TABLES

Table 12.1.1 Equations of the Hydrodynamic Model

< Equations of Continuity >

Upper Layer

$$\frac{\partial\zeta}{\partial t} + \frac{\partial}{\partial x}\left[u_1(\zeta+H_1)\right] + \frac{\partial}{\partial y}\left[v_1(\zeta+H_1)\right] - w = 0$$

Lower Layer

$$\frac{\partial}{\partial x}(u_2 H_2) + \frac{\partial}{\partial y}(v_2 H_2) + w = 0$$

< Equations of Motion >

Upper Layer

$$\frac{\partial u_1}{\partial t} + u_1\frac{\partial u_1}{\partial x} + v_1\frac{\partial u_1}{\partial y} + w\frac{u_1-u_2}{2(\zeta+H_1)}$$
$$= fv_1 - \frac{1}{\rho_1}\left(\frac{\partial p}{\partial x}\right)_1 + A_h\left(\frac{\partial^2 u_1}{\partial x^2} + \frac{\partial^2 u_1}{\partial y^2}\right)$$
$$- \gamma_i^2(u_1-u_2)\frac{\sqrt{(u_1-u_2)^2+(v_1-v_2)^2}}{(\zeta+H_1)} + \frac{\rho_a}{\rho_1}\gamma_a^2 W_x\frac{\sqrt{W_x^2+W_y^2}}{(\zeta+H_1)}$$

$$\frac{\partial v_1}{\partial t} + u_1\frac{\partial v_1}{\partial x} + v_1\frac{\partial v_1}{\partial y} + w\frac{v_1-v_2}{2(\zeta+H_1)}$$
$$= - fu_1 - \frac{1}{\rho_1}\left(\frac{\partial p}{\partial y}\right)_1 + A_h\left(\frac{\partial^2 v_1}{\partial x^2} + \frac{\partial^2 v_1}{\partial y^2}\right)$$
$$- \gamma_i^2(v_1-v_2)\frac{\sqrt{(u_1-u_2)^2+(v_1-v_2)^2}}{(\zeta+H_1)} + \frac{\rho_a}{\rho_1}\gamma_a^2 W_y\frac{\sqrt{W_x^2+W_y^2}}{(\zeta+H_1)}$$

Lower Layer

$$\frac{\partial u_2}{\partial t} + u_2\frac{\partial u_2}{\partial x} + v_2\frac{\partial u_2}{\partial y} + w\frac{u_1-u_2}{2H_2}$$
$$= fv_2 - \frac{1}{\rho_2}\left(\frac{\partial p}{\partial x}\right)_2 + A_h\left(\frac{\partial^2 u_2}{\partial x^2} + \frac{\partial^2 u_2}{\partial y^2}\right)$$
$$+ \gamma_i^2(u_1-u_2)\frac{\sqrt{(u_1-u_2)^2+(v_1-v_2)^2}}{H_2} - \gamma_b^2 u_2\frac{\sqrt{u_2^2+v_2^2}}{H_2}$$

$$\frac{\partial v_2}{\partial t} + u_2\frac{\partial v_2}{\partial x} + v_2\frac{\partial v_2}{\partial y} + w\frac{v_1-v_2}{2H_2}$$
$$= - fu_2 - \frac{1}{\rho_2}\left(\frac{\partial p}{\partial y}\right)_2 + A_h\left(\frac{\partial^2 v_2}{\partial x^2} + \frac{\partial^2 v_2}{\partial y^2}\right)$$
$$+ \gamma_i^2(v_1-v_2)\frac{\sqrt{(u_1-u_2)^2+(v_1-v_2)^2}}{H_2} - \gamma_b^2 v_2\frac{\sqrt{u_2^2+v_2^2}}{H_2}$$

< Equations of Diffusion for Density >

Upper Layer

$$\frac{\partial}{\partial t}[\rho_1(\zeta+H_1)] + \frac{\partial}{\partial x}[u_1\rho_1(\zeta+H_1)] + \frac{\partial}{\partial y}[v_1\rho_1(\zeta+H_1)] - w\rho^*$$
$$- \frac{\partial}{\partial x}[K_x(\zeta+H_1)\frac{\partial\rho_1}{\partial x}] - \frac{\partial}{\partial y}[K_y(\zeta+H_1)\frac{\partial\rho_1}{\partial y}] + K_z\frac{2(\rho_1-\rho_2)}{H_1+H_2} = 0$$

Lower Layer

$$\frac{\partial}{\partial t}(\rho_2 H_2) + \frac{\partial}{\partial x}(u_2\rho_2 H_2) + \frac{\partial}{\partial y}(v_2\rho_2 H_2) + w\rho^*$$
$$- \frac{\partial}{\partial x}(K_x H_2\frac{\partial\rho_2}{\partial x}) - \frac{\partial}{\partial y}(K_y H_2\frac{\partial\rho_2}{\partial y}) - K_z\frac{2(\rho_1-\rho_2)}{H_1+H_2} = 0$$

where,

ζ	: water elevation(cm)
u_i, v_i	: x and y component of the i th Layer (cm/s)
w	: vertical velocity (cm/s)
A_h	: eddy viscosity (cm^2/s)
f	: Coriolis parameter ($1/s$)
γ_a^2	: surface friction constant
γ_i^2	: internal friction constant
γ_b^2	: bottom friction constant
p	: pressure ($g/cm/s^2$)
H_i	: thickness of the i th Layer (cm)
ρ_i	: density of seawater in the i th Layer(g/cm^3)
W_x, W_y	: x and y component of wind speed (cm/s)
ρ_a	: density of the air (g/cm^3)
K_x, K_y	: horizontal eddy diffusivity (cm^2/s)
K_z	: vertical eddy diffusivity (cm^2/s)
ρ^*	: $\rho^*=\rho_2$ if $w>0$
	: $\rho_*=\rho_1$ if $w<0$

$$\left(\frac{\partial p}{\partial x}\right)_i = g\rho_1\frac{\partial\zeta}{\partial x} + g\frac{\partial}{\partial x}\left(\sum_{n=1}^{i-1}\rho_n H_n + \frac{1}{2}\frac{\partial}{\partial x}\rho_i H_i\right)$$

g	: gravitational acceleration (cm/s^2)

Table 12.1.2 Equations of the Diffusion Model

Upper Layer

$$\frac{\partial S_1 H_1}{\partial t} = -\frac{\partial S_1 \cdot u_1 \cdot H_1}{\partial x} - \frac{\partial S_1 \cdot v_1 \cdot H_1}{\partial y} + \frac{\partial}{\partial x}\left(K \cdot H_1 \frac{\partial S_1}{\partial x}\right) + \frac{\partial}{\partial y}\left(K \cdot H_1 \frac{\partial S_1}{\partial y}\right)$$

$$- K_z \frac{S_1 - S_2}{(H_1 + H_2)/2} + S_{1,2} \cdot W_{1,2} - S_1 \cdot w_0 + S_{a1}$$

Lower Layer

$$\frac{\partial S_2 H_2}{\partial t} = -\frac{\partial S_2 \cdot u_2 \cdot H_2}{\partial x} - \frac{\partial S_2 \cdot v_2 \cdot H_2}{\partial y} + \frac{\partial}{\partial x}\left(K \cdot H_2 \frac{\partial S_2}{\partial x}\right) + \frac{\partial}{\partial y}\left(K \cdot H_2 \frac{\partial S_2}{\partial y}\right)$$

$$+ K_z \frac{S_1 - S_2}{(H_1 + H_2)/2} - S_{1,2} \cdot W_{1,2} + (S_1 - S_2)\, w_0 + S_{a2}$$

where,

S_n	: concentration of the SS in the n th Layer
H_n	: thickness of the n th Layer
u_n	: x component of the velocity in the n th Layer
v_n	: y component of the velocity in the n th Layer
K	: horizontal eddy diffusivity
K_z	: vertical eddy diffusivity
$W_{1,2}$	: vertical velocity
$S_{1,2}$	: $S_{1,2} = S_2$ if $W_{1,2} > 0$
	$S_{1,2} = S_1$ if $W_{1,2} < 0$
w_0	: settling rate
S_{an}	: Loads of SS in the n th Layer

Table 12.1.3 Equations of the Eutrophication Model (1/5)

< O-P >

Upper Layer

$$\frac{\partial}{\partial t}(H^{(1)} \cdot OP^{(1)}) = -\frac{\partial}{\partial x}(H^{(1)} \cdot u^{(1)} \cdot OP^{(1)}) - \frac{\partial}{\partial y}(H^{(1)} \cdot v^{(1)} \cdot OP^{(1)})$$

Advection

$$+ \frac{\partial}{\partial x}\left(K \cdot H^{(1)} \frac{\partial}{\partial x} OP^{(1)}\right) + \frac{\partial}{\partial y}\left(K \cdot H^{(1)} \frac{\partial}{\partial y} OP^{(1)}\right)$$

Diffusion

$$+ W_U(1,2) \cdot OP^{(2)} - W_L(1,2) \cdot OP^{(1)}$$

Vertical Advection

$$+ \frac{K_z}{(H^{(2)} + H^{(1)}) \times 0.5} (OP^{(2)} - OP^{(1)})$$

Vertical Diffusion

$$+ P_r^{(1)} \cdot C_1 \cdot H^{(1)} - D_p^{(1)} \cdot OP^{(1)} \cdot H^{(1)}$$

Production — Decomposition

$$- S_p^{(1)} \cdot OP^{(1)} + LOP^{(1)} / (\Delta x\, \Delta y)$$

Settling — Loads

Lower Layer

$$\frac{\partial}{\partial t}(H^{(2)} \cdot OP^{(2)}) = -\frac{\partial}{\partial x}(H^{(2)} \cdot u^{(2)} \cdot OP^{(2)}) - \frac{\partial}{\partial y}(H^{(2)} \cdot v^{(2)} \cdot OP^{(2)})$$

Advection

$$+ \frac{\partial}{\partial x}\left(K \cdot H^{(2)} \frac{\partial}{\partial x} OP^{(2)}\right) + \frac{\partial}{\partial y}\left(K \cdot H^{(2)} \frac{\partial}{\partial y} OP^{(2)}\right)$$

Diffusion

$$- W_U(2,1) \cdot OP^{(2)} + W_L(2,1) \cdot OP^{(1)}$$

Vertical Advection

$$+ \frac{K_z}{(H^{(1)} + H^{(2)}) \times 0.5} (OP^{(1)} - OP^{(2)})$$

Vertical Diffusion

$$+ P_r^{(2)} \cdot C_1 \cdot H^{(2)} - D_p^{(2)} \cdot OP^{(2)} \cdot H^{(2)}$$

Production — Decomposition

$$+ S_p^{(1)} \cdot OP^{(1)} - S_p^{(2)} \cdot OP^{(2)} + LOP^{(2)} / (\Delta x\, \Delta y)$$

Settling — Settling — Loads

Table 12.1.3 Equations of the Eutrophication Model (2/5)

< I-P >

Upper Layer

$$
\begin{aligned}
\frac{\partial}{\partial t}(H^{(1)} \cdot IP^{(1)}) = & \underbrace{- \frac{\partial}{\partial x}(H^{(1)} \cdot u^{(1)} \cdot IP^{(1)}) - \frac{\partial}{\partial y}(H^{(1)} \cdot v^{(1)} \cdot IP^{(1)})}_{\text{Advection}} \\
& \underbrace{+ \frac{\partial}{\partial x}\left(K \cdot H^{(1)} \frac{\partial}{\partial x} IP^{(1)}\right) + \frac{\partial}{\partial y}\left(K \cdot H^{(1)} \frac{\partial}{\partial y} IP^{(1)}\right)}_{\text{Diffusion}} \\
& \underbrace{+ W_U(1,2) \cdot IP^{(2)} - W_L(1,2) \cdot IP^{(1)}}_{\text{Vertical Advection}} \\
& \underbrace{+ \frac{K_Z}{(H^{(2)}+H^{(1)}) \times 0.5} (IP^{(2)} - IP^{(1)})}_{\text{Vertical Diffusion}} \\
& \underbrace{- P_r^{(1)} \cdot C_1 \cdot H^{(1)}}_{\text{Production}} \underbrace{+ D_P^{(1)} \cdot OP^{(1)} \cdot H^{(1)}}_{\text{Decomposition}} \\
& \underbrace{+ Y_P}_{\text{Release}} \underbrace{+ LIP^{(1)} / (\Delta x \, \Delta y)}_{\text{Loads}}
\end{aligned}
$$

Lower Layer

$$
\begin{aligned}
\frac{\partial}{\partial t}(H^{(2)} \cdot IP^{(2)}) = & \underbrace{- \frac{\partial}{\partial x}(H^{(2)} \cdot u^{(2)} \cdot IP^{(2)}) - \frac{\partial}{\partial y}(H^{(2)} \cdot v^{(2)} \cdot IP^{(2)})}_{\text{Advection}} \\
& \underbrace{+ \frac{\partial}{\partial x}\left(K \cdot H^{(2)} \frac{\partial}{\partial x} IP^{(2)}\right) + \frac{\partial}{\partial y}\left(K \cdot H^{(2)} \frac{\partial}{\partial y} IP^{(2)}\right)}_{\text{Diffusion}} \\
& \underbrace{- W_U(2,1) \cdot IP^{(2)} + W_L(2,1) \cdot IP^{(1)}}_{\text{Vertical Advection}} \\
& \underbrace{+ \frac{K_Z}{(H^{(1)}+H^{(2)}) \times 0.5} (IP^{(1)} - IP^{(2)})}_{\text{Vertical Diffusion}} \\
& \underbrace{- P_r^{(2)} \cdot C_1 \cdot H^{(2)}}_{\text{Production}} \underbrace{+ D_P^{(2)} \cdot OP^{(2)} \cdot H^{(2)}}_{\text{Decomposition}} \\
& \underbrace{+ Y_P}_{\text{Release}} \underbrace{+ LIP^{(2)} / (\Delta x \, \Delta y)}_{\text{Loads}}
\end{aligned}
$$

< O-N >

Upper Layer

$$
\begin{aligned}
\frac{\partial}{\partial t}(D^{(1)} \cdot ON^{(1)}) = & \underbrace{- \frac{\partial}{\partial x}(D^{(1)} \cdot u^{(1)} \cdot ON^{(1)}) - \frac{\partial}{\partial y}(D^{(1)} \cdot v^{(1)} \cdot ON^{(1)})}_{\text{Advection}} \\
& \underbrace{+ \frac{\partial}{\partial x}\left(K \cdot D^{(1)} \frac{\partial}{\partial x} ON^{(1)}\right) + \frac{\partial}{\partial y}\left(K \cdot D^{(1)} \frac{\partial}{\partial y} ON^{(1)}\right)}_{\text{Diffusion}} \\
& \underbrace{+ W_U(1,2) \cdot ON^{(2)} - W_L(1,2) \cdot ON^{(1)}}_{\text{Vertical Advection}} \\
& \underbrace{+ \frac{K_Z}{(D^{(2)}+D^{(1)}) \times 0.5} (ON^{(2)} - ON^{(1)})}_{\text{Vertical Diffusion}} \\
& \underbrace{+ P_r^{(1)} \cdot (C_1 \cdot C_2) \cdot D^{(1)}}_{\text{Production}} \underbrace{- D_N^{(1)} \cdot ON^{(1)} \cdot D^{(1)}}_{\text{Decomposition}} \\
& \underbrace{- S_N^{(1)} \cdot ON^{(1)}}_{\text{Settling}} \underbrace{+ LON^{(1)} / (\Delta x \, \Delta y)}_{\text{Loads}}
\end{aligned}
$$

Lower Layer

$$
\begin{aligned}
\frac{\partial}{\partial t}(D^{(2)} \cdot ON^{(2)}) = & \underbrace{- \frac{\partial}{\partial x}(D^{(2)} \cdot u^{(2)} \cdot ON^{(2)}) - \frac{\partial}{\partial y}(D^{(2)} \cdot v^{(2)} \cdot ON^{(2)})}_{\text{Advection}} \\
& \underbrace{+ \frac{\partial}{\partial x}\left(K \cdot D^{(2)} \frac{\partial}{\partial x} ON^{(2)}\right) + \frac{\partial}{\partial y}\left(K \cdot D^{(2)} \frac{\partial}{\partial y} ON^{(2)}\right)}_{\text{Diffusion}} \\
& \underbrace{- W_U(2,1) \cdot ON^{(2)} + W_L(2,1) \cdot ON^{(1)}}_{\text{Vertical Advection}} \\
& \underbrace{+ \frac{K_Z}{(D^{(1)}+D^{(2)}) \times 0.5} (ON^{(1)} - ON^{(2)})}_{\text{Vertical Diffusion}} \\
& \underbrace{+ P_r^{(2)} \cdot (C_1 \cdot C_2) \cdot D^{(2)}}_{\text{Production}} \underbrace{- D_N^{(2)} \cdot ON^{(2)} \cdot D^{(2)}}_{\text{Decomposition}} \\
& \underbrace{+ S_N^{(1)} \cdot ON^{(1)}}_{\text{Settling}} \underbrace{- S_N^{(2)} \cdot ON^{(2)}}_{\text{Settling}} \underbrace{+ LON^{(2)} / (\Delta x \, \Delta y)}_{\text{Loads}}
\end{aligned}
$$

Table 12.1.3 Equations of the Eutrophication Model (3/5)

< I-N >

Upper Layer

$$\frac{\partial}{\partial t}(H^{(1)} \cdot IN^{(1)}) = \underbrace{- \frac{\partial}{\partial x}(H^{(1)} \cdot u^{(1)} \cdot IN^{(1)}) - \frac{\partial}{\partial y}(H^{(1)} \cdot v^{(1)} \cdot IN^{(1)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(1)} \frac{\partial}{\partial x} IN^{(1)}) + \frac{\partial}{\partial y}(K \cdot H^{(1)} \frac{\partial}{\partial y} IN^{(1)})}_{\text{Diffusion}}$$

$$\underbrace{+ W_U(1,2) \cdot IN^{(2)} - W_L(1,2) \cdot IN^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_Z}{(H^{(2)}+H^{(1)}) \times 0.5} (IN^{(2)} - IN^{(1)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{- P_r^{(1)} \cdot (C_1 \cdot C_2) \cdot H^{(1)}}_{\text{Production}} \underbrace{+ D_N^{(1)} \cdot ON^{(1)} \cdot H^{(1)}}_{\text{Decomposition}}$$

$$\underbrace{+ Y_N}_{\text{Release}} \underbrace{+ LIN^{(1)}/(\Delta x \, \Delta y)}_{\text{Loads}}$$

Lower Layer

$$\frac{\partial}{\partial t}(H^{(2)} \cdot IN^{(2)}) = \underbrace{- \frac{\partial}{\partial x}(H^{(2)} \cdot u^{(2)} \cdot IN^{(2)}) - \frac{\partial}{\partial y}(H^{(2)} \cdot v^{(2)} \cdot IN^{(2)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(2)} \frac{\partial}{\partial x} IN^{(2)}) + \frac{\partial}{\partial y}(K \cdot H^{(2)} \frac{\partial}{\partial y} IN^{(2)})}_{\text{Diffusion}}$$

$$\underbrace{- W_U(2,1) \cdot IN^{(2)} + W_L(2,1) \cdot IN^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_Z}{(H^{(1)}+H^{(2)}) \times 0.5} (IN^{(1)} - IN^{(2)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{- P_r^{(2)} \cdot (C_1 \cdot C_2) \cdot H^{(2)}}_{\text{Production}} \underbrace{+ D_N^{(2)} \cdot ON^{(2)} \cdot H^{(2)}}_{\text{Decomposition}}$$

$$\underbrace{+ Y_N}_{\text{Release}} \underbrace{+ LIN^{(2)}/(\Delta x \, \Delta y)}_{\text{Loads}}$$

< COD1 >

Upper Layer

$$\frac{\partial}{\partial t}(H^{(1)} \cdot COD1^{(1)}) = \underbrace{- \frac{\partial}{\partial x}(H^{(1)} \cdot u^{(1)} \cdot COD1^{(1)}) - \frac{\partial}{\partial y}(H^{(1)} \cdot v^{(1)} \cdot COD1^{(1)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(1)} \frac{\partial}{\partial x} COD1^{(1)}) + \frac{\partial}{\partial y}(K \cdot H^{(1)} \frac{\partial}{\partial y} COD1^{(1)})}_{\text{Diffusion}}$$

$$\underbrace{+ W_U(1,2) \cdot COD1^{(2)} - W_L(1,2) \cdot COD1^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_Z}{(H^{(2)}+H^{(1)}) \times 0.5} (COD1^{(2)} - COD1^{(1)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{- D_{COD}^{(1)} \cdot COD1^{(1)} \cdot H^{(1)}}_{\text{Decomposition}} \underbrace{- S_{COD}^{(1)} \cdot COD1^{(1)}}_{\text{Settling}}$$

$$\underbrace{+ Y_{COD}}_{\text{Release}} \underbrace{+ LCOD^{(1)}/(\Delta x \, \Delta y)}_{\text{Loads}}$$

Lower Layer

$$\frac{\partial}{\partial t}(H^{(2)} \cdot COD1^{(2)}) = \underbrace{- \frac{\partial}{\partial x}(H^{(2)} \cdot u^{(2)} \cdot COD1^{(2)}) - \frac{\partial}{\partial y}(H^{(2)} \cdot v^{(2)} \cdot COD1^{(2)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(2)} \frac{\partial}{\partial x} COD1^{(2)}) + \frac{\partial}{\partial y}(K \cdot H^{(2)} \frac{\partial}{\partial y} COD1^{(2)})}_{\text{Diffusion}}$$

$$\underbrace{- W_U(2,1) \cdot COD1^{(2)} + W_L(2,1) \cdot COD1^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_Z}{(H^{(1)}+H^{(2)}) \times 0.5} (COD1^{(1)} - COD1^{(2)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{- D_{COD}^{(2)} \cdot COD1^{(2)} \cdot H^{(2)}}_{\text{Decomposition}} \underbrace{+ S_{COD}^{(1)} \cdot COD1^{(1)}}_{\text{Settling}} \underbrace{- S_{COD}^{(2)} \cdot COD1^{(2)}}_{\text{Settling}}$$

$$\underbrace{+ Y_{COD}}_{\text{Release}} \underbrace{+ LCOD^{(2)}/(\Delta x \, \Delta y)}_{\text{Loads}}$$

Table 12.1.3 Equations of the Eutrophication Model (4/5)

< COD2 >

Upper Layer

$$\frac{\partial}{\partial t}(H^{(1)} \cdot COD2^{(1)}) = \underbrace{-\frac{\partial}{\partial x}(H^{(1)} \cdot u^{(1)} \cdot COD2^{(1)}) - \frac{\partial}{\partial y}(H^{(1)} \cdot v^{(1)} \cdot COD2^{(1)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(1)} \frac{\partial}{\partial x} COD2^{(1)}) + \frac{\partial}{\partial y}(K \cdot H^{(1)} \frac{\partial}{\partial y} COD2^{(1)})}_{\text{Diffusion}}$$

$$\underbrace{+ W_U(1,2) \cdot COD2^{(2)} - W_L(1,2) \cdot COD2^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_z}{(H^{(2)}+H^{(1)}) \times 0.5} (COD2^{(2)} - COD2^{(1)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{+ P_r^{(1)} \cdot H^{(1)}}_{\text{Production}}$$

$$\underbrace{- D_{COD}^{(1)} \cdot COD2^{(1)} \cdot H^{(1)}}_{\text{Decomposition}} \underbrace{- S_{COD}^{(1)} \cdot COD2^{(1)}}_{\text{Settling}}$$

Lower Layer

$$\frac{\partial}{\partial t}(H^{(2)} \cdot COD2^{(2)}) = \underbrace{-\frac{\partial}{\partial x}(H^{(2)} \cdot u^{(2)} \cdot COD2^{(2)}) - \frac{\partial}{\partial y}(H^{(2)} \cdot v^{(2)} \cdot COD2^{(2)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(2)} \frac{\partial}{\partial x} COD2^{(2)}) + \frac{\partial}{\partial y}(K \cdot H^{(2)} \frac{\partial}{\partial y} COD2^{(2)})}_{\text{Diffusion}}$$

$$\underbrace{- W_U(2,1) \cdot COD2^{(2)} + W_L(2,1) \cdot COD2^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_z}{(H^{(1)}+H^{(2)}) \times 0.5} (COD2^{(1)} - COD2^{(2)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{+ P_r^{(2)} \cdot H^{(2)}}_{\text{Production}}$$

$$\underbrace{- D_{COD}^{(2)} \cdot COD2^{(2)} \cdot H^{(2)}}_{\text{Decomposition}} \underbrace{+ S_{COD}^{(1)} \cdot COD2^{(1)}}_{\text{Settling}} \underbrace{- S_{COD}^{(2)} \cdot COD2^{(2)}}_{\text{Settling}}$$

< DO >

Upper Layer

$$\frac{\partial}{\partial t}(H^{(1)} \cdot DO^{(1)}) = \underbrace{-\frac{\partial}{\partial x}(H^{(1)} \cdot u^{(1)} \cdot DO^{(1)}) - \frac{\partial}{\partial y}(H^{(1)} \cdot v^{(1)} \cdot DO^{(1)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(1)} \frac{\partial}{\partial x} DO^{(1)}) + \frac{\partial}{\partial y}(K \cdot H^{(1)} \frac{\partial}{\partial y} DO^{(1)})}_{\text{Diffusion}}$$

$$\underbrace{+ W_U(1,2) \cdot DO^{(2)} - W_L(1,2) \cdot DO^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_z}{(H^{(2)}+H^{(1)}) \times 0.5} (DO^{(2)} - DO^{(1)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{+ P_r^{(1)} \cdot (C_1 \cdot C_3) \cdot H^{(1)}}_{\text{Production}} \underbrace{- D_{COD}^{(1)} \cdot (COD1^{(1)} + COD2^{(1)}) \cdot H^{(1)} \cdot (C_1 \cdot C_3)}_{\text{Decomposition}}$$

$$\underbrace{+ K_a \cdot (DOS - DO)^{(1)} \cdot H^{(1)}}_{\text{Re-aeration}} \underbrace{- DOSH}_{\text{Consumption}} \underbrace{+ LDO^{(1)} / (\Delta x \, \Delta y)}_{\text{Loads}}$$

Lower

$$\frac{\partial}{\partial t}(H^{(2)} \cdot DO^{(2)}) = \underbrace{-\frac{\partial}{\partial x}(H^{(2)} \cdot u^{(2)} \cdot DO^{(2)}) - \frac{\partial}{\partial y}(H^{(2)} \cdot v^{(2)} \cdot DO^{(2)})}_{\text{Advection}}$$

$$\underbrace{+ \frac{\partial}{\partial x}(K \cdot H^{(2)} \frac{\partial}{\partial x} DO^{(2)}) + \frac{\partial}{\partial y}(K \cdot H^{(2)} \frac{\partial}{\partial y} DO^{(2)})}_{\text{Diffusion}}$$

$$\underbrace{- W_U(2,1) \cdot DO^{(2)} + W_L(2,1) \cdot DO^{(1)}}_{\text{Vertical Advection}}$$

$$\underbrace{+ \frac{K_z}{(H^{(1)}+H^{(2)}) \times 0.5} (DO^{(1)} - DO^{(2)})}_{\text{Vertical Diffusion}}$$

$$\underbrace{+ P_r^{(2)} \cdot (C_1 \cdot C_3) \cdot H^{(2)}}_{\text{Production}} \underbrace{- D_{COD}^{(2)} \cdot (COD1^{(2)} + COD2^{(2)}) \cdot H^{(2)} \cdot (C_1 \cdot C_3)}_{\text{Decomposition}}$$

$$\underbrace{- DOSH}_{\text{Consumption}} \underbrace{+ LDO^{(2)} / (\Delta x \, \Delta y)}_{\text{Loads}}$$

Table 12.1.3 Equations of the Eutrophication Model (5/5)

$D_P^{(\ell)}$	: Decomposition rate of O-P (/day)
$D_N^{(\ell)}$	: Decomposition rate of O-N (/day)
$D_{COD}^{(\ell)}$	: Decomposition rate of COD (/day)
$S_P^{(\ell)}$	: Settling rate of O-P (m/day)
$S_N^{(\ell)}$	: Settling rate of O-N (m/day)
$S_{COD}^{(\ell)}$	: Settling rate of COD (m/day)
Y_P	: Release rate of I-P ($g/m^2/day$)
Y_N	: Release rate of I-N ($g/m^2/day$)
Y_{COD}	: Release rate of COD ($g/m^2/day$)
$DOSH$	: Consumption rate of DO by the bottom sediment ($g/m^2/day$)
K_a	: Re-aeration constant (/day)
DOS	: Saturated concentration of DO (mg/l)
LOP	: Loads of O-P (g/day)
LIP	: Loads of I-P (g/day)
LON	: Loads of O-N (g/day)
LIN	: Loads of I-N (g/day)
$LCOD$	: Loads of COD (g/day)
LDO	: Loads of DO (g/day)
$H^{(\ell)}$	: Thickness of the ℓ th Layer (m)
C_1	: P/COD ratio by the internal production
C_2	: N/P ratio by the internal production
C_3	: DO/P ratio by the internal production
$\Delta x, \Delta y$	: Grid size in x, y direction(m)
$OP^{(\ell)}$	: Concentration of O-P in the ℓ th Layer (mg/l)
$IP^{(\ell)}$	: Concentration of I-P in the ℓ th Layer (mg/l)
$ON^{(\ell)}$	: Concentration of O-N in the ℓ th Layer (mg/l)
$IN^{(\ell)}$	: Concentration of I-N in the ℓ th Layer (mg/l)
$COD2^{(\ell)}$	: Concentration of COD by the internal production in the ℓ th Layer (mg/l)
$COD1^{(\ell)}$	: Concentration of other COD in the ℓ th Layer (mg/l)
$DO^{(\ell)}$	: Concentration of DO in the ℓ th Layer (mg/l)
$u^{(\ell)}$	: x component of the velocity in the ℓ th Layer (m/day)
$v^{(\ell)}$	: y component of the velocity in the ℓ th Layer (m/day)
$W_U(\ell 1, \ell 2)$	: Velocity of the upwelling (m/day)
$W_L(\ell 1, \ell 2)$	: Velocity of the downwelling (m/day)
K	: Horizontal eddy diffusivity (m^2/day)
K_z	: Vertical eddy diffusivity (m^2/day)
$P_r^{(\ell)}$	: Growth of COD by the internal production

$$P_r^{(\ell)} = COD2^{(\ell)} \cdot \mu max \frac{IP^{(\ell)}}{K_{IP}+IP^{(\ell)}} \cdot \frac{IN^{(\ell)}}{K_{IN}+IN^{(\ell)}} \cdot \frac{RD^{(\ell)}}{10000}$$

μmax	: Maximum growth rate (/day) by AGP Test (25℃, 10000 lux)
K_{IP}	: Half saturation constant of I-P (mg/l)
K_{IN}	: Half saturation constant of I-N (mg/l)
$RD^{(\ell)}$	: Light intensity in the ℓ th Layer (lux)

FIGURES

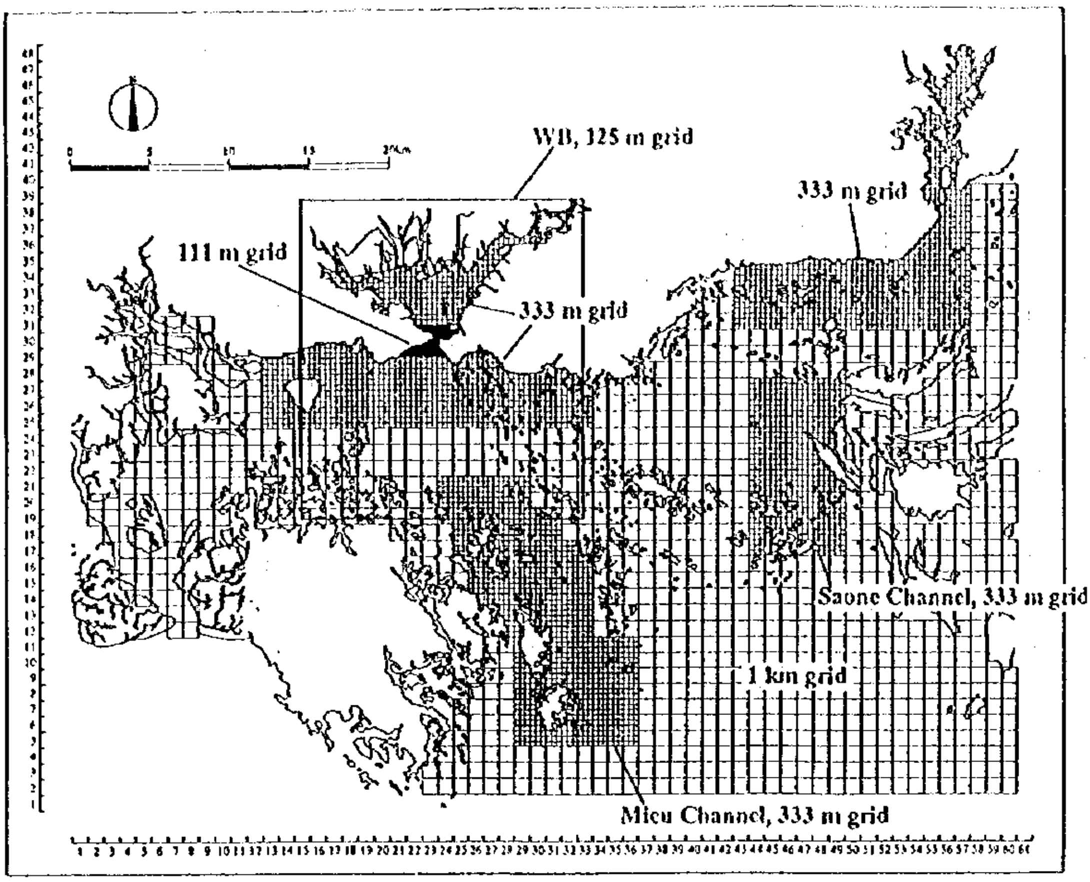


Figure 12.1.1 Model Area

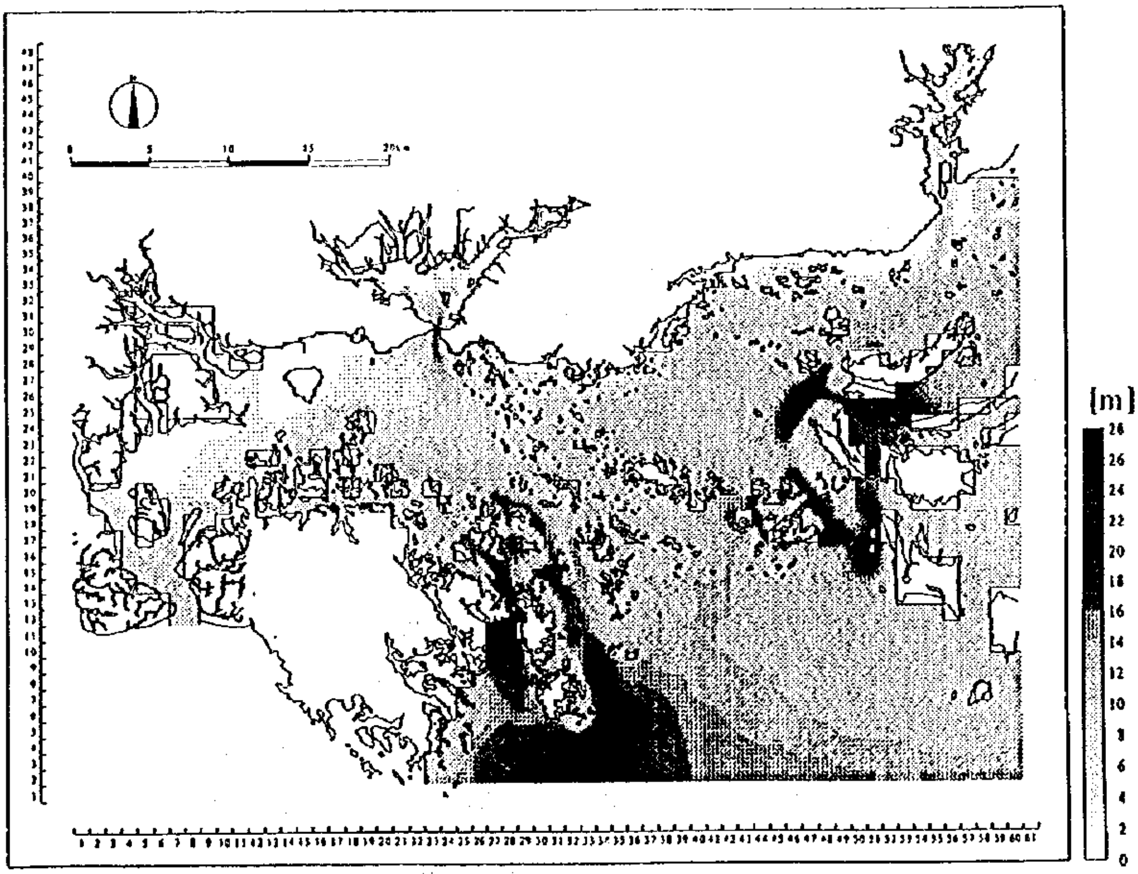


Figure 12.1.2 Bathymetry

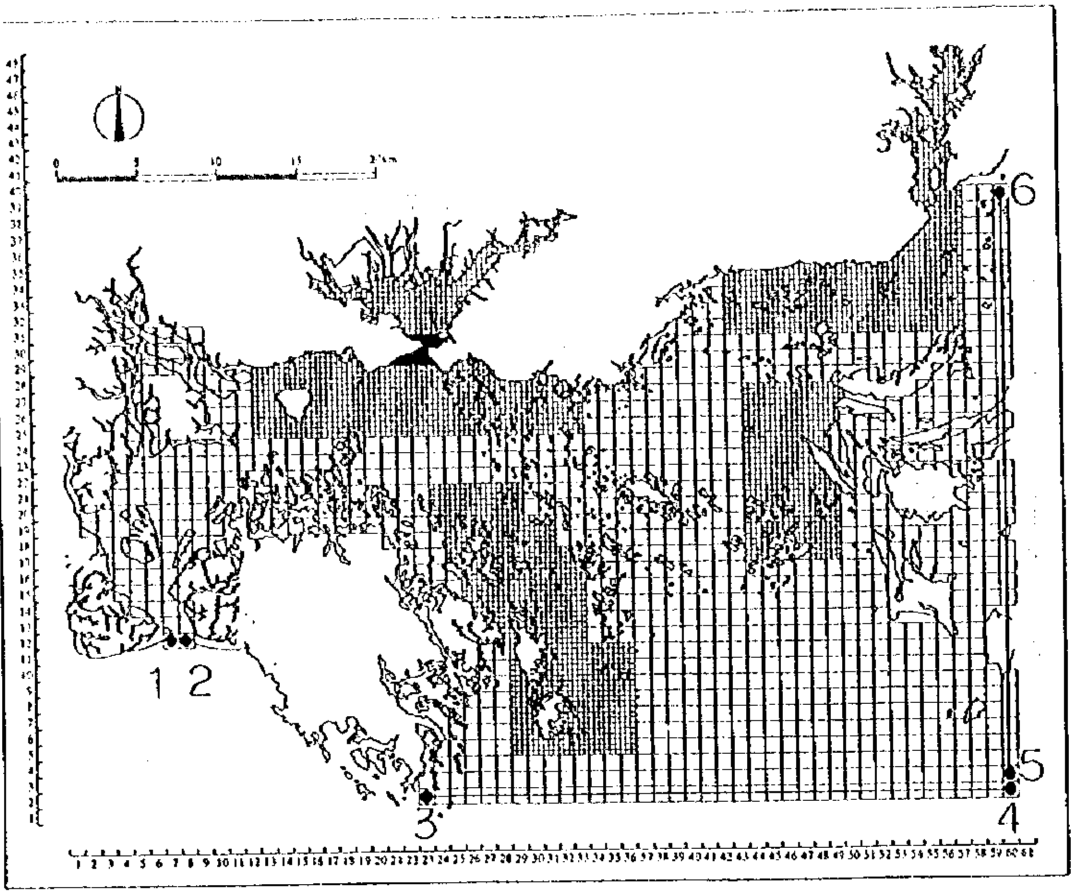


Figure 12.2.1 Locations of the Open Boundaries

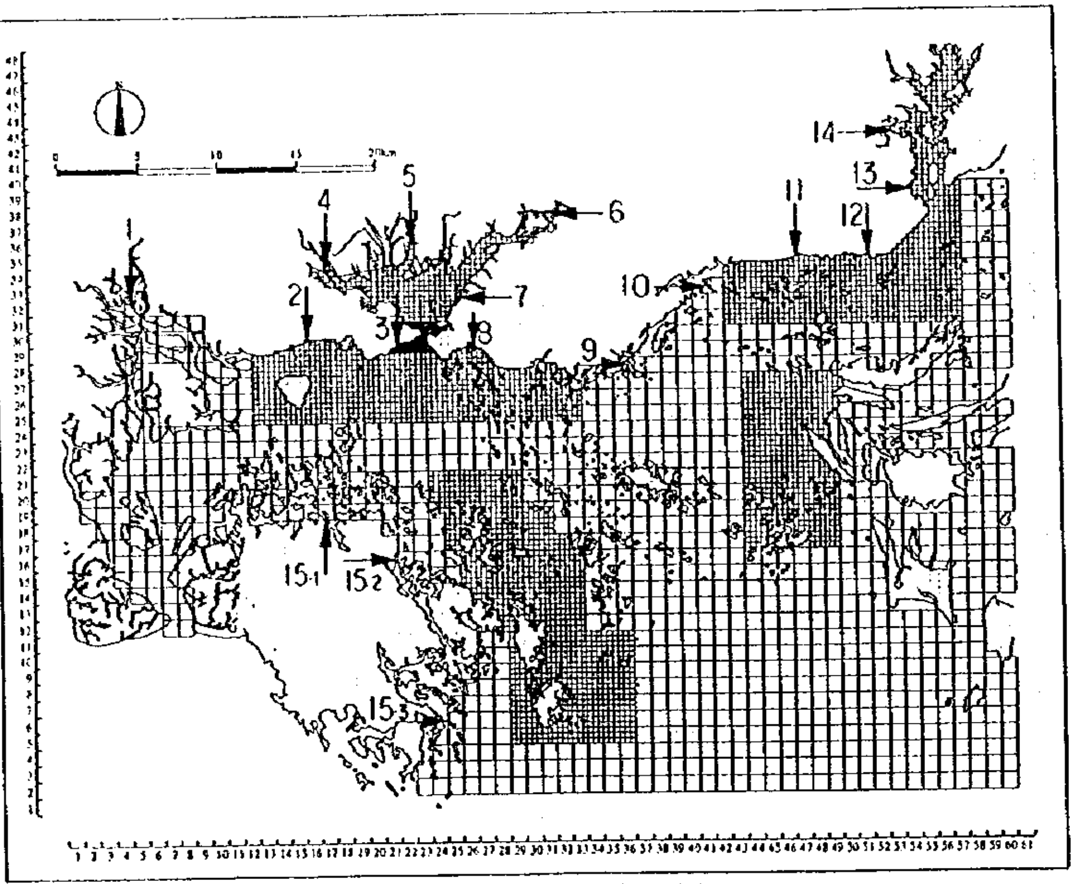


Figure 12.2.2 Locations of the River Discharges

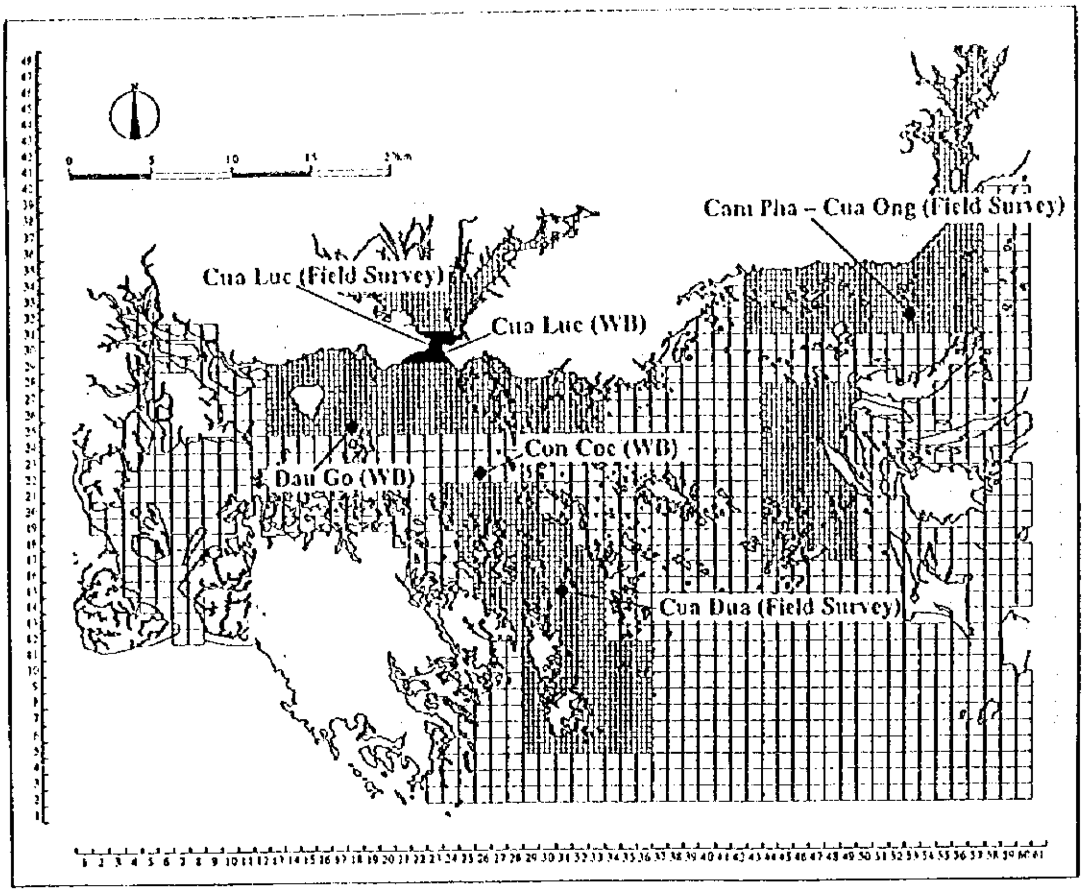


Figure 12.5.1 Locations of the Current Measuring Stations of the Field Survey and WB Study

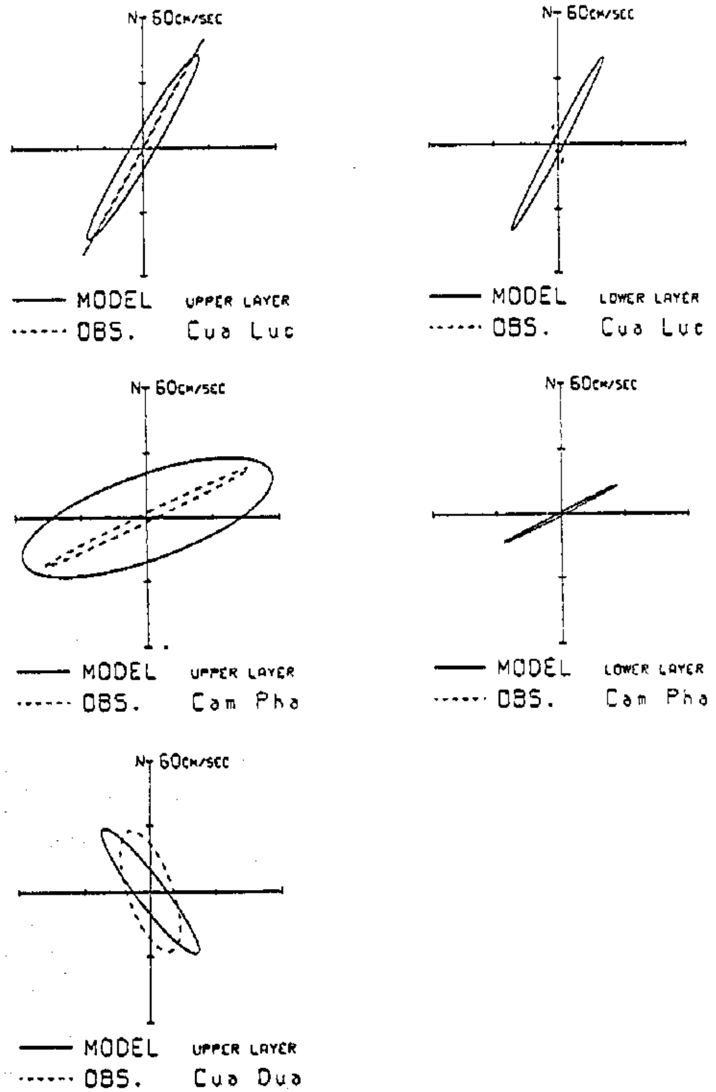


Figure 12.5.2 Comparison of the Measured and Simulated Diurnal Currents (Measured Currents: Field Survey Data)

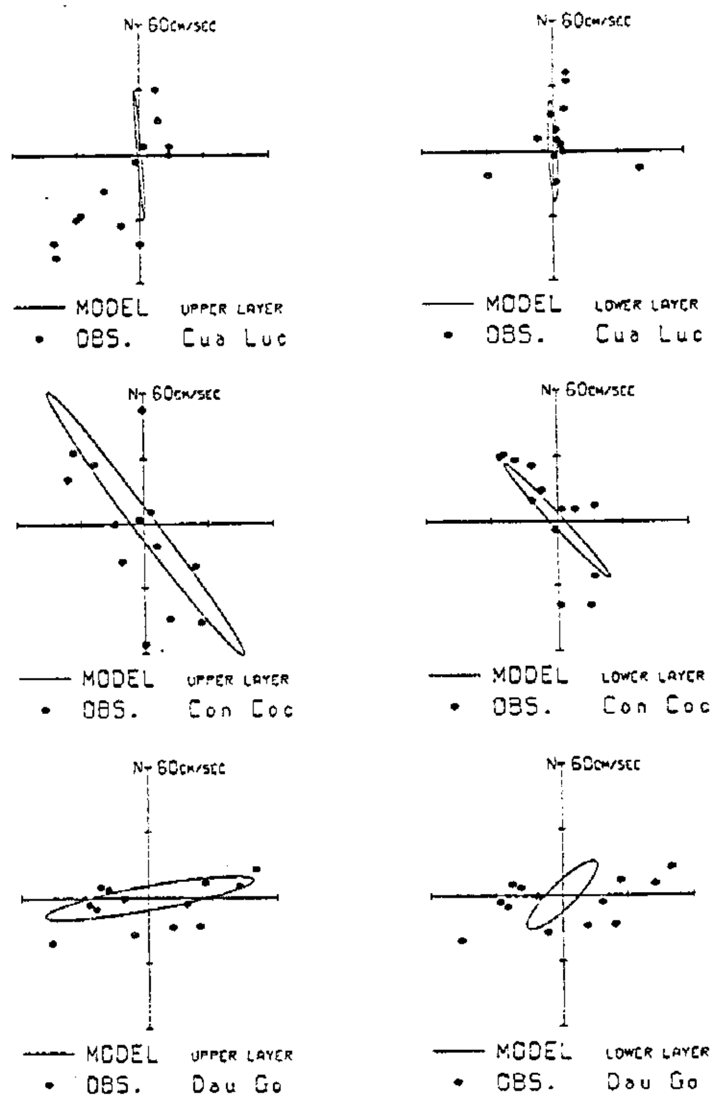


Figure 12.5.3 Comparison of the Measured and Simulated Diurnal Currents (Measured Currents: WB Study by ESSA & HIO (1997))

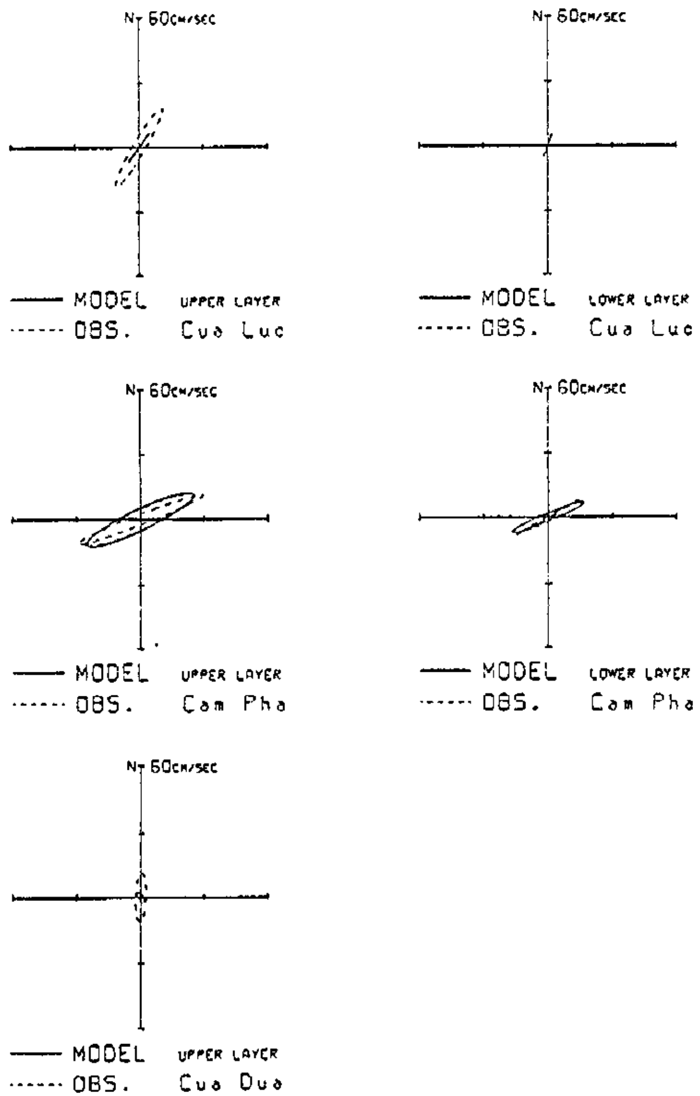


Figure 12.5.4 Comparison of the Measured and Simulated Semi-diurnal Currents (Measured Currents: Field Survey Data)

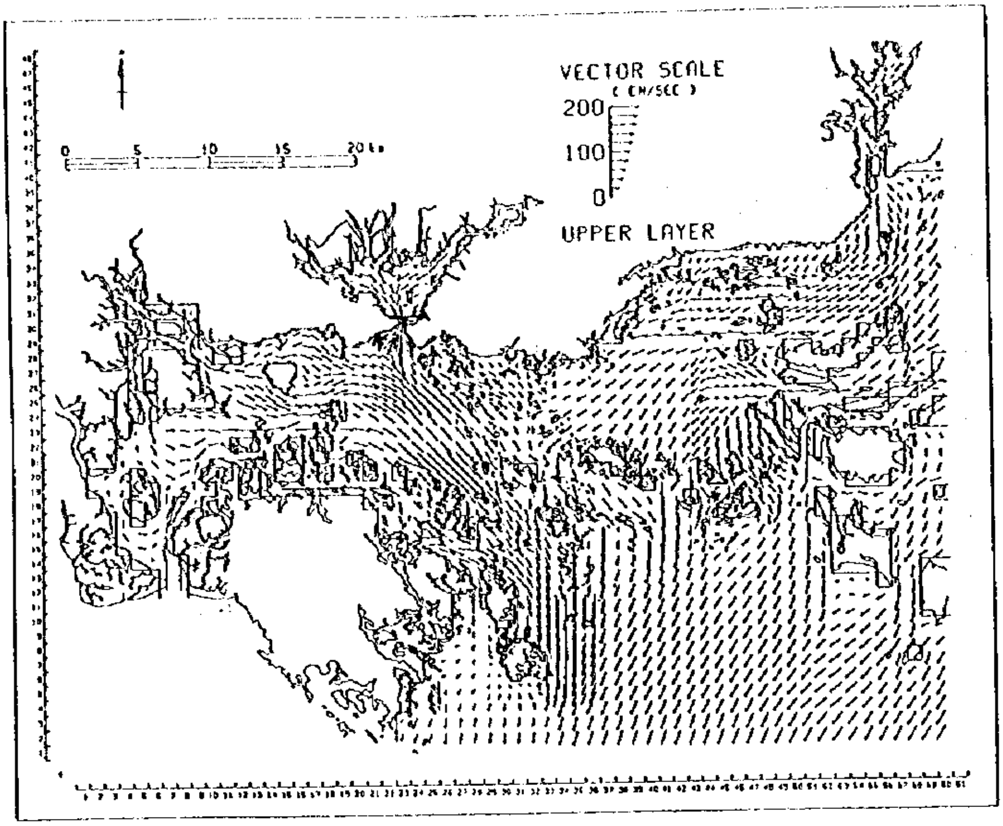


Figure 12.5.5 (1) Simulated Ebb Tide of the Upper Layer

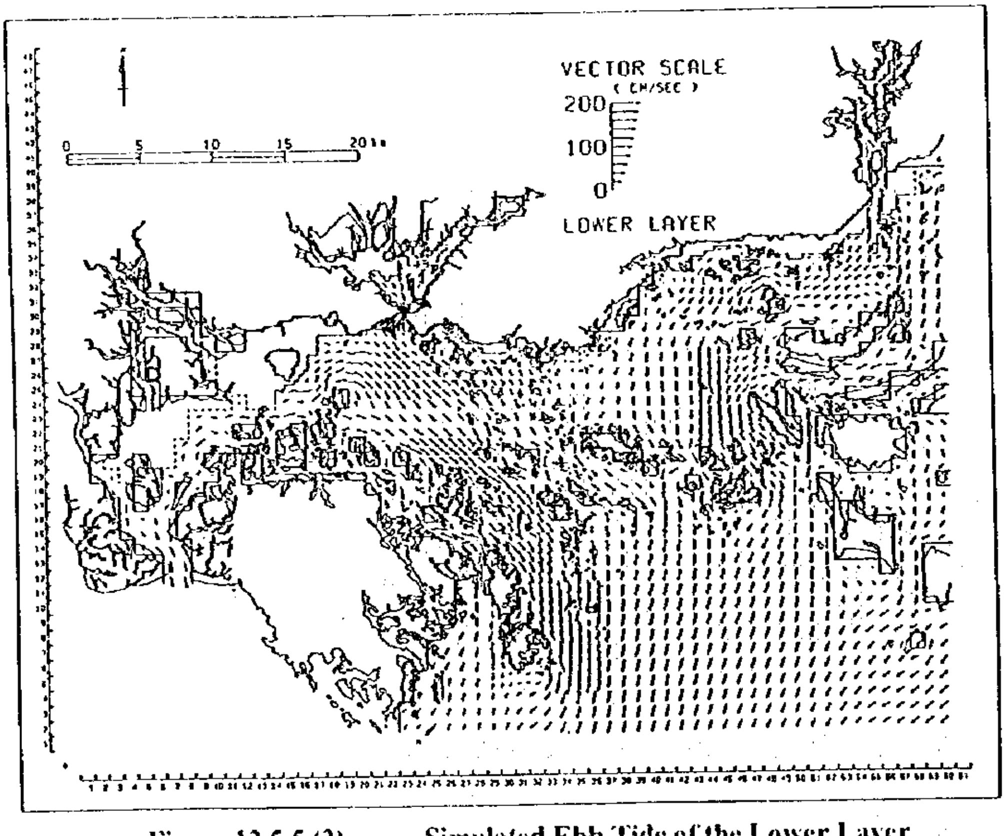


Figure 12.5.5 (2) Simulated Ebb Tide of the Lower Layer

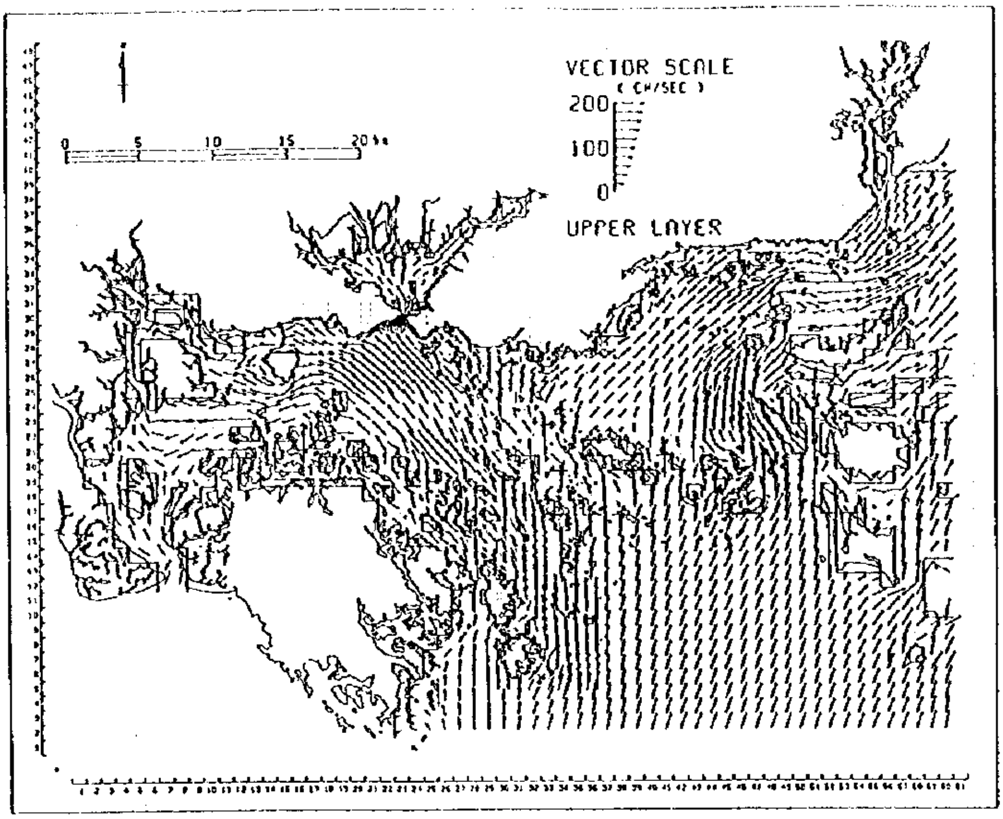


Figure 12.5.6 (1) Simulated Rising Tide of the Upper Layer

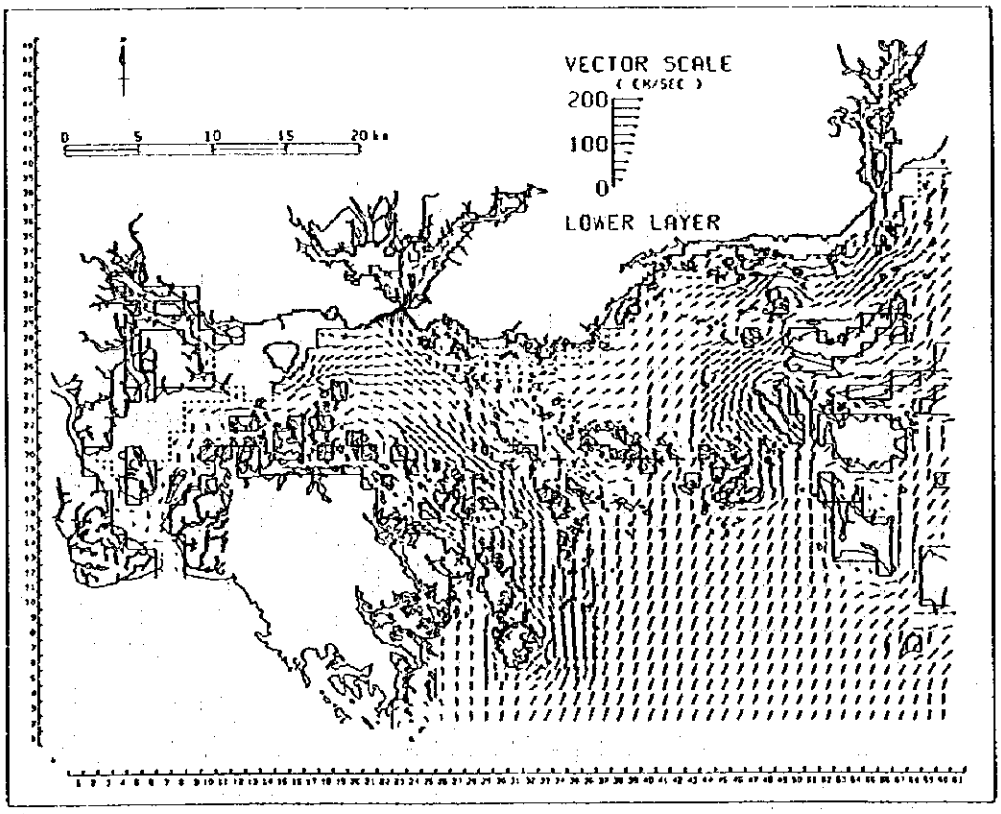


Figure 12.5.6 (2) Simulated Rising Tide of the Lower Layer

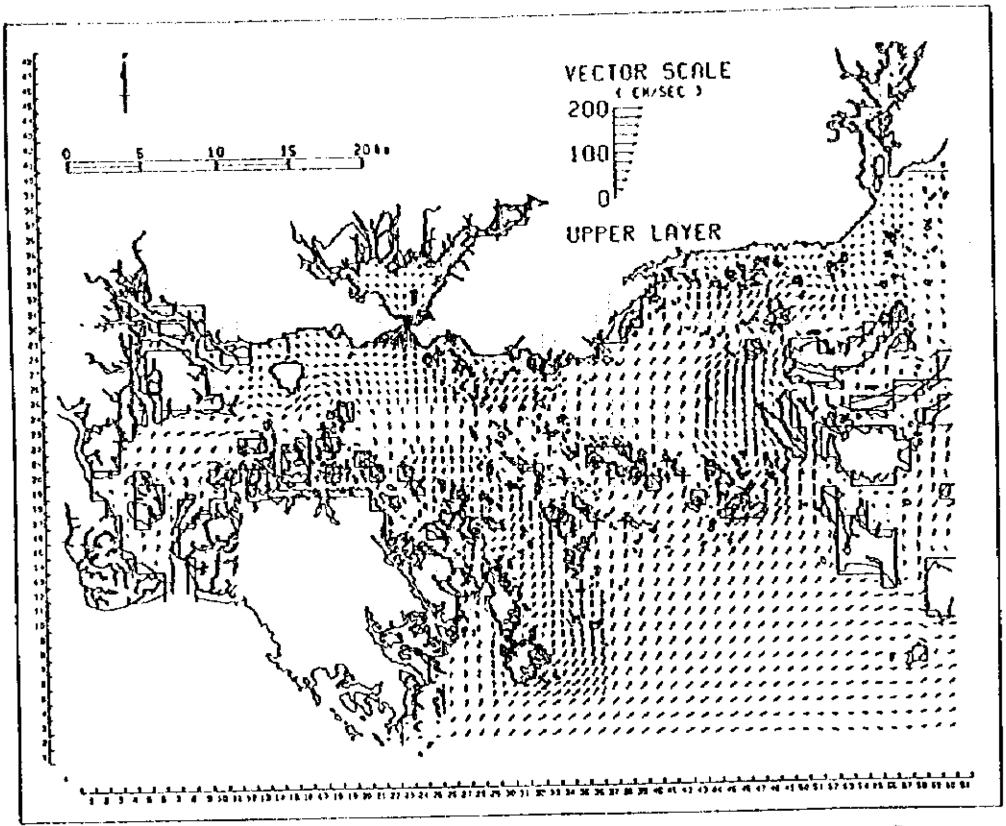


Figure 12.5.7 (1) Average of the Simulated Currents of the Upper Layer

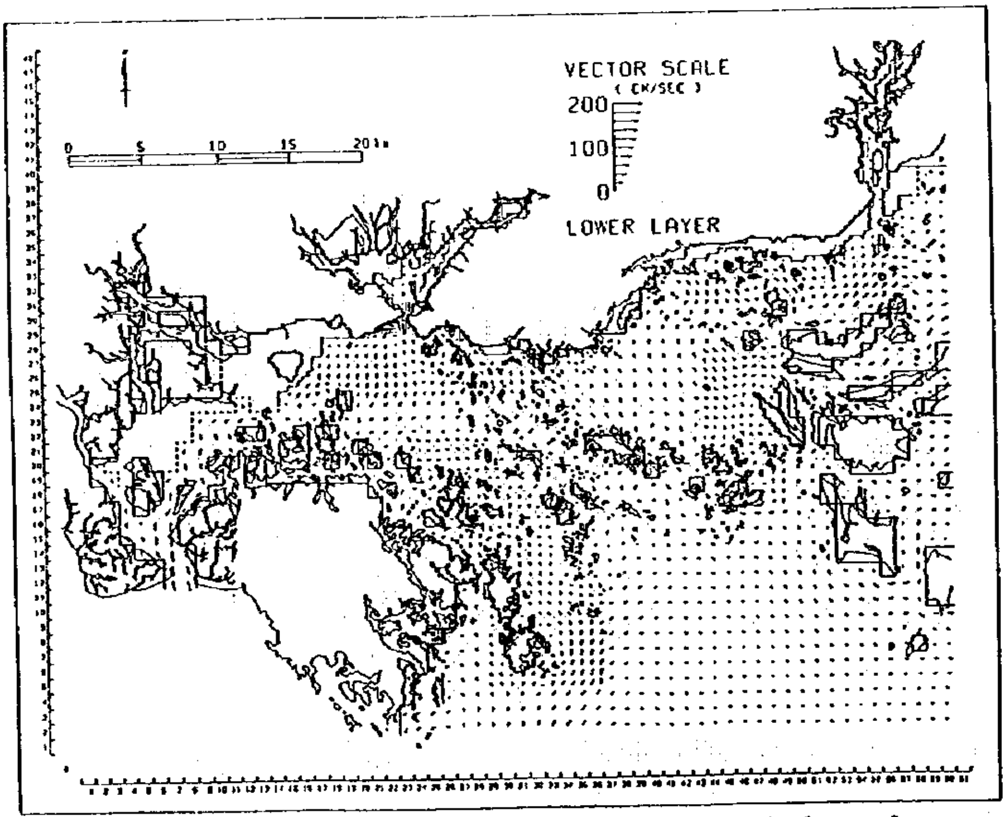


Figure 12.5.7 (2) Average of the Simulated Currents of the Lower Layer

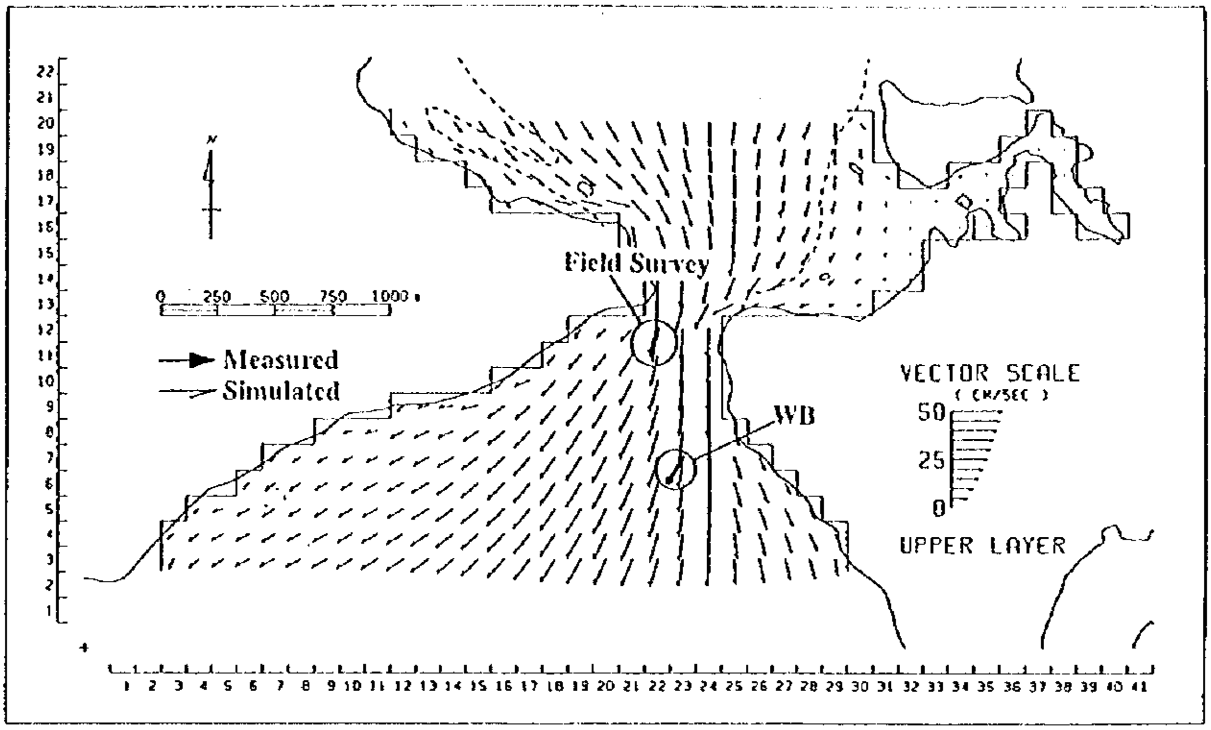


Figure 12.5.8 (1) Comparison of the Measured and Simulated Average Currents of the Upper Layer around Cua Luc (Measured Currents: Field Survey Data and WB Study by ESSA & HIO 1997)

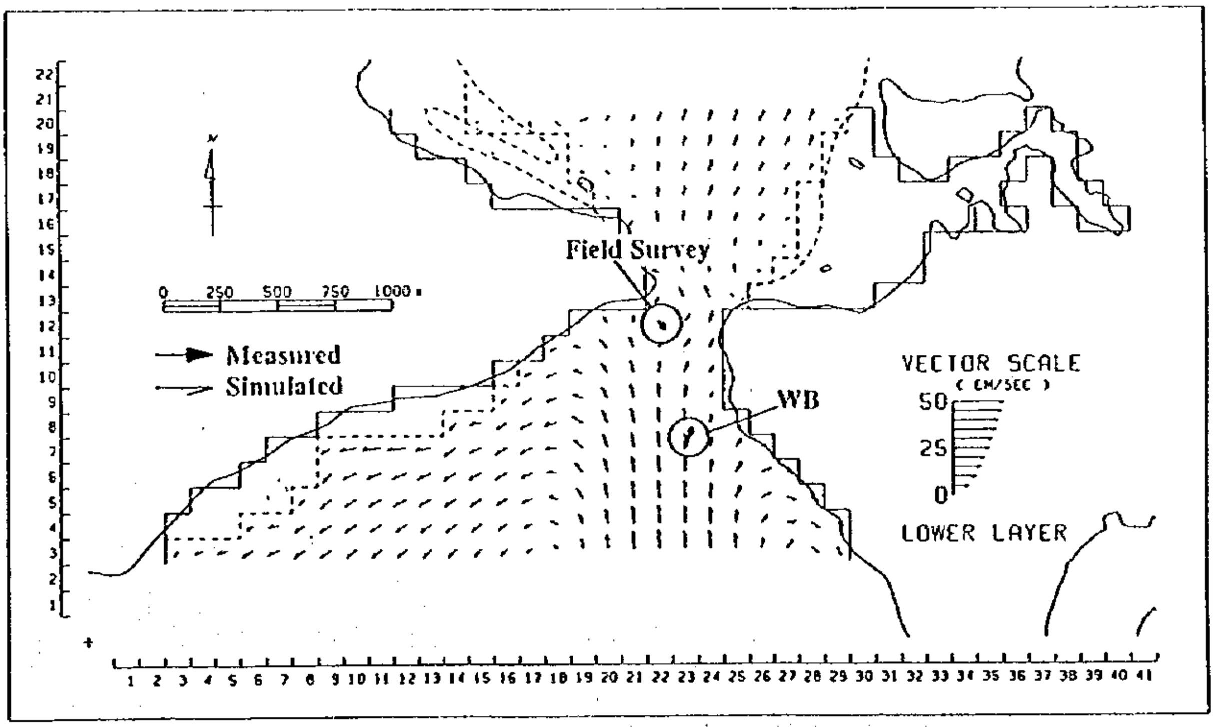


Figure 12.5.8 (2) Comparison of the Measured and Simulated Average Currents of the Lower Layer around Cua Luc (Measured Currents: Field Survey Data and WB Study by ESSA & HIO 1997)

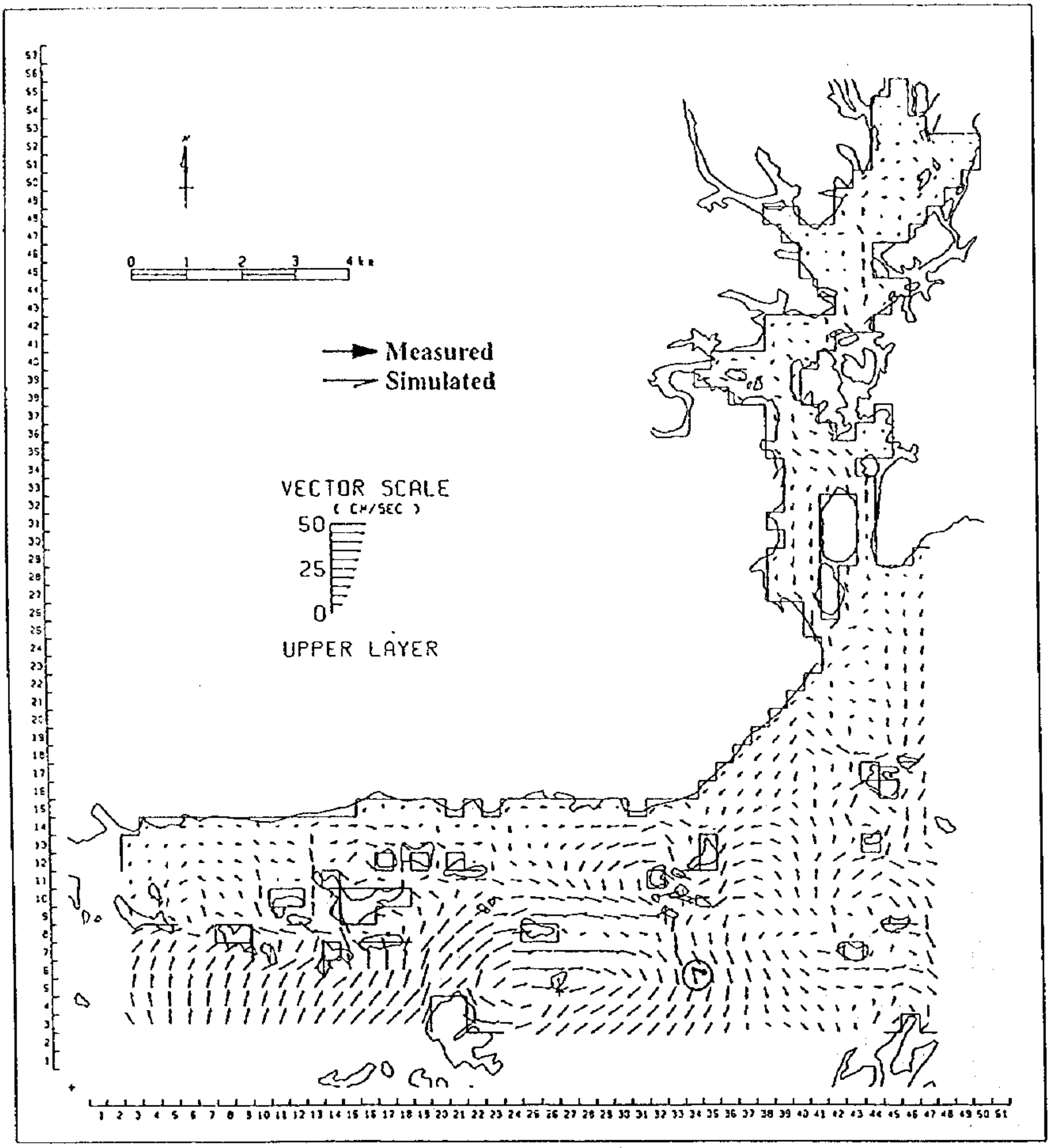


Figure 12.5.9 (1) Comparison of the Measured and Simulated Average Currents of the Upper Layer around Cam Pha – Cua Ong (Measured Currents: Field Survey Data)

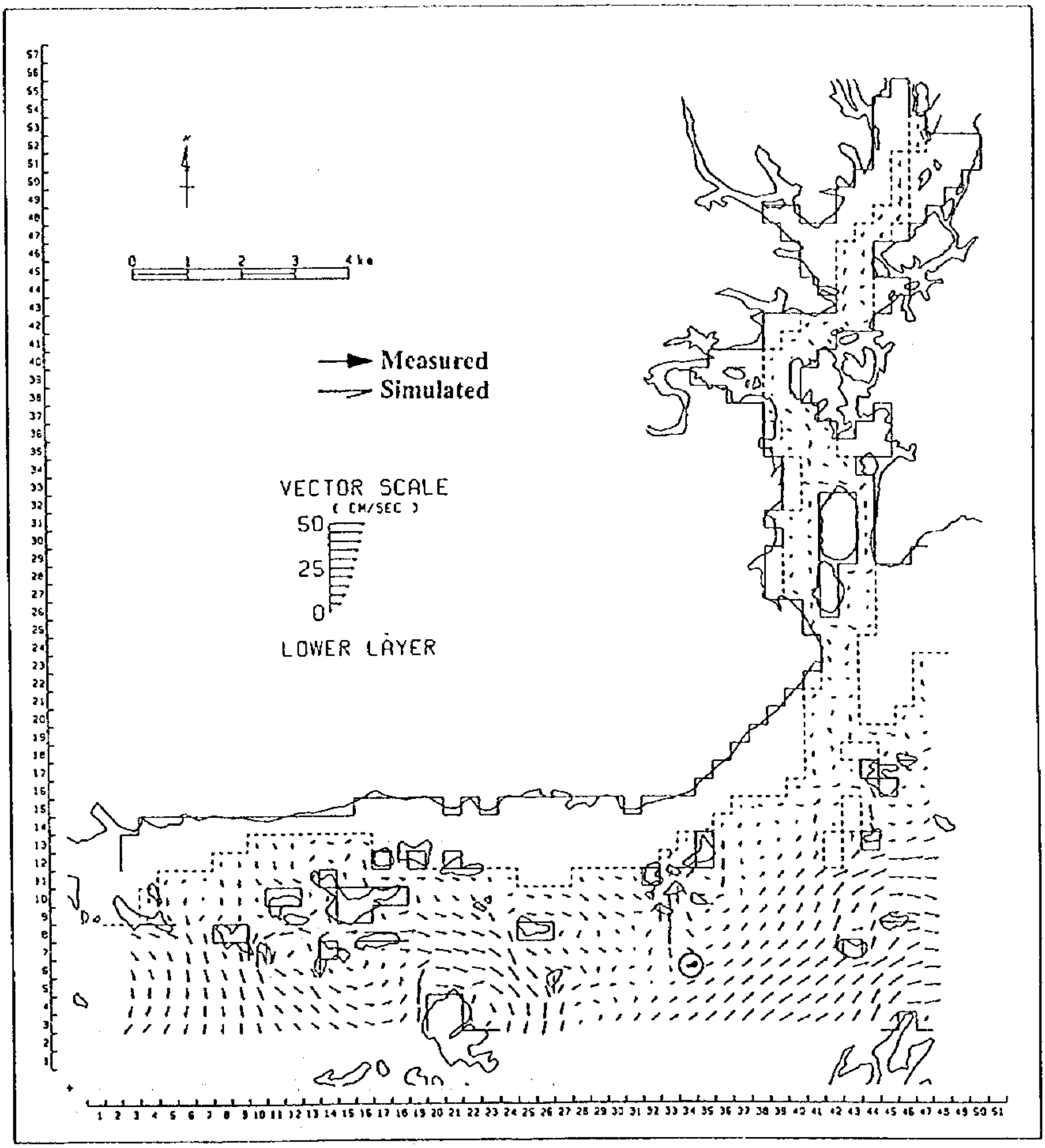


Figure 12.5.9 (2) Comparison of the Measured and Simulated Average Currents of the Lower Layer around Cam Pha – Cua Ong (Measured Currents: Field Survey Data)

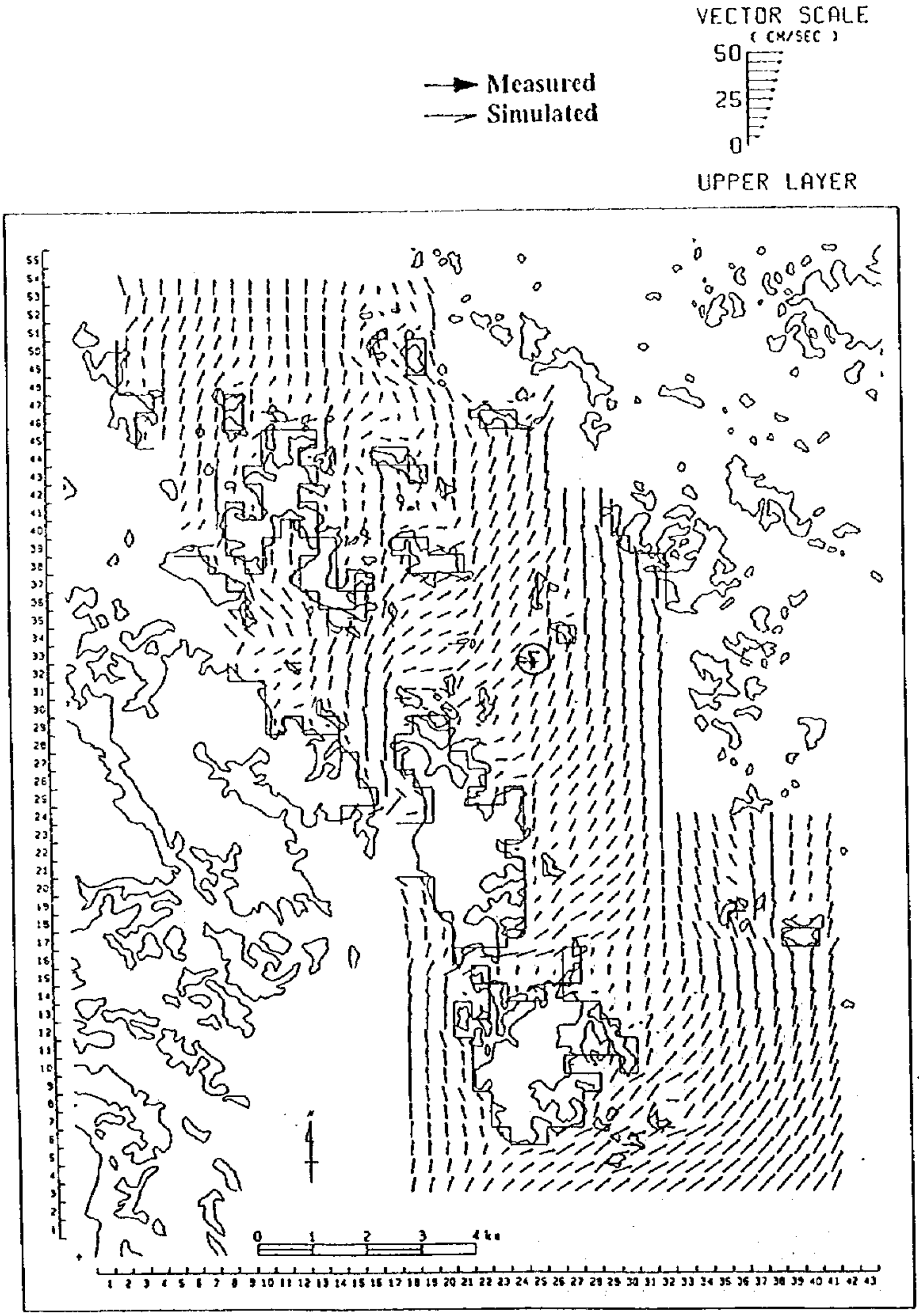


Figure 12.5.10 Comparison of the Measured and Simulated Average Currents of the Upper Layer around Cua Dua (Measured Currents: Field Survey Data)

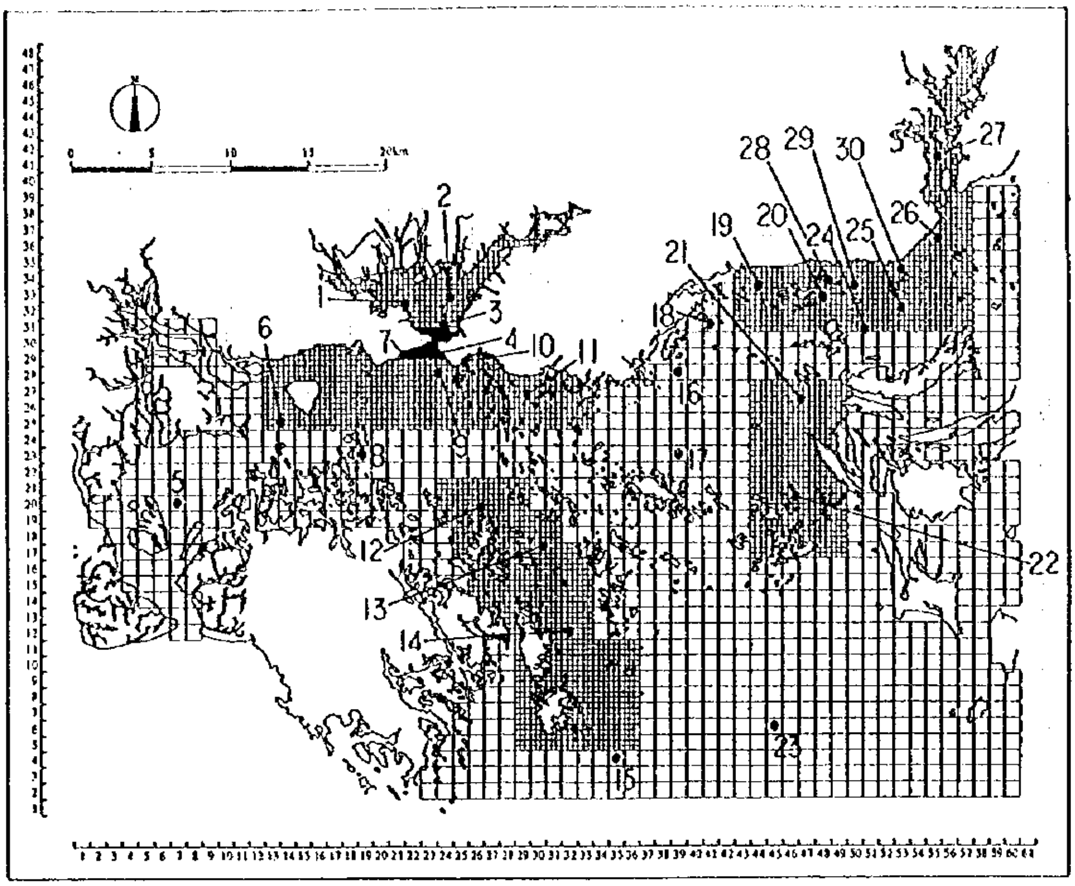


Figure 12.5.11 Locations of the Sampling Stations for the Water Quality Survey

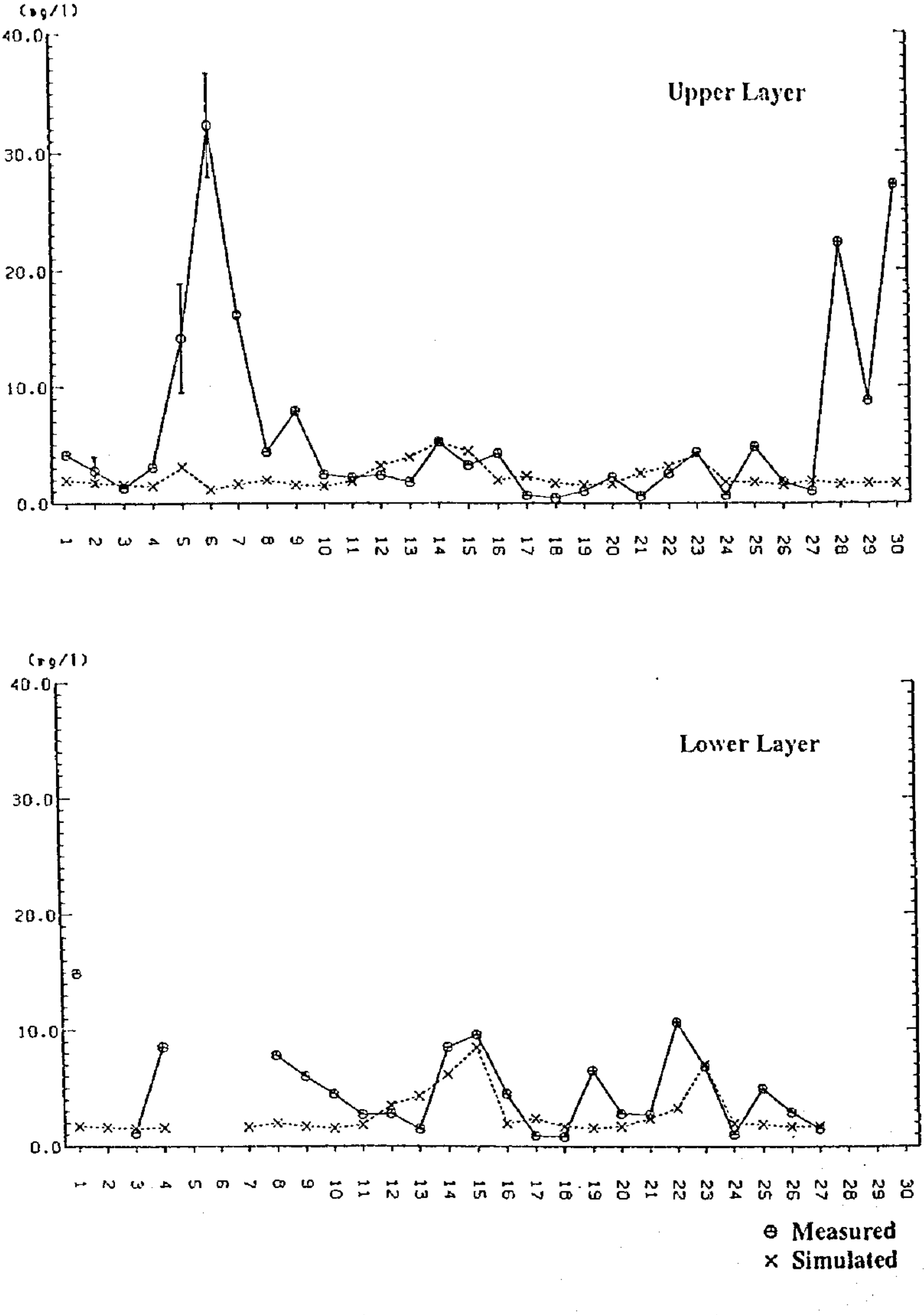


Figure 12.5.12 Comparison of the Measured and Simulated Concentrations of SS

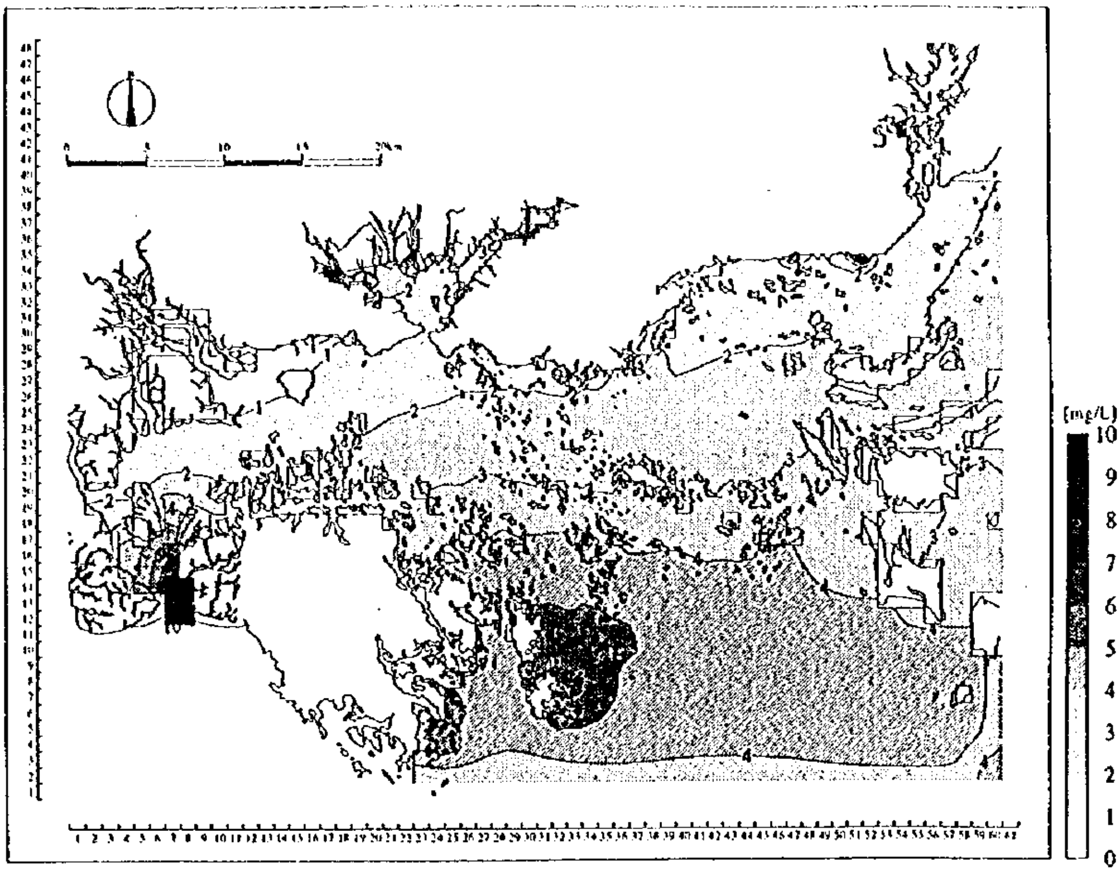


Figure 12.5.13 (1) Simulated Concentrations of SS of the Upper Layer

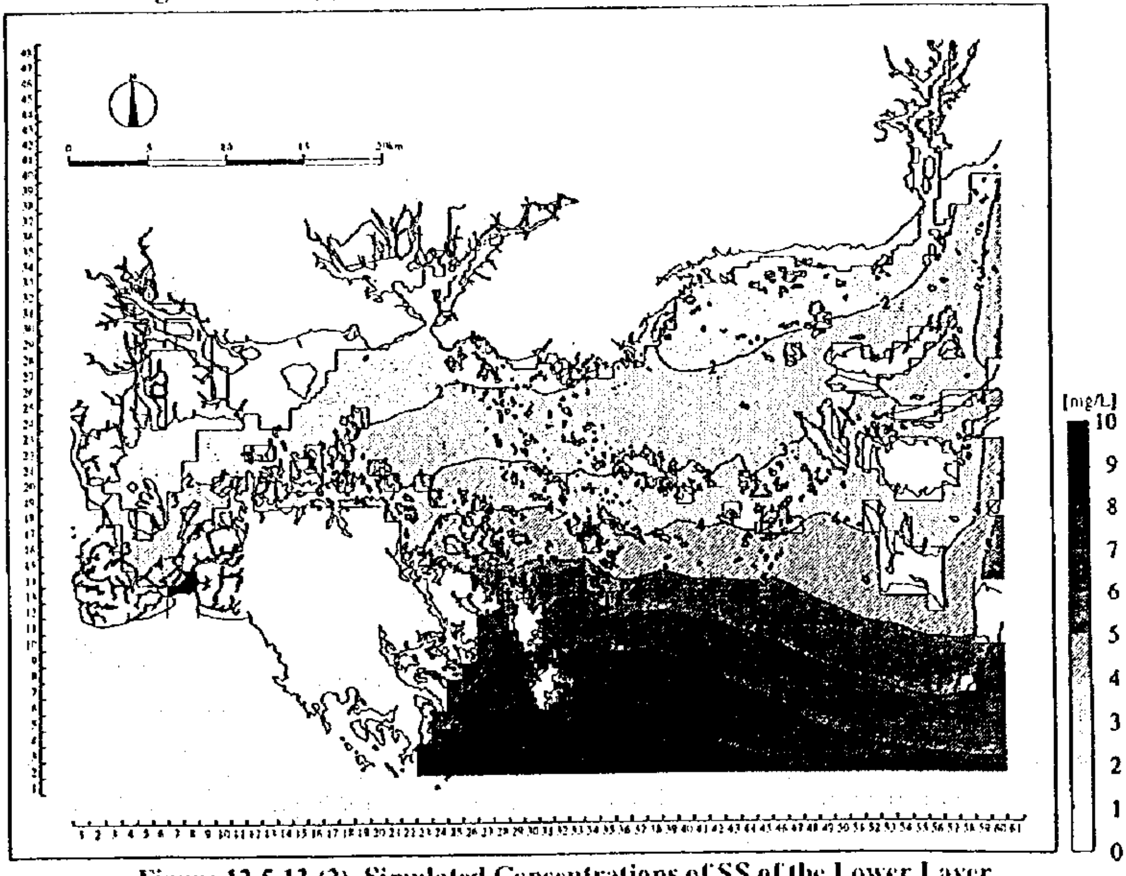


Figure 12.5.13 (2) Simulated Concentrations of SS of the Lower Layer

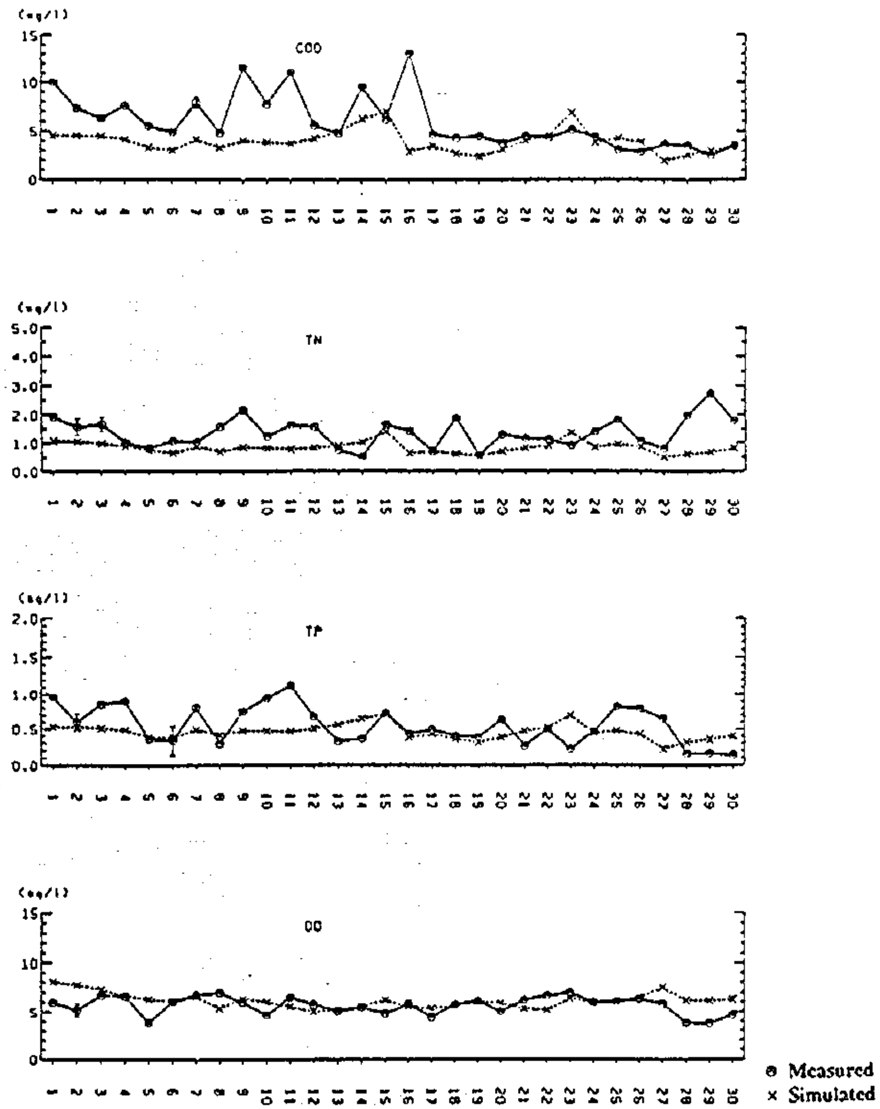


Figure 12.5.14 (1) Comparison of the Measured and Simulated Concentrations of COD, T-N, T-P, and DO for the Upper Layer

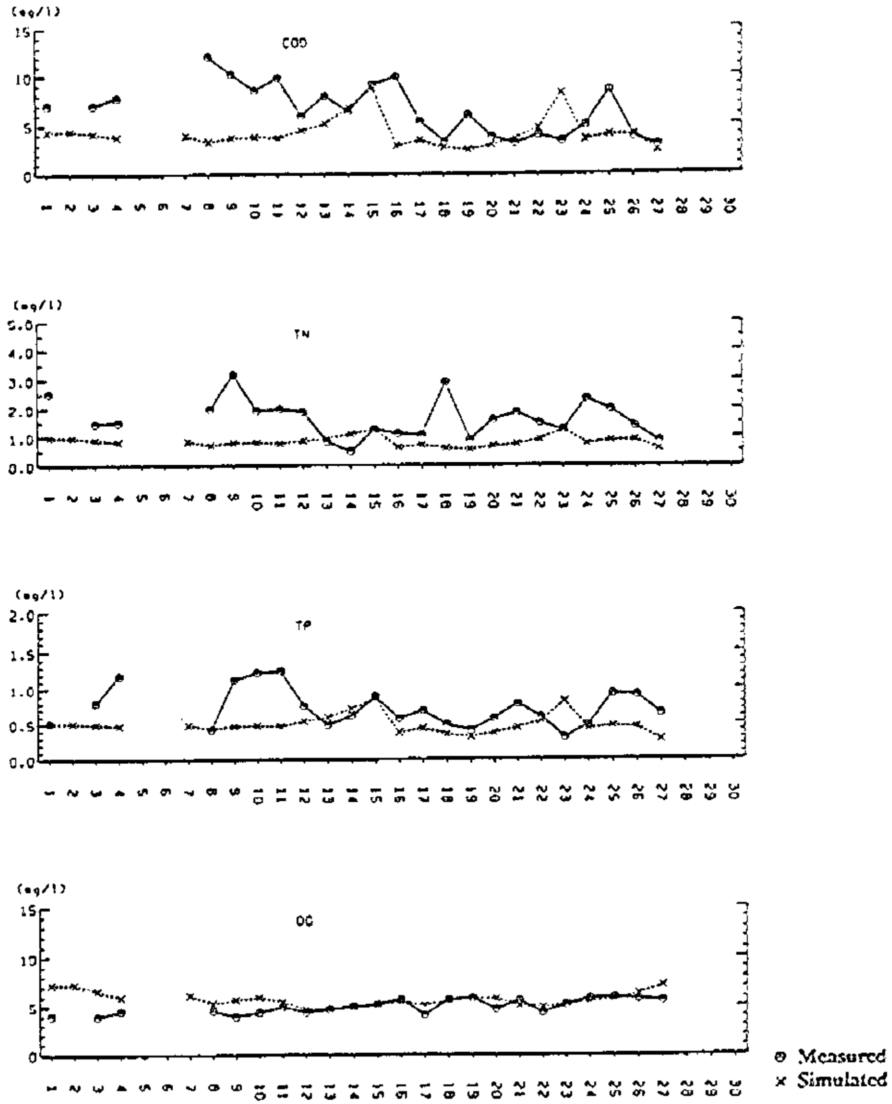


Figure 12.5.14 (2) Comparison of the Measured and Simulated Concentrations of COD. T-N. T-P. and DO for the Lower Layer

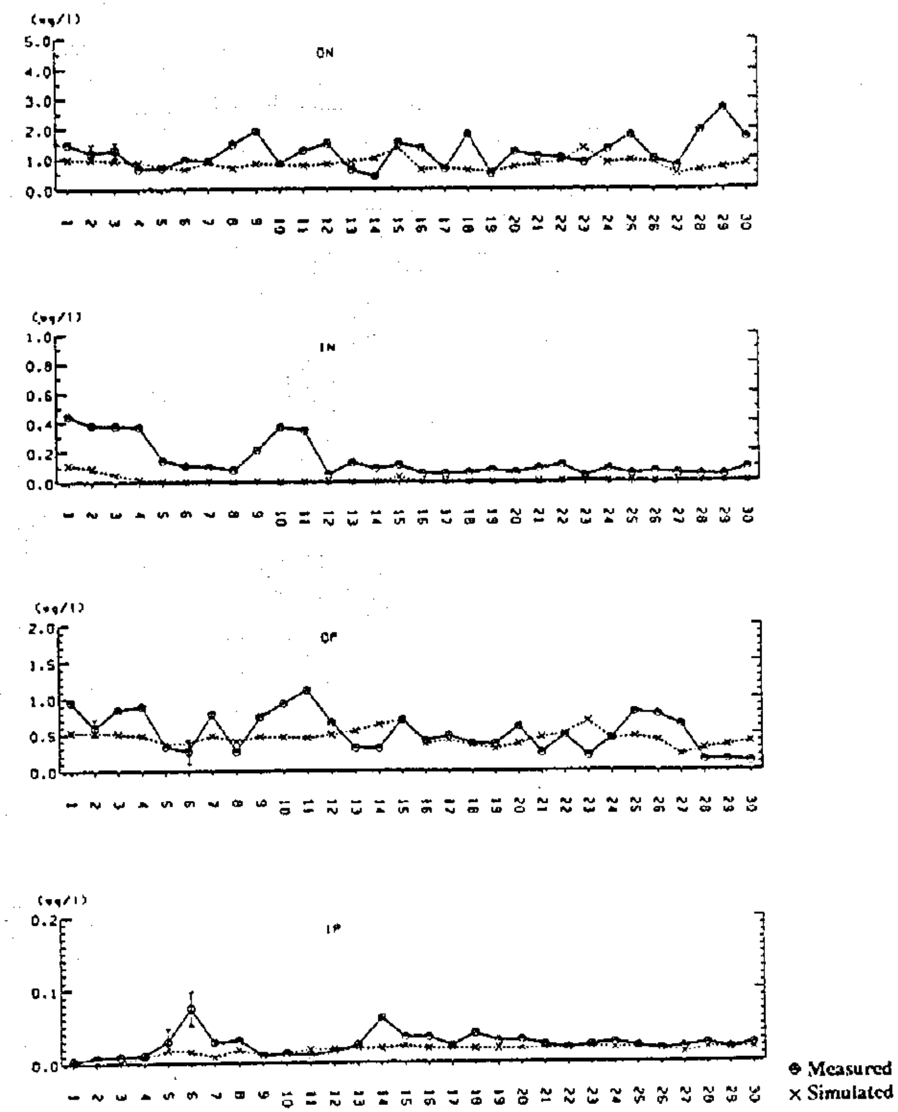
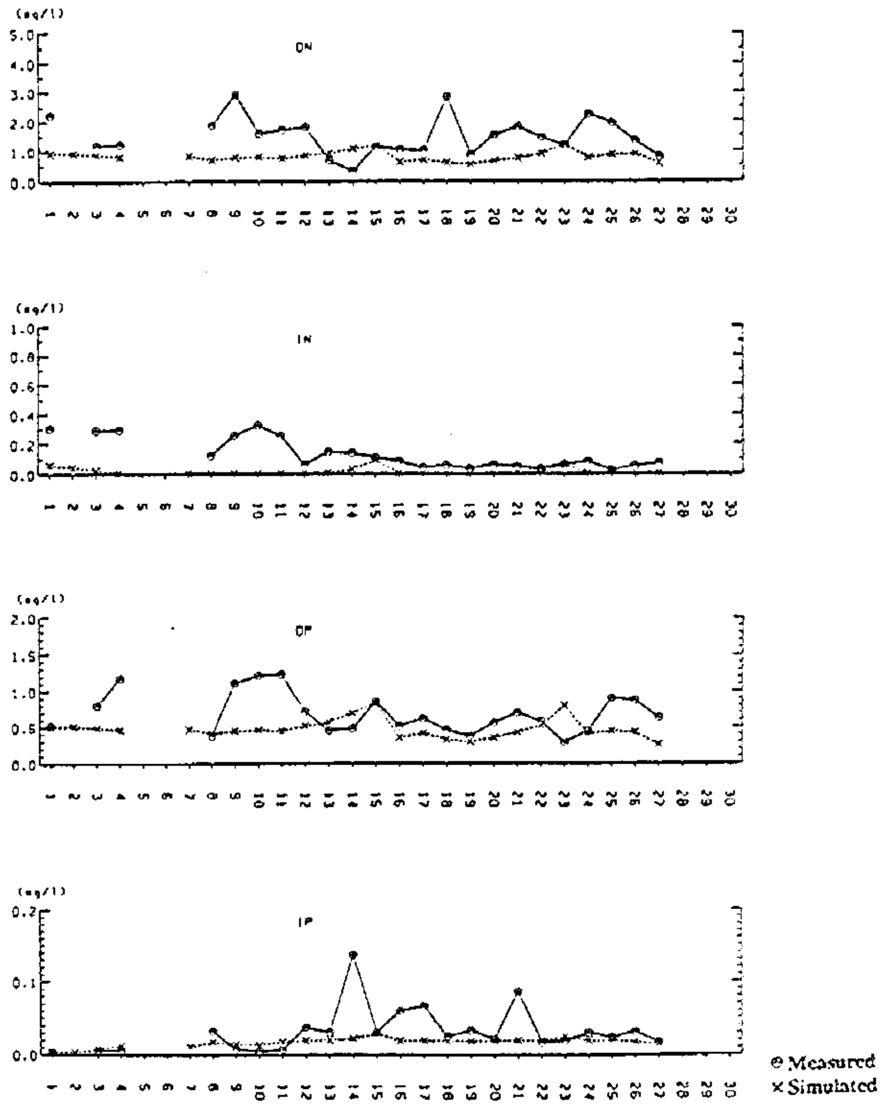


Figure 12.5.15 (1) Comparison of the Measured and Simulated Concentrations of O-N, I-N, O-P, and I-P for the Upper Layer



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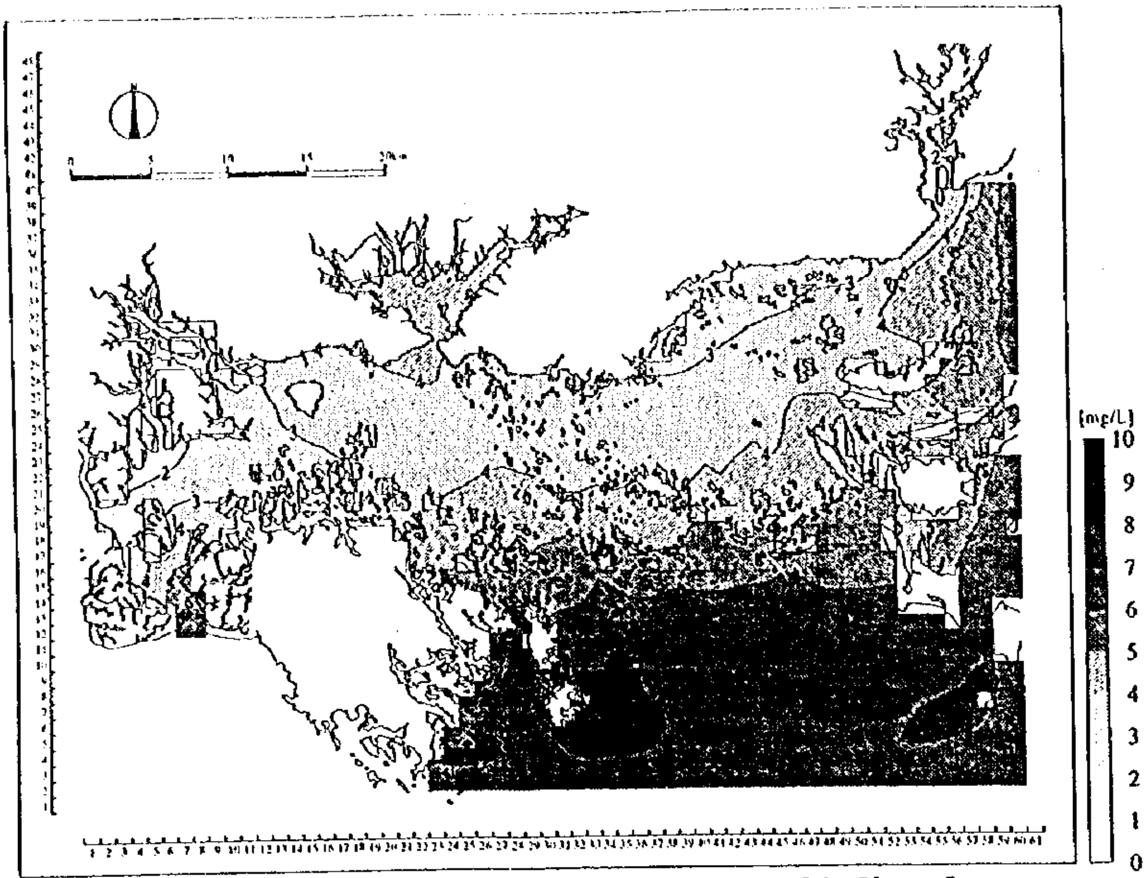


Figure 12.5.16 (1) Simulated Concentrations of COD of the Upper Layer

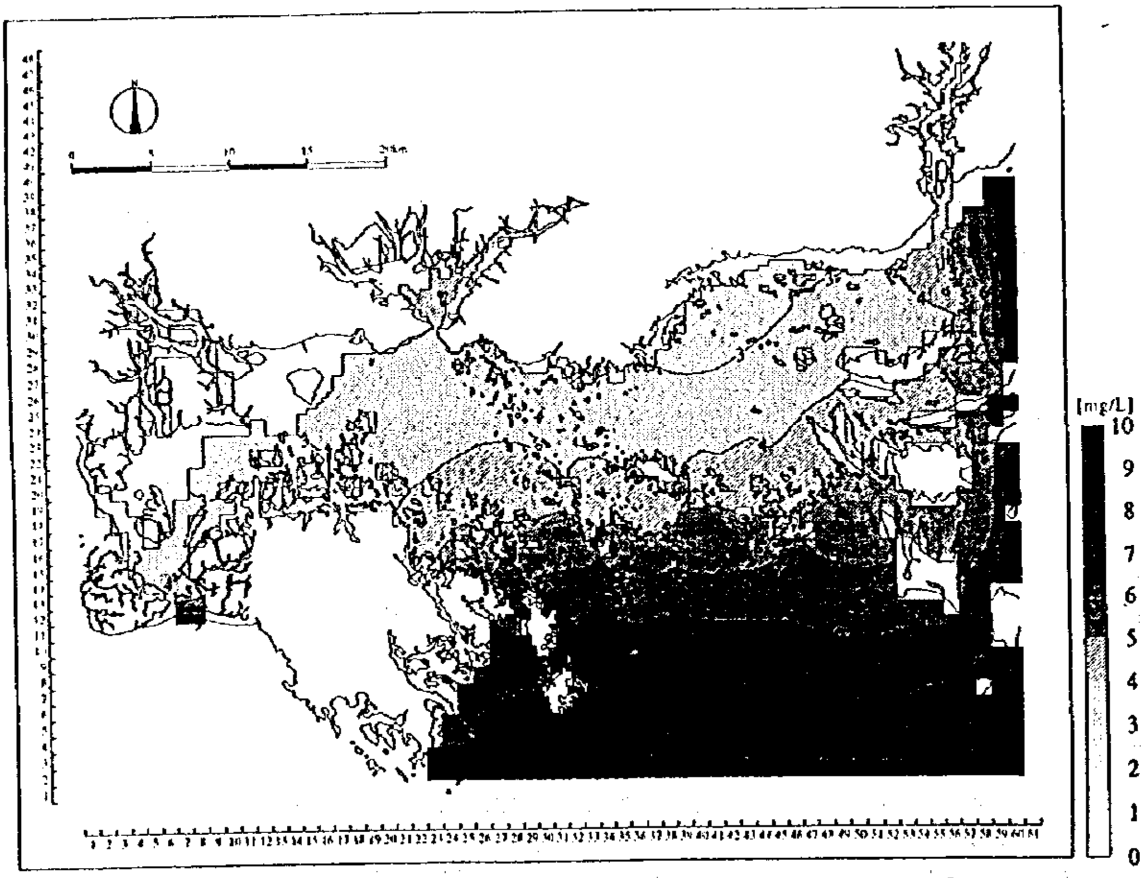


Figure 12.5.16 (2) Simulated Concentrations of COD of the Lower Layer

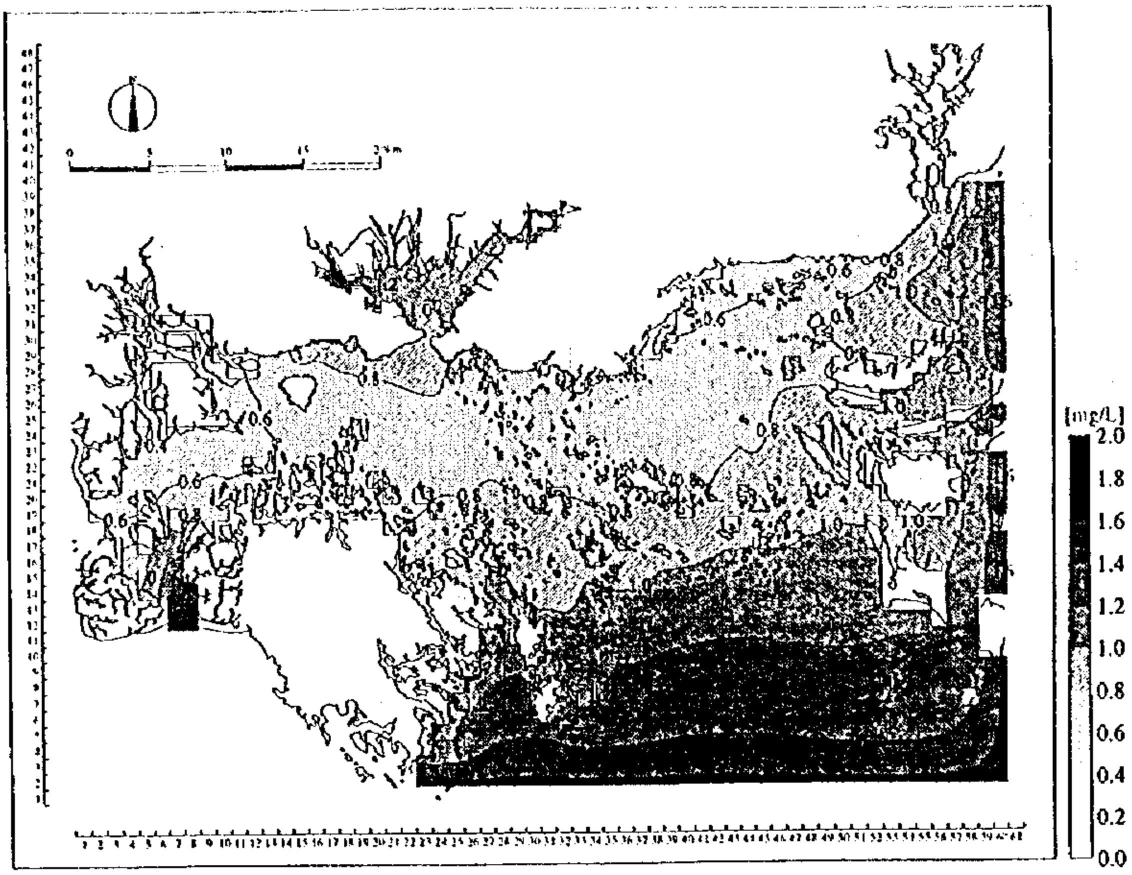


Figure 12.5.17 (1) Simulated Concentrations of T-N of the Upper Layer

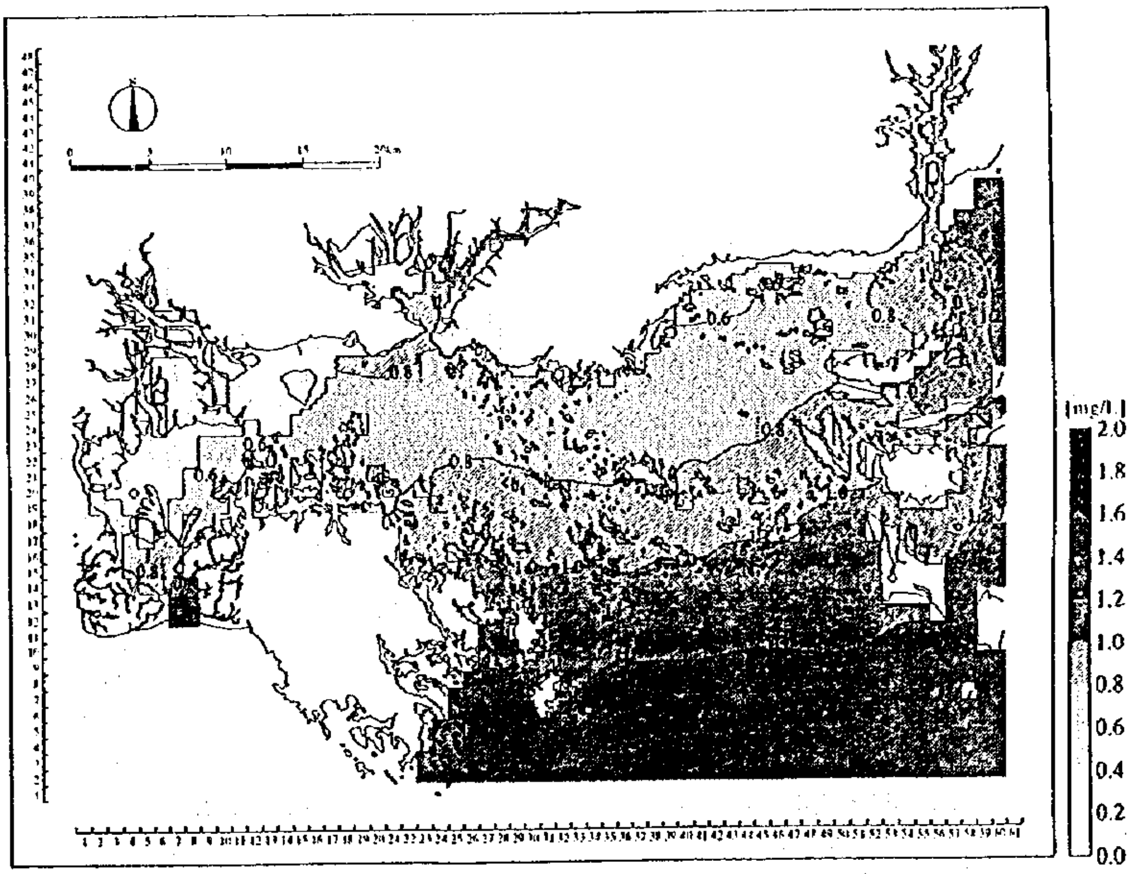


Figure 12.5.17 (2) Simulated Concentrations of T-N of the Lower Layer

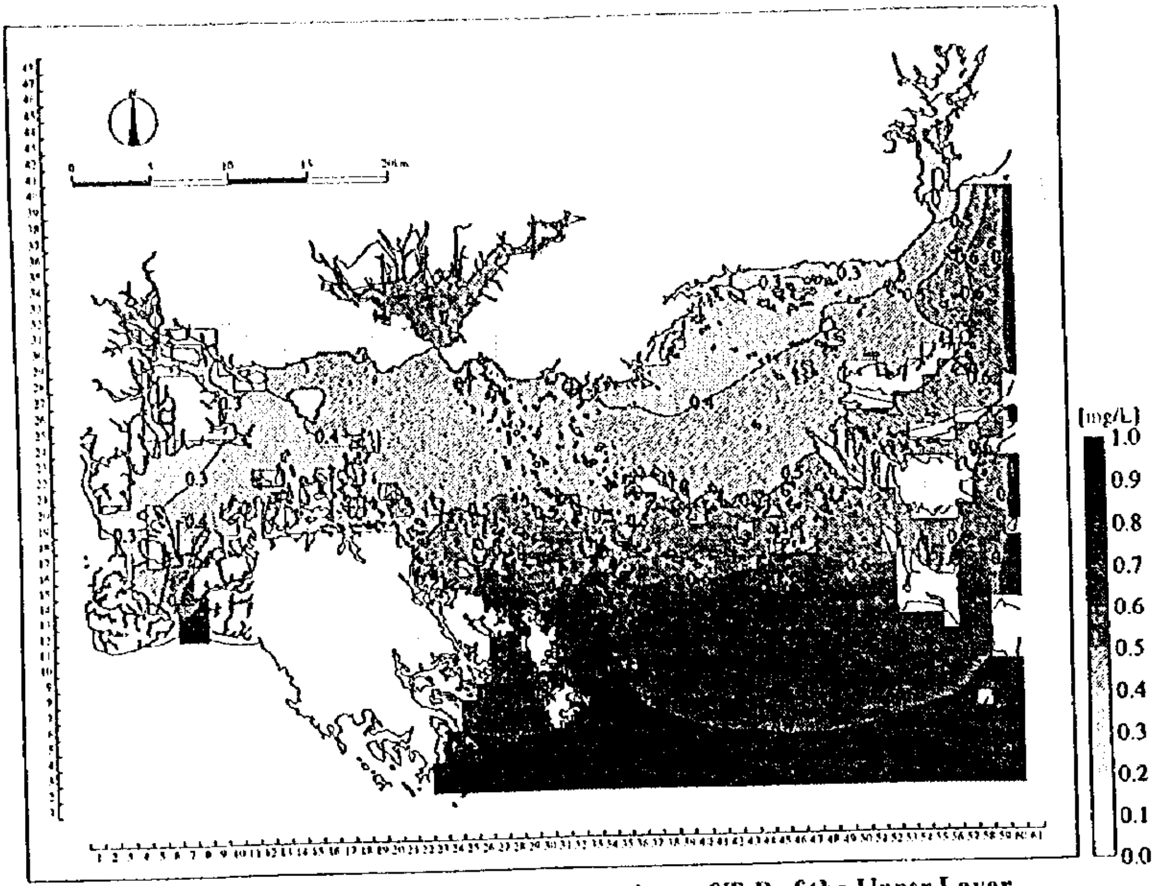


Figure 12.5.18 (1) Simulated Concentrations of T-P of the Upper Layer

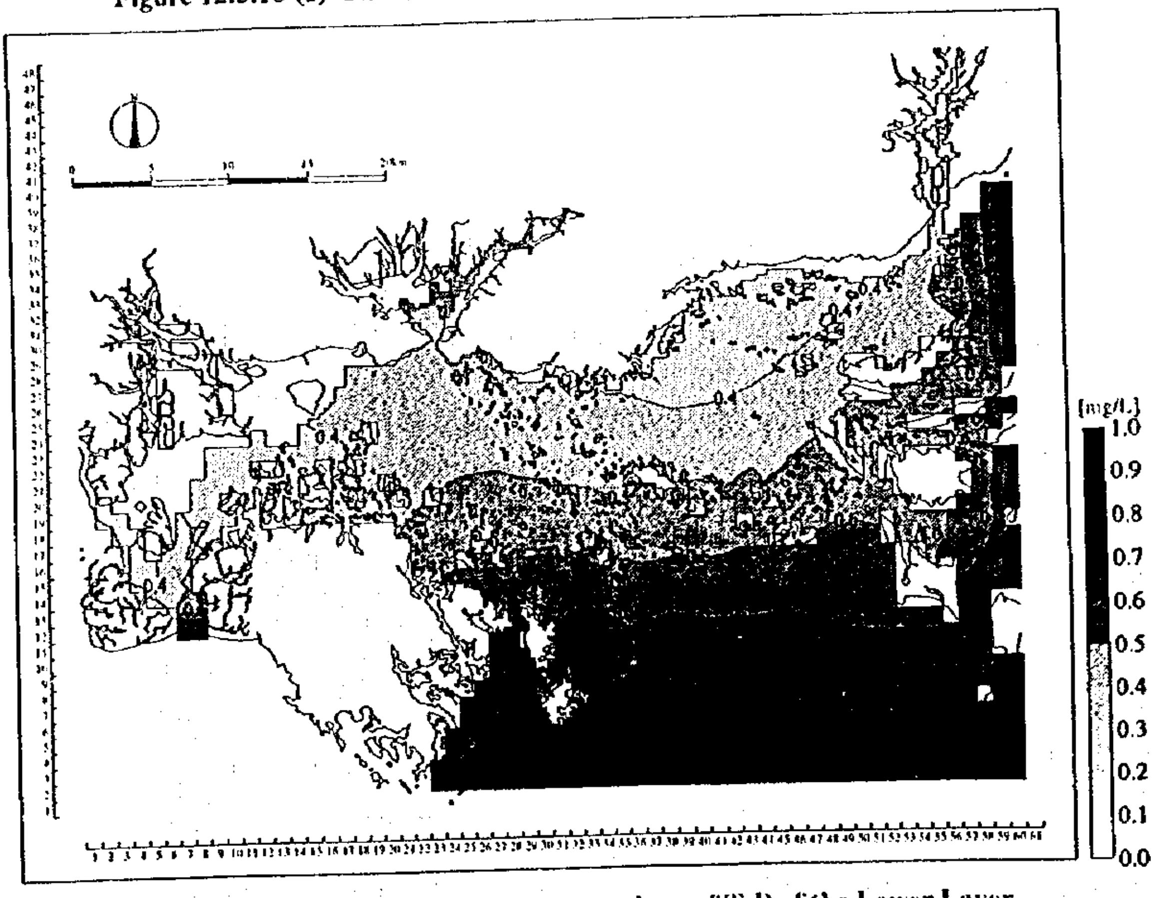


Figure 12.5.18 (2) Simulated Concentrations of T-P of the Lower Layer

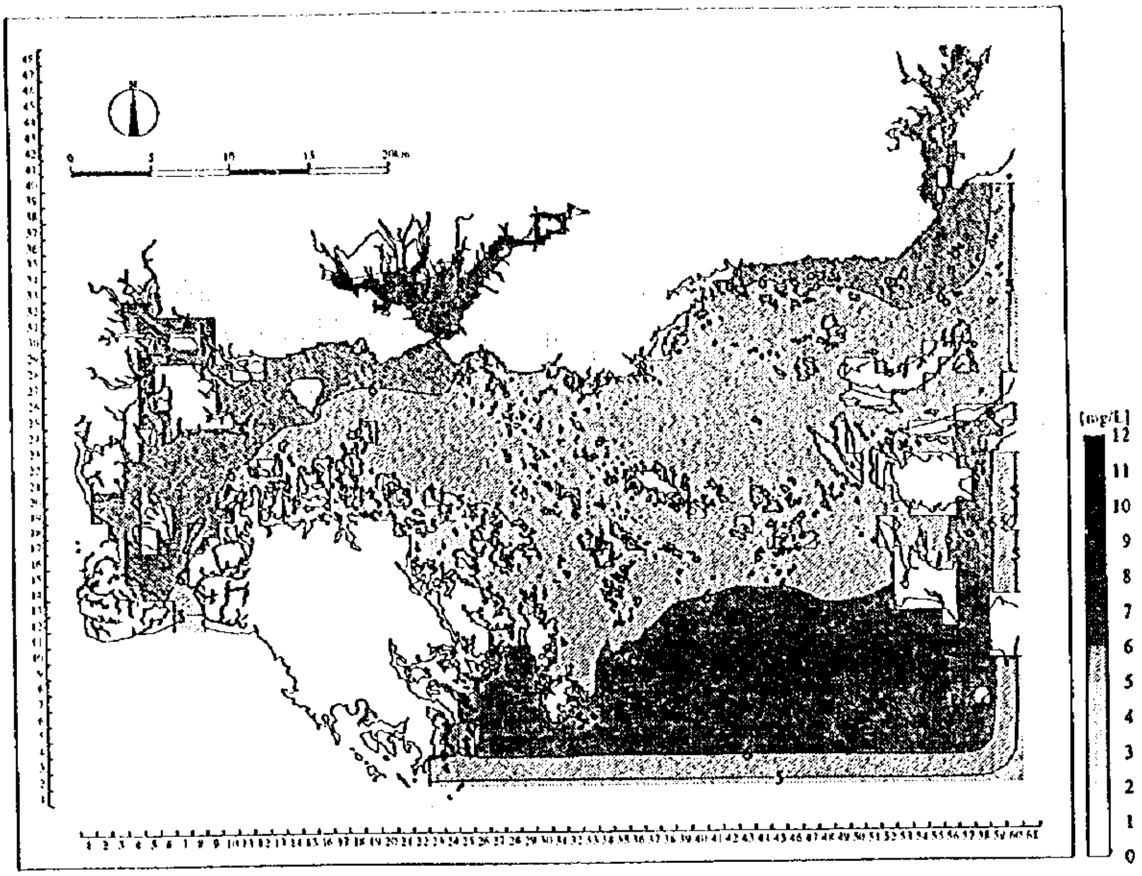


Figure 12.5.19 (1) Simulated Concentrations of DO of the Upper Layer

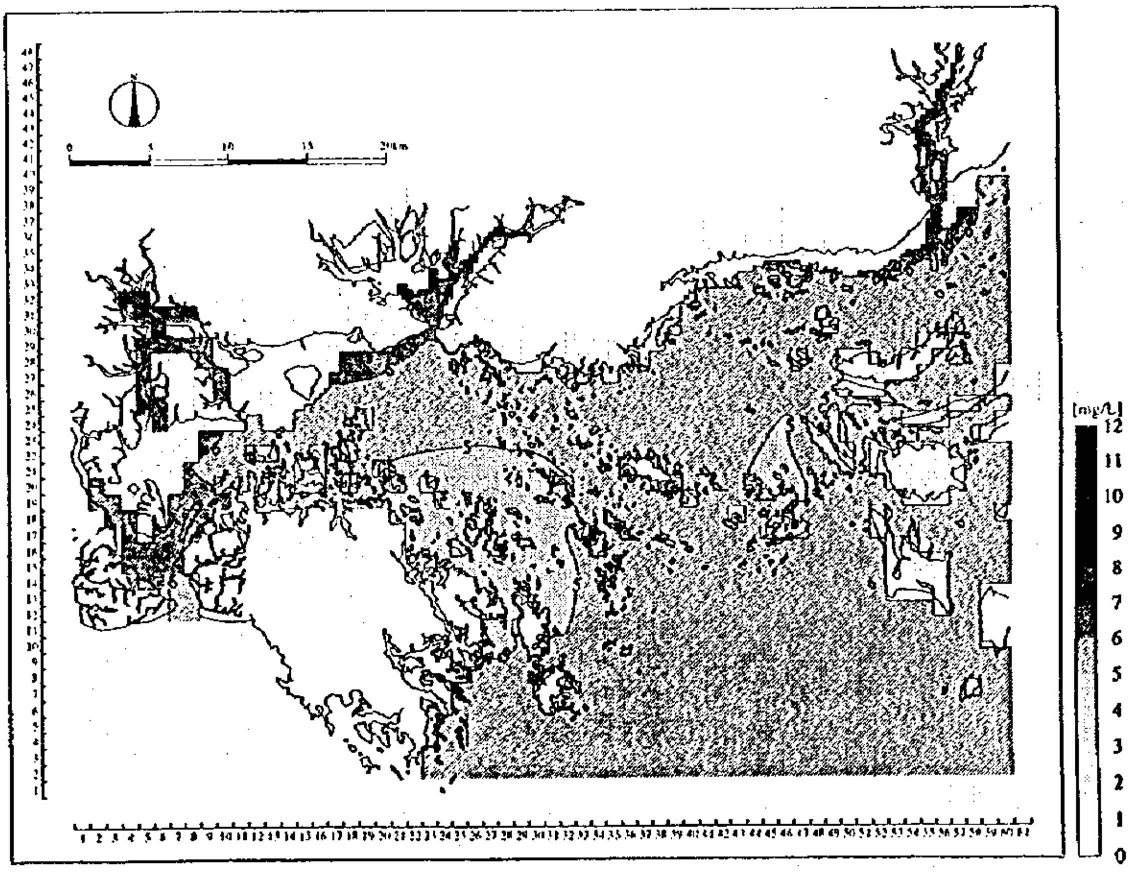


Figure 12.5.19 (2) Simulated Concentrations of DO of the Lower Layer

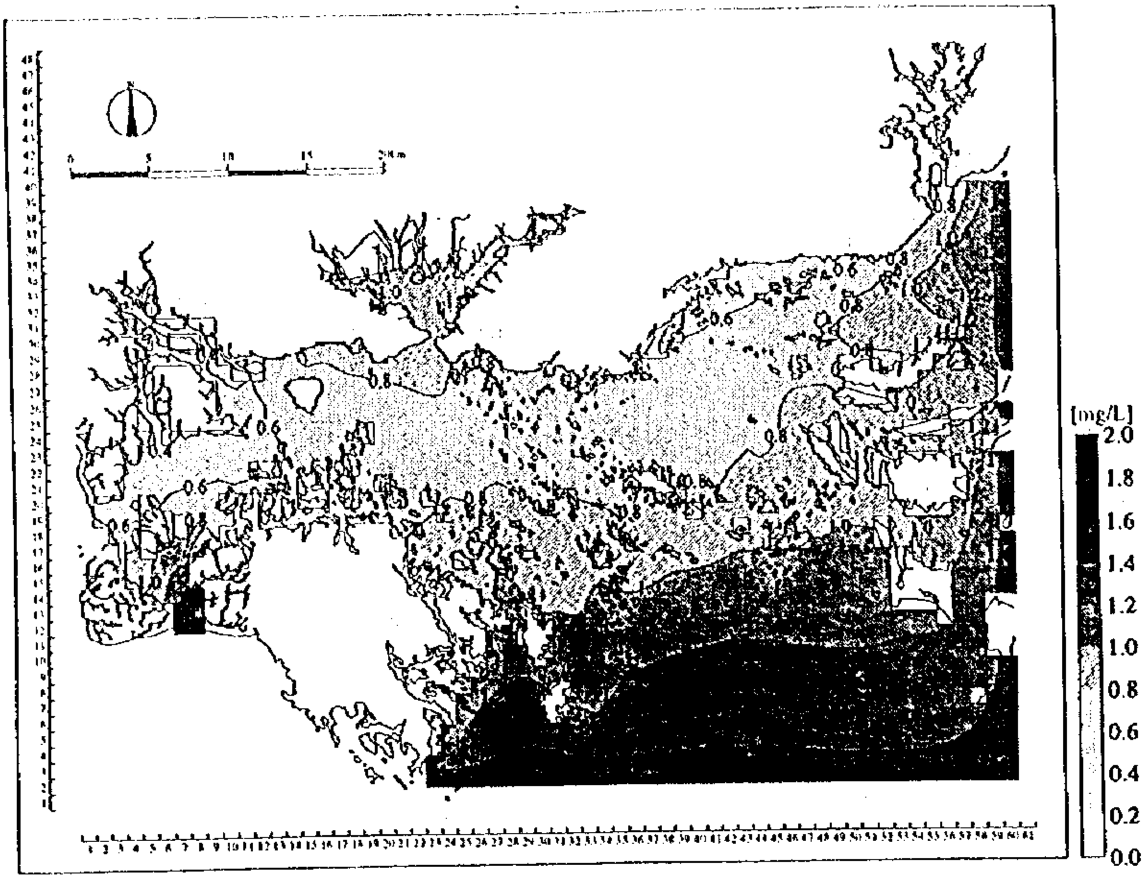


Figure 12.5.20 (1) Simulated Concentrations of O-N of the Upper Layer

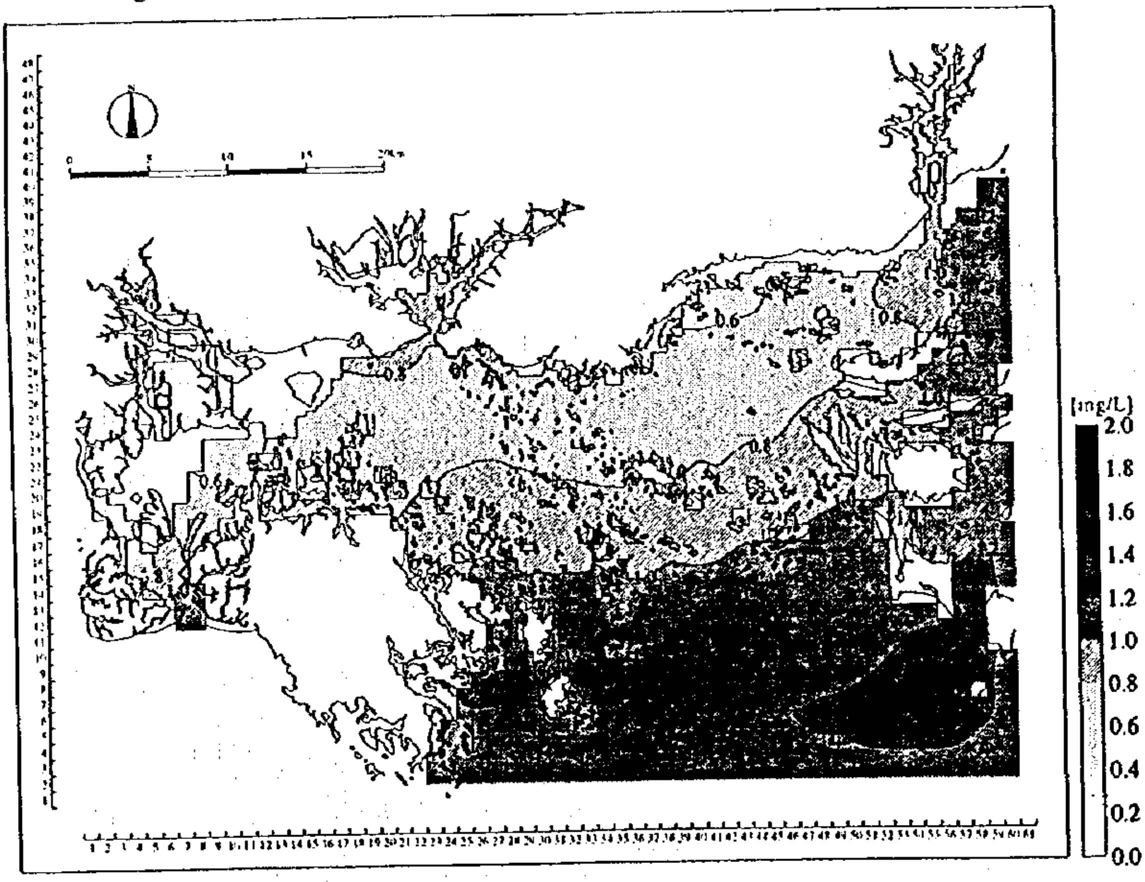


Figure 12.5.20 (2) Simulated Concentrations of O-N of the Lower Layer

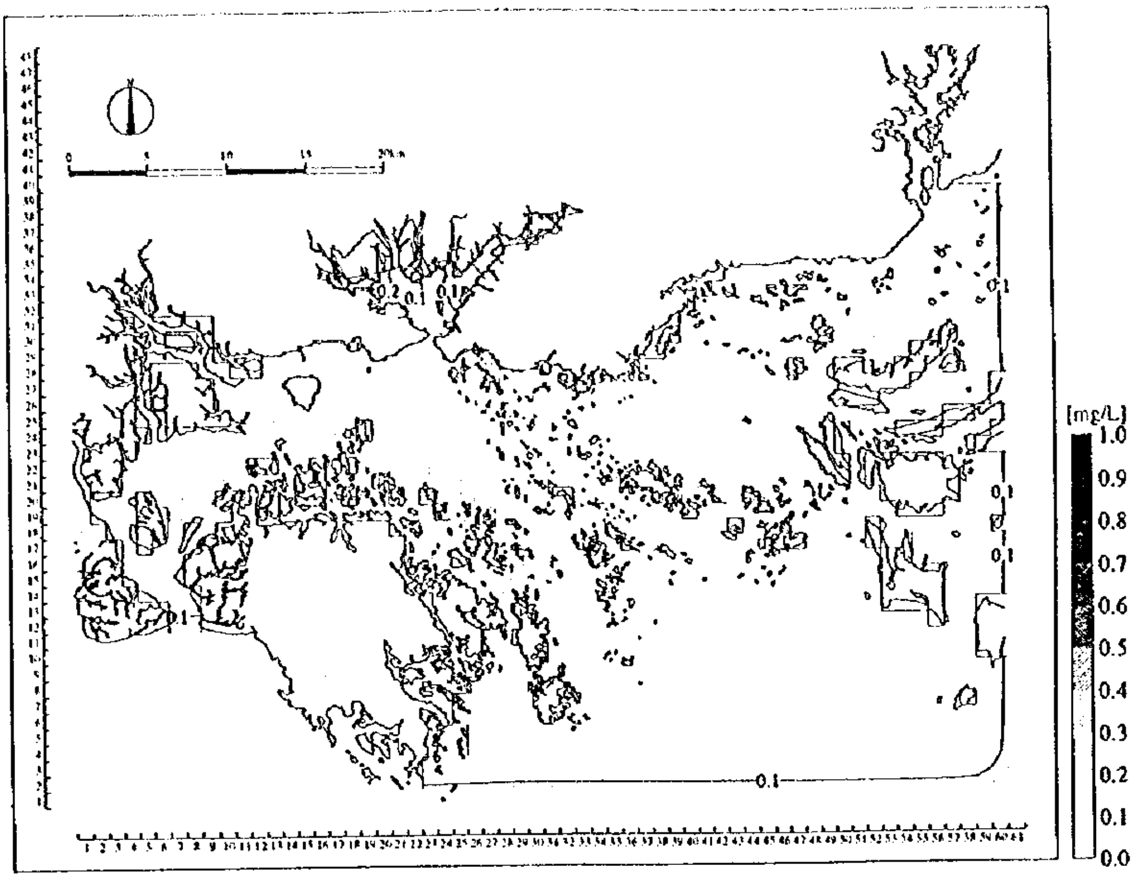


Figure 12.5.21 (1) Simulated Concentrations of I-N of the Upper Layer

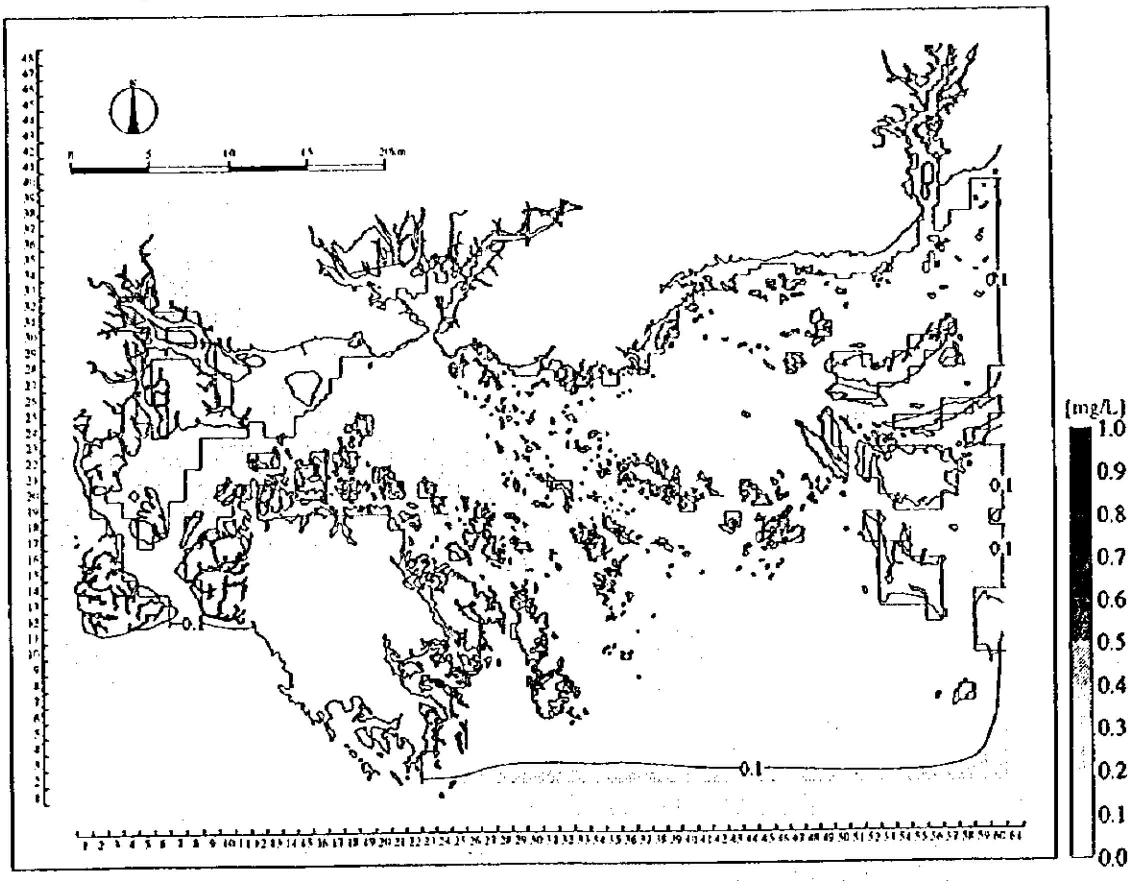


Figure 12.5.21 (2) Simulated Concentrations of I-N of the Lower Layer

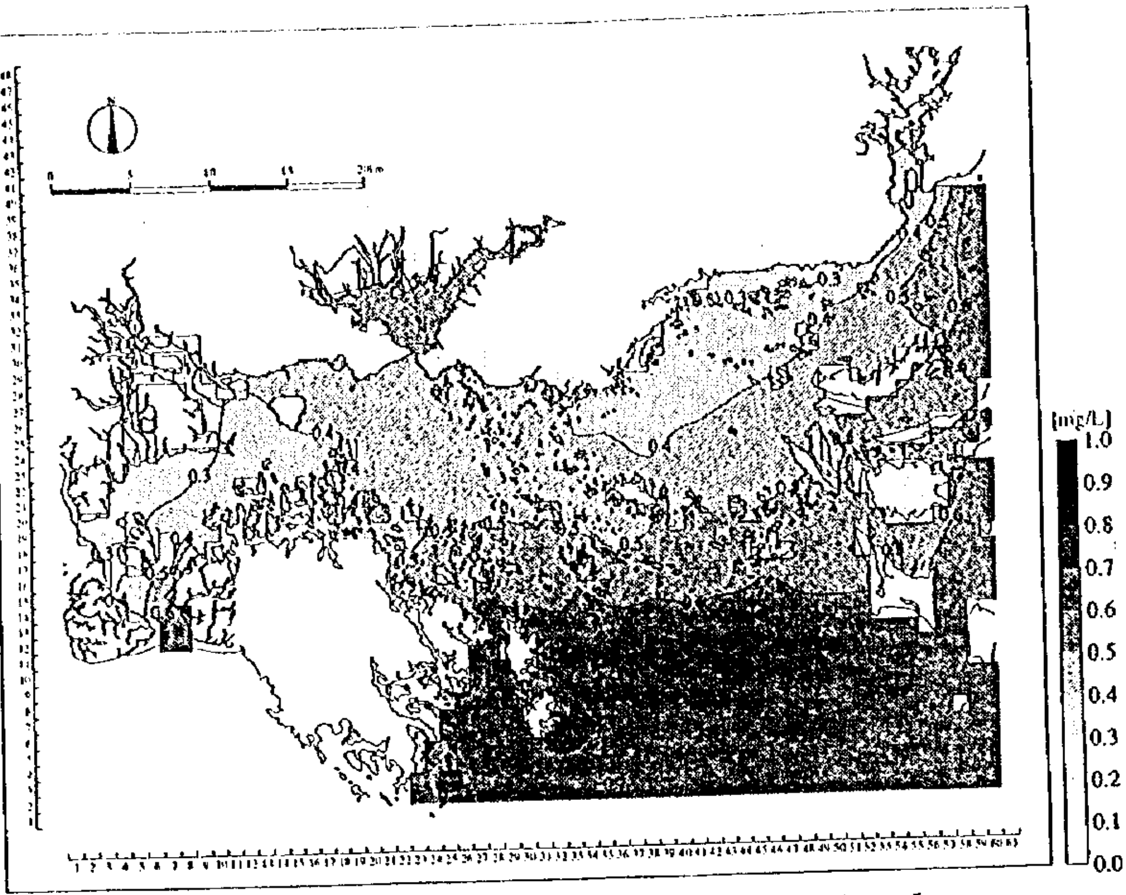
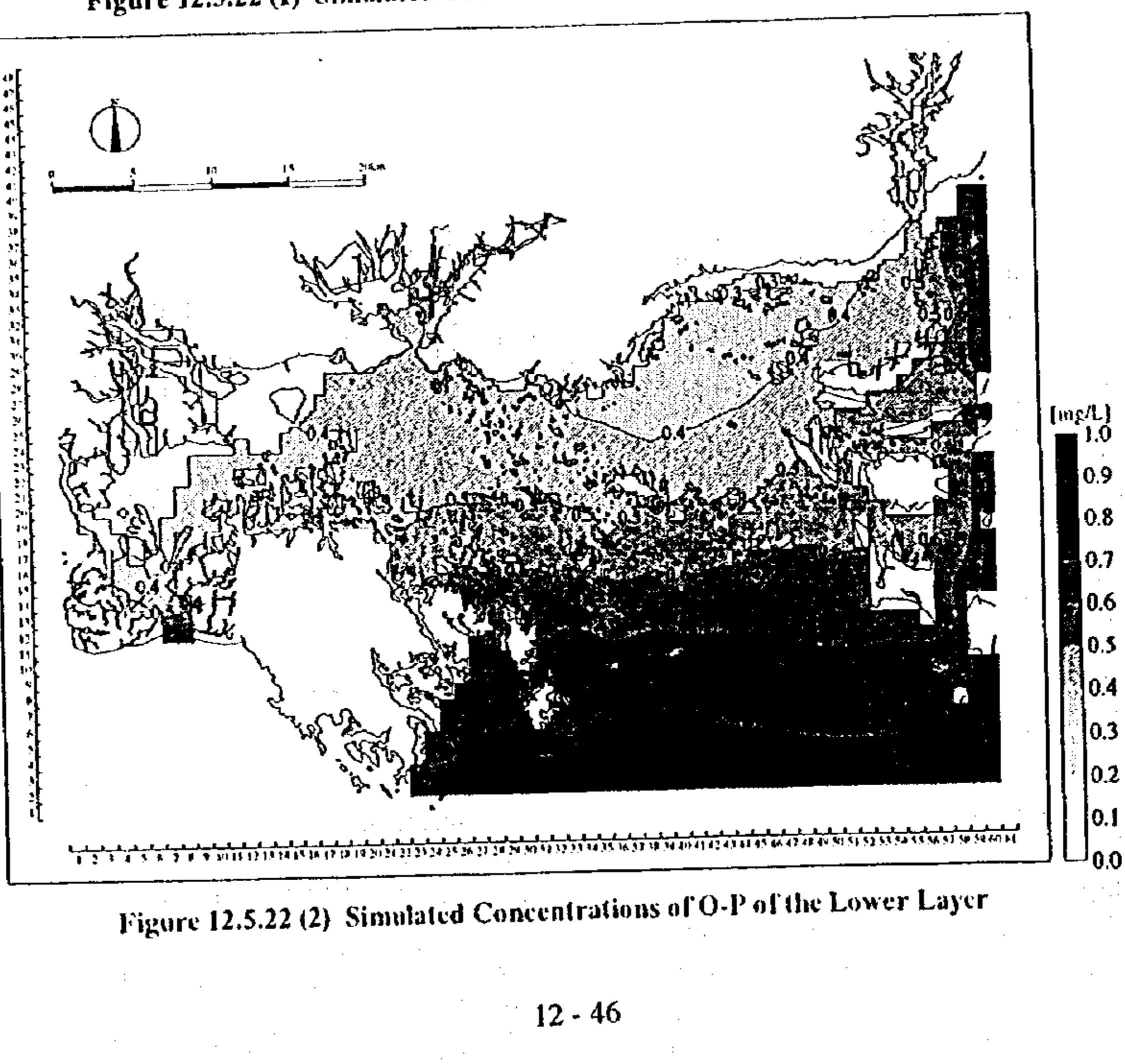


Figure 12.5.22 (1) Simulated Concentrations of O-P of the Upper Layer



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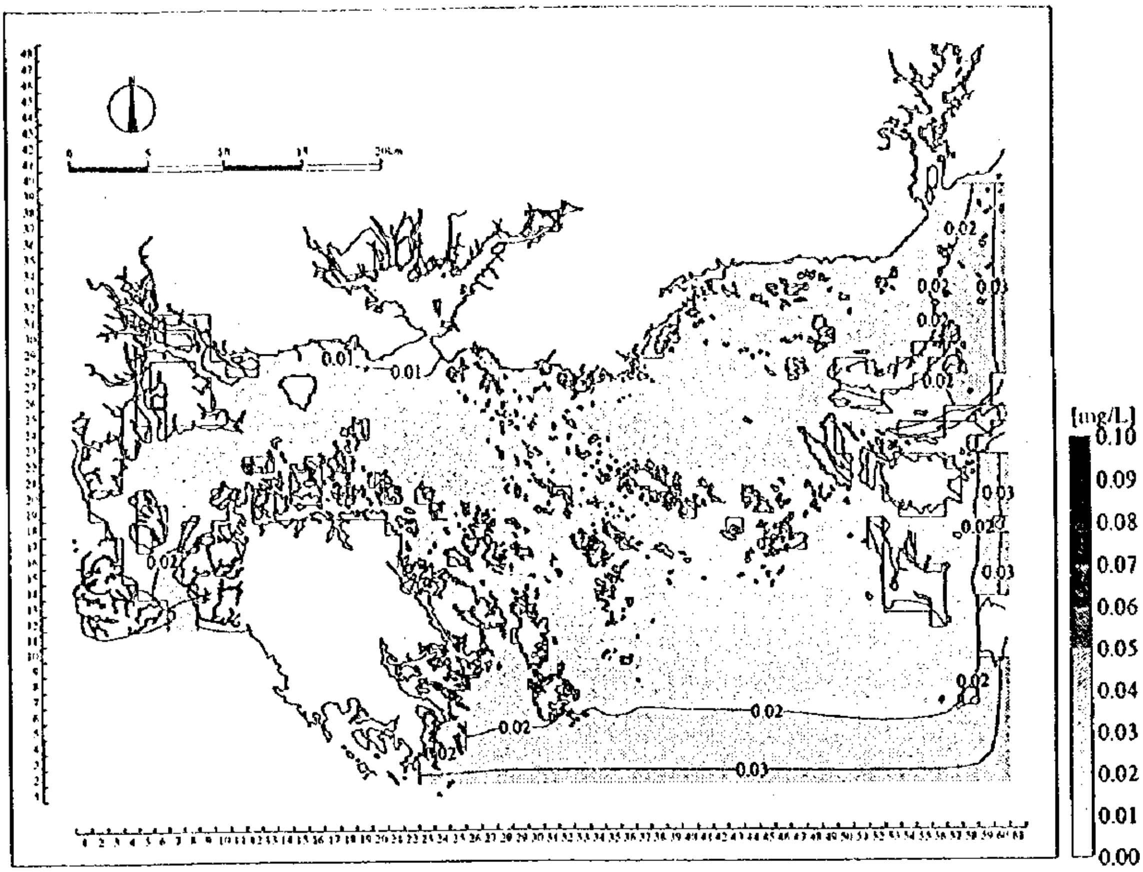


Figure 12.5.23 (1) Simulated Concentrations of I-P of the Upper Layer

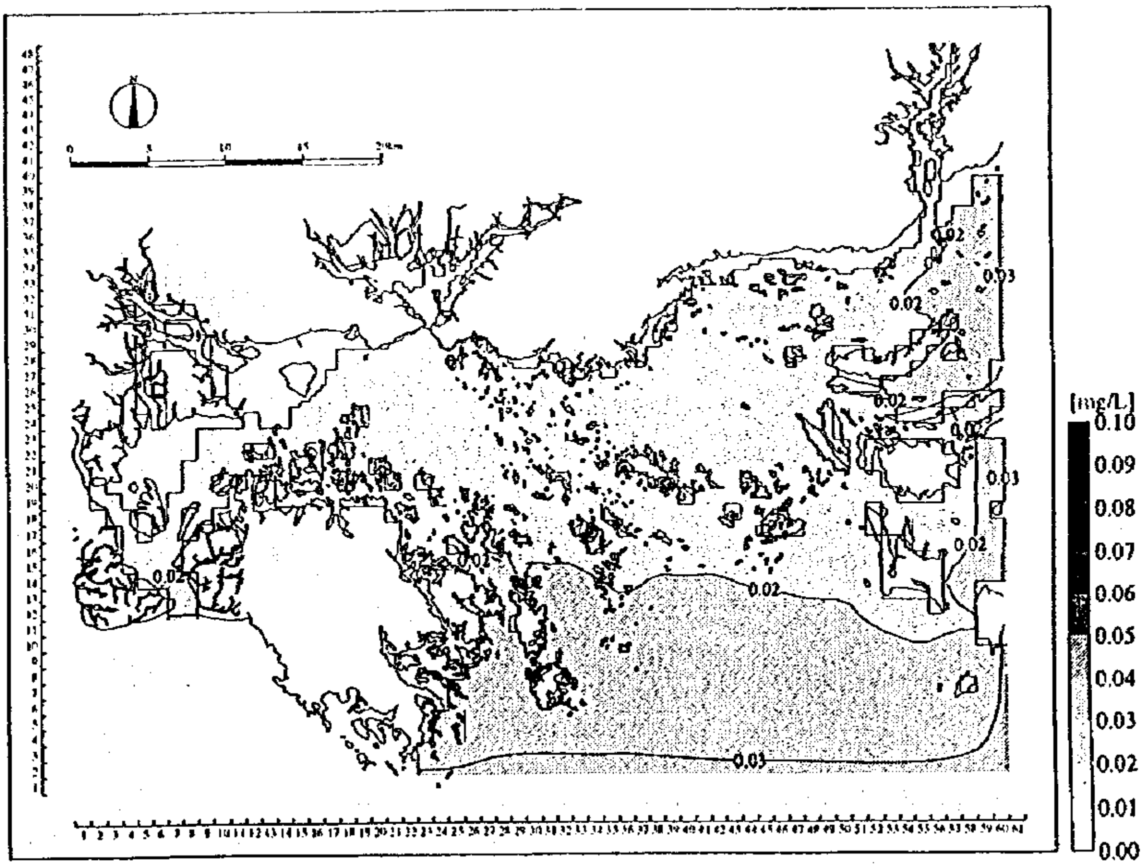


Figure 12.5.23 (2) Simulated Concentrations of I-P of the Lower Layer

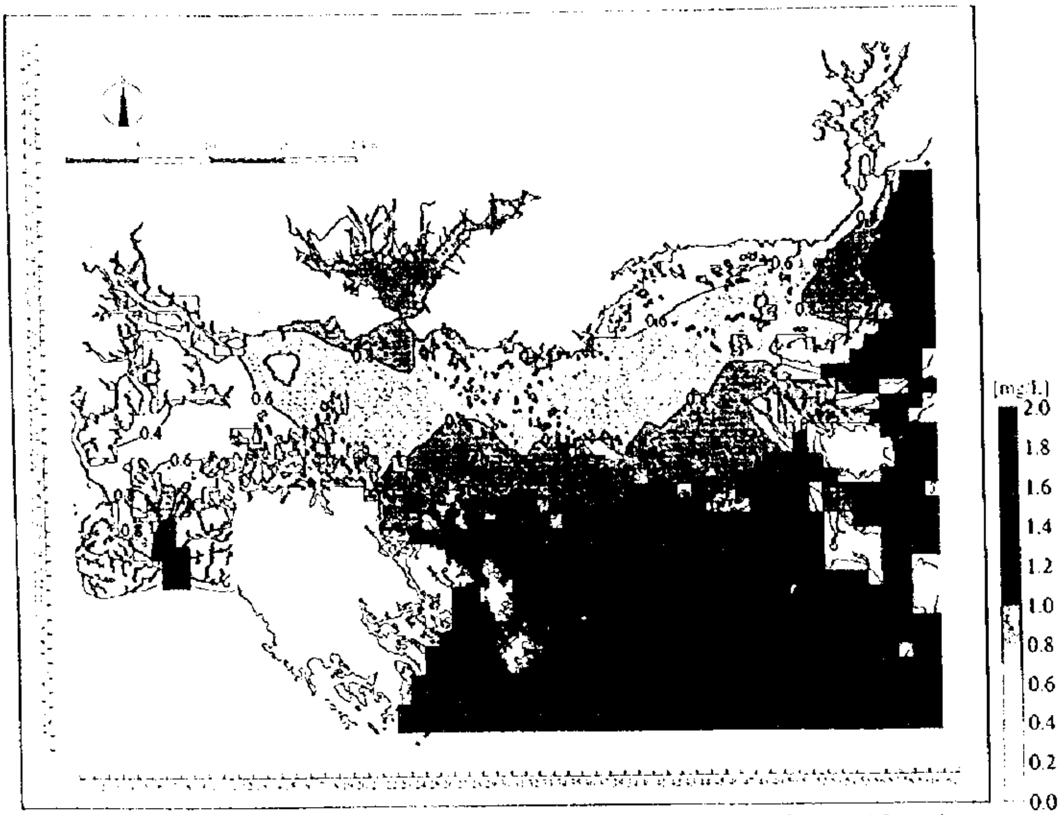


Figure 12.5.24(1) Estimated Concentrations of BOD of the Upper Layer Converted from the Simulated COD

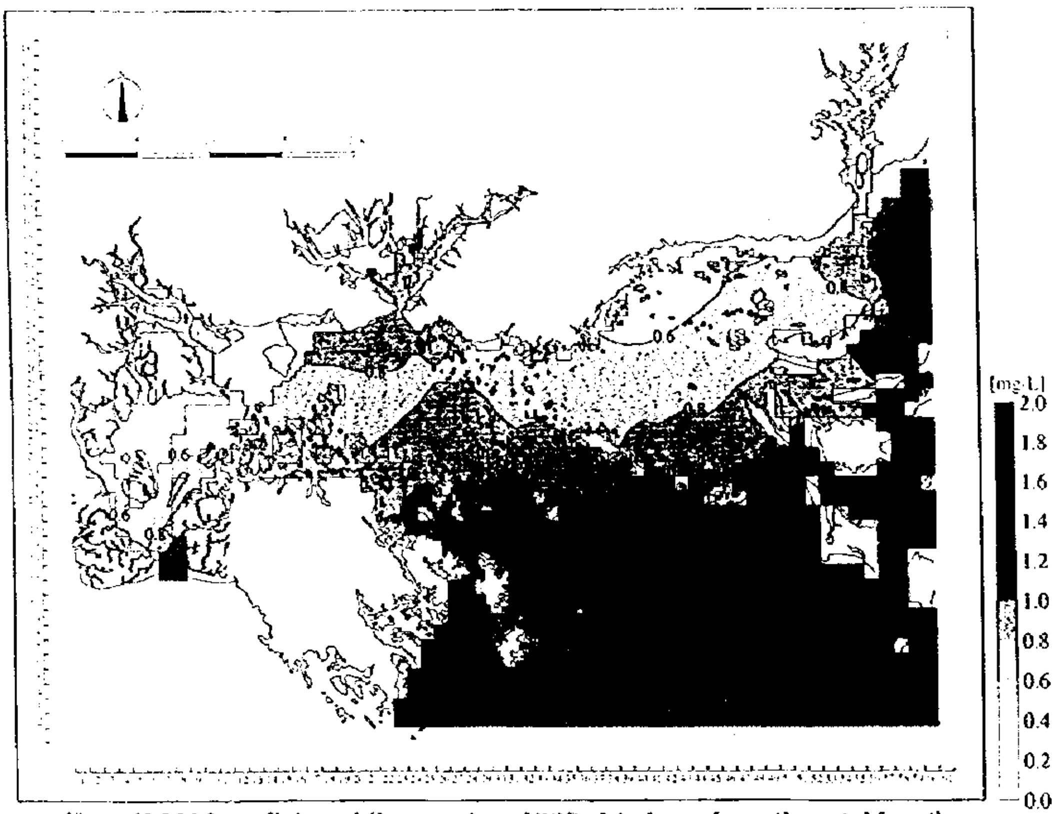


Figure 12.5.24(2) Estimated Concentrations of BOD of the Lower Layer Converted from the Simulated COD

CHAPTER 13

CHAPTER 13 FUTURE ECONOMIC DEVELOPMENT FRAME

13.1 Review of National, Provincial and City Development Master Plans

13.1.1 National Development Master Plan

The Communist Party of Vietnam has the central function of determining the direction of social and economic policies of the country. The two key policy documents presented at the Eighth Party Congress in June-July 1996 were "Political Report of the Central Committee" and "Orientation and Tasks of the 1996-2000 Five-year Plan for Socioeconomic Development".

The key economic theme of the developments is to promote industrialization and modernization, and the overall goal is to develop Vietnam into an industrialized economy by 2020. The Political Report indicates that Vietnam would continue to develop a mixed economy, and that the State economic sector together with the cooperative sector should constitute the foundation of the economy, while the private sector would account for a considerable proportion. The following three basic economic objectives were identified for the period through 2000:

- High, sustainable and efficient economic growth
- Macro-economic stabilization
- Long term development of human resources, infrastructure, technology and institutions.

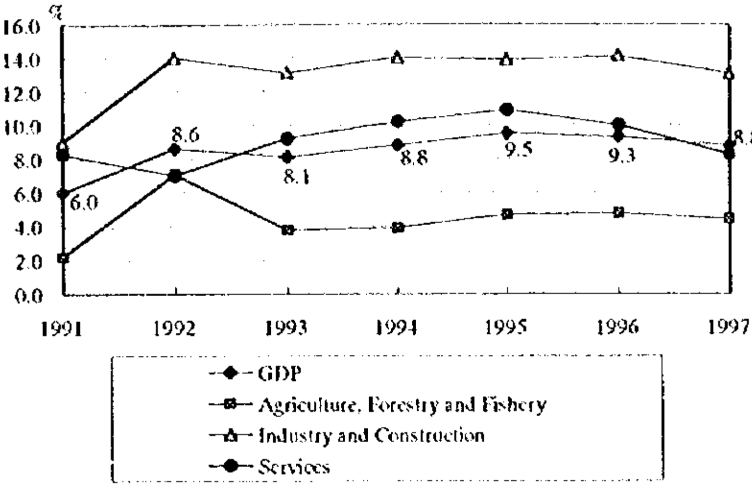
Regarding social objectives, it would be important that economic growth goes parallel with social and cultural development, so as to improve social equity. Social objectives in the medium term include concentrated efforts on employment generation, elimination of food shortage, poverty alleviation, improvement of health care and social services, and improvement of quality of and access to education and vocational training.

An important goal for regional development is to develop the key economic regions: Northern Growth Triangle (Ha Noi, Hai Phong and Ha Long), Southern Economic Focal Zone (Ho Chi Minh City, Bien Hoa and Vung Tau) and Central Growth Triangle (Quang Nam-Da Nang, Quang Ngai and Hue), but at the same time to avoid large discrepancies in economic growth among the different regions.

The major economic goals of the 1996-2000 Five-year Plan are as follows:

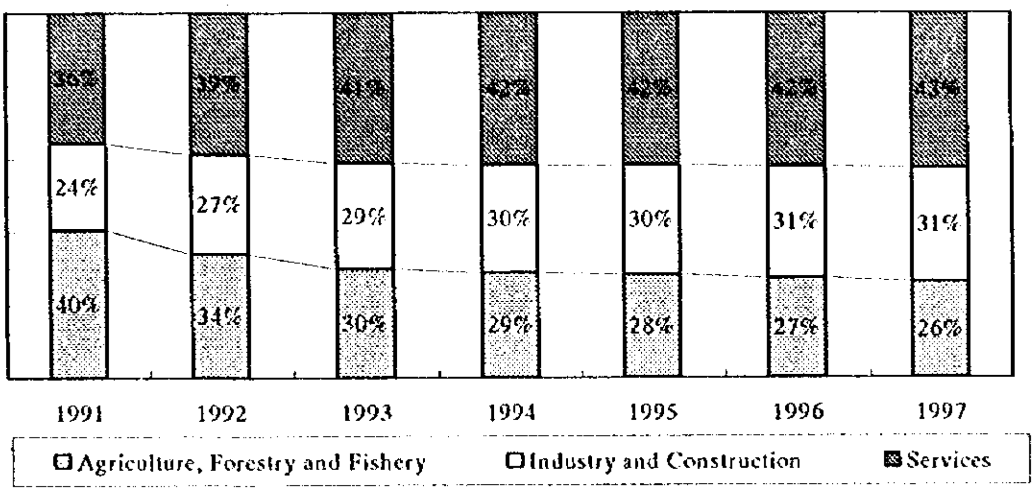
- The per capita income will have doubled the level of 1990,
- The annual average growth rate of GDP will reach 9-10%,
- The annual average growth rate of exports will reach 28-30%,
- Industry and construction will be growing at an average of 14-15% annually,
- The share of GDP accounted for by industry and construction will increase to 35% from 23% in 1990, while the share of agriculture will fall to 20% from 38%,
- The country will invest 33% of GDP compared to 15% in 1990.
- The guidelines for the economic development includes:
- Improving the efficiency of the State sector,
- Developing the potential of the other economic sectors including small and medium enterprises, and
- Broadening the forms of cooperation and joint venture activity between the State sector, local and foreign investors.

The key question is, however, whether the extraordinary high growth rates of recent years are sustainable in the long term perspective, and whether the fundamentals of economic and industrial growth are strong enough to allow growth to continue further for the next one or two decades, or whether Vietnam must change strategies and policies to achieve the long term growth that is crucial to become an industrialized economy by 2020. The influence of recent Asian financial turbulence upon the Vietnamese economy should be also carefully investigated.



Note: At constant price of 1989
Source: Statistical Yearbook 1997, General Statistical Office.

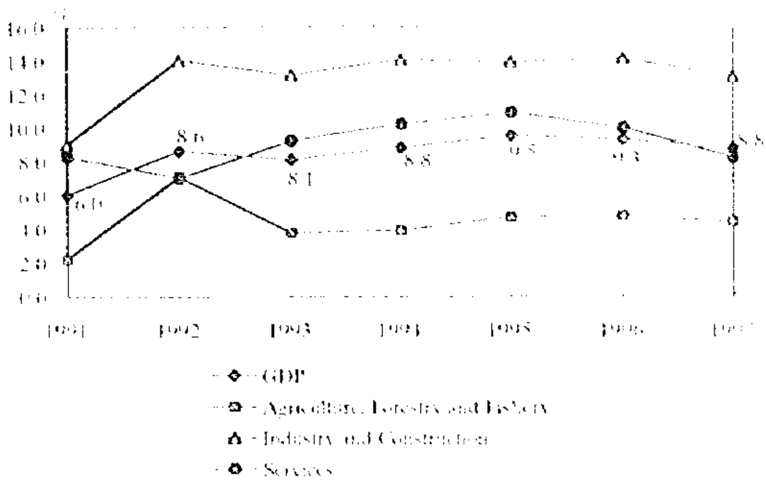
Growth Rates of GDP and Major Economic Sectors in Vietnam



Source: Statistical Yearbook 1997, General Statistical Office.

GDP Structure by Major Economic Sectors in Vietnam

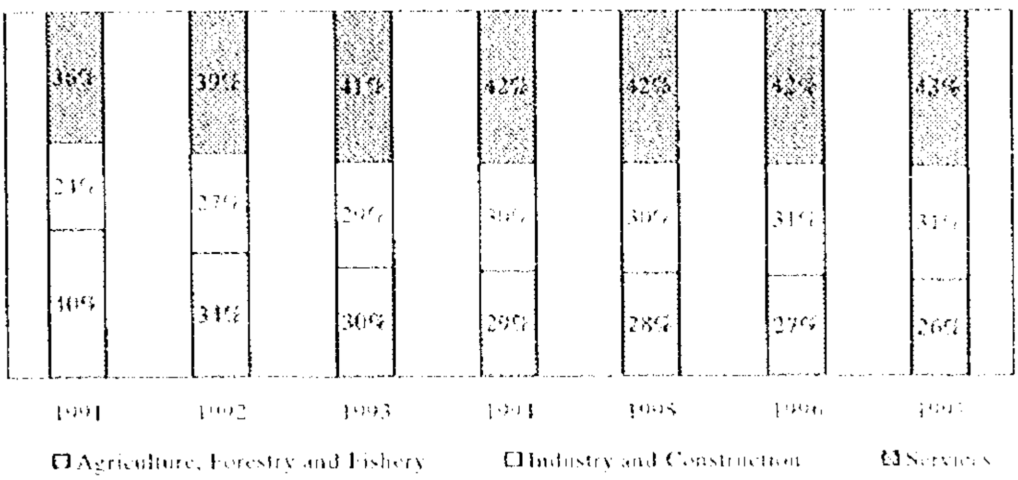
The principal features of the Public Investment Program for 1996 to 2000 are shown in the table below. Two distinct aspects may be pointed out. The first is the cumulative amount of investment around US$42 billion. This is well over twice the investment mobilized in the period 1990-1995. The second is the efficiency with which the investment will need to be deployed in terms of both project selection and utilization. The investment requirements in the plan have been projected assuming that each additional dollar of GDP requires only three dollars in gross investment. Such an incremental capital output ratio is very efficient by any standards and must need rapid productivity improvement.



Note: At constant price of 1989

Source: Statistical Yearbook 1997, General Statistical Office.

Growth Rates of GDP and Major Economic Sectors in Vietnam



Source: Statistical Yearbook 1997, General Statistical Office.

GDP Structure by Major Economic Sectors in Vietnam

The principal features of the Public Investment Program for 1996 to 2000 are shown in the table below. Two distinct aspects may be pointed out. The first is the cumulative amount of investment around US$42 billion. This is well over twice the investment mobilized in the period 1990-1995. The second is the efficiency with which the investment will need to be deployed in terms of both project selection and utilization. The investment requirements in the plan have been projected assuming that each additional dollar of GDP requires only three dollars in gross investment. Such an incremental capital output ratio is very efficient by any standards and must need rapid productivity improvement.

Macroeconomic Framework of Public Investment Program 1996-2000

- GDP growth 9-10% per annum
- ☐ Agriculture 4.5-5.0% | ☐ Industry 14-15% | ☐ Services 12-13%
- Investment requirements - US$41-42 billion with investment reaching 30% of GDP by 2000
- ☐ 52% from local savings
  - Budgetary savings - US$ 8.6 billion
  - Households savings and enterprise retained earnings - US$12.8 billion
- ☐ 48% from foreign savings
  - ODA - US$ 7.0 billion
  - FDI - US$ 13.0 billion
- Investment direction
- ☐ Agriculture 21%
- ☐ Industry (oil and gas, energy and manufacturing) 42%
- ☐ Transport, telecommunications and tourism 22%
- ☐ Social infrastructure 15%
- Investment Implementation
- ☐ Budget 21% | ☐ State own enterprises 31%
- ☐ Households and local private firms 17% | ☐ Foreign firms 31%

Source: The Public Investment Program for 1996-2000

Sectoral Share of Investment and Contributions of Economic Growth

Sector	Share of 1995 GDP (%)	Share of Investment 1996-2000 (%)	Contribution to overall GDP growth 1996-2000 (%)
Agriculture	28.4	20.8	9.8
Industry	30.0	42.3	42.2
Services	41.6	36.9	48.0

Source: General Statistical Office, 1998

13.1.2 Development Master Plan of Quang Ninh Province

The Development Master Plan of Quang Ninh Province 1995-2010 indicates the general orientation of regional development in the province. The basic planning goal is to develop Quang Ninh province into an industrial and tourism province and to become one of the growth poles in the Northern Growth Triangle. Following Table shows the breakthrough sectors. The industrial priorities will change drastically between in 1996-2000 and in 2001-2010. A shift of industrial structure from the traditional industrial sectors to new urban industrial sectors is expected to achieve the goal.

Priorities of Breakthrough Sectors in Quang Ninh Province

Sector	1996-2000	2001-2010
Construction materials	1	4
Coal mining industry	2	5
Tourism and related services	3	3
Port and related services	4	2
Export processing zones and industrial zones	5	1

Source: DOSTE, 1998

The Urban Development Master Plan of Quang Ninh province 1995-2010 (August 1995) identifies major development projects in urban and suburban areas in the province. The development direction of the study area which includes two major provincial urban centers is determined by the Urban Development Master Plan.

(1) Population Growth

The population growth of the province in the last decade has been mainly due to natural growth, and its growth rate still over 2.0%. Migration has been negligible.

Natural Population Growth of Quang Ninh Province

(Unit: 1,000 persons)

Area	1994	2000	2010	Incremental Population (1994-2010)
Ha Long City	141.2	156.2	190.6	49.4
Cam Pha Town	138.7	153.3	167.2	28.5
Uong Bi Town	86.9	95.7	117.3	30.4
Binh Lieu District	22.8	27.6	30.8	8.0
Quang Ha District	71.1	85.5	96.0	24.9
Hai Ninh District	39.5	46.3	53.3	13.8
Tien Yen District	40.1	49.2	54.3	14.2
Ba Che District	17.1	21.1	23.1	6.0
Dong Trieu District	137.4	154.9	185.5	48.1
Yen Hung District	122.2	142.0	165.0	42.8
Hoanh Bo District	50.4	61.3	69.9	19.5
Van Don District	32.3	37.0	43.4	11.1
Co To District	2.5	3.1	3.6	1.1
Total	902.2	1,033.2	1,200.0	297.8
Labor Force	470.0	600.0	730.0	260.0

Note: Ha Long will be merged with some of small towns (thi tran) of Hoanh Bo and Yen Hung by 2010. Ha Long in the table covers only the present city area.

Source: Urban Development Master Plan of Quang Ninh Province, 1995

The table shows the forecast of natural population growth. Ha Long city, Dong Trieu district and Yen Hung district will gain larger natural growth than the others. The geographical distribution pattern of population in the province, however, will remain almost the same as before by 2010.

(2) Urbanization

Ha Long, Cam Pha and Uong Bi have been already highly urbanized. In particular, the first two urban centers in the study area account for exceptionally higher urbanization ratios, 95% and 83%, respectively, in 1994 than the national average, 20.8% (in 1997). On the other hand, the present urbanization ratios in the districts don't reach 25%. The urbanization, however, will be accelerated and all districts in the province will reach 30% by 2010.

Forecast of Population and Urban Residential Area in Quang Ninh Province

Year	1994	2000		2010		Population Growth	
District/City/Town	Population	Population	Area (ha)	Population	Area (ha)	2000/1994	2010/1994
Ha Long City	141,200	230,000	1,495	460,000	2,900	1.63	3.26
Cam Pha Town	138,700	153,300	1,073	187,250	1,310	1.11	1.35
Uong Bi Town	86,900	95,700	670	117,320	822	1.10	1.35
Mong Cai District	22,736	32,410	227	42,660	299	1.43	1.88
Tien Yen District	6,530	12,300	99	19,010	152	1.88	2.91
Ba Che District	3,720	6,330	51	8,070	65	1.70	2.17
Dong Trieu District	4,860	15,490	124	55,640	390	3.19	11.45
Mao Khe District	35,000	54,210	380	75,000	525	1.55	2.14
Quang Yen District	8,650	21,300	170	49,500	396	2.46	5.72
Binh Lieu District	2,950	5,520	45	9,230	74	1.87	3.13
Cai Rong District	3,600	7,400	59	13,000	104	2.06	3.61
Quang Ha District	4,100	17,200	138	28,790	223	4.20	7.02

Source: Urban Development Master Plan of Quang Ninh Province, 1995

Forecast of Urbanization Ratio in Quang Ninh Province

District/City/Town	Total Population	Ratio of Urban Population (%)		
	1994	1994	2000	2010
Ha Long City	141,200	95	91	90
Cam Pha Town	138,700	83	85	90
Uong Bi Town	86,900	63	80	85
Mong Cai District	22,736	11	70	80
Tien Yen District	6,530	18	25	35
Ba Che District	3,720	22	30	35
Dong Trieu District	4,860	3	10	30
Mao Khe District	35,000	24	35	50
Quang Yen District	8,650	7	15	30
Troi District	7,000	14	merged into Ha Long	
Cai Rong District	3,600	11	20	30
Quang Ha District	4,100	6	20	30
Binh Lieu District	2,950	14	20	30

Source: Urban Development Master Plan of Quang Ninh Province, August, 1995

(3) Economic Growth

The economic target figures which seem to be rather ambitious are shown in the table below. The province must need an effective improvement of socioeconomic infrastructure, sufficient foreign investments and rapid productivity improvement to achieve the targets.

Major Economic Targets of Quang Ninh Province

GDP/capita in 2000	US$ 750
GDP/capita in 2010	US$ 2,600
Export value in 2000	US$ 250-300 mil.
Export value in 2010	US$ 1,300-1,500 mil.
GDP Growth Rate	
1991-1995	11.6 - 12.3%
1995-2000	11.6 - 12.3%
2001-2010	14.0 – 14.5%

Source: Urban Development Master Plan of Quang Ninh Province, 1995

(4) Industry

1) Forecast of structural change

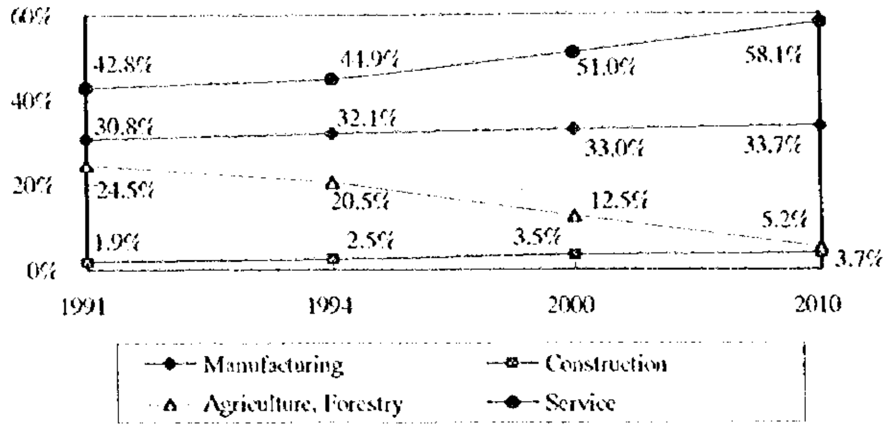
The forecasted change of GDP share by major economic sector shown in the table below will follow a rather general process as other developing areas have experienced. The share of the agriculture, forestry constantly will decrease on one hand. That of the service will increase, on the other hand. The reason of the relatively slow increase of the manufacturing is not clear here, however. The expectation of tourism development in the province may influence the forecast to some extent.

Economic Structural Change of Quang Ninh Province

(Unit: %)

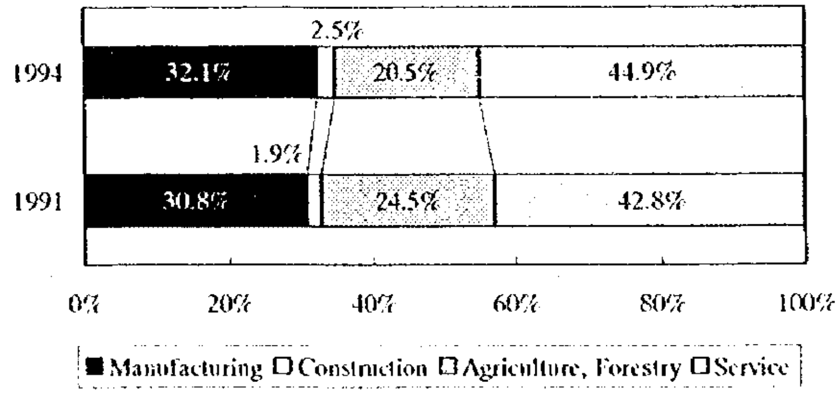
GDP Share	1991	1994	2000	2010
Manufacturing	30.8	32.1	33.0	33.7
Construction	1.9	2.5	3.5	3.7
Agriculture, Forestry	24.5	20.5	12.5	5.2
Service	42.8	44.9	51.0	58.1
Total	100.0	100.0	100.0	100.0

Source: Urban Development Master Plan of Quang Ninh Province, August, 1995



Source: Urban Development Master Plan of Quang Ninh Province, August, 1995

Economic Structural Change of Quang Ninh Province



Source: Urban Development Master Plan of Quang Ninh Province, August, 1995

Recent Economic Structure in Quang Ninh Province

2) Coal mining industry

The coal mining industry in Quang Ninh province has played an important role not only in the economic sectors of the province, but also in the national economy. The province is trying to make the industrial structure more diversified, avoiding over reliance on the coal mining industry. However, its importance to the regional economy won't change and it is expected to satisfy the following two targets: to meet the domestic demand for coal and to increase the quantity and quality for export. The next table shows the plan of coal mining production of the three major companies in the province. At present, however, major mines have been transferred to VINACOAL and they have established their own production plan. The detailed plan is reviewed in Section 3.5.

Plan of Coal Mining Production

(Unit: mill. tons)

	1997	2000	2010
Hong Gai Coal Mining Company	1.4	1.4	1.8
Uong Bi Coal Mining Company	1.2	1.2	1.2
Cam Pha Coal Mining Company	3.0	4.5	4.5
Total	5.6	7.1	7.5

Source: Urban Development Master Plan of Quang Ninh Province, 1995

Coal Reserve in Quang Ninh Province

(Unit: 1,000 tons)

Grade of Coal	Total Reserve	Open Pit	Horizontal Adit	Vertical Pit
A	80,050	28,045	31,833	20,174
B	441,479	79,355	112,974	249,150
C1	2,196,713	101,052	292,758	1,802,903
C2	805,996	7,024	33,391	765,581
Total	3,524,240*	215,476	470,356*	2,837,808

Note: The total figure marked by "*" is not equal to the sum of the elements.
Source: Master Plan of Socio-economic Development of Quang Ninh Province, 1995

3) Agriculture, forestry and fishery

The agricultural land for rice planting is rather limited in the province and its productivity is still low for lack of proper irrigation system. The rice production is not self-sufficient in the province and the supply will continuously depend on other regions in the future.

The advantageous products of the province are those of fruit trees, of trees for industrial materials such as turpentine, and of livestock. As for the forestry, planting of trees for export products such as cinnamon, anise, and turpentine will be expanded. In 10-15 years the production of 2,000 ha turpentine, of 6,000-7,000 ha cinnamon and 7,000-10,000 ha eucalyptus will be achieved.

Plan of Forestry Productions

Product	1991	Product	2005-2010
Timber	50,924 m^3	Turpentine	2,000 ha
Firewood	210,000 ha	Cinnamon	6,000-7,000 ha
Turpentine	1,329 tons	Anis	1,000 ha
		Eucalyptus	7,000-10,000 ha

Source: Urban Development Master Plan of Quang Ninh Province, 1995

The potential of fishery in the province is generally regarded as high. The fish stock along the provincial coast which is 250 km long is estimated about 20,000 to 25,000 tons per year. In addition to this, the province can exploit over 20,000 tons of fish per year from Bac Bo bay which is located offshore Ha Long bay. Besides, the amount of sea products from the tidal areas and around the islands, such as shrimp, crab and squid can reach 25,000 to 30,000 tons/year.

There are more than 40,000 ha of tidal flat in the province, in particular, along Ha Long bay and Bai Tu Long bay. The area is favorable for aquaculture of export products, such as shrimp and fish. The application and utilization of advanced technology for intensive aquaculture will be encouraged to promote the provincial fishery sector.

(5) Functional Roles of Ha Long City and Cam Pha Town

In the Urban Development Master Plan of Quang Ninh province Ha Long city and Cam Pha town are defined as follows:

Ha Long city:

- a center for tourism of international level
- a political, economic and cultural center for Quang Ninh province
- a transport interchange, a big regional commercial and service center playing a special role in terms of national defense and security

Cam Pha town:

- an important national center for coal mining and processing
- a national center for coal mining
- a concentration of coal mining service industry
- a local political, economic and cultural center for the whole town

The area of Ha Long-Cam Pha-Duong Huy (north of Cam Pha) is also defined that the "Main industries such as coal mining, mechanical industry, construction material, food processing, timber processing, printing and garment are concentrated in this area. The area is a provincial center for the development of seaport economy, tourism, tourism-related services and commerce. It has a great potential for the construction of big concentrated industrial zones."

(6) Tourism

The target figures of the tourism development in the province are shown in the next table. The tourism sector is expected to become one of the key economic sectors and, furthermore, to create new job opportunities which may contribute to solving the employment problem in the province.

Tourism Development Frame of Quang Ninh Province

Item	Category	2000	2005	2010	Unit
Number of visitors	International	530	1,000	1,250	1,000 pers.
	Domestic	360	1,100	1,260	1,000 pers.
Total	-	1,090	2,100	2,510	1,000 pers.
Revenue	International	68	212	410	US$ mil.
	Domestic	270	1,620	2,520	VND bil.
Total	-	338	1,832	2,930	VND bil.
Employees		8,000	13,900	17,400	pers.
Construction of Hotel Rooms	-				
International Standard Rooms	-	950	1,750	1,300	rooms
Domestic Rooms	-	1,250	1,900	600	rooms
Total	-	2,200	3,650	1,900	rooms

Source: Urban Development Master Plan of Quang Ninh Province, 1995

13.2 Future Development Plan

13.2.1 Development Master Plan of Ha Long City 1994-2010 (HLMP)

HLMP prepared by the Urban and Rural Planning Institute, the Ministry of Construction provides the orientation of long term socioeconomic and spatial development of Bai Chay, Hong Gai, and Cam Pha-Cua Ong in the period of 1994-2010 and further.

(1) Planning Goal

The major planning goal is described as follows:

To realize a well balanced region harmonizing with various sectors such as urban development in Bai Chay - Hong Gai area, the coal mining activity, tourism development, and industrial development.

(2) Development Phase and Expansion of City Boundary

The development of Ha Long is divided into the following three phases

First Phase from 1993 to 2000

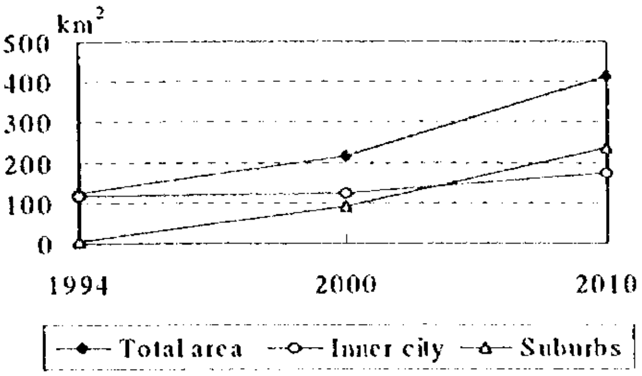
- to upgrade Hong Gai town to Ha Long city
- to expand the city boundary to Viet Hung and Dai Yen communes (Hoanh Bo district)
- to improve and construct the urban infrastructure
- to promote the construction of tourism infrastructure
- to promote the expansion of the Gieng Day industrial zone (construction material factories and the shipyard)
- to expand the deep-sea port of Cai Lan gradually

Second Phase from 2000 to 2010

- to expand the city boundary to the north and west of Cua Luc, Troi small town and part of the following communes. Le Loi, Thong Nhat, Vu Oai, Son Duong (Hoanh Bo district) and Minh Thanh (Yen Hung district)
- to build Cua Luc export processing zone (at present, Cai Lan concentrated industrial development zone) and the high tech industrial zone
- to construct the urban infrastructure, in particular, relating to transportation, water supply, sanitation and environment protection.
- to continue constructing the tourism infrastructure

Third Phase after 2010

- to expand the city boundary farther to the east, Cam Pha (excluding Cong Hoa and Cam Hai communes) and Bai Tu Long bay
- to concentrate the coal mining industry at Cam Pha area



Source: Development Master Plan of Ha Long City for 1994-2010, 1994

Future Area Expansion of Ha Long City

(3) Population and Land Area

The Forecast of population growth of Ha Long city and Cam Pha town is shown below.

Forecast of Land Area and Population in Ha Long City and Cam Pha Town

Item	1994	2000	2010
Ha Long city			
Total area (km^2)	122.7	212.5	411.7
Inner city	116.9	122.7	175.0
Suburbs	5.8	92.8	336.7
Total Population	141,200	230,000	460,000
Inner city	134,140	210,000	400,000
Suburbs	17,060	20,000	60,000
Cam Pha town			
Population	138,700	153,300	187,245
Area (ha)	48,623	48,623	48,623

Source: *ibid.*

The above forecasted figures of population in Ha Long city are based on not only natural growth, but also immigration from other areas and the expansion of the city area. The components of population growth are shown in the next table which indicates Ha Long city will receive a large amount of migration in the period of 2001-2010. The migration population in 2010, 171,000 is equivalent to 73% of the natural growth population in the same year.

Population Growth Components of Ha Long City

(Unit: 1,000 persons)

Component	1993-2000	2001-2010
Natural growth	170	235
Expansion of the city	22	34
Immigration	18	171
Others	20	20
Total	230	460

Source: Development Master Plan of Ha Long City for 1994-2010, 1994

Whether the large migration population is actualized depends on the ability of Ha Long city to create new job opportunities enough for them. Cam Pha will also receive about 20,000 migrants in the period of 1994-2010, the size of which is rather modest compared with the natural growth population (167,000) of Ha Long city.

Estimation of Annual Natural Growth Rates

(Unit: %)

Area	1993	1989-1995	1996-2000	2001-2010
Ha Long	1.56	1.56	1.35	1.10
Cam Pha	1.52	1.52	1.32	1.02
Hoanh Bo	2.24	2.24	2.04	1.50

Source: Development Master Plan of Ha Long City for 1994-2010, 1994

As for the employment of Ha Long city, the third sector is expected to gain the largest employment growth in the period of 1993-2000, in particular the commerce and tourism and the transport, post and communication. The second sector, in particular the manufacturing, will grow rapidly and its share of employment in Ha Long city will reach 55.9% in 2010 from 38.6% in 2000. It implies the structural change of employment will occur in the period of 2001-2010 from service-oriented to industry-oriented (Tables 13.2.1 and 13.2.2).

(4) Planned Economic Growth in Production

HLMP doesn't define macro-economic targets such as GDP and GDP per capita. Instead, the regional economic potential and the target of future production by major industry sector are defined as shown Table 13.2.3. The listed industrial activities have been and/or will be important key sectors to the socioeconomic development of the region. Among them, in particular, the successful implementation of industrial zone development with effective utilization of port facilities will be relatively more crucial to it.

(5) Land Use Change

The future demand for urban development land shown in the next tables and Figure 13.2.1 will grow rapidly. While the total land area of the city will become more than three times (335%) as large as in 1994, the urban land will grow over four times (424%) larger in almost the same period (1993-2010). In particular, the land for industry and housing will expand most rapidly. The growth rate of industrial land is notably highest (12.5% per annum) among the various land uses.

Land use change is generally regarded as one of the major determinants of environmental impacts on the surroundings. The impacts on the land use pattern brought about through industrial development and the residential development in the study area should be more carefully reviewed than the other sectors.

Future Demand for Urban Development Land in Ha Long City

No.	Types of land	Phase I: 193-2000			Phase II: 2000-010			Phase III: After 2000		
		Area (ha)	%	Average (m²/capita)	Area (ha)	%	Average (m²/capita)	Area (ha)	%	Average (m²/capita)
I	Civil land	636	51.8	30.3	1,425	42.5	36.5	2,458	47.1	43.5
1	Housing	420	33.9	20.0	820	24.3	21.0	1,300	25.0	23.0
2	Public construction	48	.9	2.3	78	2.3	2.5	141	2.7	2.5
3	Park-green space	84	6.8	4.0	234	6.9	6.0	565	10.9	10.0
4	Road - plaza	84	6.8	4.0	293	8.7	7.5	452	8.7	8.0
II	Non-civil land	604	48.7	28.0	1,956	57.5	50.2	2,748	52.9	48.6
1	Office	3	4.3	2.5	90	2.7	2.3	112	2.2	2.0
2	Educational facilities	11	0.9	1.0	39	1.3	1.0	65	1.2	1.2
3	Industry & small-scale industry	170	13.7	8.1	865	25.9	22.2	1,250	24.0	22.1
4	Warehouse	70	5.6	3.3	150	4.4	3.9	170	3.3	3.0
5	Port	185	14.9	8.8	462	13.7	11.9	680	13.1	12.0
6	Tourism land (except islands & mountains)	115	9.2	5.0	350	10.3	7.5	471	9.0	7.2
	Total (I + II)	1,240	100.0	59.0	3,381	100.0	86.6	5,206	100.0	92.1

Source: Development Master Plan of Ha Long City for 1994-2010, 1994

Change of Land Use Pattern in Ha Long City with Expansion of City Area

Land Use Category		Phase I: 193-2000		Phase II: 2000-2010		Phase III: After 2010	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
I	Civil Land	636	5.2	1,425	8.1	2,458	6.0
II	Non-civil Land	604	4.9	1,956	11.2	2,748	6.8
III	Reserved Land for Development	210	1.7	390	2.2	565	1.4
IV	Other Land (Hill, Mountain, Forestry, Lake, River)	10,820	88.2	13,729	78.5	34,929	85.8
Total		12,270	100.0	17,500	100.0	40,700	100.0

Source: Development Master Plan of Ha Long City for 1994-2010, 1994

(6) Urban and Infrastructure Development

1) Direction of major urban developments

Major development areas are pointed out as follows:

a) Industrial area development

Major industrial area developments will be concentrated around Bai Chay bay, in particular in the coastal area along the southwest, west and north of the estuary.

Cua Luc industrial area includes:

- Cai Lan port and port-related facilities (200 ha - 300 ha)
- Cai Lan industrial concentrated zone (100 ha)
- Ha Long shipyard area (existing, 60 ha)
- Construction material (brick and tile) industrial area (existing, 80 ha)
- Dong Dang concentrated industrial zone (150 ha)
- Hi-tech industrial zone (150 ha)
- Cement factory area (Lang Bang, Hoanh Bo district, 180 ha)
- Port of cement shipment and other small ports in the bay.

The preferable industries which are expected to be located in the Cai Lan ICZ are identified as electromechanics, precision instrument, apparel, grain milling and processing, packaging (all kinds), handicraft, and toy

On the other hand, the following industries are identified as inappropriate for the Cua Luc industrial area.

- Basic chemical production such as detergent, fertilizer, acid, and nutrient

- Wood pulp and paper making
- Seafood processing
- Industries generating radioactive wastewater

b) Tourism development area

The major tourism development area will be extended west of Ha Long city from Bai Chay to Hung Than, Yen Cu Dai Dan, and Yen Lap lake. A new complex of hotels, villas, commercial and business facilities will be constructed in Hung Thang.

The islands in Ha Long bay are classified into the following three types for the tourism promotion:

- Island with cave primarily for tourists' excursion and conservation
- Island with scenic bathing beach for small rest house and bathing
- Island with ample land for construction site for small hotel and transshipment point

c) Residential development area

The major residential developments are in the following four areas:

East Hong Gai area

This area includes the existing residential area in the central district of the old city stretching along the coast and the areas in Cao Thang - Ha Lam - Ha Tu area. The coastal area from the Cot 3 to Cot 5 and to Nam Cau Trang will be reclaimed.

Hung Thang and Kenh Dong area

The new residential area in Hung Thang will be combined with Hung Thang tourism area and become a new urban center where the political and cultural central functions can be moved from Hong Gai in future.

Dong Dang residential area

This residential area is mainly designated for workers of the concentrated industrial zone, the construction material industries and the Ha Long shipyard.

Troi - Le Loi residential area

This area is reserved for future population growth brought about by the high-tech industrial zone and the cement factories.

d) Urban central area development

The provincial political center will be located at the Coc 8 in the eastern Hong Gai central area. The main central business area will continuously concentrate in the adjacent area to the existing Hong Gai market and form a commercial complex. Furthermore, the site of the old Hong Gai coal screening plant with warehouses will be redeveloped for a main city business center. A new urban center of Ha Long city will also be developed in Hung Thang and the center will include a culture center with theaters, movies, a main library, museums, exhibition halls, etc.

e) Hong Gai coal industry area development

The master plan suggests limiting further exploitation of coal in Hong Gai area for the harmonious development with the tourism industry and conservation of the nature in Ha Long bay. The tunnel-digging method is recommended for further expansion of mining activities in the area.

2) Direction of major infrastructure development

The major infrastructure sectors of transportation, water supply and sanitation, and electricity for Ha Long city are identified in HLMP. The general direction of developments in the above sectors is reviewed in the following sections. Water supply and sanitation are separately reviewed and discussed in the corresponding chapter later.

a) Transportation

Road

The major objectives are to improve and upgrade existing roads, and to construct new roads for increasing the road density and speed-up of the traffic in the area. The improvement of National Road No. 18 is a major project including the following components. Besides, a suspension bridge (Cua Luc bridge) will be constructed across the Cua Luc strait.

- The section in the city will be improved and upgraded. In particular, in the section from Bieu Nghi to Dai Dan a divider will be constructed to separate bicycles and motor vehicles.
- The width of section in the Hung Thang new residential area will be widened up to 45 m for the tourism industry and will be equipped with a lighting system and a combined service duct of optical fiber cables and other pipes.

Railway

The major projects are as follows:

- The 1.435 m rail gauge of the national railway from Kep to Ha Long will be changed to a 1 m gauge.
- The 5 km extension from the Ha Long station to Cai Lan port with 1 m gauge will be implemented.
- Two lines of the coal transport railway between the coalmines and Hong Gai port will be removed after the function of Hong Gai port moves to Nam Cau Trang port.

Port

HLMP predicts that the total capacity of the ports in Ha Long city will reach 30-35 million tons/year. The following ports will be improved or expanded:

- Cai Lan port is regarded as the most important deep water port in the northeast region of the country and expected to contribute to the economic development of the national key economic region, "Northern Growth Triangle". The final development targets of Cai Lan port are to construct 21 of 150-360 m berths and to increase its capacity to 20-25 million tons/year. As mentioned at the previous section of this chapter, 7 berths including the existing berth will be constructed by 2005 in the first phase of the development and additional 2 berths by 2010.

- Hong Gai port will be redeveloped to a passenger and tourism port and the capacity will become to 1.5-3.0 million tons/year and to 10-50 thousands of tourists/year.
- Hon Gac port will have 1-2 new berths with a capacity of 2 million tons/year.
- Sa To port will have 5-6 berths with a capacity of 5-6 million tons/year.
- Nam Cau Trang port is primarily for small ships.

Airport

Construction of a new airport at Minh Thanh quarter, Yen Hung district is recommended in HLMP. The recommendation is that a domestic airport with a 2,400 m x 50 m runway will be constructed for small and medium aircrafts in the development phase of 2000-2010 and be expanded to an international airport after 2010.

According to the Provincial Department of Planning and Investment, the proposal was submitted to the government two years ago, but not yet approved. Therefore, a newly revised proposal is now under preparation and it will be submitted again. The 1st phase is to construct a domestic airport with a runway of 1,800m long, and the 2nd phase can be to expand it into an international airport. To implement a technical study will be approved by the government in near future. The implementation priority seems to be relatively low at present, however.

b) Electricity

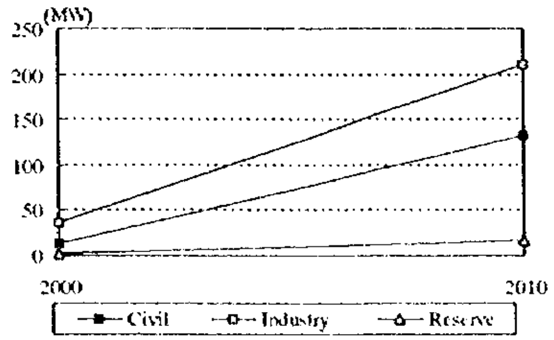
The future demand for electricity is shown in the following table and figure. The demand is forecasted to grow rapidly not only in the industrial sector, but also in the civic sector. The total demand will become over sevenfold larger in 2010 than in 2000. The planning targets of electricity supply per capita in Ha Long city are 77 W in 2000 and 330 W in 2010.

Future Demand for Electricity in Ha Long City

(Unit: MW)

Sector	Phase 1:2000	%	Phase 2:2010	%
Civil	13.2	25.6	132	36.6
Industry	35.96	69.7	210.96	58.6
Reserve	2.45	4.7	17.1	4.8
Total	51.61	100.0	360.06	100.0

Source: Development Master Plan of Ha Long City for 1994-2010, 1994



Source: Development Master Plan of Ha Long City for 1994-2010, 1994

Future Demand for Electricity in Ha Long City

Responding to the increasing future demand, the national electricity development plan - phase III identified the following projects for Quang Ninh province and Ha Long city in particular.

- Expansion of Pha Lai thermal power plant (the capacity will reach from 400 MW to 800 MW)
- Construction of a thermal power plant with a capacity 1,200 MW (4 × 300 MW) in Quang Ninh province.

At present, the expansion of Pha Lai is under construction with the financial assistance from OECF. As for a new coal thermal power station, the US company, OXBOW is now preparing a BOT (Build, Operate and Transfer) scheme project (capacity: 300 MW). The location of the site is in Vu Oai in Hoanh Bo. Low quality coal will be utilized for the plant. The technical study is already finished and the estimated construction cost is US$360 mil. The proposed sale price of electricity is allegedly more expensive than the Provincial Department of Planning and Investment estimated, however. Although the construction was expected to begin within 1998, it has been delayed because of several constraints including a shortage of budget.

The 220 KV power line from Pha Lai to Quang Ninh was planned by the Institute of Electricity Planning and Research, Ministry of Energy. In Hoanh Bo district a 220/110 KV transformer station will be constructed to distribute electricity to the surrounding area of Bai Chay bay and to Mong Duong, Tien Yen and Mong Cai. In addition, the capacities of existing transformer stations will be increased for Hong Gai and Bai Chay areas.

Electricity for the industrial areas around Cua Luc including Cai Lan concentrated industrial zone will be supplied through a 110 KV line from the Hoanh Bo transformer station.

13.2.2 Current Trend of Development Activities in the Study Area

The major development projects have been identified and some of them have already been implemented based on the general direction defined by the master plan. Generally speaking, however, the implementation schedule tends to be delayed and, furthermore, the project sizes have become smaller in some cases because of the recent international and, consequently, domestic economic turmoil. The latest list of major development projects has been compiled through interviews with and hearings from the relevant provincial and national agencies. The list shows which development projects are at present or will be surely in near future scheduled to be implemented by 2010. The list shown in table 13.2.4 is used to set the socioeconomic framework for the EMP preparation.

13.2.3 Linkage of Socioeconomic Development and Environmental Impact

The following development activities besides the coal mining activities may have major environmental impacts on the study area.

- Industrialization and relevant infrastructure development (port development, industrial zone development, road improvement, power plant, etc.)
- Tourism and commercial development and relevant infrastructure development (land reclamation, urban renewal including relocation of coal port, etc.)
- Urbanization (development of residential area and relevant infrastructure, water supply, solid waste, sewage, etc.)

- Change of land use pattern and of urban structure (distribution pattern of population and urban facilities)

The first two are categorized as the industrialization issue and the changes of land use pattern and urban structure are categorized as a complex issue which will be jointly brought about through the industrialization and urbanization. The major environmental determinants relating to the above development activities are listed in table 13.2.5. Analysis on the qualitative cause and effect relationship (partly quantitative, if possible) between the environmental determinants and the environment in the Ha Long bay area is necessary. In particular, the change of land use pattern and its environmental impacts must be focused on.

13.3 Setting Future Socioeconomic Framework

Socioeconomic development frame defines the fundamental conditions of the environmental management plan and is necessary to estimate pollution loads and their environmental impacts on the area concerned. At the beginning stage of the Study, the development frame planned by QNPC was granted to be a given condition for the EMP preparation. However, it is revealed that the existing development frame needs to be partly adjusted, responding to the current change of investment circumstances, results of the EIAs of the concrete projects, etc. In particular, the frame concerning the major development projects needs to be adjusted, i.e., their development scales and schedules. The future socioeconomic framework for the EMP preparation is shown in the following sections.

(1) Population, Employment and Land Use

The future total population of Ha Long city and Cam Pha town and the change of administrative boundary in the study area are directly adopted from the development master plan of Ha Long city. The population of sub-districts is forecast based on each sub-district's recent growth rate, as in Table 13.3.1. The total population of the year 2010 of the master plan is used as a control total for estimation of the future consolidated Ha Long City.

In addition, the following items which are already shown in the previous sections are also adopted from the development master plan of Ha Long city. They are:

- the employment change by development phase,
- the economic potential, future production and labor force demand by major industry, and
- the future demand for urban development land in Ha Long city.

(2) Tourism

The tourism development frame of Quang Ninh province is adopted as a basic frame for the EMP preparation. The number of international visitors to Ha Long is adopted directly from the provincial frame. On the other hand, the average share of domestic visitors in the study area recently account for 67.2% of the visitors to the province. This figure is used for the estimation of domestic visitors to Ha Long. The number of visitors in the peak months is also estimated based on the current data on the monthly distribution of visitors.

Future Development Frame of Tourism for the Province

Item	2000	2005	2010	
Number of visitors				
International to Ha Long	300	350	800	(1,000 pers.)
International to Mong Cai	600	650	1,000	(1,000 pers.)
Domestic for Tourism	300	380	750	(1,000 pers.)
Domestic for Religion	100	120	150	(1,000 pres.)
Total	1,300	1,500	2,700	(1,000 pers.)
Revenue	270	290	1,000	(bil vld)
Employees	3,500	4,200	15,00	(pers.)
Construction of Hotel Room				
International Standard Rooms	2,000	2,500	5,000	
Domestic Rooms	1,000	1,500	2,000	
Total	3,000	4,000	7,000	

Source: Department of Tourism, Quang Ninh Province

Estimated Number of Visitors to Ha Long Bay

(Unit: 1,000 visitors)

Item	Month	2000	2005	2010
International		300	350	800
Domestic		269	336	605
Total		569	686	1,405
International	June	30	34	79
	July	30	35	80
Domestic	June	27	33	60
	July	27	34	61

Source: Estimates by the JICA Study Team based on the data from the Department of Tourism, Quang Ninh

(3) Major Development Project

The adjusted list of the major development projects in the study area is compiled and shown in Table 13.2.4. The adjustment was made based on discussions with the relevant provincial and national agencies. Mainly, their development scales and schedules are reviewed and adjusted responding to the current change of investment circumstances.

(4) Estimated Size of the Major Industrial Development Projects in the Study Area

The industrialization and relevant infrastructure development are regarded as one of the possible environmental threats in the study area. The size of the major industrial development projects is one of the crucial factors determining their degree of environmental impacts. For the further steps of the EMP preparation, the sizes of the major projects are estimated as follows:

1) Location unit per site area of factory building

The estimation is based on location unit per site area of factory building by industry. As data on location unit is currently not available in Vietnam, the Japanese data are substitutionally adopted for the estimation. The average data from 1977 to 1995 are employed here, because the latest Japanese data may not be directly applicable to the study area and the average data minimize the fluctuation of data in the observation period. However, the data on drainage water are the latest, as the average is not available.

Location Unit per Site Area of Newly Constructed Factories from 1977 to 1996 in Japan

Period	1977 – 1996				1995
Industry	Building space	Floor space	Employees (pers./ha)	Fresh water consumption (m^3/day/ha)	Ratio of drainage to consumed fresh water (%)
Grain milling	0.291	0.412	37	368	48
Edible oil manufacturing	0.263	0.328	20	353	6
Electromechanics	0.184	0.273	79	532	16
Garment	0.240	0.306	123	392	44
Precision instrument	0.196	0.280	68	490	23
Packaging	0.309	0.368	38	198	50
Toy	0.161	0.202	42	476	21
Tile and Brick manufacturing	0.231	0.345	19	12	46
Ship building	0.206	0.243	39	730	15
Cement factory	0.114	0.126	17	343	18

Source: Japan Industrial Location Center, Survey on Industrial Location Unit, 1998

2) Estimated size of major industrial development projects

The sizes are estimated by using the data on location unit and the site areas of the major industrial development projects such as Cai Lan concentrated industrial zone development, Hoanh Bo industrial development zone, Hoanh Bo cement factory development, and Ha Long shipyard development. The results are shown in the following tables.

Estimation of Cai Lan Concentrated Industrial Park Development

Factory (Phase 1)	Site Area (ha)	Building space (ha)	Floor space (ha)	Employees (pers.)	Fresh water consumption (m^3/day)	Drainage of fresh water (m^3/day)
Grain milling	-	2.10	2.98	267	2,658	1,273
Edible oil manufacturing	-	1.90	2.37	144	1,820	113
Electromechanics	-	1.33	1.97	571	3,843	607
Garment	-	1.73	2.21	888	2,831	1,251
Precision instrument	-	1.42	2.02	491	3,539	814
Packaging	-	2.23	2.66	274	1,430	712
Toy	-	1.16	1.46	303	3,438	719
Total (Phase 1)	50.56	11.87	15.67	2,940	19,559	4,216
Development area	78 ha. Site for factories: 60.56 ha					
Factory (Phase 2)						
Electromechanics	-	5.30	7.86	2,274	15,311	2,419
Garment	-	6.91	8.81	3,540	11,282	4,987
Precision instrument	-	5.64	8.06	1,957	14,102	3,244
Packaging	-	8.89	10.59	1,094	5,699	2,838
Toy	-	4.63	5.81	1,209	13,699	2,863
Total (Phase 2)	144.0	31.37	41.13	10,073	60,093	16,350
Development area	222 ha. Site for factories : 144 ha					
Total (Phase 1 + 2)	194.56	43.24	56.79	13,013	79,653	20,567

Estimation of Hoanh Bo Industrial Park Development

Factory	Site Area (ha)	Building space (ha)	Floor space (ha)	Employees (pers.)	Fresh water consumption (m^3/day)	Drainage of fresh water (m^3/day)
Grain milling	-	9.85	13.94	1,252	12,451	5,964
Electromechanics	-	6.23	9.24	2,673	17,999	2,844
Garment	-	8.12	10.35	4,162	13,263	5,862
Precision instrument	-	6.63	9.47	2,301	16,578	3,813
Packaging	-	10.45	12.45	1,280	6,699	3,336
Toy	-	5.45	6.83	1,421	16,105	3,366
Total	-	46.72	62.29	13,094	83,095	25,185
Development area	330 ha, Site for factories: 203 ha					

Estimation of Hoanh Bo Cement Factory Development

Factory	Site Area (ha)	Building space (ha)	Floor space (ha)	Employees (pers.)	Fresh water consumption (m^3/day)	Drainage of fresh water (m^3/day)
Hoan Cau Factory (Taiwan)	50	5.7	6.3	850	17,150	3,087
Hai Long Factory (Korea)	50	5.7	6.3	850	17,150	3,087
Total	100	11.4	12.6	1,700	34,300	6,174

Note: Expected production capacity is 4-5 mil t / year in 2010 and 10-20 mill. t / year after 2010.

Estimation of Ha Long Shipyard Development

Factory	Site Area (ha)	Building space (ha)	Floor space (ha)	Employees (pers.)	Fresh water consumption (m^3/day)	Drainage of fresh water (m^3/day)
Ha Long Shipyard (present)	18	3.7	4.4	1,000	13,140	1,918
Ha Long Shipyard (future)	81	16.7	19.7	4,500	59,130	8,633

Note: Data source of no. of employees is the hearing from the Ha Long Shipyard.