Impact of Best Management Practices on Water Quality in the Nomini Creek Watershed

by

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by

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(ABSTRACT)

The Nomini Creek Watershed project was initiated in 1985 as Virginia's action in dealing with the water quality problems of the Chesapeake Bay. Nomini Creek was selected because it was an agricultural watershed with few best management practices in place at the beginning of the study and was a representative watershed for the Coastal Plain of Virginia. The watershed is located in Westmoreland County, Virginia.

The goal of the project was to provide data needed to quantify the water quality impacts of cropland BMP implementation in a watershed with a complex landuse. The data collected during the project included landuse, hydrologic, water quality, soils, and geographical data.

The goal of this study was to conduct a detailed analysis of the data collected from the Nomini Creek watershed in order to evaluate the effectiveness of a system of BMPs on the quality of surface water. The specific objectives of this study were: 1) to compile the landuse data and determine if any significant changes in cropping practices occurred during the study period, 2) determine if any changes occurred in the monthly rainfall, and runoff values over the study period, and 3) determine if any changes occurred in the monthly total suspended solids,

nitrogen, and phosphorous loadings from the watershed over the study period.

The analysis indicated no significant change in the rainfall and runoff amounts over the study period. The BMPs implemented during the study target surface runoff. Sediment bound nutrients such as ammonium and total kjeldahl nitrogen reduced during the study period and soluble nutrients such as ortho-phosphorous and total phosphorous increased during the study period.

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1.0 Introduction

1.1 Background and Justification

Nonpoint source pollution (NPS) is pollution caused by sediment, nutrients, and organic and toxic substances originating from landuse activities and/or from the atmosphere, which enters groundwater and surface water through infiltration and/or runoff (Novotny and Chesters, 1981). Because of its inherent diverse nature, NPS pollution was overlooked for many years. Increased public awareness and concern has led to a significant increase in research activities on NPS pollution control within the last two decades. Many field scale studies have been conducted to assess the impact of a single agricultural best management practice (BMP) on NPS pollution. A major drawback of conducting field or plot scale studies is the limitations imposed on the results by the narrow scope of this type of study. The plots usually contain a single landuse with a single BMP. Plot studies do not take into account multiple factors, such as lateral pollution inputs, that can influence water quality in an area with complex landuse. Due to the limitations of plot studies, it is necessary to evaluate BMPs on a watershed scale in order to assess their potential benefits. However, very few studies have investigated the effects on water quality by a system of BMPs implemented on a watershed with a complex landuse.

NPS pollution consists of sediment, nutrients, pesticides, and bacteria carried primarily by runoff from agricultural areas. The sediment fills streams and rivers and can lead to flooding during large rainfall events. The sediment also contains some nutrients and pesticides that are bound to the soil particles which would not normally enter surface waters. The increased nutrient level can cause eutrophic algae growth which causes the water to become turbid and prevents the sunlight from reaching the

submerged aquatic vegetation (SAV). Without the SAVs, many aquatic organisms can not survive. The tremendous amount of algae growth can also deprive the aquatic environment of dissolved oxygen, causing fish kills. NPS losses of pesticides from agricultural lands not only have a direct toxic effect on aquatic vegetation and animals, but some pesticides are known to accumulate in the fatty tissues of animals and, thus, can migrate up the food chain. NPS pollution is one of the major threats to the health of the Chesapeake Bay (U.S.EPA, 1983).

In 1983, a study conducted by the U.S. EPA indicated that point and nonpoint sources of pollution were responsible for the decline of the Chesapeake Bay (U.S.EPA, 1983). It further stated that NPS contribute 67% of the total nitrogen and 39% of the total phosphorous that enters the Bay. Agriculture, including cropping and livestock operations, was identified as a major contributor to the nonpoint source pollution entering the Bay. Cropland was reported to be responsible for 60% of the nitrogen and 27% of the phosphorous entering the Bay in the form of NPS pollution (U.S.EPA, 1983).

After the 1983 EPA report documented the decline of the Bay, the governors of Pennsylvania, Maryland and Virginia; the mayor of the District of Columbia; and the administrator of the EPA drafted a document known as the Chesapeake Bay Agreement. In this agreement, the three states and the District of Columbia agreed to implement cost-share programs to reduce the amount of NPS pollution entering the Bay and its tributaries.

Virginia's cost share program encourages the implementation of BMPs to help reduce NPS pollution. However, there is a lack of information on the benefits of BMPs implemented on agricultural watersheds with complex landuse. In order to evaluate the impact of BMPs, the Virginia Division of Soil and Water Conservation (VDSWC) initiated funding for two watershed monitoring projects. The first watershed study was

the Nomini Creek watershed located in Westmoreland County, Virginia, and the second was the Owl Run watershed located in Fauquier County, Virginia. These studies were initiated to evaluated the impact of implementing a system of BMPs on downstream water quality (Mostaghimi et al., 1989). The goal of the Nomini Creek watershed project was "to provide badly needed data to quantify the water quality impacts of cropland BMP implementations in a watershed with a complex landuse" (Mostaghimi et al., 1989). The goal of the Owl Run watershed project was "to evaluate the short-term and long-term effectiveness of animal waste management practices on improving quality of runoff water draining from the watershed" (Mostaghimi et al., 1989). The Nomini Creek and Owl Run watershed projects were each initiated as a 10-year study.

The data collected at the Nomini Creek and Owl Run watersheds consists of landuse, hydrologic data, water quality data, soils information, and geographical information (Mostaghimi et al., 1989). The hydrologic data consists of runoff, precipitation, temperature, humidity, evaporation, wind speed, wind direction, and solar radiation. Water quality data is collected during both dry and wet periods. Grab samples are also taken weekly and automatic storm samples are taken based on changes in stage, as measured directly upstream of the flow control structure. The samples are collected at several runoff monitoring sites in each watershed. Groundwater samples are also collected on a monthly basis from four pairs of up-gradient and down-gradient wells at Nomini Creek. The water quality samples are tested for both nutrients and pesticides. The geographical information available consist of general landuse, elevation, stream network, soil type, and watershed boundaries. This data are updated annually as the source maps change. Detailed landuse information is collected quarterly using farmer

surveys, interviews, and field observations (Mostaghimi et al., 1989).

Statistical analysis can be performed on various types of data collected on each watershed to determine the water quality impacts of a system of BMPs implemented on a watershed with complex landuse. The water quality data, such as nutrient and pesticide loadings in surface water and groundwater, can be analyzed to determine possible trends in water quality as a result of BMP implementations. The water quality data can be used to correlate with the landuse changes in order to assess the effectiveness of BMPs for reducing agricultural NPS pollution.

Very few long term studies, as comprehensive as the Nomini Creek and Owl Run watershed projects, have been conducted. The information obtained from these studies is expected to allow for a targeted approach to applying BMPs to protect water quality. This information would be of great use to farmers in making their conservation plans and help policy makers in making more informed decisions regarding the protection of soil and water resources.

1.2 Goal and Objectives

The goal of this study was to conduct a detailed analysis of the data collected from the Nomini Creek watershed in order to evaluate the effectiveness of a system of BMPs on the quality of surface water.

Objectives

The specific objectives of this study were to:

1) Compile the landuse data for the Nomini Creek watershed and determine in any significant changes in cropping practices occurred during the study period.
2) Determine if any changes occurred in the monthly rainfall, and runoff values over the study period.
3) Determine if any changes occurred in the monthly total suspended solids, nitrogen, and phosphorous loadings from the watershed over the study period.

2.0 Literature Review

The effectiveness of BMPs on improving water quality on a watershed scale has not been well documented (Braden and Uchtmann, 1985). Only a few of the early agricultural NPS control watershed programs were able to document water quality improvements following intensive implementation of BMPs (Harbridge House, Inc., 1983). This lack of response to BMPs has been attributed to the incremental process of land treatment, short duration of monitoring, and difficulty in controlling for natural and cultural variabilities (Morrison and Lake, 1981; Persson et al. 1983). Recently, however, improvements in water quality as a result of BMP implementation have been reported in some agricultural NPS projects including the Rural Clean Water Program (RCWP) projects in Idaho, Florida, and Vermont (Soil Conserv. Serv. et al. 1991; Flaig and Ritter, 1989; Natl. Water Qual. Eval. Proj. 1988). A brief summary of the RCWP projects is included in the following sections.

2.1 Watershed Monitoring Projects

An important objective of any NPS control program is to correlate water quality changes and BMP implementation, thereby, demonstrating that NPS control efforts can improve water quality and are worthy of federal, state, and local funding and support (Gale et al.,1993). Leahy (1993) stated that the nation needs reliable information about water quality in order to make scientifically-based decisions and policy. Leahy also

points out several questions that this information should answer. These include: the extent that national water quality goals are being met; the effectiveness of past actions; and the extent of various types of NPS pollution and how these types compare to point source pollution. Leahy (1993) points out that necessary data is missing because of the lack of long term studies which contain comprehensive physical, chemical, and biological data.

The Moores Creek BMP Effectiveness Monitoring Project

Edwards et al. (1993) evaluated the effect of nutrient management for direct application of poultry litter and poultry manure as the primary fertilizer sources for the Moores Creek Watershed in Northwestern Arkansas. This 6,100 ha. watershed includes Lincoln Lake, a 36 ha. lake, which is the primary water supply for the city of Lincoln. This watershed was selected because of documented water quality problems in Lincoln Lake and the high concentration of confined animal production facilities (SCS, 1990). The study was conducted over a 20-month period from September 1991 through May 1993.

Two sets of paired fields were selected from the Moores Creek watershed to evaluate the water quality impact of nutrient management as compared with unmanaged fertilizer application (Edwards et al., 1993). One pair of the fields received poultry litter applications on each field, one field following the nutrient management guidelines prescribed by SCS (1992). While the other field received unmanaged fertilizer

application. The second pair of fields received poultry manure as fertilizer with one field using nutrient management and the other field following unmanaged nutrient application (Edwards et al., 1993).

The fields used for the study were selected based on the suitability of potential monitoring sites, access, and security for monitoring equipment. The fields were then selected based on similarity of landuse (tall fescue) and management. Soil samples were collected and analyzed for all four fields. Due to the high phosphorous content of the soil in the fields scheduled to receive nutrient management, only inorganic fertilizer (NH4 - NO3) was applied in order to obtain optimal crop growth. The unmanaged fields received poultry litter and manure applications even though they contained higher phosphorous than necessary for optimal crop growth (Edwards et al., 1993).

The management practies for the two fields receiving poultry manure were grazing and fertilizer application. The landuse and management activities were approximately equal for these two fields since they were adjacent to each other. The pair of fields which received poultry litter were also managed similarly, with the exception that the unmanaged fields received cattle grazing later during the study period (Edward et al., 1993).

The objective of the study which was to determine the effectiveness of nutrient management versus unmanaged fertilizer application was not obtained due to the high phosphorous residual in the soil. However, the study did document that a small number of rainfall events were responsible for the majority of the NPS pollution from the fields.

Edwards et al. (1993) also showed that manure losses were evident in runoff from storms immediately following manure application and that as time between manure application and rainfall increased, the increased nutrient levels became less easily detectable in the water quality data. Edwards et al. (1993) also reported that fecal coliform concentration appeared to be unrelated to grazing or poultry litter/manure application and usually exceeded Arkansas' secondary contact standard of 1000 col./ 100 ml.

Rural Clean Water Program (RCWP)

The Rural Clean Water Program (RCWP) is the largest and most comprehensive monitoring program ever implemented in the U.S. (Gale et al., 1992). There were 21 funded watershed monitoring projects nationwide in the RCWP (Gale et al., 1992). BMPs were implemented on each watershed to reduce NPS pollution. Water quality monitoring programs were established to evaluate the effects of the land treatments (BMPs). The BMPs were targeted at critical areas within each watershed. Five of the watersheds were selected to undergo Comprehensive Monitoring and Evaluation (CM&E). These projects received additional funding in order to perform more extensive monitoring and evaluation (Gale et al.,1992).

Some of the RCWP projects lacked the necessary water quality monitoring data to evaluate the effectiveness of the BMPs in reducing NPS pollution (U.S.EPA, 1993). Only five of the projects (Idaho, Florida, Vermont, Utah, and Oregon) collected enough

water quality data to make an accurate analysis of the effects of BMPs on NPS pollution (U.S.EPA, 1993).

Before implementation of BMPs, adequate baseline data on water quality must be collected. This baseline information will establish a reference for future comparison of water quality data after BMP installation. Line (1993) suggests that the baseline data should be used to determine critical areas within the watershed where the BMPs should be applied (U.S.EPA, 1993). The targeting of critical areas can maximize the benefit of the BMPs and provide the fastest avenue for obtaining the project goals. The following section presents four watershed monitoring programs that were initiated under the Rural Clean Water Program.

Rock Creek, Idaho

The Rock Creek RCWP project in Twin Falls County, Idaho was established in 1981 as a 10-year water quality monitoring project with BMP implementation continuing until 1992. The project area covered 18,308 ha, with the primary agricultural uses being irrigated pasture, cropland, and rangeland (Gale et al., 1993). Rock Creek has a severe water quality problem due to the large amounts of sediment contributed from the irrigated agricultural land. The sediment contains high levels of pollutants, such as phosphorous and organic nitrogen, which impede the beneficial uses of the creek water. Streambank erosion and animal waste also contribute to the water quality problem (Gale et al., 1993).

The primary objective of the Rock Creek project was to reduce the amount of sediment, sediment-related pollutants, and animal waste discharging into Rock Creek from the surrounding agricultural lands (Gale et al., 1993). The project hoped to accomplish a reduction of 70% in sediment, 60% in phosphorous, 40% in total nitrogen, and 65% in pesticides through implementation of BMPs. The 11,396 ha critical areas identified for BMP implementation were all irrigated cropland and animal production facilities. The BMPs that were selected for implementation included sediment retention structures, irrigation water management, vegetative filter strips, cover crops, conservation tillage, and animal waste management. The BMPs were used to treat 75% of the targeted critical area on a voluntary basis (Gale et al., 1993).

The preliminary results of the project indicate that managerial BMPs such as irrigation water management and animal waste management were the most cost-effective BMPs for reducing soil loss on a per-hectare basis. Sediment reduction coefficients for the BMPs implemented in this project were developed by the USDA/ARS personnel at Kimberly, Idaho. Although irrigation practices, such as concrete ditches and gated pipe, were not the most cost-effective, they proved to be effective in gaining grower participation. Mini-basins, I-slots, sediment basins, and buried pipe runoff proved to be highly effective with reduction coefficients between 75% and 92%. Vegetative filter strips obtained reduction coefficients of 50%, irrigation improvements 5% to 40%, and conservation tillage 60% (Gale et al. 1993).

Spooner et al. (1985) outlined three data analysis procedures that should be used to document water quality improvements from agricultural NPS control programs. The three experimental designs are: 1) time trend analyses; 2) upstream-downstream analyses; and 3) paired watershed design. Chandler and Maret (1992) outlined the procedures and results used for the data analysis at Rock Creek. Time trend analysis was used to test the null hypothesis that water quality has not changed over time with the level of BMP implementation. This hypothesis was tested using a seasonal Kendall test to perform a regression analysis by comparing loading or concentration versus the BMP implementation level. Many stations within the watershed showed significant decreasing trends for variables such as sediment concentration, sediment loading, phosphorous, and fecal coliform bacteria. However, some positive trends did occur in the upper watershed with declining fecal coliform bacteria (Chandler and Maret, 1992). The upstream-downstream design was also utilized for the data analyses. The upstream concentrations were subtracted from the downstream concentrations and analyzed using a trends test. In this analyses, Chandler and Maret (1992) showed that stations which were adjusted for upstream inputs did have a significant reduction in loadings between 1982 and 1990.

The water quality goals established for the specific reduction in the amount of sediment, nutrients, and animal waste entering the Rock Creek were met (Gale et al., 1993). The analysis performed by Maret et al. (1991) and Chandler and Maret (1992), showed significant reductions in the suspended sediment concentrations and other pollutants at the agricultural drains and in the Lower Rock Creek over the 10-year study

period. A 75% decrease in sediment and a 68% decrease in phosphorous loadings from Rock Creek to the Snake River were also obtained. Reduced loadings of sediment and nutrients were documented in eight of the ten subbasins during the time period when BMP implementation occurred (Gale et al., 1993). This type of correlation indicates that the combination of BMPs applied to the study area had a significant positive impact on the sediment and nutrient loadings entering the Rock Creek.

St. Albans Bay, Vermont

St. Albans Bay is located in Northwestern Vermont on Lake Champlain in Franklin County. This project was initiated as a 10-year RCWP watershed monitoring project and lasted from 1980-1991. The total watershed area is 13,016 ha., with the majority of this area being agricultural land used primarily for dairy production. Cropland, both corn and hay, comprised 43% of the study area with the remaining area being 17% pasture, 22% woodland, and 18% urban areas and roads. Due to the large number of dairy operations in the project area (98 dairy farms with 6,5000 cows), bacteria, sediment, and nutrients from the dairy farms were the primary cause of water quality degradation in the St. Albans Bay area (Gale et al., 1993).

Approximately 50% of the project area (6,214 ha.) was defined as critical areas and targeted for BMP implementation to reduce NPS pollution. Critical areas were considered to be those areas having the most significant impact on the use of the impaired receiving waters. The goal of the project was to reduce NPS pollution and thus improve

the water quality of St. Albans Bay through the implementation of BMPs on the critical areas. In order to accomplish this goal, the project defined land treatment goals of treating 75% of the 4,631 ha. critical area and 64 farms, and managing at least 76% of the manure by weight. The project succeeded in achieving 98% of land treatment goals using animal waste management, fertilizer management, and cropland protection systems (Gale et al., 1993). A total of 74% of the defined critical areas received BMPs and 76% of the total manure produced was treated, using animal waste management BMPs. The primary BMPs used in this study were animal waste management and cropland protection systems. The animal waste management systems provided facilities for storage and handling of the dairy waste. The cropland protection systems helped to reduce field erosion through the use of conservation cropping, cover crops, and field windbreaks (Gale et al., 1993).

Four levels of water quality monitoring were utilized in the St. Albans Bay project. The first level of monitoring consisted of four stations within the bay to detect long-term trends over the life of the project. The first station was located at the beach on the Bay, the second near the wetlands, the third was an inner Bay monitoring station, and the fourth was an outer Bay monitoring station. The second level consisted of monitoring at five major subbasin tributaries to the Bay and the St. Albans City wastewater treatment plant. The third level of monitoring consisted of a paired watershed/field study. The paired watershed study consisted of the monitoring of two field drainage ditches, one below a field where conventional practices were used and the other below a field where

manure management BMPs were utilized. The fourth level of water quality monitoring consisted of four stations. The first station was the Jewett Brook station which was the closest tributary station to the Bay at the furthest upstream location affected by the backwater from St. Albans Bay. The second station was on Stevens Brook and was monitored to determine the effects of urban development on downstream agricultural use. The third station was on Buayland Brook at the outlet of a subwatershed that comprises 8% of the total watershed and was not monitored with the level 2 monitoring network. The fourth station was on Mill River just upstream of where Mill River and Rugg Brook converge. This station was initiated in order to separate the impact of Mill River from the level 2 station at Rugg Brook (Gale et al., 1993). The level 1 and level 2 stations were sampled more frequently and were analyzed for more variables than the other two levels. The analysis variables included temperature, turbidity, total suspended solids (TSS), volatile suspended solids (VSS), dissolved oxygen (DO), total phosphorous (TP), orthophosphate (OP), total Kjeldahl nitrogen (TKN), ammonia-nitrogen (NH_3-N), nitrite-(NO_2^-) and nitrate nitrogen (NO_3-N), fecal coliform (FC), and fecal streptococcus (FS). The level 3 stations were sampled only during runoff events and tested for TSS, VSS, TP, and all of the other nutrients for which level 1 and 2 were tested. The level 4 stations were sampled on average every 20 days from May - February and weekly from March - April. These samples were analyzed for turbidity, TSS, VSS, nutrients, FC, FS, temperature, DO, pH, and conductivity (Gale et al., 1993).

Due to the lack of background water quality data, pre-BMP versus post-BMP analysis was impossible. Therefore, the evaluation of trends in water quality was based on the changes in water quality as a function of time. The data was adjusted to compensate for autocorrelation by using monthly mean values. Due to the fact that these values failed to follow a normal distribution, they were transformed using log transformation. Parametric procedures, such as regression and analysis of variance (ANOVA), were then performed on the log-transformed data. The results of these procedures were interpreted in log space to bypass any bias that may be introduced into the results by back-transforming process (Meals, 1992).

Due to the complexity of the data analysis, Meals (1992) conducted a variety of tests including parametric and nonparametric procedures. The variety of procedures performed included simple linear regression against time, t-test of pre-BMP and post-BMP periods (where available), ANOVA, comparison of pre-BMP and post-BMP flow and concentration relationships, analysis of covariance (ANCOV), Mann-Whitney test, and the seasonal Kendall test. Test results did not disagree on direction of trend but only on magnitude and statistical significance (Meals, 1992).

Meals (1992) stated that phosphorous loading in tributaries to the Bay failed to decrease over the study period, and in some tributaries even increased. He explains that Nitrogen loading and export in all tributaries but one (Stevens Brook) increased. He contributed the failure to reduce nutrients in the tributaries to the nonparticipating farms.

inadequate nature, timing, or level of land treatment, and unknown lag time between implementation of BMPs and improvements in stream water quality.

Although the land treatment goal was almost met, the project failed to show any significant relationship between stream nutrient levels and the animal waste management BMPs. However, the in-stream bacteria count declined, with an increase in the number of animals within the watershed, being placed under waste management BMPs (Gale et al., 1993). Through a paired watershed study the project also found that winter spreading of manure on corn land resulted in significantly higher nitrogen and phosphorous concentrations and loadings in edge-of-field runoff, compared to when manure was applied only during the growing season (Gale, 1993).

Taylor Creek-Nubbin Slough, Florida

The Taylor Creek - Nubbin Slough (TCNS) watershed is a 48,564 ha agricultural watershed located in southern Florida directly north of Lake Okeechobee. The original monitoring network was designed and implemented in 1978 to evaluate the water quality of the headwaters of Taylor Creek. In 1980, this project was expanded to include the entire Taylor Creek-Nubbin Slough drainage basin. This expansion was primarily due to the inception of the RCWP (Osking and Gunsalis, 1992). The study area has a flat landscape with poorly drained, coarse textured soils with a low phosphorous retention capacity (Gale, 1993).

Federico et al. (1981) reported that the TCNS watershed contributed 27% of the external phosphorous load to Lake Okeechobee but only 4% of the inflowing water. The Lake provides drinking and irrigation water, supports commercial and sport fishing, and provides habitat for many migratory birds (Gale, 1993). However, Lake water is severely impaired due to eutrophic conditions from high phosphorous concentrations, similar to the problem that now plague the Chesapeake Bay. Federico et al. (1981) stated that Lake Okeechobee, which is highly productive in its current eutrophic state, is in danger of becoming hypereutrophic because of the nutrient inputs from agricultural activities.

The primary landuse and water quality goals for the TCNS watershed were to: 1) reduce phosphorous and nitrogen concentrations from the project area to Lake Okeechobee by 50%; 2) contract at least 75% of the critical area; and 3) contract with all dairy farms in the project area (Stanley et al., 1986). All dairy farms, beef cattle farms using improved pastures, and areas within two-fifths of a kilometer of a waterway were identified as critical areas within the watershed. This accounted for 25,540 ha or 52.5% of the total watershed area. Dairy and beef production within the watershed accounts for 75% of the total landuse and 98% of the identified critical area (Gale, 1993).

A high level of BMPs were installed over the project area. BMP installation contracts were established for 22,141 ha, or 87% of the critical areas, and all dairy farms within the critical areas (Gale et al., 1993). The primary BMPs installed consisted of stream protection systems; reduction of barn waste through water use efficiency and improving effluent disposal with spray irrigation; animal waste management systems;

diversion systems; grazing land protection systems; permanent vegetative cover; sediment retention structures; and water control structures (Gale et al., 1993).

The objective of the water quality monitoring was to measure phosphorous reductions over the study period and relate these changes with BMP implementation. The monitoring system originally included 38 water quality stations through 1984 and was expanded to 53 by 1988. The majority of these stations were in stream monitoring stations, located along the 9 major tributaries, downstream of BMP implementation, and at the watershed outlet to document changes within subwatersheds and the overall project area. The sites that were initiated in 1988 were installed in order to monitor BMP effectiveness downstream of each dairy farm. Grab samples were collected at the monitoring stations biweekly through 1988 and then weekly thereafter. The grab samples were analyzed for TP, OP, NO_3-N, NO_2-N, NH_3-N, TKN, pH, conductivity, chlorides, turbidity, and color (Gale et al., 1993).

An exploratory data analysis was conducted on the water quality data. This data analysis included tabular presentation of the annual means and standard deviations for water quality concentrations at each station and time plots of the entire period of record with pre-BMP, transitional, and post-BMP periods indicated (Gale, 1993). A more detailed analysis was performed to detect significant trends in the water quality data. The techniques used included the nonparametric Seasonal Kendall Tau test and linear regression to detect linear trends over time. Double mass analysis was also utilized in order to compare phosphorous concentrations with the total number of cows in each

subwatershed in order to relate changes in phosphorous concentrations to changes in the total number of cows within each subwatershed over time.

Flaig and Ritter conducted two data analysis on the water quality data from this study. The first analysis was conducted in 1987 on the data from 1978 through October, 1986. Flaig and Ritter (1987) documented significant decreasing trends over the study period. The second analysis was conducted in 1989 and included data from 1978 through 1989. They reported that the second data set (1978 - 1989), with a higher number of stations, showed a significant decrease in TP concentration, and that the magnitude of the decreasing TP concentration increased with the addition of the '88 and '89 data (Flaig and Ritter, 1989). The project exceeded its goal of a 50% reduction in TP concentration. An overall decrease in TP concentration at the watershed outlet where it enters Lake Okeechobee has also been documented even with an increase in the total number of cows in the watershed (Gale et al., 1993). Ritter and Flaig (1987) and Stanley et al. (1988) hypothesized that the decrease in TP concentration could be contributed to two dairy farm closures at Otter Creek and the large number of BMPs that were implemented in the other subwatersheds. Stanley et al. (1988) also states that there is a need for a long post-BMP monitoring period in order to isolate the affects of BMP implementation from other factors such as weather, changes in landuse and changes in management.

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