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Advances in Modeling Methodology for Agricultural Research

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To meet the increasing demand of our contemporary society on agricultural productivity, soil conservation, maintaining quality water supply, protection of ecology and environment, and effective utilization of limited financial resources, the research, engineering, planning and management of today's agricultural watersheds have become involved, complex, challenging and cost/time demanding. The research methodologies based on traditional scaled physical model testing, field observation, analytical (mathematical) prediction assisted by computing technology have found to have been ineffective, inadequate, and extremely costly in terms of money and time. Evidently, better and more cost-effective methodologies are needed. With rapid improvement in computing technology together with significant advances in mathematical/numerical modeling, a wider range of scientific research, engineering designs, planning and management problems could be investigated.

The National Center for Computational Hydroscience and Engineering of the School of Engineering at The University of Mississippi was supported by the US congress in 1989 to foster the computational modeling research in collaboration with the USDA Agricultural Research Service, National Sedimentation Laboratory. Since then, a number of computational models have been developed to study various agricultural watershed problems. These include: soil erosion and conservation, water and sediment in upland runoff and routing, sill and gully erosion, channel bank erosion and protection, dam/levee breach and flooding, dam rehabilitation, removal and sediment transport control, among other morphodynamic processes of watersheds. In the meantime, models needed for investigating water quality, impact of sediment transport on ecology and environment, etc., have also been developed. Most of these models have been demonstrated their capability of simulating the natural phenomena, at least approximately and cost-effectively, especially in time. Therefore the development of numerical models has been accelerated. With more institutions competing in producing and marketing of a large number of simulation models without carefully maintaining their quality, both professionals in the field and, especially, the professional societies, national and international, have promoted the efforts in verification and validation of the accuracy and reliability of numerical models.

The American Society of Civil Engineers is one of the leading societies in the field to have established task committees to uphold the quality of these newly developed research methodologies. The ASCE Task Committee on 3D Free Surface Flow Model Verification and Validation report was published by the ASCE in 2001. A systematic hydrodynamic model verification and validation procedure was suggested to both model developers and users how to develop and select quality models.

All computational models developed by scientists of NCCHE have been verified by analytic solutions and validated by both physical model measurements and field data to insure that models are free of mathematical and coding errors and capable of simulating real-life natural phenomena. In addition, all models of NCCHE have been continuously upgraded with newly reported physical principles and laws, as well as newly developed numerical solution methods. Furthermore, the new and more effective computing and information technologies, such as GUI, GIS databases, GPU, etc., have all been implemented to improve the capability and speed up the computing speed. In this brief review, several representative examples are presented to demonstrate the capabilities and effectiveness of the NCCHE models.

More recently, additional models and integrated modeling systems have been also developed for applications to the study of watershed processes of higher level of complications, as well as for the planning and management decision support, especially those decisions requiring the multi-disciplinary concerns. For example, an agricultural watershed management decision on what products to plant, what soil conservation, water and environmental quality to adopt, so that its profit/cost ratio can be higher and top soil and quality water can be conserved and the environmental quality can be protected to the level acceptable by our society. To support the decision makers, models capable of assessing the effectiveness of conservation of top soils, quality water supply, impacts on environment and ecology as well as predicting the agricultural products and the total costs of several selected alternative practice plans. Based on all of the reliable information generated by the agricultural engineering and cost analysis models, the soil erosion/transport models, water quality and agricultural contaminant transport/transformation models, environment/ecology quality prediction models, etc, the planning and management officials have a better way to select the best (often compromised) decision. From this simple planning and management decision support modeling system, one can see the need of a computational modeling system, which can make all the important predictions of the outcomes for each of the several options of practices systemically within a reasonable time as automatically as possible by an integrated application software system. Even though we have seen this trend is being developed for simpler applications to site-specific problems, the integrated computational modeling methodology applicable to agricultural watershed problems with higher level of complexity and multidisciplinary considerations need by our society now and especially in the future is quite challenging. Some recent ideas and accomplishments are presented; but more importantly, it's hoped that this presentation shall stimulate newer and more valuable contributions from the research professional in the field.