2. Representative Wave Investigation

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2.1 Wave Hindcast Points and Fetch

Waves with a return period of several times per year and of 10, 30 and 50 years were hindcast at 7 points shown in Figure 1. Also, the blue dot is the wave observation point. The fetch of each wave hindcast point is given in Table 1, while the fetch models in Figure 2.

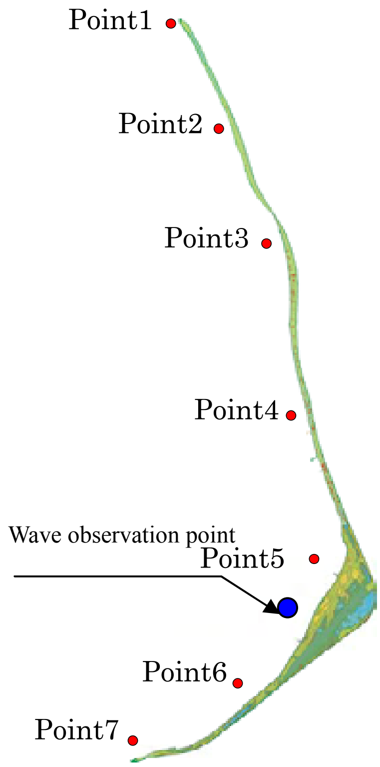


Figure 1 Wave hindcast points

Table 1 Fetch

Direction	Featch (km)						
	Point1	Point2	Point3	Point4	Point5	Point6	Point7
N	0.2	0.8	1.6	2.7	3.2	6.8	9.1
NNE	–	0.1	0.3	0.7	0.7	3.6	6.5
NE	–	–	–	–	–	1.4	3.9
ENE	–	–	–	–	–	0.5	2.0
E	–	–	–	–	–	–	–
ESE	0.6	0.1			–	–	–
SE	2.5	1.3	0.4	0.4	–	–	–
SSE	5.5	3.5	1.7	1.3	–	–	–
S	9.9	7.3	4.7	3.2	0.5	0.1	–
SSW	13.3	11.3	8.8	6.8	3.0	1.3	1.2
SW	14.0	13.5	12.3	10.5	7.1	4.5	4.0
WSW	12.5	13.6	13.7	12.9	11.0	8.5	7.6
W	8.8	11.2	12.9	13.7	13.6	12.0	10.7
WNW	5.2	8.1	10.4	12.0	13.3	13.4	12.4
NW	2.6	5.0	7.1	9.1	10.6	12.3	12.3
NNW	0.9	2.4	4.0	5.8	6.8	9.9	11.1

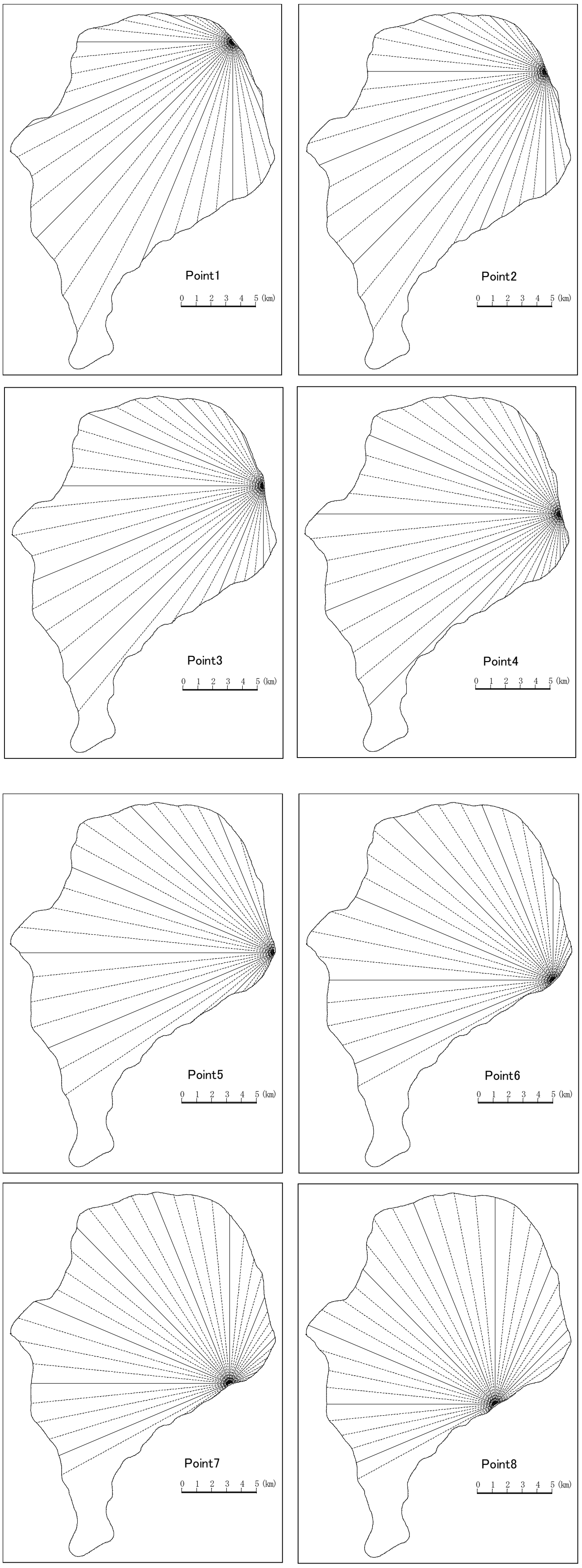


Figure 2 Fetch Models

2.2 Correction of Wave Hindcasts

(1)Investigation using wind observation data

Point1

Wave hindcast verification was undertaken with the Sverdrup, Munk and Bretschneider (SMB) method, which uses the following Wilson's formula IV, based on wave observation data from February 2 until March 19.

$$\frac{gH_{1/3}}{U^2} = 0.30\left\{1 - \frac{1}{\left[1 + 0.004(gF/U^2)^{1/2}\right]^2}\right\} \tag{1}$$

$$\frac{gT_{1/3}}{2\pi U} = 1.37\left\{1 - \frac{1}{\left[1 + 0.008(gF/U^2)^{1/3}\right]^5}\right\} \tag{2}$$

Where,

g: Gravitational acceleration (m/s^2),

U: Wind speed 10 m above sea level

$H_{1/3}$ 、 $T_{1/3}$: Significant wave height (m), signification wave period (s), and

F: Fetch (m).

Hindcasting was conducted for an eleven day period, from February 2 to 12, because there was no observation data from February 13 for Funafuti port (see wave hindcast I in Table 2).

Table 2 Wind observation and wave hindcast periods

Month	February														March								
Day	2	4	6	8	10	12	14	16	18	20	22	24	26	28	2	4	6	8	10	12	14	16	18
Wind observation				– 2/12																			
Wave observation				2/2–2/19											2/20–3/19								
Wave hindcast Ⅰ			2/2–2/12																				
Wave hindcast Ⅱ									2/2 – 3/19														

† Wave hindcast □ : Using observation wind data

††Wave hindcast □ : Using NCEP reanalysis wind data

The results of the calculations are given in Figure 3, however, because, the hindcast period is short in comparison to the observation values the coefficient 1.37 of formula (2) has been adjusted by 1.5 times, Figure 4.

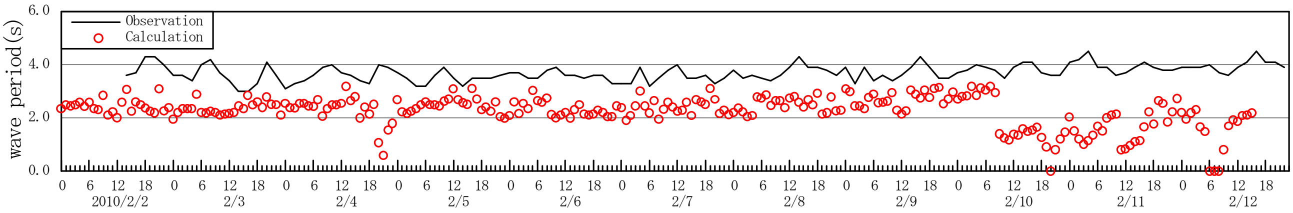


Figure 3 Difference between hindcast period and observation period before correction

The reproducibility of the wave period and height is relatively good, if data from February 10 on is omitted, as can be seen in Figure 4. From February 10 to 12 there were no waves hindcast such as those observed, however, because, for the purposes of wave hindcasting, accuracy of rough periods is more important than calm periods, verification was undertaken using NCEP (National Centers for Environmental Prediction) reanalysis wind data that includes rough conditions in March (see wave hindcast II in Table 2).

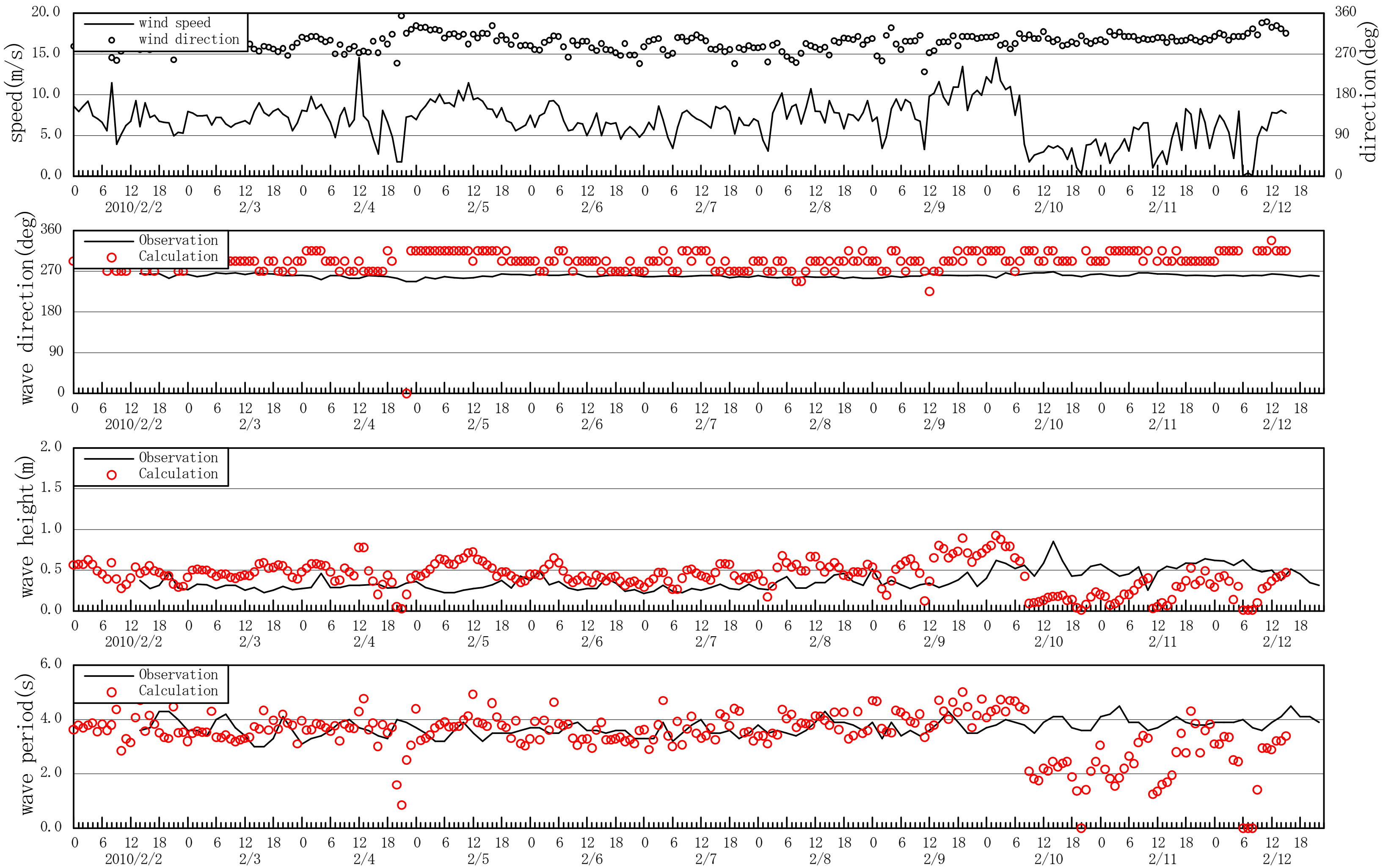
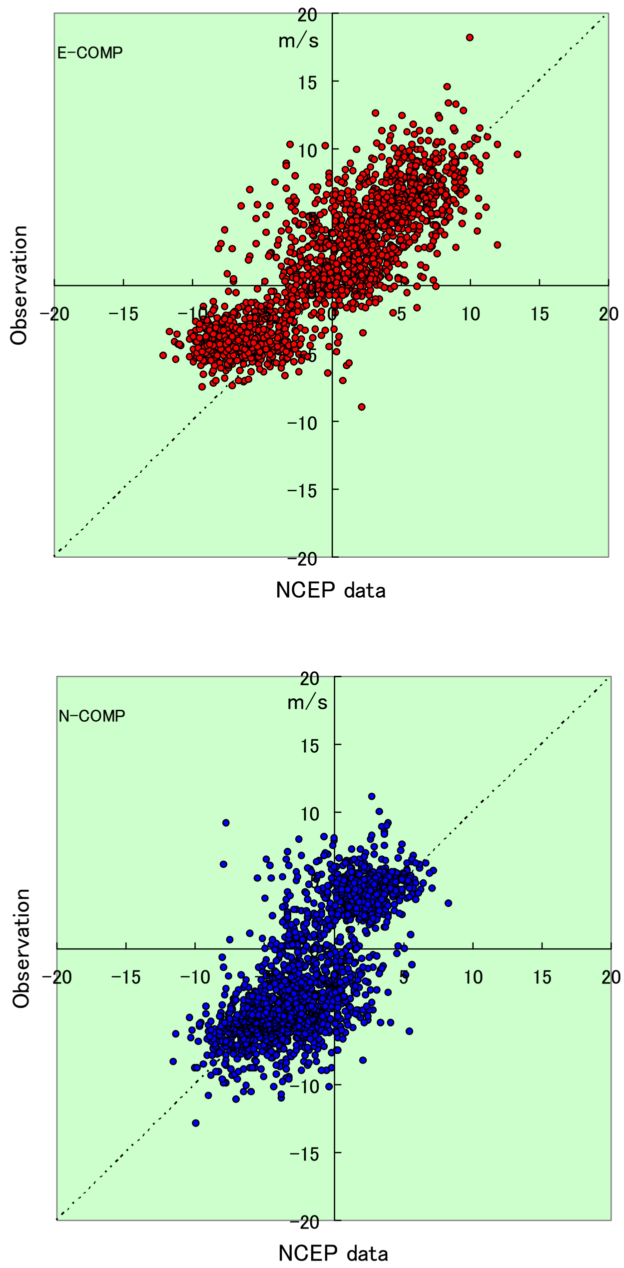


Figure 4 Comparison of observed values and results of hindcasting using wind observation data

(2) Investigation using NCEP data

The NCEP data is taken four times daily (0, 6, 12, 18h, UTC), at 2.5°grid spacing. From this, Spline interpolation was employed to conduct spatio-temporal interpolation to obtain data of one hour intervals at 8°31' northing and 179°12' 1" easting.

A correlation of NCEP data and wind observation data is given in Figure 5. The upper figure is the east-west component of wind velocity, while the lower figure is a comparative north-south wind component. It was decided to use the NCEP data without correction, because, while there is a spread in the distribution, the majority is along the diagonal.



□Wind speeds 5.0m/s and over were selected.

Figure 5 Correlation of NCEP data and wind data (Jan. 1999－Feb. 2009)

Figure 6 is a time series comparison of observed wind speed for February 2010. As mentioned above, because the four times daily NCEP data is interpolated the peak values do not match, however, trends in wind speed variation and order are good. Further, from February 10 to 12 when the observed wind speed was low, the NCEP data was 10 m/s or higher.

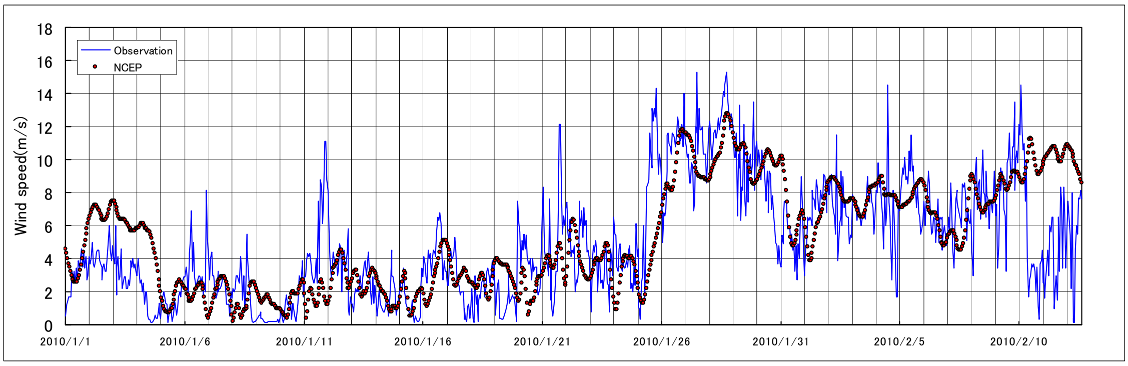


Figure 6 Correlation between NCEP and observed wind data (Feb. 2010)

Wave hindcasts using the NCEP data are shown in Figure 7 (1) to (4). Periods of high observed wave heights are February 10, March 3 to 5, and March 12 to 14. Maximum values are difficult to obtain because interpolated six-hourly wind data is used, however, the hindcast value peaks are still close to the observed values.

From this, it was determined that this model can be applied to Tuvalu by correcting the periodic coefficients.

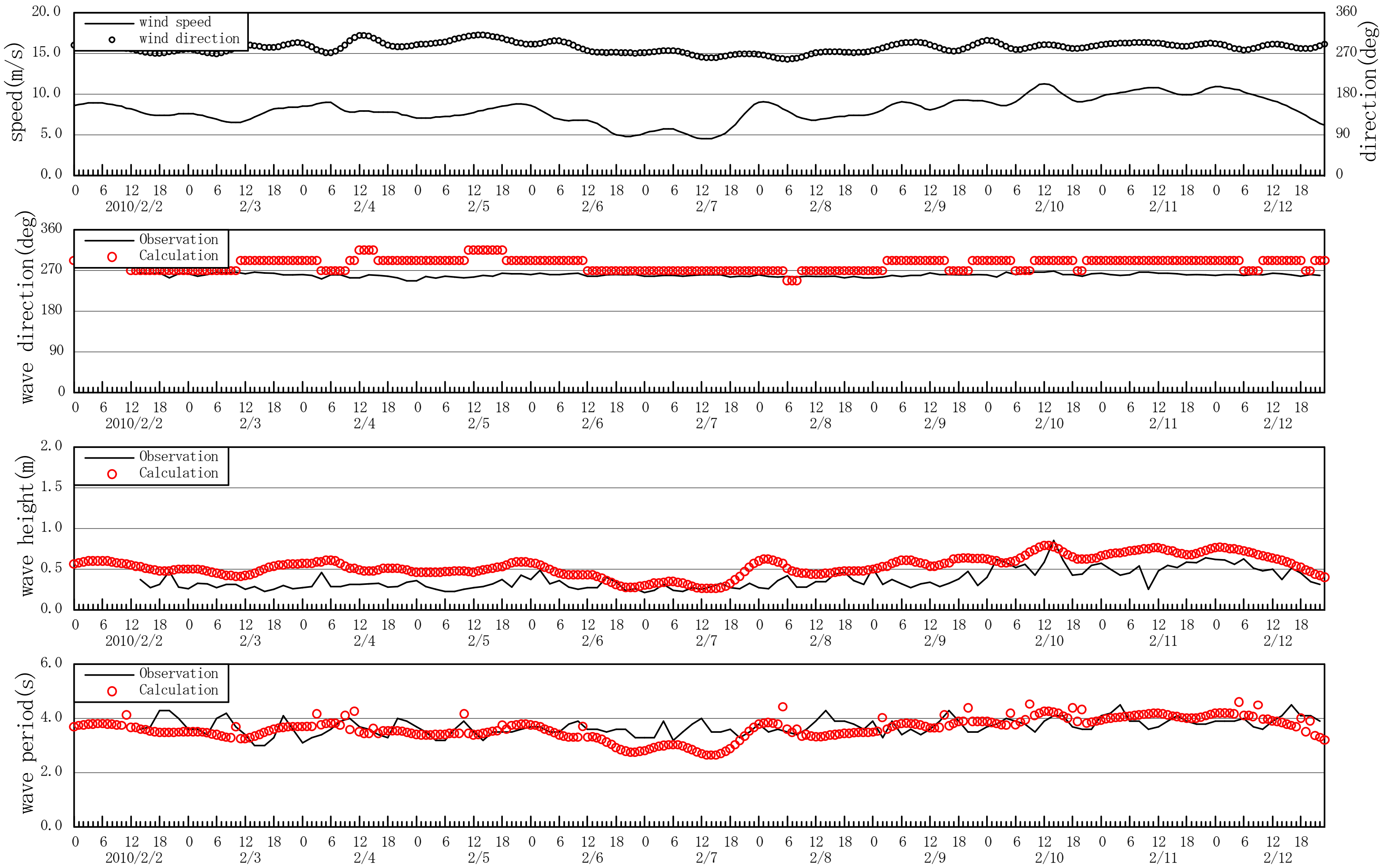


Figure 7(1) Comparison of observed values and results of hindcasting using wind observation data

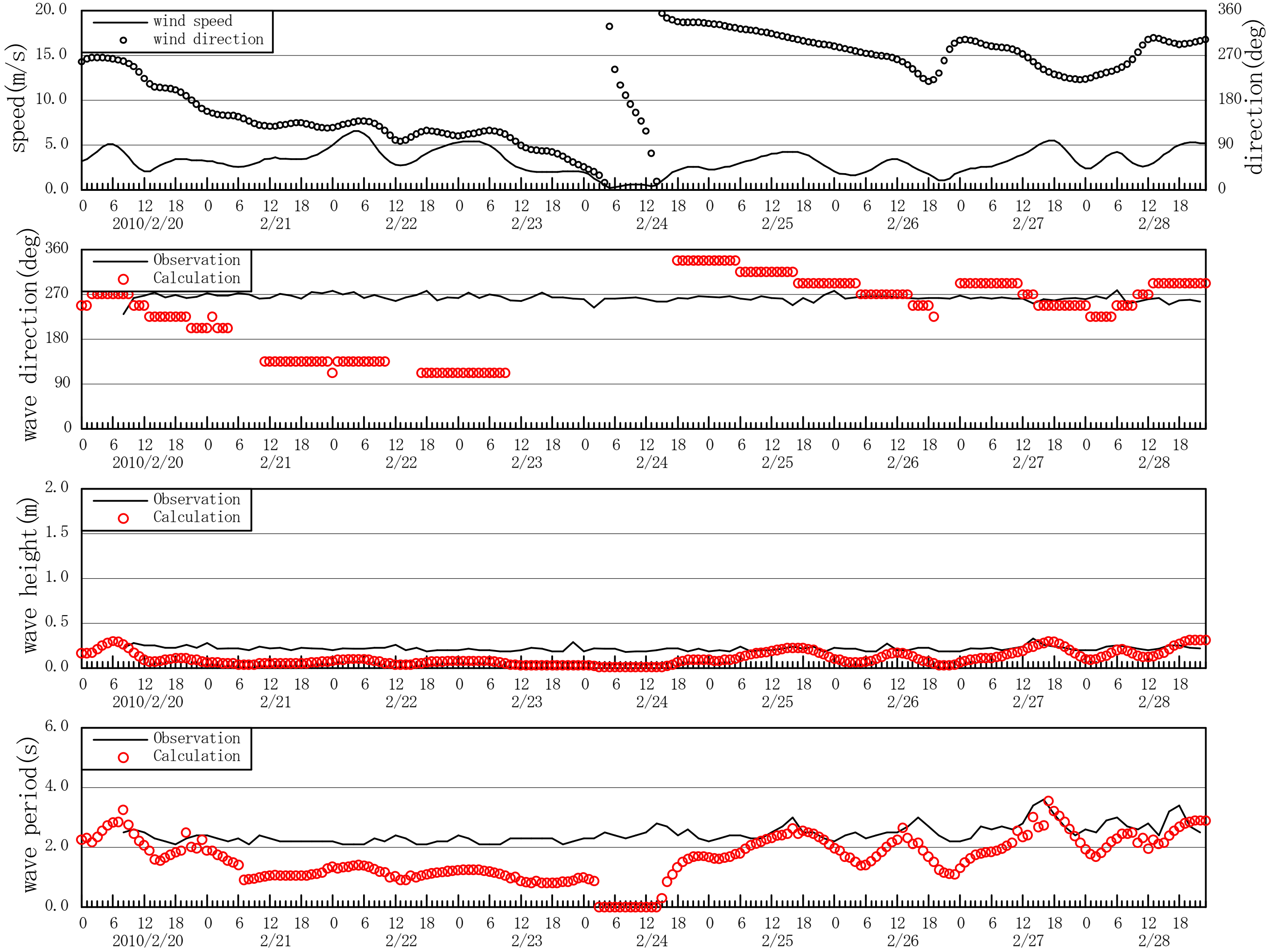


Figure 7(2) Comparison of observed values and results of hindcasting using wind observation data

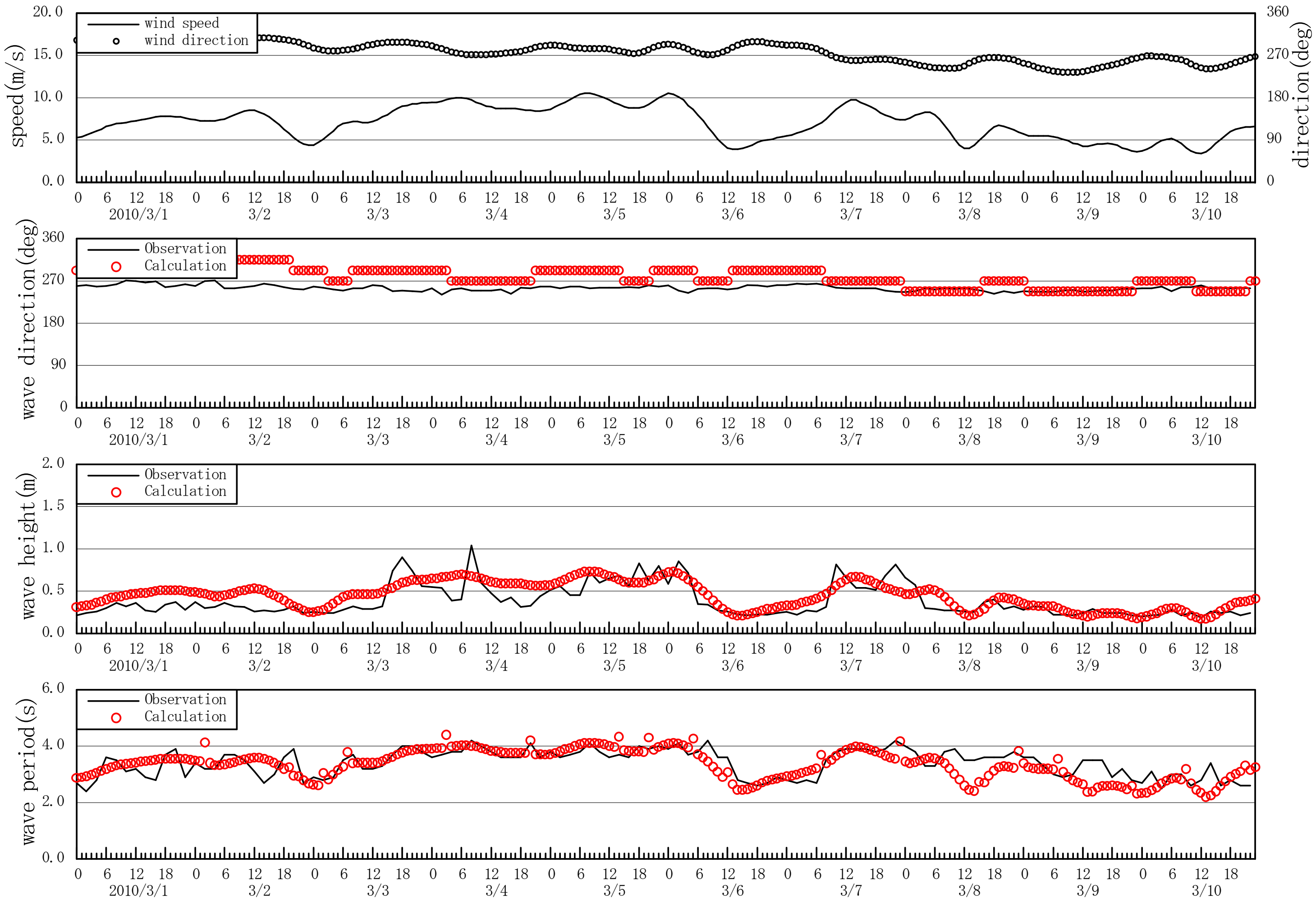


Figure 7(3) Comparison of observed values and results of hindcasting using wind observation data

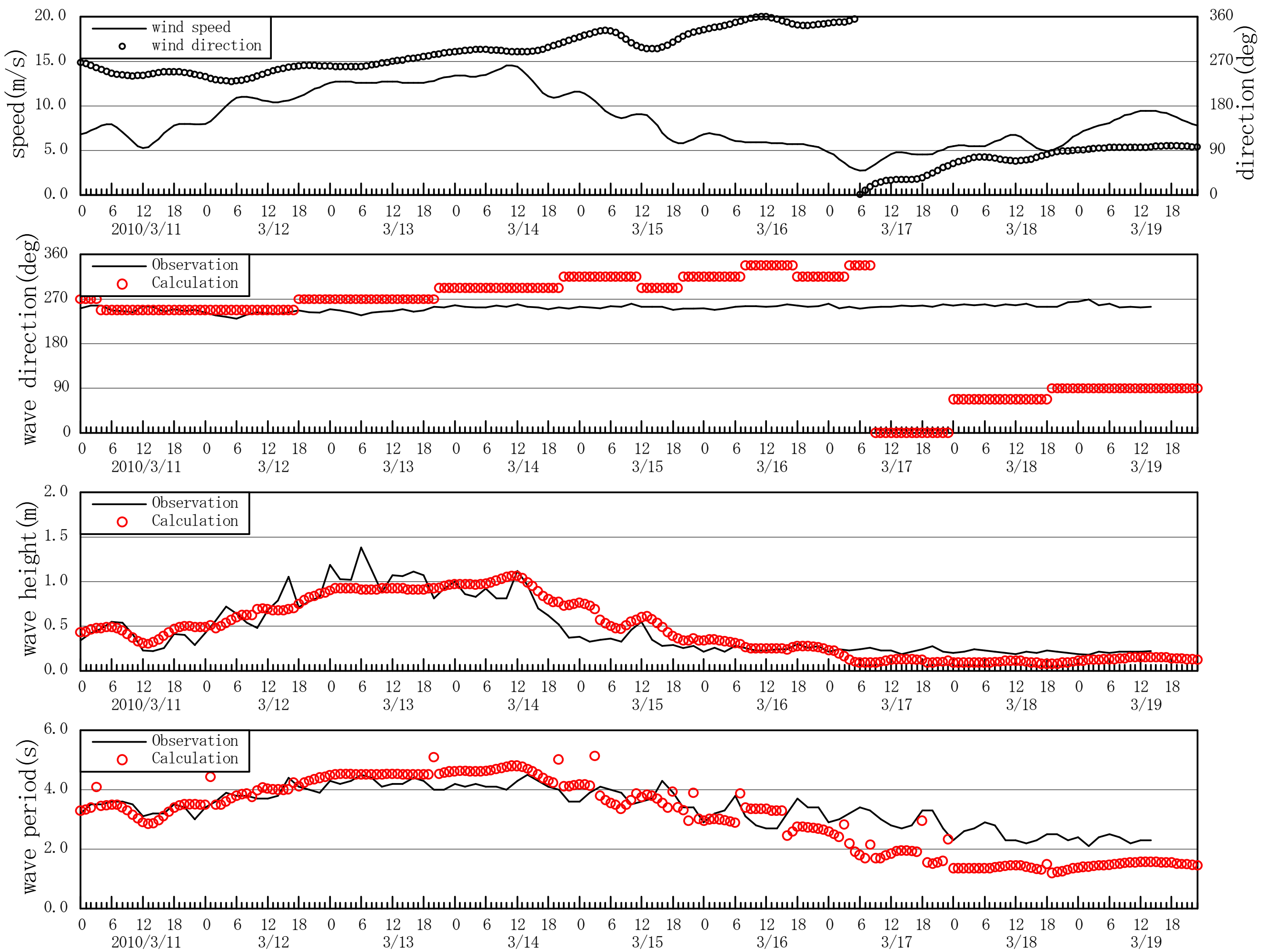


Figure 7(4) Comparison of observed values and results of hindcasting using wind observation data

2.3. Wave Return Period of Several Times per Year

Because wave data is derived from wave hindcasts and because accuracy decreases when wave height is low, the non-exceedance probability curve, Figure 8, was derived from the cumulative occurrence ratio values for wave heights 0.4 m and above, Table 3; wherein a 99% probability of non-exceedance—which is one definition of a wave return period of several times per year—wave height of 0.57 m was found. The wave period that occurs most at wave height 0.57 m from Table 3 is between 4.0 and 4.4 seconds. Therefore, the height and period of a wave of return period of several times per year derived from hindcast data is $H_{1/3}$=0.57 m and $T_{1/3}$=4.2 s. Waves observed in front of Vaiaku Lagi Hotel between February 2 and March 19, 2010, however, exceeded a wave height of 0.57 m—the green line on Figure 9 wave height time series—ten times, which is too frequent to be a wave of return period of several times per year; therefore, the wave height is too low. On the other hand, the frequency of waves exceeding a wave height of 0.85 m, the red line, is five times. It is considered that a wave height observed five times in this period, which, as the lagoon side is calm in the dry season and rough in the rainy season, corresponds to a wave of return period several times per year. Therefore, the wave height and period of return period of several times per year are $H_{1/3}$=0.85m、$T_{1/3}$=4.1s (mean values). Moreover, as a wave height of 0.85 m corresponds to a non-exceedance probability of 99.9%, this value will be used at other points to determine waves of return period of several times per year.

Table 3 Frequency of wave heights and periods (Point5)

Regulation	87672	
Observation	87672	(100.0)
Error	0	(0.0)

Site	Funafuti(Point5)												
Term	1999/ 1/ 1/ 0:00– 2008/ 12/ 31/ 23:00(Annual)												
Wave Height (m)	Wave Period (sec)											Sum	Accum. Sum
	0–0.9	1–1.9	2–2.9	3–3.4	3.5–3.9	4–4.4	4.5–4.9	5–5.4	5.5–5.9	6–6.4	6.5–6.9	7以上		
0.00 – 0.09	59932 (68.4)	15928 (18.2)	428 (0.5)	6 (0.0)	1 (0.0)								76295 (87.0)	76295 (87.0)
0.10 – 0.19		1055 (1.2)	2776 (3.2)	203 (0.2)	31 (0.0)	17 (0.0)	5 (0.0)	1 (0.0)					4088 (4.7)	80383 (91.7)
0.20 – 0.29			2073 (2.4)	399 (0.5)	178 (0.2)	56 (0.1)	17 (0.0)	4 (0.0)	1 (0.0)				2728 (3.1)	83111 (94.8)
0.30 – 0.39			633 (0.7)	731 (0.8)	223 (0.3)	103 (0.1)	30 (0.0)	9 (0.0)	1 (0.0)	2 (0.0)	1 (0.0)	2 (0.0)	1735 (2.0)	84846 (96.8)
0.40 – 0.49			9 (0.0)	798 (0.9)	281 (0.3)	132 (0.2)	46 (0.1)	13 (0.0)	4 (0.0)	2 (0.0)		1 (0.0)	1286 (1.5)	86132 (98.2)
0.50 – 0.59				63 (0.1)	474 (0.5)	108 (0.1)	38 (0.0)	20 (0.0)	5 (0.0)	1 (0.0)	1 (0.0)	2 (0.0)	712 (0.8)	86844 (99.1)
0.60 – 0.69				1 (0.0)	206 (0.2)	154 (0.2)	32 (0.0)	9 (0.0)	5 (0.0)		1 (0.0)	2 (0.0)	410 (0.5)	87254 (99.5)
0.70 – 0.79					21 (0.0)	171 (0.2)	30 (0.0)	12 (0.0)	1 (0.0)	2 (0.0)	1 (0.0)		238 (0.3)	87492 (99.8)
0.80 – 0.89						72 (0.1)	31 (0.0)	17 (0.0)	2 (0.0)				122 (0.1)	87614 (99.9)
0.90 – 0.99						5 (0.0)	17 (0.0)	9 (0.0)	4 (0.0)				35 (0.0)	87649 (100.0)
1.00 – 1.19						1 (0.0)	16 (0.0)	3 (0.0)	3 (0.0)				23 (0.0)	87672 (100.0)
1.20 – 1.39														87672 (100.0)
1.40 – 1.59														87672 (100.0)
1.60 – 1.79														87672 (100.0)
1.80 ≦														87672 (100.0)
Sum	59932 (68.4)	16983 (19.4)	5919 (6.8)	2201 (2.5)	1415 (1.6)	819 (0.9)	262 (0.3)	97 (0.1)	26 (0.0)	7 (0.0)	4 (0.0)	7 (0.0)	87672 (100.0)	* *

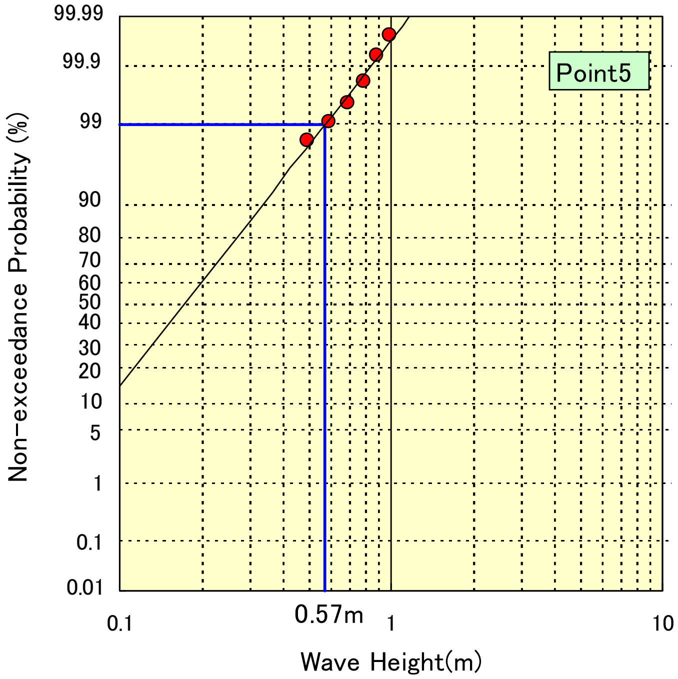


Figure 8 Non-exceedance probability curve (Point5)

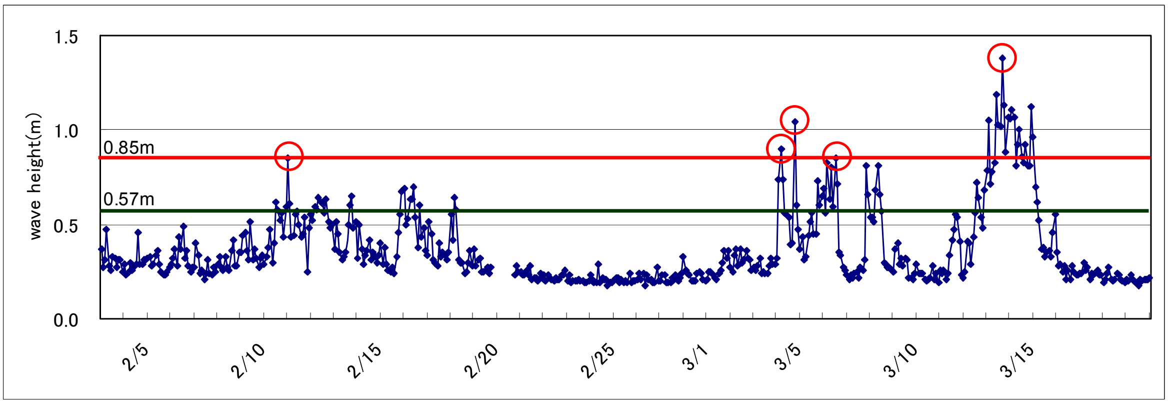


Table 4 Probability of non-exceedance according to wave hindcast points

Wave height (m)	Probability of non-exceedance(%)						
	Point1	Point2	Point3	Point4	Point5	Point6	Point7
0.50	99.03	98.60	98.21	98.01	98.01	97.89	97.83
0.51	99.15	98.75	98.39	98.20	98.19	98.08	98.03
0.52	99.25	98.89	98.56	98.37	98.35	98.25	98.20
0.53	99.34	99.02	98.71	98.53	98.50	98.40	98.36
0.54	99.42	99.13	98.84	98.67	98.63	98.53	98.50
0.55	99.49	99.22	98.96	98.80	98.75	98.66	98.64
0.56	99.55	99.31	99.06	98.91	98.86	98.77	98.76
0.57	99.61	99.38	99.15	99.01	98.96	98.88	98.86
0.58	99.65	99.45	99.24	99.10	99.05	98.97	98.96
0.59	99.70	99.51	99.31	99.19	99.13	99.06	99.05
0.60	99.73	99.57	99.38	99.26	99.21	99.14	99.13
0.61	99.76	99.61	99.44	99.33	99.27	99.21	99.21
0.62	99.79	99.65	99.50	99.39	99.33	99.27	99.27
0.63	99.82	99.69	99.55	99.45	99.39	99.33	99.34
0.64	99.84	99.72	99.59	99.50	99.44	99.39	99.39
0.65	99.86	99.75	99.63	99.54	99.49	99.44	99.44
0.66	99.87	99.78	99.67	99.58	99.53	99.48	99.49
0.67	99.89	99.80	99.70	99.62	99.57	99.52	99.53
0.68	99.90	99.82	99.73	99.66	99.60	99.56	99.57
0.69	99.91	99.84	99.75	99.69	99.64	99.60	99.60
0.70	99.92	99.86	99.78	99.71	99.67	99.63	99.64
0.71	99.93	99.87	99.80	99.74	99.69	99.66	99.67
0.72	99.94	99.89	99.82	99.76	99.72	99.68	99.69
0.73	99.95	99.90	99.83	99.78	99.74	99.71	99.72
0.74	99.95	99.91	99.85	99.80	99.76	99.73	99.74
0.75	99.96	99.92	99.86	99.82	99.78	99.75	99.76
0.76	99.96	99.93	99.88	99.83	99.80	99.77	99.78
0.77	99.97	99.93	99.89	99.85	99.81	99.79	99.80
0.78	99.97	99.94	99.90	99.86	99.83	99.80	99.81
0.79	99.97	99.95	99.91	99.87	99.84	99.82	99.83
0.80	99.98	99.95	99.91	99.88	99.85	99.83	99.84
0.81	99.98	99.96	99.92	99.89	99.86	99.84	99.85
0.82	99.98	99.96	99.93	99.90	99.87	99.86	99.86
0.83	99.98	99.96	99.94	99.91	99.88	99.87	99.87
0.84	99.98	99.97	99.94	99.92	99.89	99.88	99.88
0.85	99.99	99.97	99.95	99.92	99.90	99.89	99.89
0.86	99.99	99.97	99.95	99.93	99.91	99.89	99.90
0.87	99.99	99.98	99.96	99.94	99.91	99.90	99.91
0.88	99.99	99.98	99.96	99.94	99.92	99.91	99.91
0.89	99.99	99.98	99.96	99.95	99.93	99.91	99.92
0.90	99.99	99.98	99.97	99.95	99.93	99.92	99.93
0.91	99.99	99.98	99.97	99.95	99.94	99.93	99.93
0.92	99.99	99.99	99.97	99.96	99.94	99.93	99.94
0.93	99.99	99.99	99.97	99.96	99.95	99.94	99.94
0.94	99.99	99.99	99.98	99.96	99.95	99.94	99.95
0.95	100.00	99.99	99.98	99.97	99.95	99.94	99.95

2.4 Mean Energy Wave

The mean energy wave was calculated from wave hindcast data using the SMB method, from wind reference data for Funafuti port from 1999 to 2008.

The mean energy wave is to be used in the shoreline change prediction model, and is to be calculated with the following formulae.

Formula for wave period: $\tilde{T} = \dfrac{\sum_k n_k T_k}{\sum_k n_k}$

(1)

Formula for wave height: $\tilde{T} \cdot \tilde{H}^2 = \dfrac{\sum_k \sum_l (n_{kl} \cdot T_k \cdot H_l^2)}{\sum_k \sum_l n_{kl}}$

(2)

Formula for wave direction: $\tilde{T} \cdot \tilde{H}^2 \cos\tilde{\alpha} \cdot \sin\tilde{\alpha} = \dfrac{\sum_m \sum_k \sum_l n_{klm} \cdot T_k H_l^2 \cdot \cos\alpha_m \cdot \sin\alpha_m}{\sum_k \sum_l \sum_m n_{klm}}$

$$\tilde{\alpha} = \frac{1}{2}\sin^{-1}\left[2\frac{\sum_m \sum_k \sum_l n_{klm} \cdot T_k H_l^2 \cdot \cos\alpha_m \cdot \sin\alpha_m}{\tilde{T} \cdot \tilde{H}^2 \sum_k \sum_l \sum_m n_{klm}} \right] \quad (3)$$

Here,

H 、 T 、 α : wave height, period, and direction

$\tilde{H}$ 、 $\tilde{T}$ 、 $\tilde{\alpha}$: mean energy wave height, period, and direction

n 、 k 、 l 、 m : frequency, subscript representing period level, subscript representing wave height level, and subscript representing wave direction level

Further, the following passage "Wave to be used in planning erosion countermeasures" is taken from page 41 of the *Coastal Protection Plan Guide* (Coastal Division, Rivers Bureau, Ministry of Construction, March 1994).

> When the daily mean significant wave height is below 30 cm, the impact of these waves on erosion can be mostly ignored. Therefore it is necessary to exclude these from the reference. For example, the reference for calm period during summer on the Japan Sea coast is to be excluded. Otherwise the design wave will be under evaluated.

As such, waves of heights 0.3 m and higher were aggregated and used in formulae (1) to (3) to find the mean energy wave.

The results of the mean energy wave calculation are given in Table 5. The number of active days was calculated by dividing the number of days waves 0.3 m and higher were active in the target area by the total annual energy. When calculating the shoreline change prediction model, the mean energy wave is made active for 18 days for a year's calculation.

Table 5　Representative wave (mean energy wave)

Parameter	Height (m)	Period (s)	Direction (°)	Active days
Mean energy wave	0.52	3.6	288.4 (Area L-C:which is 36.7° clockwise to wave action perpendicular to the mean coastline vector of the target area, 341..7°. Area L-D:which is 6° anticlockwise to wave action perpendicular to the mean coastline vector of the target area, 24.4°)	18

2.5 Wave Return Period

Wave return periods were calculated using the Bretschneider method based on past wind speed probabilities, Table 6. The Bretschneider method of hindcasting is suited to hindcasting waves in shallow seas where waves are easily impacted by seabed friction; whereby significant wave height, $H_{1/3}$, can be obtained from Figure 10, based on: fetch, F; wind speed, U; and water depth, h. Wave period is calculated, based on past observation results, with the relevant formula:

$$T_{1/3} = 3.86\sqrt{H_{1/3}} \qquad \text{(units: s, m)}$$

Table 6 Wind speed probability of westerly in Funafuti lagoon, return period wave and water level rise

Return Period (year)	Wind speed (m/s)	Wave height (m)	Wave period (sec)	Barometric tide and wave setup combine(m)
5	11.1	0.8	3.5	
10	15.6	1.2	4.2	0.19
15	18.2	1.4	4.6	
20	20.1	1.6	4.8	0.26
30	22.8	1.9	5.2	
50	26.1	2.2	5.6	0.38
75	28.8	2.5	5.8	
100	30.7	2.7	6.0	

Carter (wind and sea analysis FUNAFUTI LAGOON, TUVALU1986)

Waves of 10-, 30- and 50-year return periods for Point1 to Point7 are as shown in Table 7.

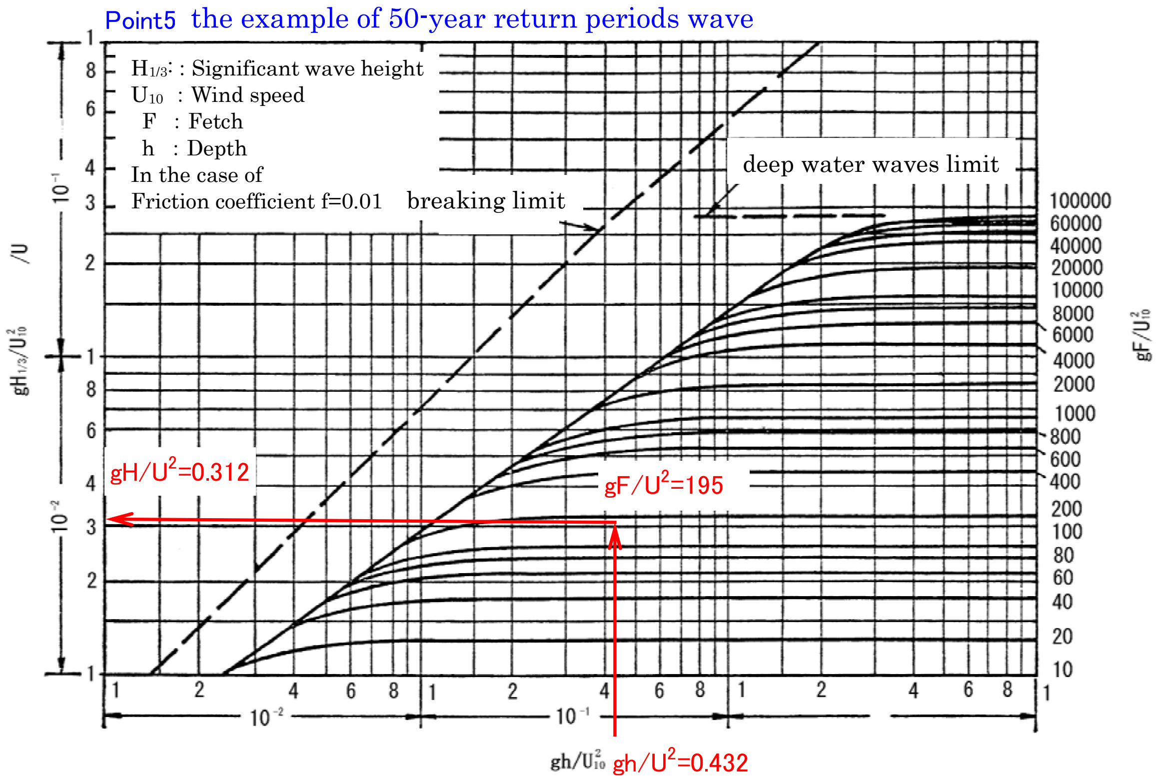


Figure 10 Fetch of shallow water waves (hydrological formula)

Table 7 Return period waves at each hindcast point

Site	Return period(yr)	Wind speed (m/s)	Fech (km)	Depth (m)	gh/U^2	gF/U^2	gHo/U^2	Wave height $H_{1/3}$ (m)	Wave period $T_{1/3}$(s)
Point1	10	15.6	14.0	30	1.208	565	0.049	1.23	4.3
	30	22.8			0.566	264	0.035	1.85	5.2
	50	26.1			0.432	202	0.031	2.15	5.7
Point2	10	15.6	13.6	30	1.208	546	0.049	1.21	4.2
	30	22.8			0.566	255	0.035	1.85	5.2
	50	26.1			0.432	195	0.031	2.15	5.7
Point3	10	15.6	13.7	30	1.208	553	0.049	1.22	4.3
	30	22.8			0.566	259	0.035	1.85	5.2
	50	26.1			0.432	198	0.031	2.15	5.7
Point4	10	15.6	13.7	30	1.208	552	0.049	1.22	4.3
	30	22.8			0.566	258	0.035	1.85	5.2
	50	26.1			0.432	197	0.031	2.15	5.7
Point5	10	15.6	13.6	30	1.208	546	0.049	1.21	4.2
	30	22.8			0.566	256	0.035	1.85	5.2
	50	26.1			0.432	195	0.031	2.15	5.7
Point6	10	15.6	13.4	30	1.208	539	0.049	1.20	4.2
	30	22.8			0.566	252	0.035	1.85	5.2
	50	26.1			0.432	192	0.031	2.15	5.7
Point7	10	15.6	12.4	30	1.208	497	0.047	1.17	4.2
	30	22.8			0.566	233	0.035	1.85	5.2
	50	26.1			0.432	178	0.031	2.15	5.7

※Fetch is applied the longest distance.
Depth is given average depth in lagoon.

3. One-Line Theory Model to Evaluate the Beach Transformation

3. One-Line Theory Model to Evaluate the Beach Transformation

3.1 The outline of 1line model

1 line model (one-line theory model) for the predictive calculation of shoreline changes was utilized. The shoreline changes is captured by this model, which is composed of the following 2 sub-programs 1) The calculation of wave field 2) The calculation of shoreline changes. The calculation flow of this model is as shown in the figure 3.1. In the wave field, refraction, the diffraction and shallow-water transformation were calculated. Then wave breaker height and wave direction are figured out to estimate longshore sediment transport rate. In the calculation of shoreline changes, longshore sediment transport rate allocated in every Δx on the grid line towards to coastal direction by wave breaker height and wave breaker direction is estimated. Shoreline change Δy is figured by using this previously mentioned and the equation for sand mass conservation.

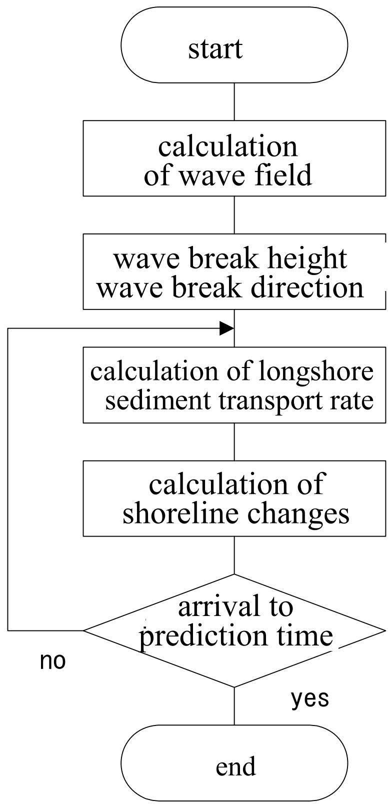


Figure 3.1 The flowchart of 1 line model (one-line theory model)

(1) The calculation on the wave field

Refraction of multidirectional random wave and shallow-water transformation can be simultaneously solved. Moreover, regarding diffraction transformation, the applicable energy balance equation is also utilized from a practical standpoint.

Basic Equation

Stationary wave filed is assumed in the following

1) No temporal alteration occurs on the wave condition 2) The period of component wave remains unchanged 3) Given with the exception that the dissipation of energy of wave breaking, external energy does not exist. Then the energy balance equation is expressed as the following.

$$\frac{\partial}{\partial x}(Sv_x)+\frac{\partial}{\partial y}(Sv_y)+\frac{\partial}{\partial \theta}(Sv_\theta)=-\varepsilon_b' S \tag{1}$$

x、y are horizontal coordinate and defined as shown figure **1.2**. S is directional spectrum、θ is the wave direction angle circled in a counterclockwise direction from x axis. ε_b is energy dissipation coefficient. Also, characteristic velocity（v_x, v_y, v_θ）is the following.

$$v=\begin{Bmatrix} v_x \\ v_y \\ v_\theta \end{Bmatrix}=\begin{Bmatrix} C_g\cos\theta \\ C_g\sin\theta \\ \frac{C_g}{C}\left(\frac{\partial C}{\partial x}\sin\theta-\frac{\partial C}{\partial y}\cos\theta\right) \end{Bmatrix} \tag{2}$$

C is the wave celerity , Cg is the group velocity.

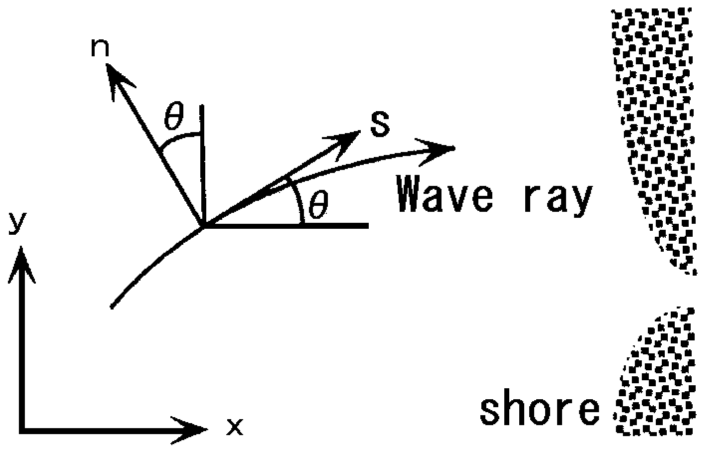


Figure 3.2 Definition method of coordinate system

Calculation of breaker height

Energy dissipation coefficient ε'_b is treated as dissipation rate for losing energy within unit of time through the breaking. This wave is assumed that it inversely relates against average time taken for the input-output in the computational grid and given in the following equation

$$\varepsilon'_b = \frac{\varepsilon_b C}{\sqrt{\delta x \delta y}} \tag{3}$$

Hereto、δx、δy is the size of the computational grid of x, y direction. The dimensionless quantity ε_b is expressed the ratio of wave energy of breaking in the grid. Given that after breaking, wave height is closed to Rayleigh distribution. According to breaker height when entering the computational grid, H_{bi} and breaker height when outgoing from the computational grid H_{bo}, the following equation is applicable.

$$\varepsilon_b = \frac{\left[\int_0^{H_{bi}/H_{1/3}} P_E(H_s^*)dH_s^* - \int_0^{H_{bo}/H_{1/3}} P_E(H_s^*)dH_s^*\right]}{\int_0^{H_{bi}/H_{1/3}} P_E(H_s^*)dH_s^*}$$

$$= 1 - \frac{1-\left\{1+\frac{\pi}{4}\left(\alpha\frac{H_{bo}}{H_{1/3}}\right)^2\right\}\exp\left\{-\frac{\pi}{4}\left(\alpha\frac{H_{bo}}{H_{1/3}}\right)^2\right\}}{1-\left\{1+\frac{\pi}{4}\left(\alpha\frac{H_{bi}}{H_{1/3}}\right)^2\right\}\exp\left\{-\frac{\pi}{4}\left(\alpha\frac{H_{bi}}{H_{1/3}}\right)^2\right\}} \tag{4}$$

Hereto、$P_E(H)$ is the wave energy distribution.

$$P_E = \frac{\pi^2}{8}\alpha^4 H_s^{*3}\exp\left[-\frac{\pi}{4}(\alpha H_s^*)^2\right] \tag{5}$$

$$H_s^* = \frac{H}{H_{1/3}} \quad , \quad \alpha = \frac{H_{1/3}}{\overline{H}}$$

Hereto 、$\overline{H}$ is average height. Regarding the estimation of breaker height of H_{bo}、 and H_{bi},, the following indicator of breaking is utilized. Then breaking is commonly occurred with a certain range.

$$\frac{H_b}{L_0} = A\left[1-\exp\left\{-1.5\frac{\pi h}{L_0}(1+15\tanh^{4/3}\beta)\right\}\right] \tag{6}$$

Here, H_b is breaker height. Lo is offshore wave wavelength. h is breaker depth. tanβ is sea-bottom slope. Also, A is coefficient depending on the location within breaker zone. As A is 0.18, all waves with breaker height over H_{b1} are broken. As A is 0.12, wave less than H_{b2} is not broken. It is assumed that the case of wave with the probability of the breaking waves from A=0.12 to A=0.18, they are linearly changed.

(2)Calculation of shoreline change

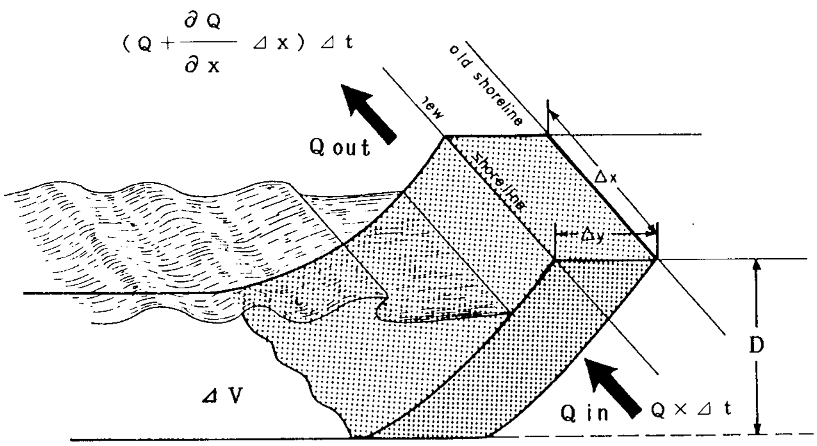
As shown conceptual diagram 1.3, towards coastal direction is X axis. Towards off coast direction is Y axis. The location of shoreline is y＝y. According to basic theory of （x, t）model, it is assumed that moving towards to offshore without changing the cross-section of beachside, conservation law of sediment volume is the following equation.

$$\frac{\partial y}{\partial t}+\frac{1}{D}\left(\frac{\partial Q}{\partial x}-q\right)=0 \qquad (7)$$

Here, Q: longshore sediment transport rate, which involves the volume with porosity unit width per unit hour

D: Height of the movement of sand drift

Q: The quantity of the influx of sediment towards offshore



The calculation of longshore sediment transport rate、according to Ozasa・Brampton(1979), in addition to the suggestion equation, the following equation considering significant wave by Klaus (1981) is leveraged.

$$Q = (H_{1/3}^2 \cdot C_g)_b \left(\hat{K}_1 \sin 2\alpha_{bs} - \hat{K}_2 \frac{\partial (H_{1/3})_b}{\partial x} \cot\beta \cos\alpha_{bs} \right) \tag{8}$$

$$\hat{K}_1 = \frac{K_1}{16(\rho_s/\rho - 1)(1-\lambda)1.416^{5/2}}$$

$$\hat{K}_2 = \frac{K_2}{8(\rho_s/\rho - 1)(1-\lambda)1.416^{5/2}}$$

$(H_{1/3}^2 \cdot Cg)_b$: Energy flux based on significant waves at the braking point

$(H_{1/3})_b$: Breaker height of the significant wave

K_1, K_2: The coefficient of longshore sediment transport rate

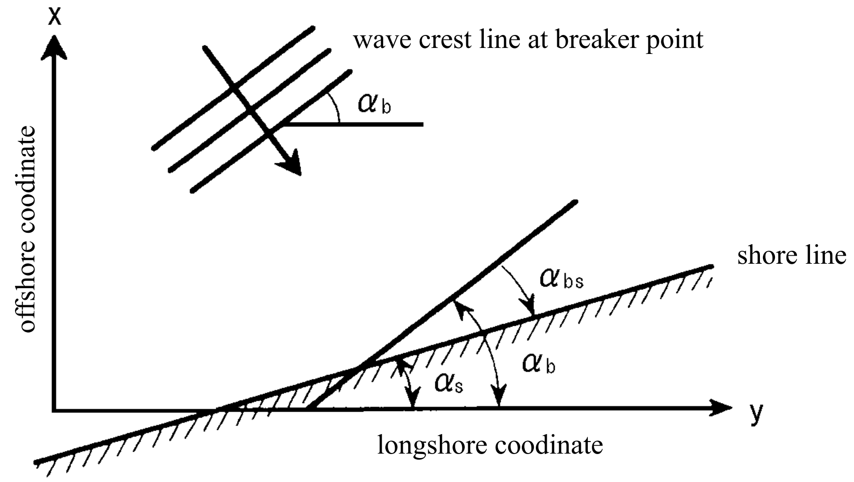
$\cot\beta$: Inverse number of sea-bottom slope

α_{bs}: The angel between shoreline and wave direction at the breaker point

ρ_s, ρ: The density for sand and sea-water

λ: The porosity of the sand

Formula (8) article 1 on the right side is related with energy flux for breaking towards sea coast. Article 2 is considered about the movement of sand drift due to water level slope due to cause of the unevenness of breaker height towards the sea coast. The effect of sand drift behind the masking structural object is calculated by article 2.



the source

Ozasa, H., Brampton,A.,H., 1979, The calculation of shoreline change with seawall, Port and harbour research institute report, Vol.18, No.4, pp.77-103.

Klaus, N., C., Isigai, S., Kubota, S., 1984, Shore line change simulation in Oarai beach-wave breaking and shore line change behind breakwater, Proceedings of Coastal Engineering, Vol.28, JSCE, pp.295-299.

PART VI: EXAMINATION AND DESIGN OF COASTAL PROTECTION MEASURES

Section 2: Data Book

1. Results of Geotechnical Test for Dredging Sand in Lagoon

1. Dredging Seabed Material Sampling Record
2. List of Soil Test Results
3. Particle Distribution Test
4. Geotechnical Classifications
5. Soil compaction Test and Corn Index Test of soil by tamping
6. Consolidation Test by stage loading of soil
7. Specific Gravity Test / Water Absorption Test of Coral Gravel
8. Passing Through Test for Geofabric and Dredged Sand
9. Soil Cement Test
   - 9-1 Slaking Test of Soil Cement
   - 9-2 Underwater Segregation Test of Soil Cement
   - 9-3 Photographs

1. Dredging Seabed Material Sampling Record

Tuvalu J-PACE : Seabed Survey <Dredging Sand Material Sampling>

	WGS84 / UTM 60L		WGS84 / Geographic		Australian C.D.L.					
Sample No.	Easting	Northing	E (D.ddd)	S (D.ddd)	Seabed Height (m)	Water Depth (m)	Tide Level (C.D.L.)	Sampling Date/Time	Samaple Taken	Remarks
DS-01	741,206.27	9,057,111.57	179.1911949	-8.5237914	-6.1	-7.4	+1.30	2010/8/25 10:20	Sample bottle 2.5kg	foraminifera(dominant), medium sand
DS-02	741,005.11	9,057,259.60	179.1893608	-8.5224637	-10.9	-12.3	+1.38	2010/8/25 10:00	Sample bottle 2.5kg	foraminifera(dominant)＋Halimeda, fine sand～medium sand
DS-03	740,803.65	9,057,408.12	179.1875240	-8.5211316	-17.9	-19.3	+1.36	2010/8/24 12:10	Sample bottle 2.5kg	Halimeda(dominant), partially foraminifera, fine sand～medium sand
DS-04	740,603.00	9,057,555.78	179.1856945	-8.5198072	-20.9	-22.1	+1.24	2010/8/24 11:30	sandbag (50kg) Sample bottle 2.5kg	Halimeda(dominant), superfine sand～fine sand
DS-05	740,401.89	9,057,704.00	179.1838609	-8.5184777	-24.1	-25.3	+1.21	2010/8/24 10:50	Sample bottle 2.5kg	Halimeda(dominant), coarse sand・medium sand
DS-06	740,201.00	9,057,852.03	179.1820293	-8.5171500	-24.9	-26.1	+1.24	2010/8/24 10:20	sandbag (40kg) Sample bottle 2.5kg	Halimeda(dominant), fragmentary Halimeda＋coarse sand

	WGS84 / UTM 60L		WGS84 / Geographic		Australian C.D.L.
Sample No.	Easting	Northing	E (D.ddd)	S (D.ddd)	Seabed Height (m)
DS-01	741,206.27	9,057,111.57	179.1911949	-8.5237914	-6.1
DS-02	741,005.11	9,057,259.60	179.1893608	-8.5224637	-10.9
DS-03	740,803.65	9,057,408.12	179.1875240	-8.5211316	-17.9
DS-04	740,603.00	9,057,555.78	179.1856945	-8.5198072	-20.9
DS-05	740,401.89	9,057,704.00	179.1838609	-8.5184777	-24.1
DS-06	740,201.00	9,057,852.03	179.1820293	-8.5171500	-24.9

Fongafale Central Area

J-PACE

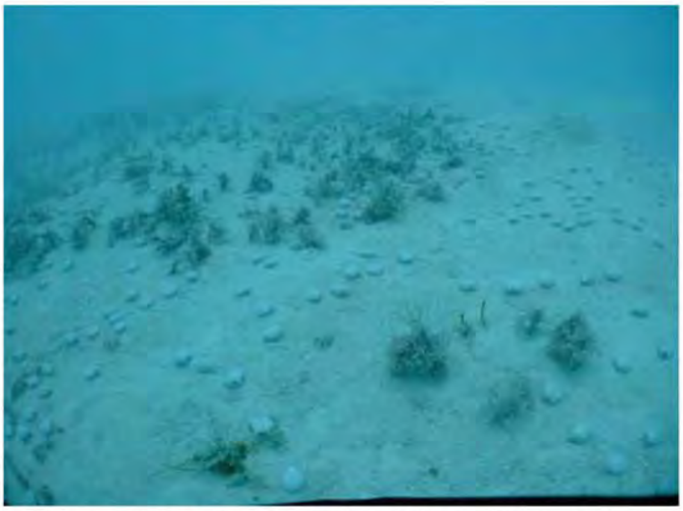
Japan - Project Against Coastal Erosion

Tuvalu J-PACE : Seabed Survey < Dredging Sand Sampling>

<table>
<tr><td>
DS-1 : 250m NW from Vaiaku Wharf (C.D.L.-6.1m)</td><td>Sea bottom is flat and bottom sediment are fine sand including large amounts of foraminiferal tests.
A kind of Halimeda opuntia f. cordata (Halimeda) exists.</td></tr>
<tr><td>
DS-2 : 500m NW from Vaiaku Wharf (C.D.L.-10.9m)</td><td>Sea bottom is rough and bottom sediment consists mainly of fine sand and foraminifera.
Halimeda opuntia f. cordata (Halimeda) existes.</td></tr>
<tr><td>
DS-3 : 750m NW from Vaiaku Wharf (C.D.L.-17.9m)</td><td>Sea bottom is flat and bottom sediment are coarse sand consists of fragments of Halimeda opuntia f. cordata (Halimeda).
A kind of Halimeda exists.
There is a baggy reef near the survey point and a kind of Halimeda opuntia f. cordata(Halimeda) and a kind of Dictyota sp. exists.
Cubic iron for anchor was observed.</td></tr>
</table>

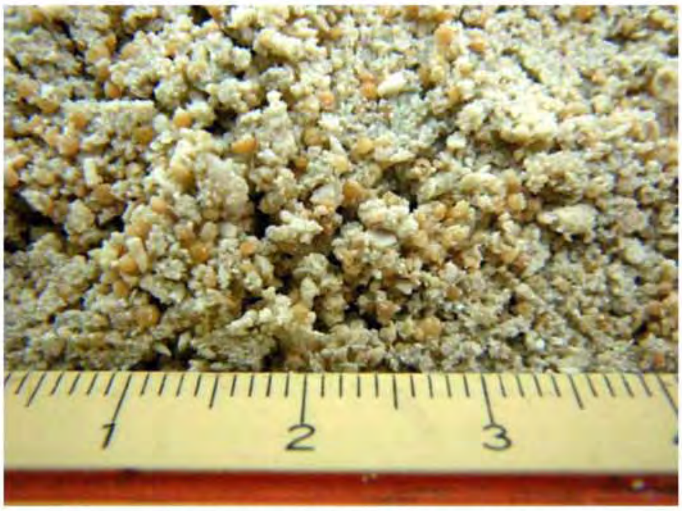
Date: 24 and 25 August, 2010

Tuvalu J-PACE : Seabed Survey < Dredging Sand Sampling>

 **DS-4 : 1000m NW from Vaiaku Wharf (C.D.L.-17.9m)**	Sea bottom is flat and bottom sediment consists of fine sand and fragments of *Halimeda opuntia f. cordata (Halimeda).* Many sea urchin (Family Loveniidae), about 80 individuals per 1 sq.m, exists at this survey point. A kind of *Halimeda opuntia f. cordata (Halimeda)* exists.
 **DS-5 : 1250m NW from Vaiaku Wharf (C.D.L.-24.1m)**	Sea bottom is rough and bottom sediment consist of fine sand. A kind of *Halimeda opuntia f. cordata (Halimeda)* can not make their habitat on the sand at this survey point. There are some reefs near the survey point, *Acropora.* sp and *Porites* sp. exists. *Halimeda opuntia f. cordata (Halimeda)* and *Dictyota* sp. exists on the rock.
 **DS-6 : 1500m NW from Vaiaku Wharf (C.D.L.-24.9m)**	Bottom sediment are coarse sand consists of fragments of *Halimeda opuntia f. cordata (Halimeda).* A kind of *Halimeda opuntia f. cordata (Halimeda)* and a kind of *Dictyota* sp. exists. Keratose exists.

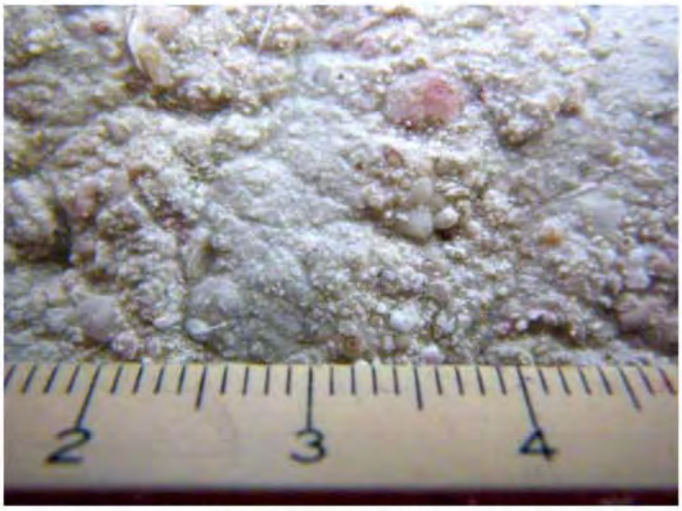
Date: 24 and 25 August, 2010

Tuvalu J-PACE : Seabed Survey < Dredging Sand Sampling>

 **DS-1 : 250m NW from Vaiaku Wharf (C.D.L.-6.1m)**	foraminifera(dominant), medium sand
 **DS-2 : 500m NW from Vaiaku Wharf (C.D.L.-10.9m)**	foraminifera(dominant)＋Halimeda, fine sand～medium sand
 **DS-3 : 750m NW from Vaiaku Wharf (C.D.L.-17.9m)**	Halimeda(dominant), partially foraminifera, fine sand～medium sand

Date: 24 and 25 August, 2010

Tuvalu J-PACE : Seabed Survey < Dredging Sand Sampling>

 **DS-4 : 1000m NW from Vaiaku Wharf (C.D.L.-17.9m)**	Halimeda(dominant), superfine sand～fine sand
 **DS-5 : 1250m NW from Vaiaku Wharf (C.D.L.-24.1m)**	Halimeda(dominant), coarse sand・medium sand
 **DS-6 : 1500m NW from Vaiaku Wharf (C.D.L.-24.9m)**	Halimeda(dominant), fragmentary Halimeda＋coarse sand, friable

Date: 24 and 25 August, 2010

Tuvalu J-PACE : Seabed Survey < Dredging Sand Sampling>

 **DS-1 to DS-6 (6 samples) : 250m to 1500m NW from Vaiaku Wharf**	Starting from the left, DS-1、DS-2、DS-3、DS-4、DS-5、DS-6
 **DS-1 : 250m NW from Vaiaku Wharf (C.D.L.-6.1m)**	Halimeda and sea cucumber collected from the sea bottom, DS-1

Date: 24 and 25 August, 2010

2. List of Soil Test Results

List of Soil Test Results (Materials)

Project Title	THE STUDY FOR ASSESSMENT OF ECOSYSTEM, COASTAL EROSION AND PROTECTION/REHABILITATION OF DAMAGED AREA IN TUVALU	Date	October 19, 2010
		The Person in Charge of Arrangement	Kazunari Yoda

	Sample Number (Depth)			DS-1	DS-2	DS-3	DS-4	DS-5	DS-6
The General	Wet Density	ρ_t	g /cm^3						
	Dry Density	ρ_d	g /cm^3						
	Density of Soil Particle	ρ_s	g /cm^3	2.760	2.810	2.844	2.823	2.828	2.849
	Natural Water Content	w_n	%						
	Void Ratio	e							
	Degree of Saturation	S_r	%						
Particle	Stone Fraction	(more than 75mm)	%	0.0	0.0	0.0	0.0	0.0	0.0
	Gravel Fraction[1)]	(2～75mm)	%	0.7	1.7	12.5	0.5	0.1	31.2
	Sand Fraction[1)]	(0.075～2mm)	%	87.7	74.8	76.6	52.4	81.3	55.5
	Silt Fraction[1)]	(0.005～0.075mm)	%	7.7	18.4	8.5	36.2	12.6	9.9
	Clay Fraction[1)]	(less than 0.005mm)	%	3.9	5.1	2.4	10.9	6.0	3.4
	Maximum Particle Size		mm	4.75	9.50	9.50	4.75	4.75	9.50
	Uniformity Coefficient	U_C		8.74	17.12	12.53	30.81	27.58	51.20
Properties of Consistency	Liquid Limit	w_L	%	NP	NP	NP	NP	NP	NP
	Plastic Limit	w_P	%	NP	NP	NP	NP	NP	NP
	Plastic Index	I_P		—	—	—	—	—	—
Classification	Class Name of Ground Materials			Sand with some Fine fraction	Sand and Fine fraction	Sand with some Fine fraction and Gravel	Sand and Fine fraction	Sand and Fine fraction	Sand and Gravel with some Fine fraction
	Class Symbol			(S-F)	(SF)	(S-FG)	(SF)	(SF)	(SG-F)
Compaction	Test Method						A-c		
	Maximum Dry Unit Weight	ρ_{dmax}	g /cm3				1.301		
	Optimum Moisture Content	w_{opt}	%				31.3		
CBR	Test Method								
	Expantion Ratio	r_e	%						
	Water Content After Penetration Test	w_2	%						
	Average CBR		%						
	CBR (% Adjustment)		%						
Cone Index	Tamping Number of Times		Number of Times / Layers						
	Cone Index	q_C	kN/m2						
	Maximum Density of Sand	ρ_{dmax}	g /cm3				1.243		
	Minimum Density of Sand	ρ_{dmax}	g /cm3				0.884		
	pH Test of Sand			8.6			8.4		
	Coefficient of Permeability (Constant Head)	k15	cm/s				6.64E-4		
	Coefficient of Permeability (Falling Head)	k15	cm/s				5.37E-4		
	Product Ratio		(g/cm^3)						

Special Instruction

1) A percentage by the soil materials which are less than 75mm except stone fraction is indicated.

[1kN/m^2 ≒ 0.0102kgf/cm^2]

List of Soil Test Results (Materials)

Project Title	THE STUDY FOR ASSESSMENT OF ECOSYSTEM, COASTAL EROSION AND PROTECTION/REHABILITATION OF DAMAGED AREA IN TUVALU	Date	October 19, 2010
		The Person in Charge of Arrangement	Kazunari Yoda

Sample Number (Depth)				CR-1					
The General	Wet Density	ρ_t	g /cm³						
	Dry Density	ρ_d	g /cm³						
	Density of Soil Particle	ρ_s	g /cm³						
	Natural Water Content	w_n	%						
	Void Ratio	e							
	Degree of Saturation	S_r	%						
Particle	Stone Fraction	(more than 75mm)	%						
	Gravel Fraction 1)	(2～75mm)	%						
	Sand Fraction 1)	(0.075～2mm)	%						
	Silt Fraction 1)	(0.005～0.075mm)	%						
	Clay Fraction 1)	(less than 0.005mm)	%						
	Maximum Particle Size		mm						
	Uniformity Coefficient	U_C							
Properties of Consistency	Liquid Limit	w_L	%						
	Plastic Limit	w_P	%						
	Plastic Index	I_P							
Classification	Class Name of Ground Materials								
	Class Symbol								
Compaction	Test Method								
	Maximum Dry Unit Weight	ρ_{dmax}	g /cm3						
	Optimum Moisture Content	w_{opt}	%						
CBR	Test Method								
	Expantion Ratio	r_e	%						
	Water Content After Penetration Test	w_2	%						
	Average CBR		%						
	CBR (% Adjustment)		%						
Cone Index	Tamping Number of Times		Number of Times / Layers						
	Cone Index	q_C	kN/m2						
	Maximum Density of Sand	ρ_{dmax}	g /cm3						
	Minimum Density of Sand	ρ_{dmax}	g /cm3						
	pH Test of Sand								
	Coefficient of Permeability (Constant Head)	k15	cm/s						
	Coefficient of Permeability (Falling Head)	k15	cm/s						
	Product Ratio		(g/cm³)	2.44					

Special Instruction

1) A percentage by the soil materials which are less than 75mm except stone fraction is indicated.

[1kN/m² ≒ 0.0102kgf/cm²]

List of Soil Test Results (Materials)

Project Title	THE STUDY FOR ASSESSMENT OF ECOSYSTEM, COASTAL EROSION AND PROTECTION/REHABILITATION OF DAMAGED AREA IN TUVALU
Date	October 19, 2010
The Person in Charge of Arrangement	Kazunari Yoda

	Sample Number (Depth)			DS-4 (ρdmx)	DS-4 (ρdmx95%)	DS-4 (w=40%)	DS-4 (Dr=100%)		
The General	Wet Density	ρ_t	g /cm^3						
	Dry Density	ρ_d	g /cm^3						
	Density of Soil Particle	ρ_s	g /cm^3						
	Natural Water Content	w_n	%						
	Void Ratio	e							
	Degree of Saturation	S_r	%						
Particle	Stone Fraction	(more than 75mm)	%						
	Gravel Fraction[1]	(2～75mm)	%						
	Sand Fraction[1]	(0.075～2mm)	%						
	Silt Fraction[1]	(0.005～0.075mm)	%						
	Clay Fraction[1]	(less than 0.005mm)	%						
	Maximum Particle Size		mm						
	Uniformity Coefficient	U_C							
Properties of Consistency	Liquid Limit	w_L	%						
	Plastic Limit	w_P	%						
	Plastic Index	I_P							
Classification	Class Name of Ground Materials								
	Class Symbol								
Compaction	Test Method								
	Maximum Dry Unit Weight	ρ_{dmax}	g /cm3						
	Optimum Moisture Content	w_{opt}	%						
CBR	Test Method								
	Expantion Ratio	r_e	%						
	Water Content After Penetration Test	w_2	%						
	Average CBR		%						
	CBR (% Adjustment)		%						
Cone Index	Tamping Number of Times		Number of Times / Layers						
	Cone Index	q_C	kN/m2						
	Maximum Density of Sand	ρ_{dmax}	g /cm3						
	Minimum Density of Sand	ρ_{dmax}	g /cm3						
	pH Test of Sand								
	Coefficient of Permeability (Constant Head)	k15	cm/s						
	Coefficient of Permeability (Falling Head)	k15	cm/s	5.55E-6	5.78E-6	1.08E-5	3.09E-5		
	Product Ratio		(g/cm^3)						

Special Instruction

1) A percentage by the soil materials which are less than 75mm except stone fraction is indicated.

[$1kN/m^2 \fallingdotseq 0.0102kgf/cm^2$]

List of Soil Test Results (Foundation Ground)

Project Title	THE STUDY FOR ASSESSMENT OF ECOSYSTEM, COASTAL EROSION AND PROTECTION/REHABILITATION OF DAMAGED AREA IN TUVALU	Date	October 19, 2010
		The Person in Charge of Arrangement	Kazunari Yoda

	Sample Number (Depth)							
			DS-4					
The General	Wet Density	ρ_t g /cm^3						
	Dry Density	ρ_d g /cm^3						
	Density of Soil Particle	ρ_s g /cm^3						
	Natural Water Content	w_n %						
	Void Ratio	e						
	Degree of Saturation	S_r %						
Particle	Stone Fraction (more than 75mm)	%						
	Gravel Fraction[1] (2～75mm)	%						
	Sand Fraction[1] (0.075～2mm)	%						
	Silt Fraction[1] (0.005～0.075mm)	%						
	Clay Fraction[1] (less than 0.005mm)	%						
	Maximum Particle Size	mm						
	Uniformity Coefficient	U_C						
Properties of Consistency	Liquid Limit	w_L %						
	Plastic Limit	w_P %						
	Plastic Index	I_P						
Classification	Class Name of Ground Materials							
	Class Symbol							
Consolidation	Test Method		Stage Loading					
	Compression Index	C_C	0.249					
	Compressive Yield Stress	P_C kN/m^2	270.9					
Unconfined Compression	Unconfined Compression Strength	q_U kN/m^2						
Shear	Test Condition							
	Total Stress	c kN/m^2						
		φ °						
	Effective Stress	c' kN/m^2						
		φ' °						

Special Instruction

1) A percentage by the soil materials which are less than 75mm except stone fraction is indicated.

[$1kN/m^2 \fallingdotseq 0.0102kgf/cm^2$]

3. Particle Distribution Test

JIS A 1204
JGS 0131

Particle Distribution Test

Project Title: Tuvalu J-PACE

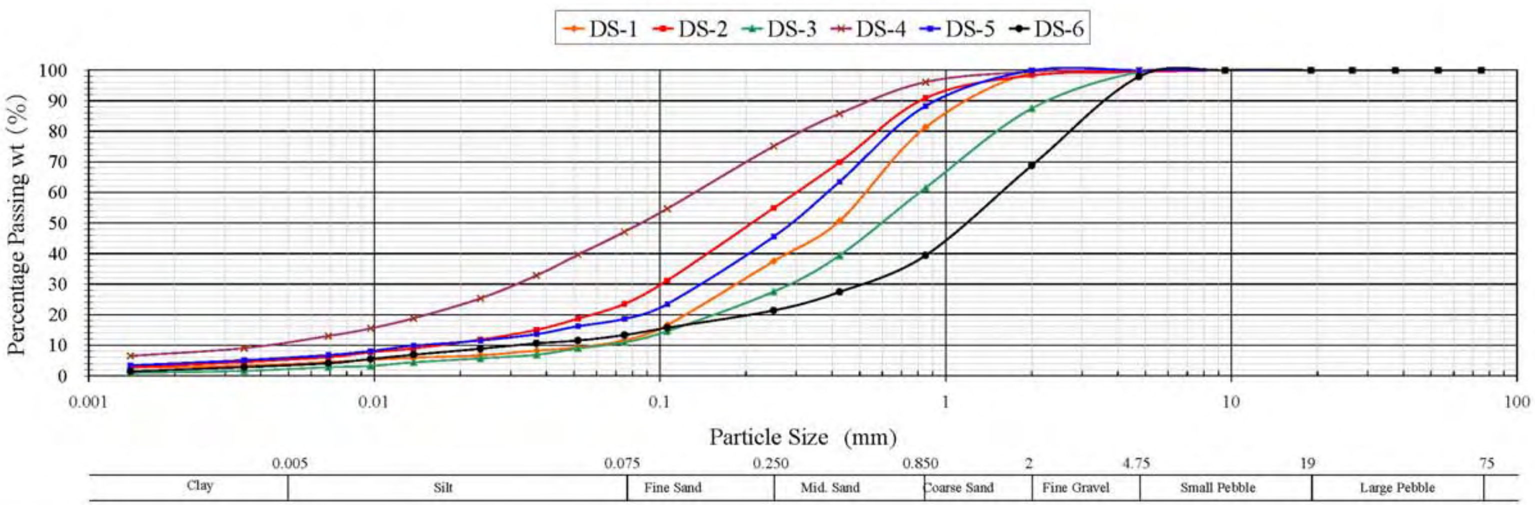
Date: 22-Sep-10

Trier: Hideaki Tsuge

	Sample No. (Depth)	DS-1 (-10.9m)	DS-2 (-17.9m)	DS-3 (-17.9m)	DS-4 (-17.9m)	DS-5 (-24.1m)	DS-6 (-24.9m)
	Size mm	Passing Sieve wt%	Passing Sieve wt%	Passing Sieve wt%	Passing Sieve wt%	Passing Sieve wt%	Passing Sieve wt%
Sieve Analysis	75.0	100.0	100.0	100.0	100.0	100.0	100.0
	53.0	100.0	100.0	100.0	100.0	100.0	100.0
	37.5	100.0	100.0	100.0	100.0	100.0	100.0
	26.5	100.0	100.0	100.0	100.0	100.0	100.0
	19.0	100.0	100.0	100.0	100.0	100.0	100.0
	9.5	100.0	100.0	100.0	100.0	100.0	100.0
	4.75	100.0	99.4	99.4	100.0	100.0	97.9
	2.0	99.3	98.3	87.5	99.5	99.9	68.8
	0.850	81.3	90.9	61.5	96.1	88.3	39.4
	0.425	50.7	69.9	39.4	85.8	63.5	27.4
	0.250	37.5	54.9	27.5	75.1	45.5	21.4
	0.106	16.6	31.2	14.6	54.7	23.5	15.7
	0.075	11.6	23.5	10.9	47.1	18.6	13.3
Sedimentation Analysis	0.0516	9.3	18.7	8.9	39.6	16.2	11.5
	0.0369	8.2	15.0	6.9	32.8	13.6	10.6
	0.0235	6.7	11.8	5.7	25.3	11.5	8.8
	0.0137	5.9	8.9	4.4	18.8	9.8	6.9
	0.0097	5.2	7.7	3.2	15.5	8.1	5.5
	0.0069	4.5	6.1	2.8	13.0	6.8	4.1
	0.0035	3.3	4.5	1.6	9.0	5.1	2.8
	0.0014	2.6	2.8	0.8	6.5	3.4	1.4

Sample No. (Depth)	DS-1 (-10.9m)	DS-2 (-17.9m)	DS-3 (-17.9m)	DS-4 (-17.9m)	DS-5 (-24.1m)	DS-6 (-24.9m)
Geotechnical Classification (JGS 0051-2009)	S-F Sand with some Fine fraction	SF Sand and Fine fraction	S-FG Sand with some Fine fraction and Gravel	FS Sand and Fine fraction	FS Sand and Fine fraction	SG-F Sand and Gravel with some Fine
Coarse Gravel %	0.0	0.0	0.0	0.0	100.0	0.0
Midium Gravel %	0.0	0.6	2.1	0.0	0.0	2.1
Fine Gravel %	0.7	1.1	11.9	0.5	0.1	29.1
Coarse Sand %	18.0	7.4	26.0	3.4	11.6	29.4
Midium Sand %	43.8	36.0	34.0	21.0	42.8	18.0
Fine Sand %	25.9	31.4	16.6	28.0	26.9	8.1
Silt %	7.7	18.4	8.5	36.2	12.6	9.9
Clay %	3.9	5.1	2.4	10.9	6.0	3.4
2mm Sieve Passing wt %	99.3	98.3	87.5	99.5	99.9	68.8
425μm Sieve Passing wt %	50.7	69.9	39.4	85.8	63.5	27.4
75μm Sieve Passing wt %	11.6	23.5	10.9	47.1	18.6	13.3
Maximum Particle Size mm	4.75	9.50	9.50	4.75	4.75	9.50
60% Particle Size $D60$ mm	0.1325	0.3013	0.8134	0.1325	0.3861	1.6026
50% Particle Size $D50$ mm	0.0860	0.2098	0.6037	0.0860	0.2880	1.2166
30% Particle Size $D30$ mm	0.0316	0.1010	0.2843	0.0316	0.1436	0.5144
20% Particle Size $D20$ mm	0.0153	0.0591	0.1584	0.0153	0.0850	0.2104
10% Particle Size $D10$ mm	0.0043	0.0176	0.0649	0.0043	0.0140	0.0313
Uniformity Coefficient Uc	30.81	17.12	12.53	30.81	27.58	51.20
Curvature Coefficient Uc'	1.75	1.92	1.53	1.75	3.81	5.28
Density ρs g/cm	2.823	2.810	2.844	2.823	2.828	2.849
Dispersing Agent Consentration, Additive Quantity	Polymer Dispersing 10 ml	Polymer Dispersing 10 ml	Polymer Dispersing 10 ml	Polymer Dispersing 10 ml	Polymer Dispersing 10 ml	Polymer Dispersing 10 ml

Particle Distribution Curve



Remarks