THE CRISP CREEK WATERSHED:

Current Conditions and Risks

January 2017

Muckleshoot Indian Tribe
Fisheries Division
Auburn, Washington

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MUCKLESHOOT INDIAN TRIBE
FISHERIES DIVISION

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EXECUTIVE SUMMARY

This report describes current watershed conditions and anticipated threats to the water resources of Crisp Creek which serves as the water supply for the Muckleshoot Indian Tribe's Keta-Crisp Hatchery. The hatchery was constructed in 1978 and was remodeled in 2015. The hatchery produces chum and coho salmon for both tribal treaty and non-tribal fisheries in Puget Sound and in the Green River.

Salmon hatcheries require an abundant supply of very clean and cold water to be successful. Crisp Creek presently has among the highest quality water of all monitored low-elevation streams in King County. The creek is dominated by groundwater flow from high-yield springs and seeps. About 82 percent of this small, 4.6 square-mile watershed lies within unincorporated King County, with the remainder inside the city of Black Diamond's urban growth boundary. Currently, close to 70 percent of the watershed is forested, but growth pressures are mounting to convert land from forest to homes and subdivisions. The Tribe is concerned that forest cover loss, storm runoff, groundwater withdrawals and contaminants that accompany development will degrade the creek and deplete its summer base flow levels, leading to impairment of the Tribe's water rights, fish health problems and reduced fish production at the hatchery.

Since the 1990s, King County has taken some steps to protect natural resources in the Crisp Creek watershed. The county acquired certain landslide-prone areas along Crisp Creek, protected agricultural lands, established rural zoning densities, and enacted Critical Areas rules. As part of the Black Diamond 1996 urban growth boundary creation that extended into the watershed, and related open space agreements, the county acquired 135 acres in the watershed including portions of Crisp Creek and other sensitive areas. Several parcels have been enrolled in the State Forest Taxation program and the county Public Benefit Rating System, perhaps helping to slow the urbanization that has degraded so many other streams in central Puget Sound.

Yet, neither the steps already taken nor current land use requirements will fully protect Crisp Creek from future water contamination, declining summer flows, warmer temperatures and siltation that are associated with the impacts of land development. As growth pressures continue, more of the watershed's forest land will be subdivided; the road network and vehicle traffic will increase; and more development will be proposed. The effectiveness of existing land use regulations and mitigation measures to protect water resources over time is uncertain. Given that a plan exists to locate a regional stormwater facility in the watershed (to serve new development including part of The Villages, a 4,800-home mixed-use development at the eastern watershed boundary); the likely future partitioning of rural forest lands; and new subdivisions such as The Ridge at Lake Sawyer Division III and The Reserve at Woodlands – the preservation of Crisp Creek's excellent water resources is far from assured.

A strategy is proposed to safeguard the future of Crisp Creek and the quality and quantity of the Keta-Crisp Hatchery water supply. Key recommendations include the conservation of priority headwater and other forest lands at imminent risk of development; comprehensive ground and surface water quality monitoring; augmented riparian and wetlands buffers; enhanced septic treatment and stormwater management, and restrictions on new private well development in favor of domestic water supply from the Covington Water District. The Tribe plans to work closely with King County, the city of Black Diamond, and others to refine and implement this strategy.

1. REPORT PURPOSE

The Muckleshoot Indian Tribe owns and operates an important salmon hatchery in the Crisp Creek watershed near the city of Black Diamond (Figure 1). Crisp Creek and its tributary springs provide the water source for the Keta-Crisp Hatchery. The purpose of this report is to describe the current watershed conditions of Crisp Creek; characterize threats to water resources; and recommend a set of actions to ensure that the water resources of Crisp Creek and water rights and water supply of the Keta-Crisp Hatchery are protected into the future.

This report updates the 1994 *Crisp Creek Watershed Conditions and Nonpoint Assessment* prepared by the Muckleshoot Indian Tribe (Carlson, 1994). Since that time, certain sensitive areas and forest lands upstream of the Tribe's hatchery have been protected as open space. However, elsewhere in the watershed, land conversion from working forest to residential and subdivision development continues. The Tribe is concerned that further losses in forest cover and other impacts of development will reduce the base flow rate and quality of the Keta-Crisp Hatchery water supply, threatening its ability to produce fish for harvest at this facility in the future.

The Tribe has operated the Keta Creek Hatchery since 1978, and more recently incorporated the adjacent Crisp Creek Rearing Ponds formerly owned by the Washington Department of Fish and Wildlife. The hatchery produces chum and coho salmon (Figure 2) for harvest by tribal members and non-Indian sport and commercial fisheries including highly popular sport fisheries in the Green River and in Elliott Bay. The Keta-Crisp Hatchery provides an indispensable portion of the salmon harvest opportunity available to the Tribe in fulfillment of fishing rights secured by treaty with the U.S. government.

Salmon culture in hatcheries requires an ample supply of excellent quality water free of fertilizers, metals, hydrocarbons, pesticides, hormones and other contaminants. Today, the water quality of Crisp Creek and the Keta-Crisp Hatchery water supply is excellent. Looking forward, the Tribe is concerned about the potential for land development and water use to degrade the water resources of Crisp Creek over time. Unless these impacts are avoided, the future of the hatchery is at risk.

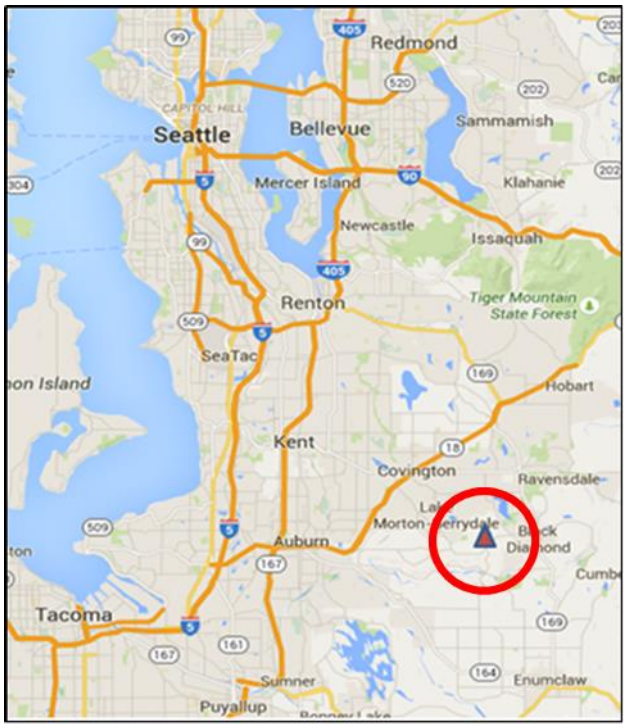

Figure 1. The location of the Crisp Creek watershed and Keta-Crisp Hatchery is shown in red.

Crisp Creek is unique among low-elevation streams in King County today in that little development exists on its banks, most of its headwaters remain forested, watershed impervious land cover is low, and its water quality is excellent. Although most land in this small 4.6 square mile watershed (Figure 3) is zoned as rural, conversion from forest to residential and urban use is ongoing. The city of Black Diamond annexed roughly 18 percent of the watershed for urban growth. Three major subdivisions were approved and built between

2002 and 2006 (Ridge at Lake Sawyer Division I, Ridge at Lake Sawyer Division II, and Meadows at Lake Sawyer). An additional plat, Ridge at Lake Sawyer Division III, has been approved and another called The Reserve at Woodlands is pending. Both plats are in the rural unincorporated portion of the watershed. Other remaining forested parcels may or will be developed for home sites or other purposes. A 40-acre regional stormwater facility in the watershed to be located west of the Black Diamond urban growth boundary was approved in 2014 by King County. A portion of this facility (0.66 acres) has already been constructed and was used in 2016 to infiltrate floodwater piped from Horseshoe Lake.

The Tribe recognizes that King County continues to work to protect natural resources in its planning, permits, parks, and public works functions, and anticipates that the city of Black Diamond will also seek to protect natural resources as its population grows. Despite these efforts, cumulative impacts to ground and surface water can be expected. The level of implementation and effectiveness of mitigation measures for future development are uncertain, and retrofitting existing development to improve water resources protection is costly and unlikely to reverse impacts entirely. As a result, the Tribe believes that additional land conservation and other measures are necessary to safeguard the water resources of Crisp Creek and the integrity of its hatchery water rights for the future.

Figure 2. Juvenile coho salmon rearing in the Keta-Crisp Hatchery ponds.

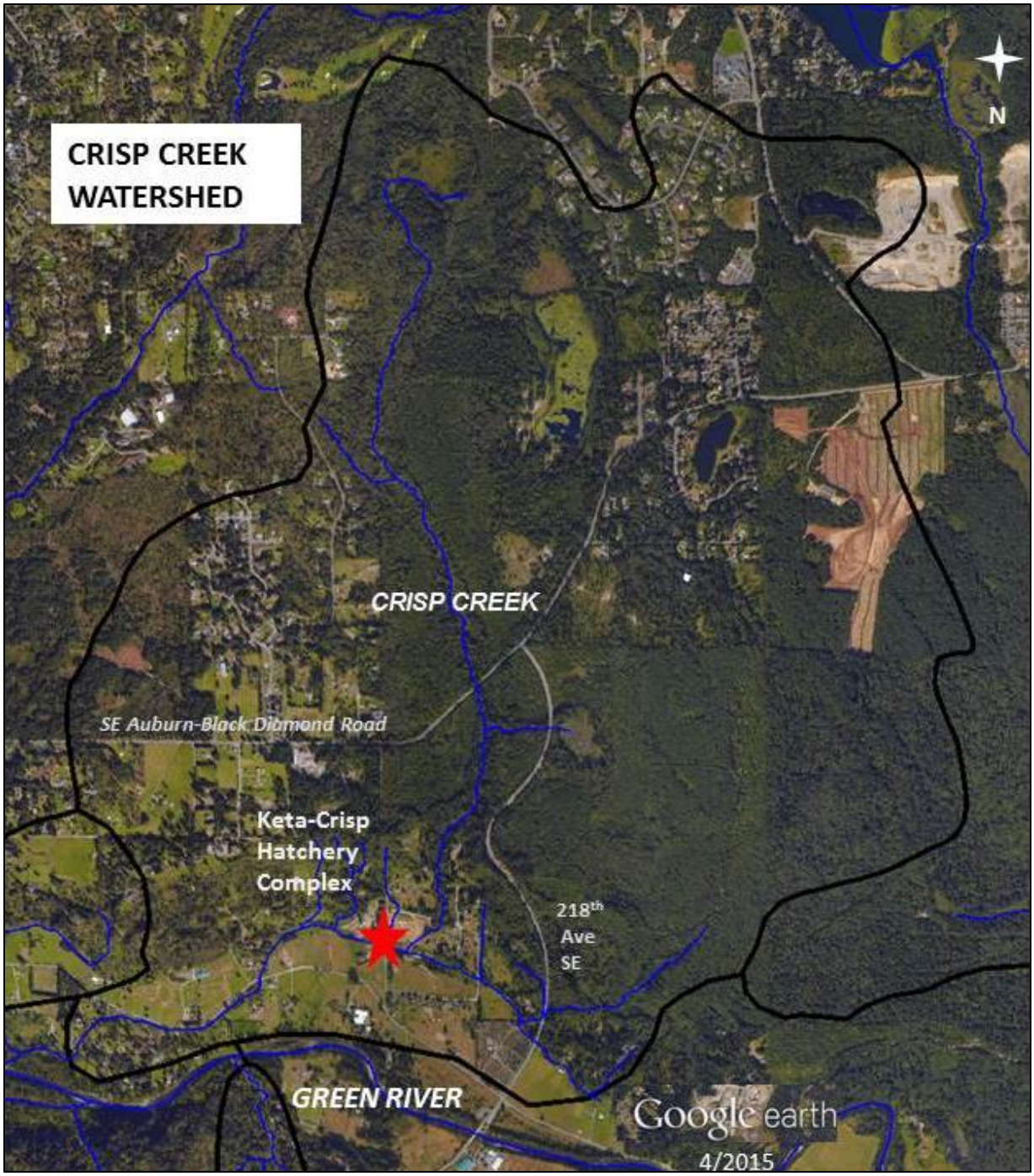

Figure 3. Crisp Creek watershed boundaries (in black and the location of the Keta-Crisp Hatchery Complex, red star). The watershed is 4.6 square miles in area, and the creek and springs (in blue) provide the water supply for the hatchery.

2. KETA-CRISP FISH HATCHERY DESCRIPTION

The Muckleshoot Indian Tribe's Keta-Crisp Hatchery (formerly known as Keta Creek Hatchery) is located east of Auburn in south King County. The hatchery is adjacent to Crisp Creek and Keta Creek, a small spring-fed tributary approximately one mile upstream from the Green River (Figure 3). The hatchery facilities were first constructed in 1978. The fish produced at the Keta-Crisp Hatchery provide indispensable fishing opportunity for tribal members as guaranteed by the United States under the treaties of Point Elliott and Medicine Creek as affirmed by the U.S. Supreme Court.

The hatchery has the capacity to raise up to 1 million coho salmon yearlings and 5 million chum fry for release in the Green River and in Elliott Bay to support tribal treaty harvest as well as non-tribal sport and commercial fisheries. A portion of the coho salmon raised at the hatchery is transferred to saltwater net pens in Elliott Bay each spring for final rearing. The net pen program is a cooperative program with the Suquamish Indian Tribe, and was initiated in 1994 as part of mitigation for the Elliott Bay Marina development. At times, the hatchery also raises fish for conservation or research purposes. All hatchery programs are coordinated with WDFW as part of salmon co-management procedures established under U.S. v Washington ("Boldt Decision" 1974) and are reviewed by the National Marine Fisheries Service for consistency with the Endangered Species Act. Fish releases from this hatchery and from the Elliott Bay Net Pens have a high survival rate, and make a major contribution to local and regional sport fishing opportunity.

Figure 4. Overview of the Keta-Crisp hatchery facilities, with rearing tanks and ponds in the foreground.

The hatchery includes the Crisp Creek Rearing Ponds, formerly known as the "Spaight Ponds" or "Straight Ponds". The ponds were acquired from a private landowner in 1975 by the Washington Department of Fish and Wildlife (WDFW) to raise coho salmon. In 1997, the Tribe began operating the ponds and they were deeded to the Tribe in 2004. Once separate facilities, the Keta Creek Hatchery and the Crisp Creek Rearing Ponds were merged in 2015 as part of a hatchery modernization project (Figure 4). The lands and parcels associated with the hatchery complex are held in trust by the U.S. Government for the Tribe.

In addition, the hatchery facilities include three earthen ponds that are used to raise catchable-sized trout in for the Tribe's popular Keta Creek fishing derby program. These trout are purchased from a supplier and fed for several months. Several times each year, the Tribe hosts a fishing derby and barbecue for the tribal community with as many as 400 adults and children attending any one event (Figure 5).

The Tribe holds a combined total of 11.23 cubic feet per second (cfs) of non-consumptive surface water rights to Crisp Creek and to Keta Springs for the purpose of fish propagation and an additional 0.02 cfs and 2 acre-feet/year for domestic use. These water rights have priority dates that range from 1975 to 1984.

Figure 5. Families enjoying a fall Keta Creek fishing derby at the hatchery. The Tribe sponsors several fishing derbies each year for tribal community members.

3. WATERSHED CONDITIONS

Crisp Creek is a small isolated watershed surrounded on three sides by the Soos Creek drainage in the Green-Duwamish basin (WRIA 9) southwest of Lake Sawyer. The watershed area is approximately 4.6 square miles. Crisp Creek flows for a total of 3.6 miles from the Covington plateau along flat to gently sloping terrain then drops down steep hillslopes to the Green River valley to join the Green River at River Mile 40.1. Crisp Creek provides spawning and rearing habitat primarily for coho and chum salmon, and cutthroat trout.

Fifty-seven percent of the watershed and most of the area upstream of the Keta-Crisp Hatchery is currently undeveloped and covered in conifer forest stands of various age classes. Until the mid-1990s, these lands were managed as commercial timberlands. Several parcels are still managed as timberlands with limited logging activity in recent years. Upstream of the hatchery, the riparian area of Crisp Creek is nearly intact and is dominated by coniferous forest. Downstream of the hatchery, the creek flows through farmlands, residential properties, and along the Green Valley Road. Riparian cover in lower Crisp Creek is limited and consists mostly of blackberry and other shrubs, and patches of deciduous trees as the creek flows through backyards to the Green River.

Older housing developments exist in pockets of the watershed, with newer large estate-style homes occupying the north end. The eastern portion of the watershed was annexed into the city of Black Diamond and will be developed at urban densities. As of late 2015, the Crisp Creek watershed has a relatively low road density of about three miles of road per square mile, and impervious surfaces comprise 5.4 percent of the watershed area (NW Indian Fish Commission, unpublished data, 2016).

SENSITIVE AREAS

Washington's Growth Management Act (RCW 36.70A) requires local governments to identify and protect sensitive or critical areas and natural resource lands, designate urban growth areas, prepare comprehensive plans and implement them through public investments and development regulations. Critical areas have been designated for the Crisp Creek watershed in unincorporated King County and collectively comprise a significant portion of the watershed (Figure 6). Erosion, landslide, seismic hazard areas, streams, wetlands and lakes are all identified as critical areas and are subject to the King County Critical Areas Ordinance (CAO, Title 21A.24). Horseshoe, Keevies, and Marjorie/Oak lakes are all identified as critical areas, along with a 15-acre sphagnum bog and Class 1 wetland in the headwaters of Crisp Creek. A 36-acre Class 2 wetland surrounds the north and west shores of Keevies Lake. Another 10-acre wetland is associated with Horseshoe Lake, and several smaller wetlands occur within the watershed.

Several springs including the Keta Springs enter Crisp Creek just south of the Auburn-Black Diamond Road and flow year-round. A tributary from the west and another from the east draining a Class 2 wetland augment streamflow in Crisp Creek upstream of the fish hatchery. Another tributary from the east flows to a wetland and enters the creek below the hatchery.

Of particular note, the 15-acre bog in the Crisp Creek headwaters is one of the last remaining peatland or sphagnum moss bogs in the county. Sphagnum bogs are unique ecosystems that are fast disappearing from the landscape (Kulzer, et al., 2001). The Crisp Creek bog has evolved over thousands of years, as a specific pattern of inundation, anaerobic conditions, low pH, microclimate,

nutrient cycling, and plant species composition all combined to form the bog. Conversion of forest uplands to impervious surfaces would decrease groundwater recharge to the bog and to the Crisp Creek headwaters. Stormwater runoff would alter the peatland chemistry, and changes in local hydrology and the timing of surface and groundwater inputs would alter the unique characteristics of this sphagnum moss, or peatland bog (Kulzer, et al., 2001). The bog drains to Crisp Creek, and changes to the bog would negatively affect the water chemistry and nutrient content of the creek.

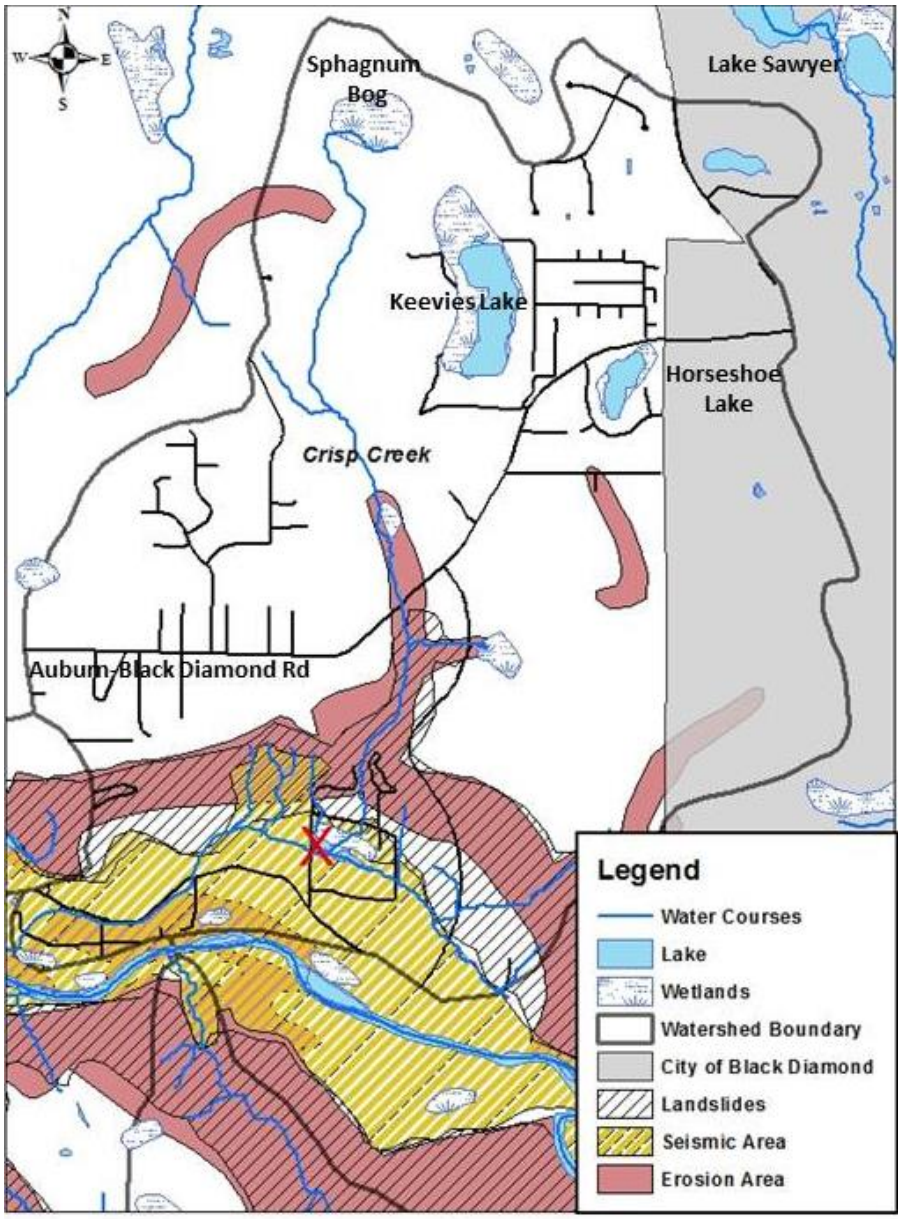

Figure 6. Sensitive areas in the Crisp Creek watershed as designated by King County. Note the large extent of erosion, seismic and landslide hazard areas in the south portion of the watershed. The red "**X**" denotes the Keta-Crisp Hatchery location. Source: http://www5.kingcounty.gov/gisdataportal/ 11-9-15.

Critical Aquifer Recharge Areas (CARAs) are classified as sensitive areas important for groundwater recharge and for vulnerability to groundwater contamination. The CARA designation is of two types, Category I and II, as defined by CAO 21A.24.313. Category I CARAs are highly susceptible to

groundwater contamination and are located within a sole source aquifer or wellhead protection area; or in an area within a one year groundwater "time of travel" to a wellhead for a Group A water system. The Diamond Springs Water Association is a Group A water system adjacent to the Keta-Crisp Hatchery. Its wellhead protection area is designated as a Category I CARA (Figure 7).

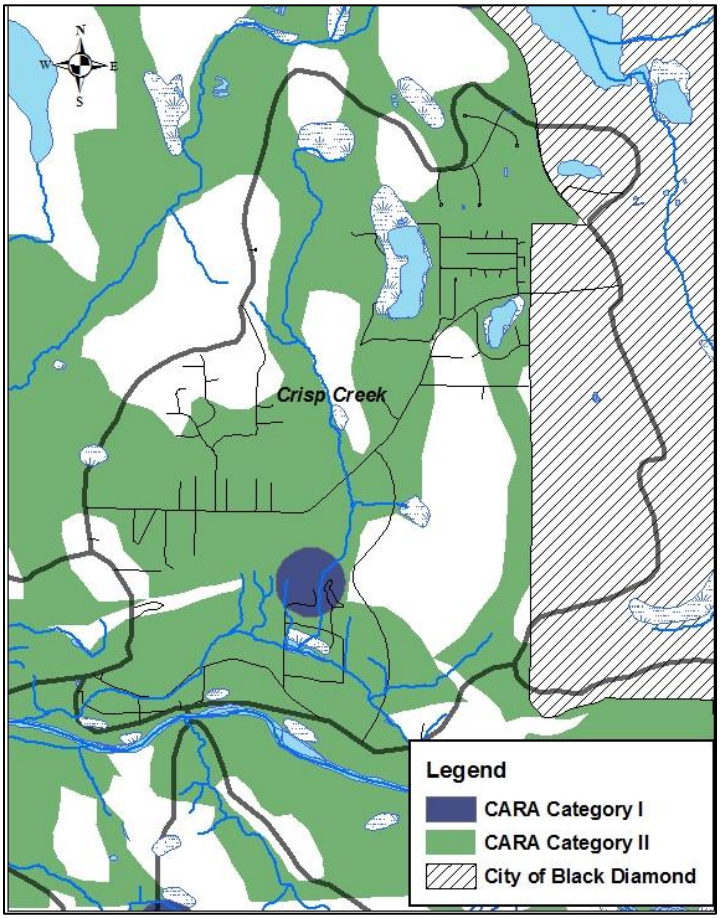

Figure 7. Critical Aquifer Recharge Areas (CARA) in the unincorporated portion of the Crisp Creek watershed.
Source: https://gismaps.kingcounty.gov/iMap/ on 2-3-2016

Category II CARAs have a medium susceptibility to ground water contamination and are located in a sole source aquifer or a wellhead protection area; or are highly susceptible to groundwater contamination but are not located in a sole source aquifer or wellhead protection area. Much of the Crisp Creek watershed is designated as a Category II CARA. Some types of development such as gravel mines, hazardous waste storage, and mining are not allowed on CARAs. For residential development, the only restriction is for on-site septic systems, per King County CAO 21A.24.316, where lots less than 1 acre are not allowed unless the system is approved by the State Department of Health and meets a higher treatment standard (standard N in WAC 426.272A); or the Seattle-King County Department of Public Health determines that it will not function on the site. Additionally, in any critical aquifer recharge area, property owners are required to properly decommission any abandoned wells (CAO 21A.24.316).

The Crisp Creek basin was rated as having a "High Condition" in the King County 2005 Critical Areas Ordinance (CAO), Title 21A.24.065. This rating reflects areas with low development intensity, e.g., substantial forest cover, few road crossings at streams and wetlands, low impervious surfaces, and little shoreline armoring. A High Condition rating also indicates a significant biological value based on presence or use by critical species or the presence of rare, endangered or highly sensitive habitats. However, the CAO provides no specific guidance for land use actions or regulations for basins designated as "High Condition".

King County has acquired several steep landslide and erosion-prone areas in the unincorporated area of the watershed for protection (see Figure 22); however other sensitive areas remain at risk from the impacts of future development and growth.

GROUNDWATER

Groundwater is a critical part of the hydrologic cycle in the Crisp Creek watershed as it provides a majority of the streamflow in the creek and its springs. The geology of the watershed helps explain the source of the groundwater that feeds Crisp Creek, providing a year-round water supply for the Keta-Crisp Hatchery.

Crisp Creek is near the southwestern end of a geologic feature called the Covington Upland drift plain, a generally flat to gently sloping area with depressions and outcrops. The drift plain is mantled by glacial till and outwash deposits from the Vashon stage of the Frasier glaciations which occurred about 15,000 years ago. Vashon recessional outwash (Qvr) deposits principally consist of well-sorted sand and gravel, and are usually very permeable and percolate rainwater fairly rapidly. These Qvr deposits occupy depressions surrounding the till outcrops or hills on the drift plain with other geologic features located along the steep slopes above the Green River (Figure 8). Qvr deposits serve as recharge areas and form the shallow water-table aquifer. The Qvr aquifer is underlain in many areas by till that can slow the vertical movement of groundwater, causing it to flow horizontally more easily. However, water also moves downward from till to the aquifer below; but at a slower rate. The deeper aquifer is called the pre-Olympian aquifer or Qpog aquifer and is very productive. It is the primary source of water to springs and seeps flowing to Crisp Creek (Figure 9) and to the Green River. The general direction of horizontal groundwater movement in the Qvr aquifer is to the southwest toward Crisp Creek and the Green River Valley (Woodward, et al. 1995). A more local analysis of flow movement in the Qvr aquifer by Associated Earth Sciences (draft, 2008) and Saltonstall, et al., 2009) also show inter-basin transfer of groundwater from the north and east, with the direction of groundwater flow to the west, southwest and south, and towards the steep hillslopes above the alluvial Green River valley (Figure 10). The groundwater flow pathway for the deeper Qpog aquifer is likely similar to that of the Qvr aquifer.

In some areas the Qvr deposits are not underlain by till, but lie directly over deposits that form the Qpog aquifer. Areas where the till layer is absent are often referred to as “windows” because the groundwater within the Qvr aquifer becomes directly hydraulically connected to the underlying pre-Olympian aquifer (Qpog). Horseshoe Lake is an example of a till “window” which explains why the lake level rises when rainfall is greater than normal. The cross-sectional view in Figure 11 illustrates this feature (AES, draft, 2008). When the level of Horseshoe Lake has threatened to flood homes around the lakeshore during these events, King County has had to pump floodwaters from the lake. Other areas with till windows in the watershed are shown in Figure 10, including a small wetland located just east of Crisp Creek and 218th Avenue SE where a new subdivision, The Reserve at Woodlands, is planned for construction.

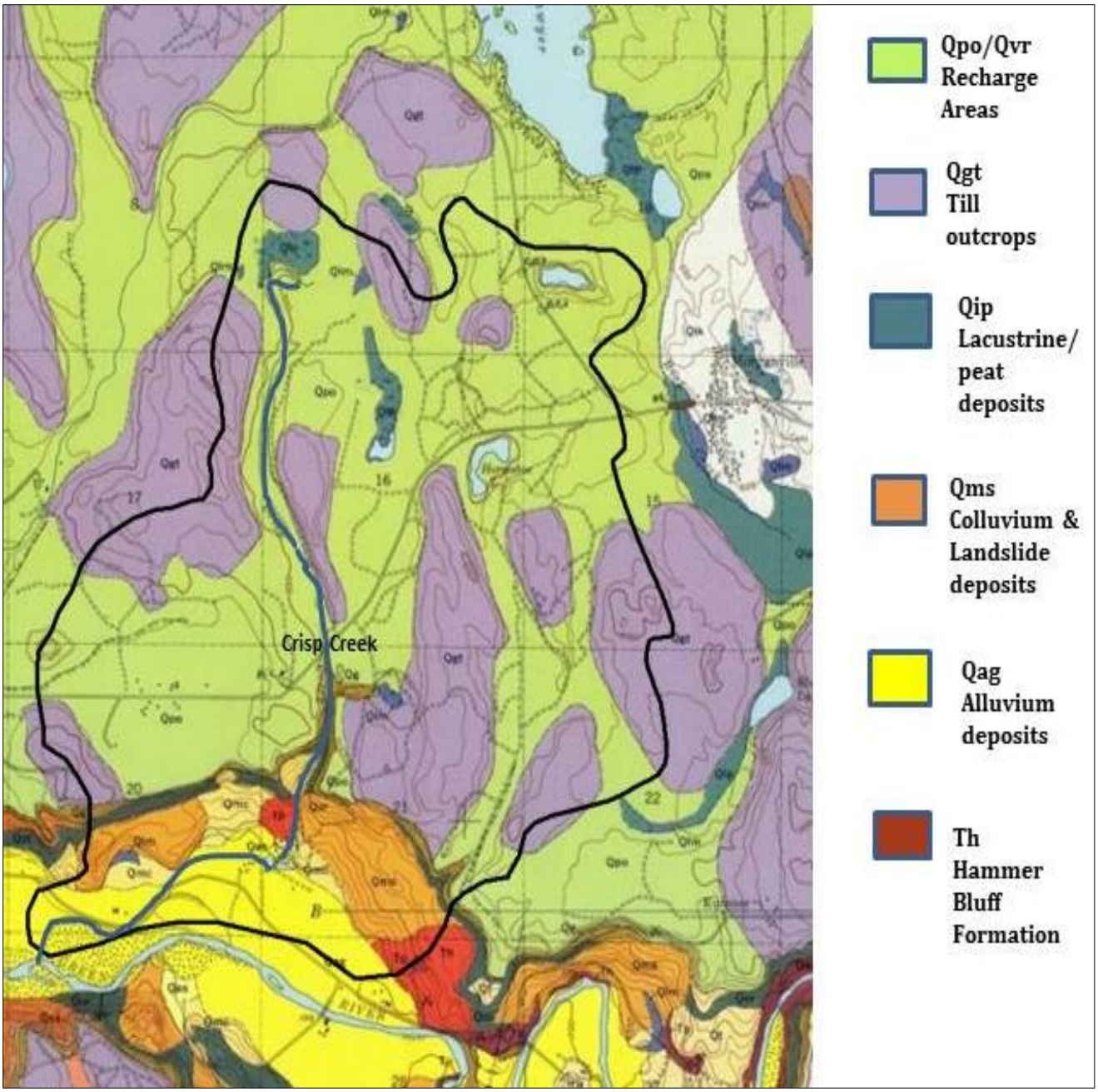

Figure 8. Surficial geology of the Crisp Creek watershed showing recharge areas formed from glacial drift outwash deposits and till outcrops. Modified from Mullineaux, 1965.

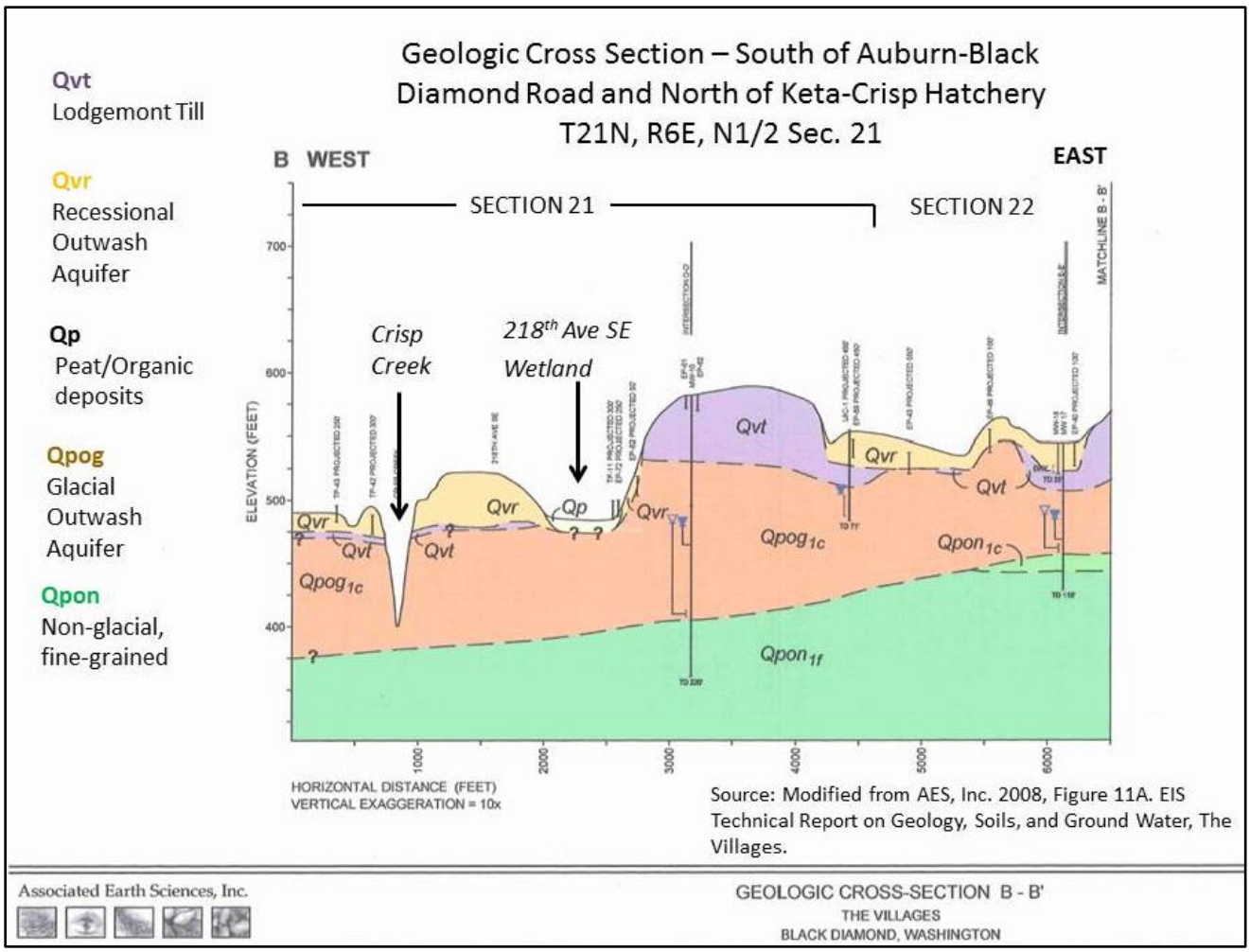

Figure 9. The Qpog aquifer is the primary source of water for Crisp Creek and is the sole source during the dry summer-fall period. The 218th Ave. SE. wetland is likely a "window" and directly connected to the Qpog aquifer, similar to Horseshoe Lake. Source: Associated Earth Sciences, Inc., Draft, 2008.

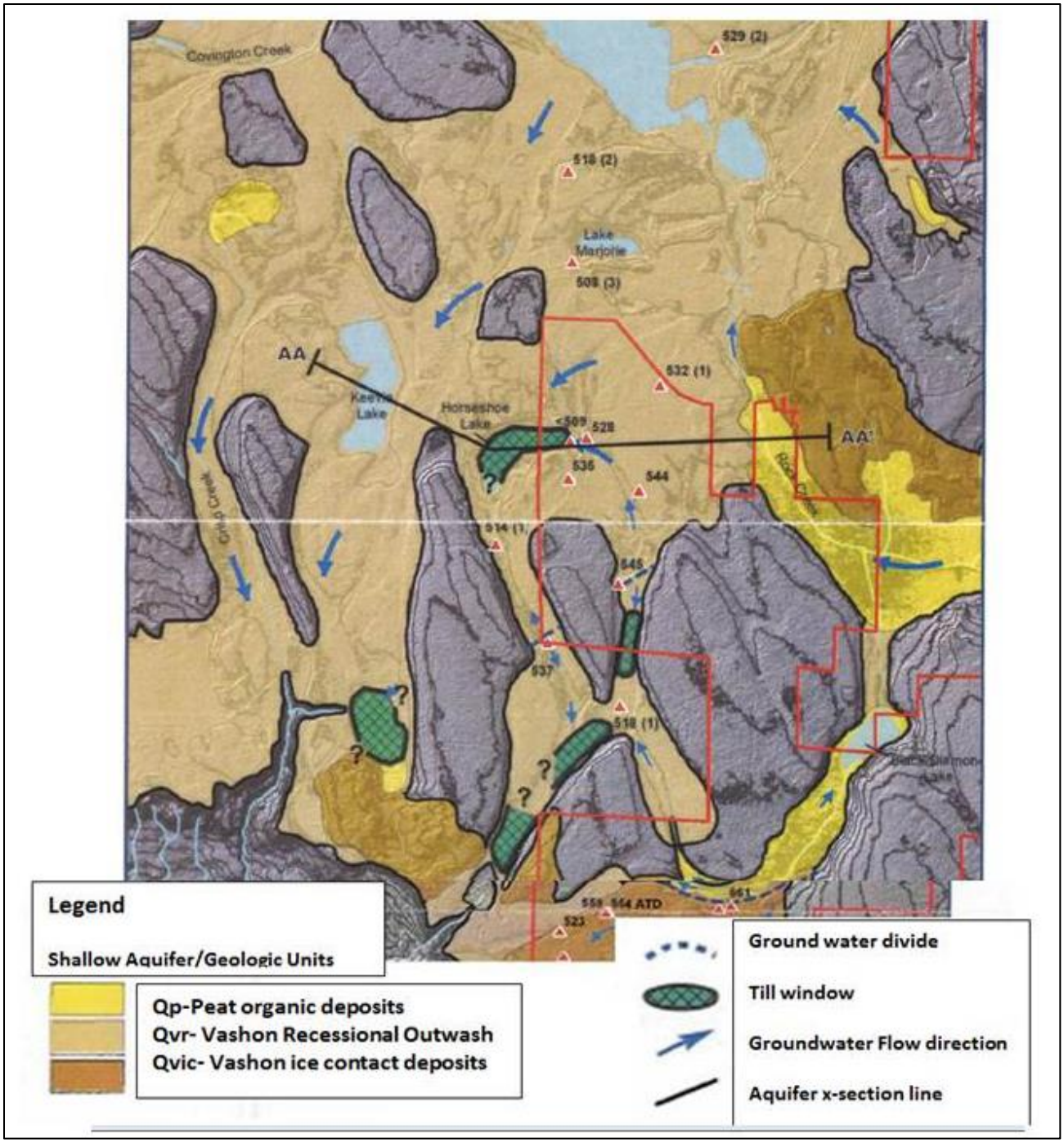

Figure 10. Blue arrows indicate direction of shallow groundwater flow for the Qvr aquifer. Source: Poster by J. Saltonstall, Associated Earth Sciences, 2009 Washington Hydrogeologic Symposium, Tacoma, WA. The location of The Villages Master Planned Development is outlined in red.

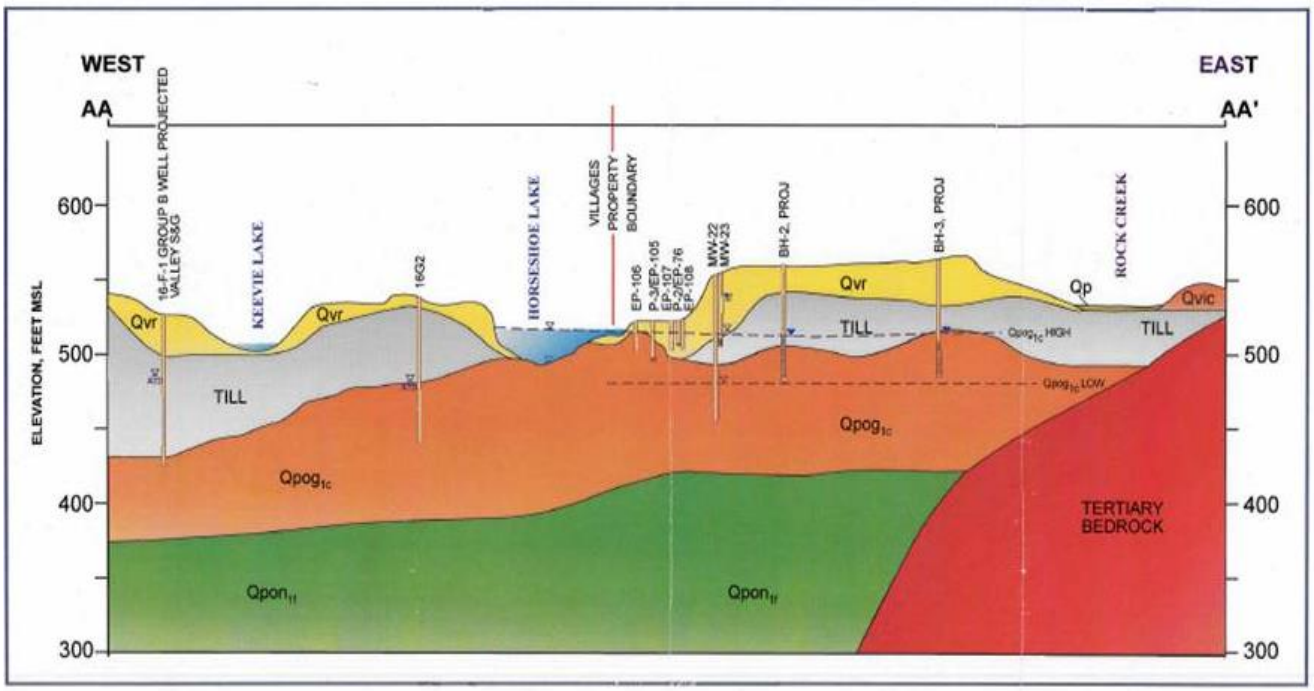

Figure 11. The Qpog aquifer is directly connected to Horseshoe Lake, the bottom of which functions as a "window" in the till where groundwater within the Qvr aquifer is in direct hydraulic connection to the underlying pre-Olympian aquifer (Qpog). Source: Poster by J. Saltonstall, Associated Earth Sciences, 2009 Washington Hydrogeologic Symposium, Tacoma, WA.

Unlike streams in the Cascade Mountains or foothills, the headwaters of Crisp Creek do not drain steep hillsides but flow over the Covington Drift Plain so topographic divides or watershed boundaries are not clearly distinct. Most of the water that recharges the aquifers is generated within the watershed by rainfall, but some transport into the watershed from the east and north and out of the basin to the west and south, do occur (AES, 2008; Saltonstall, et al., 2009; Woodward, et al, 1995). The Qvr deposits provides most of the recharge area for Crisp Creek and since those deposits and soils are mostly gravel and sand and are highly permeable, they also are very susceptible to groundwater contamination (Figure 12). Therefore, much of the Crisp Creek watershed is highly susceptible to groundwater contamination.

It is important that the groundwater resources of Crisp Creek are secured by preserving recharge areas, limiting groundwater extraction, and protecting against groundwater contamination. The proliferation of permit-exempt irrigation and domestic wells, impervious surfaces, and failing septic systems must be avoided or minimized. Since wells can provide a direct route for contaminants to enter the groundwater aquifer, and permit-exempt wells are generally not regulated or monitored, they can threaten the quality of drinking water and the hatchery's water supply. Potential sources of aquifer contamination through wells include animal feces, chemical spills, fertilizer and herbicides.

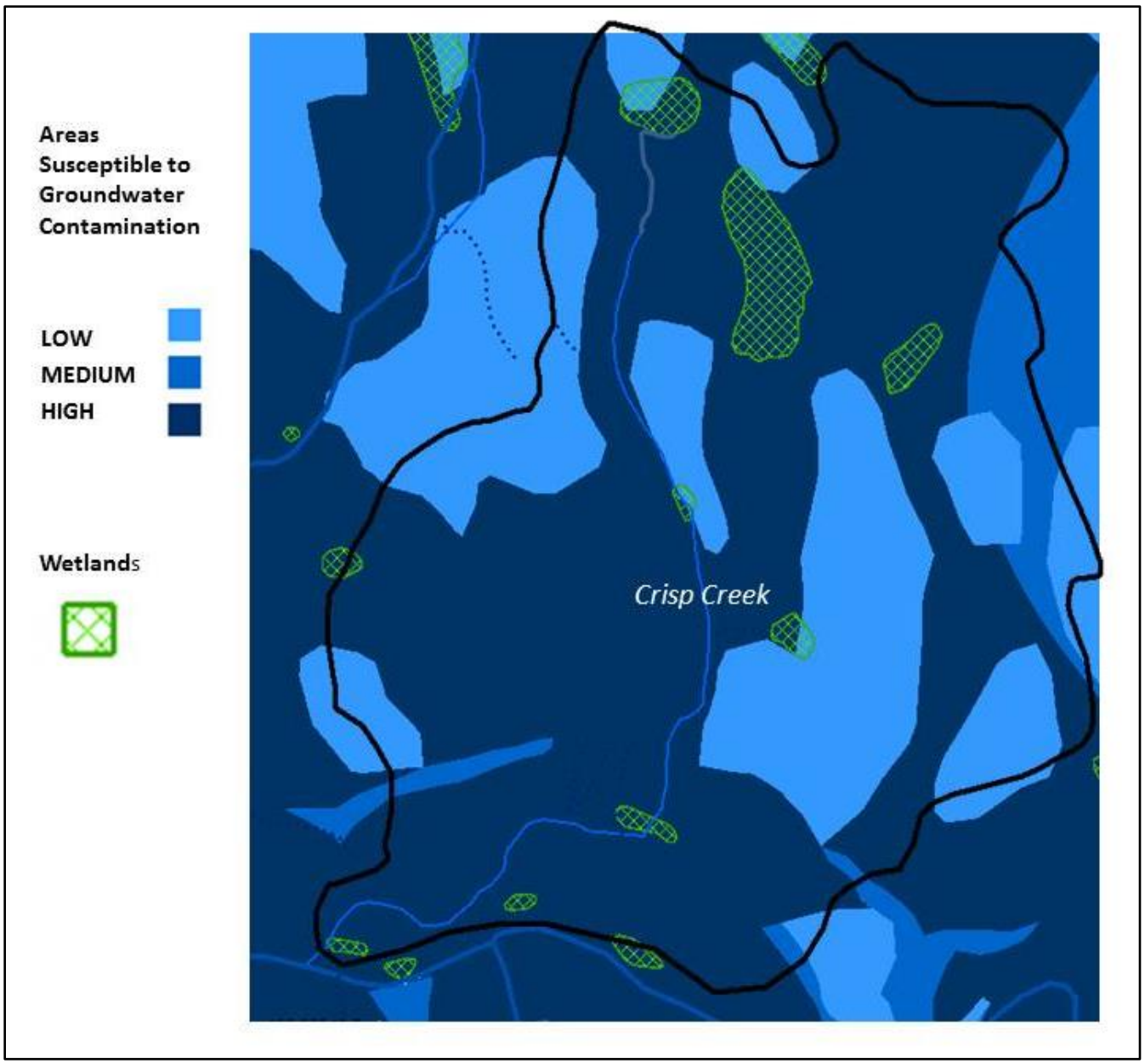

Figure 12. Large areas of glacial outwash soils (dark blue) are highly susceptible to contamination while glacial till outcrops (light blue) have a low susceptibility. Much of the Crisp Creek watershed is highly susceptible to groundwater contamination. Source: https://gismaps.kingcounty.gov/iMap/ on 4-8-16.

HYDROLOGY

Groundwater is an important component of the annual flow regime in western Washington streams and rivers as it makes up most of the base flow, especially in late summer or early fall. This is when flows are at their lowest all year, so it is crucial that as much flow as possible is retained instream to support aquatic life. In Crisp Creek, protecting the base flow from diminishment is essential to protect the Tribe's water rights and hatchery operations.

Crisp Creek is dominated by groundwater that enters the creek through seeps and springs as the creek cuts its way down the hillside above the Green River valley. The springs are located downstream of the Auburn-Black Diamond Road between elevations 320 and 400 feet (Booth, 1997). Unlike streams that receive a smaller contribution from groundwater, Crisp Creek has a more stable flow pattern during the year. In the fall, it takes some time before Crisp Creek responds to rainfall because the soils are dry and air spaces and voids in the soils must fill with water before streamflow can rise. Since the watershed contains much permeable outwash soil, rainwater is stored and then released slowly to the creek. In other streams where urban development replaces natural vegetation and forest cover with pavement and other impervious surfaces, the rainfall response is much more rapid with streamflows rising and falling rapidly or becoming "flashy".

Hydrologic indicators are often used to illustrate how much a watershed has been impacted from land development. High Pulse Count (HPC) and High Pulse Range (HPR) are metrics for flashiness and important indicators of hydrologic disturbance. These have been developed for King County streams (DeGasperi, et al., 2009). HPC is the number of times streamflow rises above a specified level, and HPR is the number of days between the pulses. Another metric is the ratio of the two-year peak flow to the winter base flow. All three metric values increase as a watershed becomes more urbanized, so a low value indicates a stream is in a better condition than one with a higher value. Crisp Creek has the lowest values for all three metrics compared to other streams in a King County study (Knutson, 2011) reflecting its less-developed condition. It behaves much as expected for an undeveloped, mostly forested watershed; even though it is partially developed with several existing subdivisions. Since these subdivisions are small and most are located a distance from the creek or its tributaries, much of the natural hydrology of Crisp Creek has been maintained as indicated by its low HPC value (Figure 13).

Another metric to indicate watershed condition is impervious surface area. Impervious land cover (e.g., compacted soils, rooftops, pavement) increases stormwater generation while reducing groundwater recharge. Currently, impervious surfaces comprise 5.4 percent of the Crisp Creek watershed area (NW Indian Fisheries Commission, unpublished data, 2016). While this is relatively low compared to many other basins in King County, there is no minimum threshold of impervious surface area in a watershed before adverse impacts on stream channels, water quality, or aquatic habitat occur. As stated in Booth, et al., 2002:

> *"Hydrologically and biologically, there are no truly negligible amounts of clearing or watershed imperviousness (Morley, 2000), even though our perception of, and our tolerance or, many of the associated changes in downstream channels appear to undergo a relatively abrupt transition. Almost every increment of cleared land, and of constructed pavement, is likely to result in some degree of resource degradation of loss. The decision of how much is "acceptable" is thus as much a social decision as a hydrologic one."*

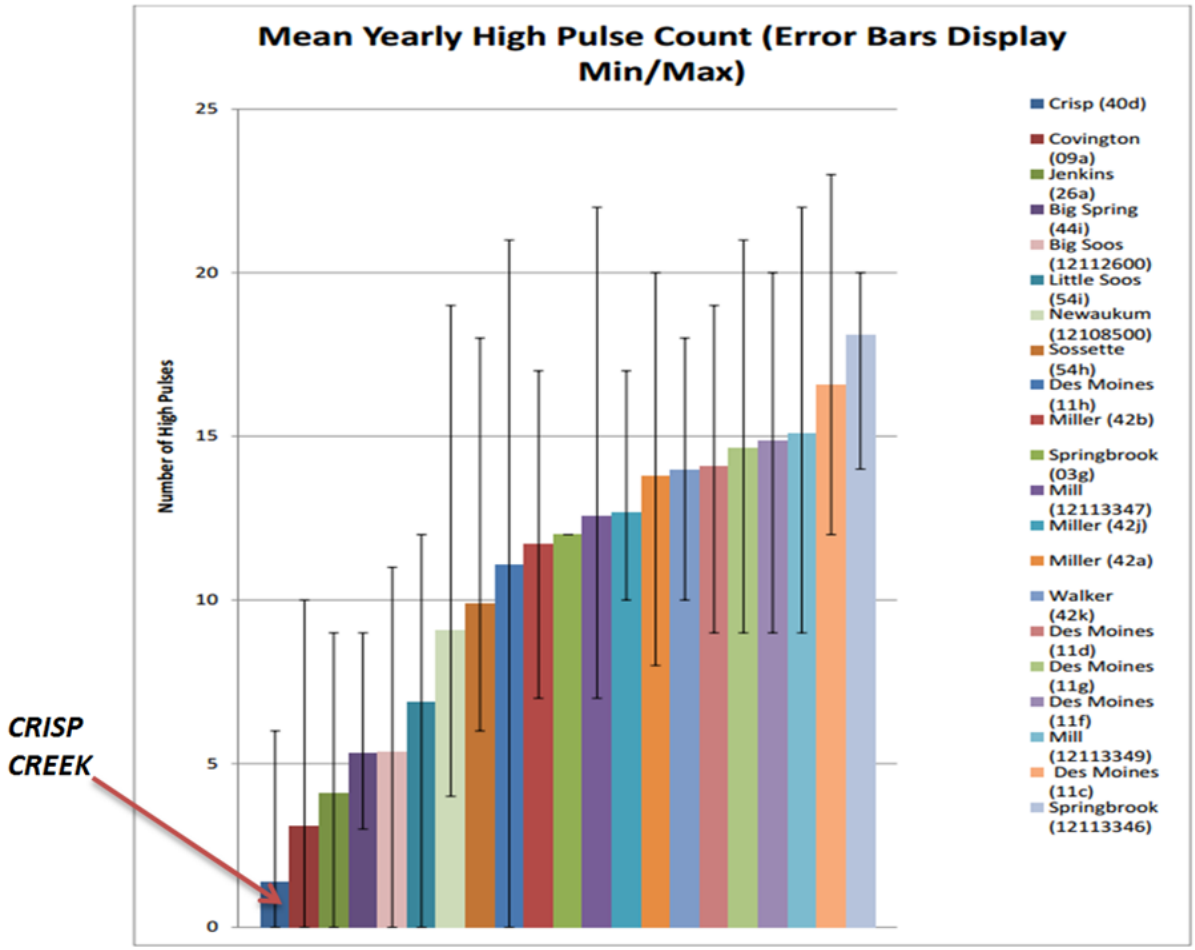

Figure 13. Crisp Creek has the lowest High Pulse Count value (2.4) indicating that it reflects a more natural and forested condition than the other streams examined, and its hydrology has not yet been significantly altered by land use changes. Source: Knutson, 2011.

Groundwater contribution to streams, which comprise a stream's dry season baseflow, can be diminished by land use. Groundwater extractions for domestic water supply, irrigation, and other purposes can further reduce streamflow (Morgan and Jones, 1999; Winter et al., 1998). As more of the existing forested lands in the Crisp Creek watershed are developed, more stormwater will runoff into the creek and less will be stored as groundwater - leading to the lower base flows and degraded stream habitat conditions observed in many other low-elevation streams in the county. Some impacts have already occurred in Crisp Creek even with minimal residential development upstream of the hatchery. A 1997 field reconnaissance found that locally severe channel erosion was common due to channel encroachment by adjacent residences (Booth, 1997).

All homes in the watershed use on-site sewage treatment and disposal via septic tanks and drain fields. Properly maintained septic systems infiltrate the water used for indoor household purposes back into the ground locally. In some instances, septic systems may result in nutrient enrichment or elevated bacteria levels that should be considered (Hinman, 2005). Septic return flow in the watershed may partially offset recharge losses from impervious and semi-pervious surfaces that occur with development; however, due to ground-disturbing activities described above, the recharge may not return to the same body of groundwater than occurred in the natural condition.

For example, septic effluent could flow to a wetland area and evaporate or be transpired by plants rather than seep into deeper groundwater as infiltrated rainfall did on the site prior to disturbance (Booth, et al., 2002).

Importation of water into the Crisp Creek watershed occurs for about 300 homes receiving water supply from the Covington Water District. The District uses a wellfield just north of Lake Sawyer in the Covington Creek drainage. Northwest Hydraulics Consultants estimated water balances in the Green River basin and found that Covington Creek experienced approximately a 70 percent depletion of the natural condition median monthly August streamflow, and a 90 percent reduction in the annual 7-day low flow due to the combined effect of groundwater extractions and water exportation out of the basin from sewering (NHC, 2005). Their analysis did not include the Crisp Creek watershed, but since roughly 300 homes currently use imported water from the Covington Water District and no large municipal well extractions exist, a net positive benefit to stream flow may occur. However, a detailed water balance for the watershed would be needed to confirm this.

Crisp Creek Streamflow

King County has measured streamflows on Crisp Creek (Gage 40D) located at the crossing with the Green River Valley Road since 1994 and also had a station located upstream (40B), above the Hatchery for a short time. However, Crisp Creek at that location is steep and too turbulent for accurate stream gaging so that site was discontinued. King County records discharges at Gage 40D on a continuous, real-time basis, but the accuracy of the gage is only rated as fair because the channel is reforming near the gage location after culvert removal work was performed in 2010 (Funke, et al., 2012).

For the 20 year period of record from Water Year 1995 to 2015, mean daily flows were 8 cfs with a maximum daily flow of 67 cfs (2/9/1996), a minimum daily flow of 2.6 cfs (11/18/1998), and a 7-day low flow (7QL) of 4.2 cfs. The 7QL is a well-established metric for dry period base flow dominated by groundwater. Keta Creek and unnamed springs enter Crisp Creek between the Tribe's hatchery intake and the gage at 40D, so flows for the hatchery water supply are lower. Flow estimates above the hatchery have been compared to measured flows at the 40D and the relationship used to generate flow statistics for the site upstream of the hatchery (Table 1).

Duration curves for the 10, 50 and 90 percent exceedance values are shown in Figure 14 for 40D and in Figure 15 for above the fish hatchery. The 10 percent exceedance or flow duration curve represents streamflows for a wet year when rainfall is greater than normal and the 90 percent curve represents a dry or lower than normal rainfall year. The 50 percent or median curve represents values where half are above and half below; similar to a normal or average year. If development proceeds at typical patterns in rural King County in the Crisp Creek watershed, storm events will look more like wet years and summer and fall flows will become more like dry years.

Table 1. Mean annual streamflows and 7-day low flows (7QL) for two sites in Crisp Creek (Water Years 1995-2015).

Stream Flows	**At Gage 40D** (cfs)	**Crisp Creek Above Hatchery** (cfs)
Mean annual flow (Q)	8.0	6.5
7-day low flow (7QL)	4.2	3.9

Wetlands and Headwater Bog

The sphagnum bog at the northern headwaters of Crisp Creek lies in a depression, and likely formed over about 12,000 years (Kulzer, et al., 2001). The bog outlet to the creek flows primarily during wet winter and spring months. The bog lies on peat or organic deposits over permeable glacial outwash sediments. It retains water, allowing time for water to infiltrate into soils to replenish and recharge groundwater that flows to Crisp Creek. Lakes and wetlands on the Covington plain are known to recharge groundwater (Woodward, et al., 1995). The wetland east of 218th Avenue SE discharges flow via a defined channel forming the main tributary to Crisp Creek during wet periods. This wetland appears to be directly connected to the underlying Qpog aquifer, the primary water source of the springs and seeps that feed Crisp Creek during dry summers and early fall. The wetland tributary usually is dry during these times; however flows as high as 8 cfs have been measured (Golder Associates, 2013) indicating a direct connection to the Qpog aquifer. The wetland north of Keevies Lake is not connected by surface flow to Crisp Creek. This wetland is set aside in an open space tract by King County.

There is concern that both the headwater bog and the 218th Avenue SE wetland will be detrimentally impacted by runoff from planned residential development at The Ridge at Lake Sawyer Division III and The Reserve at Woodlands projects, respectively. These projects are described in Appendix A.

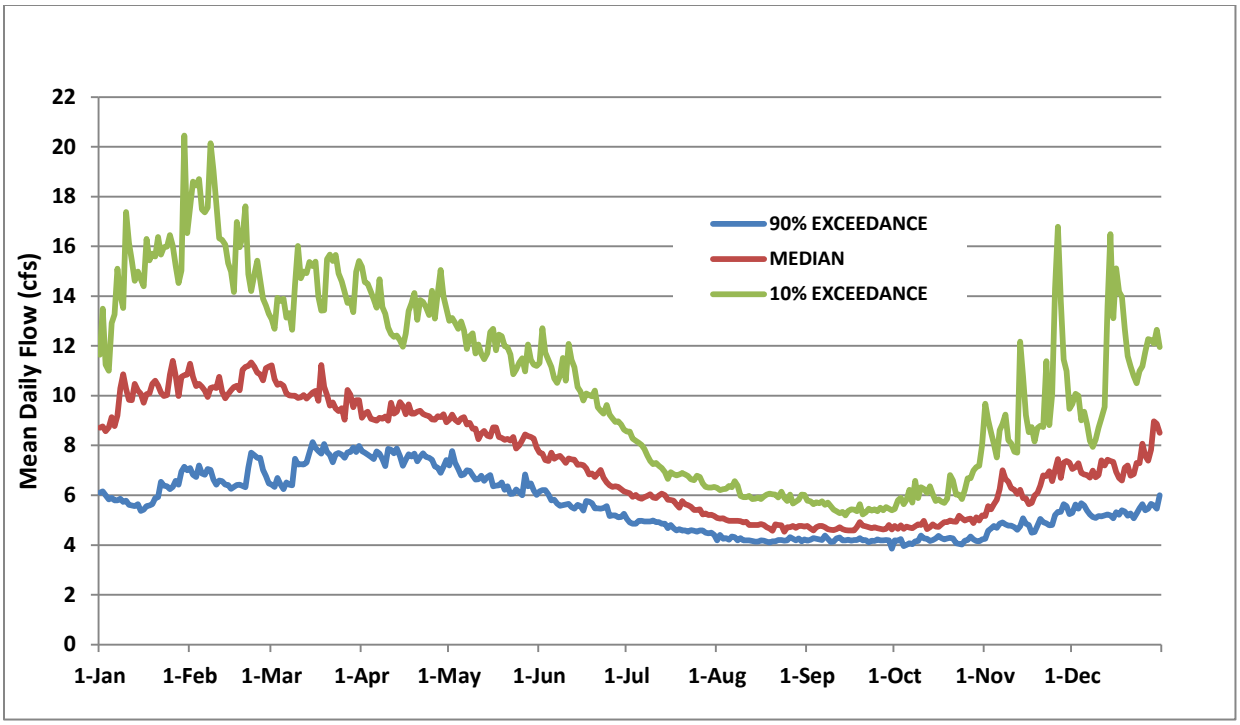

Figure 14. Flow duration curves for Crisp Creek at King County's 40D Gage site at Green Valley Road for water years 1995 to 2015. The 90%, Median, and 10% exceedance flow curves represent very dry, normal, and very wet years, respectively. Discharge values are from http://green2.kingcounty.gov/hydrology accessed on 2-12-16.

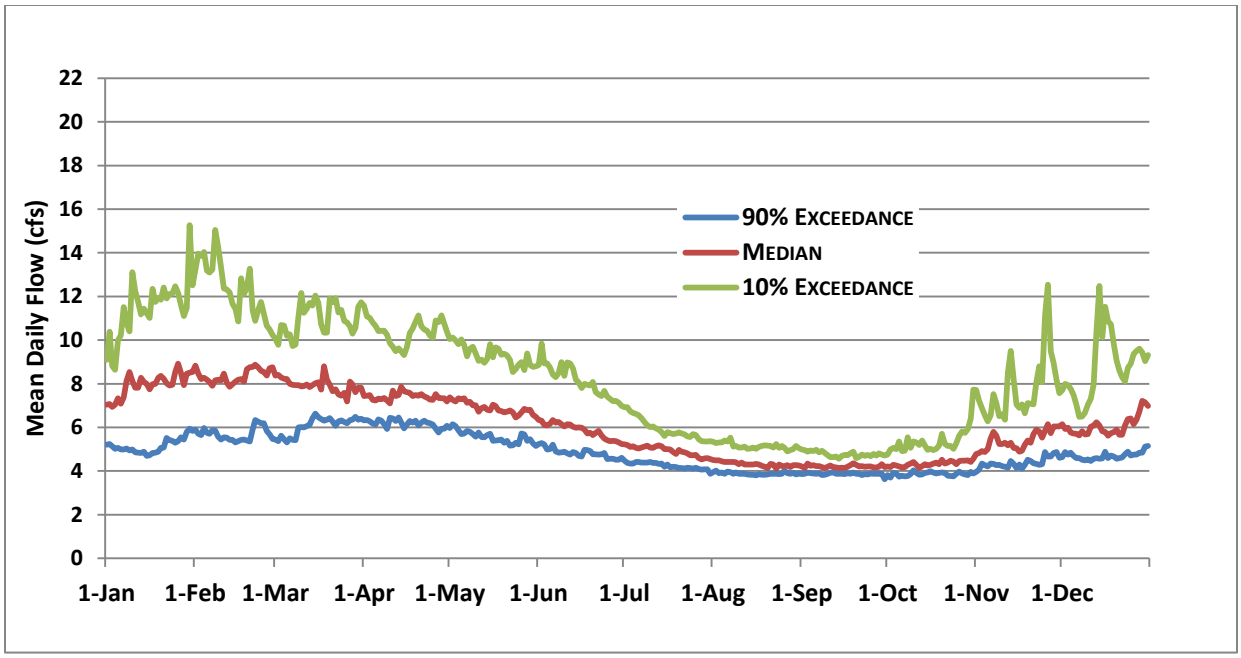

Figure 15. Flow duration curves for Crisp Creek upstream of the hatchery intakes estimated from King County's 40D Gage record for water years 1995 to 2015. The 90%, Median, and 10% exceedance flow curves represent very dry, normal, and very wet years, respectively.

Keta Springs

Keta Springs includes three springs that supply water for fish production and domestic use for the Keta-Crisp Hatchery. Groundwater is the source of the springs, which emerge from the steep hillslopes above the hatchery. Continuous recording instrumentation of the spring flow is not possible due to the steep, unstable, and erosive slopes although discrete monthly estimates have been recorded for several years. Average spring yields are about 220 gallons per minute (gpm) with peaks occurring just over 300 gpm.

Future Risks to Stream Hydrology

The Tribe is concerned that increased urbanization and development in the watershed will adversely alter natural streamflow patterns and reduce aquifer recharge in Crisp Creek, affecting the water supply and water rights of the Keta-Crisp Hatchery. Development activities including vegetation removal; land clearing and grading; modification or removal of large quantities of soils and subsoils to level building sites; drainage and stormwater system installation; and road and building construction all alter stream hydrology. Movement of heavy equipment at construction sites increases soil compaction which also reduces recharge. Groundwater contribution to streams, which comprise a stream's dry season base flow, will diminish. Changes such as higher stormflow peaks or pulses and the redistribution from base flow to stormflow because of reduced groundwater recharge from land disturbance will result (Booth, et al., 2004; Konrad, 2000; Konrad and Booth, 2002, Morley, 2000). Infiltration and intrusion of shallow groundwater along sewer lines that will be constructed in that portion of the Black Diamond urban area located within the watershed will further reduce groundwater recharge to Crisp Creek. Groundwater extractions for domestic water supply, irrigation, and other purposes can further reduce streamflow (Morgan and Jones, 1999; Winter et al., 1998).

Adverse impacts can be reduced by protecting native soils and preserving forest cover to the maximum extent possible, along with use of Low Impact Development techniques (Hinman, 2005). In the absence of substantial preventive measures to limit development impacts in the watershed, the hydrology of Crisp Creek is likely to change, and as a result, the hatchery water supply and creek habitat is likely to be degraded. Expected changes include increased stormflow peaks, durations, and frequencies; and declines in summer low flows and winter base flows as groundwater recharge diminishes. Baseflow losses are a key concern for the hatchery, considering that much of the watershed (18 percent) lies within the city of Black Diamond and will be developed at urban densities where impervious surfaces and sewer lines will reduce aquifer recharge and increase stormwater runoff. Stormwater infiltration and other mitigation may help reduce impacts to some degree, but alterations to the ground surface from grading and filling will be dramatic and runoff and infiltration pathways will likely differ from that which currently exists in a forested state. It is widely recognized that development impacts on stream hydrology cannot be fully mitigated (Booth, et al, 2002).

Landslides have occurred in the Keta Springs ravines just above the hatchery (Figure 16), most recently in 2007 and 2014, as well as in Crisp Creek. These landslide events severely impaired water quality and threatened fish health and production in the hatchery. Further development in the watershed upstream could aggravate channel scour, streambank erosion, and trigger more landslides along the creek and its springs – and potentially cause a fish kill at the hatchery, threaten homes, or affect the Diamond Springs Water Association drinking water supply.

Figure 16. Landslides on steep slopes above the Keta-Crisp Hatchery as seen in this photo from the early 1990s have periodically jeopardized salmon culture and water quality at the hatchery.

Because of the specific conditions in the Crisp Creek watershed including its relatively flat or gentle slopes on outwash soils located away from any stream channels, a 1997 report prepared for the Tribe by Derek Booth recommended that:

> *"In the "best" case, development that occurs far from the stream channel and over the thick outwash deposits will have the opportunity to infiltrate virtually all of its runoff – under such circumstances, there is little reason to expect that any surface discharges would reach the channel; the only hydrologic change would be a modest net increase in total annual recharge, owing to the reduced evapotranspiration from tree clearing, and thus an equally modest increase in overall baseflow. Conversely, in the "worst" case, development that occurs on highly infiltrated soils but so close to the stream that all runoff is directly conveyed to Crisp Creek by pipes or road ditches will result in the largest possible increase in runoff, because the hydrological conversion would be from fully infiltrative conditions to one of significant surface-runoff, with attendant changes in the magnitude, frequency and duration of peak discharges in Crisp Creek. Over much of the watershed, some of the most basic ways that we measure development - percent area cleared, imperviousness, or housing density - will be less important than certain aspects of the post-development surface-water management that normally receive little scrutiny. Location in the watershed will be important, even if the underlying slopes and soils are nominally uniform."*

Dr. Booth went on to recommend that *"in a high-resource watershed such as this, the primary focus would normally be on minimizing housing density via zoning"* and to provide physical protection of the channel by using large buffer widths.

WATER QUALITY

Crisp Creek has among the cleanest, highest quality of water among sampled streams in King County due to its low existing development and forested condition (Herrera, 2005) (Figure 17).

King County has measured water quality at a site upstream of the Keta-Crisp Hatchery (F321) since the early 1990s and at a downstream site (O321) at the Green Valley Road since 1997. Monitoring at both sites was discontinued from January 2009 to February 2013. Nutrients and other conventional parameters, along with metals, have been measured at these locations. Monitoring in Crisp Creek for specific parameters was conducted in 2001 through 2003 by King County's ambient water quality monitoring program; in 2008 by the Muckleshoot Indian Tribe Fisheries Division (MITFD); and in 2011 and 2014 by the King County DNRP Science and Technical Support Section.

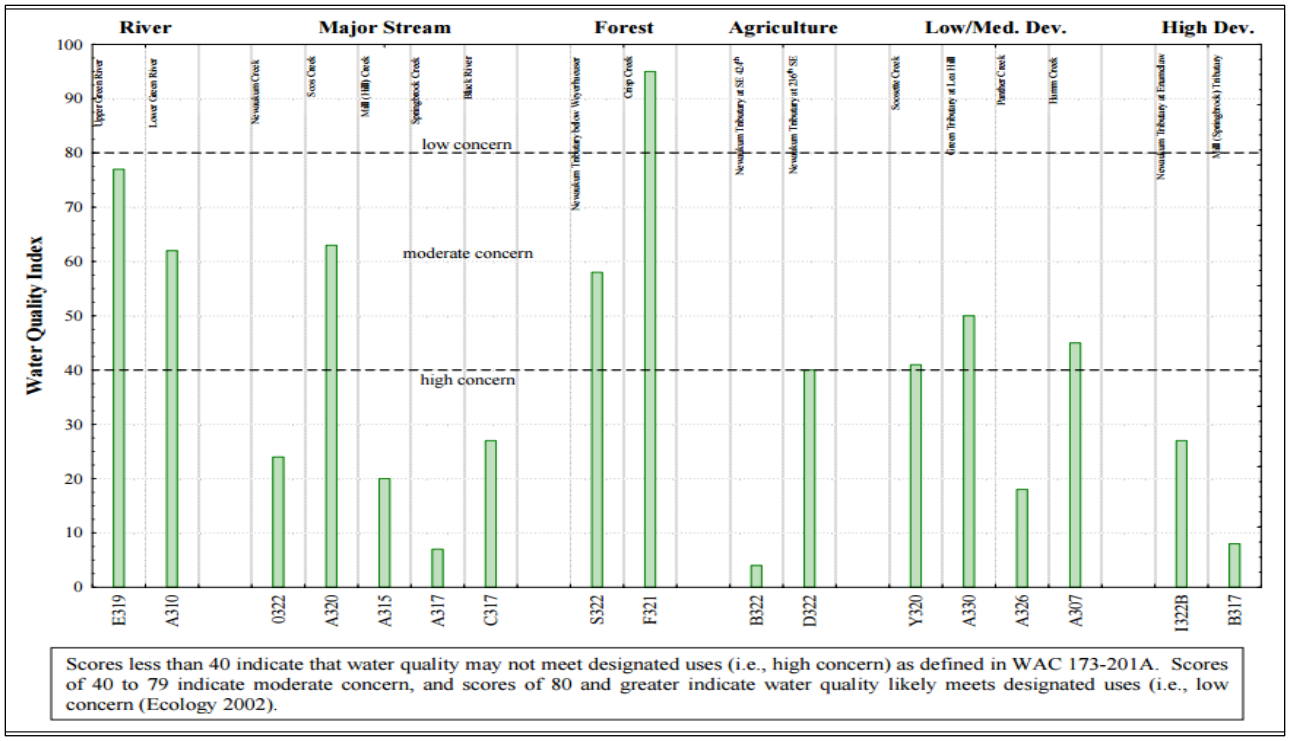

Figure 17. Crisp Creek (site F321) has the highest water quality because much of the watershed is currently in a forested condition. Source: Figure 61 from Herrera, 2005. Data is for 2003.

Water Quality Index

A Water Quality Index (WQI) rating system was developed by the Washington Department of Ecology that evaluates several water quality parameters and gives an overall rating of "high", "moderate", or "low" concern. The score is a unit-less number ranging from 10 to 100 with higher numbers reflecting higher water quality. Scores lower than 40 may not support designated uses as defined by Washington State's Water Quality Standards for Surface Waters (Chapter 173-201A WAC) and are rated as "High Concern". Scores between 40 and 79 are "Moderate Concern" and scores 80 or above indicate water quality likely supports designated uses and are "Low Concern"

(WDOE, 2002). Several water quality constituents are used to develop the score. Water quality index values were calculated for Crisp Creek by King County for Water Years 2000 to 2008 and for 2014 (http://green2.kingcounty.gov/streamsdata/WQI.aspx).

Crisp Creek at site F321, has the highest Water Quality Index score of streams and rivers monitored by King County for Water Year 2014 (Figure 18 and Table 2) and for the average for water years 2000 to 2008, and 2014 (Figure 19).

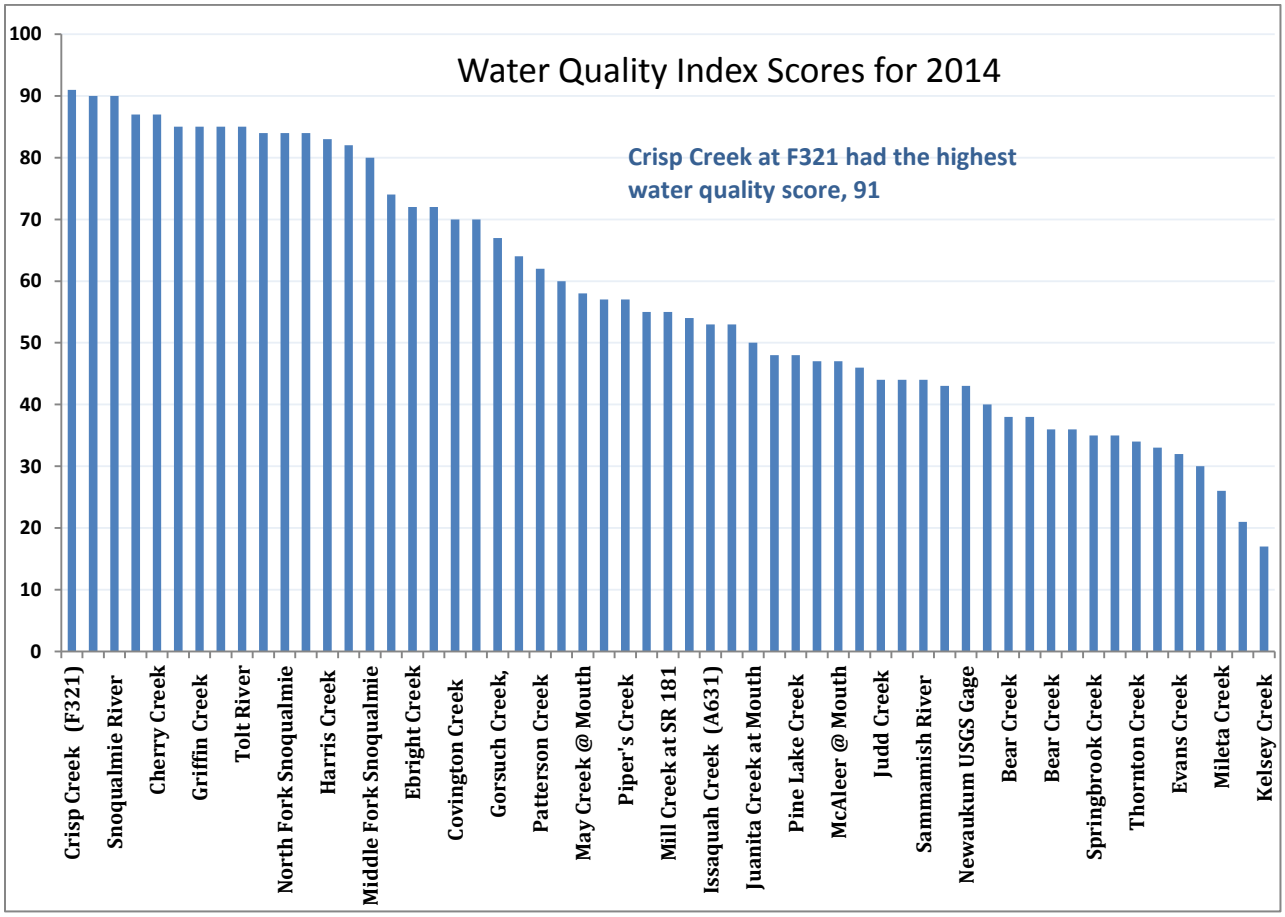

Figure 18. Overall Water Quality Index (WQI) scores for streams and rivers monitored by King County in 2014. The score for Crisp Creek at site F321 (far left) is 91. Values of 80 and above indicate the highest water quality and therefore of low concern; scores 40 to 79 are moderate concern and less than 40 are of high concern. Source: http://green2.kingcounty.gov/StreamsData/WQI.aspx accessed 10/21/2015.

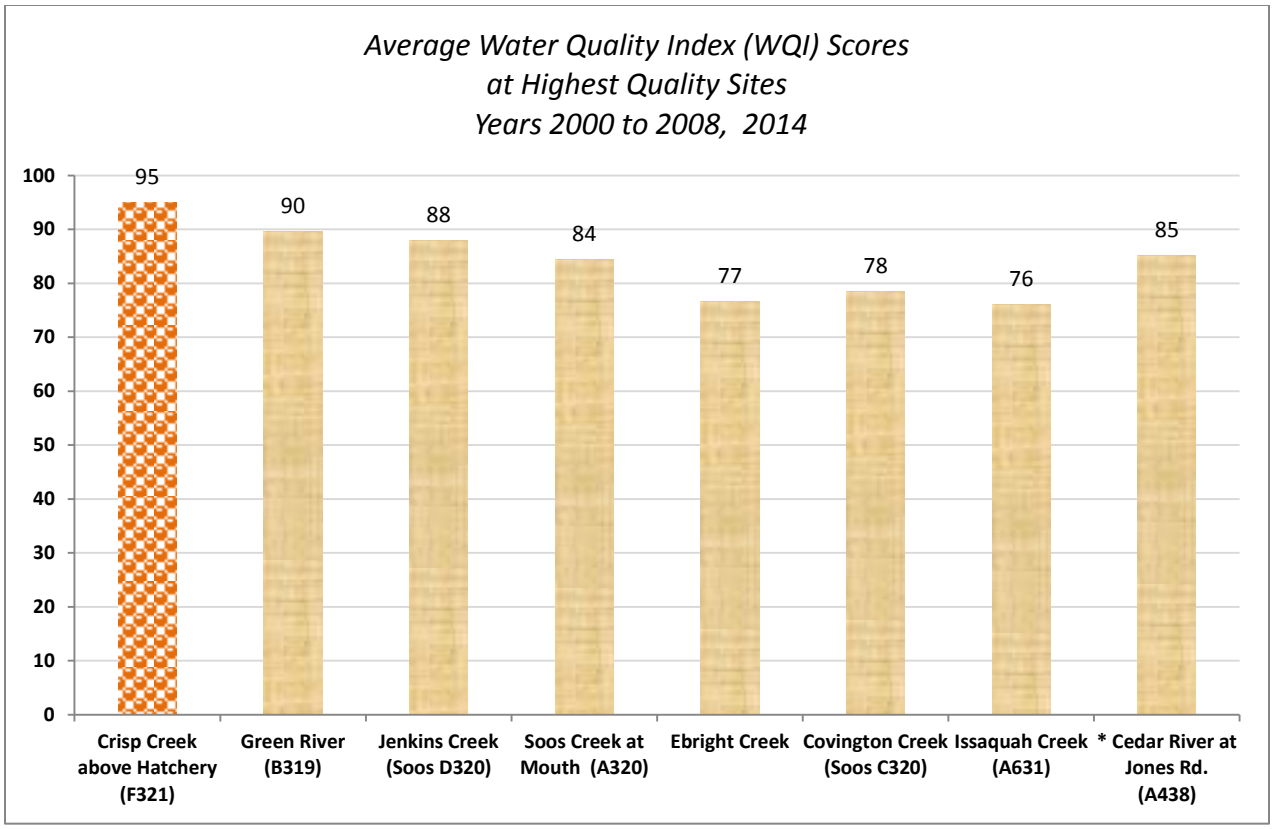

Figure 19. Average overall water quality index scores for the highest quality sites monitored by King County in 2014 and from 2000-2008. Crisp Creek has had the highest WQI score every year. Asterisk indicates no value for this site in 2014.
Source: http://green2.kingcounty.gov/streamsdata/WQI.aspx accessed 2/10/2016.

Scores for the sites with the highest annual scores (80 and above) were compiled from the King County website for each year from 2000 to 2008 and for 2014. These were based on years when Crisp Creek was monitored and a WQI score was calculated. Results are shown in Figure19, which highlights the excellent water quality of Crisp Creek, unmatched by any other stream monitored by King County for at least ten years, if not longer.

Comparison of Water Quality Data to Hatchery Management Criteria

Excellent water quality is critical for fish rearing at the Keta Crisp Hatchery. Successful salmonid rearing at a hatchery requires cool, clean water with specific ranges of water temperature, dissolved oxygen, pH, solids, and other parameters. Cool water temperature is required for hatchery supply water for successful egg incubation, egg hatching, growth and development of juveniles, and prevention of disease. Dissolved oxygen levels need to remain high for the health of fish rearing in the hatchery. Cooler water temperatures allow for higher dissolved oxygen concentrations, since oxygen becomes more soluble in water with lower temperature. In addition, as water temperature increases, the metabolic rates of fish increase, which may further deplete oxygen in the water due to increased fish respiration. Heavy metals, such as copper, zinc, lead, and cadmium, should not be introduced into water that is necessary for hatchery rearing since salmon are very easily harmed by low levels of these metals. Table 2 presents criteria for a number of water quality parameters that are vital to successful fish rearing at the hatchery. These criteria are

based on values presented by Piper et al. (1982) and Timmons et al. (2002) for fish hatchery management.

Table 2 includes the results of water quality monitoring events in Crisp Creek just upstream of the hatchery's surface water intake and in Keta Springs (Figure 20). The data collected at these locations represent the quality of the water supply available for the hatchery. Monitoring for the parameters listed in Table 2 was conducted in 2001 through 2003 by King County's ambient water quality monitoring program, in 2008 by the MITFD, and in 2011 and 2014 by the King County DNRP Science and Technical Support Section. Discrete water samples for these monitoring events were taken during all seasons, including dry-weather and storm conditions.

The monitoring results from upper Crisp Creek and Keta Springs indicate that most of the water quality criteria presented for hatchery rearing were met. Total suspended solids for all events were well within levels recommended for hatchery rearing (< 80 mg/L) and ranged from 1.0 - 10 mg/L. Dissolved copper ranged from < 0.4 (not detected above the numeric reporting limit of the analytical method) – 0.9 µg/L, was often not detected above the reporting limit, and was below the recommended threshold of 6 µg/L. Dissolved zinc ranged from < 0.5 – 1.3 µg/L, was mostly not detected above the reporting limit, and was also below the recommended threshold of 5 µg/L. Dissolved cadmium and lead were not detected above reporting limits, which were well below levels important for hatchery fish rearing. Although dissolved aluminum was measured at levels (10.4 – 70µg/L) above the recommended threshold for hatchery rearing (< 10 µg/L), these levels would not likely harm fish unless pH levels in the future fall below the lower end of the range recommended for hatchery rearing (pH < 6.5); aluminum becomes more soluble and toxic to fish as pH decreases in the water. Total iron ranged from < 50 -380 mg/L which is above the threshold recommended for hatchery rearing (< 150 mg/L).

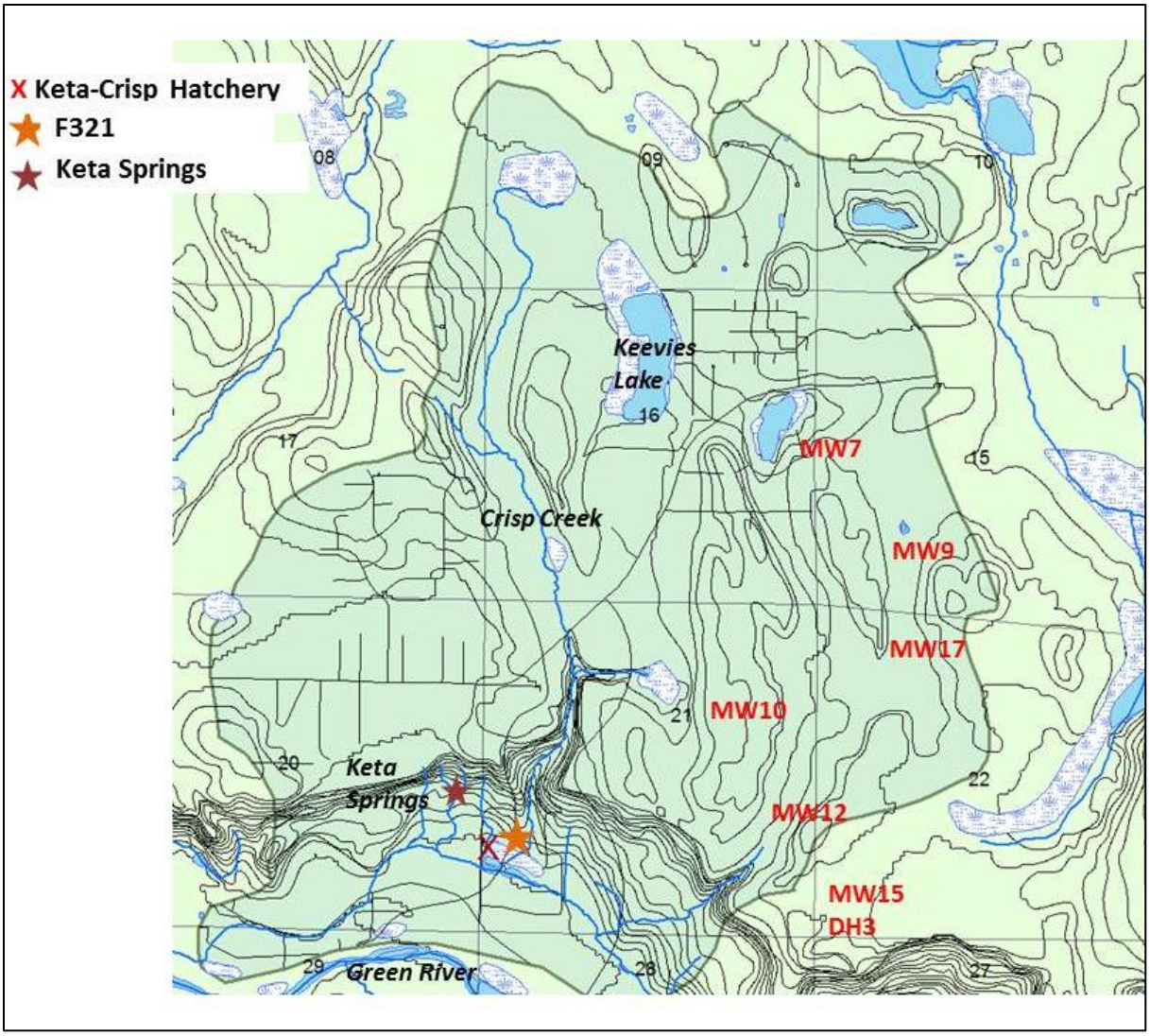

Figure 20. Surface water monitoring sites and monitoring well approximate locations (red text) in the Crisp Creek watershed.

Water hardness, total alkalinity, dissolved calcium, and dissolved magnesium were less than recommended levels for fish hatchery rearing. The lower levels of these parameters reflect the soft water typical of the regional area rather than impacts of human activities. At lower alkalinity levels, as in Crisp Creek, the buffering capacity of a waterbody against changes to pH is lower and therefore pH may change quickly as human activities alter the chemistry of the water. It is important to maintain pH levels within the range of 6.5 – 8.5 for fish rearing because higher pH levels result in higher ammonia toxicity and lower pH levels allow for a higher solubility of metals and thus a higher toxicity (more bioavailable) to fish. Water hardness represents the concentration of magnesium and calcium cations and is an important measure for fish health because higher water hardness levels lower the toxicity of most metals for fish. The lower measured levels of hardness and alkalinity indicate that Crisp Creek will be more susceptible to harmful changes in pH and in metals toxicity if human activities and land uses in the watershed increase the loads of nutrients, metals, and other pollutants into the water.

Comparison of Water Quality Data to Washington State's Surface Water Quality Standards

Several parameters vital to salmonid hatchery rearing have numeric criteria set by Washington State's Surface Water Quality Standards (Chapter 173-201A WAC), including water temperature, dissolved oxygen, pH, ammonia, copper, and zinc. These standards are established for the protection of salmonid spawning, rearing, and migration. According to the Washington State's current 303(d) list of impaired waterbodies, the only exceedances of state water quality criteria for Crisp Creek include two listings for bioassessment and one for dissolved oxygen. The two bioassessment listings are based on an evaluation of macroinvertebrate data collected in Crisp Creek. The one listing for dissolved oxygen is based on measurements taken at the mouth of the creek on Southeast Green Valley Road (WDOE, 2016).

In situ measurements for water temperature, dissolved oxygen, and pH were taken at Station F321 in upper Crisp Creek during 1993–2008 and 2013-2015 by King County and in 2008 by MITFD. Samples for total ammonia were taken during King County's monitoring events in 1993 - 2008 and 2013 – 2015 and in MITFD's 2008 monitoring events. Copper and zinc were measured in 2001 – 2003, 2011, and 2014 by King County and in 2008 by MITFD. All samples for Keta Springs were collected in 2008 by MITFD. The data collected at these locations represent the quality of the water for the hatchery water supply.

All of the values measured at Station F321 for water temperature, dissolved oxygen, and pH in Crisp Creek by MITFD and King County (Table 3) met the Washington State water quality standards. These measurements are based on single measurements collected during discrete monitoring events. Continuous water quality sampling has not been conducted, but this type of data in the future would help to determine the extent of diurnal ranges for each of these parameters, especially during critical periods. Total ammonia values measured for all monitoring events ranged from < 0.01 – 0.065 mg/L and were below Washington State's acute criterion, which is based on ambient pH values. More frequent total ammonia measurements and continuous pH data would allow for a more thorough evaluation of whether acute and chronic ammonia criteria are met. As pH levels increase in surface water, the ammonia toxicity to fish increases and the total ammonia criteria thresholds decrease; therefore lower levels of total ammonia could exceed standards if pH levels increase in the creek. It is important for Crisp Creek, as the water supply for the hatchery, to maintain high levels of dissolved oxygen, low water temperatures, low total ammonia levels, and pH levels within the range of the state criteria.

Table 2. Thresholds for some of the water quality parameters important for successful hatchery fish rearing and ranges of values measured in Crisp Creek and Keta Springs.

Parameter	Hatchery Management Criteria (Piper et al., 1982)[1]	Ranges of parameters measured at Crisp Creek upstream of Keta-Crisp Hatchery				Ranges of parameters measured in Keta Springs
		2001 - 2003 (King County station F321)	2008 (MITFD Crisp Creek at F321)	2011 (King County station F321)	2014 (King County station F321)	2008 (MITFD Keta Springs station)
Total suspended solids (mg/L)	< 80	N/A	< 2.1 – 10	1.6 – 5.1	1.0 – 5.8	1.5 - 6.7
Alkalinity, total (mg/L)	50 - 300	N/A	32.3 - 53.1	31.1 - 40.1	36.9 - 42.4	54.9 - 58.8
Hardness (mg/L)	> 100	N/A	37 - 53	31.1 - 40.6	35.9 - 41.6	66 - 70
Calcium, dissolved (mg/L)	4.0 - 160	8.3 - 14.5	9.9 - 14.8	8.3 - 10.9	10.0 - 11.7	15.4 - 16.6
Magnesium, dissolved (mg/L)	15	2.3 - 3.9	2.9 - 4.0	2.5 - 3.0	2.7 - 3.0	6.8 - 7.2
Aluminum, dissolved (µg/L)	< 10	N/A	< 20 - 70	15.1 - 49.9	10.4 - 26.2	< 50
Cadmium, dissolved (µg/L)	< 0.5	< 0.01	< 0.2	< 0.05	< 0.05	< 0.2
Copper, dissolved (µg/L)[2]	< 6	< 0.4 - 0.9	< 0.5 - 0.6	< 0.4	<0.4 - 0.5	< 0.5 - 0.5
Zinc, dissolved (µg/L) [1]	< 5	< 1.9	< 4	< 0.5 - 0.6	< 0.5 - 1.3	< 4
Lead, dissolved (µg/L)	< 20	<0.025	< 1	< 0.1	< 0.1	< 1
Iron, total (ug/L)	< 150	N/A	< 50 - 380	68 - 218	53.9 -189	< 50 - 210

[1] *Lower levels of dissolved zinc (< 5µg/L) are important for the health of fish rearing in hatcheries (Timmons et al., 2002).*

[2] *Levels as low as 2 µg/L of dissolved copper are known to harm salmonids (Sandahl, et al., 2007).*

Dissolved copper and dissolved zinc measured by King County and MITFD in Crisp Creek (Table 3) met the state's surface water quality standards, which are based on equations that incorporate ambient water hardness values. For the range of water hardness values measured in Crisp Creek (31.1 - 53 mg/L), the acute dissolved copper and dissolved zinc criteria would range from 5.7 – 9.4 µg/L and 43 – 67 µg/L, respectively. Additionally, levels of dissolved copper (2 µg/L) below the state's water quality standards are known to harm the migratory success and survival of salmonids (Sandahl, et al., 2007). The measured range of dissolved copper in Crisp Creek was below 1 µg/L. Levels of dissolved zinc well below the state's water quality criteria are also known to negatively impact salmonids (Sprague, 1968) and low dissolved zinc concentrations (<5 µg/L) are important for the protection of fish in hatcheries (Timmons et al., 2002). Dissolved zinc concentrations in Crisp Creek were not measured above 1.5 µg/L and for some samples, not detected above a reporting limit of 4 µg/L. It is important to maintain these existing low levels of dissolved zinc and copper as well as other contaminants in Crisp Creek.

Table 3. Washington State's Surface Water Quality Criteria for water temperature, dissolved oxygen, and pH for Crisp Creek and ranges measured by the Muckleshoot Indian Fisheries Division (MITFD) in 2008 and in 1993 - 2015 by King County. All data were collected as instantaneous measurements at each site.

Parameter	WA State surface water quality criteria for Crisp Creek	Ranges measured at Crisp Creek upstream of the Keta-Crisp Hatchery		
		1993 - 2008 (King County at F321)	2008 (MITFD at F321)	2013 - 2015 (King County at F321)
Water temperature °C	16 °C 7DADM[1]	0.8 - 12.1	7.4 - 10.2	7.2 - 11.2
Dissolved oxygen (mg/L)	9.5 mg/L, as a 1-day minimum	9.5 - 13.7	10.9 - 12.5	10.8 - 12.7
pH	6.5 - 8.5, with a human-caused variation of less than 0.2 units within the above range	6.6 - 8.2	7.6 - 7.9	7.6 - 8.0

[1]*The water temperature criterion is expressed as a seven-day average of the daily maximum (7DADM).*

Groundwater Quality

Limited groundwater quality data are available for the Crisp Creek watershed. Golder Associates monitored groundwater quality in several wells within the watershed in late 2006. Table 4 presents provisional data provided by Golder Associates (Golder Associates, 2008). Groundwater was sampled in wells in the shallow Qvr aquifer (MW-09, DH-3), the deep Qpog aquifer (MW-07, MW-10, MW-12, and MW-17) and in the deeper bedrock aquifer system (MW-15). See Figure 20 for a map of these monitoring well locations. Water temperature, pH, and conductivity ranged from 5.7 – 10.7 °C, 5.73 – 8.92, and 17.2 – 112.6 µS/cm for these samples, respectively. Alkalinity, water hardness, dissolved calcium, and dissolved magnesium values generally reflect the soft nature of the water that is typical of the region. Dissolved copper ranged from < 1 – 4 µg/L for all of these

samples taken in the shallow aquifer, deep aquifer, and bedrock aquifer system. Dissolved zinc was lower in the samples from the Qpog aquifer (3 – 13 µg/L) and higher in two samples (32 µg/L, 38 µg/L) including one from the shallow Qvr aquifer (MW-09) and one from the bedrock system aquifer (MW-15). Given that these data are limited in scope, additional monitoring would allow for a more comprehensive assessment of groundwater quality in the Crisp Creek watershed.

Table 4. Groundwater quality data collected in monitoring wells in the Crisp Creek watershed by Golder Associates in November 2006. Data are considered as provisional as they are reported by Golder Associates as raw data.

Parameter	MW-07	MW-09	MW-15	MW-10	MW-12	MW-17	DH-3
Aquifer Unit	Qpog	Qvr	Thb	Qpog	Qpog	Qpog	Qvr
Well depth (ft)	126	24	341.5	173	79	87.5	N/A
temperature (°C)	9.4	10.1	10.7	10	9	8.9	5.7
pH	6.45	5.73	8.92	6.64	6.11	6.62	6.14
conductivity (µs/cm)	62.3	43.1	112.6	74.8	43.1	66.7	17.2
Turbidity (NTU)	0.84	137	51.3	1.2	31.1	2.7	280
Alkalinity, total (mg/L)	52	32	140	58	38	54	10
Hardness (mg/L)	59	33	11	61	34	55	11
Calcium, dissolved (mg/L)	18	8.9	3	18	8.6	14	3.2
Magnesium, dissolved (mg/L)	3.4	2.6	0.91	4	3.1	4.8	0.81
Copper, dissolved (µg/L)	2	4	2	4	4	4	<1
Zinc, dissolved (µg/L)	9	32	38	13	6	3	2
Lead, dissolved (µg/L)	<1	<1	<1	<1	<1	<1	<1
Iron, dissolved (µg/L)	5	77	27	18	29	9	405

Qpog: pre-Olympia deep aquifer
Qvr: Vashon shallow recessional outwash aquifer
Thb: bedrock water-bearing zone
N/A: information not available

Sources of Groundwater and Surface Water Contamination

Since Crisp Creek streamflow is dominated by groundwater and much of the watershed is highly susceptible to groundwater contamination, concerns arise on sources that may contaminate aquifers in the watershed. Potential sources of groundwater contamination include vehicles, roads and parking lots; hazardous materials transportation; stormwater facilities; lawn care products; housing materials; domestic animals; and septic systems. As the watershed is developed, these sources will expand and the mobilization and routes of contamination into groundwater and surface water will increase.

Private wells can serve as direct conduits to aquifers. Contaminants such as pesticides, herbicides, fertilizers, and fecal material from animals can enter wells and degrade the water quality of the aquifer. Pollutants from vehicle traffic as well as roadway spills from transport of hazardous

substances can seep into wells, infiltrate into the soil, and move into groundwater. Well locations in the Crisp Creek watershed are shown in Figures 21 and 24.

Several stormwater facilities are located throughout the watershed (Figure 21) and are potential sources of aquifer contamination. A large regional stormwater infiltration facility is proposed in the Crisp Creek watershed to serve future developments at The Reserve at Woodlands, The Villages MPD and roads associated with these developments (Appendix A).

A wide array of contaminants are found in stormwater runoff, including metals such as copper, zinc, lead, arsenic, aluminum, and mercury; polycyclic aromatic hydrocarbons(PAHs) and petroleum hydrocarbons; and pesticides, herbicides, and phthalates. Stormwater runoff can also contain increased levels of soluble phosphorus, total phosphorus, nitrite and nitrate, ammonia, total nitrogen, and total suspended solids (Herrera, 2011). Unless stormwater runoff is minimized and adequately treated, these stormwater facilities will likely introduce pollutants into aquifers within the Crisp Creek watershed.

On-site wastewater treatment can be a source of groundwater pollution. Personal care products, pharmaceuticals, and other chemicals from household waste have been found in groundwater adjacent to and downstream of septic treatment systems (Hinkle, et al., 2005; Phillips, et al., 2015). Endocrine disruption is known to occur in fish from contaminants derived from human wastewater (Pait and Nelson, 2002; Morace et. al, 2009; USGS, 2013). Enhanced on-site treatment is needed to prevent this. The septic systems in several older dense subdivisions with small lots including Little Firs and 101 Pines may pose a greater contamination risk than newer homes subject to more protective septic system requirements.

Proposed residential developments in the watershed will lead to increased pollutant loads into groundwater from materials and products used within and around properties. Some of these pollutants will include metals from housing materials; pesticides and herbicides applied on residential and commercial properties; and emerging contaminants from personal care products and pharmaceuticals in septic systems. The rise in vehicle traffic associated with these proposed developments will lead to increased loads of heavy metals, petroleum hydrocarbons, PAHs, and other pollutants and may also lead to increased water temperature, decreased dissolved oxygen, and changes to pH and conductivity in Crisp Creek. Pollutant delivery to streams generally rises along with increased road density and vehicle use.

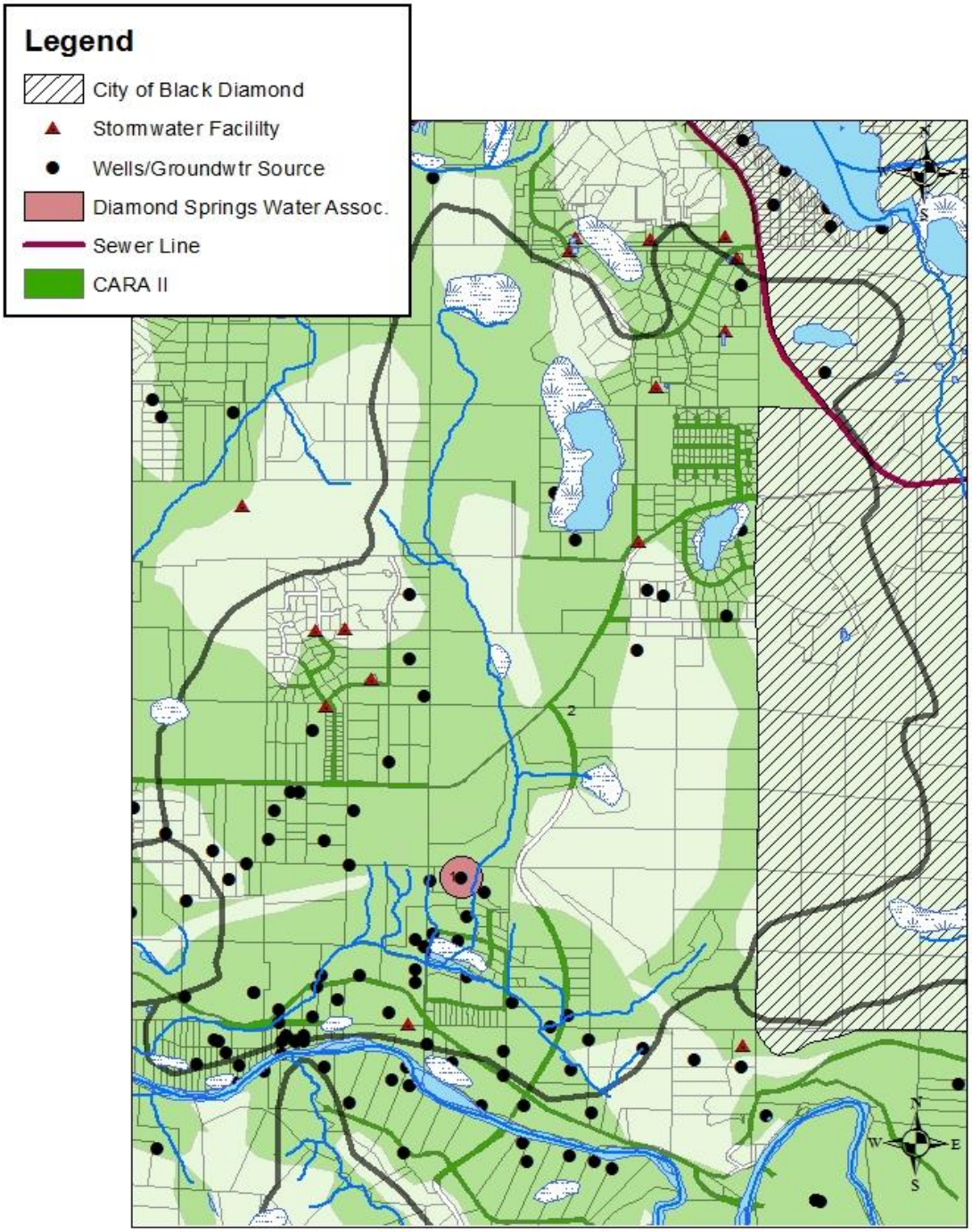

Figure 21. Stormwater detention ponds (red triangles), well and spring sources (black dots), and King County's sewer line in relation to Critical Aquifer Recharge Areas (CARA Category II) in the Crisp Creek watershed. These are potential pathways for groundwater contamination. CARA II areas are highly susceptible to groundwater contamination Additional wells northeast of Keevies Lake are not mapped here. Source: http://www5.kingcounty.gov/gisdataportal/ accessed on 4-8-16.

Measures Needed to Protect the Quality of Groundwater and Surface Water

It is important that Crisp Creek, which is the water supply for the Tribe's hatchery, continues to maintain high levels of dissolved oxygen, low water temperatures, low total ammonia levels, low levels of metals and other pollutants, and pH levels within the range of the 6.5 to 8.5. Because of the naturally low levels of hardness and alkalinity found in Crisp Creek, it will be susceptible to pH changes, ammonia toxicity and metals toxicity in the event that human activities and land use in the watershed increases the loads of nutrients, metals and other pollutants to ground and surface water.

Measures to prevent nutrients, metals and other pollutants from entering groundwater or surface water will be required in proposed subdivisions, roads projects, stormwater facilities, or other types of development in this watershed. At a minimum, these measures should include avoiding galvanized metals in housing, fences, and stormwater facilities; minimizing copper and zinc in roofing materials; preventing copper and zinc inputs from roadways and parking lots; minimizing the use of fertilizers and iron-based moss control products; and maximizing the retention of native vegetation on parcels.

Stormwater should not be discharged directly to surface water, including to and near wetlands. Stormwater facilities should include enhanced treatment to remove metals such as copper and zinc; an example of enhanced stormwater treatment is large sand filters. Operational source control best management practices should include high-efficiency street sweeping to reduce the load of metals exported from roadways to stormwater facilities.

Onsite septic systems for new residential developments should be designed with best available technology to facilitate advanced treatment of wastewater and prevent the contamination of groundwater by nutrients and by emerging contaminants from personal care products and pharmaceuticals. Examples include sand based media, bio-filter systems, and aerobic treatment units (Hinman, 2005).

Special measures should be taken to protect the hydrology and integrity of the sphagnum bog in the headwaters of Crisp Creek. Sphagnum bogs are typically acidic, with pH values well below 5. To protect the pH levels in Crisp Creek, it is important that the current volume and timing of the bog's discharge into Crisp Creek does not change. Kulzer, et al. (2001) discuss the importance of maintaining the chemistry and natural rate of decomposition of peat in sphagnum bogs. These authors discuss the impacts of runoff from land clearing and residential properties on sphagnum bogs; pollutants in stormwater runoff can lead to an accelerated rate of decomposition of peat in sphagnum bogs, which in turn causes an increased export of nutrients to downstream waters. Therefore, it is important to prevent stormwater runoff from entering the sphagnum bog in the headwaters of Crisp Creek.

LAND USE

The majority or 82 percent of the Crisp Creek watershed lies within rural King County. The remaining 18 percent (530 acres) was annexed into the city of Black Diamond and will be developed at urban densities (City of Black Diamond Comprehensive Plan, 2009; City of Black Diamond Ordinance 10-946 approving The Villages Master Planned Development 9/20/2010). Zoning in the unincorporated county portion of the watershed is mostly designated Rural, with 5 acres per housing unit (RA-5) and lesser amounts of Rural 10 acre (RA-10) and Agricultural (A-10) zoning. Agricultural lands are located near lower Crisp Creek in the Green River valley (Table 5). Most of these are enrolled in the county's Farmland Preservation Program under which development rights were secured. County-owned public lands and open space tracts comprise about 15 percent of the watershed (Figure 22).

An analysis of aerial photos show that significant logging during the early to mid-1990s reduced forest cover in the watershed to 38 percent. Regrowth has occurred such that forest cover recovered to 74 percent by 2013. As of early 2016, following clearing for development including at The Villages Phase 1A, forest cover is currently 70.5 percent. The watershed currently has a road density of about three miles of road per square mile, with impervious surfaces comprising about 5.4 percent watershed area (NW Indian Fisheries Commission, unpublished data, 2016). We note that even with limited residential development along the creek upstream of the hatchery, some land use impacts have occurred. A 1997 field reconnaissance found that locally severe channel erosion was common due to channel encroachment by adjacent residences (Booth, 1997).

Table 5. Zoning, land use designations and forest cover in the Crisp Creek watershed, which totals 2,925 acres. Note that categories overlap; for example, lands zoned A-10 may contain public lands.

LAND USE CATEGORY	Acres		Percent of Basin Area	
	2013	1992	2013	1992
King County Public Lands	175	40	6%	1%
King County Open Space Tracts	254	0	9%	0%
Farmland Preservation	196	196	7%	7%
Urban-City of Black Diamond	530	70	18%	2%
Rural RA-5 Zoning	1923	1923	66%	66%
RA-10 Zoning	150	150	5%	5%
A-10 Lands (Agriculture 10 acre)	258	258	9%	9%
Forest Cover	2152	1901	74%	65%

Data source: 2013 values taken or estimated from King County iMap accessed 2/23/2016. 1992 values from Carlson, unpublished data, 1993.

Past Land Use Decisions and Future Outlook

King County adopted Ordinance 12534 in 1996, approving the Black Diamond Urban Growth Area Agreement (BDUGAA) between the county, the city of Black Diamond, Palmer Coking Coal Company, and Plum Creek Timber Company. The BDUGAA established Black Diamond's Urban Growth Area for future annexation. It was based on the "4 to 1 Principle" where four acres of open space would be permanently protected for every acre of land added to the Urban Growth Area to be annexed to the city. For several years prior, the Tribe's Fisheries Division had worked with the

county, Cascade Land Conservancy, and Plum Creek Timber Company to develop options to conserve Plum Creek land holdings in the Crisp Creek watershed. Ultimately, Plum Creek chose to not proceed with the proposed options at that time. However, that effort helped to raise awareness among King County, Black Diamond and the development community about the need to protect Crisp Creek and the Tribe's hatchery water supply from development impacts.

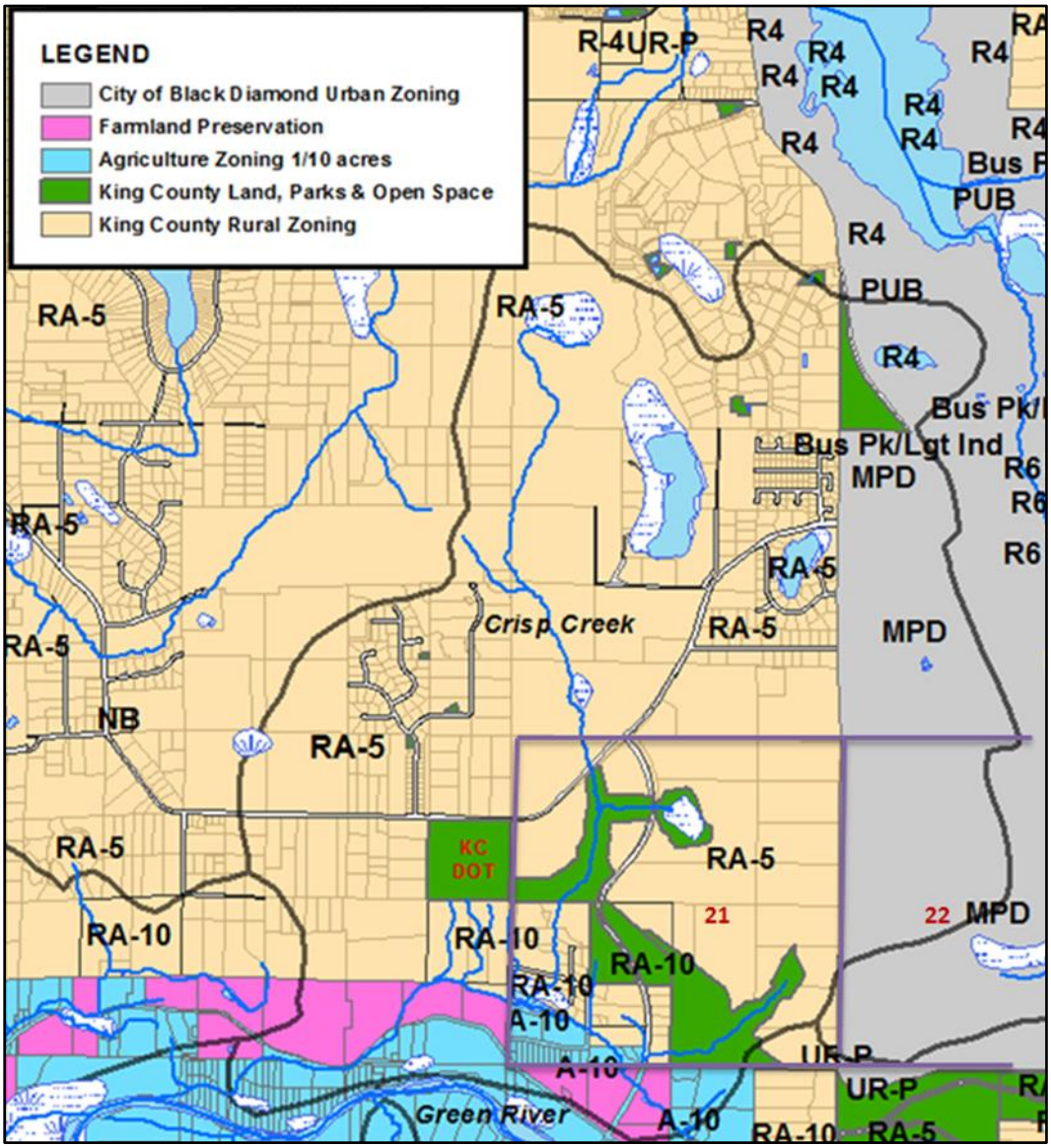

Figure 22. Zoning and land use designations in the Crisp Creek watershed. Parcels shown in green include County-owned open space lands and a road maintenance facility. Business park/light industrial land use and The Villages Master Planned Development is planned within Black Diamond's urban zoning. Source: http://gismaps.kingcounty.gov/iMap/?center=-13582776%2C5992265&scale=18055.954822&

As a follow-up to the urban growth area agreement, the Black Diamond Area Open Space Protection Agreement was approved in 2005, annexing the north and west areas of the Black Diamond Urban Growth Area to the city and conveying open space lands to King County including lands upstream of

the hatchery in Section 21 now called the "Black Diamond Natural Area" (much of the green area in Figure 22).

In 2009, an agreement between King County and BD Village Partners LP was approved per King County Ordinance 16739 which conveyed 255 acres of open space to King County from Sections 21 and 22 in tracts along Crisp Creek, in anticipation of potential future rural clustered subdivision and future segment of the county's Green to Cedar River Trail. This Ordinance also anticipated a regional stormwater facility to be located in the watershed.

In 2014, the King County Council passed Ordinance 17745 approving a new development agreement between the county and BD Village Partners LP. This agreement included a new 77-lot rural clustered subdivision on 394 acres called "The Reserve at Woodlands" to be located a short distance upstream of the Keta-Crisp Hatchery. The development agreement also included a regional stormwater facility to be constructed by BD Village Partners LP, and the transfer of a minimum 300 acres of open space and sensitive area lands for recreation trails and/or protection. Open space to be deeded to the county under this agreement includes natural areas west of 218th Avenue SE and in the southeast corner of Section 21 (included in the green area, Figure 22). The 40-acre regional stormwater facility is intended to receive stormwater from Horseshoe Lake, The Reserve at Woodlands, other rural areas, and portions of The Villages Master Planned Development, a 4,800-home mixed use development that would be constructed in the Black Diamond urban growth area, including on lands inside the Crisp Creek watershed (see Figure A1 in Appendix A).

Recognizing the Tribe's interests and concerns in the watershed, the development agreement approved by Ordinance 17745 includes the following statement:

> *"The County and BD Villages recognize that the Muckleshoot Indian Tribe ("Tribe") has a variety of interests that must be addressed as development occurs under this Agreement. These interests specifically include water quality and water quantity as it relates to the Tribe's Keta Creek Hatchery facilities and to cultural resources in the area. The parties agree that there should be early and continuous coordination with the Muckleshoot Indian Tribe so that the Tribe's interests are considered throughout all phases of development that occurs under this Agreement."*

In addition to The Reserve at Woodlands, a 15-unit subdivision called The Ridge at Lake Sawyer III was recently approved for construction in the unincorporated rural portion of the watershed (Figure 23). Earlier phases of The Ridge at Lake Sawyer (Division I and II) completed in the last decade on land that straddles the topographic divide between the Crisp and Soos Creek watersheds. The upcoming phase of The Ridge at Lake Sawyer (Division III) is of particular concern as it is located in the Crisp Creek headwaters adjacent to the sphagnum bog, a rare Class I wetland that is sensitive to water level changes and other disturbance. Disturbance of the bog and surrounding lands could result in nutrient discharges from the bog to Crisp Creek. More detailed information these developments is provided in Appendix A.

Under the King County Comprehensive Plan updated in 2016, most lands in the watershed under county jurisdiction are expected to remain in Rural Residential zoning at one unit per five acres (RA-5). Even at RA-5 zoning density, however, some water resource degradation can be expected as forest cover and aquifer recharge is lost to roads, driveways, building sites and lawns; and pollutants are introduced to ground and surface waters through stormwater runoff and septic effluent.

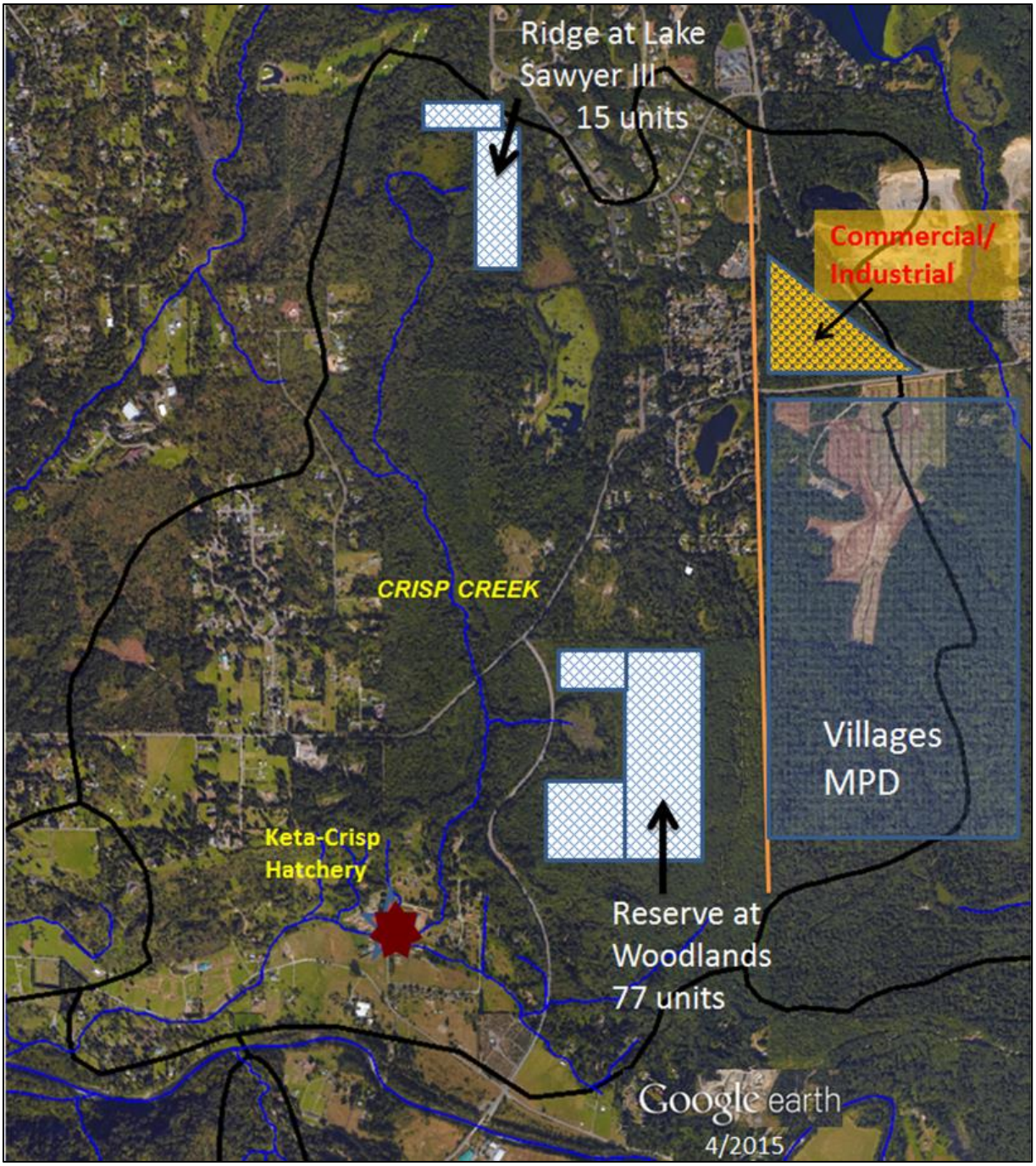

Figure 23. New subdivision housing and urban-level developments planned in the Crisp Creek watershed. Areas shown are estimated and not to scale. The orange line depicts the city of Black Diamond boundary. Modified from: http://www5.kingcounty.gov/gisdataportal/ and Google Earth.

Land Use Measures Needed to Protect Crisp Creek

Crisp Creek is at risk of groundwater recharge loss, streamflow declines, and water quality degradation from recently approved developments and from any new development that will occur in the future. It is uncertain how effective development regulations and environmental mitigation measures will be in avoiding impacts to the springs, groundwater, and surface water of Crisp Creek. Unfortunately, if degradation occurs, reversal may be impossible, therefore prevention is the best approach.

Protection of the remaining undeveloped forested lands in the watershed is urgently needed especially for high-risk and sensitive lands in the Crisp Creek headwaters and along the creek mainstem. The permanent protection of forested lands is the most certain and effective method to protect Crisp Creek water resources (Booth, 1997; Booth, 2000; Booth, 2002). Deforestation and land conversion is documented to cause detrimental impacts to stream hydrology and water quality (DeGasperi, et al, 2009; Alberti, 2005; Konrad and Booth, 2005; Carle, et al, 2005)).

Forest cover in the watershed can be expected to diminish as new developments occur. Of the 1,660 acres of watershed land upstream of the hatchery, only about one third is likely to remain fully forested in the future unless steps are taken to acquire or preserve forest lands. Nearly another third is inside the Black Diamond urban growth area and will be converted to urban uses per The Villages Master Planned Development. Most of the remaining land, except that in already existing or approved subdivisions, is zoned as RA-5 where few requirements exist to protect trees and forest cover will be lost over time as home sites or more intensive uses are developed.

In addition, early review of development proposals and close coordination is required between the Tribe, the city of Black Diamond, King County government, and developers such as BD Villages Partners LP as land use permitting for The Villages MPD, The Reserve at Woodlands and other developments proceed. Close coordination among these parties is needed to develop site-specific mitigation measures to eliminate or limit the potential for adverse impacts to the creek and to the water rights and water supply of the Keta-Crisp Hatchery.

WATER RIGHTS AND WATER USE

Given its rural setting, many homes in the Crisp Creek watershed use a well or spring for domestic water supply. In Washington State, water rights are governed by a priority system based on "first in time, first in right". Beneficial water use from a stream, river, spring or lake requires a permit or certificate from the Washington State Department of Ecology authorizing it. The use of groundwater also requires a permit or certificate unless it is used for stock watering, irrigating a non-commercial lawn or garden one-half acre in size or less, or to provide water for homes or industry limited to 5,000 gallons per day. Wells that fall under this category are also called "permit exempt wells". Water use that occurred before 1917 for surface water and 1945 for groundwater can be represented by a claim rather than permit or certificate. To determine whether a claim is the same as a right or if a water right is valid (non-municipal use must be used within 5 years) an adjudication by a Superior Court must occur. When Ecology reviews an application for a change to a water right or claim, they have authority to estimate the validity of that right or claim without using the generally costly and time-consuming adjudication process. Ecology must review a water right application to determine whether the "4-part test" is met before approving and issuing a water right permit or certificate: water must be available; it must be for a beneficial use; senior water rights cannot be impaired; and the use must be in the public interest. (http://www.ecy.wa.gov/programs/wr/rights/water-right-home.html).

For many decades, Ecology issued water rights without addressing whether there was enough water in a watershed to meet all water needs including streamflows, and as a result many rivers and streams were over-appropriated. When Green River minimum instream flows were set by WAC Chapter 173-509 in 1980, all tributaries including Crisp Creek were closed to further surface water appropriations. However, groundwater appropriations continued until Ecology denied requests for new water rights in 1996. Denials for new water rights were made because groundwater is not legally available when it is connected to or in hydraulic continuity with surface water in a closed tributary, or to the Green River when instream flows are not met. Many applicants appealed these denials until the Washington State Supreme Court upheld Ecology's decisions in 2000 (*Postema vs. Pollution Control Hearings Board (PCHB), et al*.). One of these denials was issued to the Covington Water District's request for a new well in the Crisp Creek watershed. To protect the creek and its own hatchery water rights, the Muckleshoot Indian Tribe had protested the water right application and intervened on Ecology's behalf through the court process on this and other water right denials (*Covington Water Dist. vs. Washington Dep't of Ecology, Jorgensen vs. PCHB*), including the *Postema* case.

Keta-Crisp Hatchery Water Rights

The Muckleshoot Indian Tribe holds six surface water rights for the Keta-Crisp Hatchery from both its original Keta Creek Hatchery and for the Crisp Rearing ponds previously owned by WDFW. Crisp Creek supplies water for fish propagation and Keta Springs provides water for both domestic and fish production use.

Under state law, the Tribe holds a combined total of 10.55 cubic feet per second (cfs) of non-consumptive surface water rights to Crisp Creek and 0.68 cfs from Keta Springs for the purpose of fish propagation. The Tribe holds an additional 0.02 cfs and 2.0 acre-feet/year for domestic use. These rights have priority dates that range from 1975 to 1984 (Table 6). These rights under state law are in addition to the Tribe's unadjudicated reserved rights under federal law. *Winters v. United* States, 207 U.S. 564 (1908). Tribal water rights pertain to off-reservation land when necessary to

support a treaty fishing right. *United States v. Adair*, 723 F.2d 1394 (9th Cir. 1983). Moreover, such rights have been repeatedly held to pertain to groundwater that is hydraulically connected to surface water. *See, e.g., United States v. Orr Water Ditch Co*, 600 F.3d 1152 (9th. Cir. 2010); *In re Gen. Adjudication of All Rights to Use Water in the Gila River Sys. and Source*, 989 P.2d 739 (Ariz. 1999); *Agua Caliente Band of Cahuilla Indians v. Coachella Valley Water Dist*., No. EDCV 13-883-JGB, 2015 WL 1600065 (C.D. Cal. Mar. 20, 2015), appeal argued and submitted, No. 15-55896 (9th Cir. Oct. 18, 2016).

Table 6. State-issued water rights for the Keta-Crisp Hatchery. Qi is instantaneous rate in cubic feet per second. Qa is annual volume in acre-feet per year.

Water Right No.	Source	Qi (cfs)	Qa (af/yr)	Priority Date	Water Use	Type
S1-22503C	Crisp Creek	8	na	5/29/1975	Fish Propagation	Non-consumptive
S1-24508C	Crisp Creek	0.55	na	7/27/1984	Fish Propagation	Non-consumptive
S1-23839C	Crisp Creek	2	na	3/30/1981	Fish Propagation	Non-consumptive
S1-23733C	Keta Springs	0.01	1	12/5/1980	Domestic	Consumptive
S1-22989C	Keta Springs	0.01	1	9/29/1977	Domestic	Consumptive
	Keta Springs	0.68	na	9/29/1977	Fish Propagation	Non-consumptive

Other Water Rights and Use

Other water rights and claims in the watershed occur both upstream of the hatchery and downstream in the Green River valley. In the state of Washington's seniority-based water rights system, an inventory of rights and claims is important especially during a drought if junior water rights are impairing senior rights. An inventory may also be used to estimate the total water use and develop a water budget, evaluate risks to the water supply, and determine whether and how many wells are exempt from permitting requirements. Table B1 in Appendix B lists all rights and claims in the Crisp Creek watershed along with water quantities and priority dates. In addition to the Tribe's water rights, there are 21 rights and claims for Crisp Creek, various springs, and groundwater for domestic and irrigation use. These types of uses are considered to be consumptive in that most if not all of the water leaves the system, while fish propagation is a non-consumptive water use because water is returned downstream close to where it is withdrawn.

The only Group A system (system serving over 14 connections) among the water right and claim holders in the Crisp Creek watershed is the Diamond Springs Water Association, a small water purveyor that diverts water from springs which are tributary to Crisp Creek. Diamond Springs supplies water to single family homes adjacent to the Keta-Crisp Hatchery and is approved for 50 connections (https://fortress.wa.gov/doh/eh/portal/odw/si/Intro.aspx). The Tribe and the Diamond Springs Water Association have worked together to strive to protect both water supply sources.

There are nine Group B systems in the watershed, which serve from two to 14 connections. All appear to be covered by water rights or claims (Table B2, Appendix B). Many existing wells in the

watershed are authorized by water right certificates and claims; however, wells located along or south of the Green Valley Road and north of Keevies Lake in The Ridge at Lake Sawyer Division II subdivsion are permit-exempt wells (Figure 24). Domestic supply for the homes in The Ridge at Lake Sawyer development is provided by the Covington Water District (CWD), with irrigation provided by wells. The Reserve at Woodlands will also be served by the CWD though they have not yet applied for a Water Availability Certificate from the District. The CWD is Group A water utility system serving much of the Soos Creek and Crisp Creek watersheds (Figure 25). The CWD has had concerns with the drilling of permit-exempt wells within or just outside of its water service area. The CWD's concerns relate to aquifer protection, water quality, and customer service equity (Carollo Engineers, 2015, draft), the latter associated with sharing the cost of CWD's investment in the Tacoma Second Supply Project that provides water from the Green River for regional growth.

In order to protect the limited supply of groundwater that feeds Crisp Creek, both domestic and irrigation water for new development should be supplied by the CWD rather than from new wells. A proliferation of exempt wells in the Crisp Creek watershed could impair the water rights for the Keta-Crisp Hatchery.

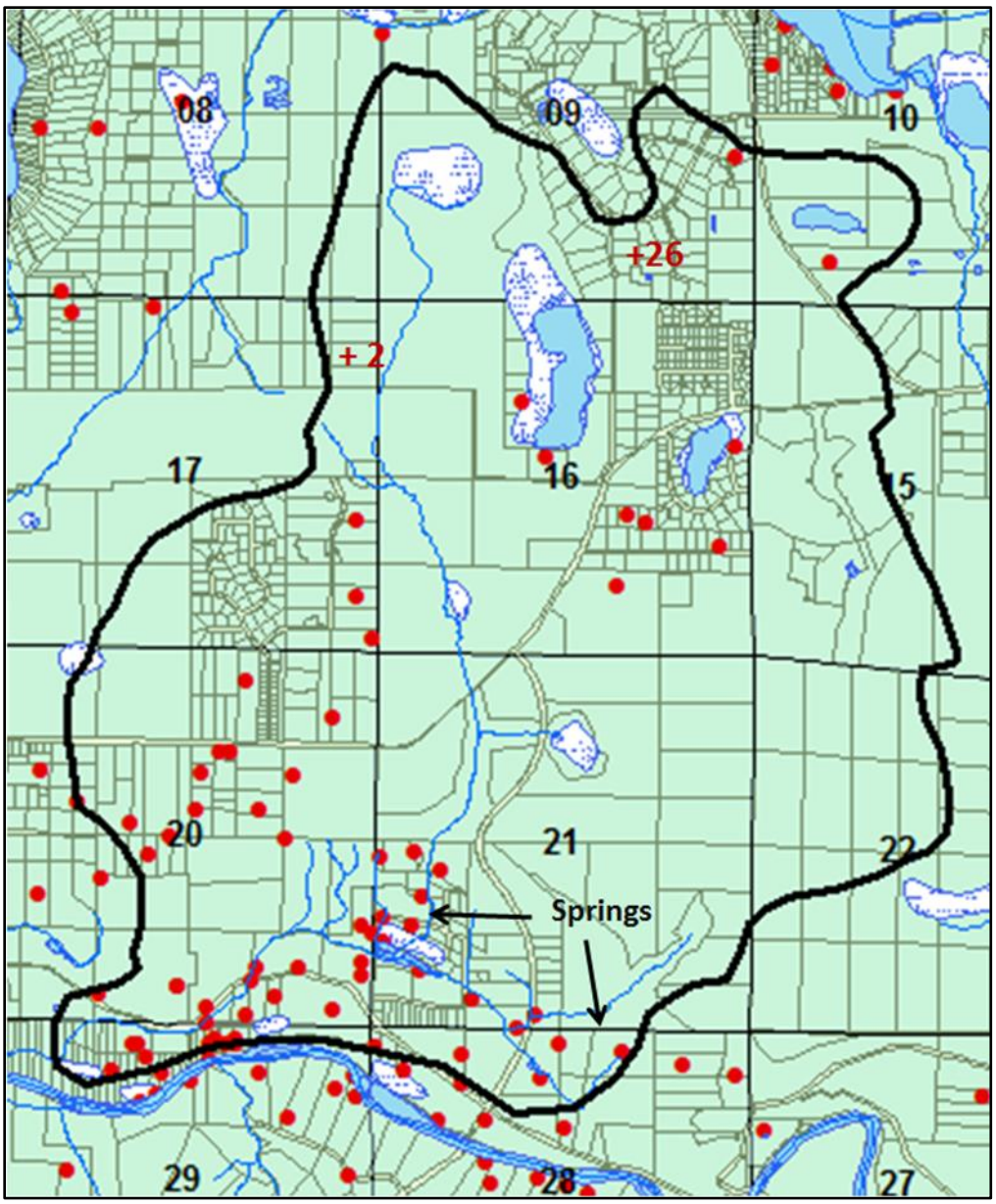

Figure 24. Well and springs diversion points in the Crisp Creek watershed. Each red dot represents a groundwater source. Most dots are wells, and many have documented water rights. The red numbers "+ 2" and "+ 26" are recently developed permit-exempt irrigation wells not shown on the GIS layer. As of April 2016, we estimate that 80 wells are active in the watershed and approximately 54 of these wells are located upstream of the Tribe's hatchery. Source: https://gismaps.kingcounty.gov/iMap/ on 4-8-16.

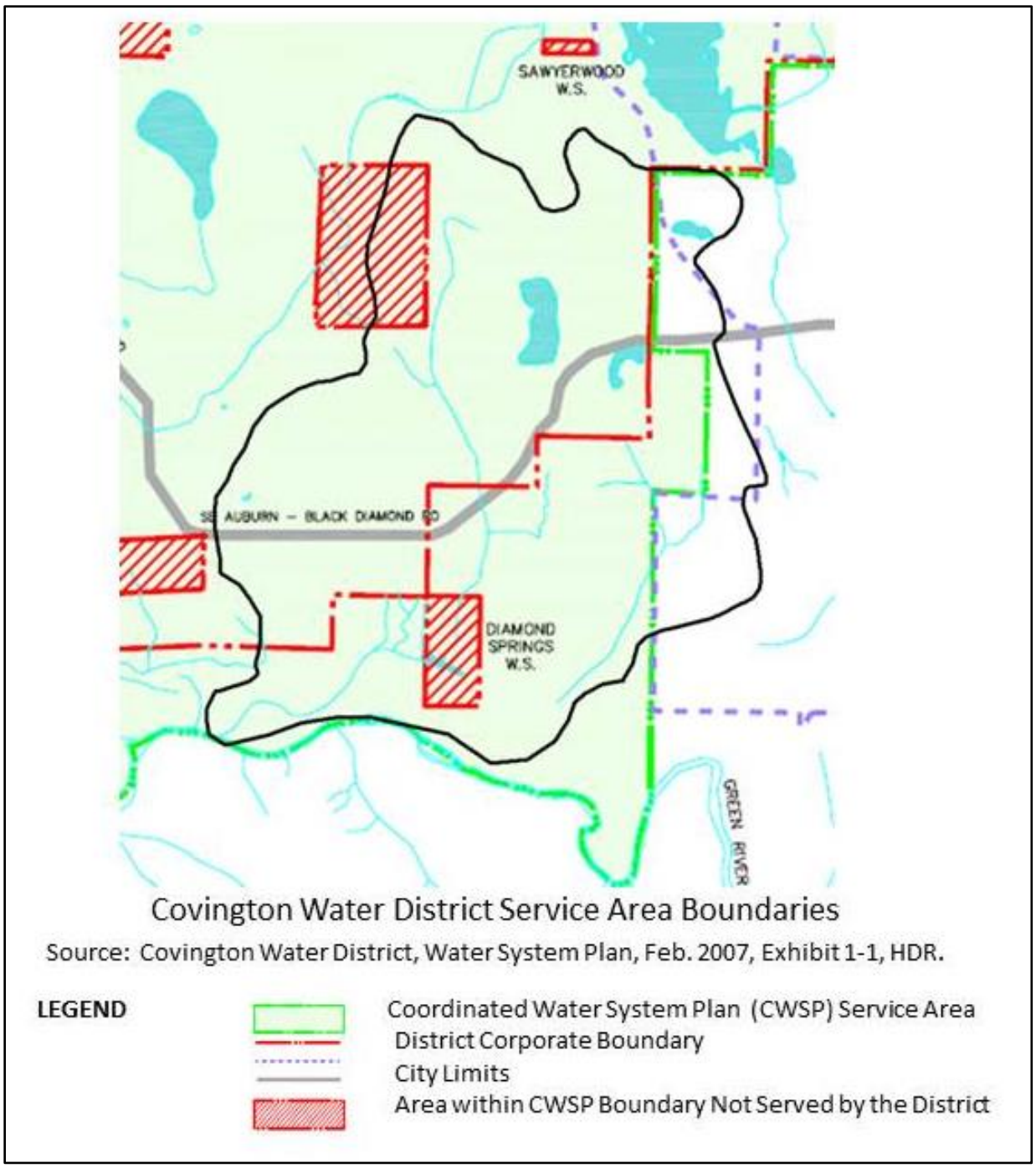

Figure 25. The green line shows the boundaries of where the Covington Water District has the responsibility to provide water service. Most of the Crisp Creek watershed is within the District's service area boundaries. Figure modified from HDR, 2007.

4. CRISP CREEK WATER RESOURCE PROTECTION STRATEGY

This section proposes a strategy to safeguard the excellent water resources of the Crisp Creek and the water supply and water rights of the Muckleshoot Indian Tribe's Keta-Crisp Hatchery. The strategy consists of near term and longer term measures and objectives labeled as Level I and Level II recommendations. The Tribe plans to work with King County and the City of Black Diamond to refine and further develop these recommendations, and to help secure the necessary resources and support for their implementation.

Level I recommendations address immediate threats to the quality and quantity of surface water and groundwater posed by development. The threats are described in this report and include aquifer recharge and streamflow losses from new well construction and impervious surfaces, drainage and construction site alteration; pollution from septic effluent and storm runoff – all of which is expected to affect the levels of contaminants, pH, sediment, and nutrient in Crisp Creek. Level I recommendations should be implemented in the next one to three years to preserve opportunities that may otherwise be lost to development.

Level II recommendations support longer term water resource protection once the more imminent threats are reduced. Level II recommendations should be implemented within the next three to five years. These recommendations are given below and described in the following pages.

Level I Recommendations

1. Maintain forest cover in the watershed through land acquisitions, easements, transfer of development rights, and tax benefit programs.
2. Protect upper Crisp Creek and its headwater bog through land acquisitions, easements, transfer of development rights, and additional development mitigation measures.
3. Protect a minimum 200-foot wide corridor along Crisp Creek and its tributary springs and wetlands upstream of the Auburn-Black Diamond Road.
4. Limit the proliferation of private domestic and irrigation wells.
5. Implement a comprehensive ground and surface water monitoring program for the Crisp Creek watershed.

Level II Recommendations

6. Modify or supplement development regulations in the watershed to reduce impacts to surface and groundwater.
7. Reduce the impacts of public and private roads, trails, and transportation projects on water resources.
8. Promote public and agency awareness about the high quality of Crisp Creek water resources, the sensitive downstream hatchery water supply, and the need for stewardship.

Description of Level I Recommendations

1. **Maintain forest cover in the watershed through land acquisitions, easements, transfer of development rights, and tax benefit programs.**

   Of the 1,660 acres of the Crisp Creek watershed that are upstream of the hatchery, only about one third is likely to remain in a fully forested condition as a result of the Black Diamond Annexation and future development unless steps are taken soon to preserve forest land cover. Most land outside of existing or approved subdivisions and the Black Diamond urban growth boundary are zoned RA-5. Forest cover on currently forested RA-5 lands will shrink over time as home sites or other uses are developed.

   Preserving forest land cover is often recognized as the single most effective strategy to avoid degradation of ground and surface waters (e.g., Booth, D. et al. 2002; Booth D., 2000). Along with fee simple acquisition, we recommend expanded use of state and county programs such as Transfer of Development Rights, Public Benefit Rating System taxation, Forest Land Taxation, and identification of new opportunities for conservation easements to maintain forest cover in the watershed.

   Some properties are protected temporarily. Twelve parcels comprising 129 acres are enrolled in the King County Public Benefit Rating System which provides tax incentives for land maintained as open space and forest. An opportunity exists to expand the use of these tax incentives along with King County's Transfer of Development Rights program (TDR) to permanently conserve forest cover in the watershed.

   Most of the Crisp Creek watershed has been designated as a Rural Forestry Focus Area by the County. These are geographic areas where special efforts are needed and feasible to maintain forest cover and the practice of sustainable forestry. The Rural Forest Focus Areas' primary mechanism for forestland protection is the Transfer of Development Rights program, in which these areas are priority "sending sites or areas" per King County's Comprehensive Land Use Plan policies. The TDR program website describes the TDR as a *"voluntary, incentive-based, and free market-driven approach to preserve land and steer development away from rural and resource lands into Urban Areas. Rural landowners realize economic return through the sale of development rights to private developers who are then able to build more compactly in designated unincorporated urban areas and partner cities. Countywide, the TDR program has protected 141,500 acres of rural and resource land to date".*

   To assist with water resource protection, we recommend that Rural Forest Focus Areas in the Crisp Creek watershed be assigned the highest priority in the county as a "sending site" for development rights transfers, where development credits would be sent elsewhere to a "receiving site" with lower conservation value in exchange for conserving lands in the watershed.

2. **Protect upper Crisp Creek and its headwater sphagnum bog through land acquisitions, easements, transfer of development rights, and additional development mitigation measures.**

   The permanent protection of remaining undeveloped properties along upper Crisp Creek by fee simple acquisition, transfer of development rights, and use of conservation easements will provide the greatest certainty of water resources protection. These properties are mapped in Appendix A. The identification of willing sellers and funding sources to acquire properties and easements, and opportunities to use the Transfer of Development Rights program in the watershed should occur as soon as possible.

   Unfortunately, the property at the Crisp Creek headwaters containing the sensitive sphagnum bog ("the headwater bog') is soon to be developed. King County approved a preliminary plat for 15 homes for The Ridge at Lake Sawyer Division III (APN 7299810250) at this property, and some roads and water lines have been constructed as of April 2016. The sphagnum bog and perhaps 16 other small wetlands occupy the property. Limited road access has thus far prevented some of these lots from being developed. Adjacent parcels are likely to be developed if a road extension to the west is approved. Development of homes and a road network in these headwater-area properties will impact the hydrology and water quality of Crisp Creek and nearby Covington Creek. As noted earlier, impacts on sphagnum bogs from runoff related to land clearing and development are known to be serious. Pollutants in stormwater and human wastewater can lead to an accelerated rate of peat decomposition in sphagnum bogs, which in turn causes the export of nutrients to downstream waters. Therefore, it is important that stormwater and septic wastewater is prevented from entering the sphagnum bog or the headwater area of the creek.

   Although the developer for The Ridge at Lake Sawyer Division III worked with the Tribe's Fisheries Division staff in 2007 on project mitigation measures, not all of the recommended mitigation measures were adopted. Further, all development impacts cannot be fully mitigated. For example, some fertilizer, hormones, personal care products, caffeine, medications, detergents, pesticides, contaminants from septic systems, and oil, grease, metals and sediment carried by road runoff will likely eventually enter the bog, the groundwater, and Crisp Creek.

   The planned Reserve at Woodlands subdivision also poses risks to the Keta-Crisp Hatchery water supply. Water quality and changes in local groundwater flow pathways are a concern. Even though most of the property will be put into open space tracts by King County, the 77-lot subdivision still may result in unavoidable degradation of water resources. This subdivision is upstream and close to the hatchery and is sited along a tributary and a wetland that discharges directly into Crisp Creek. Like Horseshoe Lake, this wetland is a "till window" directly connected to the Qpog aquifer that feeds Crisp Creek. As such, there is the potential for a flooding problem similar to that which now occurs at Horseshoe Lake. The Reserve at Woodlands also involves the construction of a regional stormwater facility that will receive stormwater from The Reserve at Woodlands, from a portion of The Villages Master Planned Development, and from floodwaters pumped from Horseshoe Lake. Close coordination among the Tribe, the city of Black Diamond and King County on all implementing permits will be needed to identify mitigation measures needed to protect water resources and the Keta-Crisp Hatchery water supply.

3. **Protect a minimum 200-foot wide riparian corridor along Crisp Creek and its tributary springs and wetlands upstream of the Auburn-Black Diamond Road.**

   A 200-foot or wider riparian corridor should be protected through fee acquisition, conservation easement or other means to provide prevent disturbance of Crisp Creek, its tributaries and wetlands, on all properties upstream of the Auburn-Black Diamond Road. Preserving a robust vegetated riparian buffer zone will maintain shade and prevent water temperature warming, absorb and filter pollutants, and provide high quality habitat for fish and wildlife.

   Eight land parcels totaling 237.49 acres border or include Crisp Creek or its tributary or wetlands, and almost all of these are presently undeveloped. Of this total, just 2.17 acres are permanently protected; the remainder could be developed in the near future. The Tribe owns a 2.02-acre parcel (APN1721069020) that is held in a permanent protection status. Part of another parcel (0.15 acres) is protected per a recorded tract (APN Tract 172106TR-A). Four of the eight parcels totaling 209.24 acres are currently undeveloped and are designated as forest land under RCW 84.33.120-130.

   Finally, 23 acres of a single 160-acre forested parcel lies within the watershed at its west boundary and borders a portion of Crisp Creek and a small tributary. This 160-acre parcel is owned by the Camp Berachah Ministries and is currently used as a retreat. Of these eight parcels along Crisp Creek, the five that are not in any type of protected status are zoned RA-5 and may soon be developed for home sites given the short platting and development pattern at adjacent parcels.

4. **Limit the proliferation of private domestic and irrigation wells.**

   Groundwater withdrawals can reduce streamflows in Crisp Creek. While the effect of private wells and community water systems in the watershed is currently small, the number of wells and their impact on streamflows could grow over time if no action is taken. In many areas of the county, the number of permit-exempt wells has grown sharply over time with new development.

   The water service area boundaries of the Covington Water District (CWD) include the Crisp Creek watershed (Figure 25). The CWD is part of a regional water supply system that promotes water use efficiency and conservation among its customers, and seeks to curtail water use in drought emergencies. The CWD meters water usage – providing regular feedback to homeowners and businesses about their water usage on monthly water bills. Compared to private or small group wells, water service from CWD would better help conserve water, reduce the risk of groundwater contamination at well heads, and improve drought response in the watershed. The CWD has water supply available. For these reasons, development in the watershed should be served by the Covington Water District for both domestic and irrigation supply.

   Consistent with RCW 90.54.020, 70.116, and 70.119A, the King County code recognizes that waters systems such as CWD are the preferred means of water service within the Rural Area. New individual or group wells should be prohibited in the watershed, and an agreement to that effect should be developed between King County, the CWD and the Department of Ecology. King County should ensure compliance with county code 13.24.138-B.5 conditions where a well that cannot be "reasonably and timely" served by a Group A system now, will connect in the future.

New water connection or water availability certificate requests, service area expansions, and new exempt well construction will be closely monitored by the Tribe with the cooperation of King County DPER, CWD and others.

5. **Implement a comprehensive ground and surface water monitoring program for the Crisp Creek watershed.**

The Tribe's Fisheries Division has begun working with King County to plan and implement a comprehensive, long-term monitoring program for ground and surface water quality and quantity throughout the Crisp Creek watershed. It is important that baseline surface and ground water quality and hydrologic characteristics in the watershed are evaluated prior to development of the proposed regional stormwater facility; The Reserve at Woodlands; The Villages Master Planned Development; and associated increases in roads and traffic. Because a greater understanding of groundwater flow direction in and around these developments and the stormwater facility is required for monitoring purposes, monitoring ground water elevations at several monitoring wells in this vicinity is essential.

Existing and new monitoring wells should be sampled for water quality in both wet and dry seasons. Surface water monitoring should occur monthly and during storm events at various locations along Crisp Creek and above and below selected wetlands. Water quality parameters for surface and ground water sampling should include those that are typically found in stormwater or in residential areas; are mobile in groundwater; and are harmful to salmonids and/or hatchery operations. These parameters include metals such as arsenic, aluminum, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. Other parameters required include dissolved calcium, dissolved magnesium, soluble phosphorus, total phosphorus, nitrite and nitrate, ammonia, total nitrogen, water hardness, water temperature, dissolved oxygen, pH, and conductivity. Selected parameters in the following groups of chemicals should be monitored as well: polycyclic aromatic hydrocarbons, petroleum hydrocarbons, pesticides, phthalates, and emerging contaminants from personal care products and pharmaceuticals.

Continued surface and ground water monitoring will be important once the master planned developments and regional stormwater facility are in place. Since construction of the stormwater facility may alter groundwater pathways, it will be important to monitor groundwater from new wells that would encircle the facility. This would also allow for early detection of transport of contaminants from the stormwater facility.

Description of Level II Recommendations:

6. Modify or supplement development regulations to reduce impacts to surface and groundwater in the Crisp Creek watershed.

The county regulates development impacts through its land use codes, including but not limited to the zoning code, critical areas ordinance, and stormwater regulations. While King County has more restrictive regulations compared to many other jurisdictions, they still are often not sufficient to avoid impacts to Crisp Creek surface and groundwater. Researchers have found that stormwater pollutants that harm salmon are not always fully removed with common treatment methods. High levels of antidepressants, cholesterol medication, bug spray, ibuprofen, personal-care products and other contaminants have been found in treated wastewater and in the tissues of juvenile Chinook salmon in Puget Sound. As noted earlier, personal care products, pharmaceuticals, and other chemicals have been found in groundwater adjacent to and downstream of onsite wastewater treatment systems, and endocrine disruption occurs in fish from contaminants derived from human wastewater.

One problem is that stormwater treatment is not always mandated; some developments fall below certain regulatory thresholds where treatment is not required. And when treatment is mandatory, the treatment method required can be less effective than other available technologies or methods in removing pollutants. As a result, development projects can have individual or cumulative impacts leading to water quality degradation despite treatment and unsuccessful mitigation. Stormwater regulations in the Crisp Creek watershed need to be strengthened or supplemented to ensure the maximization of treatment and infiltration. Any direct discharge of stormwater runoff into wetlands or surface water should be prohibited.

Crisp Creek is identified as a "high" condition basin under the 2005 Critical Areas Ordinance (CAO); although this designation does not appear to carry increased regulatory protection beyond the normal CAO rules. We recommend that a "Special Water Resources Protection Area" or similar mechanism be established for Crisp Creek to provide added water resource protection in this watershed. This could be accomplished through updates to the Black Diamond and King County comprehensive land use plans and regulations. Added protections would include requirements for enhanced stormwater infiltration and treatment for new developments, forest retention, impervious surface limits, restrict use of galvanized metals, in housing, fences and public works facilities; minimize copper and zinc in roofing; prevent copper and zinc inputs from roads and parking areas; minimize use of pesticides; control nutrient and iron loading to ground and surface water from pesticide, fertilizer and moss control products; and enhanced technology and construction methods for onsite septic treatment.

As part of this recommendation, the Tribe plans to work with King County and Black Diamond to institutionalize early tribal notification and close coordination with regard to all land use plans, permits and proposals in the Crisp Creek watershed.

7. **Reduce the impacts of public and private roads, recreation trails, and transportation projects on water resources.**

   Roads and trails can have adverse effects on water quality and stream hydrology. Road runoff can deliver sediment into streams and wetlands, along with metals such as copper, zinc, petrochemicals, and other metals or chemical contaminants that are toxic to fish. Some roads in the watershed were constructed before current road standards and stormwater regulations were established, increasing the likelihood of contaminant delivery to the creek or wetlands.

   To prevent stormwater contaminants from entering Crisp Creek, recommended measures include frequent/regular street sweeping using high-efficiency sweepers; adding cross-drain culverts to roadways; directing road runoff to facilities for treatment and infiltration; and expanded use of bio-swales.

   Recreation trail alignments should avoid intrusion into the Crisp Creek riparian areas including spring and wetland buffers, and be situated away from the hatchery to limit the potential for erosion, pollution, vandalism, dumping, and other problems. The Tribe will work with King County and city of Black Diamond to ensure that (1) public roads are frequently swept; (2) swales or other stormwater treatment facilities are added to public roads; (3) proposed trail alignments avoid sensitive areas; (4) tree retention is maximized in roads and trail projects; and (5) forest landowners have updated road management plans consistent with DNR Road Maintenance and Abandonment Plan standards.

8. **Promote public and agency awareness about the high quality of Crisp Creek water resources and the sensitive downstream hatchery water supply, and encourage stewardship activities.**

   Many watershed residents, developers, elected officials, and county and city personnel may be unaware of the Keta-Crisp Hatchery, or the exceptional water resources of the Crisp Creek watershed. They may be unaware of that the creek exists, or that the hatchery makes important contributions to salmon fishing opportunity in the Green River and in Puget Sound. They may not know how to reduce their own impacts on groundwater or avoid pollution of the creek.

   Tribal staff will work with King County and the city of Black Diamond to promote increased awareness about the high quality Crisp Creek water resources and the beneficial use of water at the Keta-Crisp Hatchery and steps needed to preserve these for the future.

   Finally, parts of the creek's riparian corridor lack natural vegetation cover or are infested with reed canary grass or other invasive plants, particularly in the lower mile of the creek. These conditions allow water temperatures to rise and provide poor instream habitat for adult salmon returning to the hatchery and for other adult and juvenile fish that use the creek. Opportunities exist to work with King Conservation District, landowners, and others to implement riparian improvement projects in the watershed focusing on the lower mile of the creek.

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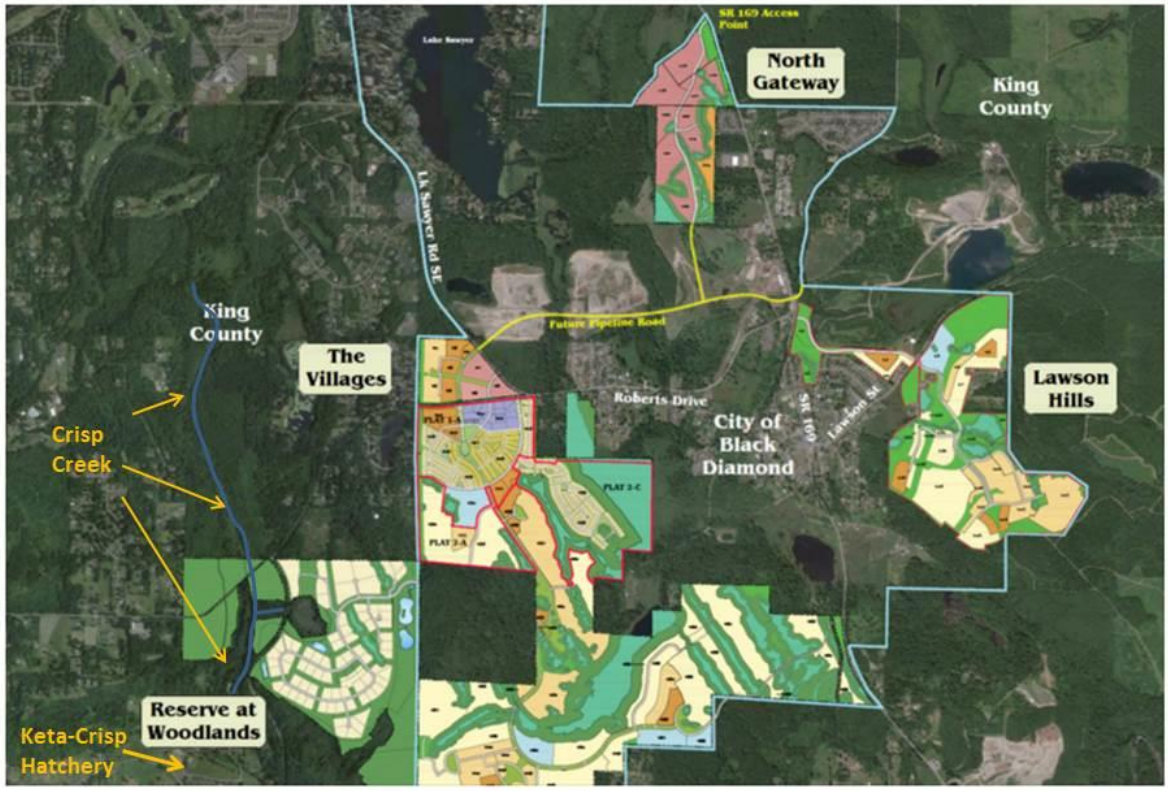
APPENDIX A

PLANNED SUBDIVISIONS IN THE CRISP CREEK WATERSHED

The Villages MPD

The Villages Master Plan Development is a 1,196 acre development located within the City of Black Diamond boundaries, including lands annexed from King County. The Villages MPD will be phased in over the next 10 to 20 years. The Villages MPD website describes the development as follows:

> The Villages rests on 1,196 acres primarily located south and west of Historic Black Diamond and Morganville. It includes 4,800 residential units in both single and multi-family dwellings as well as approximately 775,000 square feet of space for employment uses including commercial, retail, restaurants, office, light industrial and civic uses. Multiple school sites are strategically located on the property, as are 481 acres of land designated for open space, a wide variety of recreational uses and a network of trails that will connect to existing and planned trails throughout the community.
> http://www.inblackdiamond.com/see-our-plans/view-the-villages/ Accessed 11/24/15.



Source:http://www.bizjournals.com/seattle/blog/2015/12/new-partner-for-huge-master-planned-communities-in.html#i1 accessed 3/31/2016. Modified.

FIGURE A1. Aerial view of planned The Villages MPD and The Reserve at Woodlands subdivision.

The Reserve at Woodlands Development

The Black Diamond Urban Growth Area Agreement also identified open space lands in the city and in King County for protection. That agreement has been implemented with the majority of the open space conveyed through open space agreements. In 2009, an Open Space Agreement between King County and BD Village Partners, LP was approved where BD Villages would set aside more open space than required with the "4 to 1 Principle" as long as they would also have a development agreement to place the open space tracts as part of a rural clustered subdivision that would include the regional stormwater facility. The rural clustered subdivision is called the Reserve at Woodlands and 77 lots and homes will be built on lands previously managed as timberlands. The homes will be clustered to be located east of Crisp Creek and east of 218th Ave SE. Conceptual development plans have been developed. See Figure A2.

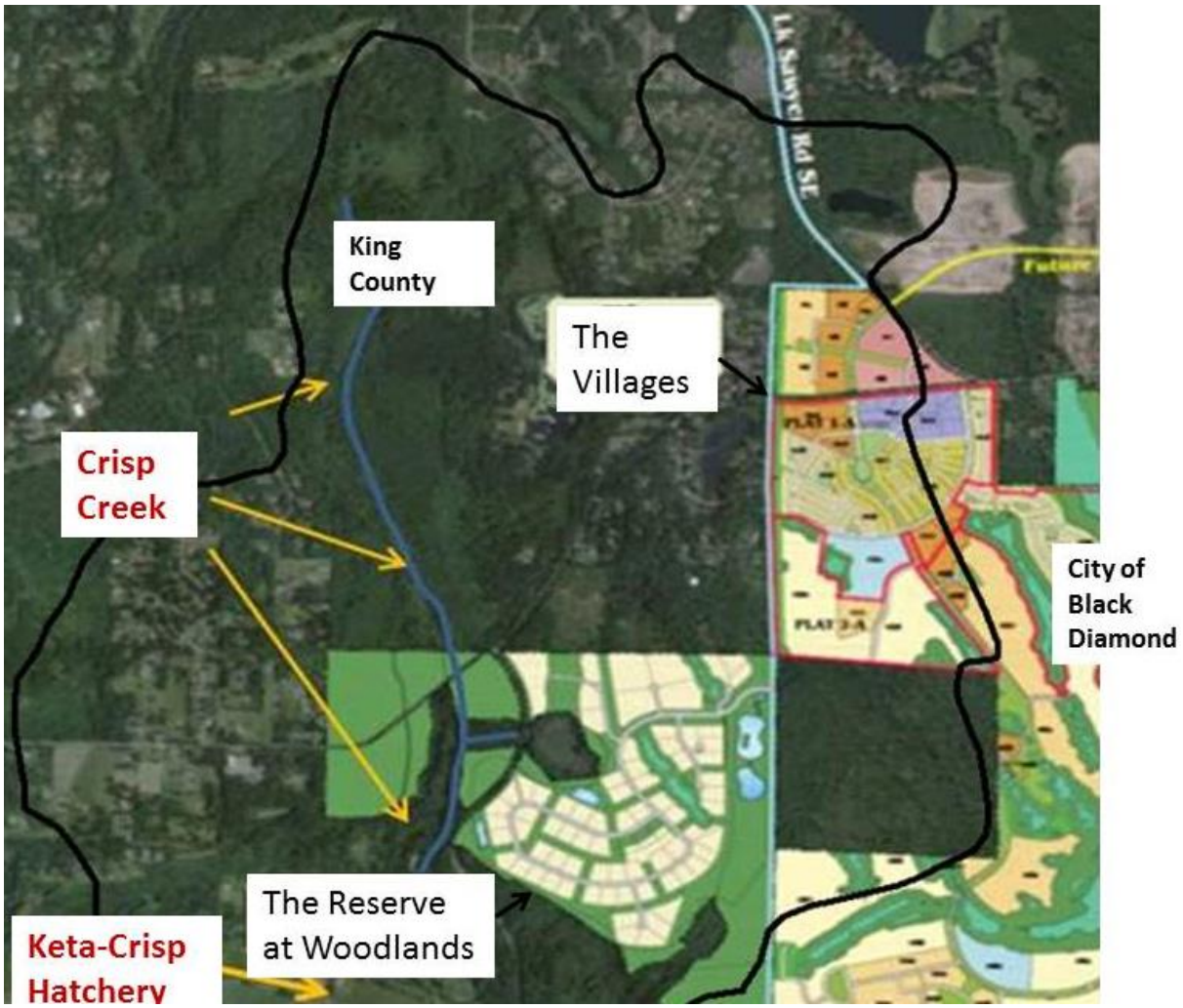


FIGURE A2. Conceptual site plan for The Reserve at Woodlands subdivision in the Crisp Creek watershed. Accessed and modified on 3/31/2016 from: *http://www.bizjournals.com/seattle/blog/2015/12/new-partner-for-huge-master-planned-communities-in.html#i1*

Tribal Fisheries Division representatives met with King County and BD Villages, LP and their consultants in 2014 to discuss issues of concern with the development as well as with the regional stormwater facility, a 40-acre storage and treatment facility (Figure A3). Regional stormwater from the Villages MPD within the Black Diamond city limits, stormwater from the Reserve at Woodlands, and flood waters from Horseshoe Lake will be diverted to the infiltration site of the facility, which is located in the NE quadrant of Section 21 in the Crisp Creek basin. The Tribe is very much concerned about the degradation of groundwater quality from the stormwater facility and contamination of the aquifer that supplies the Keta-Crisp Hatchery Complex. The facility lies within an area with a high susceptibility to groundwater contamination (Figure A4) and within an area of groundwater recharge to Crisp Creek .Concerns also exist that the wetland east of 218th Avenue SE which discharges into a tributary to Crisp Creek, could develop into another "Horseshoe Lake" flooding problem because the wetlands are also overlies a "till window" to the Qpog aquifer. Horseshoe Lake experiences high water levels during high rainfall winters that cause flooding of adjacent homes in the development.

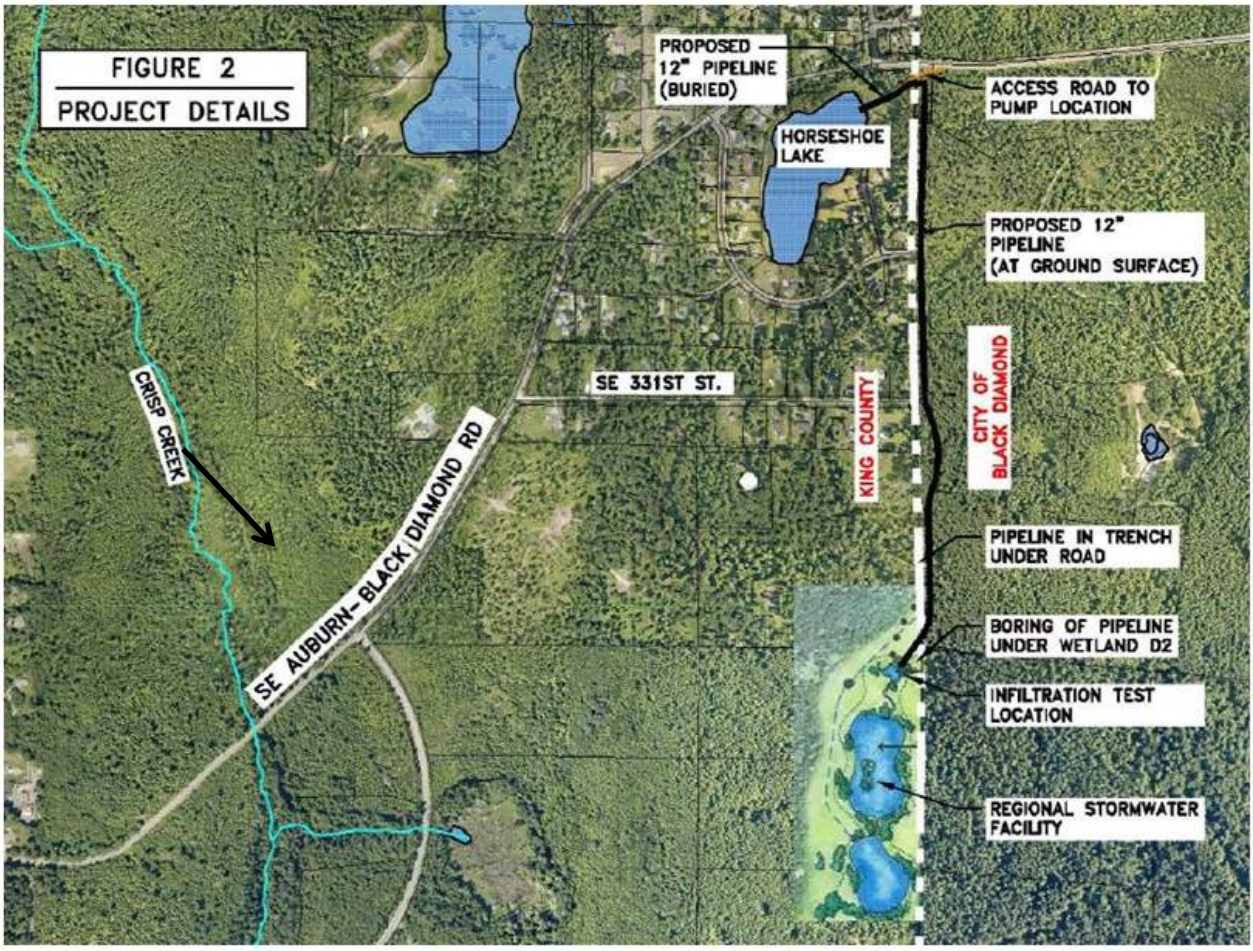


Figure A3. The Reserve at Woodlands is located in the Crisp Creek watershed in an important tributary basin (in Section 21) upstream of the hatchery intake. Source: Development Agreement between King County & BD Villages Partners, LP. Exhibit 7, p. 107

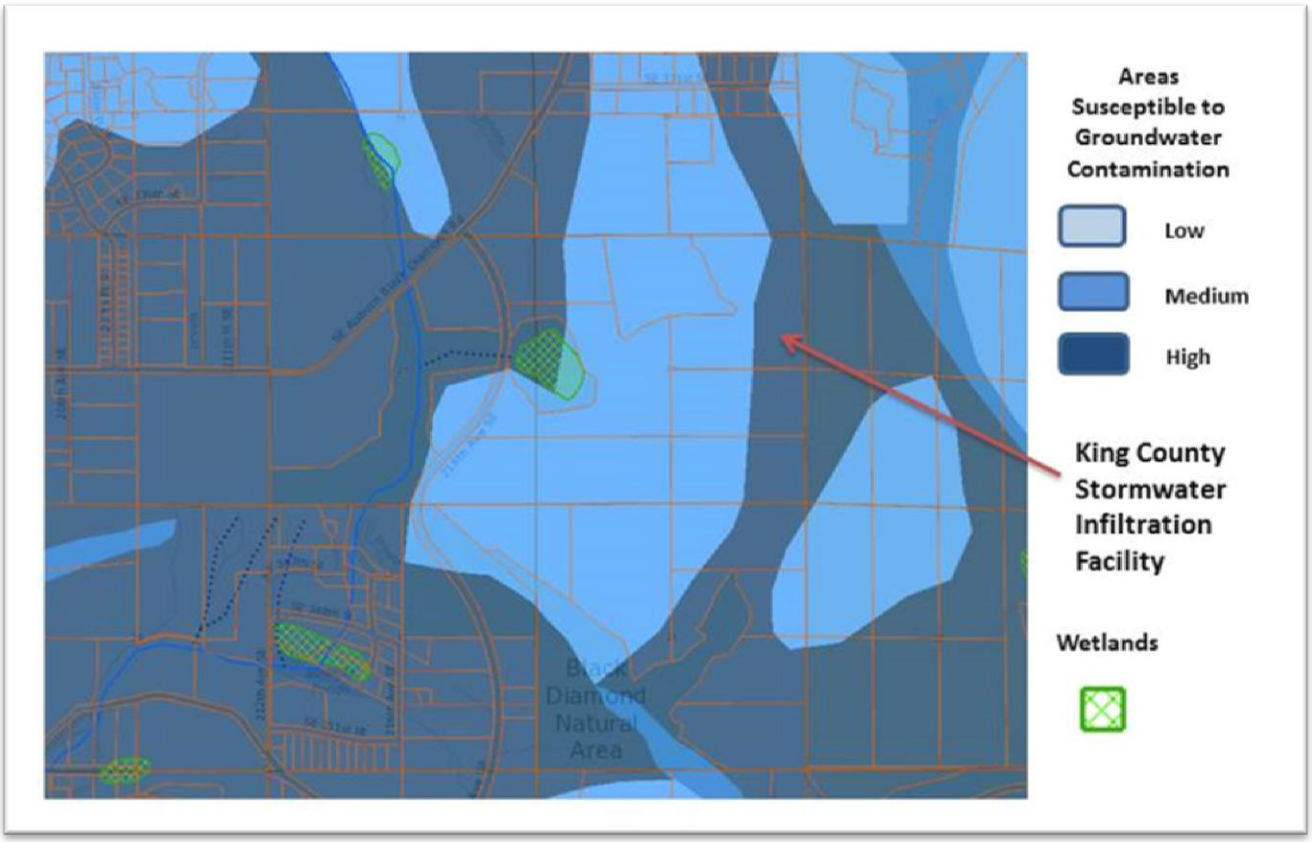


Figure A4. The King County Regional Stormwater Facility is located in an area of high susceptibility to groundwater contamination. Source: modified from https://gismaps.kingcounty.gov/iMap/

The project site for The Reserve at Woodlands includes several separate parcels (Figure A5). Parcels F6 – F11 will be developed as the Woodlands Development per agreements between BD Villages LP (aka Yarrow Bay, renamed Oakpointe) and King County. Parcels F1 to F4 are open space tracts that will be deeded to King County upon final plat map approval. Parcels F6 to F11 will be developed with a 77 lot clustered subdivision, stormwater facilities, county access easements, and small open space areas. Crisp Creek flows within the blue areas (except for the King County Roads Division parcel) which are also designated as Critical Areas due to landslide and erosion hazard risks and are part of the previously dedicated Black Diamond Natural Area.

Parcels F12 – F16 (Figure A6) will include residential lots and stormwater facilities (open space). F17 and F18 will be deeded to King County as open space. Crisp Creek flows within the blue areas and the parcels labeled "King County" are designated as Critical Areas due to landslide and erosion hazard risks and are part of the previously dedicated Black Diamond Natural Area.

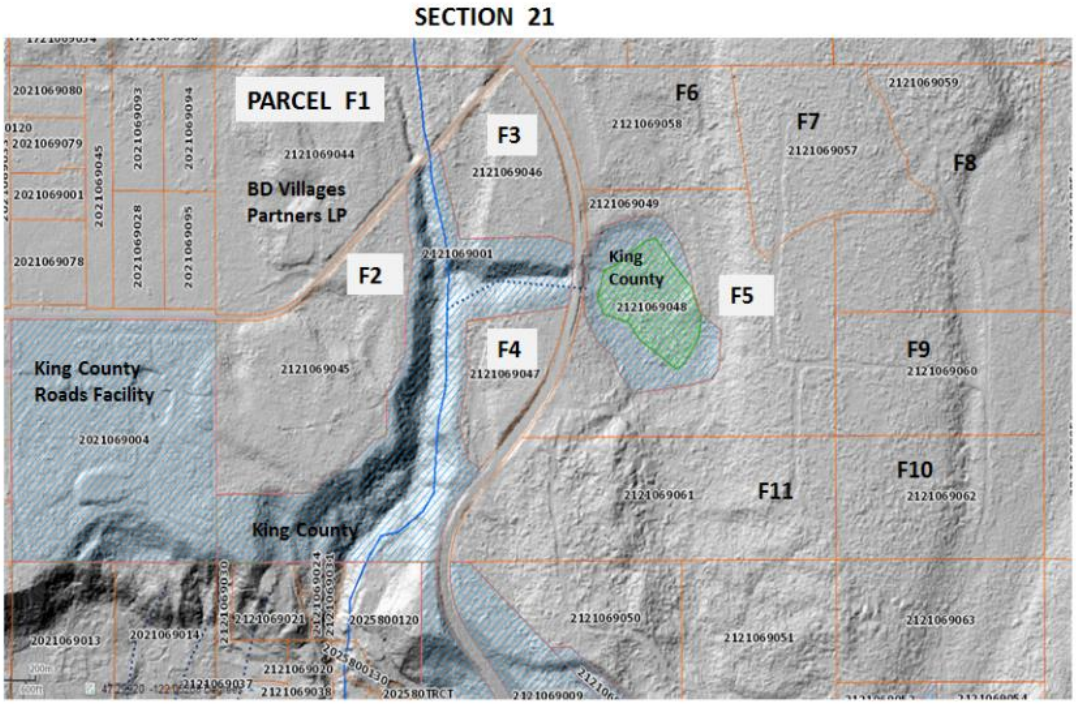


FIGURE A5. Parcels F1 to F11 comprise the lands that are included in The Reserve at Woodlands subdivision project, in Section 21 of Township 21N and Range 6E. Source: modified from https://gismaps.kingcounty.gov/iMap/ Accessed Nov. 2015.

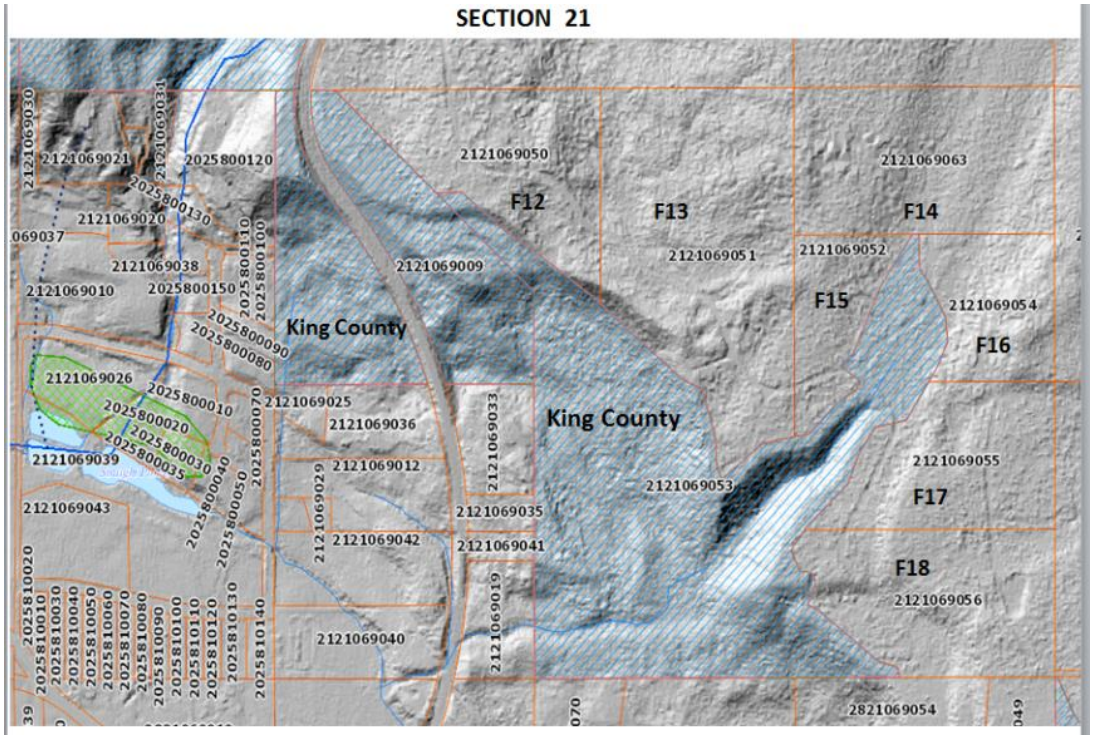


FIGURE A6. Parcels F12 to F18 comprise the lands that are included in The Reserve at Woodlands subdivision project, in Section 21 of Township 21N and Range 6E. Source: modified from https://gismaps.kingcounty.gov/iMap/ Accessed Nov. 2015.

Ridge at Lake Sawyer Division III

The Ridge at Lake Sawyer Division III is part of the large scale developments including the Ridge at Lake Sawyer Division I and II and the Meadows at Lake Sawyer. These previous subdivisions are located in the area west of Lake Sawyer and are contained mostly within the Covington Creek watershed. The original development proposal included a large 116 acre property previously owned by Plum Creek Timber Company and six or seven 20-acre parcels. The landowner subsequently sold four those tracts plus the large one and as discussed in the main report body, the large property is now being developed with roads and water transmission lines. The sphagnum bog which forms the headwaters of Crisp Creek are included in the 116 acre parcel. The current development has been downscaled to 15 lots. Representatives from the Tribe's Fisheries Division met with the previous owner and developer in 2013 to recommend mitigation measures to reduce impacts on Crisp Creek and the bog, a Class I wetland. Subsequently, a King County Hearing Examiner included those measures in the final project decision (L07P0018 Hearing Examiner Decision. Sept 4, 2013) as excerpted below:

18. The applicant has volunteered to the following conditions which shall be included in Covenant, Conditions, and Restrictions (CC&Rs) enforced by the Homeowners' Association. Conditions 18(b)-(d) shall also be shown on the final plat:

a. To distribute educational materials to homeowners regarding minimizing the use of pesticides, moss control, and fertilizers and information regarding available alternatives that protect fish and other aquatic life.

b. To restrict and not allow metal roofing on future residences. A note to this effect shall be shown on the final plat as well as the CC&Rs.

c. No logging will be allowed in the open space and critical area tracts. A note to this effect shall be shown on the final plat.

d. Future lot owners shall not be allowed to drill exempt irrigation wells on the lots. A note to this effect shall be shown on the final plat.

19. The existing well (vicinity of lot 15) shall be removed/decommissioned in accordance with DOE regulations.

Apparantly, issues with road access have put a hold on further development of the other parcels. A road north of the bog would involve filling of wetlands, a road from the west invovles crossing Covington creek and wetlands and access from the northwest and south would invovle agreements, or easements from multiple private landowners.

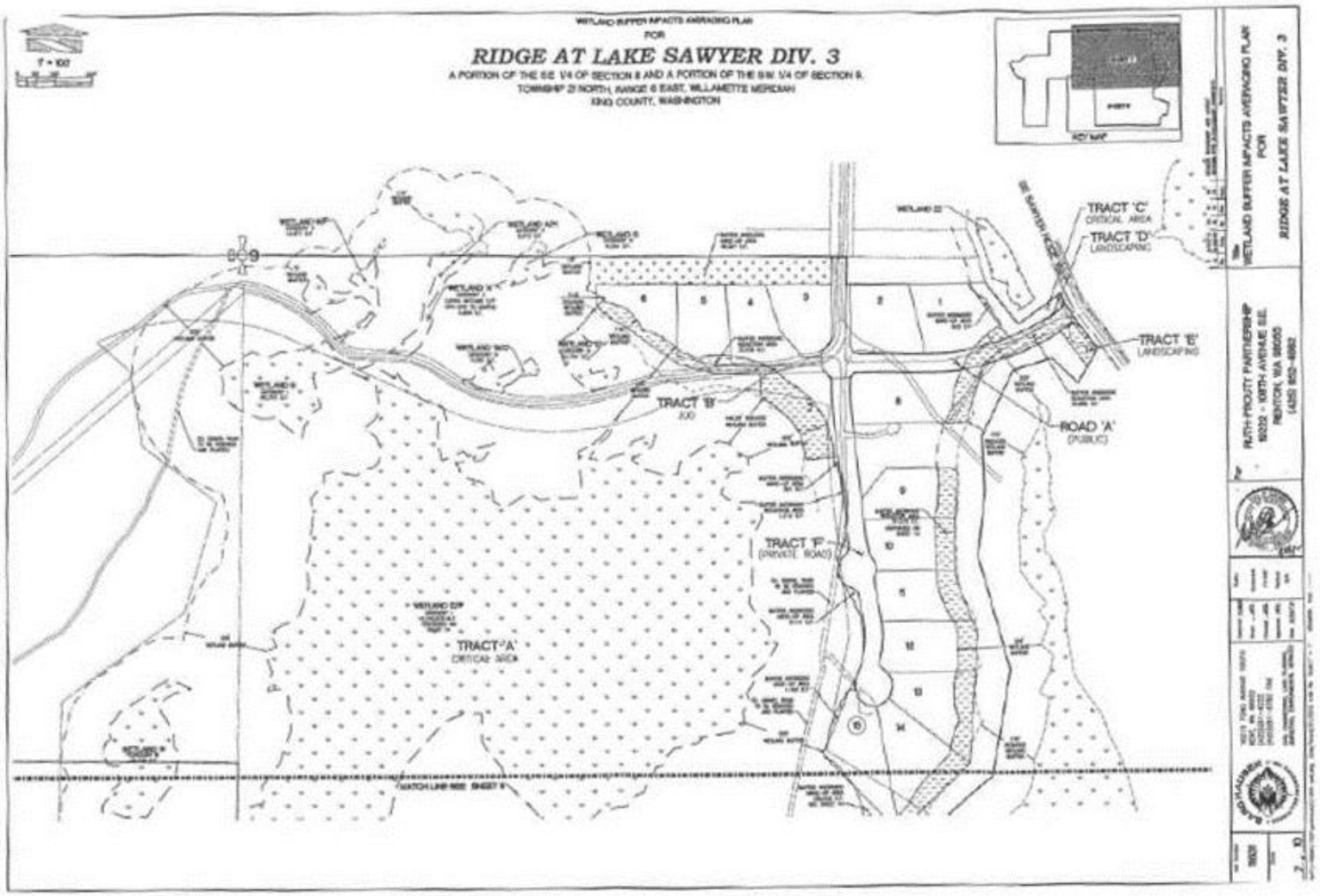


Figure A7. The Ridge at Lake Sawyer Division III preliminary plat plan. The 15 lot project is sited in the headwaters of Crisp Creek, Section 9 of Township 21N and Range 6E. Source: Plate 7 of 10, L07P0018 Hearing Examiner Decision. Sep 4, 2013). As of May 5, 2016, 8 lots with paved roads and water lines installed are advertised as for sale. Tract A is a high quality bog that forms the headwaters of Crisp Creek. T21N, R6E, Section 9.

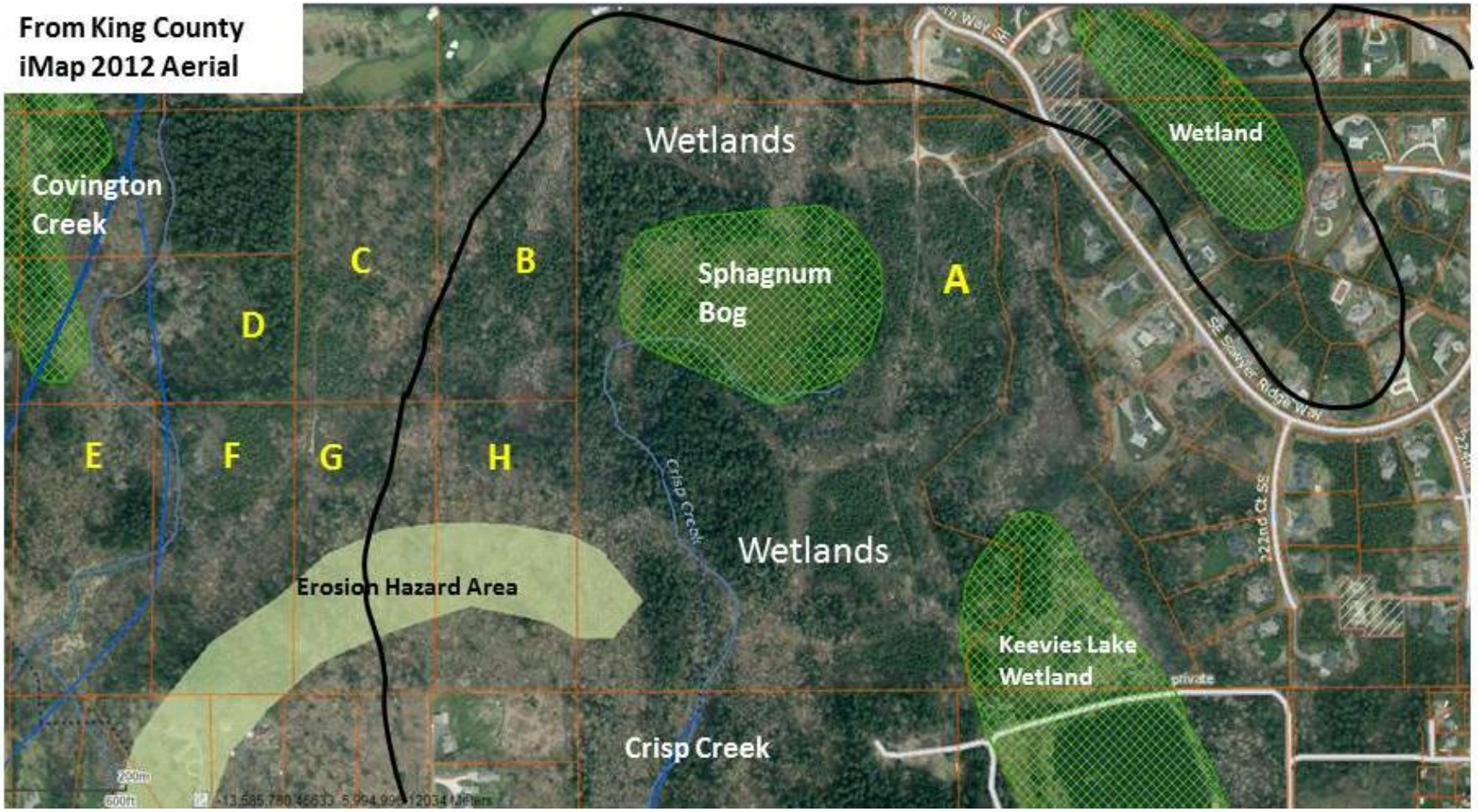


Figure A8. The Ridge at Lake Sawyer Division III parcel (A) and seven 20 acre parcels originally associated with the project (B through H). Parcel A is the largest at 116 acres. Parcels A, B, C, D, and F are currently owned by Barghausen Consulting, Inc. Parcels E, G, and H are owned by William Ruth. Development of parcels B and H pose a high risk to the water quality of Crisp Creek. Development of the remaining parcels could reduce water quality in Covington Creek. Source: modified from https://gismaps.kingcounty.gov/iMap/ 5-11-16.

APPENDIX B
WATER RIGHTS AND CLAIMS IN THE CRISP CREEK WATERSHED

TABLE B1. All water rights and claims in the Crisp Creek watershed, not including those associated with the Keta-Crisp Hatchery.

CERTIFICATES	SOURCE	SEC	Qi (cfs)	Qa (af/yr)	NAME	Priority Date	USE	Type
S1-14672CWRIS	SPRING	20	0.25	50	HIGGINS	1958	IRR	Con
S1-22591CWRIS	SPRING	21	0.05	3	SPAIGHT	1975	DM	Con
G1-23628CWRIS	SPRING	21	0.09	24	DSWA	1980	DM	Con
S1-22852CWRIS	SPRING	28	0.02	2	MATHERS	1977	DS	Con
S1-23057CWRIS	SPRING	28	0.06	4.5	W&S ENT.	1978	DM/FP	Con
S1-22591CWRIS	SPRING	20	0.05	3	SPAIGHT (Lynn)	1979	DM	Con
G1-25140CWRIS	WELL	17	12 gpm	4	SORTUN	1987	DM	Con
CLAIMS			**Qi (gpm)**	**Qa (af/yr)**				
G1- 124344CL	WELL	16	20	6	VALLEY SAND & GRAVEL	1974*	DM/IRR	Con
G1-086917CS	WELL	16	na	na	PATTISON	1974		Con
G1-087261CL	WELL	16	na	na	EVANS	1974		Con
S1-043382CL	CRISP CR	21	na	na	SCHMIDT	1915	IRR	Con
S1-043383CL	SPRING	21	na	na	DSWA	1915		Con
S1-043384CL	SPRING	21	na	na	DSWA	1915		Con
S1-040920CL	CRISP CR	21		50	SPAIGHT	1911	IRR	Con
G1-164086CL	WELL	20	10	6	SHANNON	1974	DM/IRR	Con
G1-054255CS	WELL	20	na	na	KROGSTADT	1974	DM/IRR	Con
G1-144840CS	WELL	20	na	na	CORBETT	1974	DM/IRR	Con
G1-020140CL	WELL	20	8	17.3	BUBLITZ		DM/IRR	Con
G1-002244CL	WELL	20	50	20	PHIPPS	1971	DM/IRR	Con
G1-001222	WELL	20	12	1	MANN	1971	DM/IRR	Con
G1-084663CS	WELL	20	na	na	SIMON		DM/IRR	Con

DSWA is Diamond Springs Water Assoc. IRR=Irrigation DM=Domestic Multiple DS Domestic Single FP= Fish Propagation Con= Consumptive Non= Nonconsumptive. Source: (https://fortress.wa.gov/ecy/waterresources/map/WaterResourcesExplorer.aspx) Accessed Jan. 2016

Table B 2. Group B water systems located within the Crisp Creek watershed as of 2016.

System Name	Section	# Connections Served	# Connections Approved
W&S #1	28	5	Undetermined
Valley View	20	6	Undetermined
Scott/Sorenson	20	4	4
Cascade View	20	0	Undetermined
Krogstadt	20	2	Undetermined
Valley Sand & Gravel	16	3	3
U-FIRS #2	17	2	2
Bingaman	21	2	Undetermined
Heady/Juerns	21	2	Undetermined

Source: https://fortress.wa.gov/doh/eh/portal/odw/si/Intro.aspx accessed 1/14&15/2016.