CHAPTER 4

Determination of a Safe Method for the Removal of Salmonids Prior to Excavation of Agricultural Waterways

4.1 Introduction to Safe 'Defishing' Method(s) (Goal 3)

Although there is little published information on salmonid use of small watercourses associated with agricultural areas in King County's riverine floodplains and on the Enumclaw Plateau, waterways within these areas are known to be used by various salmonid species (Berge 2002; King County DNRP 2001). A broad research study was developed to determine effective and economical means to maintain agricultural watercourses while protecting fish habitat. To achieve this objective, a research plan for twelve specific goals was created (Washington State University and the University of Washington 2006), with one of those goals to be addressed in this chapter. The intent of research presented in this chapter was to determine a method for safe and effective removal of fish ("defishing") preliminary to excavation of agricultural waterways.

King County's agricultural area is closely associated with an extensive drainage network. Approximately 483 kilometers (300 miles) of watercourses, excluding the mainstems (and braids) of the major rivers, flow through King County's five agricultural production districts (APDs): Lower Green River, Upper Green River, Enumclaw, Sammamish, and Snoqualmie.

Over time, many floodplain agricultural areas have become subject to more frequent and prolonged flooding due, in part, to accumulation of sediments and vegetation within the channels. Anecdotal reports from various areas within King County indicate that the need for maintenance of agricultural drainage channels to remove excess sediment and vegetation has increased in recent decades due to increased runoff from urban and suburban development on the slopes above many of the active farming areas.

The customary method of maintaining watercourses by dredging is contrary to some of the current methods of fish habitat protection and restoration. King County initiated its Agricultural Drainage Assistance Program (ADAP) to provide assistance to landowners interested in maintaining drainage in agricultural waterways in accordance with King County's Areas Ordinance and clearing and grading code. King County's public rule for the maintenance of agricultural watercourse (King County DDES 2001) requires fish removal from salmonid bearing waterways prior to any mechanical excavation activity. The goal of this study component was therefore to determine a method for the safe and effective removal of fish preliminary to excavation, an activity commonly referred to as 'defishing'.

With the assistance of KCDNRP staff, the following research hypotheses were posed in relation to this study component:

1. Related to the collection of juvenile salmonids, sampling efficiency does not vary across fish removal procedures (including electrofishing and various trapping methods).
2. Related to the collection of juvenile salmonids, observed sampling related mortality does not vary across fish removal procedures.

Professional experience and consultations with KCDNRP staff suggested that backpack electrofishing and trapping are the most effective techniques for sampling juvenile salmonids from the wide range of habitat conditions found within agricultural waterways. Monitoring methods selected for this study therefore included backpack electrofishing and four trap configurations (empty, baited, lighted and baited/lighted). Thompson and Rahel (1996) and Kulp and Moore (2000) discussed electrofishing as a potential means of removing brook and rainbow trout, respectively. Numerous other methods have also been used effectively for removal of fish from streams and lakes (Strach et al. 1989). Additional methods (e.g. seining) were considered but not thought to be practical due to the excessively heavy cover in most agricultural waterways. Consequently, these additional methods were not included in the study.

Defishing prior to agricultural watercourse maintenance activities is an important step in reducing fish mortality related to those activities. Although not included within the stated research hypothesis, an overview of mortality incurred due to the various fish sampling techniques evaluated during this study is also included in this report. This information is intended to provide additional information to King County and other resource managers regarding the ‘safety’ (from a fish’s perspective) of each sampling method.

4.2 Methods

4.2.1 Site Selection

As part of a larger research project, this study utilized sites selected to meet the needs of the broader scale project which, ultimately, provided data suitable for assessment of efficiency and ‘safety’ of various fish collection techniques. Initial site selections for the overall research projects included consultation with King County staff, utilizing County GIS layers, staff knowledge, willing landowners, and site visits. During site selection, efforts were made to ensure that representative numbers of sites were selected across various vegetative and flow regimes commonly observed in the County’s agricultural areas.

This study was conducted in waterways in or near King County's Agricultural Production Districts (APDs), which are composed of approximately 40,600 acres (16,430 hectares) zoned for agricultural use. Sampling to compare efficiency of, and fish mortality related to various fish collection methods took place in waterways within the Snoqualmie APD at locations believed to be representative of those found throughout the county’s five APDs. Maps of study sites where fish collections took place are presented in Appendix 4-A.

4.2.2 Fish Collection and Processing

For this study component, only data collected during the maximum allowable time window for maintenance activities within agricultural waterways (July 15-Oct 15; King County DDES 2001) were assessed. Sampling to compare efficiency of various sampling methods and mortality associated with that sampling took place during August, 2004 and September, 2005.

Sampling protocols differing slightly between the first (August 2004) and second (September 2005) sampling periods. The study layout during the first sampling period was most representative of conditions during typical site evaluations or population surveys, whereas the study layout during the final period was most representative of conditions that exist during defishing activities immediately preceding agricultural watercourse ditch maintenance activities.

During the first sampling period, electrofishing and trapping evaluations at each site were conducted in separate but similar sub-reaches. Electrofishing was conducted once per day for multiple days allowing thorough evaluation of sampling efficiency in relatively undisturbed or 'clean' conditions. Trapping was conducted continuously over a multi-day sampling period with traps checked twice each day.

During the second sampling event, trapping and electrofishing evaluations at each site were conducted in the same sampling reach. For several consecutive days, traps were set late each day and retrieved the next morning. Electrofishing surveys at each site were conducted once or twice each day for several consecutive days. When multiple electrofishing surveys were conducted at the same site on the same date, the second survey was performed as soon as possible following the first (after allowing fish captured during the first survey to be processed and released). Doing so allowed comparison of electrofishing effectiveness between optimal (clean) and disturbed or 'dirty' conditions when sediment had been stirred up and visibility was reduced.

As previously described, 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). Sub-reaches were established at each site using 0.6cm (0.25 inch) mesh block nets placed at both the upstream and the downstream ends of the selected reach. Block nets were equipped with float lines on the surface and were set into the available bottom substrate to meet the assumptions of a closed system necessary for the study (Peterson et al. 2005).

Electrofishing was conducted using a Smith Root, Inc. model 12 backpack electrofisher with a 6 foot electrode pole and an 11 inch electrode ring covered with 1/4 inch mesh netting. Fish stunned by the electrofisher were collected either with a separate dip net or using the net covered electrode ring; when collecting fish with the electrode ring, power to the electrode was temporarily terminated to eliminate harm or further stress to the fish. Fish were collected by electrofishing according to protocols defined by the National Marine Fisheries Service (2000).

Trapping was conducted with standard steel mesh minnow traps 17 inches long with a 9 inch diameter and a 1 inch access opening on each end. Trap mesh had openings 0.25 x 0.5 inches. Traps were baited with approximately 1.5 ounces of tuna fish wrapped in mosquito netting and lighted using 6 inch cylume light sticks. Various colors of light sticks were used depending upon availability although an attempt was made to use a single color of light stick at each site during each sampling event. Both bait and light sticks were attached in the center of the minnow trap and changed each time a trap was checked and reset. Upon completion of all trapping activities the corresponding sub-reach was electrofished to increase numbers of fish captured or recaptured and improve precision of the population estimate and subsequent estimates of sampling efficiency.

Repeated sampling was conducted (multi-pass electrofishing and multiple day/nights of trapping) with replacement. Fish captured in the initial pass were marked by clipping one pelvic fin prior to their release back into the study reach. An estimate of salmonid population size within each reach was determined using standard depletion mark-recapture methods (see Van Den Avyle (1993) for a review and discussion of applicable methods). This approach allowed for estimation of initial population size, and back calculation of capture efficiency and sampling bias related to each electrofishing pass/trapping event (e.g. each trap-day or trap-night).

In most cases, length (mm) and weight (to nearest 0.5 g) data were obtained from all fish collected. When numbers of fish collected were substantial enough to result in fish being retained for extended periods during data recording (e.g. resulting in undue stress to fish), length and weight information were collected only from a representative sample of each species. Any mortality of fish was recorded, as were notes regarding individuals which were 'highly stressed' meaning they were not dead, but were believed potentially likely to die later due to sampling related activities.

4.2.3 Data Analysis

For analyses data from all salmonid species captured were pooled. This was done to allow inclusion of data from those species rarely observed or captured in insufficient numbers to allow for subsequent population estimation (e.g. cutthroat trout and Chinook salmon). In addition, preliminary analysis indicated that salmonid captures by each of the four trap configurations (empty, lighted, baited, lighted/baited) were most frequently zero or very near zero, indicating a general ineffectiveness of traps for collecting salmonids. For this reason, data from all trap configurations was pooled within each sampling site/event and subsequent analyses completed without regard to trap configuration or time of day.

Population estimates were obtained using Schnabel's (1938) approximation to the maximum likelihood estimator of population, ***N***, from multiple censuses (Ricker 1975), as adjusted by Chapman (1952, 1954):

$$N = \sum_{i=1}^{m} \frac{C_i \; M_i}{R+1} \qquad (4\text{-}1)$$

where m is the number of sampling periods, M_i is the total number of fish marked at the start of sampling period i, C_i is the total number of fish captured during sampling event i, and R is the total number of recaptures during the experiment.

Approximate 95% confidence limits for this estimator were obtained by treating R as a Poisson variable and substituting relevant limits determined by Ricker (1975; presented in Lockwood and Schneider 2000) for R in the equation above. This approach to calculation of confidence intervals was considered more appropriate than more conventional approaches because the number of recaptures (R) encountered at each site/sampling period was typically small (e.g. <25; Van Den Avyle 1993).

To estimate sampling efficiency (proportion of fish collected) of each sampling method, the total number of fish captured (C) in a given sampling reach/event using a given sampling method was divided by the associated estimate of population abundance (N) for the same reach/sampling event. In this manner, efficiency was estimated as a percent of the total estimated population collected by a given sampling technique during a single sampling event.

Sampling mortality was estimated as the percent of salmonids captured which died during capture and/or subsequent handling related to their capture. Mortality estimates were made for each distinct trapping or electrofishing sample. In the case of trapping, mortality estimates were not made for individual traps, but rather across all (12) traps set at a given site on a given date.

Separate analysis of variance (ANOVA) test were used to evaluate differences in mean capture efficiencies and mean sampling mortality across factors (sampling method and surrounding habitat type). Due to the unbalanced design[1] of the study, the General Linear Model procedure (PROC GLM command in SAS) was used to perform all analysis of variance tests. Evaluation of differences in mean catch efficiencies relied upon test statistics derived using the Type III sums of squares, also due to the unbalanced nature of the study design. The ANOVA model evaluated was:

$$\text{Sampling Efficiency} = \text{Sampling Method} + \text{Habitat Type} + \text{Interactions} \qquad (4\text{-}2)$$

where sampling methods are trapping, clean electrofishing or dirty electrofishing: habitat type is either RCG, mixed or cleared, and interactions include all combinations of these two factors (e.g. trapping in mixed vegetation).

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[1] The term 'unbalanced design' refers to the fact that unequal numbers of samples were obtained in the various treatment groups across sampling events. This situation does not negatively impact the study, but does require additional consideration during data analyses.

4.3 Results

4.3.1 Preliminary Analyses

Preliminary analyses and data review suggested that efficiency of various fish collection techniques was dependent on the vegetative regime (amount and/or type of surrounding and in-channel vegetation; Figure 4-1). Mean efficiency of electrofishing surveys under 'clean' conditions appeared potentially more effective in a RCG dominated regime (38.0%) than in either mixed (22.3%) or cleared (7.7%) vegetative regimes. Mean trapping efficiency appeared potentially greater in RCG and cleared habitats (20.4 and 22.5%, respectively) than in those areas with a mixed vegetative regime (1.3%).

Preliminary analyses also indicated that observed sampling mortality was related not only to sampling method, but also the vegetative habitat being sampled (Figure 4-2). At the RCG dominated habitat site sampled, no mortality was observed for any of the three tested sampling techniques. Under 'clean' electrofishing conditions, mean sampling mortality in cleared habitat (11.4%) appeared greater than that in mixed habitats (4.3%). When trapping, sixty percent mortality was observed in a single sample; no mortality was observed in trapping surveys in RCG or mixed habitats.

Due to preliminary analyses, inclusion of interaction terms was deemed necessary during further analyses in order to fully understand sampling efficiency and related mortality within agricultural waterways. However, based on the unbalanced nature of the data, least squares evaluation of efficiency differences across sampling technique, vegetative regime, and the interaction of those factors was not feasible. Preliminary analyses without inclusion of interaction terms indicated that there was no significant difference in observed sampling efficiency while electrofishing under 'clean' and 'dirty' conditions (ANOVA, $p=0.9663$). The same finding was noted for preliminary analysis of mortality related to various sampling techniques (ANOVA, $p=0.8931$). Electrofishing survey results were therefore lumped into a single category (electrofishing, without regard to water clarity) for subsequent analyses. This modification to the study design resulted in sufficient sample sizes to evaluate the effects of sampling techniques (2 levels), habitat type (3 levels), and the interaction of these terms on sampling efficiency and/or related mortality.

Concern over the impact of differing reach lengths on trapping results was investigated and found not to be significant. The same number of traps (12) was used in each study reach effectively increasing trap density in shorter reaches, over that of longer reaches. Since the majority of available data was collected in mixed vegetative habitats, that data was used to evaluate the impact of variable reach length on the results. In regressing efficiency estimates on reach length, the relationship was found to be non-significant ($r^2=0.052$, $p=0.431$) indicating that use of variable reach lengths did not notably impact results or findings of this study. According to findings in Chapter 3 of this report, increasing the trap density would result in additional catch but we do not believe it would appreciably alter the CPUE observed in any sampling reach/event. Since CPUE (and not catch) was used for this assessment and related analyses, it is believed that study results would be similar even if a higher number or density of traps had been used.

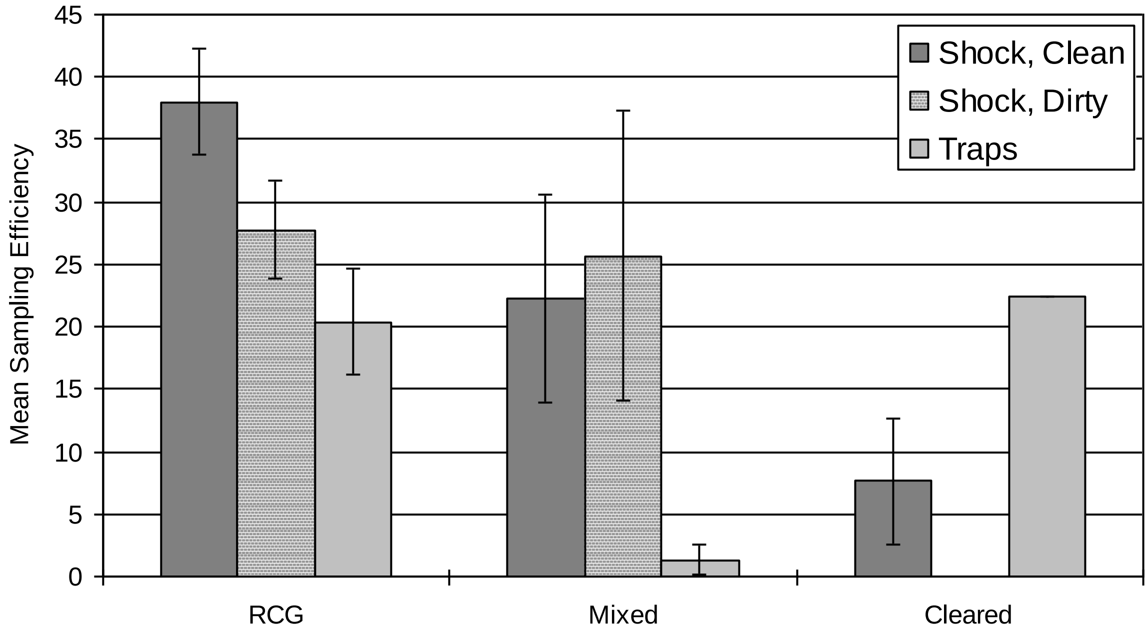

Figure 4-1. Mean sampling efficiency by habitat and sampling method; Error bars are ± one standard deviation.

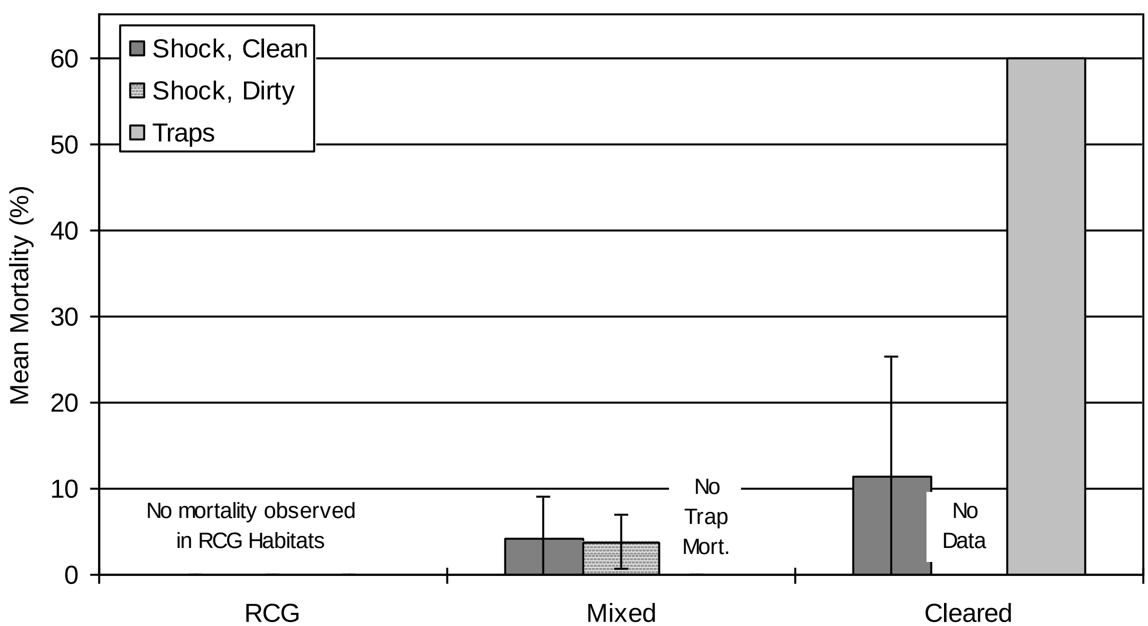

Figure 4-2. Mean sampling mortality by habitat and sampling method; Error bars are ± one standard deviation.

4.3.2 Sampling Efficiency

Sampling related to this study goal was performed at a total of five sites across three sampling periods (Table 4-1). Three different habitat regimes were sampled including predominantly RCG (2 sites), mixed vegetation (2 sites), and no vegetation due to recent maintenance activity ('cleared', 1 site).

During August, 2004 salmonid population estimates (and subsequent estimates of sampling efficiency) were possible at only two of three sites sampled (Table 4-1); at one of those sites, population estimation was only feasible in one of two sampled sub-reaches. At the Turner-A site (mixed vegetation) the shocking and trapping sub-reaches had estimated populations of 311 and 458 salmonids, respectively (Table 4-2). During the same sampling period, salmonid population estimation was also possible within the trapped sub-reach at the Nelson-B site (mixed vegetation) where a population of 79 salmonids was estimated. In both trapped sub-reaches (Turner-A and Nelson-B sites), confidence in population estimates were negatively impacted by low (<5) numbers of recaptured salmonids during the experiment resulting in very wide confidence intervals around the estimates (Table 4-2; Appendix 4-B).

Table 4-1. Characterization of timing and location of sampling efficiency and bias surveys (shaded blocks). Salmonid species collected are listed; Bold print indicates that estimation of a population size was possible for a given species.

Site Name	Vegetative Habitat	August 2004		September 2005
		Electrofishing	Trapping	Combined[1]
Turner-A	Mixed	**Coho**, **Cutthroat**	**Coho**, **Cutthroat**	
Nelson-B	Mixed	No Salmonids	**Coho**	**Coho**, Chinook
Decker-A	Reed Canarygrass	No Fish	No Salmonids	
Olney-B	Reed Canarygrass			**Coho**, **Cutthroat**
Olney-D	Cleared			**Coho**

1 During September, 2005 trapping and electrofishing were conducted in a single sub-reach.

Table 4-2. Summary of salmonid population, catch, mortality, and sampling efficiency for sampled sites where population estimates were feasible during August, 2004.

Site[1]	Method	Salmonid Population Estimate (95% CI)	Sampling Round	Salmonid Catch (#)	Salmonid Mortality (#)	Salmonid Mortality (% of catch)	Sampling Efficiency (%)	Efficiency Range[2]
Turner-A	Shock, Clean	311 (210-540)	1	48	3	6.25	15	9-23
			2	55	4	7.27	18	10-26
			3	38	0	0.00	12	7-18
	Traps	458 (224-2,289)	1	6	0	0.00	1	0-3
			2	4	0	0.00	1	0-2
			3	12	0	0.00	3	1-5
			4	4	0	0.00	1	0-2
			5	3	0	0.00	1	0-1
			6	1	0	0.00	0	0-0
	Shock, Clean (trap reach)	458 (224-2,289)	7	65	0	0.00	14	3-29
Nelson-B	Traps	79 (28-1,580)	1	1	0	0.00	1	0-4
			2	0	0	--	0.0	N/A
			3	1	0	0.00	1	0-4
			4	1	0	0.00	1	0-4
			5	3	0	0.00	4	0-11
			6	1	0	0.00	1	0-4
	Shock, Clean (trap reach)	79 (28-1,580)	7	20	1	5.00	25	1-71

1 Data are presented here only for sites where population estimates were feasible; Appendix 4-B includes detailed data on all sites sampled.
2 Efficiency range divides salmonid catch by upper and lower confidence intervals of the population estimate.

Estimates of sampling efficiency showed a similar pattern at both sites for which data was available from August, 2004 (Table 4-2). Both sites had a mixed vegetative regime, and at both sites efficiency of electrofishing surveys was greater than that estimated via trapping surveys. Estimated electrofishing efficiency at the Turner-A site ranged from approximately 12-18 percent across various samples; estimates of trapping efficiency at the same site ranged up to 2.6 percent but were typically less than one percent. At the Nelson-B site and single estimate of electrofishing efficiency was 25.3 percent whereas multiple estimates of trapping efficiency ranged from 0-3.8 percent.

During September, 2005 salmonid population estimates were possible at all sites sampled. Based on combined sampling (shocking and trapping) at each site, salmonid population estimates were 189, 36, and 200 at the Nelson-B (mixed vegetation), Olney-B (RCG vegetation) and Olney-D (cleared of vegetation) sites, respectively (Table 4-3). Sufficient numbers (≥ 5) of salmonids were recaptured at all sites during September, 2005 to allow confident estimation of population size within each sampling reach (Table 4-3; See Appendix 4-B).

Estimates of sampling efficiency during September, 2005 were variable across both sampling method and vegetative habitat sampled (Table 4-3). At the Nelson-B site (mixed vegetation) a pattern similar to that noted in earlier surveys was observed, with estimates of electrofishing efficiency (17.5-33.9 percent) notably greater than those estimated for trapping surveys (0-3.7 percent). Under a RCG dominated vegetative regime at the Olney-B site, a similar but much less pronounced pattern was observed with estimated efficiency of electrofishing surveys (25.0-41.7 percent) only slightly greater than that for trapping surveys (16.7-25.0 percent). Based on limited sampling, an inverse pattern was observed at the recently cleared site (Olney-D) where a single estimate of trapping efficiency (22.5 percent) was substantially greater than estimates of electrofishing efficiency (3.0-13.0 percent).

The overall model evaluating effects of sampling method, habitat type and the interaction of those terms on sampling efficiency was highly significant (ANOVA, $p<0.0001$; Table 4-4). Individually, sampling method, habitat type, and interaction terms were all found to be significant within the model (ANOVA, $p<0.015$).

When considering only sampling method, pairwise comparisons indicate that sampling efficiency for electrofishing surveys (21.5%) is significantly greater than that observed for trapping surveys (14.7%; Table 4-5). Considering only vegetative regimes (without consideration of sampling method), mean sampling efficiency does not differ significantly between cleared (15.1%) or mixed (12.1%) vegetative regimes although overall efficiency in these habitats was significantly less than that observed in sampled RCG habitats (27.1%).

When considering sampling method and surrounding vegetation in concert, mean estimated efficiency of electrofishing surveys in cleared habitat areas was 7.7 percent and significantly less than that in a single RCG habitat (22.9%) which, in turn, was significantly less than that observed at sites with mixed vegetation (33.9%; Table 4-5). When trapping, mean estimated efficiency in cleared (22.5%) and RCG (20.4%) habitats were similar and both significantly greater than that observed in mixed vegetative habitats (1.3%; Table 4-5).

Table 4-3. Summary of salmonid population, catch, mortality, and sampling efficiency for sampled sites where population estimates were feasible during September, 2005.

Site[1]	Salmonid Population Estimate (95% CI)	Sampling Round	Method[2]	Salmonid Catch (mortalities)	Salmonid Mortality (#)	Salmonid Mortality (% of catch)	Sampling Efficiency (%)	Efficiency Range[3]
Olney-B	36 (25-61)	1	Shock, Clean	15	0	0.00	42	25-60
		2	Traps	9	0	0.00	25	15-36
		3	Shock, Clean	14	0	0.00	39	23-56
		4	Shock, Dirty	9	0	0.00	25	15-36
		5	Traps	6	0	0.00	17	10-24
		6	Shock, Clean	12	0	0.00	33	20-48
		7	Shock, Dirty	11	0	0.00	31	18-44
		8	Traps	7	0	0.00	19	11-28
Olney-D	200 (111-573)	1	Shock, Clean	14	1	7.14	7	2-13
		2	Traps	45	27	60.00	23	8-41
		3	Shock, Clean	26	7	26.92	13	5-23
		4	Shock, Clean	6	0	0.00	3	1-5
Nelson-B	189 (159-229)	1	Shock, Clean	64	0	0.00	34	28-40
		2	Traps	7	0	0.00	4	3-4
		3	Shock, Clean	58	8	13.79	31	25-36
		4	Shock, Dirty	64	1	1.56	34	28-40
		5	Traps	0	0	--	0	N/A
		6	Shock, Clean	54	1	1.85	29	24-34
		7	Shock, Dirty	33	2	6.06	18	14-21
		8	Traps	2	0	0.00	1	1-1

1 Data are presented here only for sites where population estimates were feasible; Appendix 4-B includes detailed data on all sites sampled.

2 Shocks are designated as 'Clean' for initial shock on a given day or 'Dirty' for subsequent shocks when disturbed sediment reduced visibility and fish were recently disturbed and potentially forced deeper into available cover.

3 Efficiency range divides salmonid catch by upper and lower confidence intervals of the population estimate.

Table 4-4. ANOVA results for evaluations of differences in sampling efficiency by sampling technique, habitat type, or the interaction of those factors.

Source	DF	Sum of Squares	Mean Square	F-Value	Prob > F
Model	5	5490.2	1098.0	36.87	**<0.0001**
Error	31	923.2	29.8		
Corrected Total	36	6413.4			
Individual Factors[a]					
Sampling Method	1	202.06	202.06	6.79	**0.0140**
Habitat	2	1285.52	642.76	21.58	**<0.0001**
Method x Habitat	2	907.86	453.93	15.24	**<0.0001**

a – For individual factors, Type III sum of squares are presented.

Table 4-5. Least square summary statistics for, and results of pairwise comparisons between, sampling efficiency at various factor levels.

Factor / Level	Sample Size	Least Squares Mean - Efficiency	90% Confidence Limits	Statistical Differences[1]
Sampling Method				
Electrofishing	18	21.49	19.04 – 23.95	a
Trapping	17	14.74	11.09 – 18.39	b
Vegetative Habitat				
Cleared	4	15.08	9.74 – 20.43	a
Mixed	23	12.14	10.25 – 14.03	a
RCG	8	27.13	23.75 – 30.51	b
Interactions				
Electrofish x Cleared	3	7.67	2.32 – 13.01	a d
Electrofish x Mixed	10	22.93	20.00 – 25.85	b
Electrofish x RCG	5	33.89	29.75 – 38.03	c
Trap x Cleared	1	22.50	13.25 – 31.75	a b c
Trap x Mixed	13	1.34	0 – 3.73	a d
Trap x RCG	3	20.37	15.03 – 25.71	b

1 Within each factor group, levels with the same letter are not statistically different from one another ($p \geq 0.10$).

In mixed vegetative cover, observed trapping efficiency (1.3%) was significantly lower than that of electrofishing surveys (22.9%). In RCG dominated habitats, trapping efficiency (20.4%) was significantly less than electrofishing efficiency (33.9%) although the disparity between techniques was much less than that observed in mixed vegetative cover. In habitat areas cleared of vegetation, mean sampling efficiency of trapping (22.5) and electrofishing (7.7%) did not differ significantly although sample sizes were limited (1 and 3, respectively) for this comparison.

4.3.3 Sampling Mortality

Sampling to evaluate salmonid mortality while using various sampling techniques was performed at the same sites and timelines as those used to evaluate sampling efficiency (Table 4-1). Three different habitat regimes were sampled including predominantly RCG (2 sites), mixed vegetation (2 sites), and no vegetation due to recent maintenance activity ('cleared', 1 site).

Estimates of sampling mortality showed a similar pattern at both sites for which data was available from August, 2004 (Table 4-2). Both sites had a mixed vegetative regime, and at both sites mortality observed during electrofishing surveys was greater than that observed in trapping surveys. Mortality estimates during electrofishing surveys ranged from zero to 7.3 percent with mortality observed during three of five samples. No mortality was observed during twelve trapping surveys in August, 2004.

Estimates of sampling mortality during September, 2005 were variable across both sampling method and vegetative habitat sampled (Table 4-3). At the Olney-B site (RCG), no mortality was observed during trapping or electrofishing surveys. At the Olney-D site where vegetation had recently been cleared from the channel mortality was incurred during two of three electrofishing samples (range 7.1 - 26.9%) as well as during a single trapping survey (60% mortality). At the Nelson-B site (mixed vegetation) no mortality was observed during trapping surveys although salmonids sampled incurred some level of mortality during four of five electrofishing surveys conducted (range 1.6 – 13.8%).

The overall model evaluating effects of sampling method, habitat type and the interaction of those terms on sampling mortality was highly significant (ANOVA, $p<0.0001$; Table 4-6). Individually, sampling method, habitat type, and interaction terms were all found to be significant within the model (ANOVA, $p<0.0001$).

When considering only sampling method, pairwise comparisons indicate that sampling mortality observed during electrofishing surveys (5.18%) is significantly less than that observed for trapping surveys (20.0%; Table 4-7). Considering only vegetative regimes (without consideration of sampling method), mean sampling mortality does not differ significantly between RCG (0.0%) or mixed (2.1%) vegetative regimes although observed mortality in these habitats was significantly less than that observed in a habitat area recently cleared of vegetation (35.7%).

When considering sampling method and surrounding vegetation in concert, mean observed mortality during electrofishing surveys in cleared habitat areas was 11.36 percent and significantly greater than that observed during electrofishing surveys in RCG habitat (0.0%);

electrofishing mortality in mixed vegetation (4.2%) did not differ significantly from that in either RCG or cleared habitats (Table 4-7). When trapping, mean mortality in the cleared habitat area (60.0%) was significantly greater than that observed in both the RCG and mixed vegetative habitats where observed mortality was zero percent (Table 4-7).

In RCG and mixed vegetative cover, observed mortality for trapping and electrofishing surveys did not differ significantly. In cleared habitat, mortality observed during a single trapping survey (60.0%) was significantly greater than that observed during corresponding electrofishing surveys (11.4%).

It is important to note that high observed mortality rates during both electrofishing and trapping surveys in cleared habitats are believed to be primarily due to reduced water quality at the time of sampling, and not due to the sampling methods used. This situation is detailed further in the subsequent discussion section.

Table 4-6. ANOVA results for evaluations of differences in sampling mortality by sampling technique, habitat type, or the interaction of those factors.

Source	DF	Sum of Squares	Mean Square	F-Value	Prob > F
Model	5	3634.1	726.8	37.36	<**0.0001**
Error	29	564.2	19.5		
Corrected Total	34	4198.3			
Individual Factors[a]					
Sampling Method	1	4.10	4.10	0.21	<**0.0001**
Habitat	2	1776.58	888.29	45.66	<**0.0001**
Method x Habitat	2	1853.45	926.73	47.63	<**0.0001**

a – For individual factors, Type III sum of squares are presented.

Table 4-7. Least square summary statistics for, and results of pairwise comparisons between, sampling mortality at various factor levels.

Factor / Level	Sample Size	Least Squares Mean - Mortality	90% Confidence Limits	Statistical Differences[1]
Sampling Method				
Electrofishing		5.18	3.19 – 7.17	a
Trapping		20.00	17.03 – 22.97	b
Vegetative Habitat				
Cleared		35.68	31.35 – 40.00	a
Mixed		2.09	0.51 – 3.67	b
RCG		0.00	0 – 2.74	b
Interactions				
Electrofish x Cleared		11.36	7.03 – 15.68	a
Electrofish x Mixed		4.18	1.81 – 6.55	a b
Electrofish x RCG		0.00	0 – 3.35	b
Trap x Cleared		60.00	52.51 – 67.49	c
Trap x Mixed		0.00	0 – 2.07	b
Trap x RCG		0.00	0 – 4.33	b

1 Within each factor group, levels with the same letter are not statistically different from one another ($p \geq 0.10$).

4.4 Discussion

Our goal in this study component was to provide information useful to resource managers involved in maintenance and associated defishing of agricultural waterways in King County. Findings of this study largely support continuation of the existing King County protocol (Berge 2003) for defishing prior to maintenance activities in agricultural waterways. Various additions or modifications to that protocol are suggested.

For the purpose of this study, we were tasked to evaluate differences in very different sampling techniques. When comparing trapping and electrofishing efficiency or mortality, it is difficult to compare results directly between methods because one cannot easily define how much trapping effort equates to a given amount of electrofishing effort. However if one assumes that, from the perspective of a management entity, similar sampling effort has been expended when a similar amount of time and cost resources have been utilized, then we believe that our comparisons of sampling effort (and associated mortality) are meaningful. Electrofishing effort requires a single site visit which may include one or more electrofishing samples or efforts using a complex set of sampling equipment, with at least two persons involved at all times for safety reasons. Trapping effort involves far less complex equipment which can be rapidly deployed or retrieved and, although it requires two site visits per event (one to set and one to pull traps), in small channels this effort can often be conducted safely by a single person. For these reasons we believe it is reasonable, for the purpose of this study, to compare efficiency and related mortality of one electrofishing pass with that of one 8-12 hour trapping session involving multiple traps.

We do not believe that the uncertainty associated with some population estimates negatively impacted the results of this study. In evaluating efficiency of various fish sampling techniques in agricultural waterways, we relied on our ability to make relatively accurate estimates of population abundance in the sampled reaches. We relied on mark-recapture techniques to estimate population abundance and, in some cases, the number of recaptures was low (e.g. <5) leading to wide confidence intervals around the corresponding estimates of abundance. Wide confidence intervals around population estimates were noted during August, 2004 in mixed vegetative habitats. During September, 2005 when sampling in mixed vegetative habitats, numbers of fish recaptured was higher and the confidence intervals around population estimates were correspondingly narrower. For these mixed habitat areas, the same patterns in sampling efficiency between sampling techniques were observed in both August, 2004 and September, 2005, and the same conclusions would be drawn based on results from either sampling period. This suggests that, although low numbers of salmonid recaptures during the initial sampling period lessened confidence in corresponding population estimates, they did not impact study results.

4.4.1 Sampling Efficiency

Although sampling efficiency is quite variable, we believe that fish capture efficiency in agricultural waterways via electrofishing will generally be greater than that of trapping across the range of habitats observed in agricultural waterways. Sampling efficiency of single pass electrofishing was found to be substantially higher than that of trapping over 8-12 hours with multiple traps in channels influenced by RCG dominated or mixed vegetative habitats. In habitat areas recently cleared of vegetation, no significant difference was found between electrofishing and trapping efficiency. In areas cleared of vegetation, findings related to trapping efficiency were based on a single observation which may limit their utility.

To achieve substantial removal of fish from agricultural waterways, a minimum of 6-8 sampling events will likely be necessary at a minimum, and additional events will likely be necessary in some circumstances. Across the range of sampling efficiencies estimated during this study, Table 4-8 shows the expected percent of fish which would be removed during multiple rounds of defishing activities (assuming capture efficiency is consistent over multiple sampling events). This information is for illustrative purposes only, since sampling efficiency will depend on a variety of factors including sampling method and habitat type, and will likely vary between sampling events. Although, not evaluated as part of this study, it is also possible that sampling efficiency is density dependent, and would decline as the fish population is reduced.

In this study, electrofishing efficiency ranged from approximately 8-34 percent dependent upon habitat type; trapping efficiency ranged from approximately 2-23 percent dependent upon habitat type (refer to Table 4-5 for actual numbers by habitat type). Assuming an overall average capture efficiency of approximately 20 percent, Table 4-8 illustrates that approximately seven sampling events would be required to achieve at least 75 percent removal of fish from an agricultural waterway. Removal of 90 percent of the fish would require approximately 11 sampling events. If expected sampling efficiency is below 20 percent, the number of sampling events required to achieve a given level of fish removal will increase.

Based on findings of this study we recommend the continued use of multiple sampling methods (trapping and electrofishing) for fish removal prior to maintenance activities in agricultural waterways, consistent with general methods described by Berge (2003). We recommend an expanded use of electrofishing over a more dispersed timeframe than is currently prescribed by KCDNRP (Berge 2003).

Table 4-8. Estimated percent of fish removed following a given number of sampling events at representative sampling efficiencies. Bold and shaded cells indicate when fish removal of 75 or 90 percent, respectively, would be achieved.

Estimated Efficiency (%)	**Number of Fish Removal Events**													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
5	10	14	19	23	26	30	34	37	40	43	46	49	51	54
10	19	27	34	41	47	52	57	61	65	69	72	**75**	77	79
15	28	39	48	56	62	68	73	**77**	80	83	86	88	**90**	91
20	36	49	59	67	74	**79**	83	87	89	**91**	93	95	96	96
25	44	58	68	**76**	82	87	**90**	92	94	96	97	98	98	99
30	51	66	**76**	83	88	**92**	94	96	97	98	99	99	99	100

When traps are employed as part of defishing strategies, the channel segment(s) to be defished should be saturated with as many traps as is practical, consistent with the existing defishing protocol in use by King County (Berge 2003). The density of traps deployed during this study ranged from 4 - 6 traps per 100 feet of channel. Increasing trap density by 50 percent (by deploying the same number of traps in shorter sampling reaches) resulted in no notable increase in sampling efficiency (on a reach specific basis) in mixed vegetative habitats[2]. It is unknown if further increases in trap density (e.g. to 10 – 12 traps per 100 feet of channel) would result in significant increases in sampling efficiency. However, relative to other sampling methods deployment and retrieval of traps is not a particularly time consuming process, and once a decision is made to deploy traps, increasing the number of traps deployed would result in a minimal increase in effort and associated cost.

When traps are to be deployed overnight, pre-dawn water quality should be assessed prior to trap deployment. If any concern exists about the possibility of severely reduced nighttime DO minima, traps should not be deployed overnight. Observations during this study illustrated that in circumstances of severely reduced water quality, fish mortality during overnight trapping exercises can be high. We therefore recommend inclusion of minimum water quality criteria which would shift defishing efforts away from overnight trapping and place more reliance on daytime sampling via trapping and/or electrofishing.

Whenever practical, electrofishing efforts should not only be conducted as a final removal effort as described by Berge (2003), but also for several days prior to maintenance activity. Based in large part on the greater overall efficiency observed in electrofishing surveys, electrofishing should be conducted during site visits when trapping activities are being conducted. Optimally this would include 1-2 electrofishing passes conducted each day for five days prior to maintenance activity during site visits currently aimed at setting or retrieving fish traps. Inclusion of additional electrofishing effort should not however preclude continuation of the existing protocol of multi-pass electrofishing conducted on the final day prior to maintenance activities.

Based on the relatively high sampling efficiencies observed, electrofishing should be used for defishing activities whenever possible. In some cases watercourses that are too deep or too wide to electrofish effectively may be encountered during fish removal efforts. In these instances, best professional judgment will be required by on site personnel to determine the best sampling technique (or combination of techniques) to use. If a substantial portion of the waterway can be electrofished from each bank in a safe manner with reasonable effectiveness, performing one shock from each bank will likely provide a greater sampling efficiency than trapping techniques, and electrofishing in this manner would likely remain the most efficient and effective manner to de-fish the waterway. Alternatively, electrofishing during the dewatering phase of the project when the channel becomes more accessible would be advised. If safety or channel characteristics preclude these manners of electrofishing, other sampling techniques (e.g. seining

[2] To estimate sampling efficiency (proportion of fish collected) of each sampling method, the total number of fish captured in a given sampling reach/event using a given sampling method was divided by the associated estimate of population abundance for the same reach/sampling event. In this manner, efficiency was estimated as a percent of the total estimated population collected by a given sampling technique during a single sampling event.

or trapping) should be considered based on site characteristics including bank and in channel cover, and water depth, and velocity.

The recommendation to conduct only 1-2 electrofishing passes per day during initial electrofishing efforts should maximize fish collection while minimizing stress and/or mortality associated with that collection. Data gathered during this study found no statistical difference in sampling efficiency when electrofishing in 'clean' conditions and subsequently in 'dirty' conditions although sample sizes for these comparisons were small. Cross and Stott (1975) illustrated that electrofishing at frequent intervals impacts catchability of fish being sampled, with decreased catchability in later samples as fish become more disturbed and presumably move deeper into available cover.

4.4.2 Sampling Mortality or 'Safety'

Although we believed it was important to present the data gathered, we believe that results of this study as they relate to sampling mortality or 'safety' are potentially misleading and should be used with caution. Substantially reduced water quality at some study sites, particularly the site cleared of vegetation, were believed to be the primary cause of elevated mortality rates observed during this study, particularly during September, 2005 surveys. Reduced water quality conditions at some study sights may or may not have been directly tied to surrounding and in channel vegetative habitat regimes.

Water quality monitoring equipment was not available for use at the time sampling occurred during September, 2005 so no direct measurements of dissolved oxygen (DO) were made at the time fish sampling was being conducted. However, DO measurements at each study site were made by KCDNRP staff one or two days prior to the onset of sampling related to this study under similar weather conditions. Those measurements indicated mid-day DO levels of 1.0-1.7 mg/l at the site cleared of vegetation, and modestly higher levels at the sites with mixed and RCG vegetation (2.0-4.0 mg/l; Tom Nelson KCDNRP, personal communication with Tom Cichosz, September, 2005).

The accepted minimum DO level for extended salmonid use has been stated to be 5.0 mg/l (Bell 1991; Bjornn and Reiser 1991). Davis (1975) found that freshwater salmonid populations begin to show initial distress symptoms when DO levels fall below 6.0 mg/l, and that most fish are substantially affected by DO levels below 4.25 mg/l. High water temperatures and corresponding reductions in oxygen solubility can compound stresses to fish related to reduced DO levels (Bjornn and Reiser 1991). Dissolved oxygen levels in small channels can be reduced substantially during periods of high temperature and low flows, particularly if organic debris is abundant in those channels (Hall and Lantz 1969); this combination of factors is common to King County's agricultural waterways during the summer months.

Although seasonal reductions in water quality (including increased temperature and decreased DO) are expected in most waterways during the summer months, we believe that water quality conditions observed during this study were reduced further than expected given normal seasonal conditions. Monitoring conducted for other purposes in late July and early October did record instances where DO levels were similar to those observed during this study (1-4 mg/l) although typical DO levels recorded at fish sampling sites in those periods were 3-6 mg/l.

Given that daytime DO levels were believe to be less than 2 mg/l at the 'cleared' site, it is believed that localized anoxic (or very nearly so) conditions may have existed during the nighttime hours, resulting in the mortality of fish trapped within those localized areas. The salmonid mortality observed due to trapping at the 'cleared' site (60% of salmonids captured) was incurred during an overnight sampling period. Diurnal cycles resulting in DO maxima during the day and DO minima during the night are common in natural waters due to diurnal variations in oxygen supply (e.g. photosynthesis) and demand (e.g. respiration and decomposition; Wetzel 2001). Field notes indicate that observed mortality was not consistent across all traps deployed, but was greatest (often complete) in those traps set in deeper portions of the channel, supporting the hypothesis of localized overnight oxygen depletion at that sampling site.

Based on these findings, we recommend that the existing protocols for defishing of agricultural waterways (Berge 2003) be modified to include criteria or guidelines to prevent elevated mortality during overnight sampling practices when poor water quality conditions exist. These guidelines may relate to water quality (e.g. if daytime DO levels are less than 4.0mg/l, do not deploy traps overnight), observed mortality (e.g. if more than 20 percent mortality is observed during an initial overnight trapping session, overnight trapping activities shall cease), or both[3].

It is important to note that any criteria tied to defishing mortality may establish allowable levels (e.g. 20%) much higher than those typically considered acceptable for general fish surveys (e.g. <5%). Since defishing activities will precede dewatering and maintenance activities, any fish not removed will most likely be killed. For that reason, sampling procedures which elevated successfully remove abundant fish alive are preferable to a cessation of the defishing effort due to that elevated mortality.

In summary, we believe that results presented for mixed vegetation sites are likely representative of expected sampling mortality during defishing activities, since data represent the average observed from multiple sites collected across multiple sampling events. However, comparisons of sampling mortality related to RCG and cleared habitat areas are questionable since findings related to both habitats are based on single sampling event at a single location. Additionally, water quality during sampling at those sites was not believed to be representative of expected conditions in similar habitats during other sampling periods. In these habitats, we believe that the mortality rates observed during this study most likely represent 'worst-case' water quality scenarios.

[3] Numbers presented are examples, not recommendations; it is beyond the scope of this study to recommend numerical water quality or mortality criteria. Any development of water quality criteria based on the findings of this study should likely consider both temperature and dissolved oxygen levels.

4.5 Conclusions and Recommendations

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 (Berge 2003). 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; this is consistent with general methods described by Berge (2003) and currently used by King County. However, based on the findings of this study, some additions or modifications to that protocol are recommended for consideration by King County:

1. When practical, additional electrofishing activities should be conducted over the several days prior to maintenance activities when trapping activities are already being conducted. Optimally this would include a single electrofishing pass conducted prior to the setting of fish traps each day for five days prior to maintenance activity. In this manner, trapping might be conducted during the daylight or nighttime hours (or both), depending on the ability of KCDNRP staff to deploy and retrieve the traps. Inclusion of additional electrofishing effort would not preclude continuation of the existing protocol of multi-pass electrofishing conducted on the final day prior to maintenance activities.
2. Findings of this study illustrated that in some circumstances of reduced water quality fish mortality during overnight trapping exercises can be very high. We therefore recommend inclusion of minimum water quality criteria (e.g. Temperature and D.O., presumably measured during daylight hours) under which overnight trapping would occur and an explanation of conditions that would potentially lead to termination of overnight trapping exercises.

4.6 References

Bell, M. C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Portland: U. S. Army Corps of Engineers.

Berge, H. B.. 2002. 2001 Annual Monitoring Report. King County Agricultural Drainage Assistance Program. King County Department of Natural Resources and Parks. Available at: ftp://dnr.metrokc.gov/dnr/library/2002/kcr763.pdf

Berge, H.B. 2003. Defishing Protocol for King County Agricultural Drainage Assistance Program (ADAP). King County Department of Natural Resources and Parks. 2 pp.

Bjornn, T. C. and D. W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. In: Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. M. R. Meehan, Ed. Bethesda, MD: American Fisheries Society Special Publications, pp. 83-138.

Chapman, D. G. 1952. Inverse multiple and sequential sample censuses. Biometrics 8:286-306.

Chapman, D. G. 1954. The estimation of biological populations. Ann. Mathemat. Stat. 25:1-15.

Cross, D.G. and B. Stott. 1975. The effects of electrofishing on the subsequent capture of fish. Journal of Fish Biology 7:349-357.

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. Journal of the Fisheries Research Board of Canada 32:2295-2332.

Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 *in* Northcote, T.G. (ed.). 1969. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Institute of Fisheries. Vancouver, British Columbia.

King County Department of Development and Environmental Services (DDES). 2001. Public Rules Chapter 21A-24. Sensitive areas: Maintenance of agricultural ditches and streams used by salmonids.

King County Department of Natural Resources and Parks. 2001. Agricultural Drainage Assistance Program. Website accessed November 12, 2006. <http://dnr.metrokc.gov/wlr/waterres/fnd/salmonids.htm>.

Kulp, M.A. and S.E. Moore. 2000. Multiple electrofishing removals for eliminating rainbow trout in a small southern Appalachian stream. North American Journal of Fisheries Management. Vol.20(1): 259-266.

Lockwood, Roger N. and J. C. Schneider. 2000. Stream fish population estimates by mark-and-recapture and depletion methods. Chapter 7 *in* Schneider, James C. (ed.) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

National Marine Fisheries Service. 2000. Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act. 5pp.

Tom Nelson KCDNRP, personal communication with Tom Cichosz, September, 2005.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. No. 191, 382 p.

Strach, Russell M. and T.C. Bjornn. 1989. Brook trout removal, stocking cutthroat trout fry, and tributary closures as means for restoring cutthroat trout in Priest Lake tributaries. Idaho Department of Fish and Game job completion report, project F-71-R-12, Subproject III, Job no. 1.

Thompson, P.D. and F.J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small Rocky Mountain streams. North American Journal of Fisheries Management. Vol.16(2): 332-339.

Van Den Avyle, M.J. 1993. Dynamics of exploited fish populations. Pages 105-136 *in* C.C. Kohler and S.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Washington State University and University of Washington. 2006. A Study of Agricultural Drainage in the Puget Sound Lowlands to Determine Practices which Minimize Detrimental Effects on Salmonids: Sampling and Analysis Plan. Prepared for the King County Department of Natural Resources and Parks, Water and Land Resources Division.

Wetzel, R.G. 2001. Limnology. Third Edition. Academic Press, San Diego. 1006 pp.

Appendix 4-A: Locator maps of sampling sites.

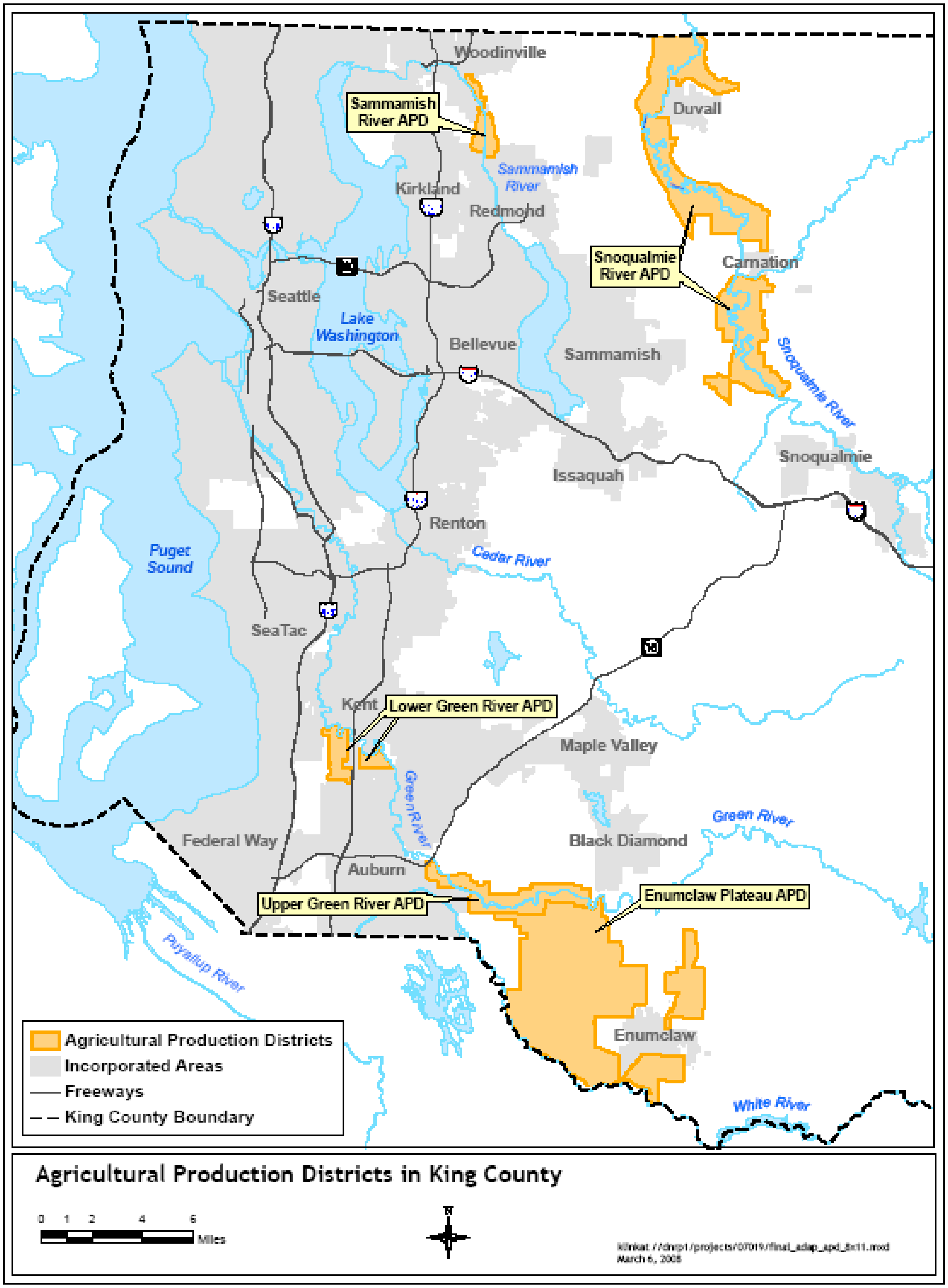

Figure 4-A -3. Agricultural Production Districts and incorporated areas within King County.

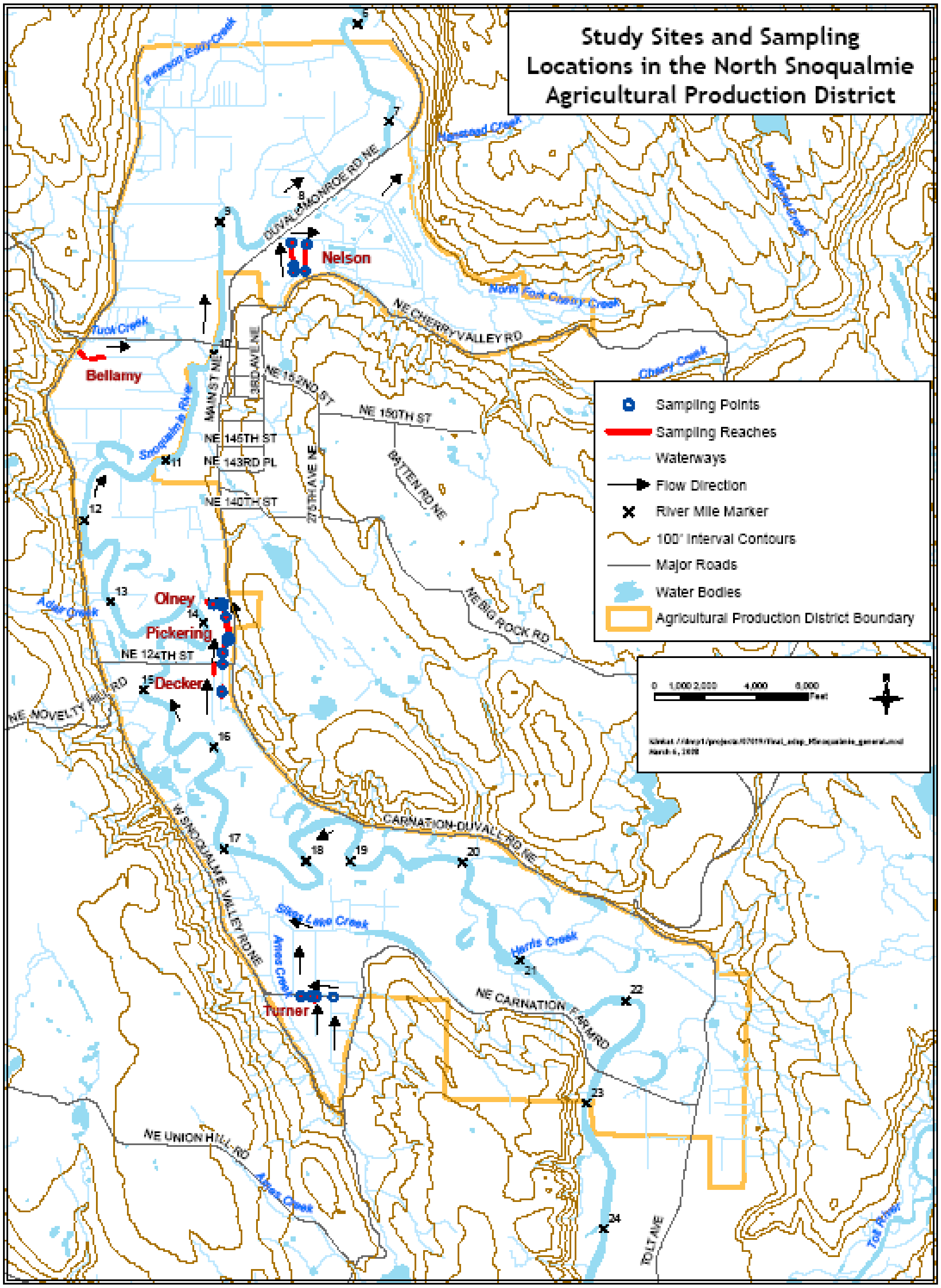

Figure 4-A -4. Overview of study sites and sampling locations in the North Snoqualmie Agricultural Production District.

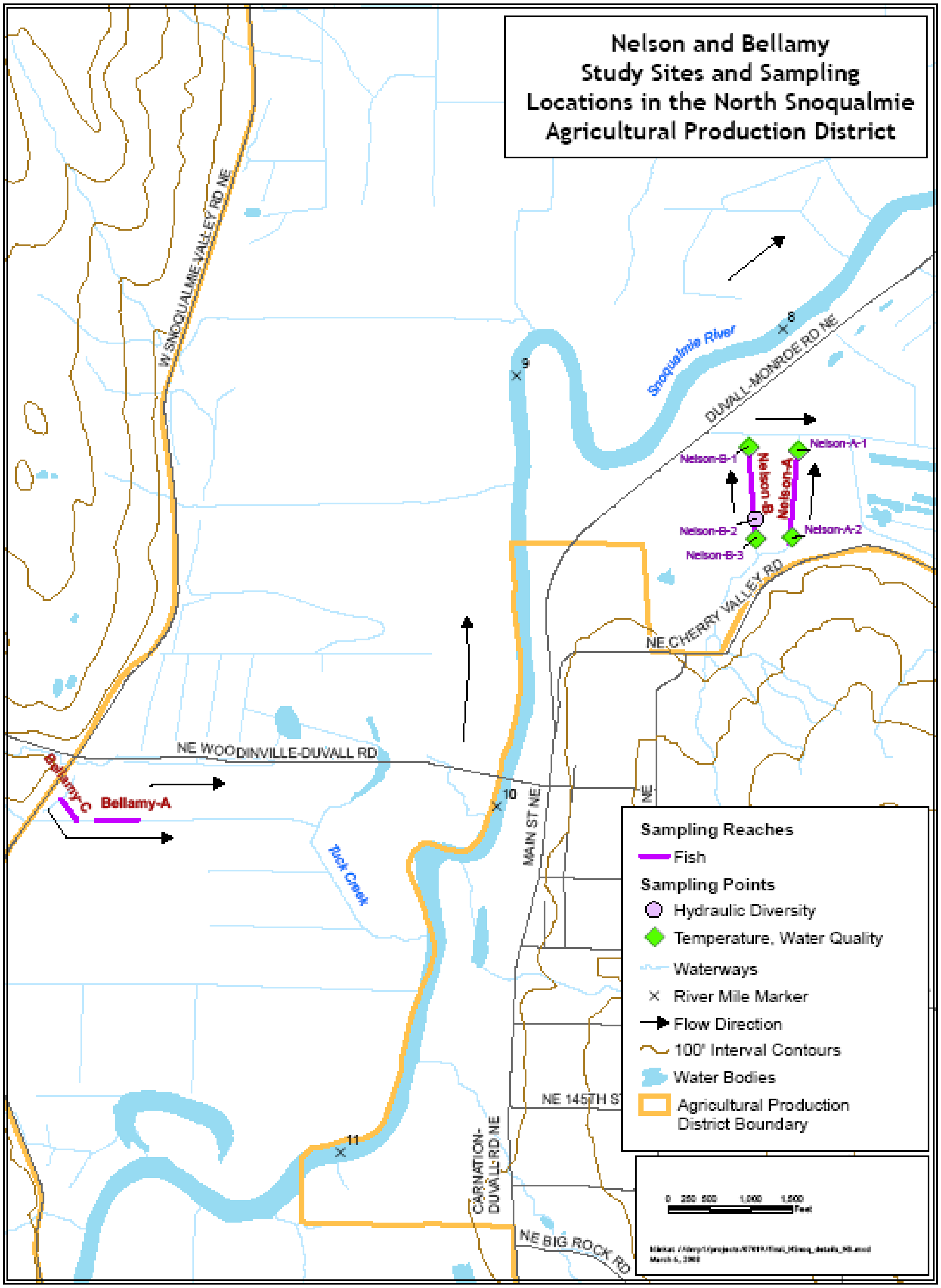

Figure 4-A -5. Detail of study sites and sampling locations in the northern portions of the North Snoqualmie Agricultural Production District.

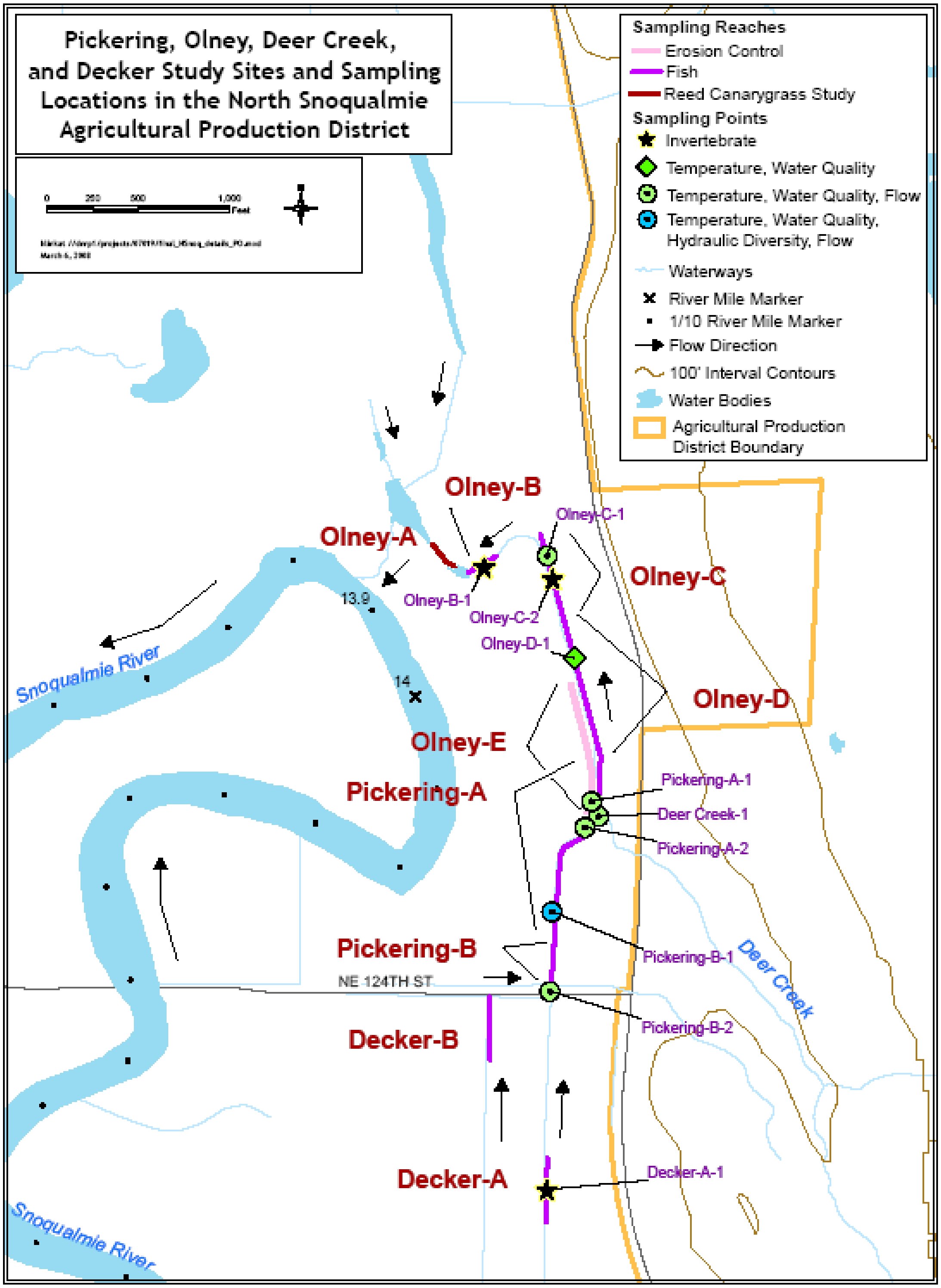

Figure 4-A -6. Detail of study sites and sampling locations in the central portions of the North Snoqualmie Agricultural Production District.

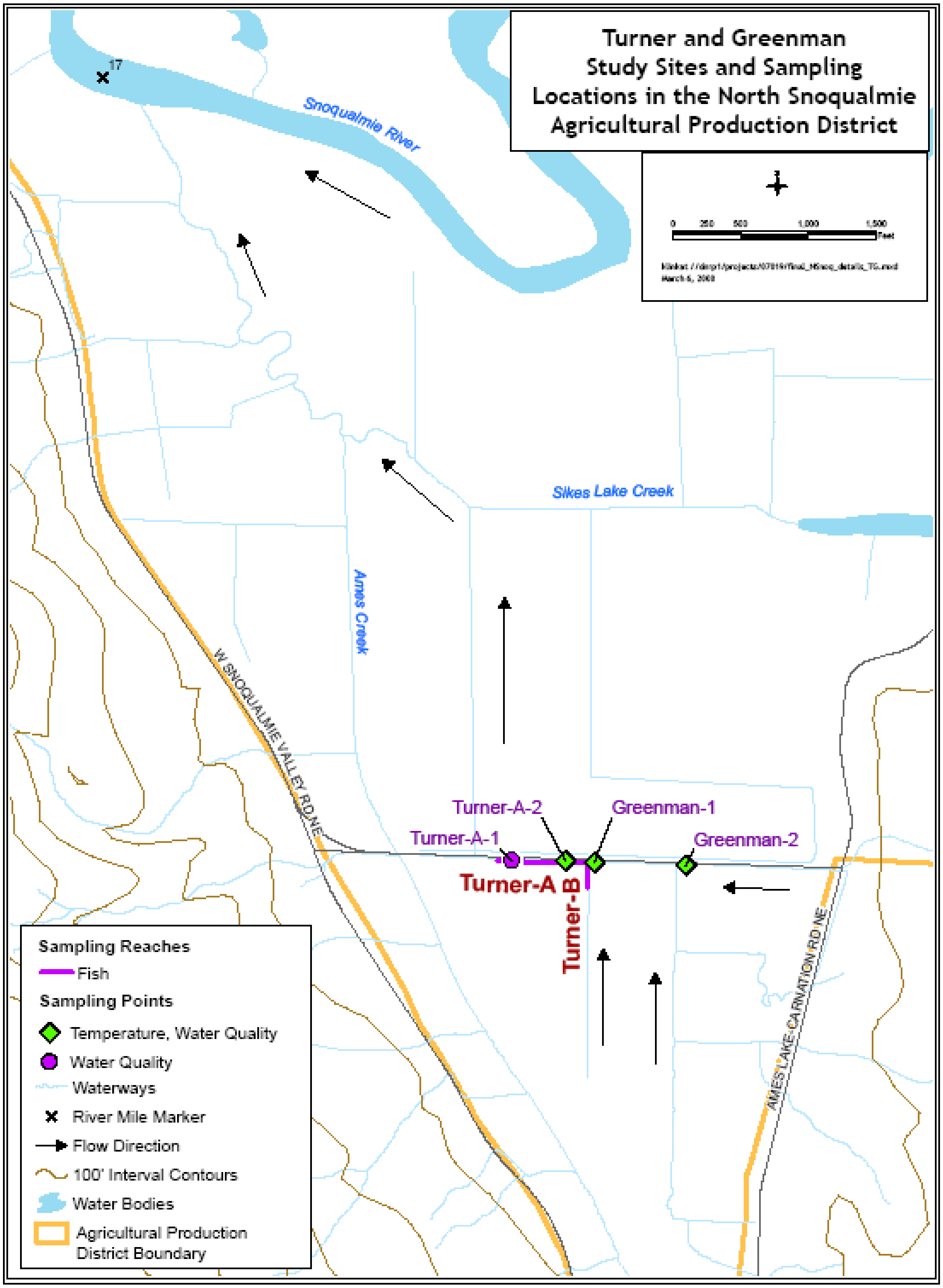

Figure 4-A -7. Detail of study sites and sampling locations in the southern portions of the North Snoqualmie Agricultural Production District.

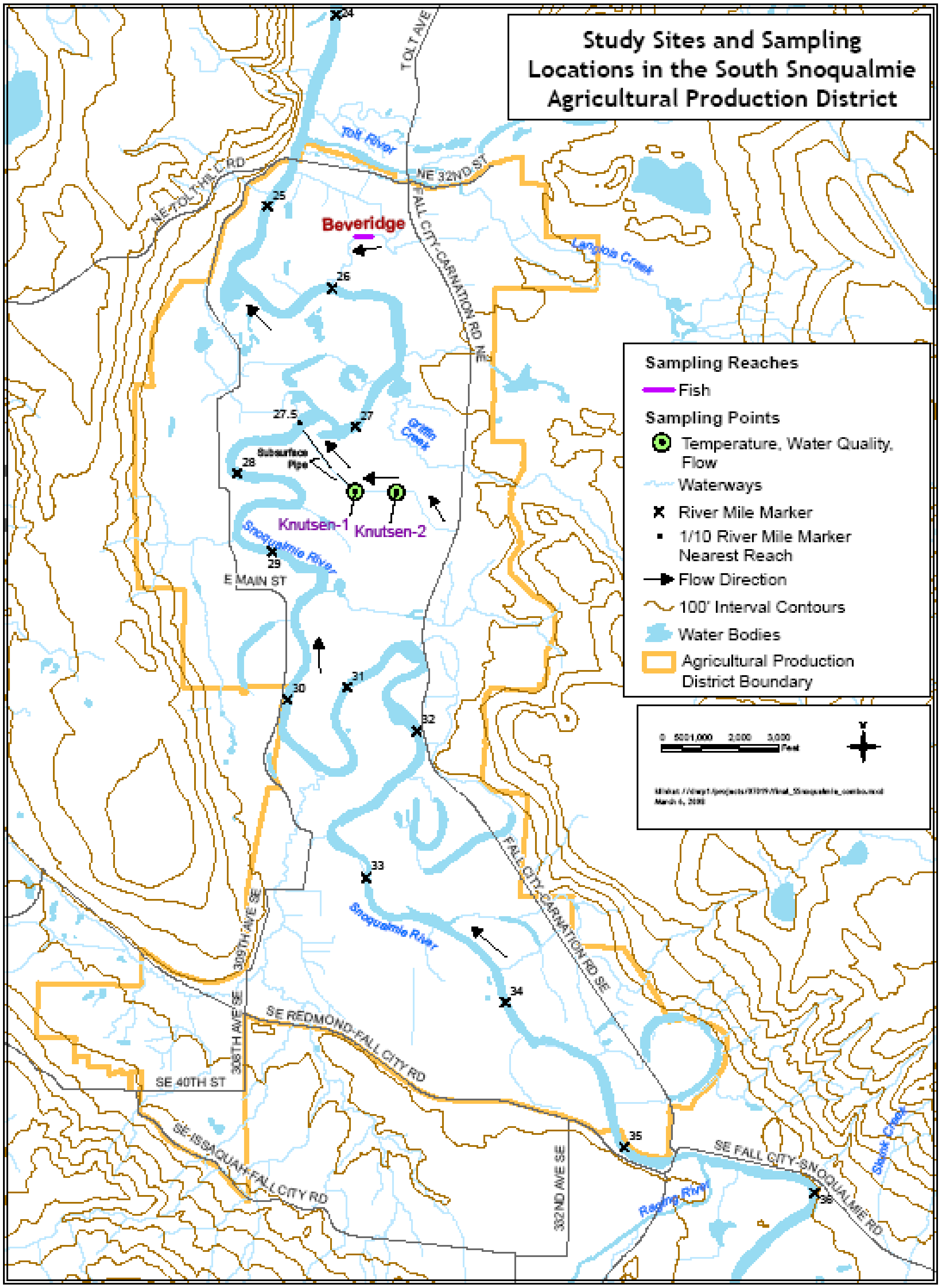

Figure 4-A -8. Detail of study sites and sampling locations in the South Snoqualmie Agricultural Production District.

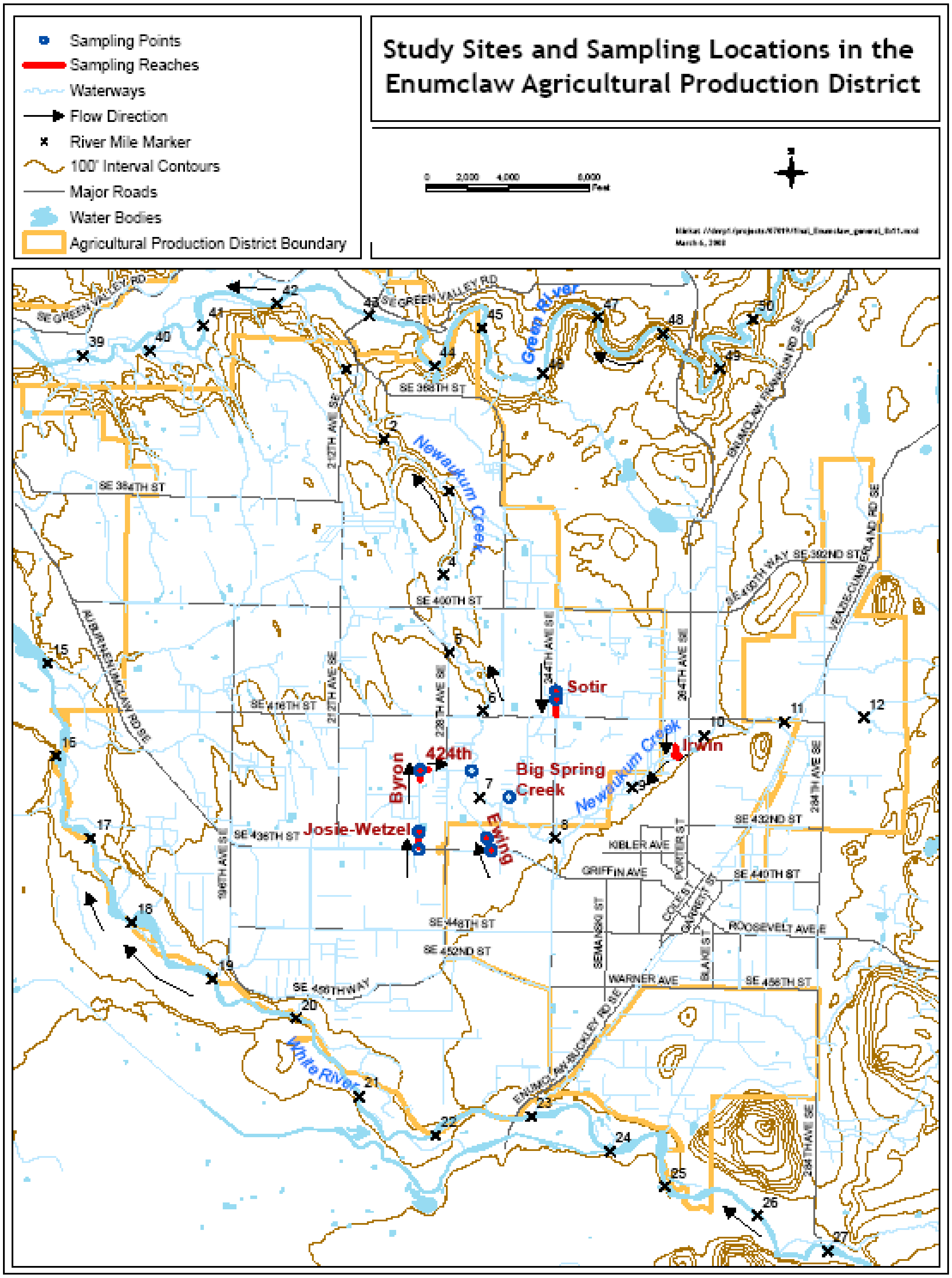

Figure 4-A -9. Overview of study sites and sampling locations in the Enumclaw Agricultural Production District.

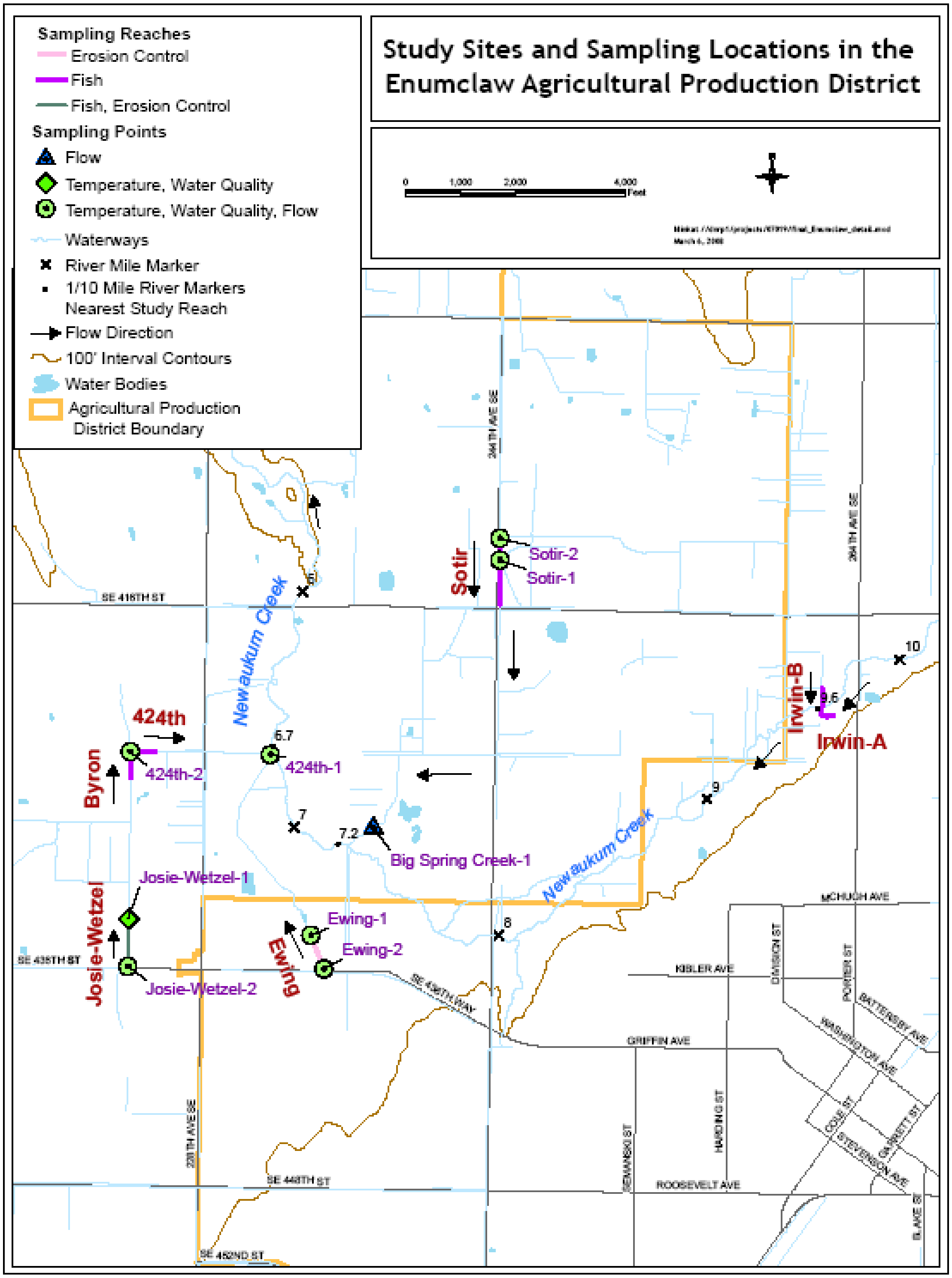

Figure 4-A -10. Detail of study sites and sampling locations in the Enumclaw Agricultural Production District.

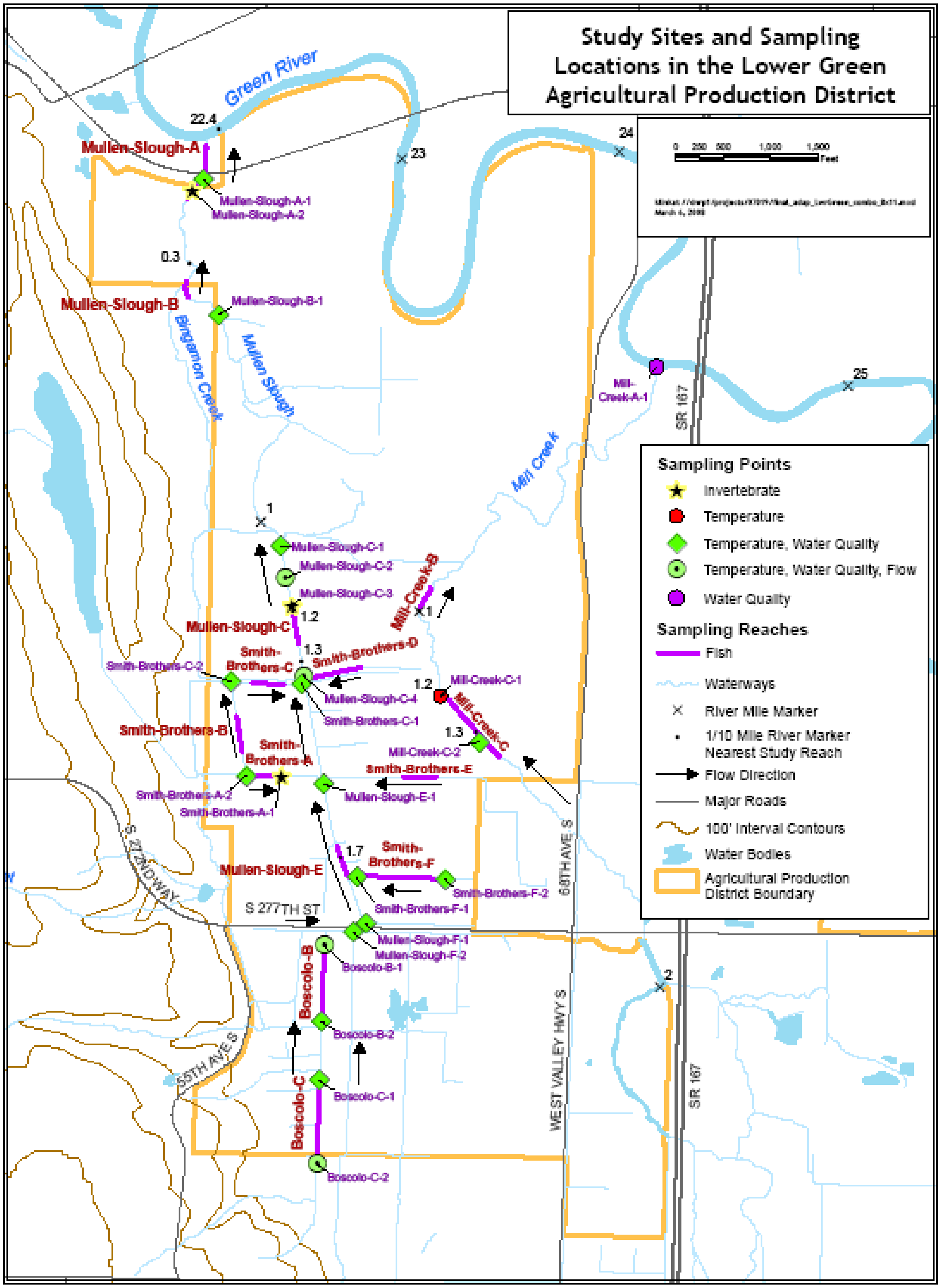

Figure 4-A-11. Study sites and sampling locations in the Lower Green Agricultural Production District.

Appendix 4-B: Salmonid density, catch and CPUE data by site and sampling event.

Appendix 4-B 1. Summary of population estimates and associated mark, capture, and recapture information and 95% confidence intervals for sites sampled during August, 2004.

Site	Sampling Method	Species	Reach Length (ft)	Reach Width (ft)	Recaptures (R)	Marks (M)	Total Captures (C)	Pop. Estimate (N)	Lower 95% CI	Upper 95% CI
Decker-A	Combined[1]	No Salmonid	150	10	N/A	N/A	N/A	N/A	N/A	N/A
Turner	Shock	Coho	300	12	18	92	136	303	203	538
		Cutthroat			1	2	5	4[2]	1	70
		Salmonids			19	94	141	311	210	540
	Trap	Coho	300	12	4	28	85	377[2]	185	1886
		Cutthroat			0	2	10	N/A	N/A	N/A
		Salmonids			4	30	95	458[2]	224	2289
Nelson-B	Shock	Coho	250	8	0	0	2	N/A	N/A	N/A
	Trap	Coho	250	8	1	7	27	79[2]	28	1580

1 Shocking and trapping were conducted during the day and night, respectively, in the same reach due to limited available space at this site.
2 Population estimate is questionable based on the limited number (<5) of recaptures encountered.

Appendix 4-B 2. Summary of population estimates and associated mark, capture, and recapture information and 95% confidence intervals for sites sampled during September, 2005.

Site	Sampling Method	Species	Reach Length (ft)	Reach Width (ft)	R	M	C	Pop. Estimate (N)	Lower 95% CI	Upper 95% CI
Nelson-B	Combined[1]	Salmonids[2]	200	7	117	143	282	189	159	229
Olney-B	Combined[1]	Coho	175	8	40	29	70	32	22	58
		Cutthroat			9	4	13	4	2	10
		Salmonids			49	33	83	36	26	57
Olney-D	Combined [1,3]	Coho	175	22	7	49	91	200	111	573

1 During September 2005, shocking and trapping were conducted during the day and night, respectively, in the same reach.
2 One fish was initially misidentified as a coho and re-classified as a Chinook after being recaptured; all other salmonids were coho.
3 Traps were used for only one night and their use was discontinued due to high mortality of trapped fish; Sampling was predominantly electrofishing