FY 2004 Annual Report for Water Quality and Management National Program 201

<u>Introduction</u>

Water quantity and quality issues have increasingly become the focus of attention of United States citizens, private and public organizations, and units of government striving to meet competing demands while protecting the environment and public health. Sound agricultural management practices are required to ensure success in maintaining a healthy and productive land and water base that sustains local communities, food and fiber production, and also protects and restores critical natural systems. Research in this National Program addresses three component problem areas: (1) agricultural watershed management; (2) irrigation and drainage management; and (3) water quality protection and management. The purpose of the Water Quality and Management National Program is to provide practical tools and techniques to meet the needs of farmers, ranchers, and other entities involved in controlling, assessing, regulating, and managing water resources.

ARS in cooperation with the Natural Resources Conservation Service (NRCS), Cooperative Research Extension and Education Service, USDA Office of Risk Assessment and Cost Benefit Analysis, Environmental Protection and other Federal and State agencies have developed a watershed assessment program and a national assessment effort. This program is the Conservation Effects Assessment Project (CEAP). The purpose of CEAP is to provide the farming community, the conservation community, the general public, the Office of Management and Budget, legislators, and others involved with environmental policy issues an accounting of the environmental effects or benefits obtained from USDA conservation program expenditures.

The centerpiece of the watershed assessment program is the ARS "benchmark" watersheds. The term benchmark is used to distinguish the ARS watersheds from other watersheds where watershed assessment research is being initiated under CEAP. Also, the concept of benchmark watersheds is used to differentiate the larger scale ARS watersheds from field scale ARS research activity. ARS has 60 scientists at nine locations contributing to the research activity on 12-benchmark watersheds. The location are: Ames, IA, Tifton, GA, El Reno, OK, Temple, TX, Oxford, MS, University Park, PA, Columbia, MO, West Lafayette, IN, and Columbus, OH**.** The 12-benchmark watersheds represent primarily rain-fed or non-irrigated cropland. In addition to these locations, ARS scientists from Ft. Collins, CO, are coordinating a portion of the modeling activities.

The research assessments on the ARS benchmark watersheds are intended to determine an optimal selection and placement of conservation management practices to achieve specific water quality and other environmental goals, as well as provide initial information important to assessing the economic and social factors that facilitate or impede implementation of these conservation practices. ARS is developing plans to partner with Economic Research Service, NRCS, and several universities to enhance the economic and social science efforts within the CEAP program. An ARS research plan for the 12-benchmark watersheds has been peer reviewed and is being implemented in 2005 as the first national watershed project aimed at quantifying improvements in water derived from implementing economically feasible conservation practices. The first report from this effort is scheduled in late 2006.

In 2004, the Agricultural Drainage Management Systems (ADMS) Task Force was fully implemented by ARS, NRCS, and CSREES in cooperation with land improvement contractors, drainage industry representatives, private consultants, and farm organizations in seven Midwestern States of Iowa, Illinois, Indiana, Minnesota, Missouri, Ohio, and Wisconsin. The new era for agricultural drainage is based on removing a minimal amount of excess surface water and managing shallow water tables to achieve an optimal mix of economic and social benefits while safeguarding key ecological functions. The initial focus has been highly successful where, under the lead of ARS, NRCS and State Agriculture Extension Engineers working with farmers and cooperators, have rapidly begun to install controlled drainage systems on existing and new surface and subsurface drainage systems. Numerous workshops/meetings were held in 2004 and many more workshops and conferences are being planned for 2005. The ADMS Task Force has been designated as the first technical working group for the ARS, NRCS, CSREES Partnership Management Team, where a charter, action plan, flyers, posters, and several technical documents have been implemented. Numerous educational brochures and handouts have been developed and distributed to the public via two specialty conferences in 2004.

International activities have also been expanded in FY 2004. Five cooperative projects related to soil erosion by water and wind, were developed with the U.S.-China Center for Soil and Water Conservation and Environmental Protection. This center is located on the campus of the Northwest Sci-Tech University of Agriculture and Forestry (NWSUAF) in Yangling, China. The U.S. counterpart is located at the Colorado State University, Fort Collins, Colorado. In November of 2004 ARS scientists from West Lafayette, Indiana traveled to Yangling, China to provide a 2-week workshop on how to use the Water Erosion Prediction Project model. In 2005 ARS scientists will be traveling to Yangling to provide training in the use of the Revised Universal Soil Loss Equation model, the Wind Erosion Prediction System model, and other technology. Chinese scientists are helping ARS scientists design state-of-the art gully erosion experiments that will be conducted in China. Results from these experiments will be then integrated into the ARS models for use in the United States as well as China.

Irrigation Management Systems (IMS) project has been developed by three ARS locations in cooperation with partners from Israel, the Palestinian Territory, and Jordan. A successful IMS Workshop was held in Jordan with full participation from Middle East partners. Funding for the multi-location Middle East project has been provided by the U.S. Department of State. In addition, the U.S. Department of State is funding a series of projects with Pakistan to share technology on water quality and management practices in arid and semi-arid landscapes. The projects range from development of efficient irrigation systems to revegetation of drastically disturbed native rangelands to control upland erosion and sedimentation of vital flood control and water supply structures.

Selected Accomplishments from the Water Quality and Management national program.

<u>SWAT is being used worldwide to assess environmental impact</u>. SWAT, which stands for Soil and Water Assessment Tool, was developed over the past 30 years by a team of ARS researchers at Temple, Texas, in cooperation with other ARS scientists in Bushland, TX, El Reno, OK, Tucson, AZ, Ft. Collins, CO, Miami, FL, Ames, IA, and Tifton, GA. Over the past 4 years, the

U.S. Environmental Protection Agency and ARS have made SWAT available to State agencies and consultants throughout the nation to evaluate and assess water quality impairments and to assist in developing watershed plans for addressing specific problems. The Natural Resources Conservation Service used the SWAT model in its 1997 Resource Conservation Appraisal, in which the first national assessment of agricultural water use, tillage systems and fertilizer management was made. In 2004, NRCS and ARS are again using SWAT to work together to quantify the environmental benefits of conservation practices at the national scale and the watershed scale for the Conservation Effects Assessment Project (CEAP). The newest version of SWAT has been distributed to hundreds of scientists and engineers at universities, government agencies, and consulting firms throughout the world and several international training conferences have been held over the past 2 years.

Management of nitrogen improved to sustain water quality. Proper management of nitrogen in agricultural systems while understanding its transport and transformations is becoming increasingly important to agricultural producers and to modern society. ARS scientists developed a book that included the Nitrate Leaching and Economic Analysis Package (NLEAP) computer model developed earlier by ARS. Since their release, both the book and the NLEAP model have been used Worldwide. ARS scientists continue to update the model in response to user requests to address special situations or unique applications. An updated version of the NLEAP model has been delivered to the Natural Resources Conservation Service (NRCS) and can be downloaded from NRCS web site.

Adoption and use of the phosphorus (P) index is widespread. In response to mounting water quality concerns, many states have developed guidelines for land application of phosphorus (P) based on the potential for P loss in agricultural runoff. These actions have been spurred, in part, by a federal initiative in which the U.S. Environmental Protection Agency and USDA created a joint strategy to implement Comprehensive Nutrient Management Plans (CNMPs) on Animal Feeding Operations by 2008, which considers both agronomic and environmental impacts of applied P. To address this need, ARS led the development and refinement of a P Index to rank the vulnerability of fields to P loss in runoff and identify those at greatest risk for loss. The Natural Resource Conservation Service (NRCS) has adopted the use of the P index in 47 States as the basis for development of CMNPs, and over 2000 NRCS field agents and nutrient management consultants across the U.S. have received training. Widespread adoption and use of the P Index is resulting in the first significant reduction in the threat to water quality from nonpoint sources of P. Economic benefits of using this approach are estimated at $204 to $355 million and include increased recreational use of waters, better shellfish harvest, fewer fish kills, lower drinking water treatment costs, and reduced loss of livestock to disease.

Critical sources of nutrients exported from watershed are delineated. In the northeastern U.S., agricultural runoff is a major source of N and P input to waters such as Lake Champlain, Lake Erie, and Chesapeake Bay, which are impaired by eutrophication and associated harmful algal blooms. To remediate these and other waters around the world, environmental action agencies have moved from trying to treat impaired waters to identifying and controlling nutrient sources within contributing watersheds. ARS scientists conducted multi-scale, watershed-based studies of key chemical and hydrologic factors controlling P and N export from agricultural watersheds to locate where they originate on the landscape and enable appropriate remedial measures to be targeted to their critical source areas. It was found that most of the P exported (>80%) from agricultural watersheds in PA, NY, and MD came from only a small area of the watershed (<20%) during a few, rapid storm events. Because most of the P exported predictably occurs during short periods and from critical source areas within the much larger watershed, remediation can be targeted to these times and areas. In contrast to P, N was exported from most of the watershed area and depending on the groundwater flow pathways, can take up to 20 years to flow from a field to river channel. These results show the need for site-specific management strategies for P and N to account for these spatial and temporal differences in export controls. The critical source area concept of nutrient management at landscape and watershed scales is more technically defensible, quantitative, and site-specific than previous guidelines. Action agencies (NRCS and EPA) and nutrient management divisions of the livestock industry are using tools based on these concepts to more reliably evaluate the environmental effects of current and proposed agricultural practices at both regional and national levels and to provide management recommendations that support a productive and profitable agriculture, while minimizing water quality impairment.

<u>Salinity assessment technology is widely adopted</u>. Soil salinization is a major problem, causing decreased crop production and water quality problems, in irrigated lands of arid and semiarid regions of the world including the southwestern U.S. Over the past 15 years, ARS researchers at Riverside, CA, have developed technology for using electrical resistivity and electromagnetic induction sensors (EM) to measure soil salinity. Within the past 4 years, this technology was combined into a mobile platform (typically a modified spray tractor) with global positioning systems (GPS) and a computer to rapidly and remotely collect soil conductivity data with depth and spatially across a field. In cooperation with the U.S. Bureau of Reclamation, a salinity assessment network has been recently deployed throughout the Lower Colorado Region. The primary end-users of this technology include technical specialists from the U.S. Bureau of Reclamation and the Natural Resource Conservation Service along with water district personnel throughout the western U.S., various university extension specialists and research scientists in saline regions throughout the world, including Canada, Mexico, South America, Australia and the Middle East.

<u>Phyto-remediation of selenium affected soils</u>. Given the scarcity of irrigation water and the lack of drainage water disposal facilities, drain water recycling is being used on nearly 200000 ha of irrigated California soils and has resulted in an accumulation of selenium (Se) in the soils. The continued discharge of subsurface drainage water containing toxic elements such as Se and boron (B) will eventually result in the degradation of the environment and agro-ecosystem, and could lead to another disaster like that observed at the Kesterson National Wildlife Refuge in the mid-1980's. To prevent a disaster of this magnitude from reoccurring, ARS scientists in California have developed a plant-based management approach, defined as phyto-remediation that utilizes salt/B tolerant crops, e.g., canola, sunflower, salt and cordgrasss, and even transgenic mustard, to extract and volatilize Se when planted on the water- reused soils / drainage sediment. This technique has been used successfully at Red Rock Ranch (20 ha), Panoche Drainage District (50 ha), and Broadview Water District (3 ha). They determined that canola, as the best short-term performer, extracted and volatilized up to 40 % of the Se applied via drainage water between 0-30 cm depths. Over multiple years of drainage water reuse, the perennial and lower-maintenance salt and cordgrasses tolerated the elevated soil salt and B levels more effectively

than the annual crops, and removed at least 20% more Se from 0-90 cm depths than did the annual crops. Developing usable products from the crops used for removing Se, e.g., Se-enriched animal forage, biofuel, will encourage widespread usage of phytoremediation for susceptible regions in the western USA.

Fertigation can be used efficiently for all irrigation methods. Fertigation brings both nutrients and water to plants and at the same time saves money by combining two tasks into an efficient system. ARS scientists at three locations have found different ways to improve the application of fertilizer and at the same time apply water more efficiently for the three irrigation methods. Researchers from Phoenix, AZ found that improved fertilizer mixing and injection procedures can be used to improve the uniformity of the fertilizer applications. Scientists at Lincoln, NE, working with industry cooperators, developed a new electronic sensor that can be placed at different spacing atop a center-pivot irrigation system to apply variable rate fertilizer and water applications for precision farming. This same sensor can be used on a high-clearance sprayer or other types of farm implements to precisely and accurately apply variable rate fertilizer applications on both irrigated and nonirrigated (rainfed) croplands. Also, researchers at Parlier, CA, have demonstrated that applying both fertilizers and water on nearly a continuous basis through drip irrigations, which are buried underground, can prevent seepage of excess nutrients into ground waters. Although uniformity of the fertilizer applications can be higher for sprinkler and drip irrigation methods, fertigation can be within 10 to 15 percent for furrow irrigation practices. Current estimates are that various fertigation techniques will be used on 50 percent of the irrigated lands in the U.S. by 2010 for an additional increase in farm profits of at least $600 million dollars per year based on conservative estimates for fertilizer savings and increased yields alone with consideration given to environmental benefits.

Grazing cattle on lands where the groundwater was once polluted. ARS scientists in Coshocton, OH, recently concluded that cattle could be grazed on pastures that overlie these contaminated aquifers without fear of additional contamination from the nitrogen in cattle waste. The secret is to minimize or eliminate nitrogen fertilization on the pastures for several years before resuming cattle grazing to allow the system to come back into equilibrium. After two years without grazing, the ARS scientists found that the nitrate-nitrogen in groundwater was brought down from a high of 26 parts per million (ppm) to 2 to 4 ppm without any impact on livestock health or performance under both management practices, and the lack of fertilizer caused only a slight decrease in grass production. The U.S. Environmental Protection Agency guidelines for human drinking water stipulate 10 ppm as the maximum allowable safe level for nitrate-nitrogen. This is a nice finding, because it doesn't force farmers to remove cattle permanently from problem fields, as long as they first lower the nitrogen levels in the soil and then stop fertilizing the pastures at excessive levels once the cattle are again allowed on the land. Hopefully, the livestock producer owns additional land or is able to lease land for the cattle for the period of time needed to reduce previous levels of contamination to the aquifer.

Sediment is the nation’s number one pollutant in our streams. ARS scientists in Oxford, MS have developed a low-cost means of reducing gully and streambank erosion, one of the major causes of soil loss and sedimentation within our nation’s streams. Traditional measures for controlling this type of erosion require costly stone or concrete structures. The large woody debris structures, being studied by ARS scientists, provide shelter for fish and insects, restores riparian habitats, and costs less than traditional methods. The structures consist of uprooted trees stacked in crossing layers and are anchored with steel cables to the streambed. The structures reduce sediment transport, triggering natural deposition to heal channels enlarged by years of erosion. The structures cost about $25 per foot of treated bank, or 20 to 50 percent of the cost of recent stone bank-stabilization projects in the region.

Monitoring soil moisture throughout the world. Scientists from the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration, the Natural Resources Conservation, and Alabama A&M University have joined ARS scientists from Beltsville, MD, in testing and designing satellites that will one day be able to monitor global soil moisture. The techniques use sensors that require an antenna that looks like an umbrella or a satellite dish. The technique functions like a mirror, constantly reflecting radiation emitted from Earth onto sensors that measure the strength of the radiation using microwave signals emitted from soil. The ARS scientists are testing these methods for a new satellite called Hydros that NASA plans to launch by the end of the decade. Once enhanced soil moisture predictions and measurements are part of daily weather forecasts it should help predict when rainstorms will occur; provide better assessments of drought stricken areas; provide needed information for assisting in alerting the public to potential floods; and help farmers determine when to plant, fertilize, and harvest crops with more precision and accuracy than has every been available before.

Improved methods developed for estimating rainfall. ARS scientists in Boise, ID, working with the National Weather Service, developed new techniques to more accurately estimate rainfall using the National Weather Service (NWS) NAXRAD radar system. The ARS scientists found that the original methods NWS was utilizing under-estimated rainfall by 25 to 60% compared to NWS's measurements of precipitation on 6 highly instrumented experimental agricultural watersheds. NWS has reprogrammed the radar system in 2004 and has determined that the ARS derived technique has greatly improved the accuracy and precision of rainfall estimation.

The U.S. Army gets help from ARS. The U.S. Army was looking for a way to determine real-time accurate estimates of surface soil moisture to help it plan where and when they can drive vehicles without getting stuck in the mud. The U.S. Army turned to ARS scientists in Tucson, AZ, to develop a method for rapidly and accurately estimating these conditions. The ARS scientists developed a new and simple remote sensing technique of image differencing in part by using data from the long-term highly instrumented Walnut Gulch watershed. This new procedure was found to be superior to the more complex and expensive model currently used by the U.S. Army because it can account for the high rocks content commonly found in desert soils.

Water-treatment facility residues can help reduce water pollution. ARS scientists in Florence, SC, and University Park, PA, have found that residue from water-treatment processes, often discarded as waste and placed in landfills, may make a great soil amendment for preventing loss of phosphorus (P) in runoff from agricultural fields. ARS scientists have found an alum-based water-treatment residual that can increase the soil's capacity to bond phosphorus, a vital plant nutrient. The results should benefit states along the nation's mid- to-southern-Atlantic seaboard, where sandy soils generally take up and hold less P than finer-textured soils. In laboratory tests with sandy soil, the treatment increased P-binding potential four- to five-fold over that of untreated soil. If successful, this use for waste from water-treatment processing not only could get rid of the waste, but would also hold P on the land until a crop uses it. Economic benefits to the U.S. of reducing P in runoff are estimated to exceed at $200 million in addition to improving the quality of drinking water.

Synchronizing fertilizer applications with crop needs. Technologies are needed to facilitate in-season application of nitrogen fertilizer to crops to reduce fertilizer input costs and the potential for nitrate losses. ARS scientists have devised management strategies for corn and cotton that apply nitrogen fertilizer during the growing season based on crop need. Aircraft and ground-based sensors were used to identify key wavebands that were indicative of crop nitrogen status and biomass production. Working with Resource21 and Holland Scientific, in conjunction with extensive ground-based crop and soil measurements, ARS scientists developed and tested requirements and specifications for passive and active crop canopy sensors for corn. A network of six ARS locations has evaluated the sensor on corn across the Midwest during the 2004 growing season. ARS scientists also demonstrated that monitoring plant nitrogen status by spectral reflectance and chlorophyll meter measurements in cotton could be used to make real-time nitrogen management decisions reducing nitrogen application rates. A patent was issued for the apparatus and methodology of real-time, non-destructive determination of nitrogen need. A sensor developed through a CRADA with Holland Scientific and two related SBIR grants became commercially available in June 2004. Adoption of these practices can decrease on-farm costs, increase corn and cotton production, and decreases nitrate leaching.

Removal of groundwater contaminants with buried bioreactors. Contaminated groundwater presents a health risk to both humans and animals and affordable treatment methods are needed to remove the contaminants from water. ARS scientists have demonstrated that buried in situ permeable bioreactors can be used to remove nitrate and organics from groundwater. Bioreactors can be composed of different organic materials such as wood chips or vegetable oil and are buried to intercept the contaminated ground water flow. The bioreactors stimulate natural microbial activity that denitrifies nitrite and nitrate to harmless dinitrogen gas and removes chlorate, perchlorate and heavy metals. Buried bioreactors can be used to remove nitrate from water below agricultural fields before it enters tile drains or to remove contaminants in ground water before entering wells or recharging surface waters. Farmers and industry to protect surface and ground water from animal wastes, fertilizer, can use bioreactors and chemical spills.
Several commercial remediation firms are now using bioreactor technology. Sites contaminated with trichloroethylene (TCE) and spills at Travis Air Force Base, CA; Cape Canaveral Air Station, FL; Depot Hill, UT; Naval Support Activity Mid-South, TN and other military and civilian sites have been treated using vegetable oil injection.

Long-term records critical for evaluating agriculture's impact on hydrology and water quality. Given increased USDA expenditures to support the installation of conservation practices, there is a need to document the environmental improvements resulting from these investments. To do this, information is needed to understand the impacts of past management on current environmental conditions. Research conducted by ARS in Iowa is providing a better understanding of current hydrologic and water quality conditions in agricultural watersheds, and the time frame over which changes in management influence those conditions. Results showed the important role of high flows in delivering nitrate loadings to Midwest streams from subsurface drainage systems. Constructed wetlands within these watersheds would have limited effectiveness for removing nitrate during the high flows. Nitrate is also delivered to streams through base flow (ground water) contributions. Results show that nitrate in base flow can originate from nitrogen fertilizer applications made decades ago, even in small watersheds. Long-term records provide important perspectives for the evaluation of management systems, including conservation practices. Evaluation of conservation practices, installed today in individual fields, but evaluated at the outlet of watersheds must consider the full range of historical agricultural practices before accurate assessments of benefits can be accurately determined. These results remind us and encourage us that time and patience is required to improve water quality and we should not expect immediate recover when we install new conservation practices.