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Relating water quality to management practices

Gary S. Honea

To the Graduate Council:

I am submitting herewith a thesis written by Gary S. Honea entitled "Relating water quality to management practices." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering.

Ronald E. Yoder, Major Professor

We have read this thesis and recommend its acceptance:

Roland Mote, Daniel Yoder

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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RELATING WATER QUALITY TO MANAGEMENT PRACTICES

A Thesis
Presented for the
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Gary S. Honea
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ABSTRACT

Much effort is spent trying to relate water quality to management practices. Successes have been achieved, but it has often been difficult to link a change in water quality to a management practice, or to conclusively document actual water quality improvement. This research developed and attempted to prove a concept. That concept was that a systems approach could be used to develop a set of tools necessary to relate surface water quality to the management practices employed and to the responsiveness of the unit in which they are employed.

The operational unit for this research project was a well run dairy farm in Claiborne County, Tennessee. Three indices were developed for each of four contaminants; sediment, phosphorus, nitrogen, and coliform bacteria. Other contaminants could have been selected, but these four were deemed the most important. The indices are the management practice index (MPI), the system response index (SRI), and the standard water index (SWI).

The MPI evaluates how well a unit of land is being managed in terms of whether the proper Best Management Practices (BMPs) are being employed and how effectively they are being employed. The risk that may be associated with a BMP failure is also evaluated. In effect the index indicates how good a job the person is doing to keep contaminants out of the surface water. A high MPI indicates a good job is being done.

The second index is the SRI. It relates the measured level of a contaminant, the worst case potential loading of the contaminant into a stream, and the MPI. It can probably best be used to indicate the probability that a given level of contaminant will occur for a particular worst case and management scheme, or whether a system is likely to change if the worst case or management practices are altered. It can also be viewed as a responsiveness index which gives an indication of how forgiving a particular situation will be for the implemented management practices and the potential worst case loading. A high SRI indicates a responsive system, while a low index indicates a less responsive system. With a low SRI it makes little difference what management practices or system loading are used, as the system will not easily change. Its inverse can also be viewed as the buffering capacity of the system.

The final index is the SWI and is simply a ratio of the measured levels of contaminants to a standard. An SWI greater than one indicates the standard has been exceeded.

Overall the dairy farm MPIs indicated a high level of management. On a scale of 0.0 to 1.0, the overall MPIs were 0.91, 0.88, 0.92, and 0.83 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively. The SRIs for subwatershed B were -0.206, 0.0, -0.055, and 0.005 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively. Although the true ranges for these SRI values are yet undetermined, the values appear low, which would indicate a system that is low in responsiveness, or high in buffering capacity. The measured levels of contaminants are reflected in the SWI values of -0.07, 0.0, -0.15, and 0.99 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively.

Together the three indices suggest a high level of management and a low system responsiveness. The MPI results for coliform bacteria appear questionable since the SWI was near 1.0 (near the standard) even though the MPI was relatively high at 0.86 for subwatershed B.

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CHAPTER 1

INTRODUCTION

JUSTIFICATION

Past research has generally centered on relating changes in water quality to implementation of specific Best Management Practices (BMPs). The Rural Clean Water Project (RCWP) is probably the biggest and most recent attempt to correlate water quality to BMPs. Many lessons have been learned in this attempt, but oftentimes the individual projects in the program were unable to document water quality improvement as a result of a specific BMP that was implemented. Complicating factors such as partial watershed participation, several BMPs implemented at once; time required for pre, post, and implementation phases; time required to observe changes; changes in monitoring schemes, etc., helped to reduce the ability to establish correlations between implementation and changes in water quality.

Best management practices cover a wide spectrum of activities, from waste management to crop planting and management to stream protection, with a myriad of practices being associated with each major BMP. Certain BMPs are effective for reducing sediment transport, for instance, while a slightly different set of BMPs may be effective for reducing coliform bacteria loading.

In order to understand how effective these BMPs are, information must be collected on how they affect water quality. Water quality is important because of its impact on people and on the ecological balance. Typical problems encountered with the use of poor-quality water are disease transmission, gastrointestinal disturbance, tastes and odors, fish kills, and changes in an ecosystem. The quality of the water is therefore a valid concern.

Contaminant source and contaminant type should be considered when investigating the relationship of water quality to management practices. Principal sources of contaminants can be divided into two broad types, point source and nonpoint source (NPS). Point sources are those that have a well-defined point of discharge (Thomann and Mueller, 1987). Point sources are usually but not always continuous, as they can be a source for short discharges.

Nonpoint sources are characterized by a diffuse origin of discharge as opposed to originating from a well-defined point. Agricultural pollutants are generally of the nonpoint source type. Nonpoint sources include industrial parks, subdivisions, and rural residential areas. Pollutants from these sources may enter a stream, river, or lake by overland runoff or enter the groundwater by leaching through the soil. Water quality experts across the nation believe that nonpoint source pollution is the major cause of our remaining water quality problems (RCWP, 1990). However, those involved with the Rural Clean Water Program (RCWP) have stated that nonpoint source pollution can be managed, controlled, and often prevented by changing some of the ways the land is used (RCWP, 1990).

Contaminants that come primarily from agriculture fall into four categories; sediment, nutrients (nitrogen and phosphorus), bacteria, and agricultural chemicals. A set of tools are needed that will establish relationships between best management practices and system responsiveness for a given unit of land and the resulting quality of the surface water coming from that unit. These relationships would go beyond linking implementation of a BMP to a change in water quality and would begin to provide more comprehensive benchmarks by which water quality impacts can be judged.

OBJECTIVES

The point of this research was to prove a concept by developing a methodology to establish these more comprehensive benchmarks for judging water quality impacts. This was accomplished by developing a set of three indices for each contaminant that was deemed to be of major concern. The four contaminants selected were sediment, phosphorus, nitrogen, and coliform bacteria. Pesticides were not considered in this research because the added effort and complexity would have exceeded the scope of the research that was set at the beginning of this effort.

The development of indices essentially consists of several parallel efforts. The first of these is the MPI, which indicates how well a land-owner is managing a unit of land, based on application of appropriate BMPs. The second index, the SRI, indicates how much impact those and other possible BMPs are likely to have on water quality, given the water quality seen in the current situation. The third and final index developed is the SWI, which gives an indication of how well the system meets regulatory or health standards. These last two indices required the establishment of a water quality monitoring scheme.

Once the methodology was developed by establishing the three indices, it was tested on a dairy farm in East Tennessee. This was done by evaluating the management practices that were employed, estimating a worst case loading for each of the four contaminants, and by measuring the surface water quality coming from that dairy farm. Groundwater was not included in this research due to the increased complexity and resources that would have been required.

When the concept has been validated, additional research could expand this project to include groundwater which is indeed an important component in evaluating water quality. Shirmohammadi et al. (1994) pointed out, for instance, that nitrate can contaminate groundwater as a result of agricultural practices.

CHAPTER 2

REVIEW OF LITERATURE

RURAL CLEAN WATER PROGRAM

Several nationwide programs have addressed nonpoint source controls. One such program is the Rural Clean Water Program (RCWP). The RCWP is a federal program administered by the U.S. Department of Agriculture's (USDA) Agricultural Stabilization and Conservation Service (ASCS) in consultation with the U.S. Environmental Protection Agency (USEPA). The program began in 1980, with a total appropriation of $64 million that funded 21 watershed projects in 22 states across the country. The program was scheduled to terminate in 1995. All projects were required to monitor water quality (RCWP, 1990).

The RWCP has yielded much good information on nonpoint source pollution as related to BMPs. Eighteen best management practices were outlined, ranging from permanent vegetative cover and animal waste management to conservation tillage and stream protection. There were generally numerous practices grouped under each of the BMPs. The contaminants that were of the greatest concern fell into several categories, with the major ones being sediment, nutrients, bacteria, and agricultural chemicals.

One of the difficulties that was encountered in the RCWP was tying the change in a particular contaminant level to a specific BMP. For example, even though water quality improved at Lake Tholocco in Alabama, it was not certain whether the improvement was due to the decline in the number of beef cattle and hogs in the watershed, or to the implementation of BMPs (RCWP, 1990). In another instance at Bayou Bonne Idee, Louisiana, decreases in turbidity, total suspended solids, and total phosphorus were not statistically significant, perhaps because only 60% of the identified critical acreage in the drainage participated in the program (RCWP, 1990). Also the time required for changes in water quality parameters after BMP implementation can be extensive. Monitoring of water quality will have to continue at Tillamook Bay, Oregon for many more years to determine how successful the project has been, because all BMP's were not installed and because water quality sampling frequency changed during the course of the project (RCWP, 1990). For one reason or another many of the RCWP projects were unable to document water quality improvements due to BMP implementation.

It is anticipated that for NPS water quality impact studies (eutrophication, biological degradation, etc.), the incremental changes in overall water quality may not be measurable within a project period (3 - 5 years) because of the high degree of inherent variability within the system and the long response time of natural ecosystems to such subtle changes. The RCWP recommends 2-3 years for pre-BMP monitoring, and 2-3 years of post-BMP monitoring, not including a number of years for implementation (Spooner et al., 1991).

These lessons are an indication of the difficulty in determining the effect of a particular BMP on water quality leaving a watershed. Yet linking management practices and water quality is an important endeavor, Gale et al. (1992) stated that,

> "An important purpose of any NPS control program is to correlate (link) 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."

Researchers have indeed been trying to establish cause-and-effect relationships between management practices and water quality. In this respect, Spooner (1990) pointed out that a controlled experiment is the only way to confirm cause-and-effect relationships. Controlled refers to elimination of, or accounting for, all the factors that may affect the response to the treatment, so the treatment effect can be isolated. However, a controlled experiment is difficult to perform at the watershed level because resources are limited and because project goals encompass BMP implementation in all critical areas, not just in the area affected by a single BMP (Spooner, 1990). Spooner went on to point out that monitoring of farm-field scale sites is necessary to identify water quality problems and to determine relationships between land surface activities and water, but that this monitoring is not sufficient to describe cause-and-effect mechanisms.

To avoid the difficulties associated with the controlled experiment approach for each BMP, a systems type approach is envisioned where monitoring on a subwatershed scale will be accomplished. A farm-field scale would be more ideal if the monitoring and sampling scheme could be worked out. Cause-and-effect relationships would not be examined, but the goal would rather be to examine the entire system of BMPs and to establish in an empirical sense their relationship to water quality. This linking of water quality and BMPs should provide useful information to both farmers and water quality managers, and may begin to establish management practice indices and system response indices for achievable water quality.

INDICES

Much work has been done in the area of indices, and especially so in the area of water quality. This has been prompted by several factors. Increasing levels of water pollution (Dinius, 1987) have resulted in billion dollar use and control programs. A need has arisen for the development of water quality indices that provide a means for quantifying and evaluating the quality of a given body of the water. Such an index would communicate to those with limited technical knowledge the quality of water. A water quality index can thus be seen as a communication tool for transmitting information (Couillare and Lefebvre, 1985). Couillare and Lefebvre also state that a water quality index makes information more easily and rapidly interpretable than does a list of numerical values. Dinius goes on to point out that a water quality index, in order to be feasible and useful, must reduce the vast quantity of water quality information to its simplest form, even though in the process some information may be lost.

Four important uses of indices include: (1) formulating government policy, (2) evaluating effectiveness of environmental protection programs, (3) designing environmental protection programs, and (4) communicating to the general public the state of the environment and the impact of government programs on the environment (Dinius, 1987).

Dinius (1987) referenced related work which reduced water quality indices to three basic types: (1) those that translate levels of polluting elements into a quality unit based on the relationship of the quantity of each element present in the water to that water's quality; (2) those that translate levels of polluting elements into a quality unit based on some set of standards usually established by a governing unit; and (3) those that subject the value of the variables to a variety of standard statistical procedures. Dinius (1987) said that a difficulty with the systems based on standards levels is that these are established by governmental units to protect human and wildlife health and welfare, and include (very wisely) a wide margin for error; they do not therefore reflect true water quality.

Couillare and Lefebvre (1985) have outlined the operational functioning of an index. They state that most indices use parameters, weighting, rating curves, and aggregation methods. The weighting is done to assign a relative importance that differs for every parameter. The widely used rating curve is used to link a parameter's concentration with the quality of the water, and can be used as a graph or a mathematical function that transforms each value of a parameter into an approximate value or "score." Finally, the aggregation process is used to consolidate all quality scores of rating curves, and if necessary to weight those scores. The weight is based on the relative importance of a particular parameter to the other parameters considered. It is with this step that the final result or water quality index can be obtained. Among the several weighting processes found in literature, Couillare and Lefebvre (1985) point out that a weighted product is generally more appropriate than a weighted sum to assess water quality, because its mathematical properties are such that emphasis is placed on the low-value scores. The weighted product is represented by the following equation:

$$I = \overset{n}{(\pi)}\ q^{w_i}$$

where,

n = number of terms to be multiplied together,

w_i= weight assigned to the i th term being multiplied, and

π indicates the operation of multiplying together all terms immediately following it.

The weighted product method allows safer estimations of water quality than the weighted sum method. The overall index is always less than, or equal to, that of the weighted sum. This method, according to Couillare and Lefebvre (1985) eliminates overestimation of the actual quality of water. This is the aggregation method recommended if the individual contaminant indices were to be combined into a single index.

Dinius (1987) improved a previous index he had developed, which included two broad steps. The first step required the calculation of a subindex function for each of 12 individual pollutant variables. These subindex functions represent the change in level of pollutant as the quantity changes for each of the 12 individual pollutants in the water. The second step was the aggregation of the 12 individual subindex functions into one overall index using a multiplicative form and employing pollutant importance weights proposed by the members of a panel. This resulted in the first basic type of index mentioned by Dinius (1987), based on the relationship of the quantity of each element present in the water to that water's quality.

Evans and Meyers (1990) discuss a DRASTIC Index that allows a systematic evaluation of the pollution potential of any hydrogeologic setting in the United States. Fifteen mappable units called hydrogeologic settings are described for different regions in the United States. Each of these settings incorporate the major hydrogeologic factors which affect and control ground water movement, including depth to water table, net recharge, aquifer media, soil media, topography, impact of the vadose zone, and hydraulic conductivity to the aquifer. These factors form the acronym DRASTIC, and are used to infer the potential for contaminants to enter ground water.

The relative ranking scheme uses a combination of weights and ratings to produce a numerical value, called the DRASTIC Index, which helps rate areas with respect to groundwater contamination vulnerability. Evans and Meyers (1990) pointed out that in this system the major physical characteristics that affect pollution potential were identified, including especially the generally measurable characteristics such as depth to water table, soil media, and aquifer media. A numerical ranking scheme was used to assess groundwater pollution potential, and contained three significant parts: weights, ranges, and ratings. Each of the major factors was evaluated with respect to the others to determine its importance. Each factor having a significant impact on pollution potential was then divided into ranges. Finally, each range was also evaluated with respect to the others to determine its relative significance with regard to pollution potential. The factors were assigned one value per range.

These settings were chosen to represent areas larger than 40 ha in size, which limits the system to use as a screening tool and not as a site assessment methodology. The index is an additive aggregation method, and the equation for determining the index is:

$$\text{Pollution Potential} = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W$$

where,

R = Rating,
W= Weight,
D = Depth to water table,
R = Net recharge,
A = Aquifer media,
S = Soil media,
T = Topography,
I = Impact of the vadose zone,
C = Hydraulic conductivity.

The higher the DRASTIC Index, the greater the ground-water pollution potential.

SAMPLING/MONITORING

According to Spooner et al. (1985), monitoring above and below an implementation site is generally more useful for documenting the severity of an NPS problem than for documenting BMP effectiveness. This may be explained, in part, by the fact that this procedure may have low sensitivity because individual nonpoint source inputs are rather small compared to background. This would be especially significant if one BMP were being monitored. If the system as a whole were being monitored, the individual BMP would not be the focus of concern.

This technique involves sampling a flowing system over time above and below a potential nonpoint source. This design has been classically used to monitor effects of nonpoint source discharges to flowing systems. Spooner et al. (1985) state,

> "The primary advantage of this approach is that it can account for upstream inputs to the area of interest. For agricultural nonpoint source projects, this will often be important for watersheds where the upper portions are in nonagricultural land uses."

An additional advantage is that little or no coordination is required between the land treatment and water quality monitoring components of the project. The above and below design has advantages over other designs when documenting the magnitude of nonpoint sources prior to implementing BMP's.

Spooner et al. (1985) list other monitoring designs that are based on the questions to be answered. Time trend designs, where before and after implementation monitoring is accomplished, determine if a change in water quality conditions has occurred. However, a long monitoring period is required to determine if significant changes in water quality have occurred. How contaminant levels vary with time could be of importantance in identifying when contaminants are entering surface waters and could therefore aid in source identification.

Probably the best monitoring design is paired watersheds which controls for meteorologic variability and can document water quality improvements related to BMPs in a much shorter time. The disadvantage is that implementation efforts on both watersheds must be closely matched. It may be difficult to find adequate similar drainages (Spooner et al., 1985). If, however, change in water quality is not the question being answered, this design may not be the best choice.

In a progress report on optimization of sampling strategy to assess agricultural NPS pollutant loading, Klaine (1990) pointed out that a critical element for assessing agricultural NPS pollution and BMP' s is the design and implementation of monitoring programs that can provide accurate characterization of the temporal variability of agrichemicals and suspended sediments concentration in runoff waters draining croplands. These monitoring programs select small basins because the variables that affect transport of chemicals and sediments (such as climate, land uses, and soil properties) can be defined with relative accuracy. Runoff transport of chemicals and sediment in these basins occurs mainly during storms. By being able to accurately characterize the temporal variability in contaminant concentration, investigators can compute accurate loads, particularly during storm events.

Partly because much of the research for assessing nutrient export and cycling in watersheds is in forested watersheds where little variability in the nutrient concentrations is observed for runoff water, designing sampling programs to characterize the temporal variability in the concentration has not been a major concern. In such instances a relatively small number of samples are required to characterize the temporal variability in nutrient concentrations for runoff water.

However, for investigators working with transport of suspended sediment, designing sampling strategies has been an area of intensive research. Klaine (1990), in referring to work by others, points out that a relatively large number of samples are required to characterize suspended sediment as concentration may vary over several orders of magnitude particularly during storm events. He went on to report that the recommended sampling intensity of 10 samples per median hydrograph rising time (MHRT) accurately characterized the suspended sediment concentration for the example cited. His example represented large watersheds with an average MHRT of about 20 hours.

Klaine (1990) monitored water quality and stream flow in four small agricultural basins (first order streams), in the Beaver Creek Watershed in West Tennessee. In two years about 60 storm events were monitored. Water quality data included collection and analysis of water samples for the determination of the total and dissolved concentration of nitrogen and phosphorous species, selected pesticides, and suspended sediments using two automatic samplers. Their sampling interval for the storm events ranged from 5 to 15 minutes: a 5 minute interval was typically maintained during the rising and falling limbs of the hydrograph, whereas a 15 minute sampling interval was used during recession flow. Preliminary analysis showed that the absolute error in the constituent discharge rate or sensitivity of the storm load calculation to sampling intensity ranges from 25 to 100 percent as the sampling interval increased from 5 to 60 minutes, and from 100 to 200 percent when the time interval between stage measurements increased from 5 to 10 minutes.

Johnson et al. (1982b) referred to related efforts which reported that nitrogen concentrations showed a decrease from storm to storm, indicating that each storm should be sampled or an accounting made for this decrease to determine the storm quantity discharges of NO_3-N during the cropping season. This storm-to-storm effect was not as evident for NH_4-N, inorganic P, total Kjeldahl N, and Na HCO_3-extractable P, indicating that sampling of every event would not be required to determine cropping season quantity discharges of these nutrient constituents.

Once the appropriate sampling protocol has been established it is necessary to choose the contaminants that are to be considered for sampling and why they are of concern in relation to BMPs that have been employed. Investigations by the state of Tennessee, for instance, indicate that sediment, phosphorus, nitrogen, and coliform bacteria are contaminants that impact the quality of state waters most. These four contminants would therefore be good selections to monitor and sample for water quality research.

SEDIMENT

Sediment from soil erosion is the single largest pollutant in U.S. surface waters. It reduces stream and reservoir capacities, causing increased flooding, disrupting biological systems, degrading drinking water supply, and transporting nutrients, pesticides and bacteria to waterways (Johnson et al., 1982a). According to Johnson et al., farmland is recognized as the largest contributor of sediment to U. S. waters with over 6.4 billion tons of topsoil eroded each year.

Johnson et al. (1982a) point out that the USDA-SCS estimates that about 50% of the sediment in the nation's waterways is thought to come from cropland, while approximately 30% of the total probably represents the natural level of sedimentation. The areas where this sediment originate are primarily those that combine intensive agriculture, hilly topography, and erodible soil types. Johnson et al., go on to state that, in fact, the percentage of eroded soil in a watershed which becomes sediment in waterways will tend to be less in situations where the major erosion sources are either located distant from water courses or are separated from water courses by holding areas such as woodlands, other vegetated areas or sediment basins.

In attempting to determine what type of BMPs may be most effective, Razavian (1990) concluded that nonstructural (agronomic) BMPs are generally more effective for controlling erosion and nonpoint source pollution than are structurally oriented BMPs. Nonstructural BMPs in Razavian's study included agronomic change from conventional tillage to chisel plow, minimum tillage, and no-till systems. Structural BMPs were sedimentation basins (ponds).

NUTRIENTS

Phosphorus

In order to determine how various BMPs affect the amount of phosphorus in surface water some standard needs to be established defining how much phosphorus is too much. In studies of BMPs for animal waste it was found that phosphorus as phosphate (PO_4 - P) in concentrations in excess of 0.025 mg/L occurring at spring overturn in lakes and reservoirs can stimulate excessive or nuisance growths of algae and other aquatic plants (Johnson et al., 1982b). They also point out that others have suggested that critical values are 0.01 and 0.02 mg/L for soluble and total phosphorus, respectively.

To rate BMPs on their effectiveness for preventing phosphorus contamination above the acceptable standard, important factors include how it reacts with soil, how its moves, and in what forms it exists. Sharpley et al., (1993), reference work which found that phosphorus in the soil readily reacts with available calcium, iron, and aluminum to form insoluble compounds, or that it can be adsorbed to soil particles. This means that surface runoff is the general mode of phosphorus transport.

Sharpley et al. (1993) also reported on work dealing with the movement of phosphorus in particulate and dissolved forms. It was indicated that phosphorus movement in runoff occurs as particulate P (PP) and dissolved P (DP). In general, PP is the major portion (75 to 90%) of P transported in runoff from cultivated land. In terms of impact on eutrophication, bioavailable PP represents a variable (10 to 90% of PP), but long-term source of P for algal uptake. Dissolved P is for the most part immediately available for algal uptake. Together, bioavailable PP and DP movement in runoff represents the bioavailable P content of runoff (Sharpley et al., 1993).

Work is ongoing to determine whether total phosphorus or bioavailable phosphorus is of the greatest concern. Sharpley et al. (1993) refer to studies which indicate that lake productivity decreased little with reduced total P inputs and have attributed this to an increased bioavailability of P entering lakes. Therefore, the importance of management practices must be evaluated in relation to how much bioavailable P is moved from landscapes.

Sharpley et al. (1993) indicate that the first step in the movement of DP in runoff is the desorption, dissolution, and extraction of P from soil and plant material. These processes occur as rainfall or irrigation water interacts with a layer of surface soil of approximately 1 to 3 mm (0.04 to 0.12 in) before leaving the field as runoff. They conclude that the accelerated eutrophication of surface waters by P is mostly associated with inputs from surface rather than subsurface flow.

Concerning placement of fertilizer, Sharpley et al. (1993) found that runoff DP concentration from areas receiving broadcast fertilizer averaged 100 times higher than the concentrations from areas where comparable rates of fertilizer P were point-injected below the soil surface. Most phosphorus transported in runoff occurs in one or two intense events during a year. It is believed that phosphorus movement in landscapes can be reduced by careful mineral and organic fertilizer management, and by erosion and runoff control. Where possible, subsurface placement of P away from the zone of removal in runoff will reduce the potential for P movement. Phosphorus movement via erosion and runoff may be reduced by increasing cover through conservation tillage. It was found, however, that dissolved P concentrations in runoff from no-till practices were greater than from conventional practices (Sharpley et al., 1993). Reducing tillage operations also increased the portion of total P that was bioavailable in both dissolved and particulate P forms.

Filter strips or zones can effectively reduce erosion. Tile drainage, and impoundments or small reservoirs are more efficient at reducing PP than DP movement in runoff. However, studies on dissolved phosphorus concentrations in runoff from simulated rainfall on corn and soybean tillage systems (McIsaac et al., 1995) indicated that dissolved P concentrations in runoff from no-till and ridge-till systems may be problematic for surface water quality. However, Sharpley et al. (1993) referenced other studies which indicated that soluble P concentrations and losses from row-cropped land under no-till or ridge-till management may be reduced by subsurface placement of fertilizer.

McIsaac et al. (1995) refer to work done using a rainfall simulator to study the effects of conservation tillage and no-till at three rye crop residue levels. Researchers found that runoff and sediment losses decreased as crop residue levels increased, regardless of the tillage system. There is a synergistic effect in reducing runoff and soil losses with increased residue and no-till, with the greatest reductions in runoff and soil loss occurring with no-till at the greatest residue level. Average PO_4 concentrations with no-till were greater, and sediment bound P concentrations were less than those with conventional tillage. Overall, however, no-till was effective in reducing PO_4, P_{sb} (sediment bound P), and P_t (total P) losses by 91, 93, and 97% respectively, when compared to conventional tillage.

Nitrogen

Though it has been pointed out that nitrate itself is not toxic at a concentration of 10 mg/L, its reduction product, nitrite, can react with hemoglobin in the bloodstream to impair oxygen transport in warm-blooded animals. This condition of methemoglobinemia, blue baby syndrome, can be hazardous to infants younger than three months (Johnson et al., 1982b). However, total nitrogen concentrations as low as 1 to 2 mg/L have been associated with algal bloom.

COLIFORM BACTERIA

Howell et al. (1995) refer to numerous studies which show that agricultural runoff from pastures contains fecal bacteria concentrations which frequently exceed the USEPA standard for primary contact water (200 fecal coliform/100 ml). High levels of coliform bacteria are not unusual anywhere that cattle are present. Howell et al. also refer to research which found that when cattle are allowed to graze directly adjacent to streams, stream banks and bottoms may become significant bacterial reservoirs.

In Howell et al.'s (1995) study, fecal coliforms were always present in streams, and almost always exceeded primary contact water standards. They found high fecal coliform concentrations in streams both after rainfall and when cattle were present. High fecal coliform concentrations were also observed in the absence of either rain or cattle. Howell et al. also referred to research which found that fecal bacteria in sediments could be resuspended after stream bottom disturbance.

The season of the year can also influence coliform bacteria. Howell et al. referred to a 3-yr study which concluded that after the warmer weather of spring, fecal coliform numbers in runoff increased long after cattle had been removed. These results support the previous contention that even though cattle are not currently present, coliform bacteria may still be present.

CHAPTER 3

DEVELOPMENT OF THE INDICES

The indices were developed as tools to relate surface water quality to the management practices employed and to the responsiveness of a particular unit of land. Those indices were the MPI, SRI, and SWI. The MPI describes how well the land owner is managing his unit of land. The SRI gives an indication of the responsiveness of the unit to those management practices, and the SWI is an indication of how the measured contaminant level compares to the standard. First, the MPI development is addressed, followed by development of the SRI, and then the SWI. These indices were developed for sediment, phosphorus, nitrogen, and coliform bacteria. These four contaminants were chosen because they were considered four of the major NPS contaminants coming from agriculture.

These indices were developed using information taken from an actual dairy farm in Claiborne County, Tennessee. The dairy farm was divided into two subunits, a western and an eastern subwatershed, and were designated subwatershed A and subwatershed B, respectively. Although four automatic samplers were employed with one sampler on subwatershed A and three samplers on subwatershed B, comtaminant analysis was based entirely on grab samples at these points. The three sample points on the eastern subwatershed were on Davis Creek.

MANAGEMENT PRACTICE INDEX (MPI)

Briefly, the MPIs for each contaminant were developed in the following manner. The management practices for each subunit were evaluated in terms of effectiveness and risk. There were two subunits on the dairy farm where this project was accomplished. The practice ratings and risk ratings were assigned for each practice under each BMP. These were multiplied by the appropriate weights and summed to arrive at an actual and a potential total score for the subunit (subwatershed). The actual score was then divided by the potential score to arrive at the MPI, or the unit subindex. For each contaminant these subindices were averaged for an overall contaminant MPI. If desired, the individual contaminant MPIs could be aggregated into a single MPI. Although this option will be discussed later, the individual contaminant MPIs are the major point of this research. Now a more detailed development of the MPIs will be addressed.

In developing the MPI a basic concept was borrowed from the DRASTIC, relative rating system as explained by Evans and Meyers (1990). For DRASTIC ratings and weights were used to develop an index that rated the potential of a land unit for groundwater pollution. Ratings were assigned to each of seven parameters that were deemed as important in relation to groundwater contamination. Each parameter was assigned a rating and then multiplied by a weight that reflected its significance in relation to all the other parameters. The multiplied rating and weight for all seven parameters were summed to give an overall index. DRASTIC resulted in an index that provided a relative evaluation tool but was not expected to provide absolute answers.

In this research, the MPI is based on four contaminants, numerous BMPs under each contaminant, and several practices under each BMP (the MPI determination is shown in Appendix A). The weights assigned to each contaminant would reflect the relative importance of each contaminant. If it is desirable to aggregate the four contaminant MPIs into one overall MPI the weighted product method is recommended.

To facilitate use of the optional weighted product aggregation method, each of the four contaminants was given a relative weight of 0.1 to 0. 4 with the contaminant of greatest significance receiving a weight of 0. 4. Thus a weight of 0.4 would indicate the greatest potential for reducing pollution. These weights could in fact be changed to reflect the contaminant that may be of the greatest concern in a particular situation. For instance, phosphorus might be given the weight of 0.4 because it is the major contaminant that is causing eutrophication of a nearby lake. In another situation, sediment may be given a weight of 0.4 because a nearby reservoir is being silted up, resulting in decreased water holding capacity.

According to the 305(b) report by the Tennessee Department of Health and Environment (TDHE, 1990) on the status of water quality in Tennessee, the relative contributions of major water quality problems in impacted streams listed siltation as the greatest contributor followed by suspended solids, pathogen indicators, organic enrichment, and nutrients. Relative contributions of major causes in impacted lakes listed nutrients, organic enrichment, and siltation. The above weight factors were selected by considering both lakes and streams. In that same report Davis Creek was listed as an alternate target watershed for NPS projects, and its problem was listed as sediment and bacteria. They are target contaminants due in part to the Powell River into which Davis Creek empties being an interstate watershed (Virginia and Tennessee), and in part because of the high recreational value of Norris Reservoir.

Additionally, the 305(b) summary report (TDHE, 1990) indicated that by volume, the pollutants impacting the most water bodies are silt, sediment, and nutrients. Nitrogen and phosphorus are nutrients that are the major contributors to the eutrophication of water bodies. Phosphorus loss to surface water is considered especially important because it is the nutrient limiting agent for aquatic vegetation.

In the MPI evaluation scheme several BMPs are listed under each contaminant that affect the amount of that contaminant entering the surface water. Each BMP was given a relative rating factor, with the sum of all of the BMP rating factors under a particular contaminant equal to 1.0. This was done so that contaminants with different associated numbers of BMPs would be treated equally. The rating factor reflects the significance of that BMP among all the BMPs under that particular contaminant. A BMP may be listed under more than one contaminant, depending on whether it is expected to influence the level of contaminant reaching the surface water. Table 1 is an example of BMPs and their rating factors.

Under each BMP there are several related practices (the practices are defined in Appendix B). The practices under each BMP have been given ratings that sum to 1.0 and which reflect individual practice significance among all the practices under a given BMP. A risk rating factor has also been assigned to indicate the relative degree of risk if , for instance, that practice should fail and have some detrimental effect. Table 2 indicates how this weighting is done.

Table 1. An example of BMP rating factors for phosphorus.

BMP Number	BMP Name	Rating Factor
15	Fertilizer Management	0.15
2	Animal Waste Management	0.12
4	Terrace	0.09
11	Permanent Vegetative Cover On Critical Areas	0.09
13	Irrigation Water Management	0.09
8	Cropland Protective System	0.09
9	Conservation Tillage	0.09
5	Diversion Systsem	0.09
3	Strip cropping	0.09
12	Sediment Retention, Erosion/ Water Control Structures	0.09
10	Stream Protection	0.09
	Sum	1.005*

* Sum of BMP weights should sum to approximately 1.0.

Table 2. An example of relative rating factors and risk factors.

BMP 2 (Animal Waste Mgmt)	Relative Rating Factor	Risk Factor
Practice		
Diversion	0.12	0.000
Guttering	0.12	0.000
Waste Treatment Lagoon	0.09	0.278
Irrig Syst for Waste	0.09	0.167
Waste Storage Syst	0.07	0.111
Waste Storage Pond	0.07	0.111
Surface Drain	0.07	0.056
Subsurface Drain, Fld Ditch	0.07	0.056
Subsurface Drain, Main or Lat	0.07	0.056
Critical Area Planting	0.05	0.056
Grassed Waterway or Outlet	0.05	0.056
Filter Strips (Feedlots)	0.09	0.056
	Sum 0.96	Sum 1.003

To indicate how well each of these practices were implemented, each of the practices is assigned a value of 0, 1, or 2. A zero means the practice has not been implemented, a 1 means it has been implemented but is not fully effective, a 2 means it has been implemented and is effective. To indicate the risk associated with each practice a value of 0, -1, -2 has been assigned to each practice. A zero indicates no risk, a -1 indicates possible risk, and -2 indicates probable risk. Literature often cites practices that are good for controlling sediment, nitrogen, or phosphorus in surface waters, but there is no specific rank ordering of the relative effectiveness of one practice to another. Therefore, all weights and rating factors are based on best judgement after having reviewed available literature.

The evaluation procedure for the MPI begins by dividing the whole operational unit into subunits; i.e., fields, holding lots, feeding/milking areas, etc. In this research the operational unit was divided into two subwatersheds. Each subunit was then evaluated in terms of management practices employed. The evaluation sheet has a separate section for each of the four contaminants; sediment, phosphorus, nitrogen, and coliform bacteria (see Appendix A). Under each contaminant are listed the BMPs that apply and under each BMP are listed the related practices. Each subwatershed is rated independently and the ratings averaged for the final index.

For each practice there are two groups of columns. The left group of columns is for actual practice, where each practice will be given a rating of 0, 1, or 2 as mentioned earlier. The right group of columns is for optimum practice. In the actual practice group of columns the practice rating is multiplied by the rating factor and the risk rating is multiplied by the risk rating factor. The actual practice score is the sum of the two products.

For the right group of columns dealing with optimum practice, a rating is given of either 0 for not applicable or 2 to reflect the maximum value if it is applicable and could have been implemented. The optimum practice score is determined by multiplying the optimum rating by the practice rating factor.

For each BMP the actual practice scores and the optimum practice scores are individually summed and multiplied by the relative BMP rating factor for an actual BMP score and a optimum BMP score. The actual BMP scores and the optimum BMP scores are then added for an actual contaminant score and an optimum contaminant score. A contaminant subindex is computed by dividing the actual contaminant score by the optimum contaminant score. The contaminant MPI is determined by averaging the contaminant subindices for the two subunits.

This research emphasized developing and computing individual indices for each contaminant. If a single overall index for the entire unit is desired, a weighted product aggregation method is suggested as a possible approach. In this case the two contaminant subindices are not yet averaged. Instead , to obtain an overall unit index each contaminant subindex is weighted by raising it to a power equal to its contaminant weight. Then for each subunit all four weighted contaminant subindices are multiplied together for a subunit index. It is at this point that all the subunit indices are averaged for an overall unit index. Table 3 outlines the steps in the evaluation process.

Where a practice is best implemented in conjunction with another practice, a note will be added stating that if the practices are not implemented together they will be assigned a value of 1 indicating they are not effectively used.

Relative Rankings for BMPs and Practices

To compute the above described index it is necessary to assign relative rating factors to each BMP and to each practice. This has been done using

Table 3. Steps involved in the evaluation process for contaminant MPI.

Step 1 - Compute Actual and Optimum BMP scores for each contaminant,

Phosphorus	Actual Practice					Optimum Practice	
BMP 9 - (Fertilizer Management) (Rel Rat Fact 0.15)	Rating	x Rating Factor	+ Risk Factor	x Risk Rating	= Score Rating	Rating	= Score (x rating factor)
Practices							
Deter Crop Rqmts	0.33	2	0.000	0	0.660	2	0.660
Comm Fert Rqmts	0.33	2	0.500	0	0.660	0	0.660
Waste Mgmt	0.33	1	0.500	0	-0.170	2	0.660
Practice Score Total				Actual	1.150	Optimum	1.980

BMP Score= Score x Relative Rating Factor (0.15) = 0.173 0.297

Step 2 - For each contaminant add all actual BMP scores and add all optimum BMP scores,

(Sediment)	Actual BMP Score	Optimum BMP Score
BMP 9	0.21	0.21
BMP 4	0.0	0.0
BMP 13	0.0	0.0
BMP 11	0.07	0.09
BMP 8	0.18	0.18
BMP 1	0.14	0.18
BMP 3	0.00	0.00
BMP 7	0.00	0.00
BMP 12	0.00	0.00
Contaminant Scores	0.53	0.66

Step 3 - Divide Actual Contaminant score by Optimum Contaminant score to obtain a contaminant subindex for each of the four contaminants,

Contaminant Subindex = 0.53/0.66 = 0.80

Step 4 - Repeat steps 1-3 for each subunit,

Step 5 - Average contaminant subindices from all subunits for an overall contaminant index,

Table 3 (continued)

Optional (for a single overall index skip steps 4 and 5 and continue with step 6)

Step 6- Aggregate the four contaminant subindices into an index for the subwatershed using weighted product method,

$$\text{Index (subwatershed)} = (\text{Sed Subindex}^{0.4} * \text{Phos Subindex}^{0.3} * \text{N Subindex}^{0.2} * \text{Coliform Bact Subindex}^{0.1})$$

Step 7 - Repeat steps 1 - 4 for each subunit (subwatershed),

Step 8 - Average subunit indices (watershed A & watershed B),

$$\text{Overall Index} = (\text{Index A} + \text{Index B})/2.$$

best judgement based on information obtained in literature. The basis for these judgements will now be outlined.

Sediment

The conclusions and recommendations made by Johnson et al. (1982a) were primarily used as guidelines for assigning these values for sediment. They are presented below.

1. Erosion reductions on cropland are generally proportional to reductions in the amount of tillage performed. Conservation tillage systems can reduce soil losses from 47 to 99 percent compared to conventional moldboard plow techniques, and are an effective alternative in areas where no-till is not well adopted. Surface runoff from conservation tillage averages about 25% less than from conventionally tilled fields.

2. No-till is extremely effective in reducing erosion losses, with reductions of 70 to 99%, but is not adapted to all regions and requires higher management than conventional tillage. Research indicates that no-till is most effective in warmer climates in well-drained soils to moderately well-drained soils.

3. Reduced tillage systems also decrease nutrient losses but not to the same extent as soil losses. While overall nutrient losses are lower, the dissolved fractions may increase.

4. Contour farming is an effective practice for reducing erosion and surface runoff by increasing rainfall infiltration. It is best adapted to permeable soils and moderate slopes.

5. Terraces are very effective for reducing erosion losses with reductions of 50 to 98 % reported in the literature. Absorbed pesticides and nutrient losses are dramatically reduced and surface runoff decreased. However, terraces are relatively expensive to install, and nutrient leaching to groundwater may be increased when this practice is used.

6. The combination of diversions and grassed waterways is a widely accepted system for reducing erosion and sediment transport, but there are little quantitative data on loss reductions.

7. Cover crops can reduce erosion up to 95%, increase soil organic matter, and may reduce nitrate leaching. Legume cover crops provide available nitrogen for subsequent crops.

8. Rotations that include a sod crop can reduce erosion losses from 40 to 80%. The economic loss in years when a cash crop is not grown reduces the acceptability of this practice.

9. Sediment basins are effective for reducing sediment delivery from severe storms and for trapping small (1-50 μm) soil particles, but the cost-effectiveness of this practice relative to cropland protection has not been determined.

10. Although few data are available, it appears that stream bank stabilization is not a general BMP for sediment control. One study estimated that only 5% of all watershed losses were due to stream bank erosion, but a significant expenditure of funds was devoted to this practice in the cited project.

Nitrogen and Phosphorus

Nitrogen is lost from the production system mainly through leaching, as nitrate nitrogen dissolved in water moving through the soil. Magette and Weismiller (1985) indicate that some nitrogen can also be lost in surface runoff, especially if runoff occurs soon after the fertilizer is applied. They say that in general, nutrient management can be best accomplished using two techniques: 1) limiting the quantity of nutrients applied or increasing the efficiency with which they are used by crops; and 2) increasing the retention of nutrients in the field. Their studies point out that BMPs for reducing losses of nitrogen and phosphorus from field crops include: proper nutrient application rates, appropriate timing of nutrient application, appropriate method of nutrient application, reduced tillage practices, crop rotations, cover crops, critical area seeding, and ponds.

Johnson et al. (1982b) in their publication concerning animal waste, made several conclusions and recommendations for controlling inputs of phosphorus and nitrogen from animal wastes in surface and ground waters. They are included below.

1. Soil testing should be done yearly to determine in part if nitrogen is being efficiently used.

2. Manure nutrient analysis should be made just prior to land application so that nitrogen and phosphorus contents can be matched with crop requirements.

3. Rates of application should be based on crop nitrogen and phosphorus needs, otherwise excess application rates can lead to nitrate - nitrogen leaching into groundwater sources, and phosphorus accumulating in the upper soil profile where it is susceptible to erosion.

4. Applications should occur just prior to, or during, periods of maximum crop nutrient uptake, such as in either spring or summer when crops can utilize most of the nutrients. When applying wastes in the fall, up to 50% of the total nitrogen can be lost through decomposition and leaching. Winter manure applications have also shown large nutrient losses; up to 86% of the nitrogen and 94% of the phosphorus applied during the winter season can be lost in a single rainfall, or snow melt, runoff event. If fall and winter applications cannot be avoided, manure rates should be applied to a vegetative cover crop, thus reducing runoff losses.

5. Manure should be applied either by broadcasting and immediate incorporation, or by liquid injection, thus avoiding losses by ammonia volatilization and by surface runoff.

6. Vegetative filter strips should be used as a treatment for feedlot and dairy wastewater runoff. Filter strips have been found to reduce the nitrogen and phosphorus in animal waste runoff by 77% and 94%, respectively.

7. Rangeland management should include restriction of pastured animals from lakes or other impoundments and streams, and rotational grazing to prevent grass cover reduction.

Some research has shown that phosphorus concentrations can be higher in runoff from fields under conservation tillage than from those with more intense tillage. The reason for this is that phosphorus is released from decaying plant residues on the soil surface (as well as other factors). However, total phosphorus loss is much lower because conservation tillage is so effective in reducing runoff and erosion (Darst and Murphy, 1994).

Coliform Bacteria

Johnson et al. (1982b) in their publication dealing with animal waste, reference research which indicates that bacteria stored in lagoons or applied to soil die off rapidly. They also indicate that significant reductions in coliform organisms in the runoff water were seen after the runoff passed through vegetative strips.

It is recommended in the same publication by Johnson et al. (1982b), that stocking rates should be such that pasture areas are not converted from a grazing area to a holding area. Additionally pasture feeding areas should be as far removed from water courses as possible and should be periodically rotated in order to allow the denuded areas around the feed bunk to recover. This publication also points out that the most effective practice for reducing pollution from small feedlots is to divert external water around the feedlot and thus prevent clean water form picking up solid and liquid pollutants from the feedlot.

SYSTEM RESPONSE INDEX (SRI) AND STANDARD WATER INDEX (SWI)

In conjunction with a management practice index for each contaminant, there is a SRI and a SWI for each contaminant. The SRI fits into the first category of water quality indices mentioned by Dinius (1987) as one which translates the levels of polluting elements into a quantity based on the relationship of the quantity of each element present to that water's quality. The SWI fits into the category based on some set of standards. These two indices together with the MPI comprise the set of tools that were the goal of this project and that can be used to aid in management decisions relating to water quality. These two additional indices are determined for the same four parameters as the management practice index; sediment, phosphorus, nitrogen, and coliform bacteria.

Several initial steps are involved in determining the SRI and SWI. First, weekly samples are collected and analyzed for contaminant concentration. The flow is measured at each sampling point. The mass transport of each contaminant is computed by multiplying the weekly flow by the weekly concentration. This provides a measured level of mass contaminant transport.

The sampling scheme is a crucial prerequisite, because samples and flow information are important in determining SRI and SWI. For this farm the selection of sampling points was fairly straight forward. However, several farms were considered for this research but were rejected because of the difficulty in setting up a monitoring/sampling scheme. If there are no streams that can adequately represent the watershed, then overland flow must somehow be monitored and sampled. This can forseeably be a complex and difficult task. If this procedure is to be applied to other farms a method must be found that can be applied to all circumstances encountered.

A worst case scenario is computed for each contaminant. This measured value, the worst case, and the previously computed MPI are used to compute the SRI for each contaminant. This SRI indicates the degree of responsiveness of the system.

The standards for each of the contaminants are identified and compared to the weekly measured concentrations to arrive at a SWI for each contaminant. The SWI is merely a comparison of the measured concentration to the standard for each contaminanat.

The SRI is expressed by the following equation:

$$SRI = \frac{Measured}{Measured\ Theoretical} = \frac{Measured}{(WC(1 - MPI))}$$

where,

Measured = Contaminant loading in stream, kg/wk;
WC = Worst Case Loading, kg/wk;
MPI = Management Practice Index.

Note: For coliform bacteria measured and WC are in colonies/100 ml

The term "theoretical measured" is defined as WC(1-MPI) and is an attempt to express what the theoretical contaminant level would be based on the MPI. If, for instance the MPI were zero or there were no management practices employed, then the theoretical measured value would be equal to the worst case loading and would be very large. If, however, the management is nearly perfect, the measured theoretical contaminant level would be very small. The equation "blows up" when the MPI = 1.0 due to attempted division by zero.

The SRI gives an indication of the system response to contaminant loading based on the worst case expected and the level of management being employed. It may be best visualized as the probability that the water quality of the system (farming operation in this case) will change with a change in the management for a given worst case and loading (measured value). The inverse of the SRI would be the buffering capacity of the system for a particular contaminant. As the buffering capacity increases (an increased ability to keep contaminant out of surface water), the system response would decrease. In other words, for a low SRI as more contaminants are put into the system there will be little degradation of water quality, i.e., the system response will be small.

The SWI is an index of secondary interest and is merely a layman's indication of how the measured water quality compares to the applicable standard. The equation for the SWI is:

$$SWI = \frac{Measured}{Standard}$$

where,
Measured = Measured level of contaminant,
Standard = Contaminant Standard.

In the case of all but coliform bacteria there is no standard that directly applies to the contaminant being measured. However, generally accepted standards that appear in literature are being used and will be identified and discussed for each contaminant. Several assumptions have been made as to what units will be used for the four contaminants in determining these two indices. Water samples were analyzed for total solids, total phosphorus, total nitrogen, and actual coliform colonies per 100 ml of sample. A more detailed discussion of how contaminant levels, worst case scenarios, and standards were selected is now in order.

Sediment

First, to obtain a measured value for erosion and sediment loads, the water samples were analyzed in the lab for total solids. It is realized that total solids include dissolved and suspended solids, but total solids may give no good indication of the bed load of sediment that may be moving along in a siltating mode and which may comprise a majority of the sediment load especially during storms.

The worst case to be used in sediment SRI computations was determined by computing the sediment yield from the subunits using the Revised Uniform Soil Loss Equation (RUSLE). Results of the RUSLE (Haan et al., 1994) computations are in Appendix C. RUSLE is similar to the Uniform Soil Loss Equation (USLE) in that, as pointed out by Haan et al., it does not consider deposition that may occur before eroded sediment may reach the stream. The yearly erosion value was divided by 52 to obtain a weekly worst case value. In short, the total solids measured from lab analysis were related to the worst case erosion expected and to the level of management being practiced.

The Tennessee standard is expressed as total suspended solids, but this value has not been used in the SWI computation. Instead, a soil erosion of 11.2 metric tons/ha/yr (5 tons/ac/yr) is used as the standard.

<u>Phosphorus</u>

The samples were also analyzed for total phosphorus. A mean of all these values for the sampling period was related to the worst case and to the MPI when computing SRI. Phosphorus exists in many forms, with the form most likely causing eutrophication being HPO_4 or orthophosphorus, which is the dissolved form. Additional bioavailable phosphorus occurs in the particulate form and especially during large storms may be washed from the soil surface where it has adsorbed to soil particles.

Phosphorus from fertilizer occurs as P_2O_5. These forms of phosphorus are in a constant phosphorus cycle, so what forms exist and how much is in each form depends on such factors as temperature, soil pH, and available microorganisms. Therefore, in arriving at a worst case scenario only P in its basic form will be considered. The P in crops that are harvested and in manure and fertilizer that are applied are subtracted or summed to determine the net or worst case phosphorus load for the period of evaluation. The standard selected was 0.02 mg/L of total phosphorus which is the level at which eutrophication has been shown to occur. There is no Tennessee standard for phosphorus. The MPI comes from the evaluation already performed on the unit.

Nitrogen

Nitrogen (N) was handled similarly to phosphorus. The nitrogen cycle is a complex series of transformations of N from one form to another, and it is difficult to ascertain with any degree of accuracy how much is in what form. However, it is understood that N in the NO_3 form seems to be the form of major concern for "blue baby syndrome" considerations and for eutrophication. Therefore, nitrogen in its elemental form was determined from lab analysis, i.e., total nitrogen. NO_3, NO_2, and TKN were summed to arrive at total nitrogen. The concentrations of NO_2 were multiplied by 0.30, the percentage of nitrogen in NO_2 based on atomic weight. Similar to the treatment for NO_2 the concentrations of NO_3 were multiplied by 0.23. TKN includes organics and ammonia; therefore, the sum of nitrogen in NO_2, nitrogen in NO_3, and TKN represent total nitrogen.

The nitrogen concentration for each weekly composite sample is multiplied by the volume of water passing the sampling points to arrive at a nitrogen load. The worst case was determined by computing net nitrogen on the dairy farm, i.e., incoming nitrogen minus outgoing nitrogen. The standard used was 10 mg/L which is based on the levels of NO_3 that may result in "blue baby syndrome."

Coliform Bacteria

Coliform bacteria is analyzed in the lab to determine actual colonies per 100 ml of sample. A worst case scenario for comparison was based on the flush water from the dairy barn. This does not represent what may be coming off the pastures where cows are grazing or where solid manure has been spread, but it is certainly a worst case for this dairy operation. It does, however, give an idea of how much contaminant would enter the stream if the operation were on a concrete slab that sloped directly into the creek, an MPI equal to zero. This would be considered the worst case. If a beef operation were considered where the cattle were not confined, then the worst case would include the waste from grazing cattle and/or spread manure. The samples were taken before the flush water entered the solids separator for the lagoon.

Once the MPI, the worst case, and the measured levels of a contaminant have been determined, the SRI and SWI can be computed. The MPI, SRI, and SWI comprise a set of tools that a land owner can use to determine if he has a water quality problem, whether he is able to do anything about it, and what areas he should concentrate on to bring about necessary water quality improvement.

The SWI would tell him whether or not he exceeded the standard for a particular contaminant. This would be indicated by a SWI greater than one. The SRI would give him an idea of the system's responsiveness which is related to its buffering capacity. A high SRI indicates a high responsiveness and a low SRI indicates a low responsiveness. The SRI relates the measured values, the level of management, and the worst case scenario. A high MPI and a low SRI indicates that although the system is being managed well, additional management improvements would result in little or no change in water quality. A low MPI and a low SRI indicate that even though the land is not well managed, the water quality would respond little to improved management. A high MPI and a high SRI should indicate a high level of management, but additional management improvements should still result in improved water quality. A low MPI and a high SRI show the most potential for improving water quality, because the land is not being managed as well as it could be, but the system would be responsive to those management improvements. The actual field measurement of these above mentioned parameters and indices are presented in Chapter 4.

CHAPTER 4

FIELD MEASUREMENT/VALIDATION

FARM DESCRIPTION

The operational unit selected is a 105 ha (260 A) portion of a dairy farm located on Davis Creek in Claiborne County, Tennessee. The dairy farm has about 225 milking Holsteins, with about 50 to 65 head being dry at any time. There were 50 to 80 head of young cattle being fed separately. Approximately 34 ha (84 A) were planted to haylage and corn silage, and 59 ha (145 A) were used for pasture and hay. The remaining acreage is in forest from which the cattle are fenced. No-till cultivation was used over the entire farm.

The milking cows are completely enclosed in a free stall barn. The dry cows have access to feed in a different section of the free stall barn and have access to pastures for grazing. Wastes from the free stall barn are flushed into a two-stage anaerobic lagoon after going through a solids separator. The solids are stored under a covered waste storage area. Water from the second stage lagoon is recycled to a flush system in the free stall barn. For this flush system, effluent is pumped from the second stage lagoon to a 63,650 L (14,000 gal) upright storage tank which is gravity fed to flush the floor at a 27,300 L per minute (6000 gal/min) rate of discharge.

Solid waste is spread on the surface only and is not incorporated due to no-till operations. The first stage of the lagoon is pumped about twice a year, in spring and fall. The effluent after being agitated is pumped onto a 6.2 ha

(15.4 A) field just north of the lagoon and occasionally on an adjacent pasture using a big gun. The big gun and hose reel are adjusted to apply effluent at a depth of 2.5 cm (1 in.) over the entire field. A buffer area is located between this field and Davis Creek.

Davis Creek, in subwatershed B, is fenced to prevent access by cattle. A natural strip of vegetation 3 to 5 meters wide has been left along most of the length of the creek to act as a filter strip. The woodlands are also fenced to prevent cattle access.

After the silage was cut in the fall of 1994 a cover crop of wheat and vetch was planted and cut as haylage in the spring of 1995. After the 1995 silage was cut, a cover crop of only wheat was planted. Pastures are a mixture of orchard grass, fescue, and clover. A farm plan was developed by the Natural Resources Conservation Service (NRCS), and highly erodible acreage was identified and farmed in accordance with recommendations provided in the plan. A portion of the farm lies across state highway 63, but that portion of about six hectares (15 acres) has not been included in this research.

An additional area of 18 ha (45 A) on an adjoining farm (field WE) have been included in subwatershed B because of its influence on Davis Creek. Corn, hay, and tobacco are grown on this area.

The farm is located at the base of the Cumberland Mountain range and is in a karst area. There are several depressions on the property and the surrounding area. About half way through its traverse of the farm Davis Creek enters a sink area. The creek below the sink area is dry during portions of the summer and fall.

SUBUNITS

The subunits into which the dairy farm have been divided are subwatersheds. The farm is roughly split in half between the two subwatersheds, with 62 ha in subwatershed A and 43 ha in subwatershed B (fig.1). Subwatershed A drains into an intermittent stream that exits the property on the western side and eventually flows into a sinkhole. Just above this point a 152 degree v-notch weir has been constructed to accommodate approximately 283 L/s (10 cfs) of flow, which is estimated to be adequate for a 2-year, 3-hour storm on this landform. See Appendix D for the weir design and related equation.

Subwatershed B drains directly into Davis Creek.. The upper portion of the creek flows year round. As mentioned earlier , about halfway through the property the creek enters a sink area, and below the sinks the stream dries up in summer. Further downstream off the farm the stream again has year round flow after input from Vanbebber Spring. There are over 365 ha (900 A) in subwatershed B that lie above the farm. This acreage is wooded and is mostly on the steep mountainside.

The topography of the farm is such that all surface flow enters either the western intermittent stream or Davis Creek on the east, and must flow past one

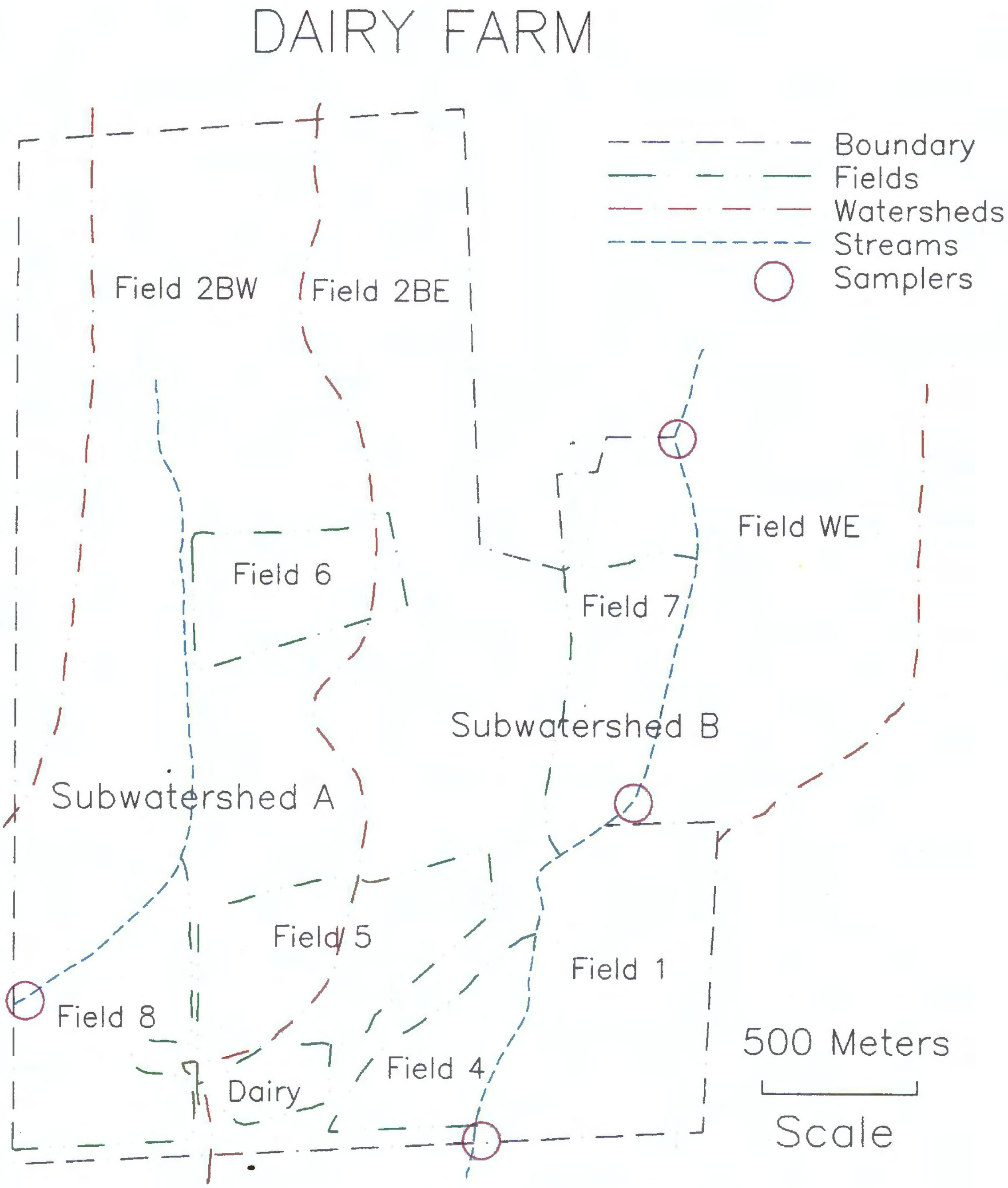


Figure 1. Schematic of Project Dairy Farm

of the four sampling points. There is a large depression in the western subwatershed, but no surface flow has been observed to flow out of the depression. As pointed out earlier, the scope of this research deals only with surface flow and does not consider subsurface flow.

The farm was divided into these two subunits because the terrain and drainage were suited to a sampling scheme of four sample points with little input from other areas outside the farm other than the primarily wooded area from which Davis Creek emerges above the farm and the 18 ha on an adjacent farm. The area drained at each sampling point is cumulative and is as follows: on subwatershed B; site one - 373 ha (921 A), site two - 428 ha (1059 A), and site three - 454 ha (1123 A); and on subwatershed A, site four - 497 ha (1228 A).

SAMPLE LOCATIONS

Four sampling locations were selected on the two subwatersheds that comprise the farm. Sampling sites number one through three are on subwatershed B and are all on Davis Creek (fig. 1). The first site is where Davis Creek enters the farm and was placed there primarily to determine the contaminants entering the farm. These levels of contamination are subtracted from the two sampling site values below it in order to determine only the contribution coming from the dairy farm, which is the unit being studied.

The second sampler is located approximately 0.5 km below the first sampler, at the point where Davis Creek enters a sink area. The sinks are most likely due to the karst topography of the area. Several tilted limestone outcrops cross the creek on the dairy farm, and progressively drain water from the year-round flow that exists above the sink area. The drier the weather, the further the sink or dry stream bed extends upstream. The second sampler was positioned at what was thought to be the beginning of the sink area. However, as extremely dry conditions prevailed through the summer months there were periods when this sample point was also dry. The intent was to sample the flow before it disappeared into the sink area. There was flow year-round into a pool approximately 25 meters above this number two sampling point. When no flow existed at the number two sampler, grab samples were taken from this pool.

The third sampler was placed at the point where Davis Creek exits the dairy farm. This area is below the sink area and dried up in late spring. However, there is flow at this location after sufficiently large storms in the summer, and there is continuous flow during most of the winter and spring.

The fourth sampler was placed on the intermittent stream at the property boundary. This intermittent stream drains subwatershed A. There was only this one sampler on subwatershed A.

INDICES

MPI

The actual evaluation of the operation looked at how well the practices employed prevented a particular contaminant from leaving the unit in surface water. Sediment, phosphorus, nitrogen, and coliform bacteria were evaluated individually.

Limitations in the MPI may be inherent due to the subjectivity of using judgement in assigning relative weights to the BMPs and practices, but those decisions were based on best interpretation of data available. It is recognized that many other factors such as climate, soil type, distance to streams, slope, etc., will influence the effectiveness of any practices employed. However, this effort is an attempt to prove a concept, and additional factors may be included as better knowledge is attained.

In the following paragraphs the management practices employed on the farm are presented under the contaminant which they most influenced to give an idea of why the practices were rated as they were. Finally, the sensitivity analyses that were conducted are presented.

Sediment

Practices employed to reduce sediment were generally decreed effective. No-till planting was used for all planted acreages. This practice and the associated remaining stubble are very effective in reducing erosion. Highly erodible acreage has been identified and farmed according to NRCS recommendations. Row crops were planted on the contour. Critical areas were left in permanent grass cover. A natural strip of vegetation and trees was left along most of the length of Davis Creek. All silage fields were planted in cover crops after the silage was cut. Pastures were divided into two different sections which provided for a degree of pasture management through planned grazing. The pastures were reseeded in September, 1995.

Phosphorus

Practices employed to reduce phosphorus runoff were generally thought to be very successful. Soil samples were taken to determine fertilizer requirement for the crops grown. Effluent pumped from the first stage of the anaerobic lagoon was analyzed for phosphorus and nitrogen content and these results were used to determine the overall nutrient requirement for the crops. However, this was not done every year as results have varied little from year to year in the past. Waste from the solids separator for the free stall barns was stored under cover and also analyzed for nutrient content, but again not every year. Results could possibly have been improved if manure analysis was done at least once a year or before each application. In accordance with the Claiborne County NRCS recommendations, only 42.5 metric tons/ha (19 tons/A) of dry manure were applied due to the high phosphorus content of the soil. For the same reason only 2.5 cm (1 in.) of lagoon effluent were applied to field number 5. Commercial fertilizer, 30% diammonium phosphate and 70% urea, was specially tailored to requirements identified by soil analyses. The dry manure was weighed to determine the weight per load, which facilitated application at the rate of 42.5 metric tons/ha.

The waste management system used for the dairy operation was deemed exceptional. A two stage anaerobic lagoon had been constructed, with a solids separator located at the entry point of the first lagoon. Effluent from the second stage was recycled and used to flush the floors of the free stall barn. The first stage of the anaerobic lagoon was agitated and pumped at least twice a year, and the effluent was applied with a traveling big gun. A buffer strip was maintained between the application field and the creek. The solids were stacked and stored under a shelter and applied under optimum conditions as long as storage capacity was not exceeded. It was spread only where a cover crop or stubble was present. Gutters had been installed on all the barns to divert runoff from the roofs.

A natural vegetative border was maintained along most of the length of the creek, except for one field on the upper end of subwatershed B where young feeder cattle were maintained. Even here, the cattle were fenced out of the stream. No-till , cover crops, and contour farming helped to reduce the total phosphorus leaving the surface, although no-till operations may have increased the percentage of soluble phosphorus in the runoff.

Nitrogen

Many of the practices employed to reduce phosphorus in runoff were also effective for reducing nitrogen that is removed in surface water. The entire waste management system and practices described earlier were major factors in reducing nitrogen in surface water. The rotations, cover crops, no-till, and permanent vegetative cover are all valid and effective practices employed on the farm. Fencing streams denies animal access and precludes direct deposit of waste into the creek.

Coliform Bacteria

The proper handling of animal waste is the primary concern in reducing coliform bacteria. The whole waste management system on the farm is thought to be exemplary as was described previously. Animal waste from grazing dry cattle can contribute coliform bacteria to the stream, but managing the pastures properly and maintaining a natural vegetative strip along the creek probably prevents much of the coliform bacteria from reaching the creek. Fencing cattle from the stream helped to reduce coliform bacteria levels in subwatershed B, but cattle were not fenced from the intermittent stream on subwatershed A. Due to no flow conditions on the western subwatershed, actual coliform bacteria levels are unknown.

The area with essentially no filter between the cattle and the creek is the feeder cattle pasture in the upper portion of subwatershed B and could be improved by installing a filter strip or possibly planting a strip of trees. The buffer between field five where the liquid manure is applied and the creek serves to help prevent any effluent that may not infiltrate immediately from running off into the creek. Storing solids in a covered dry stack for a period before spreading also helps to reduce coliform bacteria. Since no-till was used over the entire cropped acreage, solid manure was not incorporated and was a potential source for coliform bacteria.

Sensitivity Analyses

The calculated individual contaminant MPIs are listed in table 4.

Table 4. Values for subunit and overall MPI sensitivity analysis.

Contaminant	Watershed A	Watershed B	Overall Index
Sediment	0.92	0.90	0.91
Phosphorus	0.89	0.86	0.88
Nitrogen	0.92	0.91	0.92
Coliform Bacteria	0.79	0.86	0.83

Three sensitivity analyses were done to see how responsive the MPI was to changes in practices and variations in contaminant weighting. Scenario one assumed that no cropping BMPs were employed. This assumed that there were no cover crops planted, no management of hay and pasture land, no farming on the contour, no use of conservation tillage, and no stream protection.

The second scenario assumed that there were no waste management BMPs: manure was not tested, spreaders were not calibrated, and there was no attempt to apply waste at the appropriate time, rate, or method. It was also assumed that there was no lagoon or designated waste storage area, no critical area planting, and no guttering to keep clean water separate from the waste.

The third scenario assumed that a waste management system was in place, but that there was the probability of failure of the lagoon and resulting serious contamination of the receiving stream. This was an attempt to see how the risk rating procedure affected the final index. The lagoon is located in watershed B (eastern subwatershed). The results are tabulated in table 5.

Table 5. Results of MPI sensitivity analyses.

SCENARIO	ACTUAL	1*	2**	3***
Watershed A				
Sediment	0.92	0.11	0.92	0.92
Phosphorus	0.89	0.44	0.67	0.89
Nitrogen	0.92	0.35	0.79	0.92
Coliform Bacteria	0.79	0.41	0.55	0.79
Watershed B				
Sediment	0.90	0.12	0.90	0.90
Phosphorus	0.86	0.42	0.68	0.78
Nitrogen	0.91	0.41	0.80	0.90
Coliform Bacteria	0.86	0.46	0.58	0.78

* No cropping BMPs employed (no cover crops, no management of hay or pasture land, no farming on the contour, no conservation tillage) and no stream protection.

** No waste management.

*** Probable lagoon failure.

Scenario one where no conservation cropping practices were employed to reduce contaminant production, resulted in low scores for all contaminants and shows the MPI to be very responsive to cropping practices.

Scenario two involved no waste management, and had lower scores than the actual rating in all categories except sediment. Indeed, waste management practices would affect nitrogen, phosphorus, and coliform bacteria to a great degree, whereas sediment should not be affected at all.

Scenario three looked at a probable lagoon failure, and showed only slight decreases in the indices for phosphorus and coliform bacteria. There was almost no decrease in the nitrogen MPI. The index does not appear to be very responsive to risk.

As a point of comparison an expert opinion was sought. Dr. Paul Denton, Plant and Soil Science Extension Specialist of the University of Tennessee Agricultural Extension Service, was contacted and asked to rate the farm. Dr. Denton has extensive experience with the farm on which these MPIs were determined. By simply rating the farm on a scale of 0 to 10, Dr. Denton placed the farm operation at between 8.5 and 9.0, which correlates well with the contaminant MPIs rated on the 0.0 to 1.0 scale, as shown in table 4 (Denton, 1995).

The measured values for sediment, nitrogen, and phosphorus from subwatershed B seem to all track fairly well with the high MPIs computed for these contaminants on that subwatershed. For all three, the average weekly concentrations were well below any standard that was used, and correlated with MPIs of 0.90, 0.86, 0.91, and 0.83 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively. However, the measured average coliform bacteria was only slightly below the 1000 colonies/100 ml standard that was used. This is most likely due to the 45 to 80 head of feeder stock located in a small area (approximately 1 ha) adjacent to Davis Creek, and for which there was no buffer strip or filter strip. This is probably the primary source of coliform bacteria from the farm for this reach of creek. Due to this high coliform bacteria level, the MPI for coliform bacteria on this eastern subwatershed should have possibly been even lower, perhaps in the neighborhood of 0.6 to 0.7. The average level of coliform bacteria coming onto the farm was 3100 colonies/100 ml; however, the contribution of the dairy farm (991 colonies/ 100 ml) was in addition to this.

Apparently this particular contaminant index needs additional modification. Consideration should be given to taking into account the herd density per length of creek as well as distance of the cattle from the creek. By giving extra weight to these more densely stocked areas their increased influence could be more accurately reflected in the overall contaminant MPI. Additionally, for the coliform bacteria MPI an extra BMP that deals with stocking density only, could be added and given a relatively heavy weighting factor.

System Response Index (SRI) and Standard Water Index (SWI)

To obtain an SRI and SWI, information was needed in addition to worst case loading and contaminant standards. Flow and contaminant concentration at all four sampling points were also needed. Due to no flow at sites 3 and 4 during a majority of the project period the SRI and SWI are based on sampling sites 1 and 2 where data were available. Indices for watershed A (site 4) could not be calculated due to lack of flow information. Values for these parameters were calculated on a weekly basis, i.e., liters per week for flow and milligrams per liter for average concentration values. The product of these two values, after using appropriate conversion factors, provided kilograms per week of each contaminant. The values were in turn compared to the worst case and the standard to produce an SRI and SWI.

Flow was determined at each of the four sampling points. Flow measurements were necessary to convert contaminant concentration into mass transport. Although sampling began in April, regular stage measurements did not begin until the end of July. However, stage remained relatively constant during this period, and weekly flow values were interpolated from the flow measurements that were taken earlier. These earlier measurements came from the first three sample sites where numerous flow and stage measurements were taken, to use in development of flow rating curves. It was those measurements and interpolations that were used to estimate weekly flow information. The mathematical models representing these rating curves were used to compute flow from stage measurements. The rating curves are in Appendix E.

Collection

Grab samples were collected weekly and were used to determine contaminant concentration. Samples were returned to the water quality lab at the University of Tennessee to begin analysis that day and normally within two to three hours of when they were taken. This was done to conform to recommended procedures for determination of coliform bacteria levels. These samples were collected for a period of eight months, from April through November 1995. This period of sampling did not allow for the full seasonal variations that might have occurred.

Laboratory Analysis

Laboratory analysis included analysis for total solids, total phosphorus, total nitrogen, and the number of coliform bacteria colonies per 100 ml of sample. Results of sample analysis as well as all transport computations are shown in Appendix F. Mass transport was determined by multiplying the weekly contaminant concentration by the mean weekly flow at each sample location.

Total Solids

Total solids were determined from the grab samples by placing 25 ml of the sample in a Gravity Convection Drying Oven at 105 °F. The drying pans were weighed previous to adding the sample and again after the sample had been dried. From these values total solids, in g/ml were calculated. For the project period the average total solids per week was 181 g/ml at site one, and 165 g/ml at site two located near the sinks. There was a net loss of total solids of 270 kg/wk. The probable explanation is that the stream on the average loses a portion of the surface flow to subsurface flow in this karst area. There are springs between location one and two that dilute the surface flow that remains, thus resulting in a decrease in net total solids. Bedload has not been included and may comprise a large portion of the sediment transported. However, the streambed is primarily gravel and the stream flows over bedrock in some places. Total solids computations are in Appendix F.

Total Nitrogen

The samples were analyzed for total nitrogen by determining the NO_3, NO_2, and Total Kjeldahl Nitrogen (TKN). These three added together approximate total nitrogen.

There was an increase in NO_3 from site one to site two, however, there was a decrease in the TKN and total nitrogen between the same two points. The net loss in TKN can be explained in part by the fact that higher TKN levels at location one may have decreased due to microbial action that changed the organics in TKN to NO_3 by the time it reached point two. Relatively high coliform bacteria levels that were present could indicate the presence of bacteria capable of accomplishing this change.

These nitrogen concentrations were determined using a LACHAT Quick Chem 4100 Flow Injection Analyzer and a BD 46 Block Digester. Nitrogen was determined from the weekly grab sample. The average weekly total nitrogen for the period was 0.62 mg/L at site one and 0.33 mg/L at site two. These values probably decreased due to dilution from the springs entering the stream between site one and site two. The total nitrogen to NO_3 ratio was 1.26 at site two. This ratio is used to convert the 10 mg/L nitrate standard to total nitrogen for use in SWI computations.

Total Phosphorus

Total phosphorus was determined using the same basic procedure employed for total nitrogen. No detectable levels of total phosphorus were found in any of the samples analyzed.

Coliform Bacteria

Total coliform was determined from the grab sample using the Membrane Filtration Technique. The sample was diluted as necessary to get an actual colony count per 100 ml. The average weekly count for the period was 3160 colonies/100 ml at the entry point onto the farm, and 4151 colonies/100 ml at point 2, for an actual input from the farm of 991 colonies/100 ml.

The Tennessee standard for coliform bacteria is 200 colonies/100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days at intervals of not less than 12 hours. For this research, grab samples on which coliform bacteria concentrations are based were collected once a week and do not meet the above criteria. The standard used for this research is based on the standard that the concentration of the fecal coliform groups in any individual sample shall not exceed 1,000 per 100 ml, for the designated use of recreation. This standard was exceeded numerous times. The average, however, for the entire research period was just below this standard at 991 colonies/100 ml.

Worst Case Determinations

Worst case determinations were needed for all four contaminants to be used in developing the standard response index. Worst case is used in conjunction with the MPI and measured values to determine the SRI. The system response index equation for each contaminant is:

$$SRI = \frac{Measured}{Worst\ Case*(1-MPI)}$$

For sediment the worst case was determined using the RUSLE equation to determine how much soil would be lost from the farm in one year. It was assumed that there was no cover crop, no conservation tillage practices, no contouring, nor strip cropping on row cropped land. It was assumed that there was no sediment loss from pastures or forested areas. Areas were measured using a planimeter on a topographic quad sheet. Slope lengths were 400 feet or less. Erodability factors were based on the predominant soil type for each field as determined from the Soil Survey for Claiborne County, Tennessee

(1946). The total worst case soil loss for a year was computed at 678 metric tons per year for the 33.5 ha cropped area. This value after applying appropriate conversion factors, was divided by 52 to determine a weekly worst case soil loss of 13,066 kg per week.

The nitrogen and phosphorus worst case conditions were determined by computing the mass balance of these nutrients on the farm unit. The net amount of this mass balance was determined by computing the difference between input and output of these two nutrients. The determination of both input and output of nutrients into the unit was accomplished by keeping records of farm activities, crops, and produce for each subwatershed. Each subwatershed was divided into fields to facilitate tracking this data. At the end of each month the owner was interviewed to determine what had occurred during the previous month and recorded as input or output for each subunit.

For nutrient input the records kept included: how much liquid manure was pumped onto which field; the amount of solid manure from the dry stack that was used or sold; and commercial fertilizer used in each field. Also the number of dry cows and feeders were monitored in order to estimate how much nitrogen and phosphorus might be deposited on pastures from waste (MPS 1985). Additionally, the amount of feed fed to the cattle was recorded and the percentages of nitrogen and phosphorus in each feed or feed constituent was estimated (NRC, 1988). The estimated amounts of nitrogen and phosphorus in each of the inputs were summed to get a total nitrogen and phosphorus input into the unit and the values were used for nutrient mass balance computations.

A similar procedure was used for tracking output. The amount of hay and silage produced was tracked. An estimation was made of the grass grazed by dry cattle. Estimations were made of the amount of nitrogen and phosphorus in all crops and included in the computations for mass balance (NRC, 1988). The waste from lactating and dry cows which was flushed into the lagoon was estimated (MPS, 1985) and considered as output. The percentages of nitrogen and phosphorus in dairy waste was estimated and used to compute the nitrogen and phosphorus output from the unit (Van Horn et al., 1994). Additionally, the daily nutrient requirement for the lactating and dry cows was estimated and considered as output (NRC, 1988). Phosphorus and nitrogen content for milk was also estimated and used for computations of nutrient output (Van Horn et al., 1994).

The mass balance for nitrogen and phosphorus were computed using the following formula:

Net = (purchased feed that was fed+silage/haylage fed+liquid manure+solid manure+fertilizer+manure from dry cows+manure from feeders) - (silage/haylage produced+milk+corn+tobacco+daily nutrient requirement for lactating and dry cows+waste flushed into lagoon).

The detailed listing of nutrients in the unit input and output are in Appendix G. The totals for the period of the research were divided by the number of weeks to arrive at a weekly average to be used as worst cases for the SRI and SWI computations. The average weekly net nitrogen and phosphorus produced were 510 kg/wk and 175 kg/wk, respectively, for subwatershed A and 3235 kg/wk and 622 kg/wk, respectively, for subwatershed B.

From the computations of net nutrients, it is apparent that more nutrients are being input into the system than are being taken out. Some of this excess nitrogen may be leaching into the groundwater as NO_3. However, most of the nitrogen is probably being lost during the application of effluent from the first stage of the lagoon. The Midwest Plans Service "Livestock Waste Facilities Handbook" (1985) estimates that as much as 40% of the nitrogen may be lost during land application with a sprinkler irrigation system. If nitrogen is being applied at recommended rates the leaching should be near zero, and most of the unexplained difference in incoming and outgoing nitrogen would be due to losses during application. The excess phosphorus is probably being fixed in the soil and may eventually result in a buildup of phosphorus in the soil, especially at the location where the liquid manure is being applied.

The worst case for coliform bacteria was determined by taking a series of five samples from the flush water coming from the free stall barns just prior to entering the solids separator. An average value was determined by considering all the samples that were taken and for which a colony count could be made. A value of 47,600,000 colonies per 100 ml was the worst case value determined. By using the stream flow at site two, a dilution factor was determined to adjust the coliform worst case that was used in the actual SRI computations. That adjusted value was 1,261,657 colonies/100 ml. To arrive at this adjusted flow the volume of flush water per day was estimated and the ratio of the flush water volume per week to the stream flow per week at site two was computed. The worst case was multiplied by the ratio to obtain the adjusted worst case for coliform bacteria.

Once the standards and worst cases were determined and the actual contaminant levels measured, the SRI and SWI were computed using the formulas already presented. The computed values for the SRI for subwatershed B were: -0.206, 0.0, -0.055, and 0.005 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively. The negative SRIs for sediment and nitrogen are due to a net loss of these two contaminants between site one and site two. The measured concentrations of total phosphorus were always minute or too small to detect for the samples analyzed.

Based on the standards and measured levels, the SWIs were computed as a ratio of the measured level to the standard. The mean measured levels of contaminants, the standards, and the SWIs are presented in table 6. As indicated in table 6, none of the contaminants exceeded the standard. Both nitrogen and sediment levels are small in comparison to standards. Phosphorus was zero because measured values were zero or not measurable.

Table 6. SWI values for subwatershed B.

	Measured	Standard	SWI
Sediment	-16 mg/L	221 mg/L	-0.07
Phosphorus	0 mg/L	0.02 mg/L	0
Nitrogen	-0.291 mg/L	2.0 mg/L	-0.15
Coliform Bacteria	991 col/100mL	1000 col/100mL	.991

SRI and SWI Sensitivity Analysis

SRI is largely characteristic of the system, but is affected by management and worst case loading. To try to understand these relationsips, sensitivity analyses were done primarily for the SRI and to a smaller extent for the SWI. The same set of analyses were run for each of the three contaminants which were measurable from the water samples, i.e., sediment, nitrogen, and coliform bacteria. The analyses for all three contaminants exhibited similar trends, so only the analysis for nitrogen is presented.

The SRI sensitivity analysis looked at how the SRI changed in relation to three different factors. In each analysis one factor was varied while the other two remained constant. The three variables were MPI, Worst Case (WC), and Measured (the measured level of contaminant in the stream). The values were expressed in kg/wk for all but coliform bacteria, which was expressed in colonies/100 ml.

The analyses involved using values both above and below the actual measured values of MPI, WC, and Measured. The WC and Measured values approximated those actually computed or measured for the dairy farm. The data and figures for all the analyses are in Appendix H.

The first analysis looked at how SRI changed in relation to MPI while WC and Measured were held constant. MPI was varied from 0.1 to 0.9 while WC was 3780 kg/wk and Measured was 4.5 kg/wk. The SRI increased exponentially as MPI was increased from 0.1 to 0.9. As an example please refer to the graph of SRI versus MPI at figure 2. A high SRI indicates high responsiveness to contaminant loading into the system, or a high probability that a change in water quality will occur if management practices are changed. A low SRI indicates low system responsiveness to contaminant loading into the system, or a low probability of the water quality changing if management is changed, i.e., the responsiveness is low due to a higher buffering capacity.

The graph associated with this analysis assumed constant Measured and WC values. Pairs of Measured and WC values must fall somewhere on the curve represented by the graph. The fact that the MPI for the rated farm was 0.9 placed the pair of values at an SRI of 0.012. Since the actual range of the SRI has yet to be established, it is uncertain whether this represents a low or a high value. However, due to the low measured values obtained for nitrogen this is probably a relatively low value.

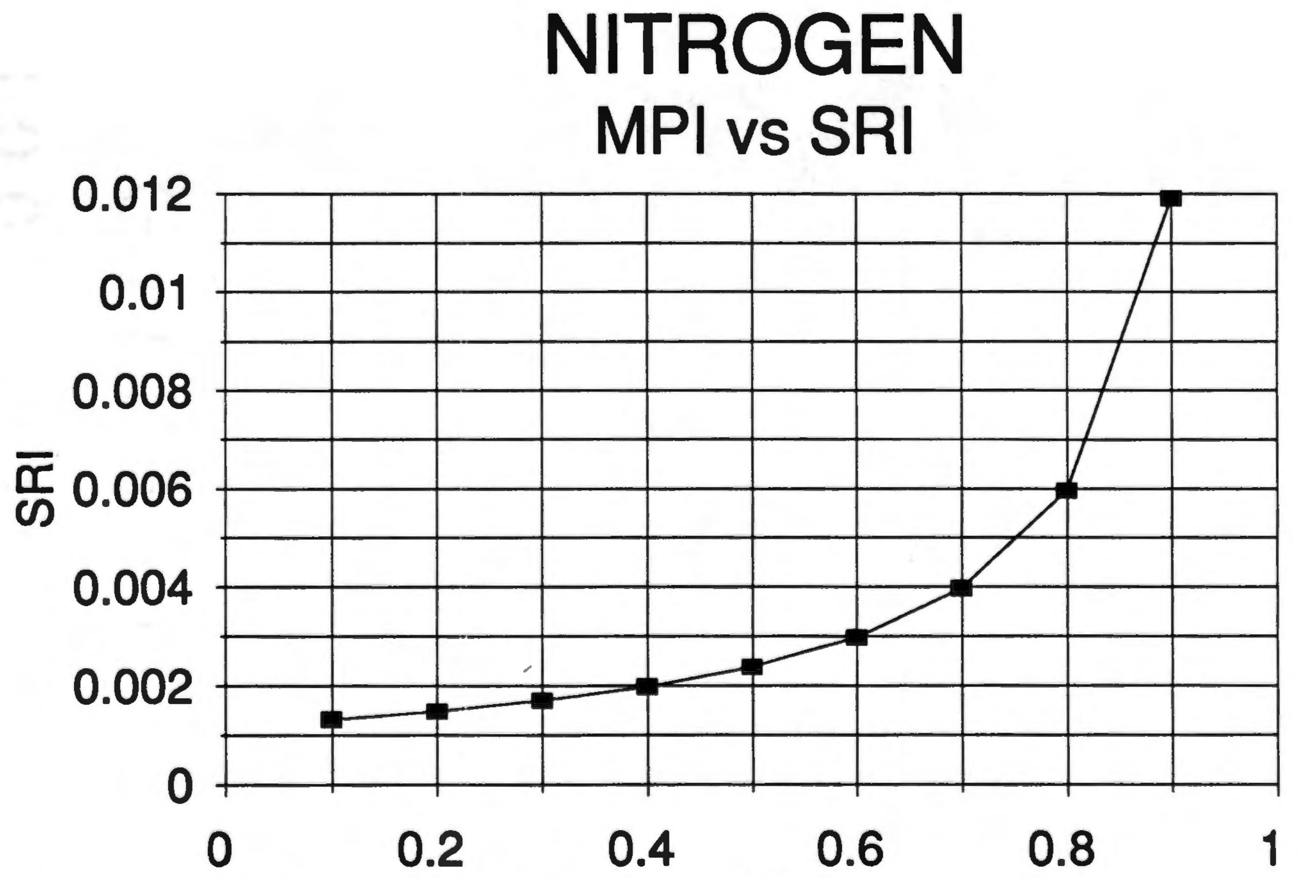


Figure 2: SRI Sensitivity Analysis for Nitrogen

The second analysis looked at the relationship between SRI and WC (see Appendix H for related curve). MPI was held constant at 0.9 and Measured was constant at 4.5 kg/wk. The MPI and Measured values approximated those actually encountered. As WC increased the SRI decreased, but not linearly. The pair of constant values, MPI and Measured, again must lie somewhere on the curve represented by the graph. For an actual WC of 3780 the SRI was about 0.012.

The third analysis considered how SRI varied with the measured level of contaminant (see Appendix H for curve). The MPI was held constant at 0.9 and WC was held at 3490 kg/wk. As Measured increased, the SRI increased linearly. As previously pointed out, the pair of constant values must lie somewhere on the line, but whether the SRI value is high or low is as yet undetermined.

The ranges of values that resulted from these analyses are: for sediment 0.01 to 15.0, for nitrogen 0.0002 to 4.5, and for coliform bacteria 0.000004 to 0.001. No values were computed for phosphorus due to no detectable levels of total phosphorus in any of the samples.

The SWI is simply an index that relates the measured level of contaminant to the standard that was used. The ranges for the SWIs in the analyses were as follows: sediment 0.013 to 3.04, nitrogen 0.0044 to 2.0, and coliform bacteria 0.2 to 4.0. For both the SRIs and the SWIs the actual ranges are unknown and can only be established after several different operations have been evaluated. At any rate, a high SRI indicates a responsive system for which the water quality should improve as management is improved. A high SWI, i.e. greater than one, indicates the standard has been exceeded. All the SWIs are based on concentration of contaminants in g/ml, but coliform is based on colonies/100 ml.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This research was aimed at using a systems approach to develop a set of tools that could be used to relate the surface water quality from a unit of land to the management practices employed on that land and to the responsiveness of that unit to those practices. The tools developed were a set of three indices for sediment, nitrogen, phosphorus, and coliform bacteria. The three indices are MPI, SRI, and SWI. The system as a whole with all of its BMPs was considered in evaluating and determining these three indices. The research was conducted on a well run dairy farm in Claiborne County, Tennessee. The MPIs were based on the owners, application of BMPs on their operation. The MPIs for sediment, phosphorus, nitrogen, and coliform bacteria were 0.92, 0.89, 0.92, and 0.79, respectively, for subwatershed A which comprised approximately half the area of the dairy farm studied. For subwatershed B the respective values were 0.90, 0.86, 0.91, and 0.86. All of the values were relatively high which reflected the high level of management on the dairy farm.

The SRI was developed with greater priority than the SWI. The SWI is simply a way to reference the standard. The SRI, however, relates the quality of the water (measured value) to both the management practices being employed, and to the worst case loading of contaminants into the stream. It is a ratio of the actual measured to the theoretical measured value based on the level of management. The theoretical measured value is defined as WC(1-MPI). The SRI can probably be best visualized as the probability that a given measured level of contaminant will exist, based on management practices and worst case loading. For a high SRI the system is responsive to changes in management and contaminant loading. On the other hand, a low SRI indicates an unresponsive system and changes in management practices and worst case loading will likely produce little change in water quality. The inverse of the SRI could be viewed as the system's buffering capacity for these contaminants. A high SRI indicating high system responsiveness would correspond to low buffering capacity.

The SRIs for subwatershed B of this dairy farm were -0.206, 0.0, 0.055, and 0.005 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively. The range of values found in the sensitivity analysis for sediment was 0.01 to 15.0, with most values being less than 1.0. The range for nitrogen was 0.0002 to 4.5 with 2/3 of the values being less than 0.002. For coliform bacteria the range was 0.000004 to 0.001 with most values below 0.0001. No analysis was accomplished on phosphorus because of the measured values of zero.

Since the sensitivity analysis was done by simply picking numbers above and below the values of contaminants actually encountered, the ranges have very little meaning at this time. The process of evaluating SRIs as well as

MPIs must be done on numerous units to begin to get a feel for the true range of these values.

The SWIs were computed to compare the measured levels of these four contaminants to the standard and were simply a ratio of the measured value to the standard. Those values were -0.07, 0.0, -0.15, and 0.99 for sediment, phosphorus, nitrogen, and coliform bacteria, respectively. The ranges for these SWIs were: sediment 0.013 to 3.04, nitrogen 0.0044 to 2.0, and coliform bacteria 0.2 to 4.0. The value of 0.0 for phosphorus was again due to no measurable levels for total phosphorus in the samples obtained during the research period.

If the ability to meet the standard can be indicated by the SWI, then the contaminants would be ranked in descending order as phosphorus, nitrogen, sediment, and coliform bacteria. However, referring to the computed MPIs, coliform bacteria was tied with phosphorus for the lowest MPI ranking. Also by referring to the ranking of SWIs, phosphorus should have been at the top of the list, but was in fact at the bottom with coliform bacteria with an MPI of 0.86. It should be pointed out that even though the order of ranking may be off, each of the contaminants did receive a high MPI reflecting a good job of management.

Concerning coliform bacteria, its true relative ranking could possibly be more accurately portrayed by considering animal density along the stream. For instance, a higher animal density per length of stream could have been given a higher emphasis by assigning a higher weight in some manner. This could possibly be accomplished in the area of stream protection, and BMPs including filter strips. A risk needs to be associated with increased system loading that is seen with higher animal densities and close proximity to streams.

In the case of phosphorus, its relative ranking might be improved by putting less weight on BMPs that are concerned with manure testing, particularly if it could be ascertained that exact application rates of waste are not crucial for a particular system. For consistency's sake some skill must be developed in assigning the ratings to practices and risks. This will require practice and possibly an accompanying set of notes that aid in doing evaluations consistently from one farm to another.

If a different unit were to be evaluated the order in which these indices could be logically used, would be to first compute the SWI to determine if the standard had been exceeded and whether any further action is necessary. Secondly, the MPI would be computed to determine how well the unit was being managed. Finally, the SRI would be computed to get an idea of the responsiveness of that system to any management changes that might be planned. The individual MPIs could be used to choose the BMPs that were scored low and which have the potential for being improved or added. This improvement of management practices is contingent upon whether the system has a high enough SRI, which would be an indication of whether that unit is expected to be responsive to those changes.

Once the SRI has been established for a unit of land, then the MPI and WC can be manipulated to achieve a desired level of water quality for a planned operation. If the SRI is known, the WC can be established based on the expected loading. For instance, if a beef operation is planned, the waste from the number of cattle expected can be estimated and a WC determined. An MPI can be selected that will fit the SRI, WC, and desired Measured contaminant level. The unknown to be manipulated would be the MPI.

One difficulty that must be dealt with in obtaining an SRI and a SWI is the problem of being able to instrument the unit to sample and measure the water quality coming from it. This project dairy farm was fairly well suited for sampling because of the stream that ran through the farm. Some units of land will have no stream but a monitoring/sampling scheme must be developed to take this into account. The difference in contaminant concentration between where water may enter and leave the unit and the associated flow rate is necessary for mass transport computations. If all water originates on the unit, then only a below monitoring/sampling scheme is necessary. In all cases, outside influences must be eliminated or accounted for.

RECOMMENDATIONS

Several other recommendations are offered based on what has been accomplished in this research so far. The MPI and SRI's need continued development and refinement. The MPI for coliform bacteria especially, needs to be improved to more closely correlate to the job of management that is being done to control that contaminant in surface water.

Evaluation of MPIs and SRIs should be done at numerous farms. This is desirable in order to determine how these indices vary from unit to unit where different levels of management are employed and which have different levels of worst case potential loading to surface water.

The sampling, flow measurements, and analyses should be continued for a longer period than eight months. This period should be at least one year to capture any variations that may be seasonal. One data point or one sampling event and flow measurement could provide enough data for SRI and SWI computation, but its application would be limited.

Potential uses for the MPI, SRI, and SWI relationship should be explored further. By establishing the system responsiveness, an SRI could be used in conjunction with an assumed worst case loading based on expected animal density and a desired level of water quality, to determine the MPI necessary to attain those goals. This would be an invaluable management tool, especially for cost effectiveness considerations when planning improvements.

To make the MPI more comprehensive, ground water needs to be included. Much of the NO_3 lost from agricultural lands may be through leaching into the groundwater and this avenue needs to be accounted for once the concept is sufficiently validated.

REFERENCES

REFERENCES

Couillare, D. and Y. Lefebvre. 1985. Analysis of water quality indices. *J. Environ. Manag.* 21(129):161-179

Darst, B.C. and L.S. Murphy. 1994. Keeping agriculture viable: industry's viewpoint. *J. Soil and Water Conserv.* 49(2):8-13.

Denton, P. 1995. Personal Communication. University of Tennessee Extension Service.

Dinius, S.H. 1987. Design of an index of water quality. *Water Resources Bull.* 23(5):833-842.

Evans, B.M. and W.L. Meyers. 1990. A GIS approach to evaluating regional groundwater pollution potential with DRASTIC. *J. of Soil and Water Conserv.* 45(2):242-245.

Gale, J.A., D.E. Line, D.L. Osmand, S.W. Doffey, J. Spooner, and J.A. Arnold. 1992. Summary Report - Evaluation of the Experimental Rural Clean Water Program. National Water Quality Evaluation Project, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C.,38p.

Haan, C.T., B.J. Barfield, and J.D. Hayes. 1994. Design Hydrology and Sedimentology for Small Catchments. New York: Academic Press.

Howell, J.M., M.S. Coyne, and P. Cornelius. 1995. Fecal bacteria in agricultural waters of the bluegrass region of Kentucky. *J. of Environ. Qual.* 24(3):411-419.

Johnson, D.A., M.K. Kreglow, S.A. Dressing, R.P. Maas, F.A. Koehler, F.J. Humenik, L. Christensen, and W. Snider. 1982a. Best Management Practices for Agricultural Nonpoint Source Control, III-Sediment. In cooperation with USEPA and USDA, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C.

Johnson, D.A., M.K. Kreglow, S.A. Dressing, R.P. Maas, F.A. Koehler, F.J. Humenik, L. Christensen, and W. Snider. 1982b. Best Management Practices for Agricultural Nonpoint Source Control, I-Animal Waste. In cooperation with USEPA and USDA, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C.

Klaine, S.J. 1990. Progress Report: Optimization of Sampling Strategy to Assess Agricultural Nonpoint Source Pollutant Loading. Submitted to Water Environment Research Foundation, Clemson University, Pendleton, S. C.

Magette, W.L., and R.A. Weismiller. 1985. Nutrient Management for Water Quality Protection. From *Bay Fact Sheet 3.* State Soil Conservation Service, USDA-ASCS, Cooperative Extension Service, University of Maryland, Maryland Assoc. Of Soil Conservation Districts, Maryland Department of the Environment, Maryland Department of Natural Resources, and USDA-SCS.

McIsaac, G.F., J.K. Mitchell, and M.C. Hirschi. 1995. Dissolved phosphorus concentrations in runoff from simulated rainfall on corn and soybean tillage systems. *J. Soil and Water Cons.* 50(4):383-387.

Midwest Plans Service (MPS). 1985. Livestock Waste Facilities Handbook, MWPS-18, Second Edition, p.10.2.

Nutrient Requirements for Dairy Cattle (NRC). 1988. Sixth Revised Edition, Washington D.C.: National Academy Press.

Razavian, D. 1990. Hydrologic responses of an agricultural watershed to various hydrologic and management conditions. *Water Resources Bull.* 26(5): 777-784.

Rural Clean Water Program (RCWP). 1990. Lessons learned from a voluntary nonpoint source control experiment. EPA 440/4-90-012, Dynamic Corp. and J. T. & A., Inc. Washington D.C.: USEPA.

Sharpley, A.N., T.C. Daniel, and D.R. Edwards. 1993. Phosphorus movement in the landscape. *J. of Prod. Agric.* 6(4):492-499.

Shirmohammadi, A., K. Yoon, W.L. Magette, and J.K. Cronk. 1994. Water quality monitoring in a mixed land use watershed. Paper presented to 1994 Winter Meeting of ASAE. Paper No. 94-2573.

Soil Survey for Claiborne County, Tennessee. 1946. Tennessee Agricultural Experiment Station and Division of Soil Survey, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, USDA. Series 1939, No.5.

Spooner, J., R.P. Mass, S.A. Dressing, M.D. Smolen, and F. J. Humenik. 1985. Appropriate designs for documenting water quality improvements from agricultural NPS control programs. In *Perspectives on Nonpoint Source Pollution.* EPA 440/5-85-001:30-34.

Spooner, J. 1990. Interpretation of Results and Reporting from Statistical Trend Models, Proceedings of the 1990 Rural Clean Water Program National Workshop, Brookings, South Dakota, 99p.

Spooner, J., J.A. Gale, S.L. Brichferd, S.W. Coffey, A.L. Lanlier, M.D. Smolen, M.D., and F.J. Humenik. 1991. NWQEP Report: Water Quality Monitoring Report for Agricultural Nonpoint Source Projects - Methods and Findings from the Rural Clean Water Program. National Water Quality Evaluation Project, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C.,pp1-150.

Tennessee Department of Health and Environment (TDHE). 1990. The Status of Water Quality in Tennessee 305(b) Report. Division of Water Pollution Control, TDHE, Nashville, TN.

Thomann, R.V. and Muller, J.A. 1987. Principles of Surface Water Quality Modeling and Control. New York: Harper Collins Publishers Inc.

Van Horn, H.H., A.C. Wilde, W.J. Powers, and R.A. Nordstredt. 1994. Components of dairy manure management systems. *J. Dairy Sci.* 77(7):2008-2030.

APPENDICES

Appendix A

Management Practice Index (MPI)

Contaminant	Actual Practice Rating	Actual Risk Rating	Notes
Watershed A	0 Not Used	0 No Risk	If rating factor is "0" then risk rating factor is "0"
Sediment	1 Use Ineffective	-1 Possible Risk	
	2 Use Effective	-2 Probable Risk	

Weight Factor 0.4

BMP	Practice	Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Optimum Practice Rating	Optimum Practice Score
		Actual Practice					Optimum Practice	
BMP 9 *	Conservation Tillage 0.148							
	Practices							
	Conservation Tillage System 4	0.4	2	0.000	0	0.800	2	0.800
	Stubble Mulching 3	0.3	0	0.000	0	0.000	0	0.000
	Contour Farming 2	0.2	2	0.000	0	0.400	2	0.400
	Crop Residue Use 1	0.1	2	0.000	0	0.200	2	0.200
		1						
		BMP Total			(Act Prac Total)	1.400	(Opt Prac Total)	1.400
		Total x Rating Factor				0.207		0.207
BMP 4	Terrace 0.148							
	Practices							
	Terrace 4,4	0.33	0	1.000	0	0.000	0	0.000
	Subsurface Drain 3	0.25	0	0.000		0.000	0	0.000
	Underground Outlet 3	0.25	0	0.000		0.000	0	0.000
	Obstruction Removal 2	0.17	0	0.000		0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 13 *	Irrig Water Mgmt 0.148							
	Practices							
	Irrig Water Conveyance 3,3	0.17	0	0.167	0	0.000	0	0.000
	Irrig Syst (drip, sprinkler, surface/subsurface) 3,3	0.17	0	0.167	0	0.000	0	0.000
	Irrig Syst Tailwater Recovery 4,4	0.22	0	0.222	0	0.000	0	0.000
	Irrig Water Management 4,4	0.22	0	0.222	0	0.000	0	0.000
	Irrig Land Leveling 0	0	0	0.000	0	0.000	0	0.000
	Structure For Water Control 4,4	0.22	0	0.222	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 11 *	Perm Veg Cover on Critical Areas 0.148							
	Practices							
	Critical Area Planting 4	0.13	1	0.000	0	0.130	2	0.260
	Fencing 2	0.07	2	0.000	0	0.140	2	0.140
	Field Borders 3	0.1	0	0.000	0	0.000	0	0.000
	Filter Strips 3	0.1	0	0.000	0	0.000	0	0.000
	Livestock Strips 3	0.1	0	0.000	0	0.000	0	0.000
	Livestock Exclusion 3	0.1	2	0.000	0	0.200	2	0.200
	Mulching (during sewing) 3	0.1	0	0.000	0	0.000	0	0.000
	Sinkhole Treatment (groundwater) 4	0.13	0	0.000	0	0.000	0	0.000
	Tree Planting 3	0.1	0	0.000	0	0.000	0	0.000
	Spoil Bank Spreading	0.07	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.470	(Opt Prac Total)	0.600
		Total x Rating Factor				0.070		0.089
BMP 8 *	Cropland Protective System 0.111							
	Practices							
	Conservation Cropping Syst (rotations) 2	0.33	2	0.000	0	0.660	2	0.660
	Cover and Green Manure Crop 3	0.5	2	0.000	0	1.000	2	1.000
	Field Windbreaks 1	0.17	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.660	(Opt Prac Total)	1.660
		Total x Rating Factor				0.184		0.184
BMP 1 *	Permanent Vegetative Cover 0.111							
	Practices							
	Pasture and Hayland Mgmt 3	0.3	1	0.000	0	0.300	2	0.600
	Proper Grazing Use (planned) 3	0.3	2	0.000	0	0.600	2	0.600
	Grasses and Legumes in Rotation 2	0.2	2	0.000	0	0.400	2	0.400
	Range Seeding 2	0.2	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.300	(Opt Prac Total)	1.600
		Total x Rating Factor				0.144		0.178
BMP 3*	Stripcropping 0.074							
	Practices							
	Stripcropping, contour 3	0.33	0	0.000	0	0.000	0	0.000
	Stripcropping, field 3	0.33	0	0.000	0	0.000	0	0.000
	Stripcropping, wind 3	0.33	0	0.000	0	0.000	0	0.000
		0.99						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 7	Waterway System 0.074							
	Practices							
	Grassed Waterway or Outlet 3,1	0.6	0	1.000	0	0.000	0	0.000
	Subsurface Drain 1	0.2	0	0.000	0	0.000	0	0.000
	Fencing 1	0.2	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 12 *	Sed Retention, Erosion/Water Cont Struct 0.111							
	Practices							
	Water or Sediment Control Basin 3,1	0.25	0	0.250	0	0.000	0	0.000
	Grade Stabilization Structure 3,1	0.25	0	0.250	0	0.000	0	0.000
	Structure For Water Control 3,1	0.25	0	0.250	0	0.000	0	0.000
	Dike 3,1	0.25	0	0.250	0	0.000	0	0.000
		1						
					(Act Prac Total)	0.000	(Opt Prac Total)	0.000
						0.000		0.000
					BMP Score Total	0.605		0.658

Sed Subindex 0.920

MANAGEMENT PRACTICE INDEX

Contaminant	Actual Practice Rating	Actual Risk Rating	Notes
Watershed A	0 Not Used	0 No Risk	If rating factor is "0" then risk rating factor is "0"
Phosphorus	1 Use Ineffective	-1 Possible Risk	
	2 Use Effective	-2 Probable Risk	

Weight Factor 0.5

BMP	Item	Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Optimum Rating	Optimum Score
		Actual Practice					Optimum Practice	
BMP 15*	Fert Mgmt 0.15							
	Practices	Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Rating	Score
	Determine Crop Rqmts 5	0.30	2	0.000	0	0.600	2	0.600
	Comm Fert Mgmt 5,3	0.30	2	0.300	0	0.600	2	0.600
	Waste Utilization 5,3	0.30	2	0.000	-1	0.100	2	0.600
	Test Manure	0.90						
		BMP Total			(Act Prac Total)	1.400	(Opt Prac Total)	1.800
		Total x Rating Factor				0.222		0.297
BMP 2*	Animal Waste Mgmt 0.12							
	Practices							
	Diversion 5,0	0.12	2	0.000	0	0.240	2	0.240
	Guttering 5,0	0.12	2	0.000	0	0.240	2	0.240
	Waste Treatment Lagoon 5,5	0.12	0	0.278	0	0.000	0	0.000
	Irrig Syst for Waste 4,3	0.09	2	0.167	0	0.180	2	0.180
	Waste Storage Structure 4,2	0.09	0	0.111	0	0.000	0	0.000
	Waste Storage Pond 3,2	0.07	0	0.111	0	0.000	0	0.000
	Surface Drain 3,1	0.07	0	0.056	0	0.000	0	0.000
	Subsurface Drain, Field Ditch 3,1	0.07	0	0.056	0	0.000	0	0.000
	Subsurface Drain, Main or Lateral 3,1	0.07	0	0.056	0	0.000	0	0.000
	Critical Area Planting 2,1	0.05	0	0.056	0	0.000	0	0.000
	Grassed Waterway or Outlet 2,1	0.05	2	0.056	0	0.100	2	0.100
	Filter Strips (Feedlots) 4,1	0.09	0	0.056	0	0.000	0	0.000
		1.01						
		BMP Total			(Act Prac Total)	0.760	(Opt Prac Total)	0.760
		Total x Rating Factor				0.091		0.091
BMP 4	Terrace 0.00							
	Terrace, Level 3,3	0.5	0	0.500	0	0.000	0	0.000
	Subsurface Drain 2,2	0.30	0	0.300	0	0.000	0	0.000
	Underground Outlet 1,1	0.17	0	0.167	0	0.000	0	0.000
		1		0.967				
BMP 11	Perm Veg Cover on Critical Areas 0.00				(Act Prac Total)	0.000	(Opt Prac Total)	0.000
						0.000		0.000
	Practices							
	Critical Area Planting 3	0.17	2	0.000	0	0.340	2	0.340
	Fencing 2	0.11	2	0.000	0	0.220	2	0.220
	Field Borders 2	0.11	0	0.000	0	0.000	0	0.000
	Filter Strips 2	0.11	0	0.000	0	0.000	0	0.000
	Livestock Strips 2	0.11	0	0.000	0	0.000	0	0.000
	Livestock Exclusion 2	0.11	2	0.000	0	0.220	2	0.220
	Mulching (during seeding) 2	0.11	0	0.000	0	0.000	0	0.000
	Tree Planting 2	0.11	0	0.000	0	0.000	0	0.000
	Spoilbank Spreading 1	0.06	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.780	(Opt Prac Total)	0.780
		Total x Rating Factor				0.070		0.070
BMP 13	Irrig Water Mgmt 0.00							
	Practices							
	Irrig Water Conveyance 3,2	0.16	0	0.102	0	0.000	0	0.000
	Irrig Syst (drip, sprinkler, surface/subsurface) 4,2	0.22	0	0.102	0	0.000	0	0.000
	Irrig Syst Tailwater Recovery 4,2	0.22	0	0.102	0	0.000	0	0.000
	Irrig Water Management 4,4	0.22	0	0.204	0	0.000	0	0.000
	Irrig Land Leveling 1,0	0.06	0	0.000	0	0.000	0	0.000
	Structure For Water Control 1,1	0.06	0	0.051	0	0.000	0	0.000
		0.96		1.001				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 8*	Cropland Protective System 0.05							
	Practices							
	Conservation Cropping Syst (rotations) 2	0.5	2	0.000	0	1.000	2	1.000
	Cover and Green Manure Crop 2	0.5	2	0.000	0	1.000	2	1.000
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.100		0.100
BMP 9*	Conservation Tillage 0.05							
	Practices							
	Contour Farming 3	0.5	2	0.000	0	1.000	2	1.000
	Crop Residue Use 2	0.33	2	0.000	0	0.660	2	0.660
	Conservation Tillage System 1 1	0.17	2	0.000		0.340	2	0.340
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.100		0.100
BMP 5	Diversion System 0.00							
	Practices							
	Dike 2,2	0.29	0	0.300	0	0.000	0	0.000
	Diversion 2,2	0.29	0	0.300	0	0.000	0	0.000
	Obstruction Removal 1,0	0.14	0	0.000	0	0.000	0	0.000
	Subsurface Drain 1,1	0.14	0	0.167	0	0.000	0	0.000
	Underground Outlet 1,1	0.14	0	0.167	0	0.000	0	0.000
		1		1.000				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 3	Strip Cropping 0.00							
	Practices							
	Stripcropping, contour 3	0.5	0	0.000	0	0.000	0	0.000
	Stripcropping, field 2	0.33	0	0.000	0	0.000	0	0.000
	Stripcropping, wind 1	0.17	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 12	Sed Retention, Erosion/Water Cont Struct 0.00							
	Practices							
	Water or Sediment Control Basin 3,3	0.43	0	0.429	0	0.000	0	0.000
	Grade Stabilization Structure 2,2	0.29	0	0.286	0	0.000	0	0.000
	Structure for Water Control 2,2	0.29	0	0.286	0	0.000	0	0.000
		1.01		1.001				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 10*	Stream Protection 0.05							
	Practices							
	Tree Planting 4	0.25	0	0.000	0	0.000	0	0.000
	Filter Strip 4	0.25	1	0.000	0	0.250	2	0.500
	Fencing Streams 3	0.19	0	0.000	0	0.000	0	0.000
	Stream Bank Protection 3	0.19	0	0.000	0	0.000	0	0.000
	Bridging Stream Crossings 2	0.125	0	0.000	0	0.000	0	0.000
		1.005						
					(Act Prac Total)	0.250	(Opt Prac Total)	0.500
						0.023		0.045
				BMP Score Total	(Act BMP Total)	0.700	(Opt BMP Total)	0.800

Phos Subindex 0.667

MANAGEMENT PRACTICE INDEX

Contaminant
Watershed A
NITROGEN

Actual Practice Rating
0 Not Used
1 Use Ineffective
2 Use Effective

Actual Risk Rating
0 No Risk
-1 Possible Risk
-2 Probable Risk

Notes
If rating factor is "0" then risk rating factor is "0"

		Weight Factor	Actual Practice: Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Optimum Practice: Rating	Score
		0.2							
BMP 15	Fert Mgmt	0.21							
	Practices								
	Determine Crop Rqmts 5,9		0.33	2	0.000	0	0.660	2	0.660
	Comm Fert Mgmt 5,3		0.33	2	0.500	0	0.660	2	0.660
	Waste Utilization 5,3		0.33	1	0.500	0	0.330	2	0.660
	Test Manure								
	Calibrate Spreader								
	Apply at proper rate, method, time								
			0.99						
			BMP Total			(Act Prac Total)	1.650	(Opt Prac Total)	1.980
			Total x Rating Factor				0.347		0.416
							(Act BMP Score)		(Opt BMP Score)
BMP 2	Animal Waste Mgmt	0.17							
	Practices								
	Diversion 5,2		0.12	0	0.111	0	0.000	0	0.000
	Guttering 5,0		0.12	2	0.000	0	0.240	2	0.240
	Waste Treatment Lagoon 5,0		0.12	0	0.000	0	0.000	0	0.000
	Irrig Syst for Waste 4,5		0.09	2	0.278	0	0.180	2	0.180
	Waste Storage Structure 4,3		0.09	0	0.167	0	0.000	0	0.000
	Waste Storage Pond 3,2		0.07	0	0.111	0	0.000	0	0.000
	Surface Drain 3,1		0.07	0	0.056	0	0.000	0	0.000
	Subsurface Drain, Field Ditch 3,1		0.07	0	0.056	0	0.000	0	0.000
	Subsurface Drain, Main or Lateral 3,1		0.07	0	0.056	0	0.000	0	0.000
	Critical Area Planting 2,1		0.05	0	0.056	0	0.000	0	0.000
	Grassed Waterway or Outlet 2,1		0.05	2	0.056	0	0.100	2	0.100
	Filter Strips (Feedlots) 4,1		0.05	0	0.056	0	0.000	0	0.000
			0.97		1.000				
			BMP Total			(Act Prac Total)	0.520	(Opt Prac Total)	0.520
			Total x Rating Factor				0.088		0.088
BMP 13	Irrig Water Mgmt	0.17							
	Practices								
	Irrig Water Conveyance 3,2		0.18	0	0.102	0	0.000	0	0.000
	Irrig Syst (drip, sprinkler, surface/subsurface) 4,2		0.24	0	0.102	0	0.000	0	0.000
	Irrig Syst Tailwater Recovery 4,2		0.24	0	0.102	0	0.000	0	0.000
	Irrig Water Management 4,4		0.24	0	0.204	0	0.000	0	0.000
	Irrig Land Leveling 1,0		0.06	0	0.000	0	0.000	0	0.000
	Structure For Water Control 1,1		0.06	0	0.081	0	0.000	0	0.000
			1.02		1.001				
			BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
			Total x Rating Factor				0.000		0.000
BMP 8	Cropland Protective System	0.13							
	Practices								
	Conservation Cropping Syst (rotations) 3		0.5	2	0.000	0	1.000	2	1.000
	Cover and Green Manure Crop 3		0.5	2	0.000	0	1.000	2	1.000
			1						
			BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
			Total x Rating Factor				0.260		0.260
BMP 1	Permanent Vegetative Cover	0.13							
	Practices								
	Pasture and Hay Land Mgmt 3		0.3	1	0.000	0	0.300	2	0.600
	Proper Grazing Use 3		0.3	2	0.000	0	0.600	2	0.600
	Grasses and Legumes in Rotation 2		0.2	2	0.000	0	0.400	2	0.400
	Range Seeding 2		0.2	0	0.000	0	0.000	0	0.000
			1						
			BMP Total			(Act Prac Total)	1.300	(Opt Prac Total)	1.600
			Total x Rating Factor				0.169		0.208
BMP 9	Conservation Tillage	0.13							
	Practices								
	Contour Farming 3		0.5	2	0.000	0	1.000	2	1.000
	Crop Residue Use 2		0.33	2	0.000	0	0.660	2	0.660
	Conservation Tillage System 1		0.17	2	0.000	0	0.340	2	0.340
			1						
			BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
			Total x Rating Factor				0.260		0.260
BMP 10	Stream Protection	0.08							
	Practices								
	Tree Planting 4		0.24	1	0.000	0	0.240	2	0.480
	Filter Strip 4		0.24	1	0.000	0	0.240	2	0.480
	Fencing Streams 4		0.24	0	0.000	0	0.000	0	0.000
	Stream Bank Protection 3		0.18	0	0.000	0	0.000	0	0.000
	Bridging Stream Crossings 2		0.12	0	0.000	0	0.000	0	0.000
			1.02						
						(Act Prac Total)	0.480	(Opt Prac Total)	0.960
							0.038		0.077
						BMP Score Totals	1.162		1.271
						Nitrogen Subindex		0.915	

MANAGEMENT PRACTICE INDEX

Contaminant	Weight Factor	Relative Rating Factor	Rating (Actual Practice)	Risk Factor	Risk Rating	Score (Actual Practice)	Rating (Optimum Practice)	Score (Optimum Practice)
COLIFORM BACTERIA	0.1							
Watershed A								
BMP 15 *	Fert Mgmt 0.22							
	Practices							
	Determine Crop Rqmts 4,0	0.44	2	0.000	0	0.880	2	0.880
	Waste Utilization 5,3	0.56	2	1.000	0	1.120	2	1.120
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.440		0.440
BMP 2 *	Animal Waste Mgmt 0.22							
	Practices							
	Diversion 4,0	0.1	0	0.000	0	0.000	0	0.000
	Guttering 4,0	0.1	2	0.000	0	0.200	2	0.200
	Waste Treatment Lagoon 3,5	0.075	0	0.250	0	0.000	2	0.150
	Irrig Syst for Waste 4,4	0.1	2	0.200	0	0.200	2	0.200
	Waste Storage Structure 4,3	0.1	0	0.150	0	0.000	0	0.000
	Waste Storage Pond 3,3	0.075	0	0.150	0	0.000	0	0.000
	Surface Drain 3,1	0.075	0	0.050	0	0.000	0	0.000
	Subsurface Drain, Field Ditch 3,1	0.075	0	0.050	0	0.000	0	0.000
	Subsurface Drain, Main or Lateral 3,1	0.075	0	0.050	0	0.000	0	0.000
	Critical Area Planting 3,0	0.075	2	0.000	0	0.150	2	0.150
	Grassed Waterway or Outlet 3,1	0.075	0	0.050	0	0.000	0	0.000
	Filter Strips (Feedlots) 3,1	0.075	0	0.050	0	0.000	0	0.000
		1		1.000				
		BMP Total			(Act Prac Total)	0.550	(Opt Prac Total)	0.700
		Total x Rating Factor				0.121		0.154
BMP 10 *	Stream Protection 0.22							
	Practices							
	Tree Planting 4	0.24	1	0.000	0	0.240	2	0.480
	Filter Strip 4	0.24	1	0.000	0	0.240	2	0.480
	Fencing Streams 4	0.24	0	0.000	0	0.000	2	0.480
	Stream Bank Protection 3	0.18	1	0.000	0	0.180	2	0.360
	Bridging Stream Crossings 2	0.12	0	0.000	0	0.000	0	0.000
		1.02						
		BMP Total			(Act Prac Total)	0.660	(Opt Prac Total)	1.800
		Total x Rating Factor				0.145		0.396
BMP 11 *	Perm Veg Cover on Critical Areas 0.09							
	Practices							
	Critical Area Planting 3	0.15	1	0.000	0	0.150	2	0.300
	Fencing 3	0.15	2	0.000	0	0.300	2	0.300
	Field Borders 3	0.15	1	0.000	0	0.150	2	0.300
	Filter Strips 3	0.15	0	0.000	0	0.000	0	0.000
	Livestock Stripe 3	0.15	0	0.000	0	0.000	0	0.000
	Livestock Exclusion 3	0.15	2	0.000	0	0.300	2	0.300
	Mulching (during sewing) 2	0.1	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.900	(Opt Prac Total)	1.200
		Total x Rating Factor				0.081		0.108
BMP 6 *	Cropland Protective System 0.09							
	Practices							
	Conservation Cropping Syst (rotations) 3	0.5	2	0.000	0	1.000	2	1.000
	Cover and Green Manure Crop 3	0.5	2	0.000	0	1.000	2	1.000
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.180		0.180
BMP 1 *	Permanent Vegetative Cover 0.09							
	Practices							
	Pasture and Hayland Mgmt 3	0.25	1	0.000	0	0.250	2	0.500
	Proper Grazing Use (planned) 3	0.25	2	0.000	0	0.500	2	0.500
	Grasses and Legumes in Rotation 3	0.25	2	0.000	0	0.500	2	0.500
	Range Seeding 3	0.25	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.250	(Opt Prac Total)	1.500
		Total x Rating Factor				0.113		0.135
BMP 9 *	Conservation Tillage 0.09							
	Practices							
	Conservation Tillage System 3	0.27	2	0.000	0	0.540	2	0.540
	Contour Farming 3	0.27	2	0.000	0	0.540	2	0.540
	Crop Residue Use 3	0.27	2	0.000	0	0.540	2	0.540
	Stubble Mulching 2	0.18	0	0.000	0	0.000	0	0.000
		0.99						
					(Act Prac Total)	1.620	(Opt Prac Total)	1.620
						0.146		0.146
					BMP Score Totals	1.226		1.559
						Coli Subindex	0.786	

MANAGEMENT PRACTICE INDEX

Contaminant	Watershed B	Actual Risk Rating	Notes
Watershed B	Actual Practice Rating	0 No Risk	If rating factor is "0" then risk rating factor is "0"
Sediment	0 Not Used	-1 Possible Risk	
	1 Use Ineffective	-2 Probable Risk	
	2 Use Effective		

Weight Factor 0.4

BMP	Practice	Actual Practice: Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Optimum Practice: Rating	Score
BMP 5 *	Conservation Tillage 0.148							
	Practices							
	Conservation Tillage System 4	0.4	2	0.000	0	0.800	2	0.800
	Stubble Mulching 3	0.3	0	0.000	0	0.000	0	0.000
	Contour Farming 2	0.2	2	0.000	0	0.400	2	0.400
	Crop Residue Use 1	0.1	2	0.000	0	0.200	2	0.200
		1.0						
		BMP Total			(Act Prac Total)	1.400	(Opt Prac Total)	1.400
		Total x Rating Factor				0.207		0.207
BMP 4	Terrace 0.148							
	Practices							
	Terrace 4,4	0.33	0	1.000	0	0.000	0	0.000
	Subsurface Drain 3,0	0.25	0	0.000		0.000	0	0.000
	Underground Outlet 3,0	0.25	0	0.000		0.000	0	0.000
	Obstruction Removal 2,0	0.17	0	0.000		0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 10 *	Irrig Water Mgmt 0.148							
	Practices							
	Irrig Water Conveyance 3,3	0.17	0	0.167	0	0.000	0	0.000
	Irrig Syst (drip, sprinkler,surface,subsurface)3,3	0.17	0	0.167	0	0.000	0	0.000
	Irrig Syst Tailwater Recovery 4,4	0.22	0	0.222	0	0.000	0	0.000
	Irrig Water Management 4,4	0.22	0	0.222	0	0.000	0	0.000
	Irrig Land Leveling 0,0	0	0	0.000	0	0.000	0	0.000
	Structure For Water Control 4,4	0.22	0	0.222	0	0.000	0	0.000
		1		1.000				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 11 *	Perm Veg Cover on Critical Areas 0.148							
	Practices							
	Critical Area Planting 4	0.13	1	0.000	0	0.130	2	0.260
	Fencing 2	0.07	2	0.000	0	0.140	2	0.140
	Field Borders 3	0.1	0	0.000	0	0.000	0	0.000
	Filter Strips 3	0.1	0	0.000	0	0.000	0	0.000
	Livestock Strips 3	0.1	1	0.000	0	0.100	2	0.200
	Livestock Exclusion 3	0.1	2	0.000	0	0.200	2	0.200
	Mulching (during sewing) 3	0.1	0	0.000	0	0.000	0	0.000
	Sinkhole Treatment (groundwater) 4	0.13	0	0.000	0	0.000	0	0.000
	Tree Planting 3	0.1	0	0.000	0	0.000	0	0.000
	Spoil Bank Spreading	0.07	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.570	(Opt Prac Total)	0.800
		Total x Rating Factor				0.084		0.118
BMP 6 *	Cropland Protective System 0.111							
	Practices							
	Conservation Cropping Syst (rotations) 2	0.33	2	0.000	0	0.660	2	0.660
	Cover and Green Manure Crop 3	0.5	2	0.000	0	1.000	2	1.000
	Field Windbreaks 1	0.17	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.660	(Opt Prac Total)	1.660
		Total x Rating Factor				0.184		0.184
BMP 1 *	Permanent Vegetative Cover 0.111							
	Practices							
	Pasture and Hayland Mgmt 3	0.3	1	0.000	0	0.300	2	0.600
	Proper Grazing Use (planned) 3	0.3	2	0.000	0	0.600	2	0.600
	Grasses and Legumes in Rotation 2	0.2	2	0.000	0	0.400	2	0.400
	Range Seeding 2	0.2	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.300	(Opt Prac Total)	1.600
		Total x Rating Factor				0.144		0.178
BMP 3*	Stripcropping 0.074							
	Practices							
	Stripcropping, contour 3	0.33	0	0.000	0	0.000	0	0.000
	Stripcropping, field 3	0.33	0	0.000	0	0.000	0	0.000
	Stripcropping, wind 3	0.33	0	0.000	0	0.000	0	0.000
		0.99						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 7	Waterway System 0.074							
	Practices							
	Grassed Waterway or Outlet 3,1	0.6	0	1.000	0	0.000	0	0.000
	Subsurface Drain 1,0	0.2	0	0.000	0	0.000	0	0.000
	Fencing 1,0	0.2	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 12 *	Sed Retention, Erosion/Water Cont Struct 0.111							
	Practices							
	Water or Sediment Control Basin 3,1	0.25	0	0.250	0	0.000	0	0.000
	Grade Stabilization Structure 3,1	0.25	0	0.250	0	0.000	0	0.000
	Structure For Water Control 3,1	0.25	0	0.250	0	0.000	0	0.000
	Dike 3,1	0.25	0	0.250	0	0.000	0	0.000
		1		1.000				
					(Act Prac Total)	0.000	(Opt Prac Total)	0.000
						0.000		0.000
					BMP Score Total	0.620		0.687

Sed Subindex 0.902

MANAGEMENT PRACTICE INDEX

Contaminant: Watershed B, Phosphorus

Actual Practice Rating: 0 Not Used; 1 Use Indicative; 2 Use Effective

Actual Risk Rating: 0 No Risk; -1 Possible Risk; -2 Probable Risk

Notes: If rating factor is "0" then risk rating factor is "0"

Weight Factor 0.3

BMP	Practice	Actual Practice: Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Optimum Practice: Score	
BMP 15*	Fert Mgmt 0.15							
	Practices							
	Determine Crop Reqmts 5,0	0.30	2	0.000	0	0.000	2	0.600
	Comm Fert Mgmt 5,3	0.30	2	0.300	0	0.600	2	0.600
	Waste Utilization 5,3	0.30	1	0.300	-1	-0.170	2	0.600
	Test Manure							
		BMP Total			(Act Prac Total)	1.100	(Opt Prac Total)	1.800
		Total x Rating Factor				0.170		0.297
BMP 2*	Animal Waste Mgmt 0.12							
	Practices							
	Diversion 5,0	0.12	2	0.000	0	0.240	2	0.240
	Guttering 5,0	0.12	2	0.000	0	0.240	0	0.000
	Waste Treatment Lagoon 5,5	0.12	2	0.270	0	0.240	2	0.240
	Irrig Syst for Waste 4,3	0.08	2	0.107	0	0.160	2	0.160
	Waste Storage Structure 4,2	0.08	2	0.111	0	0.160	2	0.160
	Waste Storage Pond 3,2	0.07	0	0.111	0	0.000	0	0.000
	Surface Drain 3,1	0.07	0	0.000	0	0.000	0	0.000
	Subsurface Drain, Field Ditch 3,1	0.07	0	0.000	0	0.000	0	0.000
	Subsurface Drain, Main or Lateral 3,1	0.07	0	0.000	0	0.000	0	0.000
	Critical Area Planting 2,1	0.05	1	0.000	-1	-0.000	2	0.100
	Grassed Waterway or Outlet 2,1	0.05	0	0.000	0	0.000	0	0.000
	Filter Strips (Feedlots) 4,1	0.00	0	0.000	0	0.000	0	0.000
		BMP Total			(Act Prac Total)	1.074	(Opt Prac Total)	0.940
		Total x Rating Factor				0.129		0.113
BMP 4	Terrace 0.00							
	Terrace, Level 3,3	0.5	0	0.500	0	0.000	0	0.000
	Subsurface Drain 2,2	0.33	0	0.333	0	0.000	0	0.000
	Underground Outlet 1,1	0.17	0	0.167	0	0.000	0	0.000
		1		1.000				
BMP 11	Perm Veg Cover on Critical Areas 0.00				(Act Prac Total)	0.000	(Opt Prac Total)	0.000
						0.000		0.000
	Practices							
	Critical Area Planting 3	0.17	2	0.000	0	0.340	2	0.340
	Fencing 2	0.11	2	0.000	0	0.220	2	0.220
	Field Borders 2	0.11	1	0.000	0	0.110	2	0.220
	Filter Strips 2	0.11	0	0.000	0	0.000	0	0.000
	Livestock Strips 2	0.11	0	0.000	0	0.000	0	0.000
	Livestock Exclusion 2	0.11	2	0.000	0	0.220	2	0.220
	Mulching (during seeding) 2	0.11	0	0.000	0	0.000	0	0.000
	Tree Planting 2	0.11	1	0.000	0	0.110	2	0.220
	Spoilbank Spreading 1	0.00	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.000	(Opt Prac Total)	1.220
		Total x Rating Factor				0.000		0.110
BMP 13	Irrig Water Mgmt 0.00							
	Practices							
	Irrig Water Conveyance 3,2	0.16	0	0.102	0	0.000	0	0.000
	Irrig Syst (drip, sprinkler, surface/subsurface) 4,2	0.22	0	0.102	0	0.000	0	0.000
	Irrig Syst Tailwater Recovery 4,2	0.22	0	0.102	0	0.000	0	0.000
	Irrig Water Management 4,4	0.22	0	0.204	0	0.000	0	0.000
	,0	0.00	0	0.000	0	0.000	0	0.000
	Structure For Water Control 1,1	0.05	0	0.001	0	0.000	0	0.000
		0.89		1.001				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 8*	Cropland Protective System 0.00							
	Practices							
	Conservation Cropping Syst (rotations) 2	0.5	2	0.000	0	1.000	2	1.000
	Cover and Green Manure Crop 2	0.5	2	0.000	0	1.000	2	1.000
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.100		0.100
BMP 9*	Conservation Tillage 0.00							
	Practices							
	Contour Farming 3	0.5	2	0.000	0	1.000	2	1.000
	Crop Residue Use 2	0.33	2	0.000	0	0.000	2	0.000
	Conservation Tillage System1 1	0.17	2	0.000	0	0.340	2	0.340
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.100		0.100
BMP 5	Diversion System 0.00							
	Practices							
	Dike 2,2	0.29	0	0.300	0	0.000	0	0.000
	Diversion 2,2	0.29	2	0.300	0	0.500	2	0.500
	Obstruction Removal 1,0	0.14	0	0.000	0	0.000	0	0.000
	Subsurface Drain 1,1	0.14	0	0.167	0	0.000	0	0.000
	Underground Outlet 1,1	0.14	0	0.167	0	0.000	0	0.000
		1		1.000				
		BMP Total			(Act Prac Total)	0.580	(Opt Prac Total)	0.500
		Total x Rating Factor				0.052		0.052
BMP 3	Strip Cropping 0.00							
	Practices							
	Stripcropping, contour 3	0.5	0	0.000	0	0.000	0	0.000
	Stripcropping, field 2	0.33	0	0.000	0	0.000	0	0.000
	Stripcropping, wind 1	0.17	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 12	Sed Retention, Erosion/Water Cont Struct 0.00							
	Practices							
	Water or Sediment Control Basin 3,3	0.40	0	0.429	0	0.000	0	0.000
	Grade Stabilization Structure 2,2	0.29	0	0.286	0	0.000	0	0.000
	Structure for Water Control 2,2	0.29	0	0.286	0	0.000	0	0.000
		1.01		1.001				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 10*	Stream Protection 0.00							
	Practices							
	Tree Planting 4	0.25	0	0.000	0	0.000	0	0.000
	Filter Strip 4	0.25	2	0.000	0	0.500	2	0.500
	Fencing Streams 3	0.19	2	0.000	0	0.380	2	0.380
	Stream Bank Protection 3	0.19	1	0.000	0	0.190	2	0.380
	Bridging Stream Crossings 2	0.125	0	0.000	0	0.000	0	0.000
		1.005						
					(Act Prac Total)	1.070	(Opt Prac Total)	1.260
						0.000		0.113
					BMP Score Total	0.000	(Opt BMP Total)	1.045
					Phos Subindex	0.001		

MANAGEMENT PRACTICE INDEX

Contaminant
Watershed B
NITROGEN

Actual Practice Rating
0 Not Used
1 Use ineffective
2 Use effective

Actual Risk Rating
0 No Risk
-1 Possible Risk
-2 Probable Risk

Notes
If rating factor is "0" then risk rating factor is "0"

Weight Factor
0.2

		Actual Practice					Optimum Practice	
		Rating Factor	Rating	Risk Rating Factor	Risk Rating	Score	Rating	Score
BMP 15	Fert Mgmt 0.21							
	Practices							
	Determine Crop Rqmts 5,0	0.33	2	0.000	0	0.660	2	0.660
	Comm Fert Mgmt 5,3	0.33	2	0.500	0	0.660	2	0.660
	Waste Utilization 5,3	0.33	1	0.500	0	0.330	2	0.660
	Test Manure							
	Calibrate Spreader							
	Apply at proper rate, method, time							
		0.99						
		BMP Total			(Act Prac Total)	1.650	(Opt Prac Total)	1.980
		Total x Rating Factor				0.347		0.416
						(Act BMP Score)		(Opt BMP Score)
BMP 2	Animal Waste Mgmt 0.17							
	Practices							
	Diversion 5,2	0.12	0	0.111	0	0.000	0	0.000
	Guttering 5,0	0.12	2	0.000	0	0.240	2	0.240
	Waste Treatment Lagoon 5,0	0.12	2	0.000	0	0.240	2	0.240
	Irrig Syst for Waste 4,5	0.09	2	0.278	0	0.180	2	0.180
	Waste Storage Structure 4,3	0.09	2	0.167	0	0.180	2	0.180
	Waste Storage Pond 3,2	0.07	0	0.111	0	0.000	0	0.000
	Surface Drain 3,1	0.07	0	0.056	0	0.000	0	0.000
	Subsurface Drain, Field Ditch 3,1	0.07	0	0.056	0	0.000	0	0.000
	Subsurface Drain, Main or Lateral 3,1	0.07	0	0.056	0	0.000	0	0.000
	Critical Area Planting 2,1	0.05	1	0.056	-1	-0.006	2	0.100
	Grassed Waterway or Outlet 2,1	0.05	2	0.056	0	0.100	2	0.100
	Filter Strips (Feedlots) 4,1	0.05	0	0.056	0	0.000	0	0.000
		0.97		1.003				
		BMP Total			(Act Prac Total)	0.934	(Opt Prac Total)	1.040
		Total x Rating Factor				0.159		0.177
BMP 13	Irrig Water Mgmt 0.17							
	Practices							
	Irrig Water Conveyance 3,2	0.18	0	0.182	0	0.000	0	0.000
	Irrig Syst (drip, sprinkler,surface/subsurface)4,2	0.24	0	0.182	0	0.000	0	0.000
	Irrig Syst Tailwater Recovery 4,3	0.24	0	0.273	0	0.000	0	0.000
	Irrig Water Management 4,3	0.24	0	0.273	0	0.000	0	0.000
	Irrig Land Leveling 1,0	0.06	0	0.000	0	0.000	0	0.000
	Structure For Water Control 1,1	0.06	0	0.091	0	0.000	0	0.000
		1.02		1.001				
		BMP Total			(Act Prac Total)	0.000	(Opt Prac Total)	0.000
		Total x Rating Factor				0.000		0.000
BMP 8	Cropland Protective Systems 0.13							
	Practices							
	Conservation Cropping Syst (rotations) 3	0.5	2	0.000	0	1.000	2	1.000
	Cover and Green Manure Crop 3	0.5	2	0.000	0	1.000	2	1.000
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.260		0.260
BMP 1	Permanent Vegetative Cover 0.13							
	Practices							
	Pasture and Hay Land Mgmt 3	0.3	1	0.000	0	0.300	2	0.600
	Proper Grazing Use 3	0.3	2	0.000	0	0.600	2	0.600
	Grasses and Legumes in Rotation 2	0.2	2	0.000	0	0.400	2	0.400
	Range Seeding 2	0.2	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.300	(Opt Prac Total)	1.600
		Total x Rating Factor				0.169		0.208
BMP 9	Conservation Tillage 0.13							
	Practices							
	Contour Farming 3	0.5	2	0.000	0	1.000	2	1.000
	Crop Residue Use 2	0.33	2	0.000	0	0.660	2	0.660
	Conservation Tillage System 1	0.17	2	0.000	0	0.340	2	0.340
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.260		0.260
BMP 10	Stream Protection 0.08							
	Practices							
	Tree Planting 4	0.24	1	0.000	0	0.240	2	0.480
	Filter Strip 4	0.24	1	0.000	0	0.240	2	0.480
	Fencing Streams 4	0.24	2	0.000	0	0.480	2	0.480
	Stream Bank Protection 3	0.18	0	0.000	0	0.000	0	0.000
	Bridging Stream Crossings 2	0.12	0	0.000	0	0.000	0	0.000
		1.02						
					(Act Prac Total)	0.960	(Opt Prac Total)	1.440
						0.077		0.115
					BMP Score Totals	1.271		1.397
					Nitrogen Subindex		0.910	

MANAGEMENT PRACTICE INDEX

Contaminant	Weight Factor	Relative Rating Factor	Actual Practice Rating	Risk Rating Factor	Risk Rating	Score	Optimum Practice Rating	Score
COLIFORM BACTERIA	0.1							
Watershed B								
BMP 16 *	Fert Mgmt 0.22							
	Practices							
	Determine Crop Rqmts 4	0.44	2	0.000	0	0.880	2	0.880
	Waste Utilization 5	0.56	2	0.000	0	1.120	2	1.120
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.440		0.440
BMP 2 *	Animal Waste Mgmt 0.22							
	Practices							
	Diversion 4,0	0.1	0	0.000	0	0.000	0	0.000
	Guttering 4,0	0.1	2	0.000	0	0.200	2	0.200
	Waste Treatment Lagoon 3,5	0.075	2	0.236	0	0.150	2	0.150
	Irrig Syst for Waste 4,4	0.1	2	0.150	0	0.200	2	0.200
	Waste Storage Structure 4,3	0.1	2	0.143	0	0.200	2	0.200
	Waste Storage Pond 3,3	0.075	0	0.143	0	0.000	0	0.000
	Surface Drain 3,1	0.075	0	0.048	0	0.000	0	0.000
	Subsurface Drain, Field Ditch 3,1	0.075	0	0.048	0	0.000	0	0.000
	Subsurface Drain, Main or Lateral 3,1	0.075	0	0.048	0	0.000	0	0.000
	Critical Area Planting 3,1	0.075	1	0.048	-1	0.027	2	0.150
	Grassed Waterway or Outlet 3,1	0.075	0	0.048	0	0.000	0	0.000
	Filter Strips (Feedlots) 3,1	0.075	0	0.048	0	0.000	0	0.000
		1		1.002				
		BMP Total			(Act Prac Total)	0.777	(Opt Prac Total)	0.900
		Total x Rating Factor				0.171		0.198
BMP 10 *	Stream Protection 0.22							
	Practices							
	Tree Planting 4	0.24	1	0.000	0	0.240	2	0.480
	Filter Strip 4	0.24	1	0.000	0	0.240	2	0.480
	Fencing Streams 4	0.24	2	0.000	0	0.480	2	0.480
	Stream Bank Protection 3	0.18	0	0.000	0	0.000	0	0.000
	Bridging Stream Crossings 2	0.12	0	0.000	0	0.000	0	0.000
		1.02						
		BMP Total			(Act Prac Total)	0.960	(Opt Prac Total)	1.440
		Total x Rating Factor				0.211		0.317
BMP 11 *	Perm Veg Cover on Critical Areas 0.09							
	Practices							
	Critical Area Planting 3	0.15	1	0.000	0	0.150	2	0.300
	Fencing 3	0.15	2	0.000	0	0.300	2	0.300
	Field Borders 3	0.15	1	0.000	0	0.150	2	0.300
	Filter Strips 3	0.15	1	0.000	0	0.150	2	0.300
	Livestock Strips 3	0.15	0	0.000	0	0.000	0	0.000
	Livestock Exclusion 3	0.15	2	0.000	0	0.300	2	0.300
	Mulching (during sowing) 2	0.1	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.050	(Opt Prac Total)	1.500
		Total x Rating Factor				0.095		0.135
BMP 8 *	Cropland Protective System 0.09							
	Practices							
	Conservation Cropping Syst (rotations) 3	0.5	2	0.000	0	1.000	2	1.000
	Cover and Green Manure Crop 3	0.5	2	0.000	0	1.000	2	1.000
		1						
		BMP Total			(Act Prac Total)	2.000	(Opt Prac Total)	2.000
		Total x Rating Factor				0.180		0.180
BMP 1 *	Permanent Vegetative Cover 0.09							
	Practices							
	Pasture and Hayland Mgmt 3	0.25	1	0.000	0	0.250	2	0.500
	Proper Grazing Use (planned) 3	0.25	1	0.000	0	0.250	2	0.500
	Grasses and Legumes in Rotation 3	0.25	2	0.000	0	0.500	2	0.500
	Range Seeding 3	0.25	0	0.000	0	0.000	0	0.000
		1						
		BMP Total			(Act Prac Total)	1.000	(Opt Prac Total)	1.500
		Total x Rating Factor				0.090		0.135
BMP 9 *	Conservation Tillage 0.09							
	Practices							
	Conservation Tillage System 3	0.27	2	0.000	0	0.540	2	0.540
	Contour Farming 3	0.27	2	0.000	0	0.540	2	0.540
	Crop Residue Use 3	0.27	2	0.000	0	0.540	2	0.540
	Stubble Mulching 2	0.18	0	0.000	0	0.000	0	0.000
		0.99						
					(Act Prac Total)	1.620	(Opt Prac Total)	1.620
						0.146		0.146
					BMP Score Totals	1.333		1.551

Col Subindex 0.859

Appendix B

Glossary of Terms

GLOSSARY OF TERMS

Animal Waste Management System - A system of structural works (such as a lagoon, dry stack facility, gutters, and/or tanks) designed to retain liquid and solid waste and polluted runoff from animal feeding areas, milking areas, and other confinement areas and to provide for their subsequent disposal or use.

Conservation Cropping System - Growing crops in combination with needed cultural and management measures; e.g., cropping system using rotation of grasses and legumes of other crop species.

Contour Farming - Cultivation, planting, and other practices are done with the topographic contour rather than with the slope of the land.

Critical Area Planting - Planting vegetation such as trees, shrubs, vines, grasses, or legumes on critically eroding areas.

Crop Residue Use - Using plant residues such as stems, stover, leaves, etc., to protect cultivated fields during periods of greatest erosion potential.

Diversion - A channel (with supporting ridges on the lower side) constructed across a slope to break slope lengths, to reduce overland runoff volume, and to reduce erosion.

Fencing - The use of fence material to create a barrier to livestock or other traffic which would create erosive conditions on treated or untreated areas.

Field Border - A strip of permanent vegetation (trees, shrubs, grasses, or legumes) established along field margins to trap eroded soil and associated pollutants.

Filter Strip (field border) - A strip of permanent vegetation (trees, shrubs, grasses or legumes) established along field margins to trap eroded soil and associated pollutants.

Grade Stabilization Structure - A structure to stabilize the grade or to control head cutting (active erosion) in natural or artificial channels.

Grasses Waterway or Outlet - A natural or constructed waterway or water outlet, shaped or graded as needed and established with suitable vegetation, for safe disposal of field, diversion, or terrace runoff. Acts as a trap for sediment and associated pollutants.

Minimum Tillage - Limiting the number of cultural operations to only those properly timed and essential to produce a crop and prevent excessive soil loss. This entails planting in stubble from previous crops or double-crop planting with minimal soil disturbance.

Mulching - The application of plant residues or other materials not produced on-site, to the soil surface to reduce erosion, conserve moisture, and help establish plant cover.

Pasture and Hay Land Planting - The proper treatment and use of land planted in grasses and/or legumes to prolong forage life, to protect the soil, and to reduce water loss.

Pasture and Hay Land Planting - The establishment of long-term stands of adapted forage plants to control erosion, produce forage, and to adjust land use.

Planned Grazing Systems - The management of grassland or grass-legume pastures to provide sustained production for livestock while minimizing soil erosion.

Proper Application of Fertilizer - Management of fertilizer by proper placement and application rate so that plant utilization is maximized and loss is minimized. Basic policy: Fertilize- by-Soil Test Analysis.

Streambank Protection - Stabilizing streambanks with vegetation of suitable structural armoring to prevent erosion.

Stripcropping (contour) - The practice of growing contour strips of grass or close-growing crops alternated with strips of clean-tilled crops or fallow land to reduce soil erosion.

Terrace - An earthen embankment, channel, or a combination ridge and channel constructed across a slope so as to conduct runoff water at a nonerosive velocity to a stable outlet.

Appendix C

RUSLE Computations

SOIL LOSS ANALYSIS FOR WORST CASE (RUSLE)

Watershed A

Field	Crop	Area Acres	Hectares	Slope	Slope Length	R	K	LS	C	P	Erosion (tons/ac/yr)	Total Tons/yr	Kgs/yr	Kgs/wk
5 (1/2)	Silage	7.7	3.1	4.2	400	175	0.166	0.908	0.342	1	9.0	69	62869	1209
6	Silage	5.0	2.0	4.2	300	175	0.166	0.817	0.342	1	8.1	41	36741	707
8	Silage	15.3	6.2	3.4	350	175	0.166	0.670	0.342	1	6.7	103	92996	1788
	Total	28.0	11.3								23.8	212	192606	3704

Watershed B

Field	Crop	Area Acres	Hectares	Slope	Slope Length	R	K	LS	C	P	Erosion (tons/ac/yr)	Total Tons/yr	Kgs/yr	Kgs/wk
WE	Corn	3.5	1.4	3.0	200	175	0.171	0.485	0.398	1	5.8	20	18416	354
WE	Tobacco	0.7	0.3	2.0	300	175	0.171	0.300	0.390	1	3.5	2	2223	43
1	Silage	23.5	9.5	4.3	200	175	0.310	0.721	0.342	1	13.0	306	277148	5330
4	Silage	8.3	3.4	2.0	400	175	0.411	0.373	0.342	1	9.2	76	69273	1332
5 (1/2)	Silage	7.7	3.1	4.2	400	175	0.166	0.908	0.342	1	9.0	69	62869	1209
7	Silage	11.0	4.5	7.5	175	175	0.378	1.100	0.342	1	25.0	275	249478	4798
	Total	54.7	22.1								65.5	749	679407	13066

Appendix D

Weir Design and Related Equation

V Notch Weir

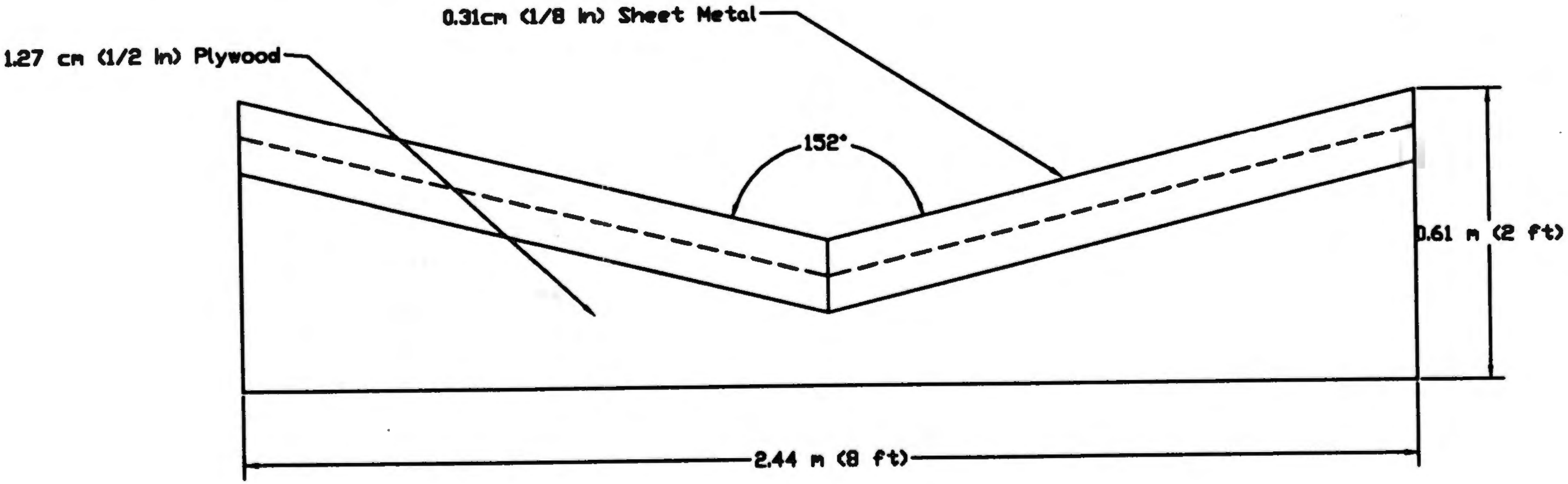
Formula for Weir Flow Rate

Q=(2.51+0.0066*tan(theta/2)+(0.3292+0.5074/tan(theta/2))*log H)*tan(theta/2)*H^2.5

Q = Discharge, ft^3/sec

Theta = Total angle of V notch

H = Head above point of zero flow on V notch, ft



Appendix E

Davis Creek Data and Rating Curves

Davis Creek Rating Curves

Rating Curve #1

Head (ft)	Flow(cfs) Measured	Flow (cfs) Predicted	Difference	Error
0	0.000	0.081	0.081	
0.02		0.223	0.223	
0.12		0.546	0.546	
0.15	0.340	0.699	0.359	1.056
0.21	1.240	1.171	0.069	0.055
0.22		1.277	1.277	
0.28	2.180	2.108	0.072	0.033
0.32		2.882	2.882	
0.33	4.590	3.106	1.484	0.323
0.42		5.781	5.781	
0.52		10.390	10.390	
0.53	8.570	10.960	2.390	0.279
0.62		17.118	17.118	
0.63	19.130	17.924	1.206	0.063
0.72		26.378	26.378	
0.82		38.580	38.580	
0.92		54.132	54.132	
			9.586	0.302 (avg)

a+bx^3+c^.5
a= 0.0813
b= 68.1800
c= 1.0007

Rating Curve #2

Head (ft)	Flow(cfs) Measured	Flow (cfs) Predicted	Difference	Error
0	0	-0.146	0.146	
0.06		-0.126	0.126	
0.16		0.247	0.247	
0.24	0.54	0.844	0.304	0.563
0.26		1.032	1.032	
0.34	1.81	1.920	0.110	0.061
0.36		2.175	2.175	
0.38	2.53	2.442	0.088	0.035
0.43	2.88	3.160	0.280	0.097
0.46		3.624	3.624	
0.54	5.71	4.967	0.743	0.130
0.56		5.326	5.326	
0.66		7.234	7.234	
0.76		9.303	9.303	
0.86		11.491	11.491	
0.87	11.28	11.715	0.435	0.039
1.06		16.062	16.062	
1.09	16.91	16.756	0.154	0.009
				0.133 (avg)

y=a+bx^1.5+cx^2+dx^2.5
a= -0.1464
b= -8.2024
c= 44.4230
d= -21.3978

Rating Curve #3

Head (ft)	Flow(cfs) Measured	Flow (cfs) Predicted	Difference	Error
0	0	-0.114	0.114	
0.04		-0.104	0.104	
0.14		1.236	1.236	
0.15	0.94	1.421	0.481	0.512
0.19	1.89	2.234	0.344	0.182
0.24		3.396	3.396	
0.27	5	4.164	0.836	0.167
0.34		6.139	6.139	
0.44		9.360	9.360	
0.62	16.05	16.175	0.125	0.008
0.64		17.005	17.005	
0.74		21.354	21.354	
0.84		26.020	26.020	
0.94		30.982	30.982	
1.04		36.223	36.223	
1.14		41.728	41.728	
1.24		47.487	47.487	
1.34		53.488	53.488	
1.44		59.722	59.722	
1.54		66.181	66.181	
			24.757	0.217 (avg)

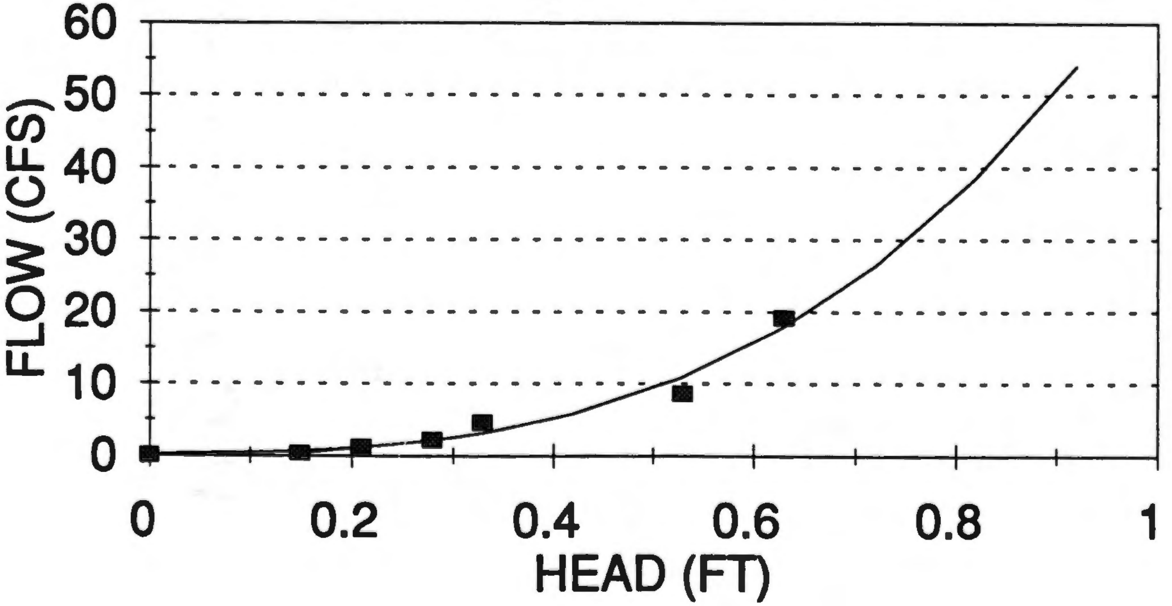
y=a+b+x^1.5+c^.5
a= -0.1137
b= 35.5820
c= -1.3747

NOTES: Measured flow is the flow determined from actual flow measurements and is the basis for the flow rating curves.

Predicted flow is the flow that is computed by using head measurements and the rating curves developed for each sampling point.

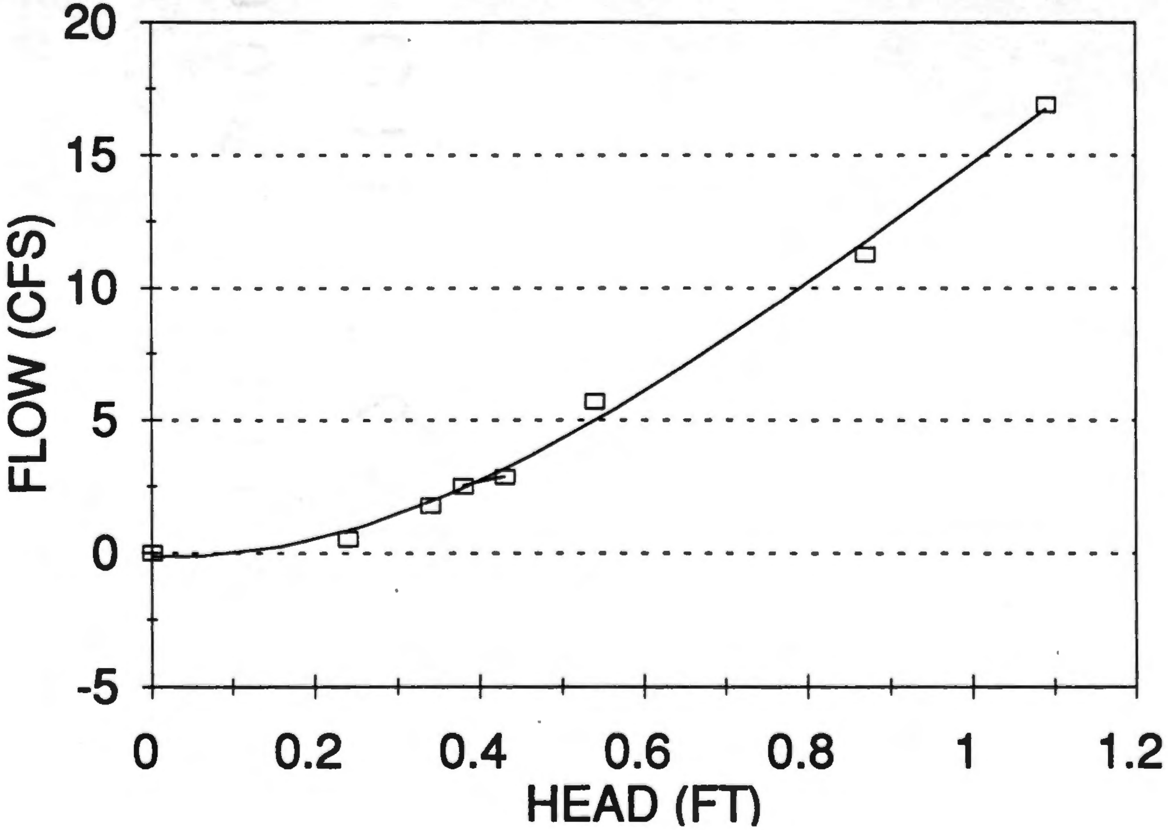
DAVIS CREEK RATING CURVE

CURVE #1



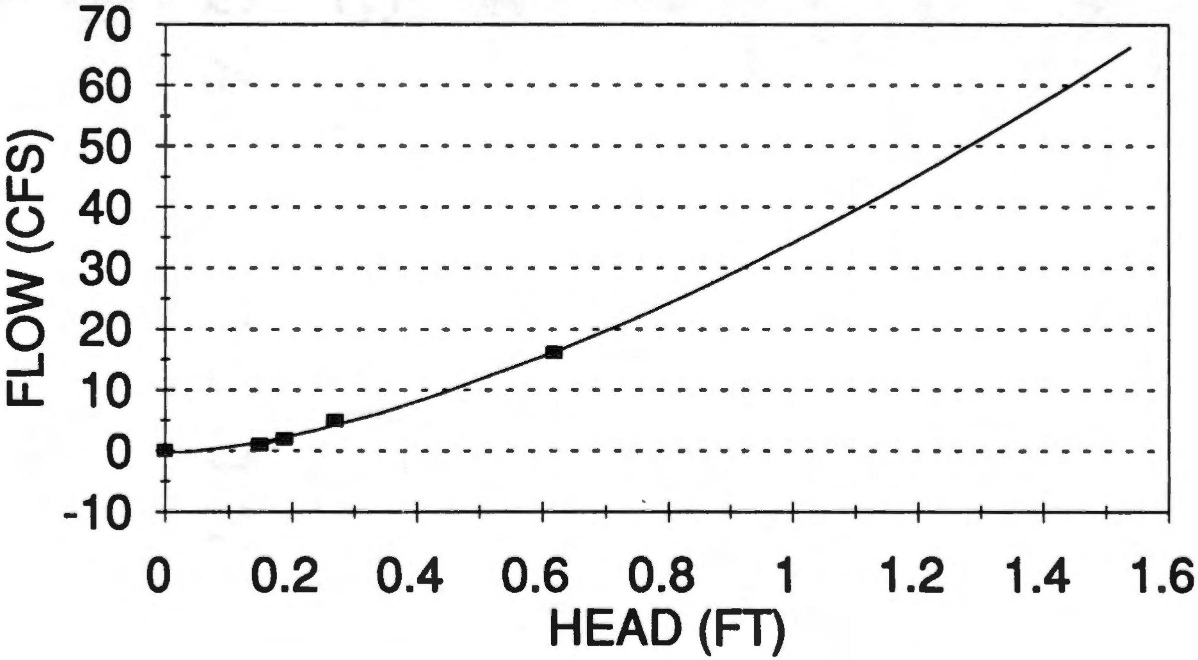
DAVIS CREEK RATING CURVE

CURVE #2



DAVIS CREEK RATING CURVE

CURVE #3



Appendix F

Sample and Flow Data

TOTAL SOLIDS ANALYSES

SAMPLE ANALYSIS

	Week	Total Solids (mg/L)						
		G1G	G1S	G2G	G2S	G3G	G3S	G4G
13 Apr	1	166.00	160.00	176.00	166.00			
20 Apr	2	268.00		176.00				
27 Apr	3	108.00	140.00	128.00	124.00	120	128	
4May	4	116.00	88.00	136.00	116.00	124	148	
11May	5	100.00	112.00	96.00	96.00	100	112	192
18 May	6	544.00	140.00	136.00	172.00	140	192	664
25 May	7	140.00	132.00	144.00	132.00		148	
1 Jun	8	108.00	164.00	172.00	120.00		0	
8 Jun	9	66.00	104.00	120.00	104.00	80	0	1562
15 Jun	10	100.00	164.00	192.00	180.00	0	0	1312
22 Jun	11	144.00	136.00	168.00	92.00	0	0	
29 Jun	12	186.00	132.00	206.00	176.00	0	0	
6 Jul	13	120.00		120.00	156.00	0	0	
13 Jul	14	280.00	176.00		172.00	0	0	
20 Jul	15	216.00	196.00			0	0	
27 Jul	16	364.00	264.00	176.00		0	0	
3Aug	17	228.00	388.00	212.00		0	0	
10 Aug	18	68.00	116.00	116.00	108.00	0	0	
17 Aug	19	204.00		240.00	196.00	0	0	
24 Aug	20	164.00		156.00	156.00	0	0	
30 Aug	21	188.00		140.00		0	0	
6 Sept	22	180.00	180.00	160.00		0	0	
13 Sept	23	208.00		116.00		0	0	
20 Sept	24	256.00		220.00		0	0	
27 Sept	25	112.00	152.00	112.00		0	0	
4 Oct	26	192.00			240.00	0	0	
11 Oct	27	208.00	216.00	244.00	216.00	0	0	
18 Oct	28	116.00	128.00	84.00	132.00	0	0	
25 Oct	29	200.00	216.00	192.00	204.00			
1 Nov	30	88.00	92.00	120.00	120.00			
8 Nov	31	236.00	632.00	308.00	264.00	248		208
15 Nov	32	140.00	200.00	164.00	156.00	200		
22 Nov	33	176.00	168.00	196.00	188.00			
29 NOv	34	164.00	172.00	176.00	188.00	200		
		181.00	183.38	164.58	158.96	44.89	28.00	787.60

Legend

G1G	Grab Sample, Site 1
G2G	Grab Sample, Site 2
G3G	Grab Sample, Site 3
G4G	Grab Sample, Site 4

TOTAL SOLIDS ANALYSES

				Total Phosphorus (mg/L)		
G1G	G1S	G2G	G2S	G3G	G3S	G4G
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	
	0.00		0.00		0.00	

TOTAL NITROGEN ANALYSIS

Total Nitrogen (mg/L) NO2								NO3									TKN								TN/NO3 Ratio
G1G	G1S	G2G	G2S	G3G	G3S	G4G	G4S	G1G	G1S	G2G	G2S	G3G	G3S	G4G	G4S		G1G	G1S	G2G	G2S	G3G	G3S	G4G	G4S	
0.00	0.10	0.00	0.00					0.18	0.11	0.16	0.10					-0.02	0.03		0.02	0.00		0.00		0.00	
0.00	0.00	0.00	0.00					0.17	0.11	0.24	0.15					0.07	0.02		1.80	0.00		0.00		0.00	
0.01	0.00	0.00	0.00	0.00	0.00			0.07	0.06	0.09	0.09	0.07	0.06			0.02	0.00	0.00	0.09	0.00	0.00	0.00		0.00	
0.00	0.04	0.00	0.00	0.00	0.12			0.06	0.07	0.11	0.06	0.11	0.17			0.03	0.24		0.01	0.00	0.30	0.00		0.00	
			0.01		0.09			0.11	0.04	0.17	0.06	0.20	0.20			0.06	0.44		0.08	0.00	0.23	0.00	0.81	0.00	
0.00	0.00	0.01	0.00	0.00	0.01	0.00		0.31	0.12	0.38	0.19	0.56	0.21			0.07	0.36		0.04	0.00	0.28	0.00	0.72	0.00	
0.00	0.00	0.00	0.00		0.00			0.31	0.28	0.48	0.35		0.38			0.17	0.41		0.24	0.00		0.00		0.00	
0.00	0.00	0.00	0.00					0.27	0.28	0.42	0.35					0.15	0.38		0.21	0.00		0.00		0.00	
0.00	0.00	0.00	0.00	0.00		0.00		0.19	0.19	0.41	0.35	0.37		0.00		0.22	0.34		0.00	0.00	0.49	0.00	8.12	0.00	
0.00	0.00	0.00	0.00			0.00		0.20	0.19	0.37	0.35			0.02		0.17	0.00		0.00	0.00		0.00	14.36	0.00	
0.00	0.00	0.00	0.00					0.26	0.23	0.43	0.38					0.17	0.25		0.41	0.00		0.00		0.00	
0.00	0.00	0.00	0.00					0.26	0.30	0.48	0.43					0.22	0.39		0.40	0.00		0.00		0.00	
0.00	0.00	0.00	0.00					0.29	0.30	0.54	0.47					0.25	0.57		0.70	0.00		0.00		0.00	
0.00	0.00	0.00	0.49					0.35	0.42		0.55					-0.35	0.00			0.00		0.00		0.00	
0.00	0.00							0.33	0.34							-0.33				0.00		0.00		0.00	
0.00	0.00	0.00						0.47	0.38	0.60						0.13	0.27		0.00	0.00		0.00		0.00	
								0.29		0.34						0.05	0.00		0.00	0.00		0.00		0.00	
								0.20	0.32	0.44	0.47					0.24				0.00		0.00		0.00	
0.00	0.00	0.00						0.19		0.60	0.53					0.41				0.00		0.00		0.00	
0.00	0.00	0.00						0.10		0.50	1.63					0.40	3.69		1.94	0.00		0.00		0.00	
0.11		0.10						0.03		0.40						0.37	0.52		1.61			0.00		0.00	
0.00		0.00						0.06	0.11	0.26						0.20	0.00		0.00			0.00		0.00	
0.16		0.00						0.13		0.31						0.18	0.00		0.00			0.00		0.00	
0.00		0.00						0.06		0.02						-0.04	0.00		0.00			0.00		0.00	
0.00		0.00						0.06	0.07	0.15						0.09	0.36		0.23			0.00		0.00	
								0.01	0.08	0.08	0.19					0.07								0.00	
0.17								0.16	0.02	0.19	0.26					0.03								0.00	
								0.09	0.08	0.34	0.21					0.25								0.00	
				0.00	0.00	0.00	0.00	0.06	0.07	0.14	0.14					0.06	1.21		<0.02					0.00	
				0.00	0.00	0.00	0.00	0.08	0.15	0.31	0.27					0.23	7.89		<0.02					0.00	
				0.00	0.00	0.00	0.00	0.52	0.43	1.01	0.84	3.26		3.09		0.49	1.21		1.49		1.26		<0.02	0.00	
								0.64	0.48		0.97					-0.64									
								0.46	0.55	0.65	0.89					0.19									
				0.05				0.41	0.50	0.34	0.42	0.57				-0.07									
0.02	0.01	0.01	0.04	0.01	0.03	0.00	0.00	0.22	0.22	0.35	0.40	0.73	0.20	1.04		0.10	0.78	0.00	0.37	0.00	0.43	0.00	4.80	0.00	1.26

			Coliform Bacteria (colonies/100ml)								
			G1G	G2G	G3G	G4G	G5G	G6G	G7G	G8G	G2G-G1G
	13 Apr	1	200.00	700.00			400.00				500.00
	20 Apr	2	3200.00	3000.00			200.00				0.00
pump lag	27 Apr	3	500.00	500.00	1400.00		400.00				0.00
& spd sol	4May	4	200.00	2100.00	3300.00		900.00				1900.00
	11May	5	1000.00	2100.00	2500.00	49000.00	7000.00				1100.00
	18 May	6	2600.00	1500.00	1600.00	************	600.00				0.00
	25 May	7	24000.00	3000.00			900.00				0.00
	1 Jun	8	5000.00	11000.00			600.00				6000.00
	8 Jun	9	1000.00	10000.00	22000.00	41000.00	7000.00				9000.00
	15 Jun	10	1500.00	1900.00		6000.00	500.00				400.00
	22 Jun	11	2000.00	4000.00			<100				2000.00
	29 Jun	12	2000.00	7000.00			2000.00				5000.00
	6 Jul	13	2000.00	1000.00			300.00				0.00
	13 Jul	14	1300.00				100.00				0.00
	20 Jul	15	15000.00				200.00				0.00
	27 Jul	16	11000.00	17000.00			<100				6000.00
	3Aug	17	1900.00	2100.00			2400.00				200.00
	10 Aug	18	13000.00	39000.00			4000.00				26000.00
	17 Aug	19	1000.00	1000.00			500.00				0.00
spd sol 8	24 Aug	20	1000.00	1000.00			300.00	20000000.00			0.00
	30 Aug	21	<1000	1000.00			2000.00	10000000.00			1000.00
	6 Sept	22	1200.00	1700.00			800.00				500.00
	13 Sept	23	9000.00	1100.00			100.00				0.00
pmp lag	20 Sept	24	700.00	1800.00			1000.00				1100.00
	27 Sept	25	1400.00	2100.00			500.00				700.00
	4 Oct	26	1600.00	4400.00			500.00		100.00	200.00	2800.00
	11 Oct	27	<100	200.00			300.00				200.00
	18 Oct	28	100.00	900.00			1600.00				800.00
	25 Oct	29	<100	600.00			100.00				600.00
	1 Nov	30	<100	2300.00			800.00	88000000.00			2300.00
	8 Nov	31	700.00	3700.00	6300.00	1800.00	8000.00				3000.00
	15 Nov	32	100.00	800.00	1900.00		1419.35	50000000.00			700.00
	22 Nov	33					1100.00				0.00
	29 Nov	34	100.00	200.00	400.00		500.00	70000000.00			100.00
											0.00
			3160.61	4151.61	4925.00	43560.00	1382.92	47600000.00	100.00	0.00	991.01

MASS TRANSPORT ANALYSIS

	Week	h1 (ft)	q1 (ft^3/sec)	h2 (ft)	q2 (ft^3/sec)	q1 (L/week)	q2 (L/week)	sed conc 1 (mg/L) Grab	sed conc 2 (mg/L) Grab	sed q1*c1 (kg/wk)	sed q2*c2 (kg/wk)	net sed (kg/wk) (grab) Grab	TN c1 (mg/L) (grab)	TN c2 (mg/L) (grab)	N c1*q1 (kg/wk)	N c2*q2 (kg/wk)	net N (kg/wk)	tot P c1 (mg/l) (grab) (grab)	tot P c2 (mg/l) (grab)	P c1*q1 (kg/wk) (grab)	P c2*q2 (kg/wk) (grab) (grab)	net P (kg/wk)
13 Apr	1		0.57		0.00	9765892.35	0	166.00	176.00	1621.14	0.00	-1621.14	0.06	0.06	0.62	0.00	-0.62	0.00	0.00	0.00	0.00	0.00
20 Apr	2		0.57		0.54	9765892	9251898	268.00	176.00	2617.26	1628.33	-988.93	0.95	1.65	9.32	15.25	5.93	0.00	0.00	0.00	0.00	0.00
27 Apr	3		0.57		0.54	9765892	9251898	108.00	128.00	1054.72	1184.24	129.53	0.02	0.11	0.17	1.00	0.83	0.00	0.00	0.00	0.00	0.00
4May	4		2.60		4.00	44546176	68532578	116.00	136.00	5167.36	9320.43	4153.07	0.26	0.03	11.40	2.19	-9.21	0.00	0.00	0.00	0.00	0.00
11May	5		4.60		5.70	78812465	97658924	100.00	96.00	7881.25	9375.26	1494.01	0.46	0.09	36.41	9.18	-27.23	0.00	0.00	0.00	0.00	0.00
18 May	6		2.62		4.10	44888839	70245892	544.00	136.00	24419.53	9553.44	-14866.09	0.42	0.12	18.94	8.36	-10.58	0.00	0.00	0.00	0.00	0.00
25 May	7		1.35		3.50	23129745	59966006	140.00	144.00	3238.16	8635.10	5396.94	0.47	0.34	10.92	20.15	9.23	0.00	0.00	0.00	0.00	0.00
1 Jun	8		1.35		1.10	23129745	18846459	108.00	172.00	2498.01	3241.59	743.58	0.41	0.29	9.58	5.54	-4.03	0.00	0.00	0.00	0.00	0.00
8 Jun	9		1.35		0.50	23129745	8566572	66.00	120.00	1526.56	1027.99	-498.57	0.38	0.08	8.74	0.70	-8.04	0.00	0.00	0.00	0.00	0.00
15 Jun	10		1.35		0.50	23129745	8566572	100.00	192.00	2312.97	1644.78	-668.19	0.04	0.07	0.93	0.63	-0.29	0.00	0.00	0.00	0.00	0.00
22 Jun	11		1.35		0.50	23129745	8566572	144.00	168.00	3330.68	1439.18	-1891.50	0.30	0.50	6.99	4.25	-2.74	0.00	0.00	0.00	0.00	0.00
29 Jun	12		1.35		0.50	23129745	8566572	186.00	206.00	4302.13	1764.71	-2537.42	0.44	0.50	10.22	4.25	-5.97	0.00	0.00	0.00	0.00	0.00
6 Jul	13		1.35		0.33	23129745	5653938	120.00	120.00	2775.57	678.47	-2097.10	0.63	0.81	14.53	4.57	-9.96	0.00	0.00	0.00	0.00	0.00
13 Jul	14		1.35		0.00	23129745	0	280.00		6476.33	0.00	-6476.33	0.07	0.00	1.62	0.00	-1.62	0.00	0.00	0.00	0.00	0.00
20 Jul	15		0.07		0.00	1199320	0	216.00		259.05	0.00	-259.05	0.07	0.00	0.08	0.00	-0.08	0.00	0.00	0.00	0.00	0.00
27 Jul	16	0.12	0.55	0	0.00	9350949	7264688	364.00	176.00	3403.75	1278.59	-2125.16	0.36	0.12	3.40	0.87	-2.53	0.00	0.00	0.00	0.00	0.00
3Aug	17	0.15	0.70	0.13	0.42	11975946	0	228.00	212.00	2730.52	1540.11	-1190.40	0.06	0.07	0.69	0.49	-0.20	0.00	0.00	0.00	0.00	0.00
10 Aug	18	0.225	1.33	0	0.00	22831831	0	68.00	116.00	1552.56	0.00	-1552.56	0.04	0.09	0.91	0.00	-0.91	0.00	0.00	0.00	0.00	0.00
17 Aug	19	0.11	0.50	0.05	0.00	8634336	0	204.00	240.00	1761.40	0.00	-1761.40	0.04	0.12	0.33	0.00	-0.33	0.00	0.00	0.00	0.00	0.00
17 Aug	20	0.09	0.43	0	0.00	7388239	0	164.00	156.00	1211.67	0.00	-1211.67	3.71	2.04	27.41	0.00	-27.41	0.00	0.00	0.00	0.00	0.00
24 Aug	21	0.08	0.40	0	0.00	6840579	0	188.00	140.00	1286.03	0.00	-1286.03	0.56	1.62	3.82	0.00	-3.82	0.00	0.00	0.00	0.00	0.00
6 Sept	22	0.08	0.40	0	0.00	6840579	0	180.00	160.00	1231.30	0.00	-1231.30	0.01	0.05	0.06	0.00	-0.06	0.00	0.00	0.00	0.00	0.00
13 Sept	23	0.14	0.64	0	0.00	11013676	0	208.00	116.00	2290.84	0.00	-2290.84	0.07	0.06	0.82	0.00	-0.82	0.00	0.00	0.00	0.00	0.00
20 Sept	24	0.09	0.43	0	0.00	7388239	0	256.00	220.00	1891.39	0.00	-1891.39	0.01	0.00	0.09	0.00	-0.09	0.00	0.00	0.00	0.00	0.00
27 Sept	25	0.24	1.51	0.18	0.89	25941108	15180770	112.00	112.00	2905.40	1700.25	-1205.16	0.37	0.26	9.65	3.95	-5.70	0.00	0.00	0.00	0.00	0.00
4Oct	26	0.08	0.40	0.17	0.78	6840579	13445166	192.00		1313.39	0.00	-1313.39	0.00	0.02	0.01	0.22	0.20	0.00	0.00	0.00	0.00	0.00
11 Oct	27	0.22	1.28	0.25	1.71	21873458	29213088	208.00	244.00	4549.68	7127.99	2578.31	0.08	0.04	1.82	1.11	-0.71	0.00	0.00	0.00	0.00	0.00
18 Oct	28	0.22	1.28	0.17	0.78	21873458	13445166	116.00	84.00	2537.32	1129.39	-1407.93	0.02	0.07	0.39	0.91	0.52	0.00	0.00	0.00	0.00	0.00
25 Oct	29	0.245	1.58	0.115	0.31	27058610	5283398	200.00	192.00	5411.72	1014.41	-4397.31	1.22	0.03	33.07	0.15	-32.92	0.00	0.00	0.00	0.00	0.00
1 Nov	30	0.37	4.14	0.15	0.60	70992707	10197742	88.00	120.00	6247.36	1223.73	-5023.63	7.91	0.06	561.27	0.63	-560.64	0.00	0.00	0.00	0.00	0.00
8 Nov	31	0.3	2.47	0.6	7.59	42324136	130070825	236.00	308.00	9988.50	40061.81	30073.32	1.31	1.69	55.61	220.08	164.47	0.00	0.00	0.00	0.00	0.00
15 Nov	32	0.23	1.39	0.31	2.54	23828624	43499140	140.00	164.00	3336.01	7133.86	3797.85	0.13	0.00	3.05	0.00	-3.05	0.00	0.00	0.00	0.00	0.00
22 Nov	33	0.23	1.39	0.11	0.27	23828624	4666374	176.00	196.00	4193.84	914.61	-3279.23	0.09	0.13	2.19	0.61	-1.59	0.00	0.00	0.00	0.00	0.00
29 Nov	34	0.35	3.60	0.47	5.18	61621019	88817917	164.00	176.00	10105.85	15631.96	5526.11	0.06	0.07	5.05	6.04	0.99	0.00	0.00	0.00	0.00	0.00
		0.188	1.377	0.142	1.261	23594975	21610534	181	165	4042	3772	-270	0.620	0.329	25.004	9.151	-15.853	0.000	0.000	0.000	0.000	0.000

Appendix G

Mass Balance Computations

MASS BALANCE N AND P FOR WC

INPUT	(Waste/Fertilizer)													
Liquid	(Lagoon)	(lb/1000gal)	(kg/L)	Conversion Factors		Acreages	Acres	Hectares	Dry Cows	kg/day/hd	kg/day/ha			
	N	0.90	0.000100	Dairy Manure Density (dry)	0.80 kg/L	Field #1	33.5	83	N	0.130	0.033 (Milked*1/2 time in pasture)			
	P	3.30	0.001021	ac-in to L (kg)	102740.00 L	Field #2	15.3	38	P	0.056	0.005			
Dry	(Stack)			gal/ft^3	7.50	Field #2BE	57.0	141						
	%N	0.005				Field #2BW	88.0	217	Feeders(3600)			Feeders(4750)	kg/day/hd	kg/day/ha
	%P	0.001				Field #4	8.3	21	N	0.148	0.057	N	0.282	0.082
Fertilizer	(30% Diammonium Phosphate 70% Urea)					Field #5 (1/2)	7.7	19	P	0.022	0.010	P	0.037	0.017
	%N	0.301				Field #6	10.3	25	Feeders(3750)			Feeders(5500)		
	%P	0.060				Field #7	11.0	27	N	0.160	0.073	N	0.305	0.110
						Field #8	15.3	38	P	0.004	0.011	P	0.040	0.021
						Field #9 (Dairy)	3.5	9	Feeders(4000)			Feeders(6500)		
						Field #WE	40.2	99	N	0.192	0.087	N	0.277	0.126
						Corn	3.5	9	P	0.026	0.010	P	0.050	0.023
						Tobacco	0.7	2						
						Hay	36.0	89						

Watershed A

		Liquid				Solids					Fertilizer				Dry Cows			Feeders		
	Field	in	ac-in	N (kg)	P (kgs)	tons/ac	kg/ha	kg	N (kg)	P (kg)	lb/ac	kg/ha	N (kg)	P (kg)	# head	N (kg)	P (kg)	# head	N (kg)	P (kg)
April	6	0	0	0	0	0	0	0	0	0	600	672.48	6692	1101	0	0	0	0	0	0
May		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October		0	0	0	0	5	11204	286154	1454	314	0	0	0	0	0	0	0	0	0	0
November		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December																				
	Total	0	0	0	0	5	11204	286154	1454	314			6692	1101	0	0	0	0	0	0
	Field	in	ac-in	N (kg)	P (kgs)	tons/ac	kg/ha	kg	N (kg)	P (kg)	lb/ac	kg/ha	N (kg)	P (kg)	# head	N (kg)	P (kg)	# head	N (kg)	P (kg)
April	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December																				
	Total	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0
	Field	in	ac-in	N (kg)	P (kgs)	tons/ac	kg/ha	kg	N (kg)	P (kg)	lb/ac	kg/ha	N (kg)	P (kg)	# head	N (kg)	P (kg)	# head	N (kg)	P (kg)
April	5 (1/2 field)	1	8	4086	1010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September		1	8	4086	1010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October		1	8	4088	1010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November			0	483	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December																				
	Total	3	23	12747	4056	0	0	0	0	0			0	0	0	0	0	0	0	0
	Field	in	ac-in	N (kg)	P (kgs)	tons/ac	kg/ha	kg	N (kg)	P (kg)	lb/ac	kg/ha	N (kg)	P (kg)	# head	N (kg)	P (kg)	# head	N (kg)	P (kg)
April	2BW(1/2 dry cows)	0	0	0	0	0	0	0	0	0	0	0	0	0	30	64	22	0	0	0
May		0	0	0	0	0	0	0	0	0	0	0	0	0	65	122	40	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	60	84	37	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	38	71	28	0	0	0
August		0	0	0	0	0	0	0	0	0	0	0	0	0	50	94	37	0	0	0
September		0	0	0	0	0	0	0	0	0	0	0	0	0	60	113	45	0	0	0
October		1	1	756	280	0	0	0	0	0	0	0	0	0	51	98	38	0	0	0
November		0	0	0	0	0	0	0	0	0	0	0	0	0	40	75	30	0	0	0
December																				
	Total	1	1	756	280	0	0	0	0	0	0	0	0	0		722	288	0	0	0
	Watershed A input			13506	4630				1454	314			6692	1101		722	288	0	0	0

MASS BALANCE N AND P FOR WC

	Watershed B		Liquid				Solids					Fertilizer					Dry Cows			Feeders			
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	
April		1	0	0	0	0	10	42575	2472276	12800	2720	600	672.40	19200	2664		0	0	0	0	0	0	
May			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
June			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
July			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
August			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
September			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
October			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
November			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
December																							
	Totals		0	0	0	0	10	42575	2472276	12800	2720			19200	2664		0	0	0	0	0	0	
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	
April		4	0	0	0	0	0	0	0	0	0	600	672.40	5383	962		0	0	0	0	0	0	
May			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
June			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
July			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
August			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
September			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
October			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
November			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
December																							
	Total		0	0	0	0	0	0	0	0	0			5383	962	0	0	0	0	0	0	0	
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	
April	6 (1/2 field)		1	8	4095	1519	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
May			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
June			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
July			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
August			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
September			1	8	4095	1519	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
October			1	8	4095	1519	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
November				0	463	113	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
December																							
	Total		3	23	12747	4671	0	0	0	0	0			0	0	0	0	0	0	0	0	0	
			Liquid				Solids					Fertilizer					Dry Cows			Feeders			
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	
April		7		0	0	0	0	0	0	0	0	600	672.40	7147	1261		0	0	0	0	0	0	
May				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
June				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
July				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
August				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
September				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
October				0	0	0	5	11204	304636	1593	385	0	0	0	0		0	0	0	0	0	0	
November				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
December																							
	Total		0	0	0	0	5	11204	304636	1593	385			7147	1261	0	0	0	0	0	0	0	
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	
April		8		0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
May				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
June				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
July				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
August				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
September				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
October				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
November				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
December																							
	Total		0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	
April	WE			0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
May				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
June				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
July				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
August				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
September				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
October				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
November				0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
December																							
	Total		0	0	0	0	0	0	0	0	0			0	0		0	0	0	0	0	0	
	Field		in	ac-in	N (kg)	P (kgs)	tons/ac	kg/hac	kg	N (kg)	P (kg)	lbs/ac	kg/hac	N (kg)	P (kg)		# head	N (kg)	P (kg)	# head	N (kg)	P (kg)	weight (kg)
April	2SE (1/2 dry cows)			0	0	0	0	0	0	0	0	0	0	0	0		30	69	32	45	91	13	170
May				0	0	0	0	0	0	0	0	0	0	0	0		65	132	40	45	101	16	200
June				0	0	0	0	0	0	0	0	0	0	0	0		58	94	37	45	118	21	225
July				0	0	0	0	0	0	0	0	0	0	0	0		35	71	30	90	207	42	250
August				0	0	0	0	0	0	0	0	0	0	0	0		60	84	37	90	207	82	275
September				0	0	0	0	0	0	0	0	0	0	0	0		60	113	45	90	232	84	300
October				0	0	0	0	0	0	0	0	0	0	0	0		91	96	38	92	224	42	325
November				0	0	0	0	0	0	0	0	0	0	0	0		40	75	30	92	224	42	350
December																							
	Total		0	0	0	0	0	0	0	0	0			0	0	0		722	298	490	1804	293	
	Watershed B Input			23	12747	4671	24	54081	2896425	15886	3306			27608	4667			722	298	490	1804	293	

MASS BALANCE N AND P FOR WC

OUTPUT

	Field	Liquid in		N (kg)	P (kg)	Solids tons	kg	N (kg)	P (kg)	Fertilizer lb/ac	kg/hec	N (kg)	P (kg)	Dry Cows # head	N (kg)	P (kg)	Feeders # head	N (kg)	P (kg)
April	Sold		0	0	0	30	27216	109	30										
May			0	0	0	0	0	0	0										
June			0	0	0	0	0	0	0										
July			0	0	0	0	0	0	0										
August			0	0	0	0	0	0	0										
September			0	0	0	30	27216	109	30										
October			0	0	0	192	174180	890	192										
November			0	0	0	0	0	0	0										
December																			
	Total	0	0	0	0	252	226611	1108	251					0	0	0	0	0	0

Crops/Pasture		May	wheat/vetch haylage Fields 8 (3/4),2		15999 lbs/ac	
Haylage (Vetch & Wheat)			hay (3 1/3 tons) Fields 1 & 7		3333 lbs/ac	
% N	0.00424					
% P	0.00075		silage (fields 6,7,1,4,8,5)		35000 lbs/ac	
Hay (Wheat & Vetch)				%N	0.013	
% N	0.0232			%P	0.002	
% P	0.0026					
			tobacco	N	0.040	lb/lb crop
Pasture (Fescue, Orchard Grass, & Clover)		Hay		P	0.005	lb/lb crop
% N	0.0237	0.014				
% P	0.0041	0.003	corn	N		
Kgs grazed per cow per day	4.55			P		

Watershed A

	Field	kgs haylage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kg)		# cows	kgs grazed	N (kg)	P (kg)
April	8	0	0	0		0	0	0		0	0	0	0
May		0	0	0		0	0	0		0	0	0	0
June		0				0	0	0		0	0	0	0
July		0				0	0	0		0	0	0	0
August		183867	2193	380		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	183867	2193	380	0	0	0	0	0	0	0	0	0
	Field	kgs haylage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kg)		# cows	kgs grazed	N (kg)	P (kg)
April	6	0	0	0		0	0	0		0	0	0	0
May		105958	462	82		0	0	0		0	0	0	0
June		0	0	0		0	0	0		0	0	0	0
July		0	0	0		0	0	0		0	0	0	0
August		246117	1001	102		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	352075	1463	284	0	0	0	0	0	0	0	0	0
	Field	kgs haylage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kg)		# cows	kgs grazed	N (kg)	P (kg)
April	5 (1/2)	0	0	0		0	0	0		0	0	0	0
May		0	0	0		0	0	0		65	1343	31	3
June		0	0	0		0	0	0		0	0	0	0
July		0				0	0	0		0	0	0	0
August		122353	1640	266		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	122353	1640	266	0	0	0	0	0	65	1343	31	3
	Field	kgs haylage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kg)		# cows	kgs grazed	N (kg)	P (kg)
April	2SW	0	0	0		0	0	0		15	888	28	4
May		0	0	0		0	0	0		30	2113	65	9
June		0	0	0		0				25	1540	48	6
July		0	0	0		22246	318	65		10	1217	37	5
August		0	0	0		0	0	0		25	1801	48	7
September		0	0	0		0	0	0		30	1650	57	8
October		0	0	0		0	0	0		25	1801	48	7
November		0	0	0		0	0	0		28	1208	38	5
December													
	Total	0	0	0	0	22246	318	65	0	192	12108	372	50
	Watershed A Output		3935	888		22246	318	65			13452	403	53

MASS BALANCE N AND P FOR WC

Watershed B

Month	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	1	0	0	0		0	0	0		0	0	0	0
May		0	0	0		[illegible]	[illegible]	92		0	0	0	0
June		0				0	0	0		0	0	0	0
July		0				7710	110	22		0	0	0	0
August		373416	8004	622		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0									
December													
	Total	373416	8004	622	0	43278	936	115	0	0	0	0	0
	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	4	0	0	0		0	0	0		0	0	0	0
May		0	0	0		12586	201	33		0	0	0	0
June		0				0	0	0		0	0	0	0
July		0				0	0	0		0	0	0	0
August		131687	1767	260		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	131687	1767	260	0	12586	201	33	0	0	0	0	0
	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	5 (1/2 field)	0	0	0		0	0	0		0	0	0	0
May		0	0	0		0	0	0		0	0	0	0
June		0				0	0	0		0	0	0	0
July		0				0	0	0		0	0	0	0
August		122383	1640	260		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	122383	1640	260	0	0	0	0	0	0	0	0	0
	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	7	0	0	0		0	0	0		0	0	0	0
May		0	0	0		10046	386	43		0	0	0	0
June		0				0	0	0		0	0	0	0
July		0				0	0	0		0	0	0	0
August		174790	2342	386		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	174790	2342	386	0	10046	386	43	0	0	0	0	0
	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	9	0	0	0		0	0	0		0	0	0	0
May		0	0	0		0	0	0		0	0	0	0
June		0	0	0		0	0	0		0	0	0	0
July		0	0	0		0	0	0		0	0	0	0
August		0	0	0		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November						0	0	0		0	0	0	0
December													
	Total	0	0	0	0	0	0	0	0	0	0	0	0
	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	WE	0	0	0		0	0	0		0	0	0	0
May		0	0	0		0	0	0		0	0	0	0
June		0	0	0		24101	346	70		0	0	0	0
July		0	0	0		0	0	0		0	0	0	0
August		0	0	0		0	0	0		0	0	0	0
September		0	0	0		0	0	0		0	0	0	0
October		0	0	0		0	0	0		0	0	0	0
November		0	0	0		0	0	0		0	0	0	0
December													
	Total	0	0	0	0	24101	346	70	0	0	0	0	0
	Field	kgs hay/sage/silage	N (kg)	P (kg)		kgs hay	N (kg)	P (kgs)		# cows	kgs grazed	N (kg)	P (kg)
April	2SE	0	0	0		0	0	0		15	880	30	4
May		0	0	0		0	0	0		32	1682	61	8
June						0	0	0		25	1640	40	6
July						25434	384	74		15	1217	37	5
August										25	1601	40	7
September										30	1680	57	6
October										28	1685	61	7
November										30	1280	30	5
December													
	Total	0	0	0	0	25434	384	74	0		12043	370	40
	Watershed B Output	858446	10788	1795	0	122007	2221	384	0		12043	370	40

Field WE (continued)

Month	Tobacco	lbs/ac	Total kgs	N (kgs)	P (kgs)	Corn	bu/ac	Total Bu	N (kgs)	P (kgs)
April	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0
November		2000	685	26	3		60		127	21
Total				26	3				127	21
Watershed B Output				26	3				127	21

MASS BALANCE N AND P FOR WC

milk	% P	0.001
	% N	0.005

Freestall Barn (Field # 9)

Lactating Cows

		Purchased Feed					Daily Nutrient Requirement				Waste Produced				Milk Production		
Month	Head	Days/Month	kg N/hd/day	kg P/hd/day	Total N (kg)	Total P (kg)	kg N /day/hd	kg P /day/hd	Tot N (kg)	Tot P (kg)	lb N /day/hd	kg P /day/hd	kg N	kg P	kgs Milk	N (kgs)	P (kgs)
April	161	30	1.75	0.29	8473	1377	0.06	0.02	314	61	0.34	0.05	1635	237	145280	741	148
May	169	31	1.75	0.29	8864	1441	0.06	0.02	328	65	0.34	0.05	1700	248	149340	762	149
June	175	30	1.75	0.29	9210	1497	0.06	0.02	341	66	0.34	0.05	1766	257	140740	718	141
July	185	31	1.75	0.29	10061	1636	0.06	0.02	372	96	0.34	0.05	1869	261	149620	764	150
August	185	31	1.75	0.29	10061	1636	0.06	0.02	372	96	0.34	0.05	1869	261	136200	695	136
September	190	30	1.75	0.29	9999	1685	0.06	0.02	370	96	0.34	0.05	1916	279	133830	683	134
October	190	31	1.75	0.29	10333	1679	0.06	0.02	382	99	0.34	0.05	1981	289	140740	718	141
November	190	30	1.75	0.29	9999	1685	0.06	0.02	370	96	0.34	0.05	1916	279	141523	722	142
December																	
					77000	12514			2850	737			14796	2152	1137500	5802	1138

Dry Cows

		Feed					Daily Nutrient Requirement				Waste Produced			
Month	Head	Days/Month	N kg/day/hd	P kg/day/hd	Tot N	Tot P	kg N /day/hd	lb P /day/hd	Tot N	Tot P	kg N /day/hd	kg P /day/hd	kg N	kg P
April	38	30	0.774	0.072	886	88	0.06	0.02	68	15	0.17	0.02	192	22
May	65	31	0.774	0.072	1559	145	0.06	0.02	131	34	0.17	0.02	330	40
June	50	30	0.774	0.072	1160	108	0.06	0.02	97	25	0.17	0.02	253	37
July	38	31	0.774	0.072	911	85	0.06	0.02	76	20	0.17	0.02	198	29
August	50	31	0.774	0.072	1199	111	0.06	0.02	101	26	0.17	0.02	261	36
September	60	30	0.774	0.072	1393	129	0.06	0.02	117	30	0.17	0.02	303	44
October	51	31	0.774	0.072	1223	113	0.06	0.02	106	27	0.17	0.02	266	39
November	40	30	0.774	0.072	928	86	0.06	0.02	76	20	0.17	0.02	202	29
December														
					9670	841			761	197			1975	267

Net =

Input - Output = purchased feed + silage/haylage fed + liq man + solid Man + fert + man dry cows + man feeders - (silage/haylage/hay produced + milk + corn + tobacco + daily nutrient rqmt + waste)

			kgs/wk (tot /8 mo/4wks)
Net Nitrogen = (Watershed A)	N Out - N In =	16324	510
Net Nitrogen = (Watershed B)	N Out - N In =	103505	3235
Net Phosphorus = (Watershed A)	P Out - P In =	5610	175
Net Phosphorus = (Watershed B)	P Out - P Fin =	19908	622

Appendix H

SRI Sensitivity Analysis for Nitrogen

GRAPH PARAMETERS

	mea (kg/wk)	worst case (kg/wk)	MPI	mea t	mea/mea t SRI	std (kg/wk)	mea/std SWI	mea/worst case
NITROGEN	1	1000	0.9	100	0.0100000	227	0.0044	0.0010000
	1	1000	0.8	200	0.0050000	227	0.0044	0.0010000
0.91	1	1000	0.7	300	0.0033333	227	0.0044	0.0010000
	1	1000	0.6	400	0.0025000	227	0.0044	0.0010000
	1	1000	0.5	500	0.0020000	227	0.0044	0.0010000
	1	1000	0.4	600	0.0016667	227	0.0044	0.0010000
	1	1000	0.3	700	0.0014286	227	0.0044	0.0010000
	1	1000	0.2	800	0.0012500	227	0.0044	0.0010000
	1	1000	0.1	900	0.0011111	227	0.0044	0.0010000
	1	2000	0.9	200	0.0050000	227	0.0044	0.0005000
	1	2000	0.8	400	0.0025000	227	0.0044	0.0005000
	1	2000	0.7	600	0.0016667	227	0.0044	0.0005000
	1	2000	0.6	800	0.0012500	227	0.0044	0.0005000
	1	2000	0.5	1000	0.0010000	227	0.0044	0.0005000
	1	2000	0.4	1200	0.0008333	227	0.0044	0.0005000
	1	2000	0.3	1400	0.0007143	227	0.0044	0.0005000
	1	2000	0.2	1600	0.0006250	227	0.0044	0.0005000
	1	2000	0.1	1800	0.0005556	227	0.0044	0.0005000
	1	3780	0.9	378	0.0026455	227	0.0044	0.0002646
	1	3780	0.8	756	0.0013228	227	0.0044	0.0002646
	1	3780	0.7	1134	0.0008818	227	0.0044	0.0002646
	1	3780	0.6	1512	0.0006614	227	0.0044	0.0002646
	1	3780	0.5	1890	0.0005291	227	0.0044	0.0002646
	1	3780	0.4	2268	0.0004409	227	0.0044	0.0002646
	1	3780	0.3	2646	0.0003779	227	0.0044	0.0002646
	1	3780	0.2	3024	0.0003307	227	0.0044	0.0002646
	1	3780	0.1	3402	0.0002939	227	0.0044	0.0002646
	1	5000	0.9	500	0.0020000	227	0.0044	0.0002000
	1	5000	0.8	1000	0.0010000	227	0.0044	0.0002000
	1	5000	0.7	1500	0.0006667	227	0.0044	0.0002000
	1	5000	0.6	2000	0.0005000	227	0.0044	0.0002000
	1	5000	0.5	2500	0.0004000	227	0.0044	0.0002000
	1	5000	0.4	3000	0.0003333	227	0.0044	0.0002000
	1	5000	0.3	3500	0.0002857	227	0.0044	0.0002000
	1	5000	0.2	4000	0.0002500	227	0.0044	0.0002000
	1	5000	0.1	4500	0.0002222	227	0.0044	0.0002000
	2	1000	0.9	100	0.0200000	227	0.0088	0.0020000
	2	1000	0.8	200	0.0100000	227	0.0088	0.0020000
	2	1000	0.7	300	0.0066667	227	0.0088	0.0020000
	2	1000	0.6	400	0.0050000	227	0.0088	0.0020000
	2	1000	0.5	500	0.0040000	227	0.0088	0.0020000
	2	1000	0.4	600	0.0033333	227	0.0088	0.0020000
	2	1000	0.3	700	0.0028571	227	0.0088	0.0020000
	2	1000	0.2	800	0.0025000	227	0.0088	0.0020000
	2	1000	0.1	900	0.0022222	227	0.0088	0.0020000
	2	2000	0.9	200	0.0100000	227	0.0088	0.0010000
	2	2000	0.8	400	0.0050000	227	0.0088	0.0010000
	2	2000	0.7	600	0.0033333	227	0.0088	0.0010000
	2	2000	0.6	800	0.0025000	227	0.0088	0.0010000
	2	2000	0.5	1000	0.0020000	227	0.0088	0.0010000
	2	2000	0.4	1200	0.0016667	227	0.0088	0.0010000
	2	2000	0.3	1400	0.0014286	227	0.0088	0.0010000
	2	2000	0.2	1600	0.0012500	227	0.0088	0.0010000
	2	2000	0.1	1800	0.0011111	227	0.0088	0.0010000
	2	3780	0.9	378	0.0052910	227	0.0088	0.0005291
	2	3780	0.8	756	0.0026455	227	0.0088	0.0005291
	2	3780	0.7	1134	0.0017637	227	0.0088	0.0005291
	2	3780	0.6	1512	0.0013228	227	0.0088	0.0005291
	2	3780	0.5	1890	0.0010582	227	0.0088	0.0005291
	2	3780	0.4	2268	0.0008818	227	0.0088	0.0005291
	2	3780	0.3	2646	0.0007559	227	0.0088	0.0005291
	2	3780	0.2	3024	0.0006614	227	0.0088	0.0005291
	2	3780	0.1	3402	0.0005879	227	0.0088	0.0005291

	worst case (kg/wk)	MPI	mea t	mea/mea t SRI	std (kg/wk)	mea/std SWI	mea/worst case
2	5000	0.9	500	0.0040000	227	0.0088	0.0004000
2	5000	0.8	1000	0.0020000	227	0.0088	0.0004000
2	5000	0.7	1500	0.0013333	227	0.0088	0.0004000
2	5000	0.6	2000	0.0010000	227	0.0088	0.0004000
2	5000	0.5	2500	0.0008000	227	0.0088	0.0004000
2	5000	0.4	3000	0.0006667	227	0.0088	0.0004000
2	5000	0.3	3500	0.0005714	227	0.0088	0.0004000
2	5000	0.2	4000	0.0005000	227	0.0088	0.0004000
2	5000	0.1	4500	0.0004444	227	0.0088	0.0004000
4.5	1000	0.9	100	0.0450000	227	0.0198	0.0045000
4.5	1000	0.8	200	0.0225000	227	0.0198	0.0045000
4.5	1000	0.7	300	0.0150000	227	0.0198	0.0045000
4.5	1000	0.6	400	0.0112500	227	0.0198	0.0045000
4.5	1000	0.5	500	0.0090000	227	0.0198	0.0045000
4.5	1000	0.4	600	0.0075000	227	0.0198	0.0045000
4.5	1000	0.3	700	0.0064286	227	0.0198	0.0045000
4.5	1000	0.2	800	0.0056250	227	0.0198	0.0045000
4.5	1000	0.1	900	0.0050000	227	0.0198	0.0045000
4.5	2000	0.9	200	0.0225000	227	0.0198	0.0022500
4.5	2000	0.8	400	0.0112500	227	0.0198	0.0022500
4.5	2000	0.7	600	0.0075000	227	0.0198	0.0022500
4.5	2000	0.6	800	0.0056250	227	0.0198	0.0022500
4.5	2000	0.5	1000	0.0045000	227	0.0198	0.0022500
4.5	2000	0.4	1200	0.0037500	227	0.0198	0.0022500
4.5	2000	0.3	1400	0.0032143	227	0.0198	0.0022500
4.5	2000	0.2	1600	0.0028125	227	0.0198	0.0022500
4.5	2000	0.1	1800	0.0025000	227	0.0198	0.0022500
4.5	3780	0.9	378	0.0119048	227	0.0198	0.0011905
4.5	3780	0.8	756	0.0059524	227	0.0198	0.0011905
4.5	3780	0.7	1134	0.0039683	227	0.0198	0.0011905
4.5	3780	0.6	1512	0.0029762	227	0.0198	0.0011905
4.5	3780	0.5	1890	0.0023810	227	0.0198	0.0011905
4.5	3780	0.4	2268	0.0019841	227	0.0198	0.0011905
4.5	3780	0.3	2646	0.0017007	227	0.0198	0.0011905
4.5	3780	0.2	3024	0.0014881	227	0.0198	0.0011905
4.5	3780	0.1	3402	0.0013228	227	0.0198	0.0011905
4.5	5000	0.9	500	0.0090000	227	0.0198	0.0009000
4.5	5000	0.8	1000	0.0045000	227	0.0198	0.0009000
4.5	5000	0.7	1500	0.0030000	227	0.0198	0.0009000
4.5	5000	0.6	2000	0.0022500	227	0.0198	0.0009000
4.5	5000	0.5	2500	0.0018000	227	0.0198	0.0009000
4.5	5000	0.4	3000	0.0015000	227	0.0198	0.0009000
4.5	5000	0.3	3500	0.0012857	227	0.0198	0.0009000
4.5	5000	0.2	4000	0.0011250	227	0.0198	0.0009000
4.5	5000	0.1	4500	0.0010000	227	0.0198	0.0009000
5	1000	0.9	100	0.0500000	227	0.0220	0.0050000
5	1000	0.8	200	0.0250000	227	0.0220	0.0050000
5	1000	0.7	300	0.0166667	227	0.0220	0.0050000
5	1000	0.6	400	0.0125000	227	0.0220	0.0050000
5	1000	0.5	500	0.0100000	227	0.0220	0.0050000
5	1000	0.4	600	0.0083333	227	0.0220	0.0050000
5	1000	0.3	700	0.0071429	227	0.0220	0.0050000
5	1000	0.2	800	0.0062500	227	0.0220	0.0050000
5	1000	0.1	900	0.0055556	227	0.0220	0.0050000
5	2000	0.9	200	0.0250000	227	0.0220	0.0025000
5	2000	0.8	400	0.0125000	227	0.0220	0.0025000
5	2000	0.7	600	0.0083333	227	0.0220	0.0025000
5	2000	0.6	800	0.0062500	227	0.0220	0.0025000
5	2000	0.5	1000	0.0050000	227	0.0220	0.0025000
5	2000	0.4	1200	0.0041667	227	0.0220	0.0025000
5	2000	0.3	1400	0.0035714	227	0.0220	0.0025000
5	2000	0.2	1600	0.0031250	227	0.0220	0.0025000
5	2000	0.1	1800	0.0027778	227	0.0220	0.0025000

5	worst case	MPI	mea t	mea/mea t	std	mea/std	mea/worst case
5	(kg/wk)			SRI	(kg/wk)	SWI	
5	3780	0.9	378	0.0132275	227	0.0220	0.0013228
5	3780	0.8	756	0.0066138	227	0.0220	0.0013228
5	3780	0.7	1134	0.0044092	227	0.0220	0.0013228
5	3780	0.6	1512	0.0033069	227	0.0220	0.0013228
5	3780	0.5	1890	0.0026455	227	0.0220	0.0013228
5	3780	0.4	2268	0.0022046	227	0.0220	0.0013228
5	3780	0.3	2646	0.0018896	227	0.0220	0.0013228
5	3780	0.2	3024	0.0016534	227	0.0220	0.0013228
5	3780	0.1	3402	0.0014697	227	0.0220	0.0013228
5	5000	0.9	500	0.0100000	227	0.0220	0.0010000
5	5000	0.8	1000	0.0050000	227	0.0220	0.0010000
5	5000	0.7	1500	0.0033333	227	0.0220	0.0010000
5	5000	0.6	2000	0.0025000	227	0.0220	0.0010000
5	5000	0.5	2500	0.0020000	227	0.0220	0.0010000
5	5000	0.4	3000	0.0016667	227	0.0220	0.0010000
5	5000	0.3	3500	0.0014286	227	0.0220	0.0010000
5	5000	0.2	4000	0.0012500	227	0.0220	0.0010000
5	5000	0.1	4500	0.0011111	227	0.0220	0.0010000
6	1000	0.9	100	0.0600000	227	0.0264	0.0060000
6	1000	0.8	200	0.0300000	227	0.0264	0.0060000
6	1000	0.7	300	0.0200000	227	0.0264	0.0060000
6	1000	0.6	400	0.0150000	227	0.0264	0.0060000
6	1000	0.5	500	0.0120000	227	0.0264	0.0060000
6	1000	0.4	600	0.0100000	227	0.0264	0.0060000
6	1000	0.3	700	0.0085714	227	0.0264	0.0060000
6	1000	0.2	800	0.0075000	227	0.0264	0.0060000
6	1000	0.1	900	0.0066667	227	0.0264	0.0060000
6	2000	0.9	200	0.0300000	227	0.0264	0.0030000
6	2000	0.8	400	0.0150000	227	0.0264	0.0030000
6	2000	0.7	600	0.0100000	227	0.0264	0.0030000
6	2000	0.6	800	0.0075000	227	0.0264	0.0030000
6	2000	0.5	1000	0.0060000	227	0.0264	0.0030000
6	2000	0.4	1200	0.0050000	227	0.0264	0.0030000
6	2000	0.3	1400	0.0042857	227	0.0264	0.0030000
6	2000	0.2	1600	0.0037500	227	0.0264	0.0030000
6	2000	0.1	1800	0.0033333	227	0.0264	0.0030000
6	3780	0.9	378	0.0158730	179	0.0335	0.0015873
6	3780	0.8	756	0.0079365	179	0.0335	0.0015873
6	3780	0.7	1134	0.0052910	179	0.0335	0.0015873
6	3780	0.6	1512	0.0039683	179	0.0335	0.0015873
6	3780	0.5	1890	0.0031746	179	0.0335	0.0015873
6	3780	0.4	2268	0.0026455	179	0.0335	0.0015873
6	3780	0.3	2646	0.0022676	179	0.0335	0.0015873
6	3780	0.2	3024	0.0019841	179	0.0335	0.0015873
6	3780	0.1	3402	0.0017637	179	0.0335	0.0015873
6	5000	0.9	500	0.0120000	227	0.0264	0.0012000
6	5000	0.8	1000	0.0060000	227	0.0264	0.0012000
6	5000	0.7	1500	0.0040000	227	0.0264	0.0012000
6	5000	0.6	2000	0.0030000	227	0.0264	0.0012000
6	5000	0.5	2500	0.0024000	227	0.0264	0.0012000
6	5000	0.4	3000	0.0020000	227	0.0264	0.0012000
6	5000	0.3	3500	0.0017143	227	0.0264	0.0012000
6	5000	0.2	4000	0.0015000	227	0.0264	0.0012000
6	5000	0.1	4500	0.0013333	227	0.0264	0.0012000
227	1000	0.9	100	2.2700000	227	1.0000	0.2270000
227	1000	0.8	200	1.1350000	227	1.0000	0.2270000
227	1000	0.7	300	0.7566667	227	1.0000	0.2270000
227	1000	0.6	400	0.5675000	227	1.0000	0.2270000
227	1000	0.5	500	0.4540000	227	1.0000	0.2270000
227	1000	0.4	600	0.3783333	227	1.0000	0.2270000
227	1000	0.3	700	0.3242857	227	1.0000	0.2270000
227	1000	0.2	800	0.2837500	227	1.0000	0.2270000
227	1000	0.1	900	0.2522222	227	1.0000	0.2270000

mea (kg/wk)	worst case (kg/wk)	MPI	mea t	mea/mea t SRI	std (kg/wk)	mea/std SWI	mea/worst case
227	2000	0.9	200	1.1350000	227	1.0000	0.1135000
227	2000	0.8	400	0.5675000	227	1.0000	0.1135000
227	2000	0.7	600	0.3783333	227	1.0000	0.1135000
227	2000	0.6	800	0.2837500	227	1.0000	0.1135000
227	2000	0.5	1000	0.2270000	227	1.0000	0.1135000
227	2000	0.4	1200	0.1891667	227	1.0000	0.1135000
227	2000	0.3	1400	0.1621429	227	1.0000	0.1135000
227	2000	0.2	1600	0.1418750	227	1.0000	0.1135000
227	2000	0.1	1800	0.1261111	227	1.0000	0.1135000
227	3780	0.9	378	0.6005291	227	1.0000	0.0600529
227	3780	0.8	756	0.3002646	227	1.0000	0.0600529
227	3780	0.7	1134	0.2001764	227	1.0000	0.0600529
227	3780	0.6	1512	0.1501323	227	1.0000	0.0600529
227	3780	0.5	1890	0.1201058	227	1.0000	0.0600529
227	3780	0.4	2268	0.1000882	227	1.0000	0.0600529
227	3780	0.3	2646	0.0857899	227	1.0000	0.0600529
227	3780	0.2	3024	0.0750661	227	1.0000	0.0600529
227	3780	0.1	3402	0.0667255	227	1.0000	0.0600529
227	5000	0.9	500	0.4540000	227	1.0000	0.0454000
227	5000	0.8	1000	0.2270000	227	1.0000	0.0454000
227	5000	0.7	1500	0.1513333	227	1.0000	0.0454000
227	5000	0.6	2000	0.1135000	227	1.0000	0.0454000
227	5000	0.5	2500	0.0908000	227	1.0000	0.0454000
227	5000	0.4	3000	0.0756667	227	1.0000	0.0454000
227	5000	0.3	3500	0.0000000	227	0.0000	0.0000000
227	5000	0.2	4000	0.0000000	227	0.0000	0.0000000
227	5000	0.1	4500	0.0504444	227	1.0000	0.0454000
454	1000	0.9	100	4.5400000	227	2.0000	0.4540000
454	1000	0.8	200	2.2700000	227	2.0000	0.4540000
454	1000	0.7	300	1.5133333	227	2.0000	0.4540000
454	1000	0.6	400	1.1350000	227	2.0000	0.4540000
454	1000	0.5	500	0.9080000	227	2.0000	0.4540000
454	1000	0.4	600	0.7566667	227	2.0000	0.4540000
454	1000	0.3	700	0.6485714	227	2.0000	0.4540000
454	1000	0.2	800	0.5675000	227	2.0000	0.4540000
454	1000	0.1	900	0.5044444	227	2.0000	0.4540000
454	2000	0.9	200	2.2700000	227	2.0000	0.2270000
454	2000	0.8	400	1.1350000	227	2.0000	0.2270000
454	2000	0.7	600	0.7566667	227	2.0000	0.2270000
454	2000	0.6	800	0.5675000	227	2.0000	0.2270000
454	2000	0.5	1000	0.4540000	227	2.0000	0.2270000
454	2000	0.4	1200	0.3783333	227	2.0000	0.2270000
454	2000	0.3	1400	0.3242857	227	2.0000	0.2270000
454	2000	0.2	1600	0.2837500	227	2.0000	0.2270000
454	2000	0.1	1800	0.2522222	227	2.0000	0.2270000
454	3780	0.9	378	1.2010582	227	2.0000	0.1201058
454	3780	0.8	756	0.6005291	227	2.0000	0.1201058
454	3780	0.7	1134	0.4003527	227	2.0000	0.1201058
454	3780	0.6	1512	0.3002646	227	2.0000	0.1201058
454	3780	0.5	1890	0.2402116	227	2.0000	0.1201058
454	3780	0.4	2268	0.2001764	227	2.0000	0.1201058
454	3780	0.3	2646	0.1715797	227	2.0000	0.1201058
454	3780	0.2	3024	0.1501323	227	2.0000	0.1201058
454	3780	0.1	3402	0.1334509	227	2.0000	0.1201058
454	5000	0.9	500	0.9080000	227	2.0000	0.0908000
454	5000	0.8	1000	0.4540000	227	2.0000	0.0908000
454	5000	0.7	1500	0.3026667	227	2.0000	0.0908000
454	5000	0.6	2000	0.2270000	227	2.0000	0.0908000
454	5000	0.5	2500	0.1816000	227	2.0000	0.0908000
454	5000	0.4	3000	0.1513333	227	2.0000	0.0908000
454	5000	0.3	3500	0.0571429	227	0.8811	0.0400000
454	5000	0.2	4000	0.0500000	227	0.8811	0.0400000
454	5000	0.1	4500	0.1008889	227	2.0000	0.0908000

SED

mpi	0.1-0.9	mpi	0.90	mpi	0.90
wc	13739	mea	394.00	wc	13739.00
mea	394				

mpi	sri	wc	sri	mea	sri
0.9	0.287	5000	0.788	200	0.146
0.8	0.143	10000	0.394	394	0.287
0.7	0.096	13739	0.287	600	0.437
0.6	0.072	15000	0.131	7589	5.524
0.5	0.057			15178	11.047
0.4	0.048				
0.3	0.041				
0.2	0.036				
0.1	0.032				

Nitrogen

mpi	0.1-0.9	mpi	0.90	mpi	0.90
wc	3780	mea	4.50	wc	3780.00
mea	4.5				

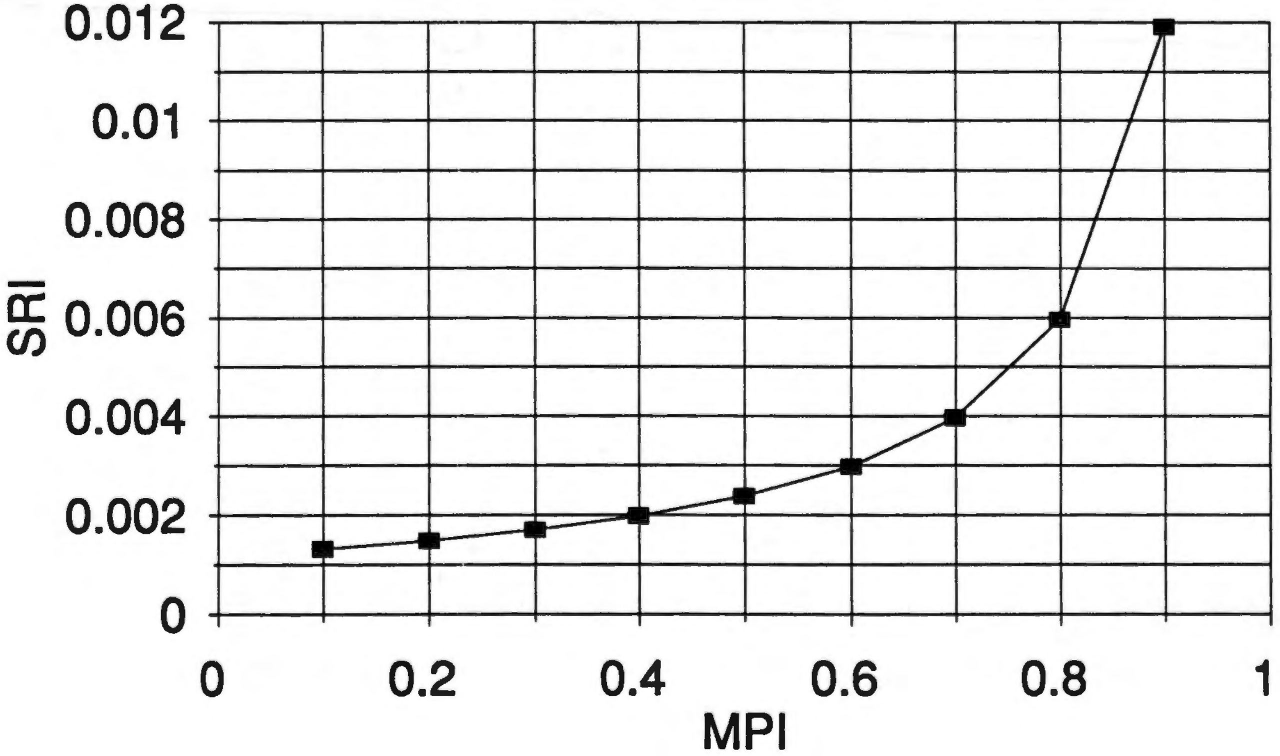
mpi	sri	wc	sri	mea	sri
0.9	0.0119048	1000	0.0450000	1.00	0.002646
0.8	0.0059524	2000	0.0225000	2.00	0.005291
0.7	0.0039683	3490	0.0119000	4.50	0.011905
0.6	0.0029762	5000	0.0090000	5.00	0.013228
0.5	0.002381			6.00	0.015830
0.4	0.0019841			227.00	0.600529
0.3	0.0017007			454.00	1.201058
0.2	0.0014881				
0.1	0.0013228				

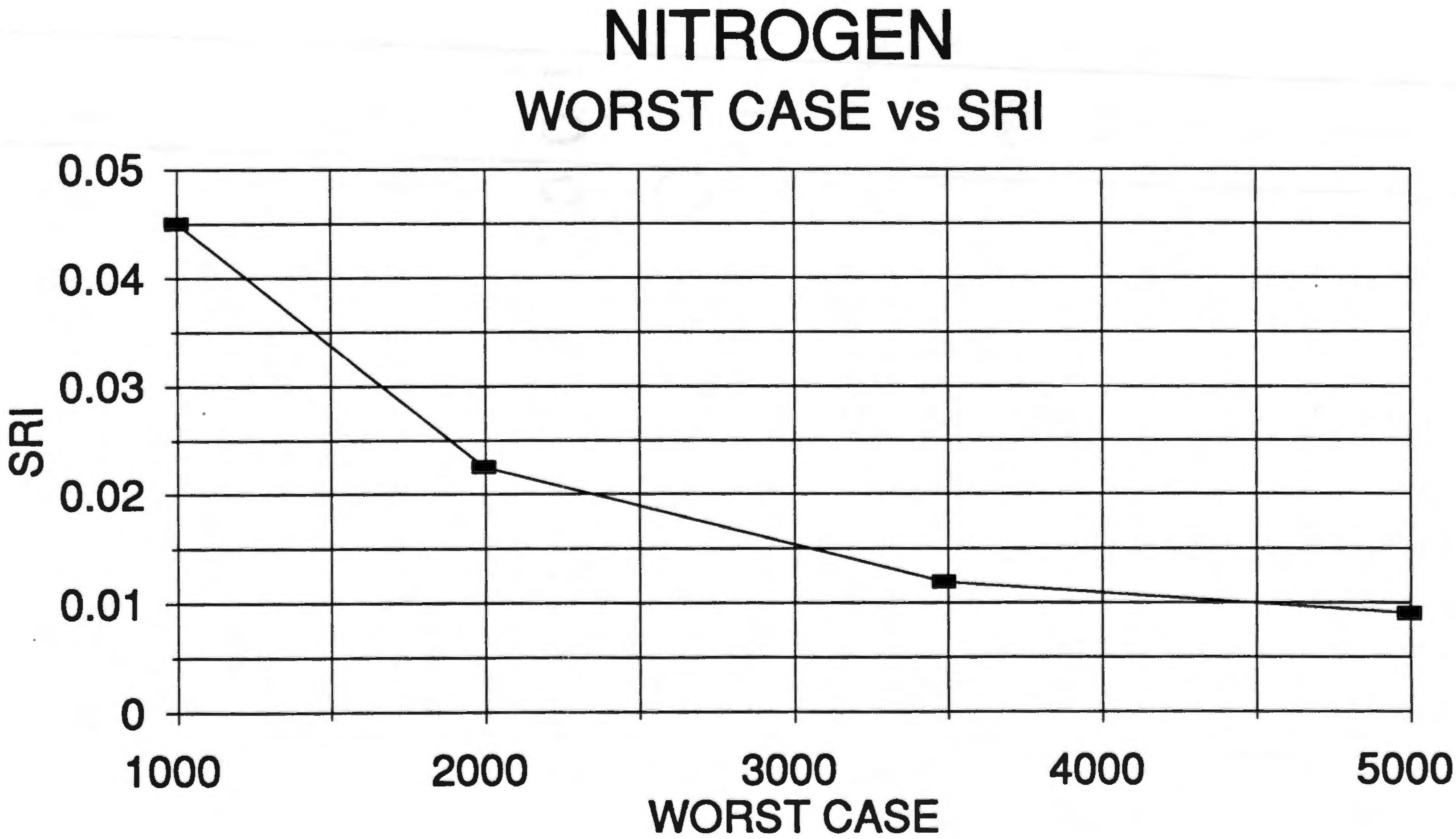
Coli Bac

mpi	0.1-0.9	mpi	0.90	mpi	0.90
wc	47000000	mea	2294.00	wc	47000000.00
mea	2294				

MPI	sri	wc	sri	mea	sri
0.9	0.000488	20000000	0.001147	200	0.000043
0.8	0.000244	47000000	0.000448	400	0.000085
0.7	0.000163	60000000	0.000382	1000	0.000213
0.6	0.000122	80000000	0.000287	2000	0.000426
0.5	9.8E-05	100000000	0.000287	2294	0.000488
0.4	8.1E-05			4000	0.000851
0.3	7E-05				
0.2	6.1E-05				
0.1	5.4E-05				

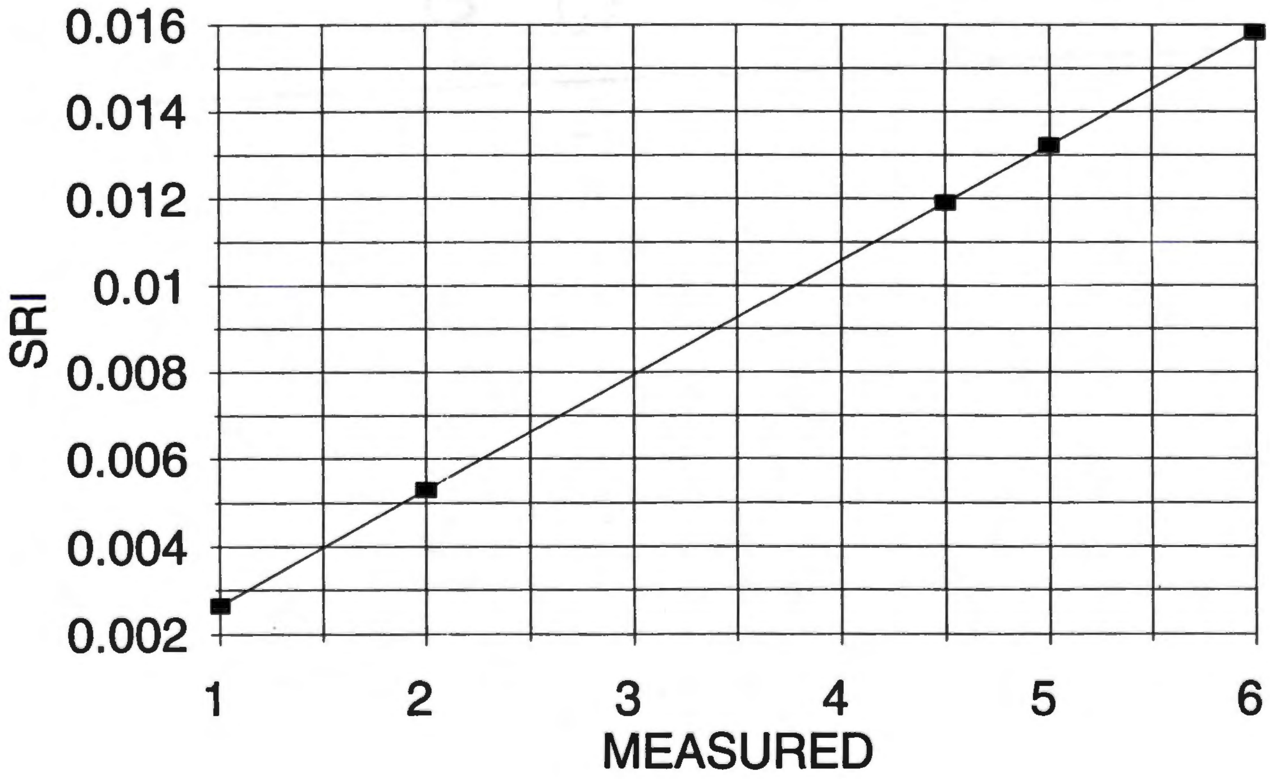
NITROGEN
MPI vs SRI




NITROGEN
WORST CASE vs SRI
0.05
0.04
0.03
0.02
0.01
0
SRI
1000
2000
3000
4000
5000
WORST CASE

NITROGEN

MEASURED vs SRI



VITA

Gary S. Honea was born in Talihina, Oklahoma on March 7, 1950. He attended schools in the public systems of Concord and Portsmith, New Hampshire and the Humphreys County, Tennessee Public School System, where he graduated from McEwen High School in June, 1968. He entered The University of Tennessee, Knoxville during August of 1968 where in December, 1972 he received the Bachelor of Science in Agricultural Engineering and a commission as a second lieutenant in the United States Air Force. While on active duty in the military he received a Master of Science in Management Science from Troy State University in June, 1984. After retiring from the United States Air Force in February, 1993, he entered the Master's program in Agricultural Engineering at The University of Tennessee, Knoxville in September, 1993, officially receiving the Master's degree in May, 1996.

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