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中文题名	三维水沙及水质数学模型的研究与应用
英文题名	Three-dimensional Mathematical Model of Sediment-laden Flow and Water Quality
中文关键词	三维数值模拟;水沙输运;富营养化;斜对角方法;多维迎风格式
英文关键词	three-dimensional numerical simulation;flow and sediment transport;eutrophication model;diagonal Cartesian method;multidimensional upwind scheme
中文文摘	不同水体中的水流、泥沙、污染物等物质输运及生态动力学过程均具有三维特性。描述该特性的三维数学模型发展至今，已经获得了相当的经验，但仍迫切需要加强对其理论方法及实际应用的研究。本文在已有工作的基础上，发展了三维水沙水质数学模型，能够根据需求利用不同计算手段对水沙输移及其引起的河床变形、污染物的对流扩散和水体富营养化等现象进行三维数值模拟。从模拟区域的特征和三维模拟的求解特点出发，三维数学模型的方程与求解模式分为两大类，一类是全三维模型，适用于河道水槽等相对区域较小、而紊动性较强的区域，采用标准的 双方程紊流模型和 SIMPLE 算法求解。论文利用矩形水槽方柱绕流算例对模型进行了验证，并应用到具有多个桥墩的实际河道中，较好地反映了桥墩群修建前后环流发展以及自由水面的变化情况；进一步，研究又从数值计算的网格分析出发，将不平衡输沙长度取为网格长度的函数，改进后的水沙模型较好地模拟了多丁坝永定河水沙分布、河床变形规律。另一类是分层三维模型，适用于水域较宽阔的河口海岸及湖泊水库的模拟，采用 M-Y2.5 阶紊流模型及过程分裂法求解。为了解决不规则边岸的拟合问题，采用斜对角笛卡尔方法改进模型计算的边界网格，有效地削减了边界处的锯齿效应；为了缓解在网格 Peclet 数较大情况下传统迎风格式出现的假扩散现象，采用多维迎风格式处理对流项，并利用旋转 45 度后的方腔流算例对格式进行了对比验证。论文对模型在水环境领域的应用进行了深入研究，采用太阳辐射引起的水面热交换方程和以浮游植物生长动力学为基础的富营养化模型，模拟了电厂温排水在潮汐海域中的三维扩散运动和官厅水库的富营养化现象，全面的反映了水体分层规律，以及富营养化水体中叶绿素浓度、氮磷营养物质的循环过程等。从模型在典型区域水沙及水环境中的应用中可看出，发展后的三维数学模型提高了计算精度和计算效率，扩大了应用范围，为三维数学模型的广泛使用提供了重要的技术支持。
外文文摘	Three-dimensional (3D) movement is an important characteristic of water flow and transports of sediments and other water quality constituents. In the past several decades, many numerical models have been developed to describe 3D flow structures. Yet, due to its complexity, continuing research is still needed for the improvement of both fundament theory and application methodology in 3D numerical modeling. In this dissertation, a 3D mathematical model on sediment transport and water quality is improved to meet the needs for the different engineering projects. The model is capable of simulating the special 3D characteristics of water flow, sediment transport and river bed deformation, water temperature stratification, and eutrophication in lakes or reservoirs, etc.Based on different fluid dynamics in different water regions, two kinds of 3D numerical models are presented respectively. The first kind is the full 3D model, which focuses on the small scale with strong turbulence such as river or flume. The turbulent model and structural curvilinear grid are applied in the model, in which the water level is resolved with 2D possion-equaion and the model technique is SIMPLE. The bed load transport model is improved by introducing the non-equilibrium adaptation length to classify different numerical scheme, addressed the relationship with the size of the calculated cell. The enhanced model is used to calculate the velocity field and water level variations by the piers in Liangshui River near Beijing South Railway Station and the flow and sediment transport around groynework located in Yongding River respectively. The results from model simulating indicate that the enhanced model can reasonabely characterize the 3D feature of secondary flow, sediment concentration and river bed deformation caused by the construction of the hydro structure.Another kind of model is multiple-layer quasi 3D model for large modeling for estuaries, lakes, reservoirs and coastal waters. A turbulent model of Mellor-Yamada level 2.5 and mode-split solution technique are applied in the model. The 3D diagonal Cartesian method is used to improve the boundary zigzag effects caused by the orthogonal grids, and the multidimensional upwind scheme is adopted to improve the false diffusion caused by traditional upwind scheme in large grid Peclet number

	situations. In order to evaluate the multidimensional upwind scheme, a test case of rotating the cavity flow in 45 degree is selected to compare the numerical calculation cases at the different Reynolds numbers. Based on the equation of the solar radiant heat exchange at water surface, and the phytoplankton growth model, a water temperature and eutrophication model is presented in this dissertation. The 3D convection-diffusion process in tidal water of power plant thermal discharge and the water quality process in Guanting reservoir are simulated by this model. Numerical results show that the model is efficient and reliable in modeling the stratification induced by water temperature and the Chl-a & nutrient cycle process in eutrophication reservoir.The successful applications of the model in hydrodynamic, sediment and water environment have demonstrated the improvement of 3D numerical model enhanced in this study. It shows that the enhanced model leads to the increase of model accuracy, efficiency and model capability for various engineering applications. The model presented in this study can be used as a useful tool to support for further applications of engineering problem.
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