White Paper

Holistic Water Resources Management:

A Professional Education Plan

2 September 2009

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SUMMARY

Watershed-scale management for sustainable use of water resources is a topic of considerable interest to many, ranging from EPA's to the Corps of Engineers to state and local agencies. Actually accomplishing watershed-scale management is difficult for a variety of reasons, including a lack of people knowledgeable in the many disciplines and cognizant of all the stakeholders involved in watershed processes.

This document presents a proposed framework to meet the educational needs for watershed management -- to give professional water resources managers the knowledge, skills, and tools to successful implement holistic watershed management.

Holistic watershed management is defined here as practices and processes designed to achieve sustainable water resources use for the benefit of humans and the natural environment throughout the watershed.

The framework includes an outline of coursework, which at its highest two levels can be categorized as:

A. WATERSHED PROCESSES
    1. What is a watershed?
    2. Watershed Processes
    3. Stressors
    4. Synthesis of Watershed Processes
B. MANAGEMENT PRACTICES
    1. What is watershed management?
    2. Social, Cultural, & Economic Processes
    3. Laws, Policies, and Practices
    4. Management Practices
    5. Analysis and Synthesis Tools
    6. Watershed Management Plans

[1] Healthy Watersheds – Healthy Coasts

Other requirements (discussed further below) include:

1. Scalability of instruction – short courses to university courses
2. Instruction in both the "why" and the "how" with hands-on experience in the latter.
3. Low cost continuing education, including travel-free webinars and online courses
4. University-credit courses available via distance for working professionals
5. Flexible prerequisite threshold
6. Seamless integration of topics
7. Transferability – applicable to a wide variety to watershed types
8. Current - regularly updated to reflect new policies, science and management approaches

We propose to develop coursework in Holistic Watershed Management using a stepwise approach and a cohesive team of subject matter experts and instructional method experts to produce and use materials ranging from a two-semester program of classroom instruction, case study site visits, and extensive hands-on applications to a series of one- to two-hour webinars to complement EPA's existing watershed Academy Modules.

PURPOSE

This document presents a proposal to meet the educational needs expressed in surveys taken by the Northern Gulf Institute and NOAA Coastal Services Center plus other discussions[2] – a framework to give professional water resources managers the knowledge, skills, and tools to successful implement holistic watershed management adhering to the theme, Healthy Watersheds – Healthy Coasts.

Holistic watershed management is defined here as practices and processes designed to achieve sustainable water resources use for the benefit of humans and the natural environment throughout the watershed. Holistic management will lead to healthy watersheds which contribute to healthy coasts and oceans.

BACKGROUND

Three Mississippi State University projects funded through NOAA's Northern Gulf Institute (NGI) addressed aspects of water resources management from a watershed perspective: 1) Spatial Technology and High Performance Computing for Improving Prediction of Surface Water Quality, 2) Watershed Modeling Improvements to Enhance Coastal Ecosystems, and 3) Modeling Mobile Bay Sediments and Pollutants with New Technologies. These three projects, each addressing different aspects of watershed processes and management, have been linked

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[2] Notably W. D. Martin, S. L. Ashby, and L. E. Parsons of the Corps of Engineers, J. Chapman and R. Ingram of Mississippi DEQ, and C. F. Zabawa of EPA.

by using the Mobile Basin as their demonstration site. Therefore, it was logical to combine some efforts of these three projects for greater efficiency.

One combined effort of the NGI projects was the stakeholder outreach component. Tagert et al.[3] reported that Mobile Basin stakeholders identified the following as priority educational needs:

- A holistic sustainability approach to watershed management
- Collaboration rather than confrontation in water management
- Educational K-12 materials
- Water resources conservation teaching tools and experiences for high schools

NOAA's Coastal Services Center (CSC) also performed an extensive research needs assessment.[4] Education-related findings included the following extracts from the CSC report:

- *… more outreach, training, and technical assistance to ensure that NOAA's information and tools are truly useful to constituents and other users.*
- *Supporting and Fostering an Ecosystem-based Approach to Management*
    - *This concept needs to be defined in concrete action steps. There is widespread support for the idea of an ecosystem-based approach, but both resource managers and local decision-makers need a better understanding of how it can be implemented.*
    - *One of the most challenging aspects of implementing an ecosystem-based approach to management is successfully involving the myriad of players who represent the multiple issues and jurisdictions involved.*
    - *Resource managers need socioeconomic tools and data, as well as natural science information and tools.*
    - *Within the topic of awareness and education, participants stressed the need for education on the connections among elements of ecosystems and between human activity and ecosystem impacts.*

DEFINITION OF TERMS

Watersheds

The term "watershed" is commonly used to describe an area of the earth's surface from which water flows downhill to a single outflow point.[5] The area encompassed may either be small,

[3] Tagert, Mary Love, Kimberly Ann Collins, William H. McAnally, Jairo N. Diaz-Ramirez, Ph.D., 2008, Mobile Basin Stakeholder Needs and Assessment: Year One Report, Northern Gulf Institute, Stennis Space Center, Mississippi.

[4] CSC, 2007, Needs Assessment for the NOAA Gulf Coast Services Center, Final Draft, National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. November 27.

[5] Blacks Law Dictionary does not define "watershed".

such as that which an ephemeral stream drains only during precipitation events, or be large, such the Mississippi River Valley, which drains nearly half the United States through the main stem Mississippi River and its thousands of tributary rivers and streams. Although some attempts have been made to create a hierarchical system of terms based on size, such as catchment, watershed, sub-basin and basin, a systematic nomenclature has not gained widespread acceptance, except for the numerical Hydrologic Unit Code (HUC) employed by the U.S. Geological Survey.[6] Figure 1 shows the southeastern U.S. with its myriad streams and Mobile Basin watershed's sub-watershed 7-digit HUCs identified. Although the Tennessee River is part of the Mississippi River watershed, in this figure it is shown as connected to the Mobile Basin because of the release of navigation lockage water from the Tennessee into the Tombigbee River, a tributary to Mobile Bay.

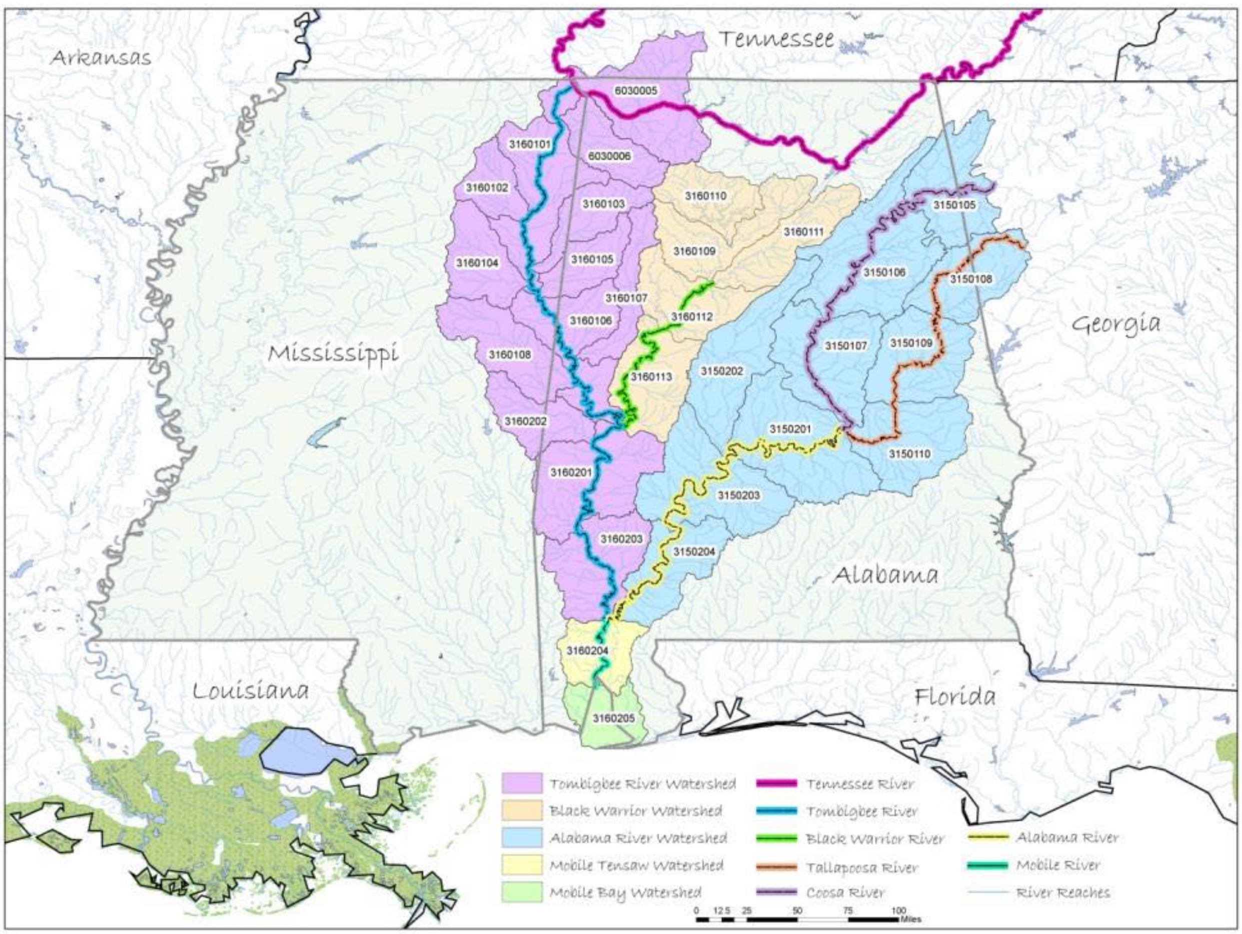

Figure 1. Mobile Basin watershed with 7-digit Hydrologic Unit Codes (HUCs) identified

[6] Hydrologic Unit Maps, U.S. Geological Survey, Washington, DC. http://water.usgs.gov/GIS/huc.html.

Water Resources Management

As used here, Water Resources is defined as the total supply of surface and ground water suitable for use, and Water Resources Management as the process of ensuring that water of sufficient quantity and quality is available for beneficial uses. Management includes regulatory actions to conserve and protect water resources, planning to provide future resources, and actions and structures to store, divert, purify, and use water. Beneficial uses subject to management include the traditional classifications of agricultural, industrial, municipal, hydropower, navigation, and recreation plus environmental quality and habitat. Storm and flood damage reduction, representing the inverse problem of too much water or water in the wrong place, is included in the water resources management definition also. Figure 2 illustrates a schematic watershed with important elements of the hydrologic cycle and human modifications.

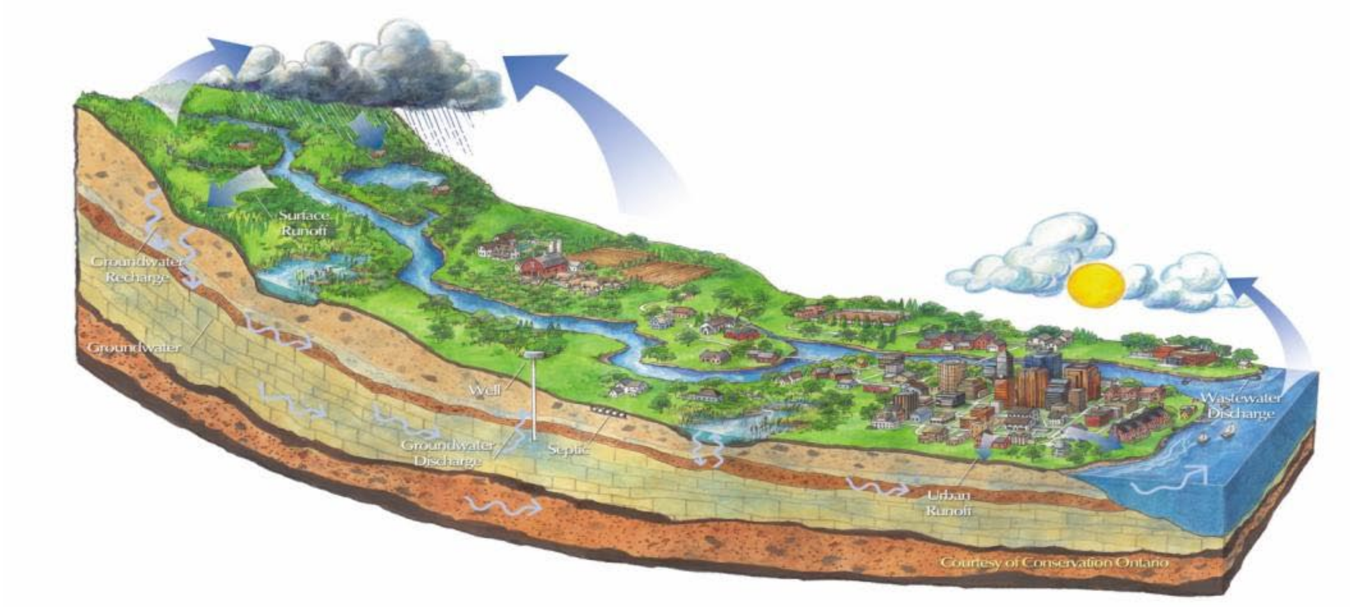

Figure 2. Watershed schematic with hydrologic cycle and human alterations. (Courtesy of Conservation Ontario)

Other resources, ranging from minerals to trees to fish, either affect water resources (e.g., mine leachate entering streams) or are affected by them (e.g., fish habitat) and so activities that might be called natural resources management are closely related to water resources management. Similarly, since economic development hinges upon adequate water supplies among other resources (such as labor and transportation) and affects water resources through water usage and changes in land use, economic development is inextricably linked with water resources and water resources management.

Management of water resources from a watershed perspective, mentioned in the Background section, is related to concepts and terms such as "integrated water resources management", "total water management", "watershed management", and "regional management." Total Water Management is defined by the American Water Works Association Research Foundation as "…the exercise of stewardship of water resources for the greatest good of society and the environment. A basic principle of Total Water Management is that the supply is renewable, but limited, and should be managed on a sustainable-use basis."[7]

The AWRA definition includes the concept of sustainability, which the American Society of Civil Engineers defines for water resources as:

> *Sustainable water resource systems are those designed and managed to meet the needs of people living in the future as well as those of us living today.*

A frequent criticism of the sustainability concept is that it's idealistic and impossible — any use of resources is bound to decrease the amount available to future generations. However, that criticism is no more valid than saying that we need not strive for safety, since perfect safety is never achieved. Absolute environmental sustainability can be an ideal goal that is balanced with economic development and the cultural fabric of a region, which are implicitly included in the above sustainability definition.

The Corps of Engineers[8] defines watershed perspective planning as:

> *… accomplished within the context of an understanding and appreciation of the impacts of considered actions on other natural and human resources in the watershed. In carrying out planning activities, we should encourage the active participation of all interested groups and use of the full spectrum of technical disciplines in activities and decision-making. We also should take into account: the interconnectedness of water and land resources (a systems approach); the dynamic nature of the economy and the environment; and the variability of social interests over time. Specifically, civil works planning should consider the sustainability of future watershed resources, specifically taking into account environmental quality, economic development and social well-being.*

[7] American Water Works Association Research Foundation. "Minutes of Workshop on Total Water Management," Seattle, WA and Denver, CO: American Water Works Association, August 1996.

[8] Engineer Regulation 1105-1-100, Planning Guidance Notebook, 2000, http://140.194.76.129/publications/eng-regs/

The Tennessee Valley Authority is often cited as the model for managing a watershed for multiple purposes. Chartered by the Federal government in 1933, its intended purpose was "… in the interest of the National defense and for agricultural and industrial development, and to improve navigation in the Tennessee River and to control the destructive flood waters in the Tennessee River and Mississippi River Basins, …"[9] TVA became an engine for not just economic growth, but also education, cultural preservation, and environmental stewardship, all centered around water management.[10]

Another term that leads to many of the same conclusions as the watershed perspective is "systems", sometimes expressed as systems thinking, systems engineering, etc. and appears in the Corps of Engineers' definition above.

Eugene Odum, one of the great pioneers of modern ecology and author of *Fundamentals of Ecology* (Odum 1953) employed the concept of interdependence of all the actors on the stage, biotic and abiotic, a concept also known as holism.[11]

Holistic Watershed Management

We use the phrase "Holistic Watershed Management" to denote the practice and process of achieving sustainable water resources use for the benefit of humans and the natural environment throughout the watershed.

The word holistic has often been misused, but is so uniquely descriptive of what this work strives for that we are compelled to use it. Derived from the Greek *holos*, meaning "altogether" or "entire", which was defined by Aristotle (350 BCE) as, "the whole is greater than the sum of the parts". Jan Smuts is credited with coining the English term holism, which he described as "the tendency in nature to form wholes that are greater than the sum of the parts through creative evolution."[12] The definition has been refined and applied in diverse fields, most vividly by Douglas Adams as the "fundamental interconnectedness of all things".[13] Adams' definition helps to remind us first, that economic development and a healthy ecosystem are fundamentally connected as interacting contributions to the quality of life, and second, that what happens in one part of a watershed affects other, often unseen aspects and areas of the

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[9] United States Code, 1933, *16 U.S.C. § 831, et seq.* "Tennessee Valley Authority Act of 1933."

[10] Recently TVA has been criticized for becoming just another power company willing to sacrifice the common good for revenues.

[11] Fundamentals of ecology. Philadelphia: W. B. Saunders Company, 1953. 383 P

[12] J. Smuts, *Holism and Evolution,* 1926. Reprinted in 1999 by Sierra Sunrise Publishing. Smuts was a military leader, statesman (the only person to sign the charters of both the League of Nations and United Nations), and scholar (Albert Einstein said that Smuts was one of only 11 people in the world who understood the Theory of Relativity).

[13] Douglas Adams, *Dirk Gently's Holistic Detective Agency*, 1987, Pocket Books, NY.

watershed. Figure 3 illustrates just a few graphical depictions which attempt to capture aspects of this holistic view.

Smuts' concept of holism was much more than interconnectedness. He saw it as a active force in the universe, responsible for organizing "wholes". He defined wholes as "… composites which have an internal structure, function, or character which clearly differentiates them from mere mechanical additions or constructions …". He described as wholes a water molecule (more than a simple mixture of hydrogen and oxygen atoms), cells (more than a collection of water, minerals, and organic molecules), an organism (more than a collection of cells), and the universe. We might add ecosystems, societies, and watersheds to his list of wholes.

Smuts presented holism as the "… ultimate synthesizing, ordering, organizing, regulating activity in the universe …".

Examples of at least the interconnectedness of Smuts' "wholes" abound.

- Paine reported on a set of coastal ecosystems in which 15 large species existed in relative equilibrium. Removing the starfish from some of the systems resulted in a crash so severe that one year later only 8 species dominated, while the control systems remained in balance.[14]
- Savory describes a lush, wildlife-rich Luangwa Valley in Zambia that was converted to a national park and game preserve by relocating local hunting and farming villages. Within a few decades the landscape became denuded of vegetation, serious riverbank erosion occurred, and game species all but disappeared, because villagers were replaced by park employees and tourists.[15]
- Weins and Roberts attribute the decline of bottomland hardwood wetlands along the Wolf River in Tennessee to headcutting, a stream erosion process that moves from a downstream disturbance (such as channelization) to upstream areas far from the original disturbance.[16]

Why Healthy Watersheds – Healthy Coasts?

Water should be managed as a Smuts-type whole from the top of the watershed to the sea. Political boundaries, which often divide water management responsibilities across multiple jurisdictions, almost guarantee conflict and mismanagement. Management at the watershed level is a sensible way to proceed, with a few caveats.

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[14] Paine, 1966, Food Web Complexity and Species Diversity, *American Naturalist*, Vol 100, No. 910:65-75

[15] Allan Savory, 1999, *Holistic Management: A New Framework for Decision Making*, Island Press, Washington, DC.

[16] K. Weins and T. Roberts, 2003, "Effects of headcutting on the bottomland hardwood wetlands adjacent to the Wolf River, Tennessee," *WRP Technical Notes Collection* (ERDC TN-WRP-HS-CP-2.1), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/wrtc/wrp/tnotes/tnotes.html*.

One caveat is that large aquifers often transcend watershed boundaries, so management of ground water may, in some circumstances, require and even larger perspective. It must also be noted that ecosystems do not have boundaries along watershed lines, nor do human communities, so where the watershed processes intersect ecosystems and human communities (including the essential economic systems) a perspective larger that watersheds may be needed. For example, migrating waterfowl traverse many watersheds each year. Conversely, since land use and other terrestrial processes affect water, water resources management must necessarily include some aspects of land management issues, including zoning, building codes, highways, etc.

Finally, we must recognize that healthy watersheds are necessary (but not sufficient) for healthy coasts and oceans. The infamous Dead Zone in the Gulf of Mexico is usually ascribed to the flow of nutrients from the Mississippi River watershed, the largest in North America. If that is the cause, then we must improve the health of the watershed in order to improve the Gulf's health. Thus we use the phrase, "Healthy Watersheds – Healthy Coasts as the underlying goal of this white paper.

SCOPE

The proposal lays out a framework for university-level coursework and professional short courses for the primary and secondary audiences such that a curriculum can developed and tested.

The educational plan presented here assumes a target audience of working professionals and full-time students. The professionals are employed primarily in local, state, and Federal agencies with resources management responsibilities related to water, including those working specifically on water resources issues, but extending to those involved in land and biological resources. They probably have a technical degree in one of the sciences or engineering, but may be self- or on-the-job-educated in water and watershed issues. A strong secondary professional audience would be persons working for non-government organizations, such as environmental advocacy or economic development, and consulting firms serving all the above. The target full-time students will be upper level or graduate students in science, engineering, technology, and administration with some earth or hydrologic science coursework.

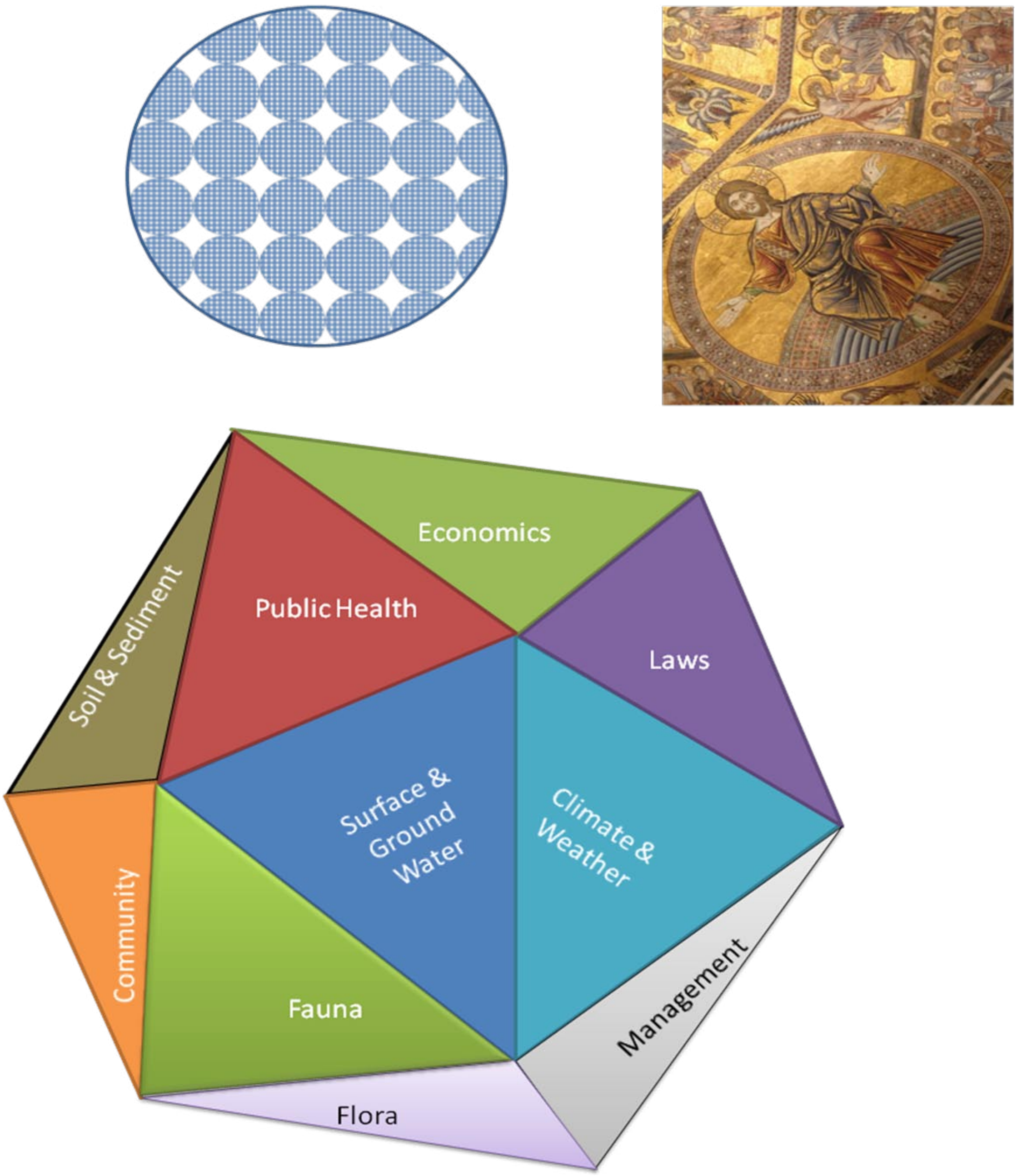

Figure 3. Holism envisioned in various ways. From upper left clockwise, a “Whole” consisting of many individual “Wholes”, a mosaic of individual tiles that create an artwork masterpiece, a rhomboid depiction of issues that contribute to a community’s culture.

WHAT'S NEEDED

The educational needs shown in the Background and Definition of Terms sections illustrate the wide range of knowledge needed to manage water resources – technical knowledge about physical processes, ecosystems and human systems, organizational and geographic knowledge about jurisdictions and issues, and abilities to make connections and implement solutions. As once workshop participant put it, "What is it I need to know to do my job? Everything!"

Any listing of topics for which knowledge is needed for successful water resources management with a watershed perspective must of necessity contain something less than the "everything" cited by that workshop participant. Consultation with stakeholders in the Mobile Basin and with colleagues in state and federal agencies has generated the following outline and attached detail.

A. WATERSHED PROCESSES
    1. What is a watershed?
        a. Definitions: hydrologic and legal
        b. Watersheds in context of human systems and ecosystems
    2. Watershed Processes
        a. Geology and Soils
        b. Hydrology, Hydraulics, Morphology
        c. Atmosphere, Climate and Weather
        d. Water Quality
        e. Natural flora and fauna
        f. Ecosystem Processes
        g. Geography and Zones – Arid, Humid, Tropical, upland to sea
        h. Human Activities
        i. Culture and Social Systems
    3. Stressors
        a. Earthquakes, volcanoes, landslides, & debris flows
        b. Climate & Weather Variability
        c. Storms and Floods
        d. Invasive Species
        e. Faunal Imbalance
        f. Human Effects
    4. Synthesis of Watershed Processes

B. MANAGEMENT PRACTICES

1. What is watershed management?
    a. Self management at scales: plots to watershed-wide
    b. Regulatory Management
2. Social, Cultural, & Economic Processes
    a. Stakeholders' multiple perspectives
    b. Balancing public interests – culture, health, economics, environment
    c. Working with groups
3. Laws, Policies, and Practices
    a. Local, Tribal, State, & Federal Laws
    b. Political Jurisdictions & Transboundary Issues
    c. Codes and Regulations
    d. Ethical Requirements
    e. Roles of Private Sector and Non-Governmental Organizations
    f. Financing
4. Management Practices
    a. Assessment and Problem identification
    b. Education and Communications
    c. Remedies, e.g., Total Maximum Daily Loads
    d. Matching Practices to Watershed Assessment and Problem Identification
    e. Best Practices by Sector: Ag, commercial, forestry, etc.
    f. Monitoring and Adaptive Management
5. Analysis and Synthesis Tools
    a. Tools Introduction
    b. Data Sources and Data Collection
    c. Multi-objective Analyses
    d. Geographic Information Systems
    e. Geotechnical Predictions
    f. Climate & Weather Prediction
    g. Hydrologic and Hydraulic Modeling
    h. Water Quality Modeling
    i. Biotic Predictions & Modeling
    j. Social & Economic Predictions and Modeling
    k. Decision Support Tools
6. Watershed Management Plans
    a. Contents of a Plan
    b. Steps in constructing a Plan
    c. Case Studies

Other requirements for education are common to nearly all professions and topics. Previously cited in brief, they include:

1. Scalability of instruction – university coursework ranging from a major degree or minor and short, continuing education courses ranging from a few hours to a week.
2. Instruction in both the "why" and the "how" with vibrant visualization, multiple learning modes, and hands-on experience in applications.
3. Low cost continuing education, including travel-free webinars and online courses
4. University-credit courses available via distance for working professionals desiring a degree or Certification credit for agency use in supporting education.
5. Flexible prerequisite threshold – establishing prerequisites such that students are neither bored by excessive review nor overwhelmed by new terms and concepts but avoids the course becoming another stovepipe with a long list of prerequisites.
6. Seamless integration of topics – avoiding having a series of subject matter experts deliver unconnected lectures.
7. Transferability – applicable to a wide variety to watershed types (floodplains, arid regions, etc.)
8. Current - regularly updated to reflect new policies, science and management approaches

AVAILABLE RESOURCES

A plethora of materials are available for watershed management education. However, most of those materials are narrowly focused on a specific profession and discipline. Foresters, hydrologists, biologists, engineers and others have university curricula and short courses on many watershed topics, but nearly always with an understandably reductionist, specialty perspective that is reconcilable with a holistic view only if the student has nearly unlimited time and brain capacity. For example, the Civil and Environmental Engineering Department at Mississippi State University offers the semester-long graduate level water resources courses shown in Figure 4 and Biological Sciences offers the courses shown in Figure 5. A similar list of courses could be shown for several disciplines, including Landscape Architecture, Geosciences, Forestry, Soil Sciences, Business, Sociology, etc. From the composite list (or one like it from most universities) a student could construct a coursework plan that would reasonably prepare a person for performing watershed management; albeit one requiring many years to acquire all the necessary courses and their pre-requisites.

Several organizations offer coursework that at least partially addresses the need. For example, Montana State University's Department of Animal and Range Sciences offers a curriculum in

Watershed Management which "… emphasizes an ecologically-based approach to watershed conservation and control of non-point source pollutants arising from livestock production and other land uses"[17] and a water resources minor with course requirements as shown in Figure 6. Both are based on 4-year bachelors' degree programs.

Michigan State University offers a certificate in Watershed Management[18] consisting of four modules:

1. Watershed Concepts
2. Building and Implementing Watershed Management Plans
3. Watershed Assessments and Tools
4. Legal, Financial, and Institutional Frameworks for Watershed Management

with each module consisting of a semester-long web-based course which can be taken for university credit.

The American Society of Civil Engineers offers educational opportunities in the form of live seminars and workshops, courses on CD, and short, live webcasts (webinars).[19] Nearly all are highly focused and in the reductionist mode, such as "GIS in Water Resources," but could be used as part of an integrated curriculum.

Numerous short courses on various watershed topics are offered, such as the Texas Water Resources Research Institute's 4-day Watershed Planning course[20], for which the topics are listed in Figure 7. Most focus on a given state or zone, such as arid regions, or are aimed at a particular demographic and all struggle with the holistic versus reductionist perspective.

Several state and federal agencies have developed training for employees in watershed related topics, and sometimes make those offerings available to non-employees. For example, the Corps of Engineers Learning Center lists dozens of courses in its "Purple Book."[21]

[17] http://www.montana.edu/wwwcat/programs/wtsm.html
[18] http://35.9.116.206/IWR/vu/watershed.html
[19] https://secure.asce.org/ASCEWebsite/ESTORE/CategoryListing.aspx
[20] http://watershedplanning.tamu.edu/docs/courses/2009-08/flyer.pdf
[21] http://pdsc.usace.army.mil/downloads/PurpleBook2009.pdf

EPA's Office of Water has done an admirable job assembling online educational components for watershed education on its Watershed Academy web site.[22] It provides instruction through more than 50 modules grouped into the categories:

- Introductory
- Watershed Ecology
- Watershed Change
- Analysis and Planning
- Management Practices
- Community/Social/Water Law

The modules can be downloaded for study and self-testing, and completion of a minimum number of modules with satisfactory scores permits the user to receive a Certificate of Completion from EPA.

EPA is making its multiple watershed-related resources more readily available with a new "Watershed Central" web site[23] to facilitate web access to watershed materials across all of EPA's program and office web pages.

In the arena of K-12 education and public outreach, virtual labs, such as those produced by Explore Learning[24] offer great promise for providing the hands-on experiences needed for optimal learning. University level virtual labs are significantly more complex and difficult to construct, but, coupled with high performance visualization and gaming technology, offer great potential for experiential learning.[25]

Of these resources and others known to us, none exactly fulfils the need identified by our stakeholders, although the EPA Watershed Academy and Michigan State University's come closest. Further, we note that no known person or extraterrestrial being possesses the requisite knowledge to teach well all the subjects in our stakeholders' needs outline, yet the use of team-teaching almost guarantees gaps, overlaps, and disconnects among subjects unless the course is extraordinarily well coordinated with the goal of seamless coverage. For these and other reasons we propose in the following section something that seems to be unique.

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[22] http://www.epa.gov/owow/watershed/wacademy/

[23] http://www.epa.gov/watershedcentral/

[24] http://www.explorelearning.com/index.cfm?method=cCorp.dspLearnMore

[25] "Serious Gaming for Water Managers" Presentation by Phil Amburn, MSU

PROPOSAL

We propose to develop coursework in Holistic Watershed Management using a stepwise approach and a cohesive team of subject matter experts and instructional method experts. We will produce, in sequence:

1. A two-semester program of classroom instruction, case study site visits, and extensive hands-on applications (aka assignments and project labs).
2. A one-semester overview course with some hands-on applications (assignments)
3. A set of virtual labs employing scientific visualization and serious gaming technology to replicate and extend aspects of the university labs curriculum.
4. A four-day-long short course with hands-on applications (projects)
5. A series of one- to two-hour webinars to complement EPA's existing watershed Academy Modules.

By developing these components in a stepwise fashion, the team can move from the familiar context of a graduate level university course to the highly focused short forms needed for webinars while preserving the connectedness of the topics and the connectedness of all things required for holistic management.

The two semester course will be constructed around the matrix shown in Tables 1-3. It will begin with a one semester course on watershed processes, followed by a one semester course in watershed planning, and culmination in a one semester laboratory course of hands-on application to a real watershed. The second semester and lab course might be conducted concurrently.

The course curriculum will be developed by a team that includes subject matter specialists, educational methods experts, and visualization and utilization experts. For each topic a lecture plan will be prepared following a checklist common to every topic:

1. Introduction
2. Terms and Concepts
3. General Theory
4. Practical Application
5. Examples
6. Exercises
7. Reading List

Then the team will craft the coursework from the detailed outlines, linking the materials so that a seamless presentation with a consistent look, feel, and depth of coverage is achieved. The instructional team will deliver draft lectures to each other and revise them based on instructor-team interaction before offering the courses formally.

After completion of the 3 semester program, the courses will be evaluated and modified for the next cycle in order to further smooth connections and fill gaps. Then it will be condensed into a single one-semester course with hands-on learning incorporated. Finally, it will be distilled into a 4-day-long short course. A final evaluation will be used to refine the complement of courses, at which point they will become incorporated in the MSU curriculum and offered both to on-campus students and distance students via our eLearning technology. As appropriate, modules will be made available to the EPA Watershed Academy and other organizations' learning centers.

ACKNOWLEDGEMENTS

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CE 4183/6183. Waterborne Transportation. Planning and design of Marine Transportation System facilities. Components and stakeholders of the MTS. Navigation vessels and their characteristics. Planning, design and operation of navigation ports, channels, and locks.

CE 4513/6513 Engineering Hydrology. Hydrologic processes; rainfall-runoff analysis; groundwater flow; frequency analysis; hydrologic design.

CE 4523/6523 Open Channel Hydraulics. Continuity, energy and momentum principles in open channel flow; flow resistance; uniform and non-uniform flow; channel controls and transitions; unsteady flow routing.

CE 4533/6533. Computations in Water Resources. Review of relevant numerical analysis; numerical methods for kinematic wave, St. Venant, Boussinesq and depth-averaged equations; simulation of one- and two-dimensional free-surface flows.

CE 4563/6563. Sedimentation Engineering – Processes by which cohesive and non-cohesive sediments are transported, deposited, and eroded. Computation of transport rates. Design and operation solutions to sediment problems.

CE 4843/6843 Advanced Sanitary Analysis. Introduction to advanced theoretical concepts in sanitary engineering analysis with special emphasis on inorganic, organic, and physical chemistry.

CE 4873/6873 Water & Wastewater Engineering. Two hours lecture. One hour laboratory. Evaluation of municipal water and waste-water characteristics and flows; application of various unit processes/unit operations for the treatment of municipal water and wastewater.

CE 8543. Tidal Hydraulics. Bay and estuarine hydrodynamics, transport, and engineering. Unsteady, non-uniform stratified flows, tides, currents, waves, circulation, salinity intrusion, and sedimentation. Engineering analyses and works.

CE 8563. Groundwater Resource Evaluation. . Groundwater movement; Darcy's law; equations of groundwater flow; confined and unconfined flow; wells and well field analysis; groundwater quality; aquifer management. Nonconservative pollutants in natural waters.

CE 8573 Environmental Quality. Discussion of physical/ chemical/ biological processes impacting conventional and toxic materials in surface waters. Overview of characteristics of rivers/streams, lakes and estuaries related to environmental quality.

CE 8803 Unit Operations in Environmental Engineering I. Theory and application of physical and chemical unit processes and operations available for the treatment of water and wastewater.

CE 8823 Unit Operations in Environmental Engineering II. Theory and application of biological processes available for the treatment of wastewater.

CE 8843 Water Treatment Plant Design. An in-depth consideration of criteria for the selection of water sources for a potable supply. Theory and design considerations for selecting treatment alternatives.

CE 8923 Surface Water Quality Modeling. Development of the mathematical formulations describing the distribution of concentration of conservative and nonconservative pollutants describing the distribution of concentration of conservative in natural waters.

CE 8933 Surface Water Quality Modeling II. An advanced examination of surface water quality modeling including an overview of the present state-of-the-art as related to modeling of eutrophication and toxic materials (organic chemicals and metals) and review of recent trends.

CE 8953 Fine Sediment Processes. Clay mineralogy. Physical and chemical processes controlling fine-grained sediment transport, erosion, and deposition. Numerical modeling of fine sediment transport. Environmental effects of sediment.

Figure 4. Water Resources Management Graduate Coursework in Civil and Environmental Engineering at MSU

BIO 6213 Plant Ecology. Plant behavior in relation to environment; developmental variations; successional trends; stabilization of plant communities. (Fall).

BIO 6224 Aquatic Botany. Growth forms,taxonomy and morphology, and physiological adaptations of hydrophytic vegetation; ecological interactions involving hydrophytes; function of plants in aquatic ecosystems.

BIO 6324 Soil Microbiology. Soil microorganisms and their importance in ammonification, nitrification, and other biological processes.

BIO 6404 Environmental Micro. Terrestrial, aquatic, and subsurface microbial ecosystems. Microbiology of water and wastewater treatment, solid waste disposal, landfarming, impact of hazardous waste, and environmental reclamation.

BIO 6513 Ichthyology (Prerequisite: BIO 1504 or equivalent). Two hours lecture. Three hours laboratory. Structure, evolution, classification, and life histories of fishes of the world with emphasis on North American freshwater forms.

BIO 8043 Ecology & Environ. Investigation of biodiversity, ecological hierarchies, and interactions between biota and the environment. Includes as introduction to contemporary environmental science issues. BIO 8103 Advanced Ecology. Selected topics with special references to bioenergetics, population and human ecology; with student research project.

BIO 8113 Biogeography . Study of the geographic distribution of life. Emphasis placed on climatic, geologic, and human influence, dispersal mechanisms and evolutionary history.

BIO 8123 Physiological Ecol. An advanced study of physiological and metabolic adaptations of animals to variable factors in the environment.

BIO 8163 Invasion Ecology . Theoretical and empirical ecology of species invasion. Discussion-based with an emphasis understanding the invasion process from ecological, evolutionary, and biogeographical perspectives.

Figure 5. Water Resources-Related Graduate Coursework in Biological Sciences at MSU

Required Course List	Credits
Water Resources Law	2
Intro to Physical Geography	4

Water Management And Policy Course List	Credits
Take two of the following:	
Natural Resource Policy	2
Bus Senior Seminar	4
Econ of Natural Resources	3
Benefit-Cost Analysis	3
American Environmental History	3
Managerial Analysis Act I	3
Environmental Sociology	3

Water Science And Technology Course List	Credits
Take two of the following:	
Water Management	3
Principles of Ecology	3
Limnology	3
Phycology	3
Stream Ecology	3
Environmental Science	3
Surface Water Resource	3
Hydrogeology	3
Snow Dynamic & Accumulation	3
Principles of F&WL Mgt	3
Weather and Climate	3
Environ Chemistry	3
Soil Physics	3
Pollution Science	3

Figure 6. Coursework for a Water Resources Minor at Montana State University (adapted from: http://www.montana.edu/wwwcat/programs/wtsm.html)

1. Introduction
2. Nine Elements of a Watershed Protection Plan
3. State and Federal Perspectives on WPPs.
4. EPA Watershed Plan Builder
5. Working with Stakeholders to Move the Process Forward
6. Using Outreach to Develop & Implement WPPs
7. Partnership Building Experiences in Plum Creek
8. Communicating to Diverse Audiences to Achieve Your Goals
9. Web-Based Tools for Watershed Assessment & Management
10. Defining the Scope of the WPP.
11. Gathering data to assess your watershed.
12. Analyzing Data to Characterize Your Watershed.
13. Overview of Models for Estimating Pollutant Loads & Reductions
14. Perspectives on Monitoring, Modeling and Decision Making
15. Setting Goals & Identifying Load Reductions Needed
16. Pollutant Fate and Transport Mechanisms.
17. Agricultural NPS Measures and WQMPs.
18. Urban NPS Measures.
19. Wastewater Treatment Systems.
20. Other Approaches to Managing Pollutant Sources.
21. Prioritizing and Selecting Management Measures
22. Targeting Critical Areas and Scheduling Implementation.
23. Developing Interim Milestones & Criteria to Measure Progress.
24. Designing & Implementing Effectiveness Monitoring
25. Using Volunteer Monitoring For Assessment and Outreach
26. Texas Watershed Steward Program
27. Financing Watershed Implementation
28. Putting It All Together – Then What?

Figure 7. Topics in Texas Watershed Planning Course. (Adapted from http://watershedplanning.tamu.edu/docs/courses/2008-06/agenda.pdf)

Table 1: FIRST MODULE: WATERSHED PROCESSES

TOPIC	Hours	EPA Watershed Academy Module
1. Introduction	2	
a. Definitions: Hydrologic and Legal		Why watersheds?
b. Watersheds, Ecoregions, and human systems		Ecosystem services: benefits to human societies
c. Goals and Organization of the Course/Module		
2. Watershed Processes	20	
a. Geology and Soils		
b. Hydrology, Hydraulics, Morphology		
i. Hydrologic Unitsand stream order		
ii. Hydrologic Cycle – Surface and groundwater		
iii. Hydrodynamics		
iv. Geomorphologic Processes		
c. Atmosphere, Climate and Weather		
i. Climate and change		
ii. Weather-landscape interactions and predictions		
iii. Air quality and air deposition		
d. Water Quality		
e. Natural flora and fauna		
i. Terrestrial		Birds: bellwethers of watershed health

ii. Aquatic		Sustaining healthy aquatic ecosystems
f. Ecosystem Processes at Watershed & Ecoregion Scales		Introduction to watershed ecology Biodiversity and ecosystem functioning: maintaining natural life support processes
g. Geography and Zones – Arid, Humid, Tropical		
i. Upland		
ii. Streams		Protecting instream flows: how much water does a river need? Stream corridor structure
iii. Lakes & Reservoirs		Understanding lake ecology
iv. Wetlands		Wetland functions and values
v. Estuaries and Bays		The role of nearshore ecosystems as fish and shellfish nurseries
vi. Coastal zone		
h. Human Activities		Agents of watershed change Human alteration of the global Nitrogen cycle Nonpoint source pollution with Nitrogen and Phosphorus Growth and Water Resources
i. Landscape alteration		
ii. Water use		
iii. Hydromodification		
i. Culture and Social Systems		
3. Stressors	10	
a. Earthquakes, volcanoes, landslides, & debris flows		
b. Climate & Weather Variability		Watersheds: Connecting Weather to the Environment Weather and the Built Environment
c. Storms and Floods		
d. Invasive Species		Invasive non-native species

e. Faunal Imbalance		
f. Human Effects		Growth and Water Resources Nutrient pollution of coastal rivers, bays, and seas
4. Synthesis of Watershed Processes	10	
a. Connecting the Pieces		
b. Scalability and Understanding		
c. Specialists, Generalists, and Role of Teams		
TOTAL	42	

Table 2: SECOND MODULE: WATERSHED MANAGEMENT

TOPIC	Hours	EPA Watershed Academy
1. Introduction	3	
a. What is watershed management?		Principles of watershed management
b. Self-management at scales: plots to watersheds		
c. Regulatory Management		
d. Goals and Organization of the Course/Module		
2. Social, Cultural, & Economic Processes	8	
a. Stakeholders' multiple perspectives		
b. Balancing Public Interests – culture, health, economics, and environment		Economics of sustainability
c. Working with groups		
i. Group psychology		
ii. Communicating with stakeholders		
iii. Meetings, controversy and compromise		
3. Laws, Policies, and Practices	8	
a. Local, Tribal, State, & Federal Laws		Introduction to the Clean Water Act Key Concepts of Water Quality Standards Introduction to the Safe Drinking Water Act of 1996
b. Political Jurisdictions & Transboundary Issues, Basin Commissions		Statewide watershed management executive overview
c. Codes and Regulations		
d. Ethical Requirements		
e. Roles of Private Sector and Non-Governmental Organizations		
f. Financing		Developing a Sustainable Finance Plan
4. Management Practices	8	
a. Assessment and Problem identification		
b. Education and Communications		Getting in step: a guide for conducting watershed outreach campaigns
c. Remedies, e.g., Total Maximum Daily Loads		

TOPIC	Hours	EPA Watershed Academy
d. Matching Practices to Watershed Assessment and Problem Identification, scalability		
e. Best Practices by Sector		
i. Agriculture		Agricultural management practices for water quality protection
ii. Commercial & Residential		Source water protection: Best Management Practices and other Measures for protecting drinking water supplies Controlling underground injection of wastewater Advanced drinking water technology workshop Managing transient non-community drinking water systems
iii. Construction		
iv. Mining		
v. Silviculture		Forestry Best Management Practices in watersheds
vi. Transportation		
vii. Conservation Services		Stream corridor restoration tools Restoration: what's right/wrong with This picture
viii. Natural Resources Management		Applying ecological principles to management of the U.S. national forests Ecological principles for managing land use
f. Monitoring and Adaptive Management		Monitoring consortiums
5. Analysis and Synthesis Tools	8	
a. Tools Introduction		
b. Data Sources and Data Collection		Training in Use of the National Hydrography Data Set
c. Multi-objective Analyses		
d. Geographic Information Systems		
e. Geotechnical Predictions		
f. Climate & Weather Prediction		
g. Hydrologic and Hydraulic Modeling		Watershed modeling

TOPIC	Hours	EPA Watershed Academy
h. Water Quality Modeling		
i. Biotic Predictions & Modeling		Watershed ecological risk assessment
j. Social & Economic Predictions and Modeling		
k. Decision Support Tools		
6. Watershed Management Plans	10	Introduction to the watershed planning process
a. Contents of a Plan		
b. Steps in constructing a Plan		
i. Planning phase		
ii. Priority settings		
iii. Watershed strategy development		
iv. Implementation		
v. Evaluation		Rapid bioassessment protocols Watershed ecological risk assessment
vi. Monitoring		Overview of watershed monitoring
c. Case Studies		Top ten watershed lessons learned
TOTAL	43	

Table 3. **THIRD MODULE: APPLICATION (Labs)**

TOPIC	Hours	
1. Introduction	1	
2. Information Gathering	8	
3. Stakeholder Engagement	4	
4. Statement of Goals, Objectives, Targets	4	
5. Define Significant Processes and Stressors	8	
6. Apply Tools in Tiered Process	4	
7. Prepare Management Plan in Iterative Process	20	
8. Present Final Plan	8	
TOTAL	57	