g. Perkin and Klawon 2004). These bluffs ranged from 30 to 50 ft in height. The GS should only be considered a buffer; to determine stability more accurately for each site over the next 100 years needs a geotechnical specialist.

The ES and GS are combined to the form the EHA (Table 5). The EHA is a buffer of expected erosion if the channel erodes beyond the edge of the HMZ or AHZ. The EHA is measured from the outer edge of the HMZ or AHZ. The EHA was truncated to follow along the base of Pleistocene hillslopes (Schasse 2003); these hillslopes are covered in the Clallam Critical Areas Ordinance under Landslide Hazards.

Table 5. Erosion Hazard Area buffers measured from the edge of each CMZ zone.

CMZ zones	Extent of EHA
HMZ	Full
AHZ (hatched)	Full
AHZ (high avulsion risk)	Full
AHZ (moderate avulsion risk)	1/2[1]
AHZ (low avulsion risk)	none

[1] Except for GS, where the full buffer is used.

Disconnected Migration Area (DMA)

Dikes can limit portions of the CMZ to channel movement. Where this occurs behind a publicly maintained dike that is built to withstand the 100-year flood, it is called a Disconnected Migration Area (DMA). Any DMA will not have an associated Erosion Hazard Area (EHA), since these dikes are publicly maintained and channel movement is not allowed. The Army Corps dike (Reach 2), Beebe dike (Reach 2), the Dungeness Meadows dike (Reach 5), and lower Haller dike (Reach 5) were the four dikes to comply with the state Ecology definition (see Legal requirements for CMZ's), and the HMZ behind the dike was defined as DMA. We did not have any information for the RR Bridge dike (Reach 4), Kinkade Island dike (Reach 6) and City of Sequim dike (Reach 6) to determine if they complied with the State requirements. The HMZ behind these latter three dikes was included within the CMZ. All other areas of bank armoring did not satisfy state requirements and were included within the CMZ.

Channel Migration Zone

The CMZ boundary should be considered a moderate to high risk CMZ boundary. The CMZ boundary contains active channels and swales that have been active during the period of the photo record (1942 to 2005), or are likely be active or eroded within the next 100 years. The two areas near RR Bridge that were rated at Low avulsion risk were not included within this CMZ boundary (Table 5; see Reach 4, CMZ description by geomorphic reach for further discussion). The 1914 map containing the low avulsion risk channels are found in Figure 3.

Comparison of the existing CMHZ to the proposed CMZ

The existing Channel Meander Hazard Zone, as mapped in the Clallam County Critical Areas Ordinance, is shown as a transparent brown band (Figure 4). The proposed updated CMZ boundary is shown as a yellow line.

CMZ description by geomorphic reach

Reach 1, Mouth to Schoolhouse Bridge

This is the modern delta that begins at roughly the Schoolhouse Bridge (RM 0.7), and extends to the river mouth. Much of this delta has been created since 1870, when the river channel was moved by early settlers or naturally cut due north across the fan (Figure 2, Reach 1). During the past 150 years, the delta of the Dungeness River has extended (prograded) northward 1875 ft into Dungeness Bay. This marks the boundary of the northern edge of the Historic Migration Zone (HMZ). The southern edge of the HMZ is defined by the 1855 main channel. The eastern edge is defined by a 1914 and 1942 river distributary channels that existed prior to construction of the ACOE dike in 1962. The portion of HMZ behind the dike is disconnected migration area (DMA).

The HMZ is very dynamic in this reach; the river channel could easily avulse along several historic paths: northeast around the northern end of the ACOE dike (M. Heins, Dungeness Farms, personal communication), west along the 1855 channel, west along the 1914/1942/1965 main river channel, or create a new channel across the Rivers End property (Herrera 2008a and BOR 2007b). During the 1990's, the 1855 main channel and swales to the south have carried flood flows. The avulsion risk between the bluff to the south and HMZ is rated High (Figure 2, Reach 1). Since 2001, Clallam County, Washington Department of Fish and Wildlife, and Jamestown S'Klallam Tribe have purchased land and decommissioned houses at Rivers End. The remaining public living at Rivers End and the infrastructure are at high risk. Recent 2008 flood flows have been observed flowing down the 1914/1942/1965 main river channel, and flood modeling shows several potential avulsion pathways between Rivers End houses and the bluff to the south (BOR 2007b, Herrera 2008a).

Reach 2, Schoolhouse Bridge to upriver end of ACOE dike

This reach is bounded by the Army Corps dike to the east, and to the west by either a resistant clay bank or the Beebe dike (Figure 2, Reach 2). This reach is the site of proposed dike setback/restoration project on both sides of the river. Prior to dike construction, each floodplain was utilized by flood flows (FWS 1962), which was reaffirmed in recent flood modeling (BOR 2007a). In addition, the Beebe dike (the old Seamonds dike, BOR 2002) cut off a long side channel of the 1914 river channel, the left bank of the 1914 and 1942 river channels, and presently truncates channel meanders; this accounts for the large DMA behind the west Beebe dike. While the Beebe dike is not a publicly maintained facility, it is exceptionally large and constructed equal to or taller than the Corps dike across the river (BOR 2002). Recent flood modeling of the reach shows that the Corps dike will be overtopped in one place in a 100-year flood (BOR 2007a). The riverbed has aggraded (filled in) up to 8 ft in certain locations (BOR 2002, 2007a). See Reach 5 for a further discussion of sediment transport and deposition in this reach.

Prior to construction of the Corps dike, cedar plank walls were in place in the lower ½ of the Corps dike that restricted channel migration and flooding to the east at roughly the 2 year level (BOR 2002). Collins (2005) speculated that as recently as 400 years ago, the mouth of the Dungeness could have been located at the present-day mouth of Meadowbrook Creek. While Meadowbrook Creek and the floodplain to the east historically provided flood relief prior to construction of the Corps dike, in general the floodplain to the east was not considered as a DMA. The river channel has not migrated further east for almost 100 years (1914 Tax Assessors Map). The BOR (2002) dated charcoal wood fragments in the east floodplain at 295-665 years BP (at 2 ft depth), suggesting relative stability of the main channel in its current location for at least the past 250 years, although those fragments could have been deposited from upriver locations.

On the east bank, the EHA is found only between the eastern edge of the HMZ/AHZ and the Army Corps dike. On the west bank the EHA is bound by the Beebe dike and constrained downstream by the clay bluff and bank.

Reach 3, Upriver end of ACOE dike to Burlingame Bridge

The portion of river near the Hurd Creek hatchery (lower end of this reach) is very active (Figure 2, Reach 3). The 1914 map shows a great deal of channel activity in this area. The 1914 map shows an old channel that loops to the east crossing present-day Woodcock Rd (Figure 3). In March 1997, floodwater followed this 1914 swale and moved north out of Anderson side channel crossing Woodcock Rd just west of Community Lane and then across the floodplain into Hurd Creek. The County subsequently placed a larger culvert under Woodcock Rd at this swale. The approaches to Woodcock Bridge protect the downstream landowner to the west of this swale. Based on the 1997 flooding, it was identified as a Moderate Risk Avulsion Pathway.

The avulsion pathway just downstream of Woodcock Road on the east bank is rated as a High risk. This area flooded in the 1997 and 2002 floods. In addition, the BOR modeling showed substantial flooding at greater than 25 year events. In this case, the avulsion would drop down into Hurd Creek; the headcut could initiate there and migrate back to the river (Figure 2, Reach 3).

On the west bank, the dividing line between AHZ and DMA is the southern end of the Beebe dike. Relatively deep swales are found upriver of the Beebe dike on the west bank, forming the AHZ. The two landowners east of Ward Rd and directly adjacent to the AHZ are at erosion risk from an avulsion into one of these swales. Lowering the long-term risk is the presence of large cedars, alders, and cottonwoods along the swale.

Directly upriver on the west bank, Ward Rd is actively eroding for about a ½ mile south to near Woodcock Bridge. Within this ½ mile, gravel bars on the river are very near to the same height as the road surface. The riprap placed to protect the road is also holding the river thalweg (deepest part of the channel) next to the road, causing further erosion risk. A long-term solution is to move the road west away from the river.

Between Woodcock Bridge and Burlingame Bridge, existing side channels create a relatively wide HMZ. Properties on the east bank upstream of Woodcock Bridge and both banks upstream of Burlingame Bridge are at high risk of erosion. The east approaches of both bridges confines the floodplain which increases hazard to existing structures.

Reach 4, Burlingame Bridge to downstream end of the Dungeness Meadows dike

Due to the lack of dikes and bank armoring, this reach contains some of the best salmon habitat in the lower river and there is room for the river to migrate in this reach (Figure 2, Reach 4). The majority of flowing side channels is found on the east side of the river. Most houses are set well back from the active river channel. Notable exceptions are just upriver of Burlingame Bridge (both banks), the east bank from Hwy 101 down-river roughly 500 ft (along Kaiser Rd), and the west bank downriver from the end of Dungeness Meadows dike along Taylor-cutoff Road (north of the CCD ditch outtake).

Downstream of the RR Bridge in the hayfield on the west bank, up to 200 ft of terrace erosion occurred between 1985 and 1994. Clallam County stabilized this bank with bioengineered logs in 1995 (Hagen 2002b). Jamestown S'Klallam Tribe and Clallam Conservation District constructed further logjams on gravel bars near the western bank in 1997 and 1998. Two more logjams will be constructed for fish habitat in 2008. Along this same bank is a flood channel identified in the 1914 map (Figure 3). The 2002 flood of record did not flood into this swale (Hagen 2002a). The 100-year flood modeling came within 6 inches of flowing into this channel but did not flood (Herrera 2006, Mark Ruebel, Herrera Environmental, personal communication). Based upon our criteria (no flooding in the photo record, no flooding in the model); we rated it as a Low avulsion risk.

At RR Bridge a small dike protects the east floodplain from channel avulsion. This dike and bridge footings, narrow the floodplain roughly 25%; at this already naturally constricted site (Herrera draft). West of the bridge, the trestle pilings are at risk to channel avulsion. Several avulsion pathways (active side channels) exist directly west of the bridge itself, and further west along a side channel (Herrera 2006). The bridge itself is on steel pilings with a concrete cap and is not at risk to channel movement (Herrera 2008b).

In the 1914 tax map, a large channel leaves the Dungeness River east just downstream of Hwy 101, flowing three miles and eventually forming Hurd Creek (Figure 3). The main riverbed has almost certainly degraded (lowered) since 1914 (see the Dungeness Meadows to Canyon Creek section and Geologic Setting for a more complete discussion), leaving the 1914 flood channel dry. There are presently many residential homes along and within this historic 1914 flood channel. Hydraulic modeling of 100 yr flood events of the area did not wet the entrance to that channel (Herrera 2006), however that is based upon existing channel bed elevation; riverbeds can move dramatically up and down during floods. We consider this a Low Avulsion Hazard risk. Even though the channel apparently has not flooded since the early 1900's; it would be wise to maintain unimpeded swales on the floodplain and not construct more homes within the swales.

Reach 5, Dungeness Meadows dike to May Rd.

Due to dike building and bank armoring over the past 40 years, this reach has converted from a Wandering River reach to a Straight and Entrenched reach (Figure 2, Reach 5). The 0.6 miles long Dungeness Meadows dike was first constructed in 1972 (Clark and Clark 1998). Much of the dike was built riverward of the 1965 channel. The dike was extended northwest in 1992 to cut off a side channel formed during a flood (this side channel defines the eastern edge of the HMZ).

Through the mid-1990's, there was a perception the river had too much gravel; approximately 200,000 yd^3 was removed by Clallam County and private landowners on the Dungeness River from the early to mid 1990's, potentially exceeding the river sediment budget for that period (BOR 2002, pg 66 and 71). Roughly 56,000 yd^3 was excavated from Hwy 101 to Dungeness Meadows dike (Freudenthal personal communication), and the rest in reach 2 and 3. During the December 1995 flood event, the bed alongside the dike degraded (lowered) up to 8 ft., threatening to undermine the new spur dike.

The entire reach from May Rd to the downstream end of Dungeness Meadows dike appears to have degraded up to several feet over the past 50 years (BOR 2003). Down river of the Dungeness Meadows dike on the left bank, the old Clallam-Cline-Dungeness irrigation outtake is now suspended 3-4 ft above the active river channel (removal of a weir built across the river channel may have contributed to this downcutting). Close examination of the 1942 and 1965 aerial photos show numerous flood channels throughout this reach that are no longer activated by floods. The large secondary channel (active in 1942 and still visible in 1965) across from the upriver end of Dungeness Meadows dike did not carry water in the 2002 flood of record (Hagen 2002a). In fact the river did not flood to a great extent, the west bank across from the Dungeness Meadows dike during the 2002 flood of record (Hagen 2002a). A side channel (on DNR land upriver from the Powerlines) identified for restoration in 1997, was found suspended several feet above the river channel when field investigated in 2003 and 2007.

This perception of too much gravel in the river is still held today by some riverside landowners. The likelihood is that two major factors, dike building and increased frequency of flooding over the past 20 years, have contributed to the lowering (degrading) of the channel bed in Reach 5 and the raising of the channel bed (aggrading) in Reach 2. The dike building that occurred in Reach 5 removed floodplain from its normal function of storing sediment and flood waters. At the same time, the dikes increased sediment transport capacity (ie more energy for channel bed erosion), thereby transporting more sediment than what would have occurred naturally. The gravel traps constructed in this reach likely contributed over the short-term to bed degradation. In Reach 2, where the channel gradient flattens and sediment naturally is stored, dikes also prevent sediment storage in the floodplain, confining storage to the channel bed causing aggradation. The landowner response in Reach 2 was also gravel traps. The long-term solution is not more gravel traps, but to setback dikes (to the extent possible) in each reach to restore the channel migration zone.

The west bank from the Powerlines downstream for 1.5 miles (near where the river is closes to Taylor Cutoff Rd) is actively eroding (BOR 2003). Over the past 10 years, landowners (and Jamestown S'Klallam Tribe) have placed mostly log revetments at various locations to slow erosion. The long-term solution is moving or removing houses at risk from river movement and planting trees along the bank to help reduce erosion. An unfortunate by-product of the Dungeness Meadows dike is accelerated bank erosion across from and downstream of the dike.

The other major dike in this reach is the lower Haller dike (RM 8.6 to 8.9). The downstream end of the lower Haller dike was constructed between 1957 and 1965. In the 1957 aerial photo, they were bulldozing sediment off a bar into a sugar dike which would become the downstream end of the lower Haller dike. The extension appeared to be completed in the 1965 photo. The downstream portion of the lower Haller dike was overtopped and reoccupied by flood flows in March 1997. The dike was reconstructed in 1998 and lengthened downstream of the affected landowner from the 1997 flood. This was an NRCS-funded dike reconstruction/extension. It is not known who is responsible for dike maintenance and whether the Lower Haller dike was built to withstand the 100 year flood event. However, the BOR 100-year flood modeling did not overtop the dike (BOR 2003). It is also unknown whether the three protected landowners have the resources for dike maintenance. This dike falls into a gray area whether it should be included within the CMZ; we decided that the dike is substantial enough for the CMZ boundary to run along the dike. Across from the upstream end of the lower Haller dike, is an armored bank (also armored in 1998) that constricts channel migration at this location (BOR 2003). The several other smaller dikes and numerous areas of bank armoring that also exist in Reach 5 (BOR 2003) are found within the CMZ.

We identified three avulsion pathways in Reach 5; two were rated Moderate risk, and one High risk (Figure 2, Reach 5). At the downstream end of the Dungeness Meadows dike, swales in the floodplain exist behind and downstream of the dike. Erosion of the bank just downstream of the dike could allow floodwaters to activate these swales. This is at Moderate risk of avulsion. At the upstream end of the dike, just below the Powerlines, the Independent ditch outtake is identified as a High risk avulsion pathway. The ditch is open to the river with highly erodible banks; the most likely scenario is the avulsion would return to the existing riverbed just upriver of the irrigation headgate. On the west bank downstream of the Powerlines, is the entrance to a flood channel active in the 1940's and 1950's. This flood channel is now a vegetated swale with houses constructed on both sides of the swale. This swale is at Moderate risk to channel avulsion.

Reach 6, May Rd. to Canyon Creek

Three dikes are found in this reach. The largest two are the Kinkade Island levee (1100 ft), and the Sequim Rainy well levee (across the river from Canyon Creek and downstream to near the entrance to Kinkade side channels). The Dungeness Hatchery dike is a sugar dike (composed of riverbed material) that is well forested, low, and difficult to discern from a naturally vegetated riverbank.

Kinkade Island lies between the Dungeness River and Kinkade Side Channel (locally known as Kinkade Creek). At the upriver end, three braids form Kinkade side channel. Two of the braids are naturally armored by large logjams and standing trees, and drop rapidly in elevation away from the main channel. Since the 1960's, the side channel has captured an increasing proportion of the main flow, more recently up to 1/2 of the river discharge during flood events (BOR 2003). For this reason, Kinkade side channel was identified as High risk to avulsion. In the December 2001 and January 2002 flood events, a significant amount of erosion occurred near houses built next to the side channel, and one house spectacularly fell in during the January 2002 flood (its roof is on the cover of this report). All the homes on Kinkade Island and on the right bank of Kinkade Creek are also at high risk to channel erosion. All of Kinkade Island is either in the HMZ or EHA.

Across from Kinkade Island is the Dungeness Hatchery. Canyon Creek is a tributary to the Dungeness River and enters at the south end of the Hatchery property. From 1905 to 1945, the hatchery was located at the mouth of Canyon Creek (Keeting 1976). The 1914 tax map (and a 1907 photo in Keeting 1976) shows the main Dungeness River running through where existing hatchery rearing ponds are now located. This swale is mapped as a Moderate risk to avulsion. Forested sugar dikes constructed 50 years ago and logjams built within the last decade by Clallam County somewhat reduce the likelihood of avulsion into the hatchery rearing ponds. In 1999, it was proposed to remove these sugar dikes and setback the hatchery rearing ponds and the dikes away from this avulsion area (Rymer et al. 1999). This recommendation was re-affirmed in a detailed reach-level geomorphic assessment report (pg 35, BOR 2003) in part to relieve pressure to avulsion into Kinkade Creek.

Further downstream on the west bank are high bluffs (older alluvium, Schasse 2003) upon which Fish Hatchery Rd is located. These bluffs are eroding, the road was setback from the bluff between the 1985 and 1994 photo sets. Clallam County armored the toe of the bluff however the bluff is at risk of further erosion.

On the east bank across the river from the Moderate Avulsion risk are six houses along River Rd. The Bureau of Reclamation identified this bank as at risk of erosion, portions are actively eroding (BOR 2003). A seventh house, on the outside bend of the channel, suffered significant bank erosion following the March 1997 flood and had to be removed.

Conclusion

The lower Dungeness River is a steep, avulsion-dominated, gravel bedded river. As the channel migrates, large trees are input into the river creating high quality salmon habitat. Abandoned channels are favored rearing habitat by juvenile salmonids. This is the natural process that salmon evolved within for thousands of years. When human settlement simplifies or limits this process, it can negatively impact the river and also potentially endanger people, their houses, and roads.

This report can be utilized in several ways. One is to justify additional dike building and bank armoring to attempt to control channel migration. It must be recognized that any attempts to control channel migration through dikes and bank armoring is a financial contract to maintain those structures forever. A more cost effective way to expend public and private resources is to examine patterns of development, consider where development is inappropriately located and purchase houses at risk.

At minimum the maps can be used through the Clallam County Critical Areas Ordinance and Shorelines Master Program to indentify and limit at-risk development within or directly adjacent to Channel Migration Zones. It is hoped that these maps will be utilized to promote better decisions in the future, for the benefit of the river and all of us who depend upon a healthy river ecosystem.

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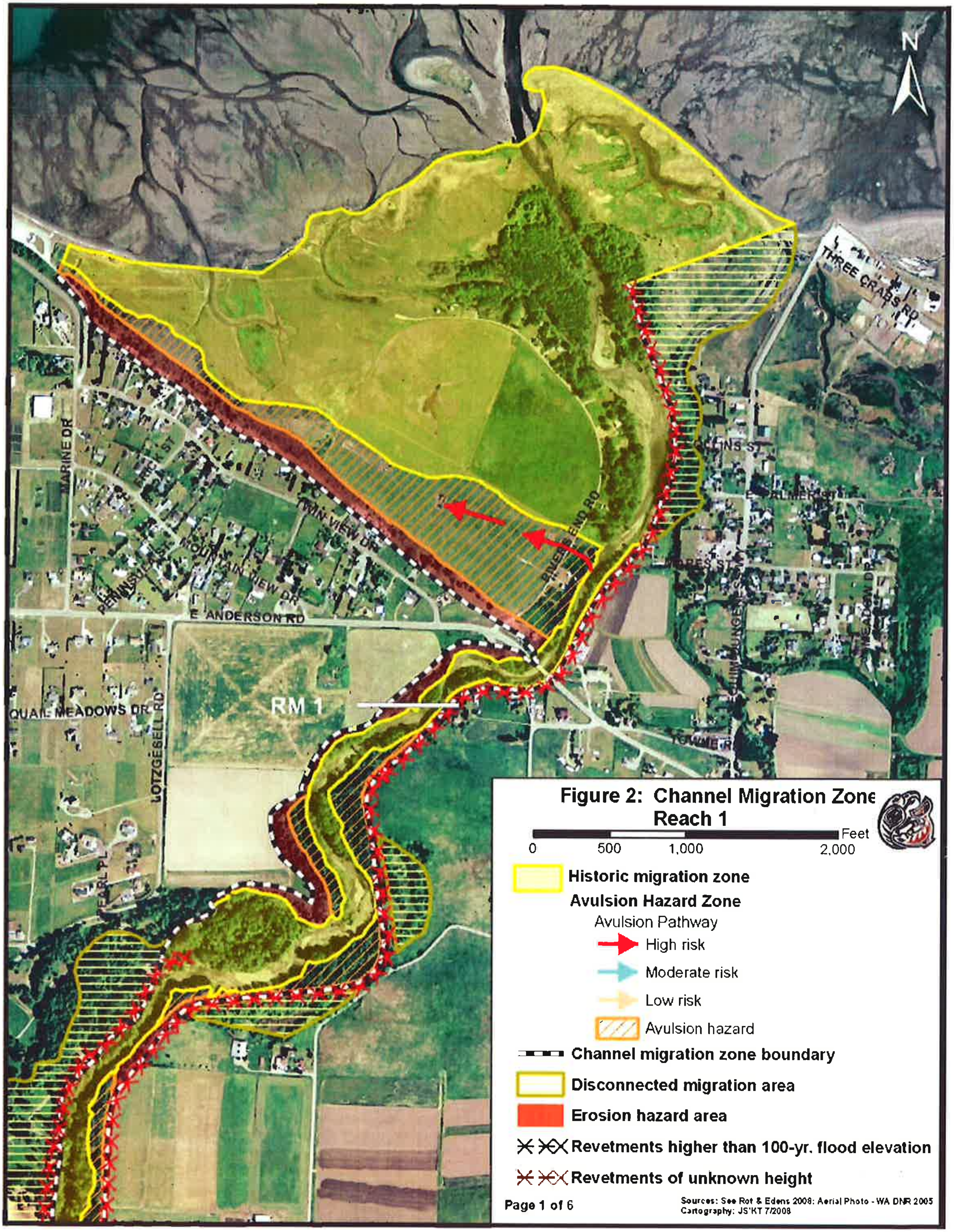

N
THREE CRABS RD
MARINE DR
TWIN VIEW DR
MOUNTAIN VIEW DR
PENINSULA
E ANDERSON RD
RIVER'S END RD
RM 1
QUAIL MEADOWS DR
LOTZGESELL RD
EARL PL
TOWNE RD
Figure 2: Channel Migration Zone
Reach 1
Feet
0
500
1,000
2,000
Historic migration zone
Avulsion Hazard Zone
Avulsion Pathway
High risk
Moderate risk
Low risk
Avulsion hazard
Channel migration zone boundary
Disconnected migration area
Erosion hazard area
Revetments higher than 100-yr. flood elevation
Revetments of unknown height
Page 1 of 6
Sources: See Rot & Edens 2008; Aerial Photo - WA DNR 2005
Cartography: JS/KT 7/2008

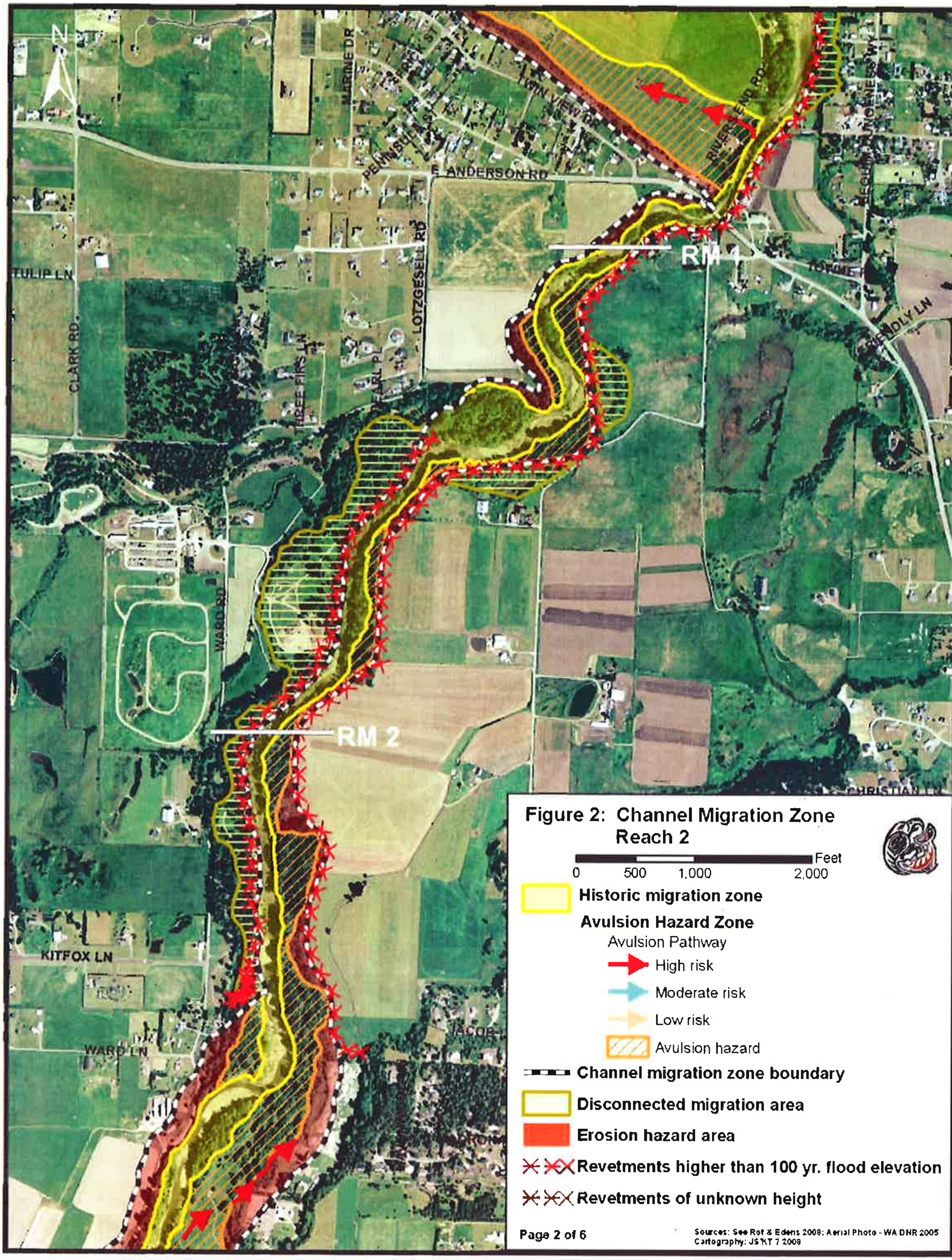
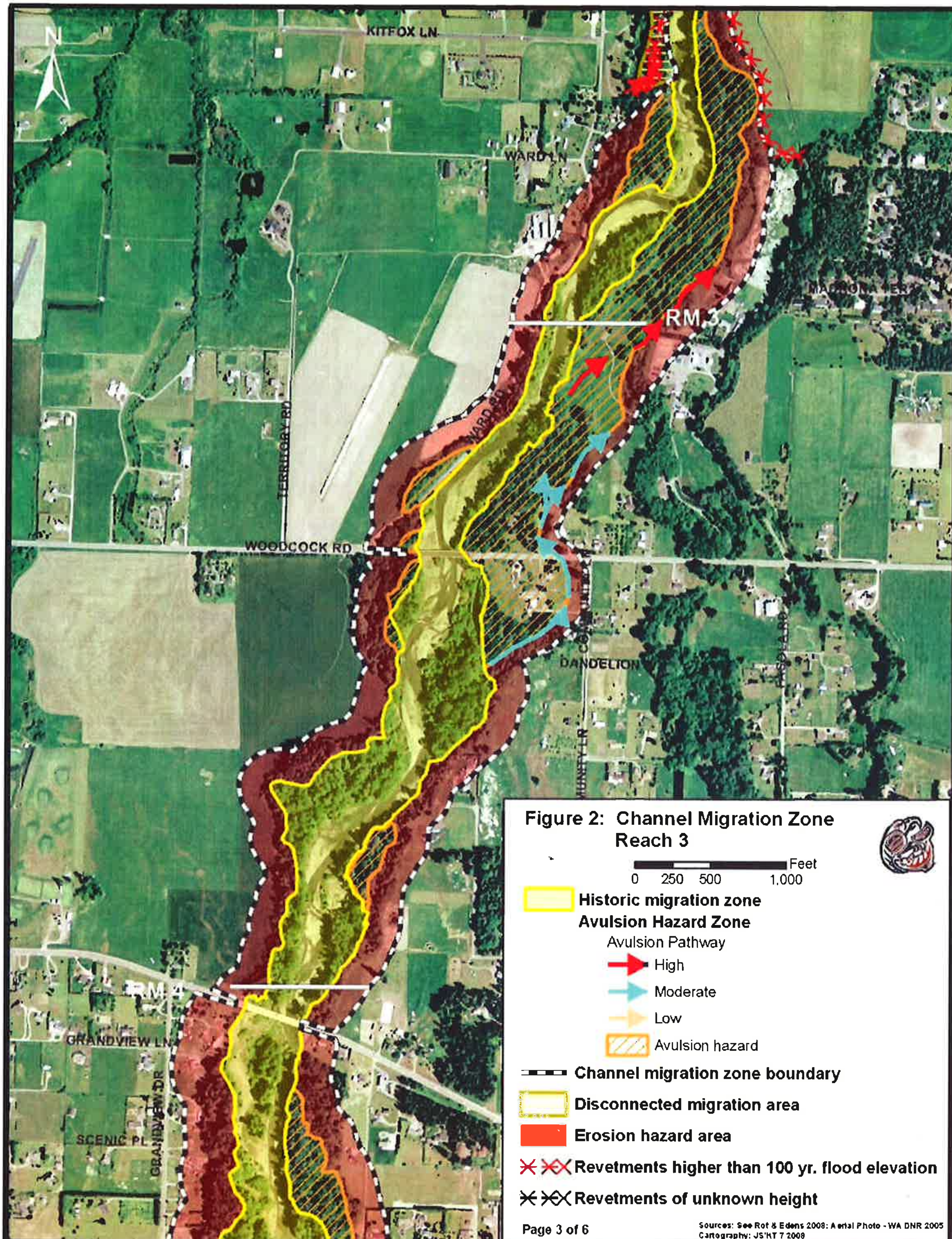


Figure 2: Channel Migration Zone Reach 2


N
KITFOX LN
WARD LN
MADRONA TER
RM 3
WARD RD
TERRITORY RD
WOODCOCK RD
DANDELION
RM 4
GRANDVIEW LN
GRANDVIEW DR
SCENIC PL
Figure 2: Channel Migration Zone Reach 3
Feet
0 250 500 1,000
Historic migration zone
Avulsion Hazard Zone
Avulsion Pathway
High
Moderate
Low
Avulsion hazard
Channel migration zone boundary
Disconnected migration area
Erosion hazard area
Revetments higher than 100 yr. flood elevation
Revetments of unknown height
Page 3 of 6
Sources: See Rot & Edens 2008; Aerial Photo - WA DNR 2005
Cartography: JS'KT 7 2008

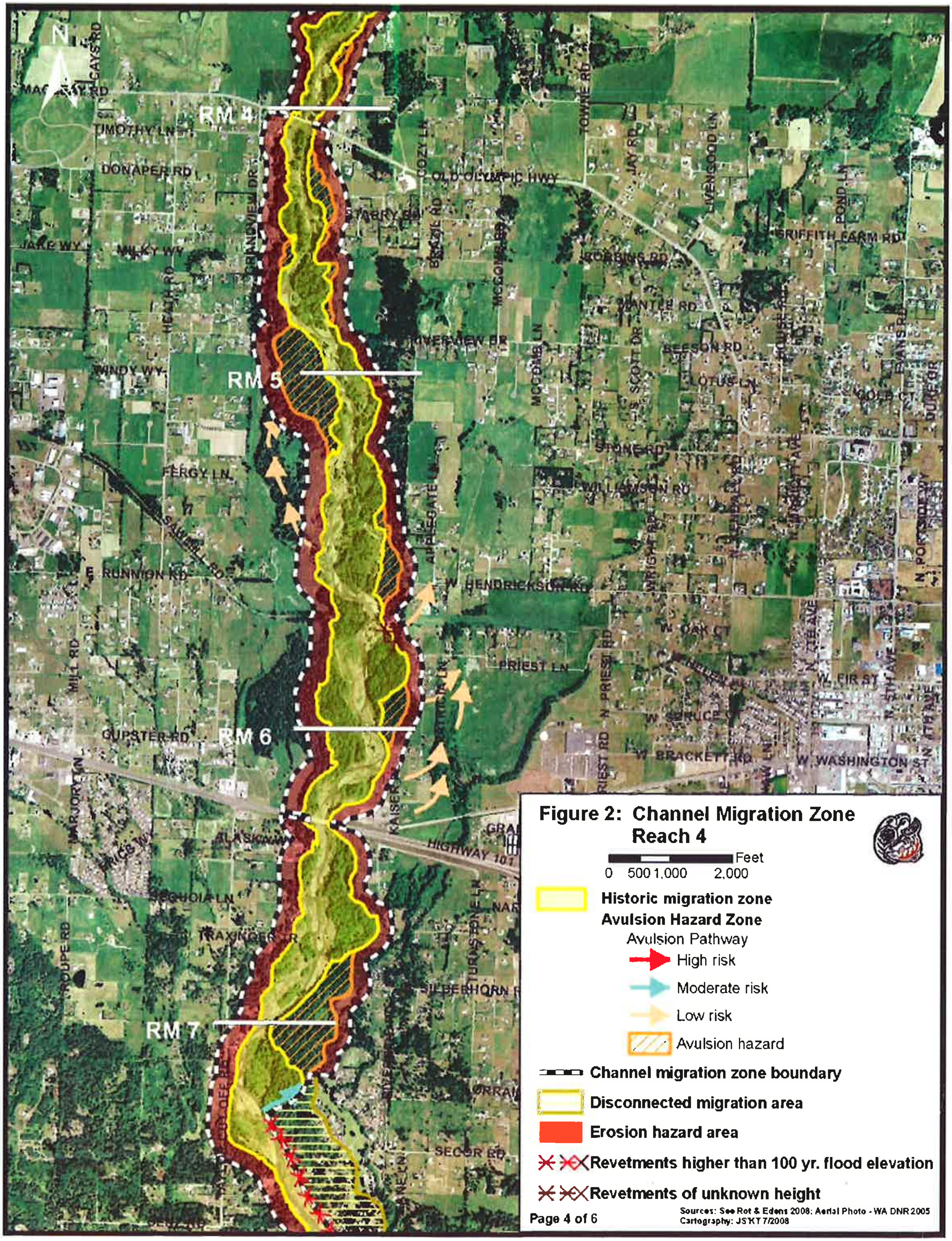


Figure 2: Channel Migration Zone Reach 4

Figure 4: Comparison of proposed CMHZ and existing CMHZ

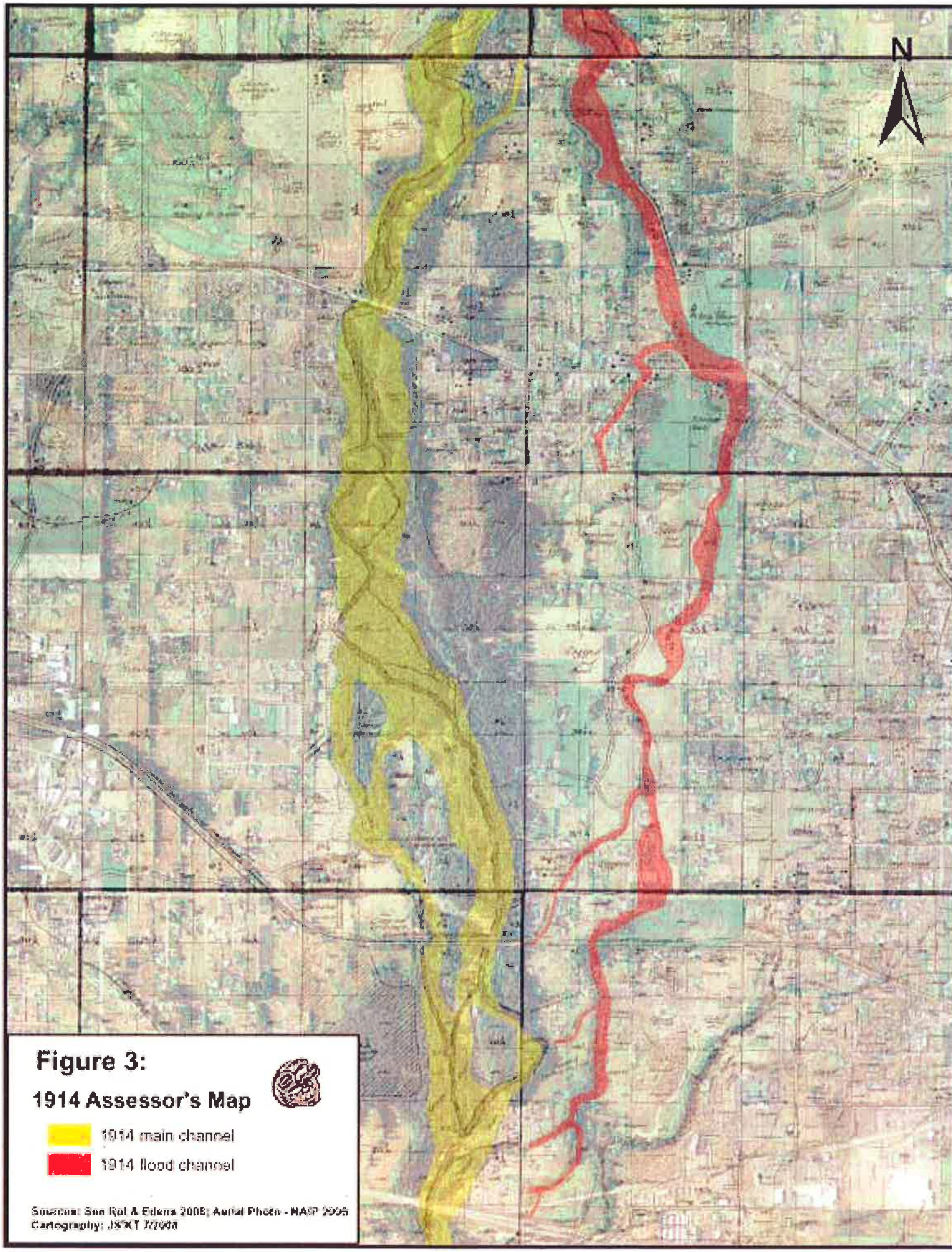


Figure 3:

1914 Assessor's Map

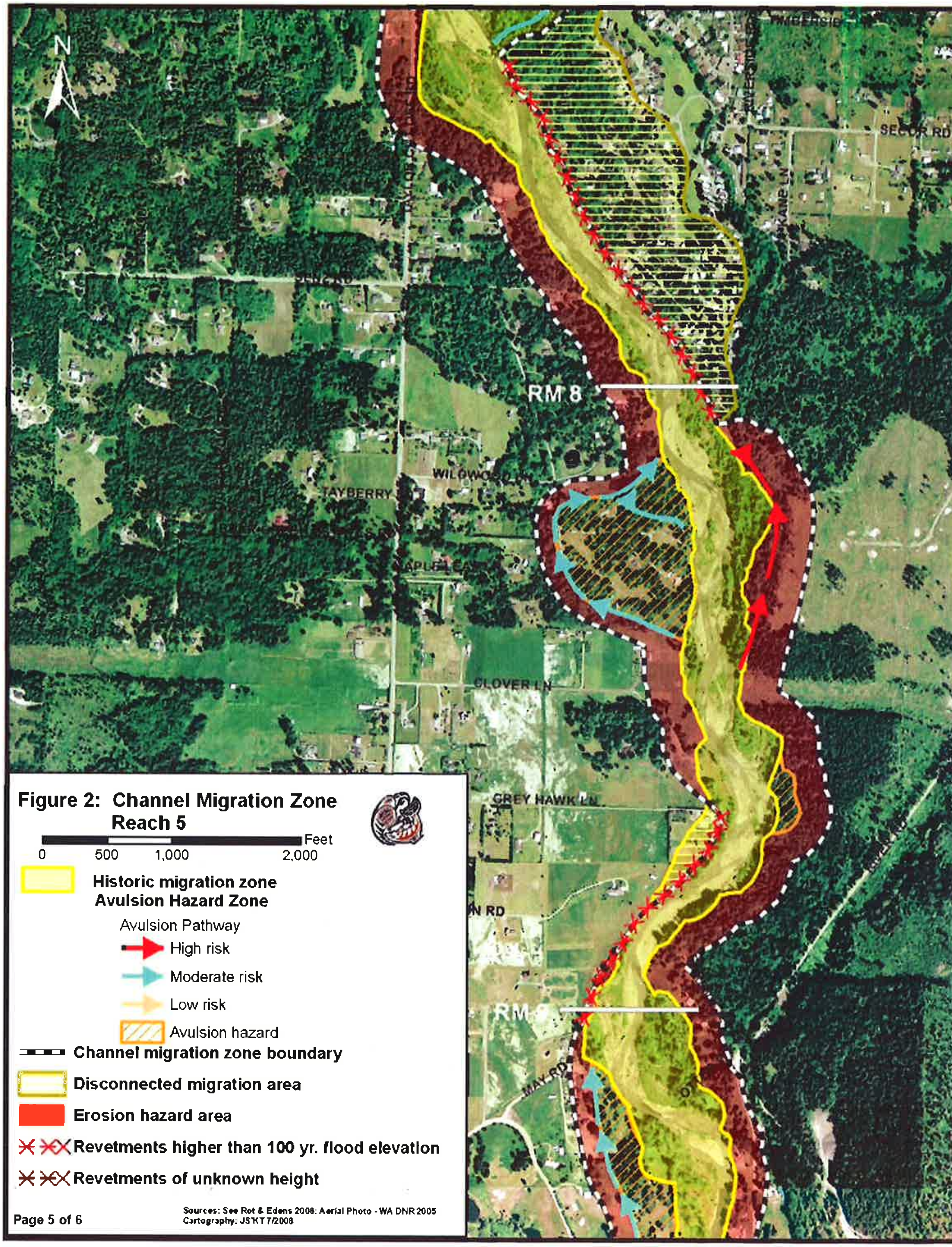


Figure 2: Channel Migration Zone Reach 5

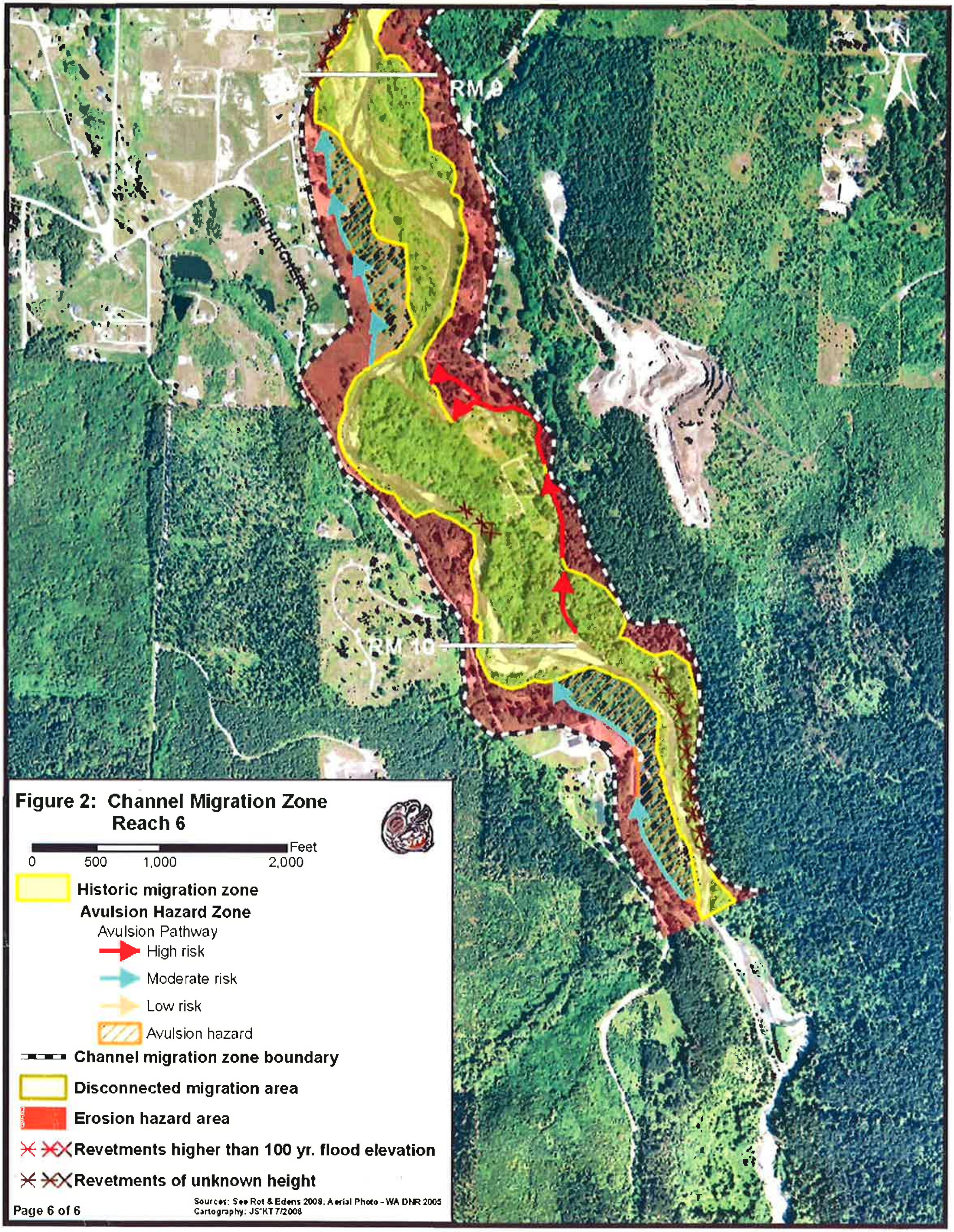


Figure 2: Channel Migration Zone Reach 6