Geomorphology and Hydrology Assessment
for
Curtin Creek

by

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1 Purpose

A geomorphology and hydrology assessment was conducted for Curtin Creek to help understand the dynamic processes at work within the basin and their interrelation with human influences. The understanding will provide insights into the mechanisms that create real or perceived watershed and stream corridor impairments. Additionally, the assessment provides an understanding of how basin physical conditions and processes influence current and potential future hydrology, channel morphology, flooding, channel erosion, water quality and fish and wildlife habitat. Results of the assessment were used to form management recommendations and identify future capital stormwater and habitat restoration projects.

2 Methods

2.1 Watershed Conditions

Available data and documentation regarding watershed conditions were collected, including: historic and current aerial photography; soils data; geologic maps and reports; topographic data; land cover and land use data; stormwater infrastructure data; existing hydraulic models and floodplain mapping; feature inventory data; and available technical reports. A field reconnaissance was conducted on April 7-8, 2008 to observe current conditions with regard to channel form, stream stability, riparian vegetation, channel bed and bank material, woody debris, surrounding land use, hydraulic structures, sinuosity, hydromodifications and floodplain connectivity. The field observations are summarized in Appendix A. Field photographs are hyperlinked in the provided ArcGIS project file (SNAP_StudyArea_Basins.mxd).

The available data and documentation were reviewed and evaluated in combination with field observations to characterize the existing basin physical conditions and provide insight into the physical processes and human influences that are the controlling factors on the hydrology and geomorphology of Curtin Creek. The details of this effort are presented in Section 3.1.

2.2 Hydrology

The Curtin Creek basin and tributary basin areas were delineated using the provided topographic data. Available hydrologic data from the stream flow gage at NE 139th Street were collected and evaluated. The period of record for the gage is from 3/6/2003 to present. The available record was too short to conduct peak or low flow frequency analyses. However, an HSPF hydrologic model is available for the Salmon Creek basin which includes the Curtin Creek subbasin. Peak flow statistics were developed from the HSPF model output. Low flow conditions were characterized based on the available data and model output. A quantitative indicator of the flashiness of a basin is the value of T_{Qmean}, which is the portion of time mean daily flows exceed the mean annual flow. T_{Qmean} was determined using the available flow data from the NE 139th Street gage for water years 2003-2007. T_{Qmean} was also determined from the available HSPF model output data for the existing and future conditions.

2.3 Geomorphology

The morphologic characteristics for Curtin Creek were characterized. This effort included evaluation of channel planform, channel profile, and valley geometry. Channel planform was characterized using current aerial photography supplemented with LiDAR derived stream centerlines (Clark County, 2004). Channel profiles were created using data from the HEC-RAS model for Curtin Creek (WEST, 2005). Cross sections were located along the Curtin Creek valley. Cross section spacing was selected to best represent the variations in valley form and how the form transitions from upstream to downstream. Elevation data for each cross section were extracted from the digital terrain model (DTM) of the basin and aligned along a common central axis for plotting purposes. The DTM was developed from the available 2-foot contour interval topographic mapping (Clark County, 2003).

Incipient motion particle size characteristics for Curtin Creek were estimated from HEC-RAS hydraulic model output data for a range of flow conditions. The incipient motion particle sizes were compared to the bed material size characteristics for Curtin Creek to understand the flow conditions that are necessary for bed material transport.

In addition to the evaluation of morphologic characteristics of the channels, a discussion regarding the role of large woody debris in channel development is provided.

3 Results

3.1 Watershed Conditions

3.1.1 Geology

Curtin Creek is a 10.7 square mile drainage basin located within the Orchards Quadrangle (USGS, 1990), which is in the northern part of the Portland Basin, a roughly 770 square mile topographic and structural depression in the central Puget-Willamette Lowland (Beeson et al, 1989; Swanson et al, 1993; Yeats et al, 1996; Evarts, 2004). The Portland Basin is approximately 40 miles long and 20 miles wide, with its long axis oriented northwest (Evarts, 2004). Previous studies (L.M. Liberty, 2003; Swanson et al, 1993; Mabey and Madin, 1995) indicate that as much as 1,800 feet of late Miocene and younger sediments have accumulated in the deepest part of the basin near Vancouver. Most of the basin-fill material was carried in from the east by the Columbia River (Evarts, 2004) which flows westward just south of the Orchards quadrangle. A geologic map of the Orchards Quadrangle is currently in preparation; however, the Geology of the Curtin Creek basin (Figure 1) is depicted in the 1:100,000 scale Vancouver Quadrangle compiled by Phillips (1987).

The physiography of the Orchards Quadrangle is dominantly a nearly flat surface of elevation 250 to 300 feet developed on the basin-fill sediments. The ground surface displays elongated ridges and troughs that trend in an east-west or southeast-northwest orientation. These may be bed forms that were created by the Missoula Floods similar to those described by Howard (2002) in the adjacent Battleground Quadrangle.

The geologic formation that dominates the surface of the Curtin Creek basin is the Pleistocene Alluvium resulting from deposition of cataclysmic flood deposits of clay, silt, and fine to medium sand. Late in the last glacial period, a series of glacial outburst floods from Glacial Lake Missoula flowed down the Columbia River valley and ponded in the Portland Basin. This resulted in deposition of silt and fine sand sediments as much as 100 feet thick (Waitt, 1994, 1996; Evarts, 2004).

Underlying the Cataclysmic Flood Deposits is Pleistocene or late Pliocene age conglomerate beds of sand, gravel and cobble of Columbia River and Cascadian origin (Troutdale Formation). The Plio-Pleistocene conglomerate is characterized by coarse grain size, moderate to good sorting, open and sand matrix, well developed clast imbrication, and crude stratification which suggest deposition by fluvial processes (Evarts, 2004). The Plio-Pleistocene conglomerate was previously referred to by Mundorff (1964) as the Upper Troutdale Formation. As seen in Figure

1, the Plio-Pleistocene conglomerate (Troutdale Formation) is exposed at the confluence of Curtin Creek with Salmon Creek where Salmon Creek has incised through the Pleistocene Alluvium (Cataclysmic Flood Deposits) and exposed the Plio-Pleistocene conglomerate (Troutdale Formation). Although not shown on the geology map, discontinuous peat and wetland marsh deposits are found along the wide valley bottom of Curtin Creek between NE 90th Street and 129th Street and in the upper basin near I-205 and Padden Parkway (personal communication with Rod Swanson, 2008). These deposits tend to correspond to the Semiahmoo muck soils shown in Figure 4 and swampy areas shown in Figure 6.

Although not shown on the geologic map, an exposures of what appeared to be a very course hyaloclastite, with similar characteristics to the Troutdale formation are know to occur north of NE 78th Street and west of the Crossroads Community Church (personal communication with Rod Swanson, 2008).

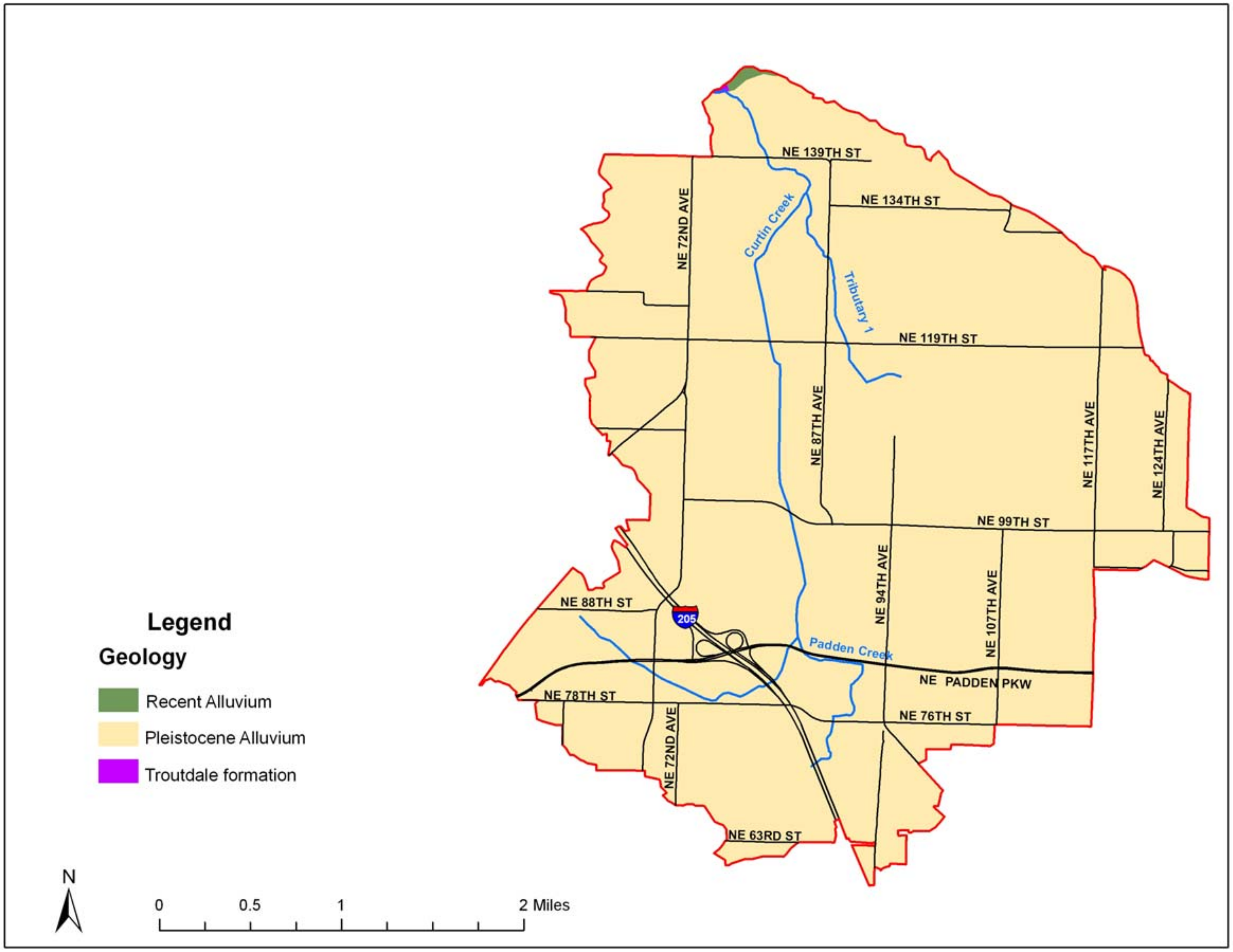

Figure 1. Geologic Map of the Curtin Creek basin (data from DNR Open File Report #87-10).

3.1.2 Streams

Curtin Creek is a 2nd order tributary to Salmon Creek and is approximately 5 miles in length. The headwaters are located in the southwestern most portion of the basin near NE 188th Street. From its headwaters, the stream flows southeast to NE 78th Street; then turns northeast passing under I-205 and Padden Parkway; then north to its confluence with Salmon Creek. Major tributaries include Padden Creek and one unnamed tributary. For discussion purposes, the unnamed tributary was given the name of Tributary 1. Padden Creek originates west of I-205 and joins Curtin Creek just downstream of Padden Parkway. Tributary 1 originates between NE 99th Street and NE 119th Street and joins Curtin Creek just upstream of NE 139th Street. A map showing the boundaries of the Curtin Creek basin is shown in Figure 2. The 10.7 square mile drainage basin is approximately 3 miles wide from east to west 4 miles long from north to south.

Streams in the basin generally have bed and bank material consisting of clay-, silt-, and sand-sized sediment owing to the fine grained nature of the Cataclysmic Flood Deposits that formed the parent bedrock and soils that cover the majority of the basin. Portions of Padden Creek have bed material consisting of fine gravel which may originate from an underlying gravel facies component of the Cataclysmic Flood Deposits similar to those describe by Evarts and O'Connor (2008) for the nearby Camas Quadrangle.

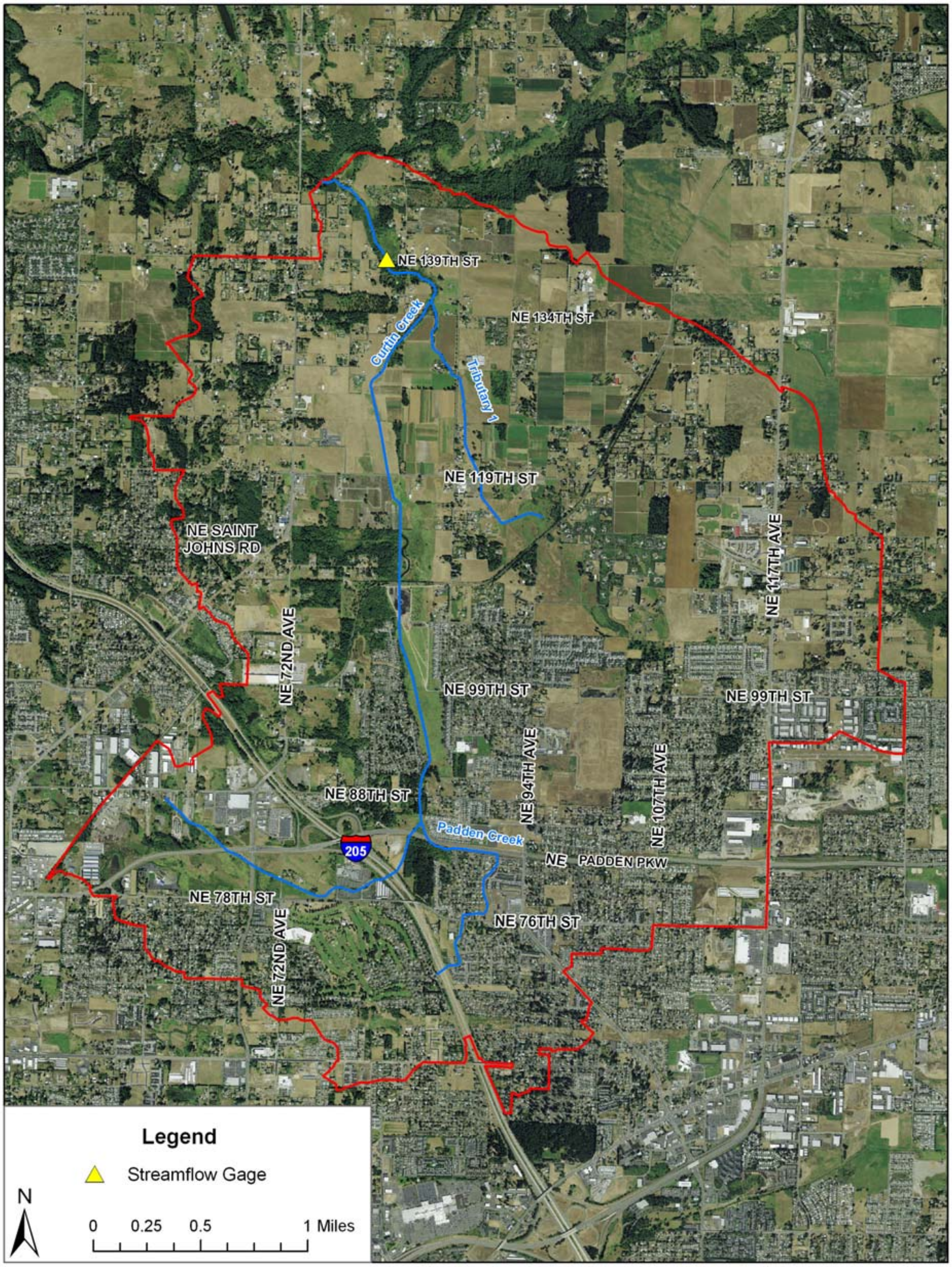

Figure 2. Curtin Creek drainage basin map

3.1.3 Soils

Curtin Creek basin soils are primarily in Hydrologic Soil Group B which comprises 86.7% of basin area. The remaining soils are in Group A, 1.2%; Group C, 2.0%; and Group D, 10.1% of basin area. An NRCS hydrologic soil group map is shown in Figure 3. As seen in the figure, the majority of Curtin Creek is located within the Group C and D soils.

Mapped soil units in the Curtin Creek basin include: Cove silty clay loam, 1.7% of basin area; Hillsboro loam, 34.8% of basin area; Hillsboro silt loam, 21.9% of basin area; Lauren gravelly loam, 0.9% of basin area; McBee silt loam, 6.6% of basin area; Pits, 1.2% of basin area; Semiahmoo muck, 3.7% of basin area; Sifton gravelly loam, 21.1% of basin area; Tisch silt loam, 0.1% of basin area; and Wind River gravelly loam, 8.0% of basin area. An NRCS soil map is shown in Figure 4. Watershed soils generally consist of clay, silt and sand sized material derived from the underlying Cataclysmic Flood Deposits. These fine soils are the source materials that are supplied to the stream channels as a result of surface erosion.

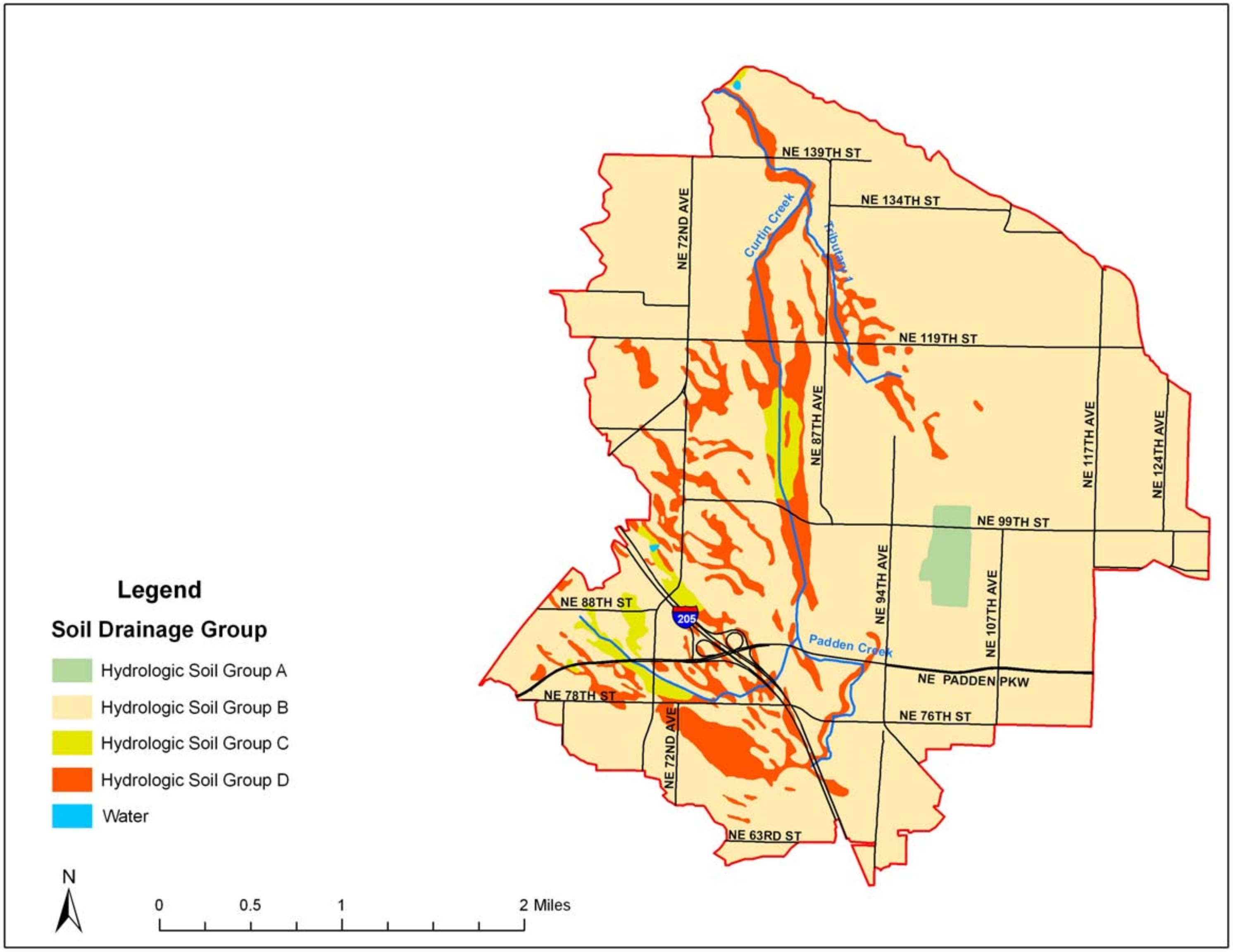

Figure 3. Hydrologic soil group classification of soils in Curtin Creek Basin (data from NRCS, 2004).

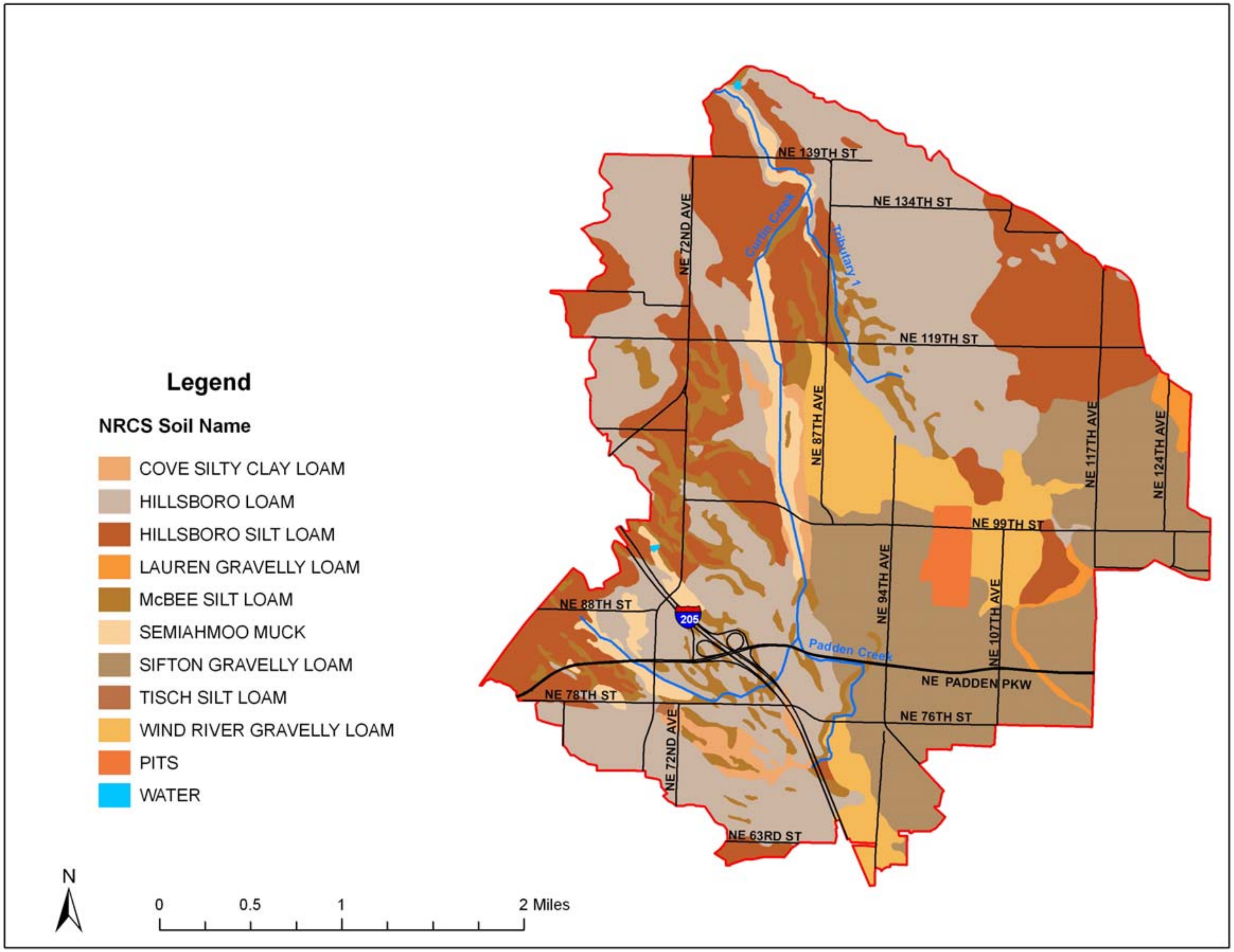

Figure 4. Soils map for the Curtin Creek Basin (data from NRCS, 2004).

3.1.4 Topography

The topography of Curtin Creek basin is characterized by nearly flat, slightly dissected surfaces with a broad shallow valley oriented in an approximately north-northwest/south-southeast alignment. Elevations range from approximately 320 feet in the southwestern edge of the basin to approximately 160 feet at the northern edge near confluence with Salmon Creek. The average basin elevation is 244 feet and the average watershed slope is 3.5 percent (Wierenga, 2005). Floodplain terraces are generally narrow or nonexistent in the upper portion of the basin. Approximately 0.4 miles downstream of Padden Parkway, Curtin Creek enters a very broad valley where the floodplain terrace expands to nearly 1,000 feet in width and extends nearly 1.5 miles northward to a location 0.4 miles downstream of 119th Street. At this location Curtin Creek enters a more confined valley with floodplain terraces that range between 300 and 400 feet in width. Moderately steep slopes (erosional scarps) occur adjacent to the floodplain terraces. The erosional scarps likely developed from a combination of erosion during the Missoula Floods and by incision and lateral migration of Curtin Creek into the Cataclysmic Flood Deposits. A shaded topographic relief map of the basin that illustrates the general extent of floodplain terraces is shown in Figure 5.

3.1.5 Disturbances

There is little documentation available regarding significant historic disturbances in the Curtin Creek basin. Forest fires and flooding were likely the main disturbances prior to Euro-American settlement. Since much of the forest land was converted to agricultural uses in the early 20th century, forest fires have likely not been a significant source of disturbance in the basin since that time. Historic flooding along Curtin Creek is not well documented; however, records of flooding along other streams in Clark County suggest that significant flooding occurred in 1964, 1977, and 1996. Flooding continues to provide periodic disturbance and may likely have increased in severity as the basin land cover was converted from forest to agriculture and more recently from agriculture to a mix of agriculture, urban housing and commercial development. Future flooding conditions are likely to be exacerbated by future increases in impervious surface area. Significant human-caused disturbance in the basin includes land cover and land use changes and the creation of drainage channels. Details of these disturbances are described in Section 3.1.6.

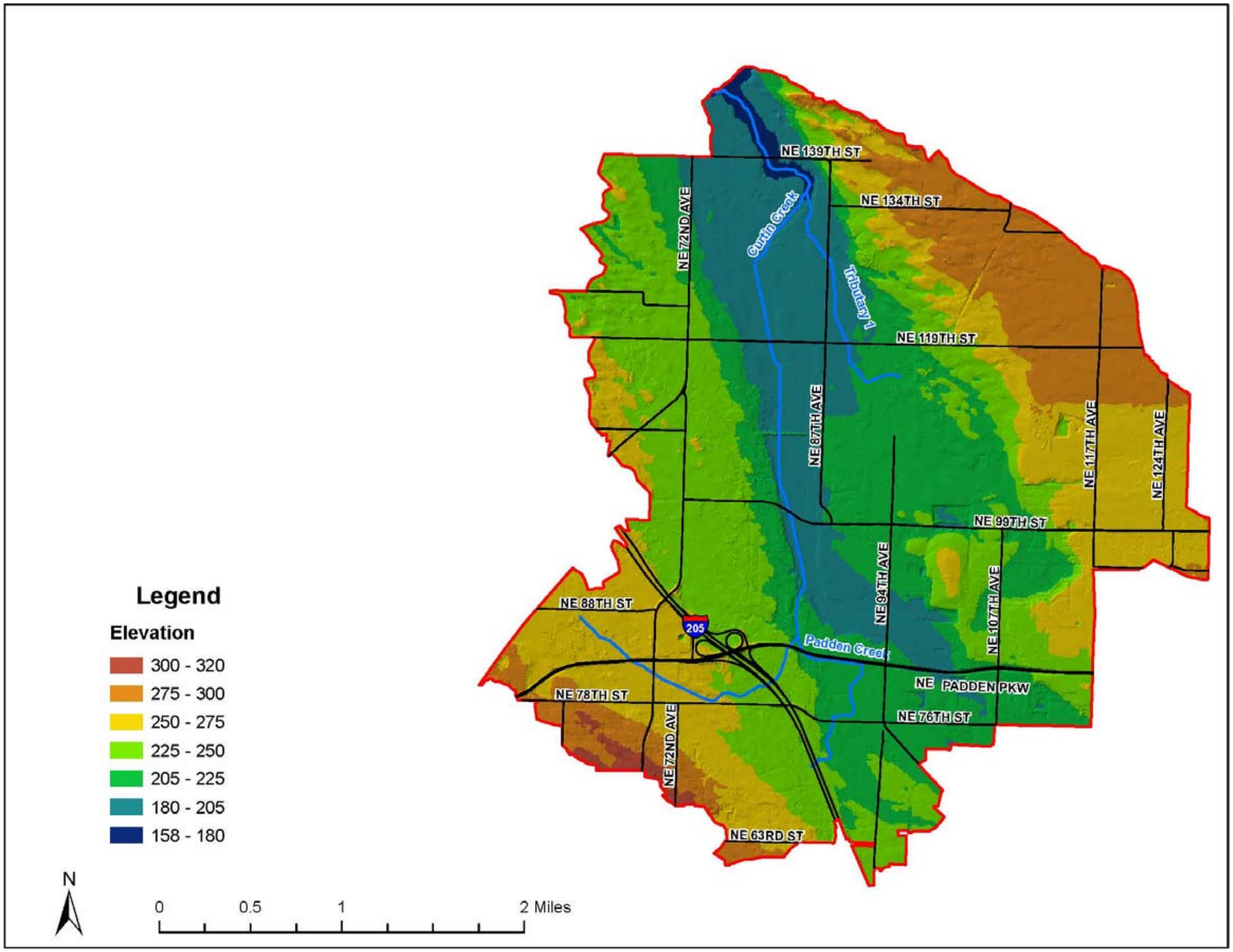

Figure 5. Topographic relief map of the Curtin Creek Basin.

3.1.6 Land Cover and Land Use

3.1.6.1 Historic

Historic land use conditions in the Curtin Creek basin are not well documented. Cadastral survey maps (Figure 6) and surveyors notes from 1856 (BLM, 2008) show that a significant portion of the basin was forested with Fir and Alder with an undergrowth of Hazel, Willow and Vine Maple. A small portion of the upper basin located south of NE 99th Street and east of Curtin Creek was classified as rolling prairie. Much of the central portion of the basin was shown to have marshy soil conditions. No stream channels were mapped in the upper and middle portion of the basin. A single thread channel located in the lower portion of the basin is shown to have emanated from a marshy area and flow to the north to its confluence with Salmon Creek. It appears that the majority of the channel system in the Curtin Creek basin was constructed after 1856 in an attempt to improve drainage conditions to facilitate agriculture. Several small farms and at least one Native American village were present in the basin. No roads existed in the basin; however, they did exist to the south in the current location of SR 500. Available historic aerial photography indicates that much of the native forests had been cleared and the land converted for agricultural use by the year 1955. The current system of channels had also been developed by 1955.

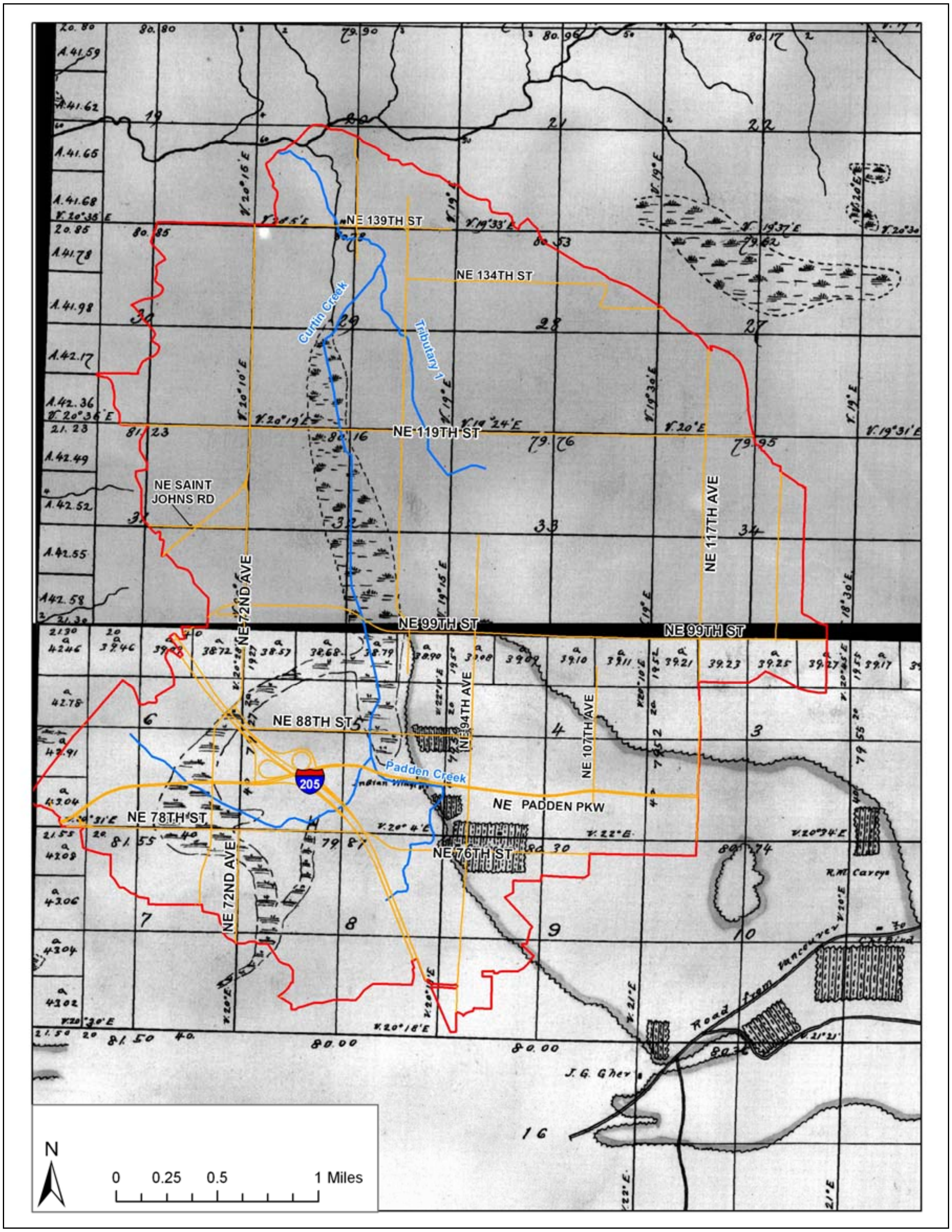

Figure 6. 1856 cadastral survey map (BLM, 2008) for Curtin Creek overlain with drainage basin boundary, current channel location and major road network.

3.1.6.2 Current

The current basin land use consists primarily of suburban residences and commercial developments. The area south of NE 104th Street is nearly completely built out with urban residential and commercial developments. The area along NE 72nd Ave between Padden Parkway and 104th Street is largely undeveloped as much of the area is considered wetland. Patches of agriculture and forest land are interspersed throughout the basin but are more prominent north of 119th Street. In 2002, the basin land cover was 6.8% forested, 18.3% canopy (individual or small patches of trees), 10.5% impervious, and 64.2% non-canopy (Figure 7). The small patches of forest lands that remain are more prominent in the western portion of the basin.

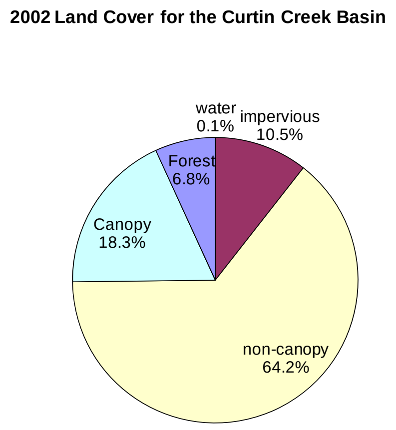

Figure 7. Land cover characteristics for the Curtin Creek basin (data from Clark County 2002 Land Cover shapefile)

3.1.6.3 Future

Future land use for the Curtin Creek basin is characterized in the document "Clark County 20-Year Comprehensive Growth Management Plan 2004-2024". The current land use zoning for the basin was extracted from the accompanying GIS coverage and is provided in Table 1.

Table 1. Land Use Zoning in Curtin Creek Basin

Zone	Percentage of Curtin Creek Basin
Urban	79.4
Rural Residential	10.0
Agricultural	8.9
Parks and Open Space	1.7

As seen in the table, approximately 8.9 percent of the basin is zoned for agricultural use and 10.0 percent is zoned for rural residential development. These areas would be expected to have minimal increases in impervious surface area and therefore the least impact on future hydrologic conditions resulting from build out of the current comprehensive plan and zoning. The zoning for the remaining 79.4 percent of the basin is a mix of urban industrial, commercial and residential development which would be expected to have the highest proportion of impervious area and therefore the largest impact on future hydrologic conditions resulting from build out of the current comprehensive plan and zoning.

A land use zoning map is provided in Figure 8. As seen in the figure, the areas that are expected to have the greatest increase in impervious surface area and therefore the greatest impact on future hydrologic conditions are located in south of 119th Street. The central portion of the basin north of 119th Street is expected to have only minimal increases in impervious areas and therefore the least impact on future hydrologic conditions.

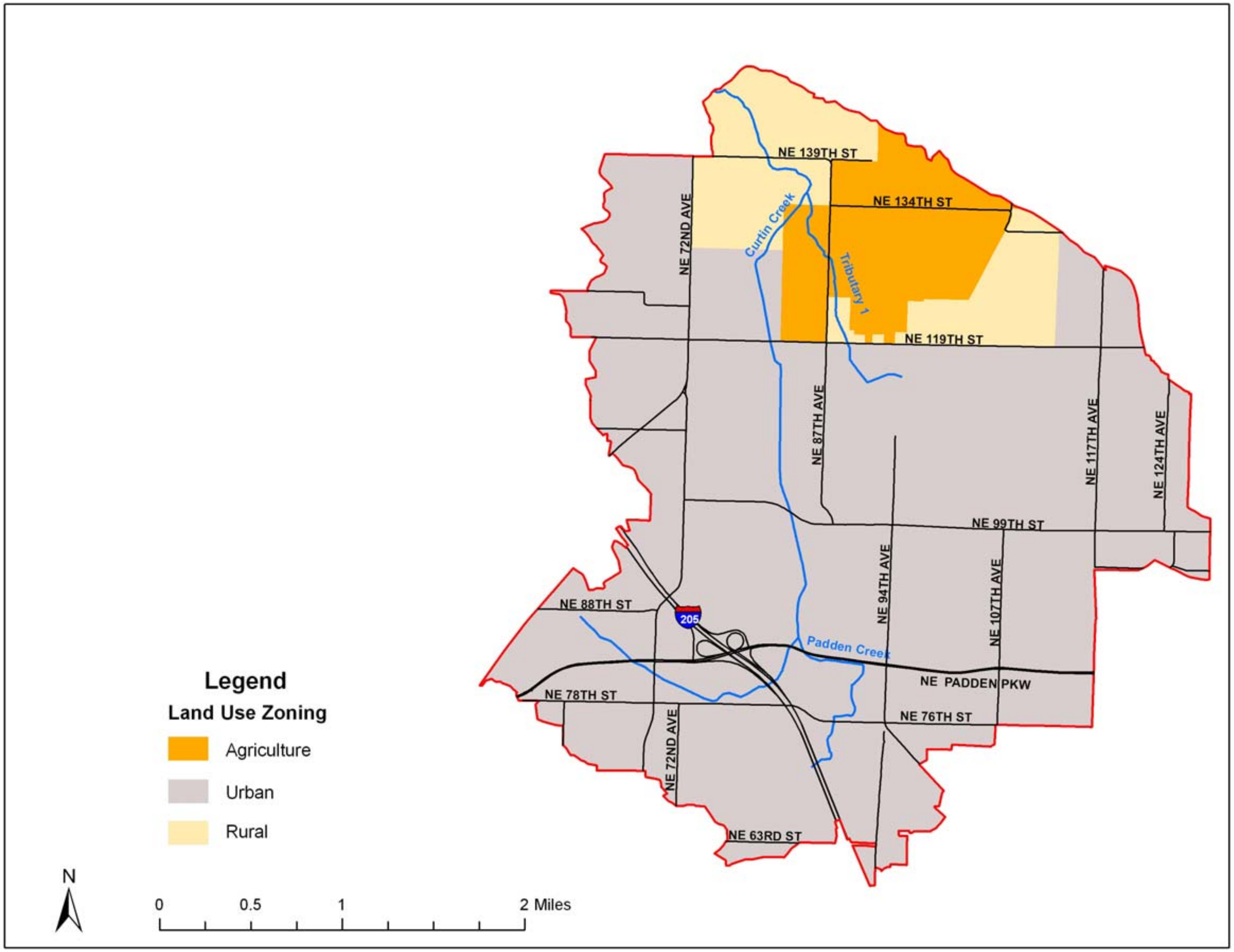

Figure 8. Land use zoning (data from Clark County Comprehensive Growth Management Plan).

3.1.7 Hydromodifications

Hydromodifications that have occurred in the Curtin Creek basin include the following: private dams and associated ponds; stormwater detention ponds; stormwater piping, culvert and bridge stream crossings; and drainage ditches in fields and along roadways. Direct water withdrawal from streams for irrigation purposes may also be occurring, but identification of their location and extent was beyond the scope of this investigation.

3.1.7.1 Dams and Ponds

Private dams and associated ponds have been observed within the Curtin Creek basin. However, these types of modification are not prevalent in the basin and are typically offline from the main channel. The ponds appear to be mostly for aesthetic/recreational purposes and may be responsible for incremental increases in water temperature during parts of the year resulting from increased exposure to solar radiation. Fecal coliform contamination from waterfowl is an additional concern.

3.1.7.2 Stormwater Facilities

Stormwater detention basins are associated with more recent residential and commercial development in the Curtin Creek basin. Stormwater detention ponds temporarily store excess runoff that results from the construction of impervious surfaces. The detention ponds are typically designed to control peak flows and are likely increasing the duration of moderate flows that over time may result in the incision and subsequent instability of downstream channels. Stormwater piping is found mostly in the southern portion of the basin where there are a greater number of high density residential neighborhoods and commercial developments compared to the northern portion of the basin which is rural. Much of the stormwater pipe networks that exists in the eastern portion of the basin are routed to Class V injection wells or other types of retention facilities and therefore do not directly drain to the open channel system.

3.1.7.3 Drainage Ditches

As previously mentioned, the system of stream channels located upstream of NE 129th Street are a network of ditches that were originally constructed to improve drainage conditions for agriculture. When combined with the smaller drainage ditches that exist in farm fields and along roadways, the drainage density in the basin is much greater than would otherwise occur. The increased drainage density results in a reduction in the time of concentration and therefore quicker runoff response to precipitation and increased peak flows. Drainage ditches also reduce the amount of water that would otherwise infiltrate into the surrounding soils and later be released to the streams as base flow during dry periods. In locations where treatment facilities have not been developed, roadway drainage ditches may convey pollutants that are washed from the road surface and conveyed directly to stream channels.

3.1.7.4 Hydraulic Structures

Culvert and bridge crossings locally modify the hydraulics of the stream both upstream and downstream of the structure. This effect usually results in a disruption in the natural sediment transport characteristics of the involved stream channel. In locations where the size of the hydraulic opening is restricted, backwater conditions will occur during moderate and high flows. Reduced stream velocities and shear stresses due to backwater often result in increased sediment deposition upstream of the hydraulic structure and decreased sediment supply to downstream reaches.

If significant floodplain storage is available upstream of the structure, temporary storage of flood waters can occur and result in a reduction in downstream peak flows. In contrast to upstream hydraulic conditions, downstream of the structure, stream velocities and shear stresses are locally increased by the restricted hydraulic opening. If not mitigated by an energy dissipation device, this usually results in scour of the channel bed material that often leaves the culvert outlet invert perched above the downstream water surface during moderate and low flows. If the disruption in sediment transport by the hydraulic structure is significant, degradation of downstream reaches may occur. Similarly, culverts and bridges affect the ability of the stream channels to migrate. This impact may alter sediment transport and the form of the upstream and downstream channel.

Figure 9 shows a channel shear stress profile of Curtin Creek developed from the existing HEC-RAS hydraulic model (WEST, 2005). The RAS model was modified to include future conditions flows for Curtin Creek based on an available HSPF hydrologic model (MGS, 2002). As seen in the figure, the channel shear stress for the 2-year recurrence interval flood is significantly reduced upstream of and significantly increased downstream of various road crossings, most notably NE 76th Ave and NE 82nd Ave. No significant erosion issues were observed downstream of NE 82nd Ave. Minor scour of the channel and sloughing of the bank downstream of the NE 76th Ave culvert was observed. Also seen in the figure is a significant spike in the shear stress upstream of Padden Parkway where a nickpoint is located. At this location an approximately 6 to 8 foot high waterfall was observed (see Figure 10).

Channel shear stress is also seen to spike just downstream of NE 88th Street. At this location, Curtin Creek descends a moderately steep slope before entering a broad and nearly flat valley bottom located approximately at River Mile (RM) 3.2. As seen in Figure 9, except for immediately downstream of NE 82nd Ave, the future conditions 2-year flow is not expected to significantly alter the magnitude of channel shear stress. Downstream of NE 82nd Ave, channel shear stress is significantly reduced for future conditions flows. Although the magnitude of the 2-year flow for future conditions is greater than for existing conditions, the higher discharge results in greater backwater from the bridge located downstream at NE 139th. The increased backwater elevation reduces channel velocities and shear stress at NE 82nd Ave.

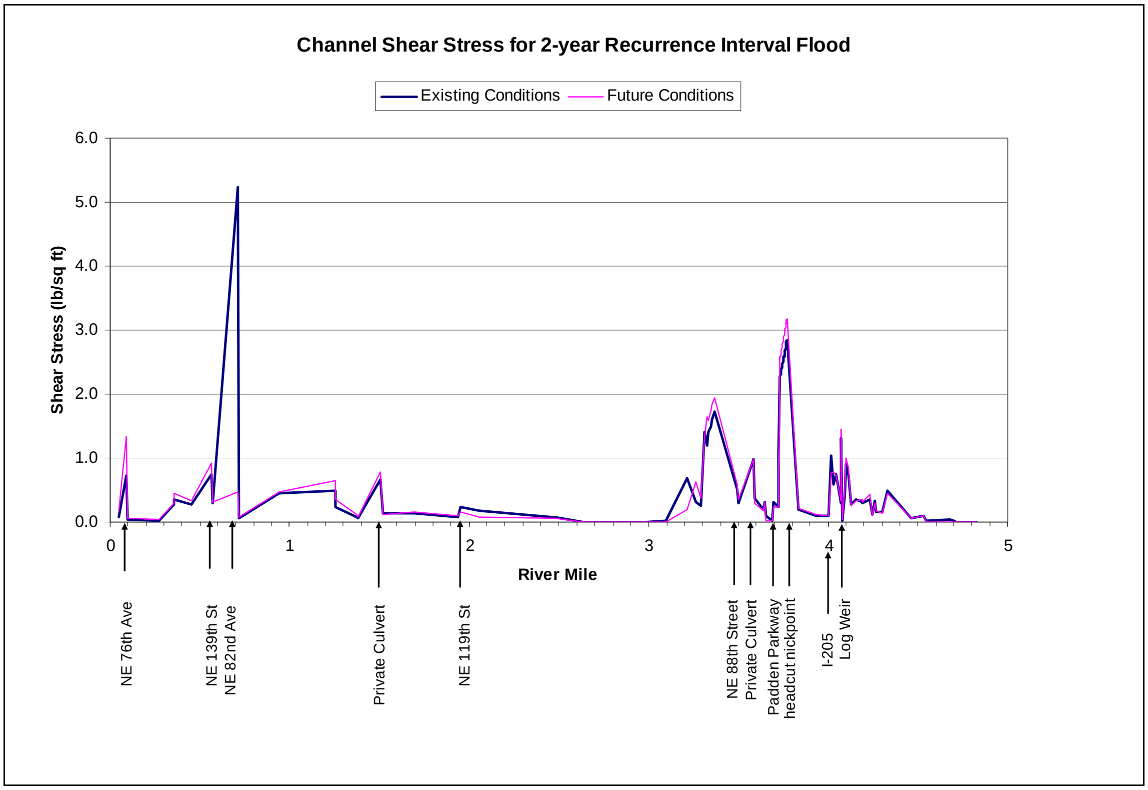

Figure 9. Channel shear stress profile for 2-year flood along Curtin Creek (WEST, 2005).

Figure 10. Waterfall at headcut nickpoint locate approximately 100 feet upstream of Padden Parkway.

As seen in Figure 11, the relative percentage of the total 10-year peak flood discharge conveyed in the floodplain is influenced by several existing road crossings. Backwater conditions upstream from the road culverts result in a greater portion of the total discharge being conveyed within the floodplain. Downstream of the culverts, the discharge is mostly confined to the channel. It should also be noted that the stream reaches with the greatest percentage of flow in the floodplain shown in Figure 11 are seen in Figure 9 to have the lowest values of shear stress while the more confined reaches which have little or not flow in the floodplain have larger values of shear stress.

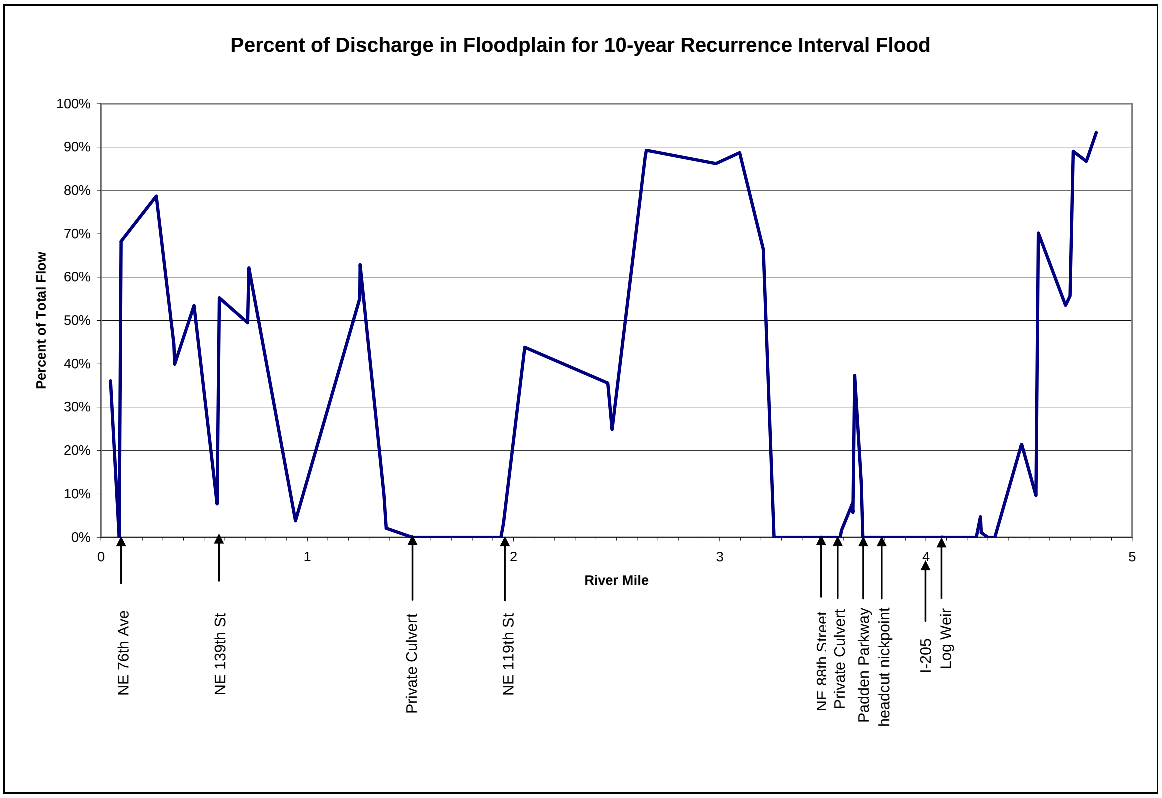

Figure 11. Percentage of total existing conditions 10-year peak discharge conveyed in the Curtin Creek floodplain (WEST, 2005)

3.1.8 Conclusions

- The upper and middle portion of the Curtin Creek basin are expected to experience additional impacts to future hydrologic conditions resulting from build out of the current comprehensive plan and zoning. These areas are likely to experience changes to the geomorphic characteristics of the stream channels. Although future land use conditions in the lower portion of the basin are not expected to change significantly from current conditions, the lower portion of Curtin Creek is likely to undergo morphologic change as peak flows and/or flow durations originating in the upper and middle portion of the basin increase.

- Although not prevalent in the basin, dams and associated ponds have resulted in localized alterations to the natural hydrologic, geomorphic and water quality conditions of Curtin Creek. This is resulting in alterations to the sediment transport conditions, elevation of water temperatures, and is contributing to increased contamination from waterfowl.

- Class V injection wells and other stormwater retention facilities present in the eastern portion of the basin are likely helping to reduce the hydrologic impacts normally associated with increased impervious surface area from urban development.

- Stormwater detention facilities will need to be designed to manage peak flows and flow durations of erosive discharges. Otherwise, channel incision, headcutting and subsequent bank failures will occur. Degradation of the channel will be especially pronounced in the steeper gradient stream reaches and downstream of hydraulic structures that currently exhibit relatively high values of shear stress.

- The system of stream channels located upstream of NE 129th Street are a network of ditches that were originally constructed to improve drainage conditions for agriculture. When combined with the smaller drainage ditches that exist in farm fields and along roadways, the drainage density in the basin is much greater than would otherwise occur. This has resulted in the drainage of natural wetlands, increased peak flows, and reductions in groundwater recharge. Where treatment facilities are not installed, roadway drainage ditches convey pollutants directly to stream channels.

- Culverts and bridges are altering sediment transport conditions and locally prevent channel migration. Culvert crossings at NE 76th Ave, Padden Parkway and the east parking lot entrance to Crossroads Church were seen to have channel degradation and/or local scour occurring downstream. Unless mitigated, future increases in peak flows and/or flow durations will exacerbate existing scour conditions at these locations.

- Culvert crossings significantly influence the amount of floodwaters that are conveyed and/or stored in the floodplain. Replacement of culverts with structures having greater hydraulic efficiency and therefore less backwater, will result in greater concentration of flows in the channel and less floodplain connectivity immediately upstream of the structure. Culvert replacement may also result in increased flows downstream of the structure as a result of lost floodplain storage. Unless mitigated, localized impacts to the stream channel in the form incision and bank failures will occur. Mitigation could be in the form of woody debris jams and grade control structures. The installation of woody debris jams will result in increased channel roughness, reduced stream velocities and shear stresses, higher water surface elevations, and greater connectivity between the channel and floodplain. Grade control structures would help prevent channel incision.

3.1.9 Recommendations

- Develop projects that restore the hydrologic and habitat functions of areas that historically were considered wetlands. Specifically, wetland restoration projects located within the wide valley bottom containing Curtin Creek between NE 90th Street and 129th Street would help protect the lower reach of Curtin Creek from future increases in erosive flows.

- It is noted that the land use zoning map provides a broad level of detail regarding land use for a 20-year period (2004-2024). Those portions of the basin that are expected to experience the least amount of development over this time period should not be ignored. Reestablishment of riparian corridors along the lower portion of Curtin Creek will provide greater protection to the stream channel as development pressure in the upper and middle portion of the basin increases in the future.

- Dams and associated ponds should be individually evaluated to determine the impact each is having on the hydrology, water quality and geomorphology of the involved stream. This could be used to prioritize both modifications to and/or removal of existing structures.

- Existing stormwater infiltration facilities are present in the eastern portion of the basin. Much of this portion of the basin is composed of gravelly loam soils derived from a coarser grained facies of the Cataclysmic Flood Deposits. Infiltration facilities should be considered the preferred option for disposal of stormwater in this area as long as site specific soil and groundwater conditions are appropriate.

- Existing and future stormwater detention facilities should be evaluated through the use of continuous simulation hydrologic modeling to understand the magnitude of modifications to the duration of flows compared to predevelopment conditions.

- Ensure appropriate BMPs are being implemented with regard to maintenance of drainage ditches and discourage the development of new drainage ditches that have a direct connection to natural channels.

- Use geomorphically based performance standards when designing and constructing new or replacement hydraulic structures at road crossings. Designs should allow for lateral and longitudinal continuity and connectivity of both the channel and functional floodplain in addition to hydraulic design considerations. Potential upstream and downstream impacts resulting from the replacement structure and mitigation for these impacts must be considered during design. Mitigation in the form of woody debris jams and grade control or other appropriate measures should be installed to offset the loss of floodplain connectivity and channel incision that would likely occur as a result of the replacement structure.

- Install energy dissipation devises downstream of culverts where scour has degraded the downstream channel. Culvert crossings at NE 76th Ave, Padden Parkway and the east parking lot entrance to Crossroads Church are exhibiting these conditions.

3.2 Hydrology

3.2.1 Drainage Basin

The Curtin Creek basin is approximately 10.7 square miles in total area. A summary of tributary drainage basin areas is provided in Table 2. Average annual precipitation over the basin is 44 inches (NRCS, 1998). Curtin Creek is a 2nd order tributary to Salmon Creek and is approximately 5 miles in length. Major tributaries to Curtin Creek include Padden Creek and Tributary 1. All stream channels in the Curtin Creek basin are considered head water streams (1st or 2nd order) (Wierenga, 2005). Approximately 6.1 percent of the basin is mapped as wetland and 2.6 percent is mapped as floodplain (Wierenga, 2005). The percentages of wetland and floodplain area suggests that portions of the basin will store and attenuate flood waters.

Table 2. Curtin Creek drainage basin areas.

Stream	Drainage Area (sq. mi.)	Percent of Total
Curtin Creek	10.7	100
Padden Creek	1.2	11
Tributary 1	3.6	34

Approximately, 87 percent of the basin soils are type B (well drained), 12 percent of the basin soils are type C/D (moderate to poorly drained), and the remaining 1 percent of the basin soils are type A (excessively drained). This indicates that, except for impervious areas, there is a greater tendency for precipitation over the basin to infiltrate into the soils rather than contribute to surface runoff. Runoff rates increase in the mid and late winter months after the soil moisture levels in the basin have been replenished by late fall and early winter storm events.

3.2.2 Stream Flow Conditions

A stream gage located at NE 139th Street on Curtin Creek has been in operation since March 2003. The gage at NE 139th Street has a drainage area of 10.3 square miles, which is approximately 0.4 square miles smaller than the Curtin Creek Basin (10.7 square miles).

Mean monthly discharges for water years 2003 through 2007 are shown in Figure 12. As seen in the figure, the highest flows occur during the winter and spring months with lows flows occurring during the summer and early fall months. Mean annual flow for Curtin Creek at the gage is 9.3 cfs. Mean Annual Discharge based on output from the HSPF hydrologic model (MGS, 2002) is 13.4 cfs.

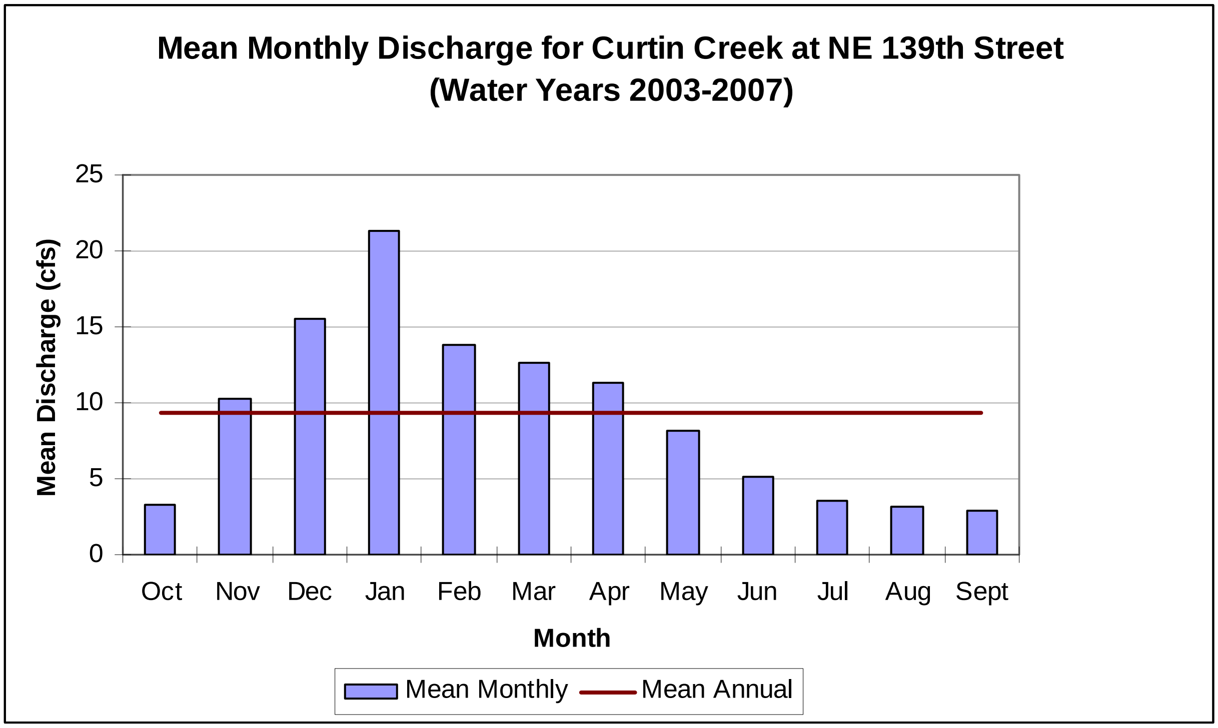

Figure 12. Mean Monthly Discharge for Curtin Creek at NE 139th Street.

The lower magnitude flows that occur during the summer and early fall months are a result of multiple contributing factors. The largest contributing factor is the temperate marine climate which tends to favor wet winters and dry summers. However, as seen in the figure, average flow conditions during the summer and fall months are not extremely low compared to average flow condition during the winter months. The relatively flat terrain, well drained soil conditions and available wetland and floodplain areas in the basin dampen the runoff response by storing a portion of the wintertime precipitation for later release in the summer and fall months. Future increases in the amount of impervious surface area will reduce infiltration and increase wintertime runoff volumes resulting in a reduction in the magnitude of summer and fall low flows. As of 2002, the total impervious area represented approximately 10.5 percent of the basin.

The maximum mean daily discharge for water years 2003 through 2006 was 56 cfs, which occurred on January 11, 2006. Figure 13 shows a winter period hydrograph for water year 2006 at NE 139th Street. As seen in the figure, flows from individual storm events can last 1 to 2 weeks or more. Both the rising and falling limbs of individual storm hydrographs are not significantly steep and take several days for the peak discharge to occur. This indicates that Curtin Creek does not have a flashy response to precipitation events at this location.

A quantitative indicator of the flashiness of a basin is the value of T_{Qmean}, which is the portion of time mean daily flows exceed the mean annual flow. Low values of T_{Qmean} are often associated with urbanized watersheds. The redistribution of water from base flow to surface runoff will decrease the fraction of time that daily discharges exceed the mean discharge. Therefore, the higher the T_{Qmean} value, the more stable or less flashy the stream. The T_{Qmean} for Curtin Creek calculated from the available data for the 139th Street gage is 0.33. Daily flows for the mouth of Curtin Creek generated from the HSPF model for existing and proposed conditions were also used to determine T_{Qmean}. Existing and future conditions values of T_{Qmean} are 0.33 and 0.31, respectively. Although Curtin Creek has significant urban development, the calculated values of T_{Qmean} are more typical of a suburban watershed. An investigation of urban and rural streams in the Puget Sound (Booth, et al, 2001) found that urban streams tended to have T_{Qmean} values of less than 0.3 while suburban streams have values greater than 0.3. The relatively high value of T_{Qmean} for Curtin Creek maybe the result of the relatively flat terrain, well drained soils and available wetland and floodplain areas in the basin.

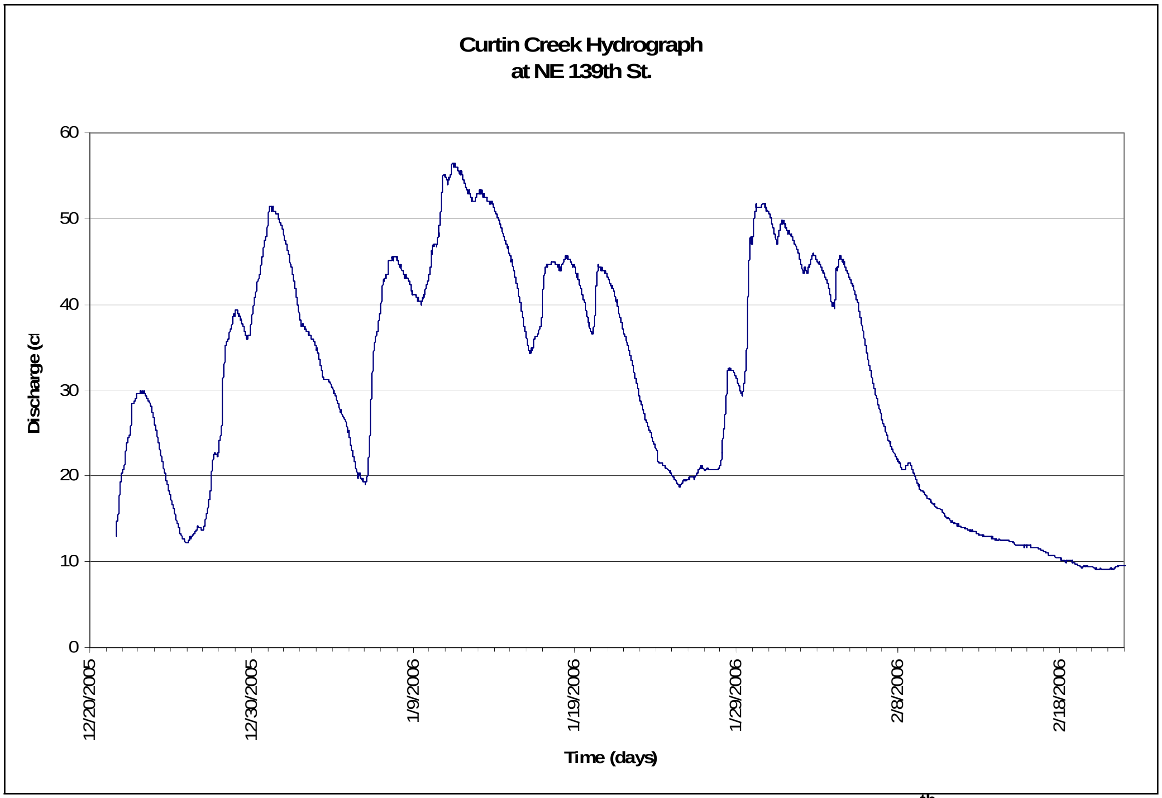

Figure 13. Winter 2006 hydrograph for Curtin Creek at NE 139th Street.

3.2.2.1 Peak Discharges

The period of record for the Curtin Creek gage at NE 139th Street is not sufficient to conduct a flood frequency analysis. Therefore, peak discharges and associated recurrence intervals for Curtin Creek were estimated using a HSPF hydrologic model for the Salmon Creek basin (MGS, 2002) which included several Curtin Creek subbasins. Existing and future conditions peak flows for selected locations along Curtin Creek are shown in Table 3. It should be noted that the existing and future conditions HSPF model (MGS, 2002) did not consider stormwater detention/infiltration facilities or the associated reduction in effective impervious area. Therefore, peak flows predicted for existing and future conditions are likely overestimated.

Available stream flow records indicate that annual peak discharges for water years 2003 to 2007 ranged from 36 to 56 cfs. In the last five years, peak discharges have been well below the magnitude of a 2-year recurrence interval flood. It should be noted that the HSPF hydrologic model for Curtin Creek (MGS, 2002) was developed in 2002, well before the stream gage was installed. Therefore, calibration of flows for Curtin Creek was not conducted. Considering that significant flooding has occurred within other Clark County basin in the last several water years, the peak discharges for Curtin Creek shown in Table 3 may be overestimated.

Table 3. Estimated peak discharges for Curtin Creek

Location	Drainage Area (mi^2)	Recurrence Interval (yrs)	Existing Discharge (cfs)	Future Discharge (cfs)
Curtin Creek basin outlet At confluence with Salmon Creek	10.7	2	200	280
		10	335	445
		20	390	510
		50	460	610
		100	520	685
		500	670	880
Curtin Creek downstream of Tributary 1 confluence	10.0	2	195	270
		10	320	430
		20	375	495
		50	450	585
		100	510	660
		500	665	840
Curtin Creek upstream of Tributary 1 confluence	6.4	2	155	230
		10	255	375
		20	300	430
		50	360	515
		100	405	580
		500	530	760
Curtin Creek at NE 109th (Railroad Crossing)	4.5	2	140	195
		10	225	315
		20	260	365
		50	315	435
		100	360	495
		500	470	650

3.2.2.2 Flow-Duration

Existing and future conditions flow-duration curves for Curtin Creek are provided in Figure 14. As seen in the figure, the existing and future conditions flow-duration curves diverge from one another at approximately 15 cfs. For future conditions, the duration of flows greater than 15 cfs is expected to increase while flows less than 15 cfs are expected to have roughly the same duration. Flows are expected to equal or exceed 15 cfs approximately 30 percent of the time. Therefore, approximately 70 percent of the time, future flow conditions will be about the same as for existing conditions. As discussed in Section 3.2.8, a discharge of 15 cfs is sufficient to transport sand sized bed material of Curtin Creek along most reaches of Curtin Creek. Therefore, for future hydrologic conditions, sediment transport rates are expected to be greater than for existing conditions approximately 30 percent of the time.

As seen in Figure 14, the flow-duration curve developed for the gage (located at NE 139th Street) is much lower than both the existing and proposed conditions curves developed from the HSPF model. As was previously noted, the existing and future conditions HSPF model (MGS, 2002) did not consider stormwater detention/infiltration facilities or the associated reduction in effective impervious area. Therefore, flow-duration curves for existing and future conditions developed from the HSPF model are likely overestimating the frequency of high flow events and underestimating the frequency of low flow events. It should be noted that the period of record for the gage is rather short and that the gage is located upstream of the location used in the

HSPF model). Therefore, the gage data may not fully represent the flow-duration conditions of the basin.

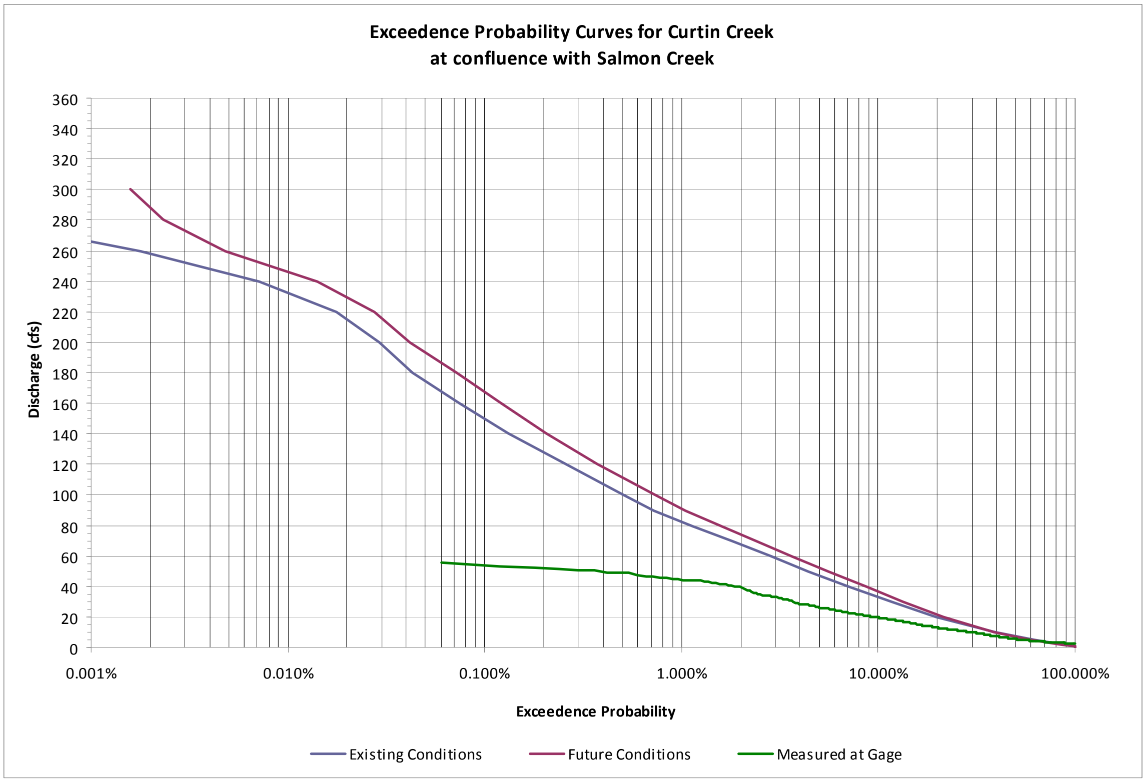

Figure 14. Flow-duration curves for Curtin Creek at the mouth.

3.2.2.3 Low Flow Conditions

The available period of record for the Curtin Creek gage at NE 139th Street is not sufficient for developing low flow statistics. However, low flow statistics developed from the HSPF hydrologic model for Curtin Creek (MGS, 2002) are provided in Table 4. As seen in the table, future low flows are not expected to be significantly lower than the existing conditions. The minimum mean daily flow recorded at the gage was 2.2 cfs which occurred on September 28, 2003. If new development relies heavily on infiltration facilities for stormwater disposal, low flows could remain the same as existing conditions or could even increase in the future.

Table 4. 7-day low flow magnitude-frequency statistics for Curtin Creek

	Discharge (cfs)				
Recurrence Interval	1.25-yr	2-yr	5-yr	10-yr	25-yr
Existing Conditions (cfs)	1.6	1.4	1.2	0.9	0.8
Future Conditions (cfs)	1.5	1.3	1.1	0.8	0.7

3.2.3 Conclusions

- The percentages of wetland and floodplain areas in the basin suggests that significant portions of the basin will store and attenuate flood waters. Therefore, opportunities are likely to exist within the basin for enhancement of existing wetlands and floodplains for the purpose of increasing available flood storage.

- Existing stormwater infiltration/retention facilities located in the eastern portion of the basin are helping to reduce the amount of runoff that would otherwise be conveyed to the channels in the Curtin Creek basin. These facilities are helping to reduce the magnitude of peak flows and the duration of erosive flows that would otherwise be associated with increased impervious area resulting from urban development.

- The T_{Qmean},a measurement of “flashiness”, for Curtin Creek is 0.33 and 0.31 for existing and future conditions, respectively. This value is more typical of suburban streams with minimal development. The relatively high value of T_{Qmean} for Curtin Creek is likely the result of the relatively flat terrain, high percentage of well drained soils and significant wetland and floodplain areas in the basin. These factors combine to reduce the flashiness of the basin. Although future development will result in a reduction in the value of T_{Qmean}, it does not appear that it will significantly increase the flashiness of Curtin Creek.

- Basin soil conditions in the eastern half of the basin do not significantly limit infiltration rates. Therefore, infiltration facilities in this portion of the basin should be a viable solution to stormwater disposal. However, a large portion of the western half of the basin is composed of soils with low infiltration capacities; therefore, benefits from the installation of infiltration facilities may not be realized except during low intensity and/or short duration storm events.

- Erosion problems were observed to be limited to a few reaches in the Curtin Creek basin. However, future changes in basin conditions that increase the duration of erosive flows, reduce riparian vegetation along channel banks, adversely alter hydraulic conditions, or impact sediment supply and transport will accelerate the existing degradation and increases the susceptibility of the remaining reaches to channel and bank erosion.

- Based on a comparison of the existing and future conditions flow-duration curves, approximately 30 percent of the time, sediment transport rates in most channel reaches are expected to be greater for future hydrologic conditions relative to existing conditions.

- Existing and future conditions HSPF model (MGS, 2002) did not consider stormwater detention/infiltration facilities or the associated reduction in effective impervious area. Therefore, the hydrology for Curtin Creek developed from the HSPF model is likely overestimating the magnitude and frequency of high flow events and underestimating the magnitude and frequency of low flow events.

3.2.4 Recommendations

- Encourage the use of Low Impact Development (LID) measures for newly developing areas in the basin. LID focuses on minimizing the amount of runoff generated from the site by minimizing to the extent practical the amount of increased impervious surface area and infiltrating and treating stormwater runoff near the source in order to best mimic the predevelopment hydrologic conditions. Where soil conditions are a limiting factor on infiltration, LID practices should be combined with traditional stormwater detention/retention facilities.

- Continue the use of Class V stormwater infiltration wells and other infiltration/retention facilities in basin areas that have appropriate soil and groundwater conditions.

- Continue monitoring stream flows at the 139th Street gage and consider the installation of an additional stream gage in the upper portion of Curtin Creek Basin at a location below and near the confluence with Padden Creek. T_{Qmean} and other streamflows statistics can be used to help evaluate the effectiveness of stormwater management practices as future development occurs in the basin. However, flow monitoring at the 139th Street gage may not capture the extent of hydrologic changes that are occurring in the upper basin. An additional stream flow gage would allow for results that represent the upper portion of the Curtin Creek basin and thus exclude the storage and attenuation of flows that occurs between approximately RM 1.5 and RM 3.0.

- Update and calibrate the existing continuous simulation hydrologic model of the Curtin Creek basin to help evaluate changes in basin hydrology associated with future development. Updates should include incorporation of the infiltration facilities and associated reduction in effective impervious area in the eastern portion of the basin. The updated model would help determine the magnitude and location of expected hydrologic changes and be useful to evaluate the effectiveness of stormwater facilities and potential mitigation projects.

- Develop more stringent stormwater flow control regulations that control peak discharges and the duration of erosive flows in order to help protect and restore stream channel and riparian habitat in the Curtin Creek basin.

- Where appropriate, develop regional stormwater detention facilities and/or enhance existing wetland and floodplain storage areas to reduce hydrologic impacts to basin stream channels.

Geomorphology

3.2.5 Channel Profiles

The channel slope, sinuosity, and bed material size were used to divide the channel into 8 separate reaches of similar geomorphic characteristics which are summarized in Table 5. Reach locations are shown in Figure 15. As seen in the table, channel sinuosity for Reaches 2 through 8 is low (1.0). This reflects the anthropogenic origins of these channelized reaches which were originally created to improve drainage conditions for agriculture. In contrast, the naturally formed channel comprising Reach 1 is considered moderately sinuous (1.2). A stream channel profile for Curtin Creek (Figure 16) was developed from the existing HEC-RAS model (WEST, 2005) developed for the preliminary FEMA Flood Insurance Study (FEMA, 2006). The profile shows the reach limits and average channel slope for each defined reach.

Table 5. Summary of reach characteristics

Reach	Extents	Average Slope	Sinuosity[1]		Bed Material
1	Mouth to Private Culvert at RM 1.5	0.003	1.2	Moderate	sand
2	Private Culvert at RM 1.5 to RM 3.3	0.0008	1.0	low	sand/silt
3	RM 3.3 to NE 88th St (~RM 3.5)	0.012	1.0	low	sand/bedrock
4	NE 88th St (~RM 3.5) to Padden Parkway	0.006	1.0	low	sand
5	Padden Parkway to headcut nickpoint (~RM 3.8)	0.044	1.0	low	sand/bedrock
6	Headcut nickpoint (~RM 3.8) to I-205	0.003	1.0	low	sand
7	I-205 to RM 4.3	0.011	1.0	low	sand/silt
8	RM 4.3 to Padden Parkway	0.001	1.0	low	sand/silt

1. Sinuosity is the ratio of the channel length to the valley length. The classification of sinuosity is based on Rosgen's Stream Classification System (1996)

Additionally, available topographic data were used to develop a DTM of the basin and extract ground profiles along the mainstem and tributary stream channel centerlines. The extracted ground profiles are shown in Figure 17. As seen in the figure, Paden Creek and Tributary 1 have similar average channel slopes of approximately 25 feet/mile (0.005).

It should be noted that a significant headcut nickpoint is located on Curtin Creek approximately 100 feet upstream of Padden Parkway. The nickpoint forms an approximately 6 to 8 foot high waterfall. Erosion resistant bedrock layers appear to be controlling the upstream migration rate of the headcut. These erosion resistant bedrock layers may be part of the Cataclysmic Flood Deposits or could possibly be part of the same formation of very course hyaloclastite which was observed further upstream as described in Section 3.1.1. Further investigation would be required to determine the long-term stability of the headcut.

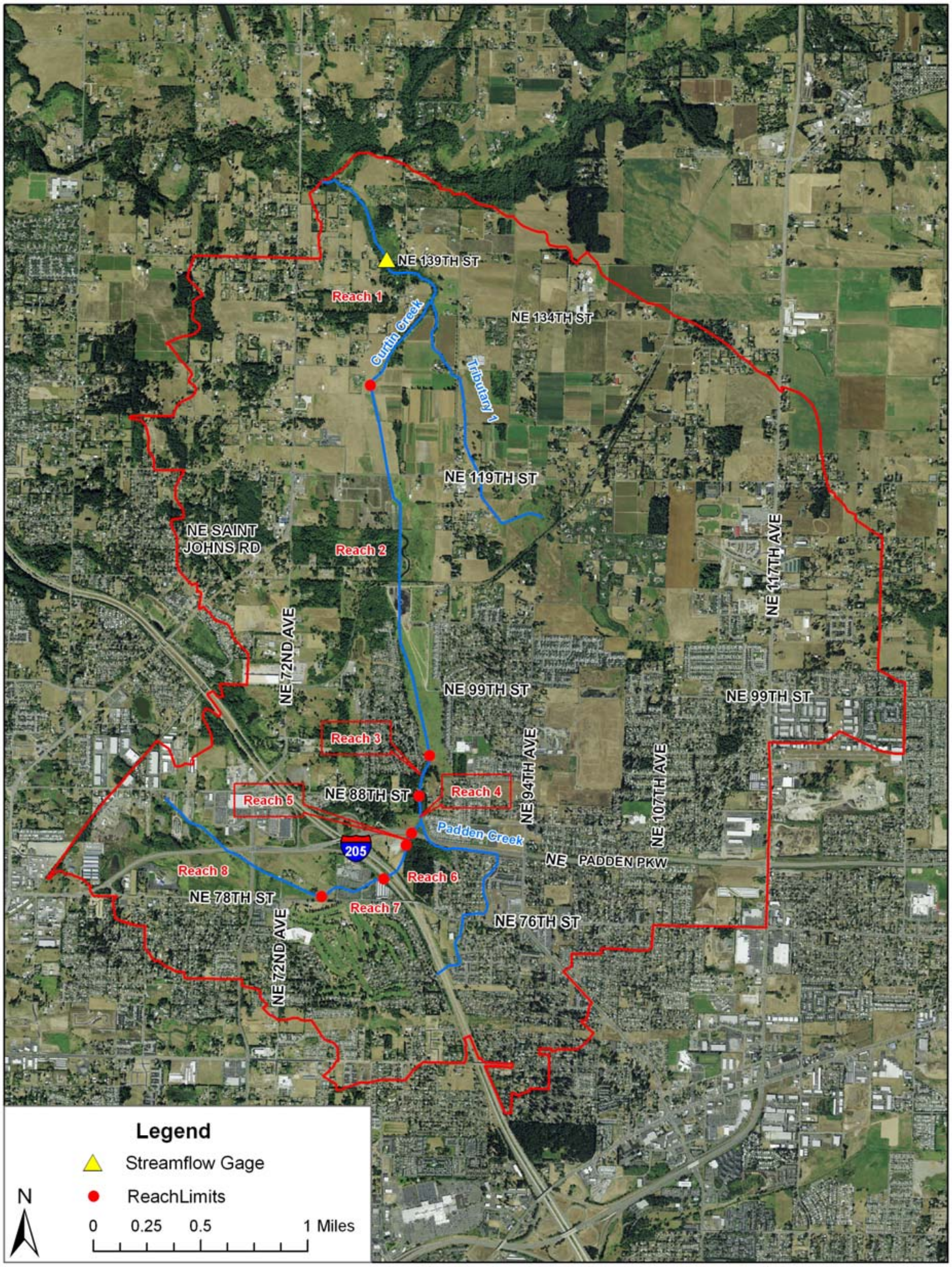

Figure 15. Location of geomorphic reaches defined for Curtin Creek.

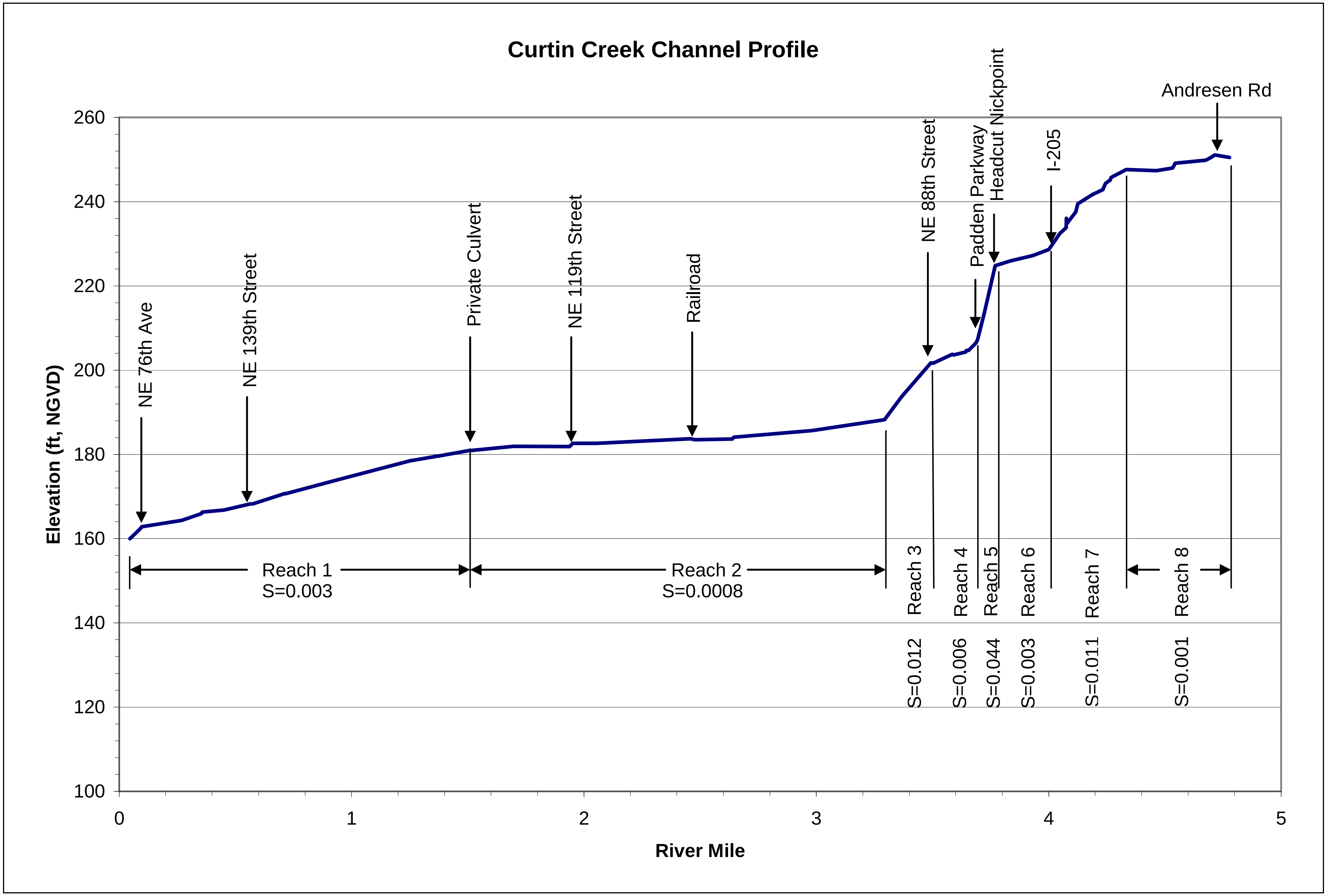

Figure 16. Stream channel profile of Curtin Creek (data from WEST, 2005).

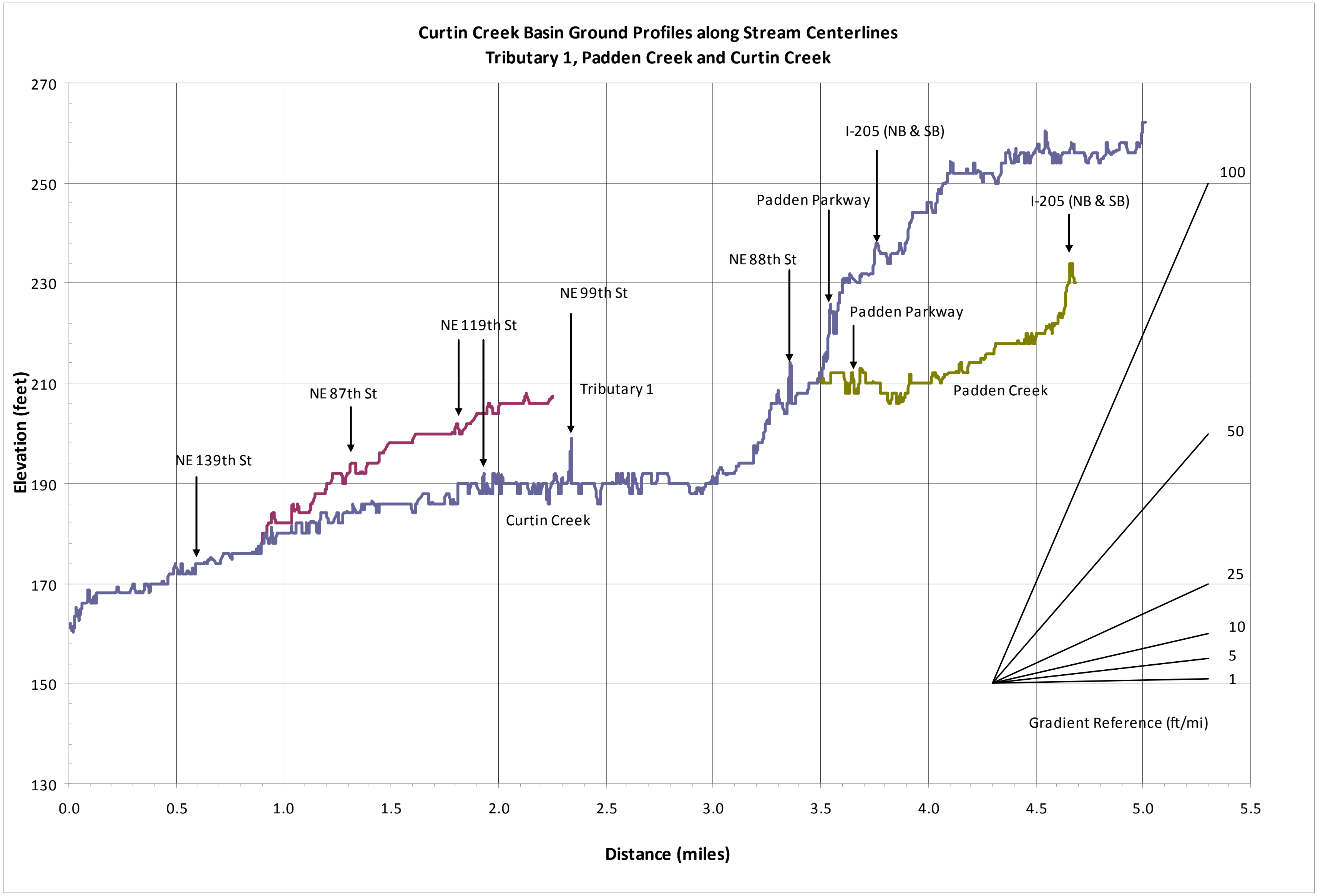

Figure 17. Ground profiles along Tributary 1, Padden Creek and Curtin Creek.

3.2.6 Channel Planform

3.2.6.1 Reaches 3 through 8

Upstream of approximately NE 134th Street, the channels are fairly straight. Evaluation of historic maps from 1856 (BLM, 2008) indicates that no channel system existed upstream of this location. The current system of channels was created to help improve drainage for agricultural use. The bed material along nearly all of Curtin Creek and its tributaries is composed of sand and silt sized sediment derived from the underlying Cataclysmic Flood Deposits. The channel reaches above RM 3.3 are generally supply limited in that for most flow conditions the channel has the ability to transport more sediment than is supplied to it. As a result, sediment deposition and resulting migration are limited in these reaches. Further, because the fine grained bed material is readily transportable, it provided little resistance to channel incision. However, in these reaches the channel and banks tend to be vegetated with grass which helps limit sediment transport by binding the bed and bank material with roots and shielding them from erosive flows. Reaches 3 through 8 drain portions of the basin that are nearly fully built out with urban residential and commercial developments.

3.2.6.2 Reach 2

Between RM 1.5 and 3.3, the channel continues to follow a nearly straight alignment. Again, this reach of channel was created to improve drainage for agricultural. In contrast to the upstream reaches, this reach is considered a transport limited reach in that sediment supply generally exceeds sediment transport capacity. Because this reach has a fairly flat gradient sediment deposition is occurring. However, the fine-grained nature of the inflowing sediment allows it to be transported as suspended load. Therefore, the majority of sediment deposition occurs in the extensive floodplain areas adjacent to both channel banks. When flows are confined to the channel, the uniform trapezoidal cross section geometry and nearly straight alignment of the channel results in a greater ability to transport sediment which tends to limit sediment deposition within the channel. There is not sufficient energy to erode the channel banks, therefore the development of a meandering planform is not expected. Any instabilities in the planform are likely to occur at the transition between Reach 3 and Reach 2 where the gradient transitions from moderately steep ($S=0.012$) to very flat ($S=0.0008$).

3.2.6.3 Reach 1

Downstream of RM 1.5, the channel becomes more sinuous and does not appear to have been significantly altered. This reach is considered a transport reach in that the sediment supply from upstream is in quasi-equilibrium with the sediment transport capacity. Temporary storage of sediment occurs in the channel and overbank areas within this reach resulting in increased sinuosity compared to the upstream reaches. Available historic aerial photography were not of sufficient resolution to determine historic channel locations or channel migration rates; however, the current channel plan form and unconfined valley form imply that the channel has migrated within the confines of the valley in the past and will likely do so in the future.

3.2.7 Valley Cross Section Geometry

Selected cross sections located along the valley of Curtin Creek were extracted from the DTM of the basin to help understand the valley geometry and how its form transitions from upstream to downstream. The locations of the extracted cross sections are shown in Figure 18. Valley cross section geometries are shown in Figure 19.

3.2.7.1 Curtin Creek Reaches 3 through 8 (cross sections 1, 2, and 3)

Reaches 3 through 8 of Curtin Creek are located within rolling terrain and valley forms that were not created by the actions of Curtin Creek. Rather, these channel reaches were created in the mid 1900's in an attempt to improve drainage conditions for agriculture.

3.2.7.2 Curtin Creek Reach 2 (cross sections 4, 5, and 6)

Reach 2 of Curtin Creek is located with a relatively wide valley. As seen in Figure 18, the bottom widths of cross sections 4, 5, and 6 are each approximately 1,000 feet wide and are at nearly the same elevation. Similar to the channel reaches located upstream, the channel along Reach 2 was constructed in the mid 1900's in an attempt to improve drainage conditions for agriculture. Historic mapping from 1856 (BLM, 2008) shows that the entire valley bottom along this reach was a large wetland. A channel emanated from the northern end of the wetland which was presumably the upstream limit of Curtin Creek prior to the upstream expansion of the channel system.

3.2.7.3 Curtin Creek Reach 1 (cross section 7)

Reach 1 of Curtin Creek is located within a moderately wide somewhat confining valley. Moderately steep slopes (erosional scarps) occur adjacent to floodplain terraces. The erosional scarps likely developed from a combination of incision during the Missoula Floods and lateral migration of Curtin Creek within the Cataclysmic Flood Deposits.

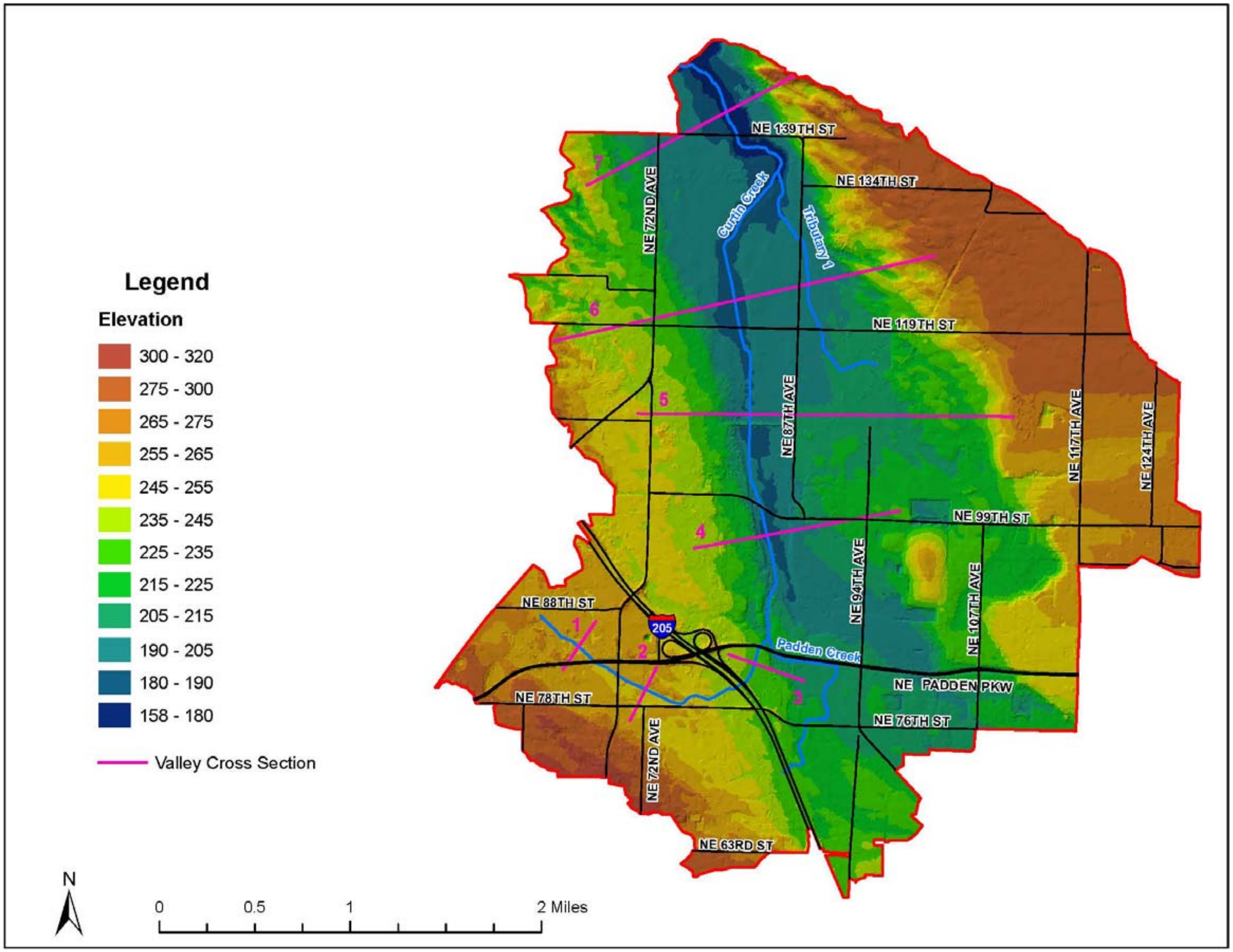

Figure 18. Location of valley cross section extracted from DTM.

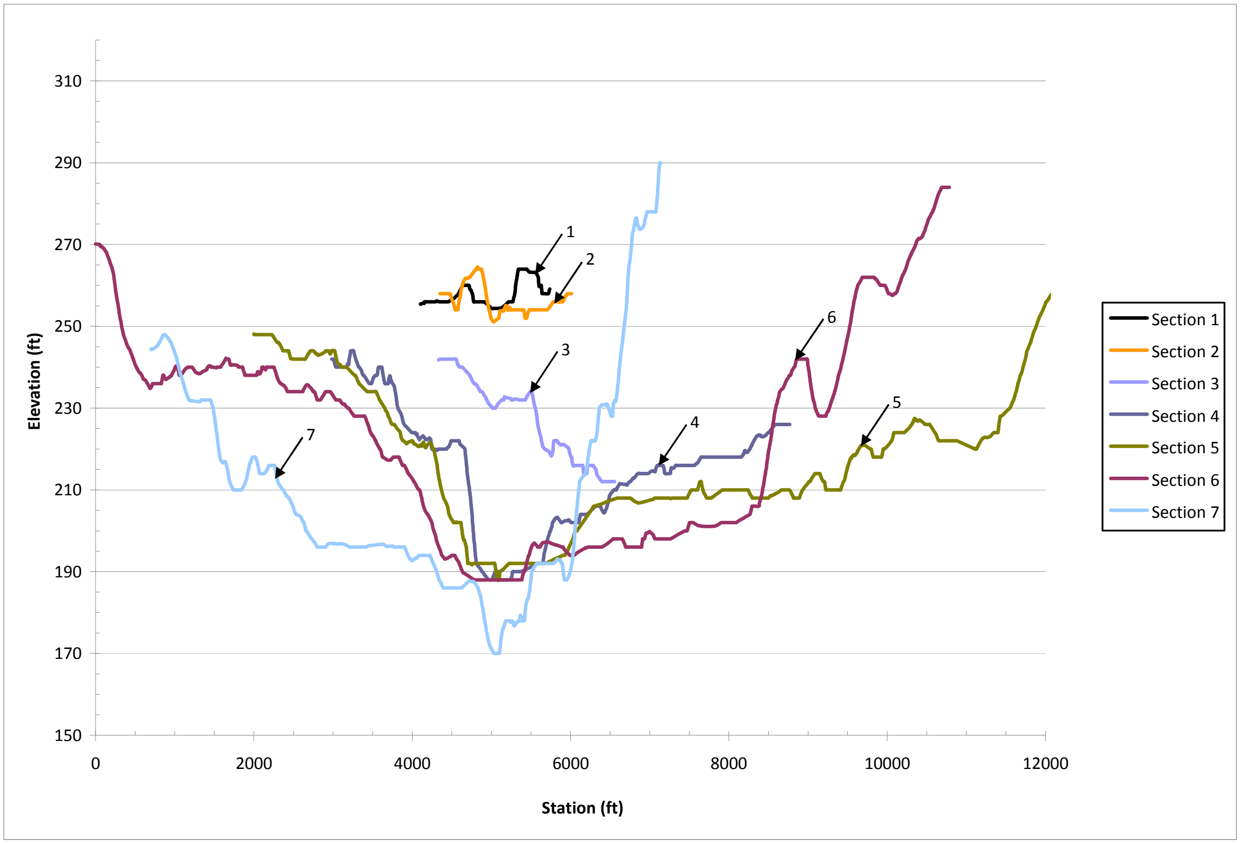

Figure 19. Valley cross sections for Curtin Creek.

3.2.8 Incipient Motion Characteristics

Incipient motion characteristics for Curtin Creek were developed from hydraulic model output (WEST, 2005). The results were compared to the bed material sediment size characteristics observed during the field reconnaissance. Bed material sizes ranged from silt and clay to sand (<2mm). Fine gravel sized material (<8mm) was observed at a few locations, usually immediately downstream of culverts, but was not prevalent in the system. Observed sediment sizes for each reach are shown in Figure 20. The average annual discharge, 50% of the 2-year discharge, and the 2-year discharge were used to calculate the incipient motion sediment sizes along Curtin Creek using Shield's diagram (Vanoni, 1975). As seen in Figure 20, Reach 1 and Reaches 3 through 8 have incipient motion particle sizes that are much greater than the bed material observed in Curtin Creek. At these locations Curtin Creek has the ability to transport the available material for most flow conditions. In Reaches 6 through 8, resistance to sediment movement is provided by grassy vegetation that lines much of the channel bed and banks. In Reaches 3 through 5, resistance to sediment movement is provided intermittently by resistant layers of bedrock. However, these reaches are experiencing both headcutting and channel incision. Reach 2 has incipient motion particle sizes that are nearly the same as the size material that is found in the bed. The ability of Curtin Creek to transport sediment through Reach 2 is much lower than for Reach 1 and Reaches 3 through 8. It should also be noted that the incipient motion particle size increases significantly downstream of several road crossings. These locations are susceptible to scour during high flow events.

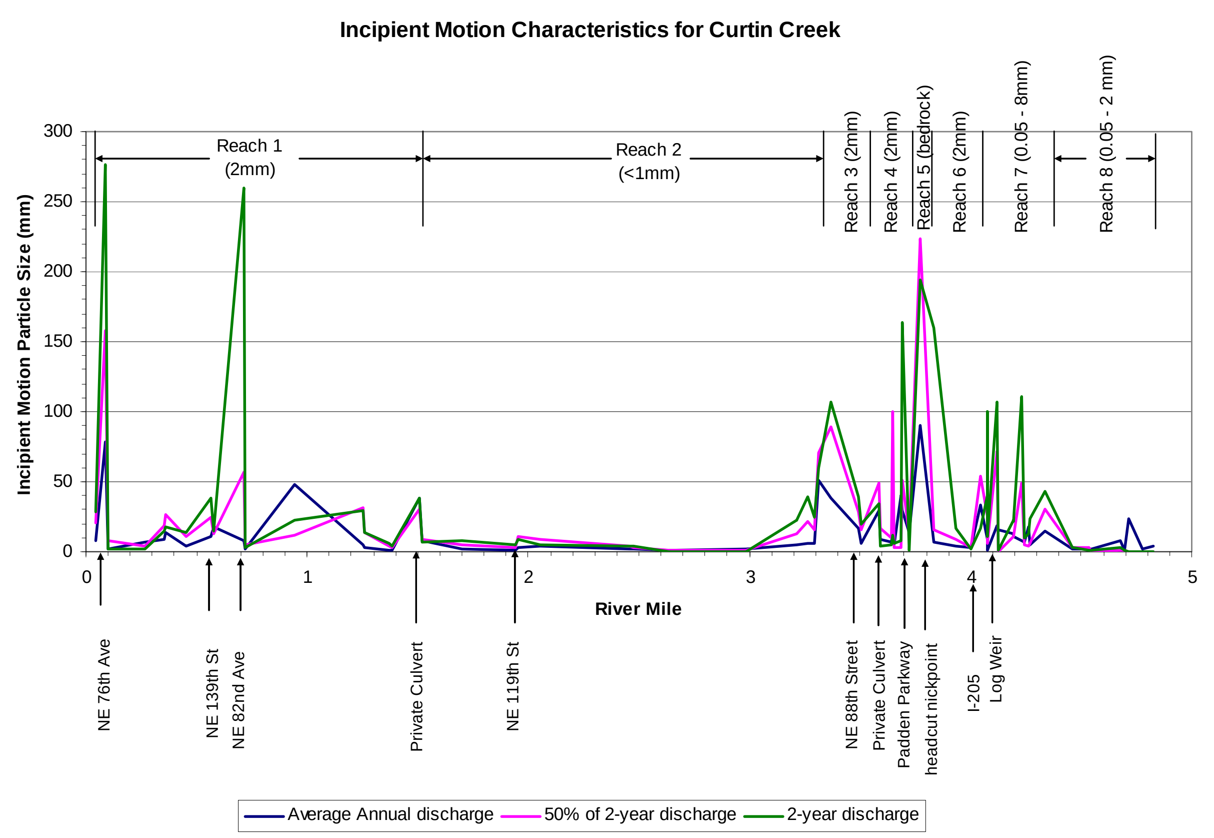

Figure 20. Incipient motion particle size characteristics for Curtin Creek.

3.2.9 Large Woody Debris

Prior to removal, large diameter trees would have provided a supply of large woody debris to the stream channels. Large woody debris likely played a significant role in the form and function of the lower reach of Curtin Creek. The size of the channel found in Reach 1 is too small to transport the majority of the wood that was contributed by the riparian forests that were once present along the stream corridor. Therefore, if not removed, the large woody debris likely remained in the channels until decay. Reach 2 was described as “open swale” in the surveyors notes from 1856 (BLM,2008). Large woody debris does not appear to have played a significant role in the form, function, or habitat of Reach 2.

Large woody debris provides roughness, helping to dissipate energy and reduces the ability of the stream to transport sediment. Woody debris can also provide a protective cover, essentially shielding the bed and banks from erosive flow conditions. Further, large woody debris can act as grade control locally reducing the channel slope, trapping sediment and preventing channel incision. Woody debris can also control local hydraulic conditions that provide complexity and a variety of habitat conditions.

The majority of the remaining forest land in the Curtin Creek basin is found in small patches within the central portion of the basin west of Curtin Creek and intermittently along Curtin Creek within a fairly narrow riparian corridor downstream of NE 29th Street . The extent to which the remaining forest lands have been altered from their conditions prior to Euro-American settlement is unknown. However, field observations indicate that the remaining forest lands do not contain a significant amount of large diameter trees suggesting that much of the original timber was likely harvested in the late 1800's and early 1900's.

3.2.10 Conclusions

The geomorphology of the streams in the Curtin Creek basin result from a combination of natural and human related controlling factors. Most notably, the construction of channels in the early 1900's at locations where none previously existed. This was done to improve drainage of the surrounding soils for agricultural uses. The planform of the channels upstream of Reach 1 was set during their initial construction and any subsequent alignment alterations. The underlying geologic formations, current hydrologic and sediment transport conditions, channel and bank vegetation, and culvert stream crossing combine to limit channel migration, channel incision and bank erosion. Alterations to the hydrologic conditions or vegetation could induce changes to the morphologic character of these channels. Specifically, increases in peak flows and/or flow durations or loss of vegetative cover could induce channel incision. Reaches 3, 4, and 5 are steeper gradient reaches that currently lack significant amounts of channel vegetation and are considered the most susceptible to channel incision.

Channel reaches that contain sufficient functional large woody debris are less susceptible to degradation by future increases in peak flows and flow durations. Enhancement and/or restoration of native riparian forests will provide a future source of large woody debris to the streams. The following sections list specific conclusions regarding the geomorphology of channel reaches located within the Curtin Creek basin.

3.2.10.1 Curtin Creek Reaches 6 through 8

- Reaches 6, 7, and 8 are considered moderately susceptible to increases in peak flows and/or increases in the duration of flows. Although the bed material is fine grained and easily transportable, existing channel and bank vegetation protect the channel and banks from erosive flow conditions. If increases in peak flows and/or the duration of flows alter the ability of vegetation to be maintained in the channel, channel incision and bank failures should be expected unless sufficient grade control is present.

3.2.10.2 Curtin Creek Reaches 3 through 5

- Reaches 3, 4, and 5 are considered to be the most susceptible to increases in peak flows and/or increases in the duration of flows. The moderately steep gradients and general lack of both channel vegetation and woody debris increase their susceptibility to erosion. Resistance to erosion is provided by resistant layers within the underlying bedrock and grade control provided by culvert crossings. An existing approximately 6 to 8 foot tall headcut nickpoint is located in Reach 5. Erosion resistant layers within the Cataclysmic Flood Deposits appear to be controlling the upstream migration rate of the headcut.

- Existing culvert crossings will continue to provide some measure of grade control with these reaches but may eventually become barriers to fish passage.

3.2.10.3 Curtin Creek Reach 2

- As previously mentioned, this reach is a transport limited reach in that, over the long-term, sediment supply generally exceeds sediment transport capacity and given the fine-grained nature of the sediment load, the majority of sediment is carried as suspended load and deposited in the floodplain. The flat gradient, wide floodplain and channelized nature of the stream make this reach the least susceptible to future increases in peak flows and/or flow durations.

- The channel slope is partially controlled at the downstream end by hydraulic conditions associated with several culvert crossings. However, given that this reach was mapped as wetland prior to the construction of the stream crossings, it is more likely that the underlying bedrock is controlling the channel gradient. Erosion resistant layers within the Cataclysmic Flood Deposits are likely controlling the channel gradient in Reach 2.

3.2.10.4 Curtin Creek Reach 1

- Reach 1 is considered a transport reach in that the sediment supply from upstream is in quasi-equilibrium with the sediment transport capacity. Temporary storage of sediment occurs in the channel and overbank areas within this reach resulting in increased sinuosity compared to the upstream reaches. The current channel plan form and unconfined valley form imply that the channel has migrated within the confines of the valley in the past and will likely do so in the future.

- Erosion resistant layers within the underlying Cataclysmic Flood Deposits are providing natural grade control in this reach. Historically, large woody debris would have also played a role in controlling erosion and channel migration. Future increases in peak flows and/or flow durations could alter the sediment transport conditions transforming this reach from a transport reach to a supply limited reach. If this occurs, channel incision and resulting bank failures would be expected.

3.2.11 Recommendations

- Restore and/or enhance riparian vegetation to provide a future source of large woody debris to the channel. Priority should be given to Reach 1 which is downstream of areas that are zoned for urban development. Emphasis should also be given to Reaches 3 through 5 which have steeper gradients, fine sediments, and higher shear stresses which make them more susceptible to incision.

- Monitor the location and geometry of the existing headcut nickpoint located approximately 100 feet upstream of Padden Parkway. Monitoring intervals should initially be once a year or based on the hydrologic record that occurs. Monitoring frequency can be adjusted based on results of the monitoring efforts. Consider developing a restoration project for this site.

- Look for opportunities to enhance/expand existing wetlands and floodplains to increase storage of floodwaters and better mimic predevelopment runoff conditions.

- Develop incentives that encourage land owners to enhance or restore riparian corridors.

- Develop education and outreach programs that promote the benefits of healthy riparian corridors. Encourage farm and ranch owners to participate in the NRCS Conservation Reserve Program http://www.nrcs.usda.gov/programs/crp/ which is administered through the Clark Conservation District http://www.clarkcd.org/

4 Summary and Conclusions

The morphology of the streams in the Curtin Creek basin is the result of a combination of natural and human related controlling factors. Most notably, the construction of channels in the early 1900's at locations where none previously existed. This was likely done to improve drainage of the surrounding soils for agricultural uses. The planform of the channels upstream of Reach 1 was set during their initial construction and any subsequent alignment alterations. The underlying geologic formations, current hydrologic and sediment transport conditions, channel and bank vegetation, and culvert stream crossing combine to limit channel migration, channel incision and bank erosion. Alterations to the hydrologic conditions or vegetation could induce changes to the morphologic character of these channels. Specifically, increases in peak flows and/or flow durations or loss of vegetative cover could induce channel incision.

Reaches 6, 7, and 8 are considered moderately susceptible to increases in peak flows and/or increases in the duration of flows. Although the bed material is fine grained and easily transportable, existing channel and bank vegetation protect the channel and banks from erosive flow conditions. If increases in peak flows and/or the duration of flows alter the ability of vegetation to be maintained in the channel, channel incision and bank failures should be expected unless sufficient grade control is present. Careful consideration should be given to any planned riparian enhancements so as not to reduce the erosion resistance provided by the existing channel and bank vegetation.

Reaches 3, 4, and 5 are steeper gradient reaches that currently lack significant amounts of channel vegetation and are considered the most susceptible to channel incision. In fact, they are currently experiencing headcutting and channel incision as a result of development in the basin. As the amount of impervious surface area in the basin increase with time, runoff volumes and peak flows will increase. Unless controlled, the sand and silt bed stream in these reaches will incise at an even faster rate. The channel incision will cause bank failures that will result in greater valley widths and increase the supply of sediment derived from the fine grained Cataclysmic Flood Deposits to downstream reaches.

Reach 2 is a transport limited reach in that, over the long-term, sediment supply generally exceeds sediment transport capacity. Because most of sediment is carried as suspended load, the majority of sediment deposition occurs in the floodplain. The flat gradient, wide floodplain and channelized nature of the stream make this reach the least susceptible to future increases in peak flows and/or flow durations. The history of this reach as a natural wetland combined with the extensive floodplain area and lack of existing development provide opportunities for floodplain and wetland enhancements as well as stormwater treatment and detention. It is noted that a regional stormwater facility was recently constructed in this reach.

Reach 1 is considered a transport reach in that the sediment supply from upstream is in quasi-equilibrium with the sediment transport capacity. Temporary storage of sediment occurs in the channel and overbank areas within this reach resulting in increased sinuosity compared to the upstream reaches. The current channel plan form and unconfined valley form imply that the channel has migrated within the confines of the valley in the past and will likely do so in the future. Erosion resistant layers within the underlying Cataclysmic Flood Deposits are providing natural grade control in this reach. Historically, large woody debris would have also played a role in controlling erosion and channel migration. Reach 1 is currently not experiencing significant geomorphic changes. However, future increases in peak flows and/or flow durations could alter the sediment transport conditions transforming this reach from a transport reach to a supply limited reach. If this occurs, channel incision and resulting bank failures would be expected.

Various alternatives exist to help protect the streams in the Curtin Creek basin from human-caused degradation. The most effective alternatives are to protect and restore riparian forest cover, protect and restore wetlands, limit the increase in effective impervious area, and properly manage runoff associated with development. Current land use zoning maps indicate that only 29 percent of the basin can be used for agriculture, parks and open space, and rural residential development. These land uses are likely to produce the least impact to streams compared to the current conditions. The remaining 79 percent is zoned for a mix of low and medium density residential, light industrial, employment center and commercial use, which would be expected to have greater proportion of impervious area and therefore a greater impact on associated basin streams.

It is noted that significant areas within the Curtin Creek basin have soil and groundwater conditions that are suitable for stormwater infiltration. Continued use of this method to dispose of stormwater runoff will help reduce the hydrologic impacts associated with urban development in the Curtin Creek basin.

Additional alternatives to limit human-caused degradation of streams in the Curtin Creek basin include specific project and management recommendations which are presented in the following sections. Implementation of these projects and management recommendations would help reduce the magnitude of current human caused impairments that have resulted from historic and current land use and minimize future impacts resulting from expected future development within the Curtin Creek basin.

5 Project Recommendations

Various potential projects could be developed to help recover existing impairments and help prevent or reduce future degradation of streams in the Curtin Creek basin. Table 6 summarizes the location and types of projects recommended.

Table 6. Recommended Stormwater Capital Improvement Projects.

Stream	Location/Reach	Impairment	Project
Curtin Creek	Reach 1	Lacks sufficient riparian vegetation	Riparian plantings
Curtin Creek	NE 76th Ave / Reach 1	Undersized culvert, scour at culvert outlet	Culvert replacement
Curtin Creek	NE 82nd Ave	Undersized culvert	Culvert replacement
Curtin Creek	NE 119th Street	Undersized culvert	Culvert replacement
Curtin Creek	Reach 2	Channelized, poor wetland connectivity, lack of riparian vegetation	Channel, floodplain and wetland enhancements, riparian plantings
Curtin Creek	Downstream of NE 88th Street / Reach 3	Generally lacks sufficient riparian vegetation, extensive blackberry, minor headcutting	Riparian plantings, blackberry removal, grade control
Curtin Creek	Between dirt access road and NE 88th Street / Reach 4	Channel has started to incise and become disconnected from floodplain	Grade control, channel and floodplain restoration
Curtin Creek	Private Culvert at RM 3.5871	Undersized culvert	Culvert replacement
Curtin Creek	Private Culvert at RM 3.6502	Undersized culvert	Culvert replacement

Curtin Creek	Between Padden Parkway and dirt access road (Padden Creek and Curtin Creek Confluence area) / Reach 4	Generally lacks sufficient riparian vegetation	Riparian plantings
Curtin Creek	Padden Parkway / Reach 4	Scour at culvert outlet	Energy dissipation/scour protection
Curtin Creek	Between I-205 and Padden Parkway / Reach 3	6’-8’ headcut nickpoint	Channel reconstruction / grade control
Curtin Creek	Between east entrance to Crossroads Community Church and I-205 / Reach 7	Extensive blackberry, log weirs maybe fish barrier	Blackberry removal and reconfiguration of log weirs
Curtin Creek	East parking lot entrance to Crossroads Community Church / Reach 7	Scour at culvert outlet	Energy dissipation/scour protection
Curtin Creek	Between Andresen Road and Crossroads Community Church / Reach 1	Generally lacks sufficient riparian vegetation, extensive blackberry	Riparian plantings, blackberry removal
Curtin Creek	NE 72nd Ave	Undersized Culvert	Culvert replacement
Curtin Creek	Between Padden Parkway and Andresen Road / Reach 1	Generally lacks sufficient riparian vegetation	Riparian plantings
Curtin Creek	Andresen Road	Undersized Culvert	Culvert replacement
Curtin Creek	Between 84th Street and Padden Parkway	Generally lacks sufficient riparian vegetation	Riparian plantings
Unnamed Tributary to Curtin Creek	Upstream of intersection of 88th Street and 64th Ave	Generally lacks sufficient riparian vegetation	Riparian plantings
Tributary 1	Upstream of NE 119th Street	Generally lacks sufficient riparian vegetation	Riparian plantings
Padden Creek	Between I-205 and Padden Parkway	Generally lacks sufficient riparian vegetation, intermittent blackberry	Riparian plantings, blackberry removal
Padden Creek	NE 76th Street	Undersized Culvert	Culvert replacement

As seen in Table 6, multiple culverts along Curtin Creek should be replaced. Hydraulic models for Curtin and Padden Creeks (WEST, 2005) indicate that these culverts are undersized resulting in significant backwater and in some cases roadway overtopping during as little as the 5-year recurrence interval flood. These culverts should be replaced with a hydraulic structure that accommodates natural fluvial processes and does not significantly alter the hydraulic and sediment transport characteristics of the channel. Potential upstream and downstream impacts resulting from the replacement structure and mitigation for these impacts must be considered during design.

The remaining recommended projects are either enhancement or establishment of a healthy riparian corridor through invasive species removal and new riparian plantings. These types of projects are considered to provide the greatest benefit to the streams in the Curtin Creek basin. From a geomorphic standpoint, an established riparian corridor will help create hydraulic roughness that reduces stream velocities and erosion potential and help reduce bank erosion. More importantly it allows for the recruitment of large woody debris which is generally lacking in the basin streams. An established functional riparian corridor will help minimize impacts associated with future increases in flow magnitudes and/or durations.

6 Management Recommendation

Various management alternatives exist to help recover existing impairments and reduce future degradation of streams in the Curtin Creek basin:

- It is noted that the land use zoning map provides a broad level of detail regarding land use for a 20-year period (2004-2024). Those portions of the basin that are expected to experience the least amount of development over this time period should not be ignored. Reestablishment of riparian corridors along the lower portion of Curtin Creek will provide greater protection to the stream channel as development pressure in the upper and middle portion of the basin increases in the future.

- Dams and associated ponds should be individually evaluated to determine the impact each is having on the hydrology, water quality and geomorphology of the involved stream. This could be used to prioritize both modifications to and/or removal of existing structures.

- Existing and future stormwater detention facilities should be evaluated through the use of continuous simulation hydrologic modeling to understand the magnitude of modifications to the duration of flows compared to predevelopment conditions.

- Ensure appropriate BMPs are being implemented with regard to maintenance of drainage ditches and discourage the development of new drainage ditches that have a direct connection to natural channels.

- Use geomorphically based performance standards when designing and constructing new or replacement hydraulic structures at road crossings. Designs should allow for lateral and longitudinal continuity and connectivity of both the channel and functional floodplain in addition to hydraulic design considerations. Potential upstream and downstream impacts resulting from the replacement structure and mitigation for these impacts must be considered during design. Mitigation in the form of woody debris jams and grade control or other appropriate measures should be installed to offset the loss of floodplain connectivity and channel incision that would likely occur as a result of the replacement structure.

- Encourage the use of Low Impact Development (LID) measures for newly developing areas in the basin. LID focuses on minimizing the amount of runoff generated from the site by minimizing to the extent practical the amount of increased impervious surface area and by infiltrating and treating stormwater runoff near the source in order to best mimic the predevelopment hydrologic conditions. Where soil conditions are a limiting factor, LID practices should be combined with traditional stormwater detention/retention facilities.

- Continue the use of Class V stormwater infiltration wells and other infiltration/retention facilities in basin areas that have appropriate soil and groundwater conditions.

- Continue monitoring stream flows at the 139th Street gage and consider the installation of an additional stream gage in the upper portion of Curtin Creek Basin at a location below and near the confluence with Padden Creek. T_{Qmean} and other streamflow statistics can be used to help evaluate the effectiveness of stormwater management practices as future development occurs in the basin. However, flow monitoring at the 139th Street gage may not capture the extent of hydrologic changes that are occurring in the upper basin. An additional stream flow gage would allow for results that represent the upper portion of the Curtin Creek basin and thus exclude the storage and attenuation of flows that occurs between approximately RM 1.5 and RM 3.0 (Reach 2).

- Update and calibrate the existing continuous simulation hydrologic model of the Curtin Creek basin to help evaluate changes in basin hydrology associated with future development. Updates should include incorporation of the infiltration facilities and associated reduction in effective impervious area in the eastern portion of the basin. The updated model would help determine the magnitude and location of expected hydrologic changes and be useful to evaluate the effectiveness of stormwater facilities and potential mitigation projects.

- Develop more stringent stormwater flow control regulations that control peak discharges and the duration of erosive flows in order to help protect and restore stream channel and riparian habitat in the Curtin Creek basin.

- Where appropriate, develop regional stormwater detention facilities and/or enhance existing wetland and floodplain storage areas. Regional facilities and/or wetland and floodplain enhancement projects should be located appropriately within the basin to reduce hydrologic impacts to Reaches 1, 3, 4, and 5 which are the most susceptible to degradation from increased flows.

- Restore and/or enhance riparian vegetation to provide a future source of large woody debris to the channel. Priority should be given to Reach 1 which is downstream of areas that are zoned for urban development. Emphasis should also be given to Reaches 3 through 5 which have steeper gradients, fine sediments, and higher shear stresses which make them more susceptible to incision.

- Monitor the location and geometry of the existing headcut nickpoint located approximately 100 feet upstream of Padden Parkway. Monitoring intervals should initially be once a year or based on the hydrologic record that occurs. Monitoring frequency can be adjusted based on results of the monitoring efforts. Consider developing a restoration project for this site.

- Develop incentives that encourage land owners to enhance or restore riparian corridors.

- Develop education and outreach programs that promote the benefits of healthy riparian corridors. Encourage farm and ranch owners to participate in the NRCS Conservation Reserve Program http://www.nrcs.usda.gov/programs/crp/ which is administered through the Clark Conservation District http://www.clarkcd.org/

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Appendix A
Summary of Field Observations

Stream	Location	Hydraulic Structure	Upstream of Road Crossing									Downstream of Road Crossing									Additional Comments
			Floodplain Connectivity	Sinuosity	Riparian Cover	Bed Material	Bank Material	Woody Debris	Land Use	Active Erosion	Potential SCIP	Floodplain Connectivity	Sinuosity	Riparian Cover	Bed Material	Bank Material	Woody Debris	Land Use	Active Erosion	Potential SCIP	
Unnamed Tributary to Curtin Creek	88th Street and 64th Ave	culvert	good	low	none	silt	silt	no	commercial	no	riparian plantings	n/a	n/a	n/a	n/a	n/a	n/a	commercial	n/a		Extensive regrading upstream of crossing. Downstream is contained in storm drain system
Unnamed Tributary to Curtin Creek (Detention Pond)	between 84th St and Padden Pkwy	detention pond	n/a	n/a	n/a	n/a	n/a	n/a	commercial	no		n/a	n/a	n/a	n/a	n/a	n/a	commercial	n/a		Stormwater detention pond
Curtin Creek	between 84th St and Padden Pkwy	n/a	good	low	poor	silt/clay/ vegetation	silt/clay/ vegetation	no	commercial	no	riparian plantings	good	low	poor	silt/clay/ vegetation	silt/clay/ vegetation	no	commercial	no	riparian plantings	
Curtin Creek	Padden Parkway	culverts (4)	good	low	poor	silt/sand/ vegetation	silt/clay/ vegetation	no	commercial	no	riparian plantings	good	low	poor	silt/sand/ vegetation	silt/clay/ vegetation	no	commercial	no	riparian plantings	
Curtin Creek	69th Ave (Andresen Rd)	culvert	good	low	poor	silt/sand	silt/clay	no	undeveloped	no	riparian plantings	good	low	moderate	silt/sand	silt/clay	no	undeveloped	no		
Curtin Creek	NE 72nd Ave	culvert	good	low	poor	silt/sand	silt/clay	no	undeveloped	no	riparian plantings	good	low	poor	sand/silt/ vegetation	silt/clay/ vegetation	no	agriculture	no	riparian plantings	
Curtin Creek	west parking lot entrance to Crossroads Community Church	culvert	moderate	low	poor	riprap armor	silt/clay	no	agriculture	no	riparian plantings/ blackberry removal /possible barrier removal	poor	low	moderate	sand/silt	silt/clay	no	commercial	no		It sounds like here is a perched culvert u/s of church property. RAS model shows 3.5 ft diameter culvert at this location.
Curtin Creek	east parking lot entrance to Crossroads Community Church	culvert	poor	low	moderate	silt/clay	silt/clay	no	commercial	no		poor	low	moderate	sand/gravel	sand/silt	no	commercial	yes	log weir modifications	Curtin Creek is conveyed through channel confined by a parking lot. Moderate riparian cover will improve with time as vegetation matures. Multiple artificial log weirs are located in this reach and are acting as grade control but may also be barriers to fish passage.
Curtin Creek	u/s of I-205	culvert	moderate	low	poor	silt/clay	silt/clay	no	commercial	no	blackberry removal / reconfiguration of existing log drop structures	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Multiple artificial log weirs are located in this reach and are acting as grade control but may also be barriers to fish passage.
Curtin Creek	between I-205 and Padden Parkway	culvert under I-205	good	high	poor - new plantings	sand/ grass	silt/clay/ grass	yes - placed in floodplain	restoration site	no		poor	low	poor	sand/silt	silt/clay	no	abandoned industrial	yes	grade control structure(s) and/or channel restoration	This area near I-205 is the site of a recent channel restoration project that has not been completely connect as of the site visit. The channel just u/s of Padden Parkway is entrenched into a narrow canyon. A significant head cut (6-8' waterfall) is located approximately 100 ft u/s of Padden Parkway.
Curtin Creek	Padden Parkway	culvert	poor	low	moderate	sand	silt/clay	minor	abandoned industrial	yes - headcut	blackberry removal, grade control, channel restoration	poor	low	poor	sand	silt/clay	no	rural residential	yes	blackberry removal, grade control	culvert outlet is perched, banks are steep and sloughing into channel
Curtin Creek	Confluence with Padden Creek	n/a	moderate	low	moderate	sand/ grass	silt/clay/ grass	no	urban residential	no	riparian plantings	moderate	low	moderate	sand/ grass	silt/clay/ grass	no	urban residential	no	riparian plantings	
Curtin Creek	dirt access road	culverts (3)	moderate	low	poor - new plantings	sand	silt/clay	no	urban residential	yes - channel degradation	woody debris placement/ floodplain reconnection	poor	low	moderate	sand	silt/clay	no	rural residential	yes	channel restoration	channel is incised and is loosing connectivity with the floodplain. Cinder blocks are placed in the channel as a form of grade control. Banks are vertical and undercut in places.
Curtin Creek	88th Street	culvert	poor	low	moderate - intermittent	sand	silt/clay	no	rural residential	yes - channel degradation	grade control, riparian plantings, floodplain reconnection	moderate	low	moderate - narrow	sand	silt/clay	minor	rural residential	no	riparian plantings	

Stream	Location	Hydraulic Structure	Upstream of Road Crossing									Downstream of Road Crossing									Additional Comments
			Floodplain Connectivity	Sinuosity	Riparian Cover	Bed Material	Bank Material	Woody Debris	Land Use	Active Erosion	Potential SCIP	Floodplain Connectivity	Sinuosity	Riparian Cover	Bed Material	Bank Material	Woody Debris	Land Use	Active Erosion	Potential SCIP	
Curtin Creek	upstream end of regional stormwater facility	culvert	moderate	low	none	sand/grass	silt/sand/ grass	no	urban residential	no	channel and floodplain restoration/ riparian plantings	good	high	none	sand/silt	silt/sand	yes - in floodplain	urban residential	no	riparian plantings	downstream is a recently completed regional stormwater facility
Curtin Creek	Railroad crossing	bridge	good	high	none	sand/silt	silt/sand	yes- in floodplain	urban residential	no	riparian plantings	good	moderate	poor - new plantings	sand/silt	silt/sand	no	agriculture	no	channel restoration	downstream of RR tracks is a mitigation project that created an overly wide meandering channel - likely allowing excessive thermal imput during the summer low flow months
Curtin Creek	NE 119th Street	culvert	moderate	low	none	sand/silt	silt/sand/ grass	no	agriculture	no	channel and floodplain restoration/ riparian plantings	good	low	none	sand/silt	silt/sand/ grass	none	agriculture	no	channel and floodplain restoration/ riparian plantings	Curtin Creek has been channelized through this reach.
Curtin Creek	NE 82nd Ave	culverts (2)	good	moderate	moderate	sand/gravel	sand/silt/ grass	minor	rural residential	no	riparian plantings	moderate	moderate	moderate	sand/gravel	sand/silt/ grass	minor	rural residential	no	riparian plantings	bark chips spread along left bank downstream of crossing appear to be for temporary access to a small dam adjacent to channel
Curtin Creek	NE 139th Street	bridge	good	moderate	moderate	sand	silt/sand/ grass	minor	rural residential	no	riparian plantings	good	moderate	moderate	sand	sand/silt/ grass	no	rural residential	no	riparian plantings	stream gage at this location.
Curtin Creek	NE 76th Ave	culvert	good	moderate	moderate	sand	silt/sand/ grass	minor	rural residential	no		moderate	low	moderate	sand	silt/sand/ grass	minor	rural residential	yes- at culvert outlet	erosion repairs, blackberry removal	
Unnamed Tributary to Curtin Creek	NE 119th Street	storm drain intlet	poor	low	none	sand/silt/ grass	silt/sand/ grass	no	rural residential/ commercial	no	channel and floodplain restoration/ riparian plantings	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	channel enters stormdrain system
Padden Creek	NE 88th Street	culvert	poor	low	none	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	blackberry removal, riparian plantings	moderate	low	poor - some new plantings	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	
Padden Creek	end of NE 74th Street	n/a	moderate	low	poor	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	moderate	low	moderate	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	
Padden Creek	NE 76th Street	culvert	moderate	low	poor	sand/silt	silt/sand/ grass	no	urban residential	no	riparian plantings	poor	low	none	unknown	silt/sand/ grass	no	urban residential	no	riparian plantings	
Padden Creek	NE 88th Ave	culvert	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	poor	low	moderate	gravel/sand	silt/sand	no	urban residential	no	blackberry removal/ riparian plantings/ floodplain reconnection	backyard fences are severly encroaching on channel
Padden Creek	end of NE 80th Street	n/a	moderate	low	poor	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	moderate	low	poor	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	during high flows, water will overtop into NE 80th Street as it appears to be at a lower elevation than the floodplain to the east.
Padden Creek	NE 81st Street	bridge	moderate	low	poor	sand/silt/ grass	silt/sand/ grass	yes-in Floodplain only	urban residential	no	riparian plantings	moderate	low	none	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	channel is somewhat entrenched and disconnected from the floodplain except during significant high flows
Padden Creek	NE 82nd Circle	culverts (3)	moderate	low	none	sand/silt/ grass	silt/sand/ grass	no	urban residential	no	riparian plantings	moderate	low	none	silt/sand	silt/sand/ grass	no	urban residential/ transportation	no	riparian plantings	channel have been modified and forms an elongated lake
Padden Creek	south side of Padden Parkway	culvert	moderate	low	poor - some new growth	sand/silt/ grass	silt/sand/ grass	no	transportation	no	riparian plantings	poor	low	moderate	sand/silt	silt/sand	no	transportation	no	blackberry removal	