April 15, 2025

PLANNING & PUBLIC WORKS

Agricultural Ditch Maintenance Workshop

An agricultural ditch is constructed to convey (move) water from one place to another in an open channel to improve working lands for food production. An agricultural ditch does not have headwaters, like a natural or modified water course, but can sometimes be fish bearing. Ditches are one of two traditional ways to address excess water, the other being systems to infiltrate water into the soil.

Why is proper drainage important for farm and ranch lands?

Increases productivity

Farmers and ranchers can get on land earlier, can harvest fields later into the fall, may be able to grow higher value cash crops, and/or can expand the livestock grazing season without degrading pastures.

Preserves soil fertility

Farms and ranches have less soil erosion and nutrient leaching.

Improves water quality

Surface waters on working lands carry less sediment, are less turbid, and have lower temperatures, important parameters for ag. drainage systems that drain into natural or modified waterways.

Expands benefits

Bankside plantings can slow down sediment accumulation by controlling weedy species, such as Reed Canary Grass, improve fish, wildlife, and natural pollinator habitat.

What can cause agriculture drainage issues?

Emergencies and natural disasters

An example would be a regional storm event that causes extensive flooding. These cannot be controlled but can be prepared for.

Sediment and biomass accumulation

This reduces system capacity, which can result in declining field drainage efficiency, and elevated groundwater levels.

Blockages

This could be due to failing private culverts, bridges or natural barriers, such as fallen trees and/or beaver dams.

Increased surface water runoff

Developing areas around farms and ranches often have an increase in impervious surfaces, less percolation into soils to groundwater, which results in more surface water to drain.

Contact Us

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Pierce County Farming & Agriculture Program

Common agricultural ditch maintenance questions:

Am I in the Pierce County drainage district?

There are seven active districts that provide drainage assistance for the lands in their respective service areas. Use the Pierce County Drainage District Map found on the Farming and Agriculture website, 'Drainage Support' webpage to see if your land is in a drainage district service area.

If not, is the water course I want to maintain an agricultural ditch?

An agricultural ditch, as an example of an artificial water course, is different than …

- **Natural Water Courses:** Have not been significantly altered from their historical flow path or floodplain in any manner and have headwaters (usually from wetlands or springs). They may or may not be fish bearing. These are highly regulated systems that are parts of the 'waters of the state' and farms and ranches are not permitted to maintain.

- **Modified Water Courses:** Historically natural systems that have been diverted, dredged, straightened, and/or diked. They may or may not be fish bearing. These were often historically developed to drain working lands. Farms and ranch may or may not maintain these systems, based upon several factors to be evaluated on a case-by-case basis. We recommend a Pierce County Agriculture Planning Program review before you initiate any maintenance. Even routine permitted maintenance may require a Washington Dept. of Fish and Wildlife (WDFW) Hydraulic Permit Application (HPA).

Where does my agricultural ditch drain to?

What forms of maintenance you can conduct and how the work is done will be based in part on the type of downstream water system—constructed, modified, or natural—and the presence of absence of fish in the drainage system.

When can I Work?

The timing of allowed agricultural ditch maintenance will depend upon the work location distinguished by the Ordinary High-Water Mark (OHWM):

- **Above the OHWM:** Hand or mechanical plant management as part of normal overall agricultural ditch maintenance can be conducted year around. Do not let organic material fall into the ditch channel.

- **Below the OHWM:** Dredging and/or hand or mechanical aquatic plant management as part of normal agricultural ditch maintenance will often be restricted to a time of the year called the 'fish window', even if the ditch is dry. The WDFW fish window is a watershed-specific time when the fewest number of fish are present / would be impacted, and water levels are the lowest. Some type of HPA is usually required if water is present in the ditch during the fish window and fish are known to use the ditch at certain times of the year.

What can I do and how do I do it properly?

Important-the following dredging maintenance descriptions assume that you are conducting the work on a historic agricultural ditch during the appropriate fish window, that it has water in it, and you are neither expanding nor modifying the ditch system.

- **Temporary silt fence:** Before you start maintenance dredging activities, install a temporary silt fence, immediately downstream and across the channel. This is an especially important step, if your agricultural ditch drains into water courses known to have fish.
    - Keep it in place during your maintenance dredging work.
    - Take out collected sediments from behind the silt fence after you are done.

   - Remove it within two days of completing your maintenance dredging work.

- **Dredging positioning:** Use equipment in good repair—no major fluid leaks—for agricultural ditch maintenance:
   - Work from upstream to downstream to let channel vegetation to help filter and trap disturbed sediments.
   - Use equipment from one side of the ditch only to preserve the natural vegetation on the other side.
   - Work from the top versus waterside of your selected ditch bank to minimize natural vegetation damage and to maintain the proper slope of the bank.

- **Dredging Dos:**
   - Only dredge to the absolute minimum necessary to achieve the originally designed channel width, depth, gradient, and position on the landscape. Any significant modification from the historical system would be considered new / or expanded work, that may require permits or be illegal.
   - Remove and properly dispose of all dredge spoils away from the agricultural ditch. Castings left along a ditch bank may be considered illegal fill.
   - Leave existing large woody material embedded in the channel bank or streambed undisturbed and intact. Woody debris that is blocking the channel itself can be removed or cut back to the streambed or channel bank.

- **Dredging Don'ts:**
   - Continue to dredge an agricultural ditch if you see fish. Please stop your dredging and contact a regional Washington State Dept. of Fish and Wildlife area biologist to confirm next steps.
   - Our Washington Department of Fish and Wildlife Region 6, Habitat Biologists are:

Miles Penk: Puyallup-White Rivers Basin
Cell: (360) 480-2908
Miles.Penk@dfw.wa.gov

Portia Leigh: Nisqually Basin, Chambers Clover Creek
Cell: (360) 480-3510
Portia.Leigh@dfw.wa.gov

Brian Blossom: Key Peninsula Watershed
Cell: 564.669.4343
Brian.Blossom@dfw.wa.gov

Hedgerow Plantings for Agriculture Ditches

The concept of narrow vegetative buffers along agriculture ditches and waterways has proven successful on the westside. Fast-growing native species, spaced on tight centers, quickly outcompete invasives that clog waterways, provide habitat for pollinators and other wildlife, and effectively filter sediments and pollutants to preserve water quality. Plant species that tolerate mowing are selected to allow for access to a buffered waterway if needed. Ninebark, twinberry, and red osier dogwood perform especially well. Willow is also effective but can be too aggressive and clog the waterway.

Figure 1: Duffner Ditch, Whatcom County: In 2011 (left) and 2019 (right)

Nancy's Ditch, Riverside Agriculture District, Pierce County

In spring 2023, eight-foot-wide buffers were established along both sides of a 1000-foot stretch of Nancy's Ditch. Twinberry and red osier dogwood were planted on three-foot centers using bare root plant material. Brush cutting and herbicide maintenance was completed in the fall of 2023 and the spring, summer and fall of 2024. Maintenance is planned for 2025 as well, with the hope that the buffer canopy will close adequately to eliminate the need for further maintenance. Maintenance costs in years one through three are slightly higher than standard ditch maintenance costs, although an established buffer eliminates the need for regular ditch maintenance for the long term.

Table 1: Nancy's Ditch hedgerow cost breakdown

Project item	Nancy's Ditch Project Cost	Cost / 1 linear ft buffer*
Site preparation	$ 3000	$ 1.50
Buffer installation labor	$12,000	$ 6.00
Buffer installation plant material	$ 5000	$ 2.50
Yearly maintenance*	$11,000 x 3 years = $33,000	$16.50

* 8 ft wide buffer, three rows of plants spaced on 3 ft centers

** Maintenance required Y1, Y2 and Y3

Agricultural Waterway Buffer Study
Whatcom County, Washington
2012

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Summary
In the summer of 2012, four different planted agricultural waterway buffers in Whatcom County, Washington were monitored for air temperature and effective shade. Buffer areas examined in this study consisted of the following widths: 0 feet (no buffer), 5 feet, 15 feet, 35 feet, and 180 feet. This work focused on agricultural waterways ranging from 4-13', with an average width of 8'. Temperature sensors monitored air temperature outside the buffer, within the buffer, and over the waterway and hemispherical photographs were taken to compute effective shade cover. All buffer characteristics including density, height, and species composition were described. Results suggest that narrow (5', and 15'), dense buffers are as effective as wide (35' and 180') buffers at reducing air temperature and creating effective shade.

Objectives:
Evaluate planted buffers on agricultural waterways to determine if buffer width influences factors that affect water temperature:
1) Evaluate the effect of riparian buffer width on waterway effective shade (percent reduction of total solar radiation) and,
2) Determine whether planted buffers have a microclimate effect and whether buffer width increases that effect.

Assumptions
1) Reducing the solar radiation hitting the waterway surface (effective shade) lowers water temperature or reduces the potential water temperature increase, and
2) Reducing air temperature near the water surface (microclimate) lowers water temperature or reduces the potential water temperature increase.

Hypothesis
Shade:

1. Effective shade will increase as planted buffer width increases.

Micro-climate:

2. Average daily maximum air temperature will be lower within the planted buffer than outside the buffer.
3. The wider the planted buffer, the greater the difference in air temperature between inside and outside of the buffer.

Methods
Site description
Data was collected at five buffer sites at four distinct geographic locations in Whatcom County, WA (Appendix 1-5). Buffer width for this study is defined as the length of a transect perpendicular to the stream channel. Each transect begins at the edge of planted vegetation on one side of the channel and ends at the channel bank. Buffer areas examined in this study were: 0' (no buffer), 5', 15' (NRCS hedgerow practice standard), 35' (NRCS riparian forest buffer standard and Ecology funding policy), and 180' (NRCS riparian forest buffer standard). Two buffers, the 0' and 5' foot buffer, were adjacent to one another; the 5' buffer is downstream of

the 0' section, and share similar aspects and channel bank steepness. Channel width ranges within each buffer were: 0' buffer (2-5'), 5' buffer (3-6'), 15' buffer (4-8'), 35' buffer (5-12'), 180' buffer (5-13'). All study sites except for the 35' buffer were adjacent to active farm fields. The 0', 5', 15' buffers had either/both silage corn/hayland adjacent. The 35' buffer was adjacent to a golf course, but surrounding vegetation had not been managed in 1-3 years. It should also be noted that all sites with the exception of the 35' buffer had relatively little change in elevation in the surrounding landscape. Just east of the 35' was a 20' increase in elevation (Appendix 3) which could have impacted air flow.

In order to examine the effectiveness of vegetative buffer width on air temperature, vegetation was characterized, photos were taken using a hemispherical camera to quantify effective shade coverage (Stohr, 2008), and recorded air temperature readings at buffer sites.

Vegetation Description

Each buffer was characterized; only woody vegetation was recorded except in cases where the dominant ground cover in the buffer was grass or other herbaceous plants [In buffer sites with dense canopies, sparse herbaceous vegetation was detected]. Vegetation was described to genus or species and density was counted along three transects for each buffer. Vegetation transects paralleled the locations of the temperature sensors. Each vegetation transect consisted of two sections: one on either side of the channel (e.g. transect of a 35' buffer was actually 70' because both sides of the bank were surveyed). Vegetation along the transect was counted and identified if rooted within 1/2 m on either side of the transect line. Vegetation data was collected spatially along the transect line and were recorded within four evenly divided distances from the channel bank. In the case of the 0' buffer, vegetation was only counted from the one side (bank) of the waterway to the other. Vegetation height was also determined by randomly measuring 10 individual plants for each buffer.

Effective Shade

Effective shade photos were taken on 28 September and 1 October 2012. At the later date, some leaves had already begun to senesce and drop, therefore potentially skewing the effective shade data. Photos were taken with a hemispherical camera (Coolpix 900, Nikon Corp) oriented North, in the center of the channel, and at four feet above the channel bottom. A minimum of ten photos were taken at each buffer site (with the exception of the 0' buffer). Photos were taken at least ten feet apart throughout the length of the channel and ten feet beyond where the temperature monitoring stations were positioned at either end of the channel. Times and locations of photos were also recorded using a handheld GPS. Photos were analyzed using HemiView© (Dynamax Inc., Houston, TX) following Washington Department of Ecology's Standard Operating Procedures (SOP) (Stohr, 2008).

Temperature Data Points

In this study only air temperature was recorded, water temperature was not included because of available resources. Temperature logging stations were set up by 10 July 2012 and ended on 27 September 2012 for all sites. Temperature data was collected along three transects at each buffer site consisting of three logging stations. Each logging station consisted of one Hobo

Pendant (Onset® Computer Corporation, Pocasset, MA) temperature logger suspended within a solar radiation shield (Appendix 27). The stations were staked into the ground on posts three feet above the ground. For each transect; one logging station was placed outside the buffer in an un-shaded area, a second was placed mid-way between the furthest edge of the buffer and the center of the channel, and a third was suspended over the water channel. Data was recorded in 5-minute intervals, uploaded from the data loggers at 30-day intervals, and checked for battery longevity once a month. To evaluate the impact of buffer width on air temperature, data from sensors was compared between (sensor) location within a given buffer width across the replications (5' buffer: outside vs. mid-way vs. overwater). Daily maximum, minimum, and average temperature was calculated and then compared using PROC GLM (SAS, 2002) within each buffer but across sensor location. Before applying the model exploratory data analysis tools were used to describe data variability (e.g. portray data to identify outliers, extreme values, mode, correlation, and test for normal distribution and equal variance).

Results

Vegetation

For each buffer site, the vegetation varied by density and height (Table 1 & 2). As the width of the buffers increased, a more complex plant community was found (Table 1). The 0' and 5' buffers were characterized mainly by low, densely spaced stems of vegetation.

Table 1. Vegetation characterization (Number of plants by species and calculated density) by buffer width, 2012.

0' buffer		**5' buffer (Planted 2005)**		**15' buffer (Planted 2001/2006)**		**35' buffer (Planted 2000)**		**180' buffer (Planted 2003)**	
Species	Number of plants[a]	Species	Number of plants	Species	Number of plants	Species	Number of plants	Species	Number of plants
Rubus discolor **(Himalayan black berry)**	5	*Salix hookeriana* **(Hooker's willow)**	3	*Salix hookeriana* **(Hooker's willow)**	5	*Salix lucida* **(Pacific willow)**	10	*Populus balsamifera* **(Black cottonwood)**	5
Rosa nutkana **(nootka rose)**	20	*Cornus sericea* **(red osier dogwood)**	8	*Sambucus racemosa* **(red elderberry)**	4	*Betula papyrifera* **(paper birch)**	1	*Alnus rubra* **(Red alder)**	8
Spiraea douglasii **(Douglas spiraea)**	12	*Phalaris arundinacea* **(reed canary grass)**	b	*Lonicera involucrata* **(black twinberry)**	4	*Amelanchier alnifolia* **(serviceberry)**	3	**(Himalayan blackberry)**	3
Rubus laciniatus **(evergreen black berry)**	1	*Physocarpus capitatus* **(ninebark)**	1	*Spiraea douglasii* **(spirea)**	1	*Malus fusca* **(pacific crab apple)**	1	*Cornus sericea* **(red osier dogwood)**	14
Phalaris arundinacea **(reed canary grass)**	b	*Spiraea douglasii* **(spiraea)**	8	*Cornus sericea* **(red osier dogwood)**	5	*Populus balsamifera* **(Black cottonwood)**	2	*Salix lucida* **(Pacific willow)**	4
Plants/ft^{2b}	**1.16**	**(Himalayan blackberry)**	6	*Rhamnus alnifolia* **(alder buckthorn)**	1	*Populus deltoides* **(Aspen)**	1	*Corylus cornuta* **(beaked hazelnut)**	1
		Rosa nutkana **(nootka rose)**	4	*Thuja plicata* **(Western red cedar)**	1	*Salix sitchensis* **(Sitka willow)**	1	*Thuja plicata* **(Western red cedar)**	1
		Plants/ft^2	**0.39**	*Rosa sp.*	4	*Fraxinus latifolia* **(Oregon ash)**	2	Abies grandis **(grand fir)**	2
				Plants/ft^2	**0.22**	*Lonicera involucrata* **(black twinberry)**	1	*Rosa nutkana* **(nootka rose)**	5
						Picea sitchensis **(Sitka Spruce)**	1	*Rosa gymnocarpa* **(baldhip rose)**	1
						Plants/ft^2	**0.08**	**(Common snowberry)**	1
								Betula papyrifera **(paper birch)**	1
								Plants/ft^2	**0.03**

[a]For 0' buffer counts represent plant species along the waterway banks

[b]Each vegetation transect consisted of two sections: one on either side of the channel (e.g. transect of a 35’ buffer was actually 70’ because both sides of the bank were surveyed). Vegetation along the transect was counted and identified if rooted within 1/2 m on either side of the transect line.

Table 2. Vegetation characterization (plant height ft.) by buffer width, 2012.

Buffer Width	Mean	Maximum	Minimum
0'	6.5	10.4	1.0
5'	19.7	31.6	8.8
15'	15.1	30.4	5.0
35'	36.3	75.0	13.0
180'	34.5	75.0	6.0

Air Temperature

Daily maximum, minimum, and mean for each buffer are graphically represented in Appendix 6-19. Tables 1-5 show highest recorded maximum temperatures and lowest recorded minimum temperature for each buffer by sensor location within the buffer. Additionally, statistical results from analysis are included for the daily average, maximum, and minimum temperature and compared across sensor locations.

In the 0' (non-planted, but vegetated with reed canary grass) buffer there was no statistical difference in average temperature, but maximum temperatures were significantly higher and minimum temperatures significantly lower in sensors placed over the waterway as compared to the sensors located "outside" of the waterway.

In the 5' planted buffer (which was just downstream to the 0' "buffer") trends were quite different. Average and minimum temperatures across sensor locations exhibited no difference, but sensors outside of the buffer showed significantly ($p<0.0001$) higher daily maximum temperatures.

For both the 15' and 35' buffers average temperatures were significantly lower over the waterway as compared to the outside sensors. Additionally, maximum temperatures were significantly lower inside the buffer (both mid-way and above the water) when compared to outside of the buffer.

In the 180' buffer, average and minimum temperatures showed no significant difference when sensor location was compared, but maximum temperatures were significantly higher outside of the buffer as compared to inside.

Differences of average and maximum temperature between sensors located within (above waterway) and outside the buffers within a given buffer (Tables 3-7) width numerically increased as buffer width increased for buffers 5', 15', and 35' but this trend did not stay true for the 180' (average differences were closer to the 5' buffer and maximum differences were closer to the 15' buffer).

Table 3. Temperature values and statistical comparison across sensor locations within a non-planted (0') agricultural waterway, 2012.

Buffer Width	Sensor Location	Maximum[1]	Minimum[1]	Average[2]		Maximum[2]		Minimum[2]	
0'	Outside of Buffer	97.6	30.2	60.7	a[3]	76.7	a	45.5	a
	Over Waterway	99.5	25.4	60.2	a	82.4	b	42.9	b
			p-value	0.603		<.0001		0.01	

[1]Maximum and minimum single recorded values across all dates

[2]Average across all dates of daily maximum, daily minimum or daily average temperature

[3]Value followed are considered statistically significant when followed by a different letter (Student-Newman-Keuls Test, p=.05)

Table 4. Temperature values and statistical comparison across sensor locations within an agricultural waterway planted with 5' buffers, 2012.

Buffer Width	Sensor Location	Maximum[1]	Minimum[1]	Average[2]		Maximum[2]		Minimum[2]	
5'	Outside of Buffer	96.9	30.6	60.9	a[3]	78.0	a	47.3	a
	Within Buffer	88.1	28.1	60.0	a	73.8	b	47.1	a
	Over Waterway	88.0	28.7	59.8	a	73.4	b	46.0	a
			p-value	0.2751		<.0001		0.404	

[1]Maximum and minimum single recorded values across all dates

[2]Average across all dates of daily maximum, daily minimum or daily average temperature

[3]Value followed are considered statistically significant when followed by a different letter (Student-Newman-Keuls Test, p=.05)

Table 5. Temperature values and statistical comparison across sensor locations within an agricultural waterway planted with 15' buffers, 2012.

Buffer Width	Sensor Location	Maximum[1]	Minimum[1]	Average[2]		Maximum[2]		Minimum[2]	
15'	Outside of Buffer	93.3	32.8	61.9	a[3]	76.1	a	48.1	a
	Within Buffer	85.8	36.4	59.8	b	72.7	b	48.8	a
	Over Waterway	83.9	37.7	59.6	b	70.5	c	50.2	a
			p-value	0.002		<.0001		0.092	

[1]Maximum and minimum single recorded values across all dates

[2]Average across all dates of daily maximum, daily minimum or daily average temperature

[3]Value followed are considered statistically significant when followed by a different letter (Student-Newman-Keuls Test, p=.05)

Table 6. Temperature values and statistical comparison across sensor locations within an agricultural waterway planted with 35' buffers, 2012.

Buffer Width	Sensor Location	Maximum[1]	Minimum[1]	Average[2]		Maximum[2]		Minimum[2]	
35'	Outside of Buffer	92.6	31.4	60.4	a	76.5	a	44.7	a
	Within Buffer	86.8	27.9	58.5	ab	72.1	b	48.2	b
	Over Waterway	84.8	29.8	57.5	b	70.1	c	48.2	b
			p-value	0.0036		<.0001		<.0001	

[1]Maximum and minimum single recorded values across all dates

[2]Average across all dates of daily maximum, daily minimum or daily average temperature

[3]Value followed are considered statistically significant when followed by a different letter (Student-Newman-Keuls Test, p=.05)

Table 7. Temperature values and statistical comparison across sensor locations within an agricultural waterway planted with 180' buffers, 2012.

Buffer Width	Sensor Location	Maximum[1]	Minimum[1]	Average[2]		Maximum[2]		Minimum[2]	
180'	Outside of Buffer	95.6	31.6	61.1	a	77.8	a	46.6	a
	Within Buffer	87.9	33.9	60.5	a	73.7	b	48.0	a
	Over Waterway	86.2	33.6	59.6	a	72.4	b	47.8	a
			p-value	0.0789		<.0001		0.315	

[1]Maximum and minimum single recorded values across all dates

[2]Average across all dates of daily maximum, daily minimum or daily average temperature

[3]Value followed are considered statistically significant when followed by a different letter (Student-Newman-Keuls Test, p=.05)

Effective Shade

Effective shade was calculated by analyzing hemispherical photographs using HemiView© software. Photographs were taken on two dates in September and results are included in Table 8. Values were combined across dates. The no (0') buffer had the lowest effective shade percentages ranging from 3-22%. The remaining buffers all had effective shade percentages above 72% and ranked in numerical order (mean percentage): 76% (35' buffer), 80% (180 buffer), 87% (5' buffer), and 88% (15' buffer). Box and whiskers plots (mean, quartiles, and min/max) are included in the appendix (Appendix 21). Examples of hemispherical photos can be found in Appendix 22-26.

Table 8. Calculated effective shade (%) of different agricultural waterway buffers from photos, September 2012.

Buffer	n	Mean	Minimum	Maximum	Range
No Buffer	6	10%	3%	22%	19%
5'	29	87%	75%	99%	24%
15'	27	88%	76%	99%	23%
35'	19	79%	72%	84%	12%
180'	22	83%	74%	92%	18%

Discussion

Based on our methodology and for these particular buffer sites we can conclude that the smaller buffers (5' and 15') were as effective at reducing maximum air temperatures as larger (35' and 180') buffers. Average daily temperatures were reduced at the 15' & 35' buffer when compared to external (outside buffer) values. It should also be noted that minimum daily air temperatures in the 5', 15', and 180' buffers were not significantly different between sensor locations as was witnessed in the 35' buffer suggesting that these widths (5', 15', and 180') cool off at similar rates over the course of a 24 hr. period. This may be in part due to buffer width, but is also influenced by the plant species present. Some buffers included plant species that had an architecture that could influence air flow (in and out) more effectively than those plant species present in other buffers. Additionally, local topography could have had an impact on daily low temperatures particularly at the 35' buffer site. Calculated differences in average and maximum temperature between sensors inside and outside of the buffer suggests that hypothesis 3 did not hold true. Though a trend (numerical increase in temperature difference inside/outside buffer as width increased up to 35' buffer) existed, that did not hold true for the 180' buffer. Additionally, analysis found no statistical difference ($p = 0.52$) was discovered when these values were compared across buffer widths.

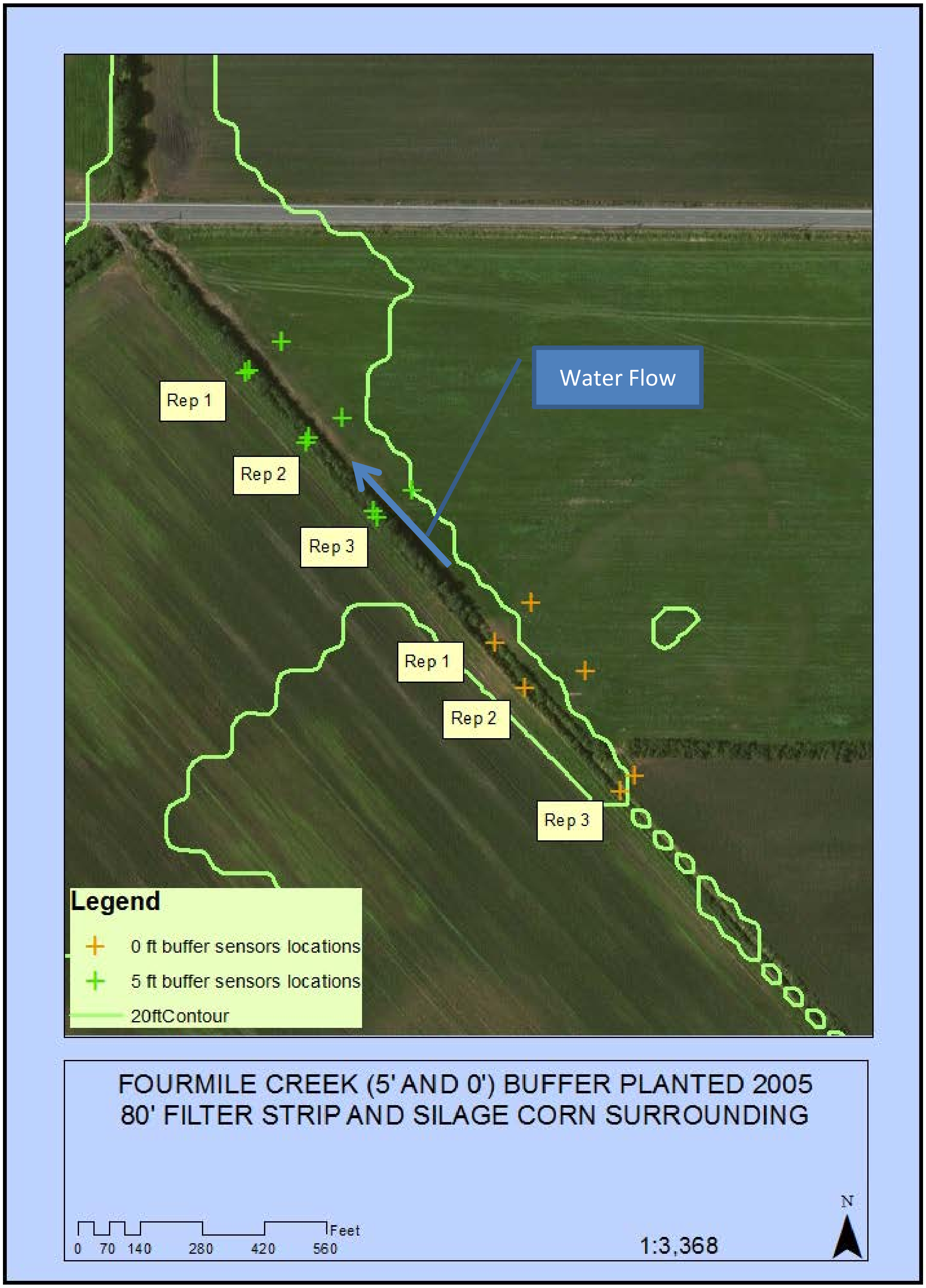
Effective shade values were not significantly different in the smaller (5' & 15') buffers when compared to the larger buffer widths (35' and 180'). The data reported herein suggests that planted buffer width does not affect the amount of shade provided by the vegetation. The amount of shade provided by these plantings in even relatively narrow buffers (~5') were very effective in shading the water surface (and lowering within buffer air temperatures), suggesting that these types of narrow buffers may be as effective in minimizing maximum summer water temperatures as wider buffers. Further work is needed to determine if this relationship does in fact exist and the extent to which it is influenced by other factors.

References

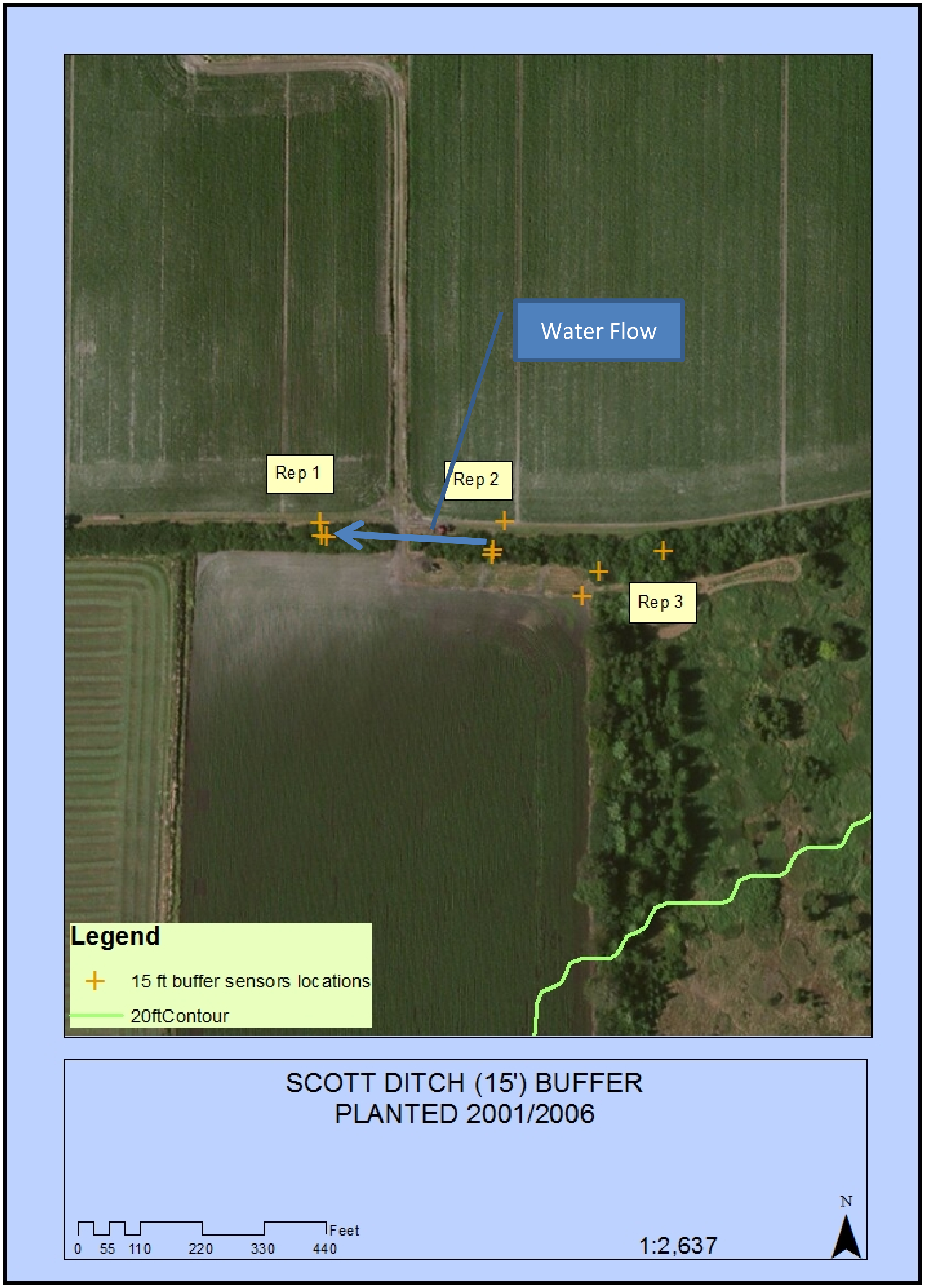
Stohr, A. 2008. Standard Operating Procedures for the computer analysis of hemispherical digital images collected as part of a temperature Total Maximum Daily Load (TMDL) or Forests and Fish Unit technical study. Washington Department of Ecology Enviuronmental Assesment Program. EAP No. EAP046

Appendices

Appendix 1. Location of temperature sensors on Fourmile Creek where 5' and 0' buffers were located.

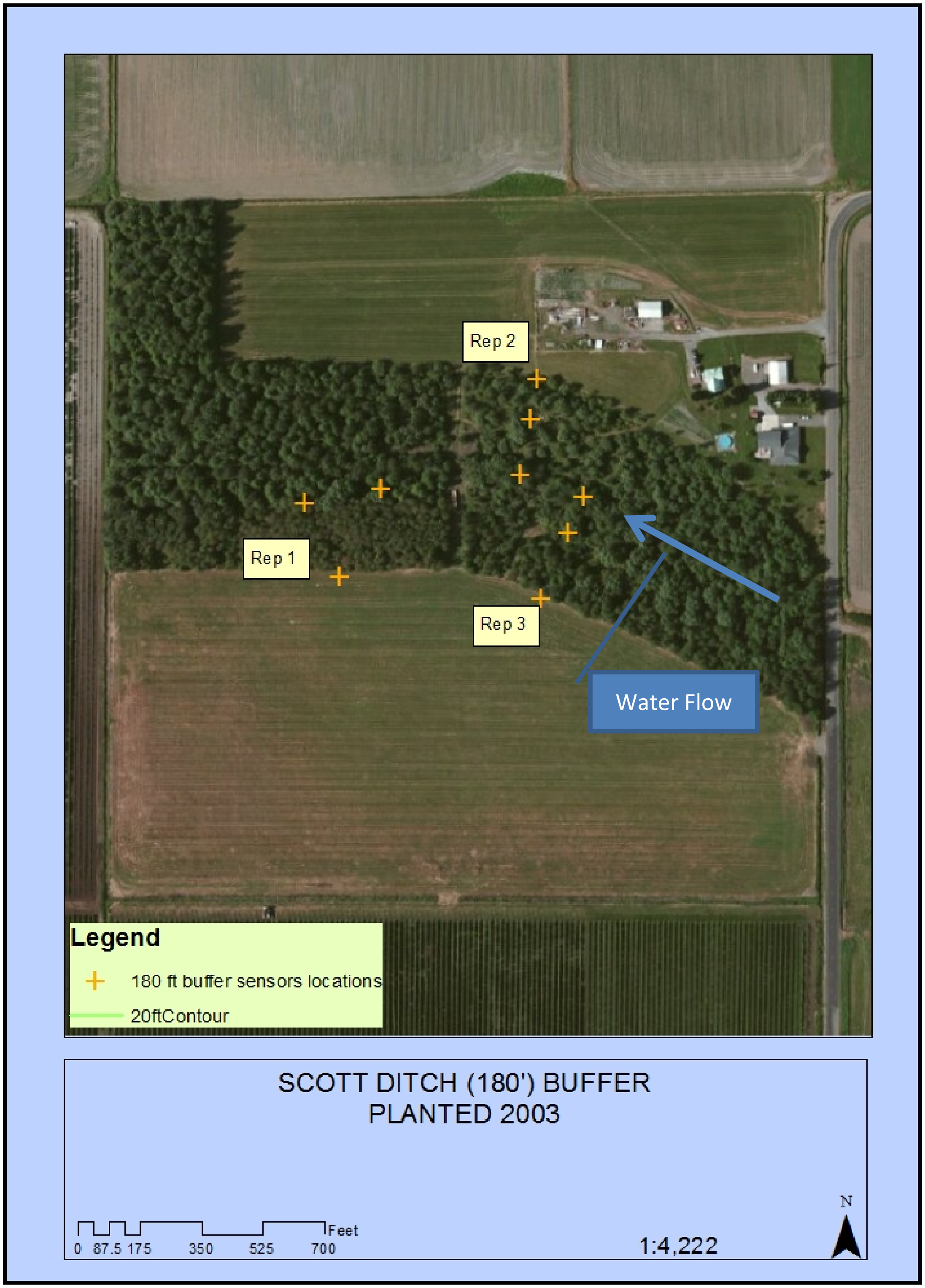


Appendix 2. Location of temperature sensors on Scott Ditch where 15'buffer was located.

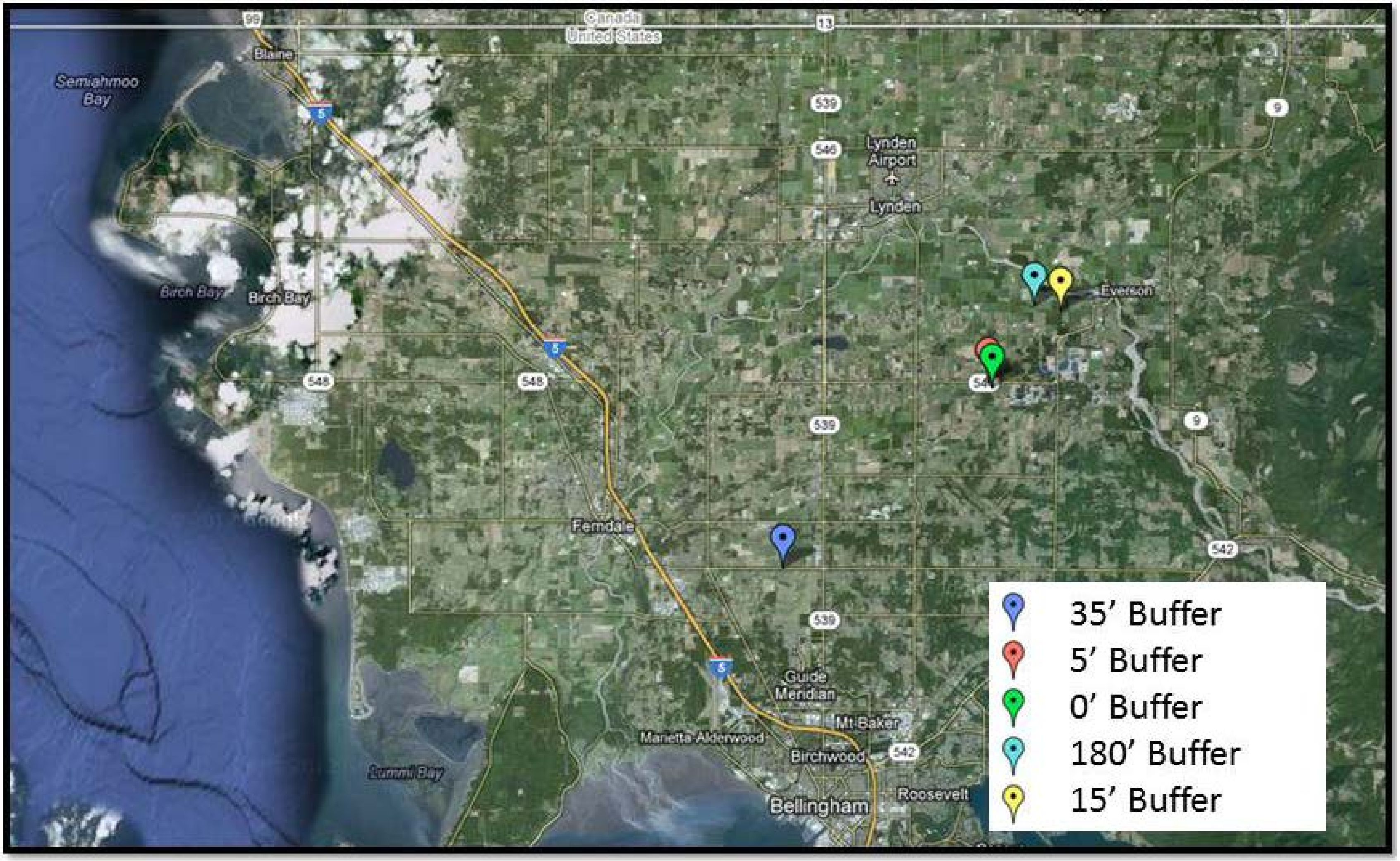


Appendix 3. Location of temperature sensors at North Bellingham Golf Course where 35'buffer was located.

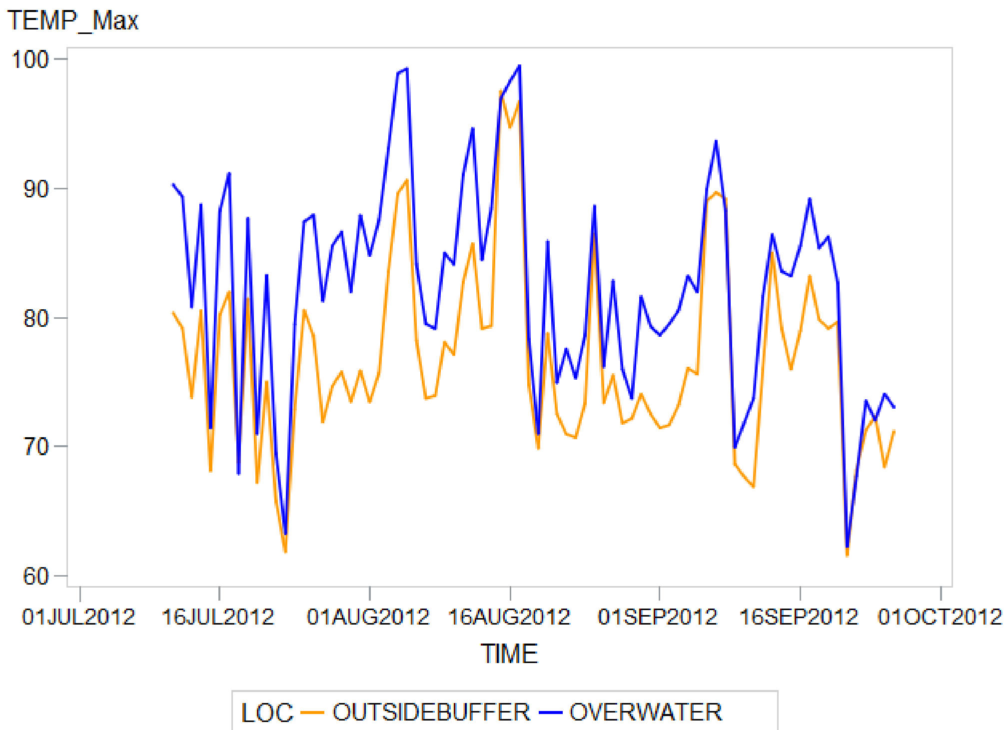
Appendix 4. Location of temperature sensors on Scott Ditch where 180'buffer was located.



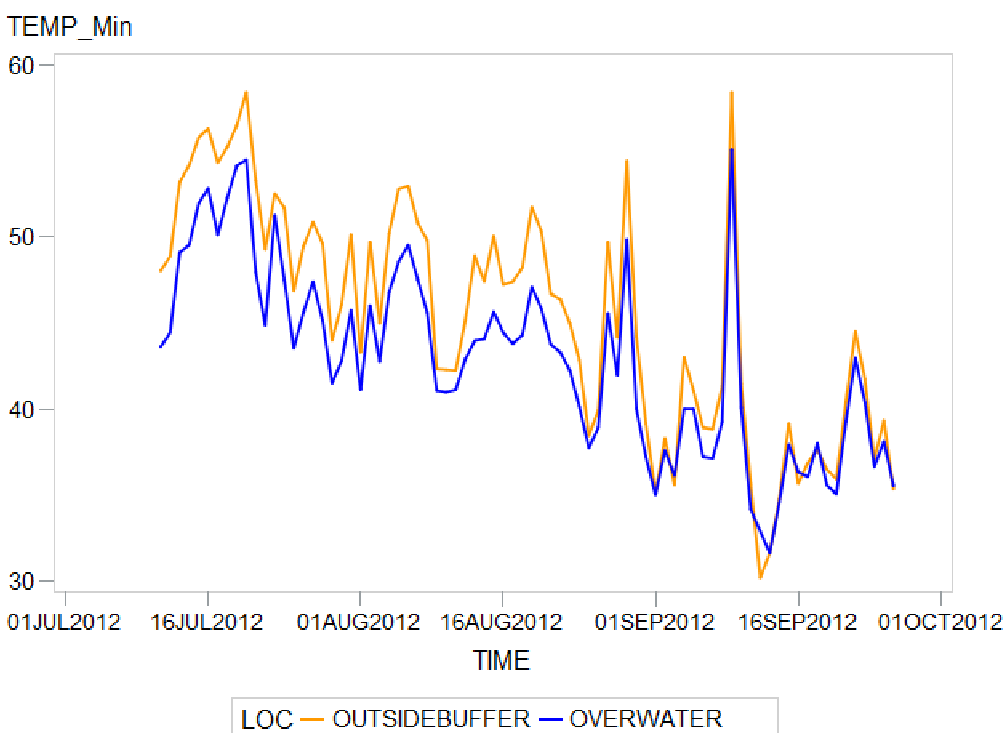
Appendix 5. Location of Agriculture Waterway Buffer Sites within Whatcom County, Washington, 2012.



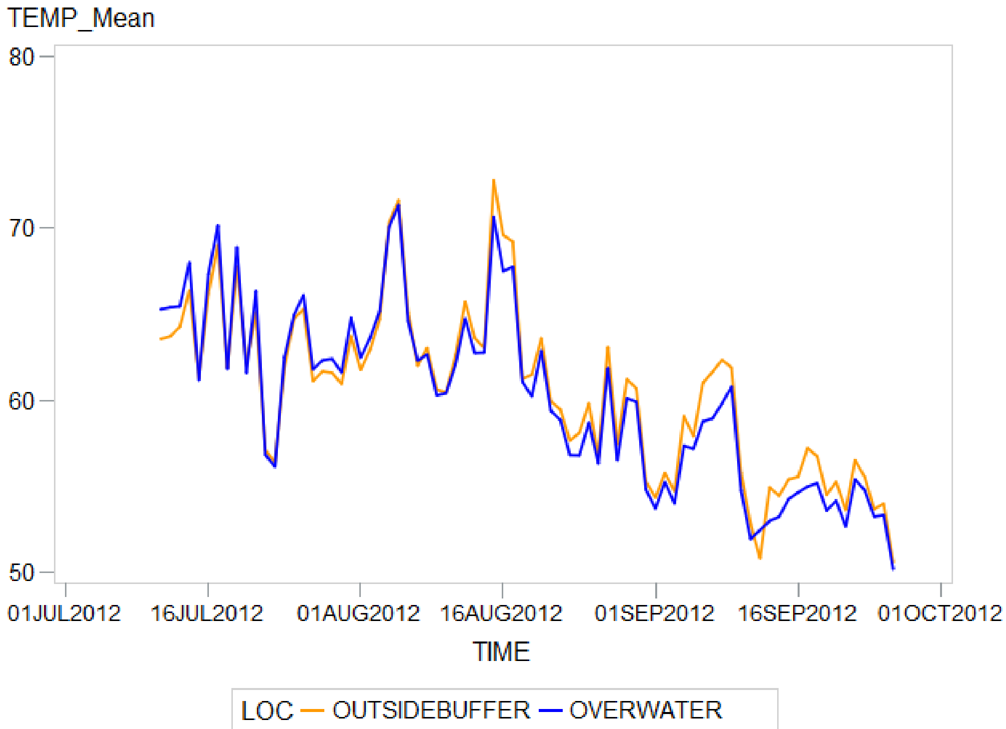
Appendix 6. Average Daily Maximum Temperature in 0' Buffer (Fourmile Creek) by Sensor Location, 2012.



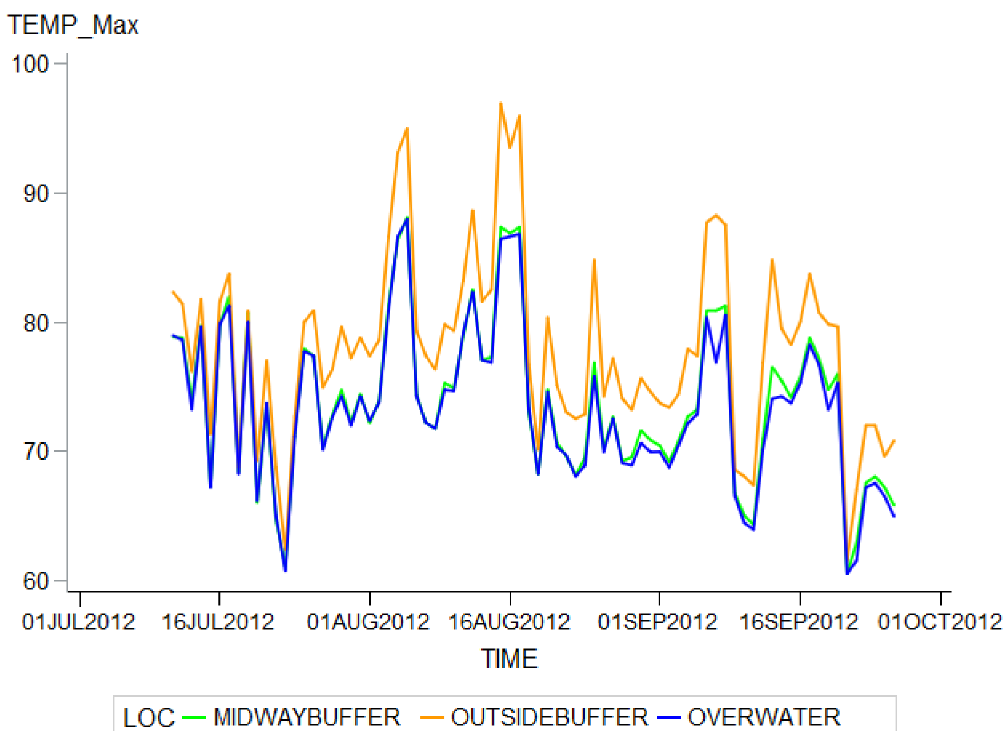
Appendix 7. Average Daily Minimum Temperature in 0' Buffer (Fourmile Creek) by Sensor Location, 2012.



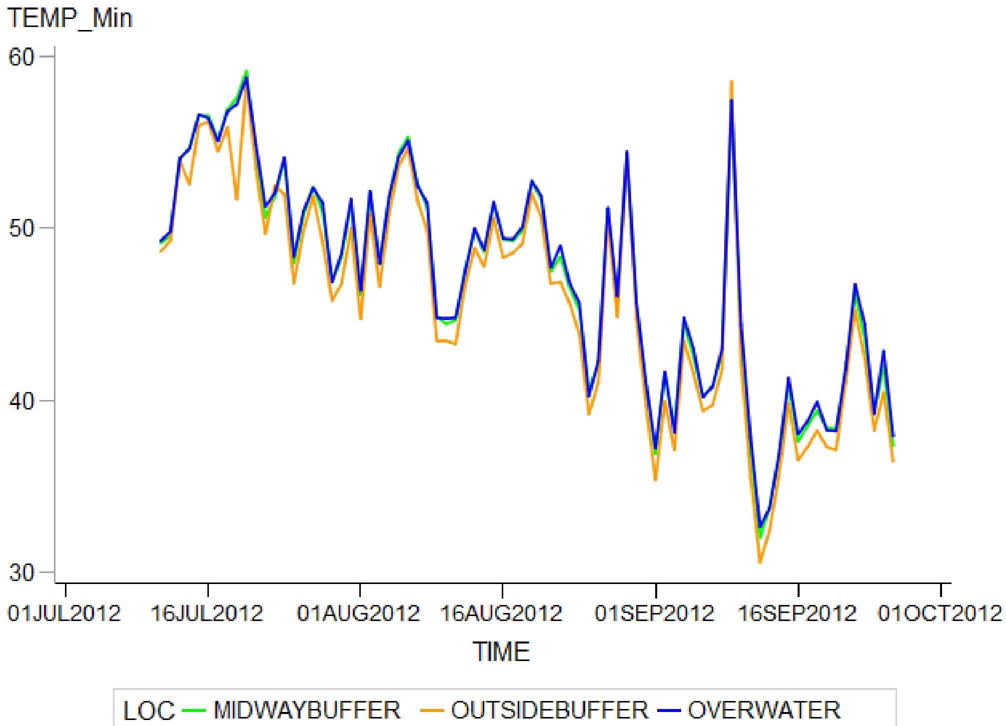
Appendix 8. Average Daily Mean Temperature in 0' Buffer (Fourmile Creek) by Sensor Location, 2012.



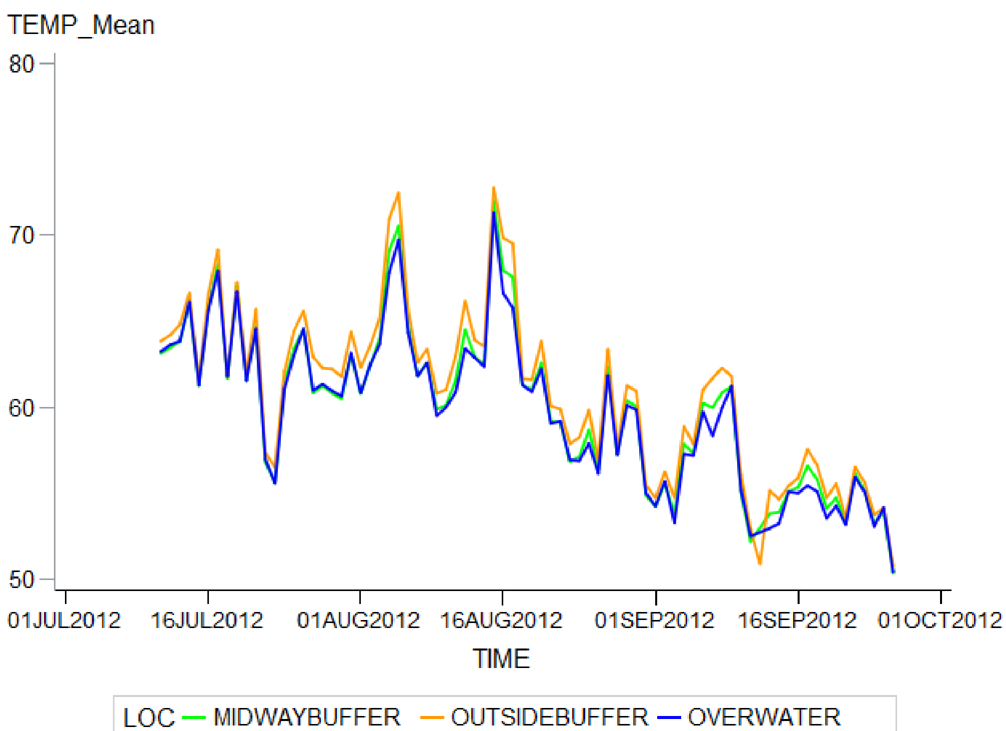
Appendix 9. Average Daily Maximum Temperature in 5' Buffer (Fourmile Creek) by Sensor Location, 2012.



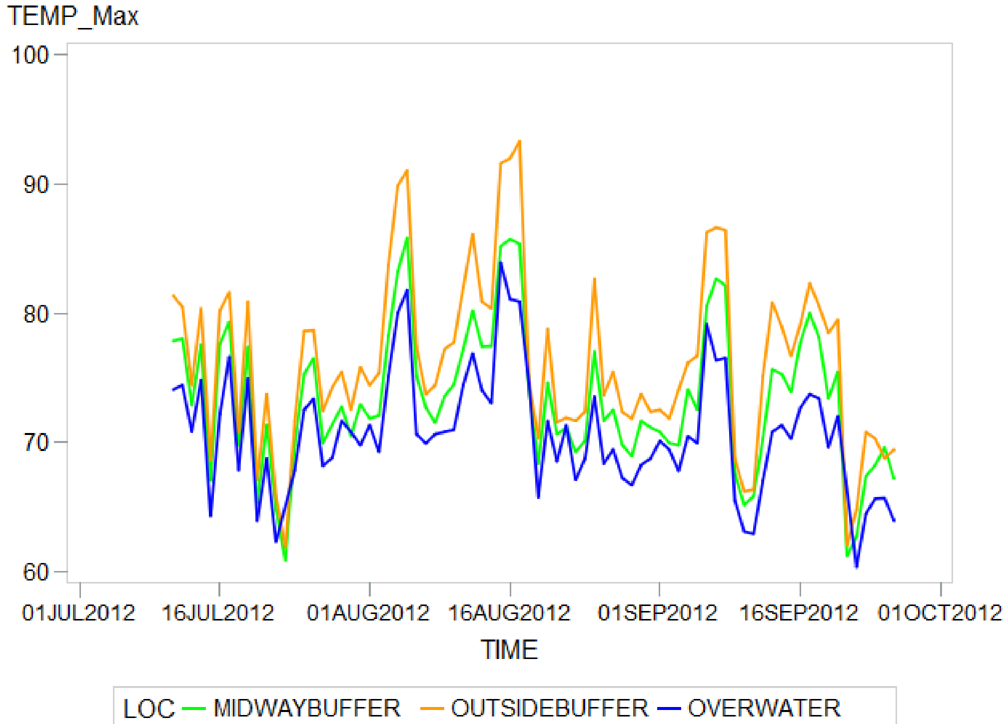
Appendix 10. Average Daily Minimum Temperature in 5' Buffer (Fourmile Creek) by Sensor Location, 2012.



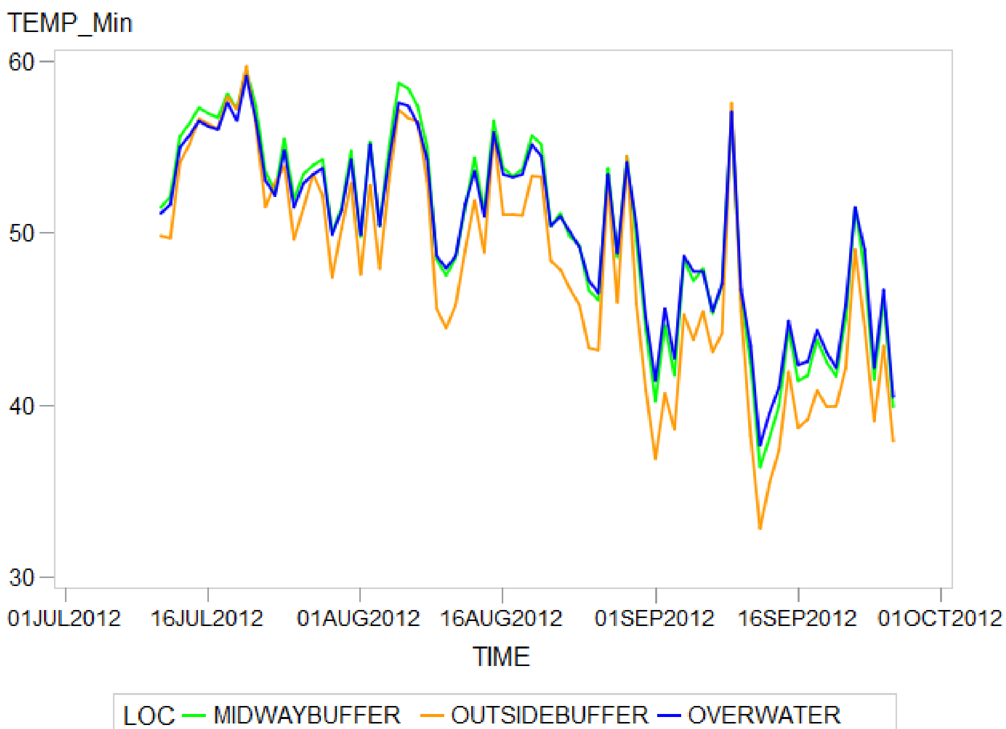
Appendix 11. Average Daily Mean Temperature in 5' Buffer (Fourmile Creek) by Sensor Location, 2012.



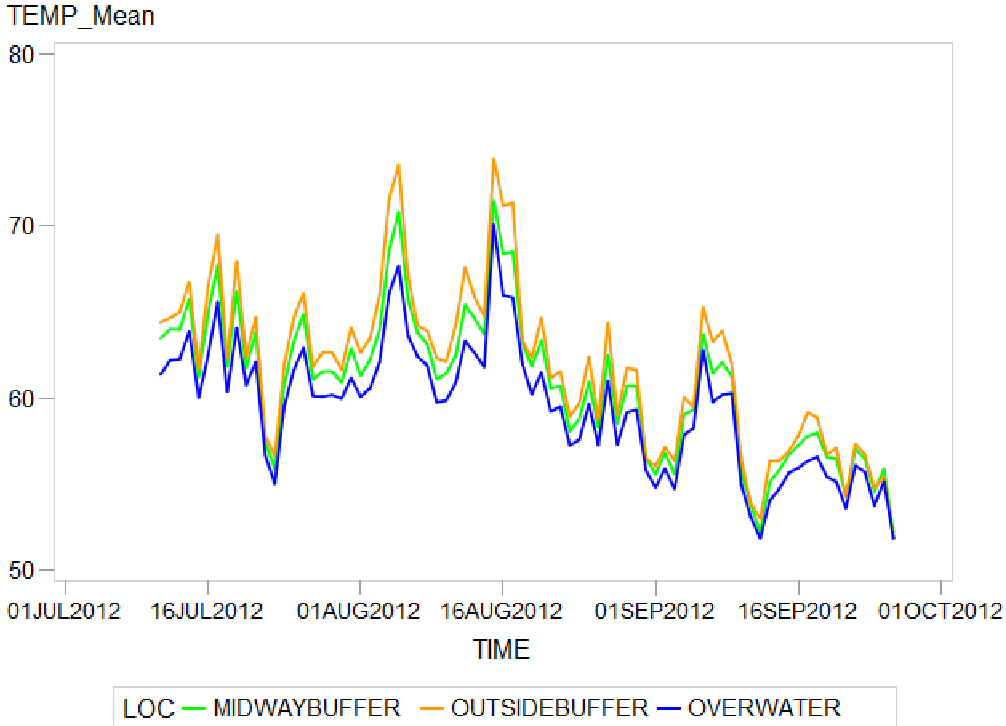
Appendix 12. Average Daily Maximum Temperature in 15' Buffer (Scott Ditch) by Sensor Location, 2012.



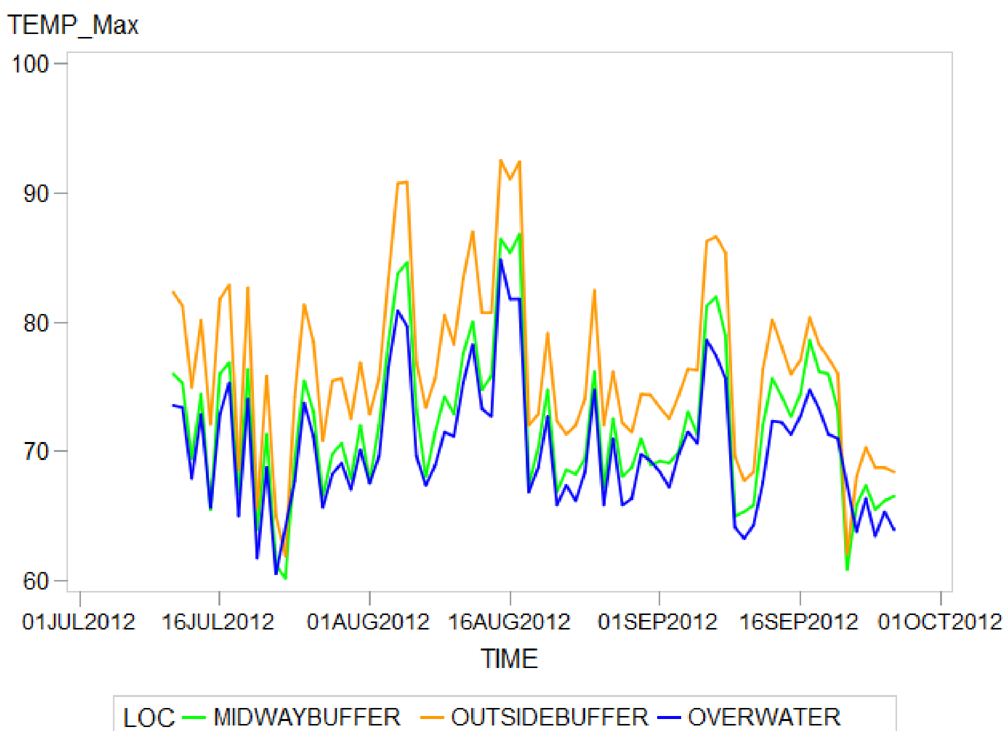
Appendix 13. Average Daily Minimum Temperature in 15' Buffer (Scott Ditch) by Sensor Location, 2012.



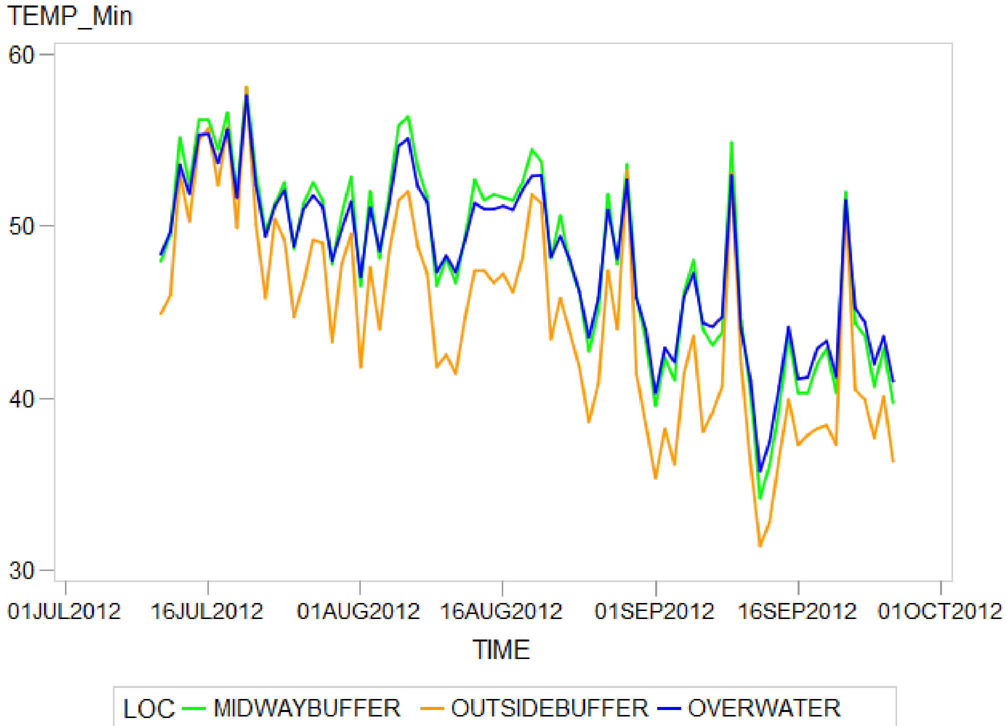
Appendix 14. Average Daily Mean Temperature in 15' Buffer (Scott Ditch) by Sensor Location, 2012.



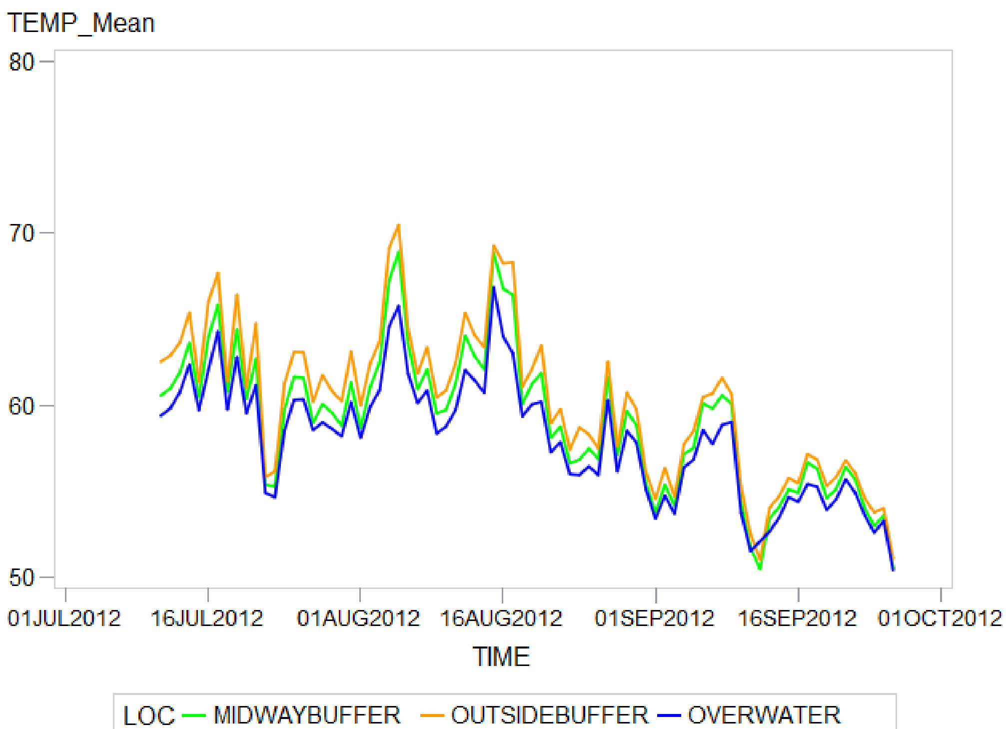
Appendix 15. Average Daily Maximum Temperature in 35' Buffer (North Bellingham Golf Course) by Sensor Location, 2012.



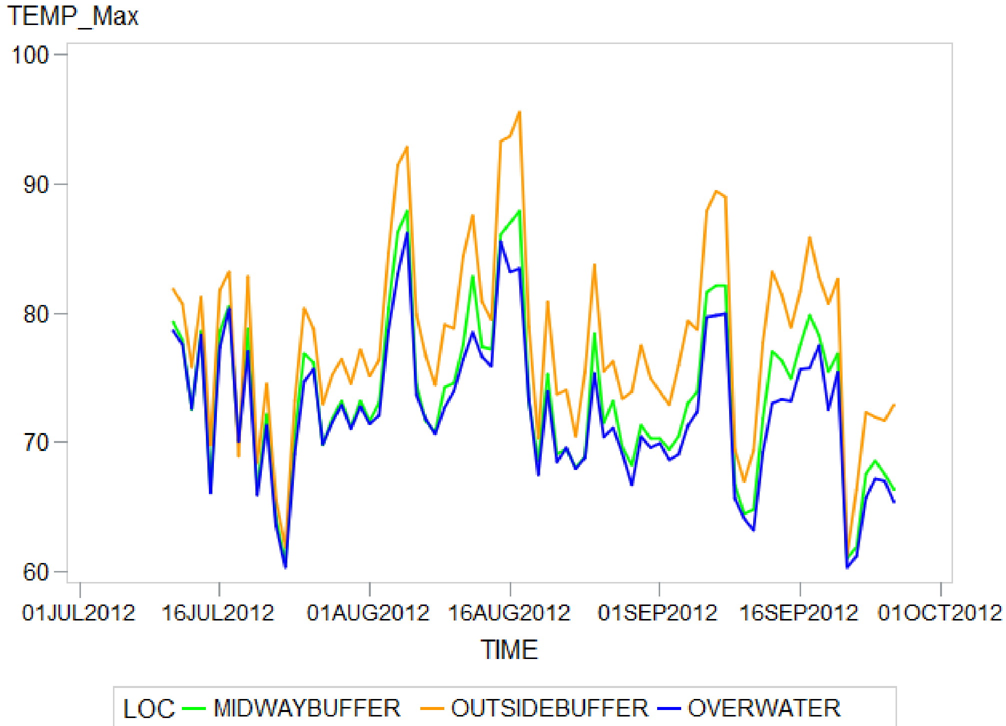
Appendix 16. Average Daily Minimum Temperature in 35' Buffer (North Bellingham Golf Course) by Sensor Location, 2012.



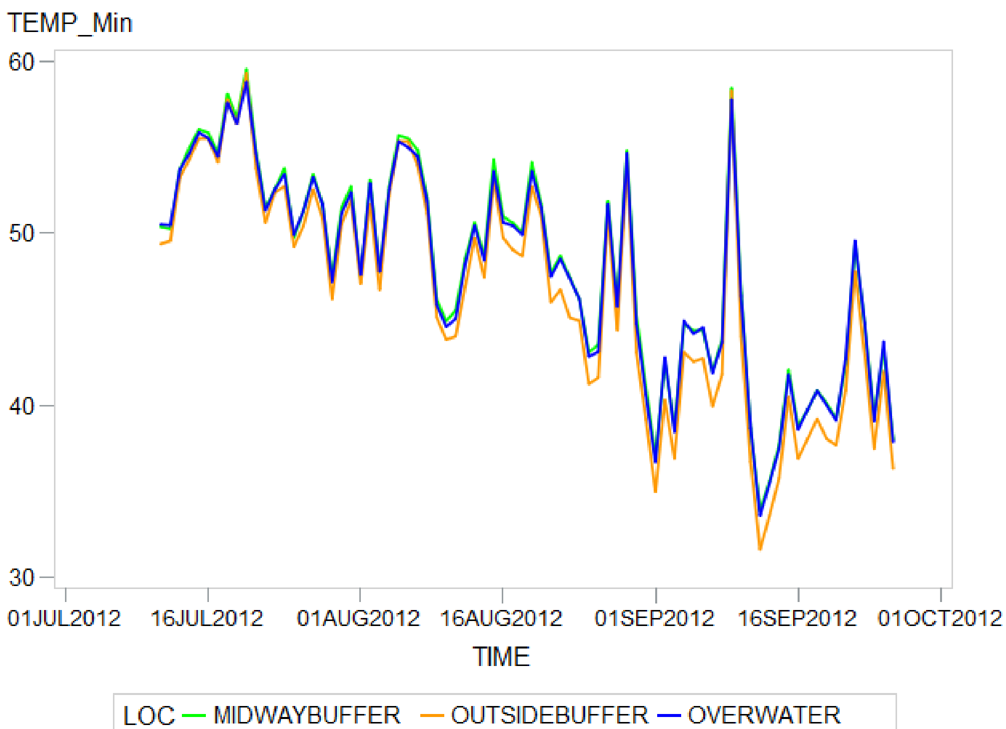
Appendix 17. Average Daily Mean Temperature in 35' Buffer (North Bellingham Golf Course) by Sensor Location, 2012.



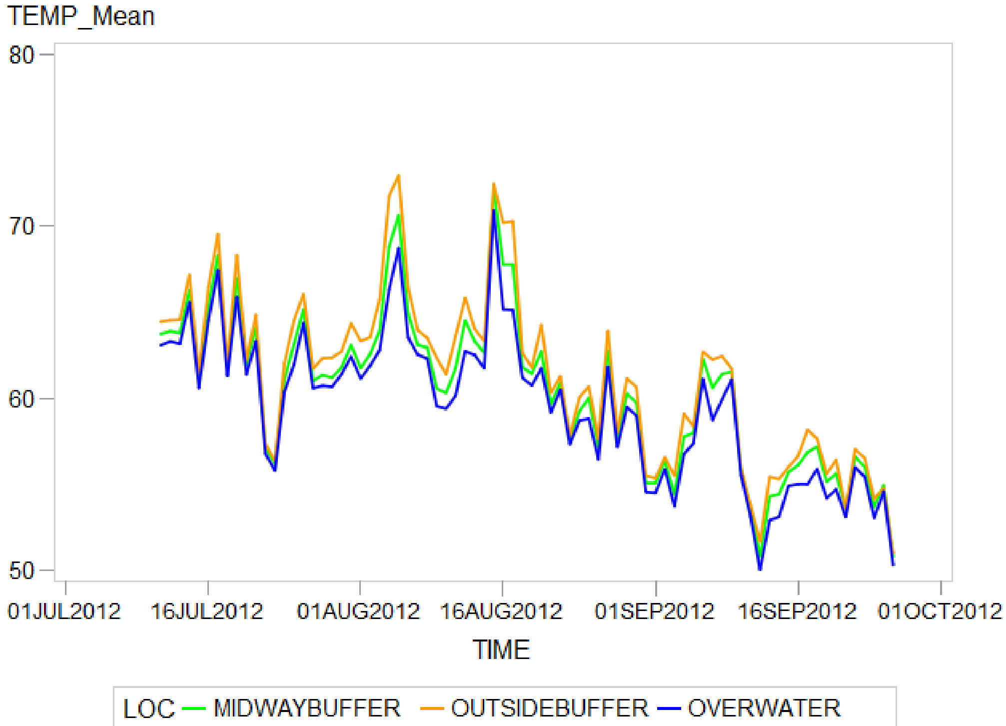
Appendix 18. Average Daily Maximum Temperature in 180' Buffer (Scott Ditch) by Sensor Location, 2012.



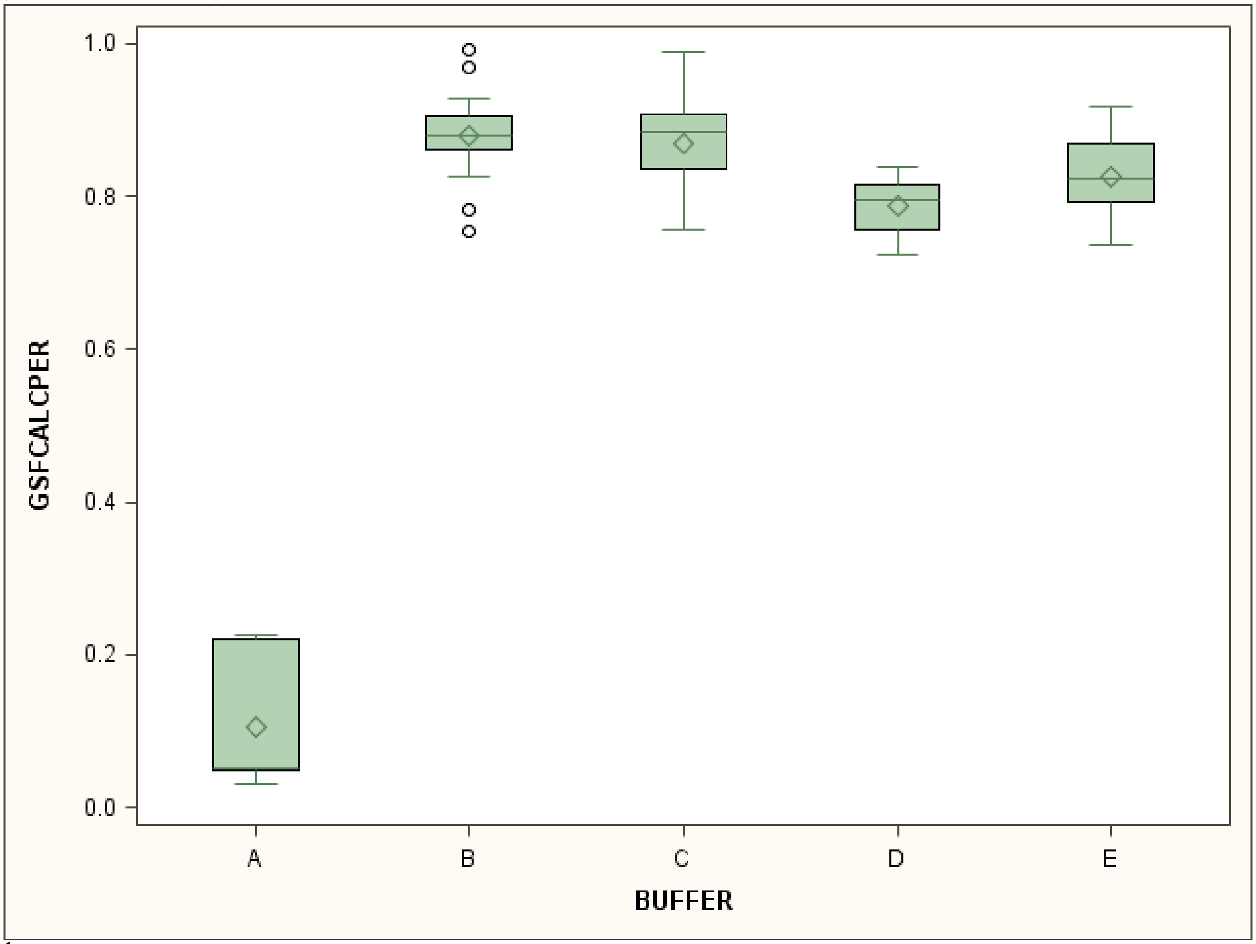
Appendix 19. Average Daily Minimum Temperature in 180' Buffer (Scott Ditch) by Sensor Location, 2012.



Appendix 20. Average Daily Mean Temperature in 180' Buffer (Scott Ditch) by Sensor Location, 2012.



Appendix 21. Calculated effective shade (%) of different agricultural waterway buffers[1] from photos taken September 2012.



[1]A = No planted buffer, B = 5' planted buffer, C = 15' planted buffer, D = 35' planted buffer, E = 180' planted buffer.

Appendix 22. Sample hemispherical Photo from 35' buffer, calculated effective shade of 76%.

Appendix 23. Sample hemispherical Photo from 180' buffer, calculated effective shade of 79%.

Appendix 24. Sample hemispherical Photo from 15’ buffer, calculated effective shade of 89%.

Appendix 25. Sample hemispherical Photo from 5’ buffer, calculated effective shade of 90%.

Appendix 26. Sample hemispherical Photo from 0' buffer, calculated effective shade of 3%.

Appendix 27. Photographs of sensor and sensor housing.