Program description SwanOneSed

Calculation of longshore sediment transport on the basis of SwanOne

The starting point is the output file from Swan. In this file in every computational point the following values are given:

- Xp coordinate along the computational profile
- Hs calculated value of H_{m0}
- T_{peak} Peak period of the spectrum
- T_{m01} period calculated with $\sqrt{(m_0/m_2)}$
- T_{m-01} period calculated with m_{-1}/m_0
- Dir main direction of the waves
- Dspr directional spreading
- h water depth below computational level
- Setup calculated wave set-up

As a first step in the calculation for every point the local wavelength is calculated. This is done with the estimator according to VISSER [1984], followed by a fast iteration to improve the value:

$$L = \sqrt{gh \cdot}\left(1 - \frac{h}{L_0}\right)T \qquad for\ \frac{h}{L_0} < 0.36$$

$$L = L_0 \qquad for\ \frac{h}{L_0} \geq 0.36$$

$$L_* = L_0 \tanh\left(\frac{2\pi h}{L}\right)$$

$$L = \frac{2L_* + L}{3}$$

Linear wave theory is used to calculate the orbital excursion:

$$a = \frac{1}{2} H_{m0} \sin\left(\frac{2\pi h}{L}\right)$$

The following approximation of the longshore velocity is based on the method of Bijker, as described in MASSIE [1986].

Friction coefficient is calculated according to formula of Jonsson (as presented in MASSIE [1986])

$$f_w = \min\left[\exp\left(-5.977 + 5.213\left(\frac{a}{r}\right)^{-0.194}\right), 0.32\right]$$

in which r is the bottom roughness. A practical value is r = 0.06 m.

The Chézy coefficient is calculated using:

$$C = 18\log^{10}\left(\frac{12h}{r}\right)$$

The wave number is:

$$n = 0.5\left[1 + \frac{4\pi h/L}{\sinh\left(4\pi h/L\right)}\right]$$

The total wave energy is:

$$E = \frac{1}{8}\rho_w g H_{m0}^2$$

The xy radiation stress component is:

$$S_{xy} = En\sin\varphi\cos\varphi$$

Because in SwanOne in every point H_{m0} and f is known, S_{xy} can be calculated straightforward in every point. Subsequently in every point the value $\mathrm{d}S_{xy}/\mathrm{d}x$ can be calculated by numerical differentiation in subsequent points.

The value $\mathrm{d}S_{xy}/\mathrm{d}x$ is in fact the force exerted on the water, trying to accelerate this. Assuming constant flow velocity, this force has to be equal to the bed shear:

$$S_{xy} = \tau_{cw}$$

An equation for the bed shear is given in MASSIE [1986] (eq. 15.37):

$$\tau_{cw} = \frac{\rho_w}{\pi C}\sqrt{2gf_w}\,u\cdot u_w$$

in which u is the longshore velocity and u_w the maximum orbital bed velocity of the wave calculated with linear wave theory:

$$u_w = \frac{\pi H_{m0}}{T_p \sinh\left(\frac{2\pi}{L}h\right)}$$

This can be rewritten as:

$$u = \frac{\frac{dS_{xy}}{dx}\pi C}{u_w \rho_w \sqrt{2gf_w}}$$

For sediment transport the formula of Van Rijn (see VAN RIJN [2013]) are used.

The critical orbital velocities are calculated as follows:

$$
\begin{aligned}
u_{cw} &= 0.24\left(\Delta g\right)^{0.66} d_{50}^{0.33} T_p^{0.33} && \text{for } 0.0001 < d_{50} < 0.0005\,\text{m}\\
&= 0.95\left(\Delta g\right)^{0.57} d_{50}^{0.43} T_p^{0.14} && \text{for } 0.0005 < d_{50} < 0.002\,\text{m}\\
u_{cc} &= 0.19 d_{50}^{0.1} \log\left(\frac{12h}{d_{90}}\right) && \text{for } 0.0001 < d_{50} < 0.0005\,\text{m}\\
&= 8.5 d_{50}^{0.6} \log\left(\frac{12h}{d_{90}}\right) && \text{for } 0.0005 < d_{50} < 0.002\,\text{m}
\end{aligned}
$$

Bed load and suspended load are computed according to Van Rijn:

$$
\begin{aligned}
S_b &= \alpha_b \rho_s u h \left(\frac{d_{50}}{h}\right)^{1.2} Me^{1.5}\\
S_s &= \alpha_s \rho_s u d_{50} Me^{2.4} d_*^{-0.6}\\
S_{tot} &= S_b + S_s
\end{aligned}
$$

The coefficients α_b and α_s are α_b= 0.015 and α_s = 0.008-0.012 are recommended in VAN RIJN [2013].

The dimensionless grain size is given by:

$$
d_* = d_{50}\left(\frac{\Delta g}{\nu^2}\right)^{1/3}
$$

in which the kinematic viscosity ν = 1.787·10^{-6} m^2/s for water of 0 °C and 1.3·10-6 m^2/s for water of 10 °C.

The multiplier *Me* is calculated using:

$$
\begin{aligned}
u_e &= u + \gamma u_w\\
\beta &= \frac{u}{u + u_w}\\
u_c &= \beta u_{cc} + (1-\beta) u_{cw}\\
Me &= \max\left[\frac{(u_e - u_c}{\sqrt{\Delta g d_{50}}}, 0\right]
\end{aligned}
$$

The coefficient γ = 0.4 for regular waves and γ = 0.8 for irregular waves.

The sediment transport formula of Van Rijn are calibrated using T_p. However, in this program preference is given to $T_{m-1,0}$. For a smooth Jonswap spectrum (which is probably used for the cases of calibrating the Van Rijn formula one may relate them using:

$$
T_p = 1.1 T_{m-1,0}
$$

Therefore in all places where Van Rijn uses T_p, this has been replaced in the SwanOneSed code by 1.1$T_{m-1,0}$

References:

MASSIE, W.W. [1986] Coastal Engineering II, Harbor and beach problems, lecture notes TU Delft

VAN RIJN, L.C. [2013] Simple general formulae for sand transport in rivers, estuaries and coastal waters. Aqua Publications, Amsterdam

VISSER, P.J. [1984] A mathematical model of uniform longshore currents and comparison with lab data, rep. nr. 82-1, fac. Civil Eng, Delft University.