Geomorphology and Hydrology Assessment
for
Allen Canyon Creek

by

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1 Purpose

A geomorphology and hydrology assessment was conducted for Allen Canyon Creek to help understand the dynamic processes at work within the basin and their interrelation with human influences. The assessment provides 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; feature inventory data; and available technical reports. A field reconnaissance was conducted on March 24, 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 the streams in the Allen Canyon Creek basin. The details of this effort are presented in Section 3.1.

2.2 Hydrology

Allen Canyon Creek basin and tributary basin areas were delineated using the provided topographic data. No gage data are available for Allen Canyon Creek. Therefore, peak flow statistics were estimated using regional regression equations (Sumioka et al, 1997).

2.3 Geomorphology

The morphologic characteristics for streams in the Allen Canyon Creek basin were characterized. This 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 by extracting elevations along the stream centerlines from a digital terrain model (DTM) developed from the available 2-foot contour interval topographic mapping (Clark County, 2003). Cross sections were located along the valleys of Allen Canyon Creek and its major tributaries. 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 DTM of the basin and aligned along a common central axis for plotting purposes.

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

Allen Canyon Creek is a 6.1 square mile drainage basin located within the Ridgefield 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 which flows northward just west of the Ridgefield quadrangle (Evarts, 2004). A geologic map of the Allen Canyon Creek basin is shown in Figure 1.

The physiography of the Ridgefield quadrangle is dominantly a nearly flat, modestly dissected surface of elevation 275 to 300 feet developed on the basin-fill sediments (Evarts, 2004). The top of the surface declines gradually westward to about 250 feet near the town of Ridgefield (Evarts, 2004). The surface is interrupted by lows hills in the south and truncated to the west and north by erosional scarps overlooking the Columbia River Floodplain and the East Fork Lewis River valley, respectively (Evarts, 2004).

Allen Canyon Creek and its tributary streams are located along the northern slope of a northwest – southeast trending anticline. The oldest of the exposed geologic formations consist of the Miocene age Sandy River Mudstone. The Sandy River Mudstone is composed of fine grained sandstone and thin bedded claystone, mudstone, and siltstone (Evarts, 2004). Some of the beds are cemented by limonite. Planer and trough crossbedding, cut and fill structures, and lenticular beds of pebbly sandstone and small-pebble conglomerate are common locally, suggesting deposition by fluvial processes (Evarts, 2004). It was previously referred to by Mundorff (1964) as the lower Troutdale Formation. The Sandy River Mudstone is exposed along the valley walls in the lower portion of the Allen Canyon Creek basin surrounding and immediately upstream of Mudd Lake.

The Sandy River Mudstone is overlain by Pleistocene or late Pliocene age conglomerate beds of sand, gravel and cobble of Columbia River and Cascadian origin. 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. The Plio-Pleistocene conglomerate is exposed along the valley walls located in the middle and lower portions of the Allen Canyon creek basin west of NW 31st Avenue.

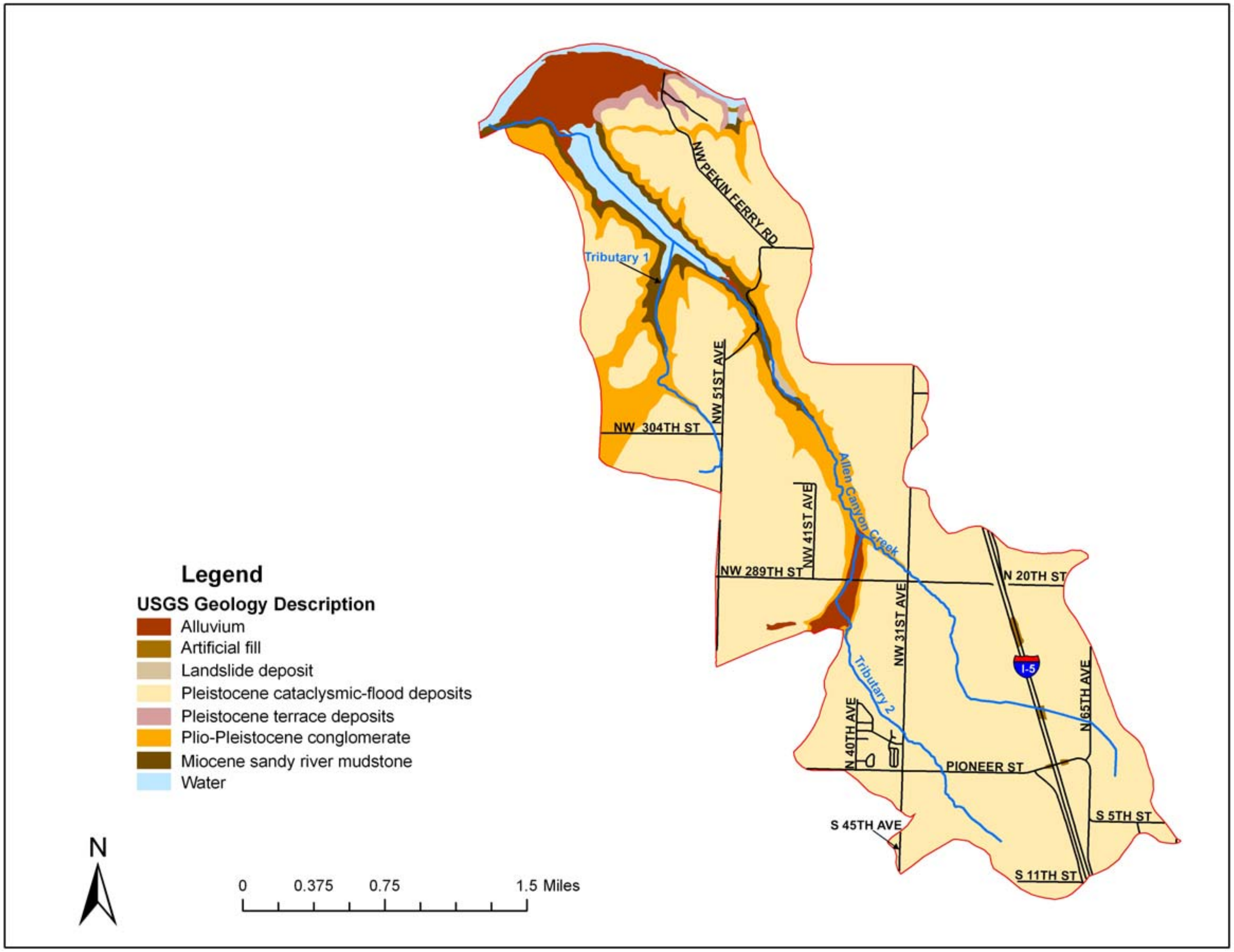

Figure 1. Geologic Map of the Upper Gee Creek basin (from Evarts, 2004).

The Plio-Pleistocene conglomerate is overlain by Pleistocene age 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). The Cataclysmic Flood Deposits form the upper surface of the majority of the Allen Canyon Creek basin. The older Sandy River Mudstone and Plio-Pleistocene conglomerate units are exposed in locations where Allen Canyon Creek has incised through the upper layer of Cataclysmic Flood Deposits.

Near the confluence of Allen Canyon Creek with the Lewis River, Pleistocene age terrace deposits consisting of unconsolidated, poorly sorted sandy pebble gravel and lithic sand are exposed. The gravel clasts are primarily Tertiary volcanic rocks eroded from the Cascade Range, indicating that the terrace sediment was transported by the Lewis River.

The depositional zones within the valley bottoms of Allen Canyon Creek and its tributaries are composed of Holocene Alluvium of silt, sand and gravel deposits which are reworked from older weakly consolidated sedimentary units.

3.1.2 Streams

Allen Canyon Creek is a 4th order tributary to the Lewis River. The mainstem extends approximately 5.5 miles. The headwaters are located in the southern most portion of the basin just east of the Interstate 5 freeway (I-5). From its headwaters, the stream flows northwest under I-5; then north, roughly paralleling I-5; then northwest through Mudd Lake to the confluence with the Lewis River. There are no named tributaries to Allen Canyon Creek. For discussion purposes, the unnamed tributaries were given the following names: Tributary 1 and Tributary 2. Tributary 1 generally flows in a northerly direction until intersecting Mudd Lake. Tributary 2 generally flows in a northwesterly direction combining with Allen Canyon Creek approximately 0.2 miles downstream of NW 289th Street. A drainage basin map showing the location of Allen Canyon Creek and its major tributaries is shown in Figure 2. The 6.1 square mile drainage basin is approximately 1.5 miles wide from east to west and 5 miles long from north to south.

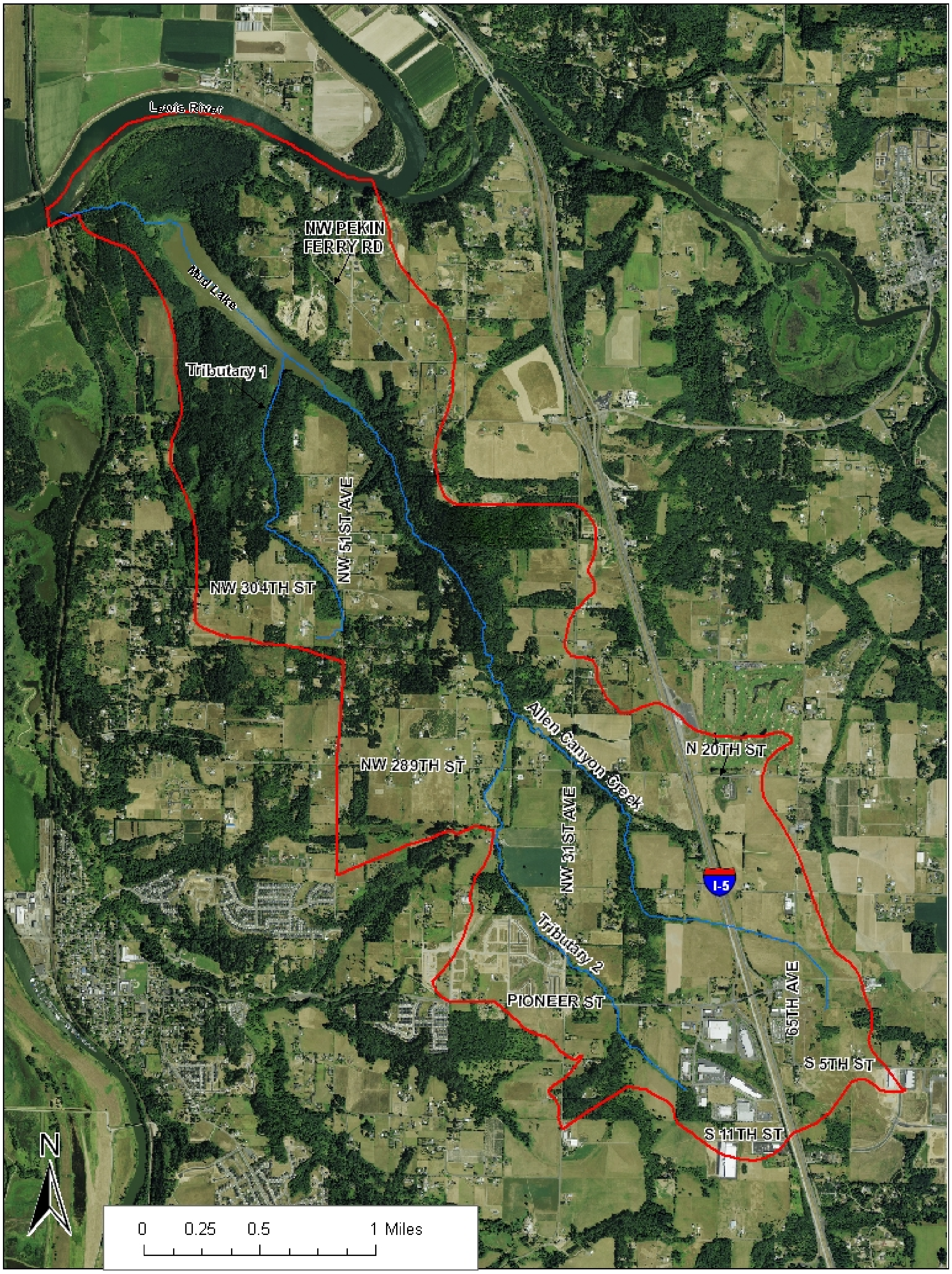

Figure 2. Allen Canyon Creek drainage basin map

Upstream of NW 289th Street, the streams 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. Bed material gradually increases in size from sand and small gravel at 289th Street to gravel and small cobble at Allen Canyon Road, located approximately 1.6 miles downstream. The increase in bed material size is the result of the stream's incision into the Plio-Pleistocene conglomerate bedrock which consists of consolidated sand-, gravel-, and cobble-sized material. Bank material in the upper basin is typically clay-, silt-, and sand-sized sediment except where the stream abuts the Plio-Pleistocene conglomerate bedrock. In the middle and lower portions of the basin (within Allen Canyon), the bank material contains small portions of gravel and cobble sized material.

3.1.3 Soils

Allen Canyon Creek basin consists primarily of soils in Hydrologic Soil Group D, 45% of basin area; and Group C, 40% of basin area; with a smaller portion in Group B, 11% of basin area and the remainder classified as water, 4% of the basin. An NRCS hydrologic soil group map is shown in Figure 3. As seen in the figure, the majority of the basin streams are located within the Group C and Group D soils.

Mapped soil units in the Allen Canyon Creek basin include: Cove silty clay loam, 8.2% of basin area; Gee silt loam, 39.5% of basin area; Hillsboro silt loam, 4.8% of basin area; Odney silt loam, 8.2% of basin area; Pilchuck fine sand, 0.3% of basin area; Puyallup fine sandy loam, 3.5% of basin area; Sara silt loam, 28.7% of basin area; Sauvie silty clay loam, 0.4% of basin area; and Washougal gravelly loam, 2.5% 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 grained soils are the source materials that are supplied to the stream channels as a result of surface erosion.

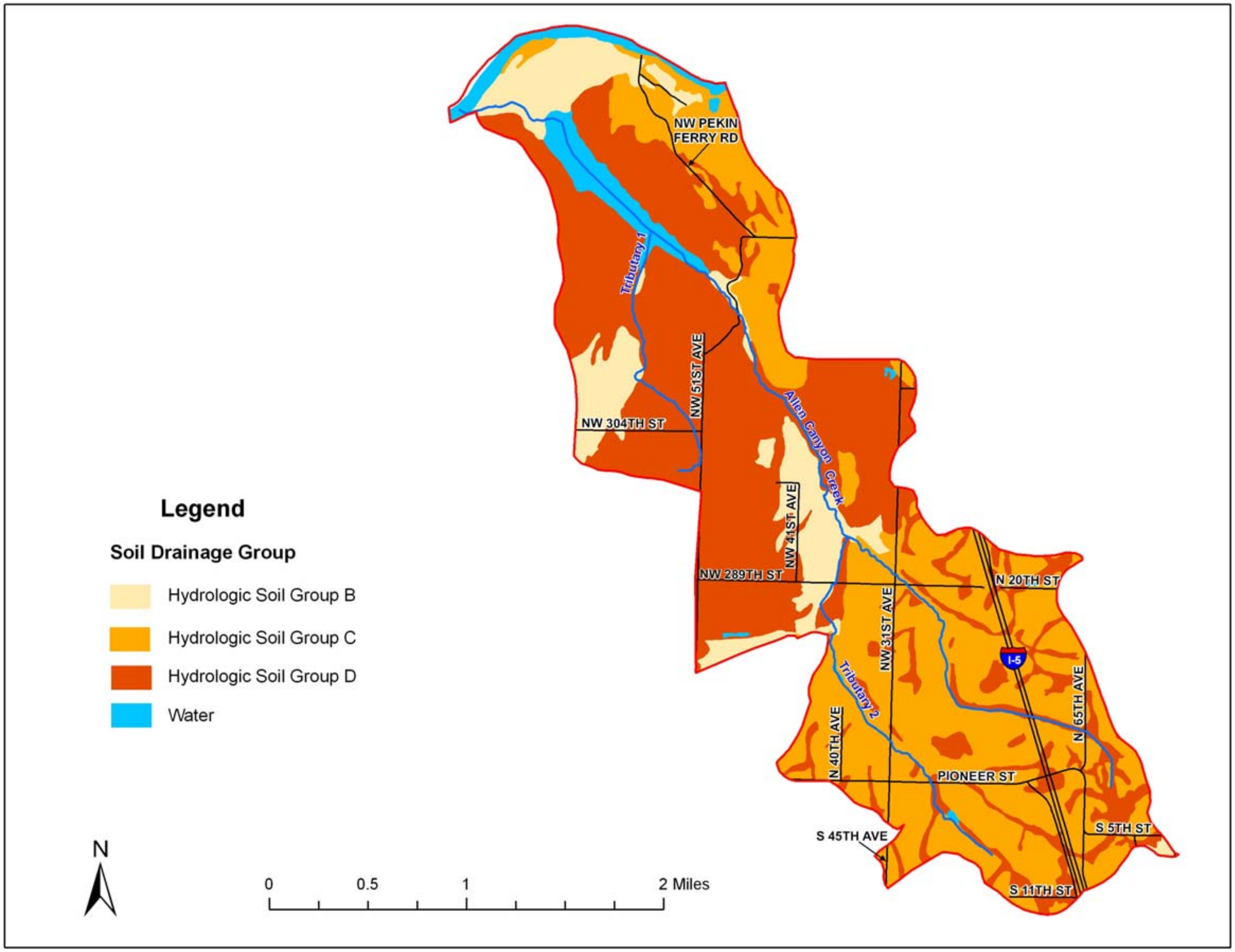

Figure 3. Hydrologic soil group classification of soils in Allen Canyon Creek Basin (data from NRCS, 2004).

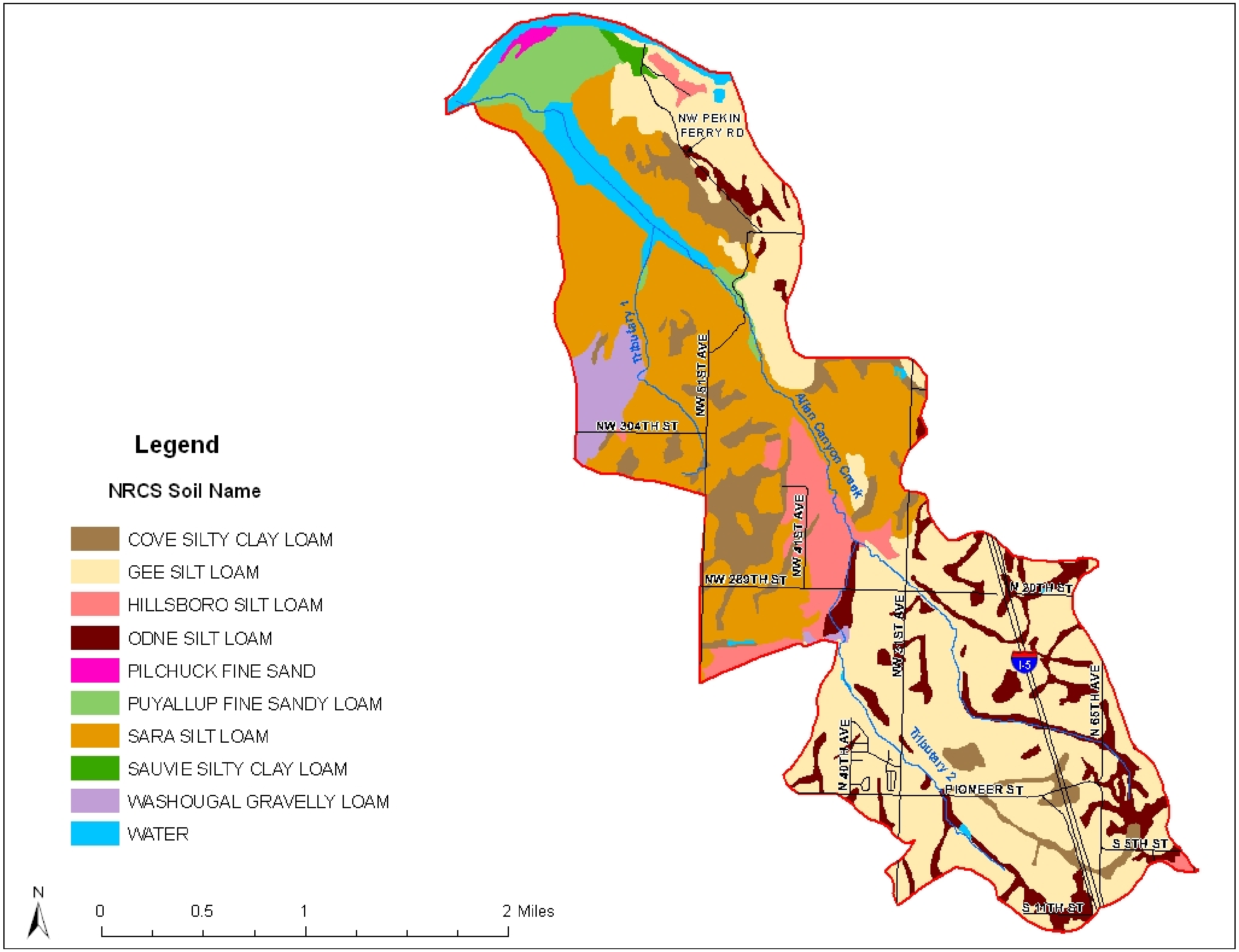

Figure 4. Soils map for the Upper Gee Creek Basin (data from NRCS, 2004).

3.1.4 Topography

The topography of Allen Canyon Creek basin is characterized by nearly flat, modestly dissected surfaces in the upper basin. The topographic relief becomes more pronounced in the middle and lower portion of the basin where Allen Canyon Creek has incised into the erodible bedrock and formed an entrenched valley. The downstream terminus of Allen Canyon Creek is Mudd Lake. The lake was formed by a natural sediment dam composed of point bar sediment deposits of the Lewis River. Elevations range from approximately 290 feet in the southeastern edge of the basin to approximately 10 feet at the confluence with the Lewis River. The average basin elevation is 175 feet and the average watershed slope is 10.3 percent (Wierenga, 2005). Moderately steep slopes (erosional scarps) occur adjacent to the mainstem and tributary stream channels and associated floodplain terraces. The erosional scarps developed by incision and lateral migration of the associated stream channels within the relatively fined grained soils and parent rock of the Cataclysmic Flood Deposits. Areas in the basin with unstable slopes tend to be located where the stream channels are directly adjacent to or impinging on the base of the erosional scarps. Floodplain terraces are generally narrow or nonexistent in the upper portion of the basin but increase to between 50 and 100 feet in Allen Canyon and expand to nearly 200 feet in width near Mudd Lake. A shaded topographic relief map of the basin is shown in Figure 5.

3.1.5 Disturbances

There is little documentation available regarding significant historic disturbances in the Allen Canyon 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 Allen Canyon Creek is not well documented; however, records of flooding along other streams in Clark County suggest that significant flooding occurred in 1964, 1977, 1996, and as discussed in Section 3.2, in 2005 and 2007. 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 industry. Future flooding conditions are likely to be exacerbated by future increase in impervious surface area.

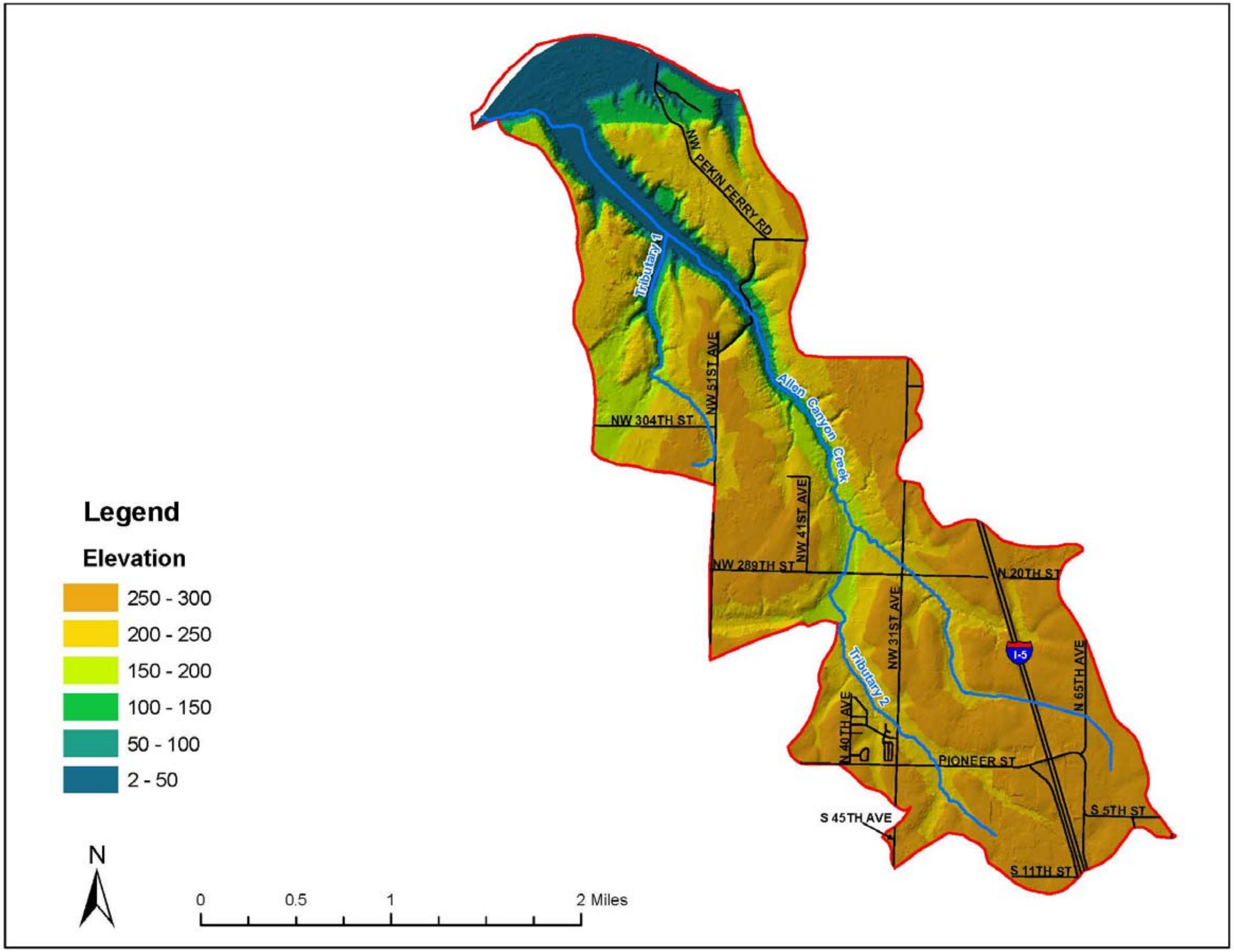

Figure 5. Topographic relief map of the Allen Canyon Creek Basin.

3.1.6 Land Cover and Land Use

3.1.6.1 Historic

Historic land use conditions in the Allen Creek basin are not well documented. However, historic land use conditions in the adjacent Gee Creek basin are published in a report entitled Gee Creek Watershed Restoration Background Report by Lynn Cornelius (2006). Given the proximity and similarity of the two basins, it is assumed that development in the Allen Canyon Creek basin is analogous to the Gee Creek basin. The following is a summary of the report.

The Upper Gee Creek basin was originally dominated by forest consisting of Fir, Cedar, Maple and Hemlock in varying stages of fire succession. Clearing of the forest began with the earliest settlements, and land was steadily converted to other uses, principally farming. Important farm products grown in the fertile basin soils include tree and berry fruit, potatoes, dairy, beef cattle, hay and grain.

With the decline of river travel for access and commerce, and the advent of land-based travel, roads were developed in the basin connecting to the nearby cities of Vancouver and Portland. As early as 1888, many of the current primary road routes were established, presumably with early versions of stream crossings, road fill, and associated stream impacts.

By the 1950's, dairy farming was recognized as the most important agricultural industry in the Ridgefield Area. In general, dominant land use eras in the watershed since Euro-American settlement have been: fishing; furbearer; timber harvest; crop, dairy, and livestock farming; rural and local industrial; rural-residential; and modern urban residential/light industrial along the I-5 corridor.

3.1.6.2 Current

The current basin land use consists primarily of rural residences, agriculture, and forest land. Suburban and industrial developments are more prominent in the southern portion of the basin. In 2002, the basin land cover was 35.4% forested, 5.3% impervious, and 55.5% non-canopy (Figure 6). The forest lands that remain tend to be focused along the stream corridors in the middle and lower portions of the basin. The upper basin tributaries tend to have sparse, intermittent or no forest cover as much of this land has been cleared for agricultural, residential development and industrial development.

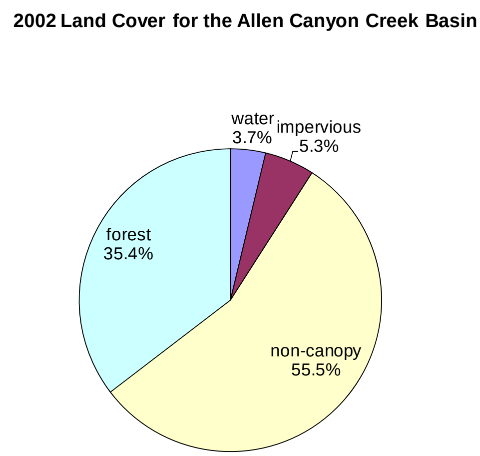

Figure 6. Land cover characteristics for the Allen Canyon Creek basin (data from Clark County 2002 Land Cover shapefile)

3.1.6.3 Future

Future land use for the Allen Canyon Creek basin is characterized in the document “Clark County 20-Year Comprehensive Growth Management Plan 2004-2024”. The 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 Allen Canyon Creek Basin

Zone	Percentage of Allen Canyon Creek Basin
Urban	32
Rural Residential	30
Agricultural	23
Forest	9
Parks and Open Space	3

As seen in the table, approximately 23 percent of the basin is zoned for agricultural use, 30 percent is zoned for rural residential development, 9 percent is zoned for forest and 3 percent is zoned for parks and open space. 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 32 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 7. 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 upper portion of the basin. The majority of the middle and lower portions of the basin are expected to have minimal increases in impervious areas and therefore the least impact on future hydrologic conditions.

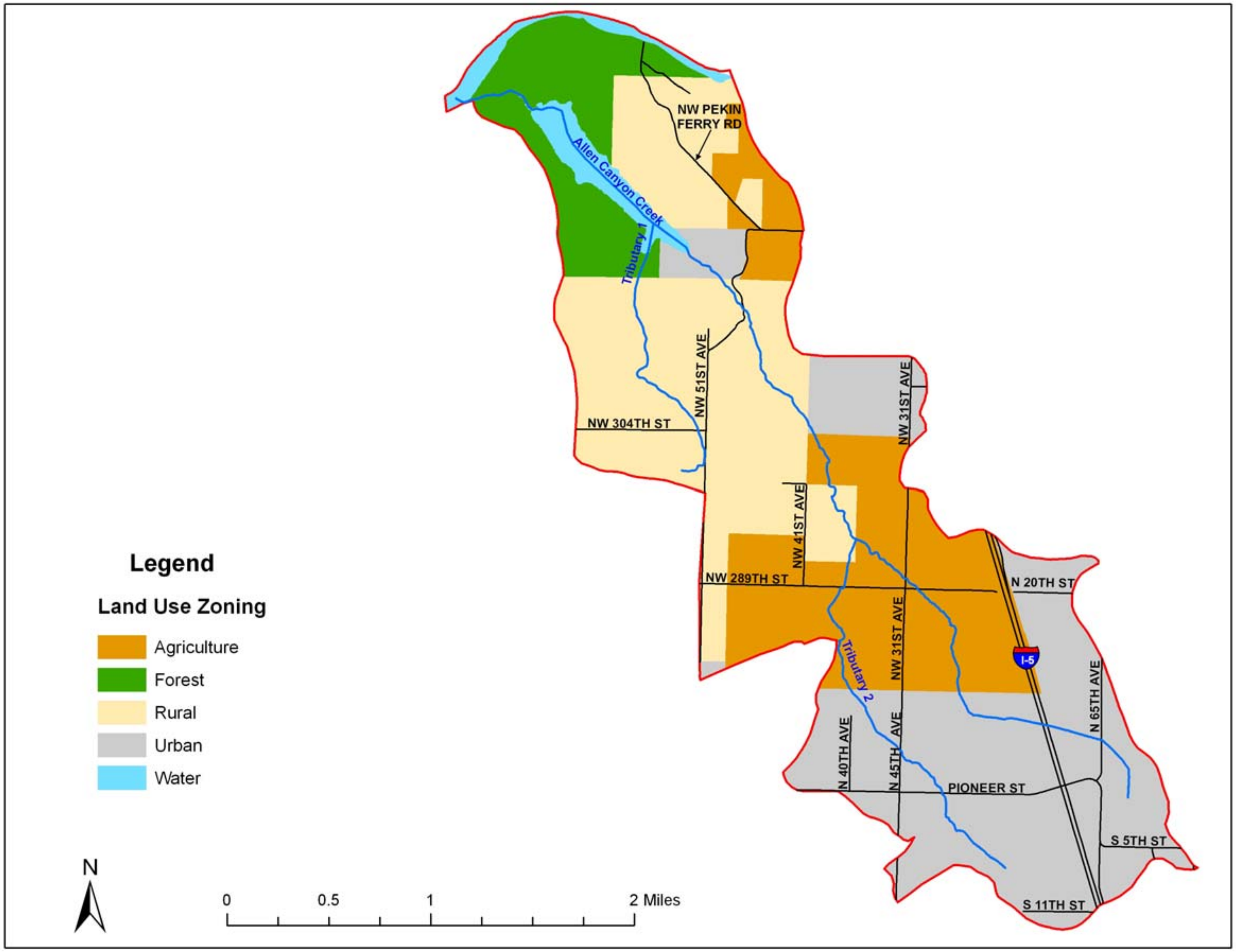

Figure 7. Land use zoning (from Clark County Comprehensive Growth Management Plan).

3.1.7 Hydromodifications

Hydromodifications that have occurred in the Allen Canyon Creek basin include the following: private dams and associated ponds; stormwater detention ponds; stormwater piping, culvert 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 along both the main stem and tributary reaches of Allen Canyon Creek. However, these types of modification are not prevalent in the basin. The ponds appear to be either for aesthetic/recreational purposes, or for irrigation/livestock use. Direct observation of the outlet works of the dams and downstream channel could not be made. Therefore, the extent to which these dams have altered the channel morphology and/or are considered barriers to fish passage is unknown. The associated ponds are likely trapping fine sediment; but are disrupting the transport of bed material. The ponds may also 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 Allen Canyon 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 present within the basin; however, it is limited in extent and is mostly found along Pioneer Street and is associated with urban and industrial developments in the upper basin.

3.1.7.3 Drainage Ditches

Drainage ditches in farm fields and along roadways result in a greater drainage density 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 stream crossings locally modify the hydraulic conditions 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 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.

3.1.8 Conclusions

- Tributary 1, which is located within the lower portion of the Allen Canyon Creek basin is expected to experience minimal impacts to future hydrologic conditions and therefore minimal changes to the geomorphic characteristics. However, unless mitigated, Allen Canyon Creek and Tributary 2 are likely to undergo significant morphologic change as peak flows and/or flow durations increase.

- Hydromodifications have resulted in alterations to the natural hydrologic, geomorphic and water quality conditions of Allen Canyon Creek. Dams and associated ponds are altering sediment transport conditions, elevating water temperatures, and contributing to increased contamination from waterfowl.

- 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 streams located within the fine grained Cataclysmic Flood Deposits.

- Drainage ditches have increased drainage density resulting in increased peak flows and reductions in groundwater recharge. Where treatment facilities are not installed, drainage ditches convey pollutants directly to stream channels.

- Culverts are altering sediment transport conditions and locally preventing channel migration.

- 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 of 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

- 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 in these areas while development pressure is low will allow a greater time period for the riparian vegetation to mature and therefore provide greater protection to the streams as development pressure 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.

3.2 Hydrology

3.2.1 Drainage Basin

The Allen Canyon Creek basin is approximately 6.1 square miles in total area. A summary of tributary drainage basin areas is provided in Table 2. Average annual precipitation over the basin is 45.7 inches (NRCS, 1998). Seventy-seven percent of the stream channels in the Allen Canyon Creek basin are considered head water streams (1^{st} or 2^{nd} order) (Wierenga, 2005). Approximately 8.6 percent of the basin is mapped as wetland and 8.2 percent is mapped as floodplain (Wierenga, 2005). The relatively large percentage of wetland and floodplain areas suggests that there are opportunities available for storage and attenuation of flood waters. However, the majority of these areas are associated with Mud Lake which is located near the outlet of the watershed and therefore would not provide any benefit to areas upstream.

Table 2. Allen Canyon Creek drainage basin areas.

Stream	Drainage Area (sq. mi.)	Percent of Total
Allen Canyon Creek	6.1	100
Tributary 1	0.8	13
Tributary 2	1.2	21

Eleven percent of the basin soils are type B (well drained) while the remaining 89 percent of the basin soils are type C/D (moderate to poorly drained) or open water (Mud Lake). This indicates that there is a greater tendency for precipitation over the basin to contribute to surface runoff rather than infiltrate for high intensity and/or longer duration storm events that exceed soil infiltration rates. For short duration and/or low intensity storm events, a greater portion of the precipitation is likely infiltrated. Runoff rates likely 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

There are no stream gages available in the Allen Canyon Creek basin. Therefore, peak discharges and associated recurrence intervals for Allen Canyon Creek were estimated from USGS flood frequency regional regression equations (Sumioka et al, 1997) and are shown in Table 3.

Table 3. Estimated peak discharges for Allen Canyon Creek

Location	Drainage Area (mi^2)	Recurrence Interval (yrs)	Discharge (cfs)
Allen Canyon Creek upstream of Allen Canyon Road	3.9	2	131
		10	213
		25	257
		50	285
		100	317
Allen Canyon Creek upstream of Tributary 2	1.3	2	49.3
		10	80.4
		25	97.3
		50	108
		100	120
Tributary 2 at confluence with main stem of Allen Canyon Creek	1.2	2	47.9
		10	78.2
		25	94.6
		50	105
		100	117

Note: Flows at the mouth of Allen Canyon Creek are influenced by natural regulation from Mud Lake and are therefore not included in the above table.

Available stream flow records for nearby Gee Creek indicate that in 2005 and 2007, floods with recurrence intervals in excess of 50-years have occurred in the Gee Creek basin. Given the close proximity of Gee Creek to Allen Canyon Creek, it is assumed that significantly high flows occurred in Allen Canyon Creek for these same storm events. However, no significant problems resulting from these recent flood events were observed in the Allen Canyon Creek basin.

Mean monthly discharges for Allen Canyon Creek were estimated by transferring mean monthly flows for Gee Creek for water years 2003 through 2007 using the drainage area ratio and are shown in Figure 8. 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.

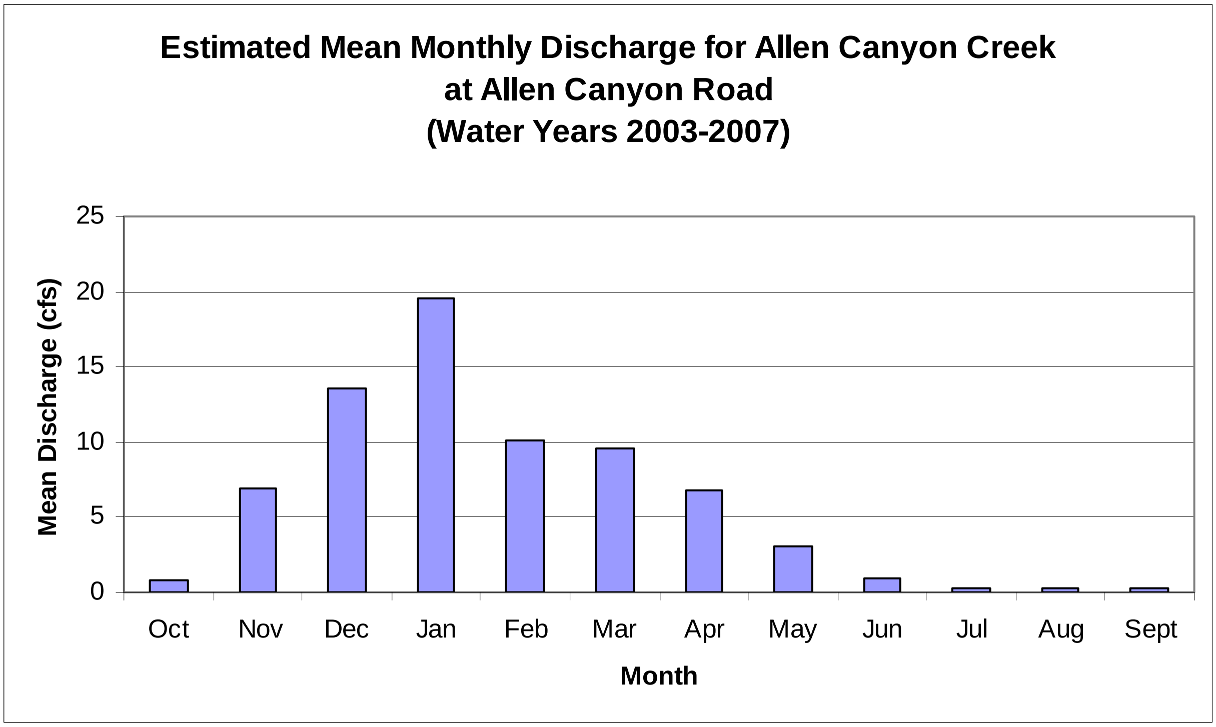

Figure 8. Estimated Mean Monthly Discharge for Allen Canyon Creek at Allen Canyon Road.

The relatively low magnitude of flows that occur during the summer and early fall months is a result of multiple contributing factors. The largest contributing factor is the temperate marine climate which tends to favor wet winters and dry summers. Additionally, the majority of the basin soils have relatively low infiltration capacities, causing much of the wintertime precipitation to run off rather than be stored in the soils and bedrock for later release to the streams. Also, the well drained topography and general absence of upland wetlands limits groundwater recharge. This may be exacerbated by surface water withdrawals for irrigation during the summer growing season. Lastly, continued increases in the amount of impervious surfaces has further reduced infiltration and likely increased wintertime runoff volumes. As of 2002, the total impervious area represented approximately 5.3 percent of the basin.

3.2.3 Conclusions

- The relatively large percentage of wetland and floodplain areas suggests that there may be enhancement opportunities available for storage and attenuation of flood waters. However, these areas are mostly associated with Mud Lake which is located near the outlet of the basin. Therefore, opportunities for enhancement of existing wetlands and floodplains for the purpose of increasing available storage for floodwaters are limited.

- Basin soil conditions limit infiltration rates for high intensity and/or longer duration storm events. Therefore, benefits from the installation of infiltration facilities may not be realized during these types of storms. However, during low intensity and/or short duration storm events the benefits would be more pronounced.

- Recent major floods resulted in minimal erosion problems along streams in the Allen Canyon Creek basin. This suggests that these streams, in their current condition, are relatively stable and not susceptible to significant degradation during large flood events.

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 result in increased susceptibility to channel and bank erosion during large floods.

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 by infiltrating and treating stormwater runoff near the source in order to best mimic the predeveloped hydrologic conditions. Where soil conditions are a limiting factor, combine LID practices with traditional stormwater detention/retention facilities.

- A stream flow gage should be located on Allen Canyon Creek to develop a better understanding of the hydrology of the basin and to monitor changes in stream flows resulting from future land use conditions.

- Develop a calibrated continuous simulation hydrologic model of the Allen Canyon Creek basin to help evaluate potential changes in basin hydrology associated with future development. The model will 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 Allen Canyon Creek basin.

- Discourage surface water withdrawals for irrigation to help promote sufficient summer low flow conditions.

3.3 Geomorphology

3.3.1 Channel Planform

The planform of the stream channels within the Allen Canyon Creek basin range from nearly straight to moderately meandering single thread channels. In the upper portion of the basin (south of NW 289th Street), the channels are fairly straight as they are either confined by the valley topography or have been altered by agricultural practices. The bed material in these stream reaches is composed of sand and silt sized sediment derived from the underlying Cataclysmic Flood Deposits. The channel reaches in the upper basin 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. This incision has confined the channel and further reduced its potential for migration.

Sinuosity increases along the middle portion of the basin (between of NW 289th Street and Allen Canyon Road) as the streams increase in size and transition to transport reaches. For transport reaches, the sediment supply from upstream is in quasi-equilibrium with the sediment transport capacity. Temporary storage of sediment occurs within these reaches resulting in increased sinuosity compared to the upstream supply reaches. Additionally, the valley bottoms become wider and thus the adjacent hill slopes have less influence on channel migration.

Sinuosity in the lower portion of the basin (downstream of Allen Canyon Road) is similar to that of the middle portion of the basin. Within the lower basin the creek transitions to a depositional reach. For depositional reaches, the sediment supply from upstream exceeds the sediment transport capacity. Permanent sediment storage occurs within this reach (both in the channel and floodplain and within Mud Lake) resulting in increased sinuosity compared to the upper basin supply reaches. Valley bottoms widths continue to increase, further reducing hill slope influences on channel migration.

3.3.2 Channel Profiles

Available topographic data were used to develop a DTM of the basin and extract ground profiles along the stream centerlines. The channel slope, sinuosity, and bed material size were used to divide the channel into 5 separate reaches of similar geomorphic characteristics which are summarized in Table 4. Reach locations are shown in Figure 9. A stream centerline ground profile for Allen Canyon Creek is shown in Figure 10.

Table 4. Summary of geomorphic reach characteristics.

Reach	Extents	Average Slope	Sinuosity[1]		Bed Material
1	Mouth to u/s end of Mud Lake	0.000	n/a	n/a	sand/silt/clay (lake deposits)
2	Mud Lake to Allen Canyon Road	0.011	1.1	low	silt/sand/gravel
3	Allen Canyon Road to ~RM 2.9	0.022	1.1	low	gravel/cobble
4	~RM 2.9 to NW 20th Ave	0.013	1.1	low	sand/gravel
5	NW 20th Ave to ~RM 5.5	0.008	1.0	low	silt/sand

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)

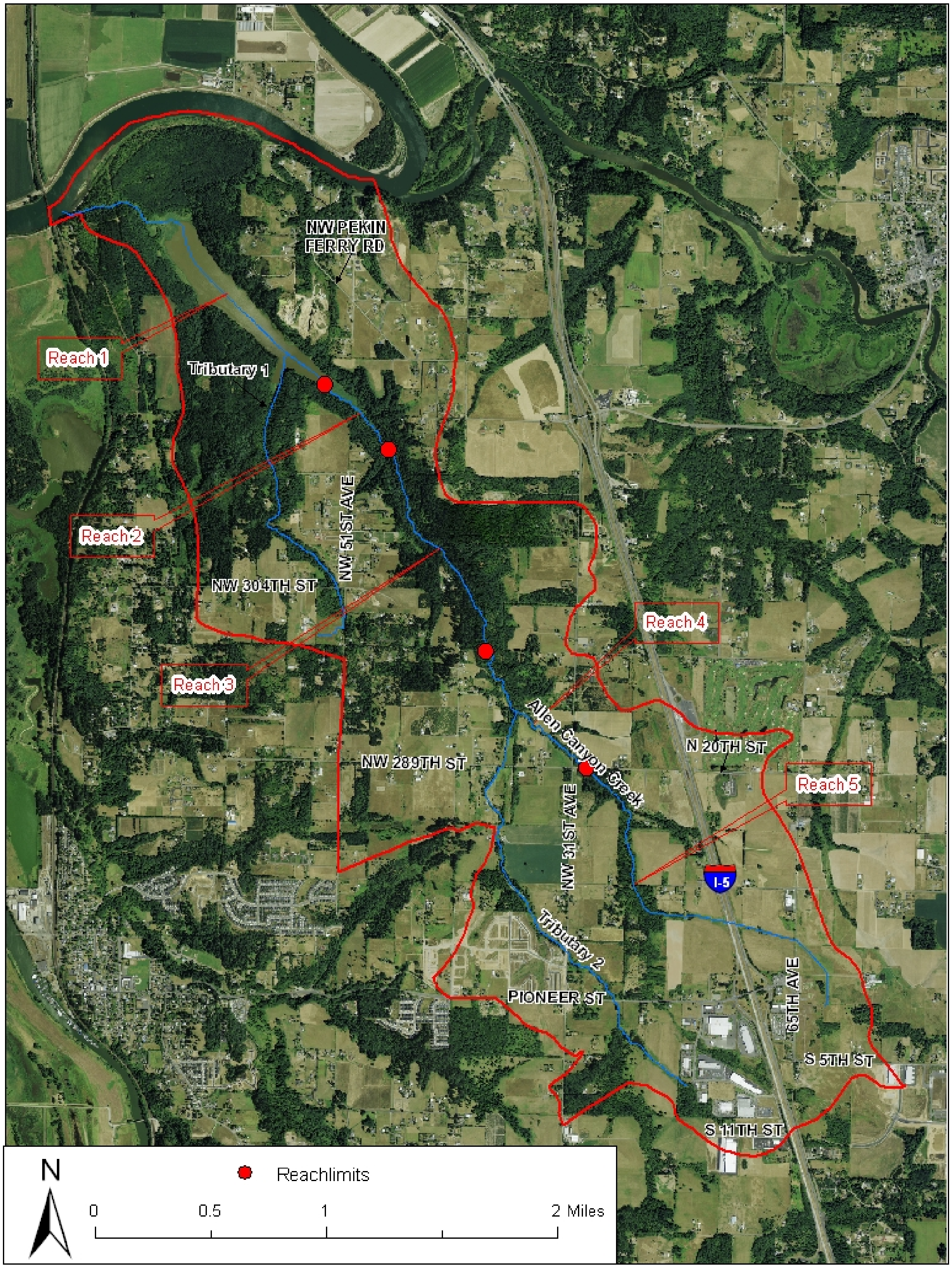

Figure 9. Location of geomorphic reaches defined for Allen Canyon Creek.

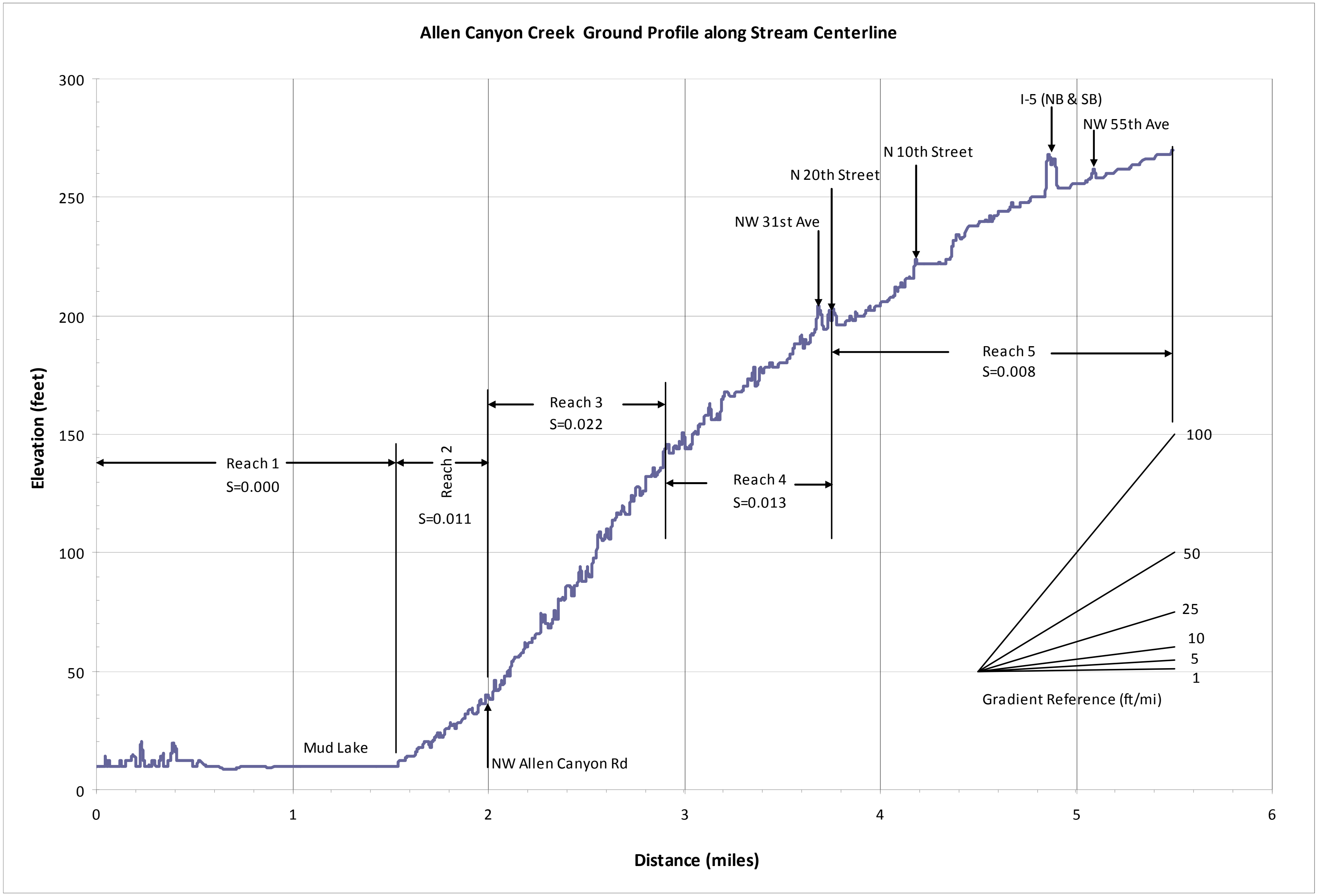

Figure 10. Ground profile along stream channel centerline for Allen Canyon Creek.

The extracted ground profiles for Tributary and 1 and Tributary 2 are shown in Figure 11. The ground profile along Allen Canyon Creek was added to the figure for reference. As seen in figure, Tributary 1 has an average channel slope of approximately 180 feet/mile (0.034) while Tributary 2 has an average slope of approximately 40 feet/mile (0.008). Tributary 1 has a significantly steeper slope compared to both Allen Canyon Creek and Tributary 2. This is likely the result of both the structure and composition of the underling geologic formations. Tributary 1 is oriented in approximately a north-south direction and is cutting across the surface of a southeast-northwest oriented anticline at approximately a 40-degree skew. The orientation of the anticline results in a northeast dip in the bedrock underlying Tributary 1. The streams orientation with respect to the dipping bedrock results in a relatively steep channel gradient. As the channel incises into the surrounding bedrock, it encountered greater resistance to erosion from the coarse grained Plio-Pleistocene conglomerate and cemented Sandy River Mudstone. Therefore, the channel is maintained at a much steeper slope than the remainder of the basin streams which are oriented approximately parallel to axis of the anticline.

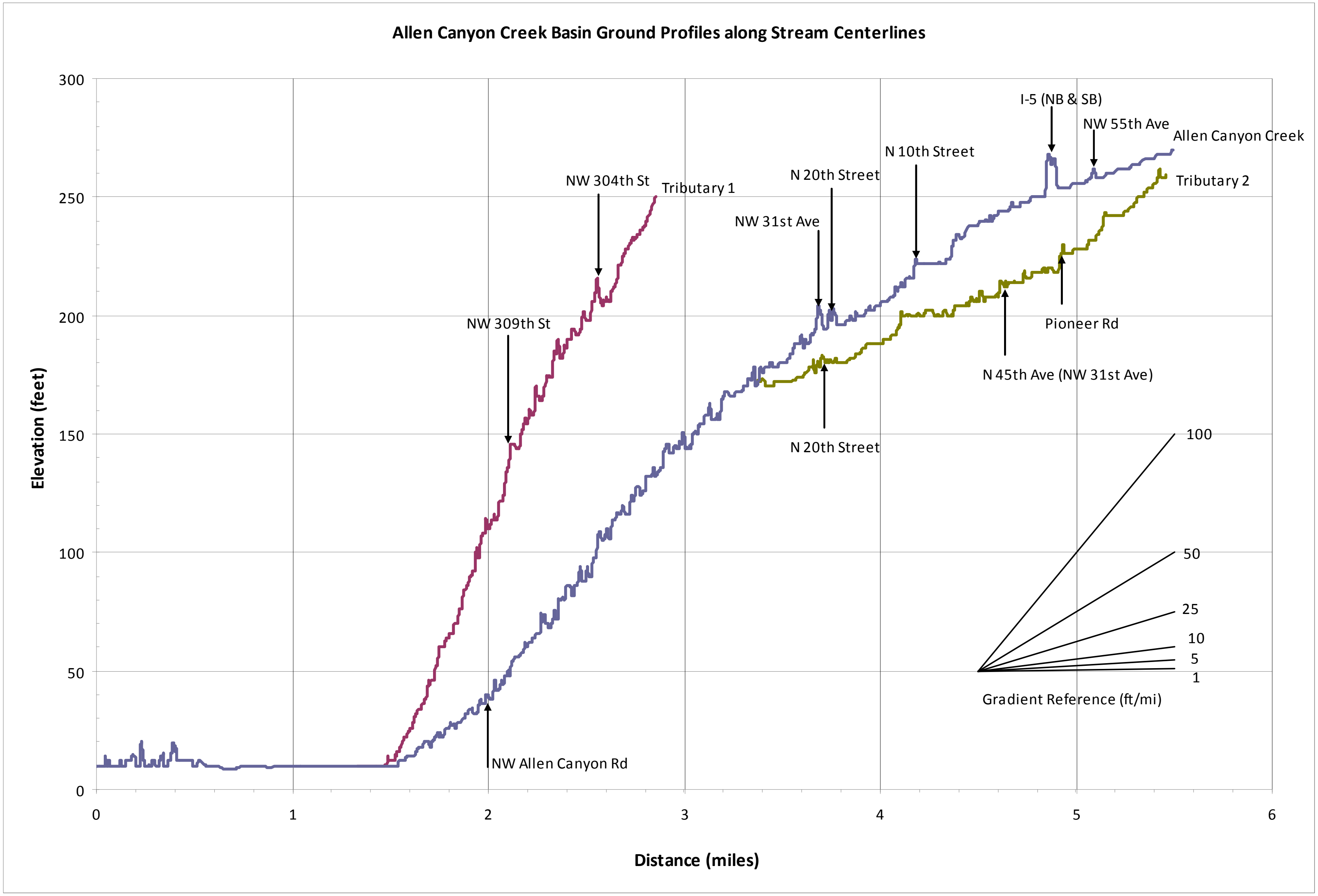

Figure 11. Ground profiles along stream channel centerlines for Allen Canyon Creek, Tributary 1 and Tributary 2.

3.3.3 Valley Cross Section Geometry

Selected cross sections located along the valleys of Allen Canyon Creek and its major tributaries 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 12. Valley cross section geometries for Allen Canyon Creek and its major tributaries are shown in Figure 13 through Figure 15.

3.3.3.1 Allen Canyon Creek Reach 5 (cross section 1 and 2), Tributary 1 (cross sections 1 and 2), and Tributary 2 upstream of N 10th Street (cross sections 1 and 2)

Allen Canyon Creek upstream of N 20th Street (Reach 5 in Figure 10), the majority of Tributary 1 and Tributary 2 upstream of N 10th Street are generally confined within a "V" shaped valley form. The confined valley form in the upper watershed is further evidence that these stream reaches are supply limited "source" reaches in that, over the long-term, sediment transport capacity generally exceeds sediment supply. These reaches will tend to incise over time and are considered to be the most susceptible to increases in peak flows and/or increases in the duration of flows that exceed the critical shear stress of the bed material. Gradual incision is expected to continue to occur with time unless there is sufficient grade control from vegetation, woody debris, or the underlying geology. Culvert crossings will continue to provide a form of grade control, although this is not typically their primary function. Further, significant discontinuities in grade at culvert outlets can have undesirable impacts on fish passage.

3.3.3.2 Allen Canyon Creek Reaches 3 and 4 (cross sections 3, 4, and 5) and Tributary 2 downstream of N 10th Street (cross sections 3 and 4)

The reach of Allen Canyon Creek between N 20th Street (NW 289th Street and Allen Canyon Road (Reaches 3 and 4 in Figure 10) and Tributary 2 downstream of N 10th Street progressively become less confined as the valley bottoms flatten and widen becoming more trapezoidal in shape. These reaches are considered "transport" reaches in that, over the long-term, sediment transport capacity generally equals sediment supply. Temporary storage of sediment occurs within these reaches resulting in increased sinuosity compared to the upstream supply reaches.

One anomaly in valley form is cross section 4 on Tributary 2 which appears to be much wider relative to the size of the channel than would be expected. Topographic data suggests that this portion of the valley as well as the rest of the Allen Canyon Creek Valley downstream to Mud Lake is likely a remnant side channel of the prehistoric Columbia River.

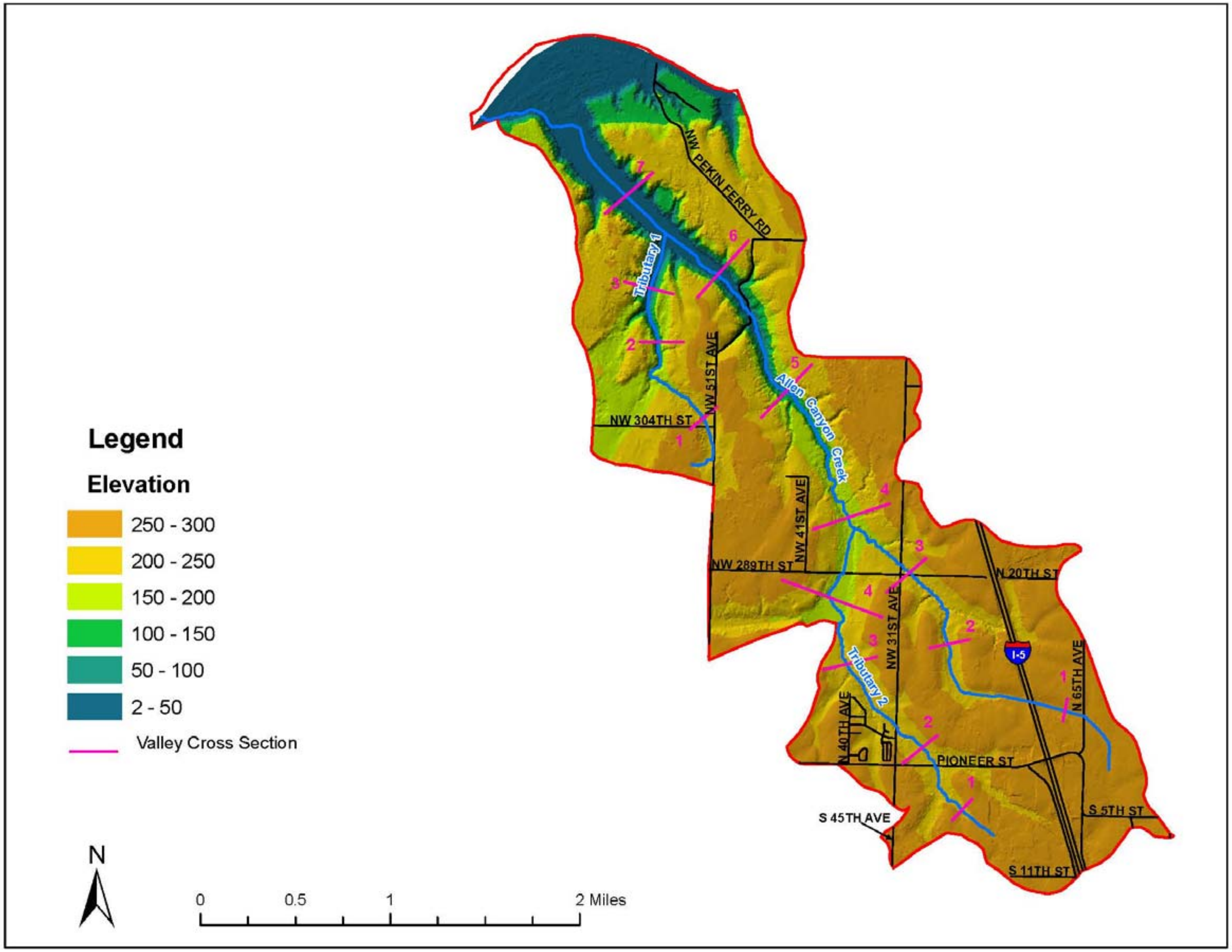

Figure 12. Location of valley cross section extracted from DTM.

3.3.3.3 Allen Canyon Creek Reaches 1 and 2 (cross sections 6 and 7)

The reaches of Allen Canyon Creek downstream of Allen Canyon Road (Reaches 1 and 2 in Figure 10) is a transport limited "response" reach in that, over the long-term, sediment supply generally exceeds sediment transport capacity. The channel slope is controlled at the downstream end by Mud Lake. This reduces the sediment transport capacity of the channel below the sediment supplied from upstream reaches resulting in long-term sediment deposition.

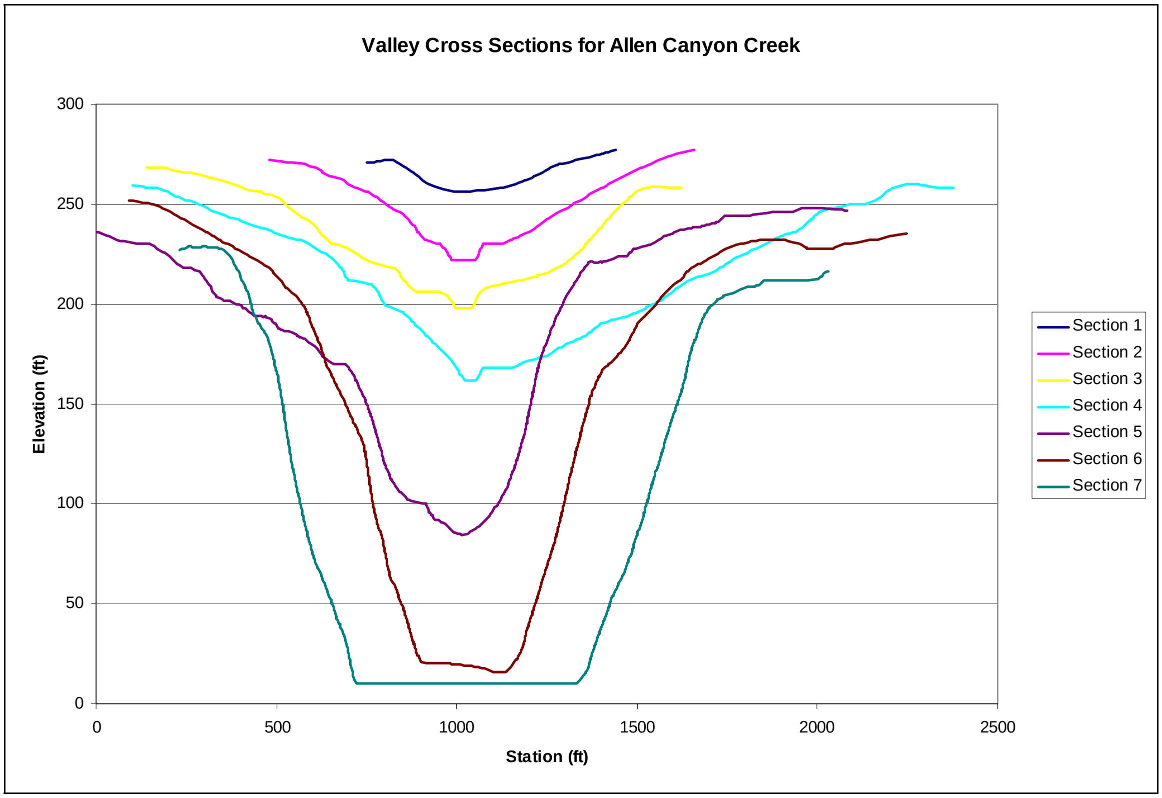

Figure 13. Valley cross sections for Allen Canyon Creek.

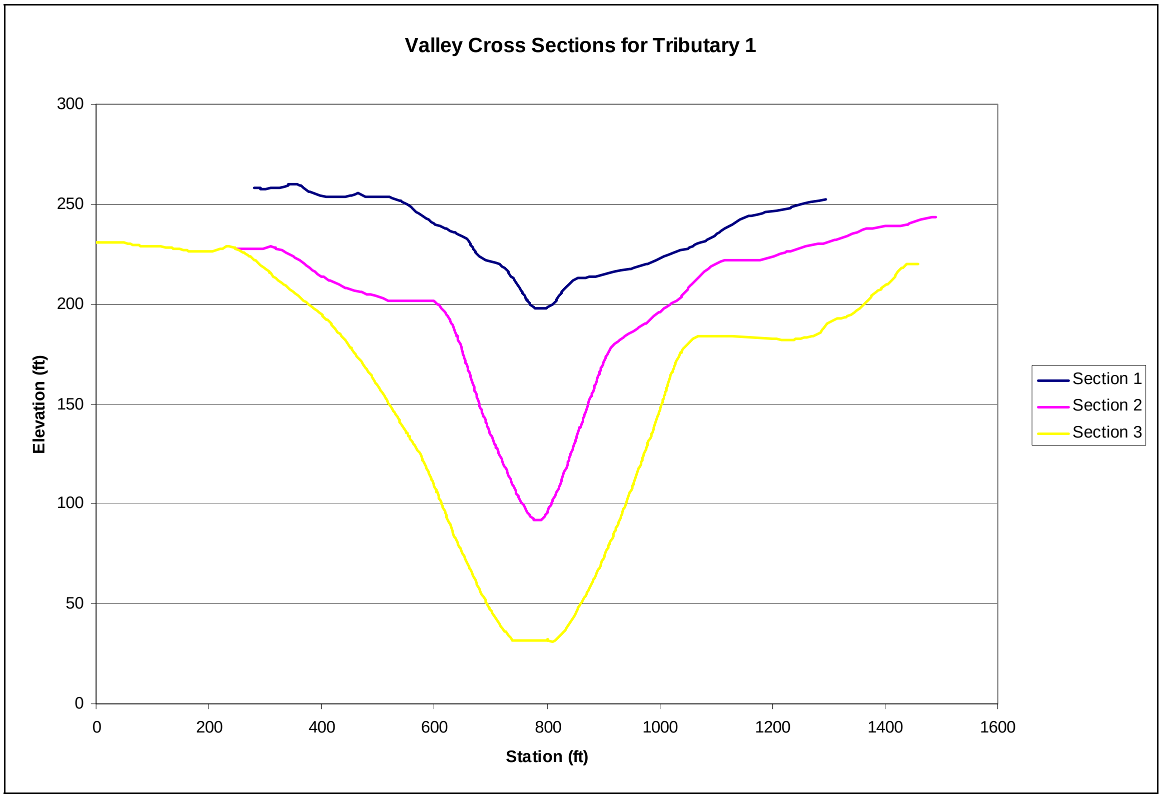

Figure 14. Valley cross sections for Tributary 1.

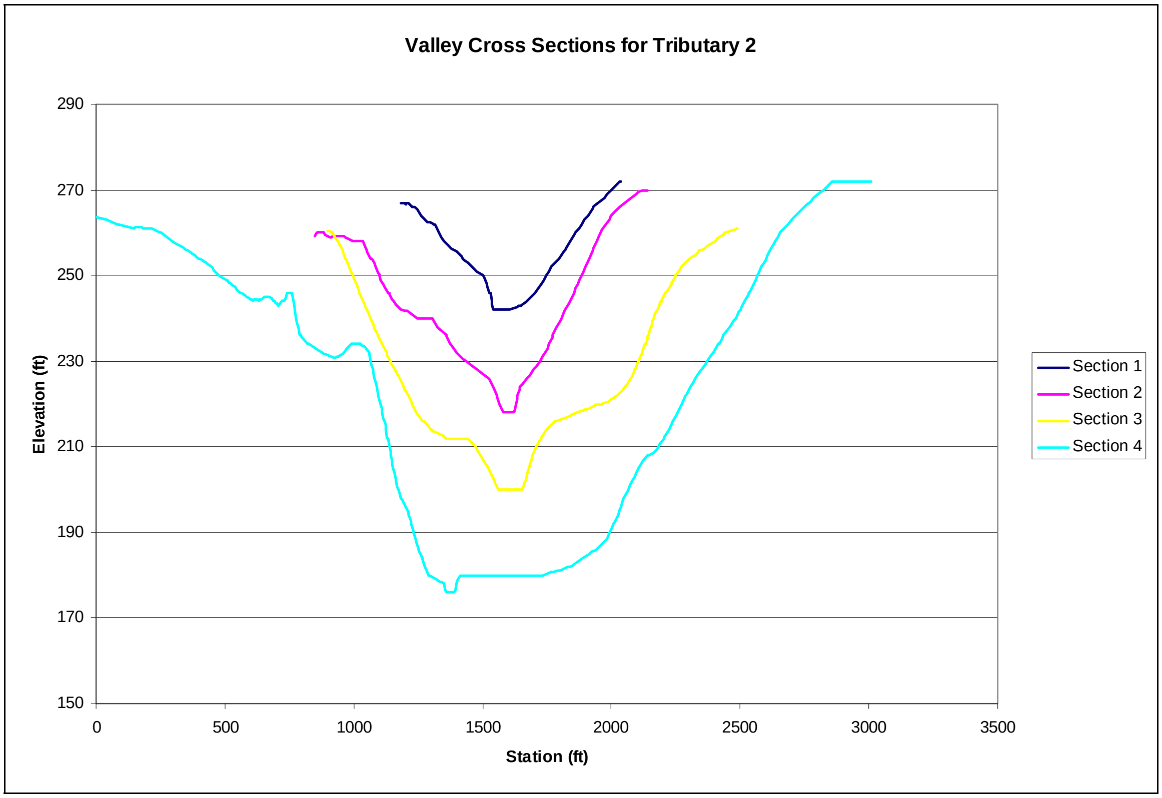

Figure 15. Valley cross sections for Tributary 2.

3.3.4 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 streams in the Allen Canyon Creek basin. The sizes of the channels found in the basin are too small to transport the majority of the wood that was contributed by the riparian forests that were once present along the stream corridors. Therefore, if not removed, the large woody debris likely remained in the channels until decay.

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 Allen Canyon Creek basin is found on steeper slopes adjacent to the mainstem and tributary stream channels and associated floodplain terraces in the middle and lower portions of the basin where the land is not conducive to farming or development. 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.

3.3.5 Conclusions

The geomorphology of the streams in the Allen Canyon Creek basin results from a combination of natural and human related controlling factors. The underlying geologic formations in the basin have the greatest control over channel planform, channel slope, and cross section geometry. The stream reaches located within the easily transported fined grained Cataclysmic Flood Deposits are the most susceptible to channel incision and have been incising into the surrounding landscape since the last glacial period. The stream reaches located within the less transportable coarse grained Plio-Pleistocene conglomerate are less susceptible to incision but more susceptible to channel widening.

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 Allen Canyon Creek basin.

3.3.5.1 Allen Canyon Creek Reach 5, Tributary 1, and Tributary 2 upstream of N 10th Street

- Unless properly managed, future increases in impervious surface area within the upper portion of the basin will result in increased peak flows and/or flow durations. These changes will likely cause channel incision in the "source" reaches within the upper basin to accelerate beyond current rates. However, either man-made or natural (such as large woody debris) grade controls would help to minimize the increased rate of incision.

- If grade controls are nonexistent, the resulting channel degradation and headcutting will move the channel initiation point further upslope, increasing the drainage density and efficiency with which the surrounding soils are drained. Channel degradation and headcutting will destabilize channel banks causing bank failures and an overall widening of the stream valley. Unless controlled the upper watershed stream reaches will transition, through both erosion and bank failures, from their current narrow "V" shaped valley form toward a deeper and broader trapezoidal shaped valley form as seen in downstream reaches.

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

- For those stream reaches that are draining portions of the watershed that are likely to experience a slow rate of development and therefore minimal changes to the existing hydrologic conditions, the above described channel changes may go unnoticed. Whereas stream reaches that drain portions of the watershed that are likely to experience higher rates of development and if not properly mitigated, significant changes to the existing hydrologic conditions, significant channel incision, headcutting, and bank failures will be readily evident.

3.3.5.2 Allen Canyon Creek Reaches 3 and 4 and Tributary 2 downstream of N 10th Street

- If future increases in flow magnitudes and/or durations occur, Reaches 3 and 4, which are underlain by the coarse grained Plio-Pleistocene conglomerate, will initially resist channel incision. Since bank material within this reach is generally composed of easily transported sand and silt sized material, increased erosion will occur along the outside of meander bends resulting in channel widening. Where the outside of the meander bend abuts the valley walls, erosion at the toe of the slope may result in slope failures. If future flows become sufficient to erode and transport the underlying coarse grained Plio-Pleistocene conglomerate bedrock, incision and bank failures will occur.

3.3.5.3 Allen Canyon Creek Reaches 1 and 2

- The "response" reach downstream of Allen Canyon Road could react in different ways to future increase in flow magnitude and/or duration. If the increased flows originate in the upper basin and if there is a proportional increase in upstream sediment supply, the additional sediment supplied to the reach will result in greater deposition rates, increased channel migration, and accelerated bank erosion. However, if the increased flows originate locally, such as from a new stormwater outfall, there will not be a proportional increase is sediment supply. In this case, the downstream hydraulic and bed controls will likely minimize significant morphologic changes.

3.3.6 Recommendations

- Restore and/or enhance riparian vegetation to provide a future source of large woody debris to the channel. Priority should be given to Allen Canyon Creek Reaches 4 and 5 as well as Tributary 2. These reaches currently lack sufficient healthy riparian vegetation, are underlain by easily eroded fine grained Cataclysmic Flood Deposits and are located within or immediately downstream of existing and future urban development.

- Although a lower priority, stream reaches that are expected to experience the least amount of development should not be ignored. Protection and/or reestablishment of riparian corridors in these areas while development pressure is low will allow a greater time period for the riparian vegetation to mature and therefore provide greater protection to the streams as development pressure increases in the future.

- Develop monetary 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 mainstem and tributary channels in the Allen Canyon Creek basin are currently not experiencing significant geomorphic changes. Their current geomorphic character results from a combination of natural and human related controlling factors. The underlying geologic formations in the basin have the greatest control over stream morphology as the size of the sediment supplied by the underlying bedrock determines the channels relative resistance to erosion. The stream reaches located within the easily transported fined grained Cataclysmic Flood Deposits are the most susceptible to channel incision and have been incising into the surrounding landscape since the last glacial period. The stream reaches located within the less transportable coarse grained Plio-Pleistocene conglomerate are the least susceptible to incision.

Conversion of the basin from its preEuro-American settlement forested condition to primarily agriculture land use in the late 1800's to early 1900's along with removal of riparian vegetation and woody debris likely resulted in an increased rate of channel incision. Since much of the road system was likely established at the same time the forests were being cleared for agriculture, the culvert stream crossings likely acted as grade control and helped resist the resulting incision just as the current stream crossing culverts are currently helping resist incision.

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 reaches in the upper portion of the basin will incise at a 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. The reach downstream of Allen Canyon Road will likely respond to the increased sediment load through acceleration of channel migration as this reach has historically been prone to sediment deposition. Bank erosion along the outside of meander bends would become more severe and could potentially accelerate erosion of the adjacent terrace slopes.

Various alternatives exist to help protect the streams in the Allen Canyon Creek basin from human-caused degradation. The most effective alternatives are to protect and restore riparian forest cover, limit the increase in effective impervious area, and properly manage runoff associated with development. Current land use zoning maps indicate that 53 percent of the basin can be used for either agriculture or rural residential development, while 12 percent is zoned for forest and open space. These areas will likely produce the least impact to streams compared to the current conditions. The remaining 32 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.

Additional alternatives to limit human-caused degradation of streams in the Allen Canyon 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 Allen Canyon Creek basin.

5 Project Recommendations

Various potential projects could be developed to help recover existing impairments and help reduce future degradation of streams in the Allen Canyon Creek basin. Table 5 summarizes the location and types of projects recommended.

Table 5. Recommended Stormwater Capital Improvement Projects.

Stream	Location/Reach	Impairment	Project
Allen Canyon Creek	From ~1800 ft u/s to ~2500 ft d/s of 65th Ave	Little or no riparian cover	Riparian plantings
Tributary 2	From Pioneer Street u/s ~700 ft	Poor riparian cover	Riparian plantings
Tributary 2	From 45th Ave d/s ~1,200 ft	Poor riparian cover	Riparian plantings
Tributary 2	From ~2100 ft u/s to ~700 ft d/s of NW 289th Street	Poor riparian cover	Riparian plantings
Tributary 1 west of 51st Ave	Immediately u/s and d/s of 304th St	Excessive blackberry	Invasive plant species removal
Unnamed Tributary to Tributary 1 west of 57th Ave	From 304th to ~800 d/s	No riparian cover	Riparian plantings
Unnamed Tributary to Tributary 2 west of 56th Ave	At Pioneer Street	Excessive scour at culvert outlet indicating excessive velocities d/s of culvert	Energy dissipater or culvert replacement

As seen in Table 5, the Unnamed Tributary culvert crossing under Pioneer Street should be retrofitted with an energy dissipater or replaced with a larger culvert. Excessive scour is occurring at the outlet of the culvert indicating excessive velocities downstream of the culvert. If replaced, the new culvert should accommodate natural fluvial processes and not significantly alter the hydraulic and sediment transport characteristics of the stream. 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 Allen Canyon 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.

Private dams and associated ponds have been observed along both the main stem and tributary reaches of Allen Canyon Creek. The benefit of removing or modifying dams would have to be carefully considered and evaluated on a case by case basis. Therefore, alteration or removal of individual dams was not included in the above list of recommended projects.

6 Management Recommendation

Various management alternatives exist to help recover existing impairments and reduce future degradation of streams in the Allen Canyon 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 in these areas while development pressure is low will allow a greater time period for the riparian vegetation to mature and therefore provide greater protection to the streams as development pressure 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.

- 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 predeveloped hydrologic conditions. Where soil conditions are a limiting factor, combine LID practices with traditional stormwater detention/retention facilities.

- A stream flow gage should be located on Allen Canyon Creek to develop a better understanding of the hydrology of the basin and to monitor changes in stream flows resulting from future land use conditions.

- Develop a calibrated continuous simulation hydrologic model of the Allen Canyon Creek basin to help evaluate potential changes in basin hydrology associated with future development. The model will 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 Allen Canyon Creek basin.

- Discourage surface water withdrawals for irrigation to help promote sufficient summer low flow conditions.

- Restore and/or enhance riparian vegetation to provide a future source of large woody debris to the channel. Priority should be given to Allen Canyon Creek Reaches 4 and 5 as well as Tributary 2. These reaches currently lack sufficient healthy riparian vegetation, are underlain by easily eroded fine grained Cataclysmic Flood Deposits and are located within or immediately downstream of existing and future urban development.

- Although a lower priority, stream reaches that are expected to experience the least amount of development should not be ignored. Protection and/or reestablishment of riparian corridors in these areas while development pressure is low will allow a greater time period for the riparian vegetation to mature and therefore provide greater protection to the streams as development pressure increases in the future.

- Develop monetary 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	
Allen Canyon Creek	65th Ave	culvert	good	low	none	silt/sand	silt/clay	no	agriculture	no	riparian plantings/ fencing	good	low	poor	silt/sand	silt/clay	no	undeveloped	no	riparian plantings	
Unnamed Tributary to Allen Canyon Creek	56th Ave	culvert	good	low	moderate	unknown	silt/clay	no	industrial	no		good	low	moderate	unknown	silt/clay	no	industrial	no		Stormwater detential pond downstream of 56th Ave
Unnamed Tributary to Allen Canyon Creek	Pioneer Street west of 56th Ave	culvert	good	low	moderate	silt/sand	silt/clay	no	undeveloped	no		good	low	moderate	sand/silt	silt/clay	yes	agriculture	minor		Scour hole below culvert, minor erosion along right bank d/s of culvert
Unnamed Tributary to Allen Canyon Creek	Pioneer Street west of 50th Ave	culvert	good	low	poor	sand/gravel	silt/sand	no	undeveloped	no	riparian plantings	good	low	moderate	sand/gravel	silt/sand	yes	agriculture	no		
Unnamed Tributary to Allen Canyon Creek	45th Avenue	culvert	good	low	moderate	sand/silt	silt/sand	minor	agriculture	no		good	low	poor	gravel/cobble	sand/gravel	minor	residential	no	riparian plantings	log grade control structure
Allen Canyon Creek	10th Street east of 45th Ave	culvert	good	low	good	sand/gravel	sand/silt	yes	undeveloped	no		good	low	excellent	sand/gravel	sand/silt	minor	undeveloped	no		
Allen Canyon Creek	289th Street	culvert	good	moderate	good	unknown	sand/silt	no	undeveloped	no		good	moderate	good	sand/gravel	sand/silt	no	agriculture	no		
Unnamed Tributary to Allen Canyon Creek	289th Street east of 38th Ave	culvert	good	low	poor	sand/gravel	silt/sand/g ravel	no	agriculture	no	riparian plantings	good	low	poor	silt/sand/gravel	sand/silt	no	agriculture	no	riparian plantings	
Unnamed Tributary to Allen Canyon Creek	299th St West of 43rd Ave	culvert	good	low	good	silt/clay	silt/clay	yes	rural residential	no		good	low	moderate (narrow width)	sand/gravel	sand/silt	minor	rural residential	no	riparian plantings	
Unnamed Tributary to Allen Canyon Creek	304th St. West of 51st Ave	culvert	good	low	good - excessive blackberry	silt/clay	silt/clay	minor	undeveloped	no	remove blackberry	good	low	good- excessive blackberry	cobble/gravel	sand/silt	minor	rural residential	yes- below culvert	remove blackberry	culvert outfall is perched - rock has been placed to reduce scour
Unnamed Tributary to Allen Canyon Creek	304th St. West of 57th Ave	culvert	good	low	poor	silt/clay	silt/clay	no	rural residential	no	riparian plantings	good	low	none	grass (silt/clay)	grass (silt/clay)	no	rural residential	no	riparian plantings	
Allen Canyon Creek	Allen Canyon Road	culverts	good	moderate	good	gravel/cobble	sand/ gravel	yes	undeveloped	no		good	moderate	good- excessive blackberry	gravel/cobble	sand/gravel	yes	undeveloped	no	remove blackberry	
Mud Lake	confluence with Allen Canyon Creek	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Unnamed Tributary to Allen Canyon Creek	Pioneer St. West of 45th Ave	culvert	good	no defined channel	no	grass (silt/sand)	grass (silt/clay)	no	agriculture	no	riparian plantings	good	low	new plantings	grass (sand/silt)	grass (silt/clay)	no	residential	no		downstream is area of new development with stormwater detention facilities
Unnamed Tributary to Allen Canyon Creek	Pioneer Canyon Drive West of 43rd Court	culvert	good	n/a	new plantings	detention ponds	grass (silt/clay)	no	residential	no		good	low	new plantings	grass (silt/sand)	grass (silt/clay)	no	residential	no		stormwater detention facilities for new residential development