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中国海洋工程咨询协会
China Association of Oceanic Engineering

# Social Organization Standard

T/CAOE 21.3-2020

# Technical guideline on coastal ecological rehabilitation for hazard mitigation —

Part 3:

# Salt marshes

海岸带生态减灾修复技术导则 第3部分：盐沼

*（English Translation）*

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# Contents

# Foreword

The T/CAOE 21 *Technical guideline on coastal ecological rehabilitation for hazard mitigation* consists of the following eleven parts:

——*Part 1: General;*

——*Part 2: Mangroves;*

——*Part 3: Salt marshes;*

——*Part 4: Coral reefs;*

——*Part 5: Seagrass bed;*

——*Part 6: Oyster reef;*

——*Part 7: Sandy coast;*

——*Part 8: Technical guide for the ecological construction of sea walls (trial);*

——*Part 9: Renovation of island-connecting sea wall and coastal engineering;*

——*Part 10: Directives for sea dike ecological construction of sea reclamation and enclosure project;*

——*Part 11: Supervising and monitoring.*

This is part 3 of the T/CAOE 21.

This part is drafted in accordance with the rules given in the GB/T 1.1-2009 *Directives for standardization-Part 1: Structure and drafting of standards*.

This part was proposed by the *Marine Early Warning and Monitoring Division, Ministry of Natural Resources*.

This standard was prepared by *China Association of Oceanic Engineering*.

This part was drafted by *National Marine Hazard Mitigation Service; Sichuan University;* and *First Institute of Oceanography, Ministry of Natural Resources*.

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# Technical guideline on coastal ecological rehabilitation for hazard mitigation — Part 3: Salt marshes

### 1 Scope

This part of T/CAOE 21 specifies the working procedures, data collection and surveys, suitability assessment, preparation of implementation plan, ecological rehabilitation technology for hazard mitigation of salt marshes, follow-up monitoring and effect assessment, quality control, as well as results and archiving, etc.

This part is applicable to the salt marsh rehabilitation for hazard mitigation in coastal protection and rehabilitation projects. It can also be used as a reference in other related works.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.GB/T 12763.2, *Specifications for oceanographic surveys— Part 2: Marine hydrographic observation*

T/CAOE 20.4, *Technical guidelines for survey and assessment of coastal ecosystem—Part 4: Salt marshes*

T/CAOE 21.1-2020, *Technical guidelines on coastal ecological rehabilitation for hazard mitigation—Part 1: General Considerations*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

**salt marsh**

wetlands with high salinity

NOTE: the coastal salt marshes are distributed in estuaries or coastal shoals and are formed by the action of seawater immersion or tidal alternation.

3.2

**salt marsh vegetation**

plants communities that grow in the range of salt marshes

NOTE：The main dominant plants in salt marshes in China are *Phragmites australis*, *Spartina alterniflora, Scirpus mariqueter, Suaeda salsa, Cyperus malaccensis* var. *brevifolius* and so on. Among them, *Spartina alterniflora* was included in the list of the first batch of invasive alien species in China.

## 4 Working procedure

According to the requirements specified in Clause 6 of T/CAOE 21.1.

## 5 Data collection and survey

5.1 Data categories for collection and surveys

The part of the salt marsh ecological rehabilitation for hazard mitigation project is in the land-sea transition zone. The location is periodically or intermittently affected by tides, and is covered with herbs or low shrubs of muddy or sandy intertidal wetland ecosystems, with vegetation coverage ≥30%. The information required for the salt marsh ecological rehabilitation for hazard mitigation project includes the general situation of the project area, salt marsh vegetation, biological community, environmental factors and threat factors, etc. The specific factors and survey methods are shown in Table 1.

Table 1 —Data categories for collection and surveys

| Survey scope | Survey elements | Survey method |
|---|---|---|
| Project area overview | Environmental overview: natural conditions, ecological characteristics, and environmental status | Data collection |
| | Geographical attributes: specific location and geographic coordinates | Field survey |
| | Policies and regulations: laws and regulations, plans | Data collection |
| Salt marsh vegetation | Distribution: area and width of vegetation zone | Remote sensing, Field survey |
| | Sample plants: type and quantity | Field survey |
| | Sample plants: density, coverage, average height, average stem diameter, biomass | Field survey |
| Biomes | Macrobenthos: species, density, biomass | Field survey |
| | Birds: species, number | Field survey |
| Environmental factors | Hydrological environment: water temperature, salinity, water level, wave elements (wave height, period, etc.) | Data collection, Field survey |
| | Sediment: particle size, pH value, total organic carbon, total salt content | Field survey |
| | Terrain: tidal marsh elevation | Field survey |
| Threat factors | Natural factors: natural hazards such as storm surges, invasion of alien species, etc. | Data collection, field survey&social survey, etc. |
| | Human factors: aquaculture activities, fisheries fishing, coastal engineering, pollution discharge status, surrounding resource utilization, tourism development activities, etc. | Data collection, field survey&social survey, etc. |

### 5.2 Ecosystem status surveys

#### 5.2.1 survey elements and methods

The field survey elements are shown in Table 1. Except for water level and ocean wave elements, the survey methods for other survey elements should be implemented in accordance with T/CAOE 20.4.

#### 5.2.2 survey time

One survey shall be carried out before the salt marsh ecological rehabilitation for any hazard mitigation project, and the survey time should be scheduled from July to October.

Follow-up monitoring and surveys shall be carried out during and after the implementation of the salt marsh ecological rehabilitation for hazard mitigation project. For the time of monitoring and survey, see Clause 9.1 of this document.

### 5.3 Field observation of hazard mitigation functions

#### 5.3.1 Measuring section and measuring point layout

The sectional observation method is adopted for the field observation of salt marsh hazard mitigation functions. The cross-section shall be as parallel as possible to the wave direction, and the plant density and the width of the vegetation zone shall be able to better reflect the situation of the entire salt marsh. When the characteristics of the salt marsh distribution area are substantially different (The difference is manifested in vegetation characteristics or environmental characteristics), multiple sections shall be selected. There are no less than two measurement points for each section, which are located at the seaward edge of the vegetation area (the seaward point) and the landward edge of the vegetation area (the landward point).

5.3.2 Observation elements and methods

The field observation elements of hazard mitigation functions include wave height and water level at seaward and landward points. The observation methods of wave elements such as wave height and period and water level should be implemented according to the relevant provisions in GB/T 12763.2.

5.3.3 Observation time

The field observation period of the hazard mitigation functions shall include the entire period impacted by storm surge (1 to 3 days before the storm surge warning until the storm surge warning is lifted).

## 6 Suitability assessment

6.1 Scope of suitability assessment

Before the implementation of the salt marsh rehabilitation project, a suitability assessment shall be carried out and a suitability assessment report should be prepared. The assessment content includes ecological status assessment, hazard mitigation function assessment, rehabilitation suitability assessment, etc. If there is no salt marsh vegetation distribution in the area, the hazard mitigation function assessment in 6.3 of this document is not required.

6.2 Ecological status assessment

Content and methods of status assessment should be implemented as specified in T/CAOE 20.4.

6.3 Hazard mitigation function assessment

6.3.1 Scope of assessment

Assessment scope covers the weakening effect of the salt marsh ecosystem on storm surges and waves. Because there are certain topographical changes in the mangrove area, the hazard mitigation function assessment of this document includes the comprehensive hazard mitigation functions of the salt marsh area including salt marsh vegetation and topographic changes.

6.3.2 Assessment indicator

Wave height attenuation rate.

6.3.3 Wave height attenuation rate

Wave height attenuation rate ($R_{wL}$) is the percentage of the ratio of the wave height attenuation ($H_0$-$H_L$) to the incoming wave height ($H_0$) after the wave passes through a certain width of the salt marsh vegetation zone during the storm surge, calculated according to formula (1).

$$R_{wL}=\frac{H_0-H_L}{H_0}\times 100\% \qquad (1)$$

Where:

$H_0$ The effective wave height at the seaward edge of the vegetation area (front measurement point), in meters (m);

$H_L$ The effective wave height at the landward edge of the vegetation area (rear measurement point), in meters (m).

6.3.4 Assessment method

sSee Annex A.

6.3.5 assessment results

According to the assessment results, the hazard mitigation performance can be divided into four grades: excellent, good, medium and weak according to the wave height attenuation rate, as shown in Table 2. For the same wave level, the higher the wave height mitigation rate, the better the hazard mitigation effect of the salt marsh, and the higher the hazard mitigation function assessment level.

Table 2 —Salt marsh hazard mitigation capacity corresponding to high wave attenuation rate

| Wave height attenuation rate | Hazard mitigation performance level |
|---|---|
| ≥60% | excellent |
| ≥30%~<60% | good |
| ≥10%~<30% | medium |
| <10% | weak |

6.4 Rehabilitation suitability assessment

Prior to the implementation of salt marsh rehabilitation, a rehabilitation suitability assessment shall be carried out. The main contents of the assessment are as follows:

——Hydrodynamics and water environment status. The water system in the project area shall be able to provide normal maintenance and regulation functions for the salt marsh ecosystem;

——Substrate conditions. The substrate in the project area shall be able to maintain the basic functions of the salt marsh. The substrate environment inside the salt marsh should be silty or peaty;

——Vegetation selection. Local plants shall be selected for rehabilitation;

——Threat factors. Activities shall be considered in project area such as aquaculture, capture fishery, coastal engineering, pollution discharge, utilization of surrounding resources, tourism development and so on. And effective management and mitigation measures should be proposed and adopted.

## 7 Implementation plan preparation

According to the requirements specified in 7.3 of T/CAOE 20.4-2020.

## 8 Salt marsh ecological rehabilitation for hazard mitigation technology

8.1 Micro-landform modification and water system connection technology

The following measures are taken for micro-landform modification and water system connection:

——For areas where tidal creeks are blocked by siltation, primary and secondary ditches can be designed according to local conditions to improve water system connectivity;
——For areas where the hydrological environment is severely disturbed by human activities, the opening position, depth, width, direction and number of tidal creeks can be determined in combination with hydrological models;
——The water system connectivity can be improved by changing the elevation of local areas, dredging small tributaries and ditches, etc.

8.2 Substrate restoration technology

The techniques should be used to substrate restoration mainly include:
——Physical methods. Measures such as deep ploughing and sun drying, adjustment of surface elevation, salt pressing and alkali drainage by fresh water and other measures can be adopted according to local conditions;
——Biological methods. Measures such as adding straw and effective microbial agents and other measures can be adopted to improve the substrate structure and nutritional conditions according to local conditions.

8.3 Vegetation restoration technology

8.3.1 Plant selection

Local plants shall be selected in priority, and the target plants shall be determined according to the natural geographical conditions of the project area. Plants with strong pollution-resistant ability, developed root systems and strong environmental adaptability should be selected.

8.3.2 Planting

When planting, a suitable planting season and planting method according to the characteristics of different plants shall be chosen. The planting seasons and planting techniques of dominant plants in salt marshes are proposed for *Phragmites australis*, *Scirpus mariqueter*, *Cyperus malaccensis* var. *brevifolius* and *Suaeda salsa*.

a）*Phragmites australis*
——Planting time should be arranged in March or April;
——Seedlings should use growing reed rhizomes, and it is advisable to choose rhizomes with 4-6 buds and 30cm-40cm in length;
——The planting method should be planting by digging holes. Each hole should be planted with 3 to 4 reed rhizomes. Each reed rhizome should have at least one bud out of the ground, and the spacing between rows shall be between 50cm×50cm and 100cm×100cm.

b）*Scirpus mariqueter*
——Planting time should be arranged in April or May;
——Seeds should be full-grained and mature in the same year to ensure germination rate;
——The sowing amount should be 50 seeds/ $m^2$～100 seeds/ $m^2$.

c）*Cyperus malaccensis* var. *brevifolius*
——Planting time should be arranged from March to November;
——Seedlings should use growing grass blocks with soil, and plant them on the day of harvesting;
——The row spacing should be between 50cm×50cm to 100cm×100cm.

d）*Suaeda salsa*

——Planting time should be arranged in March or April;
——Seeds should be full-grained and mature in the same year to ensure germination rate;
——The seeding rate should be 300 seeds/ $m^2$～500 seeds/ $m^2$.

8.3.3 Optimal design of hazard mitigation planting

8.3.3.1 The requirements of optimal design

The optimal design of the width of the salt marsh vegetation zone should comprehensively consider the morphological characteristics and growth characteristics of plants, thus allowing full performance of its hazard mitigation functions against storm surges and other marine hazards, and enhancing the marine hazard mitigation capacity of salt marsh vegetation.

8.3.3.2 The method of optimal design

The optimal design method of vegetation width based on hazard mitigation needs is as follows:
——According to local marine hazard mitigation needs, combined with regional storm surge and other marine dynamic hazard conditions, set an appropriate expected wave height attenuation rate for the rehabilitation project area. The value should be greater than 30% when the salt marsh vegetation matures;
——In order to achieve the expected wave height attenuation rate, the vegetation width needed to be planted under different sea conditions shall be calculated according to the growth parameters of the selected vegetation maturity period. The specific calculation method is shown in Annex C;
——For the same expected wave height attenuation rate, there are many combinations of vegetation planting belt width for reference. In the actual planting design, the appropriate planting belt width shall be selected from the perspective of the most reasonable economic costs.

8.4 Maintenance

8.4.1 Maintenance period

The management and protection period should be set to 3 years.

8.4.2 Management measures

The following management and protection measures should be adopted in the salt marsh rehabilitation project area:
——Beach closure protection should be implemented;
——It is necessary to clean the floating garbage regularly, prevent and control diseases and insect pests, and clean up fouling organisms and alien invasive organisms;
——After planting is completed, it is advisable to determine whether to replant or not according to the actual survival rate.

## 9 Follow-up monitoring and effect assessment

9.1 Follow-up monitoring and surveys

9.1.1 Follow-up monitoring

3 years of follow-up monitoring at least should be carried out for salt marsh rehabilitation, and the annual time should be arranged from July to October. The specific time can be adjusted according to the maturity time of the plants in each

climatic zone. The parameters of follow-up monitoring should include salt marsh vegetation, biological communities, environmental factors and threat factors (Table 1 for survey factors), which can be adjusted according to actual conditions.

9.1.2 Post-hazard surveys

The post-hazard survey focuses on salt marsh vegetation (Table 1). Other biological communities, environmental factors and threat factors can be selected according to the actual situation. The survey method is shown in 5.2 of this document. The survey should be carried out within 10 days after the storm surge.

9.2 Effect assessment

9.2.1 Hazard mitigation function assessment

According to the method specified in 6.3 of this document.

9.2.2 Ecological effect assessment

According to the results of follow-up monitoring, ecological effects of salt marsh vegetation restoration should be comprehensively evaluated. The specific assessment indicators and methods shall be implemented as specified in T/CAOE 20.4.

## 10 Quality Control

In accordance with T/CAOE 20.4-2020, Clause 8

## 11 Results and archiving

In accordance with T/CAOE 20.4-2020, Clause 9

# Annex A
# (annex informative)
# Assessment method of hazard mitigation function of salt marsh ecosystem

## A.1 Field observation method

### A.1.1 Applicability of field observation methods

The field observation method is suitable for areas to be assessed and frequently affected by hazards and the economic conditions of areas permit. In the year that the salt marsh marine hazard mitigation function assessment is carried out, at least one storm surge with significant impact on the assessment area has occurred.

### A.1.2 Observation data analysis and calculation method

According to the wave height sequence observed in the field (see 5.3 of this document for details), calculate the effective wave height sequence, select the most unfavorable (the highest effective wave height) period (the duration can be 30 minutes), and place the observation fault on the sea point and the land point. $H_0$ and $H_L$ are put into formula (1) (see 6.3.3 of this document), and the wave height attenuation rate $R_{wL}$ is calculated.

## A.2 Empirical formula method of wave height attenuation rate

### A.2.1 Applicability of empirical formula method

The empirical formula method is suitable for the assessment of the hazard mitigation functions of the salt marsh ecosystem where the slope of the section is small (because the method adopts the flat bottom assumption, it is suitable for the case where the slope of the section is less than 0.02), the vegetation variety is single, and the vegetation parameters are easy to generalize. This method can be used to quickly assess the hazard mitigation capacity of the salt marsh ecosystem.

### A.2.2 Empirical formula method

The empirical formula is used to estimate the wave height attenuation rate, and the calculation formula is shown in formula (A.1).

$$R_{wL}=\frac{\alpha L}{1+\alpha L}\times 100\% \quad \text{(A.1)}$$

Where:

$L$ The width of the vegetation zone of the evaluated salt marsh, in meters (m)

$\alpha$ Wave height attenuation coefficient, in $m^{-1}$, the theoretical expression is derived from linear wave theory, see formula (A.2).

$$\alpha=\frac{4}{9\pi}C_D DNH_0 k\frac{\sinh^3 kh_v+3\sinh kh_v}{(\sinh 2kh+2kh)\sinh kh} \quad \text{(A.2)}$$

Where:

$C_D$ Plant drag coefficient, calculated according to empirical formula (A.3);

$D$ The plant area per unit vertical height, that is, the vertical average plant diameter, and its value is $\frac{\int_0^{h_v} D(z)dz}{h_v}$, in meters (m);

$N$ The number of plants per unit area, in ind/$m^2$;

$H_0$ The effective wave height of the wave in front of the vegetation area caused by the storm surge, in meters (m);

$k$ Wave number on the front end of the vegetation zone;

$h$ The storm surge level calculated from the ground of the vegetation area, that is, the water level of the vegetation area. in meters (m);

$h_v$ The height of the plant below the water surface, when the plant height is greater than the water level $h$, that is, when the plant is out of water, $h_v=h$, when the plant height is less than the water level $h$, $h_v$ is the true height of the plant. in meters (m).

Referring to the figure A.1 for the specific meaning of some parameters.

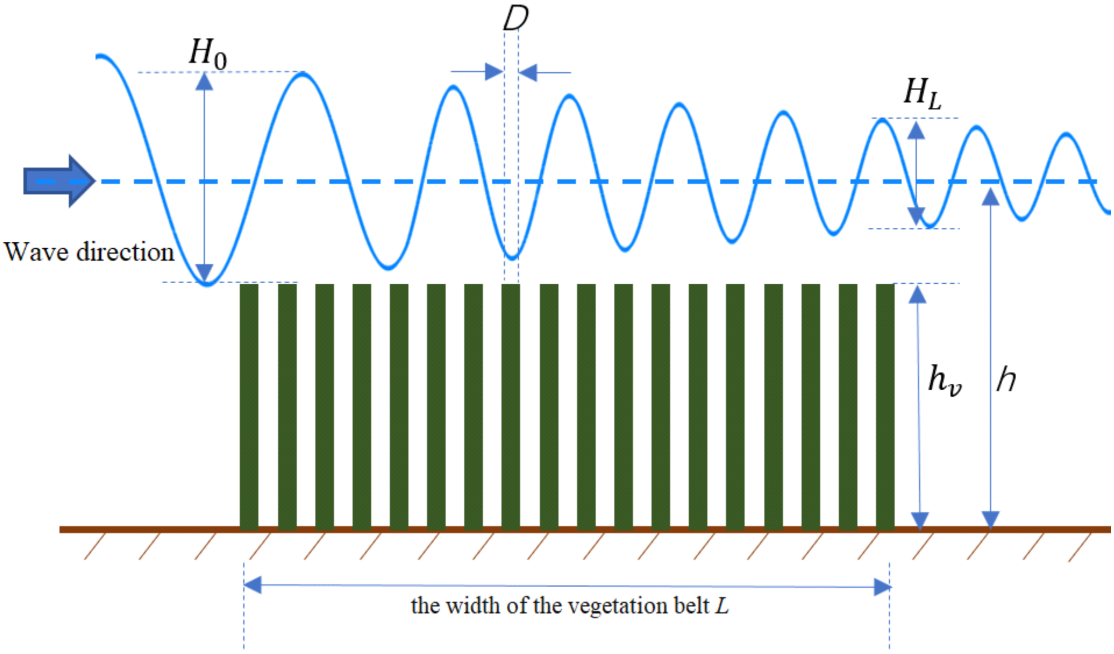


Figure A.1— Schematic diagram of relevant parameters in the empirical formula method

The plant drag coefficient $C_D$ is related to vegetation and hydrodynamic parameters. The correct selection of its value is essential to accurately assess the wave height mitigation rate of salt marsh vegetation. The calculation formula is shown in formula (A.3).

$$C_D=2\left(\frac{\alpha_0}{R_e}+\alpha_1\right)\times\left(1+\frac{\alpha_2}{KC}\right) \quad \text{(A.3)}$$

Where:

$\alpha_0$ The empirical coefficient is related to the proportion of plant volume $\phi\left(=\pi\frac{D^2}{4}N\frac{h_v}{h}\right)$, and its value can see Table A.1;

$\alpha_1$ The empirical coefficient is related to the percentage of plant volume $\phi$. For its value, please see Table A.1;

$\alpha_2$ The empirical coefficient, its value is referred to in Table A.1;

$Re$ Reynolds number, its definition is $Re=\frac{|u|D}{\upsilon}$, Where $|u|$ is the maximum velocity of the water mass point movement under the action of waves, and the velocity at the height of the highest submerged plant can be taken. According to the linear wave theory, $|u|=\frac{\pi H_0}{T}\frac{\cosh(kh_v)}{\sinh(kh)}$, $\upsilon$ is the kinematic viscosity coefficient of sea water and its value can be taken as $1\times10^{-6}\mathrm{m}^2/\mathrm{s}$.

$KC$ The definition is $KC=\frac{|u|T}{D}$, where $T$ is the wave period.

Table A.1 —Empirical coefficient of drag coefficient calculation

| parameter name | Calculation formula or value range |
| --- | --- |
| $\alpha_0$ $^a$ | $\alpha_0 = \begin{cases} 25 \pm 12 & (\phi = 0.091) \\ 84 \pm 14 & (\phi = 0.15) \\ 83.8 & (0.15 \le \phi \le 0.35) \end{cases}$ |
| $\alpha_1$ $^a$ | $\alpha_1 = (0.46 \pm 0.11) + (3.8 \pm 0.5)\phi$ |
| $\alpha_2$ $^a$ | $\alpha_2 = 5.5 \sim 9.5$ |

A.3 Physical model test method

A.3.1 Applicability of physical model test method

In cases where the frequency of regional marine hazards is low (there was no storm surge affecting the area to be assessed in the assessment year) or the observation conditions are restricted and the field observation cannot be performed, physical model test methods can be used. Compared with the empirical formula method, the advantage of the physical model experiment method is that it can evaluate the marine hazard mitigation effect of salt marsh vegetation with complex features such as diverse varieties, complex shapes, and uneven distribution.

A.3.2 Technical method

A.3.2.1 Model plant selection

The physical model needs to select model plants. The size of model plants can be determined according to the length similarity criterion according to the structural characteristics of the main poles, branches and leaves and canopy of the wetland vegetation. The length similarity scale $\lambda_L$ is shown in formula (A.4). When evaluating the marine hazard mitigation functions of salt marsh vegetation, the plant height can be used as the basis for calculating the length scale, and the value of the length scale $\lambda_L$ should not be greater than 20.

$$\lambda_L = \frac{L_p}{L_m} \cdots\cdots \text{(A.4)}$$

Where:

$L_p$ The characteristic length of the prototype. in meters (m);

$L_m$ The characteristic length of the model. in meters (m).

A.3.2.2 Model plant layout

The model plants are arranged according to the actual wetland vegetation distribution characteristics (regular rectangle, regular triangle, plum blossom, and random distribution). Model plant layout density $N_m$ and vegetation zone width $L_m$ can be calculated according to formula (A.5) and formula (A.6) according to the similar length scale:

$$N_m = N_p \lambda_L^2 \cdots\cdots \text{(A.5)}$$

Where:

$N_p$ Feature density of the prototype;

$N_m$ Feature density of the model.

$$L_m = \frac{L_p}{\lambda_L} \cdots\cdots \text{(A.6)}$$

Where:

$L_p$ The characteristic width of the prototype vegetation zone. in meters (m);

$L_m$ The characteristic width of the model vegetation zone. in meters (m).

A.3.2.3 Water level and wave conditions

According to the coastal tide and wave characteristics of the wetland to be assessed, the wave height and water level in the model hydrodynamic parameters can be calculated using the length scale, and the calculation formulas are shown in equations (A.7) and (A.8). The model test and prototype parameters shall also conform to the gravity similarity criterion, that is, the prototype Froude number $Fr_p$ and the model Froud number $Fr_p$ are equal, that is, $\frac{v_p}{\sqrt{gh_p}}=\frac{v_m}{\sqrt{gh_m}}$ . Based on length scale and similar gravity criterion, the speed ratio of prototype and model is $\frac{v_p}{v_m}=\sqrt{\frac{h_p}{h_m}}=\sqrt{\lambda_L}$. The relationship between the wave period set by the model and the real sea state period shall conform to the formula (A.9).

$$H_{0m}=\frac{H_{0p}}{\lambda_L} \quad \text{(A.7)}$$

Where:

$H_{0p}$ Prototype effective wave height, in meters (m);

$H_{0m}$ Model effective wave height, in meters (m).

$$\eta_m=\frac{\eta_p}{\lambda_L} \quad \text{(A.8)}$$

Where:

$\eta_p$ Prototype characteristic water level. in meters (m);

$\eta_m$ Model characteristic water level, in meters (m)

$$T_m=\frac{T_p}{\sqrt{\lambda_L}} \quad \text{(A.9)}$$

Where:

$T_p$ The characteristic effective wave period of the prototype hydrodynamic parameters. in seconds (s);

$T_m$ The characteristic effective wave period of the model hydrodynamic parameters. in seconds (s).

A.3.2.4 Layout of flume and measuring instrument

A.3.2.4 Layout of flume and measuring instrument

A wave-making device with active wave-absorbing function shall be arranged at the head of the sink for physical model test. The model vegetation is arranged in the flume, with a certain distance from the wave-making equipment. Set up wave-eliminating equipment behind the plant area. The laboratory usually uses a digital wave height meter to measure the attenuation of waves in the plant area. The wave height meter can be arranged in the plant area and its front and back sides. The measurement points of the wave height meter should be no less than three (the front edge, middle and rear edge of the plant belt). Please see Figure A.2 for the layout position. When the number of wave height meters is limited, one wave height meter can be fixed at the front end of the plant area, and another wave height meter can be installed on a sliding device and slide along the flume to measure the wave height changes along the plant area.

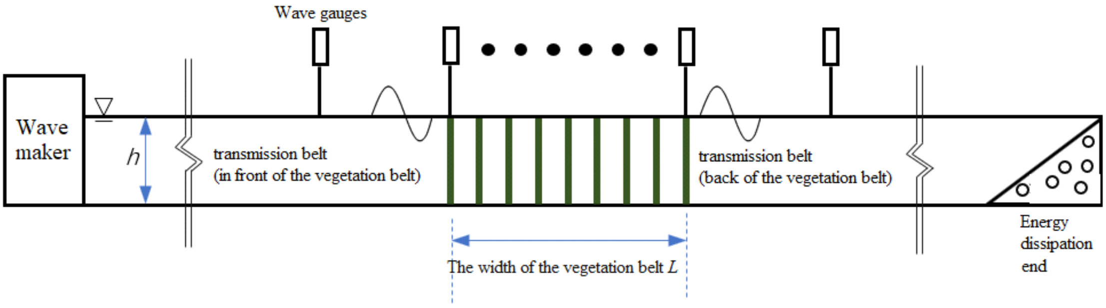


Figure A.2 —Schematic diagram of model test layout

A.3.3 Test data analysis and calculation

Using the data obtained from the model test, the water level, wave height, period and other hydrodynamic parameters of the test conditions and vegetation parameters such as the width, density, and vegetation height of the vegetation zone are calculated by formulas (A.4) to (A.9). Parameters, and the wave height $H_0$=$H_{0p}$ and $H_L$=$H_{Lp}$ (before and after the prototype salt marsh hazard mitigation vegetation area to be evaluated) is brought into formula (1) (see 6.3.3 of this document), and the wave height attenuation rate can be calculated.

## A.4 Numerical simulation method

### A.4.1 Applicability of numerical simulation

When the frequency of regional marine disasters is low (there is no storm surge affecting the area to be assessed) or the economic and technical conditions do not allow the use of field observation method, and the information of underlying surface, vegetation parameters, hydrodynamic conditions are available and mature numerical simulation technology conditions are also mastered, this method can be used to evaluate the hazard mitigation functions of salt marshes.

### A.4.2 Numerical model

There are three main types of existing numerical models for the interaction of plants and waves. One type is to directly add a plant force term to the wave model (such as the Simulating Waves Nearshore Model) to characterize the effect of plants, and to correct the relevant parameters of the model in the salt marsh area. The second one is to use a special wave current movement model in the salt marsh vegetation area. This type of model also has different processing methods, such as the fluid governing equation of wave and current motion in the vegetation area derived by regarding the vegetation area as a porous medium along with spatial averaging. The third type is statistical model, which is mainly based on the quantitative relationship between salt marsh vegetation parameters (such as plant height, density, coverage, etc.) and the interaction of waves. Specific numerical simulation can select a suitable numerical model according to actual needs and computing power and other conditions.
This document gives the fluid governing equations of wave and current motion in porous media, as follows:
The model regards the plants in the vegetation area as porous media, and derives the N-S equation by spatially averaging. The model control equations are as (A.10) and (A.11). This model can better simulate the attenuation process during wave

propagation in vegetation areas.

$$\frac{\partial\langle u_i\rangle}{\partial x_i}=0 \cdots\cdots \text{(A.10)}$$

$$\frac{\partial\langle u_i\rangle}{\partial t}+\langle u_j\rangle\frac{\partial\langle u_i\rangle}{\partial x_j}=-\frac{1}{\rho}\frac{\partial\langle P\rangle}{\partial x_i}+g_i+\nu\frac{\partial^2\langle u_i\rangle}{\partial x_i\partial x_j}-\frac{\partial^2\langle u_i'u_j'\rangle}{\partial x_j}-\langle f_i\rangle \cdots\cdots \text{(A.11)}$$

Where:

$\langle u_i\rangle$ Space average velocity in the $i$ direction (In the two-dimensional problem $i$=1, 2; In the three-dimensional problem $i$=1, 2, 3) ;

$\langle P\rangle$ Space average pressure;

$\rho$ Fluid density;

$g_i$ Gravitational acceleration in $i$ direction;

$\nu$ Fluid kinematic viscosity;

$\langle u_i'u_j'\rangle$ Spatial average Reynolds stress, which can be solved by $k$-$e$ flow model;

$\langle f_i\rangle$ Space average plant force.

The force $\langle f_i\rangle$ of vegetation area can be generalized into drag force term and inertial force term. For a single cylinder, formula (A.12) and formula (A.13) can be used to calculate its drag force and inertial force on water.

$$f_D=\frac{1}{2}\rho C_D D u|u| \cdots\cdots \text{(A.12)}$$

$$f_I=\rho C_m\frac{\pi D^2}{4}\frac{\partial u}{\partial t} \cdots\cdots \text{(A.13)}$$

Where:

$f_D$ Drag force;

$f_I$ Inertial force;

$C_D$ Drag coefficient (can be determined according to specific characteristics such as rigidity and flexibility of different plant species);

$C_m$ Inertial force coefficient (can be determined according to specific characteristics such as rigidity and flexibility of different plant species);

$\rho$ The density of the fluid in kilograms per cubic meter (kg/m$^3$);

$D$ Vertical average plant diameter (see below for specific calculation). in meters (m);

$u$ Water flow velocity in meters per second (m/s).

A.4.3 Analysis and calculation of numerical simulation results

When using numerical simulation methods to evaluate hazard mitigation functions, the real scale shall be used for simulation calculation. The wave height $H_0$ and $H_L$ (on the front and back sides of the salt marsh vegetation area to be evaluated) and the width $L$ of the vegetation zone of the assessment section should be brought into the formula (see 6.3.3 of this document), and the wave height attenuation rate $R_{wL}$ can be calculated.

## A.5 Method selection

The selection of the assessment method shall be comprehensively considered in combination with the regional site conditions, economic conditions, technical equipment and experimental conditions. When conditions permit, priority shall be given to field observation methods to directly measure and calculate the wave height mitigation rate during the storm surge. When the conditions are limited, for example, there is no storm surge impact assessment area in recent years, and field observations during storm surge hazards cannot be performed, the other three methods can be used. If the experimental conditions are limited, the empirical formula method can be used for assessment. It shall be ensured that the various parameters used in the formula truly reflect the characteristics of wetland vegetation and coastal ocean dynamics. If the experimental conditions of the physical model permit, the physical model can be used for assessment. It is necessary to ensure that the prototype vegetation parameters and ocean hydrodynamic parameters are true and reliable, and establish the physical model according to the similar criteria proposed in 6.5.3. When using numerical simulation methods for assessment, attention shall be paid to selecting reliable numerical models to ensure reasonable and accurate parameterization of plant functions. If the conditions are limited and none of the above methods can be used, you can see the results of the reference table in Annex B to obtain the required wave height attenuation rate.

# Annex B
## (annex informative)
## Reference description of wave height attenuation rate on salt marsh vegetation

The dominant species in coastal salt marsh vegetation in China mainly include *Phragmites australis, Scirpus mariqueter, Cyperus malaccensis var. brevifolius and Suaeda salsa*. Field survey and data collection found that the vegetation height of coastal salt marshes in China is usually 0.3m～3m, diameter 0.2m～3cm, and density ranges from dozens to thousands of plants per square. This document selects *Phragmites australis* and *Scirpus mariqueter*. We use the empirical formula method (see A.2.2 of this document) to calculate the corresponding wave height attenuation conditions rate with the sea state of 4 kinds of wave height (0.5m, 1.25m, 2.5m and 4m), 6 kinds of water level (1m, 2m, 3m, 4m, 5m and 6m), and 1 kind of cycle (4s), with *Phragmites australis* in 1 kind of diameter (1cm), 2 kinds of height (2m and 3m), 2 kinds of density (50 plants/ $m^2$, 100 plants/ $m^2$), with *Scirpus mariqueter* in kind of 1 diameter (0.2cm) , 2 kinds of height (0.3m and 0.6m), 2 kinds of density (800 plants/ $m^2$, 1600 plants/ $m^2$) and with 4 kinds of salt marsh vegetation belt width (50m, 100m, 200m and 400m). Consider its authenticity when combining multiple parameters (for example, when the wave height is 1m, the corresponding water level shall not be less than 2m), and the calculation results are shown in Table B.1 to Table B.4.

Table B.1 —Reference table of wave height attenuation rate of salt marsh vegetation (*Phragmites australis*) under different combination conditions

| Type: *Phragmites australis* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Average height: 2m | | | | | Base diameter: 1cm | | | | |
| Sea state | | Plant density: 50 plants/ $m^2$ | | | | Plant density: 100 plants/ $m^2$ | | | |
| | | Planting belt width/ (m) | | | | Planting belt width/ (m) | | | |
| Wave height/ (m) | Water level/ (m) | 50 | 100 | 200 | 400 | 50 | 100 | 200 | 400 |
| 0.5 | 1 | 61% | 76% | 86% | 93% | 77% | 87% | 93% | 96% |
| | 2 | 45% | 62% | 76% | 87% | 63% | 77% | 87% | 93% |
| | 3 | 21% | 35% | 52% | 69% | 36% | 53% | 69% | 82% |
| | 4 | 11% | 19% | 32% | 48% | 19% | 32% | 49% | 66% |
| | 5 | 5% | 10% | 18% | 31% | 10% | 19% | 31% | 48% |
| | 6 | 3% | 5% | 10% | 19% | 5% | 10% | 19% | 32% |
| 1.25 | 2 | 67% | 80% | 89% | 94% | 80% | 89% | 94% | 97% |
| | 3 | 40% | 57% | 73% | 84% | 58% | 73% | 84% | 92% |
| | 4 | 22% | 36% | 53% | 69% | 37% | 54% | 70% | 82% |
| | 5 | 12% | 21% | 35% | 52% | 22% | 35% | 52% | 69% |
| | 6 | 6% | 12% | 21% | 35% | 12% | 22% | 35% | 52% |
| 2.5 | 3 | 57% | 73% | 84% | 91% | 73% | 84% | 91% | 96% |
| | 4 | 36% | 53% | 69% | 82% | 53% | 70% | 82% | 90% |
| | 5 | 21% | 35% | 52% | 68% | 35% | 52% | 68% | 81% |
| | 6 | 12% | 21% | 35% | 52% | 21% | 35% | 52% | 68% |
| 4 | 5 | 30% | 46% | 63% | 77% | 46% | 63% | 78% | 87% |
| | 6 | 18% | 30% | 46% | 63% | 30% | 46% | 63% | 77% |
| NOTE: The water level value in the table refers to the tide level calculated from the ground of the vegetation area. | | | | | | | | | |

Table B.2 —Reference table of wave height attenuation rate of salt marsh vegetation (*Phragmites australis*) under different combination conditions

| Type: *Phragmites australis* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Average height: 3m | | | | | Base diameter: 1cm | | | | |
| Sea state | | Plant density: 50 plants/ $m^2$ | | | | Plant density: 100 plants/ $m^2$ | | | |
| | | Planting belt width/ (m) | | | | Planting belt width/ (m) | | | |
| Wave height/ (m) | Water level/ (m) | 50 | 100 | 200 | 400 | 50 | 100 | 200 | 400 |
| 0.5 | 1 | 61% | 76% | 86% | 93% | 77% | 87% | 93% | 96% |
| | 2 | 45% | 62% | 76% | 87% | 62% | 77% | 87% | 93% |
| | 3 | 36% | 53% | 69% | 82% | 53% | 70% | 82% | 90% |
| | 4 | 18% | 31% | 47% | 64% | 32% | 48% | 65% | 79% |
| | 5 | 9% | 17% | 30% | 46% | 18% | 30% | 46% | 63% |
| | 6 | 5% | 9% | 17% | 29% | 10% | 17% | 30% | 46% |
| 1.25 | 2 | 67% | 80% | 89% | 94% | 80% | 89% | 94% | 97% |
| | 3 | 58% | 73% | 84% | 92% | 74% | 85% | 92% | 96% |
| | 4 | 35% | 52% | 69% | 81% | 53% | 69% | 82% | 90% |
| | 5 | 20% | 34% | 50% | 67% | 34% | 51% | 67% | 81% |
| | 6 | 11% | 20% | 33% | 50% | 20% | 34% | 50% | 67% |
| 2.5 | 3 | 73% | 84% | 92% | 96% | 85% | 92% | 96% | 98% |
| | 4 | 52% | 69% | 81% | 90% | 69% | 82% | 90% | 95% |
| | 5 | 33% | 50% | 67% | 80% | 51% | 67% | 80% | 89% |
| | 6 | 20% | 33% | 50% | 66% | 33% | 50% | 67% | 80% |
| 4 | 5 | 44% | 62% | 76% | 86% | 62% | 76% | 87% | 93% |
| | 6 | 28% | 44% | 61% | 76% | 44% | 61% | 76% | 86% |
| NOTE: The water level value in the table refers to the tide level calculated from the ground of the vegetation area. | | | | | | | | | |

Table B.3— Reference table of the wave height attenuation rate of salt marsh vegetation (*Scirpus mariqueter*) under different combination conditions

| Types: *Scirpus mariqueter* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Average height: 0.3m | | | | | Base diameter: 0.1cm | | | | |
| Sea state | | Plant density: 800 plants/ $m^2$ | | | | Plant density: 1600 plants/ $m^2$ | | | |
| | | Planting belt width/ (m) | | | | Planting belt width/ (m) | | | |
| Wave height/ (m) | Water level/ (m) | 50 | 100 | 200 | 400 | 50 | 100 | 200 | 400 |
| 0.5 | 1 | 57% | 72% | 84% | 91% | 73% | 84% | 91% | 95% |
| | 2 | 22% | 36% | 53% | 69% | 36% | 53% | 69% | 82% |
| | 3 | 9% | 17% | 29% | 45% | 17% | 29% | 45% | 62% |
| | 4 | 4% | 8% | 16% | 27% | 8% | 16% | 27% | 43% |
| | 5 | 2% | 4% | 8% | 15% | 4% | 8% | 15% | 27% |
| | 6 | 1% | 2% | 4% | 9% | 2% | 4% | 9% | 16% |
| 1.25 | 2 | 41% | 58% | 73% | 85% | 58% | 73% | 85% | 92% |
| | 3 | 20% | 33% | 50% | 67% | 33% | 50% | 67% | 80% |
| | 4 | 10% | 18% | 31% | 47% | 18% | 31% | 47% | 64% |
| | 5 | 5% | 10% | 18% | 31% | 10% | 18% | 31% | 47% |
| | 6 | 3% | 5% | 10% | 18% | 5% | 10% | 18% | 31% |
| 2.5 | 3 | 33% | 50% | 67% | 80% | 50% | 67% | 80% | 89% |
| | 4 | 18% | 31% | 47% | 64% | 31% | 47% | 64% | 78% |
| | 5 | 10% | 18% | 30% | 46% | 18% | 30% | 46% | 63% |
| | 6 | 5% | 10% | 18% | 30% | 10% | 18% | 30% | 47% |
| 4 | 5 | 15% | 26% | 41% | 58% | 26% | 41% | 58% | 73% |
| | 6 | 8% | 15% | 26% | 41% | 15% | 26% | 41% | 58% |
| NOTE: The water level in the table refers to the tide level calculated from the ground of the vegetation area. | | | | | | | | | |

Table B.4 —Reference table of the wave height attenuation rate of salt marsh vegetation (*Scirpus mariqueter*) under different combination conditions

| Type: *Scirpus mariqueter* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Average height: 0.6m | | | | | Base diameter: 0.2cm | | | | |
| Sea state | | Plant density: 800 plants/ $m^2$ | | | | Plant density: 1600 plants/ $m^2$ | | | |
| | | Planting belt width/ (m) | | | | Planting belt width/ (m) | | | |
| Wave height/ (m) | Water level/ (m) | 50 | 100 | 200 | 400 | 50 | 100 | 200 | 400 |
| 0.5 | 1 | 73% | 85% | 92% | 96% | 85% | 92% | 96% | 98% |
| | 2 | 36% | 53% | 70% | 82% | 53% | 70% | 82% | 90% |
| | 3 | 17% | 30% | 46% | 63% | 30% | 46% | 63% | 77% |
| | 4 | 9% | 16% | 27% | 43% | 16% | 27% | 43% | 60% |
| | 5 | 4% | 8% | 16% | 27% | 8% | 16% | 27% | 43% |
| | 6 | 2% | 5% | 9% | 16% | 5% | 9% | 16% | 28% |
| 1.25 | 2 | 58% | 74% | 85% | 92% | 74% | 85% | 92% | 96% |
| | 3 | 34% | 51% | 67% | 80% | 51% | 67% | 80% | 89% |
| | 4 | 19% | 31% | 48% | 65% | 31% | 48% | 65% | 79% |
| | 5 | 10% | 18% | 31% | 47% | 18% | 31% | 47% | 64% |
| | 6 | 5% | 10% | 18% | 31% | 10% | 18% | 31% | 47% |
| 2.5 | 3 | 50% | 67% | 80% | 89% | 67% | 80% | 89% | 94% |
| | 4 | 31% | 47% | 64% | 78% | 47% | 64% | 78% | 88% |
| | 5 | 18% | 30% | 47% | 64% | 31% | 47% | 64% | 78% |
| | 6 | 10% | 18% | 31% | 47% | 18% | 31% | 47% | 64% |
| 4 | 5 | 26% | 41% | 58% | 74% | 41% | 58% | 74% | 85% |
| | 6 | 15% | 26% | 41% | 58% | 26% | 41% | 59% | 74% |
| NOTE: The water level value in the table refers to the tide level calculated from the ground of the vegetation area. | | | | | | | | | |

# Annex C
## (annex informative)
## Description of optimization design of vegetation planting based on hazard mitigation

C.1 Expected wave height attenuation rate setting

According to the local marine hazard mitigation needs, combined with regional wave conditions, set an appropriate expected wave height attenuation rate for the salt marsh vegetation area where vegetation is to be planted. And the value should be greater than 30% when the vegetation matures.

C.2 Optimal calculation of vegetation planting zone width and planting density

In order to achieve the expected wave height attenuation rate, the vegetation density and planting zone width required to be planted under different sea conditions shall be calculated according to the growth parameters of the selected vegetation maturity period. For empirical formula method and reference table, please see C.2.1 and C.2.2. If calculation conditions permit, the empirical formula can be used to calculate; if calculation conditions do not permit, the reference table can be consulted to find the corresponding reference value.

C.2.1 Empirical formula

The width of the planting belt shall be calculated according to the formula (C.1) based on the expected wave height attenuation rate and planting density value. The planting density shall be calculated according to the formula (C.2) based on the expected wave height attenuation rate and the value of the planting belt width. The vegetation parameters involved in the empirical formula shall be determined in sections 5.1 and 5.2 of this document.

$$L=\frac{9\pi}{4}\frac{R_L}{C_D D H_0 N k(1-R_L)}\frac{(\sinh 2kh+2kh)\sinh kh}{\sinh^3 kh_v+3\sinh kh_v} \quad \text{(C.1)}$$

$$N=\frac{9\pi}{4}\frac{R_L}{C_D D H_0 L k(1-R_L)}\frac{(\sinh 2kh+2kh)\sinh kh}{\sinh^3 kh_v+3\sinh kh_v} \quad \text{(C.2)}$$

Where:

$L$ Width of planting belt, in meters (m);

$R_L$ Expected wave height attenuation rate;

$C_D$ Plant drag coefficient, to be calculated according to empirical formula (A.3);

$N$ The number of plants per unit area, inind/m$^2$.

$H_0$ Wave height in front of vegetation zone caused by historical storm surge or hypothetical storm surge, in meters (m);

$D$ The plant area per unit vertical height, that is, the vertical average plant diameter, and its value is $\frac{\int_0^{h_v} D(z)dz}{h_v}$. in meter (m);

$k$ Wave number on the front end of planting area;

$h_v$ Plant flooding height, in meters (m);

$h$ Storm surge level calculated from the ground of the vegetation area, in meters (m).

C.2.2 Reference Table for Planting Density and Planting Belt Width of Salt Marsh Vegetation Based on Marine Hazard Mitigation

For *Phragmites australis* and *Scirpus mariqueter*, the expected mature vegetation parameters of several salt marsh plants were obtained through field surveys and data collection. Empirical formula method is used to calculate corresponding planting zone width with the sea state of 2 kinds of expected wave height attenuation rates (60%, 80%), 4 kinds of wave height (0.5m, 1.25m, 2.5m and 4m), 6 kinds of water level (1m～6m), and 1 kind of cycle (4s) and with 2 kinds of *Phragmites australis* height (2m and 3m), 1 kind of diameter (1cm), 4 kinds of planting density (200 plants/ $m^2$, 150 plants/ $m^2$, 100 plants/ $m^2$ and 50 plants/ $m^2$) and 2 kinds of *Scirpus mariqueter* height (0.3m and 0.6m), 1 kind of diameter (1cm), 4 kinds of density (1600 plants/ $m^2$, 1200 plants/ $m^2$, 800 plants/ $m^2$ and 400 plants/ $m^2$) . The results are shown from Table C.1 to Table C.4. The authenticity of multiple parameters shall be considered when combining multiple parameters (for example, when the wave height is 1m, the corresponding water level shall not be less than 2m). Under some calculation conditions, the width of the planting belt can reach thousands of meters, which is undesirable in practice. According to the actual planting situation, the requirements of hazard mitigation functions can be reduced and the appropriate planting width can be selected.

Table C.1 —Reference table for planting density and width of salt marsh vegetation (*Phragmites australis*) corresponding to expected wave height attenuation rate

| *Phragmites australis*, 2m high, 1cm in diameter | | | | | | |
|---|---|---|---|---|---|---|
| Wave height, water level and attenuation rate | | | Planting density/ (plants/ $m^2$) | | | |
| | | | 200 | 150 | 100 | 50 |
| Wave height/ (m) | Water level/ (m) | Wave height attenuation rate | Planting width/ (m) | | | |
| 0.5 | 1 | 60% | 10 | 20 | 30 | 60 |
| | | 80% | 30 | 50 | 70 | 150 |
| | 2 | 60% | 30 | 30 | 50 | 100 |
| | | 80% | 70 | 90 | 150 | 300 |
| | 3 | 60% | 80 | 100 | 150 | 350 |
| | | 80% | 200 | 300 | 450 | 900 |
| | 4 | 60% | 200 | 250 | 400 | 800 |
| | | 80% | 500 | 650 | 1000 | 2100 |
| | 5 | 60% | 400 | 550 | 800 | 1700 |
| | | 80% | 1100 | 1400 | 2200 | 4400 |
| | 6 | 60% | 800 | 1100 | 1600 | 3300 |
| | | 80% | 2100 | 2900 | 4400 | 8900 |
| 1.25 | 2 | 60% | 10 | 10 | 20 | 50 |
| | | 80% | 30 | 40 | 60 | 100 |
| | 3 | 60% | 30 | 40 | 70 | 150 |
| | | 80% | 90 | 100 | 200 | 350 |
| | 4 | 60% | 80 | 100 | 150 | 300 |
| | | 80% | 200 | 300 | 400 | 850 |
| | 5 | 60% | 150 | 200 | 350 | 700 |
| | | 80% | 450 | 600 | 900 | 1800 |
| | 6 | 60% | 350 | 450 | 650 | 1400 |
| | | 80% | 900 | 1200 | 1800 | 3600 |
| 2.5 | 3 | 60% | 20 | 20 | 30 | 70 |
| | | 80% | 40 | 60 | 90 | 200 |
| | 4 | 60% | 40 | 50 | 80 | 150 |
| | | 80% | 100 | 150 | 200 | 450 |
| | 5 | 60% | 80 | 100 | 150 | 350 |
| | | 80% | 200 | 300 | 450 | 900 |
| | 6 | 60% | 150 | 200 | 350 | 700 |
| | | 80% | 450 | 600 | 900 | 1800 |
| 4 | 5 | 60% | 50 | 70 | 100 | 200 |
| | | 80% | 150 | 200 | 300 | 550 |
| | 6 | 60% | 100 | 150 | 200 | 450 |
| | | 80% | 300 | 350 | 550 | 1100 |
| NOTE: The water level value in the table refers to the water level height calculated from the ground of the vegetation area. | | | | | | |

Table C.2 —Reference table for planting density and width of salt marsh vegetation (*Phragmites australis*) corresponding to expected wave height attenuation rate

| *Phragmites australis*, 3m high, 1cm in diameter | | | | | | |
|---|---|---|---|---|---|---|
| Wave height, water level and attenuation rate | | | Planting density/ (plants/ $m^2$) | | | |
| | | | 200 | 150 | 100 | 50 |
| Wave height/ (m) | Water level/ (m) | Wave height attenuation rate | Planting width/ (m) | | | |
| 0.5 | 1 | 60% | 10 | 20 | 30 | 60 |
| | | 80% | 30 | 50 | 70 | 150 |
| | 2 | 60% | 30 | 30 | 50 | 100 |
| | | 80% | 70 | 90 | 150 | 300 |
| | 3 | 60% | 40 | 50 | 80 | 150 |
| | | 80% | 100 | 150 | 200 | 450 |
| | 4 | 60% | 90 | 150 | 200 | 400 |
| | | 80% | 250 | 350 | 550 | 1100 |
| | 5 | 60% | 200 | 300 | 450 | 900 |
| | | 80% | 550 | 750 | 1100 | 2300 |
| | 6 | 60% | 450 | 600 | 900 | 1800 |
| | | 80% | 1100 | 1600 | 2400 | 4800 |
| 1.25 | 2 | 60% | 10 | 10 | 20 | 50 |
| | | 80% | 30 | 40 | 60 | 100 |
| | 3 | 60% | 20 | 20 | 30 | 70 |
| | | 80% | 40 | 60 | 90 | 200 |
| | 4 | 60% | 40 | 50 | 80 | 150 |
| | | 80% | 100 | 150 | 200 | 450 |
| | 5 | 60% | 80 | 100 | 200 | 350 |
| | | 80% | 250 | 300 | 450 | 950 |
| | 6 | 60% | 200 | 250 | 350 | 750 |
| | | 80% | 450 | 650 | 950 | 2000 |
| 2.5 | 3 | 60% | 10 | 10 | 20 | 30 |
| | | 80% | 20 | 30 | 40 | 90 |
| | 4 | 60% | 20 | 30 | 40 | 80 |
| | | 80% | 50 | 70 | 100 | 200 |
| | 5 | 60% | 40 | 60 | 90 | 200 |
| | | 80% | 100 | 150 | 250 | 500 |
| | 6 | 60% | 90 | 100 | 200 | 350 |
| | | 80% | 250 | 300 | 500 | 1000 |
| 4 | 5 | 60% | 30 | 40 | 60 | 100 |
| | | 80% | 70 | 100 | 150 | 300 |
| | 6 | 60% | 60 | 80 | 100 | 250 |
| | | 80% | 150 | 200 | 300 | 600 |
| NOTE: The water level value in the table refers to the water level height calculated from the ground of the vegetation area. | | | | | | |

Table C.3 —Reference table for planting density and width of salt marsh vegetation (*Scirpus mariqueter*) corresponding to expected wave height attenuation rate

| *Scirpus mariqueter*, 0.3m high, 0.2cm in diameter | | | | | | |
|---|---|---|---|---|---|---|
| Wave height, water level and attenuation rate | | | Planting density/ (plants/ $m^2$) | | | |
| | | | 1600 | 1200 | 800 | 400 |
| Wave height/ (m) | Water level/ (m) | Wave height attenuation rate | Planting width/ (m) | | | |
| 0.5 | 1 | 60% | 30 | 50 | 70 | 150 |
| | | 80% | 90 | 100 | 200 | 350 |
| | 2 | 60% | 150 | 200 | 350 | 650 |
| | | 80% | 450 | 600 | 850 | 1700 |
| | 3 | 60% | 450 | 600 | 900 | 1800 |
| | | 80% | 1200 | 1600 | 2400 | 4800 |
| | 4 | 60% | 1000 | 1300 | 2000 | 4000 |
| | | 80% | 2700 | 3500 | 5300 | 10600 |
| | 5 | 60% | 2000 | 2700 | 4100 | 8200 |
| | | 80% | 5500 | 7300 | 11000 | 21800 |
| | 6 | 60% | 4100 | 5400 | 8100 | 16200 |
| | | 80% | 10800 | 4400 | 16000 | 20500 |
| 1.25 | 2 | 60% | 70 | 90 | 150 | 250 |
| | | 80% | 200 | 250 | 350 | 700 |
| | 3 | 60% | 200 | 250 | 350 | 750 |
| | | 80% | 500 | 650 | 950 | 1900 |
| | 4 | 60% | 400 | 550 | 800 | 1600 |
| | | 80% | 1100 | 1400 | 2200 | 4400 |
| | 5 | 60% | 850 | 1100 | 1700 | 3400 |
| | | 80% | 2200 | 3000 | 4500 | 9000 |
| | 6 | 60% | 1700 | 2200 | 3300 | 6700 |
| | | 80% | 4400 | 5900 | 8900 | 17800 |
| 2.5 | 3 | 60% | 90 | 100 | 200 | 350 |
| | | 80% | 250 | 300 | 500 | 1000 |
| | 4 | 60% | 200 | 250 | 400 | 800 |
| | | 80% | 550 | 750 | 1100 | 2200 |
| | 5 | 60% | 400 | 550 | 850 | 1700 |
| | | 80% | 1100 | 1500 | 2300 | 4500 |
| | 6 | 60% | 850 | 1100 | 1700 | 3400 |
| | | 80% | 2200 | 3000 | 4500 | 8900 |
| 4 | 5 | 60% | 250 | 350 | 550 | 1100 |
| | | 80% | 700 | 950 | 1400 | 2800 |
| | 6 | 60% | 500 | 700 | 1100 | 2100 |
| | | 80% | 1400 | 1900 | 2800 | 5600 |
| NOTE: The water level value in the table refers to the water level height calculated from the ground of the vegetation area. | | | | | | |

Table C.4 —Reference Table for Planting Density and Width of Salt Marsh Vegetation (*Scirpus mariqueter*) Corresponding to Expected Wave Height Attenuation Rate

| *Scirpus mariqueter*, 0.6m high, 0.2cm in diameter | | | | | | |
|---|---|---|---|---|---|---|
| Wave height, water level and attenuation rate | | | Planting density/ (plants/ m$^2$) | | | |
| | | | 1600 | 1200 | 800 | 400 |
| Wave height/ (m) | Water level /(m) | Wave height attenuation rate | Planting width/ (m) | | | |
| 0.5 | 1 | 60% | 20 | 20 | 30 | 70 |
| | | 80% | 40 | 60 | 90 | 200 |
| | 2 | 60% | 80 | 100 | 150 | 300 |
| | | 80% | 200 | 300 | 400 | 850 |
| | 3 | 60% | 200 | 300 | 450 | 900 |
| | | 80% | 600 | 800 | 1200 | 2300 |
| | 4 | 60% | 500 | 650 | 1000 | 2000 |
| | | 80% | 1300 | 1700 | 2600 | 5300 |
| | 5 | 60% | 1000 | 1300 | 2000 | 4100 |
| | | 80% | 2700 | 3600 | 5400 | 10800 |
| | 6 | 60% | 2000 | 2700 | 4000 | 8000 |
| | | 80% | 5300 | 7100 | 10800 | 21400 |
| 1.25 | 2 | 60% | 30 | 40 | 60 | 150 |
| | | 80% | 90 | 100 | 150 | 350 |
| | 3 | 60% | 90 | 100 | 200 | 350 |
| | | 80% | 250 | 300 | 500 | 950 |
| | 4 | 60% | 200 | 250 | 400 | 800 |
| | | 80% | 550 | 700 | 1100 | 2100 |
| | 5 | 60% | 400 | 550 | 850 | 1700 |
| | | 80% | 1100 | 1500 | 2200 | 4400 |
| | 6 | 60% | 800 | 1100 | 1600 | 3300 |
| | | 80% | 2200 | 2900 | 4400 | 8800 |
| 2.5 | 3 | 60% | 40 | 60 | 90 | 200 |
| | | 80% | 100 | 150 | 250 | 500 |
| | 4 | 60% | 100 | 150 | 200 | 400 |
| | | 80% | 250 | 350 | 550 | 1100 |
| | 5 | 60% | 200 | 300 | 400 | 850 |
| | | 80% | 550 | 750 | 1100 | 2200 |
| | 6 | 60% | 400 | 550 | 850 | 1700 |
| | | 80% | 1100 | 1500 | 2200 | 4400 |
| 4 | 5 | 60% | 150 | 150 | 250 | 500 |
| | | 80% | 350 | 450 | 700 | 1400 |
| | 6 | 60% | 250 | 350 | 500 | 1000 |
| | | 80% | 700 | 900 | 1400 | 2800 |
| NOTE: The water level value in the table refers to the water level height calculated from the ground of the vegetation area. | | | | | | |