

**Final Report for
BMPs for Cranberry Farms Grant No. G0200278**

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Natural Resources Conservation Service (Carl Boyd and Mike Kellogg)

Pacific Conservation Service (Mike Johnson)

Ocean Spray Cranberries Inc.

Washington Cranberry Alliance

Grayland Cranberry Growers Association

EXECUTIVE SUMMARY

Cranberries, a native North American crop, are grown over approximately 1,600 acres of wetland in Washington, mainly in Pacific and Grays Harbor Counties. Washington State Department of Ecology's Pesticide Monitoring Program has consistently detected organophosphate (OP) pesticides in surface water drainage from cranberry farms. As a consequence, these drainage systems were TMDL listed. Because there was a perceived lack of progress by the cranberry industry in reducing pesticides in surface waters, a project was initiated using Clean Water Act Section 319 Non Point Source Funds. The objectives of the project were to assess the problem at the micro-watershed level using GIS, evaluate alternative Best Management Practices (BMPs) and provide outreach and recommendations. Project goals were to reduce surface water contamination and increase grower participation in IPM and BMPs.

GIS analysis indicated that based on linear footage of ditches, six micro-watersheds have been 100% covered by BMPs, eight were more than 90% treated, eight were between 55% and 89% treated, and three were less than 50% treated. Many of the improvements in these watershed BMPs came after 2002. Covered ditches were the preferred method of treatment. 49% of cranberry bed acreage in Grayland areas is or will be 100% subtended by effective (covered or diked) BMPs by 2007.

Several new BMPs were evaluated for efficacy. Vine-overgrowth, temporary ditch covers, hand application technology and floating filter covers were failures or so problematic that they could not be recommended over the current ditch covering. Buried drain lines, holding water structures, and new gear-driven sprinklers were worthy of consideration. In-ditch phyto-remediation and carbon cloth filters will require additional research. Based on grower preference, ditch covering remains the most practical and efficient BMP. Based on a cost-benefit analysis, there will be a net financial benefit to growers who implement ditch covering for a BMP.

Results from water quality monitoring of contained on-farm surface water indicated exponential decay of OP insecticides. Monitoring conducted off-farm in the main drainage system indicated good progress has been made by the industry (only 1 in 12 samples was above the water quality criteria). Recommendations for future water monitoring are discussed.

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, conducive to cranberry cultivation. As the local industry developed, some local waterways were channeled into a system of canals and waterways. These waterways been divided into 27 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. 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. This cranberry farm drainage system is known collectively as the Grayland Ditch.

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 organophosphates (OP): Diazinon, Lorsban, Guthion and Orthene. 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 and Anderson, 1997; Anderson and Davis, 2000). In 1996, water was sampled near the terminus of both drainage ditches and analyzed for the organophosphate pesticides Diazinon, azinphosmethyl (Guthion) and chlorpyrifos (Lorsban) on several occasions, and for 150 target analyses of other chemical classes during a single sample event (Davis and Anderson, 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 (Bicki et al., 1997; DeMoranville 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 et al., 2000; Patten 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 Native American tribe, the Shoalwater Bay Indian Tribe, had expressed its concern regarding surface water contamination issues. A 1997 EPA Report (US EPA, 1997) recommended that federal regulatory 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 was provided in the EIM database submitted to Department of Ecology.

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 evolved from 2002 to 2005 into a robust source of geographic information. This collection of geographic themes 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 was taken to assure these spatial data were among the finest available. The collection of thematic data included 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 served as a source of information that was 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 was the bog attribute table. It has been enhanced by turning it into a static rollback (temporal modeled) database, whereby the theme was measured in three different time periods. This data model was useful when determining, among other things, year to year changes in the status of cranberry bogs.

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 were useful to determine the measured position of any sample taken along a major surface water feature. Routing provided greater connectivity among 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 was more generously preserved, more accurate, and allowed greater amounts of more sensible information to be available to the user. Three questions were addressed with this data layer:

1. Where was the sample taken?
2. Where did the water originate 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, it was combined with 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, adds inherent functionality that was practical for this application of spatial data. Combining these linear surface water data with other spatial data, such as 5' cell size gridded elevation, revealed 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 identifications corresponding to Ocean Spray Grower Bed ID numbers.

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, spatial data were collected in a variety of formats from a variety of sources. Among these were both paper maps and digital data. One piece of information in particular was obtained from the Ocean Spray 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. 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 were 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 contained 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 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.

Analyte	Quantification Limit (mcg/L, ppb)		Criteria (mcg/L, ppb)
	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 was expressed in terms of Percent Recovery (%R) of matrix spikes for each compound tested. Additional internal laboratory QA procedures included daily calibration. Field quality assurance procedures included 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 randomly chosen samples, 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: In 2002 and 2003 flow readings were taken using a Global Water Flow Probe with a propeller sensor. In 2004 flow readings were taken using a Marsh-McBirney Model 2000 Flo-Mate that utilized magnetic meters for sensing difference in water pressure as water flowed around a sensor. Flow readings were taken when water samples were collected, and seasonally at many of the key culverts that bisected the Grayland drainage system. Data are reported in ft³/sec and gallons per minute (gpm). For comparative purposes, relative flow rates were recorded in the summer of 2004 for all drainage ditches in the system (dry, standing water (no flow), very slight flow, low flow, medium flow, fast flow).

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 also 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*” (Patten 2003) and WSU Statewide Water Quality meetings. Several on-site tours were also provided for stakeholders from SBIT, Washington Department of Ecology and Washington Department of Agriculture.

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 Pacific Conservation District (PCD), Natural Resource Conservation Service (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 AND DISCUSSION

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 graphic overview by watershed showing 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 and presented in the Appendix. A numerical summary of BMP mapping results by watershed are provided in Table 2. Based on a linear foot of ditch analysis, several watersheds (4, 6, 16, 17, 23, 26) have been 100% 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 projects completed to date, 57%, 3%, and 11% are covered ditches, buried pipe and diked beds, 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 3). This analysis only considers a bed completely covered with BMPs if all sides of the beds have been treated. This assessment concludes that 49% of cranberry bed acreage in Grayland areas is or will be 100% subtended by effective (covered or diked) BMPs by 2007 (closing date for the Environmental Quality Incentives Program (EQIP) contract). 4% of the acreage is abandoned and the remaining 47% remaining beds still needs at least one or more of their surrounding ditches to be treated with BMPs. This latter 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 4. What is important to note in this table, is that these differences by year largely reflect the availability of EQIP money for cranberry BMPs in each of the different years.

Additional information is provided across the watershed by locations for relative summer water flow in 2004, flow direction, contours, water quality sampling, ditch discharge flow, sampling sites and ownership (tax lots) (Table 5, Figures 4, 5, 6, 7 and 8). More detailed information on this data can be found by individual beds in the appendix.

This flow data is useful in interpreting 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 flowing through them all summer long. It is very important to note that water flow for all ditches in Grayland is dynamic. It goes from dry or almost non-existent to a very high flow based on the time of year. This has a lot of implications for water quality.

By assessing watersheds and beds on an individual basis for BMP coverage, as well as stream flows and the previous water quality 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 considerably more BMP coverage. Because of the complexity of the model, we were able to document how much a single contaminated ditch leads to a TMDL violation of the main ditch. One or two problem sites are likely to be more than adequate to maintain the TMDL listing of the main drainage ditch. Thus these watersheds (18 and 19) could constitute higher risk areas that need to be more aggressively funded by EQIP monies. In contrast, the DOE 2003 monitoring data as well as WSU's in 2004 (see table 32) indicate the Grayland Drainage Ditch Number One (northern flowing main ditch) had few problems. This may be due to the high proportion of farms in that regions with BMP treated ditches.

Figure 1. Locations of micro-watersheds within the Grayland cranberry growing area

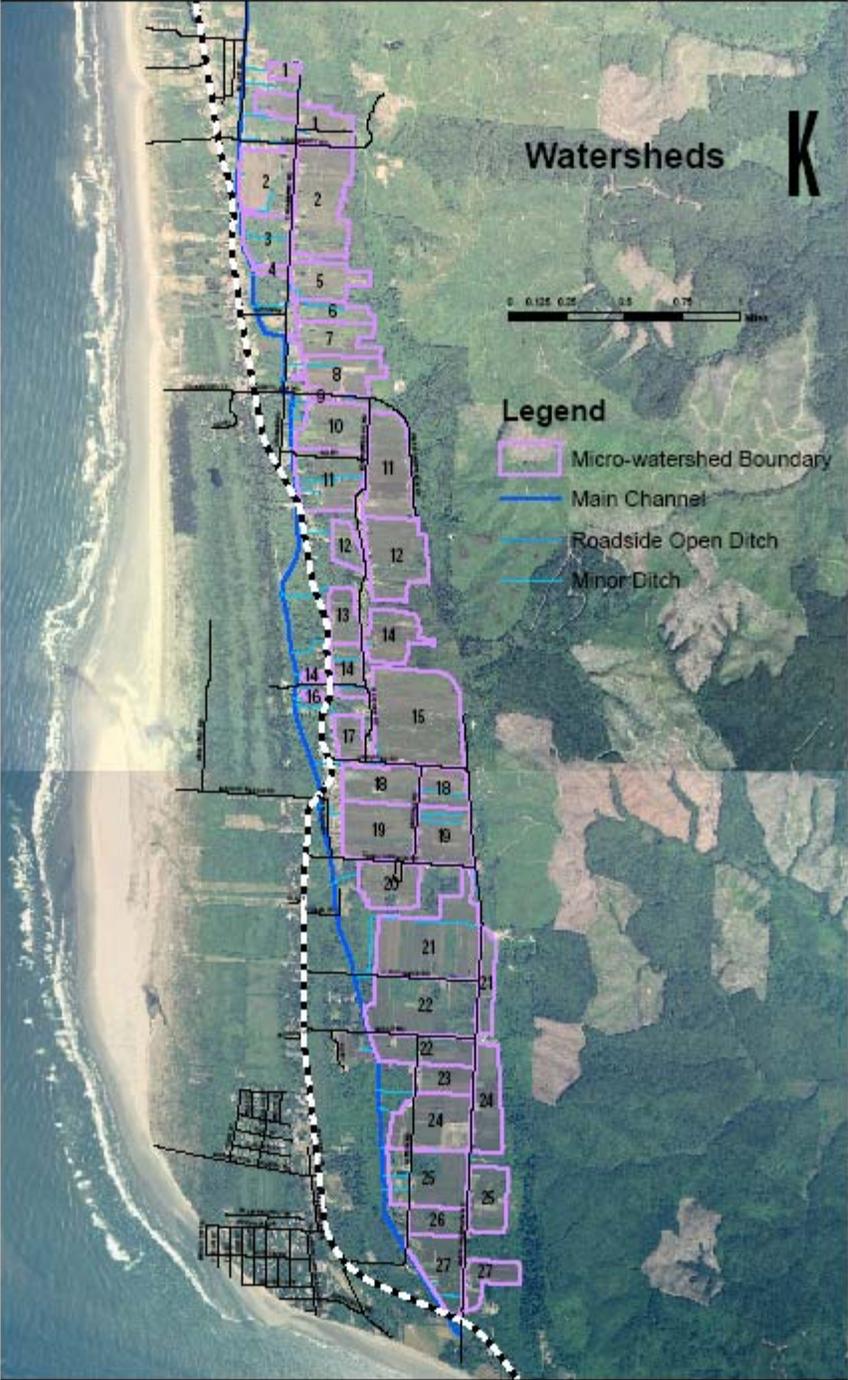


Figure 2. Overall status of the BMPs on cranberry beds in Grayland Washington in 2004

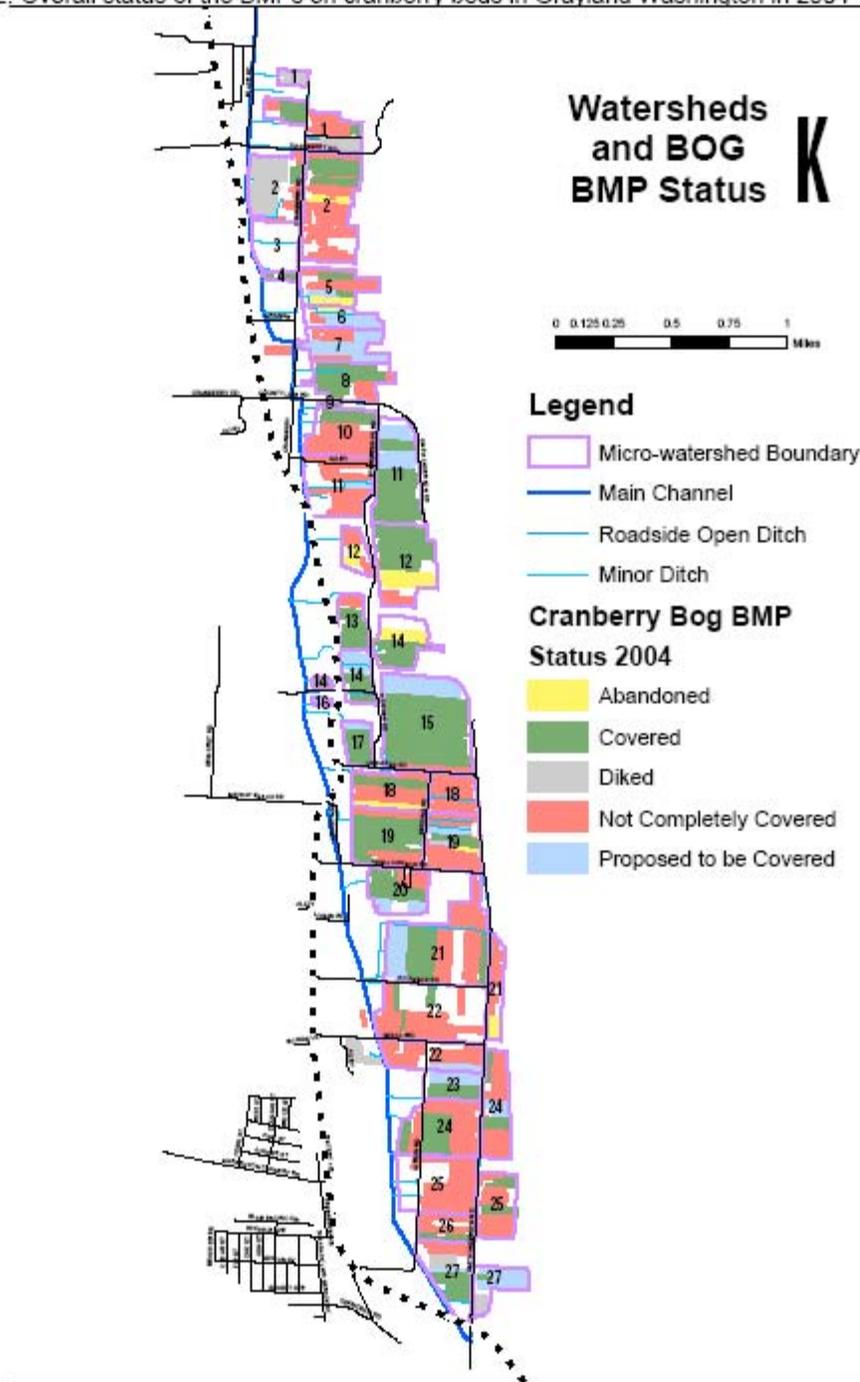


Figure 3. Grayland cranberry BMP status in 2004 by watershed and type of BMP

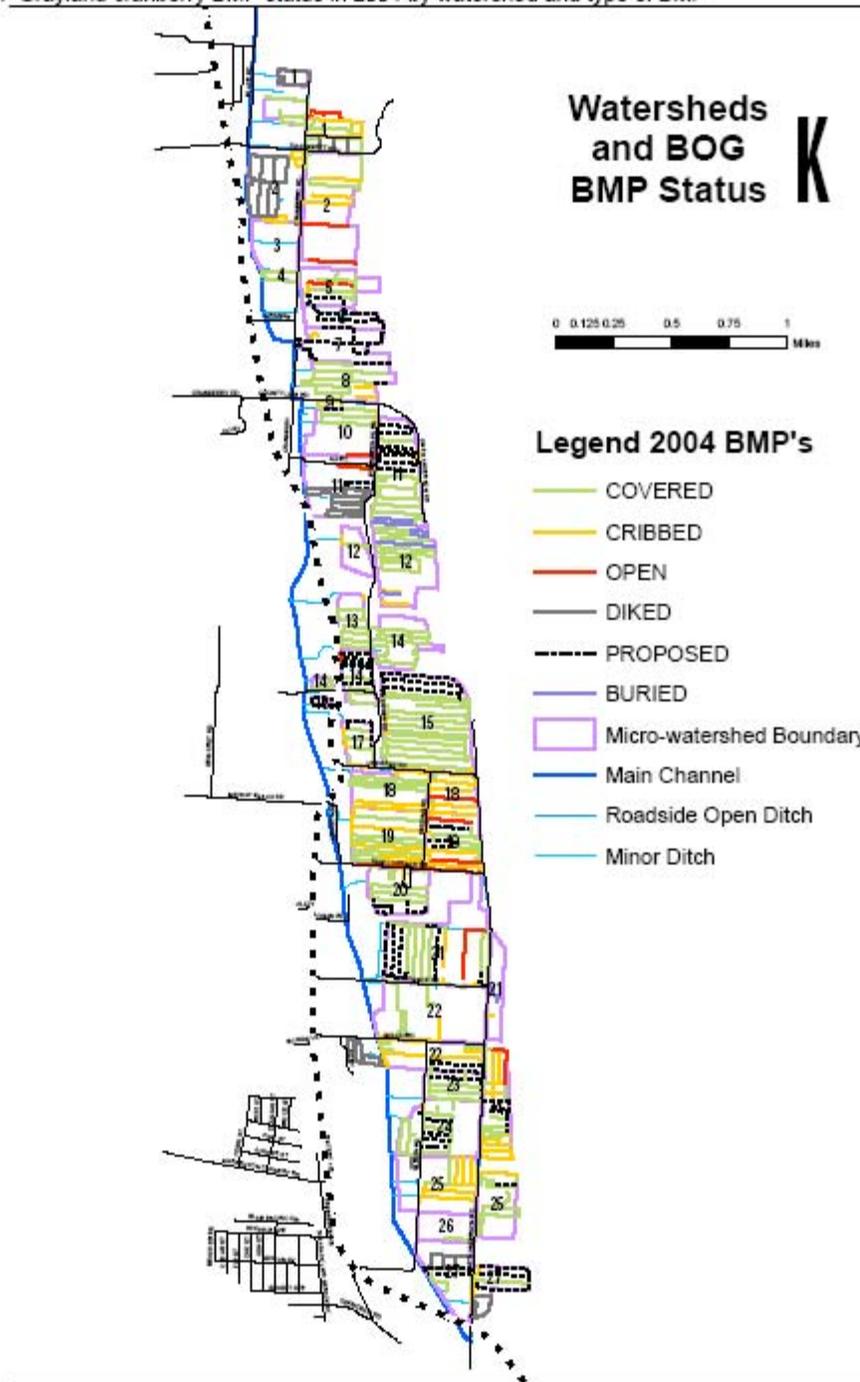


Table 2. Status of Grayland Cranberry ditches in 2004 across each micro-watershed based on linear footage of different types of ditches and percentage of ditches within each watershed covered by a BMP.

BMPs on Grayland cranberry ditches by watershed as a function of BMP type in 2004.								
Watershed	Covered	Buried	Dike	Proposed ¹	Total ditches	Total with BMPs	Ditches with BMPs	Increase in ditches with BMPs 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

¹ Proposed for BMP treatment refers to cranberry beds are under contract with NRCS with dedicated EQIP monies, but the project has not been completed.

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				
Ditch Type	Total acres of bogs ¹	Linear miles of ditch		
	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 ²	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			

¹Surrounded (100%) by specific ditch type

²Proposed for BMP treatment refers to cranberry beds are under contract with NRCS with dedicated EQIP monies, but the project has not been completed.

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

Watershed	Linear feet of BMP					
	Buried			Covered		
	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

Figure 4. Relative flow rates in major drainage ditches in the Grayland cranberry growing area in July and August 2004

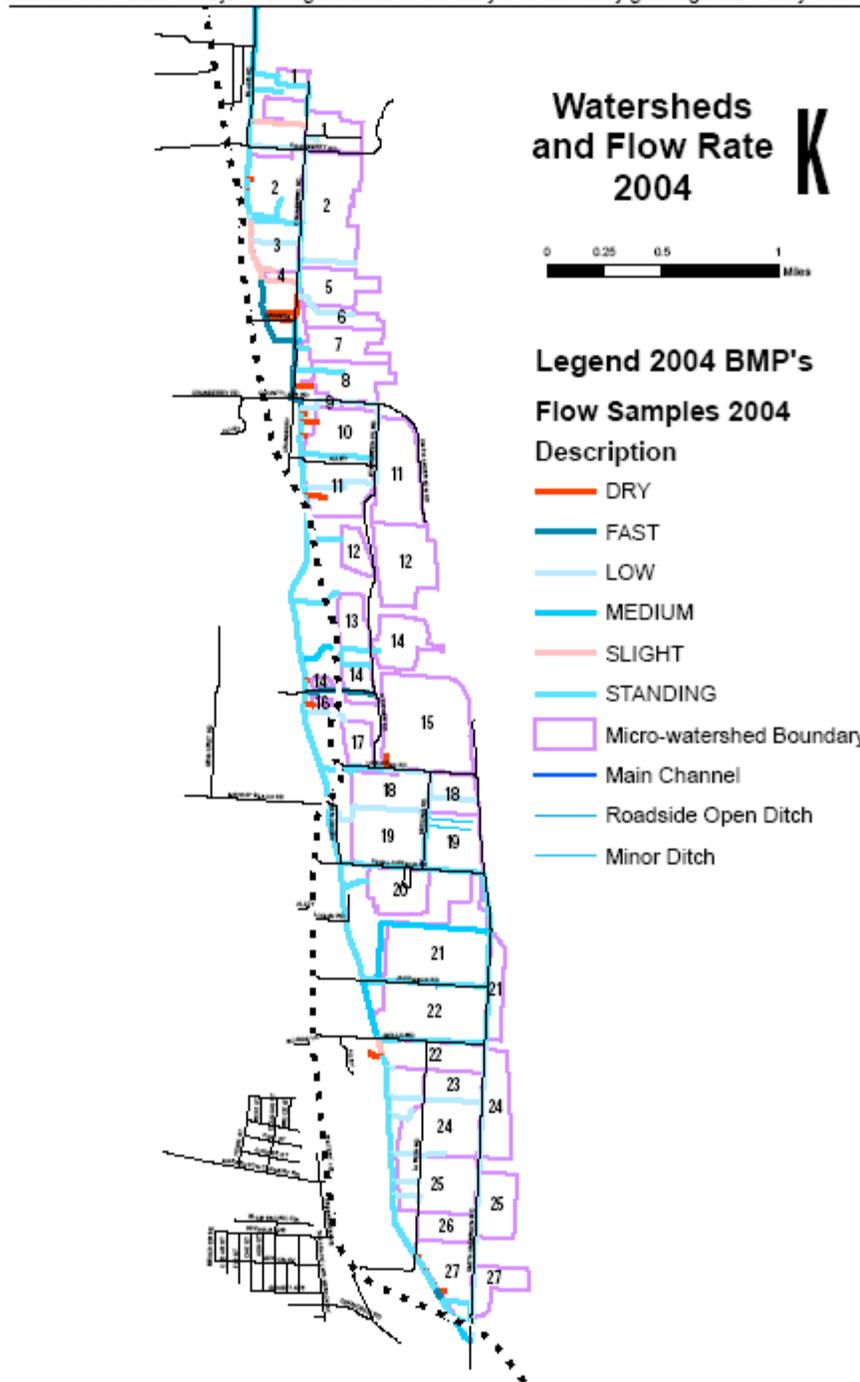


Figure 5. Flow direction of major drainage systems in the Grayland cranberry growing area.

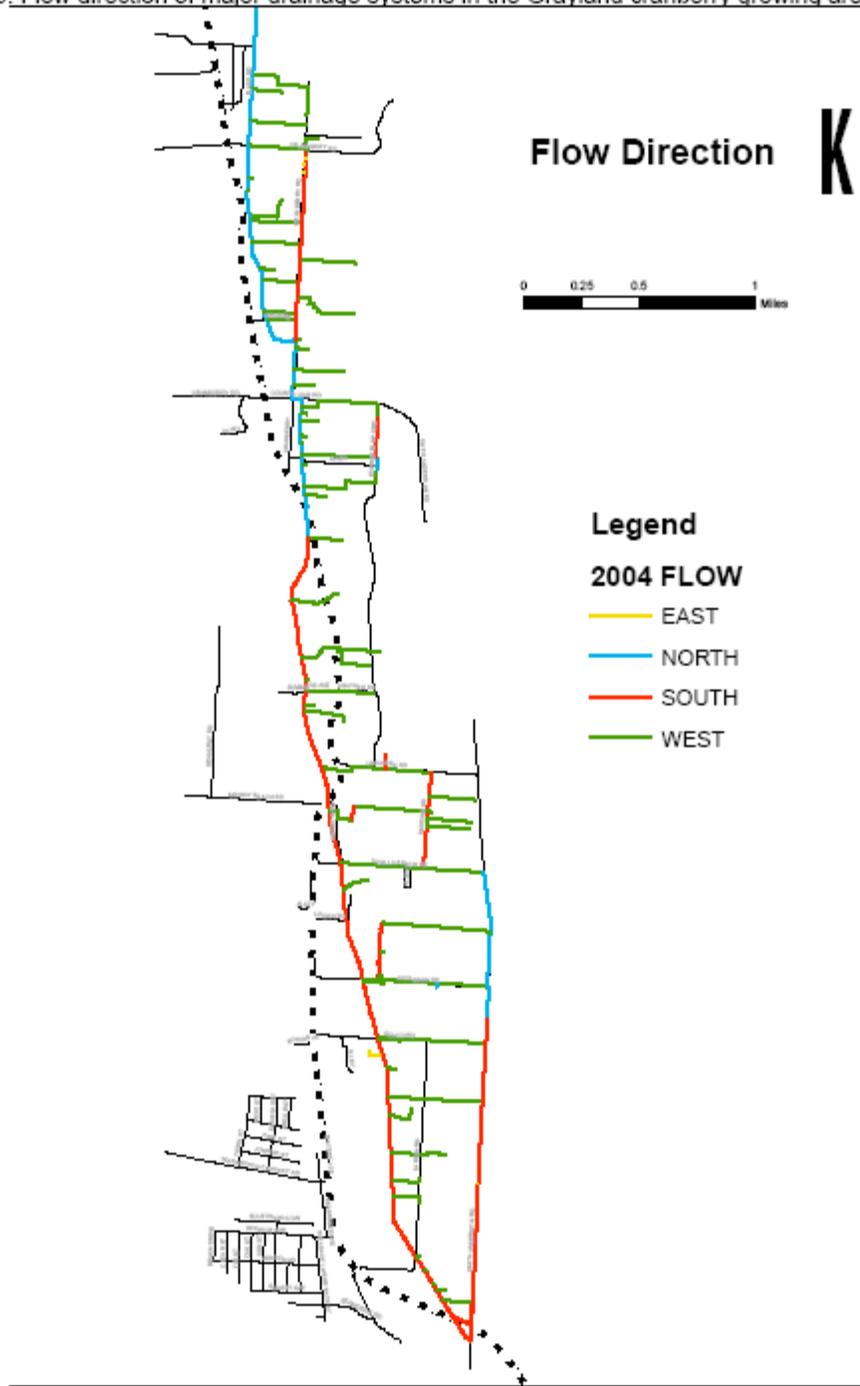


Figure 6. Elevation contours of the Grayland cranberry growing area.

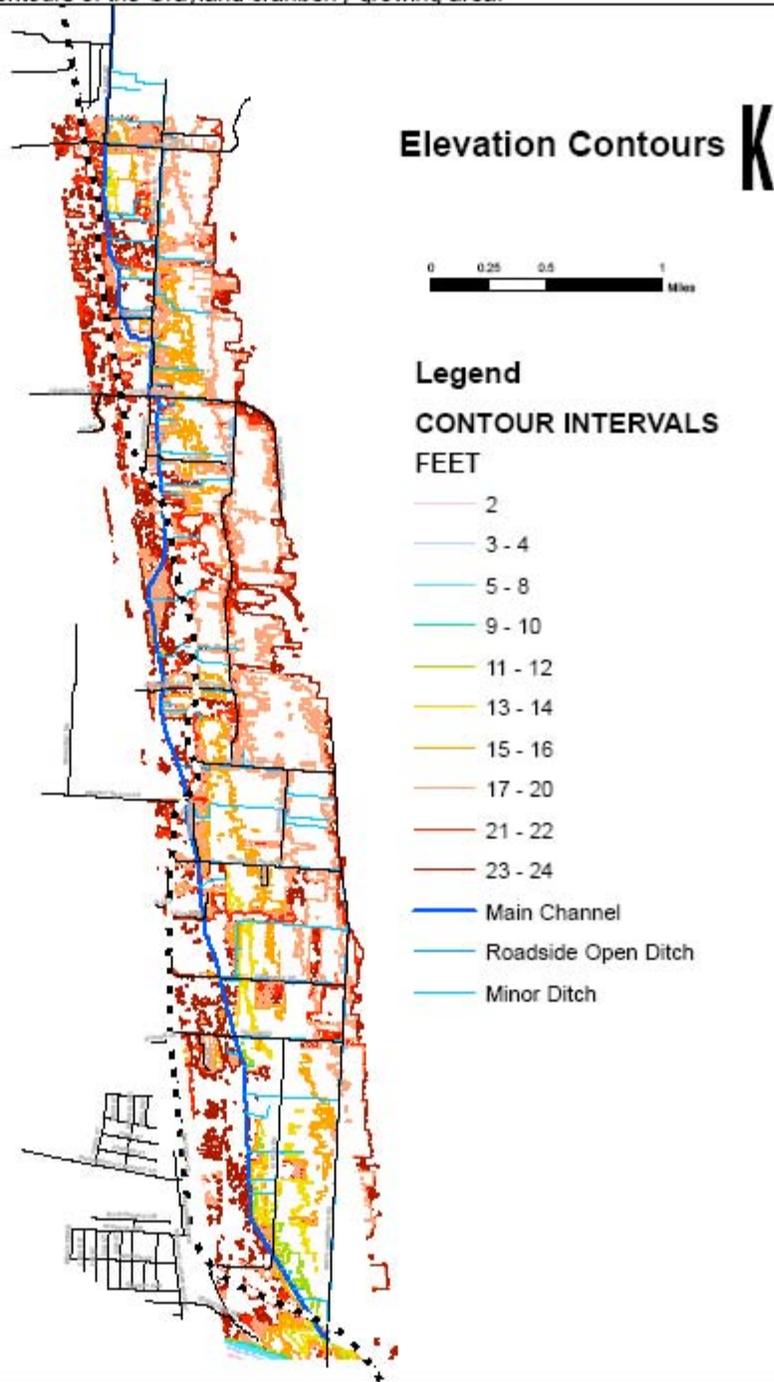


Figure 7. Water quality sample and flow measurement locations used by WSU and DOE

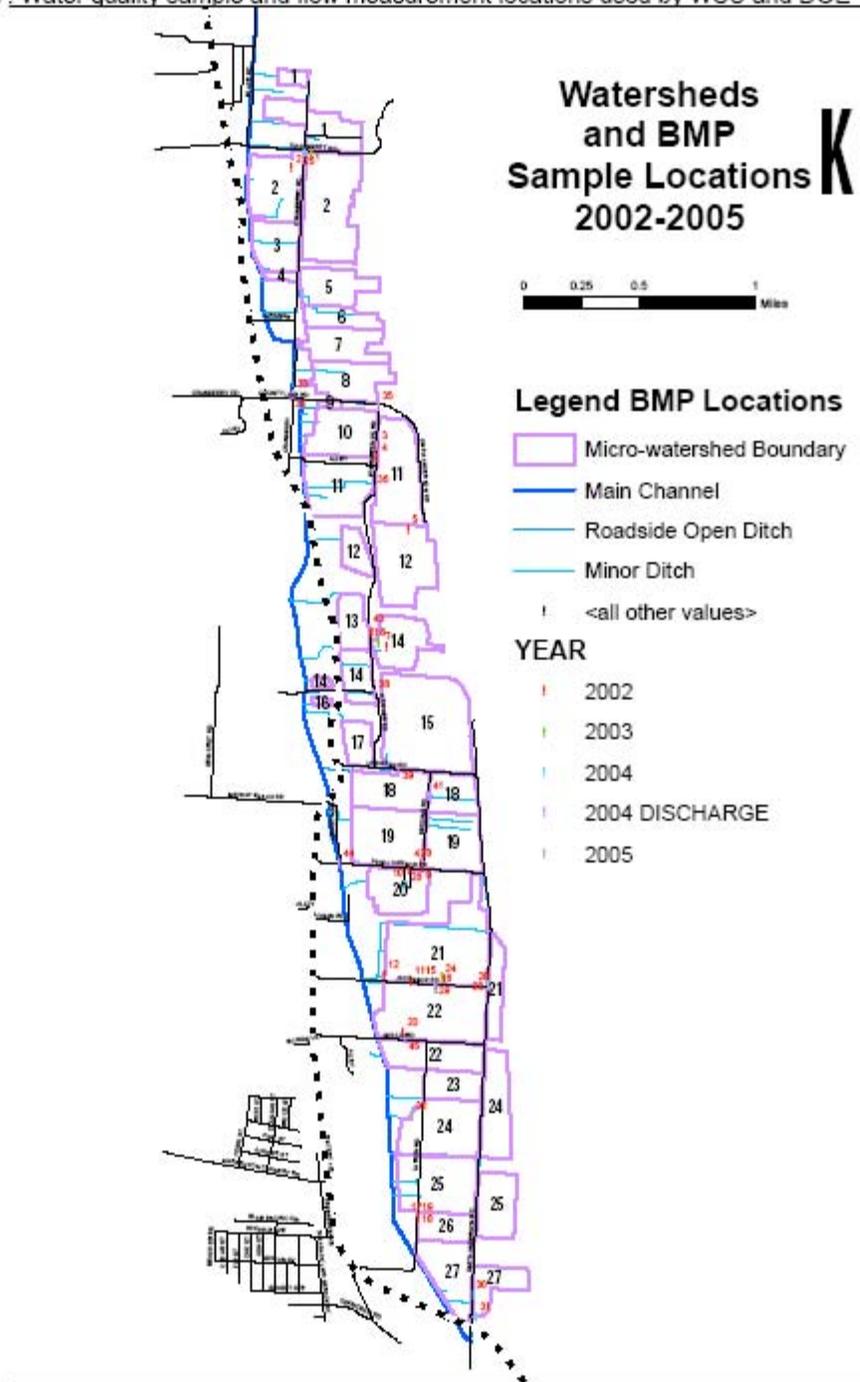


Figure 8. Taxlot information on cranberry beds in Grayland Washington.



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 (see adjacent photo). 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. Although we did not sample enough farm systems with buried drain line to be completely confident in the results, it is likely that this system is overall fairly effective for keeping insecticide 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 $\mu\text{g/liter}$					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

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 (see adjacent photo of site used in Tables 7 and 8). Since this system didn't have any summer flow, monitoring for efficacy in the surface water itself was not feasible. 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 quart 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 and should not be practiced as a BMP.



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 quart 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 $\mu\text{g}/\text{liter}$					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 Road								
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 quart 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 $\mu\text{g/liter}$					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 a field to allow for off-site mitigation (see adjacent photo of sump where water was pumped from and the site to which water was pumped). It was assumed that water flowing from this mitigation field would be free of any pesticides, since it was vegetative shrub land on 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. Unfortunately, obtaining additional monitoring samples was not feasible as this practice was only used by one grower. Despite the lack of positive results, we nevertheless would suspect that the system would be effective. However there are very few sites in Grayland available where this could be maintained as a BMP.



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

BMP type: Offsite pumping								
Location: Jacobson and Gould Roads								
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 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 (see adjacent photo of site) 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 $\mu\text{g/liter}$					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

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 hand sprayer and applying out from the ditch or sump (see adjacent photo of sprayer and sump) 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 favorable results must be viewed with caution. From a practical point of view, most growers are not willing to spray by hand along their thousands of feet of ditch two to four times during the season.

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

BMP type: Hand spraying along the ditch rather than chemigation								
Location: Udel Hansen and Redding Rods.								
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 $\mu\text{g/liter}$					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

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 adjacent photo of floating pad). Different amounts (56 and 113 g/m²) 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. The site also picked up some off-site contamination from a nearby pesticide application event. It can be concluded that these floating covers are not reliable enough to work for growers.



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 selected 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 the adaptation to an existing cranberry production system (see above photo of

sprinkler and monitoring site). 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 the sump during the application event. Thus 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. It should be noted that, in the case of drainage ditches, contaminated water can be avoided by using ditch-covering BMPs. However in areas where sprinklers do hit the water in the sump, covering is not feasible. Under these circumstances, the use of adjustable sprinklers might be an acceptable BMP. Additional efficacy testing by growers should be evaluated.

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: Non impact (no backwash) sprinklers than can be adjusted so that their flow doesn't hit surface water.								
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 the new sprinklers were not adjusted and corrected and some water from the sprinkler pattern still hit the pond. * 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 detectable 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 (see attached photos of all water holding sites). 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 to get to the non-detectable 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 rather than BMP efficacy. In the third site in 2002 (Table 16), a combination sump and ditch system was evaluated. Due to a leaky dam on the ditch end, samples were not collected on the ditch part of the system long enough to make an inference. 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.

Four holding water studies were done in 2003 (see photos of sites). 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) to 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. There was one outlier in the database (Sample 30715-02) which did not fit the general trend for these monitoring sites. If that number is removed (it was suspect), then the decrease in Guthion over time decay followed perfect ($R^2=0.99$) exponential decay (Figure 8).

In another sump where water was held all season and the grower used multiple applications 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 from the north and south sides of the sump. For the most part, the data were very uniform across sampling locations, 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 that the contaminated water seeped 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 BMPs 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 the 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 five days after the application. Once it was detected, it took 7 to 10 days to disappear. The sampling also detected Guthion. Initially we assumed it was from an application made by the neighbor. However, the application timing doesn't correspond to the detection timing. In the second 2004 monitoring site, the ditch holding the water trapped all the runoff water draining from a small, dry, sand-based cranberry bed. Flow of the beds was non-existent unless there was a rain event; thus the monitoring data differ from previous studies.

There was a single hit of Diazinon 12 days after it was applied in April, followed by hits on 52, 59, and 66 days after that (Table 23). Lorsban had hits 3 and 5 days after it was applied. No Orthene was detected after application. Because the volume of water in this ditch varied from

dry to overflowing, the concentration of insecticide in water was very variable and not predictable. It is therefore difficult to make any inferences as to insecticide degradation in water or BMP effectiveness at this site. However, by being able to at least contain the water except for major overflow events, the water holding structure installed by NRCS should be more than adequate for preventing off-site movement of insecticides.

In a similar site (small dry sand bed with dry ditches except for runoff events), insecticide behavior was fairly similar. Lorsban was detected after a major rain event 26 days after application. Diazinon was detected 5 and 10 days after application. There was a single Diazinon hit in mid-May which must have come from an adjacent farm. As with the previous site, the volume of water in this ditch varied from dry to overflowing. This made predictability of the results difficult. Nevertheless, the water-holding structure installed by NRCS should be more than adequate for preventing off-site movement of insecticides.

The last water holding sampling in 2004 was a farm pond that collected insecticides from many adjacent farms and ponds (Table 24). The timeframe for the water to move through the system was unknown and varied based on rainfall. The water level in the pond however was fairly stable over time, thus allowing for more reliable inferences about insecticide behavior. Diazinon was detected 5 days and 1 day after application, and in both cases was gone within 24 hours. Lorsban was detected 1 day after application. Its disappearance over time followed exponential decay (Figure 8). Orthene was applied, but as with previous monitoring results was not detected. There was also a Guthion detection on June 23 and 29, even though none was used. This must have come from contamination from an adjacent farm. Guthion was not detected after those dates (19 days later).

Although it was very difficult to get good clean data and clear consistent results from our monitoring data in the holding water studies, several conclusions can be made:

1. In circumstances when the monitoring data was not confounded by other variables, like changes in volume or off-site contamination or additional insecticide application, there was a general trend of an exponential decay pattern. Depending on the initial level of contamination, it generally took from 2 to 3 weeks to more than 1 month before the insecticide was no longer detectable in the sample. Based on the type of water-holding structure that a grower has, this length of water holding may or may not be feasible.
2. Prediction of contamination is difficult. Our data showed that there are often all sorts of anomalies that are likely to occur. This includes contamination from adjacent or even non-adjacent farms, unanticipated long or short half-lives, and erratic shifts in concentrations due to changes in water volume or flow.
3. The time frame when contamination can first be expected can range from minutes to weeks depending on storm events and water flows. In general, for the three insecticides that have been problematic in the Grayland Ditch (Diazinon, Lorsban and Guthion) a holding time of three weeks would provide enough buffer time to reduce off-site movement of insecticide. This is considerably longer than what is recommended on the label for cranberry applications (holding time of 3 and 5 days for Diazinon and Lorsban, respectively). Additional research should be

considered that addresses factors such as aquatic weeds that affect the variation in aquatic half-life in Grayland cranberry sumps and ponds.





Table 21



Table 22



Table 23



Table 24

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 $\mu\text{g/liter}$					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 $\mu\text{g/liter}$					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

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 Roads.								
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 Roads								
Date: 6/2/03 to 6/17/03 and 7/11/03 to 7/8/05/03								
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 $\mu\text{g/liter}$					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 Roads								
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 $\mu\text{g/liter}$					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
7/15/03	1526	after	140	NA	ND	ND	ND	30715-01*
7/15/03	1536	after	1.7	NA	ND	ND	ND	30715-02*
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*
8/05/03	1127	after	ND	NA	ND	ND	ND	30805-02*
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 9. Guthion decay in a cranberry drainage ditch in 2003

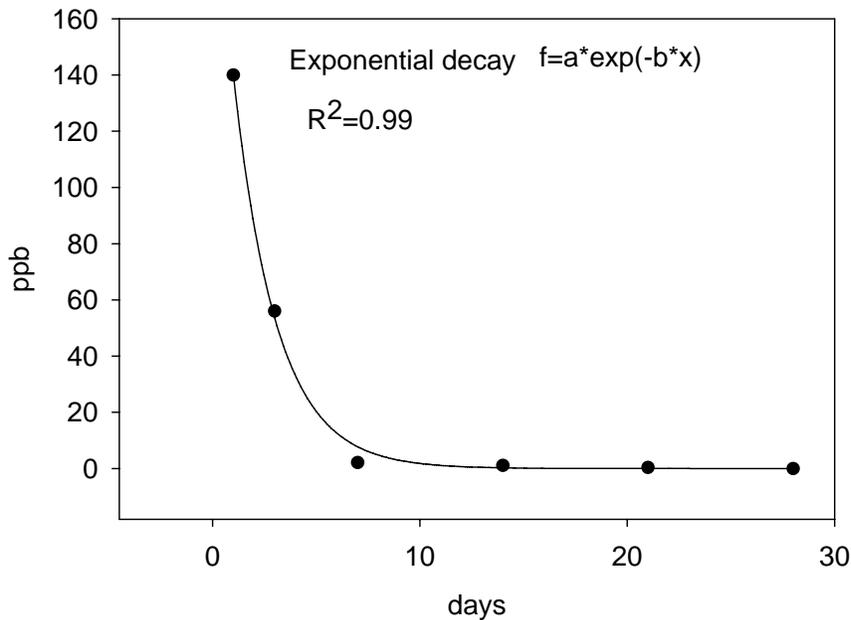


Table 19. Effectiveness of holding water in a pond as a BMP in 2003.

BMP type: Holding water in pond						
Location: Jacobson Road						
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 20. Effectiveness of holding water in ditch as a BMP in 2003.

BMP type: Holding water in ditch								
Location: Smith Anderson and Jacobson Roads								
Date: 5/30/03 to 6/17/03								
BMP Details: A plywood and sandbag dam was built 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 valve. Water was completely contained within ditch.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration $\mu\text{g/liter}$					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 21. 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 Road 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 $\mu\text{g/liter}$			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 (3 rd app.)	ND	NA	ND	40622-01
6/23/04	1120	1 day after (3 rd app.)	ND	NA	ND	40623-10
6/24/04	0915	2 days after (3 rd app.)	3	NA	ND	40624-01
6/29/04	1135	7 days after (3 rd app.)	3	NA	10	40629-03*
7/06/04	1130	4 days after (4 th app.)	2	NA	ND	40706-04*
7/07/04	1705	5 days after (4 th app.)	ND	NA	5	40708-08*
7/18/04	1500	20 days after (4 th app.)	ND	NA	N	40720-01*
7/30/04	1335	28 days after (4 th 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 22. Effectiveness of holding water in a dammed ditch as a BMP in 2004 (Larkin Road).

BMP type: Holding water								
Location: Larkin Road.								
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 $\mu\text{g/liter}$					Sample ID
			Guthion	Lorsban	Diazinon	Imidan	Orthene	
4/29/04	0850	before	ND	NA	ND	ND	ND	40430-02
5/01/04	0800	1 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	12 days	ND	NA	9.6	ND	ND	40512-03
5/19/04	1530	19 days	ND	NA	ND	ND	ND	40519-01
5/24/04	1230	3 days	1.8	NA	ND	ND	ND	40525-01
5/25/04	1200	4 days	ND	NA	ND	ND	ND	40525-06
5/27/04	1230	5 days	7	NA	ND	ND	ND	40527-04A
5/27/04	1233	5 days	8	NA	ND	ND	ND	40527-04B
6/22/04	1000	52 days	ND	NA	2	ND	ND	40622-03
6/29/04	1225	59 days	ND	NA	4	ND	ND	40629-05*
7/06/04	1225	66 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).								

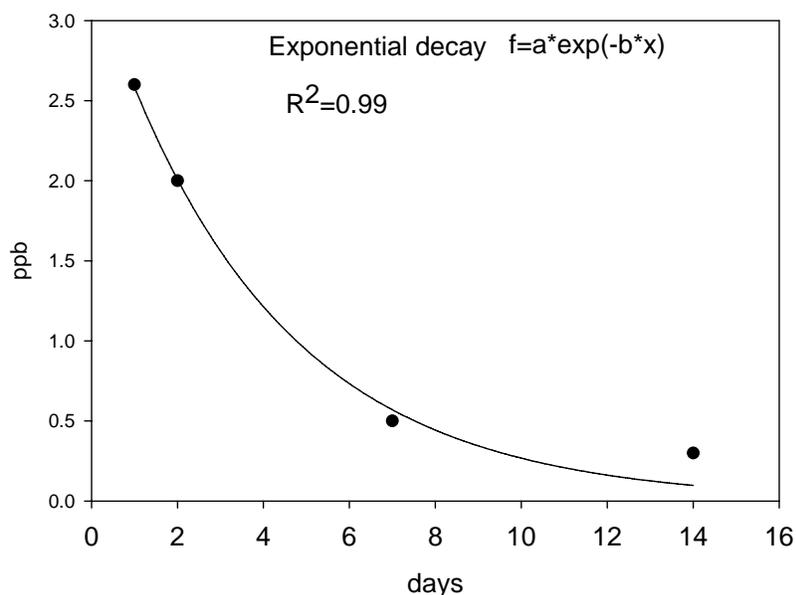
Table 23. Effectiveness of a dammed ditch as a BMP in 2004 (Jacobson Road)

BMP type: Holding water								
Location: Jacobson and Smith Anderson Roads								
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 $\mu\text{g/liter}$					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
<p>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).</p>								

Table 24. Effectiveness of holding water in a pond as a BMP in 2004.

BMP type: Holding water								
Location: Turkey and Cranberry Roads								
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).								

Figure 10. Lorsban decay in a cranberry pond in 2004



Activated Carbon filters: Two different sets of monitoring studies were done using activated carbon. In 2002, we utilized a system installed by a grower which contained charcoal pellets in a small ditch with a good water flow (Table 25) (see photo of filter and site). Before and after samples indicated that the filter reduced the amount of Guthion in the water by about half. The amount of Guthion in the water after the filter, however, was still many orders of magnitude about the critical level. In 2004, a series of monitoring studies was done using carbon filter cloth (Calgon Zorflex Activated Carbon Cloth - FM1/250) (see photos).

These were installed over small drainage culverts or across small impoundments and water was allowed to slowly move through them. In the first study, two layers of cloth reduced Guthion from 18 to 11 ppb (Table 26). In the second study, 3 and 6 layers of cloth reduced Guthion from 2 to 1 and 0.5 ppb, respectively, but it didn't have much effect on Diazinon (Table 27). In the third study Guthion was reduced from 1.7 to 1.28 to 0.78 to 0 with 0, 3, 6 and 10 layers of cloth, respectively (Table 28).

None of these studies was conducted over a long enough period of time to indicate how the product would maintain its efficacy over the season. A simulated farm pond monitoring study was set up in January 2005 to determine that effect. Water was spiked with Diazinon and then allowed to flow through 5 layers of cloth. We were hoping to detect a gradual decline of efficacy over time; however, the results varied too much and there was no pattern (Table 29). This might be due to the fact that the cloth only seemed to work on Guthion, not Diazinon. This is not what would be expected based on the higher Koc values for Diazinon than Guthion (Table 30).



Table 25. Effectiveness of activated carbon filtration as a BMP in 2002.

BMP type: Activated carbon filtration							
Location: Evergreen Park Road							
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 snugly 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 immediate after a spray event.							
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter				Sample ID
			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 had a fast flow of water during the sample event. The filter had to have minimal resistance to flow to prevent backup and overflow.							

Table 26. Effectiveness of activated carbon filtration as a BMP in 2004

BMP type: Activated carbon filtration								
Location: Turkey and Cranberry Roads								
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.								
Sampling date	Sampling time	Sample descriptor	Pesticide concentration µg/liter					Sample ID
			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 27. Effectiveness of activated carbon filtration as a BMP in 2004.

BMP type: Activated carbon filtration					
Location: Between Logan Rd. and Udel Hansen Road					
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 the filter 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

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

BMP type: Activated Carbon Filtration						
Location: Between Logan Road. and Udel Hansen Road.						
Date: 7/21/04						
BMP Details: Calgon Zorflex Activated Carbon Cloth - FM1/250						
Pesticide application details: This was a dammed ditch which contained 1.7 ppb of 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 ahead of and behind the filter 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 $\mu\text{g/liter}$			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

Table 29. Effectiveness of activated carbon filtration as a BMP in 2005.

BMP type: Charcoal filter cloth				
Location: North Larkin Road				
Date: 1/13/05				
BMP Details: pond water was spiked with Diazinon ~250 ppb and run through 5 layers of charcoal cloth filter. Sample was 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 $\mu\text{g/liter}$	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 30. General physical property data of common cranberry insecticides related to water contamination potential (PAN Pesticides Database).

Properties	Insecticide				
	Diazinon	Guthion	Lorsban	Orthene	Imidan
Water solubility (mg/l)	60	28	1.4	818,000	20
Adsorption coefficient (Koc)	1581	882	125	3	5,807
Hydrolysis (days)	138	19	58	169	0.4
Aerobic soil half-life (days)	40	44	113	3	7

Assessment of quality control of our water quality monitoring data: This study followed the QAPP closely. The full data set has been provided to DOE. Nevertheless there were several problems with the data. Flow data was often incomplete because there was no flow at the site. The concern about the effect of confounding factors (adjacent farm contamination, volume changes etc.), as previously discussed, made some inferences difficult. Samples at the laboratory approved for this study were often held beyond the standard times required by EPA. It is uncertain how much this affected the results, but any sample ID noted with a * should be considered suspect. However, the data from the vast majority of samples that were held beyond the recommended holding time do not appear to be spurious or outlier to the rest of our monitoring data. Therefore, for the purpose of making recommendation on BMPs it is not too likely that these suspect data would have changed any of our final inferences.

In a few instances there were communication mixups at the laboratory regarding the analysis of Lorsban instead of Guthion and Diazinon, so some a wrong analysis was conducted on some samples. However, in general, duplicate samples run throughout this study came out very close to each other (see Tables 22 & 23) and samples taken from different locations within the same pond came out very close to each other (see Table 20). Blind field samples located in an area where there were no farms came out with zero detections (Table 31).

Table 31. Blind field samples taken while monitoring BMPs in 2003

Sampling date	Sampling time	Pesticide concentration µg/liter					Sample ID
		Guthion	Lorsban	Diazinon	Imidan	Orthene	
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

Monitoring data of main ditch: In 2004 the location of our blind field samples was in the main ditch at Cranberry and County Line road. The results indicated only one sample violated TMDL standards for Lorsban in May. The remaining samples were all below the detection level. This data is particularly valuable as it is the first continuous monitoring of the main ditch that has been done during the entire spray season. The low level of insecticide in the north flowing ditch is an indicator that the wide-spread adoption of BMPs by growers is beginning to show positive effects. Specifically, water monitored at this site came from micro-watersheds 10, 11 and 12, which had 87, 94 and 91% of their ditches treated with BMPs.

Table 32. Blind field samples taken while monitoring BMPs in 2004.

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 was collected from the 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 a site previously monitored by DOE. * Signifies that this water sample exceeded the EPA recommended holding time before extraction (7 days) or after extraction (40 days).								

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

Education and outreach programs were provided in various formats throughout the course of this study to growers, tribal members, regulatory agencies, educators, legislators, and the general public. Attempts were made to engage regulatory agencies as part of this outreach program. One on one outreach was generally the most productive format. It retrospect, getting better participation from state regulatory agencies in outreach/education would have improved the impact of our program. Without continued regulatory outreach in tandem to our effort, it is difficult to convince the entire grower community that the problem was/is real. Temporarily (1-2 weeks) exceeding the surface water quality standards for aquatic invertebrates by a very small amount (< 1ppb) is conceptually difficult for an industry to perceive as a real problem, when they are losing the family farms because of a downturn in the price of cranberries.

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.

Surveys were used to assess growers' perception of this issue and their willingness to adopt BMPs. Prior to the start of this program, growers were willing to mainly use low cost BMPs (move sprinklers, hand spray, hold water) (Table 33). Very few (4%) were willing to cover

ditches. A survey taken in 2003 indicated that if cost-share money was provided, ditch covering was the preferred BMP (Table 34). Without cost-sharing, damming and hand-spraying were the preferred BMPs. This survey also indicated that there are several BMPs that growers don't really care for and it would take a significant educational effort to get them to use them, even if they had been proven to be effective. This included the use of biorational insecticides, charcoal filters, temporary ditch covers, and pumping water off-site. This bias against these specific BMPs is based on previous negative experiences growers had when they used them.

Several aspects of this project became very apparent, based on feedback from the grower community. For growers to implement water quality BMPs, the problem must be perceived as real, the BMP must be practical to implement and have proven efficacy, and the BMP must be cost-effective to implement. If growers are losing their farms to foreclosure, it is difficult for them to find the incentive and funds to implement BMPs to reduce their TMDL. With that caveat in mind, we calculated cost-benefit ratios of several BMPs. This was done using grower surveys to determine their exact cost, time savings, yield increases etc. Average inputs were used to determine cost and returns. These values were then used to determine how an average grower would benefit over a 20 year period if a BMP was implemented on this farm. Although the analysis was relatively simplistic (no consideration for depreciation, interest on investment, complex price payout from the Ocean Spray Cooperative or other variables), and numerous assumptions had to be made about projected returns and anticipated cost, this analysis is adequate for demonstrative purposes.

The two most accepted and used BMPs were ditch covering and buried drain line. The majority of growers prefer the covered ditch over the buried drain line. The cost to fully crib and cover an average farm ditch in Grayland (1200') during the course of this study was \$10,680; it is projected to cost \$14,610 in 2005 based on new cost of supplies (Tables 35 and 36). This amount of capital overlay assumes that one farm has only one ditch. In reality most Grayland farmers have several farms and several ditches per farm, all of about 1200' in length. Thus the capital expenditures required by growers to be fairly confident that they were not violating TMDL standards on their farms would be considerable (>\$50,000). During the course of this study, the price of cranberries was at or below the cost of production and most farmers were either losing money or breaking even. With only a few exceptions, growers were required to hold a second job in order to continue to farm.

Fortunately, the NRCS has been able to provide annual limited funding using EQIP monies to help growers implement BMPs. These monies have been limited in total value and thus only a small percentage of growers have been able to participate in any given year. With the cost-sharing provided by NRCS, the cost to implement a BMP is much more reasonable~ \$1,000 to 3,000 per 1200' of ditch (Table 35 and 36). Even with the recent cost increase in plywood, there is still considerable savings to growers.

What also became evident during this study is that growers are finding numerous benefits to these BMPs other than those of water quality. This includes ease of bed access, less cost to clean out ditches, increased yield in areas along the ditch, etc. When these returns are added into the analysis, growers indicated that they could receive up to ~\$800 per year in labor savings and crop returns (Tables 35 and 36). When cost and returns are projected over a 20 year period the implementation of a BMP like ditch covering could net the grower ~\$2,000 to \$6,000 without

cost-sharing and \$14,000 to \$16,000 with cost-sharing. Buried drain lines provide more return without cost sharing than covered ditches, but are approximately equivalent with cost sharing.

These data indicate that provided cost-sharing is available, growers can achieve a win-win solution by implementing BMPs to solve a water quality problem. Without the additional benefits provided to the grower with these selected BMPs, it is unlikely that BMP adoption would be rapidly forthcoming. Unfortunately, EQIP monies are limited and highly competitive with other commodity groups within the region and it will take considerable time to fully implement BMPs across all the watersheds in Grayland. Where those BMPs have been implemented across most of the watersheds (Watersheds 10, 11 & 12) and where there has been corresponding water quality monitoring of those watersheds, we have documented few TMDL violations.

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	4
Move sprinkler	45
Subsurface drain pipe	11
Hand spray	52
Hold water	59
Reroute water	54
Biofiltration	29
Charcoal filter	36
Low volume sprayer	39
Boom sprayer	21
Buffer strips	11
Low risk products	25
Pump water off site	18

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. Costs, returns and net benefits to cranberry growers implementing selected BMPs based on cost-share values in place for 2003/2004.

Cost	Cost per 1200 foot ditch ¹		
	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 ft² 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

Table 36. Costs, returns and net benefits to cranberry growers implementing selected BMPs based on cost-share values in place for 2005.

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 ft² 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

CONCLUSIONS:

Overall implications of the findings in relationship to TMDL violations and further

monitoring: The previous monitoring data of the Grayland Ditch from Washington Department of Ecology indicate a range of values of organophosphorous pesticides from several parts per billion, to a only a few parts per trillion (ppt), to none at all. Results varied by year, by site and by sampling time in the year. DOE samples were all collected in the main drainage ditch. The sampling done in this study was mainly confined to very small ditches and ponds. Because of the limited volume of water in the ditches and the intentional maximum exposure, their concentrations were usually higher (most were between 1 to 10 ppb; while some were up to 100⁺ ppb) than that found by DOE in the main ditch (usually < 1 ppb). Samples in the main ditch were diluted by the large volume of water draining off all the watersheds. If most of the watersheds in Grayland get protection from BMPs, then it is assumed that additional dilution of the main ditch with clean water will further reduce the pesticide concentration in the ditch. The real question that needs to be addressed is what is a reasonable expectation for water quality for the industry to achieve?

There are over a thousand acres of cranberries concentrated in a small area (<6 square miles), within a high rainfall watershed with over 60 miles of surface water drainage ditches. It is unrealistic to expect that the industry could completely prevent all TMDL violations in the future. The water quality criteria (WQC) for OP pesticides in surface water are so low (<10 ppt), that even a slight contamination at one very small site would result in the main ditch having a temporary TMDL violation. Many millions of dollars could be spent in the next few years covering every last ditch in Grayland, and it would be difficult to assure that there would never be a TMDL violation. Our results clearly show that no BMP is perfect. BMPs can certainly be used to significantly reduce surface water contamination, but not by 100%. For example with 90% ditch covering in the area of sampling, the results of our monitoring in 2004 still showed 1 sample out of 12 was in violation of the WQC. The most recent sampling by DOE (2003) found that in the north section of the ditch several were only just slightly above the WQC. If it is virtually impossible to achieve 100% compliance of WQC despite everyone's best efforts and vast expenditures, then a better gauge of TMDL compliance in this situation would be a demonstration of continued progress by the industry.

What type of water quality monitoring plans by DOE would be reasonable to demonstrate continued progress by the cranberry industry? The GIS maps of the watershed show that although a large amount of the watershed has been completely covered by BMPs, a significant portion is still contracted for BMPs based on grower sign-up plans and dedicated EQIP funding allocations. It would not be a prudent expenditure of state resources to prematurely do extensive water sampling until all the contracted EQIP funded BMPs have been completed. All proposed sites (those under contract) are scheduled for completion within the next several years. An extensive monitoring program in 2005 or 2006 would indicate that the industry is making continued progress, but some TMDL violations would still be likely. Because the results would be premature, the data would not provide a clear picture of any problem spots within the watershed or if any punitive regulatory action would be needed.

On the other hand, postponing that monitoring effort until the majority of all the proposed BMP are implemented (2007 or 2008) would provide a much better picture of the future status of the

water quality within the watershed. If at that time TMDL violations were still occurring throughout the watershed, then additional monitoring and broad-based regulatory efforts might be considered. On the other hand if TMDL violations are limited to only a few micro-watersheds, then more focused regulatory efforts would be warranted.

To provide a clear understanding of the overall picture of the watershed, it would be extremely useful to do a concomitant update all the BMPs implemented within each micro-watershed in 2007/2008. This combined database would allow DOE to make much better inferences about the relationships between BMP coverage and how they correspond to TMDL violations. It would also allow better focusing on problematic micro-watersheds and how to address violations. Finally it would allow a much better assessment of how effective the current BMPs are for solving this problem. If for example, TMDL violations were still commonplace, then we will know additional BMPs will have to be developed and implemented.

Unfortunately, in 2005 the limited amount of EQIP funding available in the region and the politics of EQIP funding priorities has meant that several high-need sites in Grayland went unfunded. It is highly likely that competition for these funds from other commodity groups (poultry producers) will prevent many of the remaining high-need ditches from being treated with BMPs in the near future. Should specific micro-watersheds remain problematic, it would not be fair to take regulatory action against growers within that watershed if they have tried to obtain, but had been continually denied EQIP funding. In fact, it would be very helpful if DOE would help assure that farms on problem cranberry watersheds received high priority for EQIP funding.

Rather than extensive monitoring for TMDL violations, a more useful option would be for DOE to assess how effective a completely BMP-treated micro-watershed is. Several micro-watersheds are at 100% compliance (those being fed from Gum Creek and Seastrand Creek, for example). Monitoring of those systems in 2007/2008 just prior to their emptying into the main drainage ditch would help show BMP efficacy across an entire micro-watershed much better than extensive monitoring along the main ditch.

One confounding variable about monitoring and TMDLs in this area is water flow. Low flows can markedly increase pesticide concentration. In these circumstances, only a few drops of contaminated sprinkler irrigation water will result in a TMDL violation. For example, in our study we had some dammed shallow ditches with concentrations of >100 PPB. These ditches had no flow and less than 1000 gallons of water in them. During a high flow event in the spring, flows in these same ditches had flows ranging from 100 to >1000 gpm (see Table 5). Thus samples taken in watersheds that are completely dry in the summer will not have any TMDL violations; those taken in a watershed with just a little flow will be concentrated and well above TMDL standards, and those taken with very high flow will be diluted below the TMDL standards. Flow data within each micro-watershed needs to be taken into consideration when interpreting the results and regulatory implication of the monitoring.

High flow events also confound BMP efficacy. In several instances, high rainfall events happened during our sampling sequences for holding water studies. To prevent flooding from occurring, the growers had to release their water before the insecticide was completely degraded.

In other instances, high rain events increased insecticide concentration in the ditch by apparently flushing it off of leaves, soil and vines into the ditch.

New BMP recommendations: One of the main goals of this project was to develop and evaluate new BMPs. Buried drain lines, vine-overgrowth, temporary ditch covers, hand application technology, floating filter covers, in-ditch phyto-remediation, carbon filters, holding water structures, and new gear-driven sprinklers were all tested. Several of these systems (vine-overgrowth, temporary ditch covers, hand application technology, floating filter covers) were failures or so problematic that they could not be recommended over the current ditch covering. Three practices (buried drain lines, holding water structures, and new gear-driven sprinklers) are worthy of consideration, and two (in-ditch phyto-remediation and carbon filters) require additional research.

There are several caveats regarding the BMPs worthy of consideration. Growers were concerned about installation problems and the cost of buried drain lines. They were messy and problematic to install. Overall there has only been limited acceptance of them. Growers like the water-holding structures and the flexibility they offer, but the time it took to degrade insecticides in water-holding situations to non-detectable levels is a concern. The best uses of these are in the limited situations where a grower can hold his/her water all summer long. Gear-driven sprinklers have some of the most potential for adoption. Unfortunately, we did not obtain enough monitoring data to make any inferences on their efficacy. Growers, however, have been installing them on their own, which is a sign of their practicality.

Two of our tested BMPs require more research before they could be recommended. Having a lot of aquatic weeds in the ditch appeared to help with pesticide degradation. There is ample data in the literature to suggest that this occurs (Gao et al. 2000). Our results were not controlled enough to make that inference, but a study which monitors this effect more closely would be merited. Cloth carbon filters showed promise in a few of our studies. We did not have time to fully evaluate them for their long-term usage, nor did we get a sense of how practical or cost-effective they would be under real world conditions. Additional work is required for that purpose.

Based on our cost-benefit study, grower surveys and the preferred grower BMPs (based on percent coverage) ditch covering remains the most practical and efficient BMP. It pays in the long-term for growers to cover their ditches. Since ditch covers can not be used to mitigate for every circumstance, there is still a need for growers to consider other BMPs as needed. This study provided some details on those options.

Watershed progress: The industry has made a lot of advances since Davis and Anderson initially reported their assessment of cranberry bog drainage pesticide contamination in 1997. The industry has been proactive and aggressively dealing with the problem. The level of contamination is at least an order of magnitude less than what was first reported. A majority of the watersheds has already been treated with BMPs and more are scheduled within the next few years. Although it is unlikely the problem will cease to exist in the near future, TMDL violations have and will continue to decline at a rapid pace. The goal of this project was to 1) reduce surface water contamination by more than 50% to 75% and 2) increase grower participation in

IPM and BMPs by more than 100%. These goals were accomplished on several of the micro-watersheds.

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Appendix

Individual breakdown of 2004 cranberry beds and ditch status by color.

Individual breakdown of 2004 BMPs, streams, and cranberry beds by aerial photo.

Individual breakdown of 2004 summer stream flow ratings across major and minor streams in Grayland by aerial photo.