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**Title**: Watershed Scale Sediment TMDL model

**Objective**: Produce a watershed analysis and management model with the ability to simulate the movement of water, sediment and associated constituents at the watershed and regional scales for long-term periods (weeks to years) and single storm events. It will also form one component of the Cascade-I regional morphology model.

**Problem**: Sediment yield from watersheds is an integral part of nonpoint source contributions to excessive sediment in receiving waters, and can adversely affect USACE water resource projects. A reliable and accurate model is needed to assess watershed sediment erosion and transport so that management practices can be evaluated and downstream problems can be diagnosed. Lumped parameter models presently in use provide too little detail and are insufficiently accurate for these tasks under present and emerging rules.

**Benefits:** The model will benefit the USACE, military, EPA and other Federal, state and local agencies by allowing a comprehensive analysis of water and sediments at the watershed and regional scales. The model will be used for locating sediment source areas, predicting mass fluxes at points within the watershed, and simulating effects of Best Management Practices (BMPs. The work will provide the major product TMDL Evaluation Models and a component of the Regional Morphology Model.

The resulting model will be most useful for management of sediment at the watershed and regional scales. The model will be used to locate sediment source areas, track sediment movement, calculate mass fluxes at watershed outlet and at interior points, and analyze the impact of BMPs. Because the model will provide information at many points within the watershed on a continuous basis, TMDLs will be calculating by integrating available information. Management practices that may affect sediment or constituent loadings can be simulated by adjusting parameter values within individual cells that represent the management practice.

The work unit addresses specific needs identified as high priority by USACE users through a series of surveys and meetings. USACE personnel expressed the high priority need for watershed and regional scale sediment models that can be used to calculate total maximum daily loadings (TMDLs) and analyze best management practices for single storm events and for long-term simulations. Personnel also expressed a concern that the models be applicable for a broad range of problems and also are useable by personnel working at the District level. This proposed work can satisfy these diverse needs.

This work produces new tools and methods for the USACE and nation. It is an integral part of the Regional Sediment Management Research Program, and thus contributes primarily to support of the USACE's navigation, flood/storm damage reduction, and environmental protection and quality missions. It supports all 8 Civil Works strategic goals and 7 of 9 Listening Session objectives identified by HQUSACE as R&D priorities. With companion work units, it employs active technology transfer and insertion.

**Work Description**: The listed benefits and major product will be realized by including needed processes in the existing comprehensive watershed hydrology model *GSSHA* (Gridded Surface Subsurface Hydrologic Analysis). *GSSHA* simulates both surface and subsurface hydrology using finite difference and finite volume methods. *GSSHA* was developed within the Watershed Systems Group of the Coastal and Hydraulics Laboratory, in collaboration with Professor Fred Ogden at the University of Connecticut. Professor Ogden was the primary developer of *CASC2D*, a Hortonian flow hydrologic model that is the predecessor of the *GSSHA* model.

*GSSHA* provides a prudent starting point for TMDL analysis at the watershed/regional level because of its stability, robustness, and applicability in a variety of hydrologic regimes. While *GSSHA* currently contains empirical sediment erosion, deposition, and transport, the model requires modifications before it can be extended beyond the scope of hydrologic analysis at the watershed scale. In order to simulate sediments, *GSSHA* requires the ability to simulate sediment source/sink areas and a viable transport algorithm. In order to extend the capability of *GSSHA* beyond watershed analysis for a limited time period, the structure of *GSSHA* needs to be more flexible and model parameters need to reflect their known seasonal variability. The following improvements to the model will be made:

1. Overland transport - Transport of sediments/constituents on the overland flow plane will be added to the *GSSHA* model in the form of the 2-D advection-dispersion (AD) equation. The 2-D AD equation will be solved using finite volume techniques. The same equation can be used to transport both sediments and other constituents associated with sediments. Upon encountering a stream segment, the constituents will be routed with a 1-D AD scheme already employed in the channels.

2. Source/Sink Terms - on the overland flow plane sediment erosion, transport and deposition will be quantified based on first principle equations. The detachment of sediments and transport limited detachment of sediments, as well as the effects or rainfall impact will be included. Currently available methods will be investigated, and the most rigorous methods that provide a fit with the *GSSHA* structure will be selected. Developments by the Processes Task Area work units, notably “Freeze-Thaw Effects” will also be incorporated into the schemes used. The work will be leveraged with ongoing work in the Military AT-40

program on rainfall impact and particle detachment. And the products for this program will be timed to take advantage of advances from the AT-40 program.

3. Seasonality of parameters - The *GSSHA* model requires a large number of parameters in order to simulate the many physical processes that determine hydrologic response. Many of these parameters have a strong seasonal variability that is not reflected in the value of the parameters. This has resulted in the model primarily being applied to simulate watersheds during the summer growing season where parameters used in the model are relatively constant. To extend the applicability of *GSSHA* to longer periods of time the model needs to reflect the seasonality of different parameters known to vary during the year. The list of seasonally varying parameters includes overland roughness, vegetation height, surface albedo, canopy resistance, and rainfall interception. The seasonality of these, and other, parameters affect both the amount and timing of water and sediment produced at the watershed and regional scales.

4. The model will be structured so that it can be embedded in the Cascade-I model being created under the “Regional Morphology Model” work unit.

Instantaneous point constituent concentrations and flows can be integrated to calculate total maximum daily loadings (TMDLs) at any point in the watershed. The implementation of processes will be done at a level that allows the model to be used by professional engineers with a basic knowledge of hydrology and sediment transport. Graphical model results will provide resource managers the information needed to easily assess current conditions and various management alternatives. The model will run in a timely manner that will allow a broad range of BMPs and multiple management scenarios to be analyzed before costly implementation in the field.

The proposed model will be used to manage water and sediment at the watershed and regional scales by varying the model grid size, and combining a number of watershed models to create a single regional model. Because the model is physics/process based, the model is not application/scale specific and can work in any type of hydrologic regime. This feature allows the model to be extrapolated to assess future conditions such as application of best management practices. Because the model will provide both overland and in-stream sediment flows, TMDLs and effects of management practices can be evaluated for both the overland and in streams and rivers. Integration of the model with *WMS 6.1* and linkage to data from various GIS applications including *GRASS* and *ARCINFO*, allows the model to be used by District level engineers and scientist, and also allows the results of the model to be used in management decisions.

The model will fit into the graphical interface being developed under the “Graphical User Environment” work unit.

The products generated as a result of this work unit will be the building blocks needed to complete the next unit for Task B3.1 - Modeling and Assessment, Improved Multi-Dimensional Sediment Processes Models. This work unit, titled Improved In-stream Sediment Routing Capabilities for the GSSHA Model, will complete the current work by addressing deficiencies in the channel routing of sediments in the current model. Major products from this work unit will include improved hydrodynamics, improved in-stream sediment transport, and the inclusion of variable grid sizes for both overland and in-stream processes.

**Products**:

The primary product of this work will be the improved GSSHA model.

| Product | Scheduled |
|---|---|
| 1. GSSHA program with overland transport algorithm | Q3/02 |
| 2. TN: Overland transport of sediments in GSSHA | Q4/02 |
| 3. TN: Watershed sediment erosion and deposition | Q2/03 |
| 3. GSSHA program with improved sediment erosion/deposition | Q4/03 |
| 4. TN: Seasonality of watershed sediment parameters | Q1/04 |
| 5. GSSHA program which includes seasonality of parameters | Q3/04 |
| 6. TN: Users manual for GSSHA with sediment transport | Q3/04 |
| 7. JP: GSSHA with overland sediment transport | Q4/04 |