FINAL PROJECT REPORT
U.S. GEOLOGICAL SURVEY SMALL GRANTS PROGRAM

Hydrogeomorphic Analysis of the Luckiamute Watershed, Central Coast Range, Oregon: Integrating Applied Watershed Science with Undergraduate Research and Community Outreach

Prepared By

Stephen B. Taylor, Ph.D.
Earth and Physical Sciences Department
Western Oregon University
Monmouth, OR 97361

Ph. 503-838-8398 email: taylors@wou.edu

Submitted To

Institute for Water and Watersheds
(*Formerly* Center for Water and Environmental Stability)
210 Strand Agricultural Hall
Oregon State University
Corvallis, OR 97331-2208

May 19, 2006

<u>Project Focus Categories</u>

Education, Geomorphological Processes, Hydrology, Sediments, Water Quality

PROJECT DESCRIPTION

Mountainous watersheds are fundamental landscape elements that form an important setting for local ecological interactions, human occupation, and water resource development. They also represent the foundational components for mass sediment transfer from continental regions to ocean basins. As such, the understanding of hydrogeomorphic variables is critical for designing sustainable water resource and habitat conservation plans. From the perspective of undergraduate training in the Earth Sciences, watersheds represent the ideal natural laboratory for student application of quantitative techniques to multivariate systems with interdependent process-response mechanisms.

This project, initiated in spring 2004, involved hydrogeomorphic analysis of the Luckiamute River basin (A_d = 815 km^2) in western Oregon (Figure 1). The Luckiamute is being used as a model watershed to integrate select components of applied research into a sequence of surface-process courses at Western Oregon University (WOU). Faculty and undergraduate Earth Science majors are currently engaged with integrated studies in fluvial geomorphology, environmental geology, hydrology, and GIS analysis. From a training perspective, the watershed-based curriculum: (1) incorporates research into the undergraduate Earth Science program at WOU, (2) engages students in socially-relevant watershed-based science (e.g. Woltemade and Blewett, 2002), (3) improves quantitative skills via coursework, lab exercises and applied research, (4) develops problem-solving and scientific skills within a regional watershed setting, and (5) fosters an interconnected perspective of watershed processes across several linked courses. The research model is placed in the context of community outreach via collaboration with a local watershed council.

The outcomes of this project are summarized in Table 1, they include: (1) a set of contextual, watershed-based, learning modules and field guides for use in an integrated course series, (2) community outreach via faculty-student interaction with the Luckiamute Watershed Council, a community-based organization dedicated to water resource conservation, (3) publishable research on hydrogeomorphic aspects of the Luckiamute Watershed, and (4) dissemination of a watershed-based undergraduate education model (www.wou.edu/luckiamute). The resulting research objectives focused on lithologic control of drainage basin morphology and characterization of local aquifer systems. In addition, the USGS funding and incentives to conduct this work have led to numerous synergistic activities, all of which are described below.

PROJECT RESULTS

Undergraduate Training and Support

Integrating undergraduate research and education in the sciences is recognized as an important model for preparing students to participate in the 21st century workforce (National Science Foundation, 2003). College graduates are increasingly required to understand complex integrated systems by applying multi-disciplinary problem solving skills. As such, there is a general lack of linked science curricula in which students systematically build a set of problem-solving skills that are applied to real-world problems (Heins and Walker, 1998). Watershed systems represent the interaction of physical and biological processes at spatial and temporal scales that are highly relevant to the community at large (Woltemade and Blewett, 2002). The results of this project form the framework for undergraduate training in applied fluvial geomorphology (ES322), environmental geology (ES473), hydrology (ES476), and applied geographic information systems (ES492) at Western Oregon University.

Ten contextual learning modules and three class-related field trip guides were created with the Luckiamute Watershed serving as the outdoor laboratory for inquiry-based, experiential discovery (Table 1, Figure 2). The learning modules include GIS techniques, field hydrology, case studies in groundwater contamination, geomorphic analysis, watershed assessment, and value-added utilization of USGS stream gage data. The Luckiamute field guides involve a range of topics including regional geology, tectonic setting, hydrogeology, environmental quality, and solid waste management. With the Luckiamute serving as the unifying theme, upper division students are exposed to linked modules distributed across four surficial-process courses, thus integrating concepts and reinforcing a watershed systems approach to Earth Science education. Specific details of the curricular products derived as part of this project are available for online review at http://www.wou.edu/luckiamute.

During the course of this project, seven WOU undergraduates were supported as research assistants: Jeff Budnick, B.S. Earth Science (graduated June 2005); Chandra Drury, B.S. Earth Science (graduated December 2005); Jamie Fisher, B.S. Earth Science (expected graduation Spring 2006); Diane Hale, B.S. Physical Geography (graduated August 2004); Jeff Kent, B.S. Earth Science (expected graduation Spring 2006); Katie Noll, B.S. Earth Science (expected graduation Winter 2007); and Rachel Pirot, B.S. Earth Science (expected graduation Fall 2007). The primary research activities conducted by the students included literature review, data compilation, GIS analysis, scientific visualization, and field geomorphology (Figure 2). In addition, the research and learning modules from this project will have lasting impact to present and future Earth Science students enrolled in

ES322 Geomorphology (n = 8-12 students / term), ES473/573 Environmental Geology (n=8-12 students / term), ES476/576 Hydrology (n= 8-12 students/term), and ES 492/592 GIS Applications in Earth Science (n = 8-12 students/term).

Community Outreach

Research, service and educational activities at Western Oregon University are directly connected to the community by way of outreach to the Luckiamute Watershed Council (LWC). WOU provides office space, computing facilities, and support services for LWC. The watershed coordinator is housed in close proximity to faculty, resulting in weekly synergistic interaction. During the course of this grant, two LWC coordinators were trained and indirectly supported as research associates: Eve Montanaro (B.S. Physical Geography, 2002, University of Oregon) and Michael Cairns (retired EPA). Community outreach activities, centered on the Luckiamute Watershed, have resulted in a number ancillary projects involving faculty and students. Value-added community products include stakeholder opinion surveys, scientific advisement on watershed assessment, assistance on restoration projects, seminars/field trips, general board advisory activities, and GIS technical support.

Research Results

Bedrock Controls on Watershed Morphology

Studies in the Oregon Coast Range have yielded numerous contributions to the understanding of mountain river systems. Published research topics include sediment budget analysis, sediment transport models, debris flow dynamics, hillslope hydrology, landslide risk modelling, effects of punctuated sediment supply, landscape evolution, and tectonic controls on bedrock erosion rates. While this rich body of work has significantly improved our geomorphic understanding of mountain river systems, most studies have been limited to landscapes underlain by bedrock of the Eocene Tyee Formation (Taylor, 2005). Few studies have been conducted in portions of the Oregon Coast Range underlain by other lithostratigraphic units. Work in other bedrock domains is needed to assess the applicability of existing models to other Coast Range landscapes. This study involved comparative morphometric analysis of HUC 6th field watersheds, using Tyee-based landscapes as a benchmark for comparison with other bedrock types in the central Oregon Coast Range.

The Luckiamute River watershed drains 815 km^2 along the east flank of the Coast Range in west-central Oregon (Figure 1). The basin is bounded by the Willamette River to the east, the crest of the Coast Range to the west, Green Mountain and Marys River to the south, and the Rickreall Creek

Watershed to the north. Land surface elevations range from 46 m (150 ft) at the confluence with the Willamette River to 1016 m (3333 ft) at Fanno Peak. The Luckiamute has an average gradient of 3 m/km, a total stream length of 90.7 km, and an average basin elevation of 277 m (910 ft). Fanno Ridge separates the watershed into two tributary subbasins, with the Little Luckiamute to the north and the main stem of the Luckiamute proper to the south (Figure 1).

Bedrock map units are grouped into four lithospatial domains, these include the Siletz River Volcanics Domain (south), the Tyee Domain (west-southwest), the Yamhill-Intrusive Domain (north-northwest), and the Spencer-Valley Fill Domain (east) (Figure 3). The Siletz River Domain comprises 19% of the watershed and is mainly seafloor basalt. The Tyee Domain (29% of total area) is underlain by arkosic sandstone lithofacies with local mafic intrusives. The Yamhill-Intrusive Domain occupies 23% of the watershed and is characterized by outcrop of marine siltstone and mafic intrusives. The Spencer-Valley Fill Domain (29%) is underlain by a patchwork of marine sandstones and Quaternary alluvium. Hillslope landforms and colluvial processes dominate the Siletz River, Tyee, and Yamhill domains, whereas fluvial landforms and alluvial processes are characteristic of the Spencer Domain (Figure 4).

Fourth-order subbasins (n = 5-6, avg. Ad = 16 km^2) were selected from each bedrock domain for subsequent terrain analysis of USGS 10-meter DEMs (Figure 5). Subbasin boundaries and channel networks used in this study are thosed derived by the Coastal Landscape Analysis and Modeling (CLAMS) group at Pacific Northwest Forest Research Lab (Miller et al., 2001). Results of comparative morphometric analyses are presented in Figure 6. Averaged quantitative parameters for the Spencer, Siletz, Yamhill, and Tyee domains include, respectively: **(1)** hypsometric integral (0.30, 0.40, 0.48, 0.29), **(2)** basin ruggedness (0.2, 1.2, 1.1, 1.6), **(3)** total drainage density (1.4, 2.3, 2.0, 2.4 km^{-1}), **(4)** Shreve magnitude (14, 49, 31, 55), **(5)** first-order stream density (0.7, 1.2, 1.0, 1.2 km^{-1}), **(6)** channel gradients (0.04, 0.13, 0.18, 0.14), **(7)** stream power index (69, 1909, 2534, 1133), **(8)** hillslope gradients (3.2, 12.7, 11.9, and 14.5 degrees), and **(9)** hillslope profile curvature (0.004, 0.008, 0.007, 0.011 m/deg). The Tyee Domain is more finely dissected by low-order stream channels and associated with more rugged hillslopes compared to the other three domains. Results of the slope analyses are consistent with debris-flow hazard models released by the Oregon Department of Forestry, suggesting that hillslopes in the Tyee Domain are most prone to slope failure (percent of domain area in hazard zone: Tyee = 38.1, Siletz = 30.2, Yamhill = 24.6, and Valley Fill = 0.7). Morphometric analysis of higher-order valley widths at 500 m increments shows that trunk drainage across the Tyee Domain covers a much wider swath of valley floor (avg. W_v = 274 m) compared to a similar-sized drainage area in the Yamhill Domain (avg. W_v = 109 m) (Figure 7). Stream power parameters suggest that while Tyee drainages are more energetic than the Spencer system, they are less potentially less effective at sediment transport than the other upland domains (Figure 6C). These data suggest that bedrock lithology exerts a strong control on hillslope morphology, style of hillslope process, and sediment-transport efficiency in headwater portions of the Luckiamute.

The interplay between hillslope transport mechanisms, delivery rates, and channel hydraulics control the volume of sediment exported or stored within a mountainous watershed. The comparatively steep, debris-flow-prone slopes and wide valley bottoms in the Tyee Domain indicate a potential for hillslope transport rates to be greater than the ability of the channel system to export sediment. Analytical results presented herein provide a preliminary dataset upon which to build a field-based sediment-storage budget for the Luckiamute watershed. The working hypothesis is that the Tyee Domain has a significantly greater volume of valley-bottom sediment in storage compared to the other upland domains (Siletz, Yamhill) (Figure 8). The model implies that spatial variation of bedrock lithology is a primary factor controlling slope gradients, hillslope delivery rates, and the resulting sediment-transport efficiency of the channel system. The rich body of work from other Tyee-based landscapes in the Oregon Coast Range will serve as the platform from which to extend future research in the Luckiamute to other bedrock domains.

Hydrogeologic Characterization

Gannet and Caldwell (1998) and Woodward et al. (1998) delineated the principle hydrostratigraphic units in the Southern Willamette Basin. In ascending order these include: (1) basement confining unit (BCU), (2) Willamette confining unit (WCU), (3) Willamette aquifer (WAq), and (4) Willamette Silt (WS). The lowermost unit is represented by indurated bedrock, while the latter three are comprised of unconsolidated alluvium and valley-fill sediments. Alluvial-fill thickness in the lower Luckiamute and Ash Creek sub-basins ranges up to 30 m (100 ft) with most localities in the 12 to 24 m (40 to 80 ft) range. Luckiamute alluvial-fill thickens to the east towards the center of the Willamette Valley, and thins upstream to a minimum near the communities of Falls City and Pedee (Caldwell, 1993; Gannett and Caldwell, 1998).

The basement confining unit is composed predominantly of Tertiary marine sedimentary rocks and related submarine basalts. This unit is characterized by relatively low permeability lithofacies with intermixed low-yield aquifer horizons and aquitards. In the lower Luckiamute and Ash Creek subbasins, BCU is composed largely of Spencer Formation strata. The Siletz River Volcanics form the basement unit in the southern portion of the watershed, along Soap Creek (Figures 3 and 9).

The Willamette confining unit is composed of unconsolidated fine-grained fluvial facies deposited by low-gradient streams during the Pleistocene. Drilling logs commonly refer to this unit as “blue clay”, “silty clay” or “shale", containing laterally discontinous sandy and gravelly interbeds. WCU is characterized by limited ground water production, however coarse-grained interbeds locally serve as aquifers. Regional yields from wells set in this unit range from 2 to 10 gallons per minute (Table 2). WCU thickness in the study area ranges from a maximum of 18 m (60 ft) at Luckiamute Landing, to less than 6 m (20 ft) upstream of Helmick State Park. The Willamette confining unit is less than 18 m (60 ft) thick in the Ash Creek subbasin.

The Willamette aquifer is composed of coarse-grained facies associated with Pleistocene alluvial fans and deposits of smaller side tributaries. This unit was referred to as the "Linn Gravel" by Allison (1953). It is characterized by thick-bedded sand and gravel facies with thin interbeds of fine-grained sand, silt and clay. WAq is locally cemented and partially indurated. Regionally, the Willamette aquifer is formed by fluvio-glacial outwash from large drainage systems in the Cascades that debouch westward onto the valley floor. Given lower summit elevations, the Coast Range was not glaciated during the Pleistocene. Thus eastward-draining tributaries to the Willamette, including the Luckiamute, tend to be smaller in area compared to those of the western Cascades, and are not associated with high-volume fluvio-glacial aquifer systems. The lower end of the Luckiamute lies approximately 30 km (18 mi) west of the Stayton and Lebanon fans, deposits of the North and South Santiam Rivers, respectively. Given the distal position of the Luckiamute in relation to large fan deposits, WAq gravels in the watershed are generally less than 6 m (20 ft) thick and are likely composed of sediments derived locally from Coast Range sources.

The Willamette Silt is the uppermost valley-fill unit and is comprised of late Pleistocene Missoula Flood deposits (map unit Qff2 of O’Connor and others, 2001). Fine-grained clay, silty clay, and silt occurs up to an elevation of 120 m (400 ft) in Luckiamute Basin and is less than 6 to 9 m (20 to 30 ft) thick (Table 2). This unit serves as a semi-confining aquitard for the Willamette aquifer, however it is partly saturated and is commonly associated with water table conditions throughout much of the Willamette Basin.

In addition to the valley ground-water system, a significant portion of the Luckiamute is served by upland bedrock aquifer horizons set in strata of the Siletz River Volcanics, Tyee Formation, Yamhill Formation, and Oligocene Intrusives. Crystalline volcanic and intrusive rocks have inherently low porosity and permeability, but secondary fracture porosity can be significant (Freeze and Cherry, 1979). In the case of the Siletz River basalts, low-grade alteration and secondary zeolitization has likely resulted in significant reduction of hydraulic conductivity. Similary, the fine-grained nature of the Tyee and Yamhill formations makes them of limited value as aquifer material (Table 2).

Hydrogeologic data were collected from field-located wells as part of the Willamette Regional Aquifer Systems Analysis (RASA) conducted by the U.S. Geological Survey (Woodward and others, 1998; Gannett and Caldwell,1998). Approximately 40% of well heads are located in unconsolidated valley-fill alluvium, with 60% situated in basement-confining or upland bedrock units (Table 2). Given that maximum alluvial fill in the Luckiamute-Ash Creek basins is generally less than 30 m (100 ft), all of the wells in the inventory have bottom depths situated in the basement-confining or upland bedrock aquifers. Average depth relations reveal that the bedrock wells have greater total depths and lower static water level elevations compared to wells situated on valley fill. Although quantitative hydraulic analyses are lacking in the Luckiamute, Gonthier (1983) documented hydraulic conductivities in the range of 0.2 to 0.3 ft/day for the Dallas-Monmouth Area. Accordingly, the average specific capacity for wells ranges from <1 to 7 gallons per minute per foot of drawdown (Woodward and others, 1998).

The Spencer-Valley Fill domain in the Luckiamute forms part of the regional Willamette aquifer system which is generally associated with unconfined potentiometric conditions. Valley-fill aquifers in the Ash Creek subbasin are hydrogeologically separated from the Luckiamute by a hydraulic divide comprised of low-permeability lithofacies in the Spencer Formation (basement confining unit of Gannett and Caldwell, 1998). The lower Luckiamute valley-fill aquifer system is characterized by eastward ground water flow and hydraulic gradients on the order of 5 ft/mi (Woodward and others, 1998). Unconsolidated valley fill is more prevalent in the Ash Creek subbasin with eastward-directed hydraulic gradients of 20 ft/mi (Caldwell, 1993). Regionally, seepage velocity in the Willamette aquifer ranges from 3 to 30 ft / day, comparable to other coarse-grained aquifers. Iverson and Haggerty (2002) conducted research in the Willamette Silt to determine hydraulic and geochemical properties. The results of their work along the Pudding River suggests that WS serves as a confining unit to the underlying Waq. Horizontal hydraulic conductivities are on the order of 0.004 to 5.53 ft/day, with vertical permeabilities of 0.008 ft/day and porosity of 40%.

Natural ground water quality ranges from good to poor in the Luckiamute-Ash Creek subbasins. Caldwell (1993) documented localized high salinity concentrations in the Monmouth-

Independence area. His study utilized trace element analyses to relate bedrock mineralogy to ground water residence times and salinity contamination risk. The results indicate that ground water in the region is associated with chloride-dominant ionic species ($CaCl_2$ and NaCl) and poses a potential water quality hazard. It is interpreted that increased salinity levels are derived from connate brine waters trapped in Tertiary marine sedimentary rocks. This saline water mixes with shallow ground water via upward migration along folds and faults in the basement confining units. Preliminary analyses of water quality data to the south indicate that similar salinity conditions may also be present in Luckiamute aquifers. Detailed quantitative analyses of Luckiamute aquifer systems are needed to delineate the physical and chemical nature of hydrogeologic processes in the basin.

SYNERGISTIC ACTIVITIES

The funding and activities associated with this project provided the catalyst for synergistic collaborations and additional research opportunities in the Luckiamute basin. A sampling these ancillary projects is provided below.

Stream Temperature Survey
(Taylor and WOU Students; WOU Foundation Funding)

Studies elsewhere in Oregon suggest that groundwater flux to streams during the summer and stream temperature are dependent on geology, with fractured or porous formations producing the highest flows per unit drainage area and the coolest streams. A comparison of small watersheds in the mid-Coast Range of Oregon indicated that those underlain by highly-fractured marine basalt have summer base flow volumes that average 3 times greater than those underlain by sandstone (Hicks 1990). Similarly, streams flowing through the central High Cascades in Oregon have unit summer flows that are 14 times greater than those flowing through the Western Cascades (Tague and Grant, 2004). Accordingly, streams draining the High Cascades are an average of 5 degrees cooler than those draining the Western Cascades.

Low flows combined with warm summer climate result in stream temperatures for portions of the Luckiamute watershed that sometime exceed the limits for juvenile steelhead trout survival and growth. The warmer stream segments in the watershed generally occur at greater distances from the headwaters. Data collected by the Oregon Department of Environmental Quality (2001) indicate that it is mainly the portion of the stream network within 15 miles of a drainage divide that is cool enough to sustain steelhead trout during the warmest part of the summer, assuming that fish will continue to occupy water that is 70 degrees or cooler (Figure 10). Streams that do not have adequate shade (shown as circles in Figure 10) are capable of approaching or exceeding 70 degrees even at closer distances to the headwaters. Fish are able to use marginally warm streams by congregating in localized zones of cooler water during the warmest part of the day. Cool water can occur at discrete points where groundwater enters (springs), become stratified at the bottom of deep pools, and occur where subsurface water flowing through gravel deposits is intercepted by the stream channel. These cool water zones are expected to be more common in porous lithologies.

With funds provided by a private donation for Luckiamute watershed research at WOU, a systematic stream temperature survey will begin in summer 2006. The objectives of this project are to compare summer low-flow stream temperatures in the Tyee domain to those of the Siletz. Stream temperatures will be examined in tandem with reach-scale discharge to evaluate the relative contribution of groundwater baseflow in each of the lithospatial domains. The preliminary hypothesis is that the streams in the marine basalts will have higher unit flows, lower overall water temperature, and greater frequency of cool water refugia when compared to streams in the Tyee domain. Differences in water characteristics between the two lithospatial domains may be great enough to influence the distribution and carrying capacity of cool-water communities of fish that use these channel systems. The results will have important implications for guiding salmonid recovery efforts in the Luckiamute basin.

<u>Invasive Plant Study</u>
(Bryan Dutton-WOU Biology and Taylor; funded by Oregon Community Foundation)

Invasive plant species in western Oregon are a pervasive problem that disrupt native habitats and create annual economic losses of millions of dollars for public and private landowners (Oregon Department of Agriculture, 2001). Nationwide, the United States experiences annual losses of over $130,000,000.00 due to non-native species (Pimentel and others, 2000). Vegetative disturbance of natural ecosystems by geomorphic and anthropogenic processes affect soil substrate conditions, nutrient availability, canopy shading (solar influx), and riparian hydrology. The most abundant concentrations of invasive species are typically associated with disturbed zones that have been altered by human activity. As such, disturbed zones on the landscape act as primary conduits for the dispersal of non-native species (Pabst and Spies, 1998). Understanding the controls on spatial distribution of invasive plants in the context of disturbance regime is critical for designing effective watershed conservation and restoration plans.

The purpose of this research is to conduct a reconnaissance survey to delineate associations between geomorphic (landslides and floods) and anthropogenic disturbance (road construction, logging, and agriculture) regimes, and distribution patterns of invasive plant species in the Luckiamute Watershed of western Oregon (after Swanson et al., 1990). The Luckiamute is associated with a unique combination of geomorphic and land-use conditions that are well-suited for the study of causal factors that control spatial distribution of invasives in the region. The results of this preliminary work will form the basis of more extensive studies in the region and have potential use for development of larger scale predictive models of invasive plant dispersion.

PROJECT DISSEMINATION

All data and reports completed as part of this project were compiled and are being distributed via internet technologies (refer to URL: http://www.wou.edu/luckiamute), the Luckiamute Watershed Council newsletter, class content modules, and a watershed seminar series. The project web site is the primary information source for students and community stakeholders. All project spatial data were compiled into a GIS and are being distributed via a dedicated server housed at Western Oregon University (Table 1). Research results and related curriculum products will be disseminated by presentation at national geoscience meetings (e.g. Taylor, 2005) and in peer-reviewed publications.

BIBLIOGRAPHY

References Cited

Allison, I.S., 1953, Geology of the Albany quadrangle, Oregon: Oregon Dept. of Geology and Mineral Industries Bulletin 37, 20 p.

Caldwell, R.R., 1993, Geochemistry, alluvial facies distribution, hydrogeology, and groundwater quality of the Dallas Monmouth area, Oregon: Unpublished M.S. Thesis, Portland State University, Portland, Oregon, 198 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Prentice-Hall, New Jersey, 604 p.

Gannett, M.W. and Caldwell, R.R., 1998, Geologic framework of the Willamette Lowland aquifer system, Oregon and Washington: U.S. Geological Survey Professional Paper 1424A, 32p.

Gonthier, J.B., 1983, Groundwater resources of the Dallas-Monmouth area, Polk, Benton, and Marion Counties, Oregon: State of Oregon Groundwater Report No. 28, 50 p.

Heins, W.A., and J.R. Walker, 1998, Using a campus waterway for undergraduate-course exercises and summer-research experiences: Journal of Geoscience Education, v. 46, p. 45-50.

Hicks, B.J. 1990. The influence of geology and timber harvest on channel morphology and salmonid populations in coastal Oregon streams. Ph.D. thesis, Oregon State University, Corvallis.

Iverson, J., and Haggerty, R., 2002, Investigation of the hydraulic, physical, and chemical buffering capacity of Missoula flood deposits for water quality and supply in the Willamette Valley of Oregon: Geological Society of America Abstracts with Programs, Cordilleran Section Meeting, v. 34, no. 5, p. 109.

National Science Foundation, 2003, National Science Foundation Strategic Plan – FY 2003-2008: NSF Publication NSF-04201, Washington, D.C., 34 p.

O'Connor, J.E., Sarna-Wojcicki, A., Wozniak, K.C., Polette, D.J., and Fleck, R.J., 2001, Origin, extent, and thickness of Quaternary geologic units in the Willamette Valley, Oregon: U.S. Geological Survey Professional Paper 1620 (with 1:250,000 maps), 52 p.

Oregon Department of Agriculture, 2001, Oregon noxious weed strategic plan: ODA Plant Division, Weed Control Program Online Resource, URL:http://www.oda.state.or.us/Plant/weed_control/plan/contents.html, updated January, 2001.

Pabst, R.J., and Spies, T.A., 1998, Distribution of herbs and shrubs in relation to landform and canopy cover in riparian forests of coastal Oregon: Canadian Journal of Botany, v. 76, p. 298-315.

Pimentel, D., Lach, L., Zuniga, R., and Morrison, D., 2000, Environmental and economic costs of nonindigenous species in the United States: BioScience, v. 50, p. 53-65.

Swanson, F.J., Franklin, J.F., and Sedell, J.R., 1990, Landscape patterns, disturbance, and management in the Pacific Northwest, USA, in Zonneveld, R.S., and Forman, R.T., eds., Changing landscapes: An ecological perspective: Springer-Verlage, New York, p. 191-213.

Tague, C. and G. Grant. 2004. Hydrogeologic controls on stream temperatures in headwater catchments in relation to forest management activities, Willamette River basin. Progress Report 1, Oregon Headwaters Research Consortium.

Taylor, S.B., 2002, Bedrock Control on Slope Gradients in the Luckiamute Watershed, Central Coast Range, Oregon: Implications for Sediment Transport and Storage: American Geophysical Union Abstracts with Programs, Fall Meeting 2002, San Francisco, California.

Taylor, S.B., 2005, Lithologic Controls on Watershed Morphology in the Central Oregon Coast Range: Towards Extrapolation of Tyee-Based Models to Other Bedrock Types – Mountain Rivers Session: Association of American Geographers, Abstracts with Programs, Annual Meeting, Denver.

Woltemade, C.J., and Blewett, W.L., 2002, Design, implementation, and assessment of an undergraduate interdisciplinary watershed research laboratory: Journal of Geoscience Education, v. 50, p. 372-379.

Woodward, D.G., Gannett, M.W., and Vaccaro, J.J., 1998, Hydrogeologic Framework of the Willamette Lowland Aquifer System, Oregon and Washington: U.S. Geological Survey Professional Paper 1424-B, 82 p.

Publications, Reports, Presentations, and Related Proposals

Taylor, 2005, In Preparation, Lithologic Controls on Watershed Morphology in the Central Oregon Coast Range: to be submitted to *Geomorphology*.

Taylor, S.B., 2005, Lithologic Controls on Watershed Morphology in the Central Oregon Coast Range: Towards Extrapolation of Tyee-Based Models to Other Bedrock Types – Mountain Rivers Session: Association of American Geographers, Abstracts with Programs, Annual Meeting, Denver.

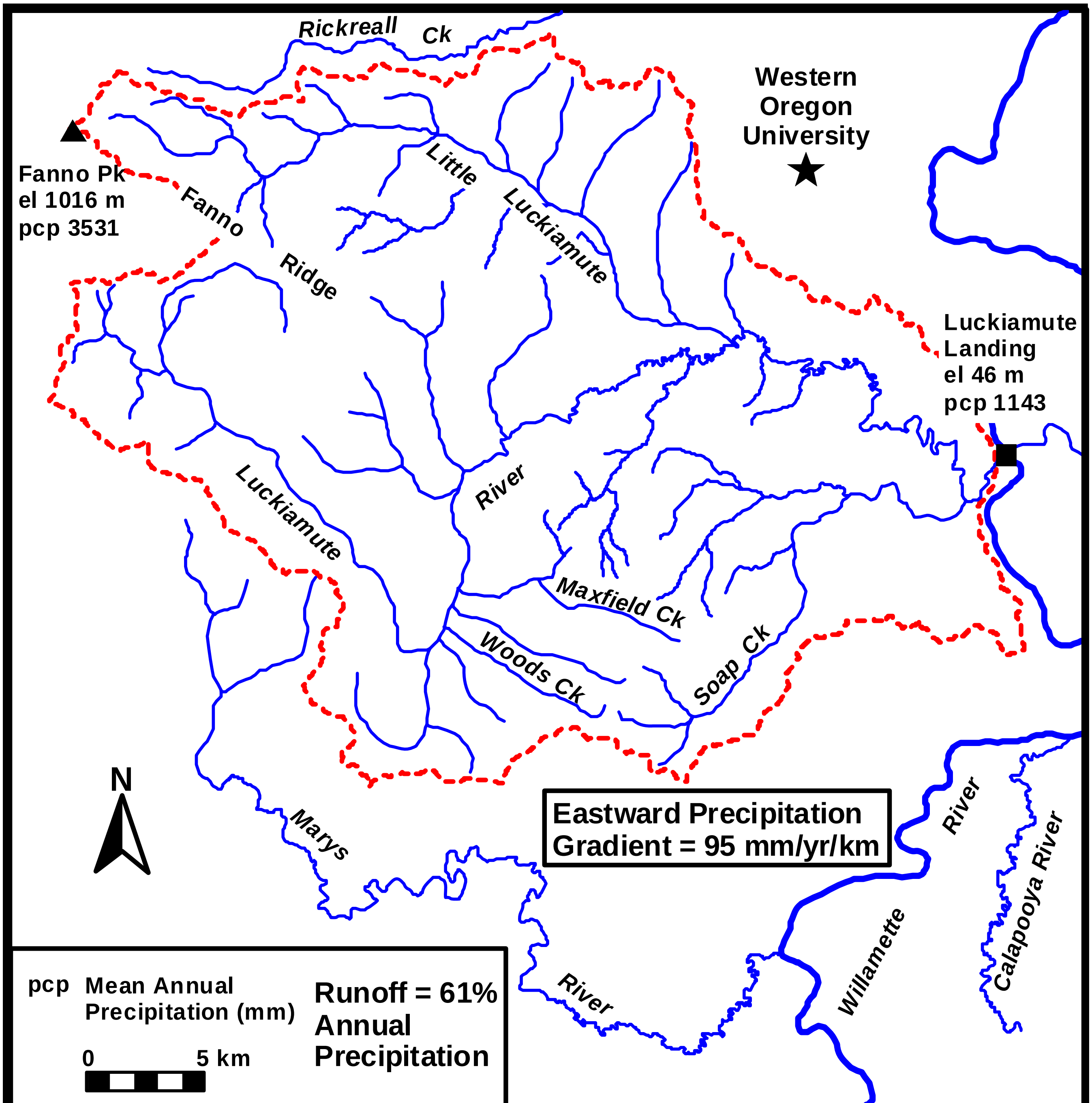
Taylor, S.B., 2004, Geology of the Luckiamute River watershed, upper Willamette Basin, Polk and Benton Counties, Oregon: *in* Garono, R.J., Anderson, B.D., Harma, K., Buhl, C., and Adamus, P., Luckiamute / Ash Creek / American Bottom Watershed Assessment: Unpublished Technical Document, Luckiamute Watershed Council, Western Oregon University, Monmouth, Oregon, Appendix A – 19 p., available on line at <URL: http://www.wou.edu/las/natsci_math/geology/luckiamute/Appendix A Geology of Luckiamute River Watershed.pdf, updated June 2004.

Taylor, S.B., 2005, Proposal for Water Quality Study: “Lithologic Controls on Water Temperature in the Luckiamute Watershed, Polk and Benton Counties, Oregon”, funding for $1500 awarded by the College of Liberal Arts and Sciences, Western Oregon University.

Dutton, B. and Taylor, S.B., 2004, Proposal for Conservation Rearch: “Geomorphic and Anthropogenic Controls on the Distribution of Invasive Plant Species in the Luckiamute Watershed, Polk and Benton Counties, Oregon”, funding for $12,000 awarded by the Oregon Community Foundation.

Dutton, B. and Taylor, S.B., 2004, Proposal for Conservation Rearch: “Geomorphic and Anthropogenic Controls on the Distribution of Invasive Plant Species in the Luckiamute Watershed, Polk and Benton Counties, Oregon”, funding for $6,000 awarded by the Western Oregon University Faculty Development Fund.

Dutton, B. and Taylor, S.B., 2005, Proposal for Invasive Plant Research: “Reconnaissance Survey of Japanese Knotweed in the Riparian Zone of the Luckiamute Watershed”, funding for $2000 awarded by the Northwest Invasive Weed Management Partnership Program.



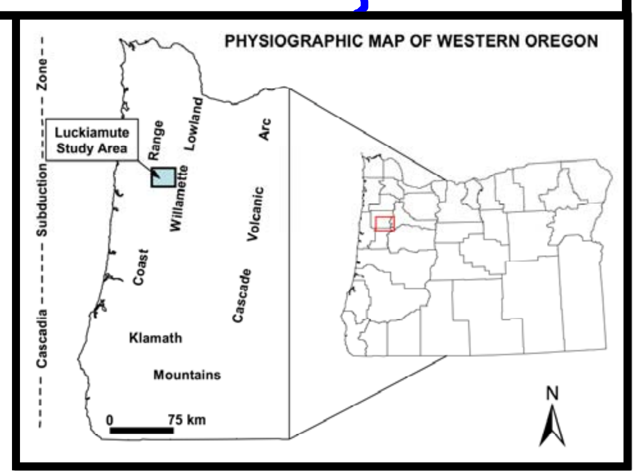


Figure 1. Location map of the Luckiamute Watershed study area.

Table 1. Summary of Luckiamute Watershed Project Deliverables (available online at www.wou.edu/luckiamute).

1. LUCKIAMUTE WATERSHED CONTEXTUAL LEARNING MODULES

ES322 Geomorphology - Introduction to Watershed Analysis - Luckiamute Basin
ES322 Geomorphology - Introduction to GIS and Luckiamute Basin
ES322 Geomorphology - Baker Ck Landslide Problem (Soap Creek Sub-basin)
ES322 Geomorphology - Helmick State Park Soil Survey Exercise (Luckiamute)
ES322 Geomorphology - Luckiamute Field Hydrology (part 1)
ES322 Geomorphology - Luckiamute Fluvial Hydrology (part 2)
ES322 Geomorphology - Luckiamute Watershed Field Portfolio Guidelines
ES473/573 Environmental Geology - Mountain Fir Groundwater Case Study
ES473/573 Environmental Geology - Luckiamute Watershed Assessment
ES476/576 Hydrology - Luckiamute Flood Hazards Lab

2. LUCKIAMUTE WATERSHED CLASS-RELATED FIELD GUIDES

Taylor (2004) Geology and Geomorphology of the Luckiamute Watershed
Taylor (2004) Field Guide to the Coffin Butte Landfill, Soap Creek Sub-basin
Taylor (2005) Hydrogeology of the Ash Creek Sub-basin

3. RELATED REPORTS AND PUBLICATIONS

Association of American Geographers-Mountain Rivers Session (Taylor, 2005)
Geology of the Luckiamute Basin (Taylor, 2004)
Luckiamute Watershed Assessment (Garono and others, 2004)
Luckiamute Watershed Assessment - Final Report (Garano and others, 2004)

4. LUCKIAMUTE GIS DATA COMPILATIONS

Bedrock Geology
- Bedrock - All Files (19.91 MB)
- Luckiamute Bedrock Geology (632.6 KB)
- State Geology (11.27 MB)
- Tyee Landscapes - Oregon Coast Range (106.0 KB)
- Willamette Valley Geology (7.92 MB)

Cultural and Geographic Data
- Benton County Taxlots (5.80 MB)
- Cultural-All Files (35.60 MB)
- Luckiamute Cultural Features (4.09 MB)
- State Features (2.51 MB)
- Polk County Taxlots (23.19 MB)

5. LUCKIAMUTE GIS DATA COMPILATIONS (con.t.)

CLAMS Coast Range Watershed Data
- Coast Range 6th-7th Field Basins (10.28 MB)
- Coast Range Streams (mideast section) (16.72 MB)
- Coast Range Streams (midwest section) (44.45 MB)
- Coast Range Streams (northeast section) (26.74 MB)
- Coast Range Streams (north section) (52.14 MB)
- Coast Range Streams (south section) (40.21 MB)
- Coast Range Streams (Umpqua section) (36.50 MB)

Geomorphology and Surficial Geology
- Debris Flow Hazards (Polk,Marion,Benton) (4.79 MB)
- Geomorphology-All Files (18.08 MB)
- Luckiamute Geomorphology (2.14 MB)
- Missoula Flood Maps (4.22 MB)
- Regional Physiography (428.1 KB)
- Willamette Surficial Geology (O'Connor et al., 2001) (6.44 MB)

Groundwater and Hydrogeology
- Luckiamute Groundwater Data (12.17 MB)

Soils
- Luckiamute Soils Data - Polk and Benton Counties (8.34 MB)

Surface Water Hydrology
- Luckiamute Surface Hydrology / Stream Channels (15.20 MB)

Topography / Elevation Models
- Luckiamute Topography / Contour Maps (56.43 MB)

Tyee Landscape Analysis
- Tyee Landscape Analysis - Test Watersheds (22.17 MB)

Vegetation
- Luckiamute Vegetation (24.03 MB)

Water Quality
- Luckiamute Water Quality (503.0 KB)

Figure 2. Western Oregon University Earth Science students actively engaged in Luckiamute Watershed learning and research modules.

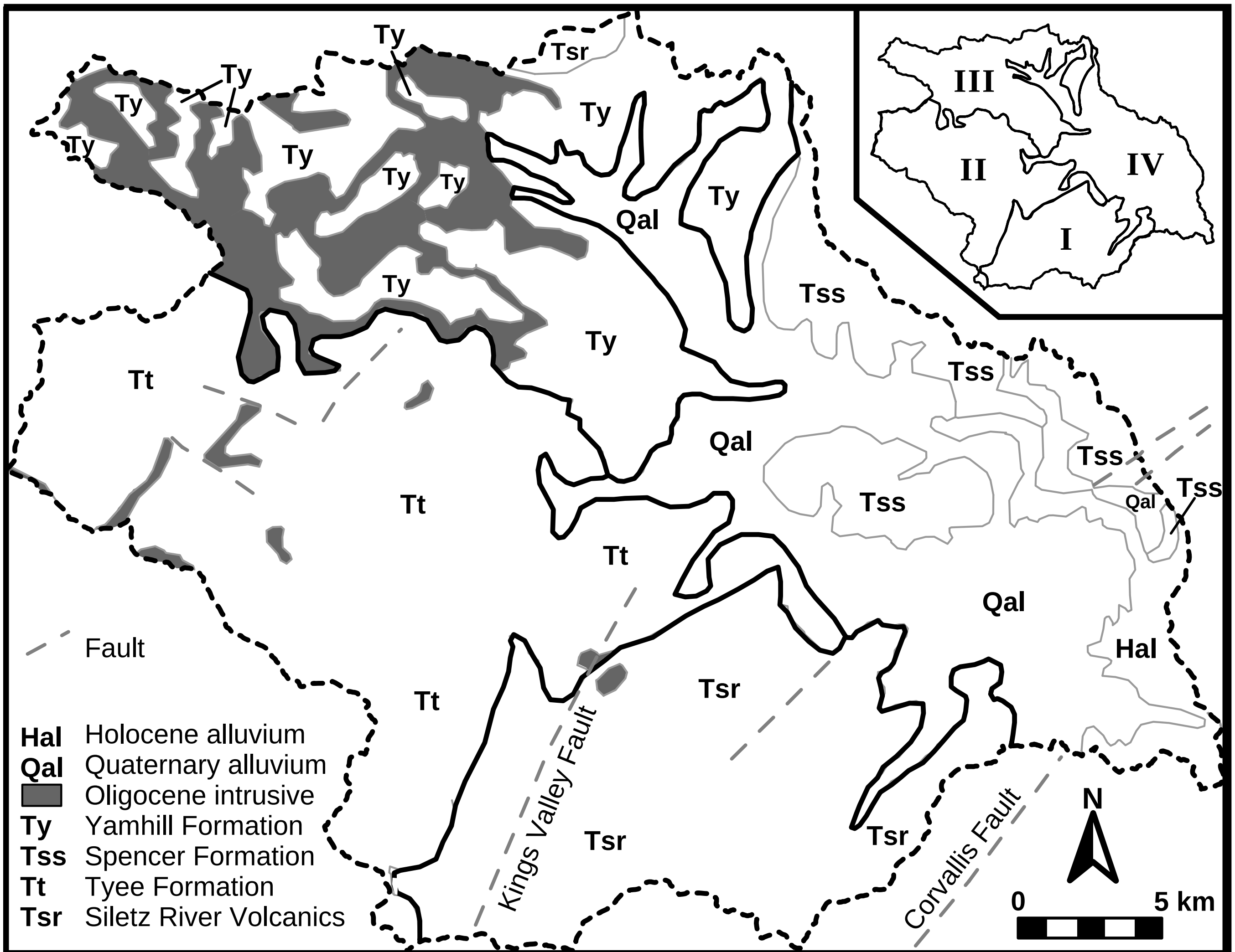
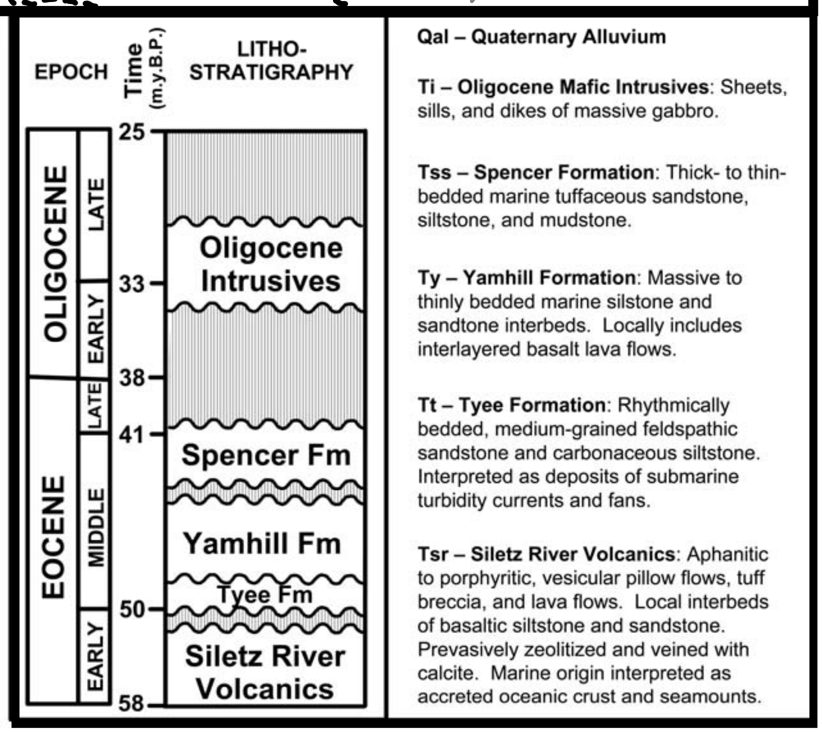
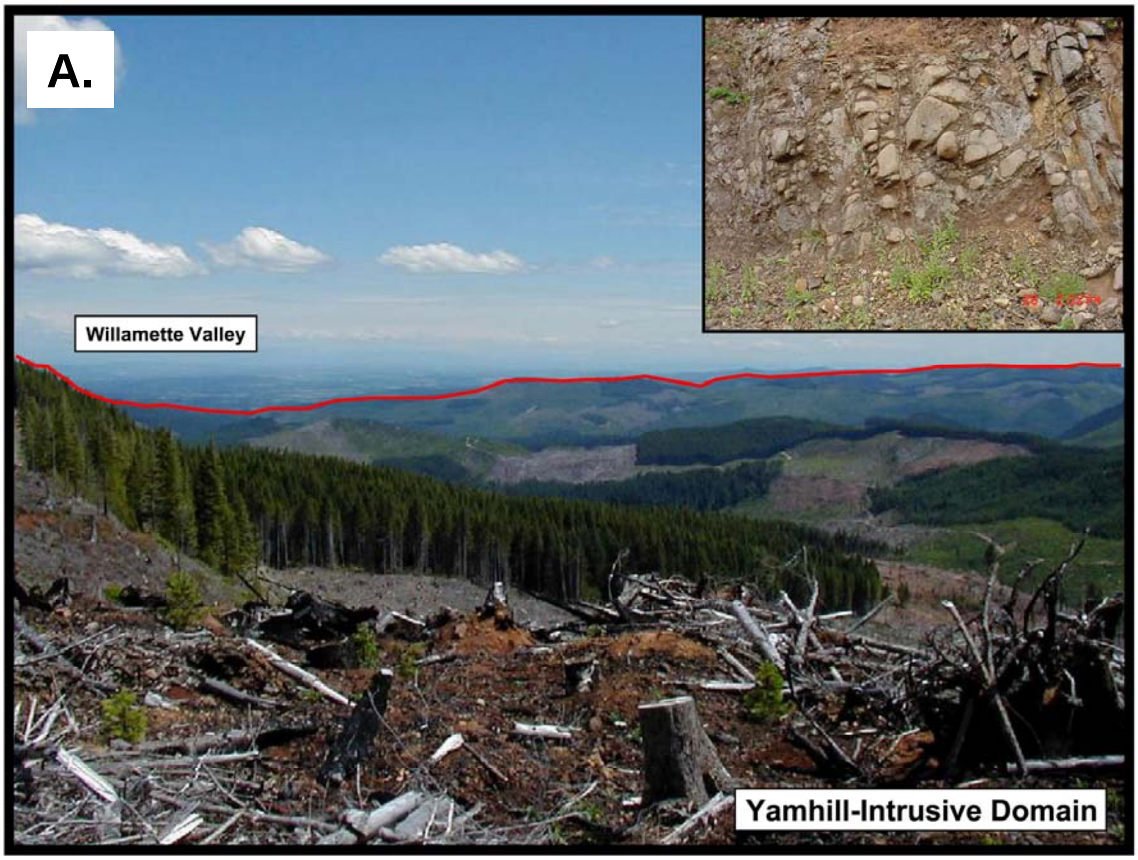


Figure 3. Bedrock geology of the Luckiamute study area.





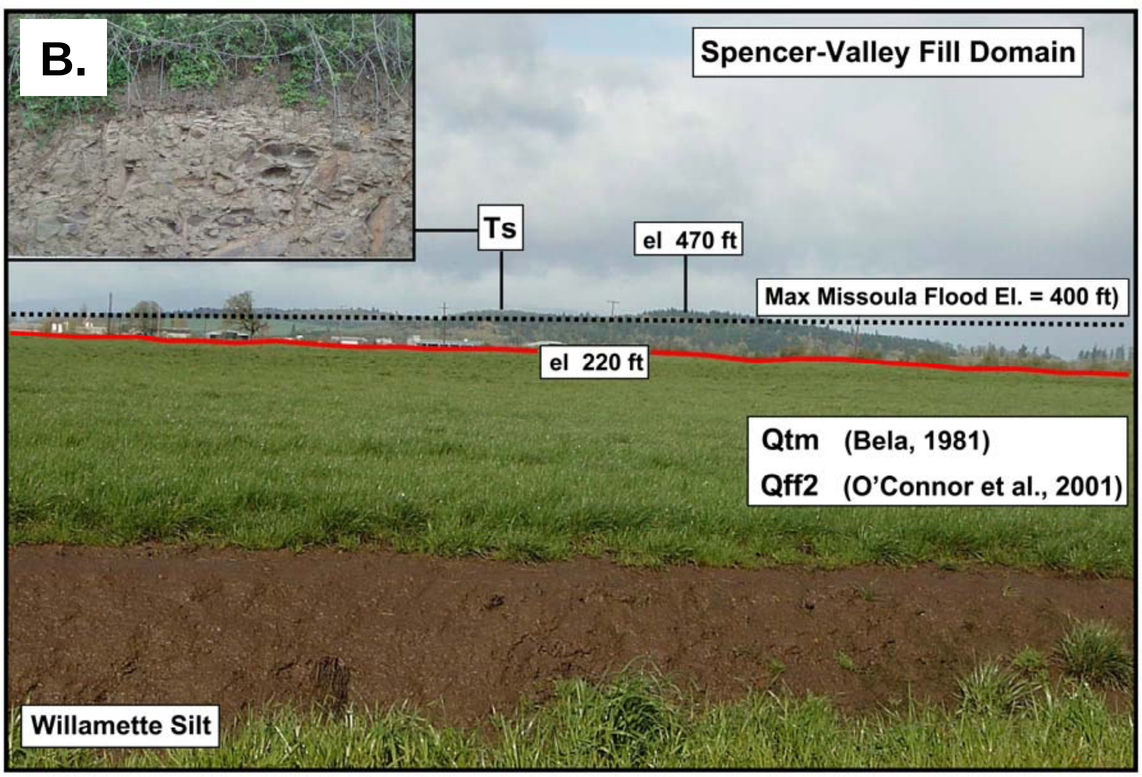


Figure 4. A. Photo showing western portion of the Luckiamute Watershed, upland landscape typical of the Yamhill-Intrusive domain. B. Photo showing eastern, lowland portion of the Luckiamute Watershed, Spencer-Valley-Fill domain.

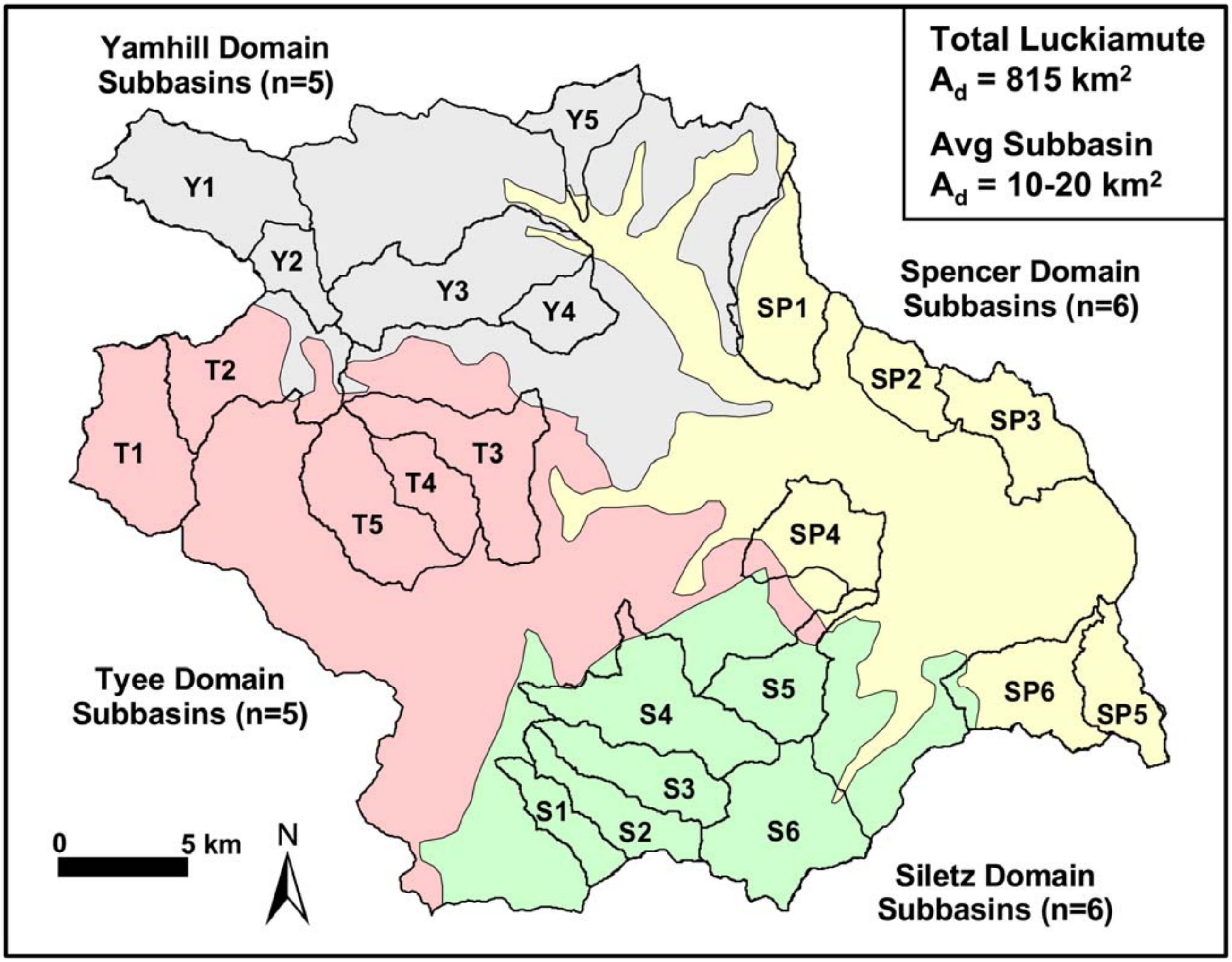


Figure 5. Location map showing fifth-field sub-basins selected for comparative geomorphic analysis in the Luckiamute Watershed.

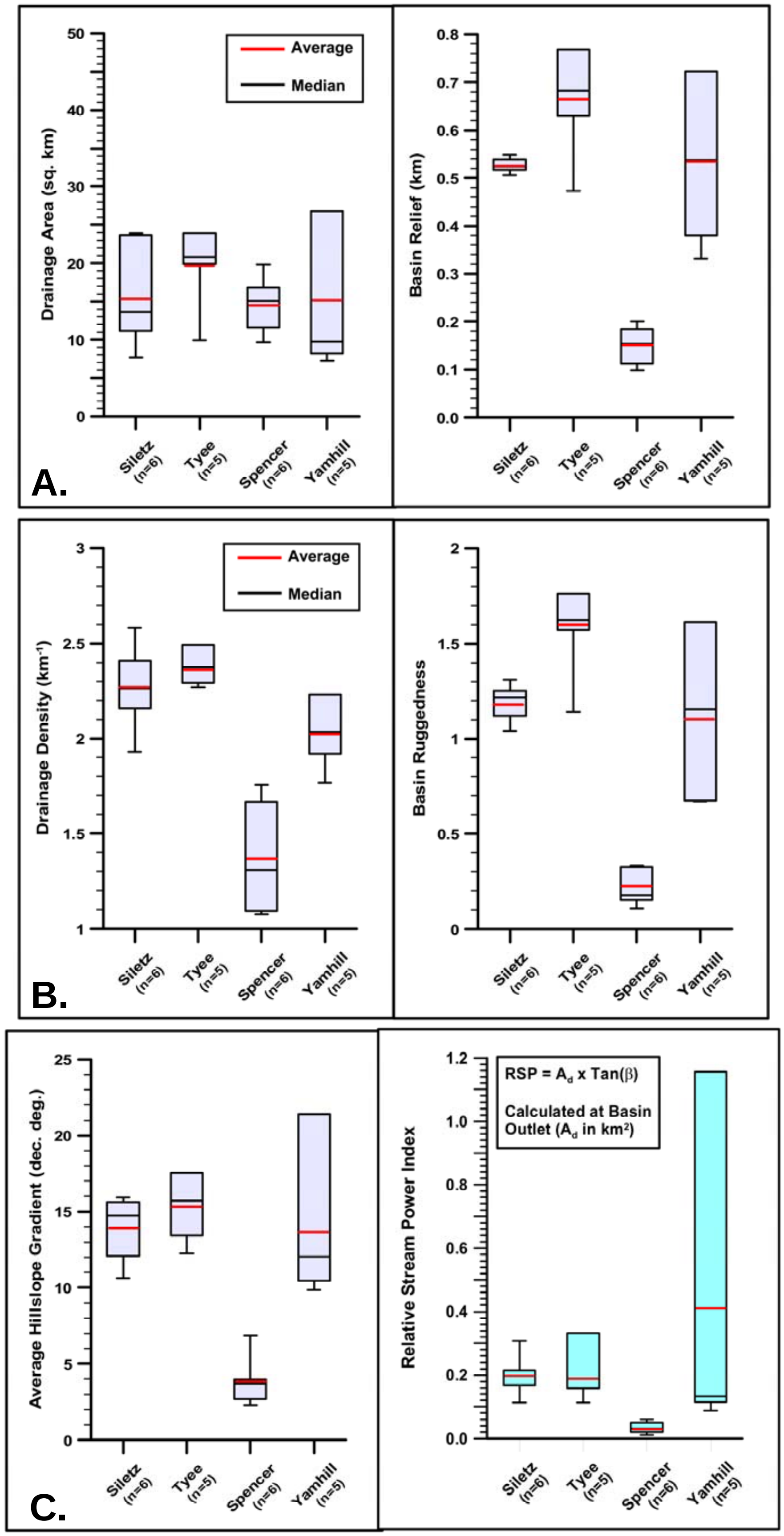


Figure 6. Results of comparative morphometric analysis of fifth-field sub-basins in the Luckiamute Watershed. Results show that the Tyee domain is associated with the steepest, most rugged high-relief landscape, whereas the Spencer is at the opposite end of the spectrum.

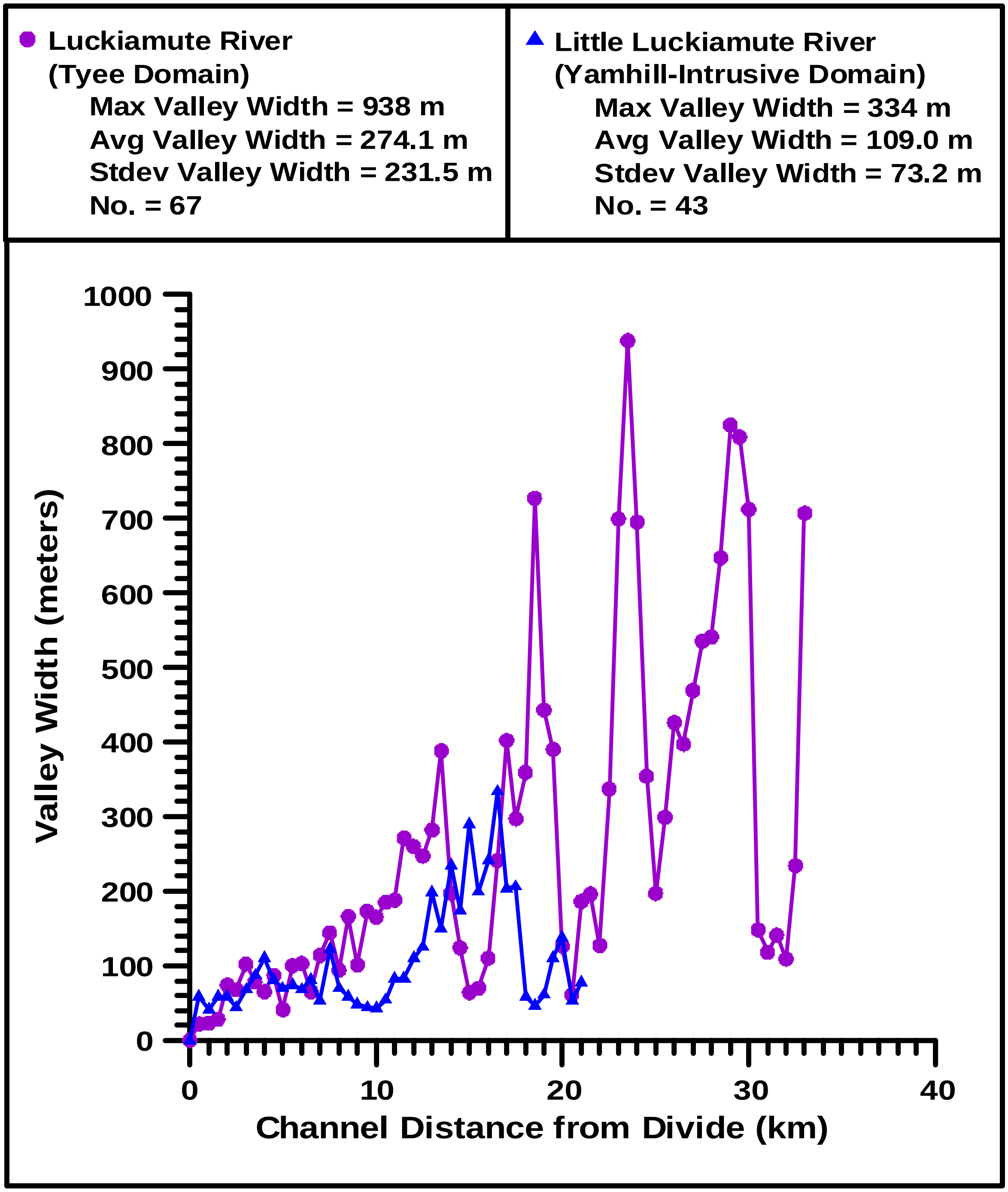


Figure 7. Plot of valley width (m) vs. channel distance from drainage divide (km) for the Luckiamute and Little Luckiamute tributaries, Tyee and Yamhill lithospatial domains, respectively.

Figure 8. A. Photo showing an under-capacity, bedrock channel reach along the Little Luckiamute tributary, Yamhill-Intrusive domain. B. Photo showing gravel-dominated reach along the main stem of the Luckiamute, Tyee domain.

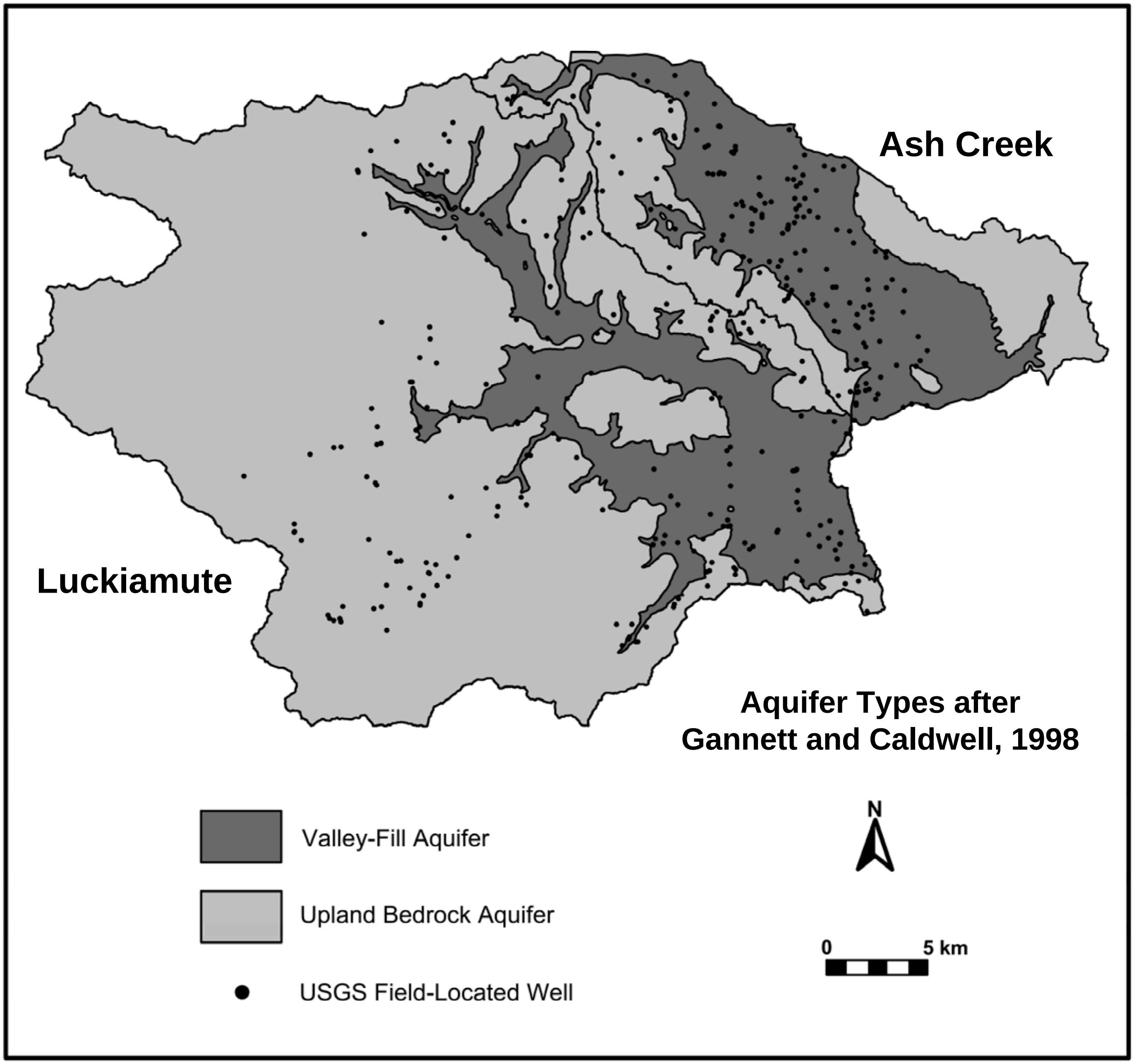


Figure 9. Aquifer type distribution in the Luckiamute-Ash Creek subbasins (after Gannett and Caldwell, 1998).

Table 2. Results of Luckiamute Well Survey (from U.S. Geological Survey Located Wells).

Surface Geology	Aquifer Unit	No. Wells	Min Depth (ft)	Max Depth (ft)	Avg Depth (ft)	Avg Deep (ft)	Avg DTW (ft)	Avg.# Specific Capacity (gpm/ft)
Qal – Holocene Alluvium	Basement Confining (Spencer Formation)	17	182	485	276	100	18	59.9
Qs – Willamette Silt	Basement Confining (Spencer Formation)	62	183	420	249	128	20	59.9
Ti – Oligocene Intrusives	Upland Bedrock (Tertiary Intrusives)	2	665	680	673	189	44	N/D
Tsr – Siletz River Volcanics	Upland Bedrock (Siletz River Volcanics)	42	235	1160	453	169	36	1.1
Tss – Spencer Formation	Upland Bedrock (Spencer Formation)	27	185	602	326	120	49	59.9
Tt – Tyee Formation	Upland Bedrock (Tyee Formation)	30	283	750	364	104	25	N/D
Ty – Yamhill Formation	Upland Bedrock (Yamhill Formation)	16	265	750	476	149	45	0.3
Luckiamute Watershed Summary		196	182	1160	402	137	34	

* Min Depth = minimum total well depth (feet), Max Depth = maximum total well depth (feet), Avg Depth = average total well depth (feet), Avg Deep = average well deepening (feet), Avg DTW = average depth to water from surface (feet)

#Specific capacity = well pumping rate (gallons per minute) divided by feet of drawdown (data from Caldwell, 1993 for Ash Creek subbasin)

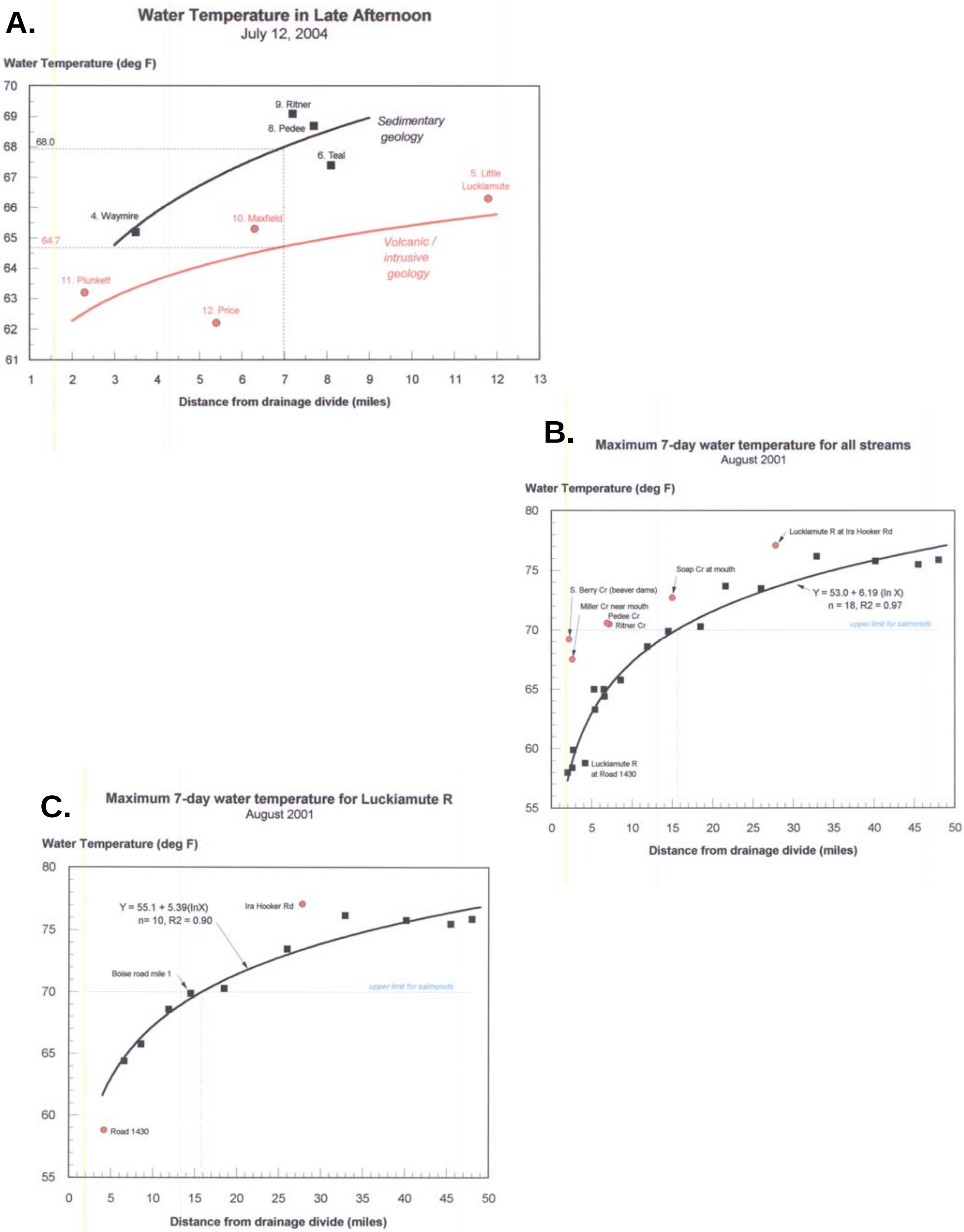


Figure 10. Results of stream temperature surveys along the Luckiamute and Little Luckiamute tributaries. A. Results from temperature sampling of the Tyee and Siletz lithospatial domains. B. and C. Results of 7-day August 2001 temperature survey by the Oregon Dept. of Environmental Quality (Andrus, 2004, personal communication).