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Appendix "C"

ON-SITE STUDY OF MAJOR WATERSHED INSTALLATIONS IN THE SOUTHEASTERN U.S.

Prepared Under Grant No. AID/211d

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For

Agency for International Development

ON SITE STUDY OF MAJOR WATERSHED INSTALLATIONS IN THE SOUTHEASTERN U.S.

To help up-date our knowledge of current research in watershed systems and modeling, a major tour of research offices and field installations in four southeastern states was completed by John L. Thames and David B. Thorud in June 1970. Research and management programs at the following installations and institutions were reviewed:

(1) Coweeta Hydrologic Laboratory
Southeastern Forest Experiment Station
U.S. Forest Service
Franklin, North Carolina

(2) School of Forestry
Duke University
Durham, North Carolina

(3) Hydrologic Division
Tennessee Valley Authority
Knoxville, Tennessee

(4) Ecological Science Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

(5) Strip-Mine Restoration Project
Northeastern Forest Experiment Station
U.S. Forest Service
Berea, Kentucky

(6) Timber and Watershed Laboratory
Fernow Experimental Forest
Northeastern Forest Experiment Station
U.S. Forest Service
Parsons, West Virginia

The goal of this trip was to improve our competence to perform research, teach, and consult on matters pertaining to watershed systems and modeling. This goal was accomplished by three general means at each location: (1) New developments were discussed with many research hydrologists and watershed managers, (2) approximately 300 photographic slides

of famous field and laboratory installations were obtained for illustration in lectures and seminars, and (3) the Department acquired a substantial up-to-date file of publications including papers and problem analyses which are usually difficult or impossible to locate by the traditional library search.

Some of the scientists visited included the following:

A. Coweeta Hydrologic Laboratory

(1) James E. Douglass
Hydrologist and Project Leader

(2) Lloyd W. Swift, Jr.
Microclimatologist

(3) J. D. Helvey
Hydrologist

(4) Wayne T. Swank
Research Forester

B. Duke University

(1) Kenneth R. Knoerr
Micrometeorologist and Hydrologist

C. Tennessee Valley Authority

(1) Roger P. Betson
Head, Hydrologic Research and Analysis Staff

(2) Donald Eckland
Hydrologist

(3) Paul Sodeman
Hydrologist

(4) Robert E. Farmer, Jr.
Plant Physiologist

D. Oak Ridge National Laboratory

(1) James W. Curlin
Soil Physicist

E. Strip-Mine Restoration Project

(1) Willie Curtis
Hydrologist

F. Timber and Watershed Laboratory-Fernow Experimental Forest

(1) James H. Patric
Hydrologist and Project Leader

(2) Charles A. Troendle
Hydrologist

(3) James N. Kochenderfer
Hydrologist and Erosion Control Expert

The subject matter discussed and studied on this trip can be divided into four general categories: (1) Evapotranspiration (ET) phenomena and their physical relationship to streamflow, (2) Hydrologic prediction of streamflow by mathematical models, (3) Erosion and land rehabilitation problems, and (4) chemical and temperature characteristics of streamflow as affected by watershed management practices.

(1) Evapotranspiration phenomena and their physical relationship to streamflow.

In a water balance analysis, it is possible to show that the magnitude of evapotranspiration loss from watersheds is inversely related to the volume of streamflow runoff. The portion of precipitation input evaporated and transpired is that much less liquid water available for streamflow runoff. It has also been shown that 50 percent or more of the annual precipitation input to watersheds may be lost to ET processes. Since the magnitude of ET is large and has been shown to vary with vegetation conditions, scientists are attempting to define vegetation conditions that will minimize ET and thereby maximize streamflow runoff, without causing flood problems.

Some of the most famous experiments involving these vegetation-ET-runoff interrelationships are conducted at the Coweeta Hydrologic Laboratory. These studies have shown, for example, that conversion of mature hardwood overstory to low growing herbaceous plants caused an increase in streamflow of about 16 inches the first year after treatment. This experiment was successfully repeated in time and space. Conversely, recent experiments have shown that the conversion of mature hardwoods to dense white pine stands on watersheds caused reductions in streamflow of up to four inches annually. These results suggest that the range of vegetation effects is large, which may provide opportunity for contrasting management objectives such as flood control versus water yield improvement. However, before results can be applied operationally, it is first necessary to define and model the involved processes in greater detail. Scientists at the Coweeta Hydrologic Laboratory and the Fernow Experimental Forest have identified some possible causes for these treatment effects on streamflow. Variation in rainfall interception, transpiration rates and possibly energy input appear to be of primary interest in this regard.

Another important process study is concerned with unsaturated soil water flow in these deep, porous Appalachian Mountain soils. Essentially, all runoff from the watersheds occurs as subsurface flow; virtually no surface runoff is observed. Since little is known about this subsurface flow, and its behavior is not yet predictable, scientists at the Coweeta Hydrologic Laboratory and the Fernow Experimental Forest have established field monoliths up to 200 feet in length and from five to about 40 feet wide. Soil water fluctuations in these monoliths and subsurface flow out of the lower ends are measured. With these data and other measurements,

the scientists hope to develop mathematical models which will predict soil water flow phenomena. To assist in this objective, a laboratory monolith with repacked soil has been constructed at the Coweeta Laboratory. The slope of this monolith can be changed and the pressure of water in soil pores is measured with tensiometers. Also, outflow at the lower end is measured following simulated precipitation events. It is hoped that flow lines and the rate of outflow can be defined mathematically for this two-dimensional experimental system.

Theoretical studies of (ET) are also being carried out by Professor Kenneth Knoerr of Duke University who has emphasized measurement of energy flux to and from leaves and whole plant canopies. One project is an attempt to construct a computer model that will simulate the flux of energy and water vapor in and through forest canopies. The results of these studies should compliment the field work being done at Coweeta and the Ferrow Experimental Forest.

(2) Hydrologic prediction of streamflow by mathematical methods.

The ultimate goal of much hydrologic research is to predict for many fixed and variable watershed conditions the streamflow timing and total volume that results from precipitation inputs. Many approaches to this problem are attempted, but one of the most logical combines an assessment of physical watershed characteristics with mathematical concepts to develop a streamflow predicting model. This is an approach being developed by the Hydrologic Research and Analysis Staff of the TVA. Such a model would have particular value for the TVA which administers a large, more-or-less controlled watershed system involving many dams which must be operated in the most efficient manner possible. Efficient management

requires accurate streamflow prediction.

In these models, watershed characteristics that affect infiltration and the timing of surface runoff must be considered, but the means for measuring these variables must be practical if operational application is to be feasible. Thus, such factors as the depth of soil horizons, their infiltration characteristics, location and areal extent are measured. Variable basin characteristics that affect surface runoff must also be considered. The antecedant soil water status is particularly important but difficult to assess on large areas. However, approximations are attempted. For example, one approach involves expressing infiltration partly as a function of total soil water storage which can be approximated on an operational basis by the Holton method. Another variable characteristic that complicates these models is the formation of crusts at the soil surface, particularly in agricultural areas. The crusts reduce infiltration rates and are also difficult to measure meaningfully. These are some of the approaches and problems that TVA scientists are considering in their model-developing program.

(3) Erosion and land rehabilitation problems

The erosion and land rehabilitation problems reviewed on this trip involved two general categories; road construction and strip mining operations on vegetated watersheds.

Roads have always been a potential source of serious erosion and sedimentation problems on watersheds, particularly when poorly designed and constructed. A road system may only disturb 5 percent of the total watershed area, but exposed soil, poor location and improper drainage

often cause large increases in localized surface runoff, with the associated erosion problems and deterioration in water quality. For these reasons, scientists at Coweeta and the Fernow Experimental Forests are designing better road systems, even though the immediate cost may be higher than, for example, "logger's choice".

One important concept is that a new road system should be designed for long-term multiple-use or potential re-use, and that several types of roads can and should be included in the same plan. For example, a first order road entitled "major access road" is well constructed with large amounts of coarse gravel cover, adequate culverts, minimum grade and other features to assure continued year-around use. A secondary road branching off the major access road is the "climbing road" which is also well constructed, drained and artificially vegetated along fill slopes. In this case, gravel-covered dips or water bars are used to divert water from the road which therefore requires slower travel than the major access road. This road is graded more crudely and is also narrower than the major access road. From the climbing road, branch "contour roads" which are spaced out more-or-less horizontally in the watershed, but are otherwise similar to the climbing road in construction. After timber harvesting is completed, contour roads are seeded and blocked from routine entry ("put-to-bed"), but are available for future use.

These designs and other modifications are being studied on an experimental basis to find a means for constructing long-term and economical road systems without causing deleterious increases in surface runoff and sedimentation.

Strip mining is an important method for acquiring coal to meet an increasing demand which currently exceeds the supply. However, strip mining probably causes more destruction on naturally vegetated watersheds than any other form of natural resource use. In some cases, up to 60 percent of the watershed area is totally reshaped due to the removal and dumping of overburden rock. Hills and ridges are completely cut off and valleys are filled in with overburden material. Naturally, these mining activities are expected to radically change streamflow regimens and have been demonstrated to cause accelerated erosion. The quality of water flowing from strip mine areas is generally expected to be low.

However, a realistic appraisal of society's dependency on natural resources, particularly fossil fuels, suggests that strip mining will continue, no matter how radically the ecology and hydrology of watersheds are changed. Evidently, it will be a long time before atomic energy significantly replaces fossil fuels for electric power generation. For example, in the U.S. alone, 60 percent of the power is produced with fossil fuels, particularly coal. East of the Mississippi River, 85 percent is produced by fossil fuels.

Consequently, it would seem logical to devise strip mining methods and land rehabilitation techniques which will minimize the hydrological and ecological damage in high-producing coal regions. This is a primary objective of the Strip-mine Restoration Project centered in Berea, Kentucky. In this project, attempts are made to prescribe the manner in which cut and fill banks are shaped, their length and slope. Means are being devised to revegetate the new soil surfaces and to retain and control precipitation which may equal or exceed 50 inches annually. If this

comparatively large precipitation input can be retained or at least detained, vegetation regrowth should be favored and erosion and streamflow sedimentation hazards will be dimished. The experience and knowledge gained from these studies should also have application to other problems and countries.

(4) Chemical and temperature characteristics of streamflow as affected by watershed management practices.

Hydrologists have given increased attention to changes in the chemical content of streamflow that result from land use practices on wildland watersheds. The use of fertilizers to increase wood production may eventaully be feasible. In anticipation of this development, scientists at Oak Ridge and the Fernow Experimental Forest are beginning to moniter the chemical content of streamflow from unfertilized watersheds for comparisons with data to be obtained after watersheds are fertilized for experimental purposes. If timber fertilization also results in stream fertilization, the ecology of streams might be radically and detrimentally affected. Consequently, this possible side-effect should be evaluated.

Water temperature is a quality factor that can significantly affect the ecology of streams, involving both fauna and flora. For example, several species of trout are believed to have specific temperature requirements for optimum development. Land use practices affect stream temperature. For example, vegetation clearing usually causes a detrimental increase in water temperature. To avoid this problem, scientists at the Fernow Experimental Forest are evaluating uncut strips left along streams in otherwise logged watersheds. Shade from this riparian vegetation may maintain stream temperatures at normal levels.

A fifth and less discreet subject considered on this trip, involved partial development of an overall perspective on resource management and hydrology and their interrelationship to more general modern problems, particularly pollution and environment. It becomes increasingly evident that natural resources and wildland hydrology are important factors in current pollution and environmental problems. Furthermore, these problems are becoming much more intense and general. For example, a high demand for coal to be used for power production in one part of the country may cause an increase in strip mining with the associated erosion and water quality problems in another region. This kind of relationship is not new with regard to coal and other resources, but the pace has quickened in modern times.

Perspectives of this nature have no direct application in physical models of watershed behavior, but are probably important in a broader analysis of the whole system within which watershed management must function. Additionally, knowledge of these relationships may have planning and management utility in other less developed countries as they begin to utilize their natural resources more fully.