Final Report for
BMPs for Cranberry Farms Grant No. G0200278

March 29, 2005

In partial fulfillment of Clean Water Act Section 319 Nonpoint Source Fund

Kim Patten
Washington State University Long Beach Research and Extension Unit

Project Organization:

Project Director: Kim Patten

Research Technicians: Nancy Rosenbower (2002-2003) and Cynthia Knudsen (2004-2005)

GIS Consultant: Mark Scott

Project partnerships:

Laboratory: Shoalwater Indian Tribe Environment Lab. Gary Burns, Director; Ron Boquest, Laboratory Director, (2002); Richard Craven, Laboratory Director (2003-2004).

Grant Manager: Cindy James, Washington State Department of Ecology

Other partnerships:
Natural Resources Conservation Service (Karl Boyd and Mike Kellogg)
Pacific Conservation Service (Mike Johnson)
Ocean Spray Cranberries Inc.
Washington Cranberry Alliance
Grayland Cranberry Growers Association

SHOULD ALL BE PAST TENSE

Introduction

Cranberries, a native North American crop, are grown over approximately 1,600 acres of wetland in Washington, mainly in Pacific and Grays Harbor Counties. The Grayland cranberry-growing region is located on the central Washington coast where it straddles both the Lower Chehalis and Willapa Water Resource Inventory Areas. Temperatures are moderate, rainfall is high, and native soils are moist peat and conductive to cranberry cultivation. As the local industry developed, some local waterways were channeled into a system of canals and waterways that come to be termed the “Grayland Ditch.” The “Grayland Ditch” has been divided into 37 micro- watersheds that drain water from streams in surrounding forested hillsides to the east, surface flows from residential properties and cranberry bogs, and perhaps some shallow groundwater that originates in the bogs. (Davis, Serdar et al. 1997). Water is channeled into either Grays Harbor County Drainage Ditch No.1 (GHCDD-1) that discharges into the South Bay of Grays Harbor to the north of the Ditch, or the Pacific County Drainage Ditch No. 1 (PCDD-1) that drains into Willapa Bay to the South.

Cranberries are subjected to the depredations of numerous pests. Basic control strategies for these pests have been the generous use of traditional first and second generation pesticides and have evolved little in the past 20 to 40 years. The leading insecticides in cranberries are four organophosphates (Ops), (diazinon, azinphosmethyl and acephate). Traditional cranberry farming in the region features pesticide applications by chemigation through a sprinkler system. Conventionally, water for chemigation and regular irrigation practices is pumped from “holding” or “sump” ponds at each farm. Depending on bog topography and sprinkler system design, run-off water from sprinkler applications can more or less be “held on farm” or returned to sumps via narrow width and usually low-flow irrigation ditches that surround each bog. Unrestrained water is channeled from farm to farm within each micro-watershed into the main ditch channel.

In 1994 and 1995, water from GHCDD-1 was sampled as part of the Department of Ecology’s Washington State Pesticide Monitoring Program. High levels of organophosphate pesticides were detected (Davis, Serdar et al. 1997; Davis 1998a; Davis 1998b). In 1996, water was sampled near the terminus of both drainage ditches (Fig 2.) and analyzed for the organophosphate pesticides diazinon, azinphosmethyl and chlorpyrifos on several occasions, and for 150 target analyses of other chemical classes during a single sample event (Davis, Serdar et al. 1997). Water quality criteria for diazinon and azinphosmethyl were frequently exceeded at both sites and for chlorpyrifos at PCDD-1 only. Carbamate pesticides were apparently analyzed for and detected at high levels twice; carbaryl levels were unacceptably high both times. Associated laboratory bioassays showed concentrations for some pesticides to be above LC50 levels of *Daphnia pulex* (Wood 1997). The 1996 assessment concluded that “more information is needed to identify the routes that transport pesticides into the drainage ditches so appropriate prevention measures can be developed.”

The Cranberry Institute responded in 1996 by sponsoring the research and development of best management practices (BMPs) to reduce pesticide contamination of adjacent irrigation ditches and surface waters (Frantz, W.T. et al. 1996). Particular BMPs were designed to reduce the impact of traditional chemigation practices by a) replacing whole-circle sprinkler heads on sprinklers adjacent to irrigation ditches with part-circle heads; b) equipping sprinkler heads with different types of spray guards; c) implementing micro-irrigation technologies and d) covering irrigation ditches and lining (e.g., “cribbing”) them with wooden planks. Simultaneously, a multi-year program to develop and implement a “reduced-risk” pest management program based on biorational compounds, enhanced monitoring tactics and alternative action thresholds was initiated (Booth, Maupin et al. 2000).

A further response by the Pacific Conservation District was to develop and administer a program to provide cranberry farmers in selected micro-watersheds with technical assistance and cost-share opportunities to implement BMPs (Clean Water Act Section 319 Nonpoint Source Fund Grant No. FP 2037). It also documented the effectiveness of the implemented BMPs to lower pesticide levels in the ditches immediately adjacent to compliant cranberry farms.

A neighboring Indian tribe, the Shoalwater Bay Indian Tribe, had expressed its concern regarding surface water contamination issues. A 1997 EPA Report (1997)EPA 910/R-96-013 recommended that the United States agencies work closely with cranberry farmers to reduce pesticide risk. In 1998 these drainage ditches were 303(d) listed by Washington State Department of Ecology for azinphosmethyl, carbaryl, chlorpyrifos, and diazinon. Despite a concerted effort from 1995 to 2000 to implement BMPs and other solutions, a recent study indicates no reduction in overall pesticide levels (Anderson and Davis 2000).

Because there was a lack of perceived progress by the cranberry industry to reduce pesticides in surface waters, additional funding was sought to develop alternative techniques and methods for mitigation. This project was submitted for funding to Clean Water Act Section 319 Nonpoint Source Fund in 2001. The project was funded and implementation began in 2002.

Project Objectives and Goals:

The overall objective in *BMPs for Cranberry Farms* Grant No. G0200278 was to assess the ability of BMPs to maintain pesticide residues below water quality criteria necessary to the protection of aquatic life, and to reduce the amount of pesticide entering the water in the Grayland cranberry bogs. There were five individual project objectives.

1. Assess the problem at the micro-watershed level using GIS to develop layers of information on current BMP implementation, stream/ditch flows (rate, volume and direction, ownership, general non-point pollution risk/status, potential to implement different BMPs and to monitor progress in reducing surface water contamination over the course of this project).

2. Research and develop new cost-effective BMPs (temporary ditch covers, new application technology, reduced pesticide rates, phyto-remediation).

3. Implement and monitor BMPs that have been previously developed and shown to be effective on a small scale but are currently not being used at the farm level, (sub-surface drainage, gear-driven sprinkler heads, sprinkler guards, coordinated rerouting of surface water and off-site spray fields.

4. Conduct educational and demonstration programs that focus on the cause of the problem and its solutions.

5. Use a comprehensive area-wide adaptive management approach based on input from monitoring, grower surveys and workshops, partnership feedback, community consensus-building discussions, economic viability, and BMP implementation.

The measurable outcomes and goals of this project were to 1) reduce surface water contamination by >50% to 75% and 2) increase grower participation in IPM and BMPs by >100%.

Methods and Procedures:

General Study Sites and Study Design

This study was conducted on cranberry farms in Grayland Washington in 2002 to 2005. GIS watershed mapping was done across the entire Grayland cranberry farming area. Within that area, farms were selected to implement BMPs and monitor efficacy throughout the course of the project. Exact study sites were determined by grower cooperation and site features. Detailed information is provided elsewhere.

Study Design by Objective

Objective 1: Assess the problem at the micro-watershed level using GIS to develop layers of information on current BMP implementation, stream/ditch flows (rate, volume and direction) ownership, general non-point pollution risk/status, potential to implement different BMPs and to monitor progress in reducing surface water contamination over the course of this project.

Introduction to creating a cranberry GIS: The Grayland Cranberry GIS has evolved from 2002 to 2005 into a robust source of geographic information. This collection of geographic themes has served as a spatial database, tracking the progression of improvements to cranberry infrastructure and as an inherent spatial component to collected data between 2002 and 2004. These data have been made with consideration for future use as a place to store the kind of anticipated spatial information pertinent to the cranberry industry for this locale. Special care has been taken to assure these spatial data are among the finest available. The collection of thematic data includes both natural and human-made features such as cranberry bogs, surface hydrography as ditches and streams, land ownership, test sample locations and elevation. Together they serve as a source of information that can be used to build GIS applications.

To give additional distinction to these data, a selection of the appropriate themes has been compiled to combine temporal information collected in 2002 and 2003 and 2004 into a single composite data set. One example is the bog attribute table. It has been enhanced by turning it into a static rollback (temporal modeled) database, whereby the theme can be measured in three different time periods. This data model is useful when determining, among other things, year to year changes in the status of cranberry bogs. It is useful to know that there is an apparent sequence to the development to the infrastructure of ditches.

An approach to modeling surface hydrography: The stream layer used in this research has been linear referenced, a procedure more traditionally known as 'routing' using the ESRI ARCINFO dynamic segmentation model. These kinds of readily measurable data are useful to determine the measured position of any sample taken along a major surface water feature. Although the standard arc attributes are useful to determine the length of a single feature, there is seemingly always something lacking. Routing provides greater connectivity amongst many surface water features by taking advantage of the hydrographic systems' full extent instead of a single piece at a time. With a completely routed hydrographic network, hydrologic connectivity of linear information is more generously preserved, more accurate, and allows greater amounts of more sensible information to be available to the user. Simple questions that these data should answer are:

1) Where was the sample taken?
2) Where did the water came from in the place where the water was sampled?
3) Where will the water flow relative to any given sample location?

Once the surface water data were made into completed routes, came the task of combining these linear surface water data with other spatial data, such as 5' cell size gridded elevations revealing stream gradient and flow direction. Additional attributes were also provided by direct field measurement. These data normally exist as point data; however the routed format permits these features to be measured as line networks. Route distances were used to determine the location of water test sites throughout the study area. Routing was used to expand the sample site from a single point to a greater potential as a linear feature.

The stream linework, as a linear referenced data model, add inherent functionality that is practical for this application of spatial data. Combining these linear surface water data with other spatial data, such as 5' cell size gridded elevation, reveals stream gradient and flow direction. Additional attributes were also provided by direct field measurement. These data normally exist as point data; however routing permits these features to be modeled as lines. Route distances were used to determine the location of water test sites throughout the study area. Routing was used to expand the sample site.

The major drainage was split into north and south components, following the natural stream flow divide that exists 2000 feet south of the Pacific/Grays Harbor County line. Each stream had been given a pre-assigned identification number from the Ocean Spray Grower Cooperative. This numeric identification was preserved in the linear referencing model, with one exception. The mainstream channel was given an ID equal to 999 for the section flowing south and 998 for the section flowing north. Tributary streams, which extend from various micro-watersheds to the main channel, have for the most part, numeric identification corresponding to Ocean Spray Grower Bed ID number.

One emphasis of collecting and creating spatial data for this project involved the unit of aggregation, the micro-watershed. The grower cooperative established 27 micro-watersheds based in part on proximity and in part on physiographic considerations. In the watershed attribute table, a user will find information based on typical spatial / overlay relationships between themes: elevation range, output stream channel, and summary cranberry surface area, including the summarized measurements of ditches.

The most detailed surface hydrographic layer among these themes exists as the ditch layer. These features exist as the perimeters of individual cranberry bogs. Ditches are immediately adjacent to a majority of existing cranberry bogs and are subsequently most important to determining the status of cranberry bogs. As a result of cranberry bog infrastructure and management practices, cranberry ditches have been identified as a feature that can be readily modified to improve the regional water quality, based on other management criteria. To follow the progression of a ditch, as it turns out, all ditches start out as open, meaning that they are essentially carved from soil. One of the first improvements to a ditch involves the installation of cribbing, or a pressure-treated (inch and a half thick) wood partition that separates water from soil along the inside and outside margin of the ditch. The next improvement involves covering the cribbing with a thin plywood covering. After a ditch is covered it is considered to be in its final state.

One focus of the development of GIS data has been placed on the type of ditch. It is important to mention that the ditch attribute table contains information about the status of ditches for 2002, 2003 and 2004. Similar to the attribute table of the bogs, the ditch also contains temporal elements, for several reasons. Potential error involved with spatial overlay and joining attributes are reduced because these data exist as a single layer instead of three. There is greater efficiency maintaining these data because there is only one spatial database.   These data, among others, have undergone several updates. In addition to improving the horizontal accuracy, new attributes are placed inside the table to help track changes made to the database.

Initial data collection: In 2002, I collected spatial data in a variety of formats from a variety of sources. Among these include both paper maps and digital data. One piece of information in particular was obtained from the cranberry cooperative, which supplied the known distribution of surface hydrography. These lines appeared only as green highlighted markings on small-scale assemblage of paper tax assessor section maps. The paper maps were copied and the information content transferred into a digital format. An attribute table was developed to hold the existing surface water identification numbers.

An early digital version of a cranberry bog coverage was obtained from the local conservation districts. This layer in its original form was virtually useless for this project because these data were in an unknown projection, generalized, the attributes were incomplete and horizontal error was variable. The attribute table however contained the unique bog identification number that was preserved when these data were re-constructed as ‘bogs’ from 2002 high-resolution air-photos.

The original tax lot digital data were obtained by the local county governments. After a sequence of processing occurred, these data needed to be re-projected, cleaned and combined to get them into a single piece covering the entire study area. Next, these data were edited to reduce horizontal error, find missing ownership information and create a polygon topology. Since their creation in 2002, tax lot data have been altered significantly by both Pacific and Grays Harbor counties. Recently new tax lot information has been made available which was created with better horizontal control, using both a control grid and use of 2002 high-resolution air-photos.

In 2003, the first highly accurate elevation, or LIDAR data, was obtained from NOAA via the University of Washington's School of Forestry Extension in Forks, Washington. The utility of these LIDAR data to relay detailed elevation information remains unsurpassed. These gridded data were originally prepared for the full 150 sq mile extent of Willapa Bay. Several things happened during the data preparation. First, to reduce the file size to a more manageable level, the elevation grid was re-sampled, making it coarser. Second the vertical datum was set to NGVD 1988, to provide standardization amongst other elevation data. Third, this project required that only a small extent of these LIDAR data was clipped from the larger extent.

Field Map Preparation: In 2002, the development of GIS data for this project was contingent on the creation of simple maps for use in the field. The purpose of field maps was to illustrate existing data while simultaneously creating new data via the map as a base. As field work continued, maps were frequently collected where new data could be obtained. A new, updated map was then produced and returned to the field where the process could start over again. The first maps contained the extent of cranberry bogs, roads and streams. As water sampling and other field activities continued, errors were found in base maps, which were identified and corrected in this reiterative process. Useful data, such as water sample sites, were established. Often hidden features with subtle surface expression were revealed. Known errors appearing in the spatial database were identified and eliminated.

Standardized field maps were created for each of the field seasons, 2002, 2003 and 2004. In each case, the most recent and accurate data was placed on the map. Maps were then printed and copies sent back to the field for use and to be updated. Redundant copies were produced for the sole purpose of marking-up in the field by field personnel. Presently a collection of 10-15 worn and torn field maps illustrate a progression of the development of the spatial data used in this study. Each field map iteration brings with it improvements to these data content, completeness and accuracy.

Sample databases: Between 2002 and 2004 many test samples were taken. Many of these were water samples, some from bogs and some from ditches. Experiments were carried out in various places. Each of these events occurred in a location that has been directly associated with these GIS point data.

Applications: Careful consideration has been made to determine the kind of applications made with these data. Typically the public is familiar with the use of maps, but not with data used to make the map. Also, the users will be farmers, administrators and managers with varying degrees of computer skills. Given these limiting factors, any GIS application must be simple to use. The following questions to the stakeholders where asked and their answers taken into to consideration for the final product.

Which layers will be displayed?
Which layers are used for a specialized application?
Are there layers that require special security consideration?
At what extent should each layer be displayed?

What colors and symbols will be used?
Should different colors and symbols be used at different scales?
Will the main functions of your application be view and query, or will users need to perform more sophisticated tasks?

There were also technical considerations to be made; including:

What type of hardware/network will users have?
Who will support the system?
What functionality must the application include?
Are plug-ins acceptable?
How much processing can the client machines handle?
Does the planned application require significant user interaction with map features?
Will the main functions of your application be view and query, or will users need to perform more sophisticated tasks?

The selected solution to this involved the use of two pieces of software used together to produce a simple user-friendly interface. First these data were prepared in ARCMAP version 9, using the map book to generate displayable and printable PDF files. The second was ImageMapper, an ARCGIS extension that uses the map layout to create HTML formatted web pages. Essentially, any layers appearing on a map display can be made to be queryable by a user. Information can be displayed both electronically and printed on paper. Updates to these map web pages require that they be re-processed in ImageMapper.

The GIS collection contains ESRI formatted, topologic data modeled themes:
POLYGON
BOG – extent of each bog attributed with unique identification and status as a temporal element.
TAX LOT – land ownership for Pacific and Grays Harbor counties.
LINE/ROUTE
DITCH – type of ditch immediately adjacent to a cranberry bog.
ROAD – elevated surface transportation pathways.
STREAM – natural and human-made surface water corridors.
POINT
BMP – best management practice experiment location.
FLOW – stream flow for 2002-2003-2004.
ECOLOGY – known Washington Department of Ecology sample locations.
PH – water attribute sample location.
WATER – miscellaneous.
GRID
ELEVATION – NOAA 2002 LIDAR data re-sampled to 5’ cells
APPLICATIONS
Image Mapper/ARCGIS MAPBOOK ATLAS – 40 page electronic and paper atlas for dissemination of data to non-GIS users.

Objectives 2 & 3:
2) Research and develop new cost-effective BMPs (temporary ditch covers, new application technology, reduced pesticide rates, phyto-remediation).

3) Implement and monitor BMPs that have been previously developed and shown to be effective on a small scale but are currently not being used at the farm level, (sub-surface drainage, gear-driven sprinkle heads, sprinkler guards, coordinated rerouting of surface water and off-site spray fields.

Data Quality Objectives and Analytical Procedures

To meet the primary objective of this project, documentation of agricultural BMPs to reduce pesticides to levels below water criteria, the plan calls for the analysis of the most common and problematic pesticides used in the Grayland region (Table 2). This work was conducted under the procedures detailed in "A Quality Assurance Project Plan for BMPS for Cranberry Farms in partial fulfillment of Clean Water Act Section 319 Nonpoint Source Fund Grant No. G0200278 by Steve Booth and Kim Patten" The analytical technique for all target analytes was performed by Shoalwater Bay Environmental Laboratory, which is fully accredited by Washington State Department of Ecology, accreditation number T1823. The method used for detection of Carbamate compounds was method 8318 EPA. Semi-volatile organics were detected by method 8270C EPA. Detection limits at the Shoalwater Bay Environmental Laboratory are below detected quantification limits for the protection of aquatic life, and water quality criteria for the protection of freshwater aquatic life as used in previous studies (Davis, Serdar et al. 1997) for each pesticide analyte.

Table 1. Proposed and previous quantification limits using analytical method EPA 8318 and 8270C, and water quality criteria for the protection of freshwater aquatic life.

	Quantification Limit (Φg/L, ppb)		Criteria (Φg/L, ppb)
Analyte	Proposed	Previous	Chronic
Diazinon	0.04	0.06	[1]0.04
Phosmet	0.10	0.08	NA
Chlorpyrifos	0.04	0.055	[2]0.04
Azinphosmethyl	0.01	0.12	[3]0.01

[1] Mencken and Cox 1994, California Department of Fish and Game.
[2] Washington State Water Quality Standards, WAC 173-201A.
[3] USEPA 1986 Quality Criteria for Water (Gold Book).

The time of each sample taken was recorded to verify the sampling schedule. Blind field samples, equipment blanks, and spike matrix samples were taken to verify laboratory testing was conducted accurately and to determine if there were errors in the sampling procedures and to verify lab accuracy. Site characteristics for each sample event were characterized by a digital photograph. The location of each site in terms of latitude and longitude was recorded for a data layer on our GIS mapping product. Water was sampled using a 100 ml pipette directly from the in-stream flow and from sampling containers that were exclusively dedicated to each site. Contamination from the ditch bottom was prevented from entering the samples by inserting the pipette beneath the water surface from a shallow angle, with the nozzle at the median depth. A different new pipette was used at each sample site and time. Grab samples were taken when there was sufficient depth from the median section of water. Anomalies were recorded along with temperature, weather conditions and any factors that could indicate excessive turbidity or upstream disturbance. Because of the unique situations caused by several BMPs it was occasionally necessary to vary sampling protocol. Those differences were noted for each BMP under the results sections.

Laboratory procedures to measure and assure quality control (QA/QC) for each sample event included a 10% matrix spike analysis and a matrix spike duplicate, a fortified blank and a method blank. Within-sample bias due to the analytical procedure will be expressed in terms of Percent Recovery (%R) of matrix spikes for each compound tested. Additional internal laboratory QA procedures include daily calibration. Field quality assurance procedures include the submission of equipment blanks, field blanks, and blind field duplicates. Each of these procedures was completed during each major spray event. Blind samples were labeled as another randomly chosen sample, and were collected from the other drainage ditch sites. The sampling indicated that there were no pesticide residues introduced through the handling of equipment.

Flow information: Marsh-McBirney Model 2000 Flo-Mate

Objective 4. Conduct educational and demonstration programs that focus on the cause of the problem and its solutions.

Educational and demonstration programs were presented to growers at least three times a year throughout the duration of this project (2002 to 2005). This occurred at the cranberry Winter Workshop in January, Grower Workshop in spring, and Cranberry Field day in the summer. Results of new BMPs were highlighted as well as any sampling updates by Washington State Department of Ecology. Highlights of the results were also presented in the Cranberry Vine Newsletters when warranted. Results were at presented at various local grower advisory boards meeting in Grayland and Long Beach, as well as annual West Coast advisory board meetings. Presentations were also made to other stakeholders (Shoalwater Bay Indian Tribe (SBIT)), Regional Water Quality meetings such as "*Getting It Done: The Role of TMDL Implementation in Watershed Restoration*" and WSU Statewide Water Quality meetings. Personal on-site tours were also provided for stakeholders from SBIT and Washington Department of Ecology.

Objective 5. Use a comprehensive area-wide adaptive management approach based on input from monitoring, grower surveys and workshops, partnership feedback, community consensus-building discussions, economic viability, and BMP implementation.

Stakeholder meetings were held with PCD, NRCS, Ocean Spray, Cranberry Alliance, and Grower Advisory Board members in 2002 and 2003 to gather input for the project. Additional meetings were held with the SBIT for project feedback. Individual grower feedback was also obtained through the use of annual surveys at the winter workshop and by posting of the GIS maps of BMPs at all grower activities and asking for corrections, suggestions and comments. Economic viability of BMPs was assessed using grower surveys to determine the cost:benefit ratio of implementing BMPs.

Results

Objective 1: Assess the problem at the micro-watershed level using GIS to develop layers of information on current BMP implementation, stream/ditch flows (rate, volume and direction), ownership, general non-point pollution risk/status, potential to implement different BMPs and to monitor progress in reducing surface water contamination over the course of this project.

An aerial overview of the study site and the 27 micro-watersheds evaluated in this study are shown in Figure 1. A graph overview by watershed the BMP status and type of BMPs implemented are indicated in Figures 2 and 3. The specific details of these maps are broken down across 40 discrete sites in Grayland in presented in Appendix 1. A numerical summary of BMP mapping results by watershed are provided in Table 1. Based on a linear foot of ditch analysis, several watersheds (4, 6, 16, 17, 23, 26) have been 100% effectively covered by BMPs, and several were >90% treated (8, 11, 12, 13, 14, 15, 20, 27). Watersheds 2, 5, 18, 19, 21, 22, 24 and 25 were between 55% and 89% treated. Only watersheds 8, 18 and 19 were less than 50% treated. Many of the improvements in these watershed BMPs came after 2002. Covered ditches were the preferred method of treatment. Of the completed projected to date, 57%, 3%, and 11% are covered, buried pipe and diked, respectively. These data are particularly important in indicating how many ditches still need to be treated with BMPs, where they are and how much EQIP monies will be needed to finish all the ditches in Grayland. This analysis varies considerably when done by area assessment in 2004 (Table 2). This analysis only considers a bed completely covered with BMPs if all sides of the beds have been treated. This assessment yields 49% of cranberry bed acreage in Grayland areas are or will be 100% subtended by effective (covered or diked) BMPs. 4% of the acreage is abandoned and the remaining 47% remaining beds still need at least one or more of their surrounding ditches to be treated with BMPs. This later method of analysis has some potential for error in that one or more sides of a bed may not have a ditch and therefore would not need a BMP. The breakdown of changes in buried and covered ditches by watershed by year is provided in Table 3. What is important to note in this table is that these differences by year largely reflect the availability of EQIP money for cranberry BMP in each of the different years.

Additional information is provided across the watershed by locations for summer water flow, water quality sampling and ditch discharge sites and ownership (tax lots) (Table 4, Figures 4, 5 and 6). More detailed information on this data can be found by individual beds in the appendix. This flow data is useful in interrupting the results of the BMPs as well the overall water quality monitoring results. Areas with dry summer ditches, for example, are less likely to be a concern than sites that have water flow through them all summer long.

By assessing watershed and beds on an individual basis for BMP coverage, as well as stream flows, historic monitoring data of DOE, several inferences can be made regarding general non-point pollution risk/status. A majority of TMDL violations have occurred at the south end of Grayland. Several of those sites have water running through them during the summer spray season and several of the watersheds in that region (18 and 19) still need considerable more BMP coverage. Thus these watersheds could constitute higher risk area.

NOTE: in figure 1 figure is mispelled..

Fgiure 1. Micro-watershed locations of Grayland cranberry farms.

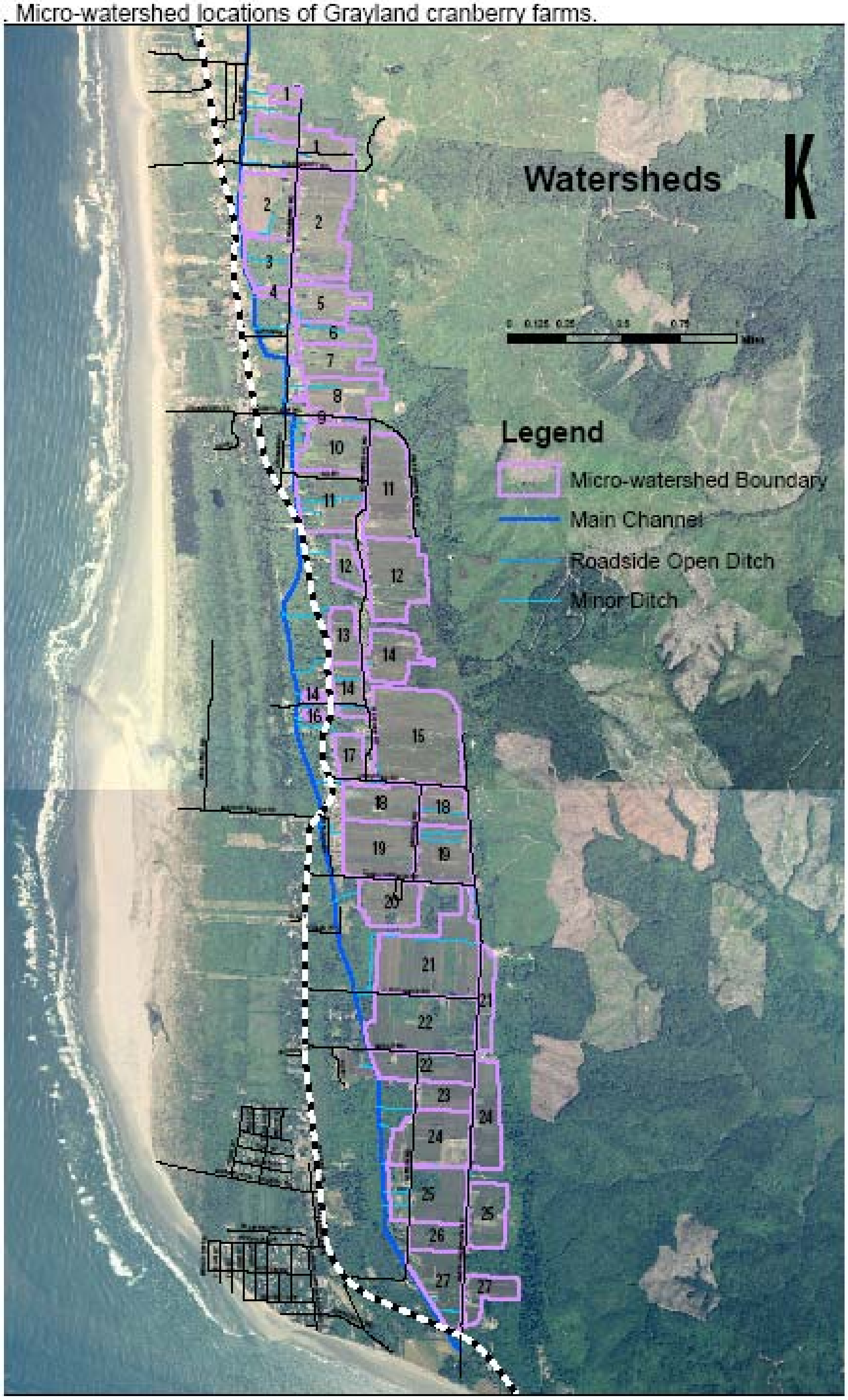
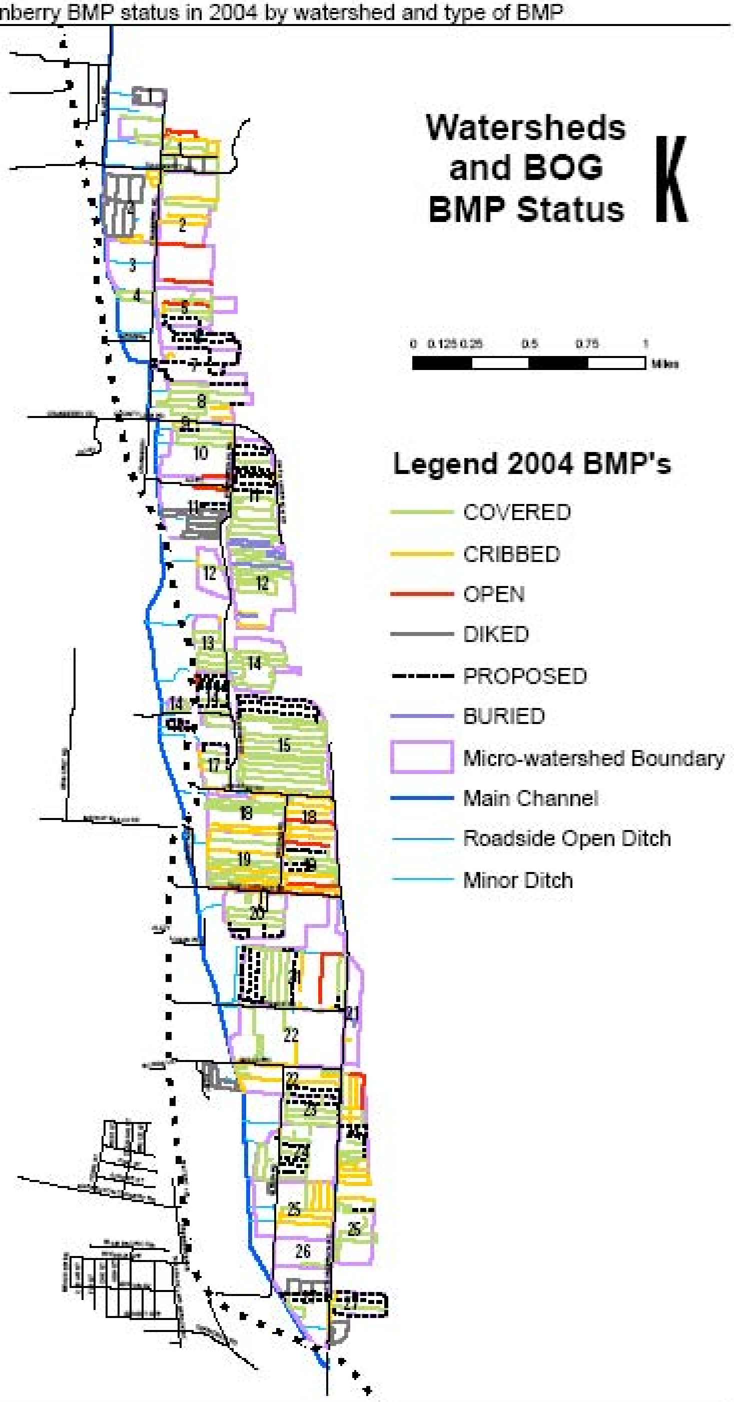


Figure 3. Grayland cranberry BMP status in 2004 by watershed and type of BMP



Fgiure 2. The overall BMP status of Grayland cranberry farms in 2004.

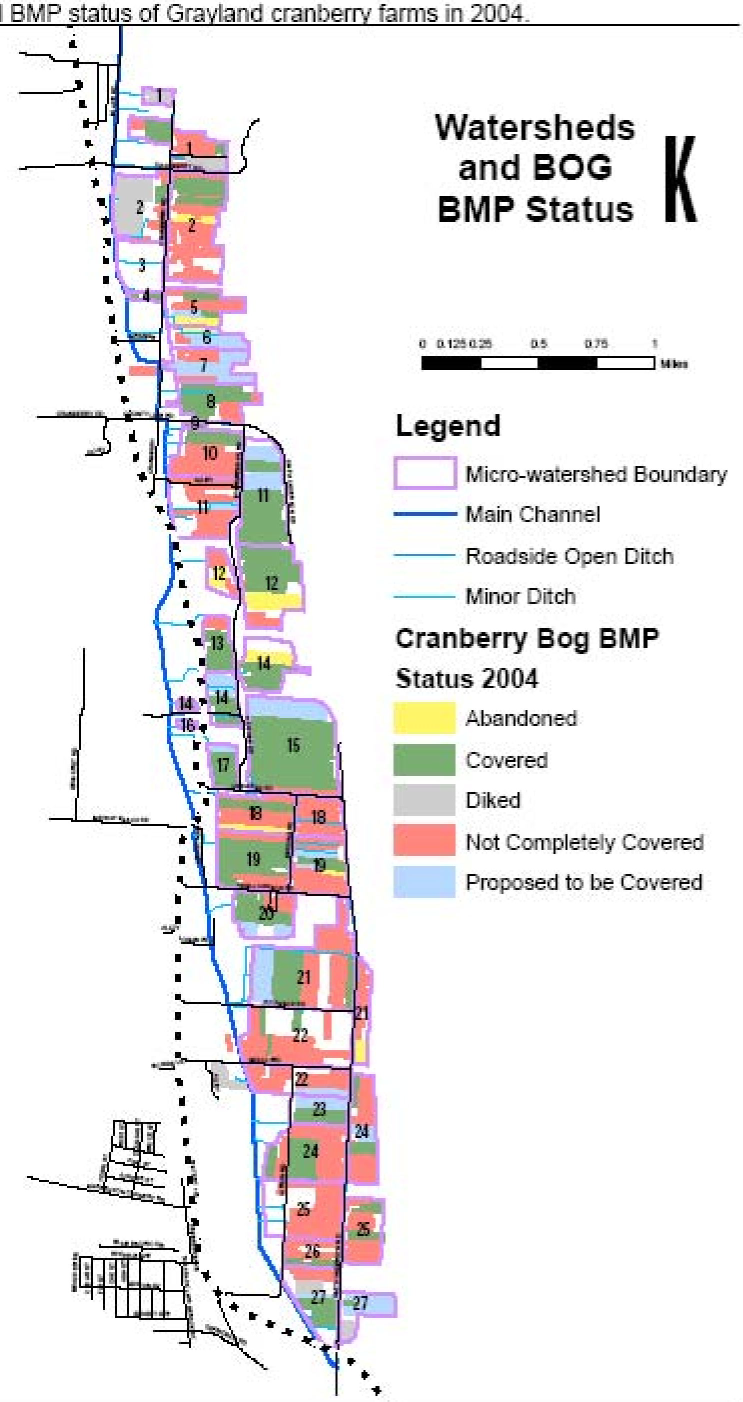


Table 2. Status of Grayland Cranberry ditches in 2004 across each micro-watershed based on the linear feet of different types of ditches and the percentage of ditches within each watershed covered by a BMP.

BMPs on Grayland cranberry ditches by watershed as a function of BMP type in 2004								
Watershed	Covered	Buried	Dike	Proposed	Total ditches	Total with BMPs	Ditches with BMPs	Increase in ditches with BMPs between 2002-2005
	Total linear feet						Percentage	
1	7,722	0	3,381	0	15,111	11,102	73	12
2	3,594	0	8,381	0	18,759	11,975	64	7
3	0	0	0	0	0	0	na	na
4	0	1,944	0	0	1,944	1,944	100	0
5	3,126	0	0	1,723	6,109	4,849	79	44
6	0	0	0	3,103	3,103	3,103	100	100
7	0	0	0	6,183	6,484	6,183	95	95
8	7,574	0	0	261	8,736	7,834	90	42
9	0	0	0	449	1,011	449	44	44
10	4,452	0	0	0	5,115	4,452	87	6
11	8,341	2,082	8,817	9,091	30,236	28,331	94	43
12	8,735	2,601	0	0	12,487	11,336	91	24
13	5,306	0	0	0	5,391	5,306	98	6
14	10,368	0	0	4,317	15,115	14,685	97	43
15	25,056	0	0	6,196	33,692	31,252	93	18
16	0	0	0	1,238	1,238	1,238	100	100
17	3,114	0	0	1,747	4,861	4,861	100	60
18	6,144	0	0	0	14,359	6,144	43	0
19	11,863	0	0	2,328	32,098	14,191	44	15
20	5,472	0	0	2,478	8,587	7,950	93	63
21	8,661	519	0	6,325	18,360	15,505	84	50
22	4,068	0	3,772	1,191	15,088	9,030	60	17
23	4,687	0	0	3,180	7,867	7,867	100	68
24	9,874	0	0	4,768	23,474	14,642	62	24
25	6,805	0	900	517	14,912	8,223	55	24
26	588	0	0	0	588	588	100	0
27	2,283	0	4,040	6,326	13,737	12,649	92	46
Total	147,833	7,146	29,290	61,422	318,461	245,690	77	29

Table 3. Status of Grayland Cranberry beds in 2004 based on the surface area completely covered by BMPs, and linear miles of different types of ditch in 2002, 2003, and 2004.

Totals for the study area				
	Total acres of bogs[1]	Linear miles of ditch		
Ditch Type	2004	2002	2003	2004
Covered	350	21.66	27.49	28.00
Cribbed		13.12	11.09	10.88
Open		3.25	3.09	2.90
Diked	45	5.55	5.55	5.55
Proposed	131	15.75	11.75	11.64
Unknown		2.96	2.96	2.96
Buried		0.99	1.35	1.35
Not covered	503			
Abandoned	37			
Total	1066			

[1]Surrounded (100%) by specific ditch type

Table 4. Change in covered and buried Grayland cranberry ditches by watershed as a function of year.

	Linear feet of BMP					
	Buried			Covered		
Watershed	2002	2003	2004	2002	2003	2004
1	0	0	0	5,888	6,750	7,722
2	0	0	0	2,322	3,594	3,594
3	0	0	0	0	0	0
4	0	1,944	1,944	1,944	0	0
5	0	0	0	2,140	3,126	3,126
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	4,188	7,574	7,574
9	0	0	0	0	0	0
10	0	0	0	4,131	4,452	4,452
11	2,581	2,082	2,082	3,922	7,193	8,341
12	2,601	2,601	2,601	5,755	8,735	8,735
13	0	0	0	5,002	5,306	5,306
14	0	0	0	8,239	10,368	10,368
15	0	0	0	25,056	25,056	25,056
16	0	0	0	0	0	0
17	0	0	0	1,931	2,497	3,114
18	0	0	0	6,144	6,144	6,144
19	0	0	0	9,297	11,863	11,863
20	0	0	0	2,75	5,472	5,472
21	519	519	519	5,812	8,661	8,661
22	0	0	0	2,727	4,068	4,068
23	0	0	0	2,545	4,687	4,687
24	0	0	0	8,968	9,874	9,874
25	0	0	0	3,680	6,805	6,805
26	0	0	0	588	588	588
27	0	0	0	2,283	2,283	2,283
Total	5701	7,146	7,146	115,136	145,095	147,833

Table 5. Water flow (cubic feet per second (CFS) and gallons per minute (GPM) measurements through selected culverts in Grayland, WA in 2004

Location	5/26/04		6/15/04		7/1/04		7/8/04		12/10/04		1/24/05	
	CFS	GPM	CFS	GPM	CFS	GPM	CFS	GPM	CFS	GPM	CFS	GPM
County Line	1.0	877.3	0.5	488.5			0.8	72.1	1.1	948.1	1.4	1276.1
Smith Anderson & Evergreen	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.9	0.0	27.8
Evergreen Road #5	0.0	0.0	0.0	0.0	0.0	0.0	DRY	DRY	0.6	19.2	0.1	82.0
Evergreen Road #6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0		
Heather Street #14	1.1	1586.4	0.5	674.0			0.2	342.5	3.1	4466.5	0.8	1142.1
Evergreen #11	0.2	81.2	0.2	72.1			0.1	27.8	1.3	596.8	0.3	120.9
Lindgren Road # 9	0.2	75.1	0.0	0.0	0.0	0.0	0.0	0.0			0.0	2.7
Redding Road #10	0.0	0.0			0.0	0.0	0.0	0.0			0.0	18.0
Redding Road #2	0.0	20.3	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0
Redding Road #4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.2	74.6
Udell Hansen & HW 105									3.6	4907.5	1.5	2047.4
Gould #14	0.1	61.8	0.0	5.8							0.1	77.7

Fgiure 4. Relative flow rates of water in Grayland cranberry ditches during July & August 2004.

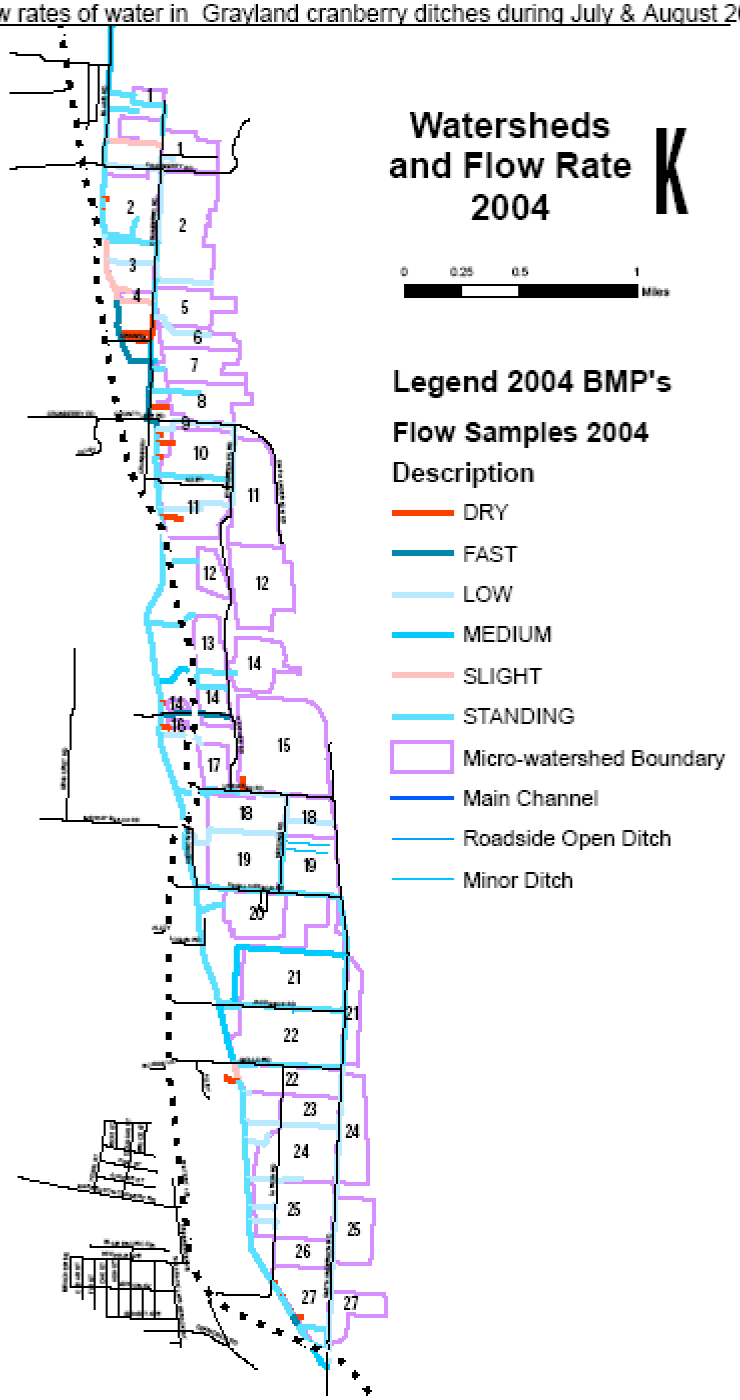
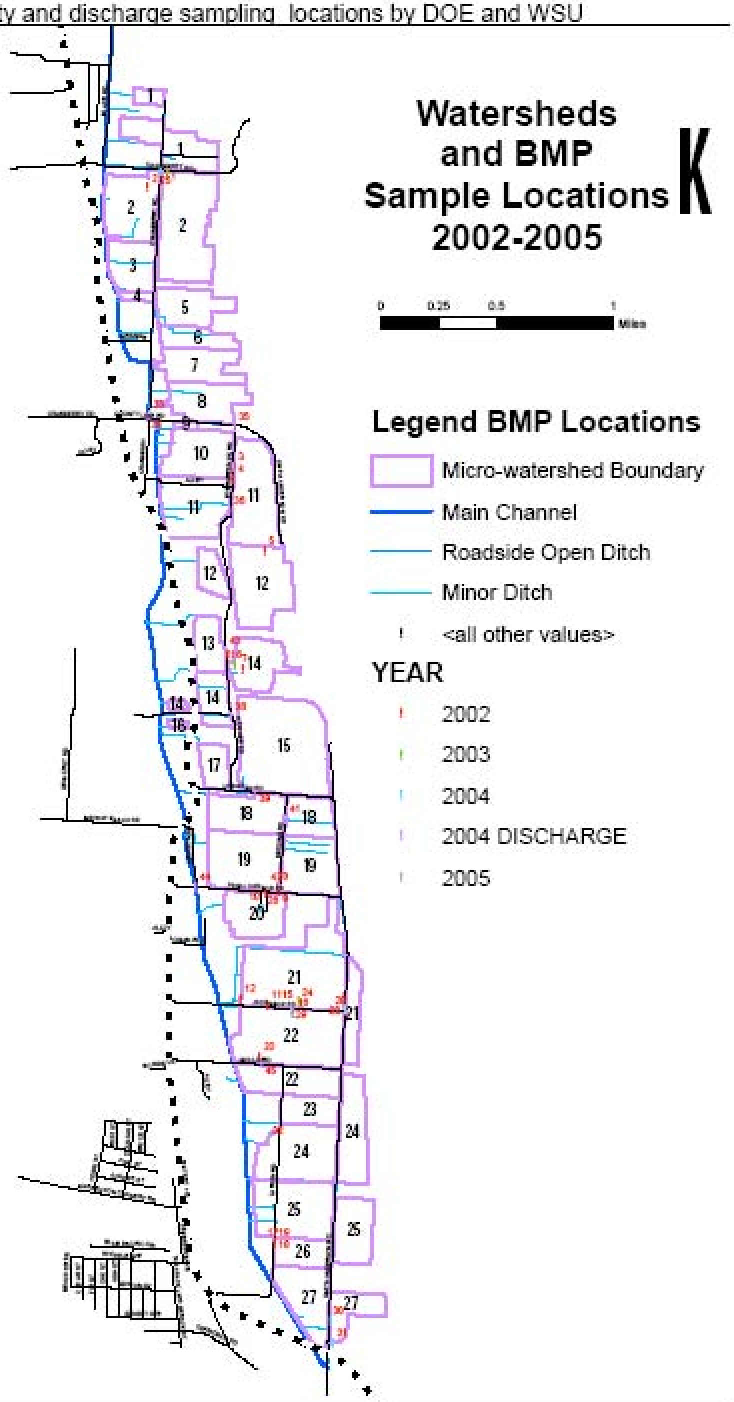
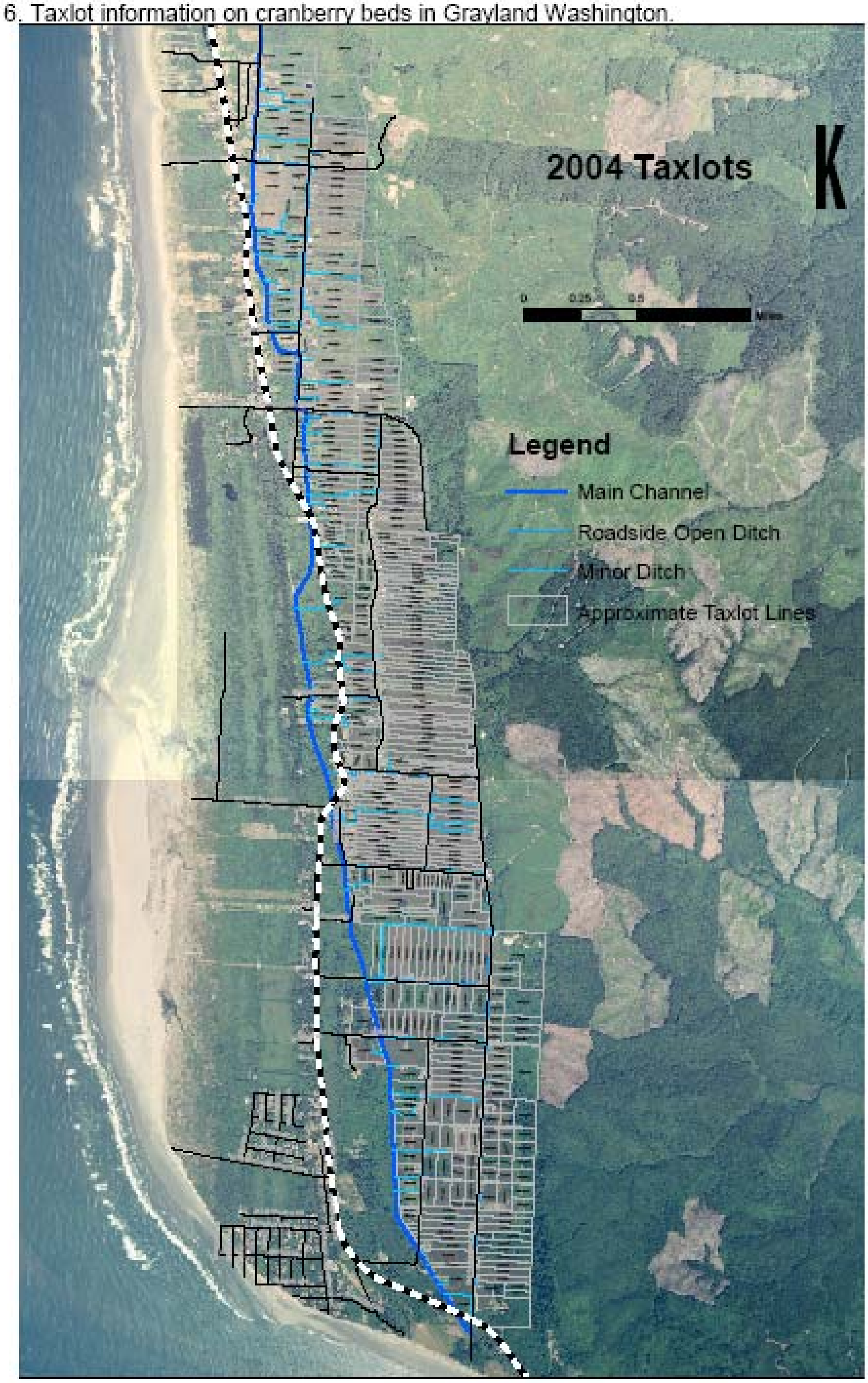


Figure 5. Water quality and discharge sampling locations by DOE and WSU



Fgiure 6. Taxlot information on cranberry beds in Grayland Washington.



Objective 2: Research and develop new cost-effective BMPs.

Objective 3: Implement and monitor BMPs that have been previously developed and shown to be effective on a small scale but are currently not being used at the farm level.

Several new BMPs were evaluated on growers' fields including buried drain lines, temporary ditch covers, new application technology, floating filter covers, in-ditch phytoremediation, carbon filters and holding water. These systems were installed and tested on growers' farms. Results are segregated by type of BMP.

Buried drain line: Monitoring was done at a site that was installed by the grower in 2002. Based on the results shown in Table 5, this type of system was fairly effective. There was a single hit of Guthion shortly after application indicating that the system was not entirely sealed from surface water.

Table 6. Effectiveness of buried perforated drain line as a BMP – 2002.

BMP type: Buried perforated drain line								
Location: Evergreen Park Road								
Date: 7/16/2002 to 7/18/02								
BMP Details: Open ditch was replaced with perforated 6" drain line (buried and covered).								
Pesticide application details: Bog was sprayed at 5:42 a.m. on 7/18/02 with Guthion 2 lb/ac								
Sampling details: Water samples were taken at the cleanup junction of the drainage system.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/16/02	1420	before application	ND	NA	ND	ND	ND	20716-05
7/18/02	0552	after	ND	NA	ND	ND	ND	20718-01
7/18/02	0612	after	8	NA	ND	ND	ND	20718-02
7/18/02	0642	after	ND	NA	ND	ND	ND	20718-03
7/18/02	0712	after	ND	NA	ND	ND	ND	20718-04
Comments:								

Vine overgrowth: Numerous farms have let the cranberry vines grow thick over small drainage ditches under the assumption that this thick cover would allow drainage, but prevent pesticides from entering the surface water system. Since this system didn't have any summer flow, monitoring for efficacy in the surface water itself was not feasible difficult. Instead we placed wide-mouth glass canning jars above and below the canopy during several pesticide application events. Any pesticides passing through the canopy would be caught in the jars. Jars were then diluted to 1 liter of water and the sample analyzed. Based on the data in tables 6 and 7, vine overgrowth does not eliminate pesticide getting into surface water.

Table 7. Effectiveness of vine overgrowth as a BMP – July 2002.

BMP type: Vine overgrowth								
Location: South Larkin								
Date: 7/16/02 to 7/17/02								
BMP Details: Thick vine cranberry coverage over the drainage ditch that should prevent insecticide movement into ditch.								
Pesticide application details: Bog was sprayed at 12:30 a.m. on 7/17/02 with Lorsban.								
Sampling details: 1 liter sample jars (wide mouth canning jars) were placed above and below vines during the application of insecticide. After the application event was over, the sample jars were filled with water to obtain enough samples for analysis.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
07/16/02	1616	before spray, below vines	NA	ND	NA	NA	NA	20716-03
07/17/02	1129	below vines	NA	0.6	NA	NA	NA	20717-08
07/17/02	1132	below vines	NA	0.4	NA	NA	NA	20717-09
07/17/02	1133	above vines	NA	ND	NA	NA	NA	20717-10
Comments on sample: Data do not reflect concentration of Lorsban in ditch, but indicate that Lorsban was able to penetrate through the thick cranberry canopy.								

Table 8. Effectiveness of vine overgrowth as a BMP – September 2002.

BMP type: Vine overgrowth								
Location: South Larkin								
Date: 9/7/2002								
BMP Details: Thick vine cranberry coverage over the drainage ditch that should prevent insecticide movement into ditch.								
Pesticide application details: Bog was sprayed at 7:00 a.m. on 9/07/02 with 2 qts/liter of Diazinon								
Sampling details: 1 liter sample jars (wide mouth canning jars) were placed above and below vines during the application of insecticide. After the application event was over the sample jars were filled with water to obtain enough sample for analysis.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
9/7/02	1200	above vines	2.0	ND	ND	ND	NA	20909-01*
9/7/02	1201	below vines	3.0	0.3	ND	ND	NA	20909-02
9/7/02	1206	above vines	ND	ND	ND	ND	NA	20909-03
9/7/02	1210	below vines	1.5	0.2	ND	ND	NA	20909-04*
9/7/02	1213	above vines	ND	ND	ND	ND	NA	20909-05*
9/7/02	1215	below vines	2.0	0.3	ND	ND	NA	20909-06*
Comments on sample: Data are not clear as to why Guthion and Lorsban showed up when Diazinon was applied. It is likely that there was a miscommunication between the owner and the applicator as to what was applied. Regardless, data do not reflect concentration of insecticide in ditch, but indicate that insecticides were able to penetrate through the thick cranberry canopy. *Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Offsite mitigation: Only one site was available for monitoring the efficacy of pumping water from a contaminated sump to field to allow for off-site mitigation. It was assumed that water flowing from this mitigation field would be free of any pesticides, since it was a vegetative shrub land on a peat soil. Unfortunately, Guthion was detected in all the samples including the before treatment sample. It was therefore highly likely that the location selected for monitoring was contaminated from an adjacent cranberry bed. Therefore the results are inconclusive.

Table 9. Effectiveness of offsite pumping as a BMP –2002.

BMP type: Offsite pumping								
Location: Jacobson and Gould Rd.								
Date: 7/16/02 to 7/19/02								
BMP Details: Grower pumped all of the water from sump onto a vacant field behind the farm. The field was covered by dense shrub on a peat soil. The field was supposed to act as a bio-filtration system for water leaving the farm.								
Pesticide application details: Bog was sprayed at 11:30 a.m. on 7/16/02 with Guthion.								
Sampling details: Water was sampled in a drainage system that left the field.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/16/02	0915	before spray	8	NA	ND	ND	ND	20716-01
7/17/02	1027	after spray	9	NA	ND	ND	ND	20717-05
7/17/02	1450	after spray	8	NA	ND	ND	ND	20717-13
7/18/02	1030	after spray	8	NA	ND	ND	ND	20718-05
Comments on sample: These values are suspect. based on the fact that, although the sampling site was downhill from the field, it was also adjacent to another cranberry bed. It is likely that the site received secondary contamination from that adjacent bed. Both before and after samples appear contaminated.								

,

Temporary Ditch Covering: A site was selected where a grower placed used plywood over the ditch during pesticide applications. This temporary cover was supposed to prevent any entry of pesticide during a chemigation event from entering the stream under the plywood. Based on the data found from one monitoring event, this system appeared to be very effective in preventing surface water contamination. Since Orthene was used as the insecticide by the grower, it is uncertain how reliable the monitoring data are. Orthene is notoriously difficult to analyze for, and rapidly degrades. The results, however, are only as reliable as the covering system. The on-off removal of this temporary covering system did not have much long-term functionality to the grower.

Table 10. Effectiveness of Temporary Ditch Covering as a BMP in 2002.

BMP type: Temporary Ditch Covering								
Location: Evergreen Park Road								
Date: 7/8/02 to 7/9/02								
BMP Details: Sheets of 4'x4' used plywood were temporarily placed over the drainage ditch along the entire length of the bed.								
Pesticide application details: Bog was sprayed at 10:59 p.m. on 7/8/02 with Orthene.								
Sampling details: The ditch was sampled at the outflow of the bed.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/8/02	1030	before	ND	NA	ND	ND	ND	20709-06
7/8/02	1109	after	ND	NA	ND	ND	ND	20709-01
7/8/02	1114	after	ND	NA	ND	ND	ND	20709-02
7/8/02	1138	after	ND	NA	ND	ND	ND	20709-03
7/9/02	1208	after	ND	NA	ND	ND	ND	20709-07
7/9/02	1239	after	ND	NA	ND	ND	ND	20709-08
Comments on sample:								

Hand spraying along the ditch: One method used to avoid ditch contamination via the chemigation process is targeting the insecticide application more precisely using a Backpack spray along the ditch to carefully avoid any off-site application to water. We evaluated this at one grower site. There was no evidence of ditch contamination using this method. However, since the grower used Orthene the showing favorable results must be viewed with caution.

Table 11. Effectiveness of hand spraying along the ditch as a BMP in 2002

BMP type:								
Location: Udel Hansen and Redding Rd.								
Date: 7/18/02								
BMP Details: Used a backpack solo-mist sprayer to treat along the edge of the farm where off-site contamination into the ditch would have traditionally occurred using chemigation system.								
Pesticide application details: Bog was sprayed at 4:35 p.m. on 7/18/02 with Orthene.								
Sampling details:								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
07/18/02	1405	before	ND	NA	ND	ND	ND	20718-06
07/18/02	1645	after	ND	NA	ND	ND	ND	20718-07
07/18/02	1647	after	ND	NA	ND	ND	ND	20719-03
Comments on sample:								

Floating filtration beds: A floating system was designed using a floating filter system from Environmental Fabrics, Inc. These 4'x 8' pads were filled with 1" recycled foam padding glued over a geotextile fabric cloth (see photo). Different amounts (56 and 113 g/m^2) of powdered activated charcoal were filled into the loose cell of each pad. Since not enough pads were available to cover an entire sump, a simulated container monitoring plan was conducted. Containers holding the pad were made and filled with water. Diazinon was sprayed over the tops of several types of charcoal-loaded pads. Water quality underneath the pads was monitored over time. Results from this monitoring study were inconclusive. Over time, insecticides were detected under all the floating filters. Apparently with rain and wind and other activity there is a loss of insecticides off the filters into the water. It can be concluded that these floating covers are not reliable enough to work for growers. The site also picked up some off-site contamination from a nearby pesticide application event.

Table 12. Effectiveness of floating filter beds in ponds as a BMP in 2002

BMP type: Floating filter beds in ponds

Location: Evergreen Park Road

Date: 9/11/02 to 9/19/02

BMP Details: Different amounts (56 and 113 g/m^2) of powered activated charcoal was filled into the loose cell of each pad

Pesticide application details: Product applied over bed with a backpack sprayer on 09/11/02 using Diazinon at the 2 qt/ac rate.

Sampling details: Samples were taken below the filter over time. Results indicate movement of Diazinon through the filter.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter			Sample ID
			Lorsban	Diazinon	Imidan	
9/11/02	0820	No filter	0.2	ND	1.0	20912-01
9/11/02	0944	High charcoal rate	ND	ND	ND	20912-02
9/11/02	0942	Low charcoal rate	ND	ND	ND	20912-03
9/11/02	0947	Filter without charcoal	ND	ND	ND	20912-04
9/13/02	0900	High charcoal rate	ND	0.2	ND	20913-01
9/13/02	0902	Low charcoal rate	ND	ND	ND	20913-02
9/13/02	0904	Filter without charcoal	ND	ND	ND	20913-03
9/16/02	0904	High charcoal rate	ND	ND	ND	20916-01
9/16/02	0906	Low charcoal rate	ND	0.9	ND	20916-02
9/16/02	0902	Filter without charcoal	ND	0.4	ND	20916-03
9/19/02	0900	High charcoal rate	ND	0.3	ND	20919-01
9/19/02	0902	Low charcoal rate	ND	ND	ND	20919-02
9/19/02	0904	Filter without charcoal	ND	ND	ND	20919-03
9/19/02	0930	High charcoal rate	ND	0.7	ND	20924-01
9/19/02	0932	Low charcoal rate	ND	ND	ND	20924-02
9/19/02	0934	Filter without charcoal	ND	ND	ND	20924-03

Comments on sample: Off-site contamination with Lorsban and Imidan must have occurred during this monitoring event.

Partial Turn Sprinklers: Traditional cranberry sprinkler systems have very little flexibility for adjusting throw, backwash, and pattern. Therefore during a chemigation event it is hard to avoid contaminating surface water. Adjustable gear-driven irrigation sprinkler heads however, can be adjusted for flow, throw, backwash, and pattern. Thus by switching over key trouble sprinklers in a bed that hit surface water it may be feasible to reduce offsite contamination. Such a system was installed at a grower site in 2004 to evaluate for their adaptation to an existing cranberry production system (see photo). The sump adjacent to the sprinklers was monitored for pesticide loading. In addition, the persistence of the insecticide used during the event was monitored over time. Sprinklers were not properly adjusted for optimal use at this site and as a consequence they hit theater during the application event and the sump contained a small amount of Lorsban. There was a contained sump with no off-site movement and under those conditions it took longer than a month before the Lorsban was no longer detected. Although we failed to obtain any viable data to justify these sprinklers as a BMP, the growers who used this system, however, did feel that it was a very user friendly system that under some circumstances could be used to reduce surface water contamination.

Table 13. Effectiveness of adjustable gear driven irrigation sprinkler heads as a BMP in 2004

BMP type: Sprinkler type (adjustable gear driven irrigation sprinkler heads) and holding water

Location: Jacobson Road

Date: 07/07/05 to 8/17/04

BMP Details: Type of sprinklers etc.

Pesticide application details: Lorsban 07/05/04 late p.m.

Sampling details: Sample 36 hours post application

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/01/04	1430	before	NA	ND	NA	NA	NA	40701-05*
7/07/04	1000	1 day	NA	0.9	NA	NA	NA	40708-05
7/08/04	1220	2 days	NA	0.9	NA	NA	NA	40708-12
7/13/04	1130	7 days	NA	0.1	NA	NA	NA	40713-02
7/20/04	1214	14 days	NA	0.7	NA	NA	NA	40720-04*
7/30/04	1330	24 days	NA	0.5	NA	NA	NA	40730-30*
8/17/04	1225	41 days	NA	ND	NA	NA	NA	40817-05*

Comments on sample: Data reflect that some Lorsban still hit the pond with the new sprinkler; they were not adjusted correctly at application time. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Holding Water: The most preferred method to mitigate for pesticides in surface water is to simply hold the water on-farm until it is no longer detectable before it is released. Two problems with this BMP are that 1) there are no data on how long it takes to hold water on-farm before it is no longer detectible or below the critical level and 2) most of the farms don't have a way to hold the water long enough to achieve that goal. Between 2002 and 2004 we monitored numerous sumps and ditches to evaluate what actually happened in the Grayland aquatic ecosystem as it related to insecticide longevity. With the help of the NRCS in 2003, we also installed numerous water containment systems on farms. These holding water on-farm systems were monitored during the 2004 spray season for efficacy.

In 2002 three sites were monitored. In the first site (Table 14) the dammed ditch contained significant weedy vegetation. Guthion went from 8 ppb to 2 ppm in ~ 2-3 weeks, and it took 2 months get to the non-detectible level. In the second site (Table 15), a closed sump, no Orthene was detected at any of the samples. This most likely reflects the problems with Orthene detection than BMP efficacy. In the third site in 2002, (Table 16), a combination sump and ditch, system was evaluated. Samples were not collected on the ditch part of the system long enough to make an inference due to a leaky dam. In the pond part of the system, Guthion was not immediately detected as it was in the ditch. It took one month before it went below the non-detection level.

Five holding water studies were done in 2003. In the north Grayland site (Table 17), early season Lorsban took ~ 2.5 weeks to drop from ~ 4 ppb to <1 ppb. Later in the season it took that same time period (2.5 weeks) reduce ~ 1ppb of Guthion to below the non-detectable level. In a mid-Grayland ditch (Table 18), it took four weeks for Guthion to drop from 140 ppb to non detectable levels and two weeks to go from 1 ppb to non detectable. The decrease in Guthion over time decay followed perfect (R^2=0.99) exponential decay (Figure 8). In a similar situation, later in the season, but lower starting levels of Guthion, it took 10 days to go from 2 ppb to non detection (Table 19). In another sump where water was held all season and the grower used multiple application of Guthion throughout the season (Table 20), the decay results are not as clean. In general it took about 2-3 weeks for Guthion to be below the non detectable level, but there was no clear exponential rate of decay. At this site two sampling locations were used North and South side of the sump. For the most part, the data were very uniform across sampling location, suggesting the sampling and laboratory protocol used throughout the course of this study were appropriate and suitable for the purpose of the study. In the final holding water study done in 2003 no Guthion was detected in the water sample at any point in time. It is not clear why there was a lack of detectable Guthion in the ditch. It is feasible the contaminated water seep past the dam before we could detect it.

In 2004 there were four sites where holding water studies were done. Although several additional sites were planned, based on the installations of BMP in 2003, the lack of adequate water during the course of this monitoring program at a few of this sites made collection of a full data set impossible. Three of 2004 sites were ditches in the southern part of Grayland. Results from the Udel Hanson and Redding site (Table 22) didn't follow the pattern of detection and decay from 2002 and 2003. Diazinon was not detected during the first two spray events and in the last two it was not detected until 5 days after the application. Once it was detected, it took 7 to 10 days to disappear. The sampling also detected Guthion. Initial we assumed it was from an application made by the neighbor. However, the application timing doesn't correspond to the detection timing.

Table 14. Effectiveness of holding water in a weedy ditch as a BMP in 2002

BMP type: Holding water in a ditch containing weeds								
Location: Redding Road								
Date: 7/16/02 to 9/14/02								
BMP Details: A ditch running between two cranberry beds that contained a high amount of aquatic weeds (mixed species) was dammed. Water was sampled over time to determine if pesticide breakdown was accelerated in a ditch containing high levels of weeds.								
Pesticide application details: Bog was sprayed at 4:30 a.m. on 7/17/02 with Guthion.								
Sampling details: Water samples were drawn from the center of the ditch.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/16/02	1506	before	ND	NA	ND	ND	ND	20716-04
7/17/02	1016	after	8	NA	ND	ND	ND	20717-04
7/20/02	1016	after	9	NA	ND	ND	ND	20719-02
7/25/02	1016	after	ND	NA	ND	ND	ND	20725-14*
8/1/02	1200	after	2	NA	ND	ND	ND	20801-01
9/14/02	1100	after	ND	NA	ND	ND	ND	20916-04
9/14/02	1110	after	ND	NA	ND	ND	ND	20916-05
Comments on sample: * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Table 15. Effectiveness of holding water in a pond as a BMP in 2002.

BMP type: Holding water in a pond

Location: Jacobson Road

Date: 7/18/02 to 7/19/02

BMP Details:

Pesticide application details: Orthene applied 7/18/02

Sampling details: water in pond post treated

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/18/02	1405	before	ND	NA	ND	ND	ND	20718-08
7/18/02	1645	after	ND	NA	ND	ND	ND	20718-09
7/19/02	1647	after	ND	NA	ND	ND	ND	20719-03

Comments on sample:

Table 16. Effectiveness of holding water in a ditch and sump as a BMP in August 2002

BMP type: Holding water in a ditch

Location: Udel Hansen and Redding Rd.

Date: 7/24/02 to 8/23/02

BMP Details: A sump and its connecting ditch that had been dammed were sampled over time to assess the degradation of insecticide.

Pesticide application details: Bog was sprayed with Guthion at 11:30 pm on 7/24, followed by an irrigation at 7:30 a.m. on 7/25

Sampling details:

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/24/02	1100	before	ND	ND	ND	ND	ND	20725-08*
7/25/02	1200	after-ditch	130	0.3	ND	ND	ND	20725-09*
7/25/02	0740	after-ditch	130	0.3	ND	ND	ND	20725-10*
7/25/02	1201	after-ditch	109	0.3	ND	ND	ND	20725-11*
7/25/02	1200	after-pond	ND	ND	ND	ND	ND	20725-12*
7/29/02	1200	after-pond	3	ND	ND	ND	ND	20729-06*
8/1/02	1200	after-pond	2	ND	ND	ND	ND	20801-01*
8/23/02	1548	after-pond	ND	ND	ND	ND	ND	20823-14*

Comments on sample: The difference in insecticide concentration between the ditch and pond may reflect water volume. The ditch was small (~1' wide x 0.5' deep ~ 1000 gallons), and had several sprinklers hitting it; the sump had two sprinklers hitting it and had a large volume of water (~80,000 gallons). * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 17. Effectiveness of holding water in a pond as a BMP in 2003

BMP type: Holding water in a pond

Location: Turkey and Cranberry

Date: 6/2/03 to 6/17/03 and 7/11/03 to 78/05/03

BMP Details: Water was completely retained on site with all water from three farms draining into the third pond. Water was sampled over time to determine degradation rate over time.

Pesticide application details: Lorsban 3 pts/ac applied 5/30/03 at 9:30 p.m. Guthion at 1 lb/ac was applied on ~ July 11.

Sampling details: Water was sampled at the outlet of the third pond.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
5/30/03	1310	before	ND	NA	ND	ND	ND	30602-03*
6/02/03	1300	after	NA	3.7	NA	NA	NA	30602-01*
6/02/03	1303	after	ND	NA	ND	ND	ND	30602-02
6/05/03	1300	after	ND	NA	ND	ND	ND	30605-01
6/05/03	1303	after	NA	5.9	NA	NA	NA	30605-02*
6/10/03	1344	after	ND	NA	ND	ND	ND	30610-01
6/10/03	1346	after	NA	4.5	NA	NA	NA	30610-02
6/17/03	1253	after	NA	0.8	NA	NA	NA	30617-02
6/17/03	1256	after	ND	NA	ND	ND	ND	30617-01
7/11/03	2105	before	ND	NA	ND	ND	ND	30711-01
7/15/03	1610	after	0.6	NA	ND	ND	ND	30715-03*
7/17/03	0830	after	0.7	NA	ND	ND	ND	30717-03
7/18/03	2100	after	1.1	NA	ND	ND	ND	30722-05*
7/22/03	1051	after	0.2	NA	ND	ND	ND	30722-03*
7/29/03	1150	after	ND	NA	ND	ND	ND	30729-03
7/31/03	0947	after	ND	NA	ND	ND	ND	30731-01
8/05/03	1147	after	ND	NA	ND	ND	ND	30805-03

Comments on sample: Samples for Guthion and Lorsban were run separately. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 18. Effectiveness of holding water in ditch as a BMP in 2003

BMP type: Holding water in ditch area.								
Location: Udel Hanson and Redding Road								
Date: 7/15/03 to 8/12/03								
BMP Details: NRCS installed dike/drain system summer 2003 to manage the flow of water off farm. Water was held in the ditch and sample over time for degradation of insecticides.								
Pesticide application details: Date sprayed 7/11/03. Guthion 1-1/2 lbs./ac.								
Sampling details:								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/15/03	1526	after	140	NA	ND	ND	ND	30715-01*
7/17/03	0852	after	56	NA	ND	ND	ND	30717-02
7/22/03	1155	after	2.1	NA	ND	ND	ND	30722-02*
7/29/03	1206	after	1.1	NA	ND	ND	ND	30729-01
8/05/03	1124	after	0.4	NA	ND	ND	ND	30805-01*
8/12/03	1114	after	ND	NA	ND	ND	ND	30812-01
Comments on sample: The ditch was small (~1' wide x 0.5' deep ~ 1000 gallons) and had several sprinklers hitting it. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Figure 7. Guthion decay in a cranberry drainage ditch in 2003

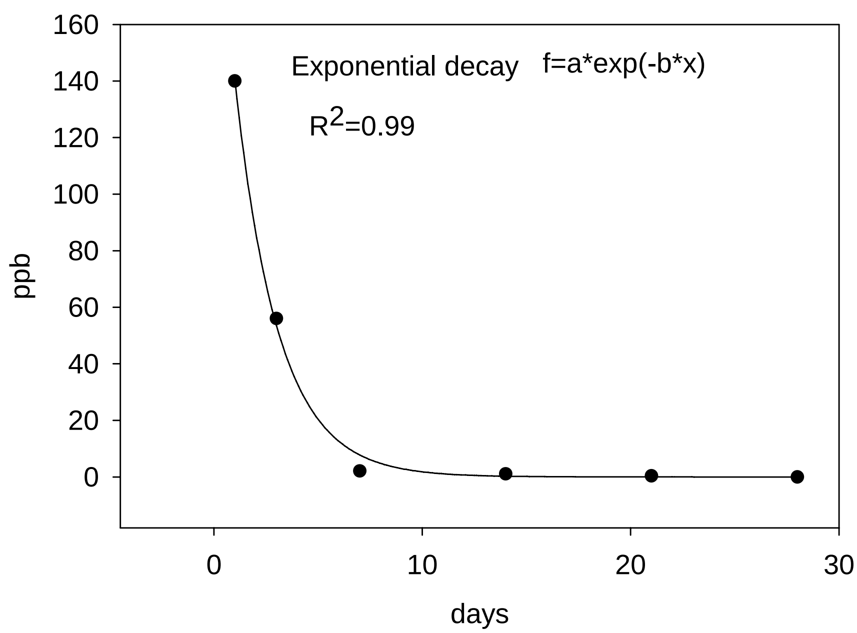


Table 19. Effectiveness of holding water in ditch as a BMP in 2003

BMP type: Holding water in ditch								
Location: Udel Hanson and Redding Road								
Date: 7/11/03 to 8/12/03								
BMP Details: Water was held in a drainage ditch and sample over time for degradation of insecticides.								
Pesticide application details: 7/11/03 Guthion 1-1/2 lbs/ac								
Sampling details: Water was sampled at the end of the ditch.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/11/03	1302	before	ND	NA	ND	ND	ND	30711-02
7/15/03	1536	after	1.7	NA	ND	ND	ND	30715-02*
7/17/03	0852	after	2.1	NA	ND	ND	ND	30717-01
7/22/03	1157	after	ND	NA	ND	ND	ND	30722-01*
7/29/03	1206	after	ND	NA	ND	ND	ND	30729-02
8/05/03	1127	after	ND	NA	ND	ND	ND	30805-02*
8/12/03	11:20	after	ND	NA	ND	ND	ND	30812-02*
Comments on sample: The ditch was small (~1' wide x 0.5' deep ~ 1000 gallons) and had several sprinklers hitting it. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Table 20. Effectiveness of holding water in a pond as a BMP in 2003

BMP type: Holding water in pond

Location: Jacobson

Date: 5/8/03 to 8/05/03

BMP Details: Grower confined his sump water during duration of sampling.

Pesticide application details: Multiple applications of Guthion at 1 lb/ac throughout the season. Approximate dates of application were May 9, May 30, July 12 and August 1.

Sampling details: Sampled at 2 locations in sump over a two month process.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter			Sample ID
			Guthion	Lorsban	Diazinon	
5/08/03	1226	before spray	1.7	NA	NA	30508-01
5/10/03	1315	S end after spray	5.3	NA	NA	30512-01
5/10/03	1320	N end after spray	9	NA	NA	30512-02
5/13/03	1320	S end after spray	6.7	NA	NA	30515-01
5/13/03	1328	N end after spray	6.9	NA	NA	30515-02
5/15/03	1311	S end after spray	4.6	NA	NA	30515-03
5/15/03	1317	N end after spray	4	NA	NA	30515-04
6/02/03	1340	S end after spray	ND	NA	NA	30602-06
6/02/03	1345	N end after spray	6.8	NA	NA	30602-07
6/05/03	1325	S end after spray	5.4	NA	NA	30605-04
6/05/03	1328	N end after spray	5.1	NA	NA	30605-05
6/10/03	1408	S end after spray	5	NA	NA	30610-05*
6/10/03	1410	N end after spray	6	NA	NA	30610-06*
6/17/03	1311	S end after spray	2	NA	NA	30617-05*
6/17/03	1313	N end after spray	4	NA	NA	30617-06*
6/24/03	1418	S end after spray	ND	NA	NA	30624-01*
6/24/03	1415	N end after spray	ND	NA	NA	30624-02*
6/02/03	1310	S end after spray	ND	NA	NA	30602-08
6/02/03	1315	N end after spray	ND	NA	NA	30602-09
6/05/03	1330	S end after spray	ND	NA	NA	30605-06
7/15/03	1512	N end after spray	1.5	NA	NA	30715-04*
7/15/03	1514	S end after spray	1.6	NA	NA	30715-05*
7/15/03	1510	N end after spray	1.4	NA	NA	30715-06*
7/17/03	0907	S end after spray	4.6	NA	NA	30717-04
7/17/03	0905	N end after spray	4.4	NA	NA	30717-05
7/22/03	1211	S end after spray	2.0	NA	NA	30722-06
7/22/03	1210	N end after spray	2.4	NA	NA	30722-07*
7/24/03	1420	S end after spray	NA	ND	ND	30729-07*
7/24/03	1422	N end after spray	NA	ND	ND	30729-08*
7/25/03	0856	S end after spray	NA	ND	ND	30729-09*
7/25/03	0857	N end after spray	NA	ND	ND	30729-10*
7/29/03	1221	S end after spray	NA	ND	ND	30729-05*
7/29/03	1219	N end after spray	NA	ND	ND	30729-06*
8/05/03	1114	S end after spray	ND	NA	NA	30805-05
8/05/03	1115	N end after spray	0.2	NA	NA	30805-06

Comments on sample: * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 21. Effectiveness of holding water in ditch as a BMP in 2003

BMP type: Holding water in ditch

Location: Smith Anderson and Jacobson

Date: 5/30/03 to 6/17/03

BMP Details: A plywood and sandbag dam was build to block the flow of water in the ditch.

Pesticide application details: Date sprayed: 5/30/03 at 8:00 a.m. Sprayed Guthion at 1 lb./ac.

Sampling details: Samples were taken in ditch before outflow value. Water was completely contained within ditch.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
5/30/03	1300	after	ND	NA	ND	ND	ND	30602-04
6/02/03	1325	after	ND	NA	ND	ND	ND	30602-05
6/05/03	1315	after	ND	NA	ND	ND	ND	30605-03
6/10/03	1403	after	ND	NA	ND	ND	ND	30610-04*
6/17/03	1319	after	ND	NA	ND	ND	ND	30617-03*

Comments on sample: No Guthion detected in any sample. No clear reason why. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 22. Effectiveness of holding water in a dammed ditch as a BMP in 2004 (Udel Hanson and Redding Road)

BMP type – Holding water

Location: Udel Hanson and Redding Road

Date: 4/29/04 to 7/30/04

BMP Details: NRCS installed dike/drain system summer 2003 to manage the flow of water off farm. Water was held in the ditch and sampled over time for degradation of insecticides.

Pesticide application details: Diazinon was applied on 04/30/04 at 0200 (2 qts. per acre), on 05/03/04 at 0100 (2 qts per acre), on 06/22/2004 (1 qt. per acre) at 0050 followed by an irrigation at 0500 and on 7/02/04 (2 qts per acre) at 0050. Neighbor sprayed with Guthion 7/3/04 at 1# /ac.

Sampling details: Samples collected at the end of ditch at the same location each time; water level fairly constant at all sample times.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter			Sample ID
			Guthion	Lorsban	Diazinon	
4/29/04	0850	before	ND	NA	ND	40430-02
5/01/04	0745	before	ND	NA	ND	40501-07
5/02/04	1130	2 days after	ND	NA	ND	40501-13
5/12/04	1245	7 days after	ND	NA	ND	40512-04
5/18/04	1330	15 days after	ND	NA	ND	40519-01
5/27/04	1130	24 days after	ND	NA	ND	40527-02*
6/22/04	0900	3 hrs after (3rd app.)	ND	NA	ND	40622-01
6/23/04	1120	1 day after (3rd app.)	ND	NA	ND	40623-10
6/24/04	0915	2 days after (3rd app.)	3	NA	ND	40624-01
6/29/04	1135	7 days after (3rd app.)	3	NA	10	40629-03*
7/06/04	1130	4 days after (4th app.)	2	NA	ND	40706-04*
7/07/04	1705	5 days after (4th app.)	ND	NA	5	40708-08*
7/18/04	1500	20 days after (4th app.)	ND	NA	N	40720-01*
7/30/04	1335	28 days after (4th app.)	ND	NA	ND	40730-28

Comments on sample: Due to a high rainfall event, water was released on 5/27/04 to prevent flooding at the bogs. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 23. Effectiveness of holding water in a dammed ditch as a BMP in 2004 (So. Smith Anderson Road)

BMP type: Holding water								
Location: So. Smith Anderson								
Date: 4/29/04 to 7/6/04								
BMP Details: NRCS installed dike/drain system in summer 2003 to manage the flow of water off farm.								
Pesticide application details: 4/30/04 early am Diazinon 2 qts per acre; 5/21/04 Guthion 1 lb/ac; 7/02/04 Orthene 1/1/3 lb ac; 7/12/04 Lorsban.								
Sampling details: Water was sampled at deepest end near the outflow value.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
4/29/04	0850	before	ND	NA	ND	ND	ND	40430-02
5/01/04	0800	2 days	NA	ND	NA	NA	NA	40501-02
5/01/04	1015	2 days	ND	NA	ND	ND	ND	40501-08
5/12/04	1215	13 days	ND	NA	9.6	ND	ND	40512-03
5/19/04	1530	20 days	ND	NA	ND	ND	ND	40519-01
5/24/04	1230	25 days	1.8	NA	ND	ND	ND	40525-01
5/25/04	1200	26 days	ND	NA	ND	ND	ND	40525-06
5/27/04	1230	27 days	7	NA	ND	ND	ND	40527-04A
5/27/04	1233	27 days	8	NA	ND	ND	ND	40527-04B
6/22/04	1000	53 days	ND	NA	2	ND	ND	40622-03
6/29/04	1225	60 days	ND	NA	4	ND	ND	40629-05*
7/06/04	1225	4 days	ND	NA	5	ND	ND	40706-03
Comments on sample: Water released from site on 5/27/04 to prevent flooding; prior to that and after that the site had only a small volume of water. After 7/6/04 the site was dry. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Table 24. Effectiveness of a dammed ditch as a BMP in 2004 (Jacobson Road)

BMP type: Holding water								
Location: Jacobson								
Date: 0/4/29/04 to 6/29/04								
BMP Details: NRCS installed dike/drain system summer 2003 to manage the flow of water off farm								
Pesticide application details: Lorsban 4/30/04 late pm; Diazinon: 6/19/04 late p.m.								
Sampling details: Water was sampled at deepest end near the outflow value.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
4/29/04	0830	before	ND	NA	ND	ND	ND	40430-01
4/30/04	1050	1 day	ND	NA	ND	ND	ND	40430-03
5/01/04	0630	2 days	ND	NA	ND	ND	ND	40501-01

5/02/04	1035	3 days	NA	ND	NA	NA	NA	40501-09
5/12/04	1130	13 days	ND	NA	1	ND	ND	40512-02
5/18/04	1430	17 days	NA	ND	NA	NA	NA	40519-02
5/27/04	1130	26 days	NA	ND	NA	NA	NA	40527-02
5/27/04	1150	26 days	NA	2	NA	NA	NA	40527-03
6/22/04	0945	3 days	ND	NA	ND	ND	ND	40622-02
6/22/04	1140	3 days	ND	NA	ND	ND	ND	40623-12
6/24/04	0930	5 days	ND	NA	5	ND	ND	40624-02
6/29/04	1155	10 days	ND	NA	5	ND	ND	40629-04*
7/06/04	1100	18 days	NA	ND	NA	NA	ND	40708-13
Comments on sample: Site had a small volume of container water (500 to 700 gallons); water was released on 5/27/04 to prevent flooding due to a large rain event. No additional sprays after 6/19/04. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Table 25. Effectiveness of holding water in a pond as a BMP in 2004

BMP type: Holding water

Location: Turkey and Cranberry

Date: 4/30/2004 to 8/5/2004

BMP Details: NRCS installed dike/drain system summer 2003 to manage the flow of water off farm.

Pesticide application details: 05/01/04 spot spraying Diazinon on adjacent beds; 05/13/04 late pm Sevin @ 2 qt/ac on 10 ac and Orthene 1lb/ac on 8 acres; 06/17/04 Diazinon 2 qt/ac; 07/03/04 and 7/06/04 Lorsban late pm on adjacent farms; 07/29/04 late pm Diazinon.

Sampling details: Back pond (last in series) was sampled at the same location every time. All water from this farm and adjacent farms eventually ended up in the back pond.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
4/30/04	1050	before	ND	NA	ND	ND	ND	40430-03
4/30/04	1100	before	ND	NA	ND	ND	ND	40430-04
4/30/04	1247	before	ND	NA	ND	ND	ND	40430-11
5/02/04	1230	1 day	ND	NA	ND	ND	ND	40501-12
5/03/04	1130	3 days	ND	NA	ND	ND	ND	40501-16
5/17/04	1150	4 days	ND	NA	ND	ND	ND	40517-01
5/25/04	1050	12 days	ND	NA	ND	ND	ND	40525-03
5/25/04	1030	12 days	ND	NA	ND	ND	ND	40525-04
6/20/04	1100	3 days	ND	NA	ND	ND	ND	40621-09
6/22/04	1500	5 days	ND	NA	3.0	ND	ND	40623-13
6/23/04	1050	6 days	6.0	NA	ND	ND	ND	40623-09
6/29/04	1100	12 days	2.0	NA	ND	ND	ND	40629-01*
7/06/04	1115	1 day	NA	2.6	NA	NA	NA	40706-06*
7/07/04	0930	2 days	NA	2	NA	NA	NA	40708-03
7/13/04	1100	7 days	NA	0.5	NA	NA	NA	40713-01
7/20/04	1055	14 days	NA	0.3	NA	NA	NA	40720-02*
7/30/04	1300	1 days	ND	NA	4	ND	ND	40730-26
8/01/04	1345	2 days	ND	NA	ND	ND	ND	40803-07*
8/05/04	0730	6 days	ND	NA	ND	ND	ND	40805-01

Comments on sample: No water moved offsite during the course of this study. Only a few sprinklers overlapped into the back pond. This would tend to minimize the likelihood of direct contamination. An adjacent large farm (down stream) could affect the water quality results by drift. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 26. Effectiveness of activated carbon filtration as a BMP in 2002

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter				Sample ID
BMP type: Activated carbon filtration							
Location: Evergreen Park							
Date: 7/17/02							
BMP Details: Activated charcoal pellets **(**4x10 mm) were packed into a filter box (4" thick x 16" tall x 12" wide) that fit snuggly within a frame within the ditch. All water moving through the cribbed ditch passed through the filter**.**							
Pesticide application details: Bog was sprayed at 1320 a.m. on 7/17 with Guthion							
Sampling details: Water was sampled before and after the after immediate after a spray event.							
			Guthion	Lorsban	Diazinon	Orthene	
7/17/02	1345	after filter	200	NA	ND	ND	20717-01
7/17/02	1348	after filter	130	NA	ND	ND	20717-02
7/17/02	1351	before filter	330	NA	ND	ND	20717-03
Comments on sample: This small ditch drained off the hill and contained at of water moving fairly fast. The filter had to have minimal resistance to flow to prevent backup and overflow.							

Table 27. Effectiveness of activated carbon filtration as a BMP in 2004

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
BMP type: Activated carbon filtration								
Location: Turkey and cranberry								
Date(s): 7/7/2004								
BMP Details: The carbon filter was Calgon Zorflex Activated Carbon Cloth - FM1/250								
Pesticide application details: Lorsban was in irrigation sump at ~ 18 ppb from a previous insecticide application. It was released through a 12" culvert with carbon filter cloth over it.								
Sampling details: Sample take on both side of cloth after water was released through cloth.								
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/07/04	1445	no filter	NA	18	NA	NA	NA	40708-07
7/07/04	1440	2 layers of filter	NA	11	NA	NA	NA	40708-06
Comments on sample: Flow stopped shortly after release of water due to equilibration of water height between both sides of the cloth.								

Table 28. Effectiveness of activated carbon filtration as a BMP in 2004

BMP type: Activated carbon filtration					
Location: Between Logan Rd. and Udel Hansen					
Date: 7/07/04					
BMP Details: Calgon Zorflex Activated Carbon Cloth - FM1/250					
Pesticide application details: Dammed ditch with Guthion and Diazinon in it. Water was routed through a 2 inch pipe with charcoal filter cloth over it.					
Sampling details: Water was collected before and after cloth.					
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter		Sample ID
			Guthion	Diazinon	
7/07/04	1700	no filter	2	5	40708-11
7/07/04	1710	3 layers	1	5	40708-09
7/07/04	1720	6 layers	0.5	3	40709-10
Comments on sample:					

Table 29. Effectiveness of activated carbon filtration as a BMP in 2004

BMP type: Activated Carbon Filtration						
Location: Between Logan Rd. and Udel Hansen.						
Date: 7/21/04						
BMP Details: Calgon Zorflex Activated Carbon Cloth - FM1/250						
Pesticide application details: Dammed ditch with Guthion. Water was routed through a layer of charcoal filter cloth that was placed at a 30 degree angle. Water flow gradually over the cloth to the other side of the sand-banked ditch.						
Sampling details: Water was collected before and after cloth;, additional layers were added for each sample time. Water was run over the cloth ~ 30 minutes prior to collecting the sample.						
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter			Sample ID
			Guthion	Diazinon	Orthene	
7/21/04	0955	0 layer	1.7	ND	ND	40721-04
7/21/04	1000	3 layers	1.28	ND	ND	40721-01
7/21/04	1030	6 layers	0.78	ND	ND	40721-02
7/21/04	1100	10 layers	ND	ND	ND	40721-03
Comments on sample:						

Table 30. Effectiveness of activated carbon filtration as a BMP in 2005

BMP type: Charcoal filter cloth

Location: Larkin

Date: 1/13/05

BMP Details: pond water was spiked with Diazinon ~250 ppb and run through 5 layers of charcoal cloth filter. Sample over taken over time to determine loss of filtration value with time.

Pesticide application details: none

Sampling details: every 25 to 50 l.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter	Sample ID
			Diazinon	
1/13/05	0845	field blank	0	50114-01
1/13/05	0905	prefilter	100	50114-02
1/13/05	0950	post-filter 1 liter	320	50114-03
1/13/05	1000	post-filter 5 liters	390	50114-04
1/13/05	1020	post-filter 25 liters	180	50114-05
1/13/05	1045	post-filter 50 liters	140	50114-06
1/13/05	1100	post-filter 75 liters	120	50114-07
1/13/05	1120	post-filter 100 liters	160	50114-08
1/13/05	1200	post-filter 150 liters	100	50114-09
1/13/05	1240	post-filter 200 liters	150	50114-10
1/13/05	1350	post-filter 300 liters	500	50114-11
1/13/05	1500	post-filter 400 liters	340	50114-12

Table 31. THIS IS A REPLACEMENT.

BMP Details: Blind field samples taken while monitoring BMPs

Pesticide application details: none

Sampling details: Water collected exact same location each time samples were collected at other sites.

Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					
			Guthion	Lorsban	Diazinon	Imidan	Orthene	Sample ID
7/15/03	1601		ND	NA	NA	NA	NA	30715-07*
7/17/03	0815		ND	NA	NA	NA	NA	30717-06
7/22/03	1100		ND	NA	NA	NA	NA	30722-04*
7/29/03	1128		ND	NA	NA	NA	NA	30729-04
8/05/03	1155		ND	NA	NA	NA	NA	30805-04

Comments on sample: * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).

Table 32. This is a replacement.

BMP type: None - blind field sample taken for comparative purposes								
Location: In main drainage ditch at Cranberry and County Line road								
Date: 5/12/2004 to 7/30/2004								
BMP Details: Blind field samples taken while monitoring BMPs								
Pesticide application details: none								
Sampling details: Water collected exact same location each time samples were collected at other sites.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
5/12/04	1115	main ditch	ND	ND	ND	ND	ND	40512-01
5/25/04	1030	main ditch	ND	ND	ND	ND	ND	40525-05
5/27/04	1045	main ditch	ND	1	ND	ND	ND	40527-01
6/21/04	1440	main ditch	ND	ND	ND	ND	ND	40621-12
6/21/04	1100	main ditch	ND	ND	ND	ND	ND	40623-11
6/29/04	1115	main ditch	ND	ND	ND	ND	ND	40629-02*
7/01/04	1405	main ditch	ND	ND	ND	ND	ND	40701-03*
7/01/04	1100	main ditch	ND	ND	ND	ND	ND	40706-01
7/08/04	0945	main ditch	ND	ND	ND	ND	ND	40708-04
7/20/04	1115	main ditch	ND	ND	ND	ND	ND	40720-03
7/30/04	1310	main ditch	ND	ND	ND	ND	ND	40730-27
7/30/04	1315	main ditch	NA	ND	NA	NA	NA	40730-29*
Comments on sample: The site for this sampling corresponds to one a DOE monitoring site, * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

Table 33. Grower survey results in 2001. Willingness to implement a BMP if they knew it worked.

BMP type	% of growers willing to use
Cover ditch	3.7
Move sprinkler	44.8
Subsurface drain pipe	11.1
Hand spray	51.9
Hold water	59.3
Reroute water	53.6
Biofiltration	28.6
Charcoal filter	35.7
Low volume sprayer	39.3
Boom sprayer	21.4
Buffer strips	10.7
Low risk products	25
Pump water off site	17.9

Table 34. Grower survey results in 2003. Willingness to implement a BMP if they knew it worked.

BMP	% of growers willing to use			
	Won't use	Might use	Will use in trouble areas	Will use with cost-sharing
Ditch covering	0	22	0	67
Temporary ditch covering	71	14	0	14
Buried drain pipe	38	0	25	25
Biorational insecticides	60	0	20	20
Damming	13	25	63	0
Charcoal filter	67	17	17	0
Thick vine coverage over ditch	38	50	13	0
Hold water in weedy ditch	44	22	33	0
Hold water in clean ditch	29	29	43	0
Pump water off site	67	17	17	0
Hand-spraying along ditch or sump	0	43	57	0

Table 35. Effectiveness of XXXX as a BMP - 2002

Costs, returns and net benefits to cranberry growers implementing selected BMPs.			
	Cost per 1200 foot ditch[1]		
Cost	Crib + cover	Cover only	Buried drain
Labor[2]	3,360	960	2,280
Materials	7,500	1,500	2,592
Total cost to grower without cost sharing[3]	10,860	2,460	4,872
Cost sharing provided by Equip[4]	9,768	1,884	2,880
Net cost to grower with cost sharing (total - cost share)[5]	1,092	576	1,992
Increased cost of production[6]	0	0	0
Increased cost of labor per year [7]	10	10	10
Increased cost of harvest of extra area from bmp strip[8]	15	15	15
Returns			
Labor savings per year, weeding and ditch cleaning[9]	499	499	499
Additional miscellaneous labor savings[10]	200	200	200
Additional crop returns from BMP strip[11]	186	188	286
Benefit to grower per year for BMP implementation[12]	860	860	960
Net Benefits			
Net increase to grower over 20 years for implementing BMP (Returns-Cost) with cost sharing[13]	16,105	16,625	17,204
Net increase to grower over 20 years for implementing BMP (Return-Cost) with no cost sharing[14]	6,337	14,737	14,324

[1] 1200 foot ditch is average length of a cranberry drainage ditch in Grayland.

[2] In all calculations, grower time was estimated at $20/hour, and hired labor at $15/hour.

[3] Cost to grower/foot*1200 feet

[4] Cribbing + cover = $6.57/ft for cribbing and $1.57/ft for cover

[5] Difference between total cost and cost sharing.

[6] Includes additional inputs like fertilizer and pesticides etc. It was assumed no additional fertilizer or pesticide inputs were required.

[7] Assumes it takes an extra ½ hour/1200' strip/year for weeding, hand spraying & maintaining bmp strip at $20/hour

[8] Assumes it takes an extra 1 hour to harvest, haul and clean the extra fruit off the 1200' strip @ $15/hour for labor

[9] Based on average of 20.8 hours from 8 grower surveys and $20/hour labor.

[10] Based on grower surveys, there were numerous miscellaneous labor savings such as ease of access. An assumption was made that these average out to a labor saving of an extra 10 hours per year @ $20/hour

[11] Data based on grower surveys. This assumes that ditch has cranberries only on one side. Cranberries could be grown on both sides, but this was not taken into account in calculations. The increased harvest area for crib + cover, cover only, and buried line was 1.3, 1.3 and 2 ft^2 per linear foot of ditch, for crib and cover, cover only and buried pipe respectively. The yield was assumed to be 150 bbl/acre @ $35/bbl.

[12] Benefit to grower = labor savings + yield - increased costs

[13] Benefit per year * 20 years- the total cost per grower with cost sharing

[14] Benefit per year * 20 years- the total cost per grower without cost sharing

FUTURE BENEFITS WITH DIFFERENT COST SHARING BUT SAME SALARIES ETC.

Table 36. Effectiveness of XXXX as a BMP – 2002

Costs, returns and net benefits to cranberry growers implementing selected BMPs.			
	Cost per 1200 foot ditch[1]		
Cost	Crib + cover	Cover only	Buried drain
Labor[2]	3,360	960	2,280
Materials	11,250	2,250	3,888
Total cost to grower without cost sharing[3]	14,610	3,210	6,168
Cost sharing provided by Equip[4]	11,475	3,600	2,376
Net cost to grower with cost sharing (total - cost share)[5]	3,135	-390	3,792
Increased cost of production[6]	0	0	0
Increased cost of labor per year [7]	10	10	10
Increased cost of harvest of extra area from BMP strip[8]	15	15	15
Returns			
Labor savings per year, weeding and ditch cleaning[9]	499	499	499
Additional miscellaneous labor savings[10]	200	200	200
Additional crop returns from bmp strip[11]	186	186	286
Benefit to grower per year for BMP implementation[12]	860	860	960
Net benefits			
Net increase to grower over 20 years for implementing BMP (return-cost) with cost sharing[13]	14,062	17,587	15,404
Net increase to grower over 20 years for implementing BMP (return-cost) with no cost sharing[14]	2,587	13,986	13,028

[1] 1200 foot ditch is average length of a cranberry drainage ditch in Grayland.

[2] In all calculations, grower time was estimated at $20/hour, and hired labor at $15/hour. This is unchanged.

[3] Cost to grower/foot*1200 feet

[4] Cribbing + cover = $6.56/ft for cribbing and $3.00/ft for cover

[5] Difference between total cost and cost sharing.

[6] Includes additional inputs like fertilizer and pesticides etc. It was assumed no additional fertilizer or pesticide inputs were required.

[7] Assumes it takes an extra ½ hour/1200' strip/year for weeding, hand spraying & maintaining bmp strip at $20/hour. This is unchanged.

[8] Assumes it takes an extra 1 hour to harvest, haul and clean the extra fruit off the 1200' strip @ $15/hour for labor. This is unchanged.

[9] Based on average of 20.8 hours from 8 grower surveys and $20/hour labor. This is unchanged.

[10] Based on grower surveys, there were numerous miscellaneous labor savings such as ease of access. An assumption was made that these average out to a labor saving of an extra 10 hours per year @ $20/hour. This is unchanged.

[11] Data based on grower surveys. This assumes that ditch has cranberries only on one side. Cranberries could be grown on both sides, but this was not taken into account in calculations. The increased harvest area for crib + cover, cover only, and buried line was 1.3, 1.3 and 2 ft^2 per linear foot of ditch, for crib and cover, cover only and buried pipe respectively. The yield was assumed to be 150 bbl/acre @ $35/bbl. This is unchanged.

[12] Benefit to grower = labor savings + yield - increased costs

[13] Benefit per year * 20 years- the total cost per grower with cost sharing

[14] Benefit per year * 20 years- the total cost per grower without cost sharing

Objective 3: Implement and monitor BMPs that have been previously developed and shown to be effective on a small scale but are currently not being used at the farm level.

Gibberish below here.
Relate results to those of previous studies in the area and discuss their relevance to future BMP implementation and subsequent water monitoring plans.

What went on in previous studies in previous years?
Over the acceptable limits in previous years?
Runoff study indicates that even if the BMPS work, more needs to be done

TELL HOW THE LOW FLOW CONDITONS AND THE HIGH FLOW CONDITIONS WERE DIFFERENT ACCORDING TO YOUR DATA THAT YOU TOOK. TELL HOW THE WATER LOOKED DIFFERENT AT LOW FLOW CONDITIONS.
DETAIL THE DATA TO INDICATE THE HIGH AND LOW FLOW WATER FLOW WAS DURING 2004.
Objective 2:

Rather, the median average, frequency and degree or range that target analyses depart from water quality criteria can be presented and discussed.

Literature cited:
Field locations : 2003 Duncan Allens Sump

(1997). The Shoalwater Bay Indian Reservation – A Limited Environmental Assessment 1994-1995, EPA.

F. D. Wilde, D. B. Ratke, J. Gibs and R. T. Iwatsubo) (1999). Collection of Water Samples In USGS National Field Manual for the Collection of Water -quality Data Book 9, USGS.

Anderson, P. and D. Davis (2000). Evaluation of Efforts to Reduce Pesticide Contamination in Cranberry Bog Drainage, Washington State Department of Ecology, Ecology Publication no. 00-03-041: 16pp. + Appendices.

Davis, D. (2000). Washington State Monitoring Program: 1994 Surface Water Sampling Report, Washington State Department of Ecology: 96-305.

Davis, D., D. Serdar and A. Johnson (1997). Assessment of Cranberry Bog Drainage Pesticide Contamination, Washington State Department of Ecology: Ecology Publication No. 97-329: 97-329 pp.

References

Anderson, P. and D. Davis (2000). Evaluation of Efforts to Reduce Pesticide Contamination in Cranberry Bog Drainage, Washington State Department of Ecology, Ecology Publication no. 00-03-041: 16pp. + Appendices.

Booth, S. R., B. Maupin and K. Patten (2000). Evaluation of Biorational Insecticides to Manage Cranberry Insect Pests in Washington State. Wareham, MA, The Cranberry Institute: 57-88.

Davis, D. (1998a). Washington State Pesticide Monitoring Program, Washington State Department of Ecology: Ecology Publication No. 98-300: 22p.+ appendices.

Davis, D. (1998b). Washington State Pesticide Monitoring Program: 1996 Surface Water Sampling Report: Ecology Publication No. 98-305, Washington State Department of Ecology: 16pp. + appendices.

Davis, D. (2000). Washington State Monitoring Program: 1994 Surface Water Sampling Report, Washington State Department of Ecology: 96-305.

Davis, D., D. Serdar and A. Johnson (1997). Assessment of Cranberry Bog Drainage Pesticide Contamination, Washington State Department of Ecology: Ecology Publication No. 97-329: 97-329 pp.

Frantz, W. T., T. Bicki, K. Talbot and E. Unruh (1996). Grayland Washington BMP Evaluation Study - Rb Cl Tracer Study, Cranberry Institute, Wareham, MA.

Wilde, F. D., D. B. Ratke, J. Gibs and R. T. Iwatsubo) (1999). Collection of Water Samples In USGS National Field Manual for the Collection of Water -quality Data Book 9, USGS.

Wood, B. (1997 Preliminary Report - Laboratory and In-situ acute toxicity of Grayland Drainage Ditch - 1 Water to Daphnia-Pulex). Washington State University, Entomology/Environmental Toxicology Program, Puyallup Washington.