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Procedia Engineering 154 (2016) 574 – 581

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Hydroinformatics, HIC 2016

Research on the Strength and Space-time Distribution of Sedimentation of Yi-Zheng Segment in Phase-Ⅱ Project of Deep Water Channel Construction of Yangtze River

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Abstract

Phase-Ⅱ Project of Deep Water Channel Construction of Yangtze River(2014-2015), including the Yi-Zheng Segment, enables the water depth of Yangtze River Channel between Nanjing and Nantong arrive 12.5 meters. This thesis analyzes the sedimentation movement of Yi-Zheng Segment with mathematical model, makes prediction of the sediment's strength and space-time distribution. The simulation results indicate that the yearly dredging quantity of 1998 and 2010, two typical hydrological years, are 1.528 million m3 and 0.499 million m3 separately. The main maintenance months are October, November and December during the dry season, while the main maintenance parts are the channel from Dadaohe to Majiakou, the channel from Majiakou to Qibaidu, the channel from Qibaidu to Longmenkou in the right branch of Shiyezhou. These results could be helped to provide support of later dredging operation for keeping deep water Channel of Yi-Zheng Segment.

Peer-review under responsibility of the organizing committee of HIC 2016

Keywords: Yangtze River, Yi-Zheng Segment, sediment's strength, sediment's space-time distribution;

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1877-7058
Peer-review under responsibility of the organizing committee of HIC 2016
doi:10.1016/j.proeng.2016.07.554

Introduction

The 12.5-meter Deep Water Channel of Yangtze River downstream Nanjing is to preliminary open up at the end of the 12th Five-Year Plan. Together with the massive deep water channel construction, the ordinary dredging maintenance quantity will rise significantly. It's rather important to forecast the time-space distribution of sediment in the 12.5-meter deep water channel, which can help to reveal the regional dredging quantity in different months, thus provides reliable support to the dredging and maintenance work plan.

Phase-Ⅱ Project of Deep Water Channel Construction of Yangtze River(2014-2015) ,including the Yi-Zheng Segment, enables the water depth of Yangtze River Channel between Nanjing and Nantong arrive 12.5 meters. This thesis analyzes the sedimentation movement of Yi-Zheng Segment with mathematical model, makes prediction of the sediment's strength and space-time distribution, and provides support of later dredging operation of deep water Channel of Yi-Zheng Segment[1-2].

Equations and Establishment of Numerical Model

(1)Hydrodynamics Equations, as in Eq. [1-3].

$$\frac{\partial Z}{\partial t}+\frac{1}{C_\xi C_\eta}\left[\frac{\partial\left(C_\eta Hu\right)}{\partial\xi}+\frac{\partial\left(C_\xi Hv\right)}{\partial\eta}\right]=0 \tag{1}$$

$$\frac{\partial(Hu)}{\partial t}+\frac{1}{C_\xi C_\eta}\left[\frac{\partial}{\partial\xi}\left(C_\eta Huu\right)+\frac{\partial}{\partial\eta}\left(C_\xi Hvu\right)+Hvu\frac{\partial C_\xi}{\partial\eta}-Hv^2\frac{\partial C_\eta}{\partial\xi}\right]=-\frac{gu\sqrt{u^2+v^2}}{C^2}-\frac{gH}{C_\xi}\frac{\partial Z}{\partial\xi}+\frac{1}{C_\xi C_\eta}\left[\frac{\partial}{\partial\xi}\left(C_\eta H\sigma_{\xi\xi}\right)+\frac{\partial}{\partial\eta}\left(C_\xi H\sigma_{\eta\xi}\right)+H\sigma_{\xi\eta}\frac{\partial C_\xi}{\partial\eta}-H\sigma_{\eta\eta}\frac{\partial C_\eta}{\partial\xi}\right] \tag{2}$$

$$\frac{\partial(Hv)}{\partial t}+\frac{1}{C_\xi C_\eta}\left[\frac{\partial}{\partial\xi}\left(C_\eta Huv\right)+\frac{\partial}{\partial\eta}\left(C_\xi Hvv\right)+Huv\frac{\partial C_\eta}{\partial\xi}-Hu^2\frac{\partial C_\xi}{\partial\eta}\right]=-\frac{gv\sqrt{u^2+v^2}}{C^2}-\frac{gH}{C_\eta}\frac{\partial Z}{\partial\eta}+\frac{1}{C_\xi C_\eta}\left[\frac{\partial}{\partial\xi}\left(C_\eta H\sigma_{\xi\eta}\right)+\frac{\partial}{\partial\eta}\left(C_\xi H\sigma_{\eta\eta}\right)+H\sigma_{\eta\xi}\frac{\partial C_\eta}{\partial\xi}-H\sigma_{\xi\xi}\frac{\partial C_\xi}{\partial\eta}\right] \tag{3}$$

Where, u and v are velocity components of V in ξ and η directions; Z is the tidal level; H is the total water depth; t is time; g is the acceleration of gravity; C is Chezy coefficient; and $\sigma_{\xi\xi}$,$\sigma_{\eta\eta}$,$\sigma_{\xi\eta}$,$\sigma_{\eta\xi}$ are turbulent shear stress[3-4].

(2)Suspended Load Sediment Transport Equation, as in Eq. [4].

$$\frac{\partial(HS_i)}{\partial t}+\frac{1}{C_\xi C_\eta}\left[\frac{\partial}{\partial\xi}(C_\eta HuS_i)+\frac{\partial}{\partial\eta}(C_\xi HvS_i)\right]=\frac{1}{C_\xi C_\eta}\left[\frac{\partial}{\partial\xi}(\frac{\varepsilon_\xi}{\sigma_s}\frac{C_\eta}{C_\varepsilon}\frac{\partial S_i}{\partial\xi})+\frac{\partial}{\partial\eta}(\frac{\varepsilon_\eta}{\sigma_s}\frac{C_\xi}{C_\eta}\frac{\partial S_i}{\partial\eta})\right]+\alpha_i\omega_i(S_i^*-S_i) \tag{4}$$

Where, α is the saturation recovery coefficient of sediment; ω_i is the settling velocity of sediment for group I; S_i is the sediment concentration of different grain size; S_i^* is the sediment carrying capacity, $S^*=K\left(u^3/gH\omega_s\right)^m$; ε_ξ and ε_η are sediment diffusion coefficient in ξ and η directions, $\varepsilon_\xi=\varepsilon_\eta=\nu_t$; σ_s is constant, 1.0 [4-5].

(3)Bed Load Sediment Transport Equation, as in Eq. [5].

$$\frac{\partial HN_i}{\partial t}+\frac{1}{C_\xi C_\eta}[\frac{\partial}{\partial\xi}(C_\eta HuN_i)+\frac{\partial}{\partial\eta}(C_\xi HvN_i)]=\beta_i\omega_{si}(N_i^*-N_i) \tag{5}$$

Where , N_i is the bed load sediment concentration for group I; ω_{si} is the settling velocity of bed load sediment for group I; $N_i^*=q_{bi}^*/Hv$; q_{bi}^* is the bed load sediment transport rate of different grain size, which is calculated by the Dou Guoren formula, $q_{bi}^*=(k/c^2)*(rr_s/(r_s-r))*m_i*(u^2+v^2)^{3/2}/(g\omega_{si})$ [4-5].

(4)Riverbed Deformation Equation, as in Eq. [6].

$$\gamma_0\frac{\partial Z_b}{\partial t}+\frac{1}{C_\xi}\frac{\partial g_{b\xi}}{\partial\xi}+\frac{1}{C_\eta}\frac{\partial g_{b\eta}}{\partial\eta}=\sum_{i=1}^n\alpha\omega_i(S_i-S_i^*) \tag{6}$$