A Study of Agricultural Drainage in the Puget Sound Lowlands to Determine Practices which Minimize Detrimental Effects on Salmonids:

Final Report

Prepared by:

Washington State University[1] and the University of Washington[2]

[1] Center for Sustainable Agriculture, WSU, Puyallup, WA
[1] State of Washington Water Research Center, WSU, Pullman, WA
[1] Biological Systems Engineering, WSU, Pullman, WA
[1] Natural Resource Sciences, WSU, Pullman, WA
[1] Statistic, WSU, Pullman, WA
[2] Center for Horticulture, UW, Seattle, WA

for

King County Department of Natural Resources and Parks
Water and Land Resources Division
201 S. Jackson Street
Suite 600
Seattle, Washington 98104

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Section	Task No.	Authors	Senior Investigators
Chapter 2	1	Tom Cichosz	Michael Barber
Chapter 3	2	Tom Cichosz	Michael Barber
Chapter 4	3	Tom Cichosz	Michael Barber
Chapter 5	4	Tom Cichosz	Michael Barber
Chapter 6	5	Elizabeth Milburn	Michael Barber
Chapter 7	6	Mark Stone	Michael Barber
Chapter 8	7	Tom Cichosz Dana Catts	Michael Barber
Chapter 9	8	Dawn Shepard	Shulin Chen Jim Dobrowolski
Chapter 10	9	Lizbeth Seebacher	Sarah Reichard
Chapter 11	10	Bingchen Zhoa Yuzhou Luo	Shulin Chen
Chapter 12	11	Bingchen Zhoa Yuzhou Luo	Shulin Chen
Chapter 13	12	Elizabeth Milburn	Michael Barber

In addition, numerous others contributed along the way including Craig Rabe, Anne Davidson, Brad Goalach, Darrin Saul, Chris Feise, and Hao Zhang. Thanks also to Barry Green for reviewing the final version of the document.

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Executive Summary

A multidisciplinary team of researchers from Washington State University and the University of Washington conducted a 5-year investigation of various practices related to agricultural watercourse maintenance. The primary focus of the investigation was related to how maintenance practices affect salmonid utilization in King County drainage systems. Four broad areas of study (fish biology, instream habitat, riparian, and sediment) were identified by KCDNPR staff during initial contract negotiations. Within each of these areas, two to four research questions were developed with methodologies and quality assurance procedures approved by King County in the project Sample Analysis Plan. Consequently, a total of twelve specific questions were addressed in this study.

In Chapter 1, a summary of the project rationale, over-arching study objective, and structure of the final report is presented. An overview of how to access project data files using GIS technology is also included.

Chapter 2 discusses the investigation regarding whether or not King County's agricultural watercourses serve as habitat for Chinook and other salmonids. Fish data collected seasonally (January/February, April, July and October) from the fall of 2002 through the spring of 2006 were analyzed for this study component. Based on statistical analysis of samples collected by electrofishing and trapping, results of this study suggest that in relation to the tested hypothesis, salmonid density (as indexed by capture frequency and/or catch rates) does vary temporally, spatially, and in relation to physical factors such as surrounding vegetative regime and flow type in King County's agricultural waterways. Specifics of that variation differ by species considered and are described in detail. General trends are also summarized in the conclusion section. Overall, the findings of this study directly support the continued application of King County public rule 21A-24 sub-sections 374, 375, and 383(b) regarding maintenance timing, fish removal prior to, and mitigation planting activities following maintenance activity.

Chapter 3 reports on the study component designed to evaluate and compare the utility of various fish collection methods for effective indexing of salmonid abundance in agricultural waterways. Electrofishing and trapping were considered the most effective methods for sampling juvenile salmonids within agricultural waterways. Monitoring methods selected for this study therefore included backpack electrofishing and four trap configurations (empty, baited, lighted, and baited/lighted). Catch-per-unit-effort (CPUE) observed at each site during each sampling event was used for regression analyses. Results of this study suggest that electrofishing CPUE provides a meaningful index of salmonid abundance across the range of habitat conditions commonly observed in agricultural waterways. Utility of electrofishing CPUE as an index of salmonid abundance can be maximized if the six recommendations made in the conclusions are practiced.

Chapter 4 discusses the study component related to determining a method for the safe and effective removal of fish prior to excavation maintenance activities, an activity commonly referred to as "defishing." Findings of this study largely support continuation of the existing King County protocol for effective removal of salmonids from agricultural waterways prior to maintenance activities in agricultural waterways. We recommend the continued use of multiple sampling methods (trapping and electrofishing) for such fish removal, with a minimum of 6-8

fish removal or sampling events prior to any maintenance activity. It is also recommended that water quality considerations be taken into account when employing traps as mortality can occur overnight due to low dissolved oxygen concentrations in some waterways.

Chapter 5 investigates the efficacy of King County ordinance requiring consideration be given to the utilization of large or small woody debris (LWD or SWD, respectively) as mitigation for impacts to in-channel cover and complexity incurred during in-channel maintenance activities. The specific roles of woody debris in low gradient, agricultural waterways may differ from those in natural streams, and has not been as thoroughly investigated to date. This study evaluated the hypothesis that the mean difference in catch rates between sub-reaches with and without installed LWD was zero. Statistically, no significant difference ($\alpha = 0.10$) in catch rates was noted between sub-reaches with and without LWD installed for Chinook or coho salmon or for all salmonids combined. The mean difference in catch rates between sub-reaches with and without LWD was lowest and statistically most relevant (0.065 fish/100 seconds of electrofishing; $p=0.111$) for Chinook salmon, although the observed count in both sub-reaches was most frequently zero. For coho salmon and all salmonids combined, the mean differences in catch rates between sub-reaches with and without LWD installed were slightly greater (0.097 and 0.104 fish/100 seconds of electrofishing, respectively) but not statistically relevant ($p>0.35$).

Based on this study, it is largely unclear if salmonid distribution in agricultural waterways is preferentially associated with installed LWD. Although statistical analyses indicate that no significant differences exist ($p > 0.10$) between salmonid abundance in reaches with and without LWD installed, numerous factors contribute to uncertainty of the statistical results. Further study at additional sights is recommended to provide a clearer picture of the potential preference of LWD by juvenile salmonids rearing in low gradient agricultural waterways.

Chapter 6 details a combination of water quality monitoring and modeling used to draw comparisons between dissolved oxygen (DO) levels in maintained vs. un-maintained agricultural waterways, and to note any differences between reaches flowing through agricultural and similar un-farmed areas. Researchers tailored an existing Washington Department of Ecology water quality model (Qual2Kw) to fit the project’s unique characteristics. This model will facilitate the County’s development of management strategies for targeted waterways. Results discussed in this chapter are focused on DO levels and a limited number of other significant variables to be used for model calibration verification. Sediment oxygen demand (SOD) was monitored and analyzed in relation to the DO balance and to facilitate in model calibration. In addition, reaeration rates were used as a key calibration variable for the model and were evaluated for both pre and post-maintenance scenarios.

Results illustrate that DO levels in agricultural waterways differ significantly from those in adjacent non-agricultural reaches, and demonstrate that maintenance activities contribute to improved DO levels in the water column. However, high SOD following maintenance activity inhibits improvement of DO to levels meeting EPA standards; Based on this study it is unclear if the observed SOD increase is a short or long-term effect of maintenance activities. It is this report’s recommendation to continue with hand-removal of vegetation but to consider mechanical dredging to increase sustainable habitat and elevate dissolved oxygen concentrations to even higher levels. While the downstream movement of sediment within watercourse systems may reduce the benefit of mechanical dredging, the overall net benefit of removing sediment from the agricultural waterways is undisputable.

Chapter 7 evaluates study results related to the question of whether large woody debris (LWD) as installed in agricultural drainage ditches by King County provides hydraulic diversity for fish. In this study, the influence of installed LWD on the flow field was investigated in two King County drainage ditches. This was accomplished through a combination of field observations and numerical simulations. High resolution turbulence measurements were made in the wake of installed LWD in two ditches using an Acoustic Doppler Velocimeter. It was found that installed LWD had a very minor influence on measured distributions of velocity magnitude, turbulent kinetic energy, and integral time scales. The observed region of influence depended on the investigated parameter and measured obstructions. However, the region of influence did not extend beyond 45 cm downstream from the installed LWD. The numerical simulation allowed for an investigation of flow parameters over a broader spatial extent and for higher flows than the observed value. The numerical simulation results agreed well with measured values. It was concluded that the installed LWD does not effectively increase the hydraulic diversity of the low-gradient drainage ditches, although it may provide instream cover for fish (Chapter 5).

Chapter 8 presents results of the study component designed to determine if reed canarygrass (RCG) regimes provide positive, negative, or neutral value to salmonids when compared to reference systems with no vegetation or with intact riparian vegetation. To do so, this study investigated salmonid weight-length relationships and relative condition, benthic community composition, and salmonid diets across a range of vegetative regimes common to agricultural waterways within King County.

Study results suggested that surrounding vegetative regime does influence biotic integrity of and salmonid food base and salmonid growth and condition in agricultural waterways. The direction of that influence (positive or negative) appears to vary between trophic levels investigated (macroinvertebrates and fish) and between salmonid species. Results suggest a positive influence of RCG dominated habitats for coho salmon, and a positive influence of natural vegetative regimes for Chinook salmon in agricultural waterways. Calculated B-IBI scores indicate very poor biological condition for all vegetative regimes sampled. Differences in B-IBI scores were noted between vegetative regimes however with mixed > natural > RCG.

Chapter 9 examines the shade effectiveness of pre-maintenance existing vegetation versus mitigation plantings, and the impacts of riparian shade on water temperature were evaluated with a reach scale study. Short reaches with uniform vegetation and uniform channel morphology were studied during summer base-flow conditions. Water temperature monitored above and below the experimental reach was used to develop and validate a physically based temperature model. Direct solar radiation was measured in and out of the shade of riparian vegetation to calibrate vegetation density for willows, Himalayan Blackberry and reed canarygrass. The developed model was found to be accurate to within 0.5 °C. Calibrated densities for buffers with complete uniform willow vegetation were 93% for mature willows, and 80% for willows approximately two years after planting. Reed canarygrass and Himalayan Blackberry growing uniformly at maturity were found to have approximately 100% calibrated densities. The difference in density between vegetation types was not found to have a significant impact on watercourse temperature. However, the presence of shade from riparian or topographic features was found to influence temperature. Narrow watercourses with vertical banks were found to be more sensitive to riparian vegetation characteristics, while wider watercourses with shallow side slopes were found to be more sensitive to air temperature. Temperature model results show that a steep incised bank increases the effectiveness of vegetation in providing riparian shade, and that shade cast by vegetation and the bank itself can decrease maximum 7-day average temperatures by approximately 0.7 °C.

Chapter 10 discusses the riparian vegetation enhancement section of this project related to finding a BMP protocol for the effective control/eradication of reed canary grass (RCG), and determining a method for providing native ground cover and woody riparian vegetation that is vigorous, shade producing and provides habitat for insects that constitute prey for salmonids. The study involved a pilot project, a principal project and a greenhouse investigation. The pilot project used small-scale treatment cells to investigate the use of Salal, clover, shade (old carpet), red cedar hog fuel (mulch), and steam in reducing RCG growth. Stem count data indicated that two treatments were particularly successful. The hogfuel and shade material treatments (whether used with or without steam) suppressed the reed canarygrass significantly when compared to the control plots and the other treatments.

The principal project was conducted at three field site locations. Eight types of vegetation were used in the RCG barrier treatment plots. The RCG barrier alone treatment was the least successful at reducing the returning RCG stem count at all three sites. The treatments involving the Hogfuel/Willow (HF/Willow) and the HF/RCG barrier were the most successful. The HF/Willow treatment was more successful at the agriculture site and the HF/RCG barrier treatment was more successful at the natural site. The HF/Willow and HF/RCG barrier treatments were not significantly different at the livestock site. Additionally, the livestock site had higher stem counts than the other two sites for the control and the other two treatments with the exception of the HF/RCG barrier treatment at the agriculture site.

Greenhouse experiments investigated the allelopathic tendencies of red cedar hogfuel on lettuce seed germination, seedling growth and RCG rhizome regrowth. The results indicate that the Red Cedar Hogfuel is allelopathic for lettuce seed germination and growth by significantly reducing the number of germinating seeds ($p = .005$) and radicle length ($p = .000$). The Red Cedar hogfuel tea also significantly reduced the RCG rhizome regrowth when comparing the stem count of the rhizomes grown with hogfuel tea versus those grown with water, with a p-value of .05 (t-Test for a paired two sample for means).

Chapter 11 investigates strategies to minimize sediment mobilization following excavation. Petri dishes were installed on the ditch bottoms to collect long-term cumulative sediments after excavation. The measurement of cumulative sediment was conducted after about two weeks of installing Petri dishes by measuring the total solids collected in Petri dishes. Temporary erosion and sediment control practices were applied at both the Watercress Creek and Ray Ewing properties. Among all tested temporary erosion and sediment control practices, hydro-seeding was suggested as the best mitigation plan. This was based on the considerations of the effectiveness and cost of hydro-seeding practice. The obvious advantage of hydro-seeding is that before the grass is fully developed, the mulch or binder plays an important role in soil erosion control, while the mulch or binder decays as the grass becomes developed.

Chapter 12 examines techniques that could extend maintenance cycles so that disruptions in the local ecosystems would occur less often. This was accomplished by looking at various erosion control methods. Erosion control treatments used in the study included peat moss, CF-900 Coir mat, wood chip mulching, sod, hydro-seeding grass, and hand-seeding grass. Quarterly or annual cumulative sediments were measured after the maintenance, by counting the visible horizontal bars in steel rods placed in the channels. At the same time, erosion amounts from the treated banks of the watercourses were estimated based on observations of rill formation on the banks. Based on the experiments and observations, upstream erosion sources were the primary contributor on the deposited sediment at these agricultural watercourses. Controlling hillside erosion from natural and development sources is therefore the key to prolonging maintenance cycles. The rill erosion on the treated banks was immeasurable and insignificant compared to the amount of cumulative sediment on the ditch bottom. It was also concluded that increasing the existing standard seeding and mulching requirements by 50% would not affect bank erosion and there was no difference in rill formation on channel slopes that were hand-seeded compared to those that were hydro-seeded.

Chapter 13 describes the investigated methodologies aimed at predicting the benefits in improved drainage associated with excavation of sediment and RCG. Periodic cleaning of agricultural waterways was quantitatively and qualitatively shown to significantly reduce the negative aspects of farmland flooding and appear to improve the economics of agriculture in King County. Numerical modeling with HEC-RAS and roughness coefficients much greater than typical reported values has been shown to produce results that accurately match measured water surface elevations. Moreover, observed agricultural improvements at the Smith Brother’s site indicated increased drainage due to hand cleaning and mechanical operations. This restoration of the land’s agricultural purpose serves both the landowner and the surrounding community which has demonstrated an interest in maintaining agricultural activities in the valley.

Chapter 14 summarizes the combined impacts of the overall research project by briefly pointing out the most significant findings in research and then looking at them in collective. It also highlights the fact that ditch maintenance is an important process for drainage and providing juvenile salmonid rearing habitat in King County. Post-maintenance water quality testing found significant improvements in dissolved oxygen levels; the temperature model predicted of temperature improvements as riparian buffers grow; and visual reports of salmonids using much larger sections of the Mullen Slough/Boscolo complex all strongly suggest that maintenance activities benefit the fish. Furthermore, reports also support the assumption that better drainage help the farmers by allowing better use of their lands. By following the general processes discussed in this report, farming and salmonids should be able to successfully co-exist.