SCOTTISH UNIVERSITIES GEOTECHNICAL NETWORK

----SUGN Research Day 2006 / University of Napier

A Process-Based Numerical Model to Predict Coastal Cliff-Beach Erosion due to Wave Actions

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  - 2.3 Energy model --- Mass movement
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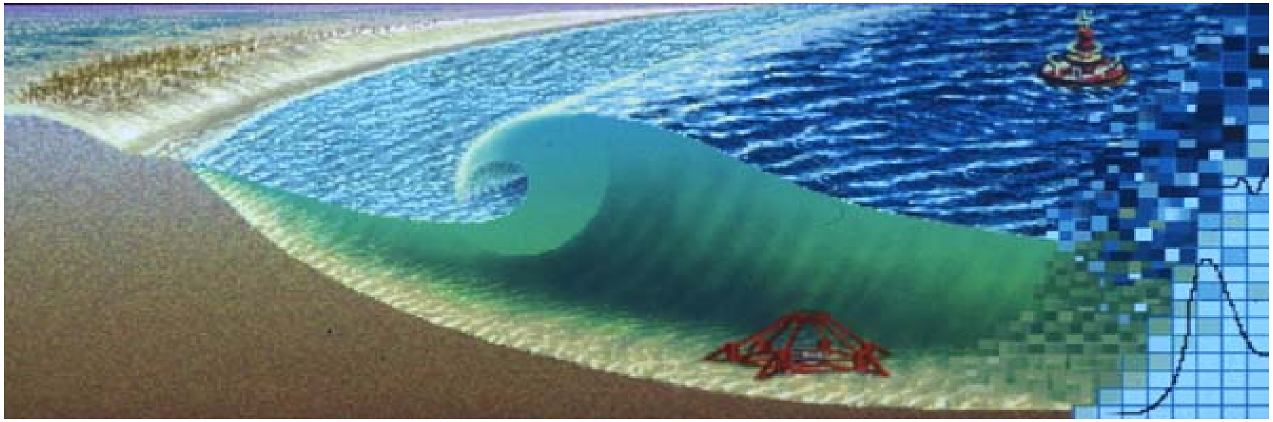
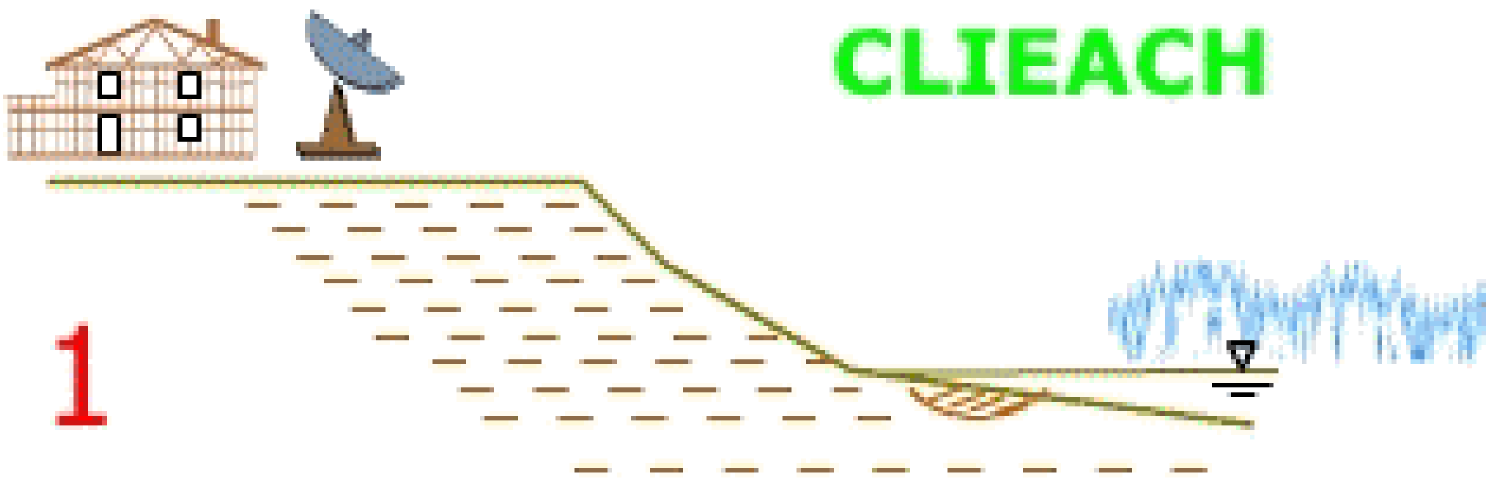
1 Mechanisms:
Cliff erosion compact



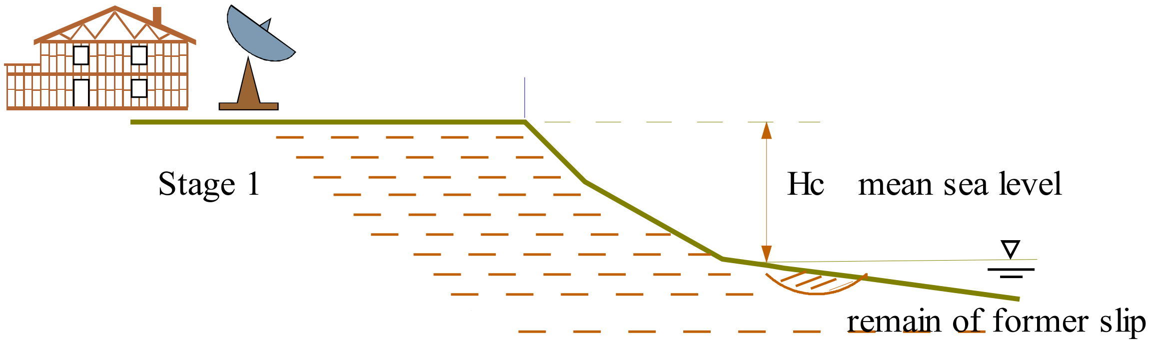
1 Mechanisms:
Cliff erosion compact

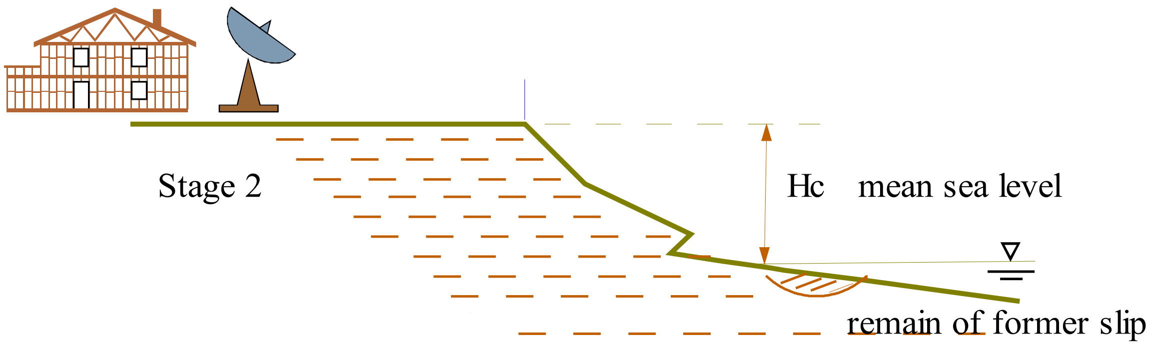
1 Mechanisms:
Cliff erosion due to wave undercutting



Continual wave action transport the debris offshore. The cliff base is again exposed to waves to suffer erosion

1 Mechanisms:
Suggested successive stages of retrogression subjected to strong toe erosion

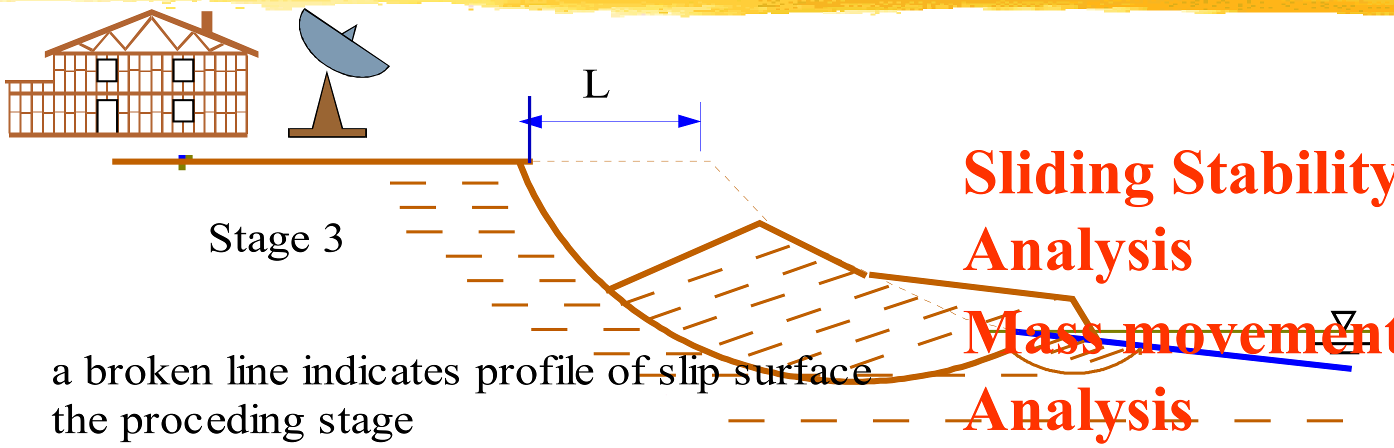




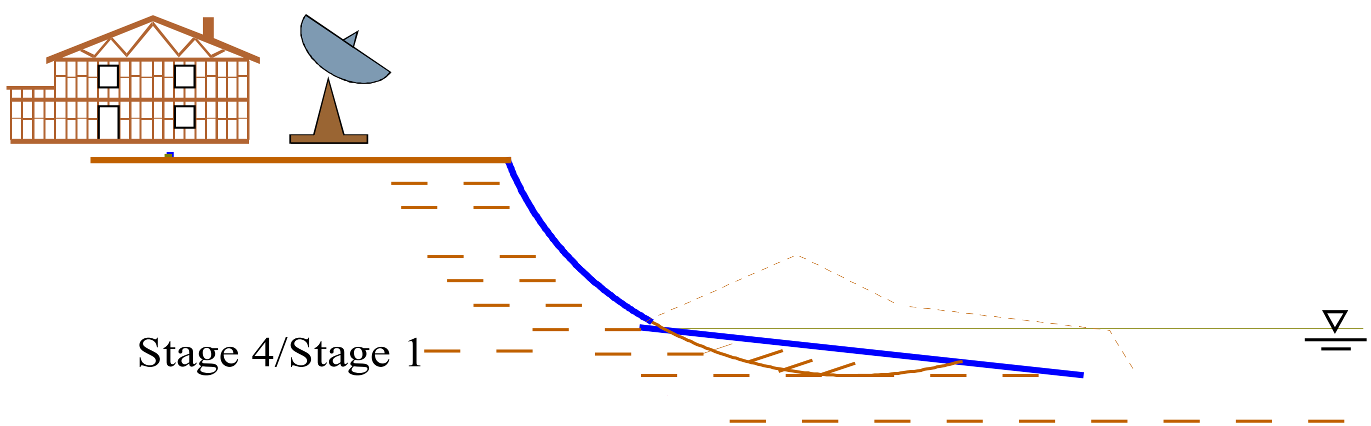
Beach Erosion

Sbeach model

1 Mechanisms:
Suggested successive stages of retrogression subjected to strong toe erosion

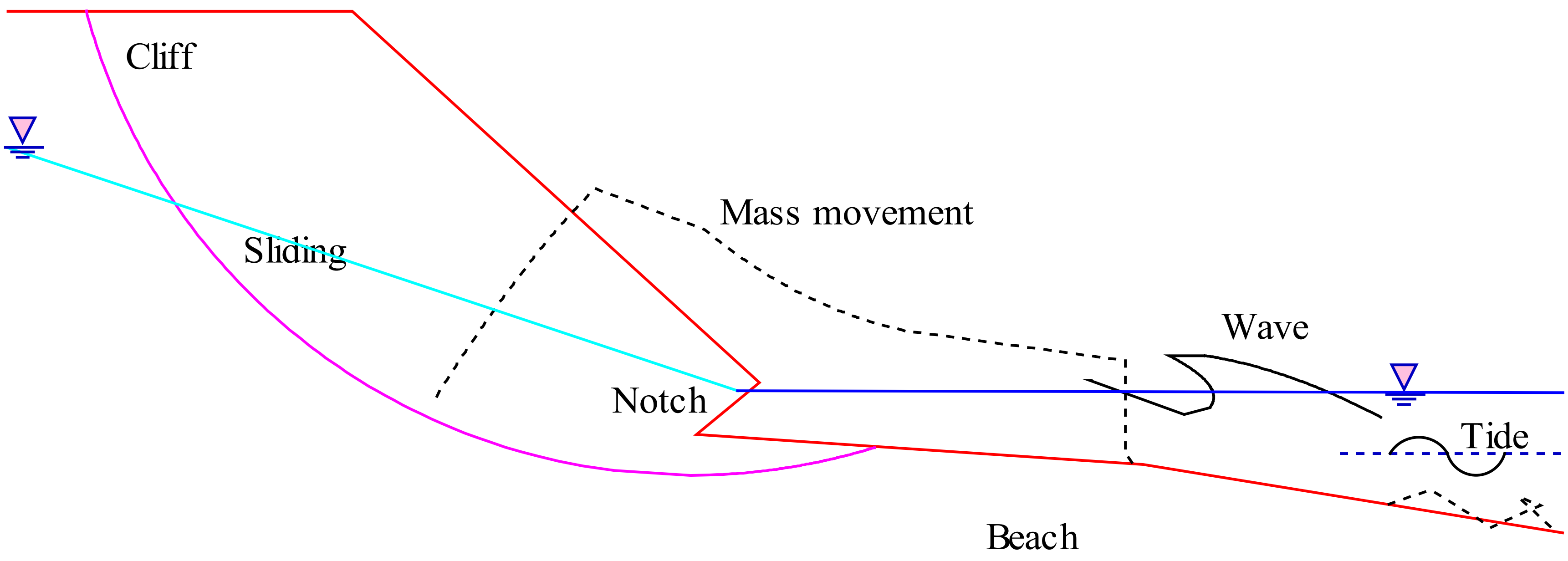


arrested failures



The sea continues to erode the face of the slipped mass. The process of grinding down beach particles into smaller and smaller pieces. Until they are carried out to deep water

Real world -> Abstract model -> Numerical model



2 Modelling: 2.1 Sbeach model
2.1.1 Control equations

Look at changes in the *beach profile* (depth as a function of offshore distance) (Karus and Larson 1989)

$$\frac{\mathrm{d}F}{\mathrm{d}x} = \frac{\kappa}{d}(F - F_{st})$$

wave transformation

$$q = K(D - D_{eq})$$

net cross-shore transport rate

$$\frac{\mathrm{d}q}{\mathrm{d}x} = \frac{\mathrm{d}d}{\mathrm{d}t}$$

beach change

$$\frac{d_i^{k+1} - d_i^k}{\Delta t} = \frac{1}{2}\left[\frac{q_{i+1}^{k+1} - q_i^{k+1}}{\Delta x} + \frac{q_{i+1}^k - q_i^k}{\Delta x}\right]$$

$$\sum_{i=1}^{N} \Delta d_i = 0$$

2 Modelling: 2.1 Sbeach model
2.1.2 Equilibrium Beach Profiles Dean (1977)

The sediment scale parameter A and the equilibrium wave energy dissipation per unit volume D* are related by (Dean 1977)

$$D_{eq} = \frac{5}{24}\rho g^{2/3}\gamma^2 A^{3/2}$$

wave energy dissipation per unit water volume

$$D = \frac{1}{d}\frac{\mathrm{d}(F)}{\mathrm{d}x} = \frac{5}{16}\rho g^{2/3}\gamma^2 d^{1/2}\frac{\mathrm{d}d}{\mathrm{d}x}$$

shallow-water wave theory

$$F = \frac{1}{8}\rho g H^2\sqrt{gd}$$

2 Modelling: 2.1 Sbeach model
2.1.3 Equilibrium beach profile

Dean (1977) has examined the forms of the EBPs that would result if the dominant destructive forces were one of the following:

- wave energy dissipation per unit water volume,
- wave energy dissipation per unit surface area;
- uniform average long-shore shear stress across the surf zone.

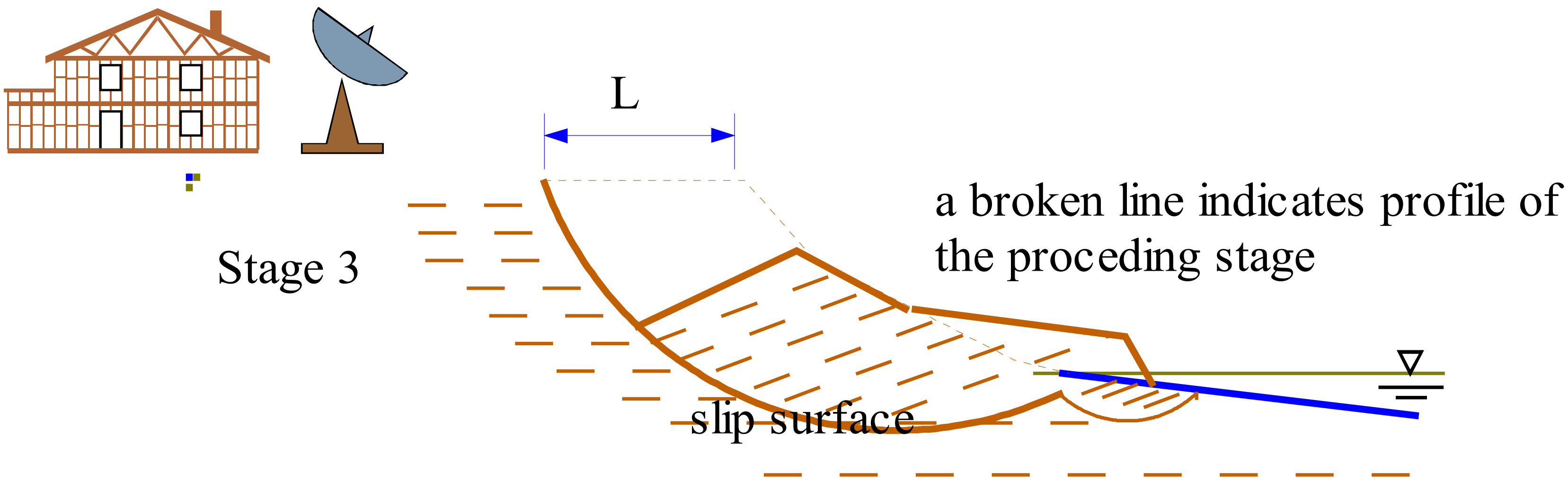
Form of the equilibrium beach profile

$$d(x) = Ax^{2/3}$$

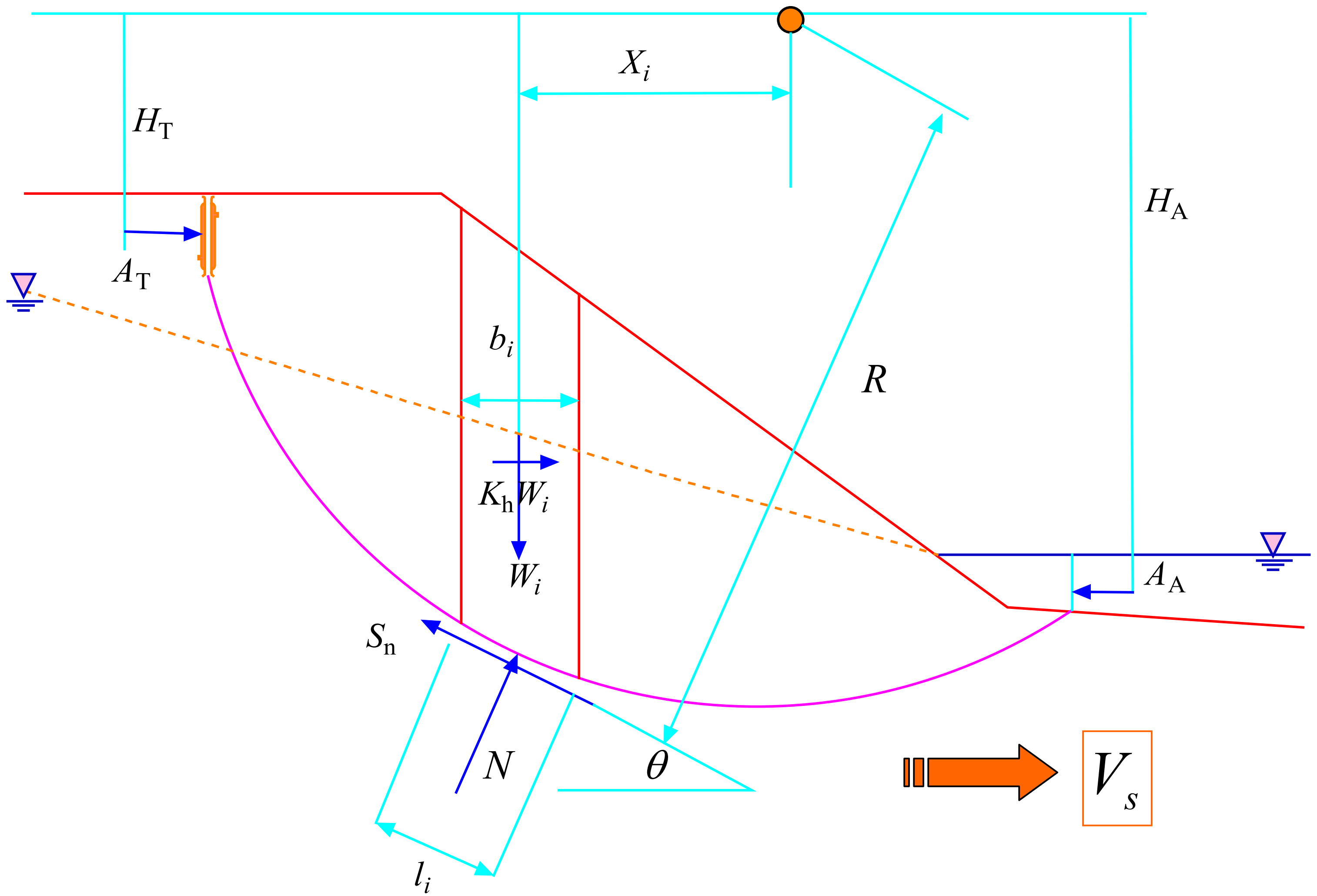
The equilibrium profile parameter A may also be correlated to sediment fall velocity as

$$A = 2.25\left(\frac{w_f^2}{g}\right)^{\frac{1}{3}}$$

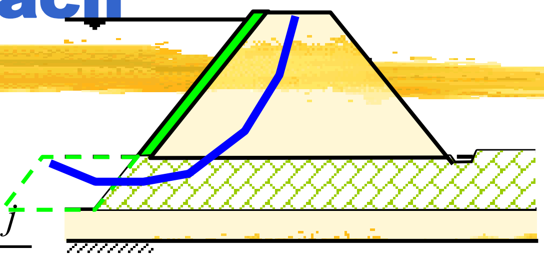
2 Modelling: 2.2 Bishop model
2.2.1 Limit equilibrium analysis
---gap the notch with bluff failure



2 Modelling: 2.2 Bishop model
2.2.2 Sketch of slice method



2 Modelling: 2.2 Bishop model
2.2.3 Equation of Bishop's approach



$$F_s = \frac{\sum \{W_j(1-\tau_u) + (X_j - X_{j+1})\}\tan(\phi')_j m_j}{\sum W_j \sin\theta_j}$$

$$m_j = \frac{1}{\cos\theta_j + \dfrac{\tan(\phi')_j \sin\theta_j}{F_s}}$$

The critical unstable standard of upper cliff is ?

Safety evaluation $F_S >= 1.2$ Criteria with experience

2 Modelling: 2.2 Bishop model
2.2.4 Soil strengthen parameters

Effective stress strengthen parameters have been used in stability analysis when the soil is below the water level.

For the gravity of soil slice should be calculated by

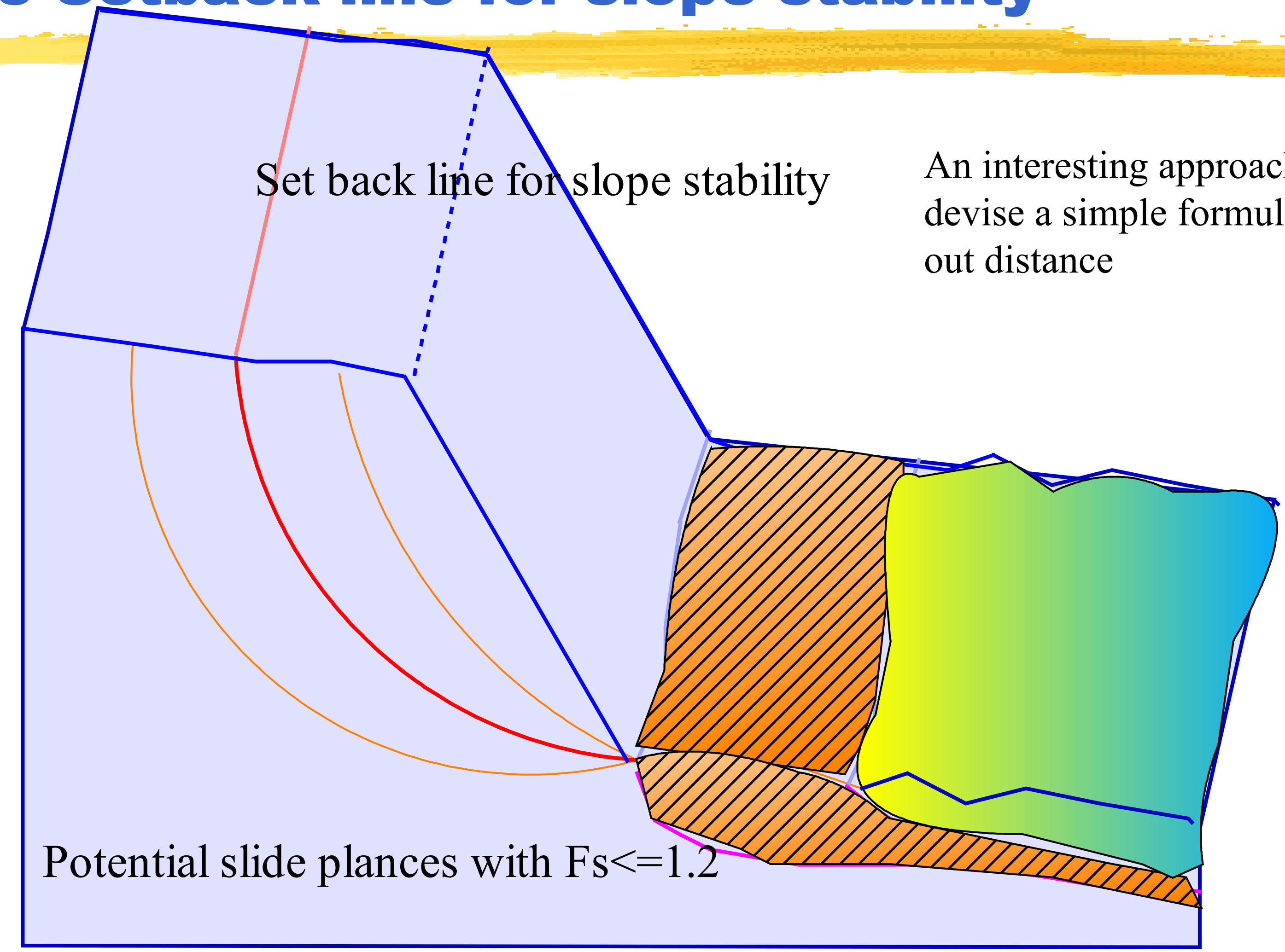
$$W_i = \gamma h_{1i} + \gamma_{\mathrm{sat}} h_{2i} + \gamma' h_{3i}$$

γ where is the natural gravity at specific water content

γ_{sat} is saturation gravity

γ' is buoyant unit weight.

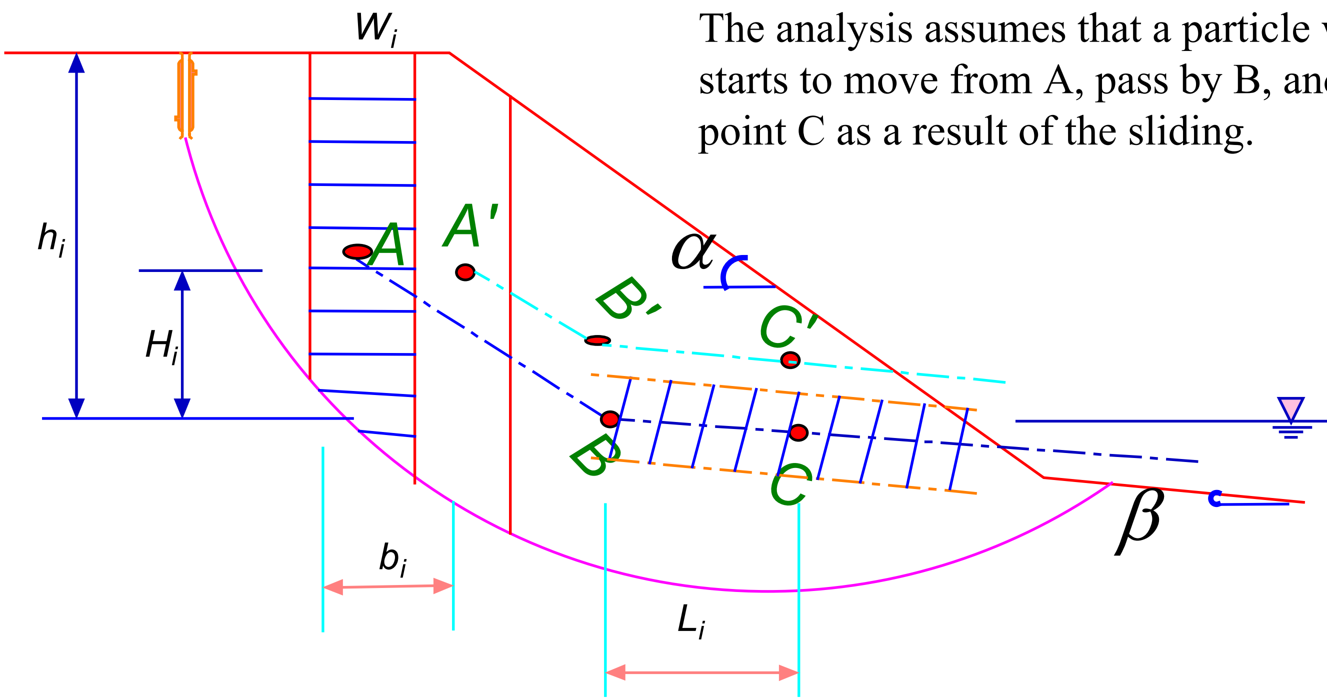
2 Modelling: 2.2 Bishop model
2.2.5 Setback line for slope stability



An interesting approach is to devise a simple formula for run-out distance

2 Modelling: 2.3 Energy model

2.3.1 Movement of potential sliding soil block



The analysis assumes that a particle with mass M starts to move from A, pass by B, and moves to point C as a result of the sliding.

The deformation characteristics during the moving will be neglected. The process of motion can be divided into two phases. AB is the transferring phase of potential energy to kinetic energy overcome friction, accelerating motion while BC is the exchange phase of kinetic energy overcome the friction.

2 Modelling: 2.3 Energy model
2.3.2 Control equations

Energy conservation equation

$$\gamma w_i h_i H_i - \gamma w_i h_i \frac{H_i}{\tan\alpha}\tan\phi_\alpha = \frac{1}{2}\frac{\gamma}{g} w_i h_i v_B^2$$

$$\frac{1}{2}\frac{\gamma}{g} w_i h_i [v_B \cos(\alpha-\beta)]^2 + \gamma w_i h_i L_i \tan\beta = \gamma w_i h_i L_i \tan\phi_\beta$$

Run out distance of the sliced block

$$L_i = H_i \frac{\cos^2(\alpha-\beta)}{\tan\alpha} \frac{\tan\alpha - \tan\phi_\alpha}{\tan\phi_\beta - \tan\beta}$$

The height of lying of slid mass (Distribution homogenise)

$$L = \frac{\sum_{i=1}^{n}(L_i * \gamma * W_i * h_i)}{\sum_{i=1}^{n}(\gamma * W_i * h_i)} \qquad \Delta h = V_s / L$$

2 Modelling:
2.4 Main procedure for each time step

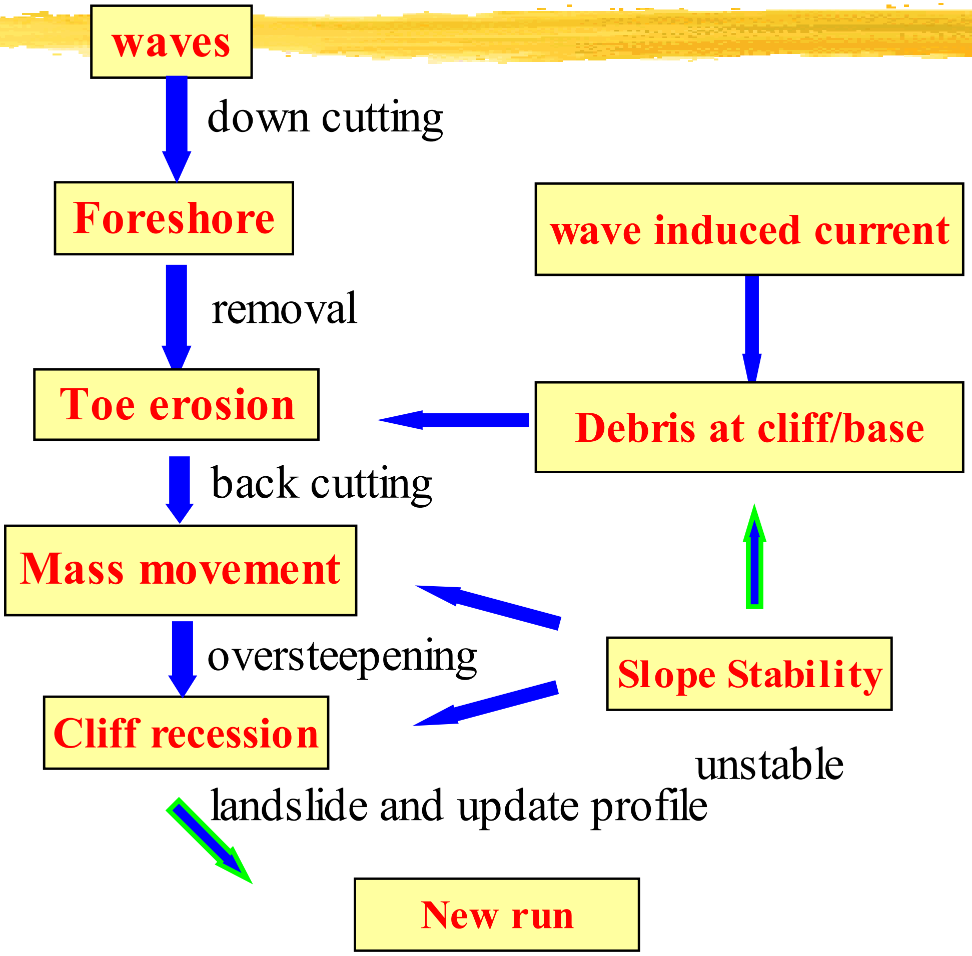
- (1) a random wave was applied to predict the wave parameters on the beach and calculate the run-up height and the wave energy flux.
- (2) The cross-shore sediment transport rate is then computed based on the energy flux dissipation per unit water volume, which can be estimated from the difference in wave energy dissipation between the existing profile and an assumed equilibrium profile shape.

2 Modelling:
2.4 Main procedure for each time step

- (3) A slope stability calculation is then carried out to establish whether the removal of material at the cliff toe or the groundwater conditions at that time-step with a certain shear strength parameters.
- (4) If a landslide does take place, the cliff geometry is updated and a volume of sediment is added onto the beach by using the mass movement method. A sediment budget calculation is used to update the beach alignment.

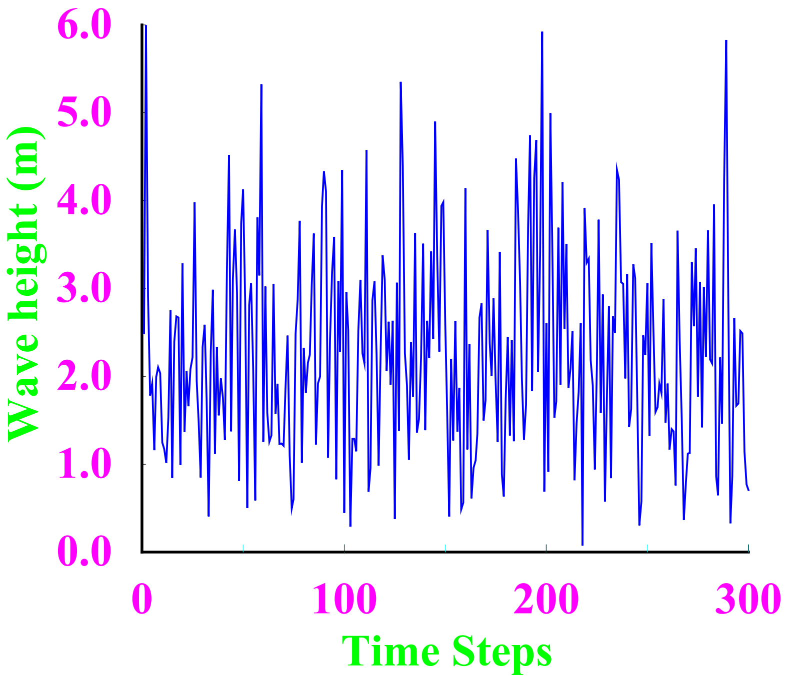
2 Modelling:

2.4 Diagrammatic representation

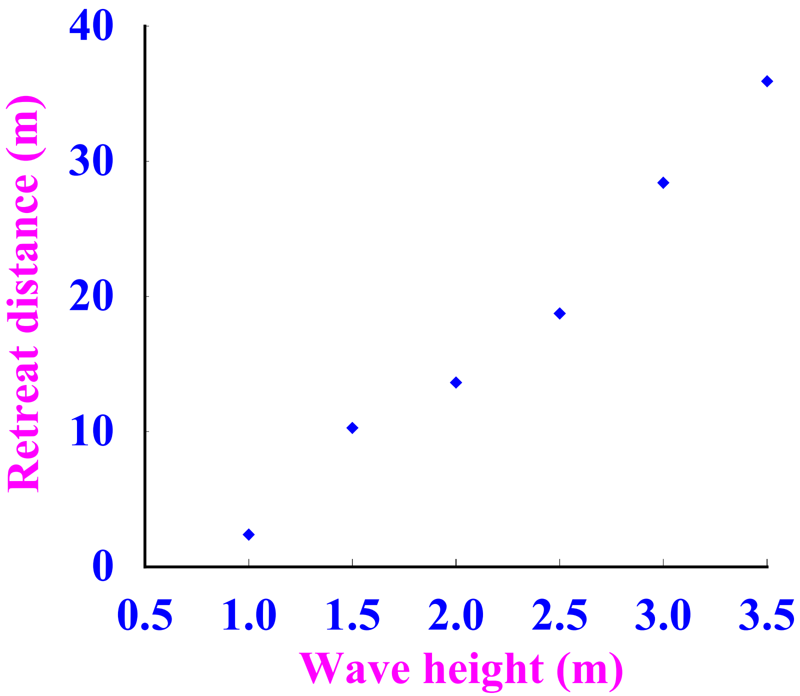


Process based numerical modeling
on cliff - beach recession system

2 Modelling:
2.5 some numerical results
Comparison between CLIEACH model with Nishi model after random wave

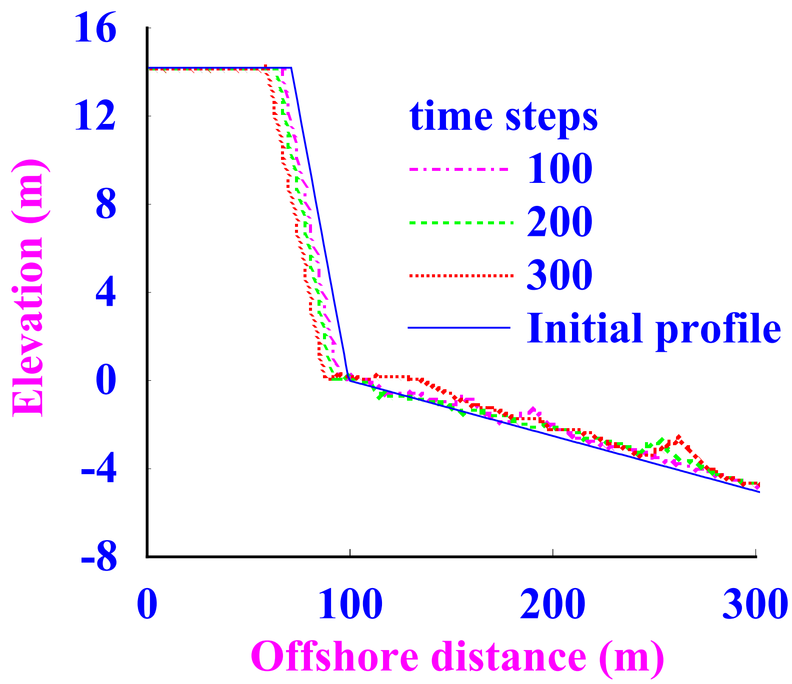


Random wave time serials

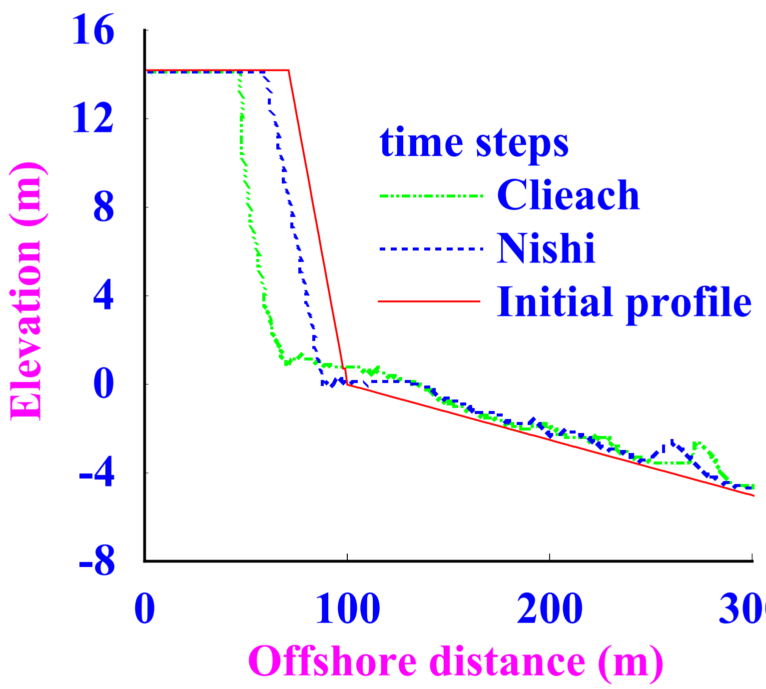


Retreat distance with RMS wave height

2 Modelling: Cliff-Beach=Clieach
2.5 some numerical results
Comparison between CLIEACH model with Nishi model after random wave

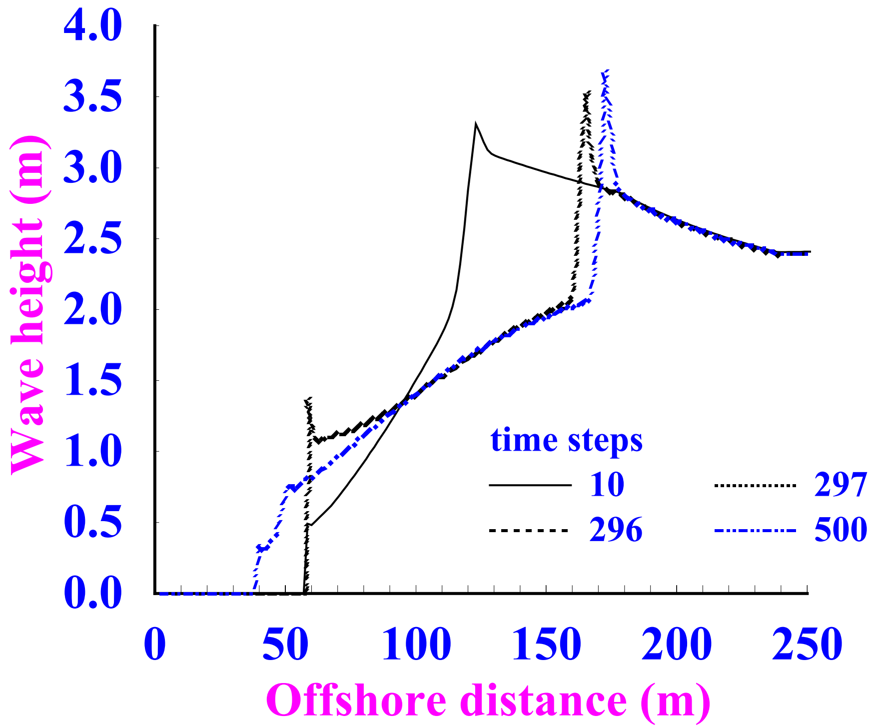


Profile response by Nishi Model

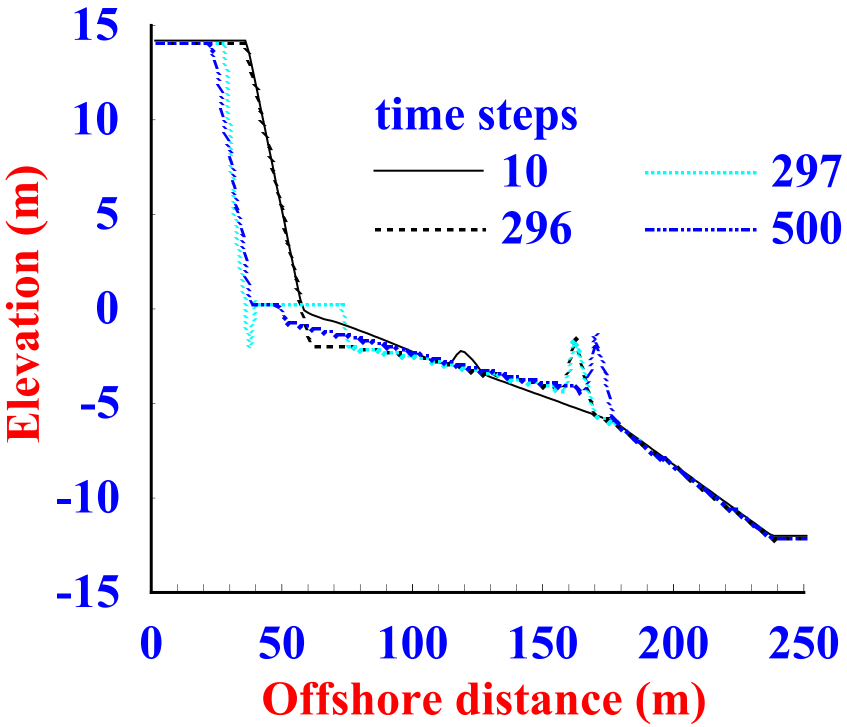


Comparison Nishi with Clieach model

2 Modelling:
2.5 some numerical results
Comparison with experiments and sites results due to regular wave actions

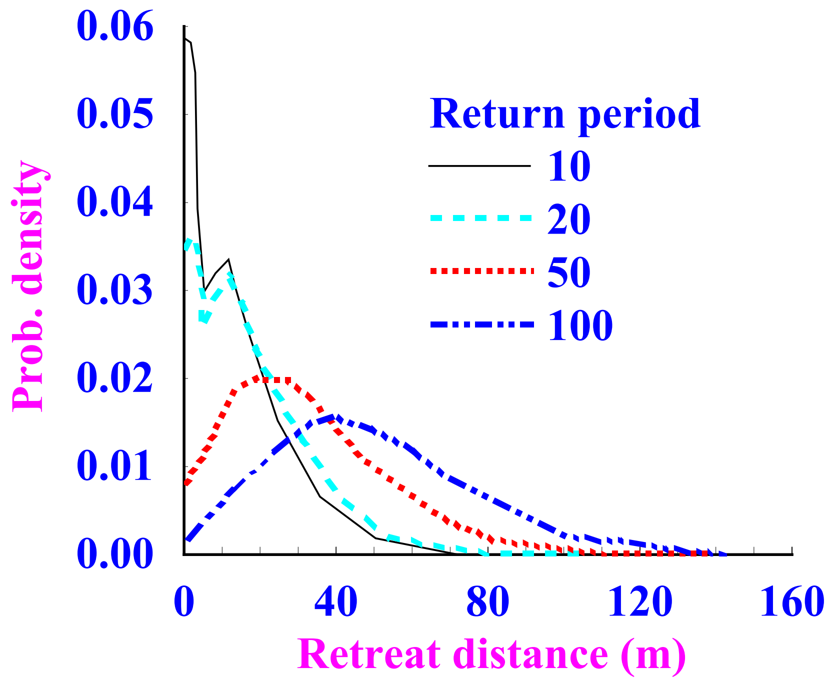


Distribution of wave height

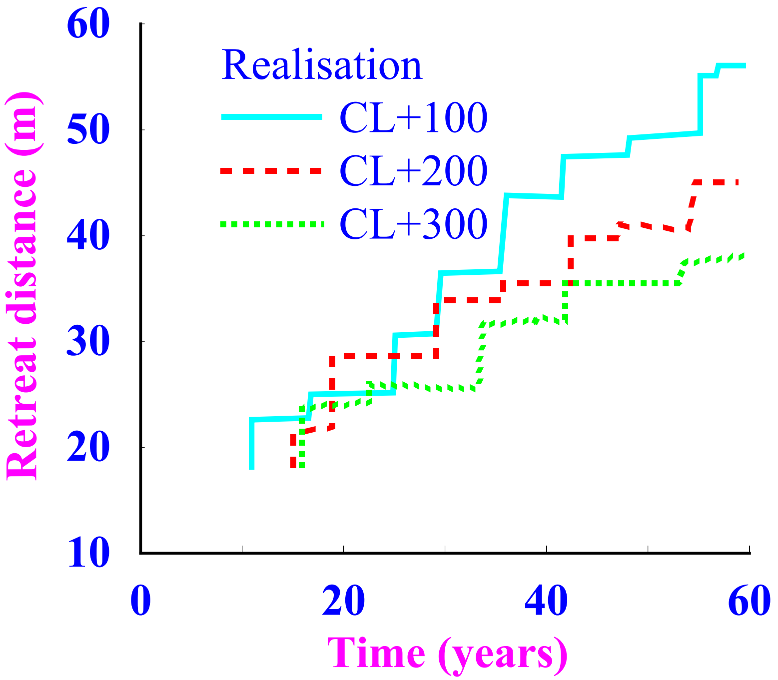


Profile elevation changing

2 Modelling:
2.5 some numerical results
Long term coastal cliff-beach profile evolution



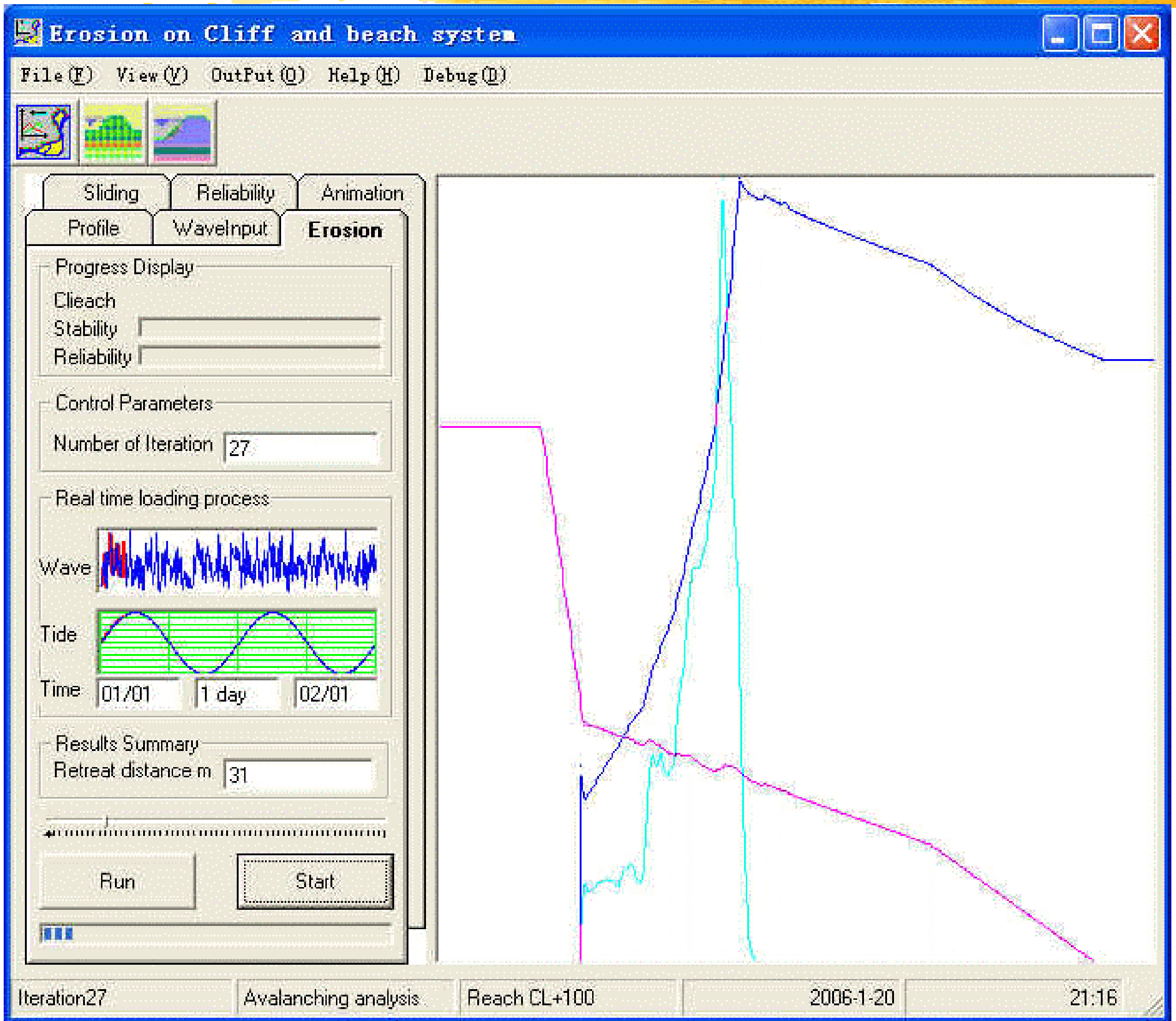
Distribution of cross shore erosion distance



Distribution of cross shore erosion time intervals

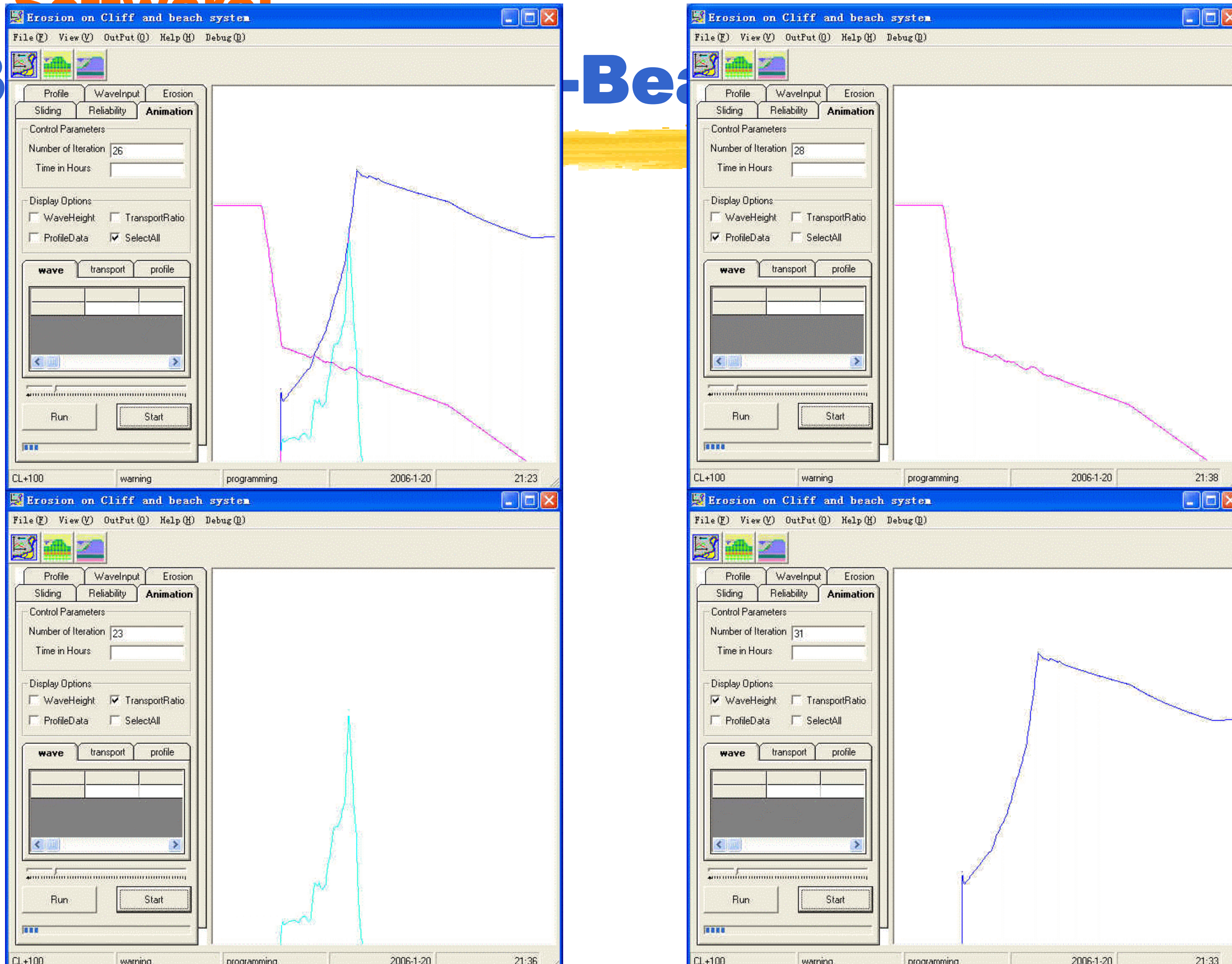
3 Software: Demonstration

3.1 Clieach = Cliff-Beach system



3 Software:

3 -Bea



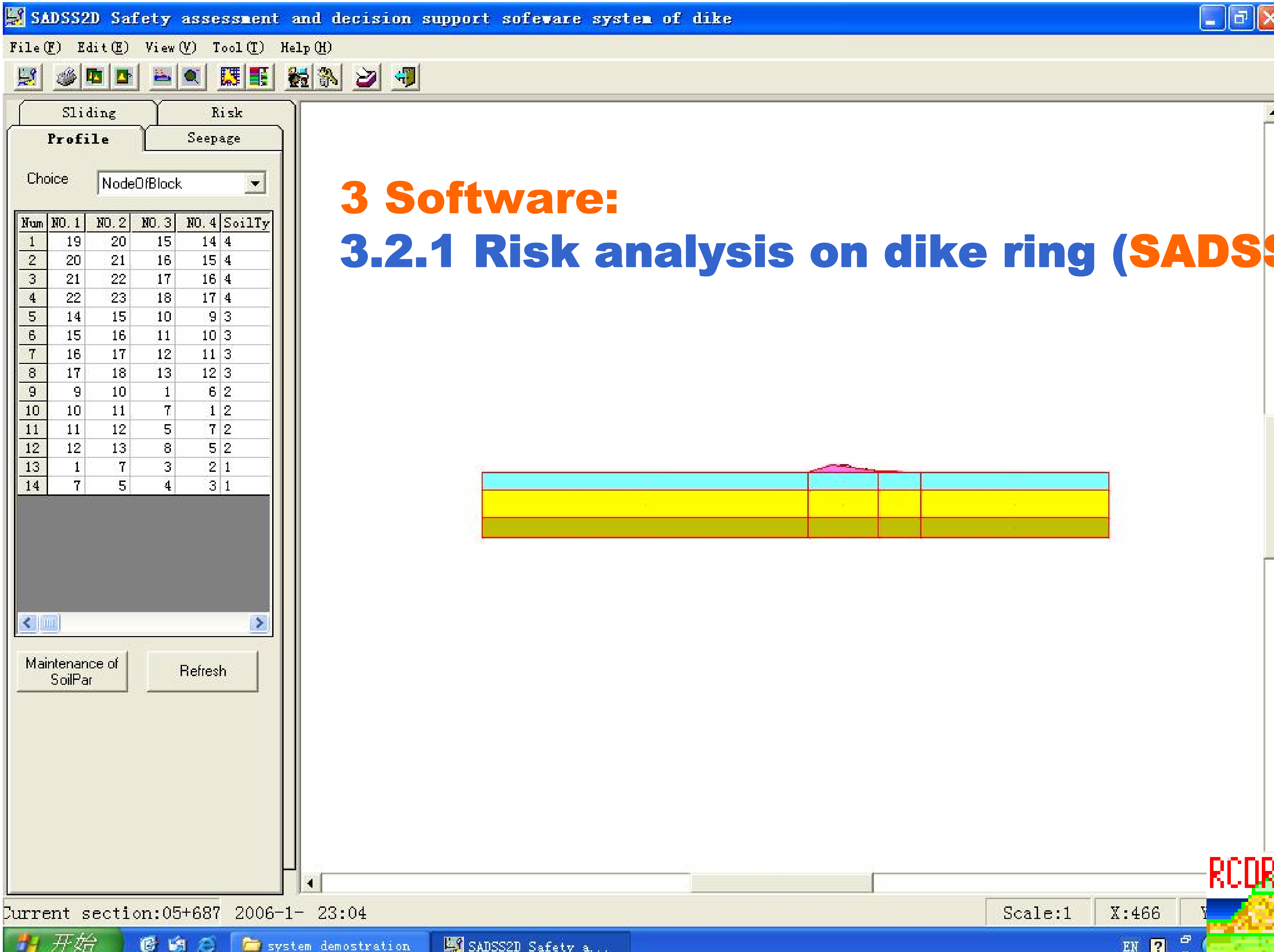
3 Software:
3.2 Some other software systems done before

- Safety Assessment and Decision Support Software System of Dike (SADSS) is a real-time computing of the risk degree platform at various flood water levels. Dynamic risk diagram on a whole dike ring system can be submitted. Different safety grade/ strengthening measures (Probabilistic and risk analysis; slope sliding analysis; seepage analysis)

- Dam safety and Risk management system (DSRMS) is a practical system developed with the ability of the conventional process and probabilistic risk evaluation. (Including consolidation, liquefaction, sliding stability, seepage and reliability assessment)

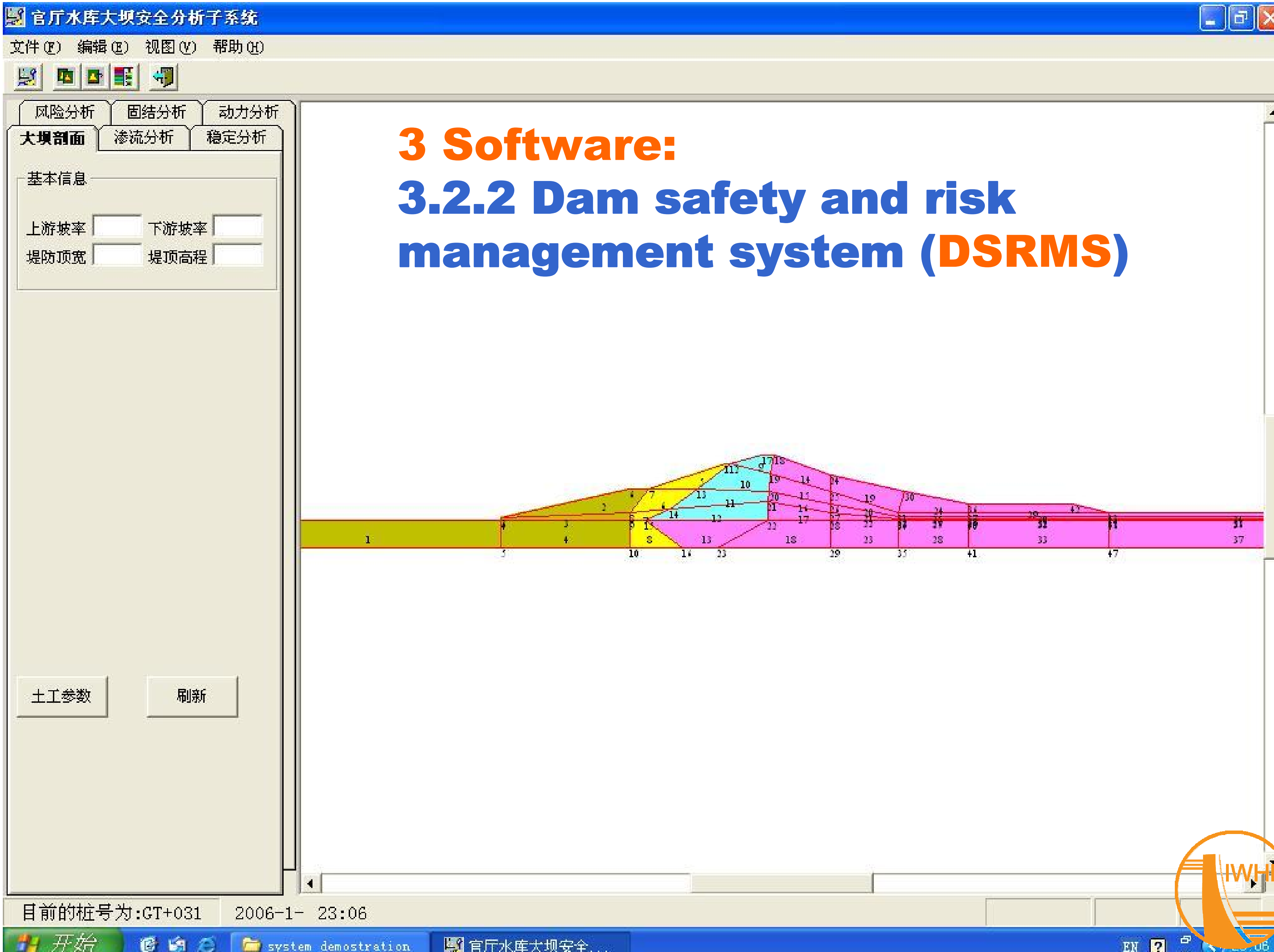
3 Software:

3.2.1 Risk analysis on dike ring (SADSS)



3 Software:

3.2.2 Dam safety and risk management system (DSRMS)



4 Conclusions & Discussions

A processed-based model for cliff beach system erosion retreat was developed to describe the combined effects of lateral erosion and mass instability in producing cliff instability impacted by high waves and water levels during severe storms. The calculation procedure is illustrated by a worked example and to explore its possible futures.

The model is based on a study of the behavior of eroding systems in general and cliff-beach evolution in particular. Insights into the relevant behaviors are drawn from the literatures, it is emphasized that cliff erosion mode cause severe dune or cliff recession in a short period of time. Which integrates established models of key processes, like hydrodynamics and beach sediment transport, it is pragmatic to model processes at the most familiar level of resolution at which they are best understood. Simplified for the mass movement simulation by mass point energy conservation theory is reasonable way to gain the new profile after sliding and succeed in avoiding the complexity essence.

More reasonable safety evaluation criteria and a robust algorithm of slope sliding stability analysis

Acknowledgements

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- Thanks to Dr. Ping Dong and other colleagues in Dundee geotechnical group

The end

The end

Thanks

Contacts

It is still developing---

Welcome you to enjoy this study---

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