Acknowledgments

This report was developed through the cooperation of a number of individuals whose names appear in Appendix B. I have tried to incorporate their concerns and their input. I had fruitful discussions with each of them (in some cases on multiple occasions). In addition, discussions with Mathilde Snel, provided additional insight to understanding the framework of MEMP and the opportunities for and difficulties of using GIS as a tool for assessing and monitoring soil erosion problems in Malawi. Many thanks to each of the individuals noted in Appendix B and special thanks to Mr. Ralph Kabwaza, Environmental Coordinator, MoREA and Mrs. E.R. M'Mangisa, Assistant Chief Environmental Officer, for their encouragement and valuable comments on draft versions of this report. I hope that the report will prove to be useful in furthering the goals of environmental monitoring in Malawi.

EXECUTIVE SUMMARY

PURPOSE

The purpose of this report is to review the watershed monitoring program of the MEMP and report on an assessment of data reporting needs by each GOM agency involved in the project. In addition, recommendations for improvement in current data collection and analysis methods are made and illustrative reporting formats provided for use by the various GOM agencies. The primary concern of this report is the components of MEMP related to soil erosion and water quality monitoring as well as rainfall monitoring.

RAINFALL RUNOFF MODELING/MONITORING

There appears to be both research and monitoring activities in the watershed monitoring aspect of MEMP. Control plot activities are "research" activities which are valuable for calibrating the SLEMSA erosion model for Malawi conditions. Field pit and stream flow measurements, on the other hand, are monitoring activities which provide temporal and spatial measures of runoff and erosion. The data requirements for application of the SLEMSA model are adequately met by the current experimental setup with the exception of adequate rainfall intensities and duration at each control plot site. Field pit data is also adequate with the exception of rainfall data at each field pit site. Additionally, the many of the field pits are oriented so that runoff is parallel to ridges while all control plots are oriented so that runoff is perpendicular to ridges. This significantly weakens the relationship between field pits and control plots and may be a sufficient reason to abandon further data collection from field pits.

Both field pits and control plot collection pits are undersized for a 20-year return period storm and, in fact, are marginal for the 2-year return period storm. Thus overtopping of pits is to be expected and data may need to be adjusted accordingly on those occasions. Pits are currently of one cubic meter capacity, but should be at least 3.15 cubic meters to accommodate a 2-year return period 24-hour storm.

A maximum number of monthly samples for a given agency to analyze should be 280 which appears to have been sufficient to have overwhelmed some of the agencies. Thus, this report recommends some options for reducing the number of samples collected and the amount of data analyzed. Regarding rainfall data, in particular, it is recommended that detailed analysis of rainfall data only for those locations where automatic gauges are located within 500m of the control plots (two at present). Such analyses need only be performed for those storms which produce runoff and it is thus necessary for field assistants to note which storms produced runoff on the raincharts or data before they are sent to the Meteorological Department. It is also recommended that two additional automated raingauges with data loggers be installed in the remaining two watersheds near the control plots. In addition runoff and sediment should be collected and analyzed only in those field pits which have a standard or automatic raingauge within 100m of the pit site. Some existing standard raingauges may be moved closer to the field pits to assure their relevancy to pit data.

Specific options for reducing the number of samples analyzed and improving the data analysis and reporting are detailed in section 3.2.2. In addition to those specific options, it is also recommended that monthly meetings be attended by those involved in data collection and analysis with presentation of progress reports by each agency. In addition, it is suggested that an annual seminar be conducted at the conclusion of the rainy season where each agency presents their annual reports with discussion and suggestions for development of the overall annual MEMP report.

MONITORING IN THE SHIRE RIVER CATCHMENT

This report makes some specific recommendations as to how a monitoring program might be undertaken in one or more watersheds within the Shire River Basin. It is suggested that such a program might make use of the SLEMSA model and NDVI together with Landsat imagery to identify critical areas and assess effects of changing land use on erosion and sedimentation.

SUGGESTED REPORTING FORMATS

Five different reporting formats are suggested including, a Meteorological Report, a Runoff and Erosion Report, a Sediment Analysis Report, a Pesticide Analysis Report and a SLEMSA Analysis Report. The first four are similar to those included in the first Environmental Monitoring Report while the SLEMSA report is suggested as an additional report which brings many aspects of the monitoring program together and begins to allow assessment of alternative land use.

ADDITIONAL RECOMMENDATIONS

Specific recommendations are included for equipment procurement which should improve data collection and analysis. In addition some specific training is recommended for Field Assistants and for all those involved in the MEMP data collection and analysis on the requirements of the SLEMSA model and its use as a tool for conservation assessment and planning.

SUMMARY

The principal recommendations and options outlined in this report are presented in the following table.

Objectives:

1. **Monitoring**
   Major watersheds, Shire River, Linthigpe, Mid-Shire mitigation areas.

2. **Research**
   Selected intensive catchments to model scenarios under different forms of environmental management, study gully erosion.

OPTIONS FOR INTENSIVE MONITORING

OPTION	JUSTIFICATION
1. Same catchments reduced sampling for sediment using field pits and control plots.	High correlation of change in fertilizer and pesticides to the amount of sediment produced
2. Reduce Sampling * Limit pesticide sampling to one date. * Limit samples analyzed to significant storms. * Limit samples analyzed to significant agronomic change.	* Pesticides haven't been applied in many fields during the past two years. * High correlation of change in fertilizer and pesticides to amount of sediment produced.
3. Selected catchments reduced sampling for sediment using control plots and field pits. * Limit field pits to those near standard raingauges. * Move raingauges next to field pits.	Lack of automatic raingauges at Njolomole and Chulu control plot sites.
4. Selected catchments reduced sampling for sediment using field pits.	Questionable value of data from field pits due to orientation, unless used to quantify gully runoff.
5. Same catchments reduced sampling for sediment using control plots.	Lack of automatic raingauge near control plots and difficulty in extrapolation when standard raingauges are near control plots.

OPTIONS FOR NATIONAL MONITORING (Training Implications)

Intensive	Extensive
Rainfall erosivity isolets	Rainfall erosivity isolets
Land use change using satellite imagery	Land use change using satellite imagery
Use of SLEMSA	Use of SLEMSA
Automatic or manual off site sediment sampling of micro-catchments	Automatic or manual off site sediment sampling of major drainages
	Use of EPA level socio-economic indicators
Use of NDVI data to monitor change	Use of NDVI data to monitor change

1.0 BACKGROUND AND APPROACH

1.1 Background

The Malawi Environmental Monitoring Program (MEMP), coordinated by the Ministry of Research and Environmental Affairs (MoREA) and supported by the Government of the United States of America through the U.S. Agency for International Development (USAID),involved an intensive monitoring program in four watersheds for the past two years. The purpose of the program was to determine the environmental impacts of policy changes that permitted small-hold farmers to grow burley tobacco and the consequent changes in land use. The program adopted a distributed approach, relying on line GOM ministries to gather and analyze data at the watershed level.

The anticipated changes in agricultural land use did not occur for a variety of reasons. As a consequence, monitoring at the watershed level proved inadequate and a parallel, more intensive approach was added using a set of sites nested within each watershed. The intensive approach has focused on monitoring sets of experimental plots on research stations and monitoring observation pits installed in farmers' fields, all within the selected watershed. As a result, data were gathered and analyzed in several different ways at different scales.

Given a certain level difficulty of collecting and analyzing the resulting vast amount of data and developing timely reports of the results, a watershed management specialist has been asked to review the watershed monitoring program and perform an assessment of data reporting needs by each GOM agency involved. The specialist was also requested to review the experimental design and the methods used for data acquisition and analysis as to their suitability for monitoring runoff and erosion in the Malawian context. Based on this analysis, the specialist was asked to make recommendations as to how the current methods might be improved for continued use in the coming growing season. Specifically, the terms of reference (TOR), a copy of which is included in Appendix E of this report, asked that the following information be included in the final report:

- an assessment of data needs and the methodologies used to meet them in the current data collection strategy;

- recommendations for improvement in current data collection and analysis methods;

- illustrative reporting format for use by GOM agencies.

In addition, the specialist was asked to present the recommendations to relevant GOM agency personnel at a seminar/workshop prior to departure.

1.2 Approach

In order to carry out the objectives of the TOR, several approaches were followed. First, a number of reports and documents relating to the current field data collection and analyses were reviewed as were other relevant reports available from GOM agencies. These documents are listed in the bibliography. Secondly, relevant individuals within the GOM agencies were interviewed and the current process discussed in some detail with them. A list of individuals with whom discussions were conducted is included in Appendix B of this report.

Erosion and runoff are principle mechanisms whereby soil, soil nutrients and agricultural chemicals are removed from crop land and transported to lakes and streams where, in abnormal concentrations, they become primary pollutants which degrade the water resource. The MEMP has undertaken a data collection and analysis program to systematically collect, analyze and evaluate data believed to characterize these mechanisms and establish their contribution to environmental degradation in Malawi.

In order to characterize the effects of different cropping systems on erosion, runoff and sedimentation, a series of "control" plots were established in four watersheds throughout the country. Data collection and analysis were relegated to relevant GOM agencies which, in turn, report results of their analysis to the delegated MEMP unit in MoREA. The primary concern of this report is the components of MEMP related to soil erosion and water quality monitoring as well as rainfall monitoring.

MEMP has correctly identified the principle variables associated with erosion, runoff and resulting stream/lake pollution as rainfall energy defined by storm intensity and duration and the resulting runoff. A draft field operations guide has been developed which identifies relevant variables and provides step-by-step procedures for data collection and preliminary analysis.

1.3 Field Visits

Control plots were visited in two watersheds (Njolomole and Kamundi) on October 5 and 6, 1996 and an additional watershed (Chilindamaji) on October 7 and 8. Fields with collection pits within the same three watersheds were also visited and in the Kamundi watershed, a stream gauging station (on the Mtemankaokwe stream) and a recording raingauge site were also visited. A recording raingauge is also located at the Chilindamaji control plot site. Given the original objective of assessing (and monitoring) the effects of different cropping systems on erosion, runoff and water quality, the field experimental design is valid and adequate although "standardization" of the collection pit size at all location ($1m^3$)has evidently resulted in undersized pits at most locations.

2.0 RAINFALL/RUNOFF MODELING

2.1 Assessment of Methodology

2.1.1 Monitoring vs Research

There appears to be two different levels of activity in the Watershed Monitoring aspect of the MEMP project which are not clearly distinguished and which, to this observer, require different levels of intensity and data analysis. Thus the erosion "control plots" are research oriented vehicles which are valuable for "calibrating" an erosion model such as SLEMSA for specific conditions in Malawi. Thus these plots and the associated rainfall data can be used to determine SLEMSA parameters for the several watersheds. Subsequently, this information can be used to analyze effects of changing land use on erosion and sediment production. Mkandawire (1996) used the 1994/95 rainfall and crop information from the Chilindamaji control plot site in the SLEMSA model to estimate erosion. While numerical values of his results cannot be directly compared to the experimental results due to some missing experimental data, the ratio of erosion from the tobacco plot and the maize plot was exactly the same as the experimental results.

On the other hand, the field pits are monitoring points to provide temporal and spatial measures of runoff and erosion in fields under various cultivation practices. In the case of the "experimental" control plots, it is necessary to collect and evaluate samples intensively so that parameters for the Soil Loss Estimation Model for Southern Africa (SLEMSA) model are properly determined. However, in the field pits, the interest is how erosion (and associated chemicals in runoff and sediment) varies with time on a broader scale. Once the SLEMSA model is calibrated and verified with control plots, it may be used to analyze different management scenarios on a watershed scale.

From the monitoring standpoint, on the other hand, it is really not so important how much runoff and sediment is produced by each storm as it is to establish the trend over a longer period of time of weeks, months and growing seasons. In this case, periodic cumulative data is likely sufficient(i.e. weekly rainfall amounts, total weekly sediment accumulations, etc.). The level of detail of a storm-by-storm analysis contributes little to the overall understanding of the process but greatly increases the effort. Thus, it is quite likely that these two levels of monitoring and "research" can be handled differently while, in fact, enhancing the output of the project.

2.1.2 Data Requirements and Collection Procedures

The designer of the field experiments referred to the variables utilized in the "Universal Soil Loss Equation" (USLE) as the important variables defining the erosion and sedimentation process. Although the Soil Loss Estimation Model for Southern Africa (SLEMSA) is the erosion model of choice in Malawi, plot design and variable selection are equally valid for either model. In either model, rainfall energy provides the mechanism for soil detachment while soil cover (as provided by crop canopy or mulches, etc.) serve to diminish the rainfall energy and protect the soil surface. Internal soil resistance to erosion is characterized by soil erodibility and field (or plot) slope and length influence the movement of soil downslope. Conservation practices such as terracing, contour farming, etc., are incorporated into both models and serve to shorten slope lengths and/or reduce slope steepness. Both "models" are used to assess erosion under field conditions by relating it to "standard" conditions defined in standard erosion plots. The SLEMSA model standard plot is 5m x 10m with a slope of 4.5% (Elwell, 1978). These were the dimensions selected for the control plots of the MEMP field studies (although slope can, and does, vary from the "standard").

Erosion, runoff and sediment production are all experimentally quantified on each control plot and field site by collection of all runoff from each storm in a pit at the field or control plot outlet. Runoff is measured directly as the amount of water collected in each pit. Erosion amount is determined by the amount of sediment collected in the pit after each storm. Water quality is determined by analyzing the runoff water in the pit for dissolved solids and certain agricultural chemicals as well as pH. Sediment collected in the pit is also analyzed for certain chemical constituents. In addition, samples are collected from a stream gaging station in each watershed to be analyzed for sediment concentration and other water quality indicators.

The data requirements for application of the SLEMSA model are adequately met by the current experimental setup with the exception of adequate rainfall intensities and duration at each control plot site. Similarly, the data requirements for monitoring at the field pit locations are met with the exception of rainfall data at each site.

2.1.3 Collection Pit Design

There is some indication that the pits are undersized as the field assistant in the Chilindamaji Watershed noted that several of the pits "overtopped" several times during the 1995/96 rainy season. A review of the design indicates it was based on a 20-year return period 24-hour storm of 50mm. However, Shela's work (1990) indicates that such a storm for the Mzuzu area would be 130mm and for the Nkhata Bay area about 210mm. The field assistant's notes at Chilindamaji showed one three day period in April 1996 with rain of 61mm, 93mm and 160mm. The 2-year return period (50% probability of exceedance each year) 24-hour storm at Mzuzu is 80mm and at Nkhata Bay, 110mm. Thus there is a strong likelihood that the pits on the Chilindamaji watershed will overflow at least once each season. If additional pits are constructed for these same size plots they should be at least twice as large in any of the regions of Malawi since the 2-year return period 24-hour storm even at Mangochi is 85mm and about 70mm at Lilongwe and 75mm at Chulu (Shela, 1991). The 1m x 1m x 1m pit is probably marginally acceptable at Njolomole but if a standard size pit is to be used at all locations it should have a capacity of at least 3.15 cubic meters to accommodate the maximum expected "annual" storm and should be of about 7 cubic meters capacity if it is to accommodate a 20-year return period 24-hour storm (5% probability of exceedance each year).

This is not to suggest that the existing pits be replaced with larger pits. However, if plots with collection pits are constructed at new sites, they should be built to at least accommodate a 2-year return period 24-hour storm. Certainly, the pits associated with the Agroforestry Project, which utilizes plots 10m x 20m (thus four times the area of the 5m x 10m plots) should have pits of at least 12.6 cubic meters capacity to avoid overflow at least once per year. A "trench" type pit running the full width of the plot (10m) and 1m deep by 1.2m wide will provide adequate volume.

It is important to be able to accommodate these large storms since they usually account for a major fraction of the erosion and ,ultimately, sediment transported to the streams.
It was noted at the three field pit sites visited that, field pits were located such that runoff flowed directly along multiple furrows into the collection pits (i.e. field pits were oriented parallel to furrows) whereas in all control plots, furrows were perpendicular to collection pits so that runoff from the uppermost furrow could only reach the pit by overtopping the furrow ridge. Thus, it is virtually certain that more runoff will be collected in field pits than in collection pits associated with control plots! If this orientation difference is true of all field pits, the orientation difference should be so noted by field assistants and taken into consideration when comparing field pit and control plot data.

2.1.4 Data Collection and Analysis

The control plots are monitored by field assistants at each site who collect samples for water and sediment analysis and measure water depths in each pit. Two liquid samples are also collected from each pit (the first after stirring to ensure all sediment is in suspension and the second for water only). Samples are labeled and stored on-site until collected for shipment to the relevant agency for analysis. In addition to the two liquid samples, a sample of the "settled" sediment is collected in a plastic bag, labeled and stored for shipment to the relevant agency for analysis. The first water sample is sent to the Water Department for chemical analysis of water and determination of sediment quantity. A random selection from the second liquid sample is sent to the Bureau of Standards for analysis of pesticide contamination. The "settled" sediment sample is sent to the Chitedze Agricultural Research Station for chemical analysis of the sediments. Similar samples are collected by farmers from pits located in their fields. During the rainy season, samples are collected daily at 8:00 am and stored locally then periodically collected and sent to the various agencies noted above for analysis. Given that there are four watersheds each with a set of three control plots and from four to six field pits, it becomes apparent that a large number of samples will be sent to the various laboratories for analysis. The field assistant's records in the Chilindamaji watershed (which probably has the highest rainfall of the watersheds being monitored) showed the number of rainy days in early 1996 varied from 16 in January to 23 in April. However, of the 23 occurring in April only 10 storms produced runoff. In this watershed, the total number of samples collected from field and control plot pits for analysis by a single agency would be on the order of 70 per month (ten runoff producing storms times seven collection pits). The total number of samples from all watersheds should thus be no more than 280 per month. However, this number of samples appears to have been sufficient to have "overwhelmed" some of the laboratories with the consequence that reports of analytical results have not been produced after the 1994-95 season. The first Environmental Monitoring Report addresses the problem by noting the need for training of technical officers in data analysis and effective reporting as well as inadequate human resources in data and information systems operations and management.

A similar problem is encountered with rainfall data. Rainfall is measured either by use of a continuously recording gauge or a "standard" gauge which measures only total 24 hr. rainfall. Each study watershed has one automatic and six or seven standard raingauges located such that, by use of standard techniques, rainfall intensities and durations could be estimated for each control plot site and field pit. However, recording raingauges are located relatively close to the control plots in only two watersheds (Chilindamaji and Kamundi). In the Chilindamaji watershed, the automatic gauge is immediately adjacent to the control plots. In the Kamundi watershed the gauge is within 500 m of the plots. In the other catchments, the separation of the control plots and automatic gauges are such that these gauges cannot be used directly to assess rainfall intensities, duration and amounts at plot sites. In these instances a more detailed analysis using a method such as the Theissen Polygon method of depth-area-duration analysis must be done to determine rainfall intensities and duration at each plot site. The rainfall data at each gauge (standard or automatic) is collected daily by a local "observer" and transmitted monthly (generally by the 10th of the following month) via post to the Meteorological Office at Chileka Airport. Generally, these reports are received by the 15th of the month although some of the data from the standard gauges is not sent until after several "proddings" by the MET office.

I was informed that a single individual is responsible for reviewing this data for consistency, collating it, reducing it to useable form and performing any additional analysis such as a depth-area-duration analysis as well as reducing the automatic rain chart data (which is in cumulative format) to intensity data. Given that there are 25 GOM full automatic stations in Malawi, 70 subsidiary stations and nearly 800 standard gauges, it is readily apparent that one individual can become overwhelmed with the task of processing data from raw to finished form in a reasonable amount of time without some automation of data processing and also provide specialized analysis such as depth-area-duration analyses for those plot sites lacking recording gauges.

2.2 Recommendations

2.2.1 Rainfall Data and Analysis

Given that rainfall is the driver for all erosion and runoff processes, it is essential to have quality rainfall data to support the field experiments. Therefore I suggest that reduction of the rainfall data to short period intensities, total duration and storm energy be limited to those catchments where the automatic gauges are within 500 meters of the control plots (currently only Chilindamaji and Kamundi).

Since the analysis of raincharts to produce intensity is labor intensive and requires considerable skill on the part of the scientist conducting the analysis, more than one individual needs to be involved in the analysis or, alternatively, the data reduction should be curtailed even further. I strongly recommend that a small digitizer be procured to aide with the rainchart analysis. This would significantly speed the analysis and free up the scientist to perform depth-area-duration analysis where required.

In addition, I recommend that automated raingauges be purchased and installed in the remaining two watersheds within 100m of the control plots. I recommend a raingauge of the tipping bucket type since it lends itself most readily to micro-processor analysis and can easily be read by an electronic data logger. Each site should also have such a data logger. The data logger can be programmed to provide intensity data in real time thus eliminating the need for extensive post-collection analysis. Such a set-up including the data-logger currently costs about $2,500 in the U.S.. It would also be necessary to acquire a data transfer module for each site which can be used to periodically transfer the data from the data logger to a computer diskette. These are currently about $500 each and this is included in the estimated $2500 total. It would be useful to acquire a micro-computer to be dedicated to post collection processing of the data logger output plus for use with the digitizer. The automated station raingauge and data logger are powered by a battery which may be continuously recharged with a solar panel so it makes a nice remote station. I recommend that these stations be purchased, installed and evaluated during the coming season and, if successful in improving the timeliness of data availability, two additional stations could be installed on the remaining catchments during the next dry season.

If runoff and sediment data is to be collected from field pits during the coming season, I recommend that standard raingauges be placed within 100m of the pit locations. This could be done by moving an existing standard gauge that is already in the watershed. Without a raingauge adjacent to the field, I question the value of collecting sediment and runoff data since it cannot be reasonably correlated with rainfall without nearby rainfall measurements.

2.2.1.1 Observations of Field Assistants

In order to facilitate data analysis, it is important that the field assistant at each site clearly note on the rainfall data that is being forwarded to the Meteorological office for reduction and analysis, which storms produced no runoff in the collection pits. It will not be necessary for the Meteorological office to do any detailed analysis of these storms and it will be sufficient to report only the total amount and duration of such storms. Field assistants should also be trained to make additional informational notes on runoff data such as breaches of ridges during a rainfall/runoff event and orientation of ridges relative to the collection pits (i.e. parallel or perpendicular flowpaths to pits).

2.2.2 Other Data

A common problem which seems associated with all agencies involved in data analysis and reporting is that they feel overwhelmed by the sheer amount of raw data/samples they are receiving for analysis. Until the skills and capabilities of the agencies involved are enhanced through experience, training and additional personnel or equipment, it seems prudent to reduce the quantity of samples being analyzed and focus on a thorough analysis and complete reporting of a smaller subset of data.

Some OPTIONS include:

1. Reduce the number of samples being analyzed:

a. Either limit analysis to samples from storms greater that some threshold (e.g. 10 mm or greater) or,

b. analyze only those samples from selected sites (e.g. only control plots plus one or two field pits in each watershed) or,

c. allow water and sediment to collect in the field pits only over several storms, say until the pit becomes at least 1/2 full before collecting samples for analysis. The field pits are more "monitoring" oriented and thus cumulative data over several storms is adequate. In this case it would be necessary to note the number of storms which each sample represents (days) and, in any case, the pits should not be left with samples uncollected for more than five days! In order to ensure that the same procedure is followed at all sites, it would be imperative to provide one or more training programs for all field assistants and farmers involved in data collection.

2. Increase the number of scientists performing the analyses. This might be done by developing a research level link to:

   a. Bunda Agricultural College environmental scientist and agricultural engineers who could perform more detailed analysis and assessment of results (small grants contract research program). In support of this activity, it may also be possible and useful to utilize students from Bunda working with one or more graduate students from the University of Arizona.

   b. Existing research programs such as GEF or MAFE demonstration plots.

3. Obtain additional equipment for more automated analyses.

4. Limit data analysis at each agency level to basic analysis and have MoREA personnel further analyze data to extract relevant information (e.g. have MET develop only the initial "break point" plot from recording raingauges and let MEMP scientist calculate intensity and associated rainfall energy).

5. A combination of the above alternatives.

2.2.3 Data Collection Coordination and Review and Monthly Progress Reports

Currently representatives from the various agencies involved meet periodically (monthly during the rainy season and bi-monthly throughout the rest of the year). These meetings have been primarily to discuss any problems. I recommend that the individuals involved in data analysis and preparation of reports for each agency meet monthly and present monthly progress reports of results for the preceding month to the group. This might be done during the rainy season commencing on January 15 (at which time a report for the November data would be presented) and continue on the 15th of each month thereafter until all monthly data sets for the rainy season have been presented. These meeting times would serve as "target dates" by which each agency would be expected to have data analyzed and summary reports written.

2.3 SLEMSA Development and Application

The erosion "control" plots and associated rainfall data can prove quite useful to development of reliable "modeling" capabilities through the application of the SLEMSA model to Malawi agricultural production areas. I believe that it is , therefore, quite important to ensure that both rainfall data and sediment data continue to be collected and analyzed at these sites. It is also important that recording raingauges be placed at the additional two control plot sites to ensure adequate rainfall energy data to accompany the erosion rate data. It would be useful to obtain, on each control plot, a reliable estimate of ground cover at several times during the season for each of the treatments. This might be done by a series of photos (taken vertically looking downward) or at least by visual estimates by the field assistants.

2.4 Future Research Opportunities

2.4.1 Erosivity Map For Malawi

There is apparently a sufficient long-term rainfall record from recording raingauges that one could analyze the data from the 25 or so gauges and construct "erosivity isohyets" for Malawi. Shela (1990) analyzed such data from 19 stations throughout Malawi to develop rainfall depth-duration-frequency curves for 9 different rainfall intensity zones in Malawi. An erosivity map would be a useful aide for utilization of the SLEMSA model to assess effects of land use changes on erosion and associated productivity loss a well as on sedimentation. The development and field "verification" of such a map could be a graduate student research topic which would contribute significantly to erosion assessment capabilities in Malawi.

2.4.2 The role of field pathways and gullies on erosion

The draft report, Siltation in the Middle Shire Valley (anon. 1996b), noted that gullying seemed to form along field access pathways on steep slopes. I noticed a similar pattern in my brief visits to the three watersheds. Gullies often account for considerably more sediment production than does field, so-called, "sheet" erosion. Thus it may be appropriate to undertake a study to assess the role of field access paths and gullies in erosion and sediment production on agricultural lands in steep areas.

3.0 TANGADZI OR SHIRE RIVER CATCHMENT

The sediment load in the Shire River poses significant problems for power generation at hydro power stations along the river. A recent report (anon. 1996b) developed estimates of erosion rates and identified areas of greatest erosion in the Middle Shire Valley. The most significant erosion was identified as taking place on marginal and highly erodible crop land in that portion of the watershed. These estimates were made by indirect methods from assessing aerial photographs. No actual sediment load measurements have been made on the Shire River in recent years although Kafundu and Laisi (1991) reported on a significant rise in the bed level of the Thuchila river at Chonde between 1958 and 1978 and attribute this rise to sediment from increased erosion in the watershed due to increased agricultural activity. From these two reports it is apparent that sedimentation in the Shire River (and tributaries) is a significant problem and that erosion from cropland appears to be a major contributor.

Therefore, it may be a useful undertaking of the MEMP to have the Water Resources Department identify one or two stream gauging sites in the Shire River Valley which could be instrumented with the American Sigma Automatic Sediment samplers to determine both suspended and bedload sediment concentrations with time. Such data would provide a real-time picture of erosion in the associated watersheds. The most significant indicator of erosion is sediment load in streams. Once the stations were established and operating satisfactorily, it would then be useful to establish a demonstration project for soil conservation on one of the watersheds and observe the effect on stream sediment load as the project develops.

Concurrently, the SLEMSA model could be applied to the project area to assess the anticipated reduction in erosion from the interventions on the watershed as well as the effects of other land use alternatives. It is appealing to consider use of the NDVI to identify areas which show possible high erosion rates. SLEMSA could then be applied to those identified areas to assess the land use effects on erosion, both presently and with anticipated changes in land use. This area might thus be used to evaluate the utility of using NDVI and SLEMSA to monitor more extensive areas than is now done with the field pits and control plots.

4.0 SUGGESTED REPORTING FORMATS

4.1 General Context

The MEMP program has relied on GOM line agencies to process raw data collected in each watershed and provide reports to MoREA. However, there appears to have been some confusion in what to report and how to report it. Thus the watershed management specialist was asked to suggest some possible "model" reporting formats for each agency. Given that there is a considerable delay between collection of data and it's delivery to the specific agencies for analysis, it appears that an annual report will be the most useful format for the immediate future. Thus, I suggest that each agency prepare a separate report for each watershed each year. Naturally, this report will be forthcoming only some months after the end of the rainy season. If the Meteorological Department delays between data collection and delivery are typical one might expect that data for the last month of the season (probably May for the Chilindamaji watershed which should have the longest season) will not arrive at the agencies for analysis until mid-June. Allowing an additional month for analysis of that data and assuming that analysis of data for prior months has been ongoing and completed, it should be possible to provide an annual report to

MEMP by August 1 of each year (reports for other watersheds may be delivered earlier).

4.2 Field Operations Guide and Reporting Guidelines

The Draft Field Operations Guide (GOM/USAID, 1995b) has presented a good framework within which to obtain data, analyze and process it and perform quality control checks. The report needs some modification (for example the water erosion examples should be redone in the SLEMSA context rather than USLE) and should be updated to reflect the changes and others current use practices. In addition to this updated guide, it would be useful to generate a more detailed reporting guide than has been possible to include in this report. The seminar to be held on October 15, 1996 may provide some useful input to develop such a guide.

4.3 Comments on the First Environmental Monitoring Report

The first MEMP environmental monitoring report was issued in October, 1995 and covered the 1994/95 season. Henninger (1996) of the World Resources Institute commented on the report in a March 1996 appraisal and made some useful suggestions. Some of these specific recommendations appear to have been heeded in preparation of the more detailed Phase One Final Report which was issued in August, 1996. The first report presented a wide range of data and information at differing levels of detail and attempted to analyze the impacts of the information presented. However, limited data analysis had been performed on most of the catchments and it was difficult to draw any comparative conclusion with only one year's data. The final report, on the other hand, covered a number of issues in greater detail. The Report and Guidelines on the Watershed Management Aspects of the Chilindamaji Catchment (Bisher, 1996), provided a good set of guidelines for data reduction and analysis and can be used by those involved to analyze data and develop reports. However, that report was devoted to only one watershed and while the writer attempted to analyze the impacts or implications of the information, it was difficult for him to so with limited data and without first-hand knowledge of the catchment and the farming systems. In part, for this reason, I am suggesting an annual seminar in which each agency presents their reports to be discussed by others involved in the project. That seminar could then be used as the basis for issuing an over-arching annual Environmental Monitoring Report.

4.4 Annual Seminar

Once all reports have been prepared, it would be useful to have a meeting (or seminar) where the scientist from the agencies involved present and discuss their reports to MEMP and other agency scientist who have been involved in the project. Such a seminar would help scientist from each agency to understand the context of their data and analysis. The associated dialogue and interaction would likely prove useful for planning the following year's campaign as well as further development and utilization of the data.

4.5 Suggested Report Formats

Preliminary formats for reporting are suggested for each of the agencies on the following pages.

[Illustrative Report Format]

MALAWI ENVIRONMENTAL MONITORING PROJECT

KAMUNDI WATERSHED - 1996-97

METEOROLOGICAL REPORT (outline)
(Prepared by Meteorological Department)

SUMMARY:

This section of the report should summarize significant meteorological events and their implied impact on runoff, erosion and water pollution in the respective watersheds. In addition, it should summarize the total rainfall occurring at the various gauges within the watershed during the rainy season. For example: "The 1996-97 season was characterized by two major storms in the Kamundi watershed, the first occurring on November 17, 1996 resulted in over 93mm of rainfall at the automated gauge site and the second on January 13 produced 130mm of rainfall at that location. The first storm delivered a total rainfall energy of 1753 J/m^2 which, given that it is early in the season and little crop cover has developed, likely resulted in significant erosion and subsequent sedimentation. The second major storm in January had a total storm energy of 2450 J/m^2. However, the actual erosion resulting from this storm is likely to be significantly less that of the November storm because crop canopies are reasonably well developed by that time of year. Total seasonal rainfall at the automated gauge site was 956mm which was 150mm below normal. Seasonal distribution of rainfall across the catchment varied from 780mm to 1057mm."

Rainfall and Erosivity in the Kamundi Watershed:

This section should present results of analyzed data in a format that other scientist can use for further analysis (such as modeling erosion or calculating runoff) and that planners and policy makers can also use as inputs into decisions without further analyses. Thus, the rainfall amount should be reported by storm for those gauges located at control plot or field pit sites. At the control plot sites (which have automatic recording gauges) rainfall duration and erosivity should also be reported storm by storm only for those storms which resulted in runoff into collection pits (generally this will be storms of at least 7mm or more). The rainfall data is the primary determinate for pollution by sediment or contamination of water by agricultural chemicals. Thus, if other agencies are to use this information to draw conclusions from their analyses, the rainfall report must precede other reports. Given that the SLEMSA is the erosion model of choice, the rainfall energy in that model is utilized simply as total storm (or seasonal) energy in units of J/m^2. The equation for calculating the energy per unit of rainfall is:

$e = 11.9 + 8.73\log_{10}(I)$ for intensities less than 76 mm/hr
and
$e = 28.3$ for intensities greater than 76 mm/hr

where e is in J/m^2/mm and I is storm (or interval) intensity in mm/hr. The procedure for calculating total storm energy is described in some detail in Annex 4 of the MEMP Phase One final report. Note that for each storm segment for which e is computed, the results of the above equation should be multiplied by the rainfall amount in mm for that segment to give energy in J/m^2 for that interval. The energy amounts for each storm segment are then summed to give total storm energy. For the SLEMSA model, the calculation procedure is identical to that describe in the above report with the exception that the total storm energy is not multiplied by the maximum 30-minute intensity of the storm. Thus, the result is actual storm energy rather than an "erosivity index".

Possible format:

Gauge Location: Kamundi Control Plots

Date	24 hr rain(mm)	Duration(min)	Rainfall Energy (J/m^2)
17 Nov	93	120	1750
5 Dec	4.3	15	nil*
10 Dec	12.2	45	230
13 Jan	130	120	2450
*****	****	***	****
etc.			
Season Total	956	na	18,017

* Note: Energy is not calculated for storms which did not produce runoff into collection pits.

Gauge Location: Field Pit #3

Date	24 hr rain(mm)
17 Nov	60
5 Dec	14
10 Dec	10
13 Jan	87
******	**
etc.	
Season Total	1053

No energy or duration is reported for this field pit since there was no recording raingauge nearby.

Similar data should be reported for all gauged sites and a similar report prepared for all watersheds.

If time and manpower permits, it would be useful to utilize Theissen Polygon analyses to develop a map of seasonal rainfall distribution across the watershed.

[Illustrative Report Format]

MALAWI ENVIRONMENTAL MONITORING PROJECT

KAMUNDI WATERSHED - 1996-97

RUNOFF AND EROSION REPORT (outline)
(Prepared by Water Resources Branch, MOW)

SUMMARY:

This section of the report should summarize significant hydrological aspects of runoff, erosion and water pollution in the respective watersheds. In addition, it should summarize the total runoff occurring from the various sample sites within the watershed during the rainy season. It should also summarize the total amount of soil eroded from each control plot and field site in terms of tonnes per hectare per year as well as total chemical loss from those sites in terms of Kg per hectare per year. Since the Water Resources Branch also is responsible for the stream flow gauge and analysis of the water and sediment sampled from the stream gauging stations, this report should provide a summary of the sediment load in the stream throughout the season and the pollutant load of agricultural chemicals as well in a manner similar to the example provided for rainfall.

Possible format:
RUNOFF PLOTS KAMUNDI WATERSHED
TABLE KC1-F
Location: Kamundi Control Plots
Plot No: 1(Fallow) Plot Area: $50m^2$

Date	Runoff	Sed.	pH	SO_4	NO_3	PO_4	Na	K	TDS
	mm	kg/ha	kg/ha............................kg/ha						
17 Nov	61	1295	7.1	0.10	0.20	0.01	11.1	26.2	35
10 Dec*	0.7	1.5	7.5	0.03	0.00	0.05	2.2	1.3	1.1
13 Jan	96	356	6.3	2.6	0.20	1.1	7.3	13.2	42
*****	****	***	**	**	**	**	**	**	**
etc.	etc	etc	etc	etc	etc	etc	etc	etc	etc
Total	802	9763	na	11.8	0.8	3.7	53	120	133

* Note: No runoff was produced by the December 5 storm and therefore, it is excluded from this analysis.

The above table should be repeated for each control plot and appropriate one-dimensional graphs may be constructed to accompany the report. All plots could be included on one graph.

TABLE K3F-T

Location: Field Pit #3(Tobacco) Plot Area: $36m^2$

Date	RUNOFF	Sed.	pH	SO_4	NO_3	PO_4	Na	K	TDS
	mm	kg/ha	kg/ha.............................kg/ha						
17 Nov	32	800		7.3	0.01	0.02	0.00	5.5	13
18									
5-10 Dec*	5.7	10	7.1	0.00	0.00	0.01	0.5	2	5
13 Jan	56	680	6.2	0.80	0.01	0.04	7.3	15	23
******	***	****	**	**	**	**	**	**	**
etc.	etc	etc	etc	etc	etc	etc	etc	etc	etc
Total	890	10,030	na	12.1	0.6	0.9	63	213	140

* Note: Runoff was accumulated in Pit #3 for December 5-10 and the samples collected thus represent two storms. The pit was sampled once per week or whenever the pit level exceeded 1/2 the maximum depth.

The above table should be repeated for each field plot which has a standard raingauge within 200m and one dimensional graphs of the data included in the report.

Since there is a stream flow gauging station with a sediment sampler on this watershed near the control plots, the report should include a time-series plot of stream flow and sediment discharge at the gauging station.

[Illustrative Report Format]

MALAWI ENVIRONMENTAL MONITORING PROJECT

KAMUNDI WATERSHED - 1996-97

SEDIMENT ANALYSIS REPORT (outline)
(Prepared by Chitedze Agricultural Research Station)

SUMMARY:

This section of the report should summarize significant aspects of chemical loss by erosion as determined from the chemical analysis of sediments. Thus the report form will be similar to that of the format for the hydrology report except that runoff and sediment amounts will not be included and the chemicals reported will be different. In addition, it should summarize the total chemical loss from those sites in terms of Kg per hectare per year.

Possible format:

RUNOFF PLOTS KAMUNDI WATERSHED
TABLE KC1-FS
Location: Kamundi Control Plots
Plot No: 1(Fallow) Plot Area: 50m^2

Date	O.M.	P	K	Ca	Mg	Cu	Zn	
	kg/ha............................kg/ha							
17 Nov		1.0	4.8	3.3	0.1	0.0	0.2	0.01
10 Dec*	0.2	1.1	2.1	0.5	0.2	0.0	0.05	
13 Jan	2.2	0.6	4.1	3.1	0.3	0.1	0.0	
*****	**	**	**	**	**	**	**	
etc.	etc	etc	etc	etc	etc	etc	etc	
Total	41	38	56	7.7	3	2.2	0.9	

* Note: No runoff or sediment was produced by the December 5 storm and therefore, it is excluded from this analysis.

The above table should be repeated for each control plot and appropriate one-dimensional graphs may be constructed to accompany the report. All plots could be included on one graph

TABLE K3F-TS

Location: Field Pit #3(Tobacco)   Plot Area: $36m^2$

Date	O.M.	P	K	Ca	Mg	Cu	Zn	
	kg/ha............................kg/ha							
17 Nov		0.9	4.2	3.1	0.5	0.2	0.1	0.05
5-10 Dec*	0.2	1.1	2.1	0.1	0.1	0.1	0.01	
13 Jan	1.2	3.6	4.1	1.1	0.1	0.0	0.03	
***	***	**	**	**	**	**	**	
etc	etc	etc	etc	etc	etc	etc	etc	
Total	21	41	48	3.3	2.1	1.8	1.0	

* Note: Runoff was accumulated in Pit #3 for December 5-10 and the samples collected thus represent two storms. The pit was sampled once per week or whenever the pit level exceeded 1/2 the maximum depth.

The above table should be repeated for each field plot which has a standard raingauge within 200m and one dimensional graphs of the data included in the report.

[Illustrative Report Format]

MALAWI ENVIRONMENTAL MONITORING PROJECT

KAMUNDI WATERSHED - 1996-97

PESTICIDE ANALYSIS REPORT (outline)

(Prepared by Malawi Bureau of Standards)

<u>SUMMARY:</u>

This section of the report should summarize significant aspects of pesticide loss from the control and field plots as determined by chemical analysis of runoff samples collected at the sites. Thus the report form will be similar to that of the format for the sediment analysis report except that the chemicals reported will be commonly used pesticides such as; lindane, aldrin, heptachlor, heptachlor epoxide and DDT. In addition, it should summarize the total chemical loss from those sites in terms of Kg per hectare per year. In addition to data from the plots, the Bureau of Standards receives water samples from the Mtemankhokwe stream gauge site near the control plots. These samples should be analyzed for the same chemicals and a time series of the chemical flows at that site reported in graphical form.

Possible format:

<u>RUNOFF PLOTS KAMUNDI WATERSHED</u>
TABLE KC1-FC
Location: Kamundi Control Plots
Plot No: 1(Fallow) Plot Area: $50m^2$

<u>Date</u>	Lindane	Aldrin	Heptachlor	Heptachlor Ep.	DDT
	kg/ha..kg/ha				
17 Nov	0.0	0.0	0.0	0.0	0
10 Dec*	0.0	0.0	0.0	0.0	0
13 Jan	0.02	0.2	0.0	0.01	0.001
*****	**	**	**	**	**
<u>etc.</u>	<u>etc</u>	<u>etc</u>	<u>etc</u>	<u>etc</u>	<u>etc</u>
Total	0.05	0.3	0.0	0.01	0.001

* Note: No runoff or sediment was produced by the December 5 storm and therefore, it is excluded from this analysis.

The above table should be repeated for each control plot and appropriate one-dimensional graphs may be constructed to accompany the report. All plots could be included on one graph.

TABLE K3F-TC

Location: Field Pit #3(Tobacco) Plot Area: 36m^2

Date	Lindane	Aldrin	Heptachlor	Heptachlor Ep.	DDT
	kg/ha...kg/ha				
17 Nov	0.01	0.1	0.01	0.0	0
5-10 Dec*	0.0	0.0	0.0	0.0	0
13 Jan	0.0	0.1	0.0	0.0	0
*****	**	**	**	**	**
etc.	etc	etc	etc	etc	etc
Total	0.03	0.4	0.01	0.0	0

* Note: Runoff was accumulated in Pit #3 for December 5-10 and the samples collected thus represent two storms. The pit was sampled once per week or whenever the pit level exceeded 1/2 the maximum depth.

The above table should be repeated for each field plot which has a standard raingauge within 200m and one dimensional graphs of the data included in the report.

[Illustrative Report Format]

MALAWI ENVIRONMENTAL MONITORING PROJECT
KAMUNDI WATERSHED - 1996-97

SLEMSA REPORT (outline)
(Prepared by Land Resources and Conservation Branch)

SUMMARY:

This section of the report should present an annual summary of the significant erosion parameters for the SLEMSA model as determined from the control plots in each watershed and the SLEMSA manual. In addition, it should utilize these parameters to estimate annual erosion from each of the three treatments in the control plots and compare the calculated loss from each treatment to that from the other treatments. It should also then compare calculated annual losses from each treatment to the measured values as reported in the Runoff and Erosion Report with emphasis on the ratio of loss from one treatment to another rather than absolute losses (e.g. the ratio of soil loss from the tobacco treatment to that of the maize treatment as calculated by SLEMSA and as measured). In preparation of this report, the actual total rainfall energy for the year and site in question as reported in the Runoff and Erosion report should be used in the SLEMSA model as the E term rather than a value calculated from the equation for annual E as presented in the SLEMSA manual. In order to facilitate this report and ensure that such reports contribute to the adaptation of SLEMSA to Malawi conditions, it is important that all measurable SLEMSA variables be accurately determined in the field. Thus, crop yields for all crops should be measured and reported. In addition accurate estimates of the percentage of canopy cover on a weekly basis are required for reliable estimates of the "i" value for the cover factor in SLEMSA. The paper prepared by Mkandawire (1996) for the Chilindamaji watershed serves as a good model for this report.

APPENDIX A

BIBLIOGRAPHY

Anonymous, 1996a. SADC/GEF, Lake Malawi/Nyasa Biodiversity Conservation Project. Revised Project Implementation Plan. February 26, 1996. 70p.

Anonymous, 1996b. Study of Siltations in the Middle Shire Valley. DRAFT REPORT. 28p.

MEMP, 1996. The Malawi Environmental Monitoring Program (MEMP I). Phase One (1993-1995). Final Report. August, 1996. USAID and The University of Arizona and Clark University. 32p with 4 Annexes.

GOM/USAID Program Environmental Affairs. 1995a. Malawi Environmental Monitoring Program. First Environmental Monitoring Report. October, 1995. 46p with Appendices.

GOM/USAID Program Environmental Affairs. 1995b. Malawi Environmental Monitoring Program. DRAFT Field Operations Guide. October, 1995.41p.

Henninger, N. 1996. Appraisal of the Malawi Environmental Monitoring Program (MEMP). (DRAFT). March, 1996. 13p

Elwell, H.A. 1978. Soil Loss Estimation: Compiled Works of the Rhodesian Multi-disciplinary Team on Soil Loss Estimation. Department of Conservation and Extension. Causeway, Rhodesia. August, 1978. 145p.

Mkandawire, V., 1996. Soil Loss Estimation for Chilindamaji Malawi Environmental Monitoring Program Catchment. Land Resources and Conservation Branch. Ministry of Agricultural and Livestock Development. Unpublished Report. 11p. October, 1996.

Mokhothu, M. Nick. 1995. Field and Catchment Water and Soil Monitoring. University of Arizona. July 17, 1995. 30p.

Shela, O.N.R. 1990. Frequency Analysis of Short Duration Rainfall Intensities in Malawi. WRB-No. TP 15. Water Resources Branch. Ministry of Works. Lilongwe. March, 1990. 35p.

van der Velden, J. 1979. A Summary of Rainfall, Pan Evaporation and Temperature Data at Pan Evaporation Stations in Malawi. Ministry of Agriculture and Natural Resources. Lilongwe. August, 1979. 9p with 6 Tables and 4 Maps.

Laisi, E.Z. 1987. Flood Frequencies in Malawi: A Basis for Design. WRB-No. TP 14. Water Resources Branch. Ministry of Works. Lilongwe. July, 1987. 34p with 10 Maps and Figures.

Kafundu, R.D. and E.Z. Laisi. 1991. Malawi's Hydrology: A Responsive Phenomenon. WRB-No.

TP 17. Water Resources Branch. Ministry of Works. June, 1991. 25p.

Laisi, E.Z., 1991. Water Resources Assessment Activities in Malawi. WRB-TP. No. 16. Water Resources Branch. Ministry of Works. February, 1991. 61p.

Schwab, G.O., D.D. Fangmeier, W.J. Elliot and R.K. Frevert. 1993. Soil and Water Conservation Engineering. 4th Edition. John Wiley and Sons. New York.

APPENDIX B

INDIVIDUALS CONTACTED

Mr. Alex Banda, Sr. Environmental Officer (MEMP), MoREA.

Mr. Robson Banda, Field Assistant, Kamundi catchment.

Mr. Kent Berger, Technical Adviser (MEMP), MoREA.

Dr. Harvey Bootsma, GEF Project, Senga Bay.

Mr. Trent Bundersund, Agro-Forestry Project, Department of Forestry.

Mr. Maxwell Gwazantini, Meteorological Department, Chelaka.

Mr. Ralph Kabwaza, Environmental Coordinator, Ministry of Research and Environmental Affairs.

Mr. Don Kamdonyo, Meteorological Department, Chileka.

Mr. Kaluwa, Ministry of Irrigation and Water Development.

Mr. Vincent Mkandawire, Land Resources and Conservation Branch, Ministry of Agricultural and Livestock Development.

Mrs. E.R. M'Mangisa, Assistant Chief Environmental Officer. MoREA.

Mr. Soko, Field Assistant, Chilindamaji catchment.

Mr. Phiri Wongani (MEMP), MoREA.

APPENDIX C

RECOMMENDED EQUIPMENT

1. Two automated raingauge stations consisting of the following equipment:

   Tipping-bucket raingauge..2@$800 -- $1,600
   Electronic Data Loggers (Campbell CR-10 or equal)............................2@$1100 -- $2,200

   Data transfer modules (to transfer data
   from data logger to computer)..2@ $250 --$500

   Batteries for station operation..$200

   Optionally solar panels can be purchased for
   continuous battery recharge

   Total estimated cost excluding shipping....................................$4,500
   and solar panels.(U.S. prices)

2. One digitizer for rainchart analysis...$2,000

3. One Pentium Micro-computer for use with digitizer
   and automated electronic rain stations...$4,000

APPENDIX D

RECOMMENDED TRAINING

1. Field Assistant Training

   I have recommended training of all Field Assistants in the field data collection process. The training should include information in the Field Operations guide (to be revised) and should include the importance of detailed field notes and notes on data sets sent to agencies to bring to the attention of those analyzing data such things as occurrence of runoff, ridge breaks, percent of ground cover in the control plots, etc. This training may be in the form of a series of workshops and should be initiated before the data collection seasons gets underway.

2. SLEMSA Training

   I recommend that a workshop be developed for the purpose of familiarizing those individuals from the cooperating agencies with the data requirements of the SLEMSA model and the use of the model. This workshop could also address the use of the curve number method for estimating runoff. A two or three day workshop would be adequate for the initial familiarization process and could be followed at the end of the season with another workshop which applies the SLEMSA to the just completed season's data sets.

APPENDIX E

TERMS OF REFERENCE

Watershed Monitoring

Problem Statement: The Malawi Environmental Monitoring Program (MEMP), Ministry of Research and Environmental Affairs (MoREA) of the Government of Malawi (GOM) supported by the U.S. Agency for International Development (USAID) has been involved in an intensive monitoring program in four watershed for the past three years. The purpose of the program was to determine the environmental impacts of policy changes that would permit small-hold farmers to cultivate burley tobacco and the consequent changes in agricultural land use. The program adopted a distributed approach, relying on line GOM ministries to gather and analyze data at the watershed level.

The anticipated changes in agricultural land used did not occur for a variety of reasons. As a consequence, monitoring at the watershed level proved inadequate and a parallel, more intensive approach was added using a set of sites nested within each watershed. The intensive approach focused on monitoring sets of experimental plots on research stations and monitoring observation pits installed in farmers' fields, all within the selected watersheds. As a result, data were gathered and analyzed in several different ways at several different scales.

Scope of Work: the watershed management (WSM) specialist will perform an assessment of data reporting needs by agency, the experimental design, and the methods used for data acquisition and analysis as to their suitability for monitoring runoff and erosion in the Malawian context. The specialist will also make recommendations as to how current methods might be improved for continued use in the coming growing season.

The WSM specialist will spend up to one week in the U.S. reviewing documents and two weeks in Malawi reviewing sites and procedures. A draft report of findings will be completed prior to departing Malawi.

Deliverables: Both a draft and a final report will be produced by the WSM specialist. The draft will be submitted prior to departing Malawi. The final report will be submitted no later than two weeks following receipt of comments from the MEMP COP and UA Principal Investigator or Project Manager.

The final report will contain:

* assessment of data needs and the methodologies used to meet them in the current data collection strategy;
* recommendations for improvement in current data collection and analysis methods;
* illustrative reporting format for use by GOM agencies.