CRYSTAL SPRINGS

ZONE OF CONTRIBUTION

Crystal Springs Water District
Odell, Oregon

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Water Balance for the Crystal Springs Zone of Contribution

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1. INTRODUCTION

Crystal Springs is located on the northeast flank of Mount Hood, approximately 8.25 miles northeast of the summit (Fig. 1). Crystal Springs is the sole potable water source for the Crystal Springs Water District. Crystal Springs Water District supplies water to the residents of the upper Hood River Valley and the eastern half of the lower Hood River Valley. The district has 2,040 connections serving a population of approximately 5,000. For public water systems serving a population greater than 3,300 the *Oregon Wellhead Protection Guidance Manual* (Stewart and Nelson, 1996) recommends the development of a conceptual hydrogeologic model that incorporates site specific hydrogeologic information.

The area of interest is located on the flank of a stratovolcano composed of a complex assemblage of lava and pyroclastic[1] flows deposited on steep slopes dissected by ravines and canyons. In this setting the simplifying assumptions necessary to use simple groundwater flow models cannot be made due to:

- The complex geometry of the hydrogeologic units,
- The large hydraulic conductivity contrasts between the centers of lava flows and the broken and vesicular[2] tops and bottoms of the flows, soil horizons, and coarse channel deposits buried beneath the lavas and pyroclastic flows,
- The likely potential that groundwater flow will diverge from a general down-gradient direction due to heterogenities, and
- The probability that the vertical component of groundwater flow is significant.

The delineation of the Crystal Springs ZOC presented in this report is based primarily on hydrogeologic mapping and developing a geomorphic history of the study area. The determination of a regional groundwater gradient and flow direction, or the development of an analytical groundwater flow model to define a ZOC for Crystal Springs are not appropriate due to the complex volcanic geology of the area. The study area and the Crystal Springs ZOC are illustrated in Figure 2 (in the pocket).

2. PREVIOUS WORK

A 1963 CH_2M study did not purport to describe a zone of contribution for Crystal Springs, nor did it describe the geology in the vicinity of the springs (CH_2M, 1963). The CH_2M engineering study presents a design for new spring water collector pipes and control structures.

Lee Engineering prepared a report in 1991 that describes the recharge area for Crystal Springs as simply the topographic watershed of Crystal Springs Creek (Weygandt Canyon) (Lee Engineering, 1991). However, the report goes on to state that the source of Crystal Springs may not come entirely from Weygandt Canyon. No explanation is given in the report regarding what controls the occurrence of Crystal Springs.

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[1] Describing a clastic rock material formed by volcanic explosion or eruption from a volcanic vent.

[2] Containing many small cavities (vesicles) formed by the expansion of gas as the lava solidified, commonly associated with top and bottom of a lava flow.

AGI Technologies prepared a letter report in 1994 addressing whether the spring was influenced by surface water. AGI stated that they could not determine size and shape of the contributing area from their available information. Rather, the report hypothesized an estimated 2 to 3 square mile potential area of contribution. This study was based on a half-day site visit and the available published reconnaissance geologic mapping (Wise, 1969). The author of the letter report describes Crystal Springs as issuing from the base of the south wall of Weygandt Canyon.

Dennis Nelson, with the Oregon Health Division, proposed in a letter dated December 3, 2001 a recharge area for Crystal Springs that was based on the AGI Technologies potential recharge area (Nelson, 2001). Mr. Nelson moved the east boundary of the potential recharge area a short distance to the east to coincide with a contact between Quaternary and Pliocene lavas.

In summary,

- The CH_2M study did not attempt to define a zone of contribution,
- The Lee Engineering study states that the recharge area is Weygandt Canyon and possible other areas outside of the canyon,
- The AGI report states that the size and shape of the contribution zone could not be determined from information then available to it, and
- The Oregon Health Division recharge area is simply based on the AGI potential area of contribution.

The past work does not take into account the complex geology of the area, nor does it adequately explain the occurrence of Crystal Springs.

3. GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The geology of the Crystal Springs study area is presented in Figure 2. This geologic map is largely based on a 1995 U.S. Geological Survey (USGS) open-file report (Sherrod and Scott). The geology was field checked and revised by Mark Yinger, an Oregon Registered Professional Geologist. The three geologic cross-sections shown on Figure 2 were produced for this report. The reader should actively consult the geology map while reading this report. The following is a brief discussion of the regional geologic setting.

The study area is located within the High Cascade physiographic province. To the west is the Western Cascade physiographic province consisting of a thick, deeply eroded accumulation of andesitic and basaltic lavas, tuffs[3], and volcaniclastic[4] sediments (Miocene to Oligocene, 10-30 m.y.[5]). The outpourings of these volcanics built up broad, coalescing stratovolcanoes[6] concurrent with the subsidence of the Western Cascade Mountain range.

To the east is the Columbia Plateau physiographic province dominated by the extensive flood basalts of the Columbia River Basalt Group (Miocene, 6-17 m.y.). The Columbia River basalts

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[3] Tuffs are consolidated rocks composed of clastic material formed by volcanic explosion from a volcanic vent.

[4] Volcaniclastics are clastic rocks containing material of volcanic origin.

[5] Million years before the present.

[6] A stratovolcano is composed of alternating layers of lava and pyroclastic (rock fragments of explosive origin) deposits.

lapped onto the deeply eroded Western Cascades and flowed down ancestral Columbia River gorges, crossing the Western Cascades and reaching the Pacific Coast.

Beginning in the late Miocene (5-8 m.y.), volcanic eruptions from vents, generally aligned along the eastern flank of the Western Cascades, built up the early High Cascades platform. This platform consists primarily of low shield volcanoes[7] that filled large graben[8] structures, which developed as the roofs of the emptied magma chambers collapsed under the loading. The development of the current large stratovolcanoes (e.g. Mount Hood) of the High Cascades started in the Pleistocene (1.6 m.y.) and continues to the present. The basaltic and basaltic andesite volcanics of the stratovolcanoes were erupted onto a terrain having significant topographic relief. The lava flows were often confined within ancient stream valleys (paleo-valleys) eroded into the early High Cascade platform and older volcanics.

In the late Miocene through Pliocene epochs northwest-southeast compression in the region resulted in broad northeast trending folds[9], reverse faults[10] and thrust faults[11], and northwest trending strike-slip[12] and normal faults[13]. This group of tectonic features is known as the Yakima fold belt or structural belt. Mount Hood is located near the southern limit of this fold belt.

During the Pleistocene period the peaks of the High Cascades were subjected to extensive glacial erosion. Volcanic activity locally melted the ice packs resulting in lahars[14] flowing down deeply incised drainages on the flanks of the mountains.

The following description of the geology and hydrogeology of the study area generally proceeds from the oldest to youngest stratigraphic units in the study area.

3.1 Columbia River Basalt Group

Middle Miocene age (12-15 m. y.) flood basalts of the Columbia River Basalt Group are likely to underlie the entire study area (Wise, 1969). In the vicinity of Mount Hood, the Columbia River basalts flowed through a broad gap in the early Cascade Mountains. This gap is likely related to folding and downwarping transverse to the Cascades Mountain range. The folding was the result of north-south compression that occurred contemporaneous with the eruption of the Miocene Columbia River flood basalts.

The Grande Ronde (Tcgn) and overlying Frenchman Springs basalts are exposed along the base of the Hood River Fault scarp approximately 1.75 miles northeast of Crystal Springs, outside of the area covered by the study area map. These exposures occur on the east side of the north-south trending Hood River Fault zone. Intense fault breccia is evident in exposures near Highway 35. The east side of the fault is up-thrown relative to the west side of the fault.

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[7] A low broad volcano composed of overlapping and interfingering basaltic lava flows.
[8] A graben is an elongate block of earth or a crustal unit that is down dropped and bounded by two faults.
[9] A fold is bend in the bedding or planar feature of a rock unit, a downward bend is a syncline and an upward bend is an anticline.
[10] A break or fracture (fault) in rock in which the hanging wall has moved up relative to the footwall.
[11] A low angle reverse fault.
[12] A fault where the dominant movement is along the strike or trend of the fault line.
[13] A fault in which the hanging wall has moved down relative to the footwall
[14] A mudflow and resulting deposit of pyroclastic material on the flank of volcano.

3.2 Dalles Formation

The late Miocene to Pliocene age (7.7 m.y.) Dalles Formation (Td) overlies the Columbia River basalts (Sherrod and Scott, 1995). There is conflicting nomenclature associated with the Dalles Formation. Farooqui and others in 1981 formally proposed to replace the Dalles Formation with the Dalles Group consisting of the Chenoweth, Tygh Valley, Deschutes, Alkali Canyon and McKay Formations (Farooqui and others, 1981a). This was based on the recognition of distinct basins of deposition for each of these formations (Farooqui and others, 1981b). The Dalles Formation was renamed the Chenoweth Formation. This nomenclature has not been adopted by the USGS. The Dalles Formation as described by Newcomb (1969) will be used in this report instead of the Chenoweth Formation.

The Dalles Formation consists of a fan of indurated[15] volcaniclastic deposits that spread to the east and northeast filling the Dalles-Umatilla and Mosier synclinal basins developed in the Columbia River basalts. The source of the Dalles Formation volcaniclastic debris is now buried beneath Quaternary age volcanics of the Cascade Mountains. The contact between the Dalles Formation and the underlying Columbia River basalt is an erosional unconformity[16] with a moderate relief of approximately 100 feet, indicating a short period of time elapsed between the last Columbia River basalt flow and the deposition of the Dalles Formation (Piper, 1932). These volcaniclastic deposits consist of interbedded andesitic agglomerate and tuff breccia; andesitic and basaltic conglomerate and sandstone; tuffaceous sandstone and siltstone; and pumiceous lapilli tuff and lithic tuff. West of the Hood River Fault zone the Dalles Formation has been down faulted and largely buried beneath the Cascade volcanics. Wise (1969) has mapped the Dalles Formation as far west as the upper canyon of the Lake Branch of the Hood River. In the southeast corner of the study area the Dalles Formation appears to interfinger with andesite flows (Taef) which, further to the south, directly overly the Grande Ronde basalts. The Dalles Formation likely underlies most if not all of the study area.

East of the Hood River fault zone, in the northeast corner of the study area, the Dalles Formation exposure is 1,200 feet to 1,800 feet thick (Wise, 1969 and Newcomb, 1969). The folding of the Columbia River basalts that created the depositional basins continued during and after the deposition of the Dalles Formation resulting in broad, gentle, east-west trending folding of the Dalles Formation.

In the study area, west of the East Fork Hood River, the Dalles Formation is exposed in the streambed of Tilly Jane Creek and beneath lava flows that cap the steep slopes of lower Tilly Jane Creek. The Dalles Formation consists of gray to reddish-gray, massive to thick-bedded bouldery sandstone, pebbly sandstone and conglomerate. The feldspar minerals of the sand matrix and andesitic clasts have been altered to clay minerals. Fractures are sparse and tight. The sandstone and conglomerate have very low permeabilities. Due to the low permeability of the Dalles Formation springs commonly occur at its contact with overlying permeable, unconsolidated volcanic sediments and lava flows. The contact with the overlying Mount Hood

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[15] Soils and sediments hardened by compression, heat or cementation.

[16] An erosional unconformity is a surface between two rock units that represents a significant period of erosion or non-deposition.

volcanics is an erosional unconformity with significant relief that generally slopes to the north and northeast. The Dalles Formation is a low permeability formation that likely underlies most if not all of the study area.

3.3 Andesite of East Fork Hood River

The porphyritic[17], two-pyroxene andesite of East Fork Hood River (Taef) is exposed east of the Hood River Fault zone (Fig. 2). Sherrod and Scott (1995) describe these andesites as overlying the Columbia River basalts south of the study area (Robinhood Creek area) and as inter-fingering with the volcaniclastic strata of the Dalles Formation to the north, within the study area. Wise (1969) describes these early Pliocene (7 m.y.) two-pyroxene andesites as lava flows overlying the Dalles Formation and as intruding the Dalles Formation. He describes occurrences along the Highway 35 as "banked" against the Dalles Formation. Wise also suggests that the intrusive plug forming Shellrock Mountain, located approximately 2.25 mile east of Crystal Springs, was a source vent for the andesite of East Fork Hood River lava flows.

The occurrence of the andesite along the East Fork of the Hood River suggests that these flows may have filled a north-south paleo-valley cut in the Dalles Formation along the base of the Hood River Fault scarp. The stratigraphic relationship between the andesite of East Fork Hood River and the Dalles Formation is complex and suggests that intrusion and eruption of the andesite of East Fork Hood River was contemporaneous with the later period of Dalles Formation deposition. The distribution of the andesite of East Fork Hood River (Taef) also indicates that there was significant topographic relief eroded on the Dalles Formation.

The andesite of East Fork Hood River in the study area is exposed in road cuts along Highway 35. Here the greenish-gray andesite exhibits intense jointing and pervasive propylitic alteration. Faults exposed in the road cuts are marked by near vertical zones of intense brecciation and alteration (apparent strike east-west). Permeability is limited to fractures that vary from tight to open.

3.4 Other Miocene to Pliocene Volcanics

In the northwest corner of the study area, Sherrod and Scott (1995) have mapped a unit referred to as the volcaniclastic rocks of Middle Fork (Tvmf). This unit is described as consisting of tuff breccia, conglomerate and sandstone. This area was mapped earlier by Wise (1969) as the Dalles Formation.

In the southeast corner of the study area there is the andesite of Tumble Creek (Tatc) and the extensive overlying andesite flows of the Lookout Mountain volcanic sequence (Tlma). The bulk of Bluegrass Ridge, approximately 5 miles south of Crystal Springs, is composed of the Lookout Mountain volcanic sequence. The Lookout Mountain volcanics also cap the ridge east of the upper East Fork Hood River.

3.5 Basaltic Andesite and Basalt of Flag Point

The basaltic andesite and basalt flows of Flag Point (QTb) issued from vents at Flag Point and Frailey Point, and near Lookout Mountain. The age of these lava flows is late Pliocene to early

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[17] Describing an igneous rock containing conspicuous crystals (phenocryst) in a fine-grained groundmass.

Pleistocene (0.8 m.y.) (Sherrod and Scott, 1995). These lavas flowed in a radial pattern primarily to the north and east, down canyons cut into the Lookout Mountain volcanics, the andesite of East Fork Hood River, and the Dalles Formation.

A remnant of one of these flows forms the hill located 1.5 miles southwest of Crystal Springs. This hill lies between Tilly Jane Creek and Weygandt Canyon. Here after this hill will be referred to as the Evans Creek Quarry hill (Fig. 2). At this location, the Flag Point basaltic andesite rests on an erosional surface developed on the Dalles Formation. Based on the areal distribution of the Flag Point basaltic andesite, the erosional surface is likely to slope in a northerly direction. The contacts with surrounding younger Mount Hood volcanics appear to be quite steep and can be observed at the Evans Creek Quarry and on Cooper Spur Road (Fig. 2). This hill of Flag Point basaltic andesite was a prominent, steep sided hill around which the Mount Hood volcanics flowed.

East of the Hood River Fault scarp springs occur at or near the contact of Flag Point basaltic andesite flows with underlying Lookout Mountain volcanics and the Dalles Formation. These include Agnes, Stroud, Blue Bucket and Knebal Springs (located east of the area shown in Fig. 2). These springs occur where ancient stream channels, buried beneath the Flag Point volcanics, intersect the ground surface. In the study area the permeability of the light-gray aphanitic[18] Flag Point basaltic andesite is primarily due to blocky cooling fractures and possibly interflow zones. However, no interflow zones were observed. If multiple flows do compose Evans Creek Quarry hill they may be flow on flow, sharp contacts with low permeability.

3.6 Basaltic Andesite of Dog River

The basaltic andesite of Dog River (Qbdr) caps the ridge east of East Fork Hood River, approximately 3 miles southeast of Crystal Springs (Fig. 2). Here the basaltic andesite of Dog River appears to conformably[19] overlie the Flag Point lavas indicating that it is not much older than the Flag Point lava flows. The basaltic andesite of Dog River lava also flowed to the northeast down an incised canyon in the Dalles Formation.

3.7 Mount Hood Volcanics

Mount Hood is an andesitic composite volcano that has been an eruptive center from late Pleistocene to as recent as 180 to 250 years ago (Cameron and Pringle, 1987). Andesite and dacite lava flows compose the bulk of the cone. Interbedded with the lavas are pyroclastic and debris flows. The Mount Hood volcanics were deposited on an eroded and dissected surface of Pliocene to Miocene lava flows and volcaniclastic sediments (Dalles Formation). Sherrod and Scott (1995) divide the Mount Hood volcanics into two groups. The older group consists primarily of thick andesite lava flows that pre-date the Polallie eruptive event and compose the bulk of the mountain. The younger Polallie and post-Polallie deposits consist primarily of pyroclastic and debris flows.

Wise (1969) mapped the older volcanics in the study area as Quaternary Mount Hood andesite flows (Qha) and pyroclastics (Qhc). In the southern part of the study area, Sherrod and Scott

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[18] Describing a fine-grained igneous rock whose individual minerals are too small to identify with the naked eye.

[19] Said of a strata or layers of rock that are parallel or nearly so representing uninterrupted deposition.

(1995) have redefined a large area of the older volcaniclastics (Qhc) as the significantly younger Polallie pyroclastics (Qhpc).

3.7.1 Older Mount Hood Volcanics

The older andesite and dacite lava flows (Qha) in the study area filled paleo-valleys[20] and paleo-canyons. The steep ridge separating the lower section of Tilly Jane Creek from East Fork Hood River is largely composed of olivine andesite that filled a paleo-canyon cut in the Dalles Formation. Exposures of the olivine andesite have been mapped further to the south and southwest (Sherrod and Scott, 1995). The exposures indicate that the flow or flows filled a paleo-canyon located between Tilly Jane Creek to the northwest and Polallie Creek to the southeast. The olivine andesite is gray to dark-gray, with some outcrops exhibiting faint flow banding. Fine feldspar laths give a felted to faintly trachytic texture. When larger feldspar phenocrysts are present, they are often nearly equidimensional rather than lath like. The granular olivine is extensively altered to iron oxides. The majority of this flow is covered by Polallie pyroclastic debris.

The intracanyon olivine andesite lava flow (Qha) forms the 200 to 250-foot high cliffs on the east side of lower Tilly Jane Creek. Large diameter (4 to 5 feet) columnar jointing columns comprise the majority of the cliffs. The columns are notable for their vertical continuity, which allow rapid vertical movement of percolating groundwater. The upper portion of the flow exhibits intense conchoidal fracturing indicative of stress caused by movement late in the cooling and solidification the lava. The bottom of the flow is finely vesicular and the vesicles are irregular in shape.

The Dalles Formation (Td) exposed beneath these olivine andesite cliffs and in the bed of Tilly Jane Creek is a massive, pinkish-gray tuffaceous sandstone with angular to sub-rounded pebble to boulder sized clasts of weathered andesite. Immediately beneath the contact with the olivine andesite The Dalles Formation is baked a dark reddish-brown to a depth of approximately 10 feet. The feldspars of the sand and clasts are altered to clays.

The very low permeability of the Dalles Formation tuffaceous sandstone greatly retards downward movement of groundwater. As a consequence, large springs occur along the contact between the olivine andesite (Qha) and the underlying Dalles Formation. The Tilly Jane springs, occurring at the base of the cliff, are marked on the study area geology map, Figure 2. The total flow volume of these springs is approximately 1,100 gallons per minute (gpm) (see attachment). There is also a spring on the east side of the ridge (Fig. 2) that again occurs at the olivine andesite/Dalles Formation contact. The flow from this spring is approximately 900 gpm.

The older andesite flows, Qha, are also exposed in the western portion of the study area (Fig. 2). Here older andesite flows compose the ridge between Elliot Creek and Coe Creek. The older andesite lava flows have filled another deep paleo-canyon. The apparent thickness of the flows is 600 to 800 feet.

The early Mount Hood pyroclastics (Qhc) in the study area occurs as a lahar on the west side of Evans Creek Quarry hill (Fig. 2). The lahar rarely forms outcrops. However, the lahar is well exposed where Cooper Spur Road crosses Weygandt Canyon (Crystal Springs Creek). The lahar

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[20] Paleo- is a descriptive term meaning old or ancient.

consists of unsorted coarse sand, pebbles, cobbles and boulders in a gray matrix of fine sand, silt and clay. The contact between the lahar and the underlying basaltic andesite of Flag Point is exposed on Cooper Spur Road, approximately 2,000 feet south of Weygandt Canyon. Here there is a thin baked soil horizon indicating that the lahar was hot. The lahar appears to have filled a northeast trending paleo-canyon and then spread out as it emerged from the canyon. The axis of the buried canyon is likely to lie to the east of Weygandt Canyon (Fig. 3). The lahar appears to be moderately permeable. In the area underlain by the lahar, on the west side of Evans Creek Quarry hill, there is little evidence of surface runoff. It appears that precipitation readily percolates downward.

3.7.2 Basaltic Andesite of Cloud Cap

The basaltic andesite of Cloud Cap (Qbac) represents the last eruptive event in the study area prior to a hiatus in volcanic activity that ended with the Polallie eruptive event. Sherrod and Scott (1995) give an age of approximately 0.6 m.y for the Cloud Cap basaltic andesite based on potassium-argon dating. The basaltic andesite of Cloud Cap varies in color from light-gray, to dark-gray, to dark-reddish-gray. Fine laths of feldspar in a glassy groundmass give a pilotaxitic texture. The fine granular olivine is generally unaltered. The freshness of the olivine can help to distinguish the basaltic andesite of Cloud Cap from the older olivine andesite (Qha). The bottoms of the Cloud Cap flows are finely vesicular and the vesicles are very irregular in shape.

These basaltic andesite lavas erupted from a vent near Cloud Cap Inn and flowed down paleo-valleys to the north and northeast. These lavas flowed around both the west and east sides of Evans Creek Quarry hill. However, the bulk of the Cloud Cap basaltic andesite flowed down the paleo-valley on the west side of the Evans Creek Quarry hill. The much smaller volume of Cloud Cap basaltic andesite which flowed to the south and east of this hill is largely covered by Polallie debris flows. The Cloud Cap flows were confined to the east and west by ridges composed largely of the older olivine andesite (Qha).

The contact between the Cloud Cap lava flows (Qbac) and the underlying older pyroclastics (Qhc) is generally poorly exposed. The contact is exposed along Cooper Spur Road just north of where it crosses Weygandt Canyon. Here it is difficult to determine the attitude of the contact. Approximately 3,500 feet further to the north, the contact is well exposed in a cut made for an irrigation ditch above Evans Creek. At this location there is a 15-foot thick, reddish-brown baked soil horizon, and the contact between the Cloud Cap lava flows (Qbac) and older pyroclastics (Qhc) dips to the southeast.

Immediately to the north and to the northeast of Crystal Springs the early Cloud Cap lava flows filled a steep walled paleo-canyon whose axis in this area is generally parallel to the short northeast flowing section of the East Fork Hood River (Fig. 3). The steep bluff cut by the modern river exposes the intracanyon Cloud Cap basaltic andesite flows. The northeast flowing section of the East Fork Hood River coincides with a northeast trending lineament observed on aerial photographs. The lineament is likely a fault that ancient streams and the East Fork Hood River have followed.

At the base of the steep bluff approximately 500 feet northwest of the Highway 35 bridge over the East Fork Hood River, intensely fractured and hydrothermally altered (propylitic) andesite of East Fork Hood River (Taef) is exposed. Immediately overlying the andesite of East Fork Hood

River is a thin coarse gravel, which is in turn overlain by Cloud Cap basaltic andesite flows with interbedded gravels and bouldery gravels. To the west, along the base of the bluff, the andesite of East Fork Hood River disappears beneath Cloud Cap basaltic andesite flows. In this area there are springs and seeps along the base of the bluff for a distance of approximately 400 feet. These springs represent groundwater flowing from gravels buried in the bottom of the ancient canyon filled by the Cloud Cap basaltic andesite flows.

On the east side of Evans Creek Quarry hill the Cloud Cap basaltic andesite is well exposed, capping the slopes above Ash Creek and the west slope of the lower Tilly Jane Creek drainage. The Cloud Cap flow capping the west slope above Tilly Jane Creek was measured at 100 feet thick. The contact with the underlying Dalles Formation sandstone is well exposed where a small spring flows from the contact (Fig. 2). When this spring was first discovered in June the flow was approximately 50 gpm. By late July the flow had decline to approximately 5 gpm, and by late September the spring was dry.

There are numerous seeps along the west bank of Tilly Jane Creek between Highway 35 and the confluence with Doe Creek. The flow from these seeps likely represents groundwater flowing primarily from the Cloud Cap/Dalles Formation contact. Ground water flowing from this contact flows down of the steep, relatively impermeable Dalles Formation surface and emerges as seeps from colluvium[21] at the base of the slope. There are many small active landslides along the west slope of the lower reach of Tilly Jane Creek. The Cloud Cap/Dalles Formation contact acts as a spillway, in that during the spring, when the groundwater level in the Cloud Cap volcanics and unconsolidated volcaniclastics is high, groundwater flows over the spillway. By late summer the groundwater flow over the spillway (Cloud Cap/Dalles Formation) has declined to very little as a result of the decline in the groundwater level in the permeable materials that fill the paleo-valley to the west.

To the north of Tilly Jane Creek, the Cloud Cap basaltic andesite thickens towards Crystal Springs. The elevation of its contact with the underlying Dalles Formation drops steadily toward the north. Ash Creek is essentially a spring creek. It is fed by springs (900 to 1,000 gpm) that occur at the Cloud Cap basaltic andesite /Dalles Formation contact. The springs are on the south slope, 20 to 80 feet above the valley bottom (Fig. 2). These springs occur on the south slope of the valley. This is because the south side of the valley is the up-dip side relative to the Cloud Cap basaltic andesite /Dalles Formation contact, and it is the up gradient side relative to groundwater flow. Approximately 900 feet up the Ash Creek valley a small cliff (25 feet high) composed of Cloud Cap andesite crosses the drainage. It is apparent that water rarely flows over this cliff.

The Stillwell well is a 200-foot deep water well located approximately 1,800 feet west of the Ash Creek springs (Fig. 2). Here the Cloud Cap basaltic andesite is approximately 90 feet thick and overlies at least 100 feet of gravels. As described above, the early Cloud Cap lava flowed down a paleo-valley on the west and north sides to Evans Creek Quarry hill, filling and blocking the lower end of the paleo-valley on the east side of the hill. Volcaniclastic sediments then filled the upper (southern) portion of this blocked drainage. These volcaniclastic sediments are the water bearing gravels encountered in the Stillwell well. Eventually, near the end of the Cloud Cap eruptive event, lavas capped the coarse sediments that had partially filled the drainage on the east

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[21] Colluvium is a deposit of loose material that has fallen to the base of a slope or cliff.

side of Evans Creek Quarry hill. These permeable, coarse sediments overlie the Dalles Formation, which has a very low permeability.

The thin basaltic andesite lava flow exposed along Cooper Spur Road between Doe Creek and Tilly Jane Creek, mapped as questionable Cloud Cap basaltic andesite by Sherrod and Scott (1995), appears to be contained within the Polallie debris deposits. A fragment of this same flow is observed approximately 2,400 feet further down Tilly Jane Creek, near the top of the east slope of the drainage (Fig. 2). It is likely that the material directly beneath the thin lava flow is actually older, weakly indurated debris associated with the Cloud Cap eruptive event. The thin basaltic andesite flow observed on Cooper Spur Road, and further down Tilly Jane Creek, is one of the last lava flows of the Cloud Cap eruptive event. This lava flowed down a broad, shallow channel in the sediments that had accumulated in the drainage on the east side of Evans Creek Quarry hill. The thin basaltic andesite flow was later cut by stream erosion into isolated pieces that were eventually surrounded and buried beneath Polallie debris. Distinguishing the Polallie debris from older, unconsolidated to weakly indurated and poorly sorted deposits can be problematic due to the similar composition and degree of weathering of their clasts.

The Cloud Cap basaltic andesite outcrops exhibit a variety of cooling fracture styles. The flow centers generally have irregular blocky fracturing and the tops and bottoms are fractured into thin conchoidal plates. The fractures are open. The openness of the fractures is in part due to movement that occurred during the late stages of cooling and solidification of the lavas. The outcrops northeast of Crystal Springs exhibit a variety of cooling fractures that include small diameter columns that radiate from cooling points and irregular loose blocks that range from several feet in diameter to fist size. These fractures are open. Generally the Cloud Cap basaltic andesite lava flows are quite permeable and water will readily percolate through them.

3.7.3 Polallie Pyroclastic Flows and Debris Flows (Qhpc)

Polallie pyroclastic and debris flows cover a large portion of the study area to the south and east of Evans Creek Quarry hill (Fig.2). The Polallie eruptive event occurred during the Fraser glaciation dated by Crandell at 12,000 to 15,000 years ago (1980). Sherrod and Scott (1995) suggest that the Polallie debris flows occurred approximately 20,000 years ago when the Fraser-age glaciers had reached their maximum extent. The Polallie debris flows are composed of unconsolidated, unsorted, subangular to subrounded andesitic pebbles, cobbles and boulders in a matrix of gray to buff colored sand. Much of the area mapped as Polallie debris flows include deposits of Polallie material that have been reworked and deposited by glaciers and streams. The reworked deposits are poorly sorted and exhibit very thick bedding indicative of deposition in a high-energy environment. The Polallie debris deposits are very permeable.

3.8 Structural Geology

Folding and faulting of the older rocks in study area is largely obscured by the overlying, relatively recent Mount Hood volcanics. As mentioned earlier, evidence of faulting can be observed in limited exposures of the andesite of East Fork Hood River along Highway 35.

The inferred north trending Hood River Fault is shown on Figure 2 (Sherrod and Scott, 1995). The Hood River Fault is a major fault that runs along the east side of the Hood River Valley.

The west side of the fault is downthrown. The scarp on the east side of the fault is approximately 1,000 feet high and is evidence of significant vertical movement on the fault.

The Hood River Fault in the study area is essentially buried beneath the Mount Hood volcanics, which it does not cut. The Hood River Fault cuts the Dalles Formation, however, in the study area no direct evidence of the fault was observed. Exposures of the Dalles Formation are limited in the vicinity of the inferred fault. The Hood River Fault is certain to have influenced the course of ancient streams that cut down into the andesite of East Fork Hood River and the Dalles Formation.

An inferred northeast trending fault is shown on Figure 2 passing just north of Crystal Springs. This is the projection of a lineament[22], visible on aerial photographs, to the east of the East Fork Hood River where it appears to cut the andesite of East Fork Hood River and the Dalles Formation. This fault may have offset the Hood River Fault as shown on Figure 2. This fault influenced the course of the short, northeast flowing section of the East Fork Hood River located to the northeast of Crystal Springs. This northeast trending fault also controlled the lower portion of the paleo-canyon, located on the north side of Evans Creek Quarry hill, that is buried beneath the early Cloud Cap basaltic andesite flows (Fig. 3).

4. CONCEPTUAL HYDROGEOLOGIC MODEL

Ground water in the vicinity of Mount Hood will flow in radial pattern away from the summit. This pattern essentially mimics the volcanic stratigraphy of the stratovolcano. This simple model becomes very complex when the details of the volcanic stratigraphy are considered. The hydrogeologic setting can be generally characterized as heterogeneous, and dominated by preferred flow paths. Examples of preferred flow paths are: eroded drainages and canyons, intracanyon flows, the very porous and permeable top and bottom of individual lava flows (interflow zones), and permeable gravels deposited in canyon and drainage bottoms buried beneath lava and pyroclastic debris flows.

There are three factors that are critical to the occurrence of Crystal Springs and the other springs in the study area: 1) the low permeability of the tuffaceous sandstone and conglomerate of the underlying Dalles Formation effectively retarding the downward movement of groundwater, 2) the topography of the Dalles Formation buried beneath the permeable Mount Hood volcanics, and 3) the high permeability of the Mount Hood volcanics. Coarse channel gravels deposited in the bottom of buried paleo-valleys cut into the Dalles Formation and older volcanics influence the flow of percolating groundwater, providing preferential groundwater flow paths. The intervening highs of the Dalles Formation act as buried groundwater flow divides.

4.1 Crystal Springs

Crystal Springs occur near the base of a slope on the south side of Crystal Springs Creek valley (AGI, 1994 and CH_2M, 1963). The spring is located approximately 1,200 feet up the valley from where Crystal Springs Creek crosses Highway 35. Crystal Springs occurs where the bottom of a paleo-valley, cut into the low permeability Dalles Formation and buried beneath the permeable

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[22] A lineament is a local or regional, linear topographic feature such as a fault line or a straight stream course.

Cloud Cap basaltic andesite and associated volcaniclastic sediments, intersects the south wall of Weygandt Canyon.

Precipitation readily percolates through the Polallie debris flows, Cloud Cap lava flows and underlying unconsolidated volcaniclastics to the watertable. The unconfined aquifer that supplies Crystal Springs and Ash Creek spring consists of the permeable Cloud Cap basaltic andesite and the underlying unconsolidated volcaniclastic sediments that filled a northerly trending paleo-valley that was eroded into the Dalles Formation. The axis of this filled paleo-valley lies between Ash Creek spring and the east base of Evans Creek Quarry hill and probably extends far up Mount Hood. The probable axis of this buried paleo-valley is shown on Figure 3. Very permeable coarse gravels buried in the bottom of this paleo-valley provide a preferential groundwater flow path to Crystal Springs.

The hydraulic properties of the unconsolidated volcaniclastic sediments that filled the upper portion of the paleo-valley during the Cloud Cap eruptive event will vary spatially depending on: changes in degree of sorting, grain orientation, percentage of fines, bedding, facies changes, and coarse channel deposits contained within the valley fill. Ground water will also preferentially flow along the broken and vesicular bottom of individual Cloud Cap lava flows.

Crystal Springs occurs just south of the intersection of two buried paleo-valleys (Fig. 3). Crystal Springs likely also receives a groundwater contribution from the buried paleo-valley located on the west and north sides of Evans Creek Quarry hill (Weygandt Canyon).

4.2 Springs Related to Crystal Springs

Ash Creek Spring

The Ash Creek spring occurrence is analogous to Crystal Springs. It also occurs at the contact of the Cloud Cap basaltic andesite with the low permeability Dalles Formation. Ash Creek spring is up gradient of Crystal Springs and is fed by the same unconfined aquifer. Like Crystal Springs, the Ash Creek spring occurs on the south slope of the drainage.

Spring Creek Below Highway 35

Immediately east of Highway 35, and approximately 300 feet south of the Crystal Springs Creek culvert beneath the highway, are several springs (1,200 gpm). These springs are the source of an unnamed spring creek. Here groundwater flows from fractured andesite of East Fork Hood River (Taef). Above these springs the andesite of East Fork Hood River is exposed in the cuts made for Highway 35 and the access road to Crystal Springs. The fractures are very open. The andesite of East Fork Hood River was likely exposed in the bottom of the buried paleo-valley immediately south of Crystal Springs and in the buried paleo-canyon just to the north of Crystal Springs. It is likely that groundwater from the same aquifer supplying Crystal Springs flows through the fractured andesite of East Fork Hood River and discharges at the springs below Highway 35. Therefore, the springs below Highway 35, which are down gradient of Crystal Springs, are hydraulically connected to Crystal Springs.

Down Gradient Springs

There are other springs down gradient of Crystal Springs, to the northeast, that are associated with the buried paleo-valley located on the west and north sides of Evans Creek Quarry hill (Weygandt Canyon) (Fig. 2 and 3). Where these springs occur the paleo-valley narrows to a steep-walled canyon. The much older andesite of East Fork Hood River forms the bottom of this paleo-canyon. The paleo-canyon was filled by early Cloud Cap basaltic andesite lava flows. The north wall of this ancient canyon consists primarily of the lahar of the older Mount Hood volcanics (Qhc). There are springs at the base of the steep bluff north of the East Fork Hood River. The volume of water flowing from these springs could only be measured in one place. The measured flow was 180 to 220 gpm. The total flow is certain to be greater than the measured flow. There is likely to be significant subsurface flow directly into recent Hood River alluvium. It is probable that Weygandt Canyon is a recharge area for these springs. Ground water from the buried paleo-valley immediately south of Crystal Springs may also contribute to these down gradient springs (Fig. 3).

The total annual outflow from Crystal Springs and associated springs is approximately 6,000 gpm. This is the sum of the flows for: Crystal Springs, Ash Creek spring, the spring creek below Highway 35, and the springs at the base of the steep bluff northeast of Crystal Springs. This flow volume is considered a minimum. There is certain to be flow that was not observed, and therefore not measured. These flows are based on measurements made by the project hydrologist, Edward Salminen (see attachment).

4.3 Tilly Jane Springs

The large springs (1,900 gpm) of lower Tilly Jane Creek are very similar to Crystal Springs and Ash Creek spring in that they also occur at the contact between the low permeability Dalles Formation and overlying permeable volcanics. The overlying unit at the Tilly Jane springs is the older Mount Hood andesite lavas (Qha). By late summer these springs provide almost all of the flow observed in Tilly Jane Creek at Highway 35.

4.4 Weygandt Canyon

Weygandt Canyon is an anomalously narrow drainage located between Tilly Jane Creek and Evans Creek (Fig. 2). Headward erosion by Tilly Jane Creek and Evans Creek has reduced and will continue to reduce the size of the Weygandt Canyon basin. This is one reason why there is very little evidence of significant surface flow in the canyon bottom. Another reason for lack of surface flow is likely related to the contact between the Cloud Cap volcanics (Qbac) and the underlying pyroclastic and debris flows (Qhc, lahar). For much of its length the canyon bottom approximately follows this contact. The bottom of the Cloud Cap lava flows are very permeable and water will readily percolate down the contact zone. The contact slopes to the west and northwest into the paleo-valley on the west and north sides of Evans Creek Quarry hill that was filled by the Cloud Cap volcanics. A significant portion of percolating groundwater in Weygandt Canyon may preferentially flow down the Cloud Cap/Qhc contact eventually reaching the permeable channel deposits in the bottom of this buried paleo-valley.

No surface water was observed in Crystal Springs Creek above the spring, or in the bottom of Weygandt Canyon. The evidence of past surface water flow in Weygandt Canyon is very minimal suggesting that surface water flow rarely occurs.

5. CRYSTAL SPRINGS ZONE OF CONTRIBUTION

The zone of contribution (ZOC) for Crystal Springs is the area in which groundwater will eventually flow to Crystal Springs and related springs. The boundary of the Crystal Springs ZOC is marked on Figure 2: Geologic Map – Crystal Springs Study Area, which is contained in the pocket of this report. The ZOC boundary is based on the conceptual hydrogeologic model and supporting data presented in preceding sections of this report.

The east boundary, starting at Crystal Springs, follows the Cloud Cap volcanics/Dalles Formation contact to a point approximately 8,500 feet south in the incised Tilly Creek drainage. From here the boundary curves to the southwest and follows a divide between buried paleo-valleys. From just north of the Cooper Spur Ski area the ZOC boundary generally follows the divide between the Doe Creek and Tilly Jane Creek and then further up the mountain it follows the divide between Polallie Creek and Tilly Jane Creek.

The west boundary of the ZOC generally follows the divide between Weygandt Canyon and Evans Creek, and higher up the mountain the divide between Tilly Jane Creek and Elliot Creek.

6. SUSCEPTIBILITY

Susceptibility is a qualitative or quantitative evaluation of the potential that contaminants released at or just below the surface will impact the aquifer supplying the spring. In general, the Mount Hood volcanics overlying the Dalles Formation are permeable and groundwater is unconfined, therefore groundwater within the ZOC is considered susceptible to contaminant impact.

An area of particular concern is the area directly up gradient (south) of Crystal Springs. This area lies between Evans Creek Quarry Hill and the eastern boundary of the ZOC, and extends south to Tilly Jane Creek. Precipitation readily percolates through the soils in this area, developed on Polallie debris flows and Cloud Cap lava flows. These soils are mapped as the Hutson sandy loam and Yallani stony loam and described has having moderately rapid permeability (USDA, 1981).

The logs for five water wells in the area generally describe sand and boulders with minor clay overlying a Cloud Cap lava flow with unconsolidated to weakly consolidated sand and gravel beneath (well logs in appendix). No significant low permeability units or aquitards are described. Reported static water levels in four of the wells varies from 90 feet to 140 feet beneath the surface. During this study the water level in the Stillwell well was monitored. Between late May and late October the water level in the Stillwell well dropped from 60.75 feet to 84.92 feet beneath the top of the casing (the well is used very little). This 24.17 foot seasonal change in the water level is an indication that the unconsolidated volcaniclastic sediments beneath the Cloud Cap lava flows is an unconfined aquifer. It is probable that the water level in the Stillwell will continue to drop until late in the year, and then begin rise in direct response to recharge from winter and spring precipitation and snow melt. A close correlation between water level fluctuations in the well and seasonal changes in precipitation indicates that rain and snow melt water that percolates into the soil migrates rapidly to the watertable.

The Shaw, Aarno and Spaziani wells, located just north of the junction of Cooper Spur and Cloud Cap roads, encounter groundwater apparently confined beneath a basaltic andesite lava flow (Fig. 2). Geologic mapping in the area indicates that the confining basaltic andesite Cloud Cap flow has a limited lateral extent. Thus the aquifer is likely only locally confined or semi-confined. Clayey beds of relatively low permeability, that may occur within the volcaniclastic sediments beneath the Cloud Cap lava flows are also likely to have limited lateral extent. Fine grained beds may grade laterally into permeable channel deposits. Like the Stillwell well, the water levels in the Shaw, Aarno and Spaziani wells are expected to fluctuate significantly in response to seasonal changes in precipitation. There are no measurements of seasonal water level fluctuations for these wells.

A test well was drilled for Mt. Hood Meadows Ski Resort in September 2001. The test well is located 900 feet southeast of the junction of Cooper Spur and Cloud Cap roads (Fig. 2). This test well is also approximately 900 feet east of the ZOC boundary. The 300-foot deep test well encounters 285 feet of unconsolidated sediments consisting of coarse gravels and boulders, including four zones of clayey gravels (Appendix). The bottom 15 feet of the boring encountered Dalles Formation conglomerate. Static water levels taken as the boring was advanced dropped markedly with depth. This indicates that groundwater flow has a strong downward vertical component. Contaminants transported by percolating water to the watertable will migrate to deeper aquifers.

7. REFERENCES

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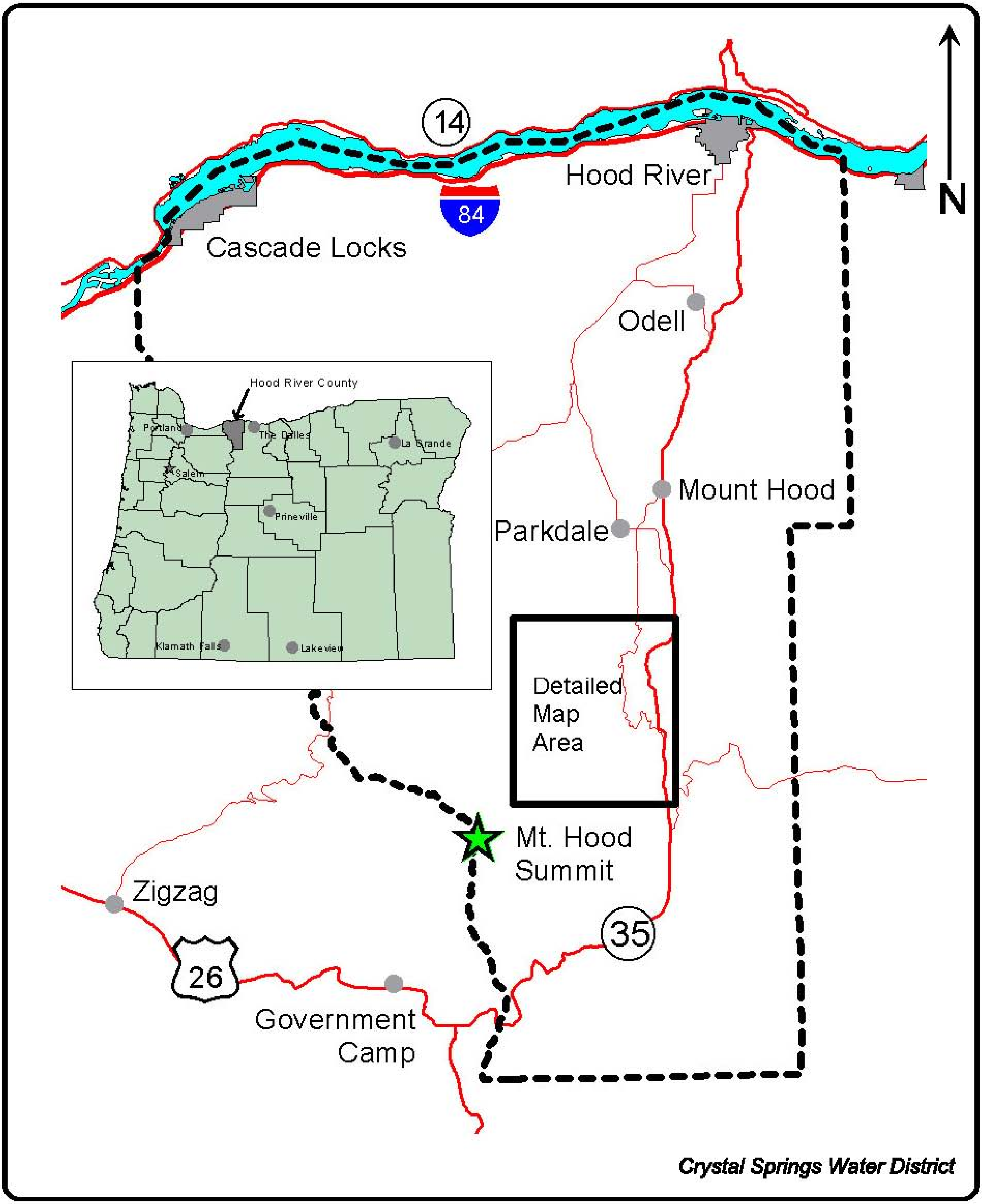
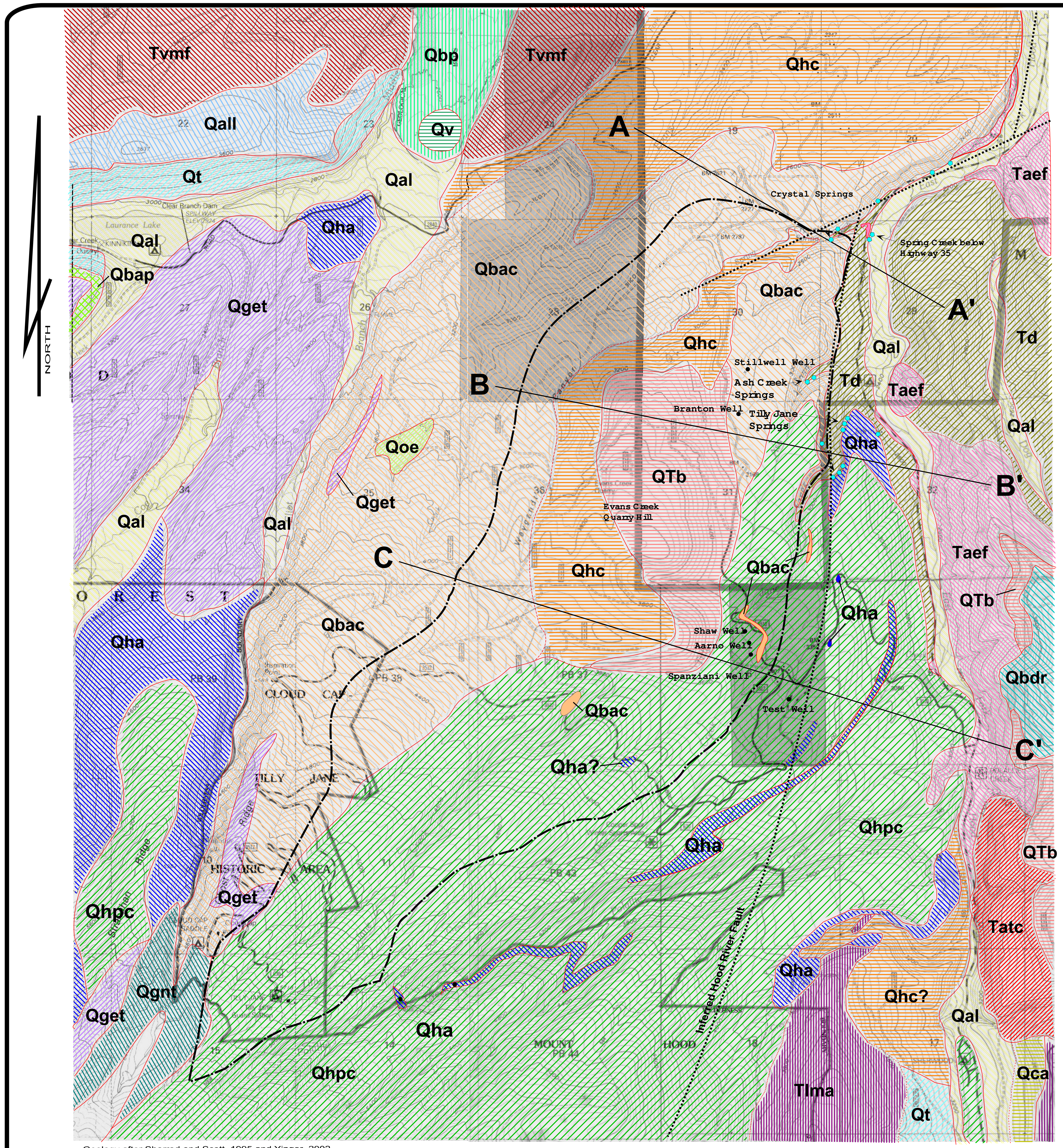


Ground water & Environmental Consultants
Mark Yinger Associates
4865 Baseline Road, Parkdale OR, 97041 - 541-352-6015

Figure 1
Site Location Map

Groundwater & Environmental Consultants
Mark Yinger Associates
4865 Baseline Road, Parkdale OR, 97041 - 541-352-6015



Geology after Sherrod and Scott, 1995 and Yinger, 2002.
Base map: USGS Mt. Hood North and Dog River 7.5 minute quadrangles

- ▨ Qal : Quaternary alluvium
- ▨ Qca : Colluvial and alluvial slope deposits
- ▨ Qt : Talus
- ▨ Qgnt : Till of neoglacial age
- ▨ Qget : Till of Evans Creek
- ▨ Qoe : Outwash of Evans Creek
- ▨ Qv : Cinder cone or small volcano
- ▨ Qbp : Basaltic andesite lava of Parkdale
- ▨ Qhpc : Polallie pyroclastic-flow and debris-flow deposits, includes older volcaniclastic deposits associated with the Cloud Cap eruptive event
- ▨ Qbap : Basaltic andesite of The Pinnacle
- ▨ Qbac : Basaltic-andesite lava of Cloud Cap
- ▨ Qhc : Pyroclastic and debris flows, undifferentiated
- ▨ Qha : Andesite and dacite lavas, undifferentiated
- ▨ Qall : Andesite lava of Laurance Lake
- ▨ Qbdr : Basaltic andesite lava of Dog River
- ▨ QTb : Basaltic andesite and basalt lava flows of Flag Point (0.8 m.y.)
- ▨ Tatc : Andesite lava of Tumble Creek
- ▨ Tlma : Andesite lava with interlayered oivine basalt flows of Lookout Moutain
- ▨ Tvmf : Volcaniclastic rocks of Middle Fork of Hood River
- ▨ Taef : Andesite lava flows of the East Fork Hood River (7-8 my)
- ▨ Td : The Dalles Formation, andesitic volcaniclastics conglomerates, sandstones, siltstones, tuff breccia (7.8 my)
- ▨ Tcgn : Grande Ronde Basalt, not exposed at surface
- ⋯ Inferred Fault
- —·— Boundary of Zone of Contribution for Crystal Springs
- C— Trace of geologic cross-sections
- ● Spring
- • Water Well

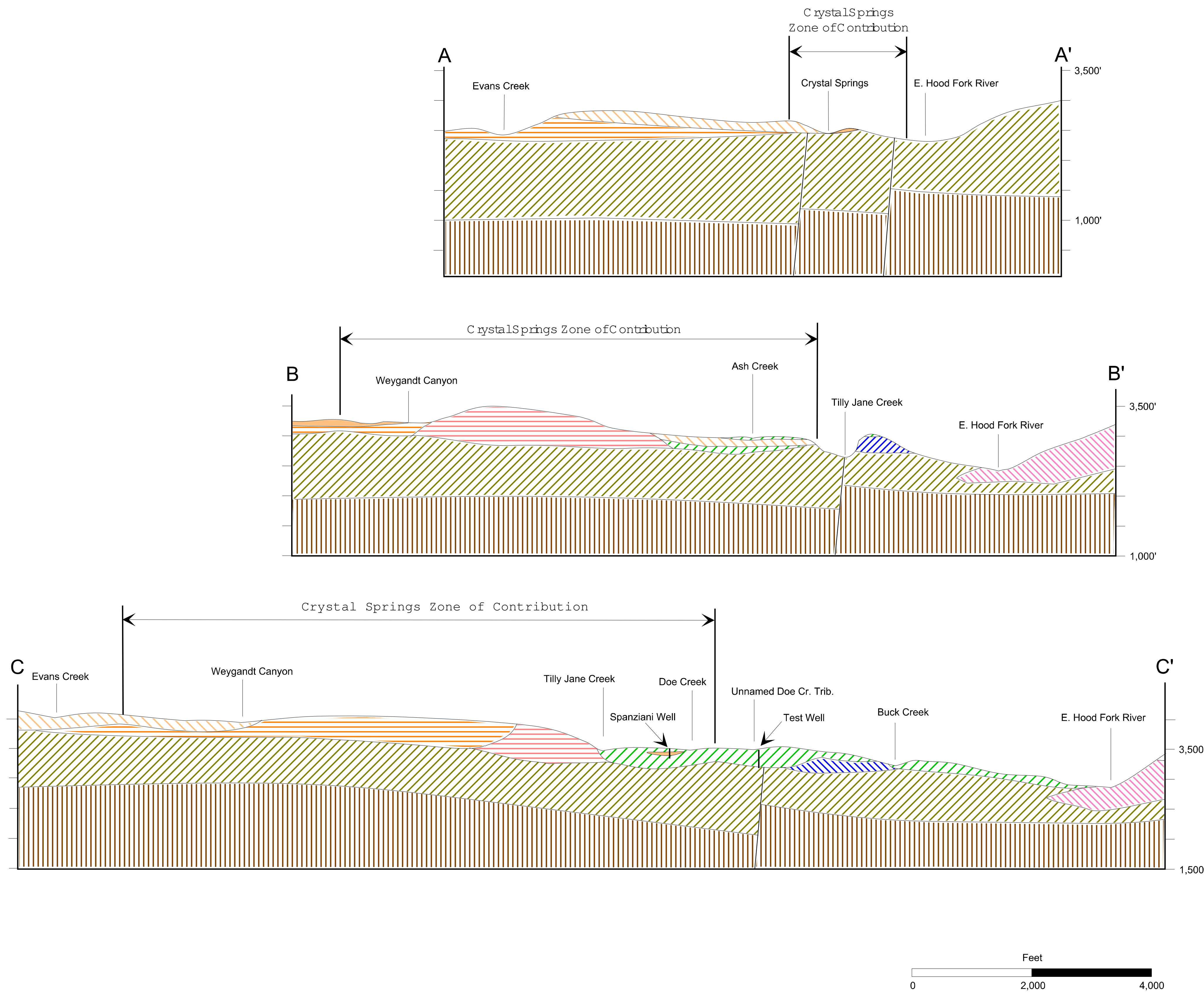
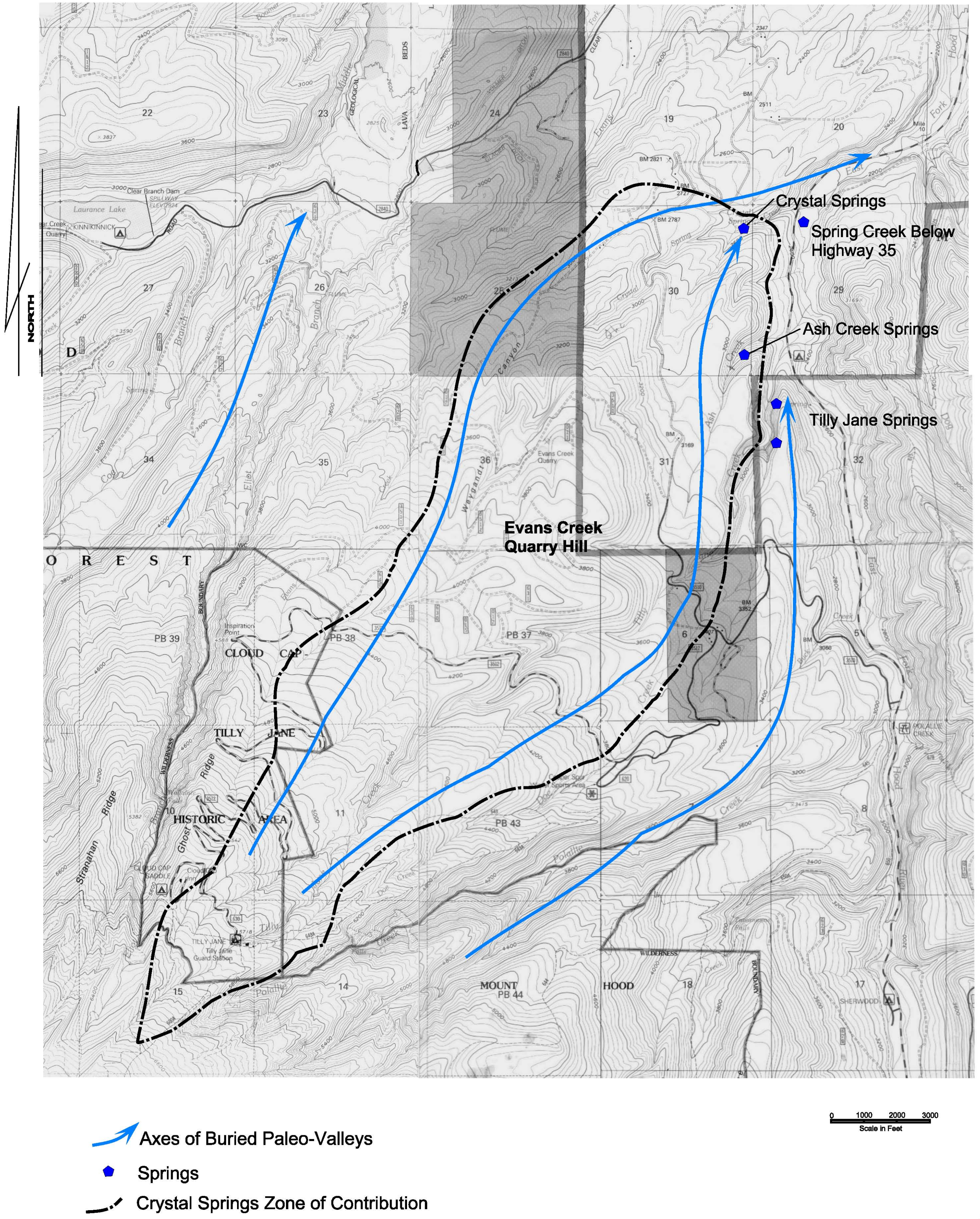


Figure: 2
Geologic Map with Zone of Contribution
Crystal Springs Study Area

Project: Crystal Springs ZOC, 01-264



Ground water & Environmental Consultants

Mark Yinger Associates

4865 Baseline Road, Parkdale OR, 97041 - 541-352-6015

Figure 3
Axes of Buried Paleo-Valleys

Appendix A

Well Logs

WATER WELL REPORT
STATE OF OREGON

HOOD
507

RECEIVED
NOV 30 1984
WATER RESOURCES DEPT.
SALEM, OREGON

PLEASE TYPE or PRINT IN INK

B

State Well No. 1S/10E-3
State Permit No.

(1) OWNER:

Name Russell Stillwell
Address 2615 S. W. Custer
City Portland, State Oregon

(2) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:

Rotary Air ☒ Driven ☐
Rotary Mud ☐ Dug ☐
☐ Bored ☐

(4) PROPOSED USE (check):

Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐
Thermal: Withdrawal ☐ Reinjection ☐

) CASING INSTALLED:

Steel ☒ Plastic ☐
Threaded ☐ Welded ☒

6 " Diam. from +1 ft. to 159 ft. Gauge .250
" Diam. from ft. to ft. Gauge

LINER INSTALLED:

" Diam. from ft. to ft. Gauge

(6) PERFORATIONS:

Perforated? ☐ Yes ☒ No
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:

Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot Size Set from ft. to ft.
Diam. Slot Size Set from ft. to ft.

(8) WELL TESTS:

Drawdown is amount water level is lowered below static level

Was a pump test made? ☐ Yes ☒ No If yes, by whom?
gal./min. with ft. drawdown after hrs.
Air test 54 gal./min. with drill stem at 115 ft. 1 hrs.
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m.
perature of water Depth artesian flow encountered ft.

(9) CONSTRUCTION:

Special standards: Yes ☐ No ☒
Well seal—Material used Cement
Well sealed from land surface to 20 ft.
Diameter of well bore to bottom of seal 10 in.
Diameter of well bore below seal 8 in.
Number of sacks of cement used in well seal 8 sacks
How was cement grout placed? Grout pump

Was pump installed? No Type HP Depth ft.
Was a drive shoe used? ☐ Yes ☒ No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of Water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.

(10) LOCATION OF WELL:

County Hood River Driller's well number
SW ¼ SE ¼ Section 30 T. 1S R. 10E W
Tax Lot # Lot Blk Subdivision
Address at well location: Cooper Spur Rd.
Hood River, Oregon

(11) WATER LEVEL: Completed well.

Depth at which water was first found 98
Static level 108 ft. below land surface. Date
Artesian pressure lbs. per square inch. Date

(12) WELL LOG:

Diameter of well below casing 6"
Depth drilled 200 ft. Depth of completed well 200

Formation: Describe color, texture, grain size and structure of materials; and sh thickness and nature of each stratum and aquifer penetrated, with at least one er for each change of formation. Report each change in position of Static Water Le and indicate principal water-bearing strata.

MATERIAL	From	To	SWL
Soil Brown	0	2	
Gravel Fine Brown	2	5	
Gravel Gray	5	11	
Rock Med. Soft Maron	11	22	
Basalt hard & Gray	22	37	
Basalt soft gray	37	63	
Basalt hard gray	63	81	
Bolcanic rock soft blk	81	98	
Gravel brown med. W/B	98	200	10

Work started 10-22 19 84 Completed 11-2 19
Date well drilling machine moved off of well 11-2 19

(unbonded) Water Well Constructor Certification (if applicable

This well was constructed under my direct supervision. Materials u and information reported above are true to my best knowledge and beli

[Signed] Date , 19

Bonded Water Well Constructor Certification:

Bond (number) Issued by: Surety Company Name

This well was drilled under my jurisdiction and this report is tru the best of my knowledge and belief.

Name Marinelli & Austin Drilling Co. (Person, firm or corporation) (Type or print)
Address P. O. Box 802, The Dalles, Or.
[Signed] Water Well Constructor
Date 11-28 , 19 8

NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the

WATER RESOURCES DEPARTMENT,
SALEM, OREGON 97310
within 30 days from the date of well completion.

HOOD
512

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

(Do not write above this line)

State Well No. 2S/9E-1

State Permit No.

(1) OWNER:
Name E. L. Shaw
Address 9307 N. E. Thompson Rd.
Portland, Oregon 97220

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☒ Driven ☐
☐ Jetted ☐
☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

5) CASING INSTALLED:
Threaded ☐ Welded ☒
6" Diam. from plus 1 ft. to 84 ft. Gage .250
1½" Diam. from 5 ft. to 140 ft. Gage PVC 160
" Diam. from ft. to ft. Gage

6) PERFORATIONS:
Perforated? ☒ Yes ☐ No.
Type of perforator used Saw cut
Size of perforations 1/8 in. by 12 in.
40 perforations from 135 ft. to 145 ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:
Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS:
Drawdown is amount water level is lowered below static level

a pump test made? ☐ Yes ☒ No If yes, by whom?
irlift
Yield: 25 gal./min. with 20 ft. drawdown after 2 hrs.
" 15 " 10 " "
" 5 " 5 " "
ler test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m.
perature of water 40° Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used Cement grout plus 5% gel
Well sealed from land surface to 84 ft.
Diameter of well bore to bottom of seal 10 in.
Diameter of well bore below seal 6 in.
Number of sacks of cement used in well seal 12 sacks
How was cement grout placed? Tremmed through casing @ 84 ft and pumped into annular bore (6 sacks) Top seal tremmed on O.D. of casing @ 30 ft. to land surface (6 sacks)

Was a drive shoe used? ☒ Yes ☐ No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:

(10) LOCATION OF WELL:
County Hood River Driller's well number
¼ ¼ Section 1 T. 2 S R. 9 E. W.
Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.
Depth at which water was first found 140
Static level 125 ft. below land surface. Date 7/18/
Artesian pressure lbs. per square inch. Date

(12) WELL LOG:
Diameter of well below casing 6"
Depth drilled 150 ft. Depth of completed well 145

Formation: Describe color, texture, grain size and structure of materi and show thickness and nature of each stratum and aquifer penetrat with at least one entry for each change of formation. Report each change position of Static Water Level and indicate principal water-bearing str

MATERIAL	From	To	SWL
Brown silty sand	0	4	
Gray-brown boulders, volcanic debris, etc.	4	36	
Large volcanic boulders-occ. clay seams	36	55	
Gray & brown boulders, sand & clay	55	65	
Fractured gray & brown basalt	65	78	
Hard gray basalt-coarse grained	78	114	
Hard gray-brown & brown basalt	114	136	
Brown volcanic debris- occ. loose	136	150	25

RECEIVED
JUL 23 1980
WATER RESOURCES DEPT
SALEM, OREGON

Work started 7/11/80 19 Completed 7/18/80 19
Date well drilling machine moved off of well 7/18/80 19

Drilling Machine Operator's Certification:
This well was constructed under my direct supervisio Materials used and information reported above are true to m best knowledge and belief.
[Signed] Date 7/21/80 19
(Drilling Machine Operator)
Drilling Machine Operator's License No. 523

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report true to the best of my knowledge and belief.
Name A. M. JANNSEN WELL DRILLING CO., INC.
(Person, firm or corporation) (Type or print)
Address 21075 SW Tualatin Valley Hwy. Aloha, O
[Signed]
(Water Well Contractor)

STATE OF OREGON

WATER WELL REPORT

(as required by ORS 537.765)

HOOD
516

RECEIVED
OCT 20 1987
WATER RESOURCES DEPT.
SALEM, OREGON

D

2S/10E-6a

(1) OWNER:

Well Number: ______
Name Terry Aarno
Address 12515 SE 18th
City Milwaukie State Or Zip 97222

(2) TYPE OF WORK:

☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD

☒ Rotary Air ☐ Rotary Mud ☐ Cable
☐ Other ______

(4) PROPOSED USE:

☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ______

(5) BORE HOLE CONSTRUCTION:

Special Construction approval Yes ☐ No ☒ Depth of Completed Well 195 ft.
Explosives used Yes ☐ No ☐ Type ______ Amount ______

HOLE			SEAL			Amount
Diameter	From	To	Material	From	To	sacks or pounds
10"	0	28	Cement &	0	28	8 bags
6"	28	195	Bentonite			

How was seal placed: Method ☐ A ☐ B ☒ C ☐ D ☐ E
☐ Other ______
Backfill placed from ______ ft. to ______ ft. Material ______
Gravel placed from ______ ft. to ______ ft. Size of gravel ______

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	0	45	.250	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:	4½"	10	185		☐	☒	☐	☐
	PVC				☐	☐	☐	☐

Final location of shoe(s) None

(7) PERFORATIONS/SCREENS:

☒ Perforations Method ______
☐ Screens Type ______ Material ______

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
150	185	½"	120	½"		☐	☒
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
10		180	1 hr.

Temperature of water ______ Depth Artesian Flow Found ______
Was a water analysis done? ☐ Yes By whom ______
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other ______

(9) LOCATION OF WELL by legal description:

County Hood River Latitude ______ Longitude ______
Township 2S N or S, Range 10 E E or W, WM.
Section 6 NW ¼ NE ¼
Tax Lot 211 Lot 7 Block ______ Subdivision Snow trac
Street Address of Well (or nearest address) Cooper Spur Inn.

(10) STATIC WATER LEVEL:

140 ft. below land surface. Date 10-4-8
Artesian pressure ______ lb. per square inch. Date ______

(11) WATER BEARING ZONES:

Depth at which water was first found 170'

From	To	Estimated Flow Rate	SWI
170	185	10	

(12) WELL LOG:

Ground elevation ______

Material	From	To	SWI
Soil	0	1	
Sandstone fine brown	1	7	
Boulders & Sandstone	7	23	
Sandstone coarse brown	23	28	
Rock hard blk	28	40	
Basalt ~~soft~~ hard grey	40	64	
Basalt soft blk	64	76	
Basalt broken grey	76	84	
Basalt soft blk	84	95	
Rock Volcanic soft blk	95	128	
Rock Volcanic blk	128	185	
Sand fine brown caving	185	195	

Date started 9-27-87 Completed 10-5-87

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

WWC Number ______
Signed ______ Date ______

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 790

43

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

HOOD 279

[illegible]
JUL 22 1991
WATER RESOURCES DEPT.
OREGON

2S/10E/6 a

(START CARD) # 24409

(1) OWNER:
Well Number:
Name Joseph Spaziani
Address 12999 S. Haven Rd.
City Oregon City State Or. Zip 97045

(2) TYPE OF WORK:
☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD
☒ Rotary Air ☐ Rotary Mud ☐ Cable
☐ Other

(4) PROPOSED USE:
☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval Yes ☐ No ☒ Depth of Completed Well 152 ~~165~~ ft.
Explosives used Yes ☐ No ☒ Type Amount

HOLE			SEAL			
Diameter	From	To	Material	From	To	Amount sacks or pounds
10	0	24				
8	24	165	Cement	0	24	10 Bags

How was seal placed: Method ☐ A ☐ B ☒ C ☐ D ☐ E
☐ Other
Backfill placed from ft. to ft. Material
Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	+1	139	.250	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

Final location of shoe(s) 139 ft.

(7) PERFORATIONS/SCREENS:
☐ Perforations Method
☐ Screens Type Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
30		165	1 hr.

Temperature of water 50 Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata:

(9) LOCATION OF WELL by legal description:
County Hood R. Latitude Longitude
Township 2 S N or S. Range 10E E or W
Section 6 SW ¼ NE ¼
Tax Lot 212 Lot Block Subdivision
Street Address of Well (or nearest address) 10656 Coope
Spur Rd. Parkdale, Or.

(10) STATIC WATER LEVEL:
90 ft. below land surface. Date 7-8-
Artesian pressure lb. per square inch. Date

(11) WATER BEARING ZONES:
Depth at which water was first found 140

From	To	Estimated Flow Rate
140	160	30

(12) WELL LOG:
Ground elevation

Material	From	To
Boulders large	0	18
SS fine hard	18	29
SS W/clay brown	29	41
Gravel med multi coloe	41	54
Rock Volcanic black	54	140
Gravel med multi colorW/B	140	160
Sand fine blk	160	165

Date started 7-2-91 Completed 7-8-91

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alter abandonment of this well is in compliance with Oregon well cons standards. Materials used and information reported above are true to knowledge and belief.

WWC Number
Signed Date

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abanc work performed on this well during the construction dates reported a work performed during this time is in compliance with Oreg construction standards. This report is true to the best of my knowle belief.

WWC Number 7
Signed Date 7-18-91

Golder Associates

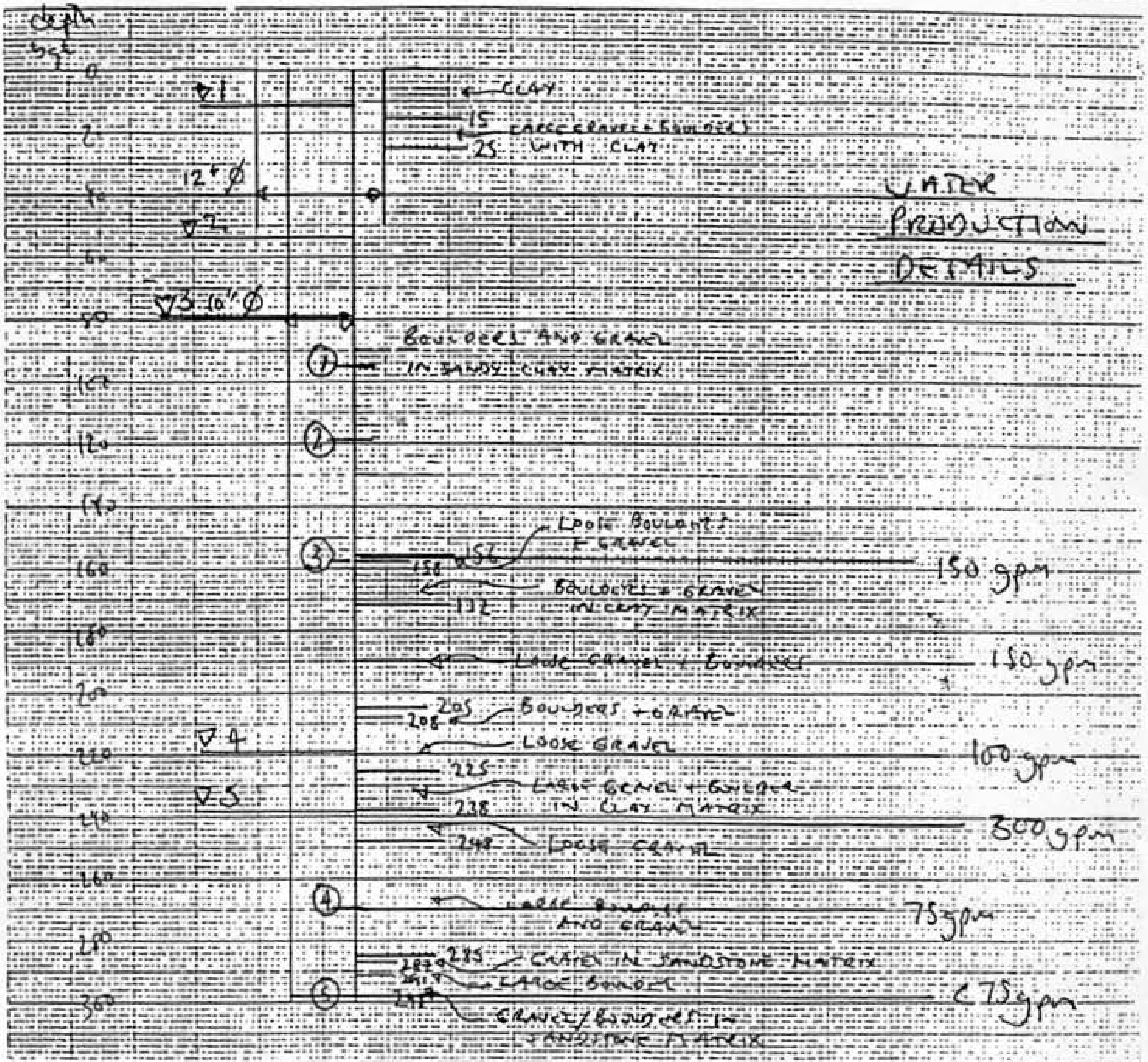
SUBJECT Mt Hood Meadows / Cooper Spur

Job No. 013-9746
Ref.

Made by Sam
Checked
Reviewed

Date 9-26-2001
Sheet 1 of

WATER PRODUCTION DETAILS



TEMPORARY
CASING
ARRANGEMENT

	B/HOLE	SWL
∇ 1	95	11.5
∇ 2	119	54 ✓
∇ 3	158	74 ✓
∇ 4	270	219 ?
∇ 5	298	238 ✓

Note: with borehole @ 280 ft b.
air passes up outside of 10"
casing indicating 10" not sealed
As production ≤ 75 gpm or less
and well does not recover
quickly after airlifting yield

#3

JUN 4 1991

Mt. Sha

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

WATER RESOURCES DEPT
SALEM, OREGON

HOOD 278

(A) 1S/10E/31 C

(START CARD) # W24416

(1) OWNER:
Well Number:
Name Donald J. Branton
Address 329 W. 21st. Street
City The Dalles OR State Zip 97058

(2) TYPE OF WORK:
☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD
☒ Rotary Air ☐ Rotary Mud ☐ Cable
☐ Other

(4) PROPOSED USE:
☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval Yes ☐ No ☒ Depth of Completed Well 505 ft.
Explosives used Yes ☐ No ☒ Type Amount

HOLE			SEAL			
Diameter	From	To	Material	From	To	Amount sacks or pounds
10"	top	25'	bentonite	top	25	12 sack
6"	25	505				

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☒ Other bentonite dumped dry
Backfill placed from ft. to ft. Material
Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	top	200'	.250	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:	4½	200	505	.250	☐	☒	☒	☐
					☐	☐	☐	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:
☒ Perforations Method saw
☐ Screens Type Material PVC

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
445	505	⅛x6	60	4½		☐	☒
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
15	100%	500	1 hr.

Temperature of water 58 Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata:

(9) LOCATION OF WELL by legal description:
County Hood River Latitude Longitude
Township 1S N or S. Range 10E E or W.
Section 31 NW ¼ NE ¼
Tax Lot 17 Lot 17 Block Subdivision
Street Address of Well (or nearest address) 5000 Mt. Shad
Parkdale OR 97041

(10) STATIC WATER LEVEL:
375 ft. below land surface. Date 5-3
Artesian pressure lb. per square inch. Date

(11) WATER BEARING ZONES:
Depth at which water was first found 93'&460'

From	To	Estimated Flow Rate
93'	120'	3 gpm
460'	505'	15 gpm

(12) WELL LOG:
Ground elevation

Material	From	To
top soil.................	0'	2
brown silt...............	2	7
gray & brown basalt med..	7	14
gray basalt,hard........	14	53
red & brown cinders......	53	93
brown basalt,porous. WB ..	93	120
brown & gray basalt,		
fractured................	120	163
gray & red cinders.......	163	190
gray & brown basalt,med..	190	330
gray basalt, porous......	330	460
gray & brown basalt,		
fractured,water bearing..	460	505

Date started 05-29-91 Completed 05-31-91

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alter abandonment of this well is in compliance with Oregon well cons standards. Materials used and information reported above are true to knowledge and belief.

WWC Number
Signed Date

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or aband work performed on this well during the construction dates reported a work performed during this time is in compliance with Oreg construction standards. This report is true to the best of my knowle belief.

WWC Number
Signed Date 05-31-

Appendix B

Stillwell Well – Static Water Levels and Elevations

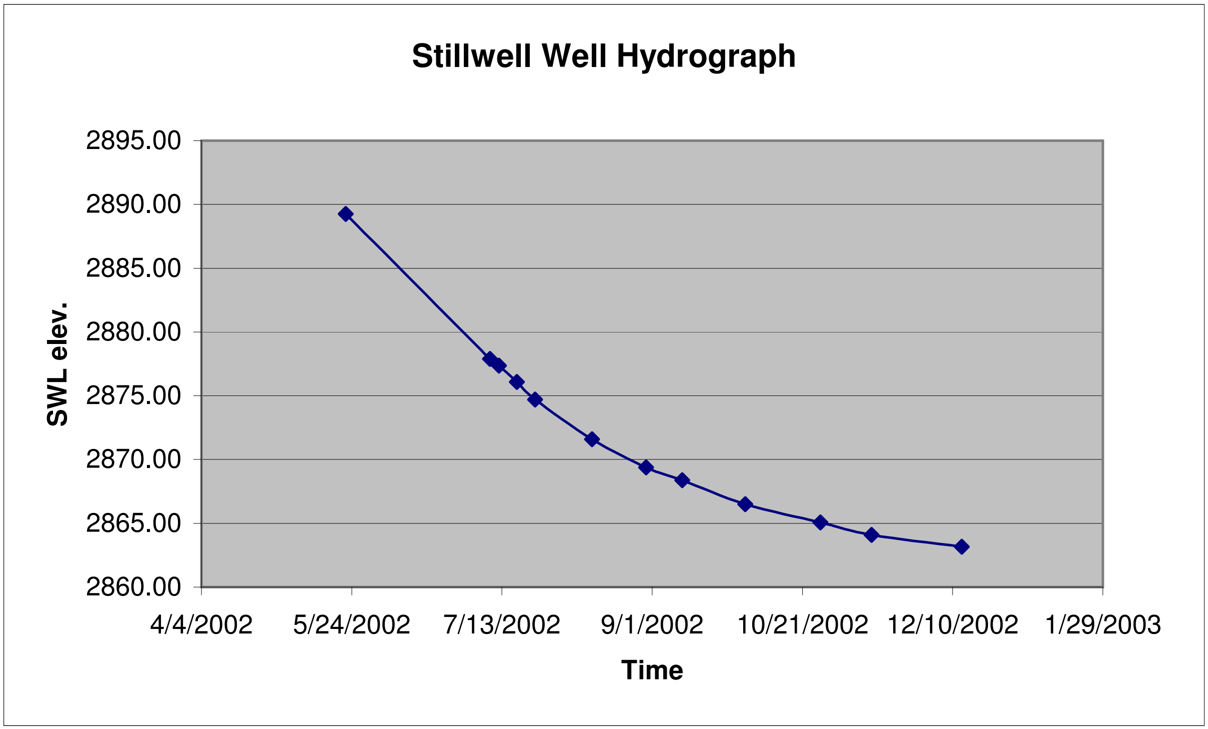
Appendix B: Stillwell Well - Static Water Levels and Elevations

Stillwell Well - Static Water Levels and Elevations

Project: Crystal Springs ZOC

Date	Static water level feet	Static water elev.* feet
5/22/2002	60.75	2889.25
7/9/2002	72.10	2877.90
7/12/2002	72.65	2877.35
7/18/2002	73.93	2876.07
7/24/2002	75.31	2874.69
8/12/2002	78.40	2871.60
8/30/2002	80.61	2869.39
9/11/2002	81.61	2868.39
10/2/2002	83.50	2866.50
10/27/2002	84.92	2865.08
11/13/2002	85.90	2864.10
12/13/2002	86.85	2863.15

* top of casing elevation 2950'.



Water Balance for the Crystal Springs zone of contribution

Prepared for:

Mark Yinger, RPG
4865 Baseline Road
Parkdale, OR 97041

Prepared by:

Ed Salminen
P.O. Box 491
Parkdale, OR 97041

October 1, 2002

Table of Contents

1.0 Introduction

A water balance accounts for the inputs and outputs of water from a given land area. A simple annual water balance was developed for the zone of contribution (ZOC) identified for Crystal Springs (Figure 1). The ZOC shown in Figure 1 is approximately 6.9 mi^2 in size. Elevations within the ZOC range from 2,450 to 6,400 feet, with a mean elevation of 3,890 feet. A water balance was used to evaluate how reasonable the identified ZOC was. Ideally, inputs to the ZOC will equal outputs from the ZOC. Slight differences between inputs and outputs would be expected given the uncertainty in estimating the components of the water balance, however, large differences would suggest that the ZOC is incorrectly delineated, or that there are significant errors in the estimation of inputs to and outputs from the system. The annual water balance for the ZOC can be expressed as follows:

$$\mathbf{Q_{out} = P_{net} = P_{annual} - ET - I - \Delta S - W}$$

Where:
Q_{out} = Annual outflow from the ZOC
P_{net} = Net annual precipitation for the zone of contribution
P_{annual} = Annual precipitation for the zone of contribution
ET = Annual evapotranspiration losses
I = Canopy interception losses
ΔS = Change in storage (snowpack, soil, groundwater, or impoundments)
W = Water withdrawals from the zone of contribution

The following sections describe how values were estimated for each of the components of the above equation. Results are summarized in the final section below.

2.0 Annual outflow from the ZOC

Creation of the water balance was complicated by the fact that water leaves the ZOC from multiple locations (e.g., Tilly Jane Creek, Ash Creek; Figure 1). Several sources of information were used to estimate the annual outflow at each location. Section 2.1 describes how annual outflow was estimated for Crystal Springs/Crystal Springs Creek, section 2.2 describes annual outflow estimates for Tilly Jane Creek, and section 2.3 covers all remaining areas.

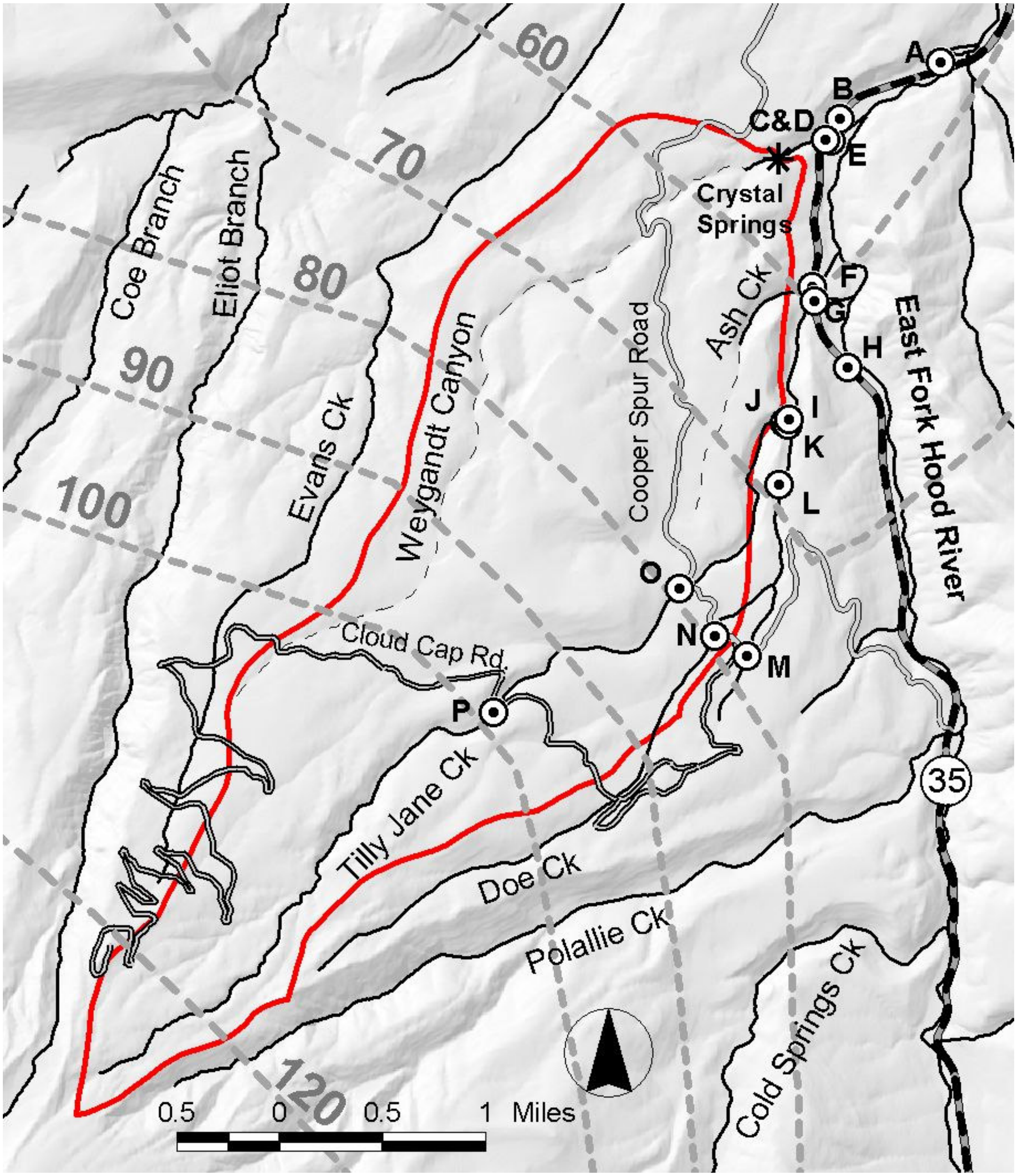


Figure 1. Crystal Springs zone of contribution (red outline). Summer 2002 streamflow measurement sites are shown as circular symbols; refer to Table 1 for site descriptions. Also shown are average annual precipitation isohyets (Daly and Taylor, 1998). Map data sources: USFS (2002), USGS (2002a).

Table 1. Streamflow measurements – summer 2002. All values are cubic feet per second (cfs). Refer to Figure 1 for site locations.

		Date of streamflow measurement						
Site	**Site description**	**6/4/2002**	**6/5/2002**	**7/3/2002**	**8/6/2002**	**8/14/2002**	**9/7/2002**	**9/20/2002**
A	Outlet of beaver pond complex					0.3	0.3	0.4
B	Unnamed spring, ~500' north of Crystal Springs access road, at Highway 35					0.5	0.4	0.4
C	Crystal Springs Creek at Highway 35		6.4	5.8	6.4		5.8	5.4
D	Small culvert next to Crystal Springs Creek at Highway 35	0.3		0.2	0.2		0.2	0.2
E	Spring Creek below Hwy 35, upstream of confluence with Crystal Springs Ck	2.5		2.7	2.7		2.4	2.6
F	Ash Creek at Highway 35	2.4		2.3	2.0		2.6	2.4
G	Tilly Jane Creek at Highway 35	9.5		8.0	5.8		4.3	3.8
H	Unnamed spring, ~2,000’ south of Tilly Jane Creek, at Highway 35		2.2	2.2	2.3			1.6
I	Tilly Jane Creek, ~100' downstream of confluence with Doe Creek		6.4		3.1			
J	Tilly Jane Creek, ~50' upstream of Doe Creek		3.8		1.4			
K	Doe Creek, ~100' upstream of confluence with Tilly Jane Creek		2.3					
L	Doe Creek at ~3,080' elevation			1.3				
M	Unnamed tributary to Doe Creek at Cooper Spur Road		0.8	1.0	0.6		0.4	0.4
N	Doe Creek at Cooper Spur Road		0.6	0.2	0.002		0	0
O	Tilly Jane Creek at Cooper Spur Road		1.5	1.5	0.02		0	0
P	Tilly Jane Creek at Cloud Cap Road			1.4	0		0	0

2.1 Crystal Springs / Crystal Springs Creek

Springflow data are available for Crystal Springs from January 1988 to present (CSWD, 2002). Measurements recorded at Crystal Springs include the volume of water that is diverted down the pipe for eventual delivery to domestic water users, as well as overflow that is returned to Crystal Springs Creek. However, an unknown component of the total spring flow is not accounted for, as it is returned to Crystal Springs Creek prior to entering the control structure where measurements are recorded. Mean seasonal flow for the period of record are shown in Figure 2.

Based on these values, mean annual flow at Crystal Springs is 4.5 cfs[1] (~ 2,000 gpm[2]) over the period of record.

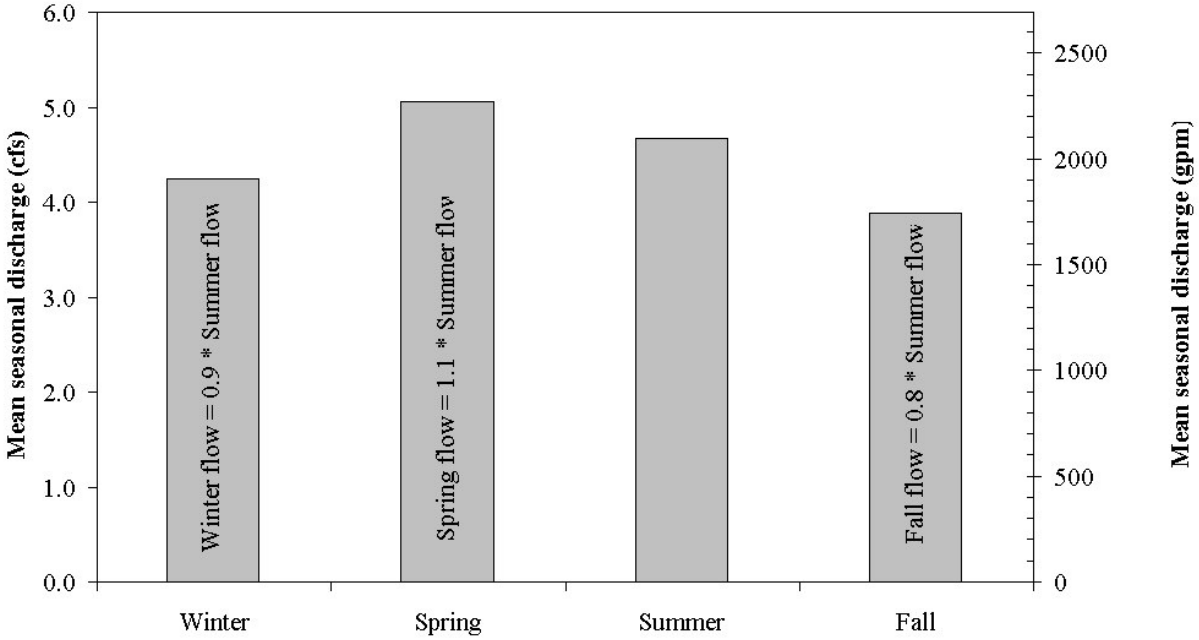


Figure 2. Mean seasonal discharge recorded at Crystal Springs for the period of record (January 1988 – present). Text indicates the ratio of seasonal flow to summer flow for each season.

Periodic stream flow measurements were taken during summer 2002 in Crystal Springs Creek downstream of the Crystal Springs water diversion (Site "C", Figure 1, Table 1). These measurements indicate that the total flow near the mouth of Crystal Springs Creek is approximately 1.7 times the flow that is recorded at the Crystal Springs diversion (Figure 3, top graph). Consequently, a value of 7.6 cfs (3,415 gpm) was used to represent the mean annual outflow for Crystal Springs/Crystal Springs Creek (Table 2).

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[1] Cubic-feet per second

[2] gallons per minute

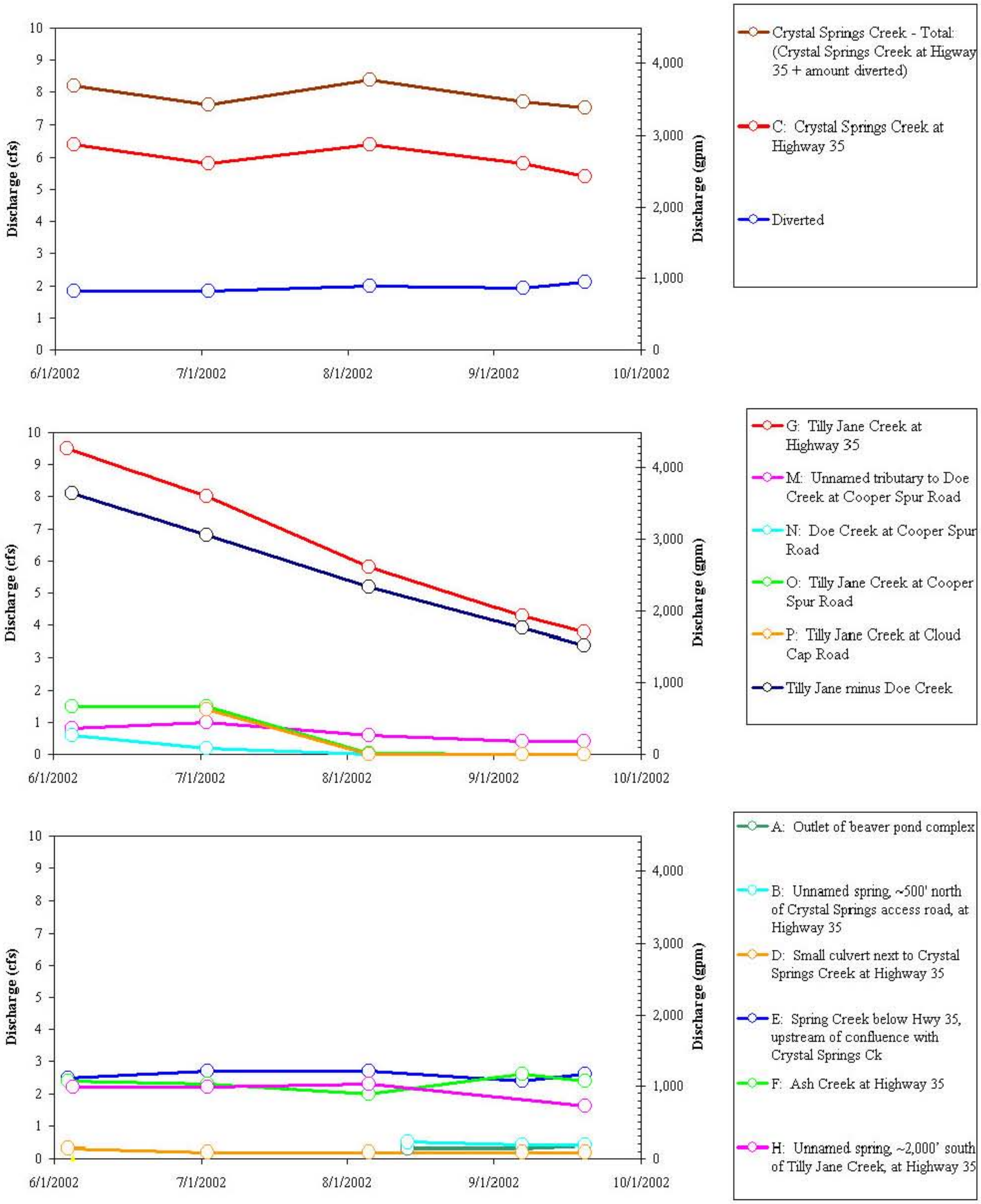

Figure 3. Graphical representation of summer 2002 stream flow measurements. Top graph shows flow measurements and calculated values for Crystal Springs/Crystal Springs Creek, middle graph show measurements for Tilly Jane Creek and tributaries, and bottom graph shows flow measurements for all other areas.

Table 2. Summary of estimated outflow from ZOC.

Component	Annual outflow (cfs)	Annual outflow (gpm)
Crystal Springs/Crystal Springs Ck.	7.6	3,415
Tilly Jane Creek	2.1	920
Ash Creek	2.2	1,000
Spring Creek	2.5	1,100
Small culvert next to Crystal Springs Creek at Highway 35	0.2	94
Outlet of beaver pond complex	0.3	142
Unnamed spring, ~500' north of Crystal Springs access road, at Highway 35	0.4	185
Total	15.3	6,856

2.2 Tilly Jane Creek

Periodic summertime stream flow measurements were taken at several locations within Tilly Jane Creek and its tributaries (Sites “G”, and “I” – “P”, Figure 1, Table 1, Figure 3 – middle graph). Streamflow originating from Doe Creek is outside of the ZOC, consequently, streamflow from site “M” (unnamed tributary to Doe Creek at Cooper Spur Road) and site “N” (Doe Creek at Cooper Spur Road) were subtracted from the flow at site “G” (Tilly Jane Creek at Highway 35), and averaged to arrive at the summertime stream flow in Tilly Jane Creek (5.5 cfs; ~2,460 gpm). The steady decline in streamflow over the course of the summer in Tilly Jane Creek (Figure 3 – middle graph) suggests that Tilly Jane Creek experiences a wider variation between seasonal flows than do the other water sources in the vicinity, all of which have a relatively constant hydrograph. Consequently, summertime values for Tilly Jane Creek were expanded to other seasons of the year using the ratio of seasonal flow to summer flow illustrated in Figure 4. Data shown in Figure 4 is from the Dog River near Parkdale stream gage, located approximately five miles southeast of Crystal Springs. Mean annual outflow for Tilly Jane Creek was estimated to be 6.2 cfs (2,770gpm). However, only a portion of the streamflow in Tilly Jane Creek originates from the ZOC. Based on field-observations of spring flow inputs to lower Tilly Jane Creek during summer 2002, it is estimated that only approximately 1/3 of the summertime streamflow in lower Tilly Jane Creek originates from the ZOC. Consequently, mean summertime streamflow for Tilly Jane Creek originating from the ZOC is estimated to be 2.1 cfs (920 gpm) (Table 2).

2.3 Other locations

Periodic summertime stream flow measurements taken at the remaining sites that drain the ZOC (i.e., sites "A", "B", "D", "E", and "F"; Figure 1, Table 1, Figure 3 – bottom graph) were used to estimate the annual outflow from these sources. Summertime values were expanded to other seasons of the year using the ratio of seasonal flow to summer flow illustrated in Figure 2. Estimated annual values for all remaining locations are given in Table 2.

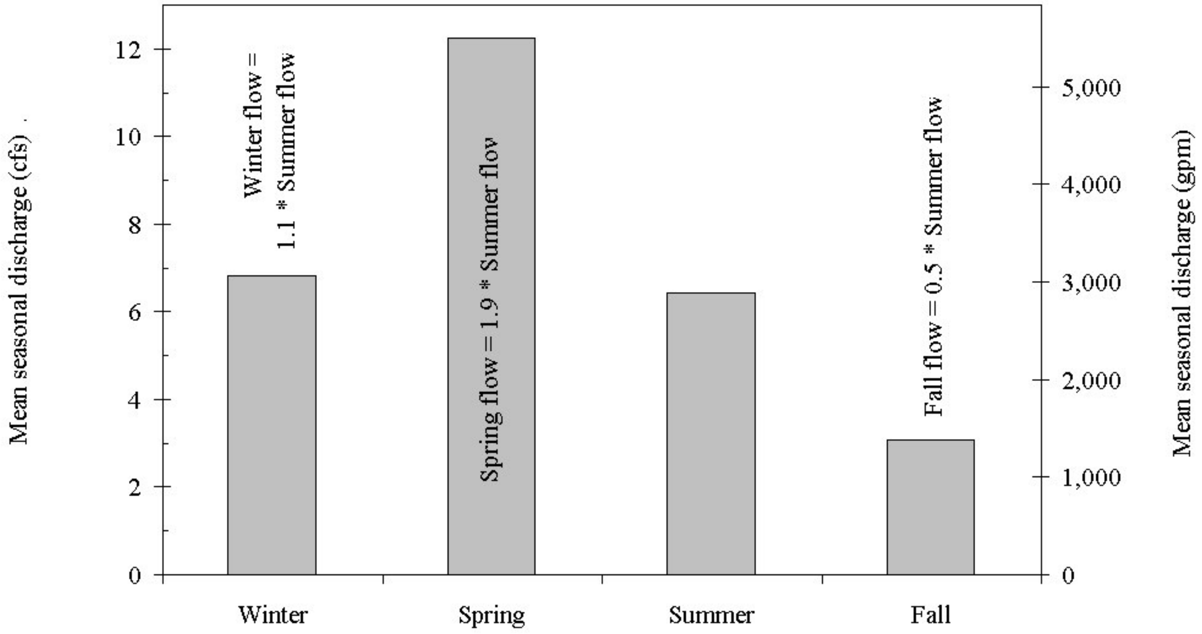

Figure 4. Mean seasonal discharge recorded at USGS gage #14113400, Dog River near Parkdale, for the period of record (October 1960 – September 1971). Text indicates the ratio of seasonal flow to summer flow for each season. Data source: USGS (2002b).

3.0 Annual precipitation

Mean annual precipitation values available from Daly and Taylor (1998; Figure 1) were used to arrive at an area-weighted mean annual precipitation value for the ZOC of 89 inches.

4.0 Annual evapotranspiration losses

Monthly evapotranspiration (ET) losses were calculated at four climate stations in the vicinity of the Crystal Springs ZOC; Parkdale 2 NNE, Greenpoint, Mt. Hood Test Site, and the Red Hill climate stations (NOAA, 2002; NRCS, 2001). Monthly ET was estimated at each location using the Thornthwaite method as outlined by Dunne and Leopold (1978). Monthly ET values were summed to arrive at an estimate of annual ET loss at each of the four stations. Regression analysis was used to arrive at an equation predicting annual ET as a function of elevation Figure 5. Annual ET was calculated by 500-foot elevation bands, and an area-weighted annual ET value of 15 inches was calculated for the ZOC.

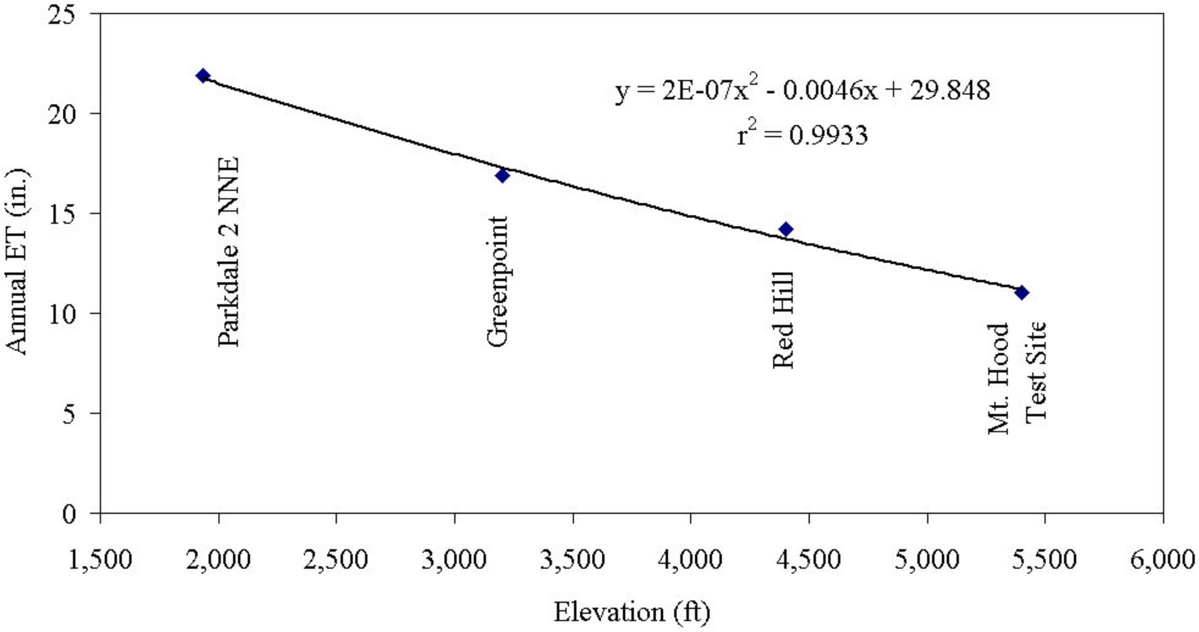

Figure 5. Annual evapotranspiration (ET) as a function of elevation.

5.0 Canopy interception losses

Vegetation intercepts a portion of the precipitation falling on an area, a further portion of which is evaporated back to the atmosphere during or after a storm event, thereby reducing the net precipitation reaching the soil (Dunne and Leopold 1978). Canopy interception estimates from several studies was reported to have a median value of 28% of gross annual precipitation within coniferous forests experiencing both rain- and snowfall (Dunne and Leopold 1978). Canopy interception loss was estimated as 28%[3] of mean annual precipitation for the ZOC.

---

[3] It is debatable if ET and interception losses are additive. Intercepted precipitation that is later evaporated may reduce the amount of total precipitation accounted for in the ET calculations. The values given here may overestimate net loss from both components.

6.0 Change in storage

On an annual basis, it is probably reasonable to ignore precipitation storage in snowpack, because there are no glaciers or permanent snowfields in the defined ZOC, and all of the snowpack can safely be assumed to melt. Likewise storage as soil moisture or in groundwater are likely to remain close to constant on a year-to-year basis (i.e., groundwater storage is not increasing or decreasing on an annual basis, even though there may be considerable within-year variation). No significant water impoundments are located within the ZOC.

7.0 Water withdrawals

The Oregon Water Resources Department (OWRD) identifies 19 separate water rights within the ZOC, three of which are held by Crystal Springs Water District (OWRD, 2002). Beneficial uses associated with the 16 remaining water rights include domestic/ group domestic, commercial, fire protection, irrigation, and livestock watering. The maximum instantaneous diversion associated with these additional water rights is 2.38 cfs (1,070 gpm). Assuming that these water rights were exercised to their full extent in all months (unlikely for irrigation), water withdrawals would total 1,723 acre-feet per year.

8.0 Summary of Water Balance:

Table 3 summarizes the estimated values for each component of the water balance. For consistency, all components have been converted to acre-feet per year. The final row in Table 3 gives the ratio of net annual precipitation to mean annual outflow for the ZOC. If all inputs and outputs were accurately estimated, than a value less than 1.0 would suggest that the delineation of the ZOC is too small, and a value greater than 1.0 suggest it is too large. The value of 1.5 given in Table 3 supports the ZOC as delineated, given the uncertainty in calculating the components of the water balance, and the likelihood that some of the outflow locations have most likely not been identified (e.g., subsurface flow discharging directly into the East Fork Hood River). Furthermore, examination of the spring flow data available for Crystal Springs (CSWD, 2002) indicates that total spring flow recorded during summer 2002 was approximately 85% of normal for the same time period over the period of record (January 1988 to present). Given that precipitation inputs are based on long-term averages, the dry conditions of summer 2002 would account for a portion of the discrepancy between inflow and outflow.

Table 3. Estimated values for components of the water balance.

		acre-feet/year
[Q_{out}]	Mean annual outflow from the ZOC (ac-ft/yr)	11,077
[P_{annual}]	Mean annual precipitation (ac-ft/yr)	32,752
[ET]	Annual evapotranspiration (ac-ft/yr)	5,575
[I]	Annual canopy interception (ac-ft/yr)	9,189
[W]	Water withdrawals from the zone of contribution	1,723
[P_{net}]	Net annual precipitation to the zone of contribution (ac-ft/yr)	16,284
Ratio of P_{net} : Q_{out}		**1.5**

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