Appendix 12-1

Details and Technical Matters of the Simulation Models

Details and technical matters of the simulation models are described in this APPENDIX.

1. Simulation Models

1.1 Hydrodynamic Model

1.1.1 Basic Equations

Basic equations of the Hydrodynamic Model consist of Motion Equation assuming uncompressed fluid in rotating system, Continuity Equation, State Equation and Advective Diffusion Equation of temperature and salinity, and Boussinesq approximation and hydrostatic pressure approximation are applied.

Boussinesq approximation is an idea that influence of density distribution to flow field only act on pressure through spatial distribution of density. Standard density is used in other field where density distribution is related.

Hydrostatic pressure approximation is an idea that the gravity and the pressure constantly equilibrate in the balance of vertical Motion Equation, and acceleration speed along vertical direction is not generated.

Both approximations are well effected in the field of sea area and estuary, where horizontal movement much dominates than vertical movement.

Basic equations are shown below.

< Continuity Equation >

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (3.1.1)$$

< Motion Equation >

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho_0}\frac{\partial p}{\partial x}+\frac{\partial}{\partial z}\left(K_M\frac{\partial u}{\partial z}\right)+F_x-Fb_{wx} \qquad (3.1.2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho_0}\frac{\partial p}{\partial y}+\frac{\partial}{\partial z}\left(K_M\frac{\partial v}{\partial z}\right)+F_y-Fb_{wy} \qquad (3.1.3)$$

$$\rho g=-\frac{\partial p}{\partial z} \qquad (3.1.4)$$

< State Equation >

$$\rho(S,\theta)=\rho_w+(b_0+b_1\theta+b_2\theta^2+b_3\theta^3+b_4\theta^4)S+(c_0+c_1\theta+c_2\theta^2)S^{3/2}+d_0S^2$$

(3.1.5)

< Advective Diffusion Equation of temperature and salinity >

$$\frac{\partial \theta}{\partial t} + u\frac{\partial \theta}{\partial x} + v\frac{\partial \theta}{\partial y} + w\frac{\partial \theta}{\partial z} = \frac{\partial}{\partial z}\left(K_H \frac{\partial \theta}{\partial z}\right) + F_\theta \tag{3.1.6}$$

$$\frac{\partial S}{\partial t} + u\frac{\partial S}{\partial x} + v\frac{\partial S}{\partial y} + w\frac{\partial S}{\partial z} = \frac{\partial}{\partial z}\left(K_H \frac{\partial S}{\partial z}\right) + F_S \tag{3.1.7}$$

'*F*'s of the right-hand member in the equations above are the effect of sea water mixing that causes homogenization of movement, water temperature and salinity by small time-scale changes of water speed and direction other than regular flow. These are expressed by the following equations.

$$F_x = \frac{\partial}{\partial x}\left[A_M \frac{\partial u}{\partial x}\right] + \frac{\partial}{\partial y}\left[A_M \frac{\partial u}{\partial y}\right] \tag{3.1.8}$$

$$F_y = \frac{\partial}{\partial y}\left[A_M \frac{\partial v}{\partial y}\right] + \frac{\partial}{\partial x}\left[A_M \frac{\partial v}{\partial x}\right] \tag{3.1.9}$$

$$F_{\theta,S} = \frac{\partial}{\partial x}\left[A_H \frac{\partial(\theta,S)}{\partial x}\right] + \frac{\partial}{\partial y}\left[A_H \frac{\partial(\theta,S)}{\partial y}\right] \tag{3.1.10}$$

Where:

x, y, z	: Cartesian coordinate system in right-hand system, Upward is positive
u, v, w	: Flow components in x, y, z direction
p	: Pressure
θ	: Water temperature
S	: Salinity
f	: Corioli's coefficient
ρ_0	: Representative density
ρ	: Density
ρ_w	: Density of pure water
b_0	: 8.24493×10^{-1}
b_1	: -4.0899×10^{-3}
b_2	: 7.6438×10^{-5}
b_3	: -8.2467×10^{-7}
b_4	: 5.3875×10^{-9}
c_0	: -5.72466×10^{-3}
c_1	: 1.0227×10^{-4}

c_2	: -1.6546×10^{-6}
d_0	: 4.8314×10^{-4}
K_M	: Vertical eddy kinematic viscosity coefficient
K_H	: Vertical eddy diffusion coefficient
A_M	: Horizontal eddy kinematic viscosity coefficient
A_H	: Horizontal eddy diffusion coefficient
g	: Gravitational acceleration
t	: Time

1.1.2 Basic Equation Related to Boundary Condition

1) Seafloor Surface

Sea bottom friction is boundary condition for sea floor surface.

Sea bottom friction is presupposed that flow speed distribution is based on the Karman constant and the logarithmic distribution low using roughness length. The Karman constant is a constant which is determined by characteristic of fluid. The roughness length is a constant which depend on the soil texture and topographical shape of the seafloor.

The equation is expressed below.

$$\rho_0 K_M \left(\frac{\partial u}{\partial z}, \frac{\partial v}{\partial z} \right) = (\tau_{bx}, \tau_{by}) \tag{3.1.11}$$

$$\rho_0 K_H \left(\frac{\partial \theta}{\partial z}, \frac{\partial S}{\partial z} \right) = (0,0) \tag{3.1.12}$$

$$w_b = -u_b \frac{\partial h}{\partial x} - v_b \frac{\partial h}{\partial y} \tag{3.1.13}$$

Where:

$$\begin{aligned} \vec{\tau}_b &= (\tau_{bx}, \tau_{by}) = \rho_0 C_D \left| \vec{\mathbf{V}}_\mathbf{b} \right| \vec{\mathbf{V}}_\mathbf{b} \\ \vec{\mathbf{V}}_\mathbf{b} &= (u_b, v_b), \left| \vec{\mathbf{V}}_\mathbf{b} \right| = \sqrt{u_b^2 + v_b^2} \end{aligned} \tag{3.1.14}$$

$\vec{\mathbf{V}}_\mathbf{b}$	: Horizontal flow vector at sea bottom
$\vec{\tau}_b$	: Seafloor stress

The suffix '*b*' is a value of mesh which faces to the seafloor.
Friction coefficient of the sea floor (C_D) is presupposed that flow speed distribution in the boundary layer is based on the logarithmic distribution low and following equation is applied.

$$C_D = \left[\frac{1}{\kappa} \ln \frac{h + z_b}{z_0} \right]^{-2} \tag{3.1.15}$$

Where:

h : Depth below datum

z_b : Vertical coordinate at the mesh (velocity definition point) which faces to the seafloor

z_0 : Roughness length(=1cm)

κ : Karman constant (=0.4)

2) Sea Surface

Boundary condition at sea surface is defined by following equations.

$$\rho_0 K_M \left(\frac{\partial u}{\partial z}, \frac{\partial v}{\partial z} \right) = (\tau_{sx}, \tau_{sy}) \tag{3.1.16}$$

$$\rho_0 K_H \left(\frac{\partial \theta}{\partial z}, \frac{\partial S}{\partial z} \right) = (Q_{suf} \,/\, C_v, 0) \tag{3.1.17}$$

$$w = \frac{\partial \eta}{\partial t} + u \frac{\partial \eta}{\partial x} + v \frac{\partial \eta}{\partial y} \tag{3.1.18}$$

Where:

Q_{suf} : Heat quantity through sea surface

Cv : Specific heat

w : Vertical flow speed

η : Water level

Sea surface friction is the effect of momentum transfer of wind to sea water caused by friction between wind and sea water and is expressed by the following equations.

$$\begin{gathered} \vec{\tau}_s = (\tau_{sx}, \tau_{sy}) = \rho_a C_a \vec{\mathbf{W}} \left| \vec{\mathbf{W}} \right| \\ \vec{\mathbf{W}} = (W_x, W_y), \left| \vec{\mathbf{W}} \right| = \sqrt{W_x^2 + W_y^2} \end{gathered} \tag{3.1.19}$$

Where:

Ca : Sea surface friction coefficient

ρ_a : Density of atmosphere

Wx, Wy : Wind speed at X, Y direction

τ_{sx}, τ_{sy} : Wind stress at X,Y direction

1.1.3 Basic Equations for Each Parameter

1) Horizontal Eddy Kinematic Viscosity Coefficient and Horizontal Eddy Diffusion Coefficient

Empirical equation by Smagorinsky(1963)[1] shown below is applied for horizontal eddy kinematic viscosity coefficient (A_M) and horizontal eddy diffusion coefficient (A_H).

$$A_{M,H} = C_{M,H} (\Delta x \times \Delta y) \left[\frac{1}{2} \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right)^2 + \left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial y} \right)^2 \right]^{1/2} + A_{MB,HB} \qquad (3.1.20)$$

Where:

C_M、C_H : Proportion coefficient (=0.1)

$A_{MB,HB}$: Horizontal eddy kinematic viscosity and horizontal eddy diffusion coefficient at background (＝10^4 cm^2/s)

2) Vertical Eddy Kinematic Viscosity Coefficient and Vertical Eddy Diffusion Coefficient

Stratification functions by Pacanowski and Philander (1981)[2] shown below are applied for vertical eddy kinematic viscosity coefficient (K_M) and vertical eddy diffusion coefficient (K_H).

$$K_M = \frac{K_{M0}}{(1 + \alpha R_i)^n} + K_{MB} \qquad (3.1.21)$$

$$K_H = \frac{K_M}{(1 + \alpha R_i)^n} + K_{HB} \qquad (3.1.22)$$

$$R_i = \frac{-\frac{g}{\rho}\left(\frac{\partial \rho}{\partial z}\right)}{\left(\frac{\partial U}{\partial z}\right)^2} \qquad (3.1.23)$$

Where:

K_{MB} : Vertical eddy kinematic viscosity coefficient at background (=1.0 cm^2/s)
K_{HB} : Vertical eddy diffusion coefficient at background (=1.0 cm^2/s)
z : Vertical coordinate from datum
U : Horizontal flow speed (cm/s)
n : 2
α : 5
K_{M0} : 100.0cm^2/s

[1] J.Smagorinsky(1963)：General Circulation Experiments with the Primitive Equations Ⅰ. The Basic Experiment, Monthly Weather Review, 91, 99-164.
[2] R. C. Pacanowski and S. G. H. Philander(1981):Parameterization of Vertical Mixing in Numerical Models of Tropical Oceans. J. Phys. Oceanogr.,11,1443-1451.

1.2 Suspended Solid Dispersion Model

1.2.1 Basic Equation

The Suspended Solid Dispersion Model uses advective diffusion equation shown below as basic equation considering sedimentation process of diffusion materials in conservative system.

$$\frac{\partial S}{\partial t}+u\frac{\partial S}{\partial x}+v\frac{\partial S}{\partial y}+\left(w-W_S\right)\frac{\partial S}{\partial z}=\frac{\partial}{\partial x}\left(K_x\frac{\partial S}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial S}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial S}{\partial z}\right)+q \tag{3.1.24}$$

Where:

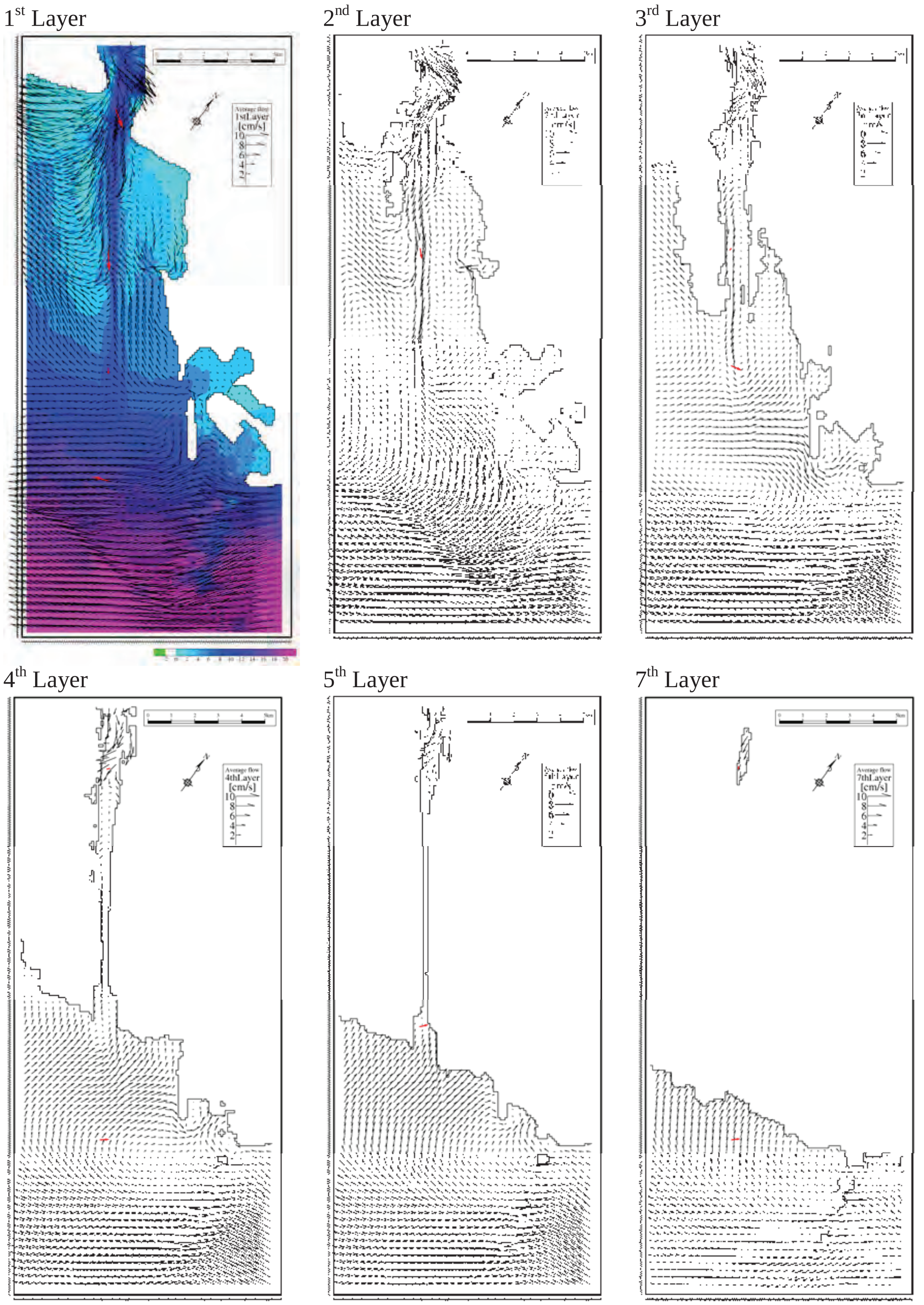
S	: Concentration of Suspended Solid (SS) (mg/L)
x,y,z	: Cartesian coordinate system in right-hand system, Upward is positive
u,v,w	: Flow components in *x,y,z direction* (cm/s)
t	: Time (s)
Kx,Ky	: Horizontal diffusion coefficient (cm^2/s)
Kz	: Vertical eddy fiffusion coefficient (cm^2/s)
q	: SS load (mg/L/s)
W_s	: Sedimentation speed (cm/s)

2. Reproducibility of the Hydrodynamic Model

After necessary parameters are set up and the hydrodynamic model was established, reproducibility of the model was confirmed, comparing with existing data.

2.1 Residual Current

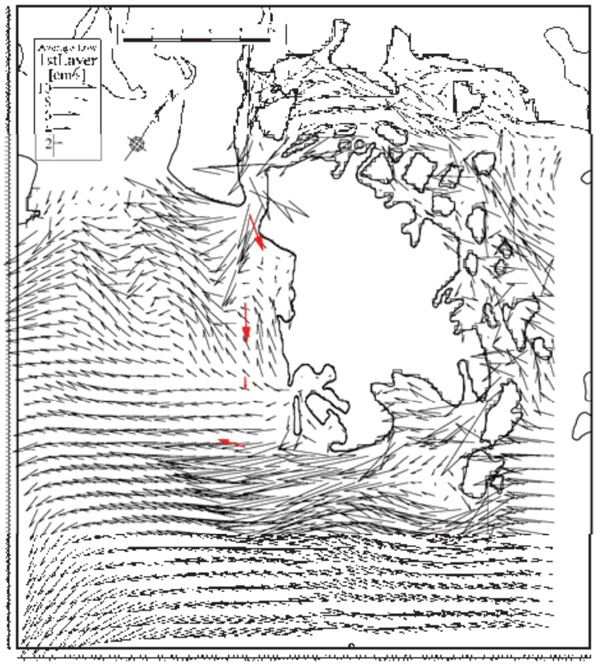
Horizontal distribution of residual currents at each layer by computation for present condition is shown in ***Figure 2.1***, ***Figure 2.2*** and ***Figure 2.3***.



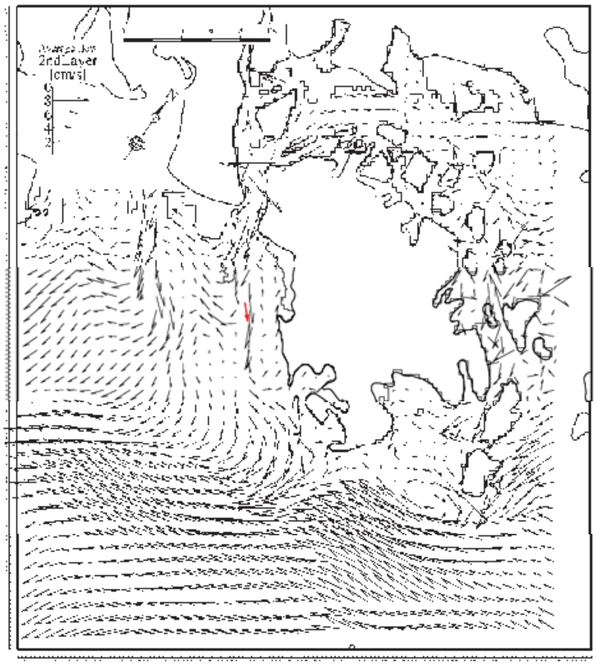
→ : camputation, → : observation(2009.11-12)

Figure 2.1 Residual Current by Computation at Present Condition (Small Domain, 100m mesh)

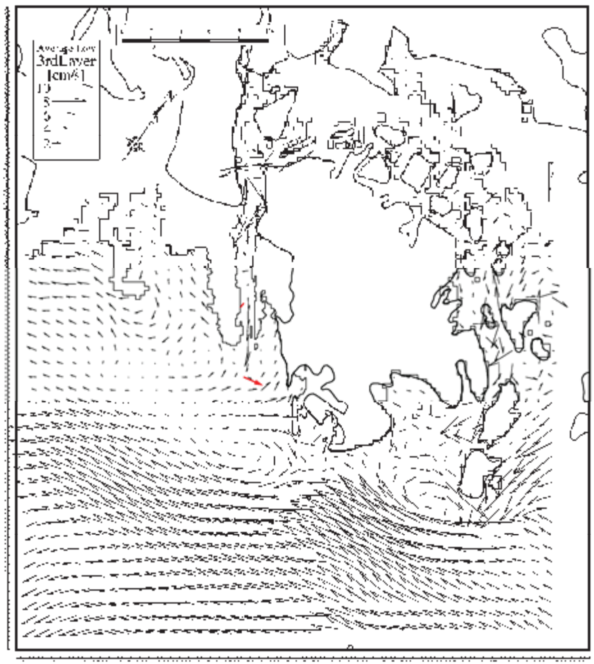
1st Layer



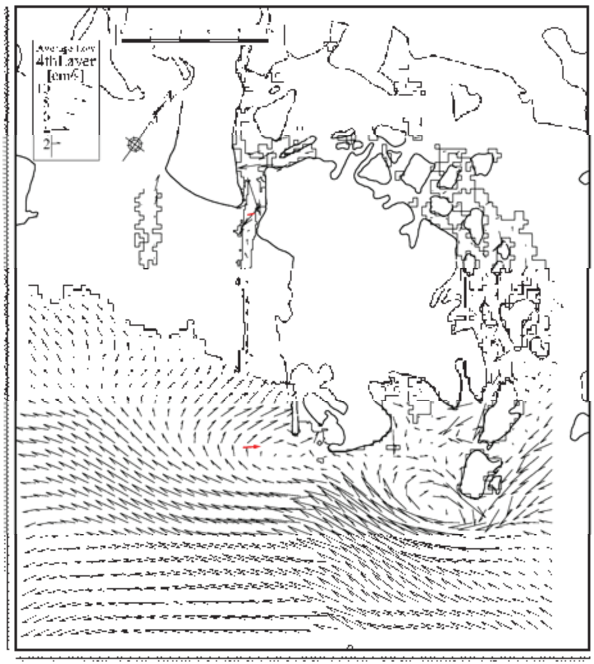
2nd Layer



3rd Layer



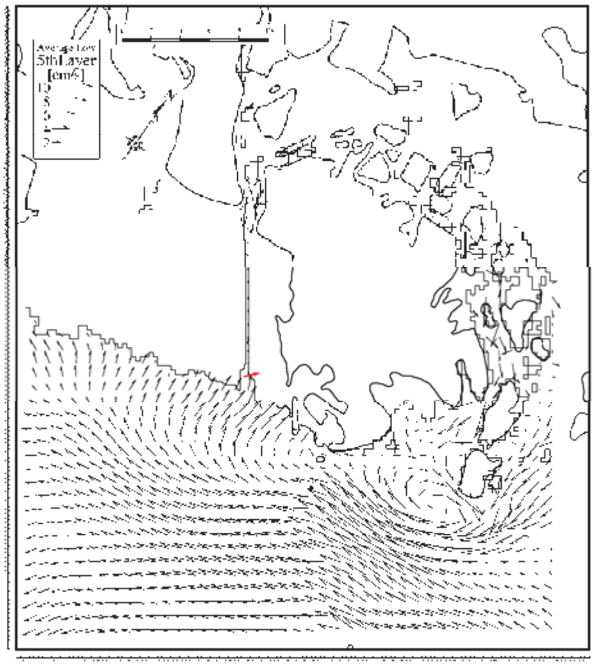
4th Layer



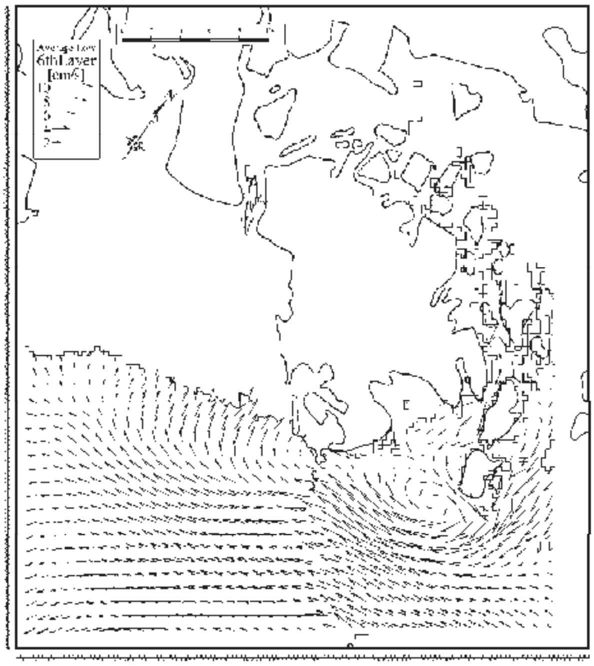
→ : computation,→ : observation(2009.11-12)

Figure 2.2 Residual Current by Computation at Present Condition (Medium Domain, 300m mesh, 1st layer - 4th layer))

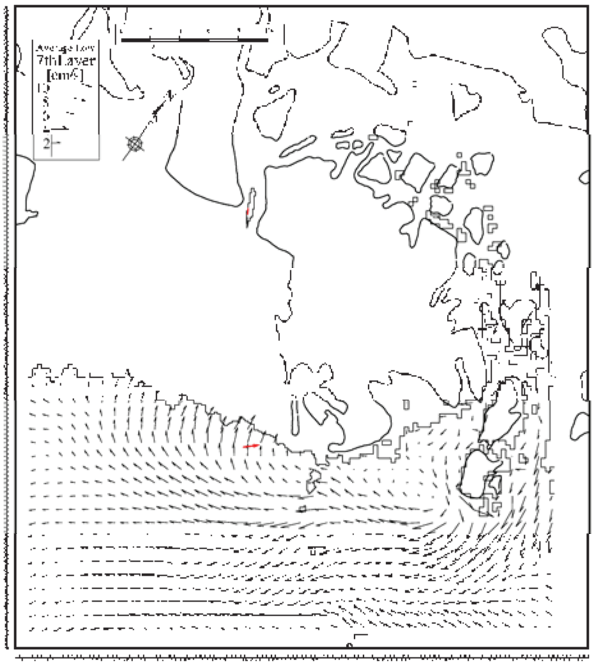
5th Layer



6th Layer



7th Layer



→ : computation, → : observation(2009.11-12)

Figure 2.3 Residual Current by Computation at Present Condition (Medium Domain, 300m mesh, 5th – 7th layer)

2.2 Distribution of Tidal Current at the Present Condition

Tidal current distributions by computation for present condition at 1st layer and 5th layer are shown in ***Figure 2.4*** and ***Figure 2.5*** for dry season and ***Figure 2.6 and Figure 2.7*** for wet season, respectively. Comparison between computation result and survey result in wet season is not studied.

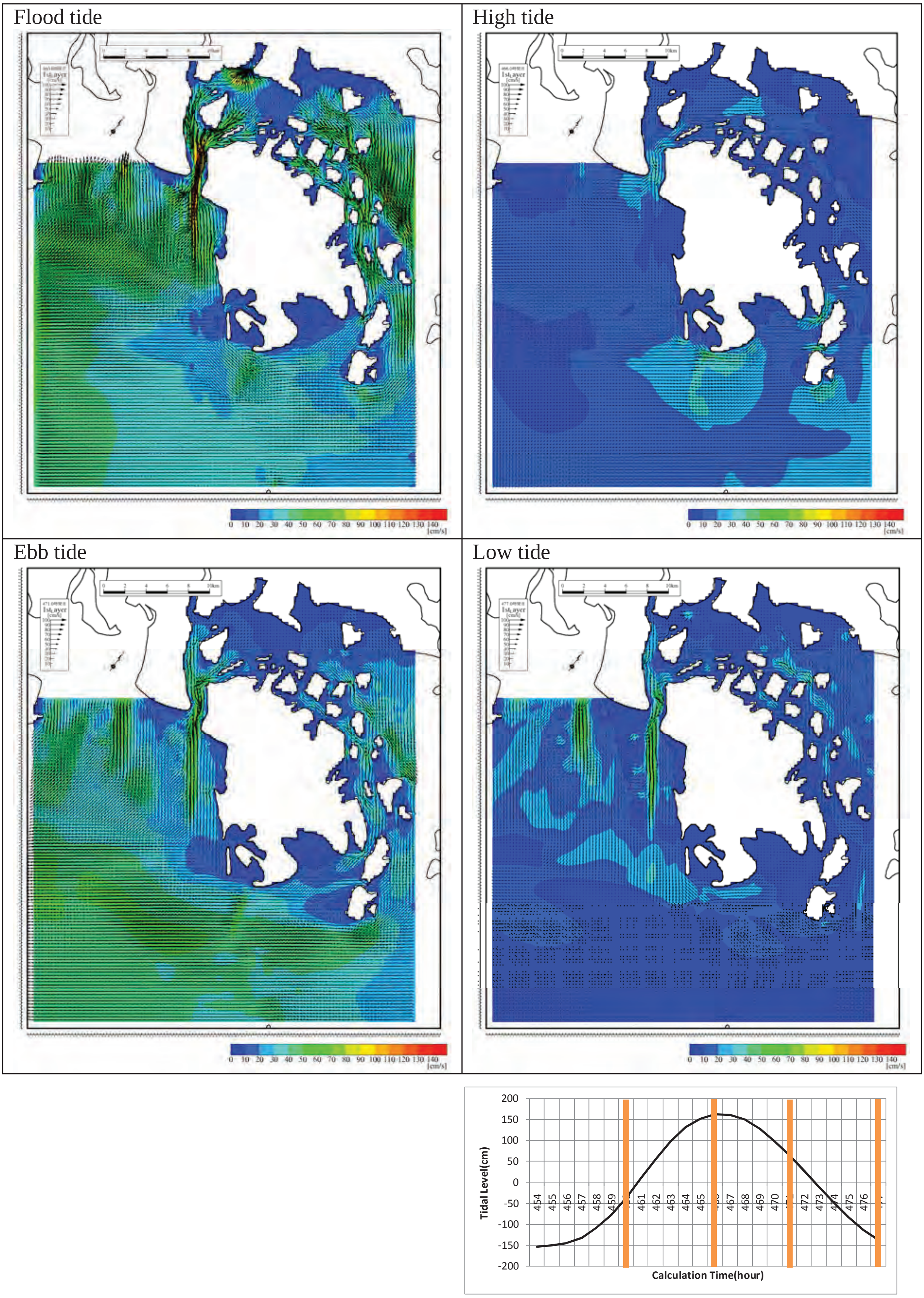


Figure 2.4 Distribution of Tidal Current by Computation at Present Condition (Dry Season：1st Layer=M.S.L.±2m)

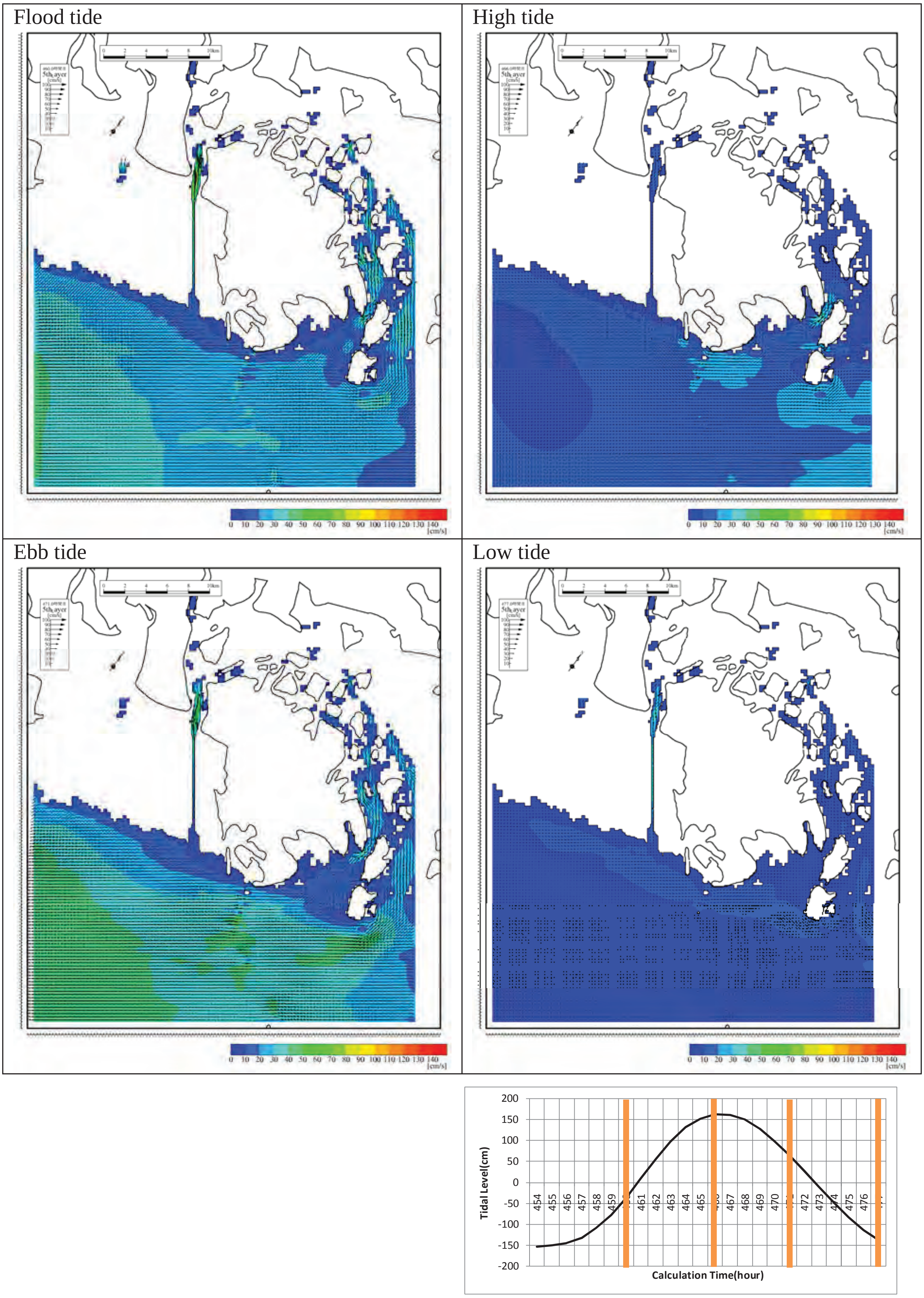


Figure 2.5 Distribution of Tidal Current by Computation at Present Condition (Dry Season：5th Layer=M.S.L.-8～10m)

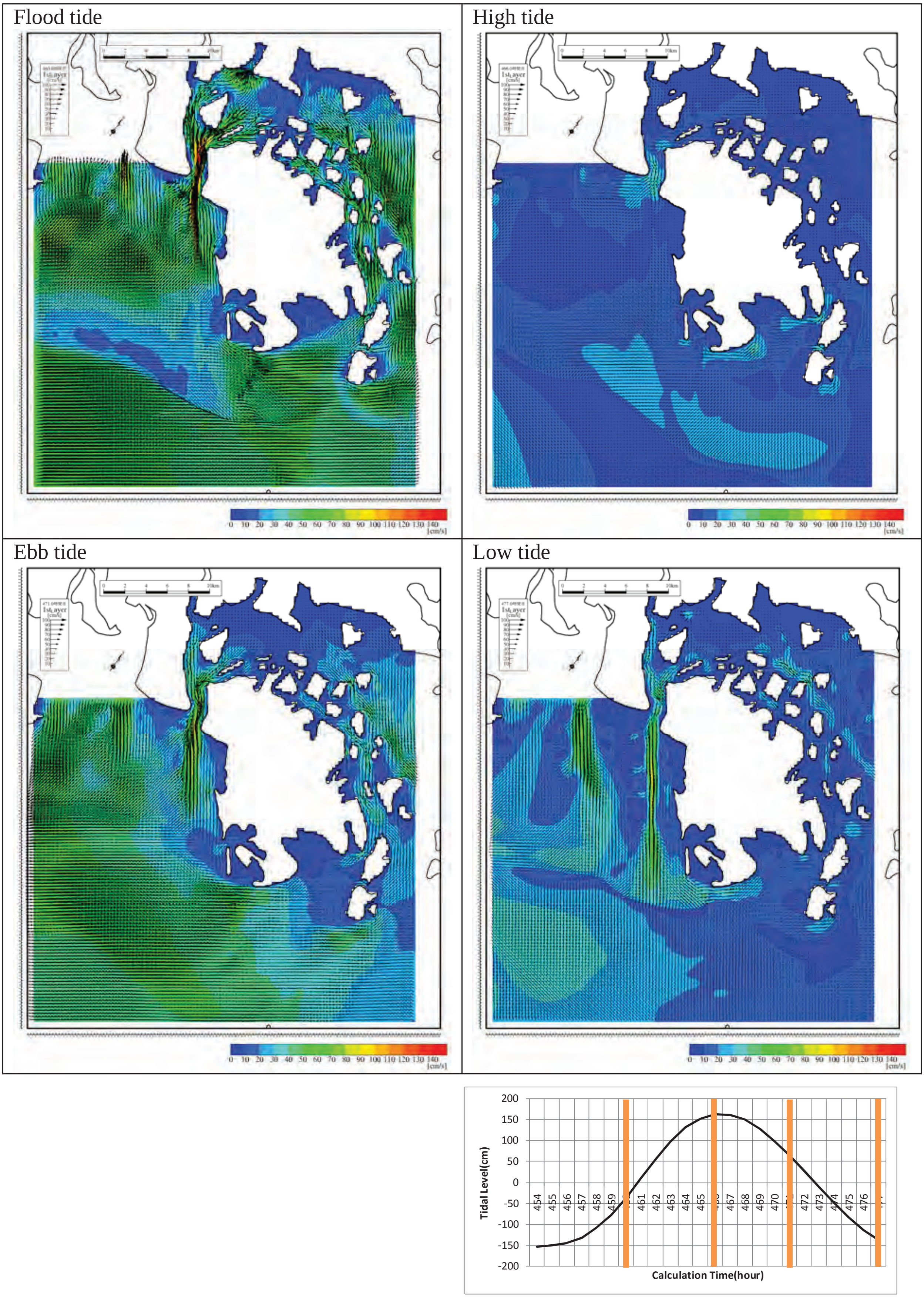


Figure 2.6 Distribution of Tidal Current by Computation at Present Condition (Wet Season : 1st Layer=M.S.L.±2m)

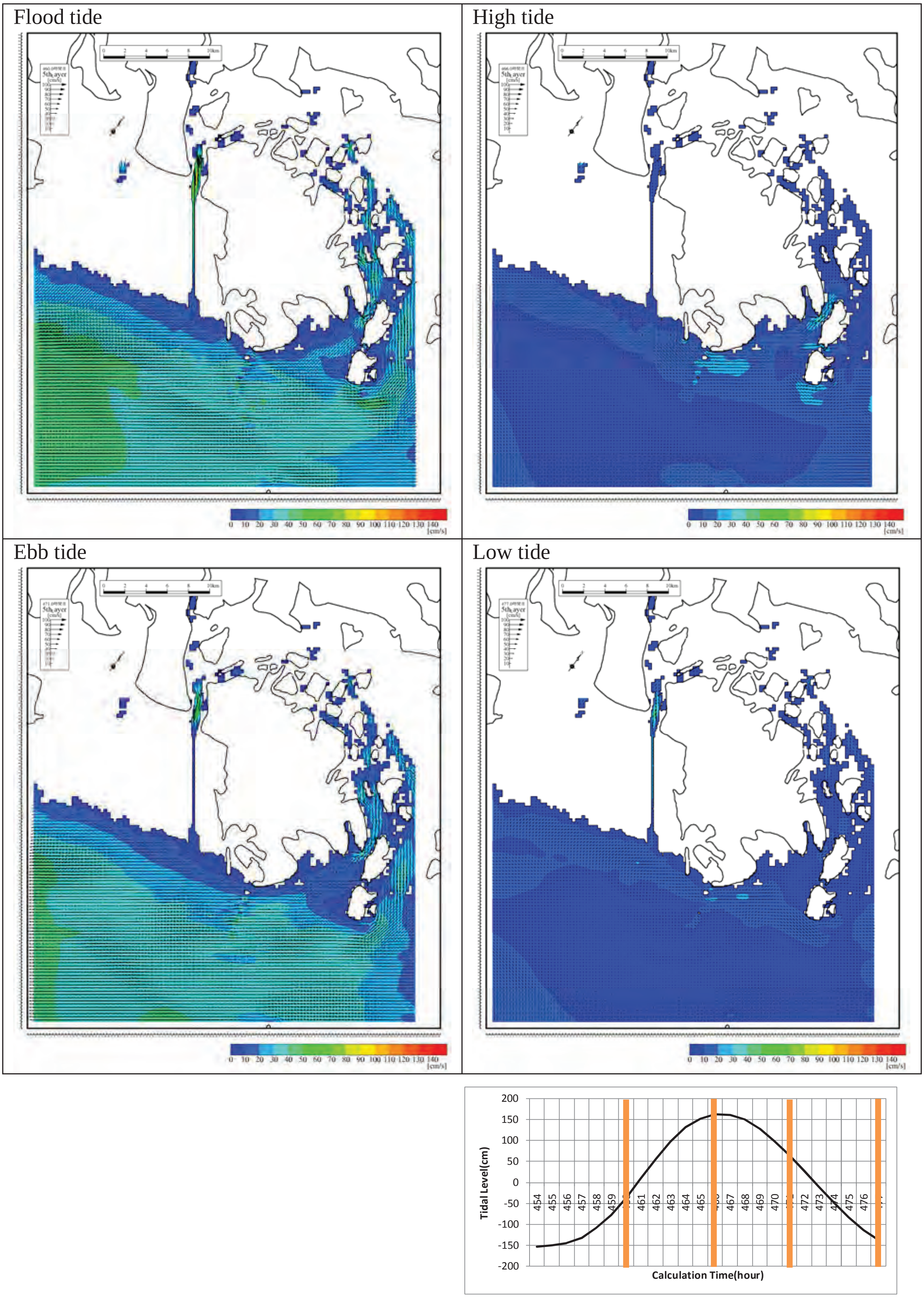


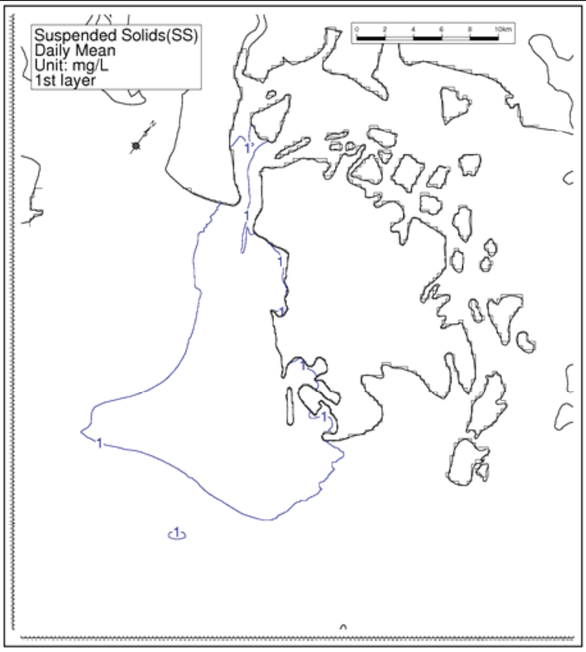
Figure 2.7 Distribution of Tidal Current by Computation at Present Condition (Wet Season：5th Layer=M.S.L.-8～10m)

3. Suspended Solid Dispersion

All outputs by computation are shown in this section.

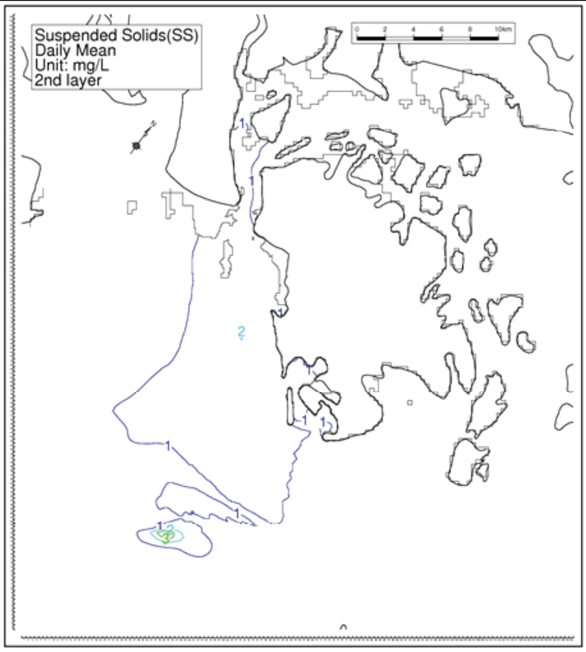
3.1 Case 1

1st layer (0-2m below surface)



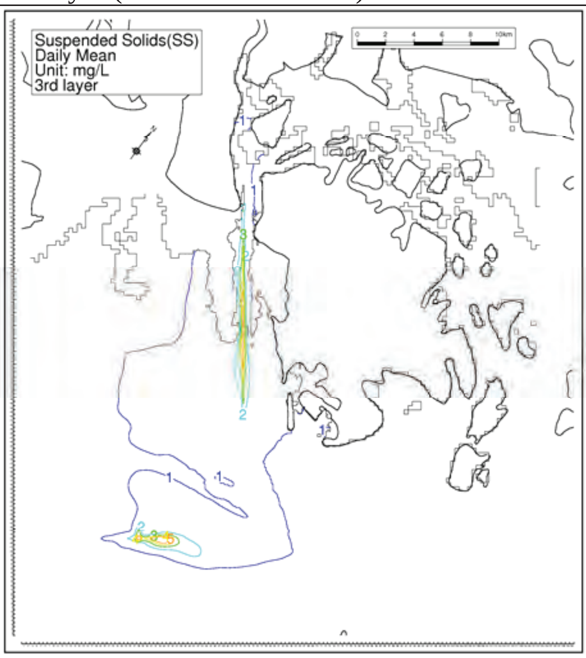
Max. SS in the area :1.6mg/L

2nd Layer (2-4m below surface)



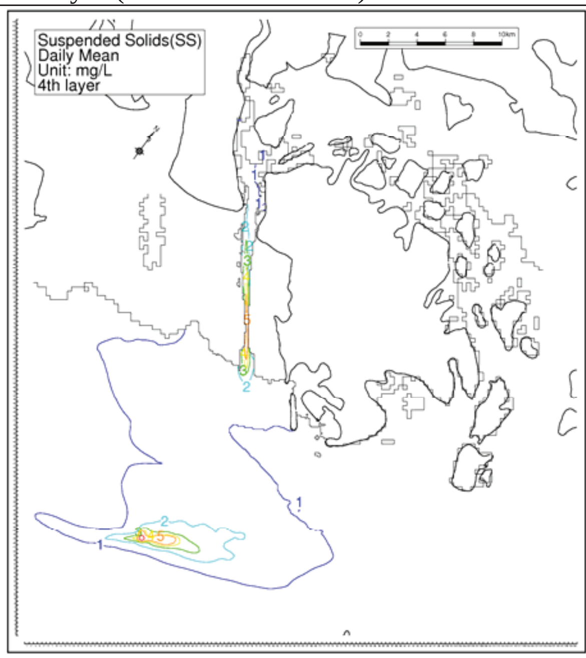
Max. SS in the area :3.8g/L

3rd Layer (4-6m below surface)



Max. SS in the area :7.4mg/L

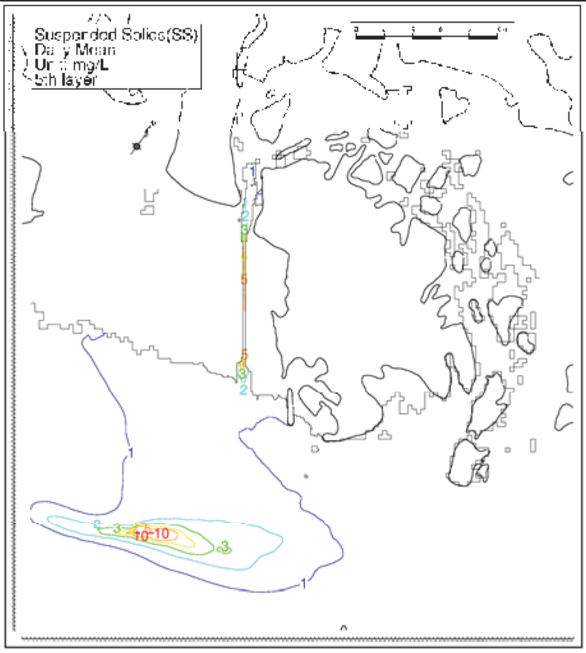
4th Layer (6-8m below surface)



Max. SS in the area :17.6mg/L

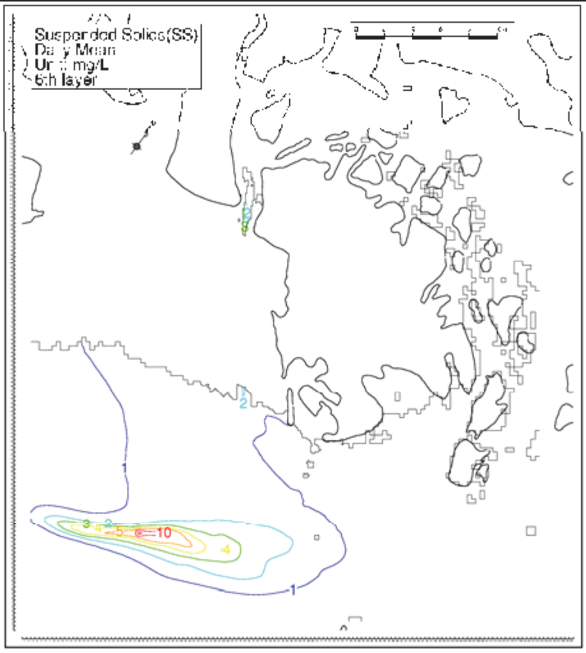
Figure 3.1 (1) SS Dispersion Prediction (Case 1, Daily Average, Medium Domain)

5th Layer (8-10m below surface)



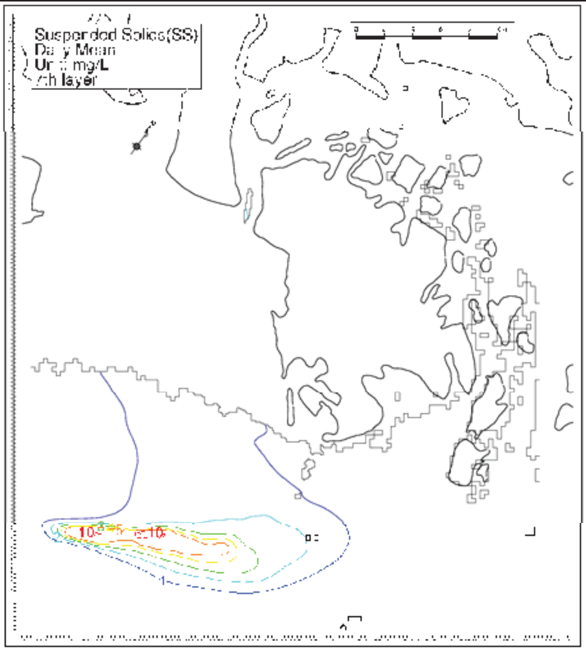
Max. SS in the area :24.2mg/L

6th Layer (10-12m below surface)



Max. SS in the area :28.1mg/L

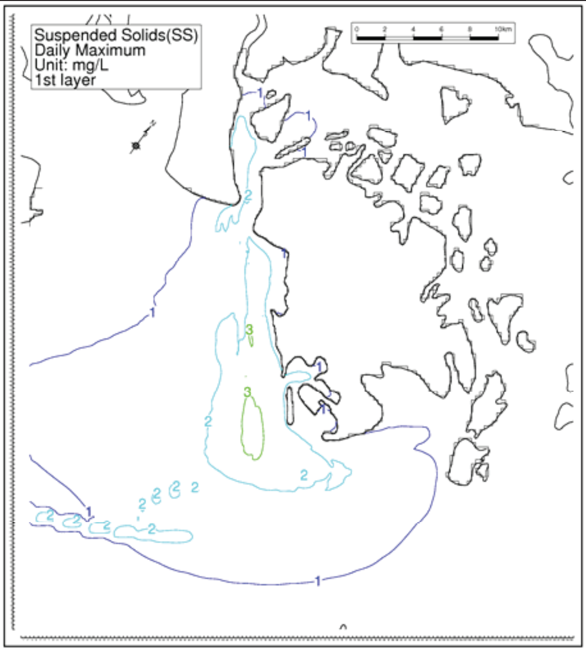
7th Layer (12m below surface-Bottom)



Max. SS in the area :27.7mg/L

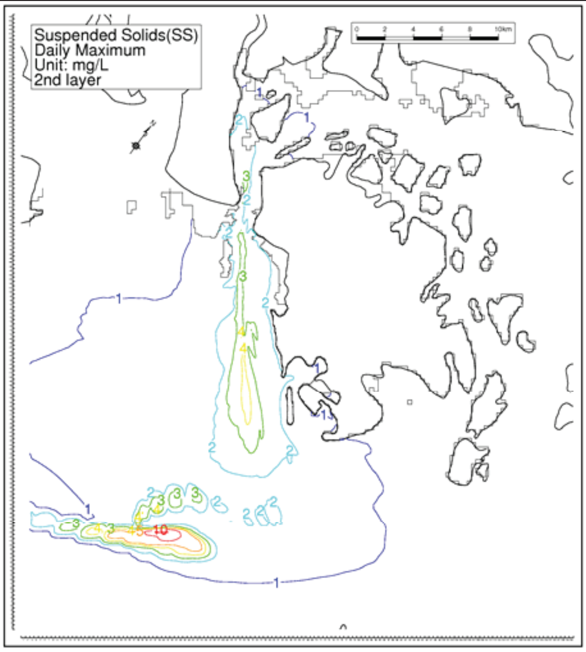
Figure 3.1 (2) SS Dispersion Prediction (Case 1, Daily Average, Medium Domain)

1st layer (0-2m below surface)



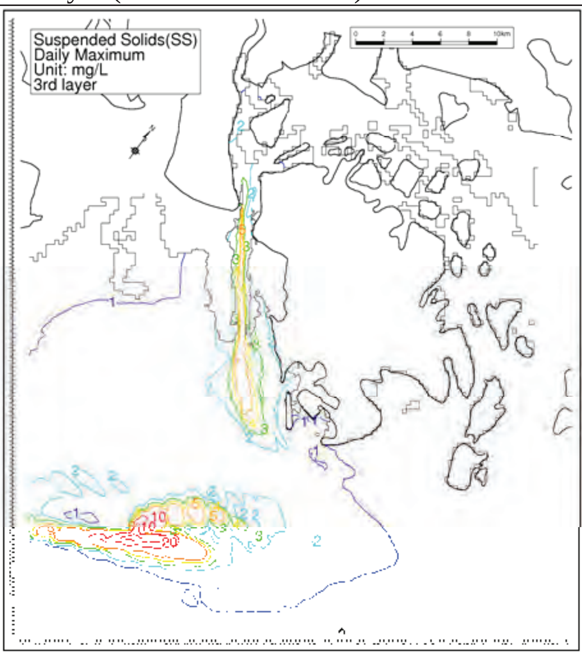
Max. SS in the area :3.3mg/L

2nd Layer (2-4m below surface)



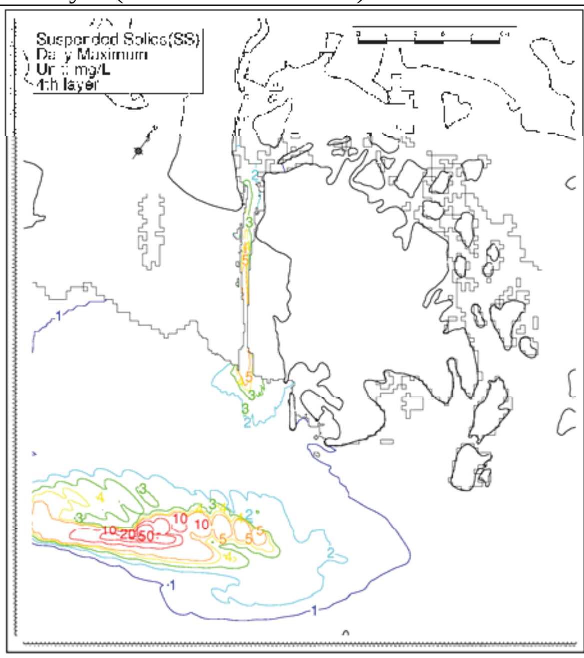
Max. SS in the area :23.2mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :63.3mg/L

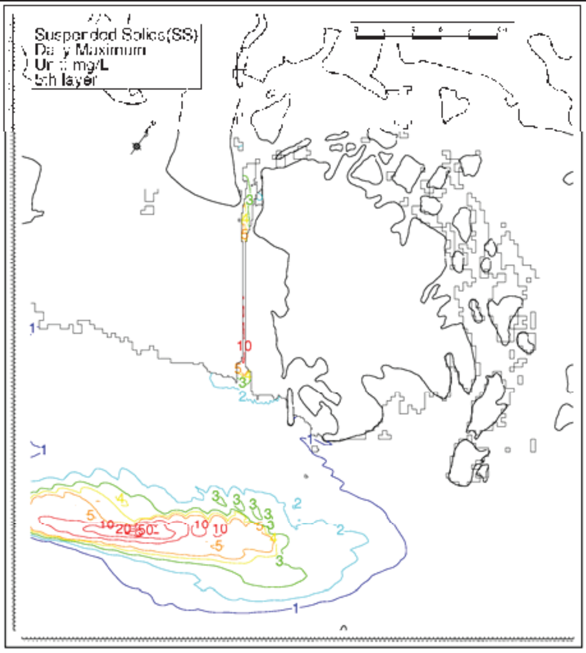
4th Layer (6-8m below surface)



Max. SS in the area :184.0mg/L

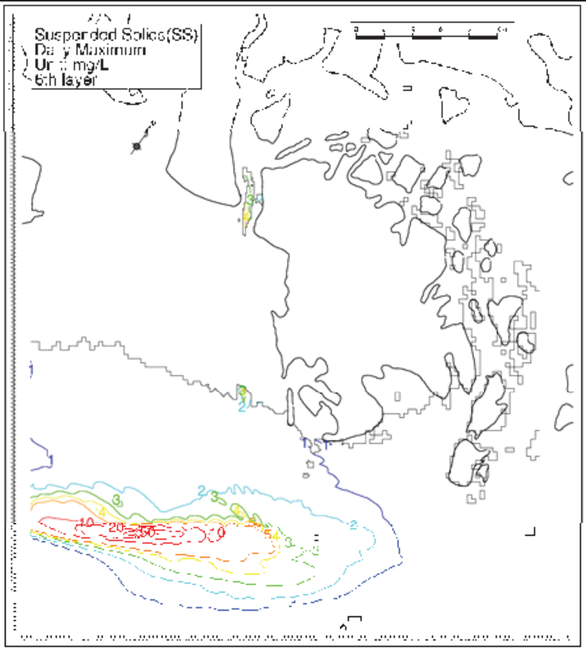
Figure 3.2 (1) SS Dispersion Prediction (Case 1, Daily Maximum, Medium Domain)

5th Layer (8-10m below surface)



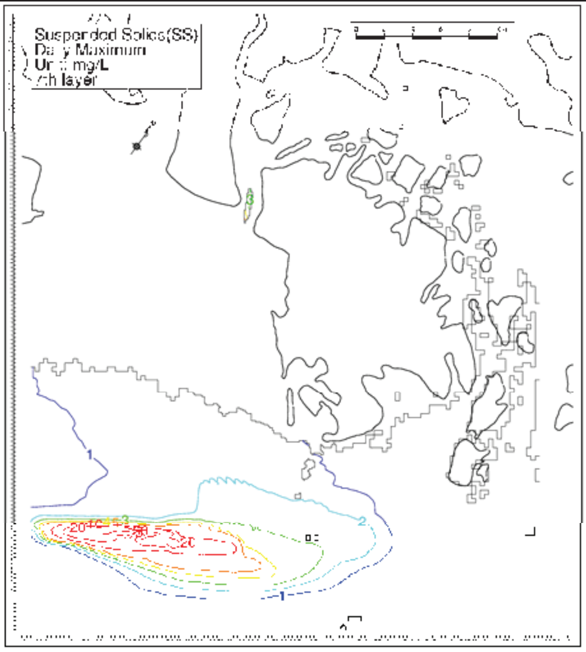
Max. SS in the area :241.0mg/L

6th Layer (10-12m below surface)



Max. SS in the area :264.0mg/L

7th Layer (12m below surface-Bottom)



Max. SS in the area :230.0mg/L

Figure 3.2 (2) SS Dispersion Prediction (Case 1, Daily Maximum, Medium Domain)

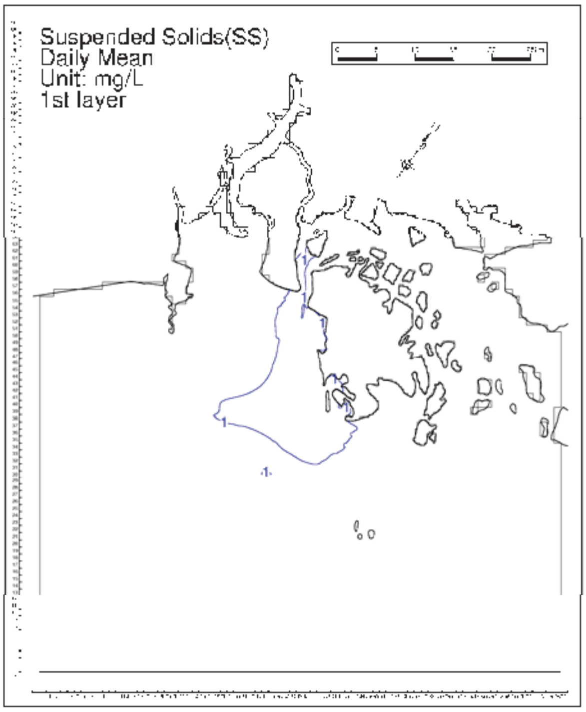
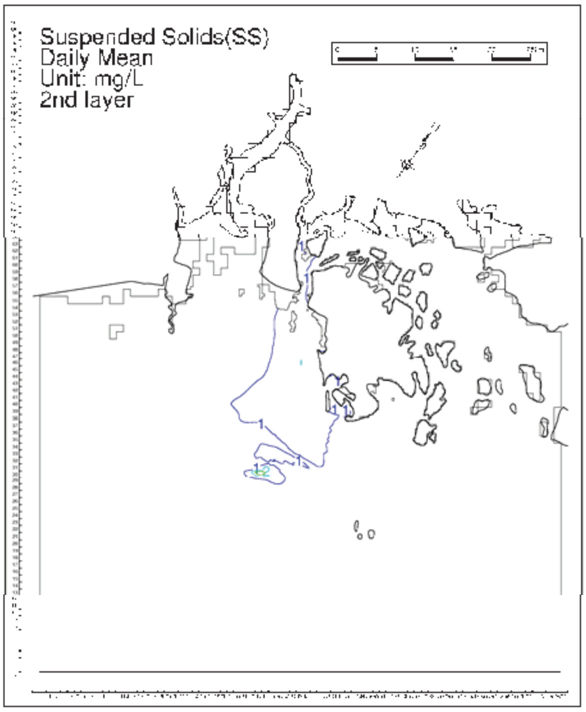
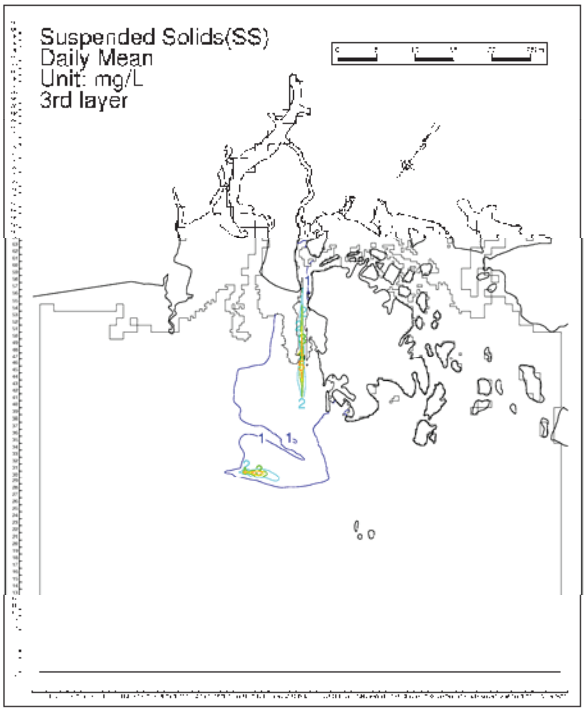
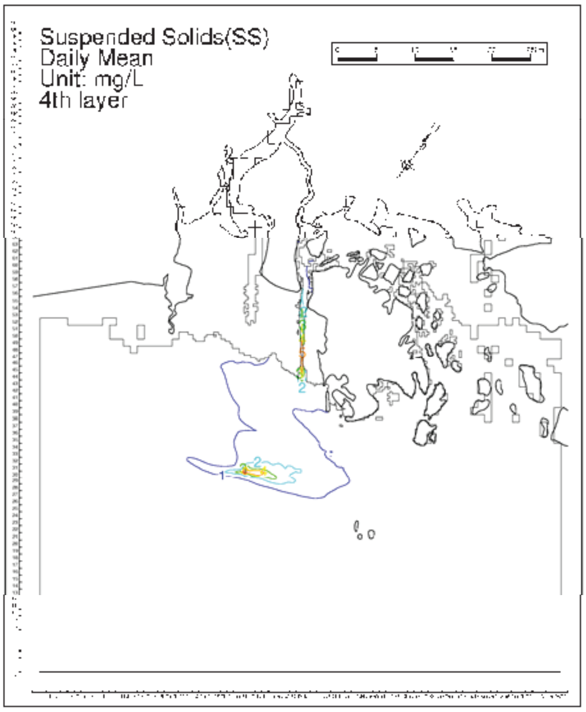
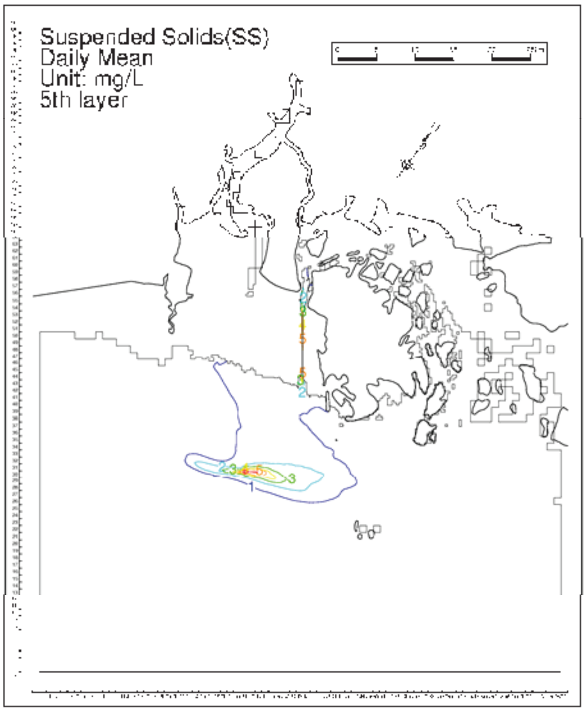
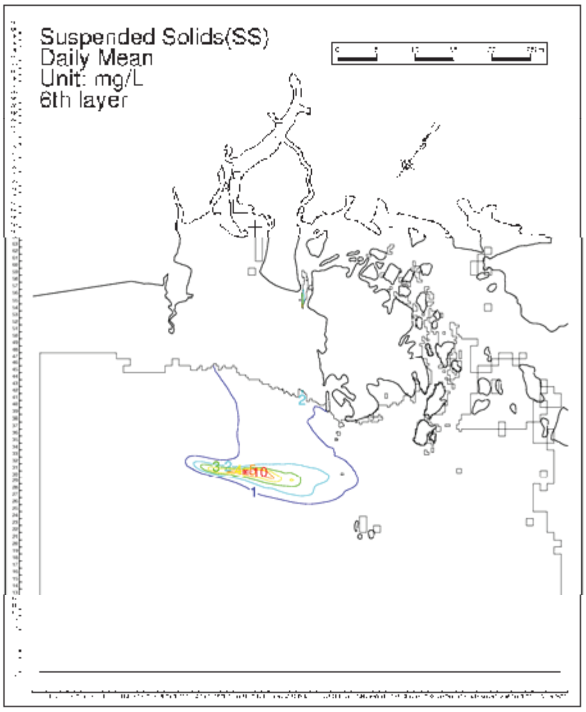
1st layer (0-2m below surface)	2nd Layer (2-4m below surface)
	
3rd Layer (4-6m below surface)	4th Layer (6-8m below surface)
	

Figure 3.3 (1) SS Dispersion Prediction (Case 1, Daily Average, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

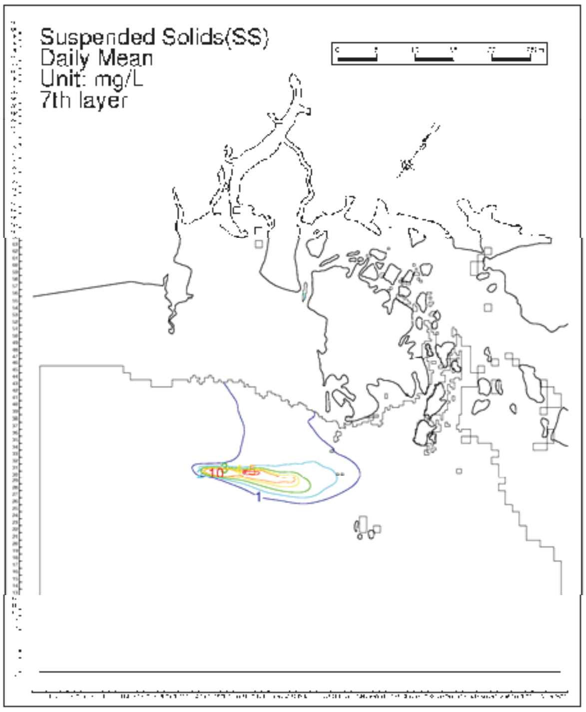
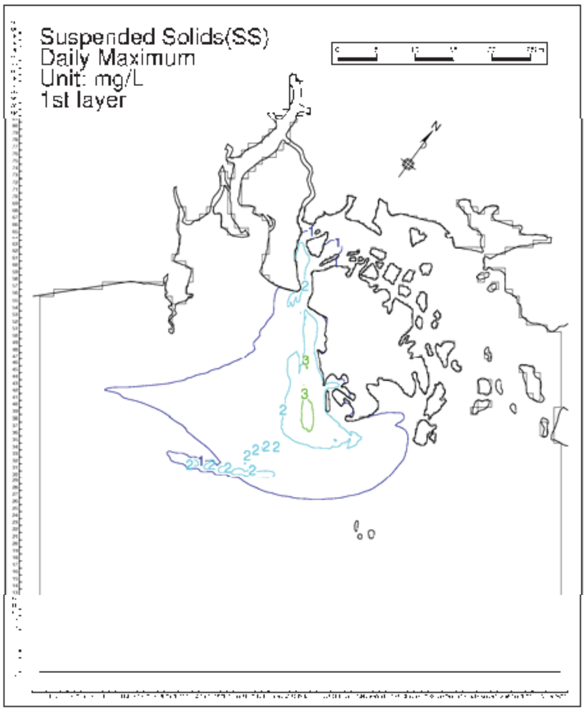
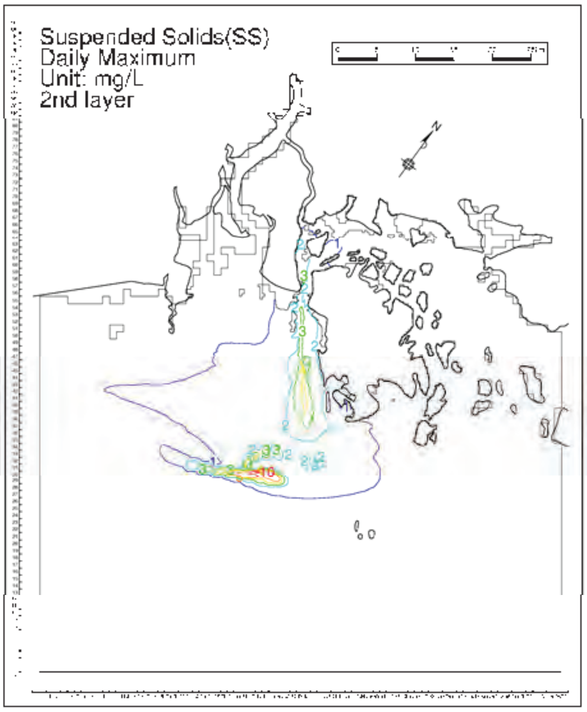


Figure 3.3 (2) SS Dispersion Prediction (Case 1, Daily Average, Large Domain)

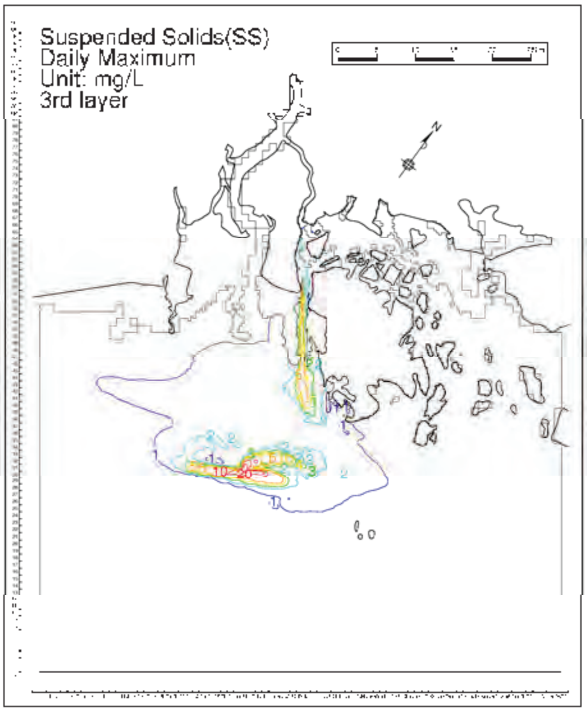
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

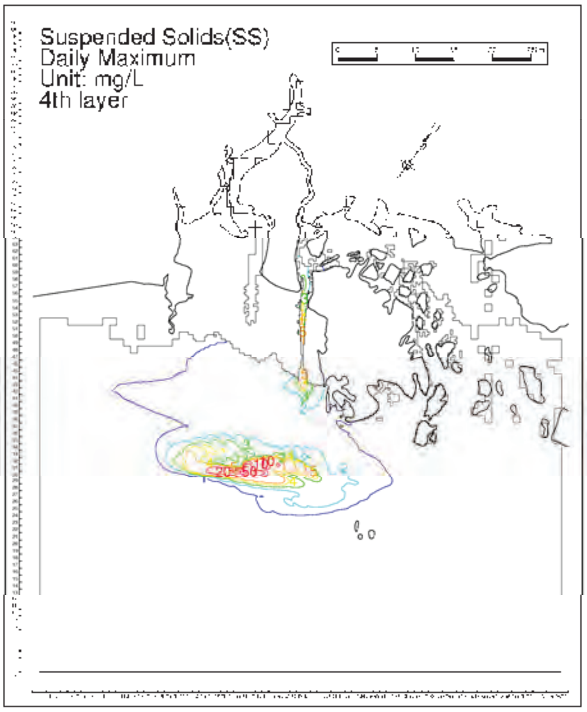
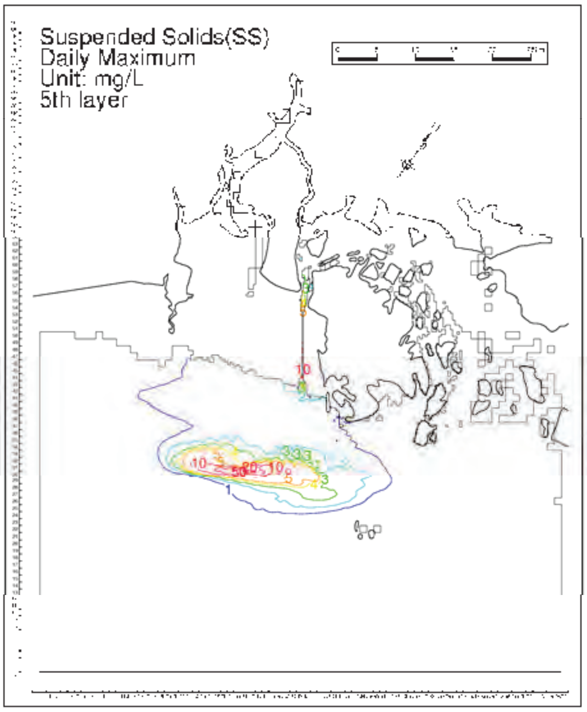
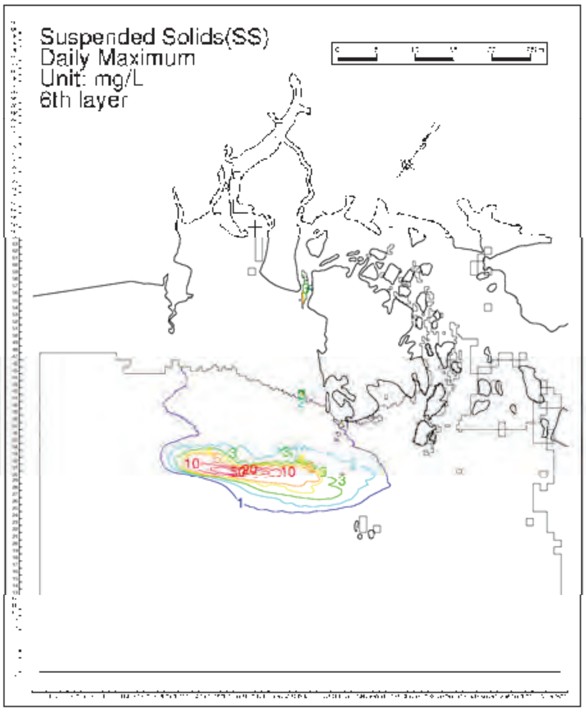


Figure 3.4 (1) SS Dispersion Prediction (Case 1, Daily Maximum, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

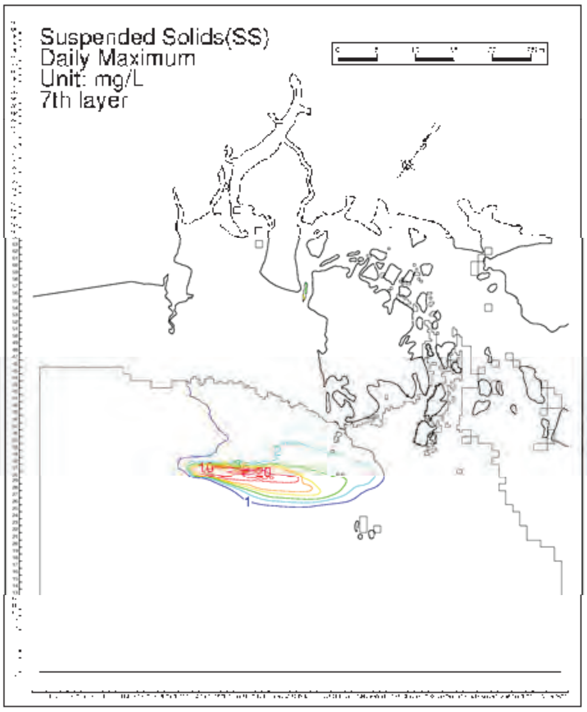
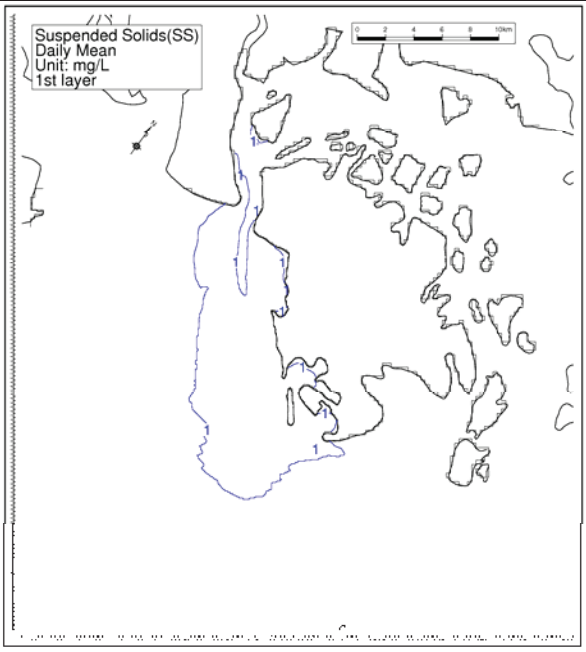


Figure 3.4 (2) SS Dispersion Prediction (Case 1, Daily Maximum, Large Domain)

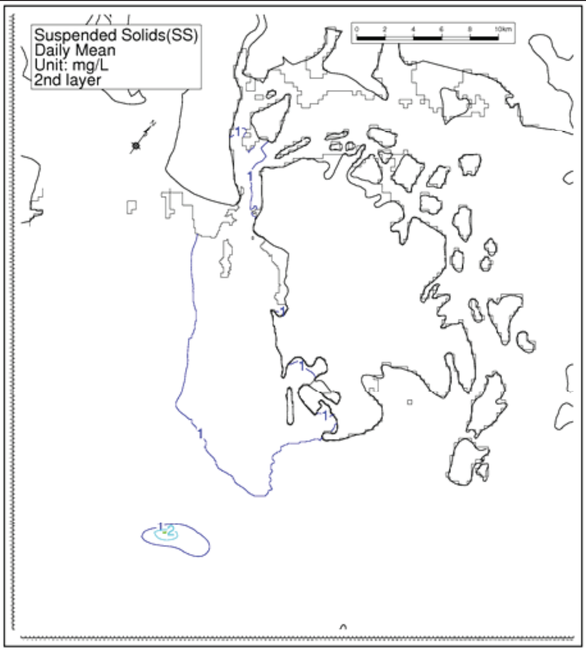
3.2 Case 2

1st layer (0-2m below surface)



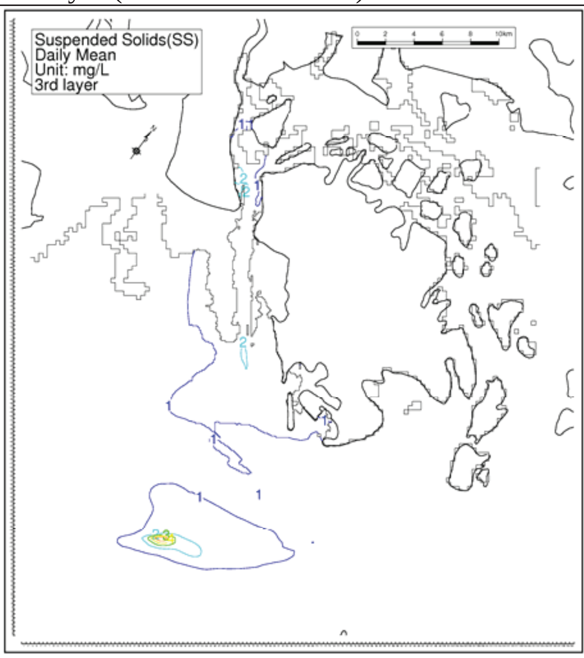
Max. SS in the area :1.8mg/L

2nd Layer (2-4m below surface)



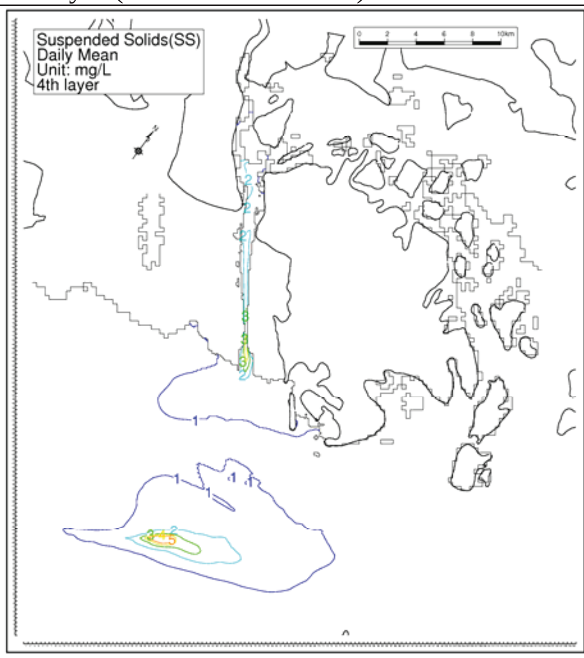
Max. SS in the area :3.1mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :6.1mg/L

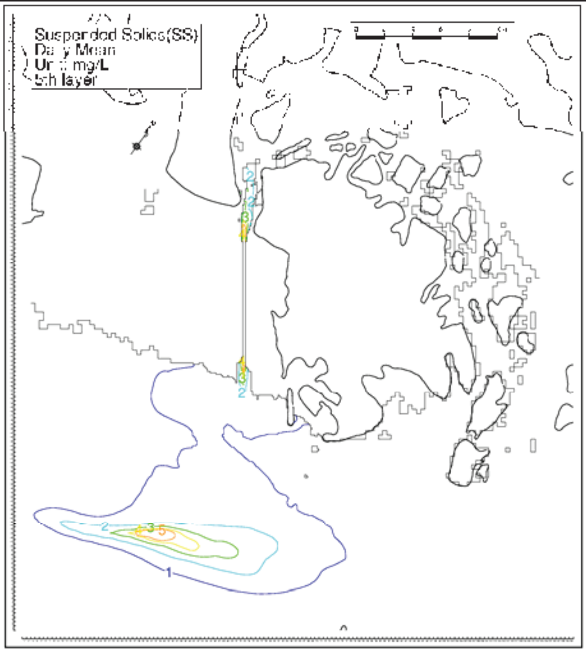
4th Layer (6-8m below surface)



Max. SS in the area :7.9mg/L

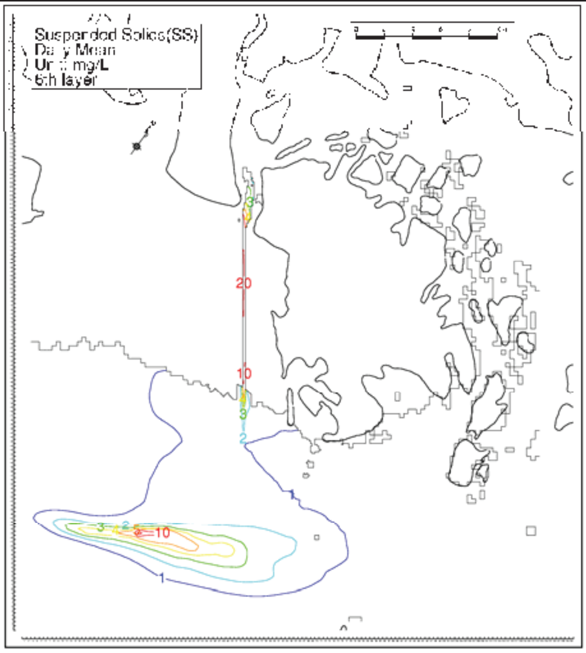
Figure 3.5 (1) SS Dispersion Prediction (Case 2, Daily Average, Medium Domain)

5th Layer (8-10m below surface)



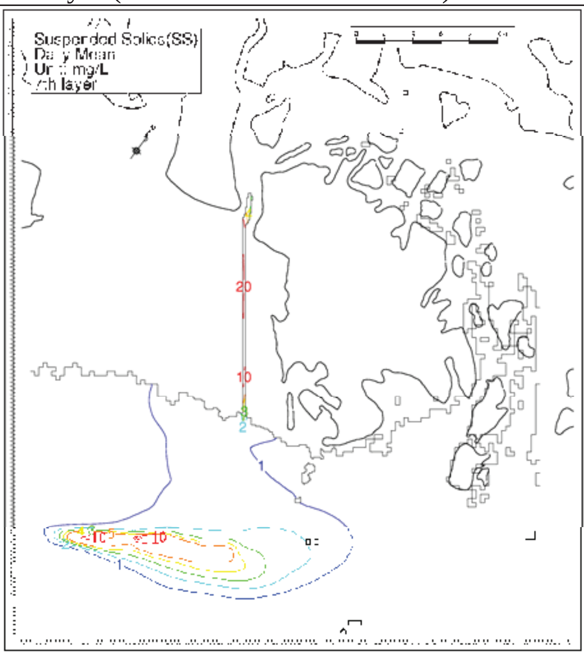
Max. SS in the area :9.8mg/L

6th Layer (10-12m below surface)



Max. SS in the area :29.1mg/L

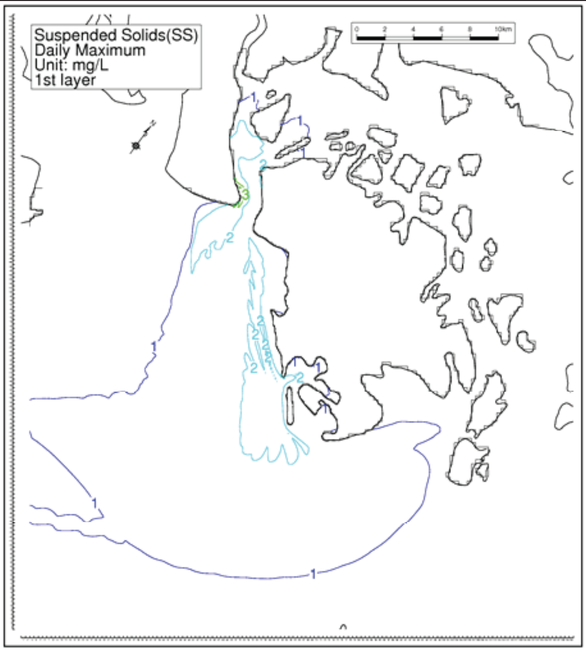
7th Layer (12m below surface-Bottom)



Max. SS in the area :32.3mg/L

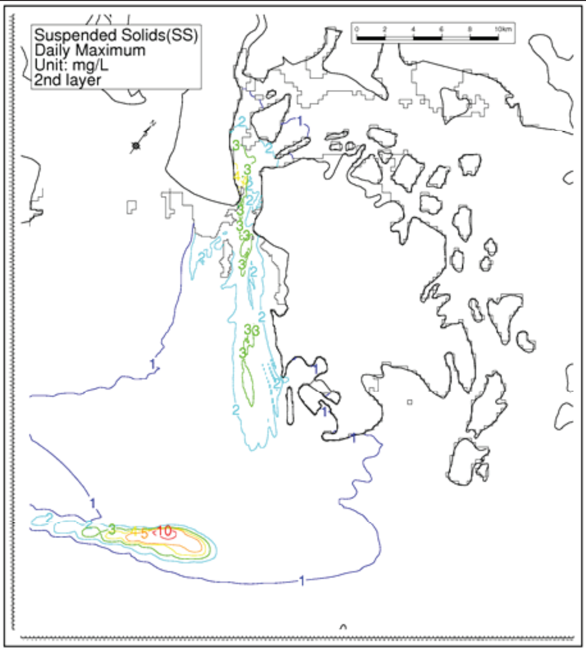
Figure 3.5 (2) SS Dispersion Prediction (Case 2, Daily Average, Medium Domain)

1st layer (0-2m below surface)



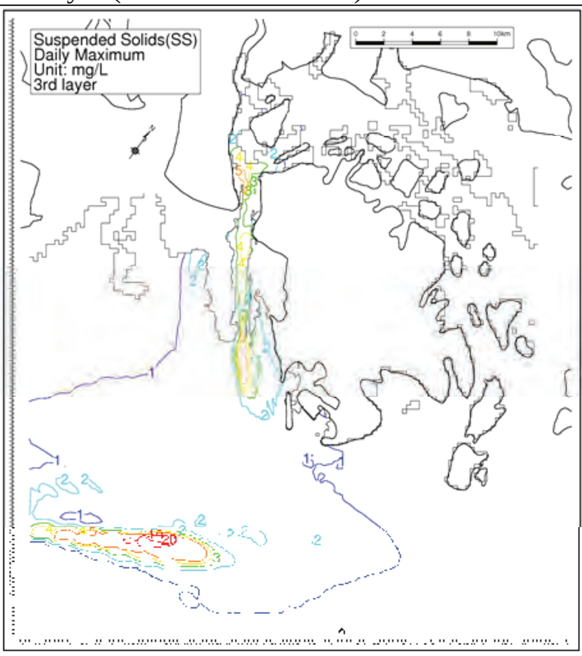
Max. SS in the area :3.7mg/L

2nd Layer (2-4m below surface)



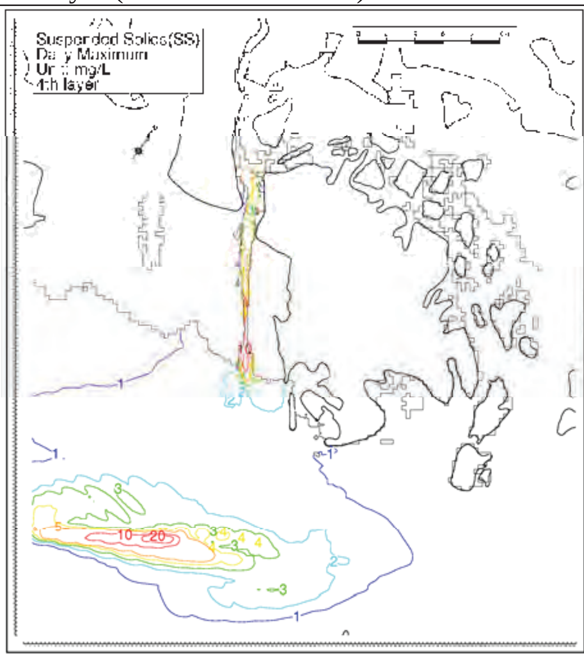
Max. SS in the area :16.0mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :34.0mg/L

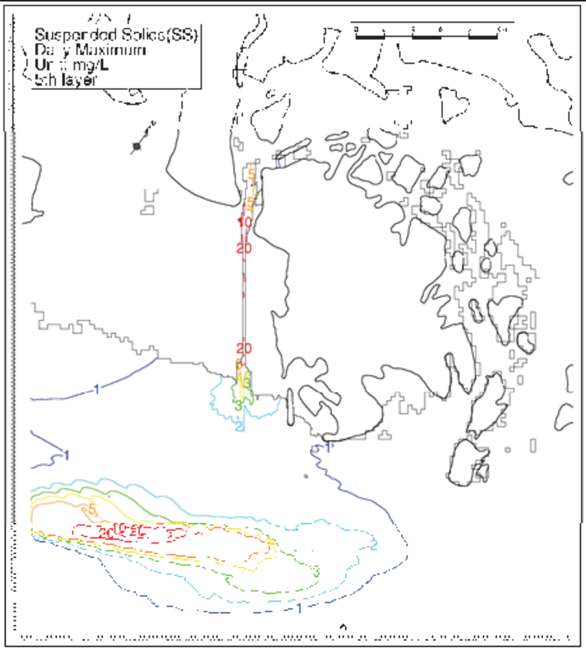
4th Layer (6-8m below surface)



Max. SS in the area :42.7mg/L

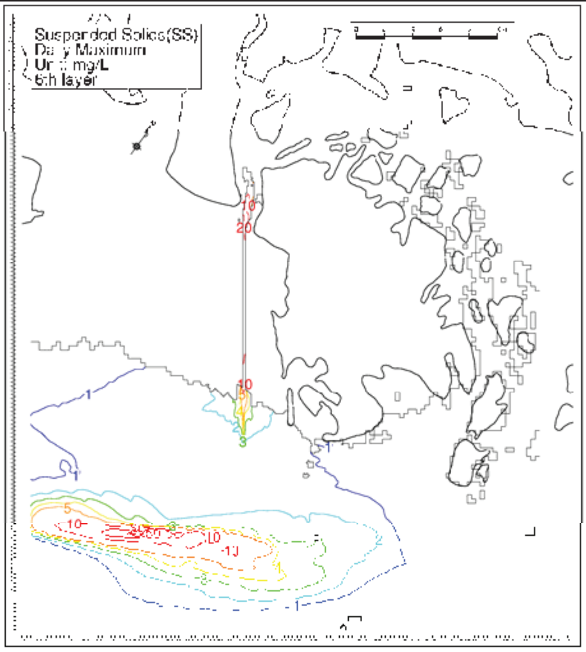
Figure 3.6 (1) SS Dispersion Prediction (Case 2, Daily Maximum, Medium Domain)

5th Layer (8-10m below surface)



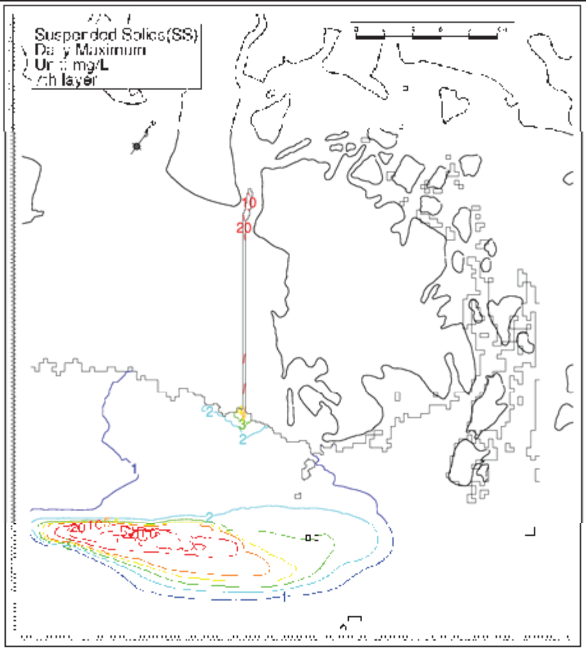
Max. SS in the area :55.6mg/L

6th Layer (10-12m below surface)



Max. SS in the area :314.0mg/L

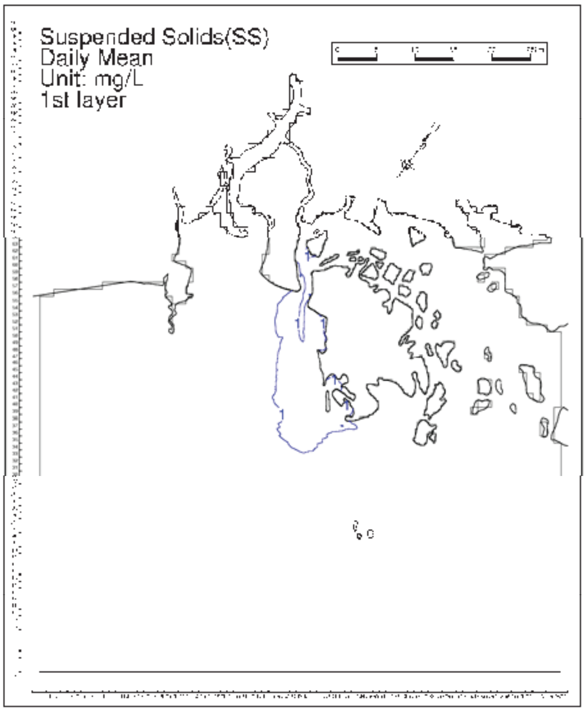
7th Layer (12m below surface-Bottom)



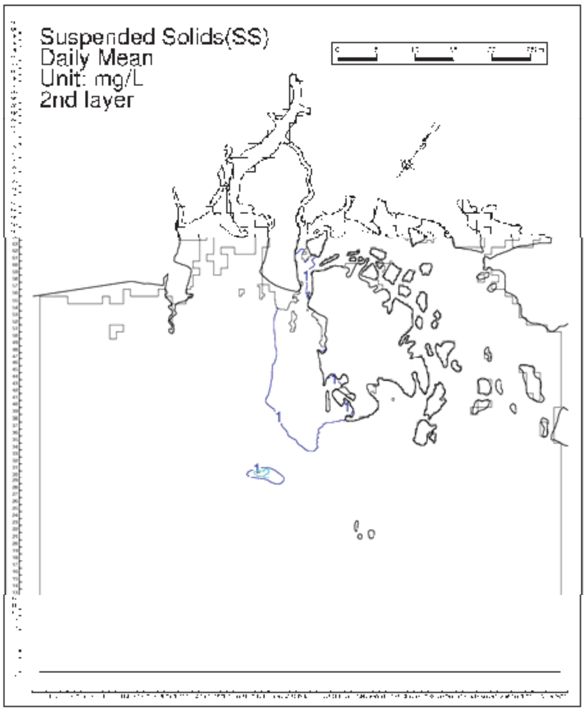
Max. SS in the area :282.0mg/L

Figure 3.6 (2) SS Dispersion Prediction (Case 2, Daily Maximum, Medium Domain)

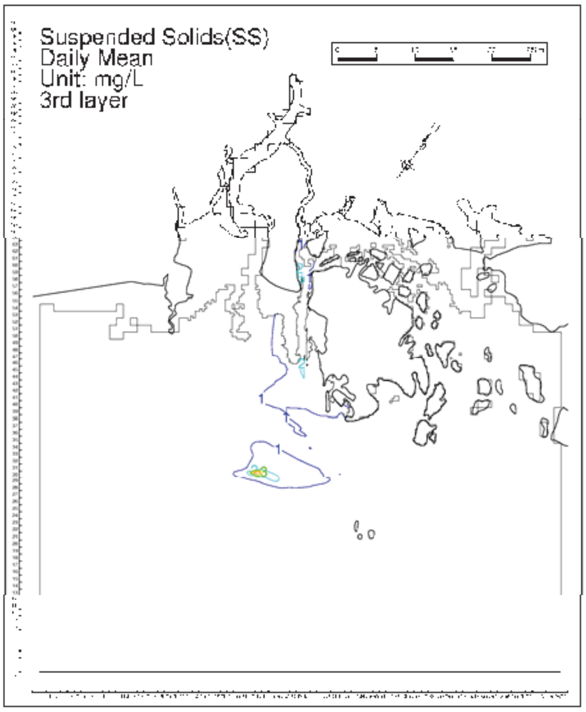
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

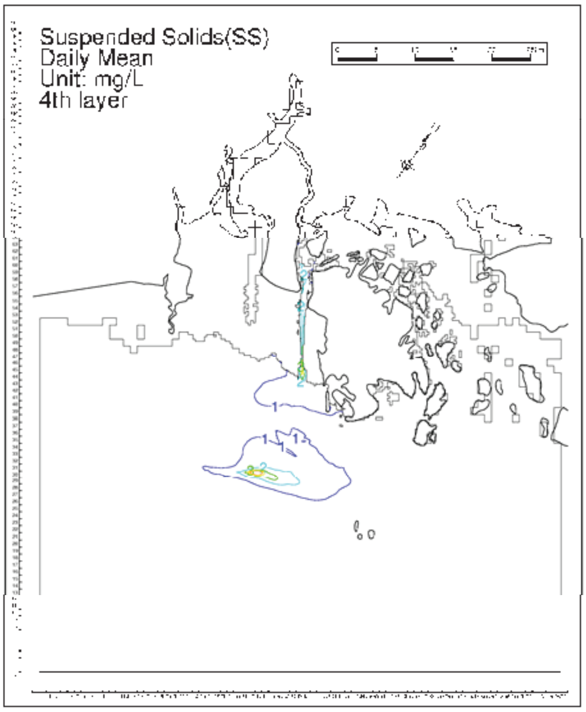
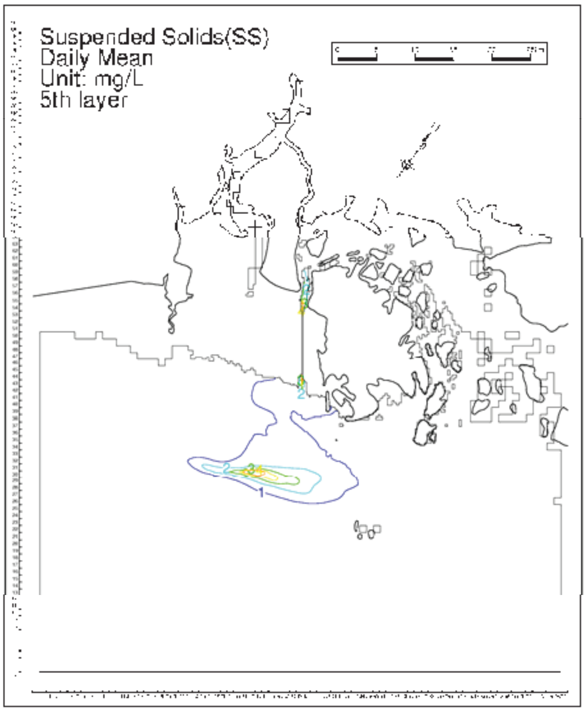
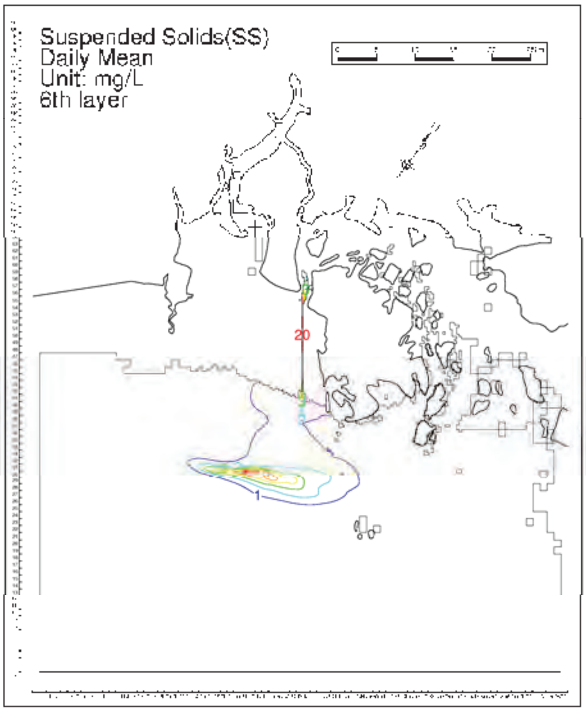


Figure 3.7 (1) SS Dispersion Prediction (Case 2, Daily Average, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

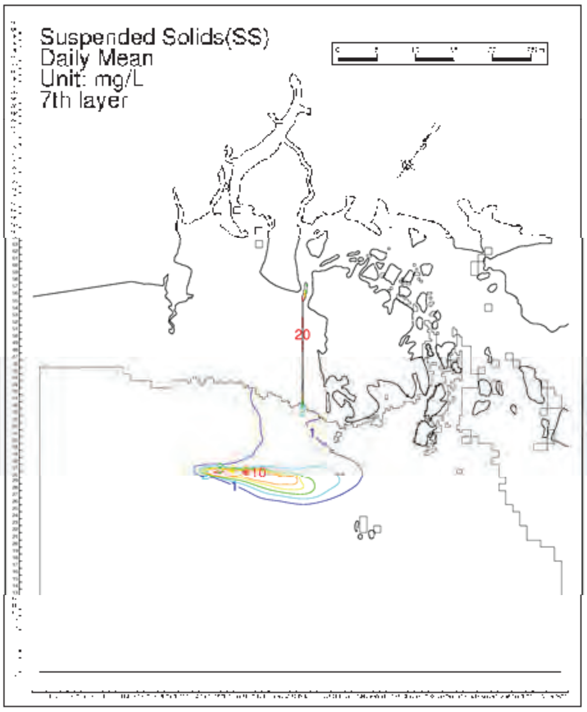
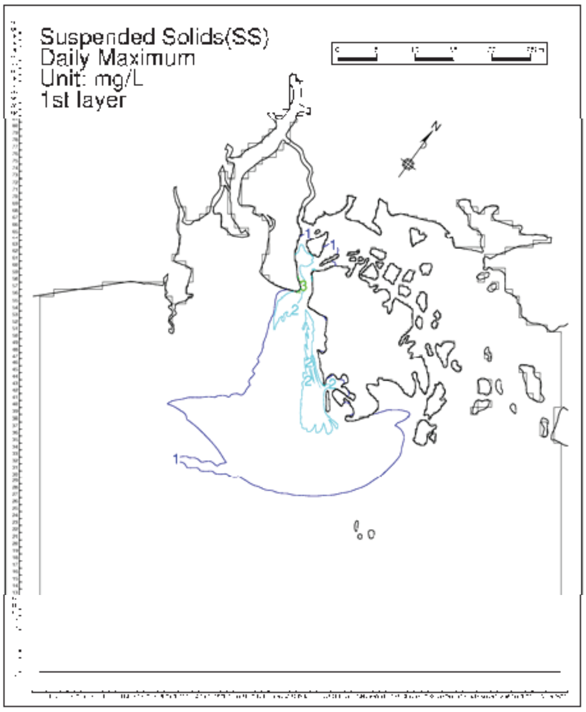
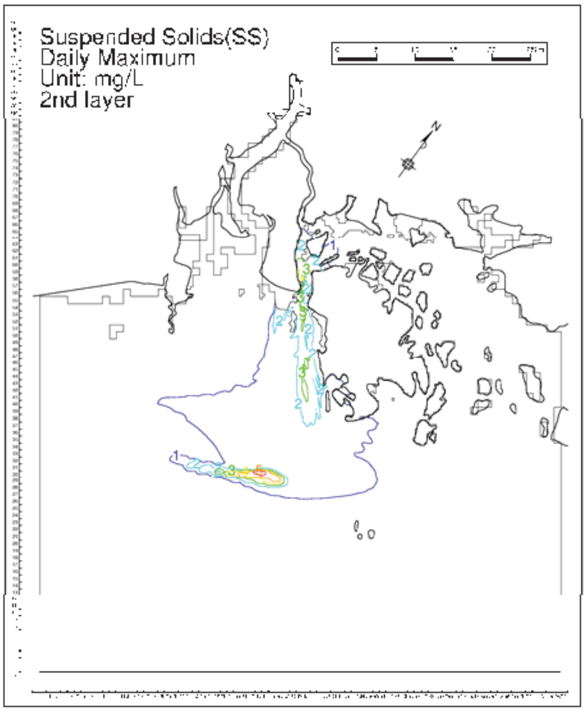


Figure 3.7 (2) SS Dispersion Prediction (Case 2, Daily Average, Large Domain)

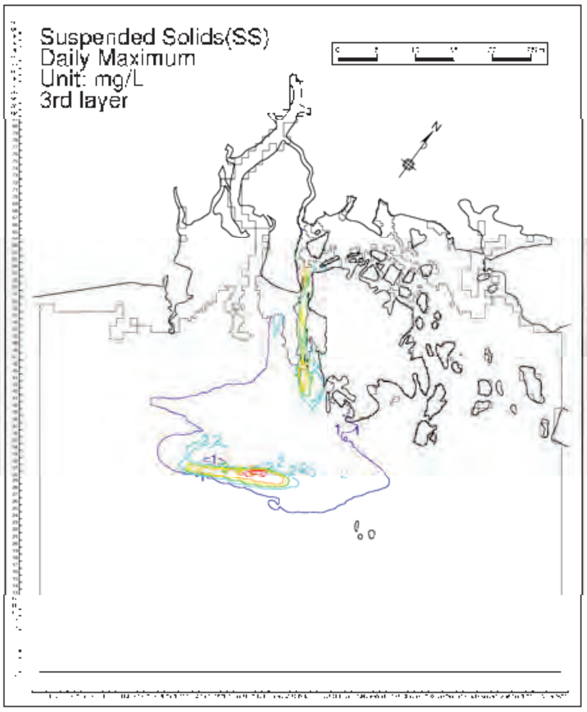
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

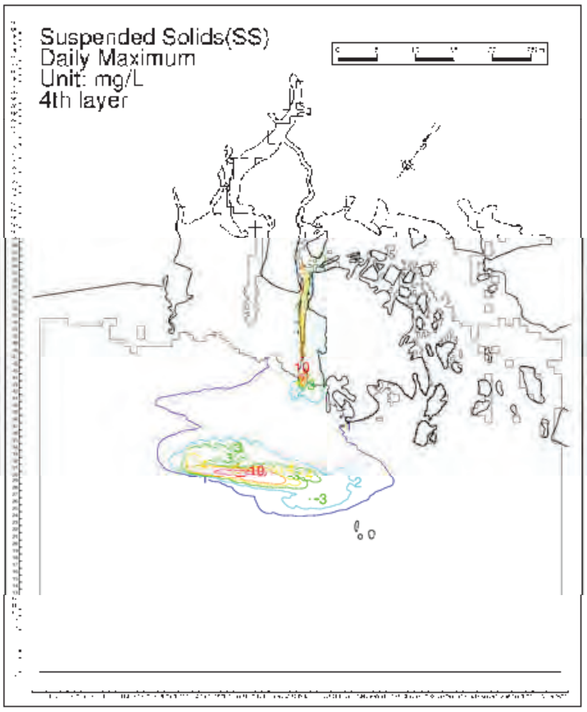
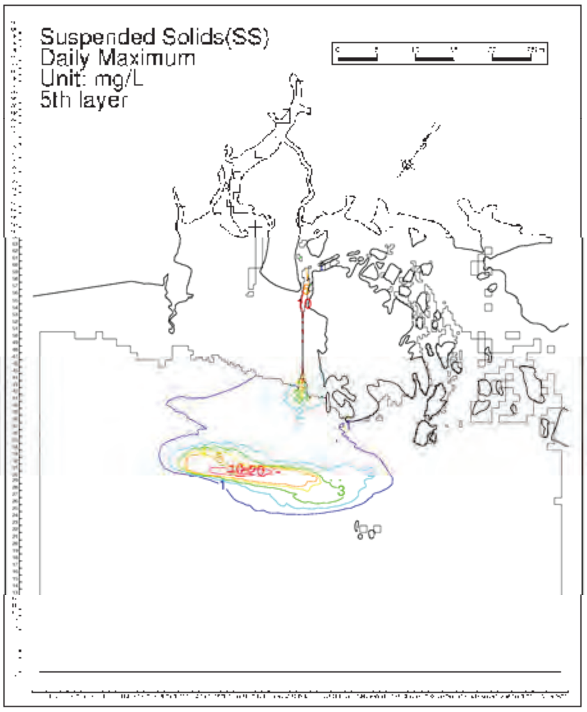
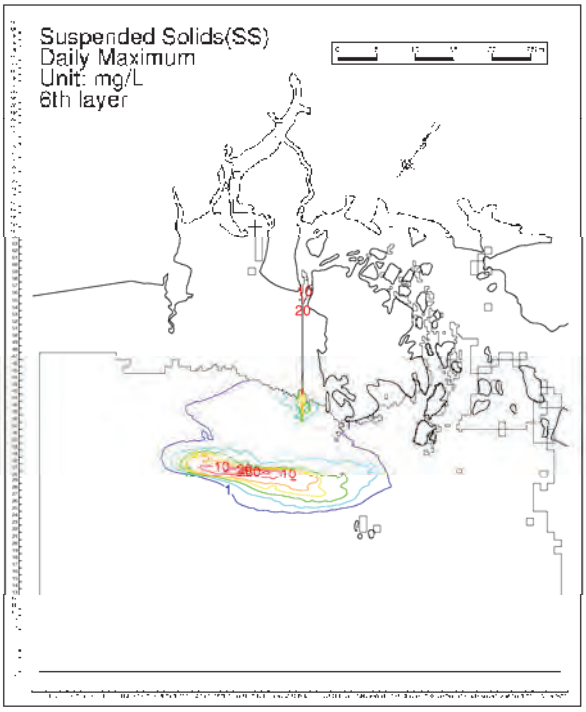


Figure 3.8 (1) SS Dispersion Prediction (Case 2, Daily Maximum, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

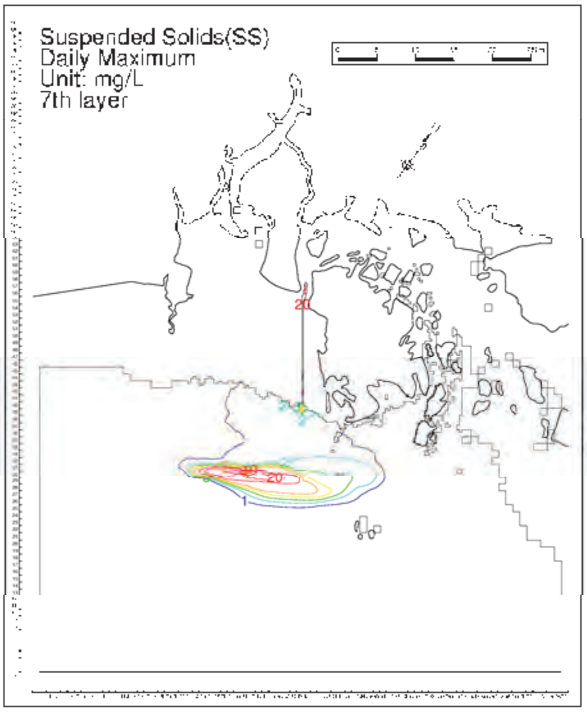
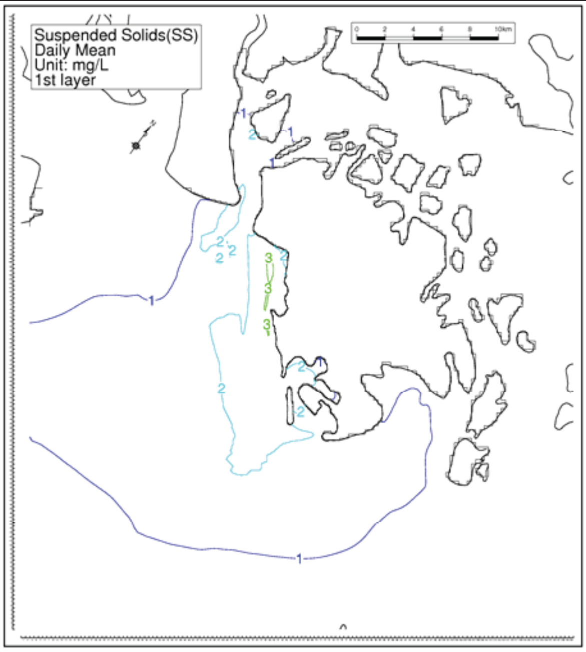


Figure 3.8 (2) SS Dispersion Prediction (Case 2, Daily Maximum, Large Domain)

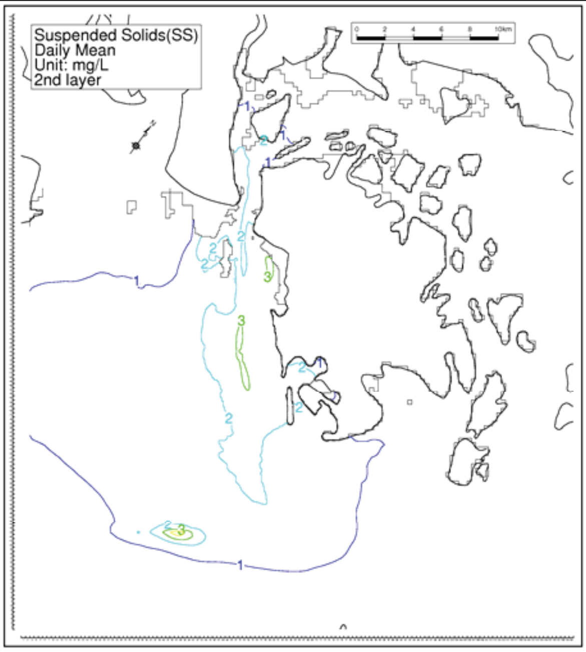
3.3 Case 3

1st layer (0-2m below surface)



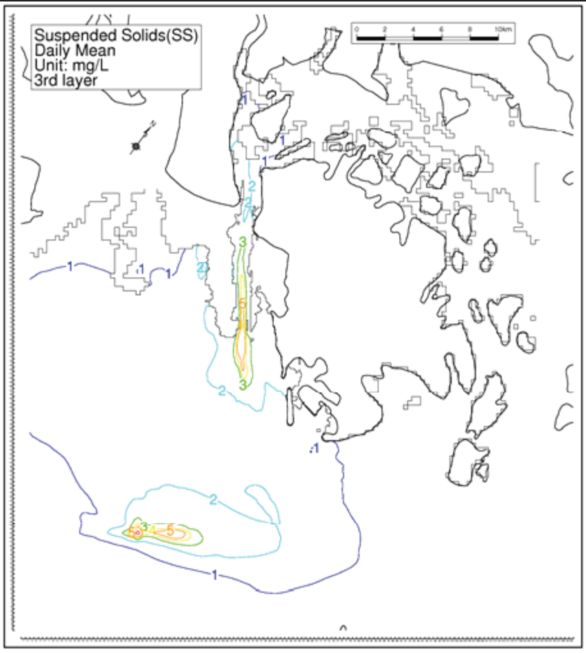
Max. SS in the area :3.1mg/L

2nd Layer (2-4m below surface)



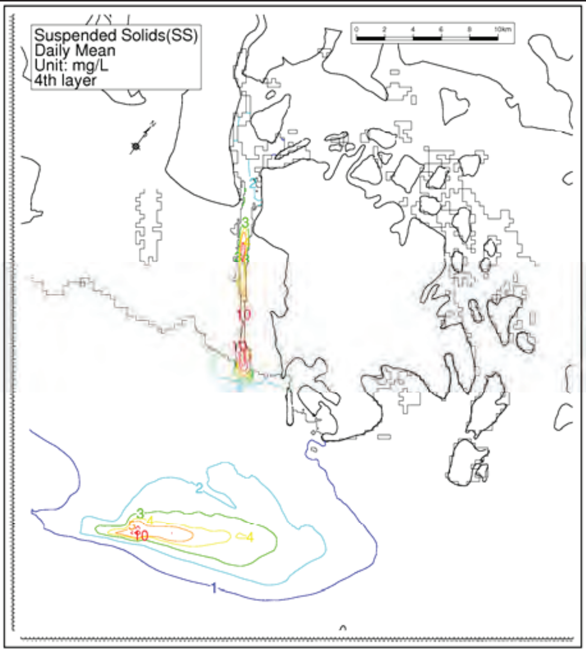
Max. SS in the area :4.5mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :14.8mg/L

4th Layer (6-8m below surface)



Max. SS in the area :47.7mg/L

Figure 3.9 (1) SS Dispersion Prediction (Case 3, Daily Average, Medium Domain)

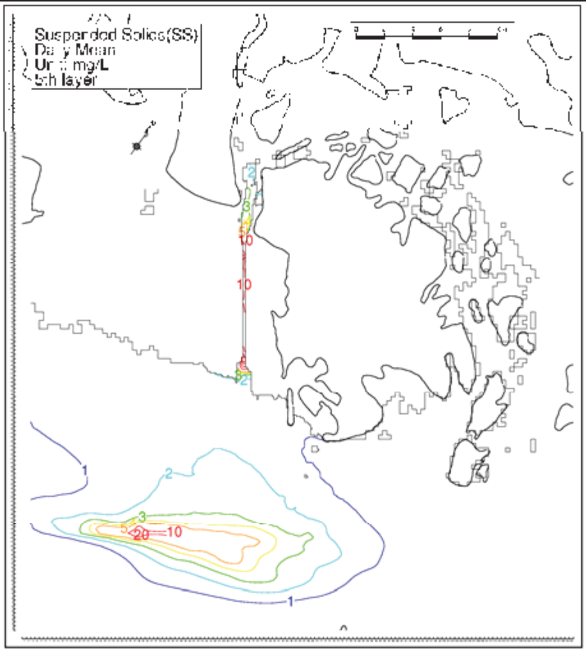
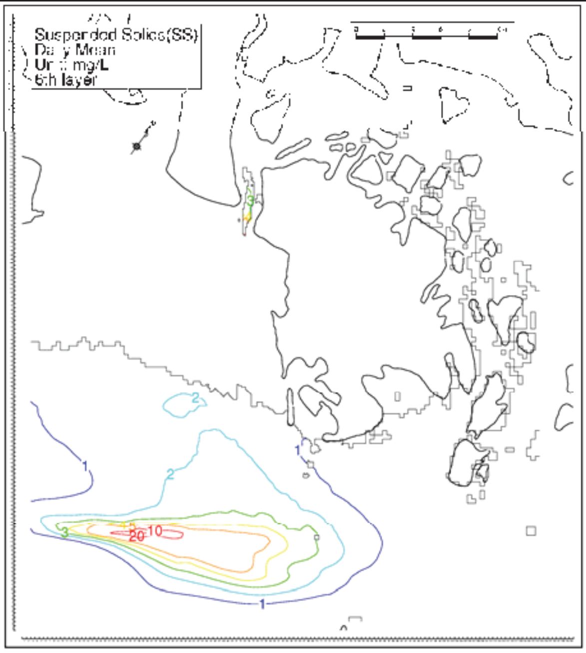
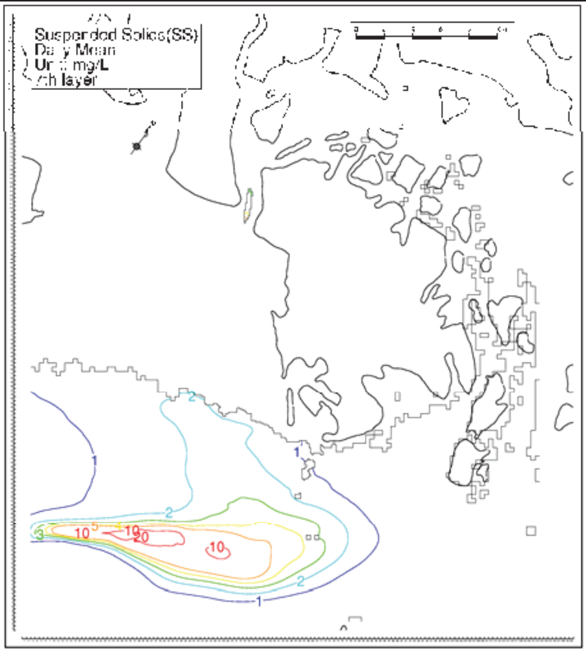
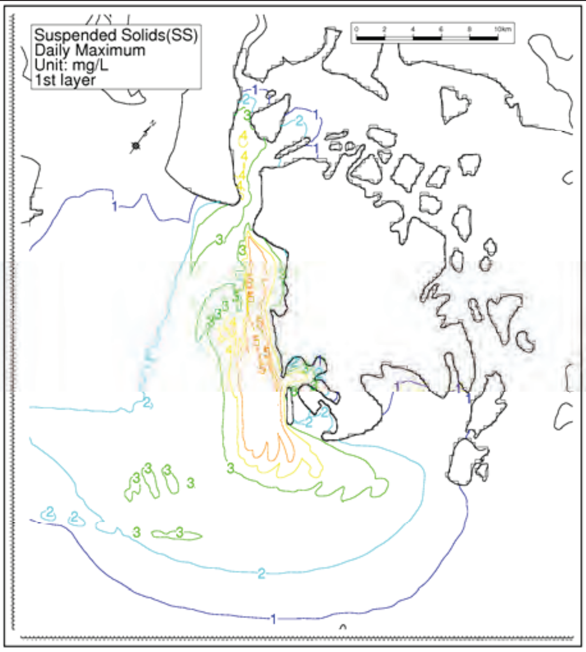
5th Layer (8-10m below surface)	6th Layer (10-12m below surface)
	
Max. SS in the area :574mg/L	Max. SS in the area :55.9mg/L
7th Layer (12m below surface-Bottom)	
	
Max. SS in the area :54.2mg/L	

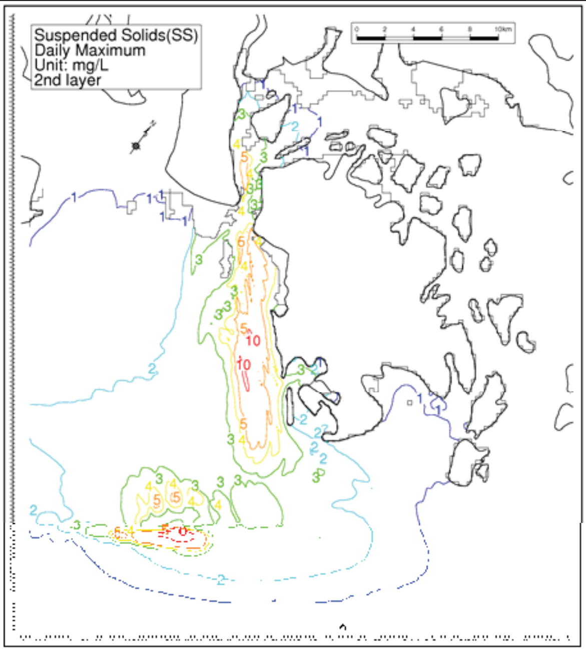
Figure 3.9 (2) SS Dispersion Prediction (Case 3, Daily Average, Medium Domain)

1st layer (0-2m below surface)



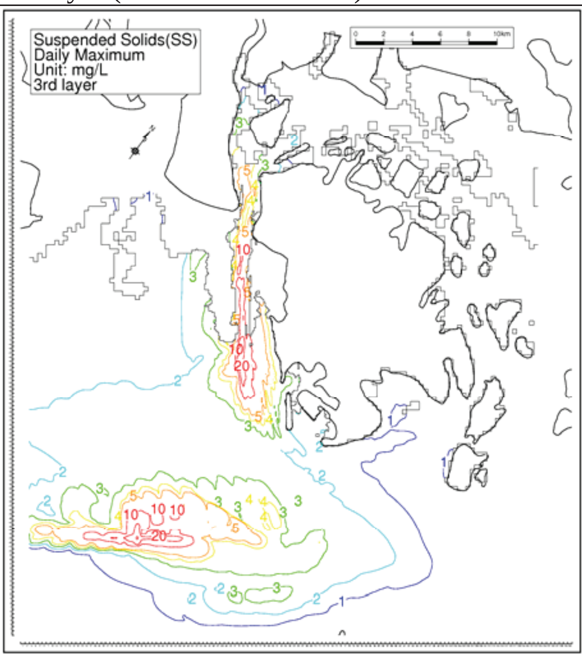
Max. SS in the area :7.8mg/L

2nd Layer (2-4m below surface)



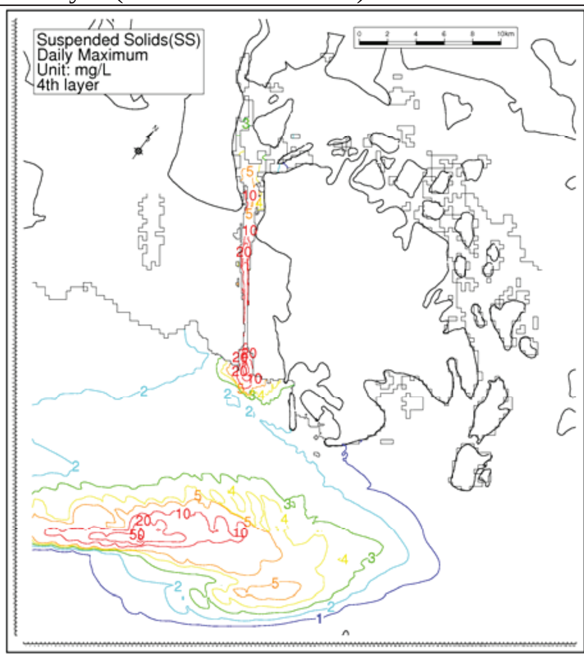
Max. SS in the area :17.5mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :61.6mg/L

4th Layer (6-8m below surface)



Max. SS in the area :149mg/L

Figure 3.10 (1) SS Dispersion Prediction (Case 3, Daily Maximum, Medium Domain)

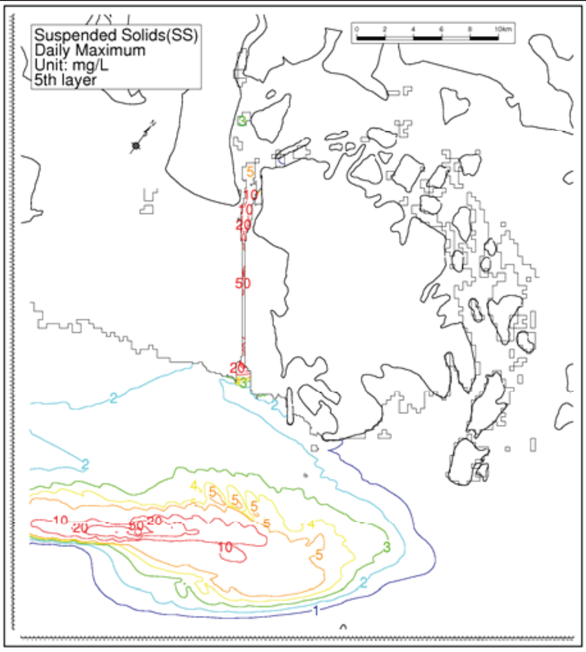
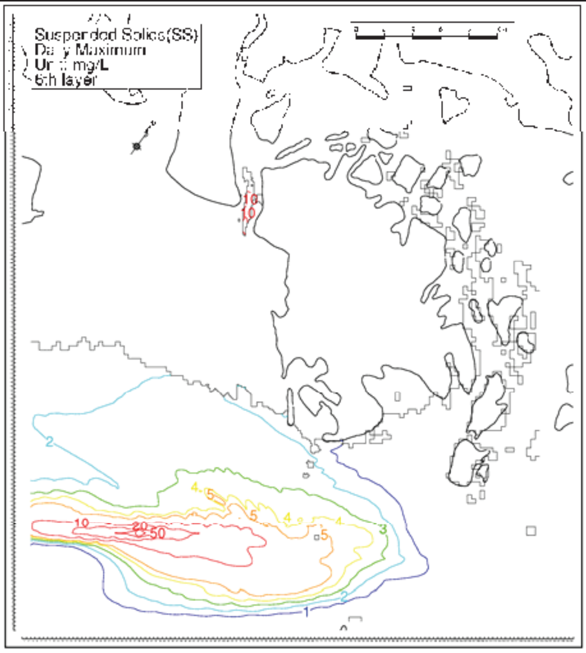
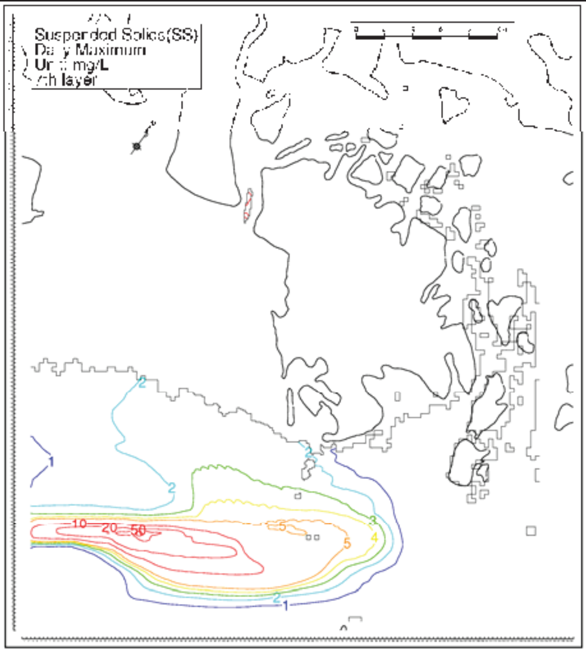
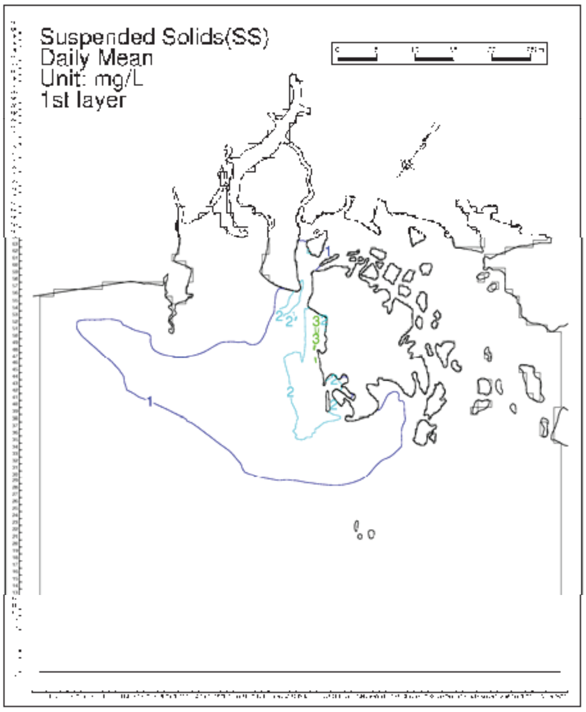
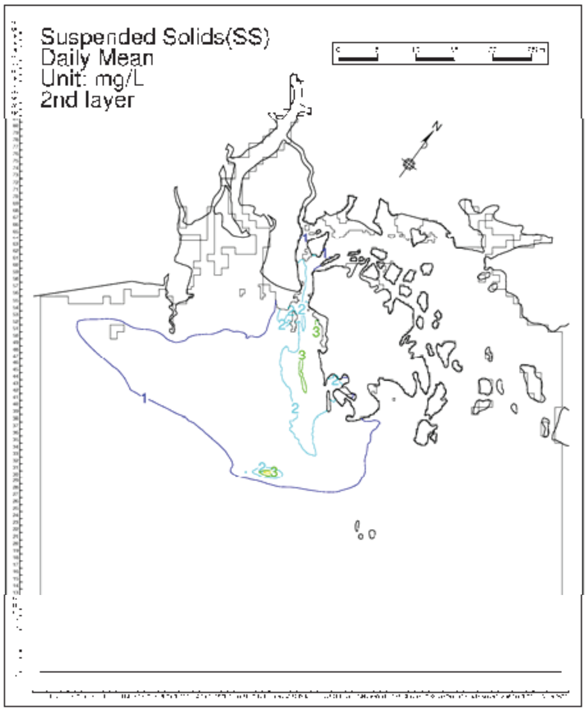
<table>
<tr><td>5th Layer (8-10m below surface)</td><td>6th Layer (10-12m below surface)</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Max. SS in the area :721mg/L</td><td>Max. SS in the area :266mg/L</td></tr>
<tr><td>7th Layer (12m below surface-Bottom)</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Max. SS in the area :190mg/L</td><td></td></tr>
</table>

Figure 3.10 (2) SS Dispersion Prediction (Case 3, Daily Maximum, Medium Domain)

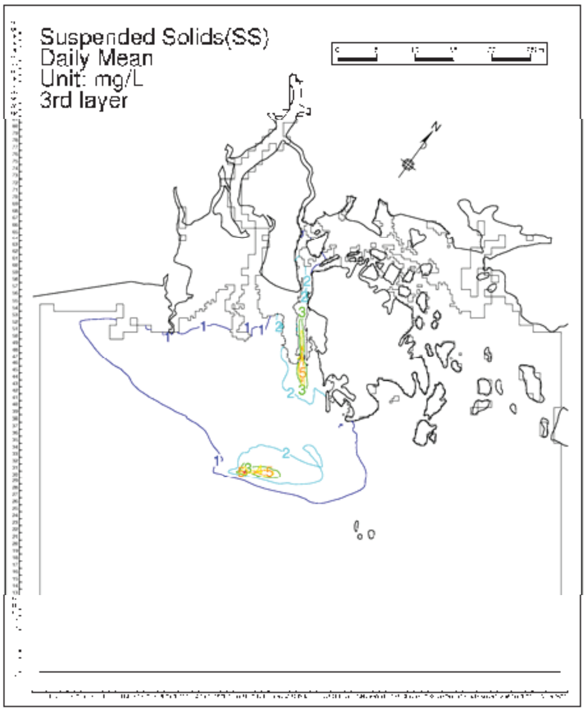
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

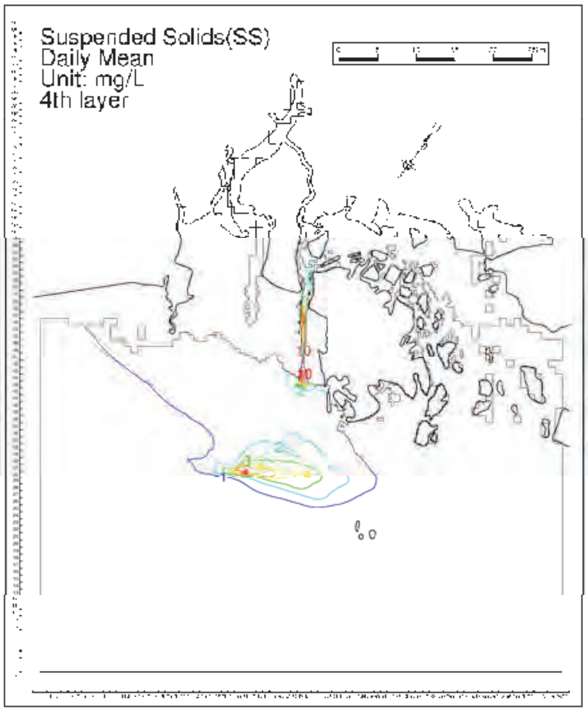
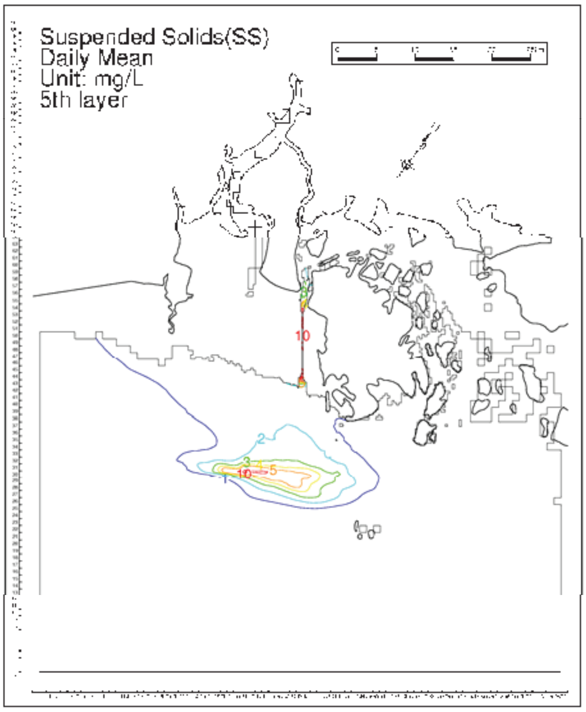
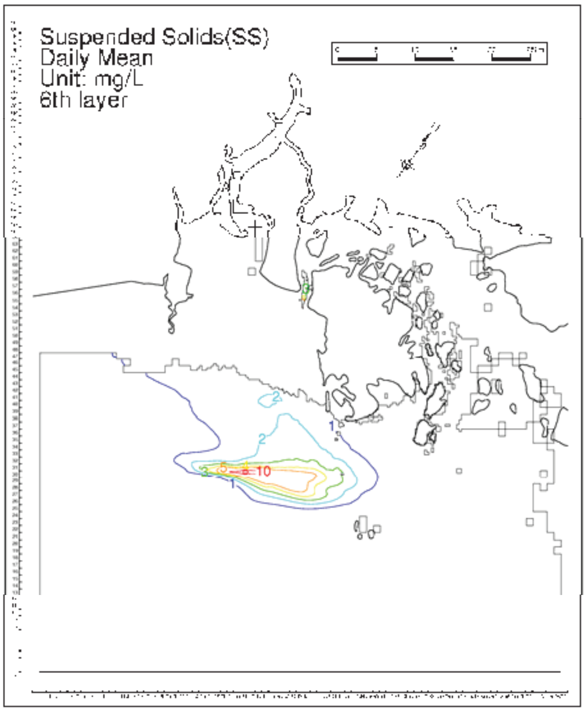


Figure 3.11 (1) SS Dispersion Prediction (Case 3, Daily Average, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

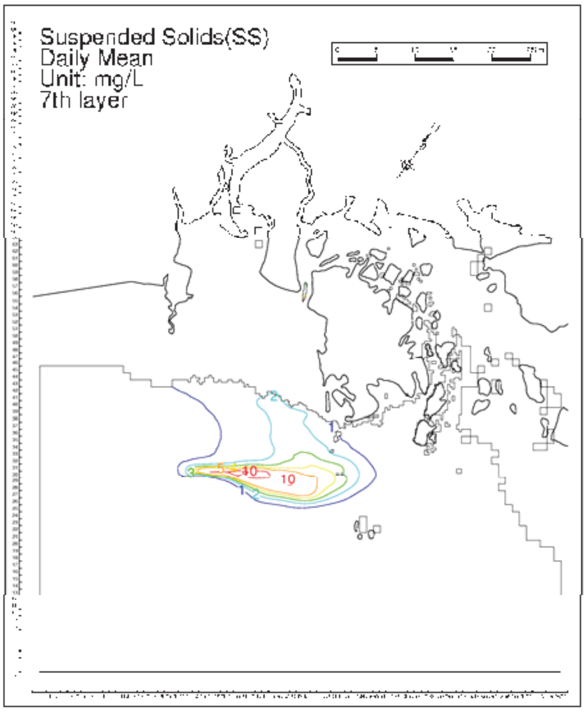
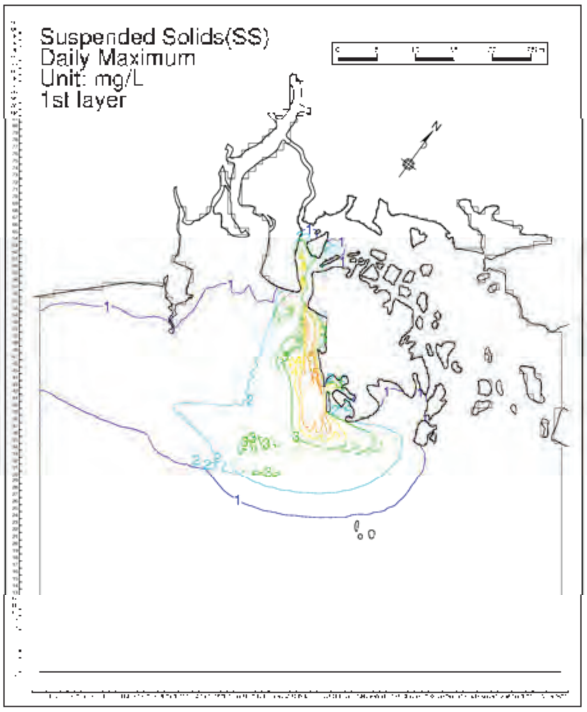
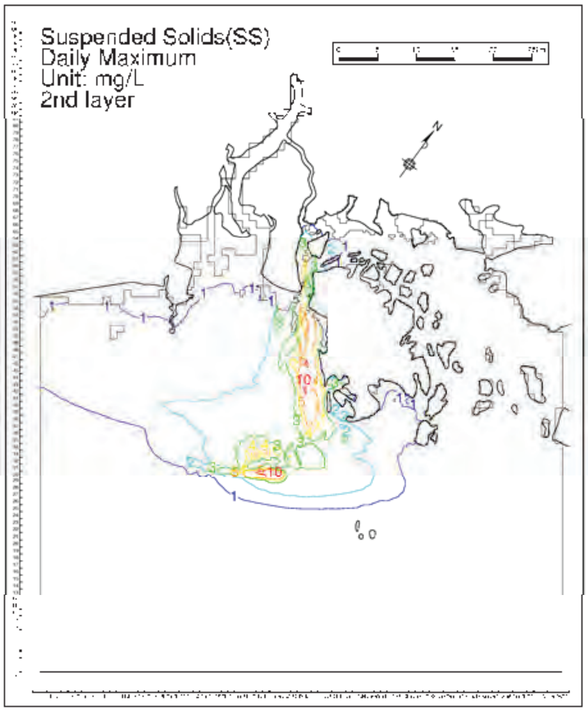


Figure 3.11 (2) SS Dispersion Prediction (Case 3, Daily Average, Large Domain)

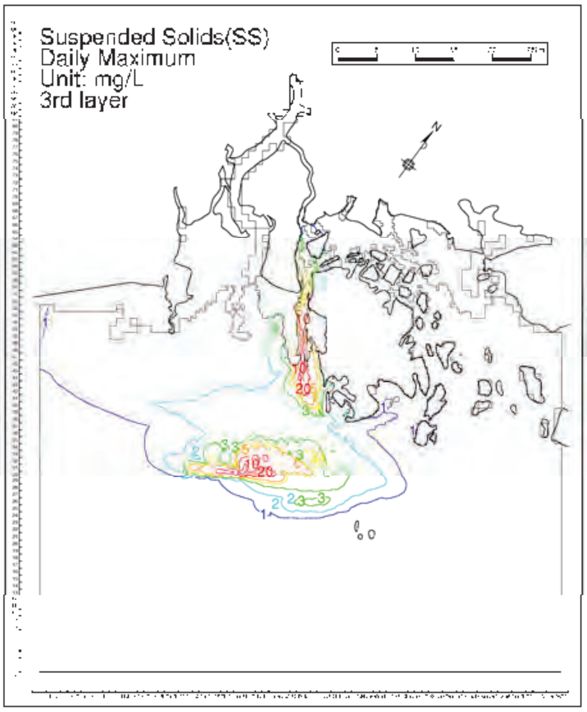
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

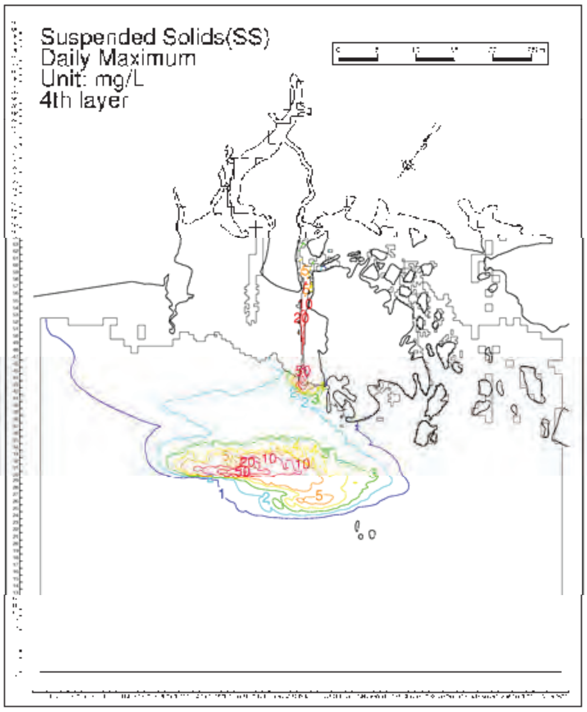
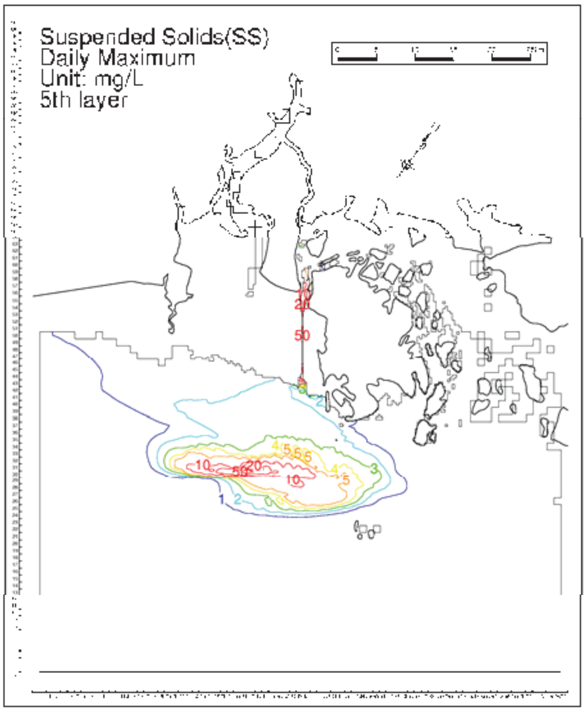
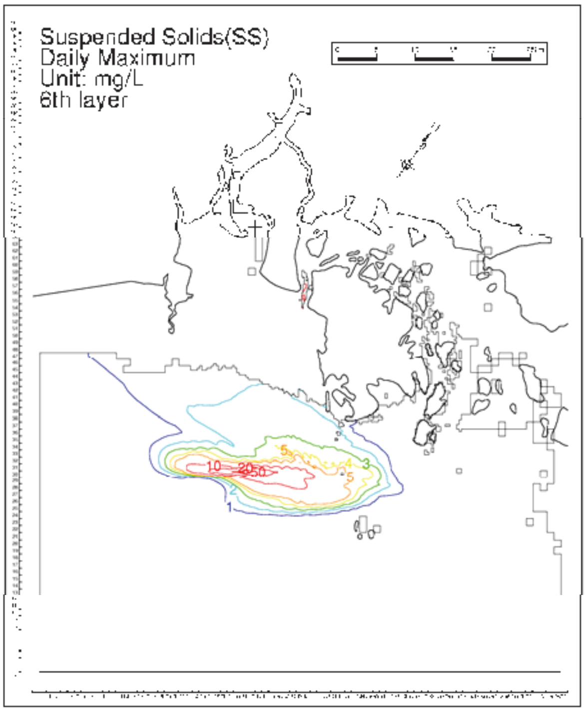


Figure 3.12 (1) SS Dispersion Prediction (Case 3, Daily Maximum, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

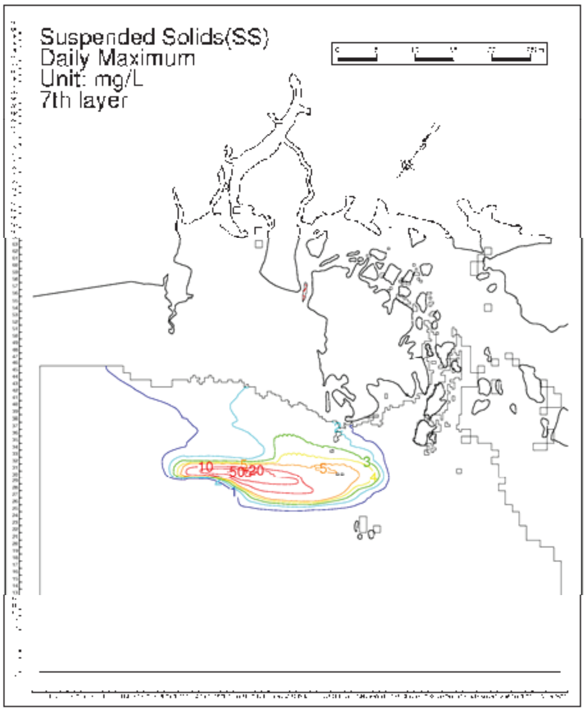
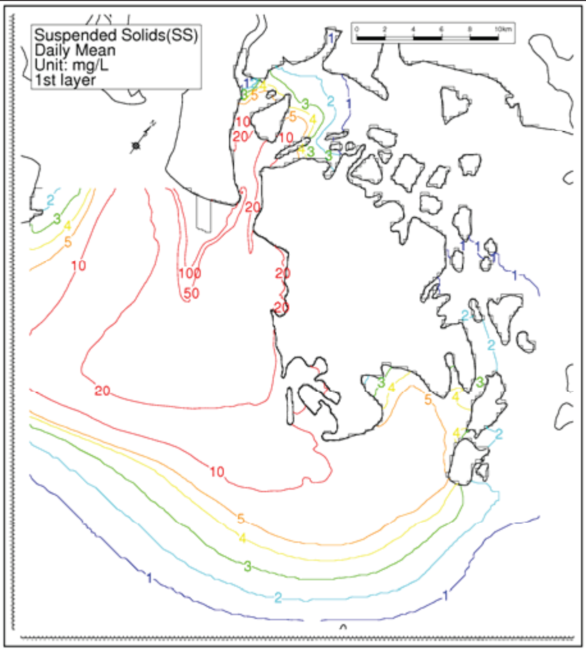


Figure 3.12 (2) SS Dispersion Prediction (Case 3, Daily Maximum, Large Domain)

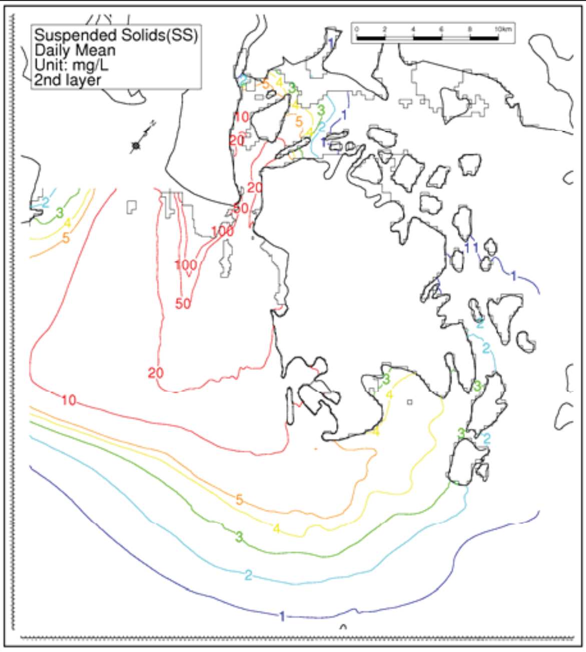
3.4 Case 4

1st layer (0-2m below surface)



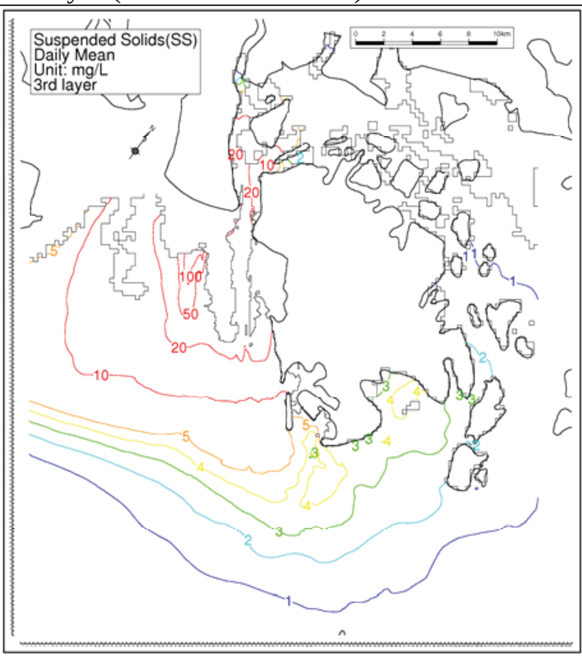
Max. SS in the area :1050mg/L

2nd Layer (2-4m below surface)



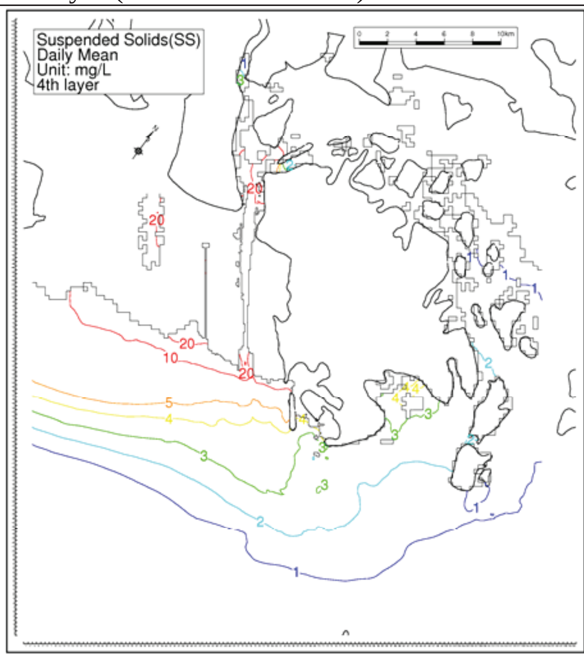
Max. SS in the area :968mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :900mg/L

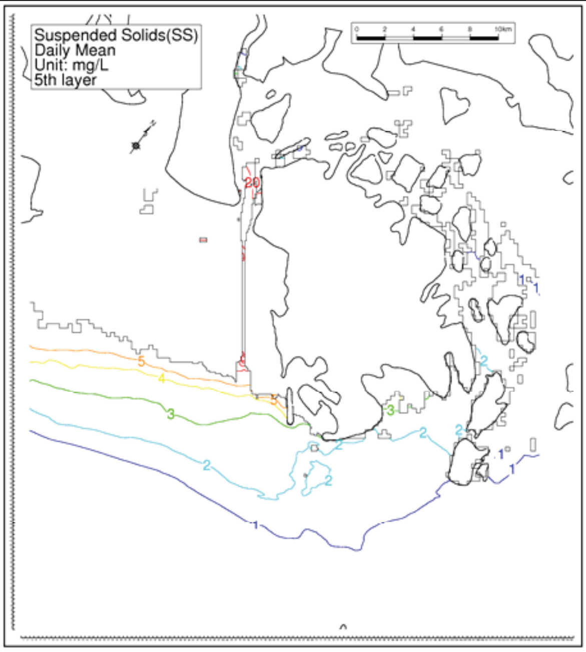
4th Layer (6-8m below surface)



Max. SS in the area :981mg/L

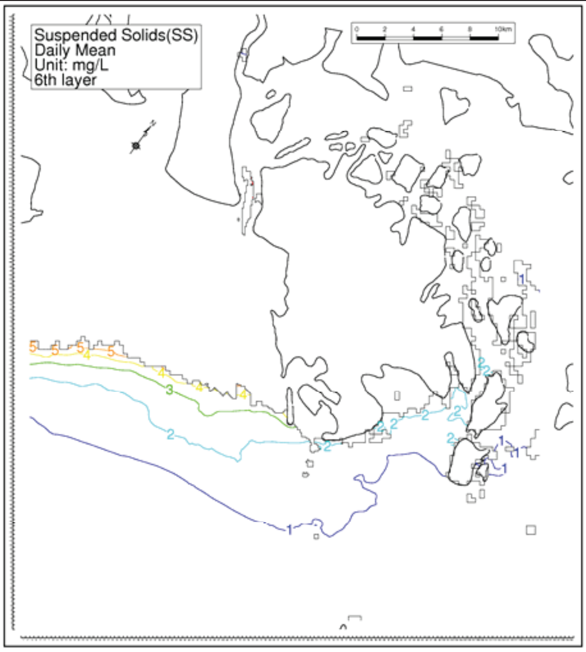
Figure 3.13 (1) SS Dispersion Prediction (Case 4, Daily Average, Medium Domain)

5th Layer (8-10m below surface)



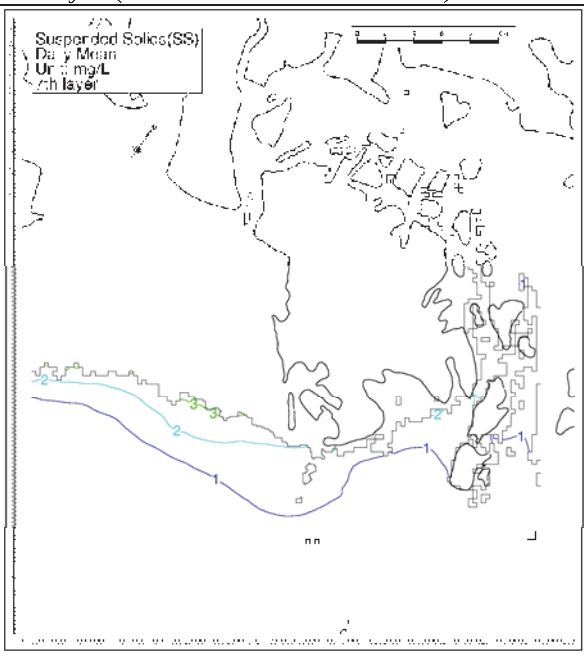
Max. SS in the area :960mg/L

6th Layer (10-12m below surface)



Max. SS in the area :55.3mg/L

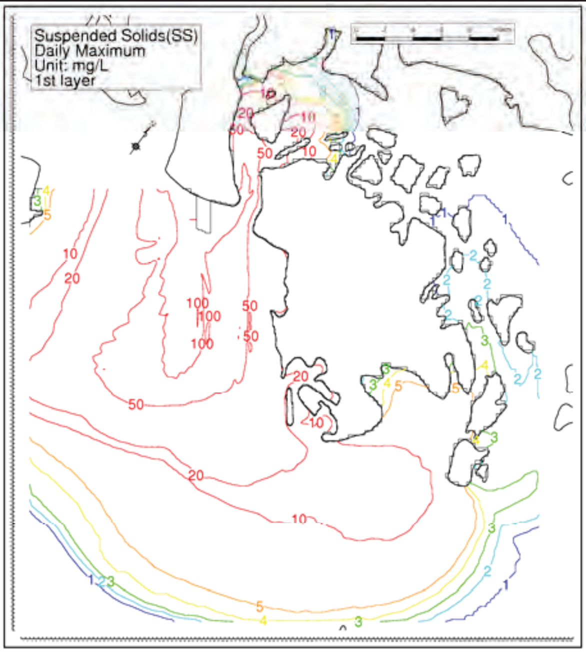
7th Layer (12m below surface-Bottom)



Max. SS in the area :28.6mg/L

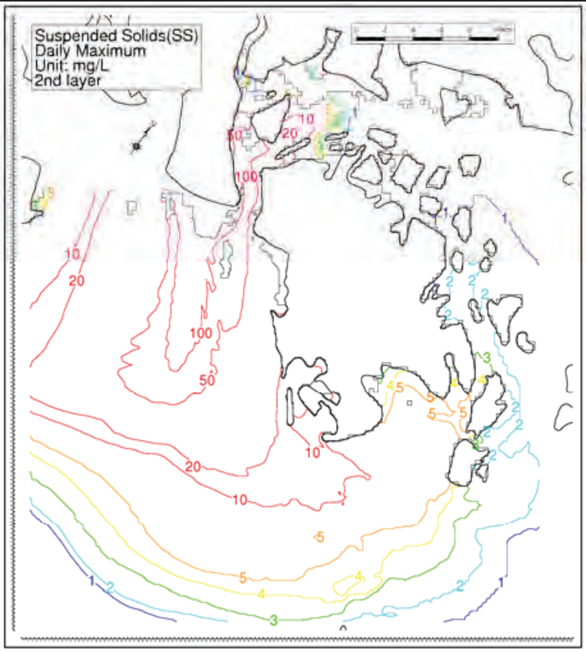
Figure 3.13 (2) SS Dispersion Prediction (Case 4, Daily Average, Medium Domain)

1st layer (0-2m below surface)



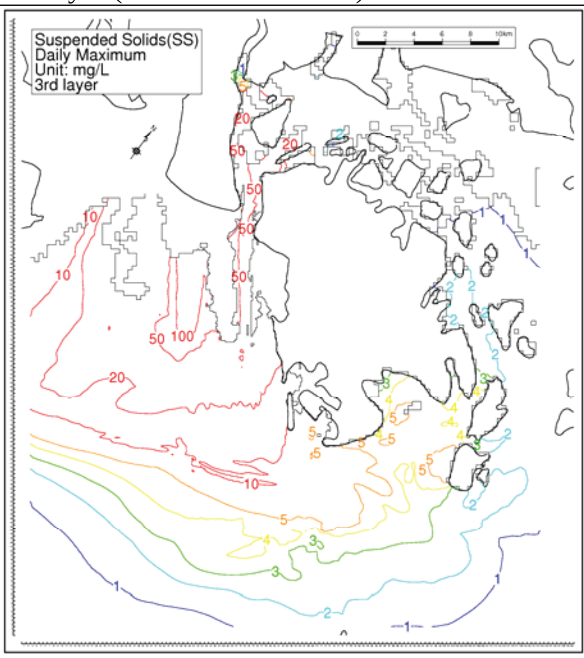
Max. SS in the area :3040mg/L

2nd Layer (2-4m below surface)



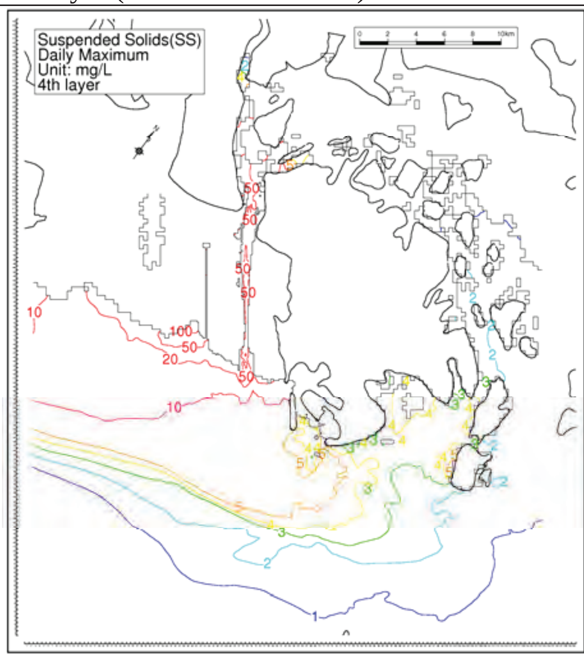
Max. SS in the area :3040mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :971mg/L

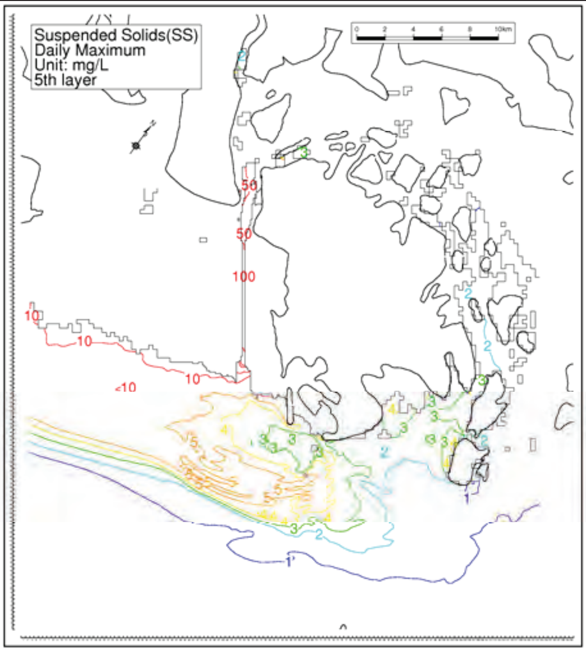
4th Layer (6-8m below surface)



Max. SS in the area :791mg/L

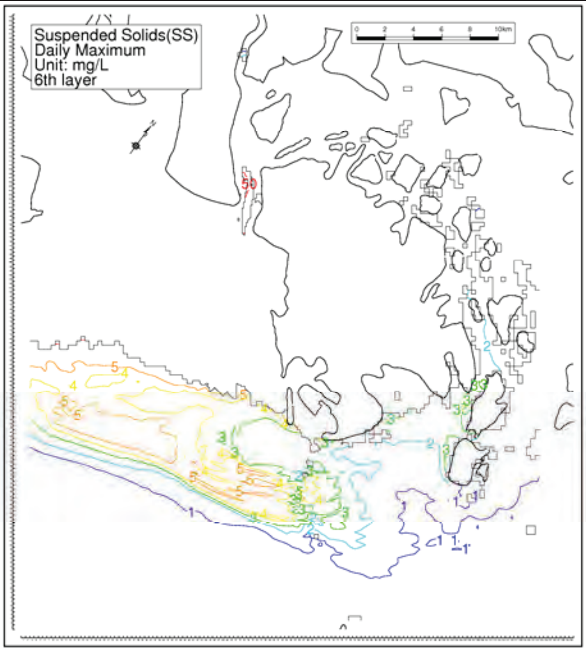
Figure 3.14 (1) SS Dispersion Prediction (Case 4, Daily Maximum, Medium Domain)

5th Layer (8-10m below surface)



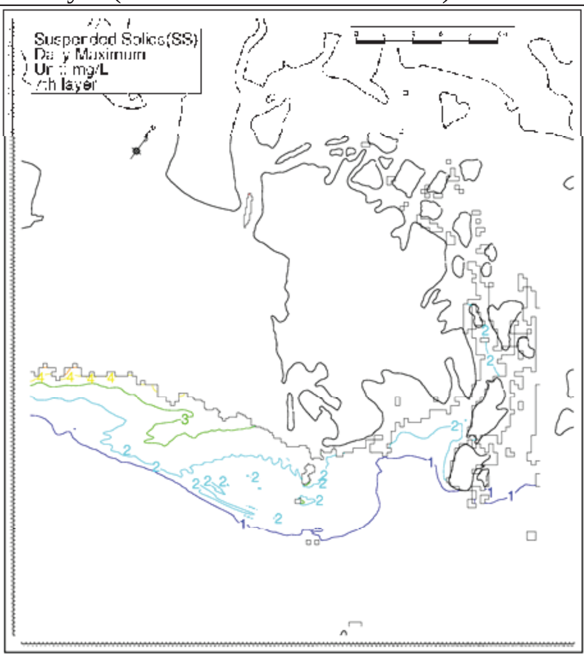
Max. SS in the area :804mg/L

6th Layer (10-12m below surface)



Max. SS in the area :125mg/L

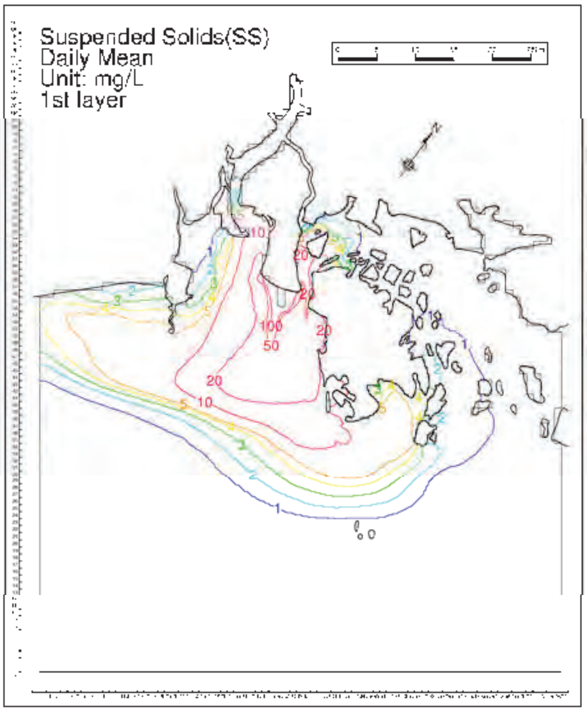
7th Layer (12m below surface-Bottom)



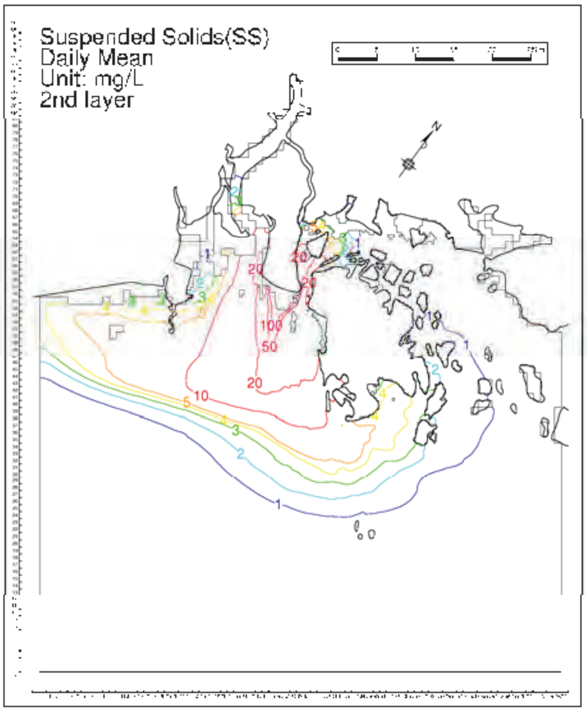
Max. SS in the area :50.3mg/L

Figure 3.14 (2) SS Dispersion Prediction (Case 4, Daily Maximum, Medium Domain)

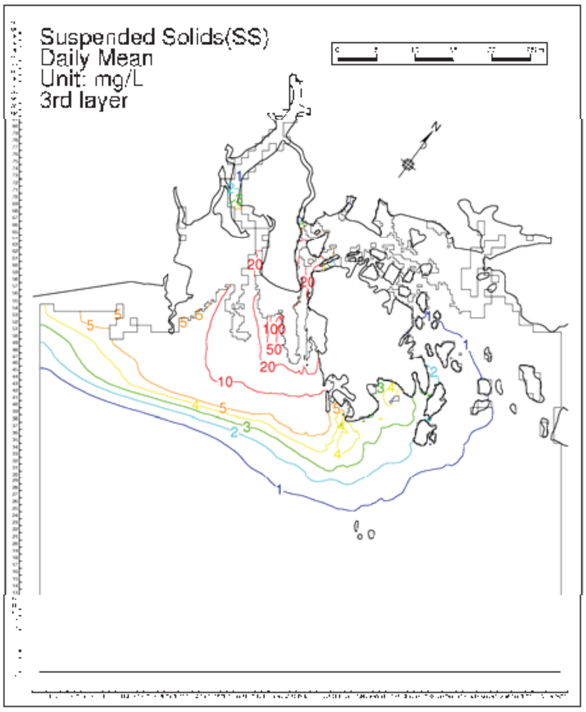
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

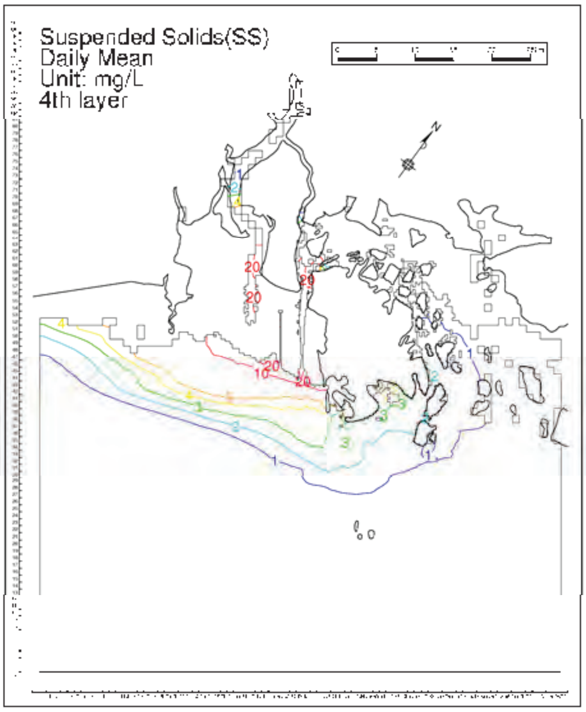


Figure 3.15 (1) SS Dispersion Prediction (Case 4, Daily Average, Large Domain)

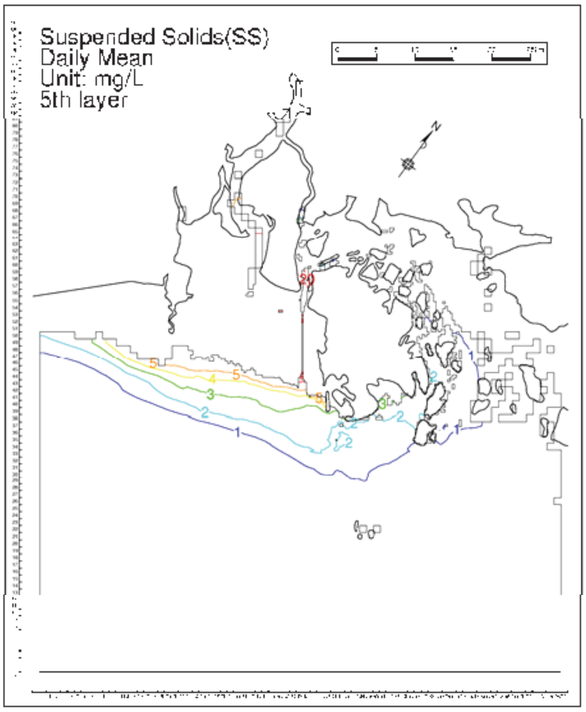
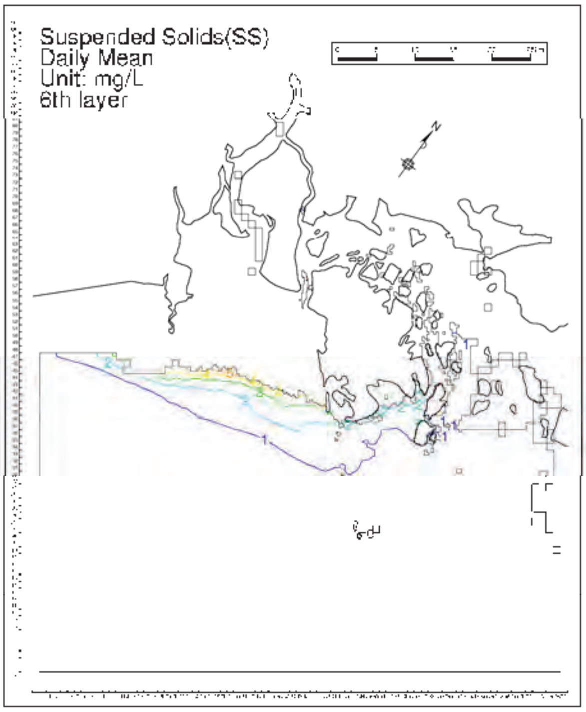
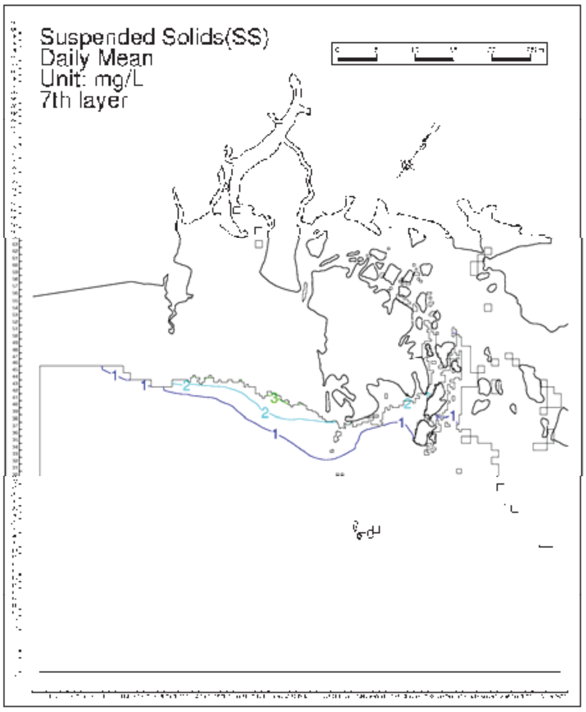
5th Layer (8-10m below surface)	6th Layer (10-12m below surface)
	
7th Layer (12m below surface-Bottom)	
	

Figure 3.15 (2) SS Dispersion Prediction (Case 4, Daily Average, Large Domain)

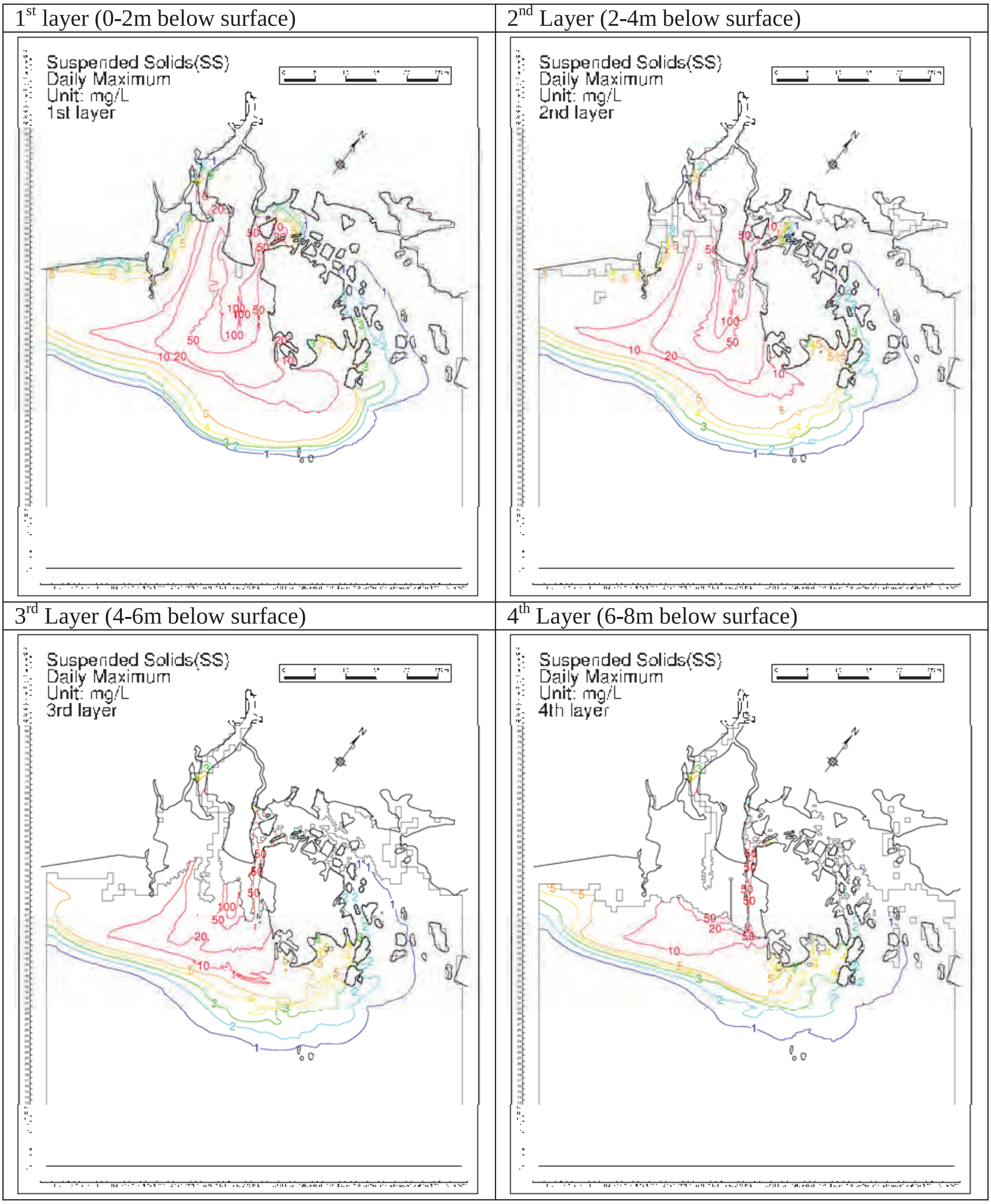
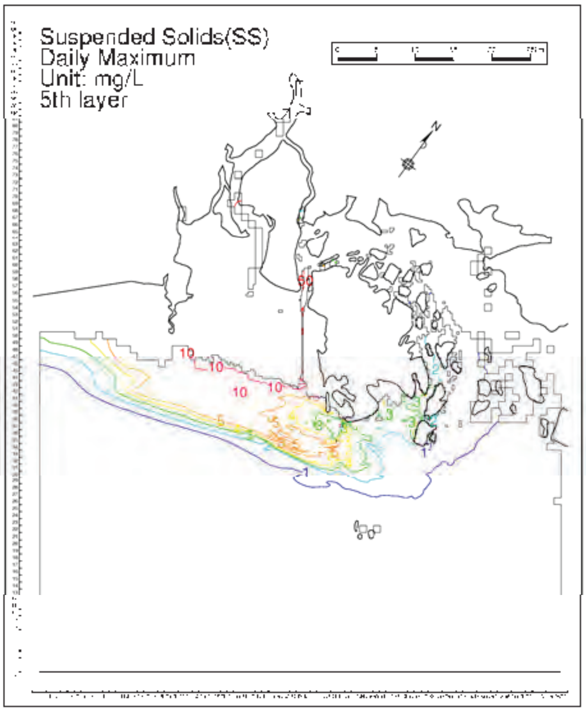
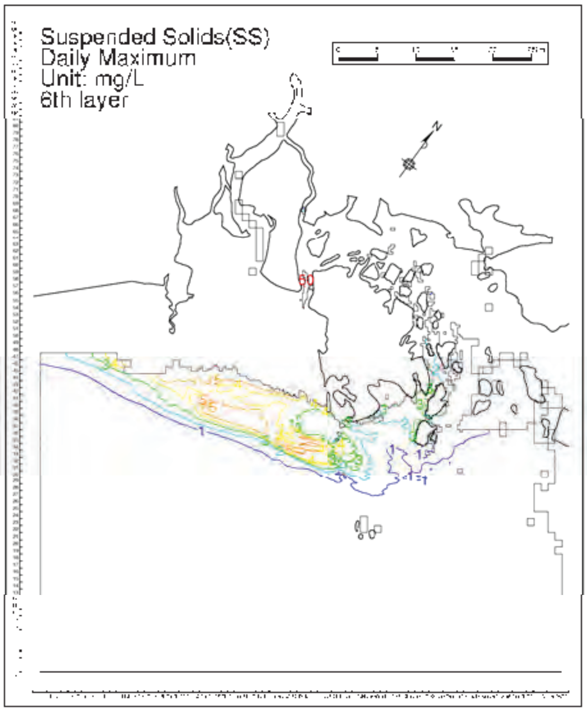


Figure 3.16 (1) SS Dispersion Prediction (Case 4, Daily Maximum, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

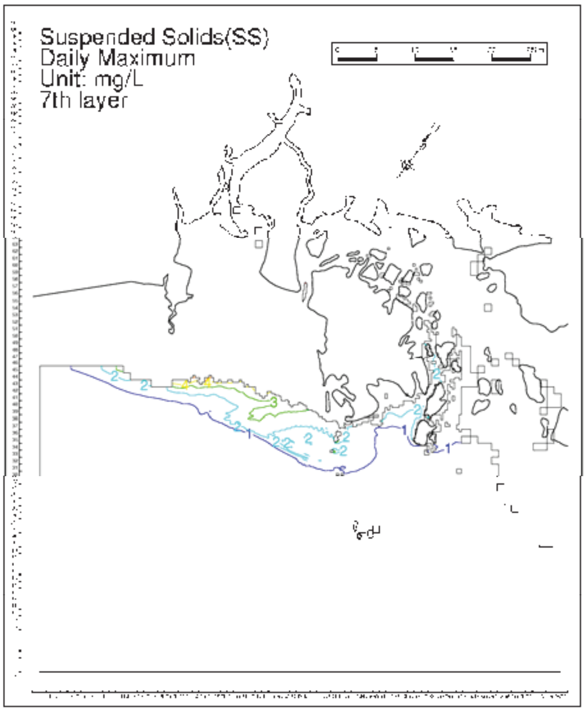
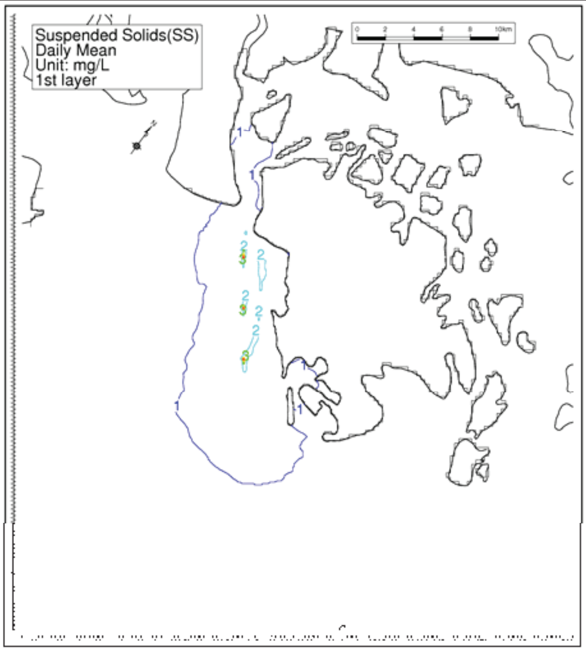


Figure 3.16 (2) SS Dispersion Prediction (Case 4, Daily Maximum, Large Domain)

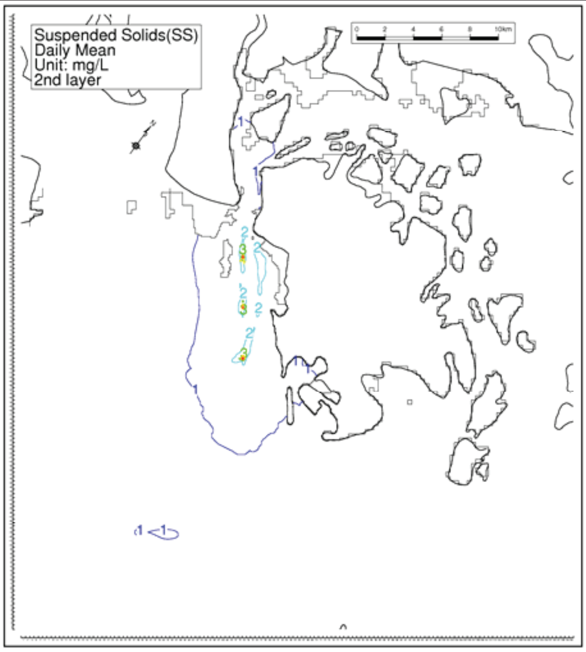
3.5 Case 5

1st layer (0-2m below surface)



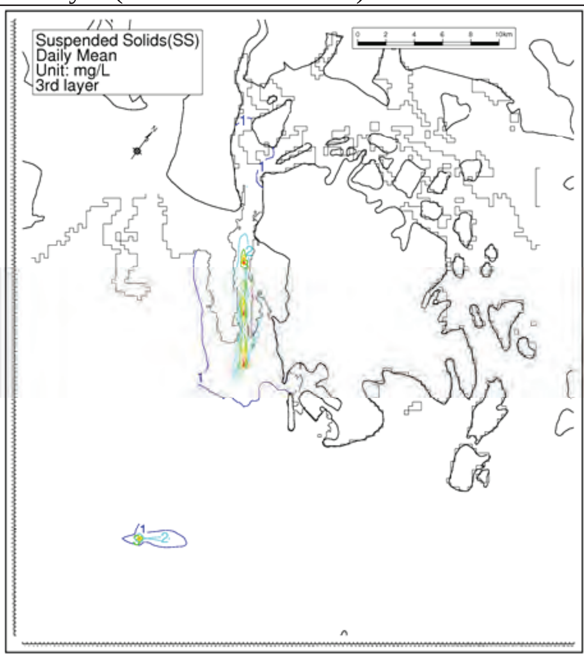
Max. SS in the area :14.4mg/L

2nd Layer (2-4m below surface)



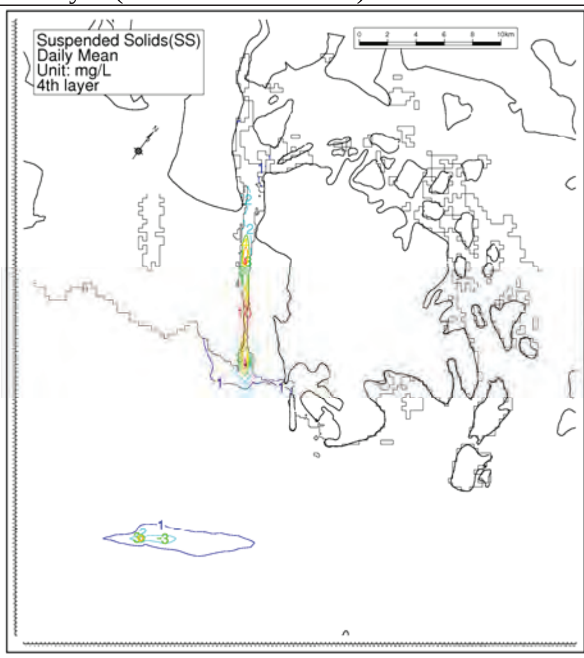
Max. SS in the area :17.3mg/L

3rd Layer (4-6m below surface)



Max. SS in the area :22.1mg/L

4th Layer (6-8m below surface)



Max. SS in the area :29.5mg/L

Figure 3.17 (1) SS Dispersion Prediction (Case 5, Daily Average, Medium Domain)

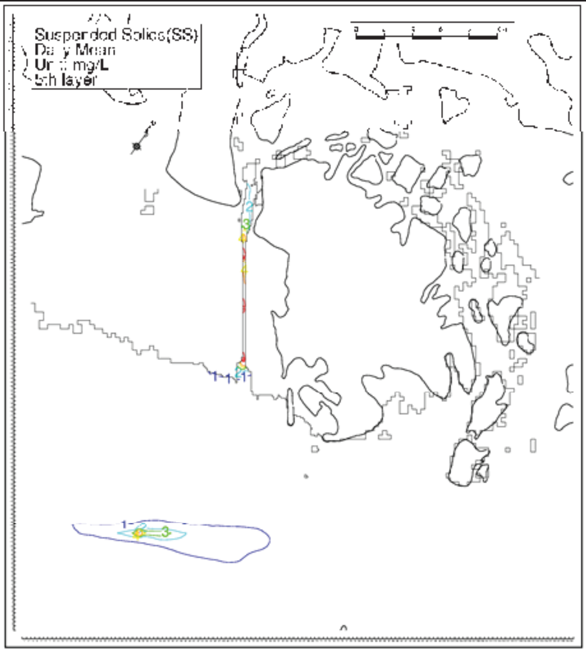
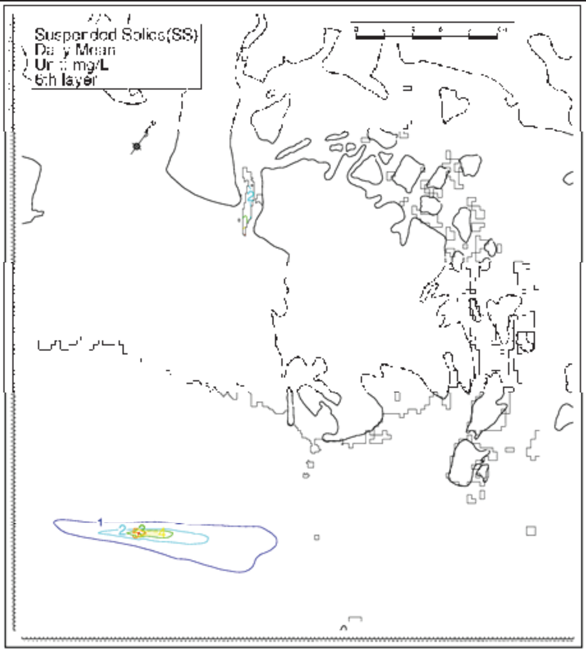
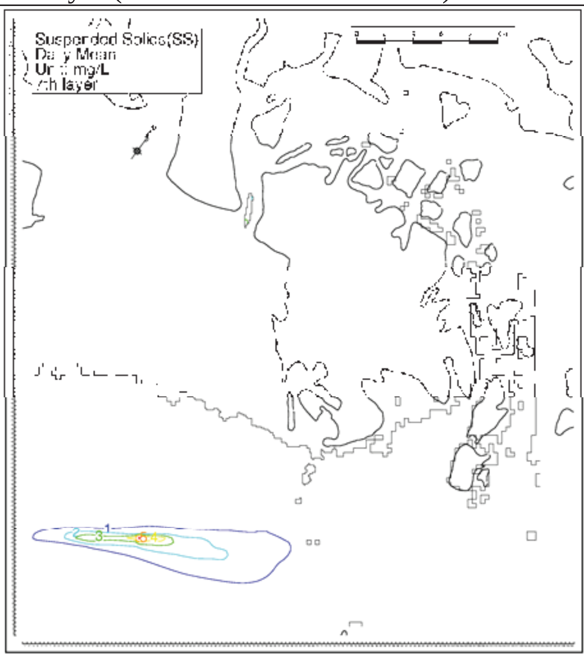
<table>
<tr><td>5th Layer (8-10m below surface)</td><td>6th Layer (10-12m below surface)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Max. SS in the area :40.0mg/L</td><td>Max. SS in the area :11.9mg/L</td></tr>
<tr><td>7th Layer (12m below surface-Bottom)</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Max. SS in the area :12.8mg/L</td><td></td></tr>
</table>

Figure 3.17 (2) SS Dispersion Prediction (Case 5, Daily Average, Medium Domain)

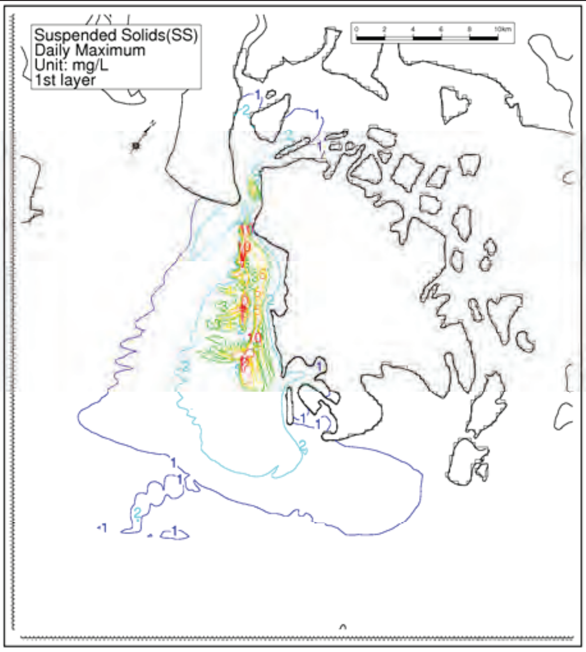
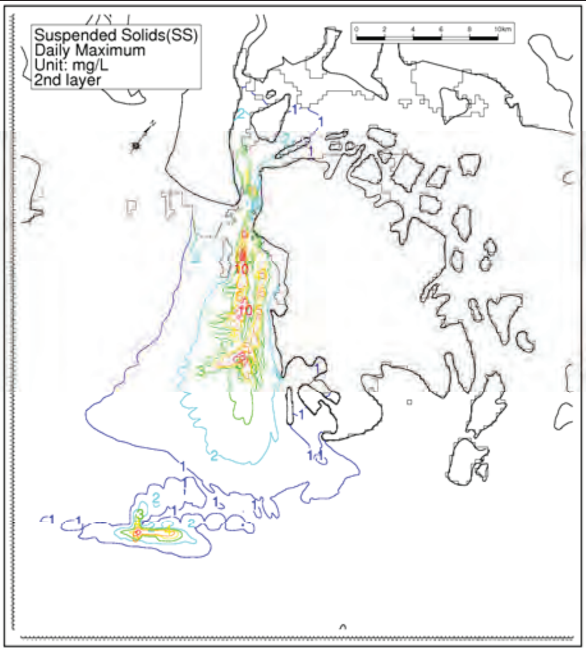
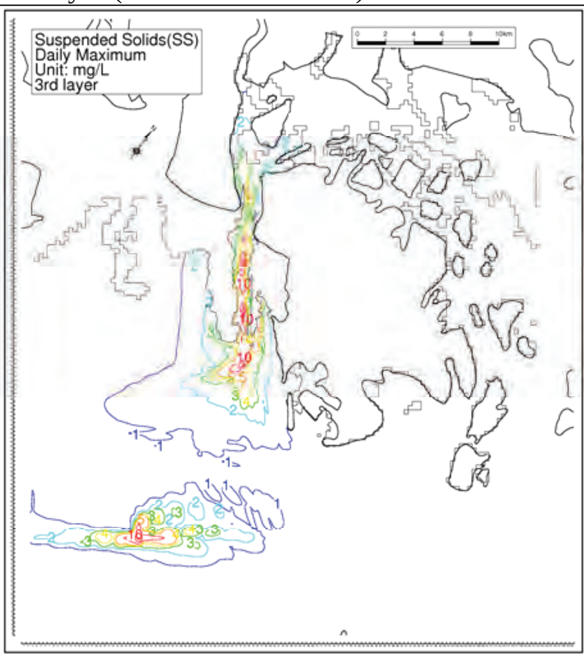
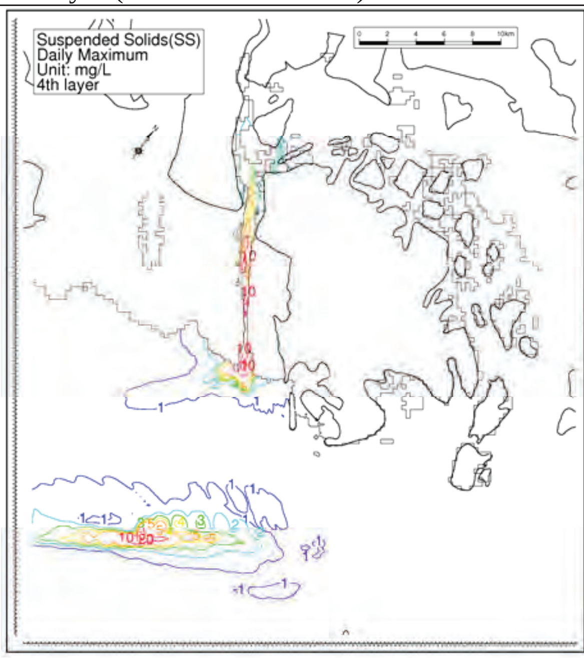
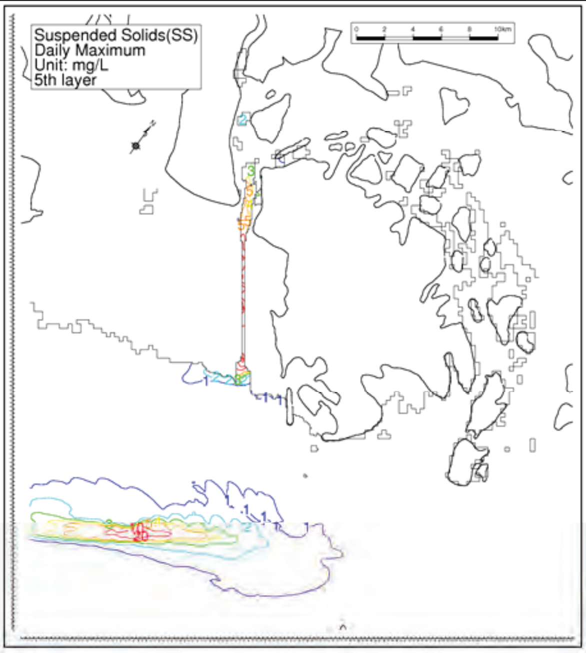
1st layer (0-2m below surface)	2nd Layer (2-4m below surface)
	
Max. SS in the area :131mg/L	Max. SS in the area :72.3mg/L
3rd Layer (4-6m below surface)	4th Layer (6-8m below surface)
	
Max. SS in the area :66.8mg/L	Max. SS in the area :114mg/L

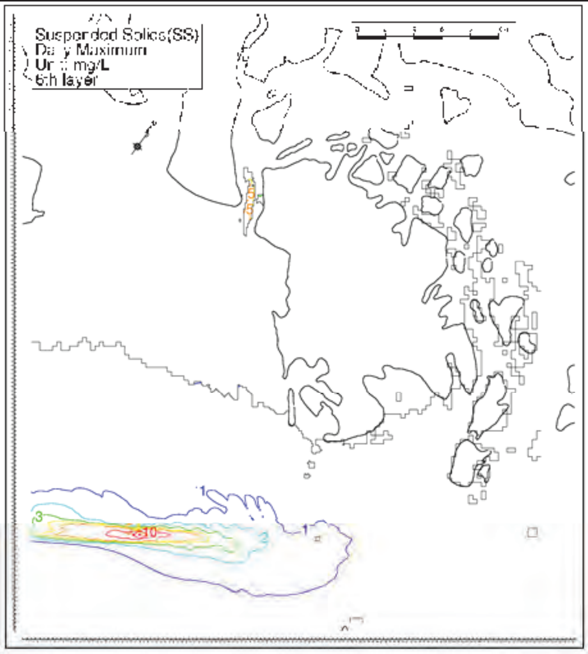
Figure 3.18 (1) SS Dispersion Prediction (Case 5, Daily Maximum, Medium Domain)

5th Layer (8-10m below surface)



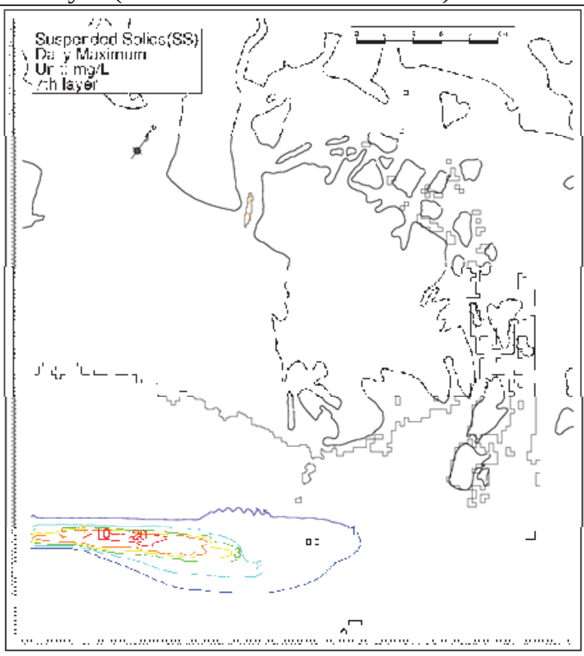
Max. SS in the area :146mg/L

6th Layer (10-12m below surface)



Max. SS in the area :68.5mg/L

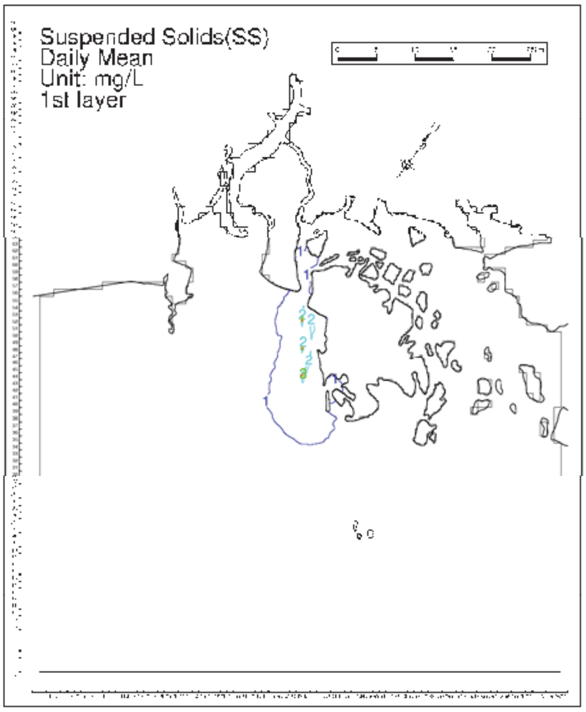
7th Layer (12m below surface-Bottom)



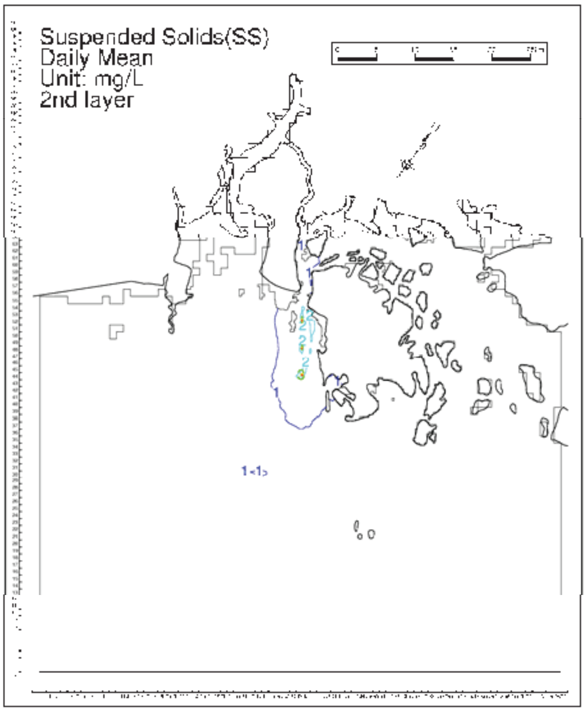
Max. SS in the area :74.5mg/L

Figure 3.18 (2) SS Dispersion Prediction (Case 5, Daily Maximum, Medium Domain)

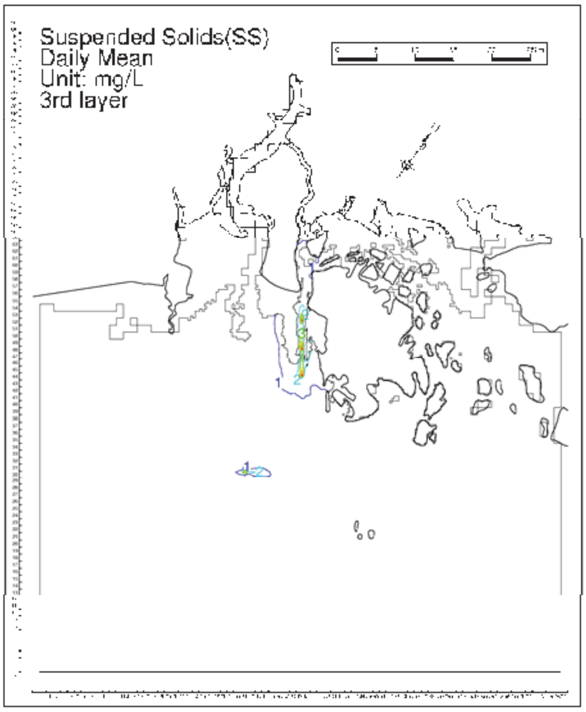
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

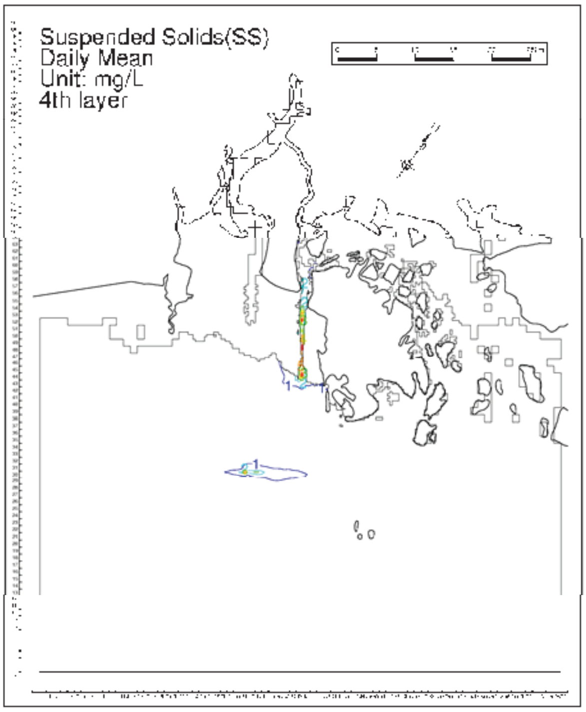
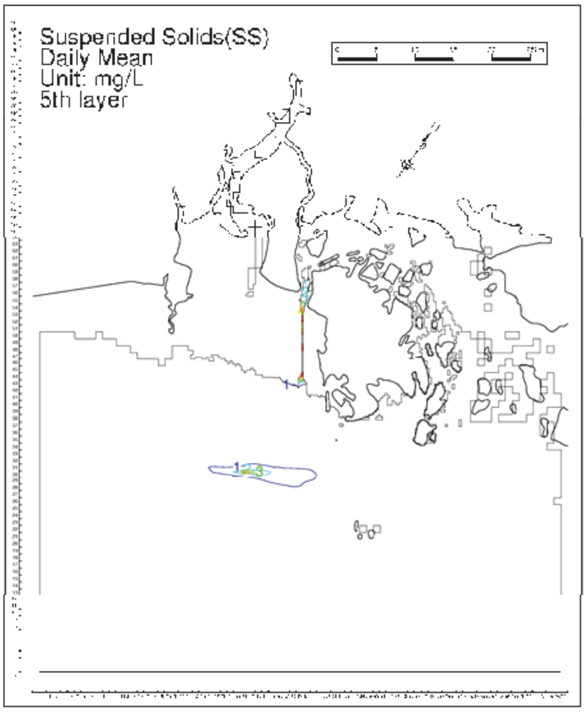
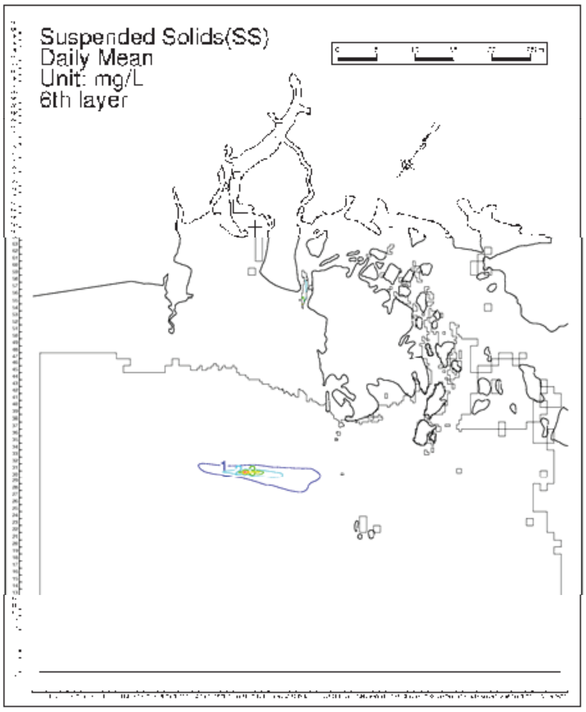


Figure 3.19 (1) SS Dispersion Prediction (Case 5, Daily Average, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

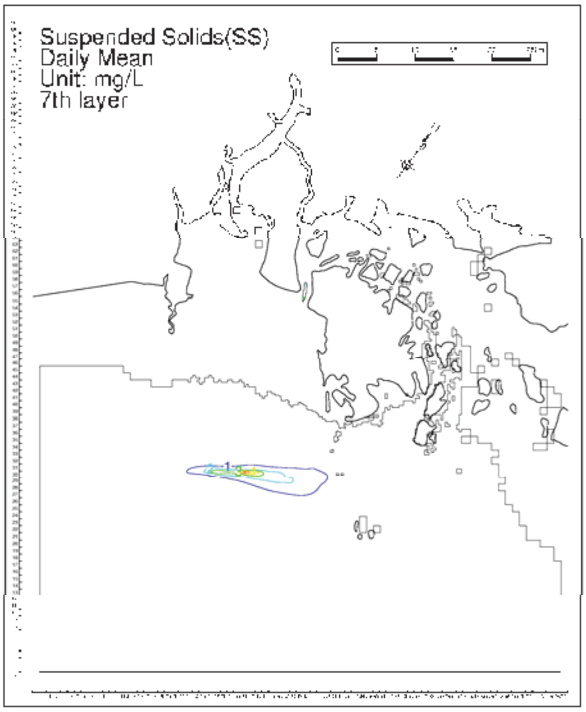
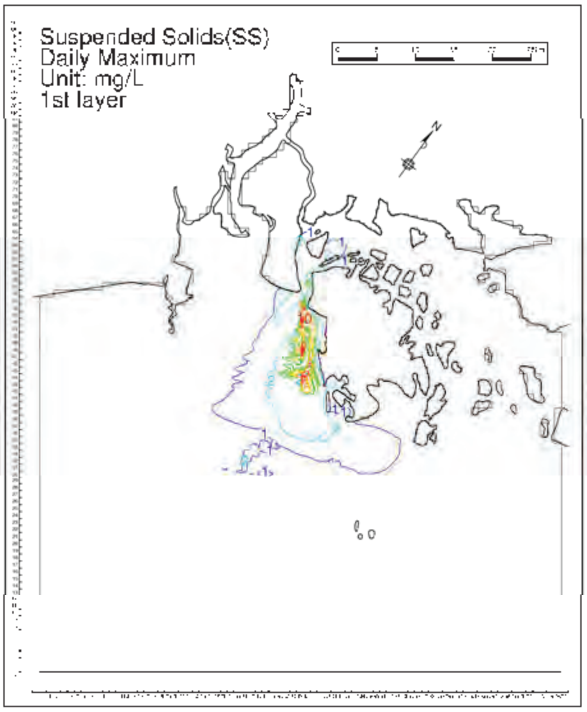
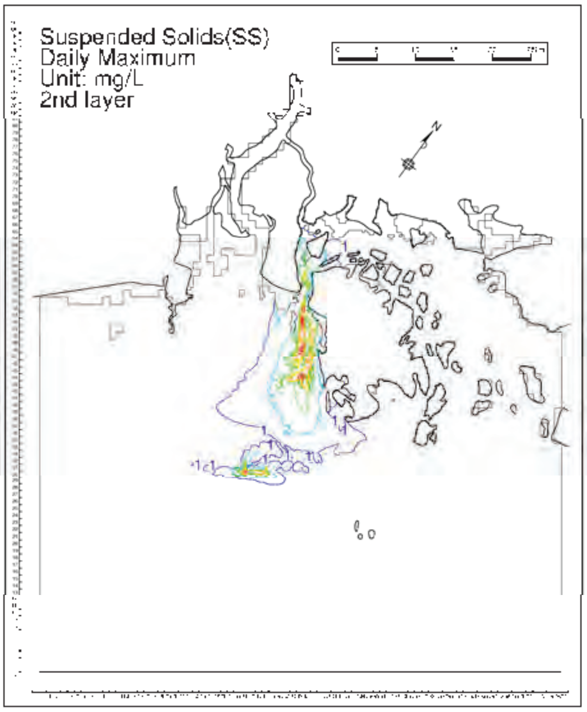


Figure 3.19 (2) SS Dispersion Prediction (Case 5, Daily Average, Large Domain)

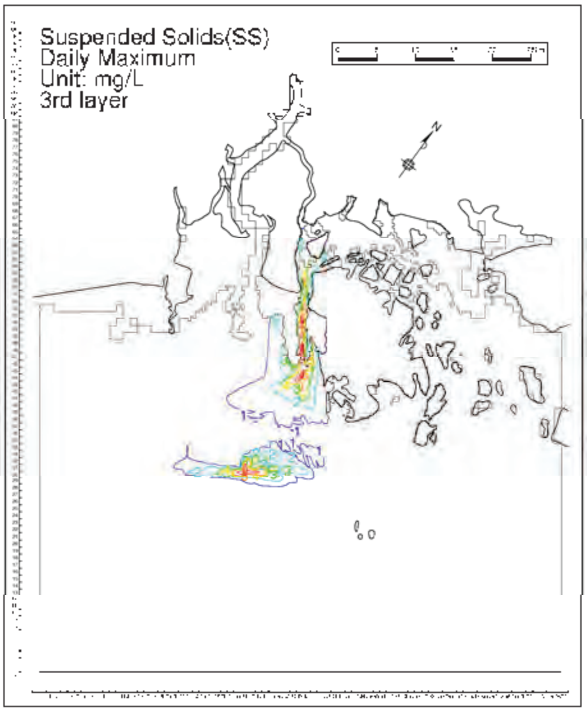
1st layer (0-2m below surface)



2nd Layer (2-4m below surface)



3rd Layer (4-6m below surface)



4th Layer (6-8m below surface)

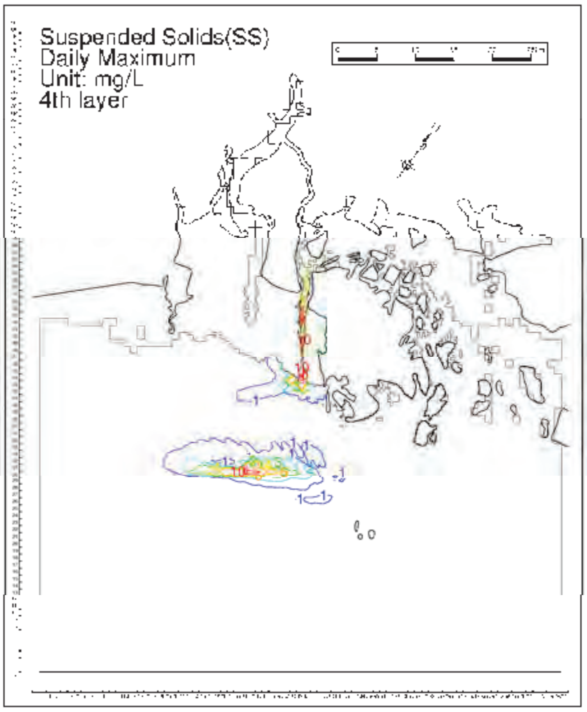
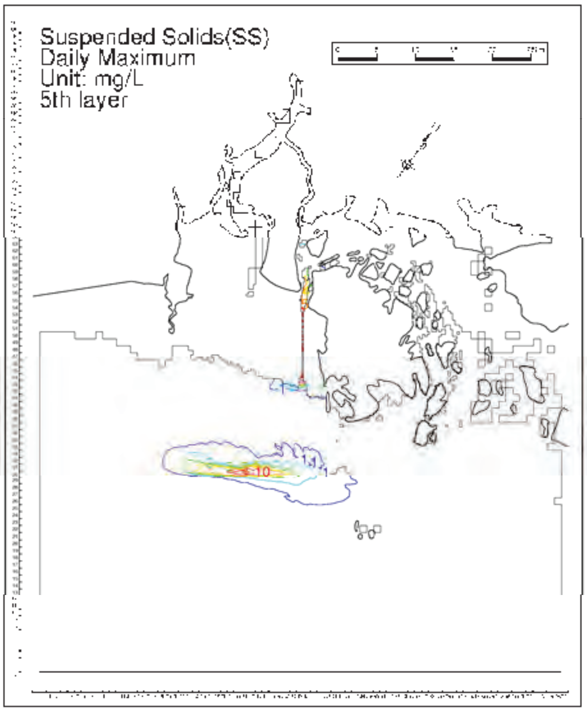
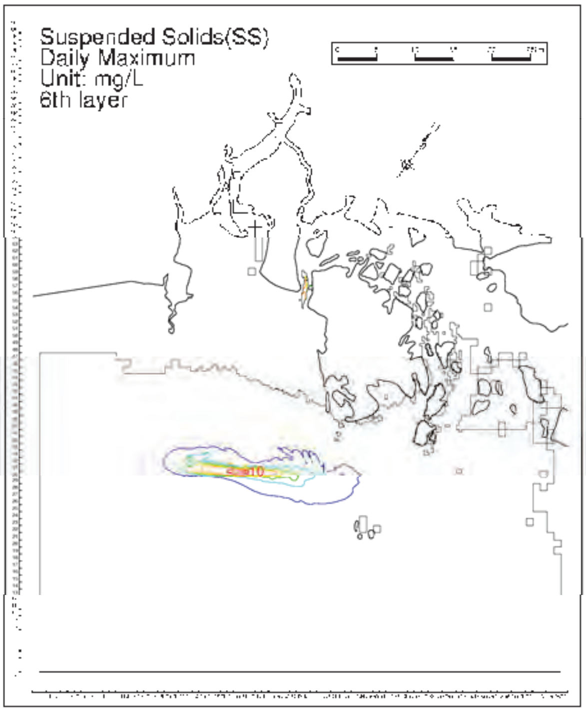


Figure 3.20 (1) SS Dispersion Prediction (Case 5, Daily Maximum, Large Domain)

5th Layer (8-10m below surface)



6th Layer (10-12m below surface)



7th Layer (12m below surface-Bottom)

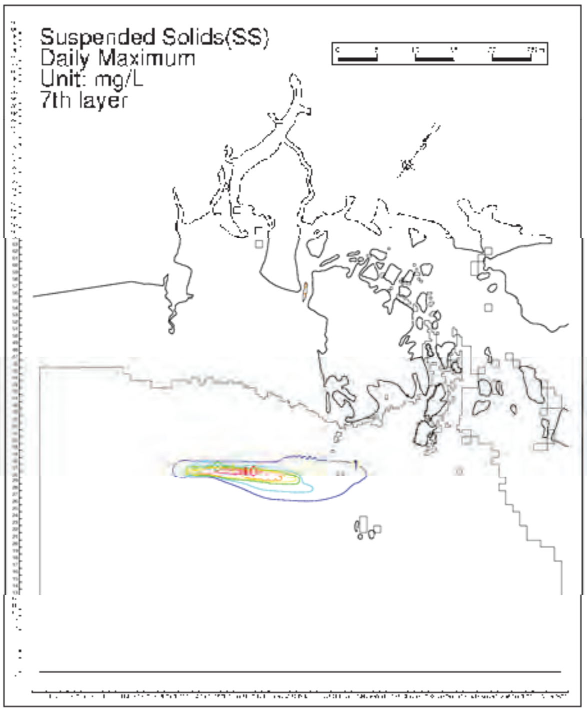


Figure 3.20 (2) SS Dispersion Prediction (Case 5, Daily Maximum, Large Domain)

Appendix 12-2

Outputs of SS Dispersion Simulation from Case 12 to Case 18

All outputs of SS dispersion simulation from Case 12 to Case 18 are stored in this APPENDIX.

1. Case 12

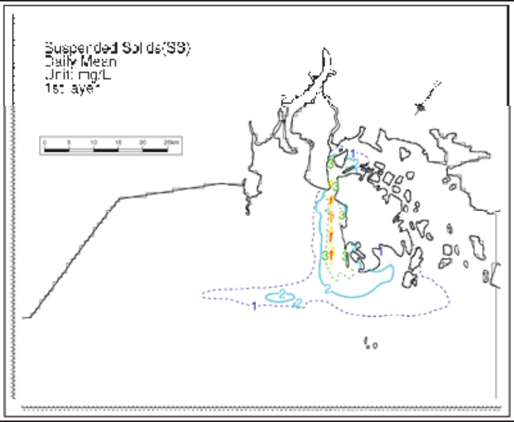
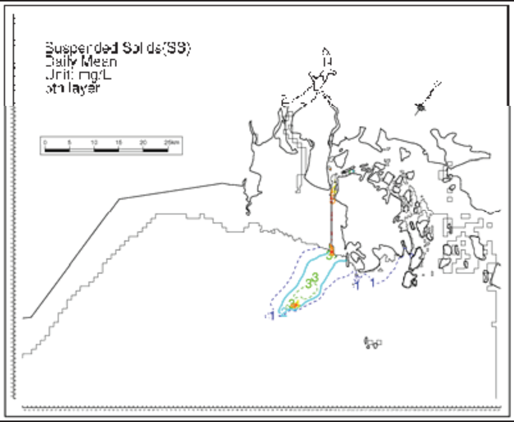
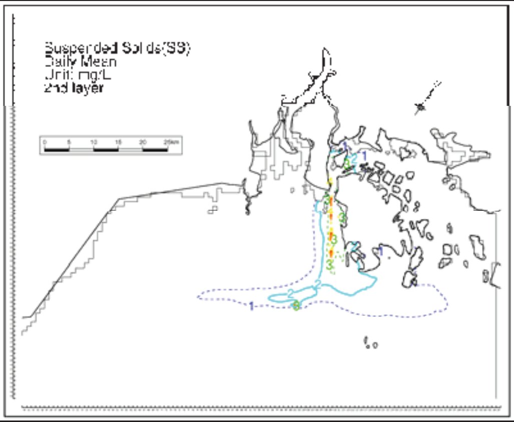
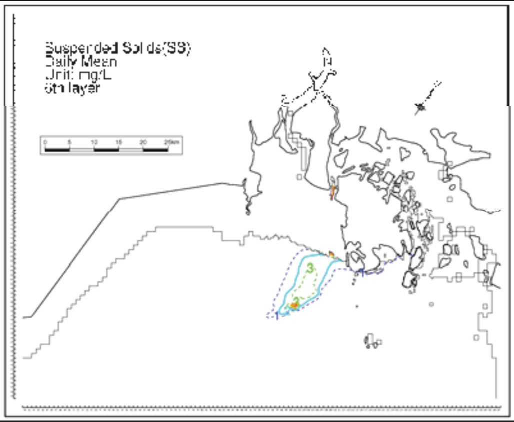
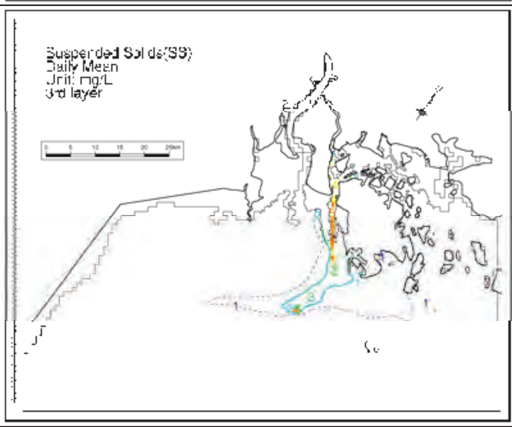
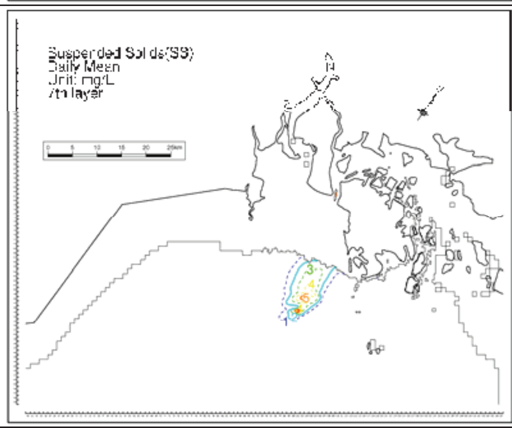
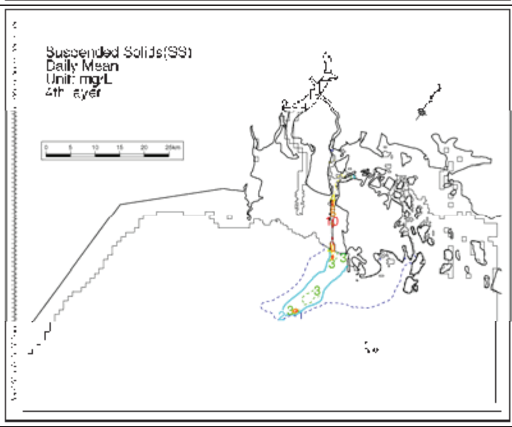
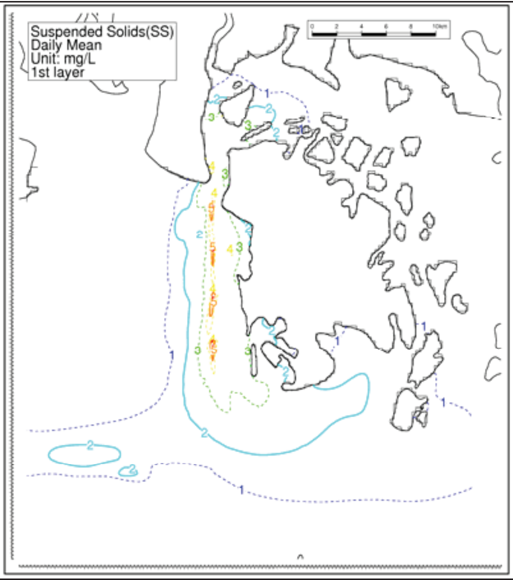
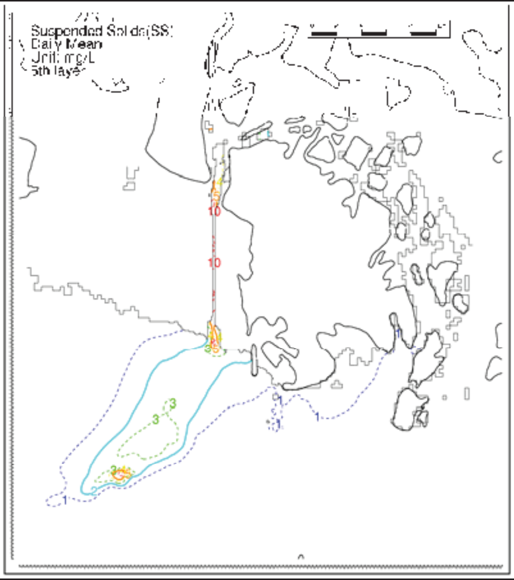
1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	
4th Layer (6～8m)			

Figure 1-1-1 SS Dispersion Prediction (Case12, Daily Average, Large Domain)

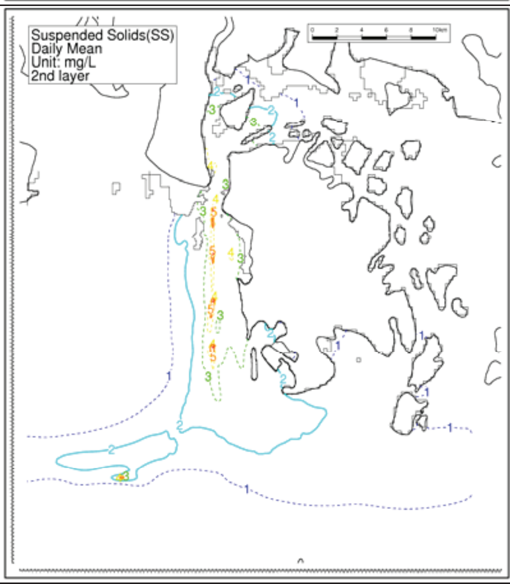
1st Layer (0～2m)



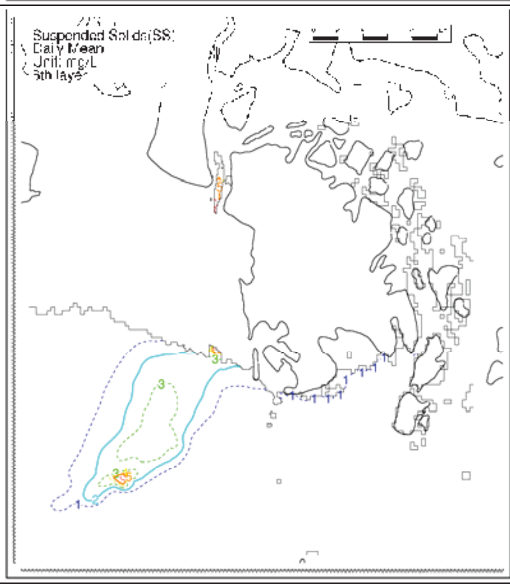
5th Layer (8～10m)



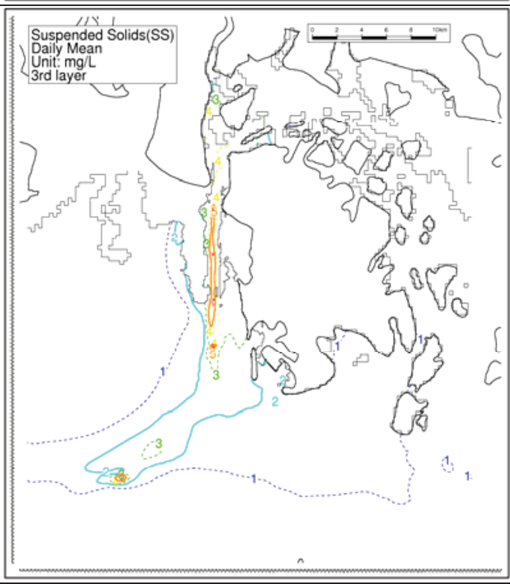
2nd Layer (2～4m)



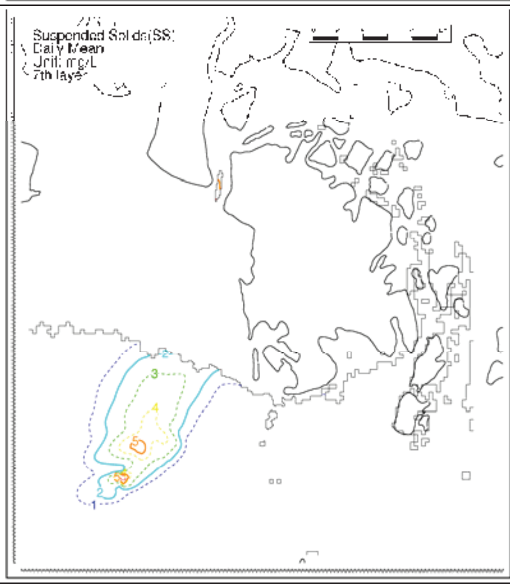
6th Layer (10～12m)



3rd Layer (4～6m)



7th Layer (12m～bottom)



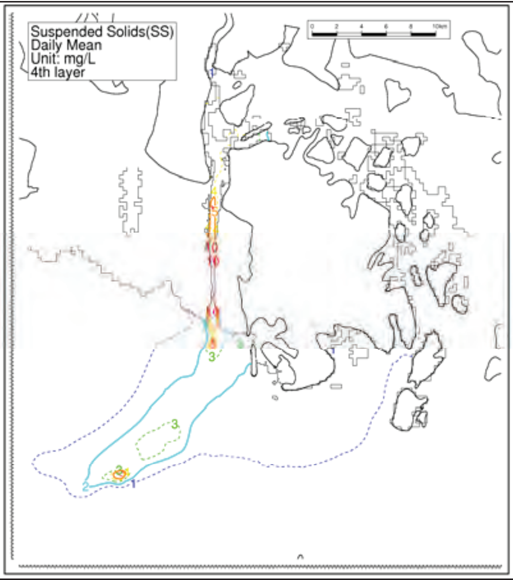
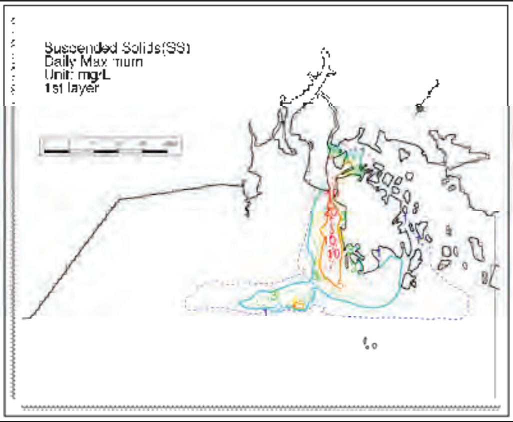
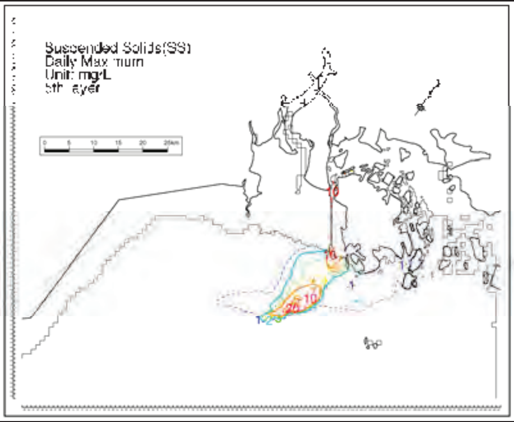
4th Layer (6~8m)			

Figure 1-1-2 SS Dispersion Prediction (Case12, Daily Average, Medium Domain)

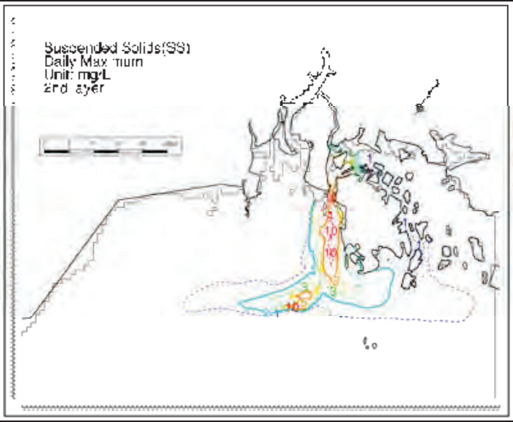
1st Layer (0~2m)



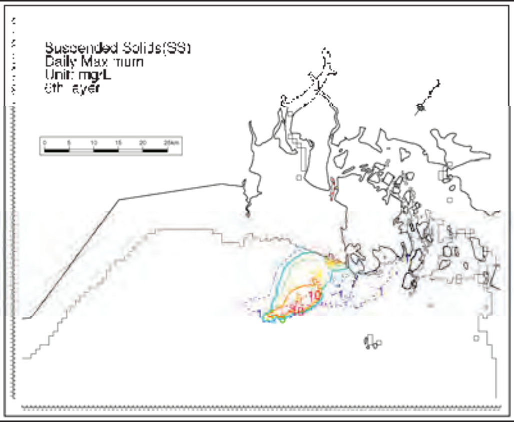
5th Layer (8~10m)



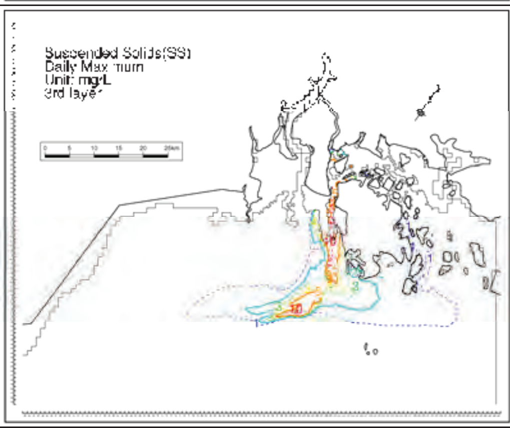
2nd Layer (2~4m)



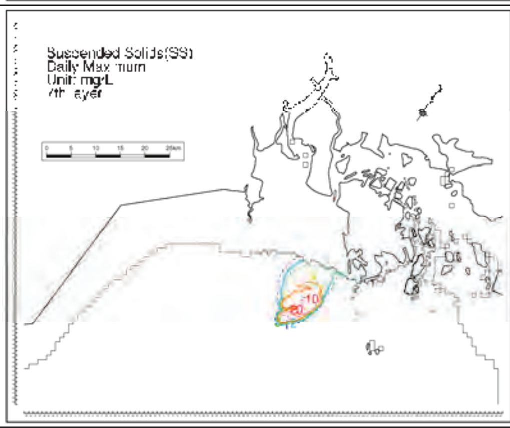
6th Layer (10~12m)



3rd Layer (4~6m)



7th Layer (12m~bottom)



4th Layer (6~8m)

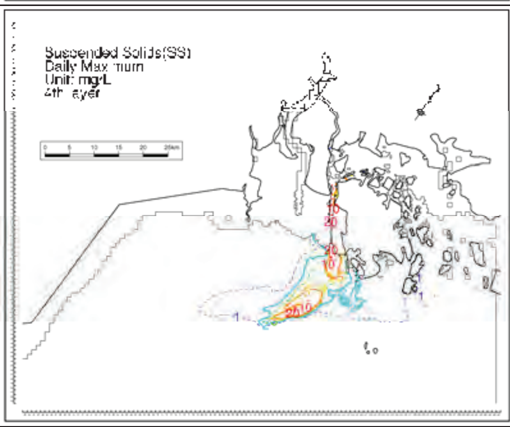
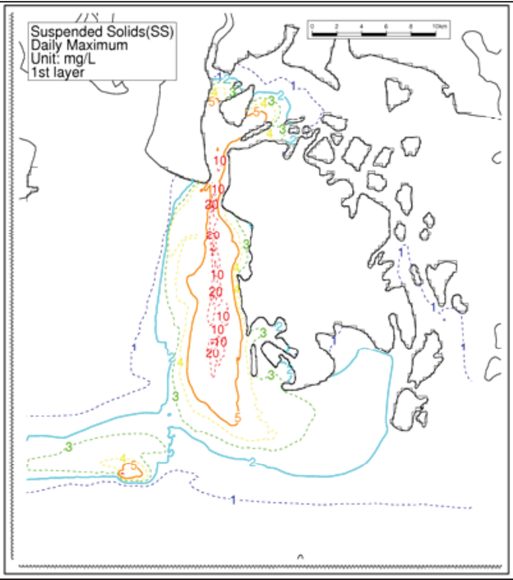
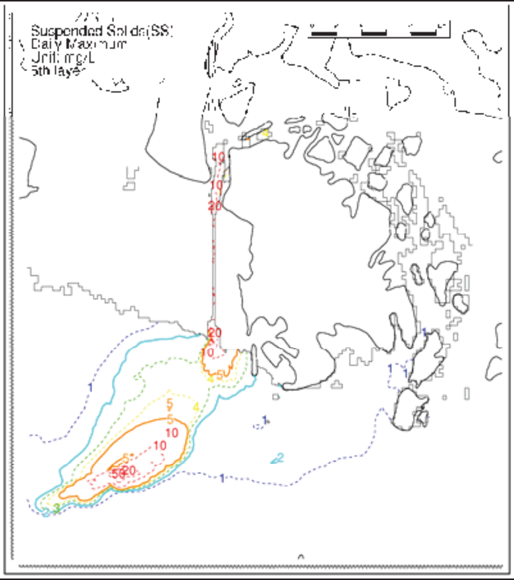
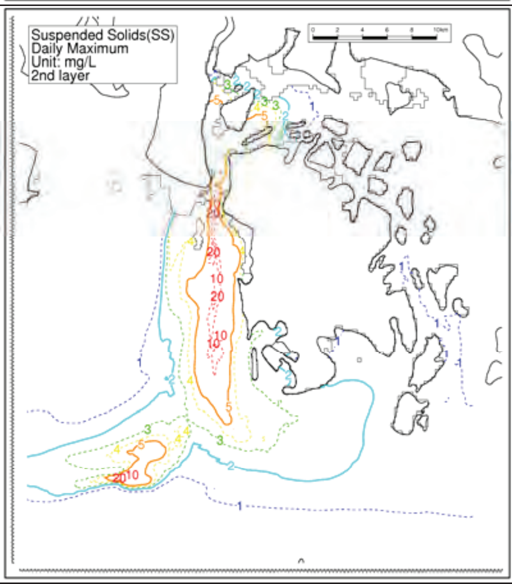
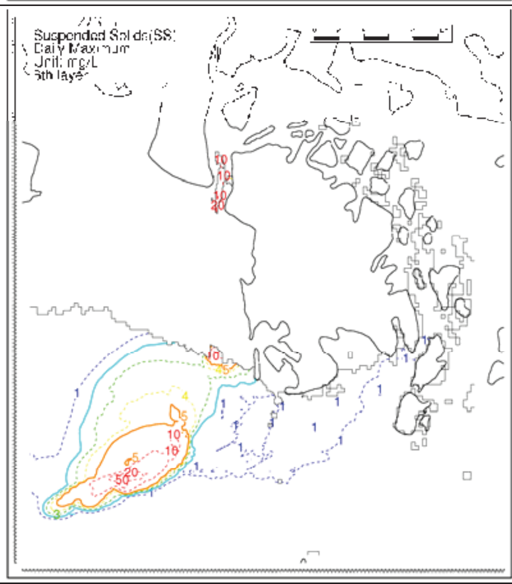
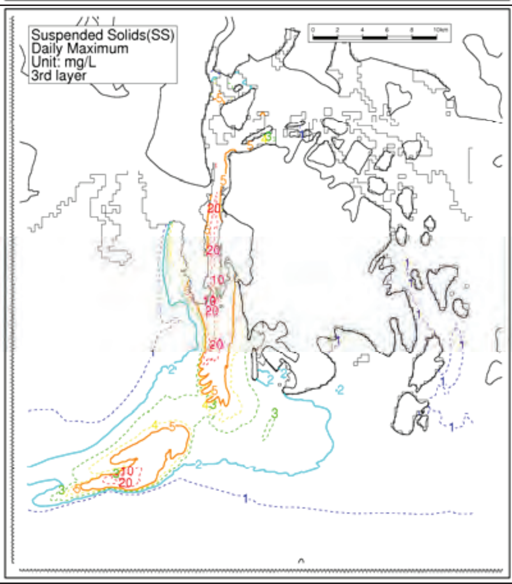
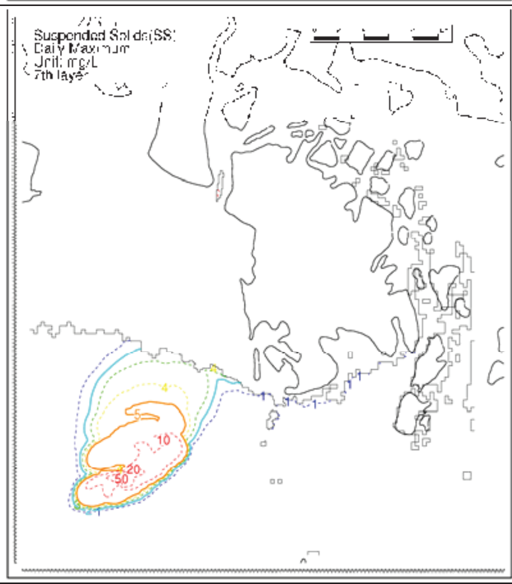


Figure 1-2-1 SS Dispersion Prediction (Case12, Daily Maximum, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

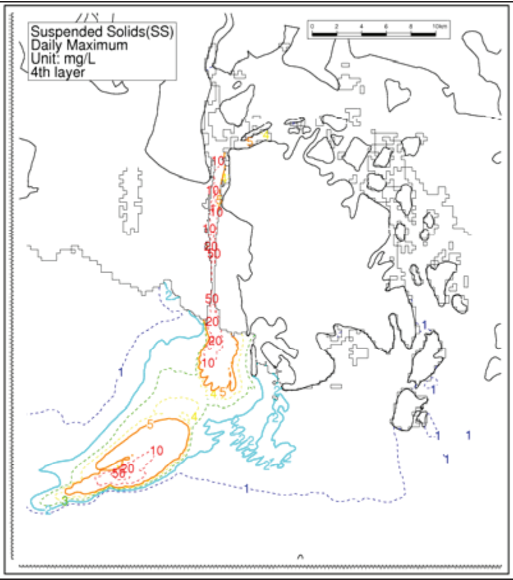
4th Layer (6~8m)			

Figure 1-2-2 SS Dispersion Prediction (Case12, Daily Maximum, Medium Domain)

2. Case 13

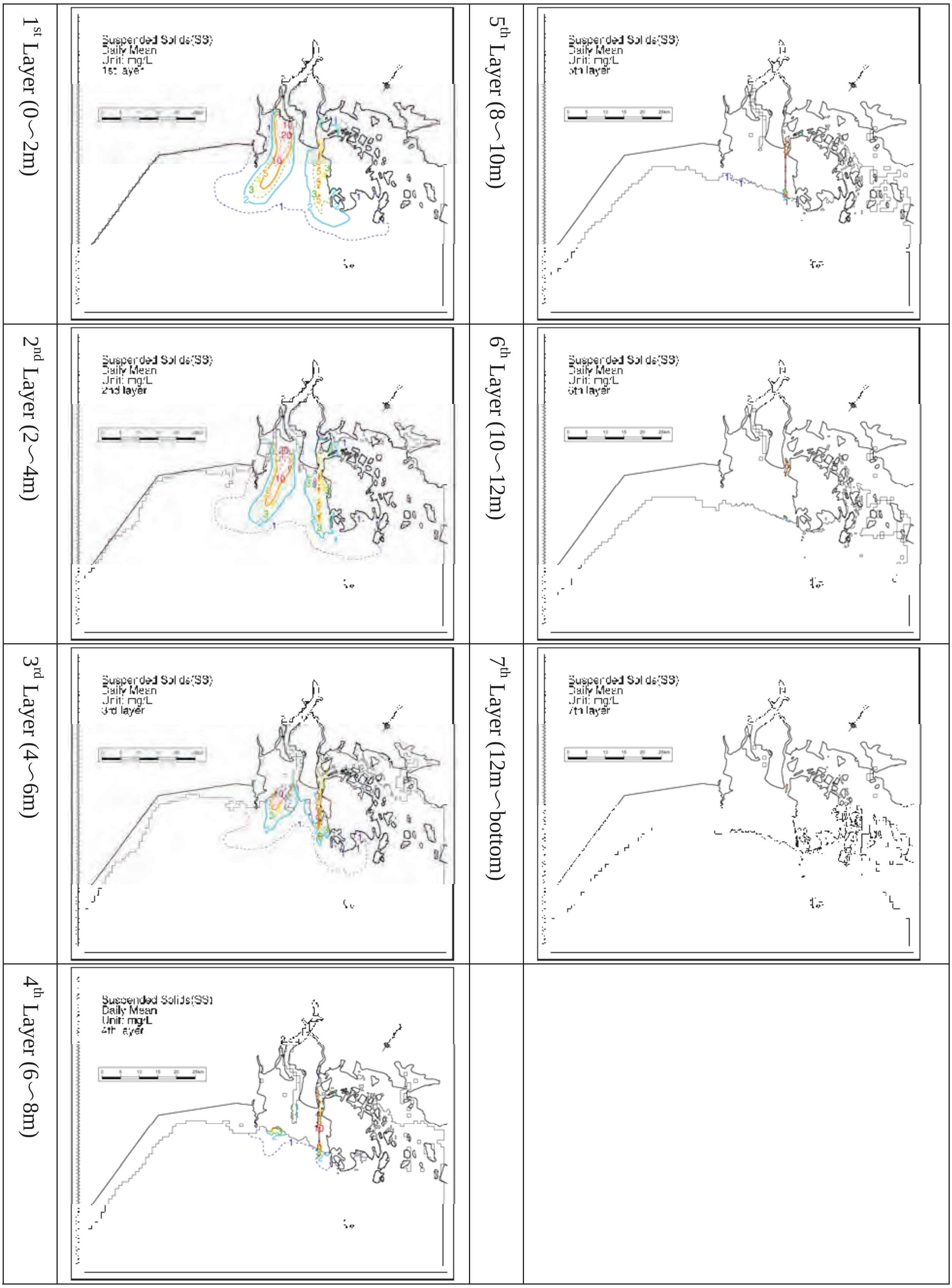
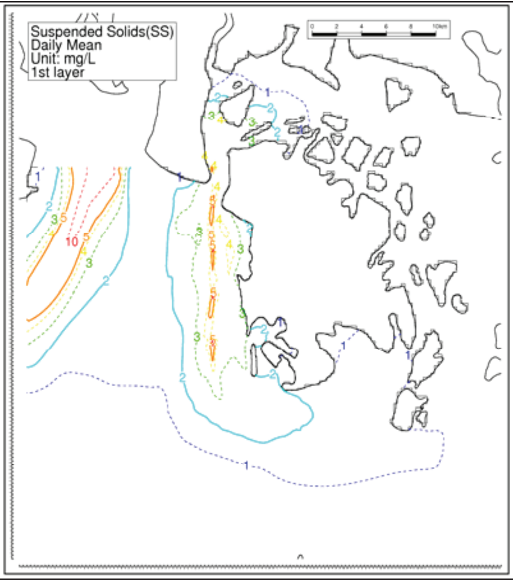
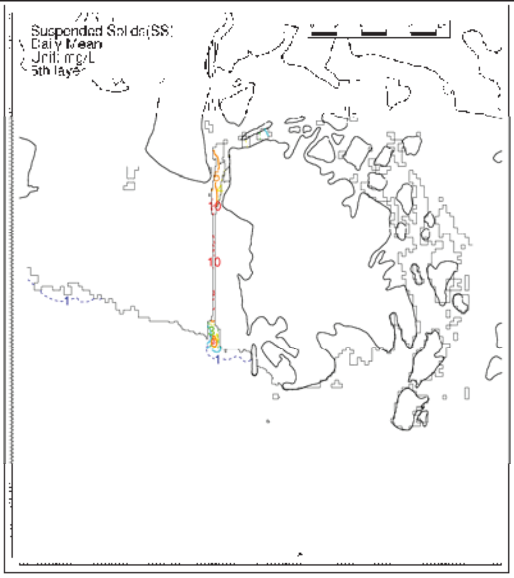
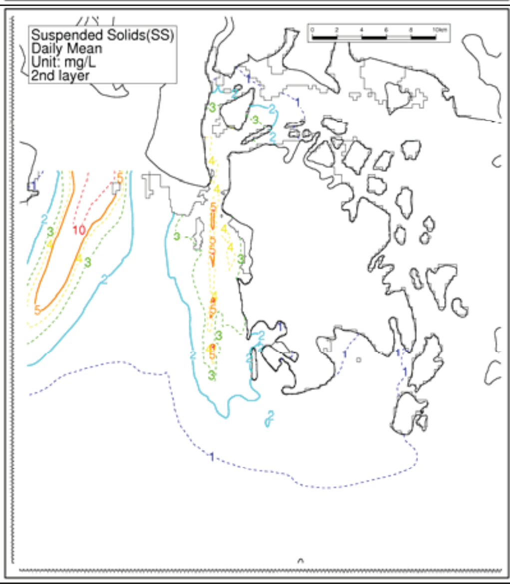
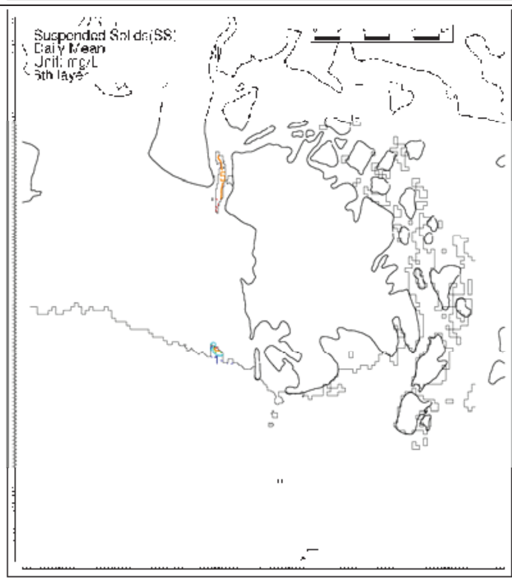
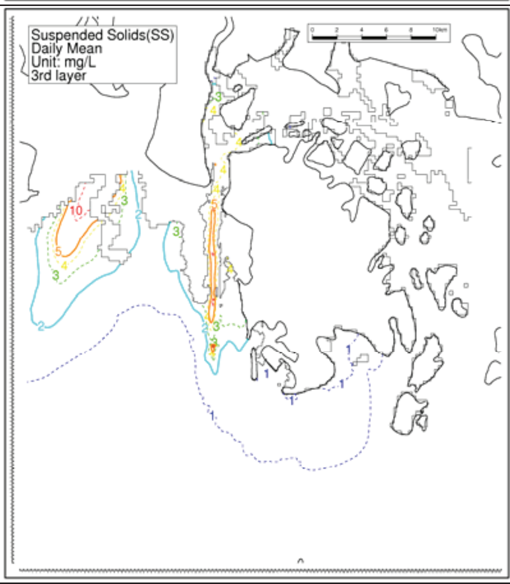
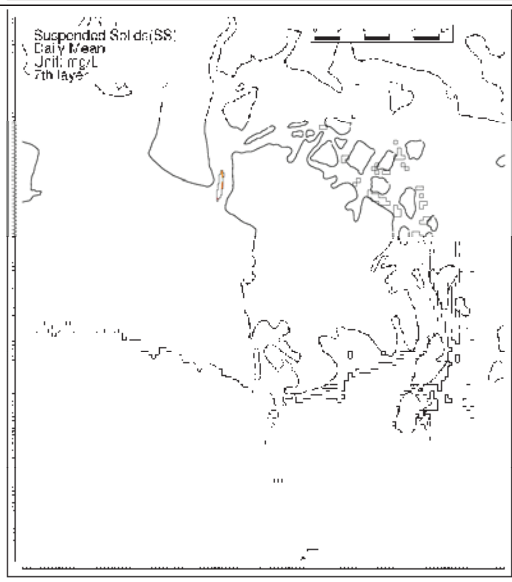


Figure 2-1-1　SS Dispersion Prediction (Case13, Daily Average, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

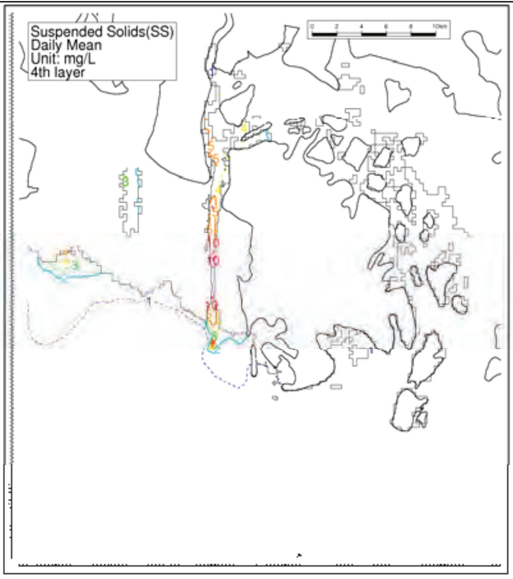
4th Layer (6~8m)			

Figure 2-1-2　SS Dispersion Prediction (Case13, Daily Average, Medium Domain)

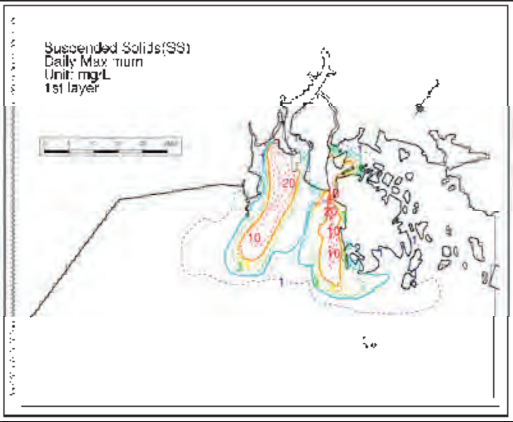
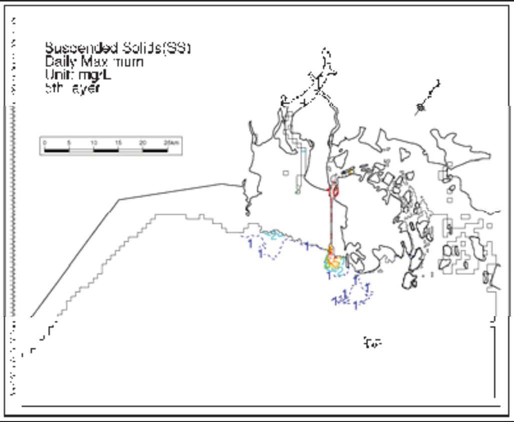
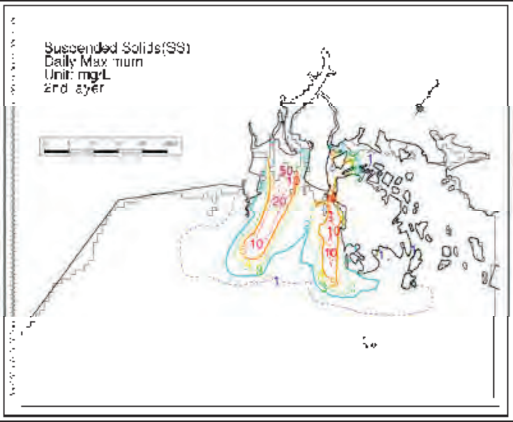
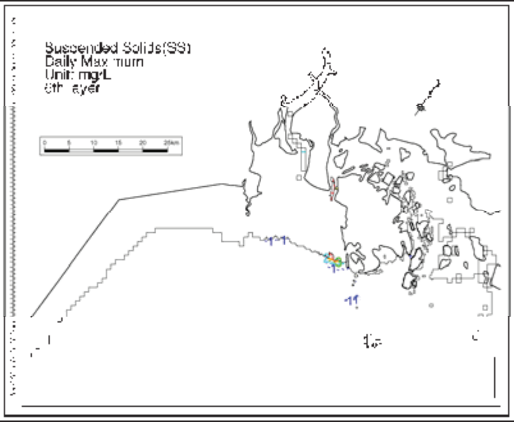
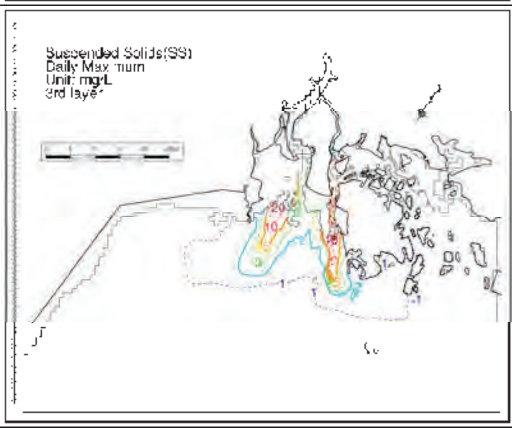
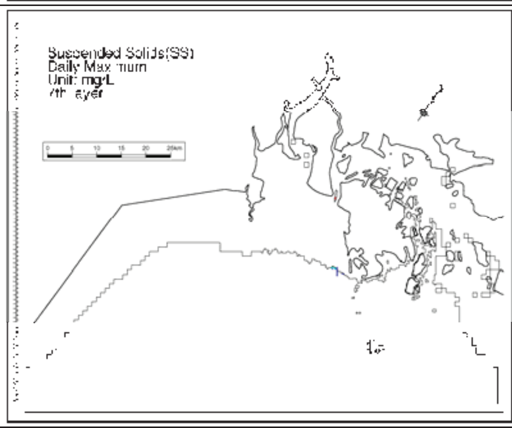
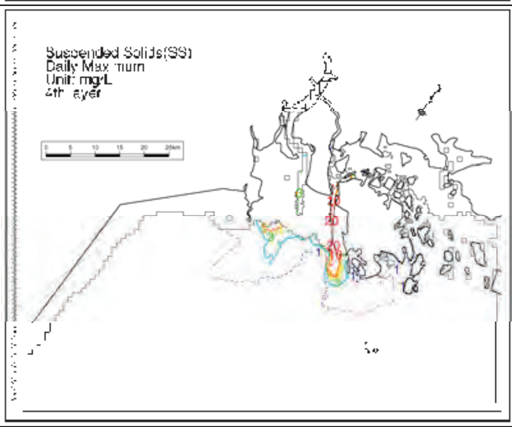
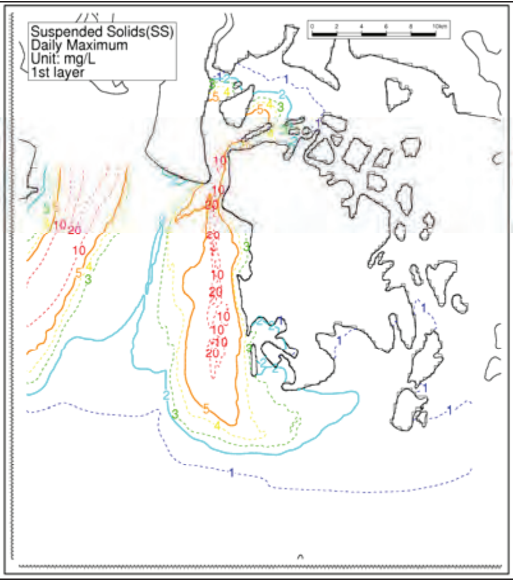
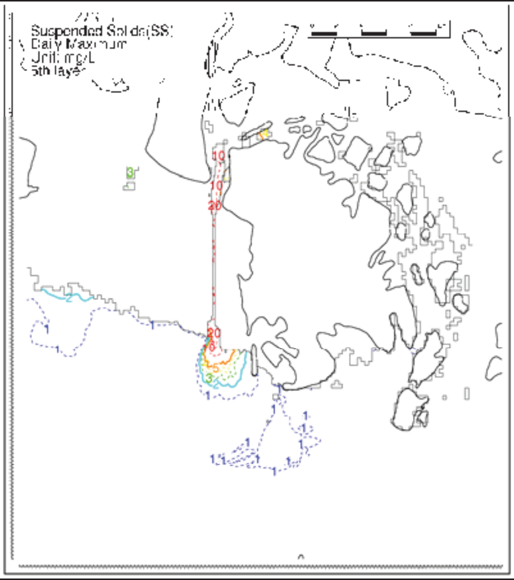
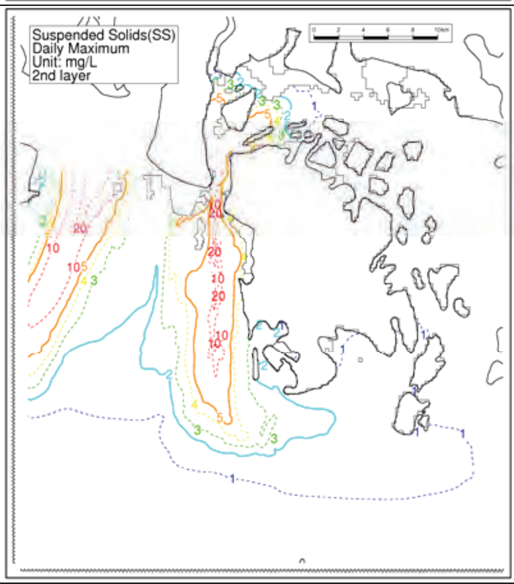
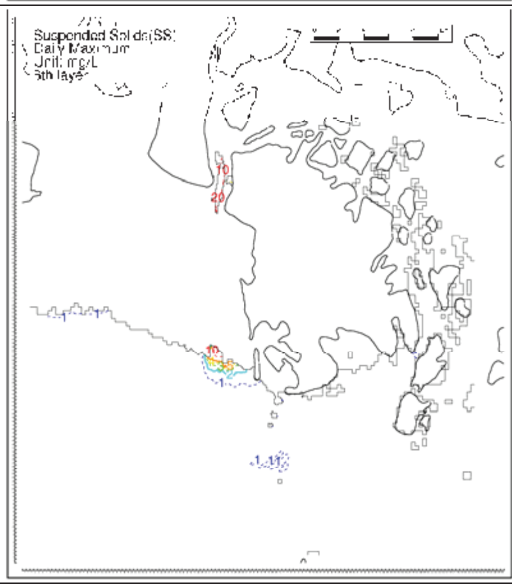
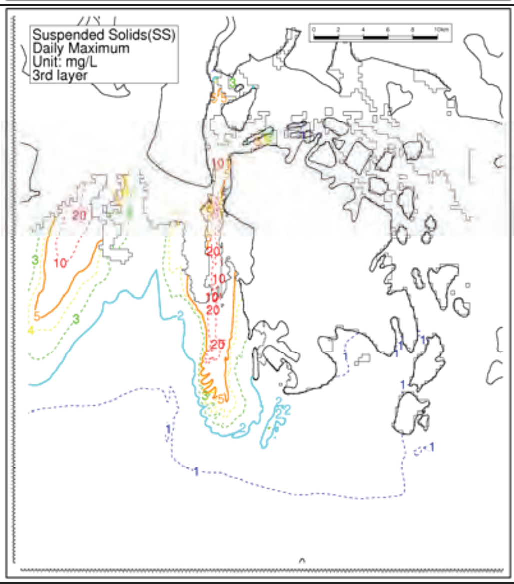
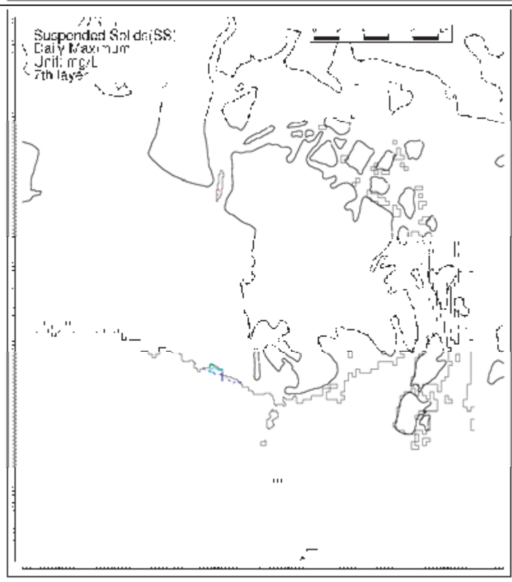
1st Layer (0~2m)		5th Layer (8~10m)	
2nd Layer (2~4m)		6th Layer (10~12m)	
3rd Layer (4~6m)		7th Layer (12m~bottom)	
4th Layer (6~8m)			

Figure 2-2-1 SS Dispersion Prediction (Case13, Daily Maximum, Large Domain)

1st Layer (0~2m)		5th Layer (8~10m)	
2nd Layer (2~4m)		6th Layer (10~12m)	
3rd Layer (4~6m)		7th Layer (12m~bottom)	

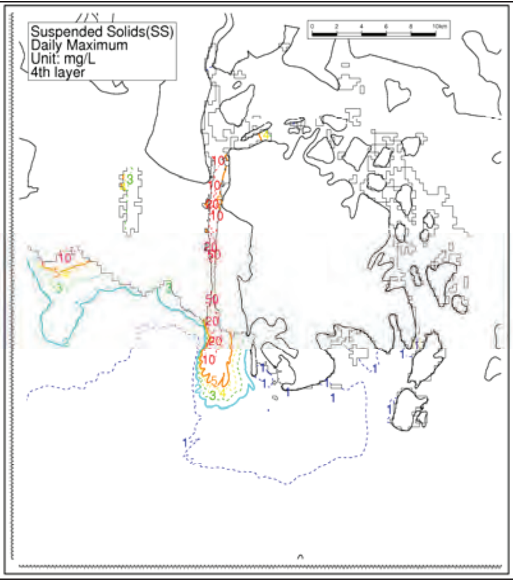
4th Layer (6～8m)			

Figure 2-2-2 SS Dispersion Prediction (Case13, Daily Maximum, Medium Domain)

3. Case 14

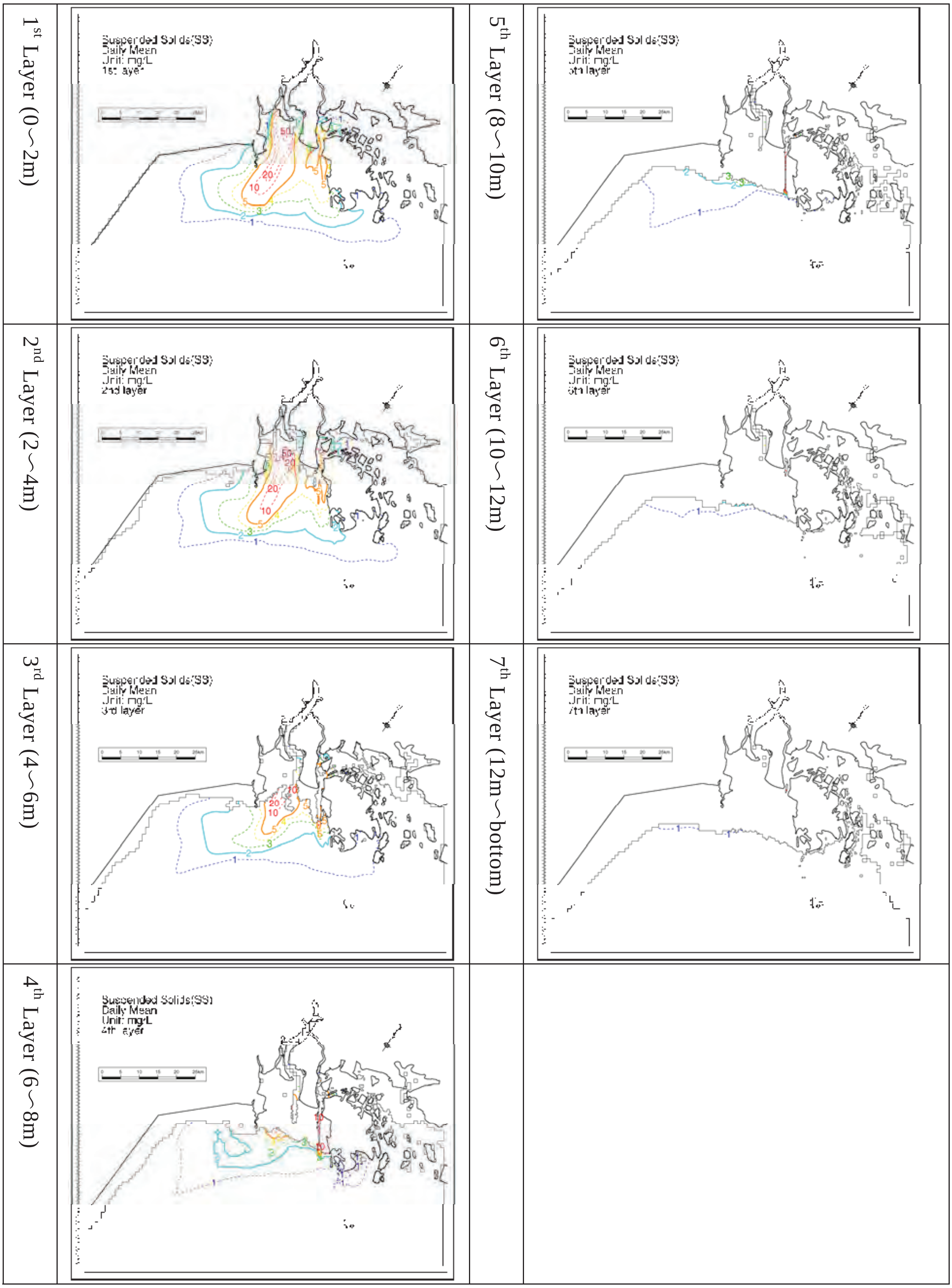
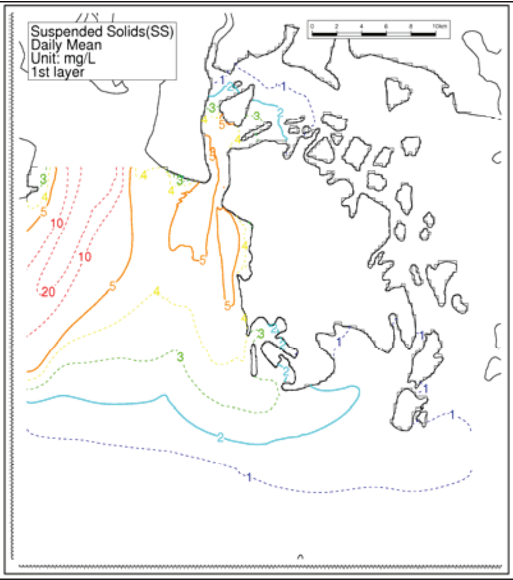
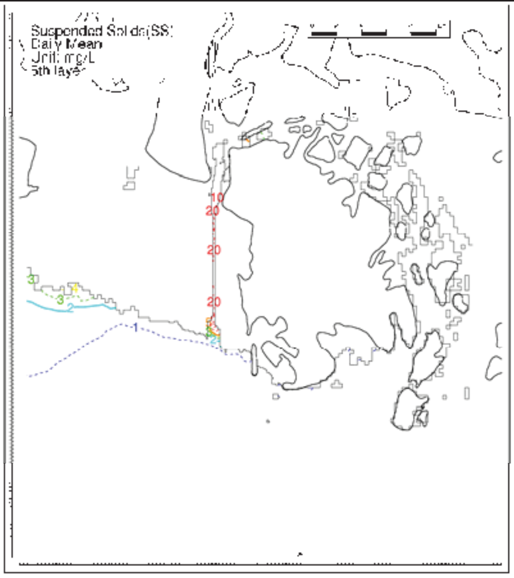
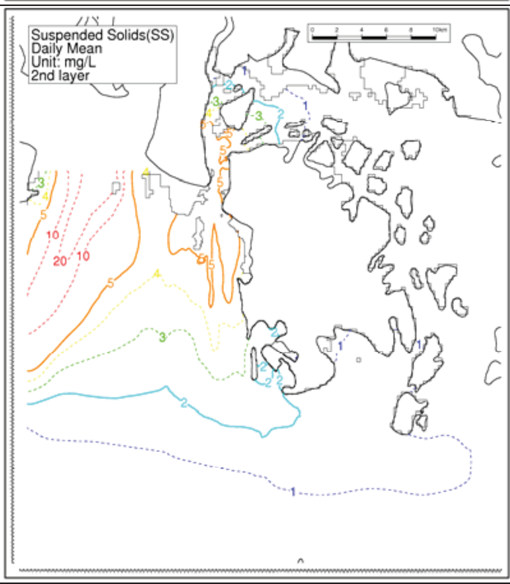
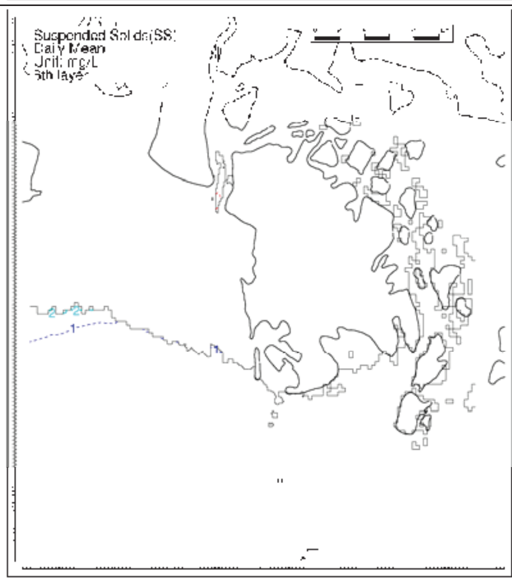
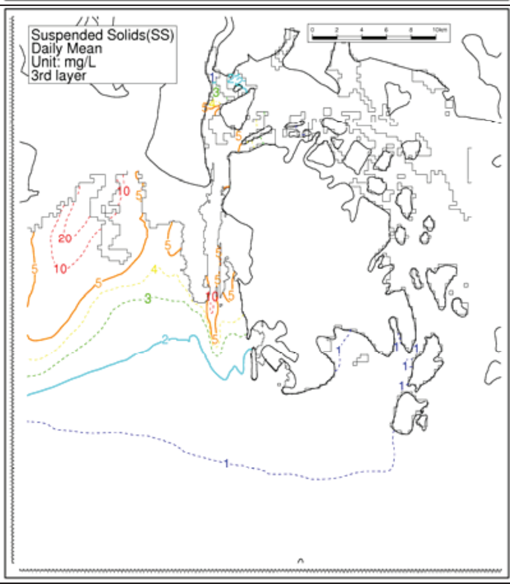
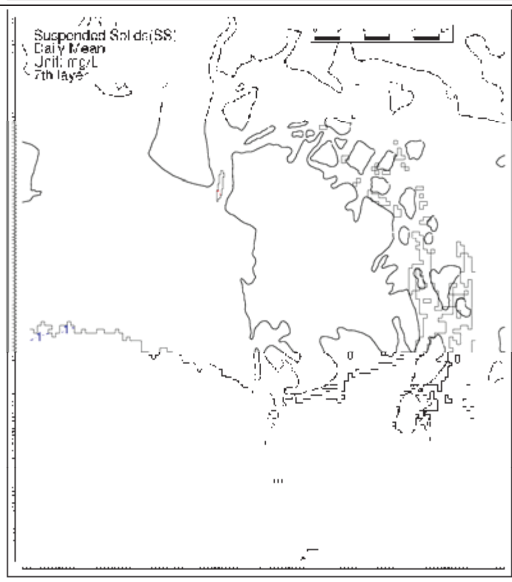


Figure 3-1-1 SS Dispersion Prediction (Case14, Daily Average, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

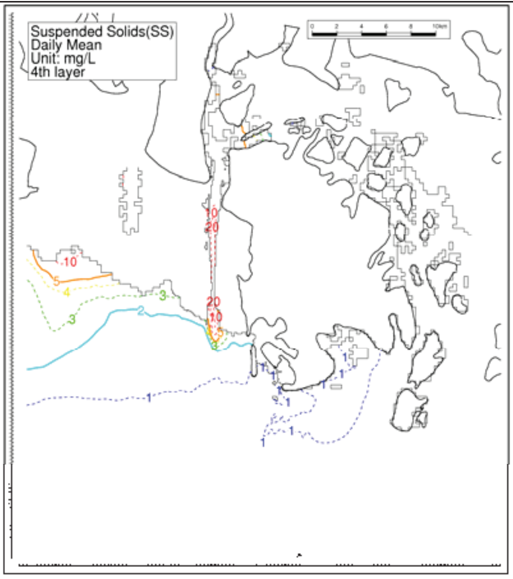
4th Layer (6～8m)			

Figure 3-1-2 SS Dispersion Prediction (Case14, Daily Average, Medium Domain)

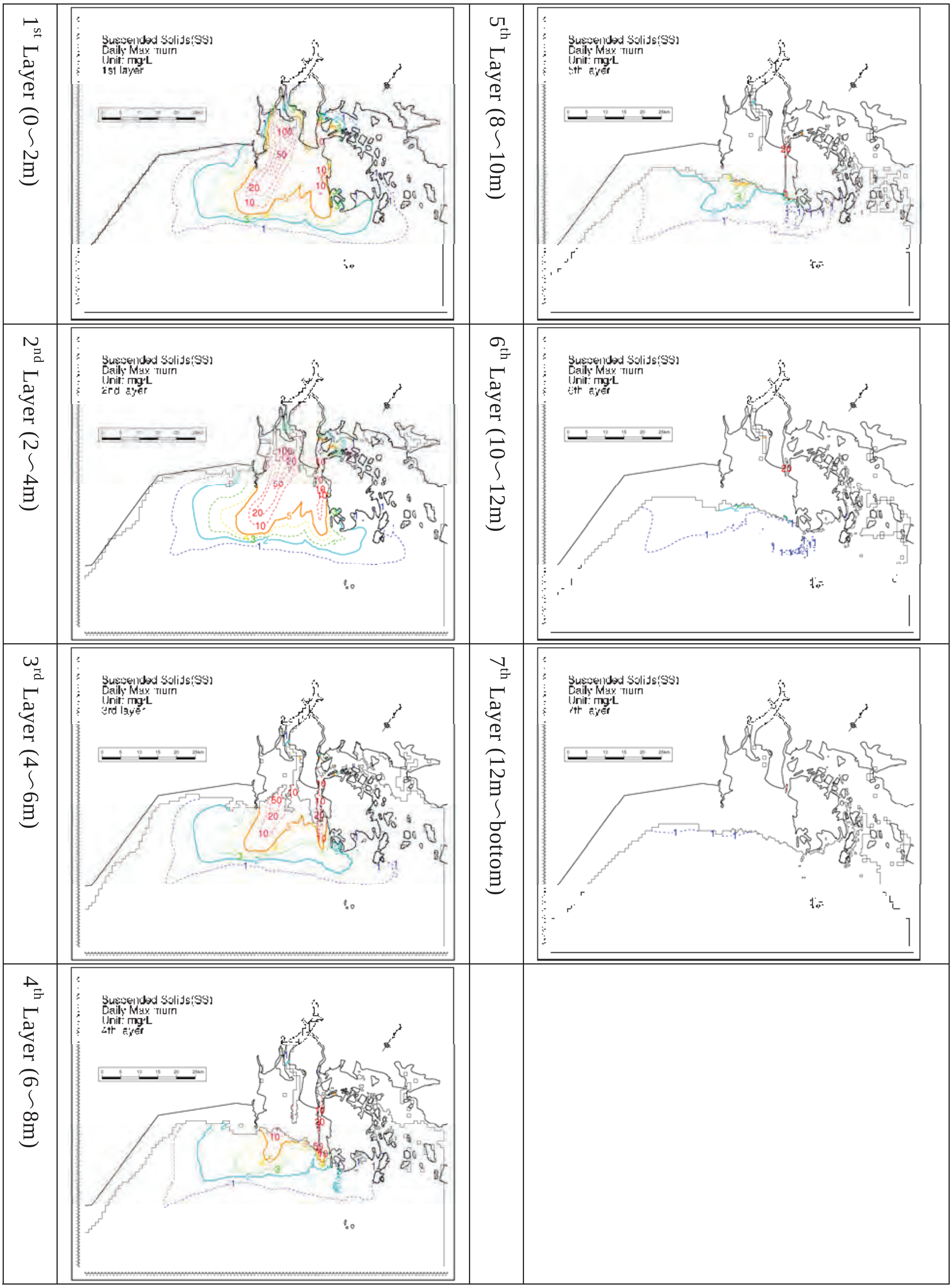
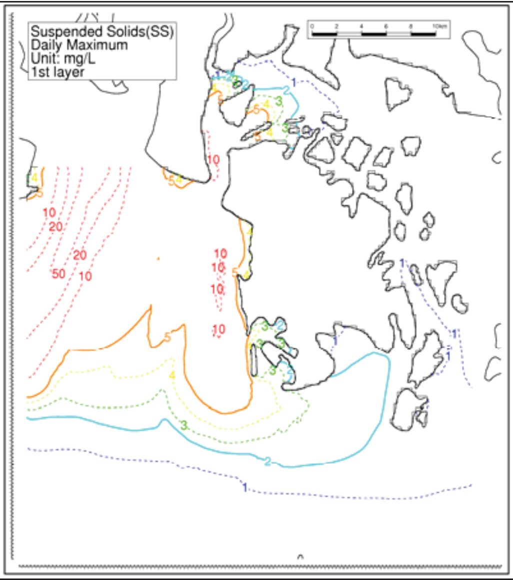
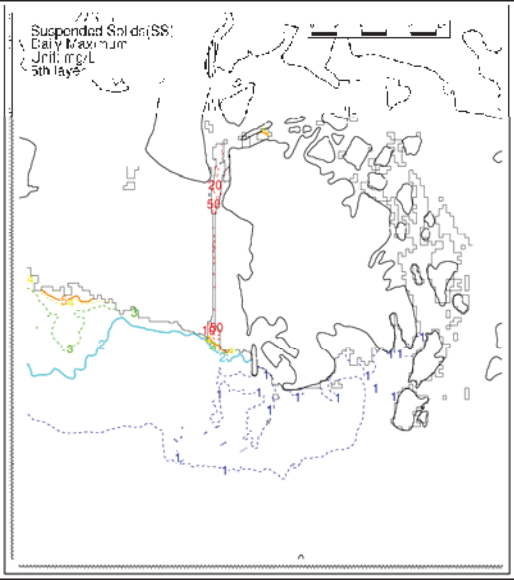
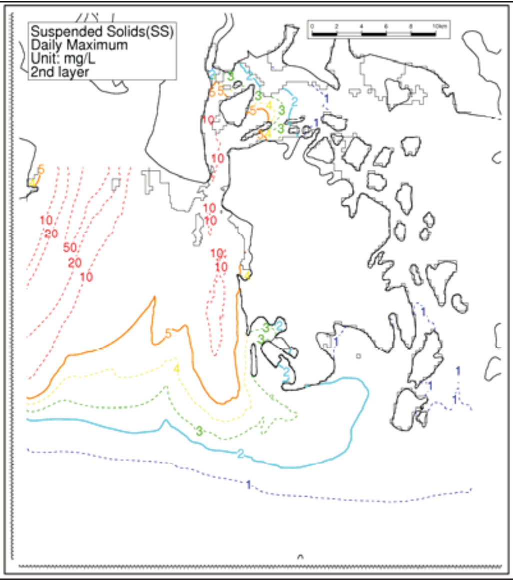
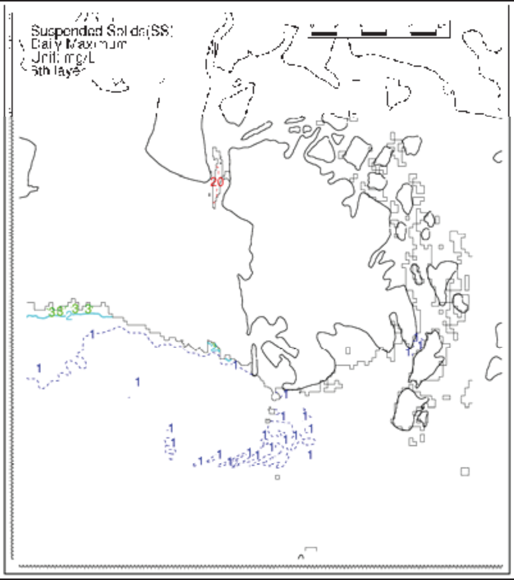
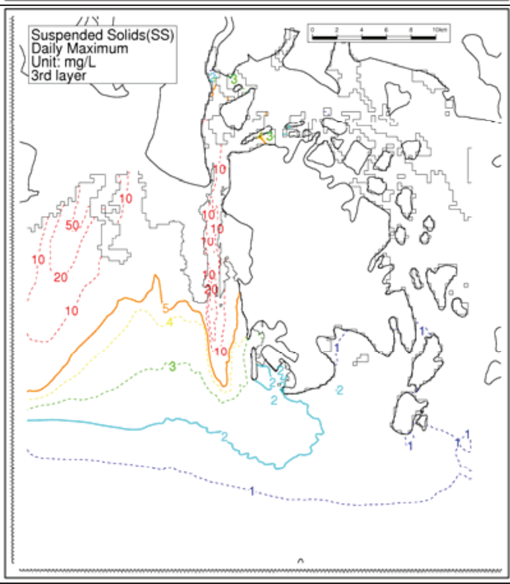
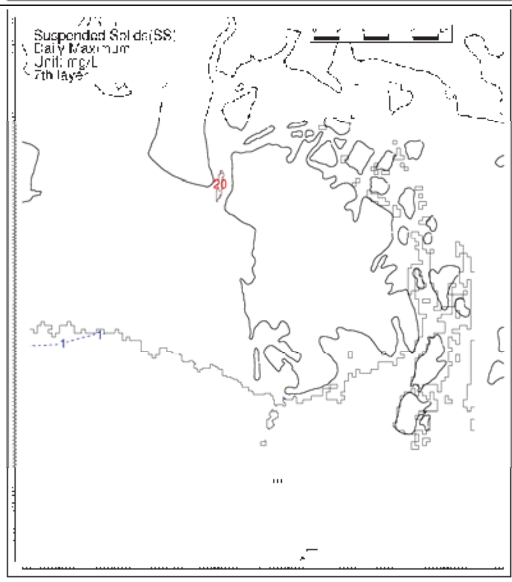


Figure 3-2-1　SS Dispersion Prediction (Case14, Daily Maximum, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

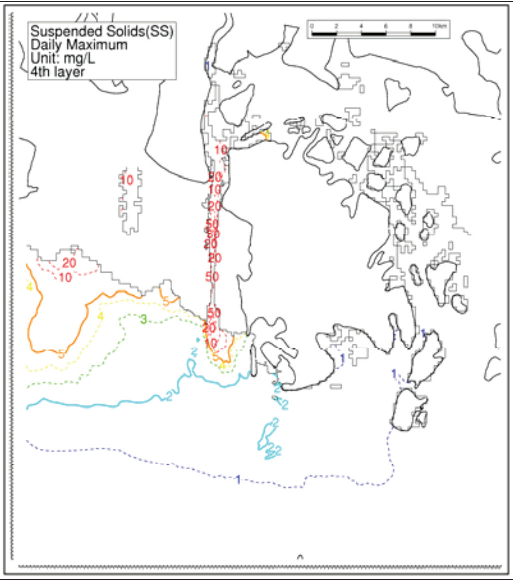
4th Layer (6～8m)			

Figure 3-2-2 SS Dispersion Prediction (Case14, Daily Maximum, Medium Domain)

4. Case 15

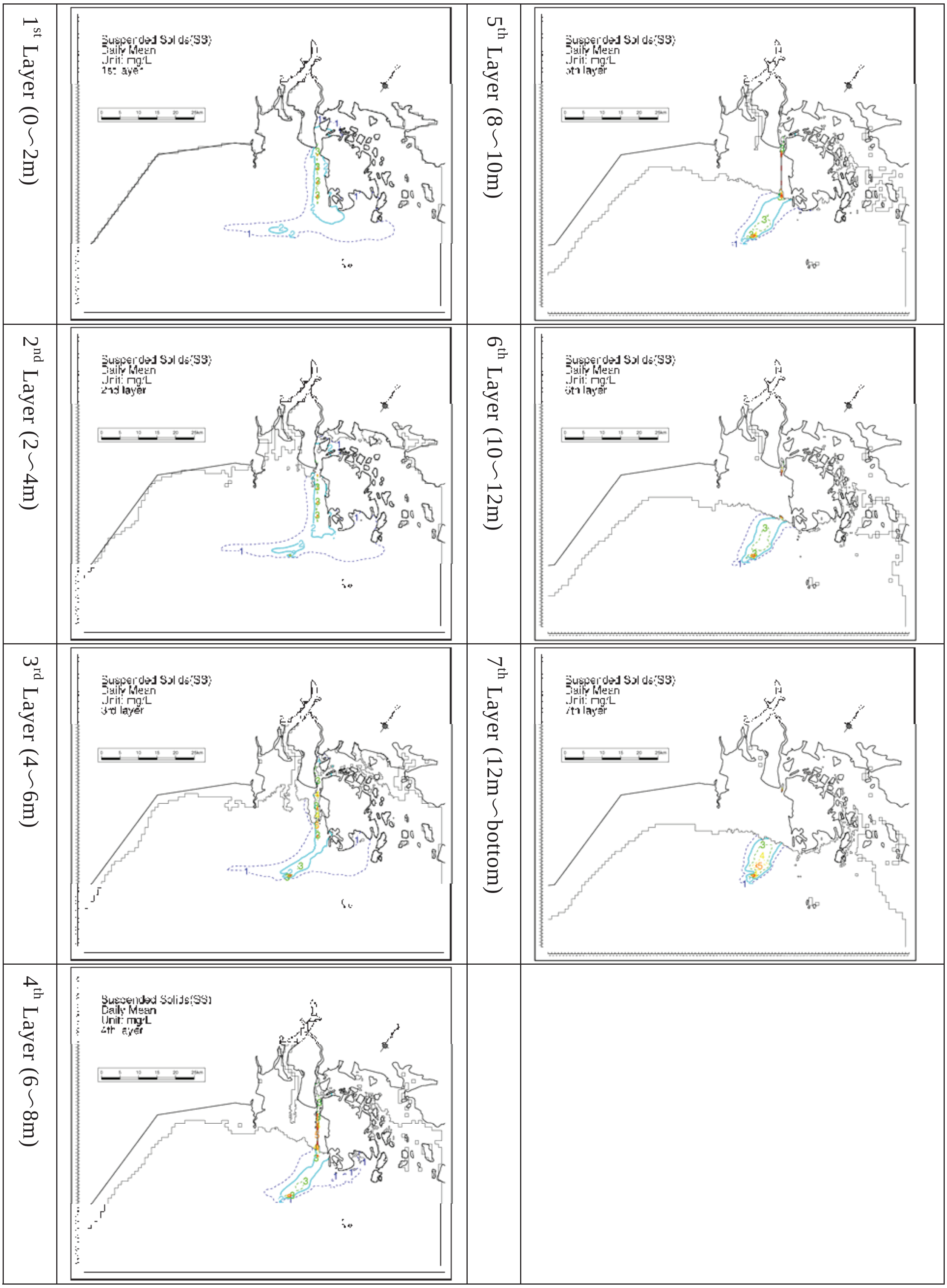
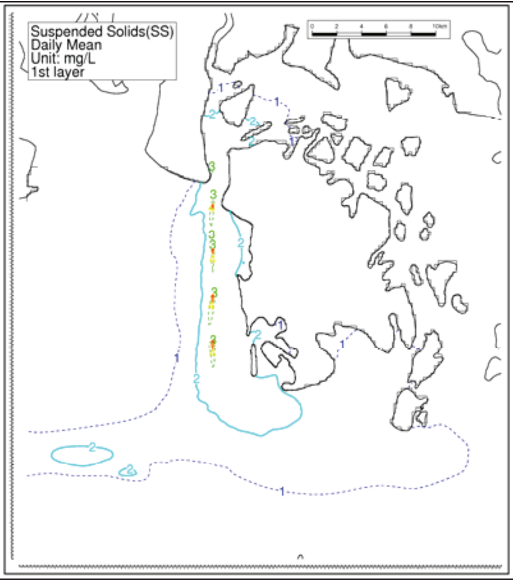
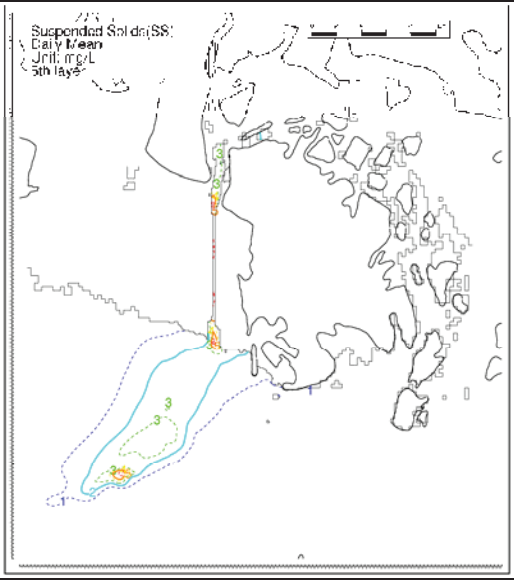
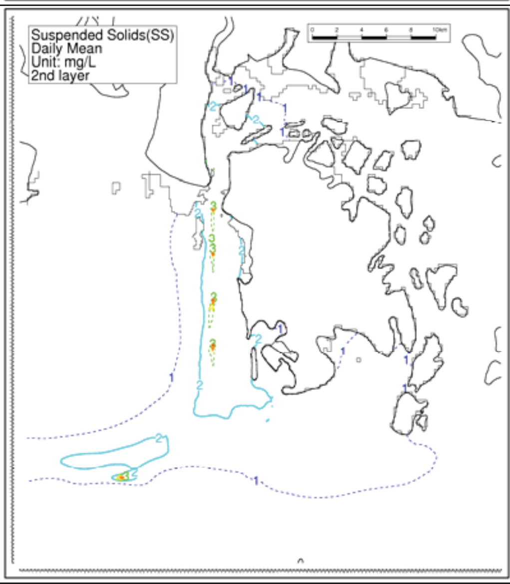
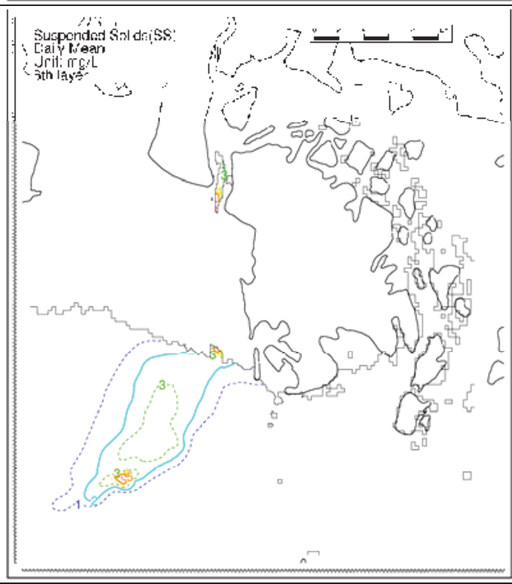
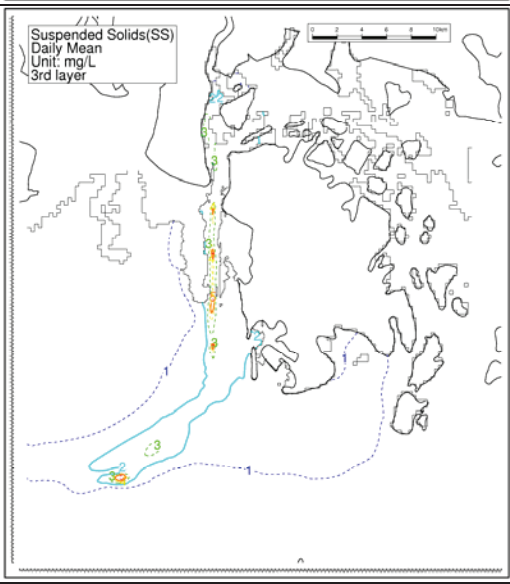
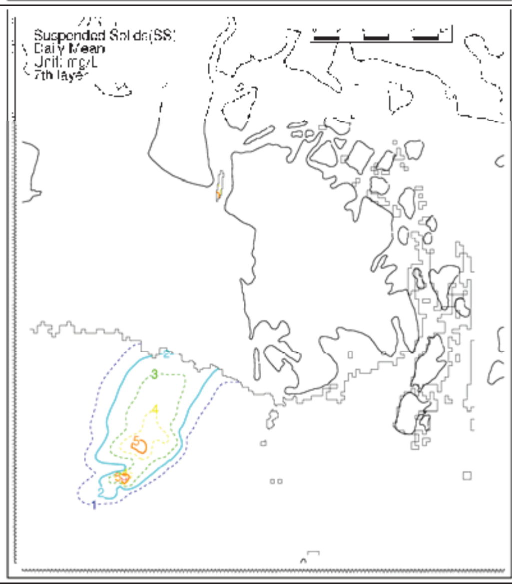


Figure 4-1-1 SS Dispersion Prediction (Case15, Daily Average, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

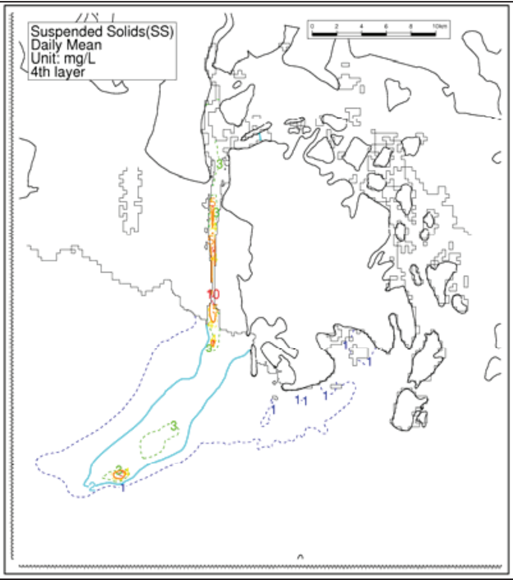
4th Layer (6～8m)			

Figure 4-1-2 SS Dispersion Prediction (Case15, Daily Average, Medium Domain)

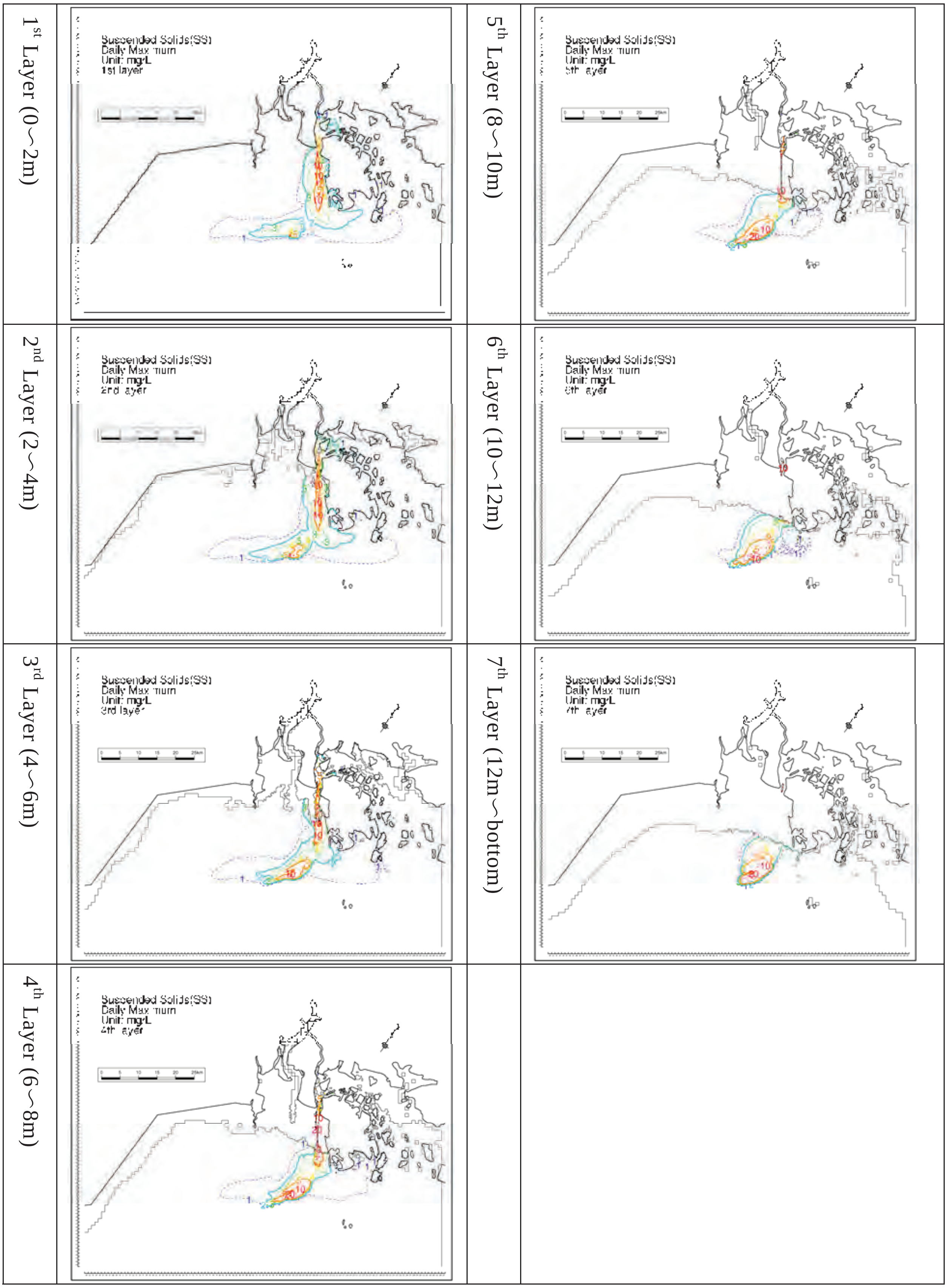
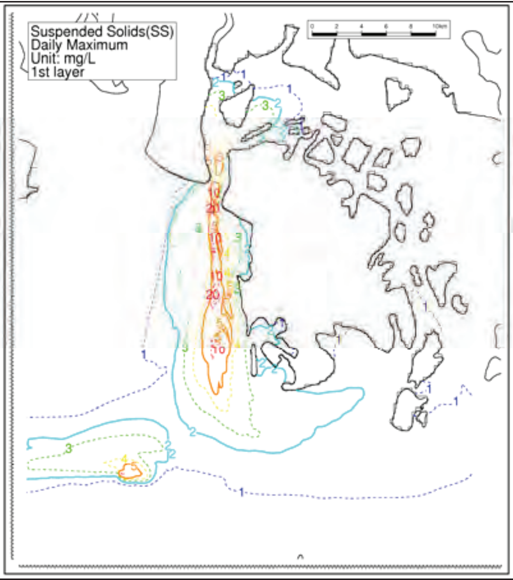
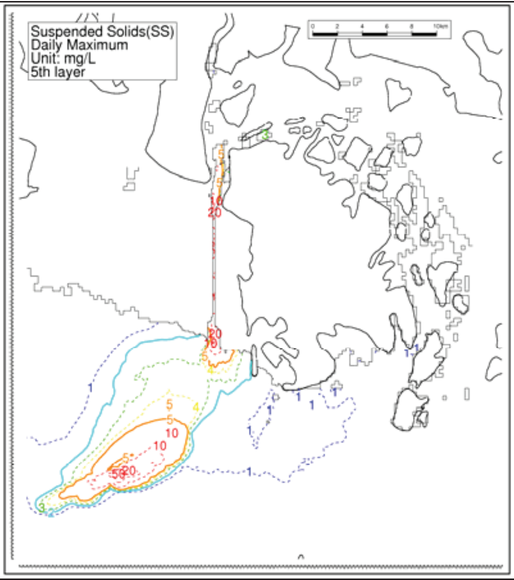
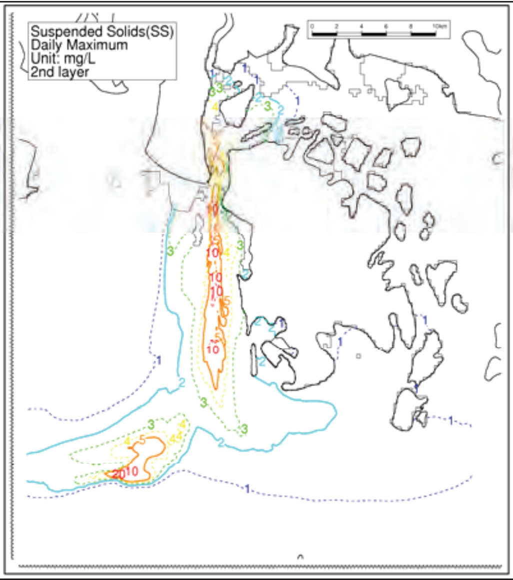
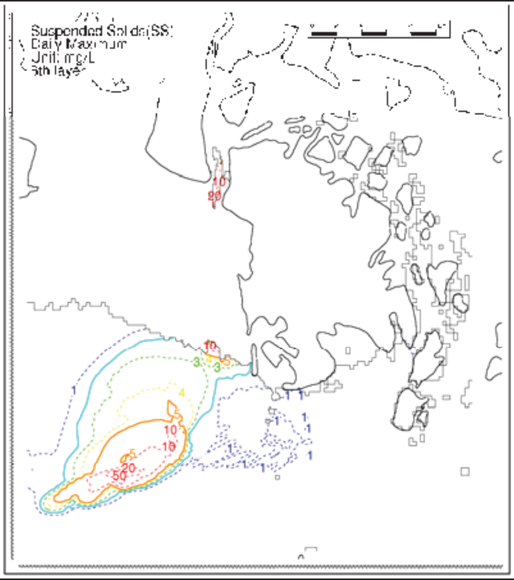
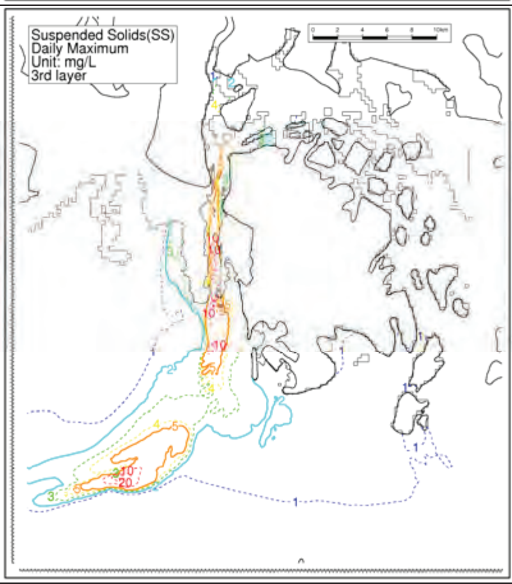
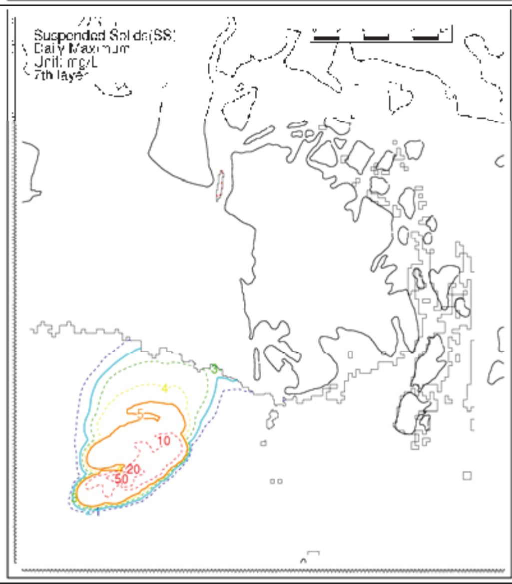


Figure 4-2-1 SS Dispersion Prediction (Case15, Daily Maximum, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

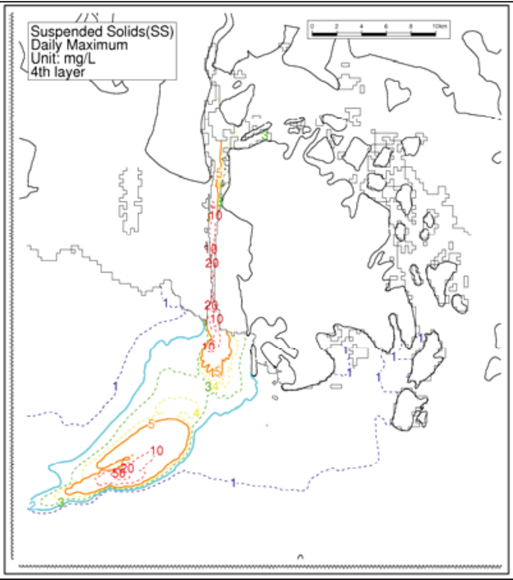
4th Layer (6～8m)			

Figure 4-2-2 SS Dispersion Prediction (Case15, Daily Maximum, Medium Domain)

5. Case 16

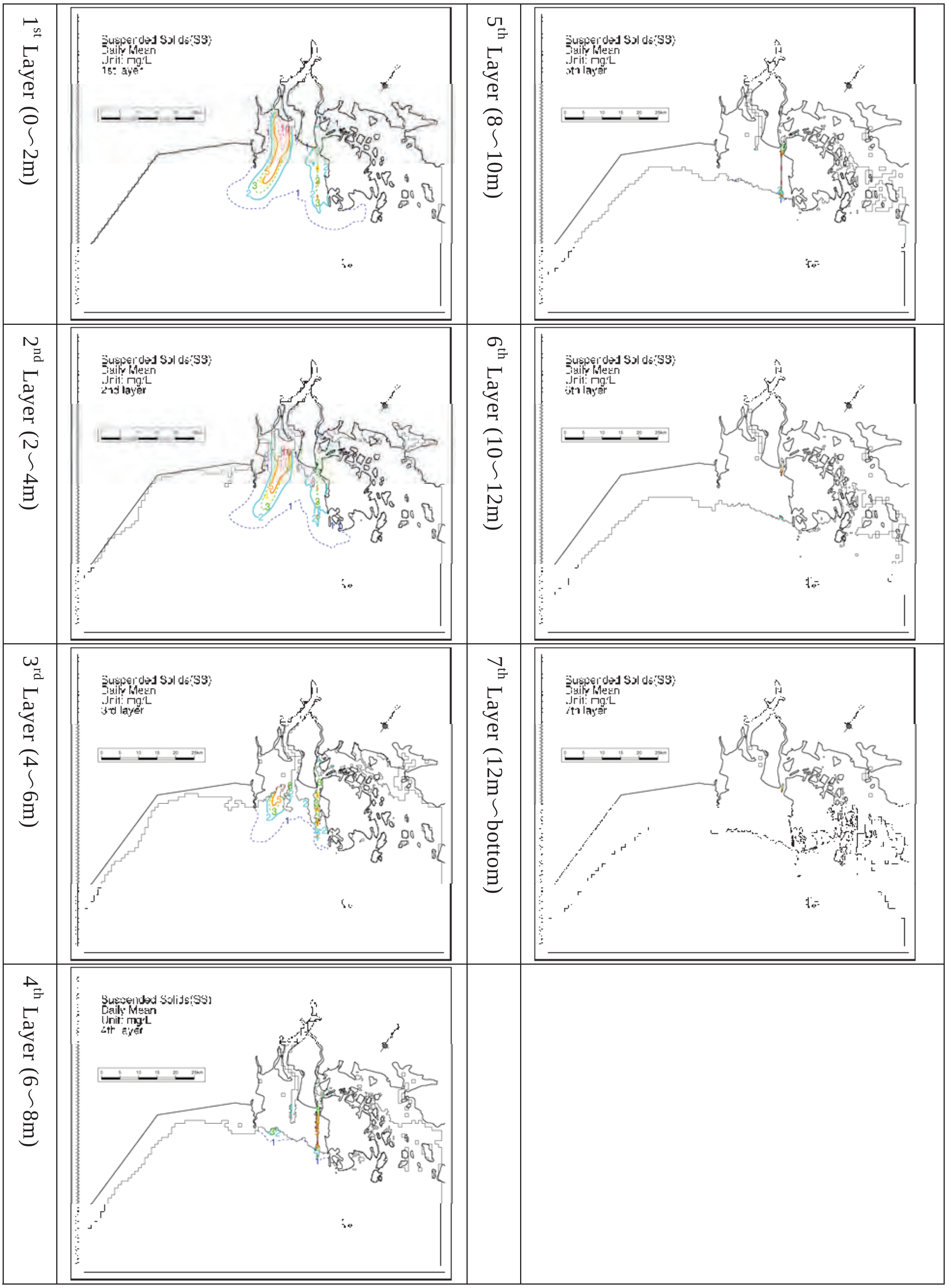
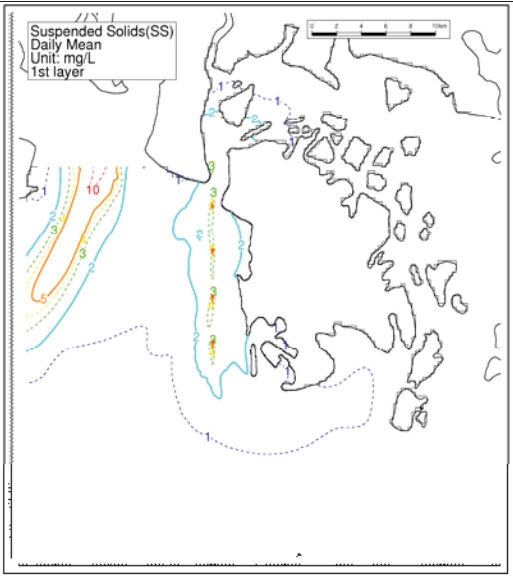
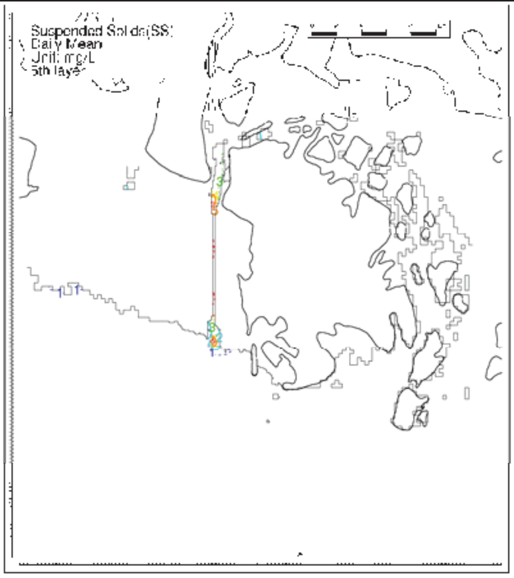


Figure 5-1-1 SS Dispersion Prediction (Case16, Daily Average, Large Domain)

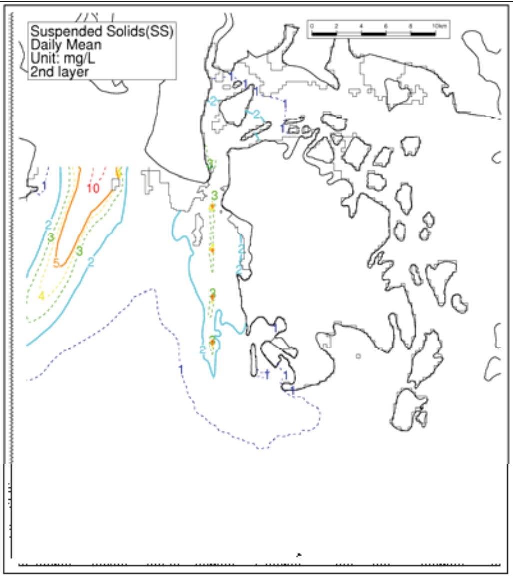
1st Layer (0～2m)



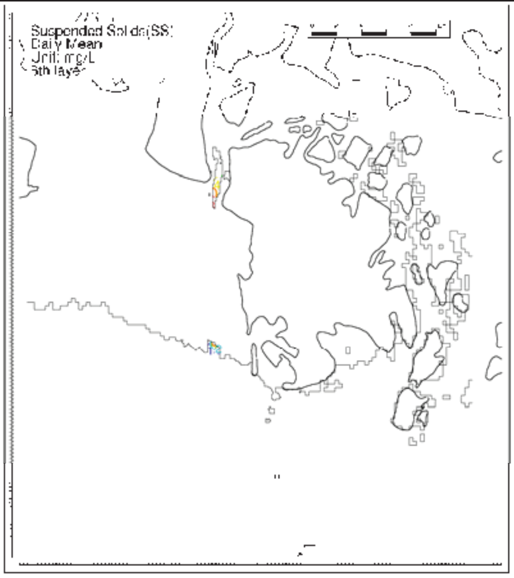
5th Layer (8～10m)



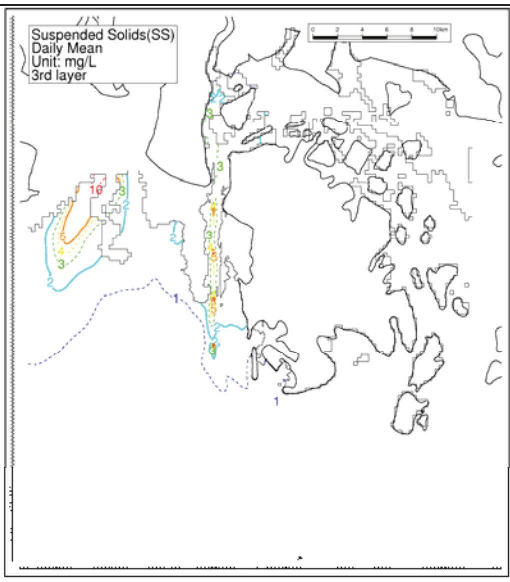
2nd Layer (2～4m)



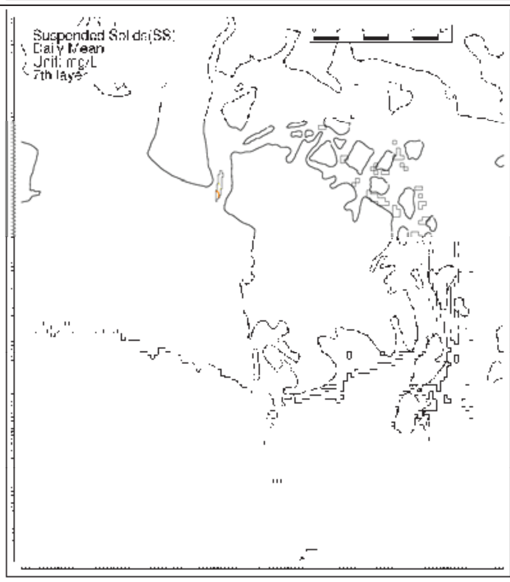
6th Layer (10～12m)



3rd Layer (4～6m)



7th Layer (12m～bottom)



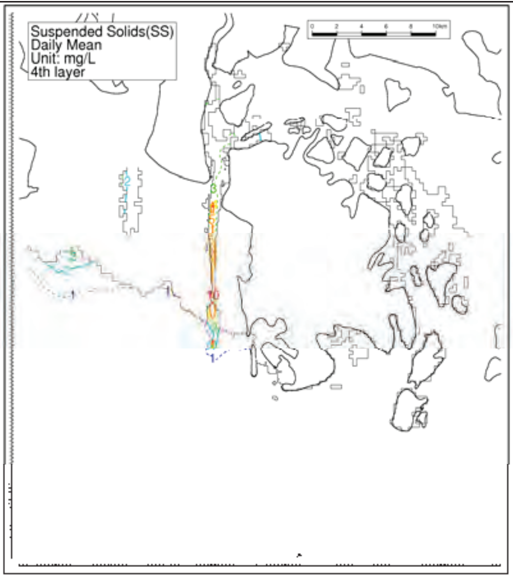
4th Layer (6～8m)			

Figure 5-1-2 SS Dispersion Prediction (Case16, Daily Average, Medium Domain)

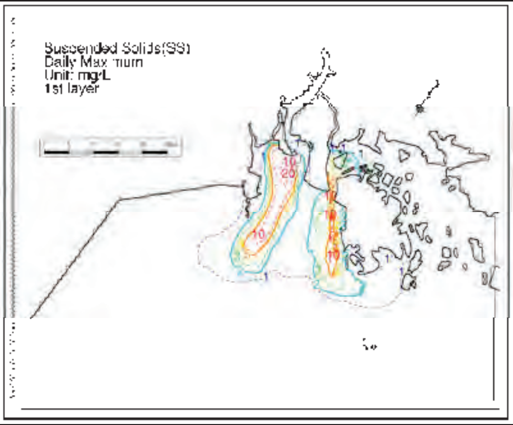
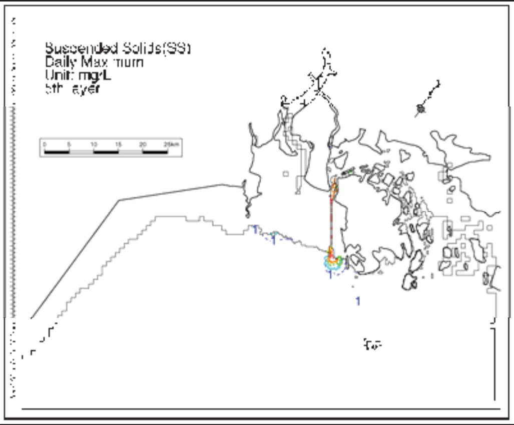
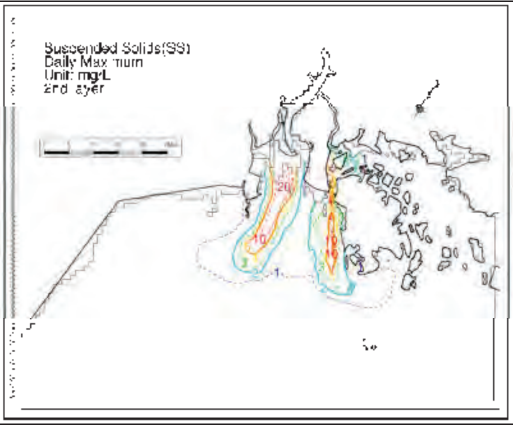
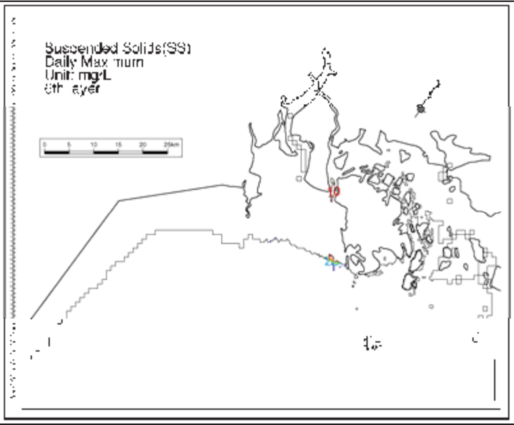
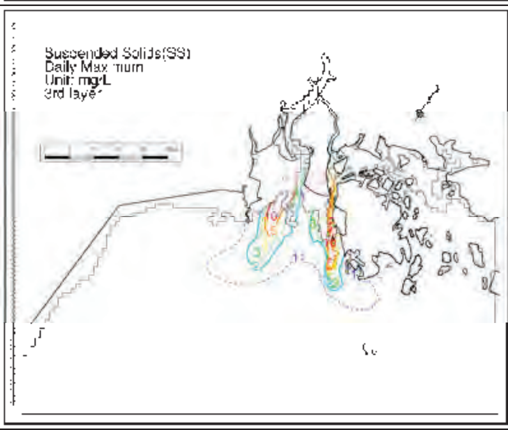
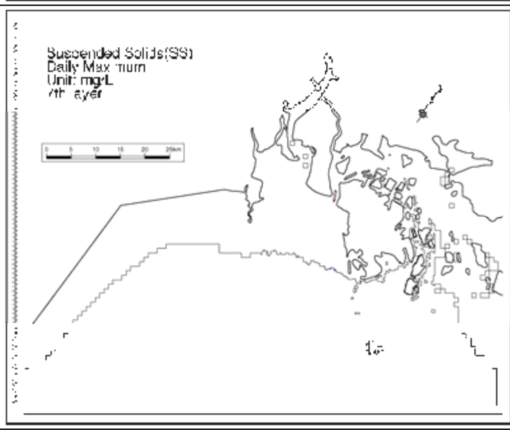
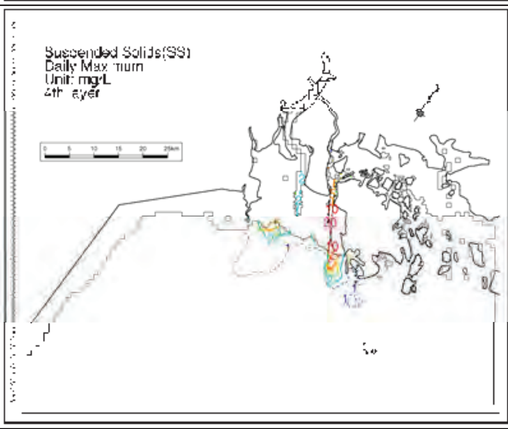
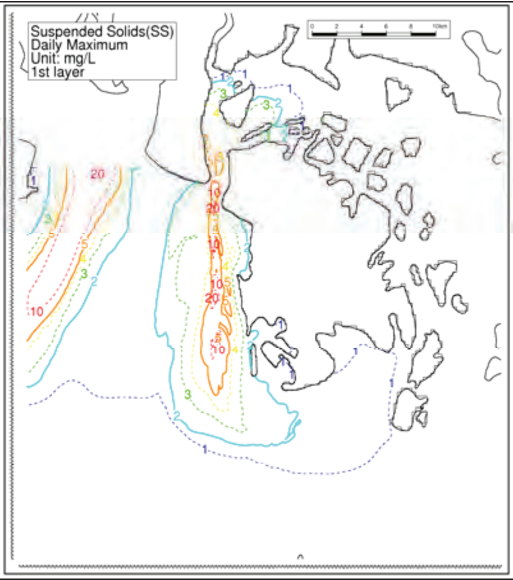
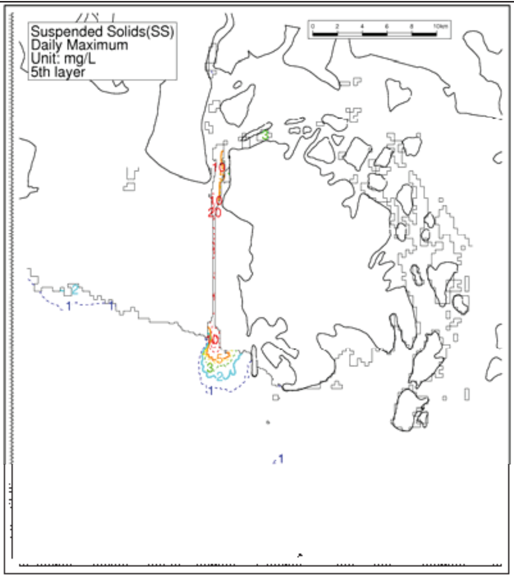
1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	
4th Layer (6～8m)			

Figure 5-2-1　SS Dispersion Prediction (Case16, Daily Maximum, Large Domain)

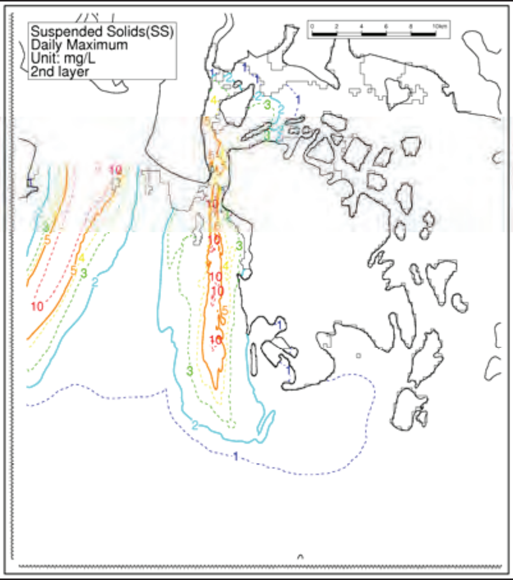
1st Layer (0～2m)



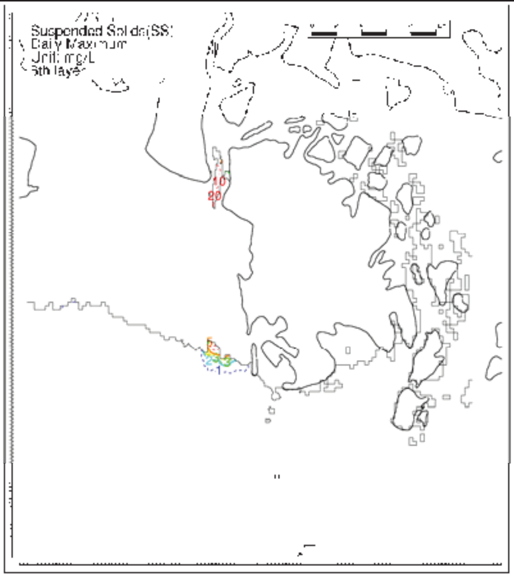
5th Layer (8～10m)



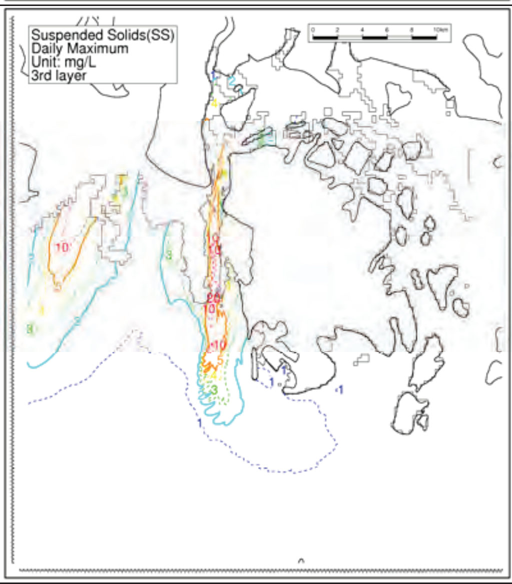
2nd Layer (2～4m)



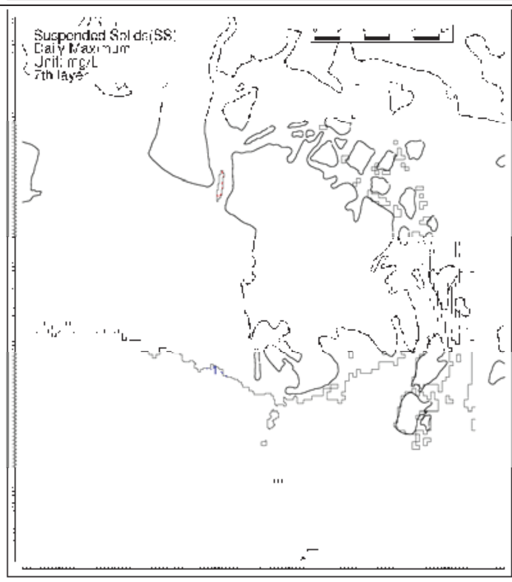
6th Layer (10～12m)



3rd Layer (4～6m)



7th Layer (12m～bottom)



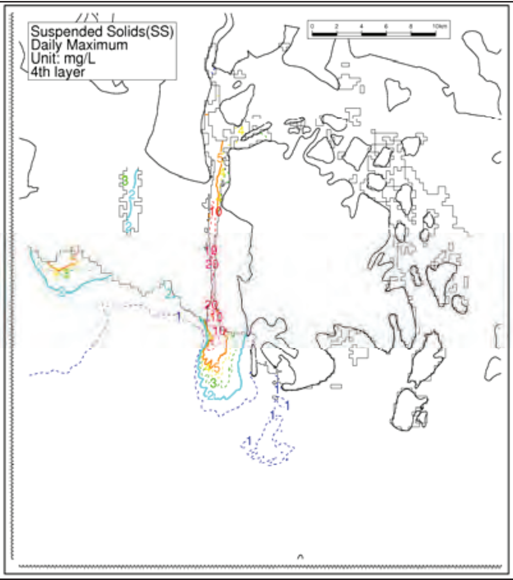
4th Layer (6~8m)			

Figure 5-2-2 SS Dispersion Prediction (Case16, Daily Maximum, Medium Domain)

6. Case 17

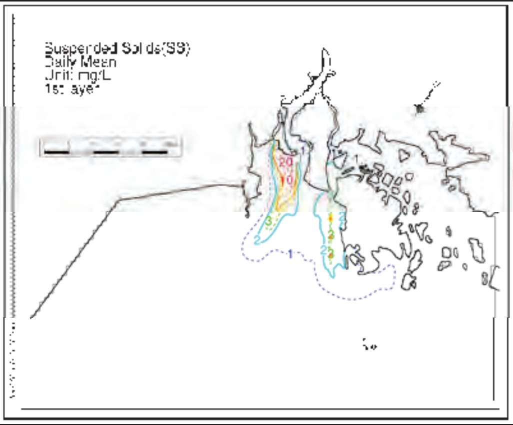
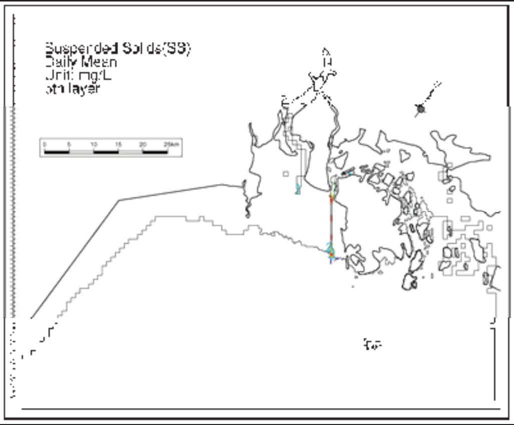
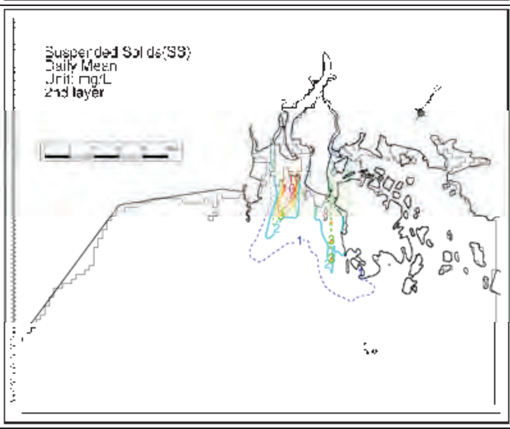
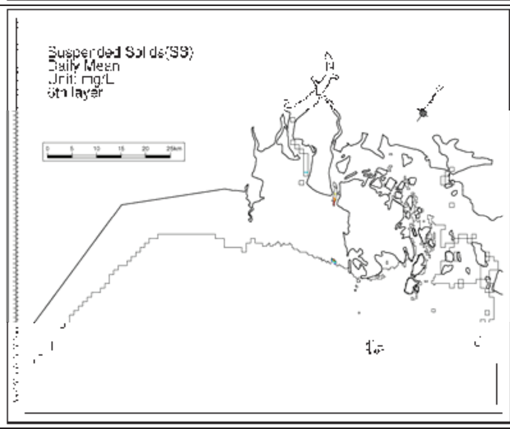
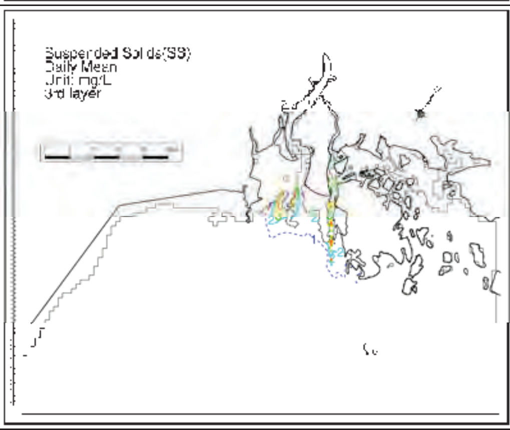
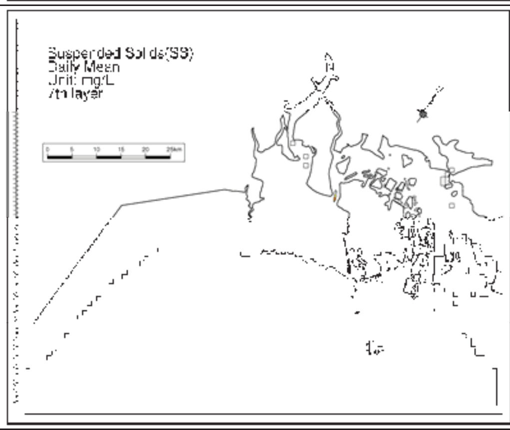
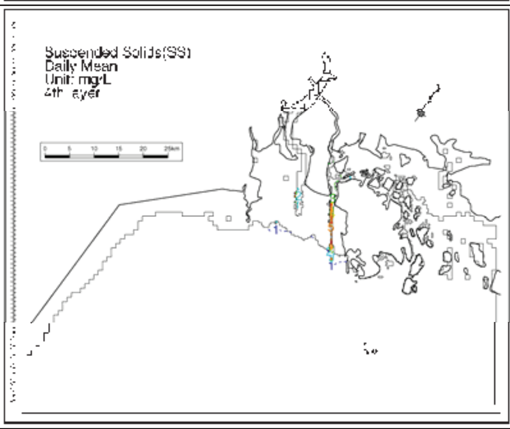
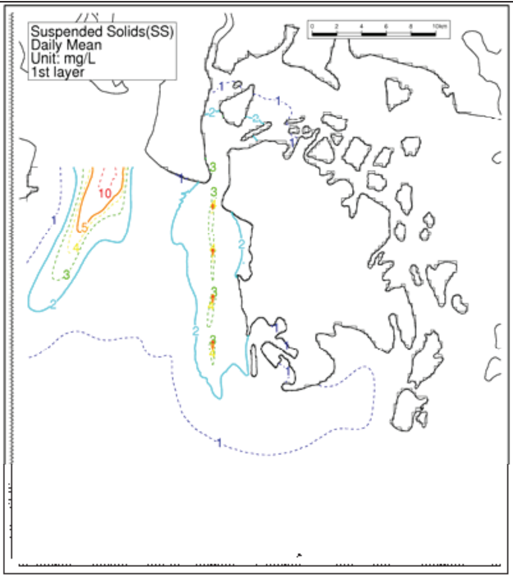
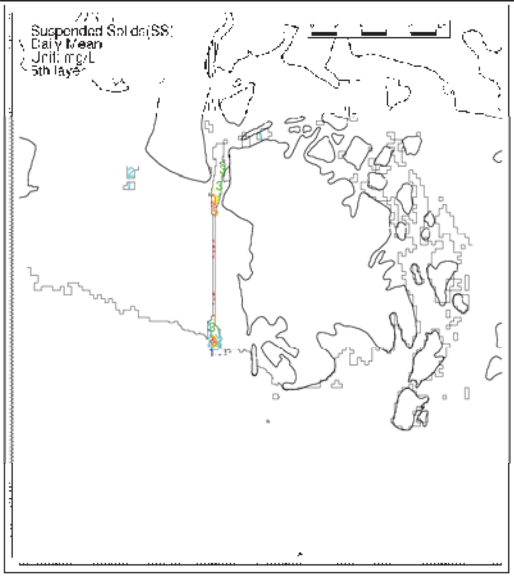
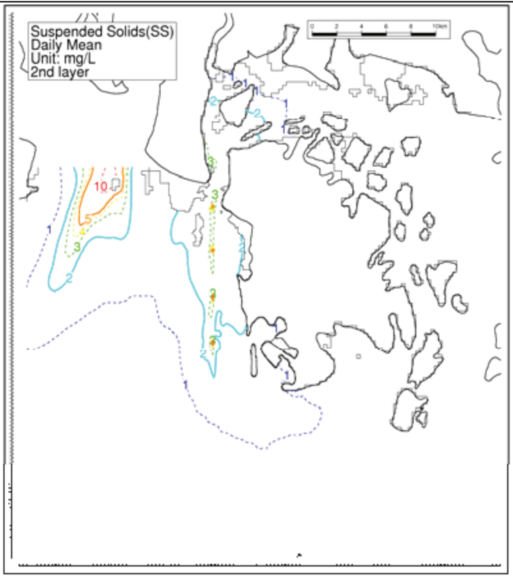
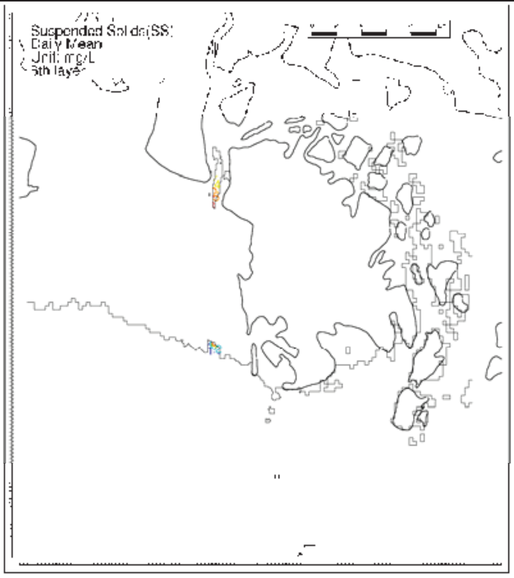
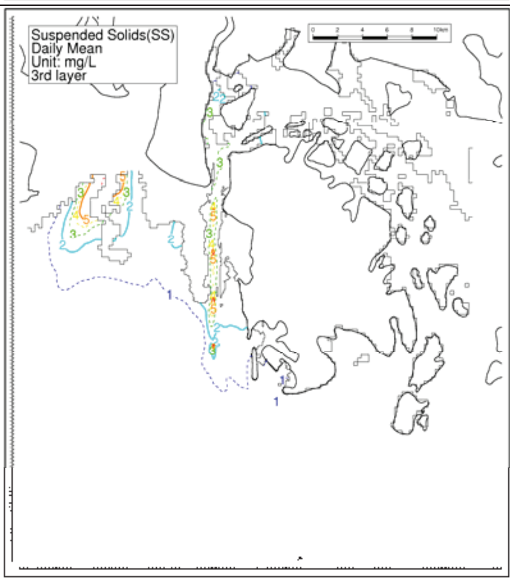
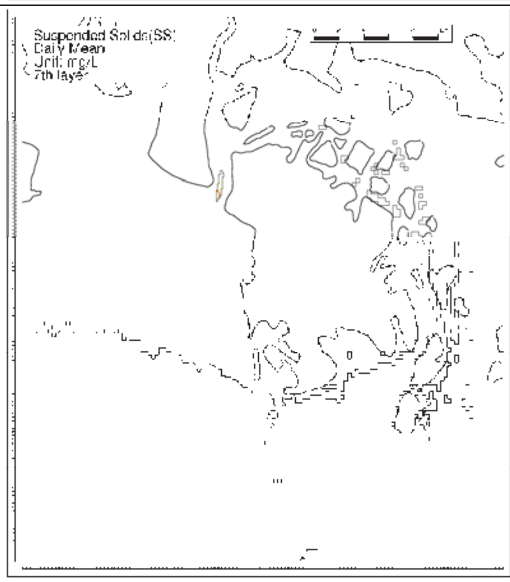
1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	
4th Layer (6～8m)			

Figure 6-1-1 SS Dispersion Prediction (Case17, Daily Average, Large Domain)

1st Layer (0～2m)	
5th Layer (8～10m)	
2nd Layer (2～4m)	
6th Layer (10～12m)	
3rd Layer (4～6m)	
7th Layer (12m～bottom)	

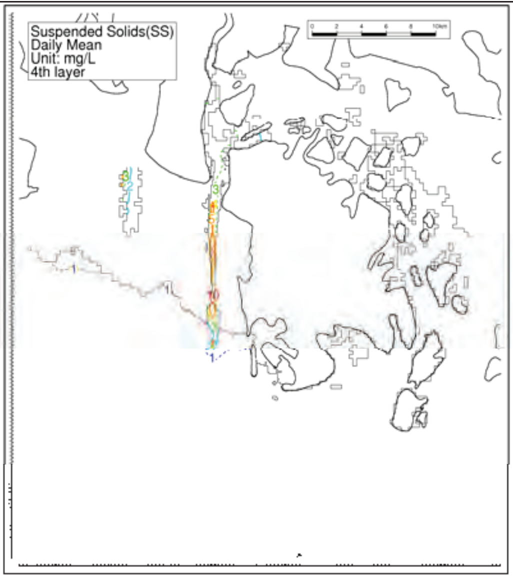
4th Layer (6~8m)			

Figure 6-1-2 SS Dispersion Prediction (Case17, Daily Average, Medium Domain)

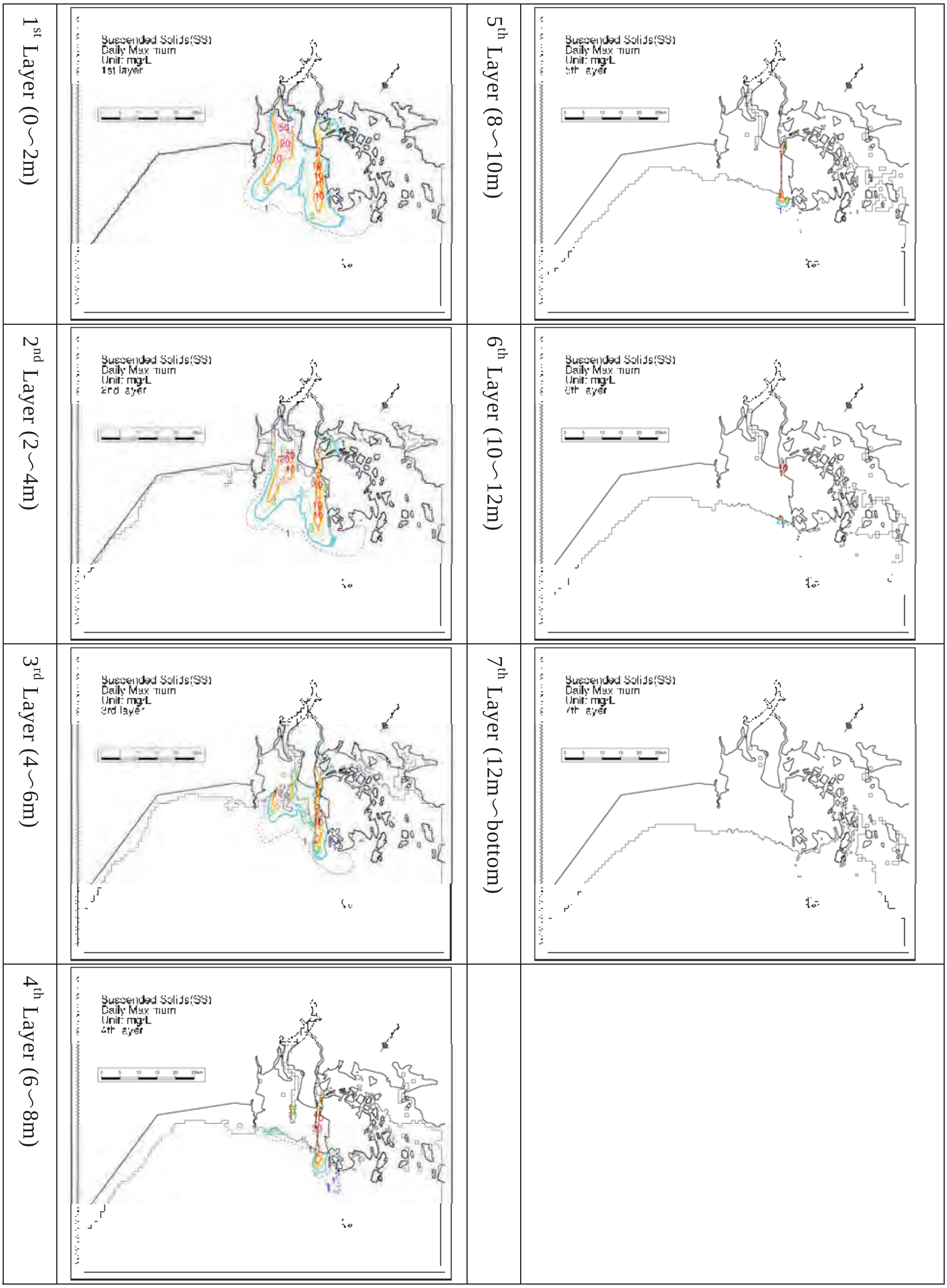
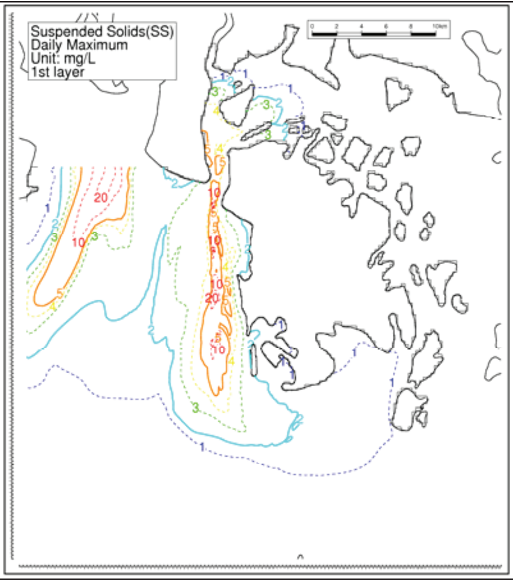
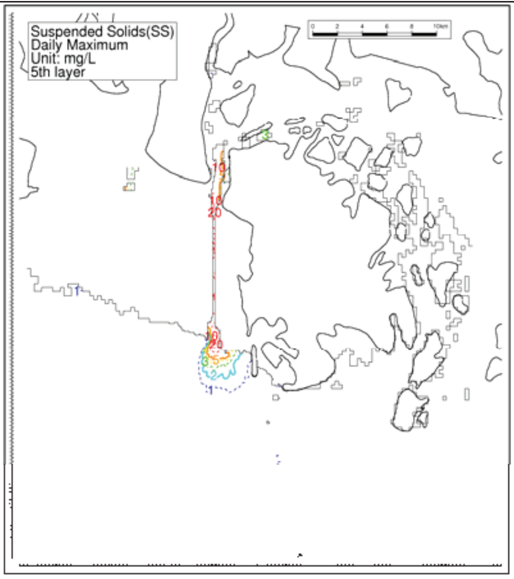
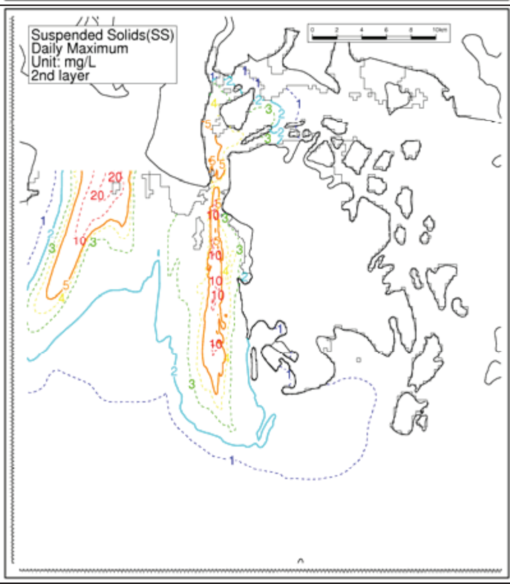
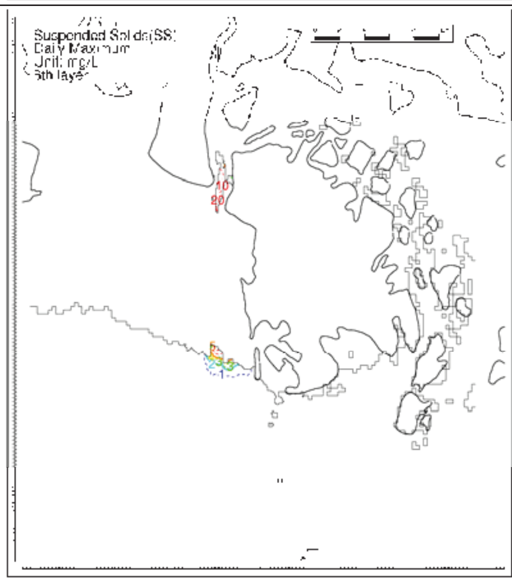
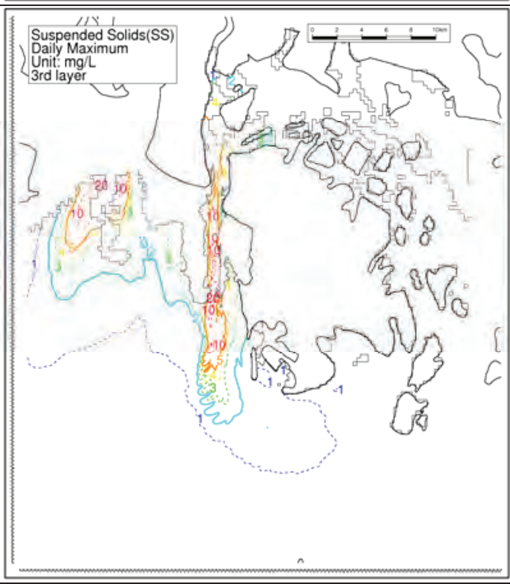
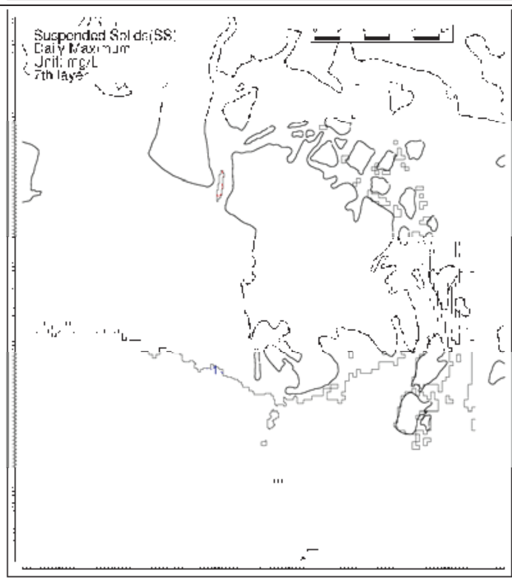


Figure 6-2-1 SS Dispersion Prediction (Case17, Daily Maximum, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

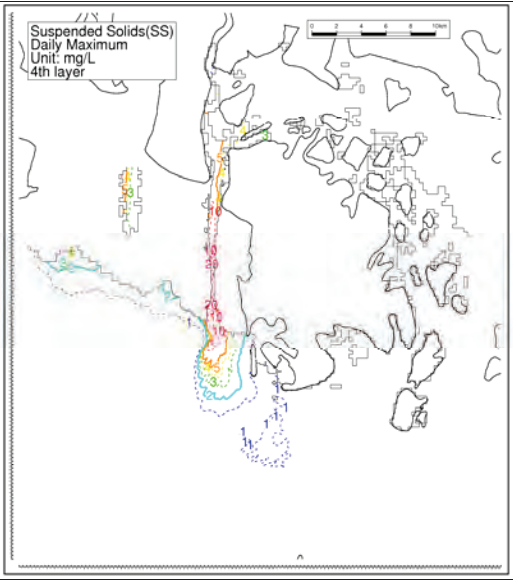
4th Layer (6~8m)			

Figure 6-2-2 SS Dispersion Prediction (Case17, Daily Maximum, Medium Domain)

7. Case 18

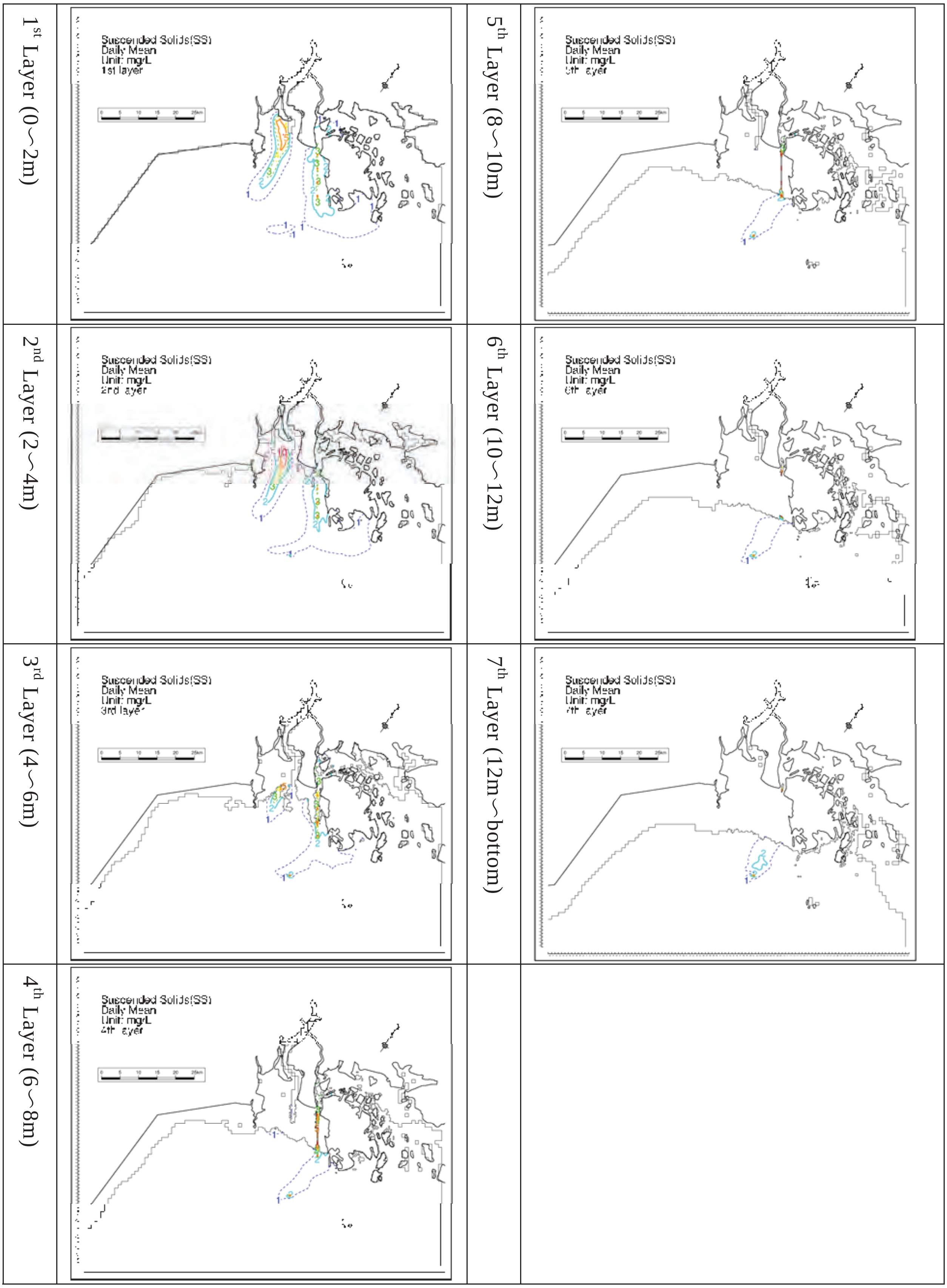
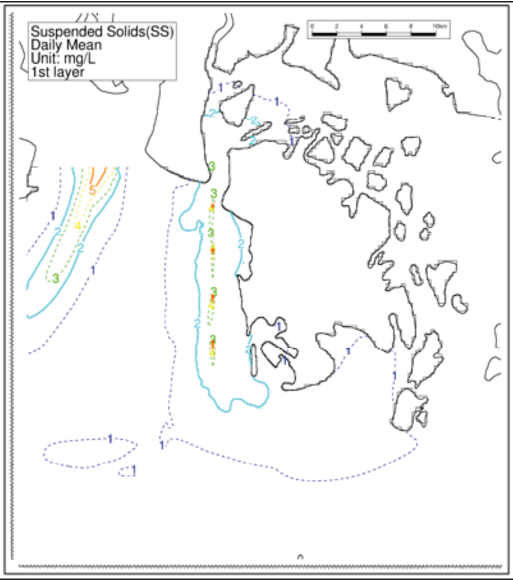
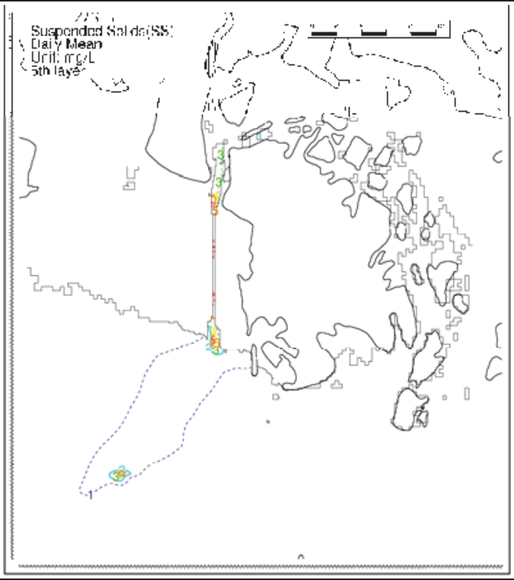
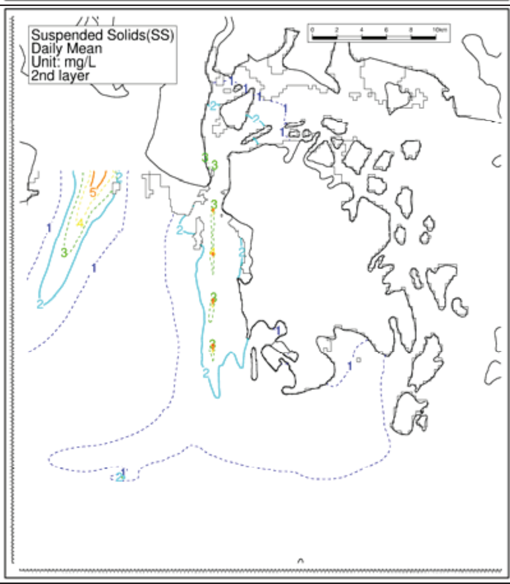
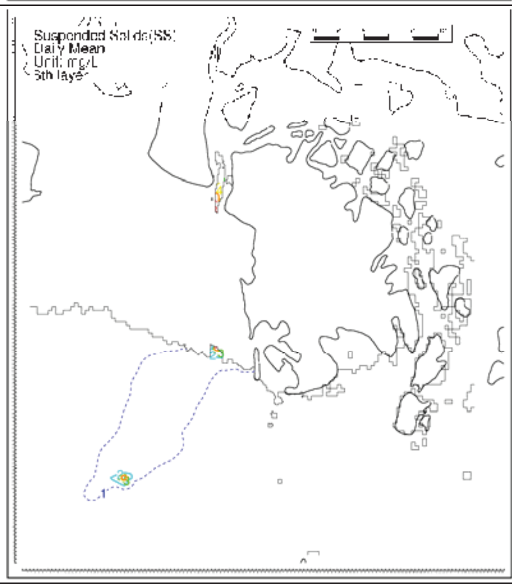
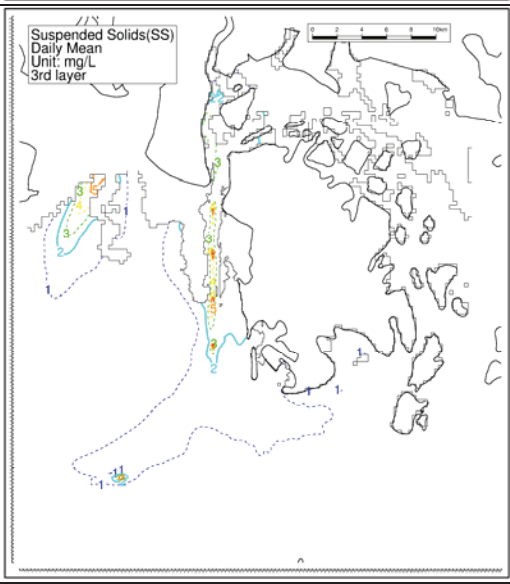
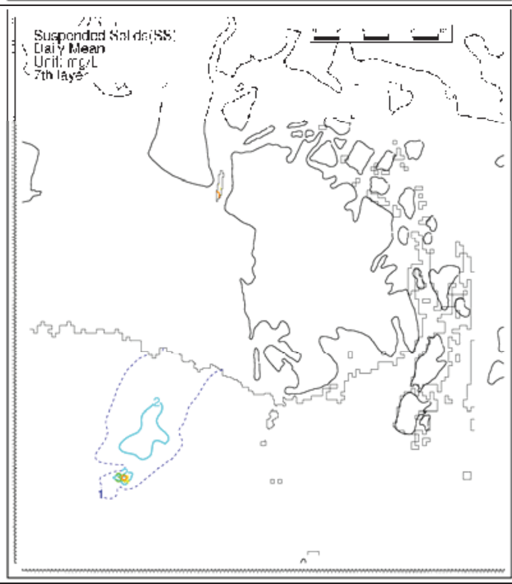


Figure 7-1-1 SS Dispersion Prediction (Case18, Daily Average, Large Domain)

1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	

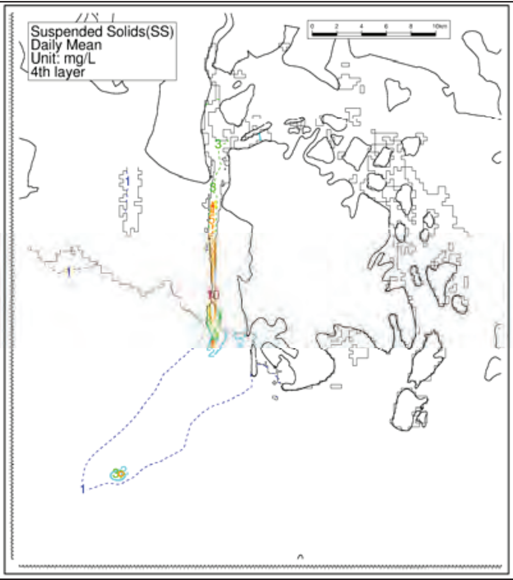
4th Layer (6~8m)			

Figure 7-1-2 SS Dispersion Prediction (Case18, Daily Average, Medium Domain)

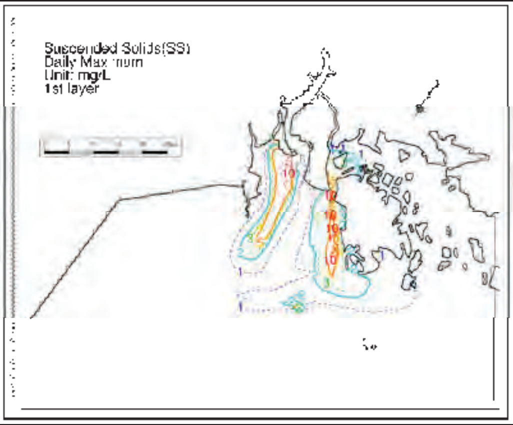
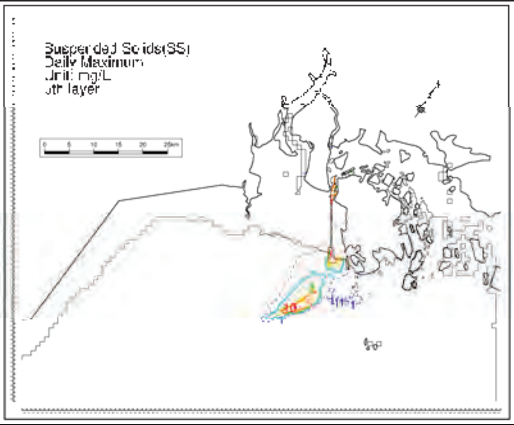
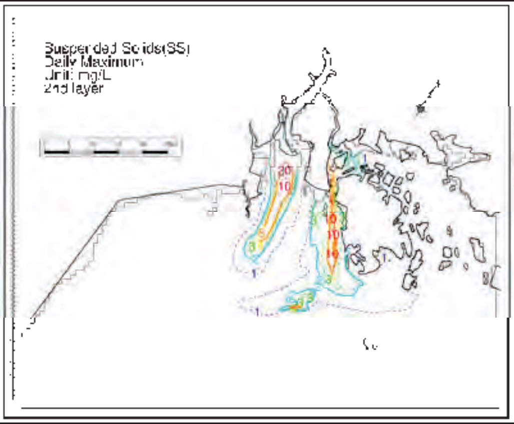
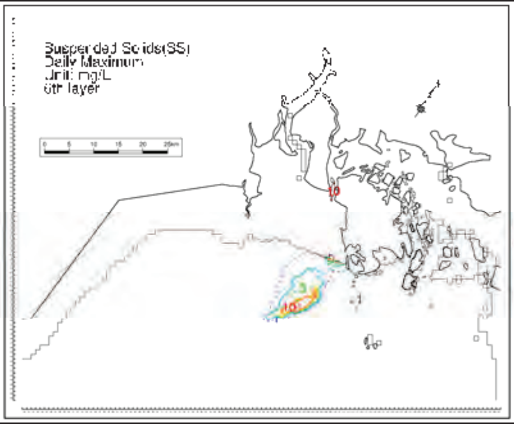
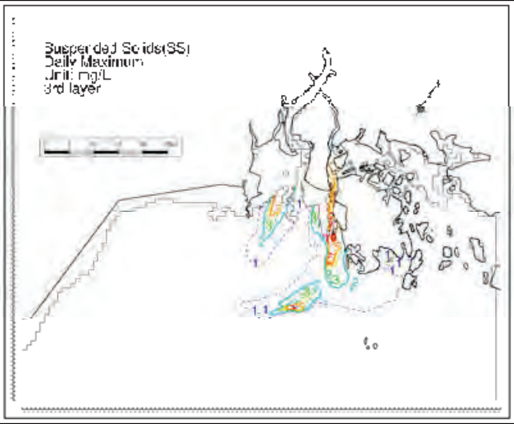
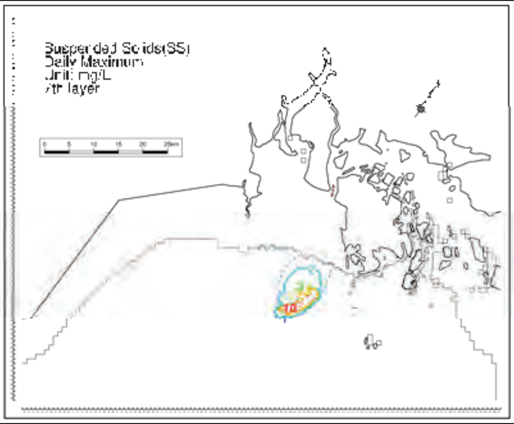
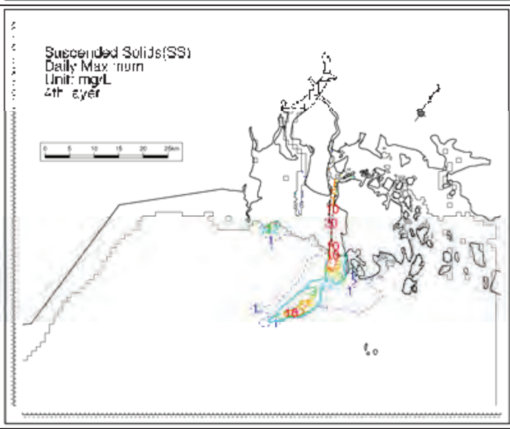
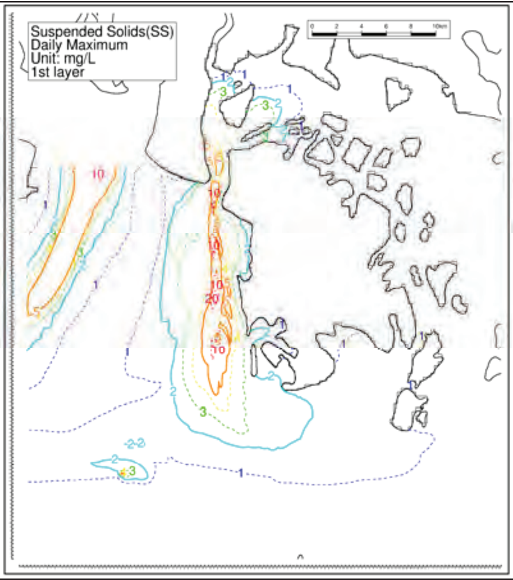
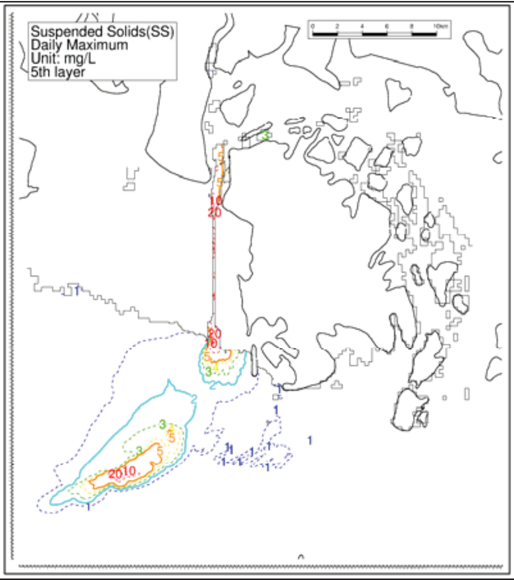
1st Layer (0～2m)		5th Layer (8～10m)	
2nd Layer (2～4m)		6th Layer (10～12m)	
3rd Layer (4～6m)		7th Layer (12m～bottom)	
4th Layer (6～8m)			

Figure 7-2-1 SS Dispersion Prediction (Case18, Daily Maximum, Large Domain)

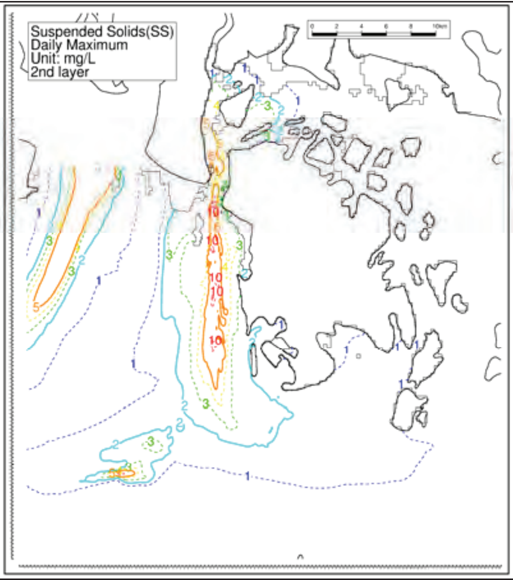
1st Layer (0～2m)



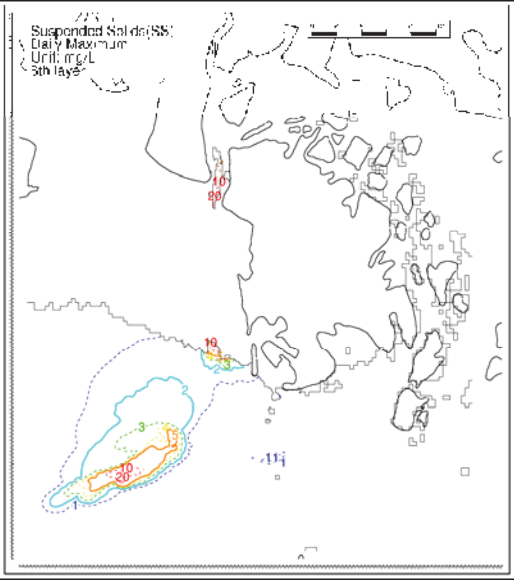
5th Layer (8～10m)



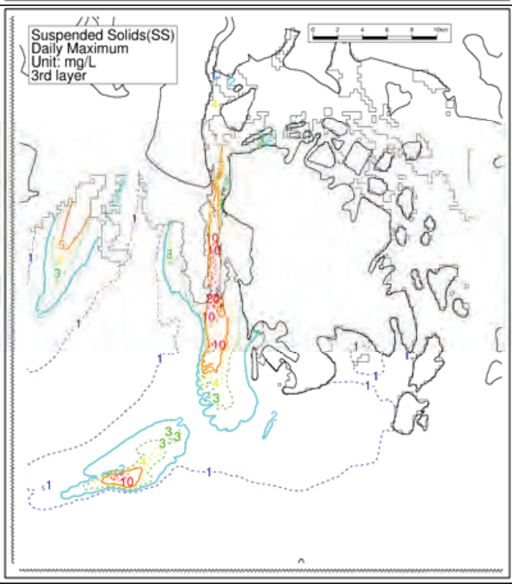
2nd Layer (2～4m)



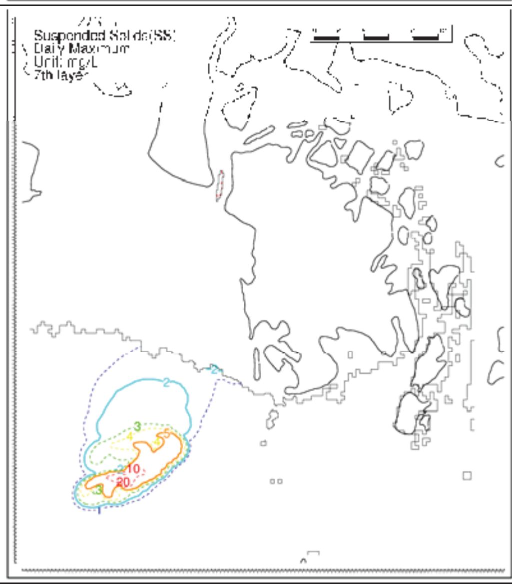
6th Layer (10～12m)



3rd Layer (4～6m)



7th Layer (12m～bottom)



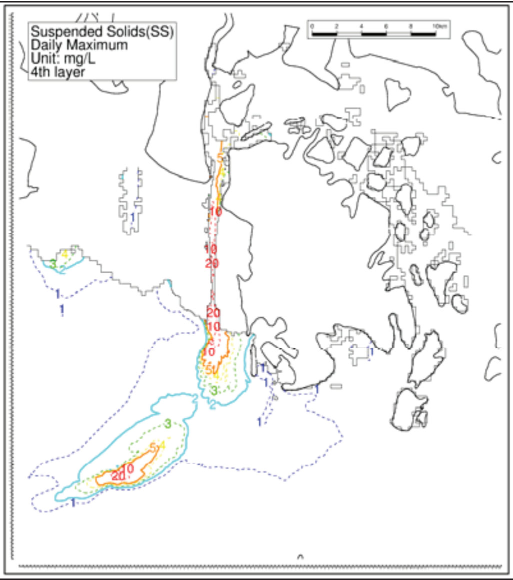
4th Layer (6～8m)			

Figure 7-2-2 SS Dispersion Prediction (Case18, Daily Maximum, Medium Domain)

Appendix 12-3

Initial Environmental Evaluation on Dumping Activity at South Dinh Vu IZ and Offshore

18May, 2012

Initial Environmental Evaluation on Dumping Activity at South Dinh Vu IZ and Offshore

JICA Study Team

1. Objective

The objective of this study is to evaluate the environmental impact on dumping of dredged soil from channel dredging in Lach Huyen Port Infrastructure Construction Project at South Dinh Vu IZ (SDV) and offshore area.

2. Present Condition of the Project Area

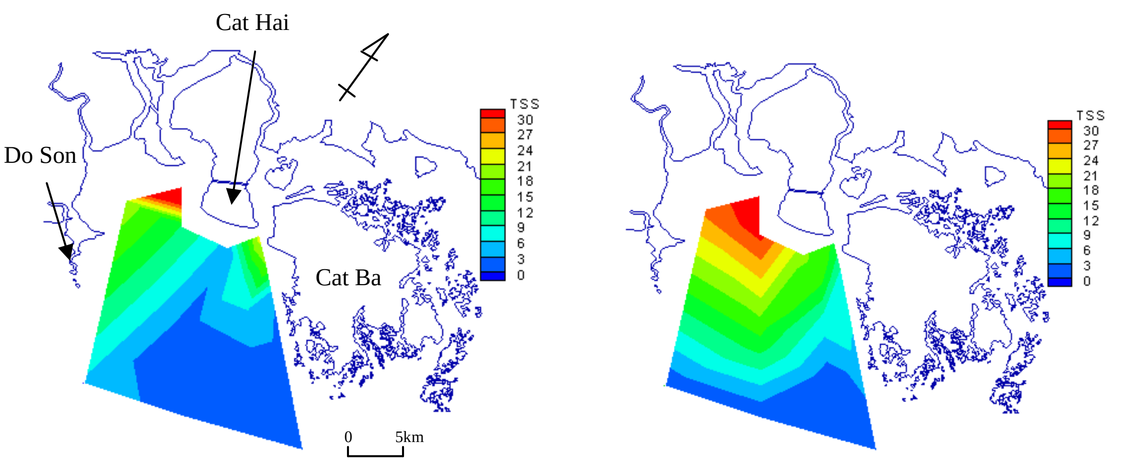
From May 2011 to August 2011, intensive field survey was conducted to know the present natural, biological and social conditions of the study area (refer to ***Chapter 3*** of the ***Final Report*** for the details).

Table 1 summarizes the characteristics of the present condition understood from the field survey, comparing between near-shore area and offshore area

Table 1 Characteristics of the present conditions

Item		Near-shore area (SDV)	Offshore area
Natural condition	Air quality	All parameters satisfy the Vietnamese Standard.	No survey was conducted
	Noise and Vibration	Sound and vibration levels satisfy the Vietnamese Standard	No survey was conducted.
	Water quality (see ***Figure 1*** for TSS)	Average SS at surface is 16.1mg/L at high tide and 18.1mg/L at low tide. T-N and T-P concentrations are higher.	Average SS at surface is 2.2mg/L at high tide and 8.4mg/L at low tide. T-N and T-P concentrations are lower.
	Vertical profile of water temperature and salinity	Water temperature and salinity at surface is low by river water influence, showing clear stratification..	Vertical profile does not show clear stratification.
	Sediment quality	Concentrations of heavy metals are higher.	Concentrations of heavy metals are lower.
	PCB, DDT, Dioxins	Dioxins were detected with low concentration.	Dioxins were detected with low concentration.
Biological condition	Protected area	Cat Ba Island is designated as a national park and a Biosphere Reserve.	East to south of Cat Ba Island is the Ha Long Bay, World National Heritage.
	Variable Habitats (Base on the literature survey: see ***Figure 2***)	Past study indicate that shallow coastal area of the Lach Huyen area contributes significantly to the high fish abundance.	Satellite image study with spot-check surveys confirmed the existence of coral reefs in Cat Ba Island, although they are diminishing.
	Mangrove	Large portion of mangroves are distributed.	-
	Seaweed/sea grass	Small patches of seagrass are distributed.	Small patches of seagrass are distributed.
	Coral	-	Coral reefs are distributed at south of Cat Ba Island and

Item		Near-shore area (SDV)	Offshore area
			Long Chau Islands.
	Phytoplankton	No special characteristics showed.	No special characteristics showed.
	Zoo plankton	Fish larva was indentified. Zooplankton density is higher.	No fish larva was found. zooplankton density is lower.
	Zoo benthos	Species abundance is higher.	Species abundance is lower.
	Demersal fish	Fish diversity and abundance tend to be higher. Two species listed in Vietnamese Red Book were found.	Fish diversity and abundance are lower.
Social condition	Economic activities and occupation	Salt production, aquaculture, fishing Vulnerable to environmental change Coastal fishing is the major occupation in Cat Hai Island. Detailed data is not available in SDV area.	Fishing



Unit: mg/L

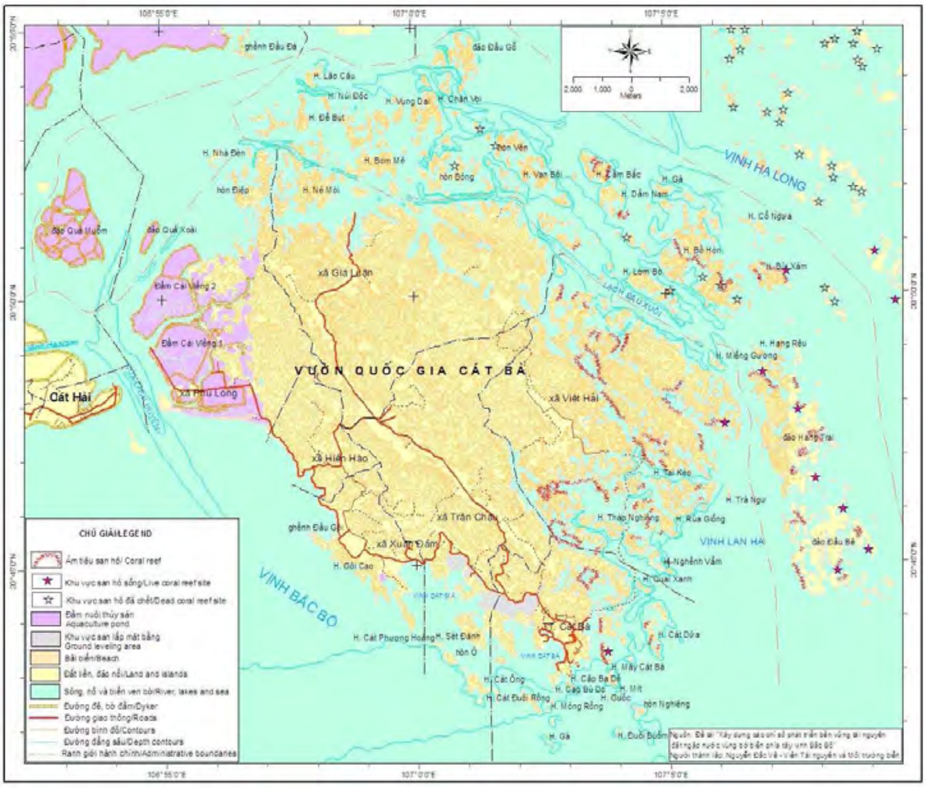
Layer: surface

High tide Low tide

Source: Field survey on DD study (May 16-17, 2011)

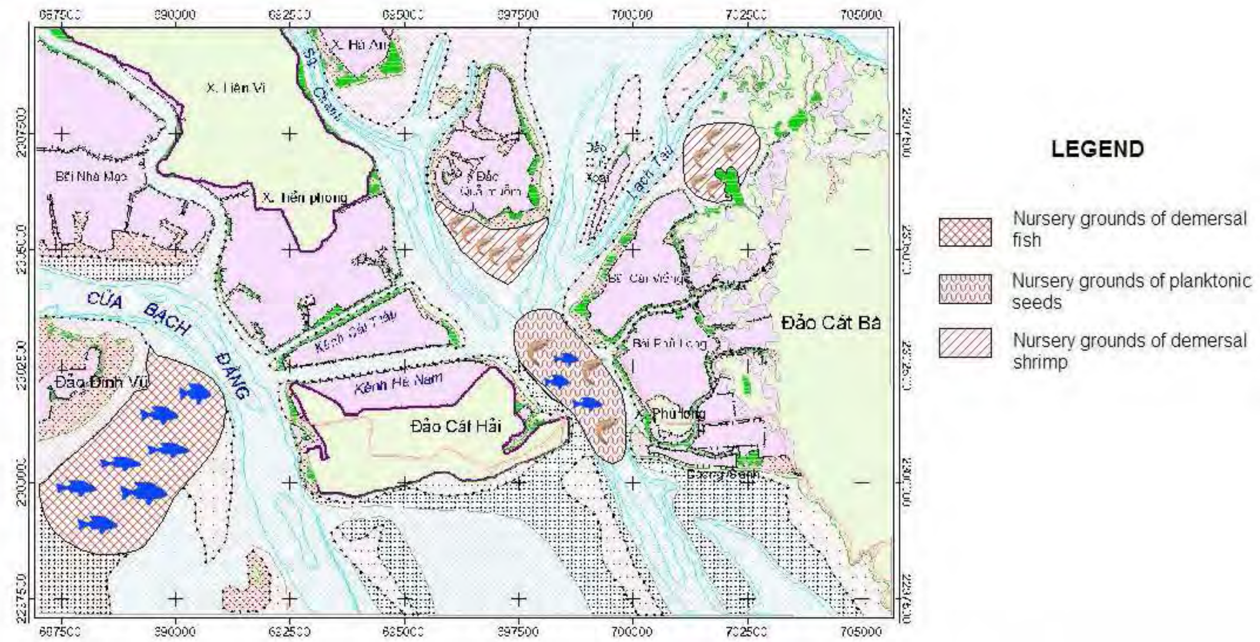
Comment: High turbid water can be seen at the head of Hai Phong Bay at both tides due to influence of river water discharge.

Figure 1 Horizontal distribution of Total Suspended Solid (TSS)



Source: Nguyen Dac Ve (2010)

Distribution of coral reef around Cat Ba Island



Source: Nguyen Thi Thu et al. (2008)

Distribution of main nursery grounds around the Lach Huyen area

Figure 2 Important habitat based on the literatures

3. SS Dispersion Simulation

This section describes the outline of SS (Suspended Solid) dispersion simulation model. For the details, refer to the ***Chapter 12.3*** and its ***Appendix*** of the ***Final Report***.

3-1. Structure of the simulation model

The simulation model consists of two numerical models as shown below.

Hydrodynamic Model	: Vertical multilayer level model which considers ebb away and submerge of tidal flat by tide transition, tidal current, density flow and wind-driven current.
SS Dispersion Model	: A model which considers process of advection, diffusion and sedimentation of suspended solid. Water level, direction and speed of the flow which is calculated by the hydrodynamic model are used for simulation input conditions.

Basic structure and relationship between the two models is shown in ***Figure 3***.

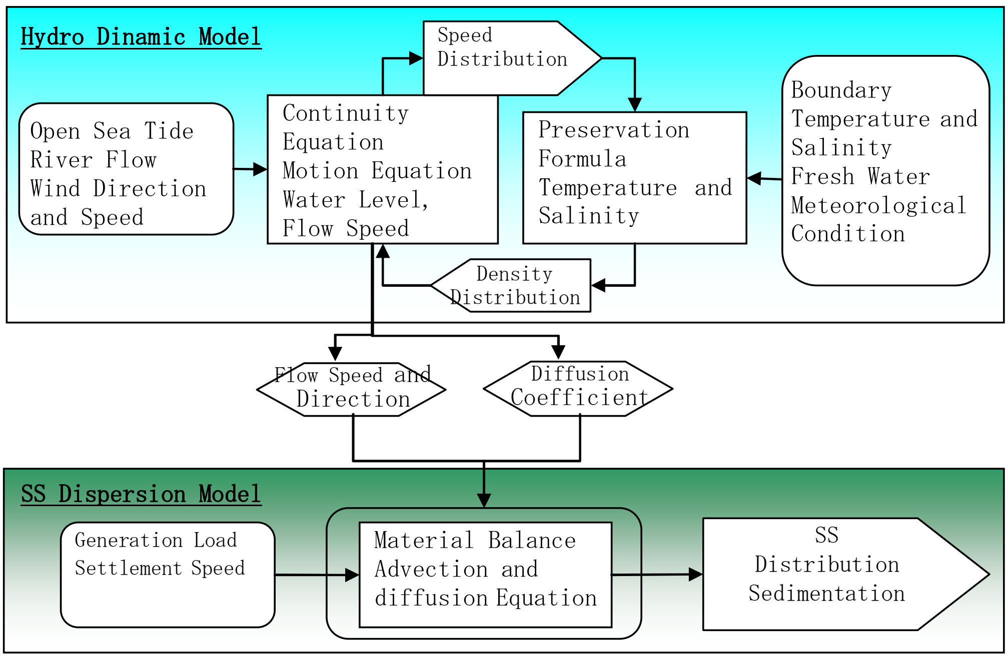


Figure 3 Basic structure of the models

And simulation area is shown in ***Figure 4***.

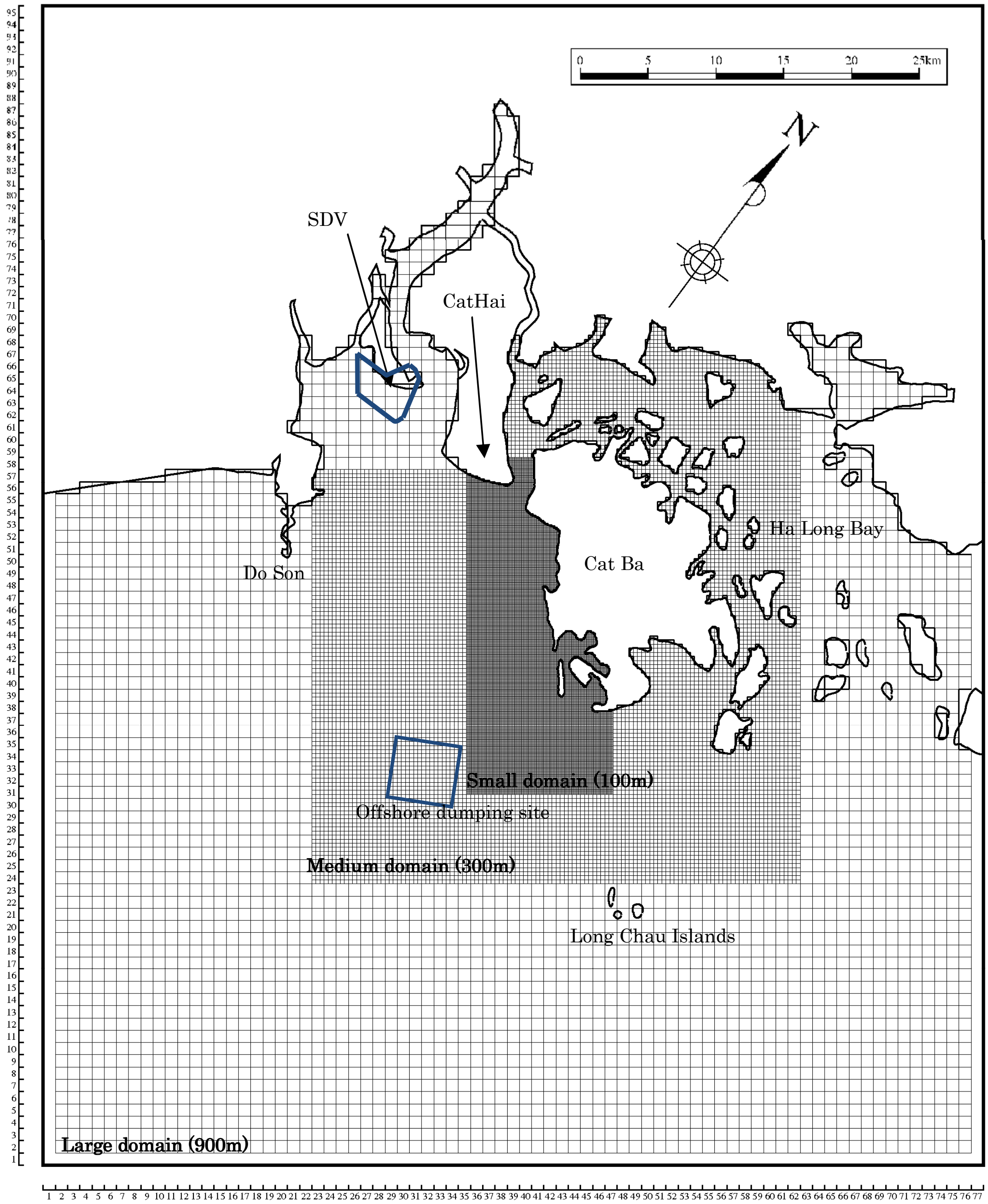


Figure 4 Simulation area and mesh partition

3-2. Computation Conditions

3-2-1. Hydrodynamic model

(1) Input data

Table 2 summarizes the data used for the hydrodynamic model.

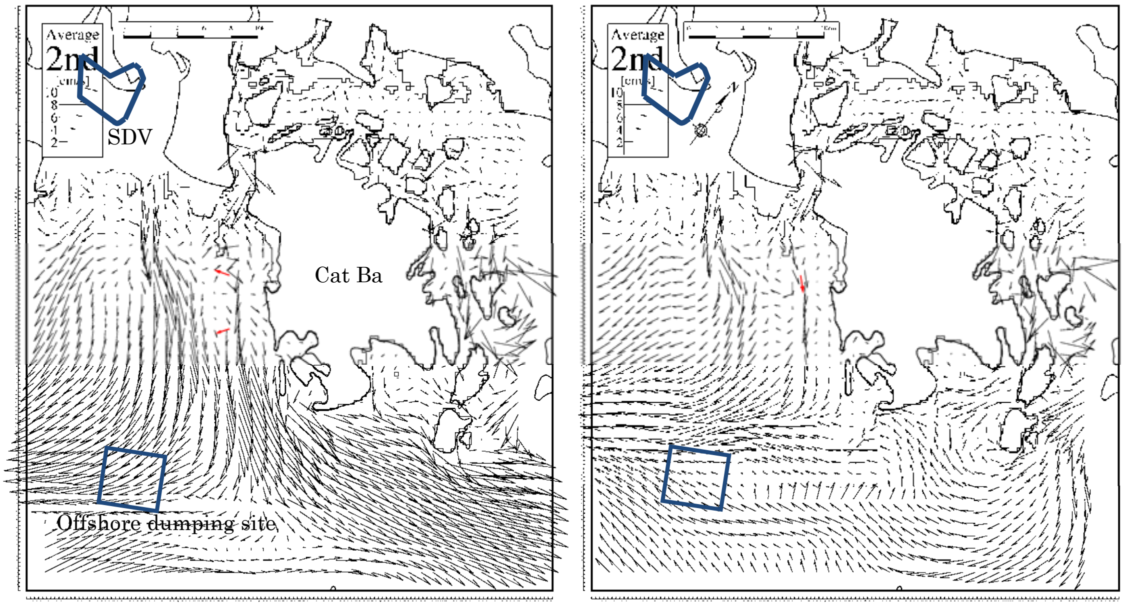
Table 2 Obtained data for the hydrodynamic model

Item	Wet Season	Dry Season	Date of Data
Topography	x		Bathymetry survey data for Lach Huyen area from 2006 to 2011
Tide level	x		November 2009, May 2011
Temperature, Salinity	x		May 2006, May 2011
Fresh Water Inflow	x		September 1999, May 1999
Meteorological Condition	x	x	Averaged monthly data from 1975 to 2005
Flow	x	x	November 2009, May 2011

Integration time was set as 20 days until fresh water inflow from the rivers and sea water density influenced by heat balance between sea surface and atmosphere is stable. And the last 24 hours are used for analysis.

(2) Hydrodynamics resume

Residual (averaged) current distribution by simulation at the 2nd layer is shown in ***Figure 5***. Field survey data is also plotted to be compared in the figures.
Residual current usually show the steady flow (dominated flow) pattern in the area.
In both seasons, offshore-ward current is dominant at near-shore area especially at the two river mouths, the east side and the west side of the CatHai Island.
Distribution of residual current in dry season at offshore area shows south-west ward current. Distribution of residual current in wet season, however, shows different resume. Offshore-ward current divides into two different direction, south-west ward and east-ward leading to the mouth of the Ha Long Bay.
Thus in this study, wet season hydrodynamics resume was used for the simulation of SS dispersion to know the worst influence to Ha Long Bay by the construction activities.



Wet Season | Dry Season

→ : simulation, → : Survey(May,2011) | → : simulation, → : Survey(Nov-Dec,2009)

Figure 5 Distribution of residual current by computation (medium domain, 2nd Layer: 2-4m below surface)

3-2-2. Suspended solid dispersion model

(1) Input data

Initial condition and boundary value (background value) for concentration of Suspended Solid are set as 0 mg/L to evaluate the diffusion area and concentration caused by the construction activities.

DD survey data of grain size test in borehole experiment[1] was used for grain size of dredged soil for simulation. Sampling points and layers are uniformly distributed horizontally along with the sea route and vertically. All available data was averaged to obtain the composition shown in ***Table 3*** and grain size distribution curve shown in ***Figure 6*** was generated.

[1] Soil Investigation Report for Port Portion - Part B-, Volume 2.3: The Appendices of Navigation Channel Area, August 2011, Portcoast

Table 3 Composition of grain size

	Grain Size	Composition
Sand	4.750-9.500 mm	0.2%
	2.000-4.750 mm	0.0%
	0.850-2.000 mm	0.6%
	0.425-0.850 mm	1.3%
	0.250-0.425 mm	0.2%
	0.075-0.250 mm	13.4%
Silt	0.005-0.075 mm	34.3%
Cray	<0.005 mm	50.0%

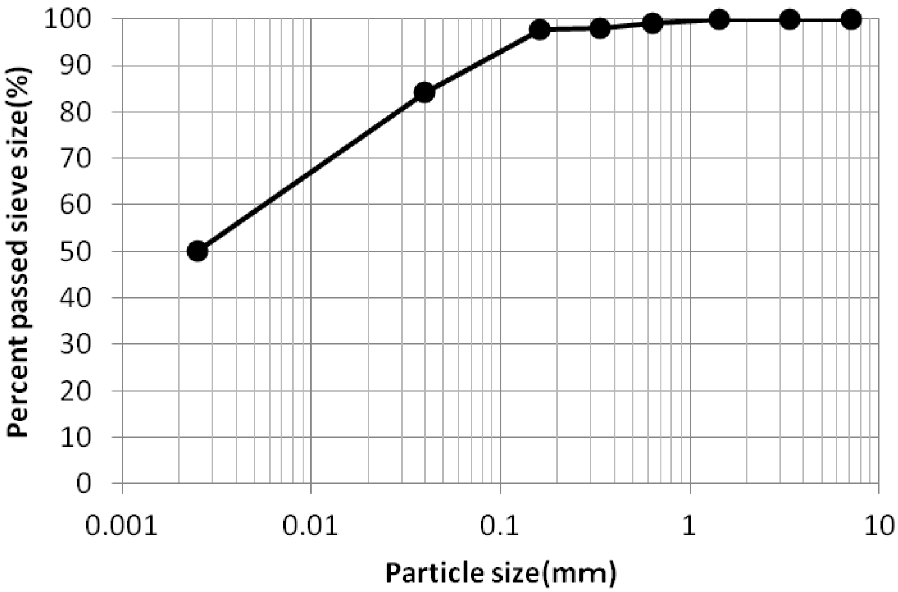


Figure 6 Grain Size Distribution Curve

Using this data and Stokes' sedimentation equation, sedimentation speed was determined. Unit load of suspended solid generation depends on the dredging/dumping method. A guideline[2] for prediction of suspended solid dispersion in Japan was referred to determine the unit load, averaging each unit load for fine particle fraction of the target dredging/dumping method in the guideline.

[2] Guideline for Prediction of Influence of Suspended Solid on Port Construction, April 2004, Ministry of Land, Infrastructure, Transport and Tourism, Japan

(2) SS Generation Load

SS generation load depends on construction method, such as grab dredging, cutter suction dredging and dumping by hopper barge, construction capability of the vessel and grain size of dredging/dumping material. The guideline[2 at page 2] lists a lot of such information based on the experimental constructions carried out in Japan to obtain such parameters and suggests proper unit load on each construction method.

In this study, the unit loads listed in the guideline were averaged to use in the simulation model, because the grain size compositions in the guideline does not much with the grain size composition in the target area of the project.

And obtained unit load is used to calculate daily SS generation load, which is used as the input data of the simulation.

Table 4 summarizes each unit load and daily load of construction method.

For the simulation at different dumping site, sum of SS generation loads as follows was used as the input data:

Offshore dumping: a + b

Dumping at SDV: a + b + c + d

50% offshore dumping + 50% dumping at SDV: (a + b) / 2 + (a + b + c + d) / 2

Table 4 SS generation load

Work Type		Vessel Type	Guideline		Calculated unit load based on the actual particle size ((t/m3)×10−3)	Work Load (m3/day/vessel)	Number of Vessel	Total Work Load (m3/day)	Daily SS Generation Load (t/day)	Working Hour
			Capability	Unit Load(t/m3) $\times 10^{-3}$						
a	Dredging	Grab dredger	25m3	15.29	18.56	**18300**	4	73200	1358.6	16
b	Dumping	Hopper barge	500m3	15.79	22.26	**4575**	16	73200	1629.4	16
c	Dredging at temporal dumping basin	CSD	4000PS	4.26	5.3	**60000**	3	180000	954.0	24
d	Discharge from embankment*1)	—	—	—	—	—	—	—	7728.6	24

*1) To determine this value, following leteratures were refered.
Hazen's theory regarding ideal sedimentation basin (extrusion effluent model)
Guideline for designing of waterworks facility, 1990, Japan Water Works Association
Manual for prediction of influence of turbidity by dredging/reclamation, March 1982, Ministry of Transportation, Japan

Equation:

$$SSd = SSg \times (1 - r)$$

where:

SSd: Daily SS generation load (t/day)
SSg: SS generation load (t/day)
r: Removal ratio: 0.717

$$r = v_c / v_0$$

where:

Vc: Settlement sped of cray (m/day): 0.43
V0: Water moving speed: Q/A (m/day): 0.6
Q: Dumping volume (m3/day): 180000
A: Area of dumping site (m2): 300000

$$SSg = Dv \times \rho_t \times C_m / 100$$

where:

Dv: Dredging volume (m3/day): 90000
ρ_t: Wet density
Cm: Mud content (%): 20

$$D_v = C_p \times G_c / 100$$

where:

Cp: Dredging cpacity: m3/day): 180000
Gc: Grainsize composition of cray (%): 50

$$\rho_t = \frac{(1 + \omega / 100)\rho_w}{\rho_w / \rho_s + \omega / S}$$

where:

ω: Water content (%): 89%
ρ_w: Water density (g/cm3): 1.02
ρ_s: Density of soil perticles: 2.68
S: Saturation degree (%): 100

4. Comparison between Dumping at SDV and Offshore

4-1. Background of the Determination of the Dumping Site

4-1-1. Offshore Dumping Site

The location of the offshore dumping site was determined with following reasons (see ***Figure 8*** for the location of the dumping site and ***Figure 7*** for construction process of offshore dumping).

- Enough distance is secured (more than 10km) from the mouth of Ha Long Bay and small islands (Long Shau Isalands) off coast of Cat Ba Island,
- Enough distance is secured (more than 10km) from Do Son swimming beach area,
- Those distances was confirmed by simplified simulation SS dispersion with existing data such as SAPROF Study before conducting detailed simulation.
- Enough water depth (more than -20m CDL) is secured to avoid disturbance of the sea bed by rough sea condition,
- This basis is based on the perception that the sea bottom sediment, stirred up by 30cm/s of water current which is theoretically caused by 2m-high-with-7seconds-frequency-wave at 20m-depth area, may not reach to shallower water layer[3, 4].
- The location is away from the entrance of the navigation channel to Hai Phong Port to avoid interference to ship navigation, and
- The location is wide enough to secure the area of 5km x 5km to retain the thickness of the dumping material within 2m.

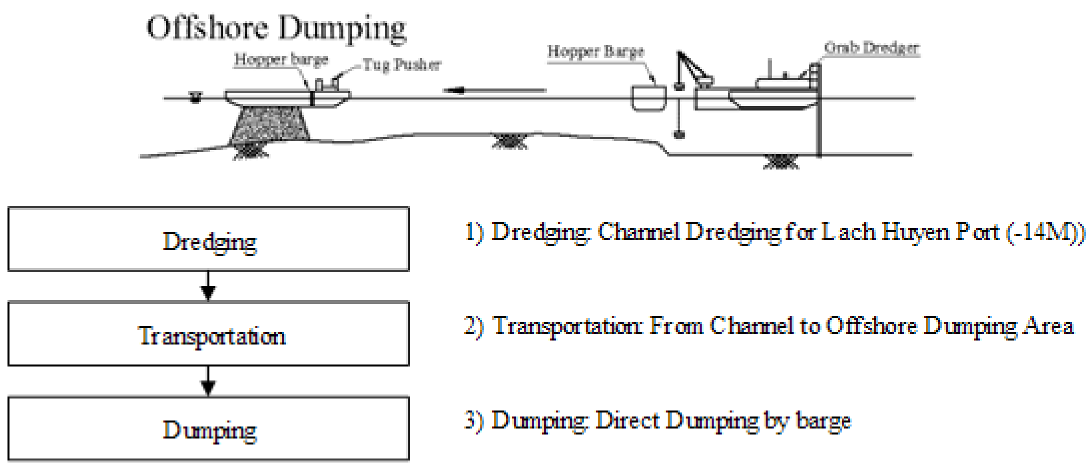


Figure 7 Construction process of offshore dumping

[3] http://www.dpri.kyoto-u.ac.jp/web_j/hapyo/03/p44.pdf
[4] http://library.jsce.or.jp/jsce/open/00549/2003/55-0097.pdf

4-1-2. Dumping site at SDV

Comparative study concluded that following conditions for dumping at SDV are reasonable from the viewpoint of time schedule and cost.

- Ha Nam Channel is used for transportation of dredged material (see ***Figure 8***).
- Temporary dumping basin will be prepared at outside of the embankment (also see ***Figure 8*** for the location and ***Figure 9*** for the construction process).

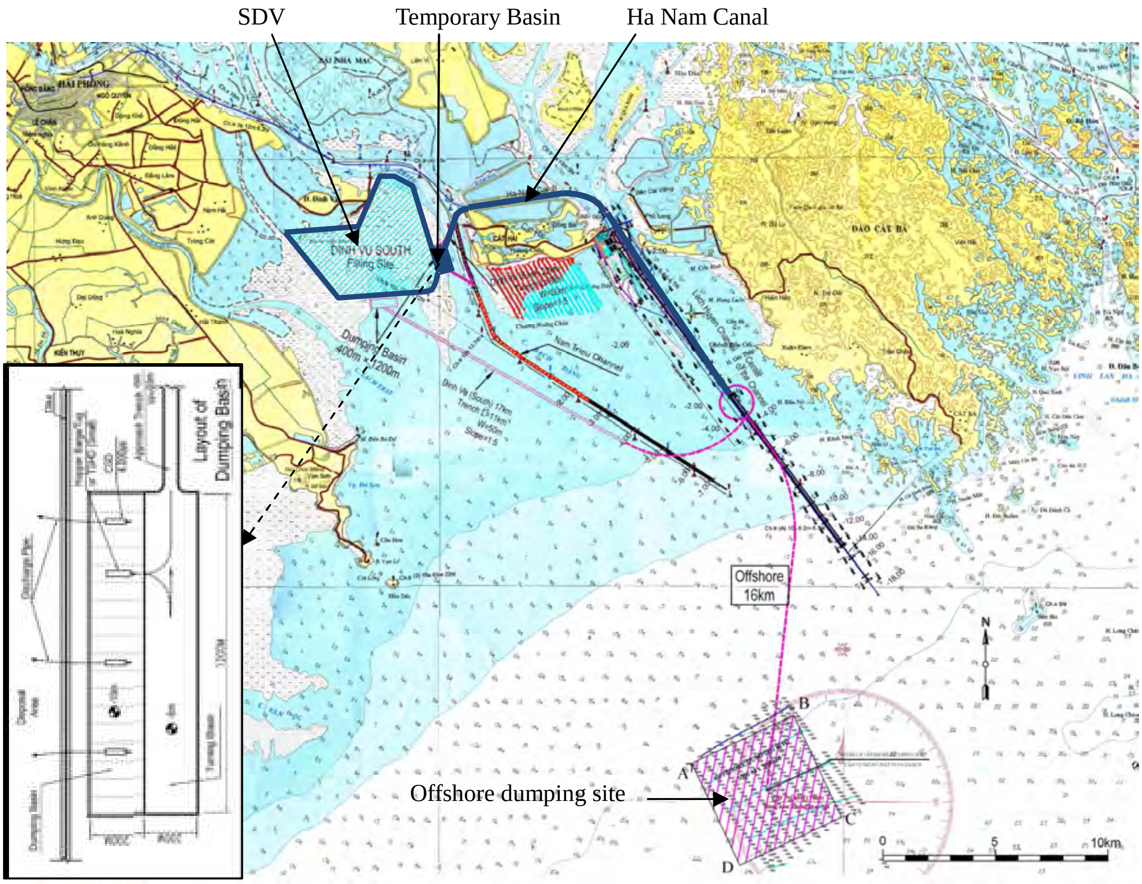
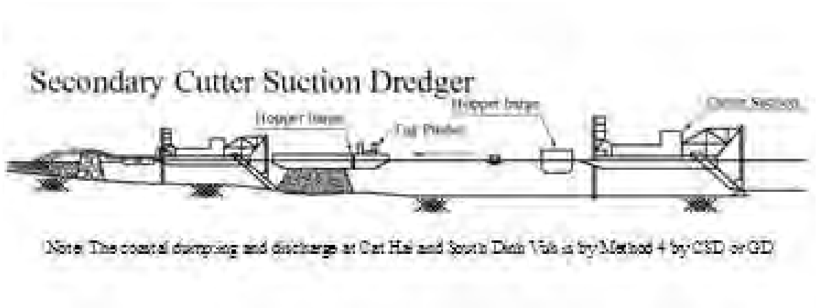
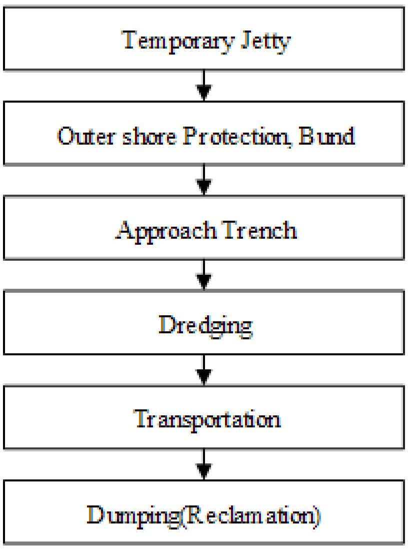


Figure 8 Locations of SDV, temporary basin, Ha Nam Canal and offshore dumping site





1) Temporary Jetty: Materials etc. Shallow draft quay & Yard

2 Outer shore Protection: Construction

3) Approach Trench and Temporary Basin Dredging for Hopper Barge

4) Dredging: Channel Dredging for Lach Huyen Port (-14M)

5) Transportation: From Channel to Dumping Area

6) Dumping: Secondary Pumping by CSD

7) Reclamation: Dredged soil executed in the Outer shore protection. (above 1)~2))

Figure 9 Construction process of dumping at near-shore (SDV)

4-2. Simulation Results

4-2-1. Simulation scenarios

Simulation scenarios are shown in ***Table 5***.

Each case was performed based on the following purposes:

- To know the difference of dispersion pattern between offshore dumping and dumping at SDV (Case 12 and 13, Case 15 and 16)
- To know the effectiveness of countermeasures to SS dispersion (Case 12 and 15, Case 13 and 16)

Table 5 Simulation scenarios

Case	Dredging		Dumping					Flow resume	Recommendation
	Method	Silt Protector	Location	Dumping ratio	Method	Embankment	Silt Protector		
Case 12	Grab $23m^3$ x 4	No	Offshore	100%	*1	-	No	Wet season	acceptable
Case 13	Grab $23m^3$ x 4	No	SDV	100%	*2	Yes	No	Wet season	
Case 15	Grab $23m^3$ x 4	Yes	Offshore	100%	*1	-	No	Wet season	suitable
Case 16	Grab $23m^3$ x 4	Yes	SDV	100%	*2	Yes	Yes	Wet season	
Case 18	Grab $23m^3$ x 4	Yes	Offshore	50%	*1	-	No	Wet season	
	Grab $23m^3$ x 4	Yes	SDV	50%	*2	Yes	Yes		

*1: Direct dumping by hopper barge

*2: Direct dumping by hopper barge at the temporary dumping basin and secondary discharging to inside the embankment by 3 units of 4,000ps-CSD (Cutter Suction Dredger)

Counter measures to control SS generation is not considered in Case 12 and 13, while silt protector/curtain is considered in Case 15 and 16.

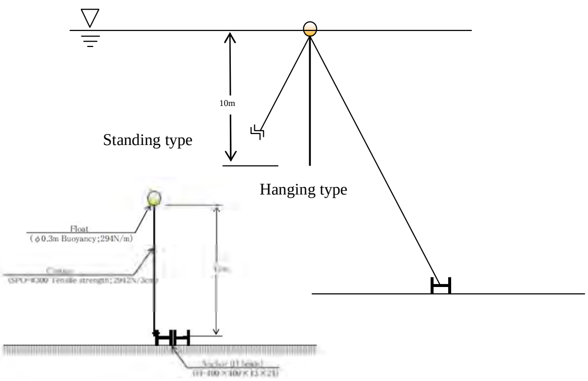
Considered countermeasures to control SS generation/dispersion are as follows:

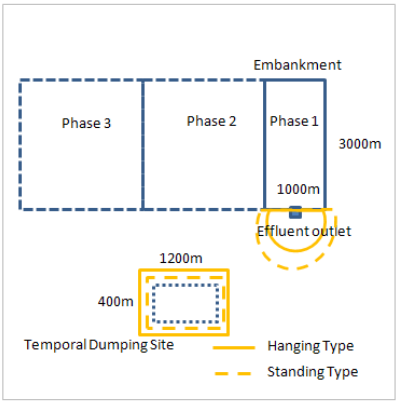
- Dredging: Frame with silt protector/curtain (see the photo in ***Figure 10***) is installed with the grab dredger. Dredging is performed in the frame. Vertical coverage of the silt protector/curtain is 80% of the depth with 40% of SS removal ratio.
- Offshore dumping: No countermeasure is considered.

- Dumping at SDV: Silt protector/curtain surrounds the temporary dumping basin and drainage effluent outlet from the embankment (refer to ***Figure 10*** for an example). SS removal ration of the silt protector/curtain is 40%.

Dredging frame with silt curtain

Source: Guideline for prediction of SS dispersion [2 at page 2].





Silt protector/curtain

Installment of silt curtains

Source: Taiyo Kogyo Corporation

Figure 10 Counter measures to SS dispersion

4-2-2 Evaluation Criteria

To evaluate the impacts by construction (human-being activity) on the environment, not much standard/guideline is available worldwide. In this study, Japanese and Canadian water quality guidelines that are aimed to protect fishery resources and aquatic life respectively were referred.

Table 6 shows the water quality standard of SS for the Japanese and Canadian guidelines.

Table 6 Japanese and Canadian water quality standards for SS

Title of guideline	SS standard
Japanese water quality standards for the protection of fishery resources (2005 version)	Anthropogenic activities should not increase SS concentration by more than **2 mg/l** over background levels.

Canadian water quality guidelines for the protection of aquatic life	Anthropogenic activities should not increase SS concentration by more than **5 mg/l** over background levels (for long term exposure).

Source of Japanese guideline: Japan Fisheries Resource Conservation Association
Source of Canadian guideline: Canadian Council of Ministers of the Environment (http://ceqg-rcqe.ccme.ca/)

Since the Japanese standard (2 mg/l) is slightly stricter than the Canadian standard (5 mg/l), the Japanese standard was applied specifically to marine organisms that are sensitive to turbidity, in which this case was hard corals. The Canadian standard on the other hand was applied generally to the other marine organisms.

4-2-3. Comparison between Offshore Dumping and Dumping at SDV (Case 12 and Case 13, Case 15 and Case 16)

SS dispersion between Case 12 and 15 (offshore dumping) and Case 13 and 16 (dumping at SDV) was compared and shown in ***Figure 12*** and ***Figure 13***. Dredging method is performed by 4 vessels of grab dredger in all cases. And any countermeasures to control SS generation are not considered in Case 12 and 13, while existing of embankment in Case 13 are considered. SS dispersion patterns were compared between Case 15 (grab dredging and offshore dumping) and Case 16 (grab dredging and dumping at SDV) with countermeasures to SS dispersion respectively. As countermeasures, silt curtain frame (see ***Figure 10***) is used for dredging in both cases and silt curtains (both hanging type and standing type: see ***Figure 10***) are used at temporary dumping basin and at effluent outlet from dumping revetment of SDV for Case 16.

Out of all outputs from the simulation in the large domain, the 2nd layer (2-4m below surface: upper layer) and the 4th layer (6-8m below surface: lower layer) of daily maximum value in each case are selected as the representative layers for dredging and dumping respectively.
Daily maximum value, here, means the broadest SS dispersion in a day after dispersion is steady.
The contour lines show the additional SS to environmental generated by dredging and dumping activities. Pale blue contour line shows 2mg/L additional SS line and orange contour line is 5mg/L additional SS line.

In the upper layer in all cases, contour lines by dredging and dumping overlap each other. The contour line of 2mg/L by offshore dumping (Case 12) spreads southwest-east directions. The contour line of dumping in Case 13 is wider than that in Case 12. This is considered that SS load from outlet of embankment and influence of river water is great. 2mg/L contour line in Case 12 does not reach to environmentally important area such as Long Shau, Do Son beach area and Cat Ba beach area, while it in Case 13 reaches to Do Son beach area.

In the lower layer, the area of contour lines is limited in both cases. However, 2mg/L contour line in Case 13 still reaches to Do Son beach area.

Dispersion pattern in Case 16, SS generated by dredging activity and SS generated by dumping activity, shows tendency to flow out toward offshore along by river flow in the upper layer in Case 16, respectively. Its area in Case 16 is a bit larger than that in Case 15, suggesting that the load by near-shore dumping is greater than offshore dumping.

In the lower layer in Case 16, the area of SS dispersion by near-shore dumping is limited and it is smaller than that by offshore dumping in Case 15. But still, 2mg/L contour line is close to Do Son beach area.

4-2-4 Effectiveness of mitigation measures (Case 12 and 15, Case 13 and 16)

Effectiveness of mitigation measures by silt protector/curtain was compared between Case 12 and 15 and Case 13 and 16 respectively and shown in ***Figure 14*** for upper layer and

Figure 15 for lower layer.

In both comparisons, it is clear that the area of SS dispersion by dredging is reduced by the measure and the dispersion area by dumping at SDV is also reduced.

As countermeasures for offshore dumping is not considered in these cases, it is understand that the threat by SS dispersion to Cat Ba beach is mainly by dredging activity, not by offshore dumping.

4-2-5 Combination dumping at different sites (Case 15, Case 16 and Case 18)

SS dispersion area by combination of different dumping site (e.g. 50% of dumping at offshore and 50% of dumping at SDV) was also studied, and shown in ***Figure 16*** comparing with Case 15 (100% of dumping at offshore) and Case 16 (100% of dumping at SDV).

Mitigation measures in all cases are undertaken.

SS dispersion area of each simulation case shown in ***Figure 13*** and ***Figure 16was*** comprehensively traced and lapped over.

Figure 11 compares the comprehensive affected area by each dumping location.

The total area itself by combination dumping is smaller than that by other dumping location; however, comprehensive affected area by combination dumping is larger than that by dumping at single location.

Combination of dumping sites remains possibility of affect to Do Son area although the area is smaller than that by 100% dumping at SDV.

Thus it can be concluded that 100% dumping at offshore is an ideal option.

Upper Layer | Lower Layer

Legend

- : Case 15 (100% dumping at offshore)
- : Case 16 (100% dumping at SDV)
- : Case 18 (50% dumping at offshore + 50% dumping at SDV)

SS dispersion area of each simulation case shown in ***Figure 13*** and ***Figure 16***was comprehensively traced and lapped over.

Figure 11 Comparison of comprehensive affected area between dumping sites

4-2-6 Findings from the simulation

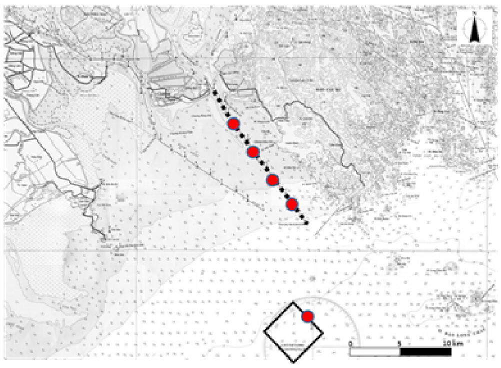
The findings from the simulation are as follows:

- Comparing simulation results between offshore dumping and dumping at SDV, the area of SS dispersion by offshore dumping is smaller than that by dumping at SDV, because the impact by discharged water from outlet of embankment is great and the effect of river flow at SDV area also enhance the SS dispersion
- Biological and socially sensitive area such as Ha Long Bay, Cat Ba beach area, Do Son beach area, Long Chau Islands will not be affected directly by offshore dumping.
- The SS dispersion by dumping at SDV might reach to Do Son beach area.
- With countermeasures by silt protector/curtain for grab dredging, temporary dumping basin and discharge outlet from embankment at SDV,

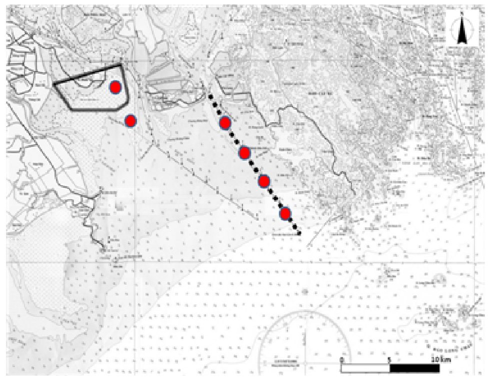
the area of SS dispersion will be reduced, although threat of impact to Do Son beach area by dumping at SDV still remains.

- By the combination of dumping at different location, such as 50% of dumping at offshore and 50% of dumping at SDV, the affected area will be broader than that by dumping at single location.

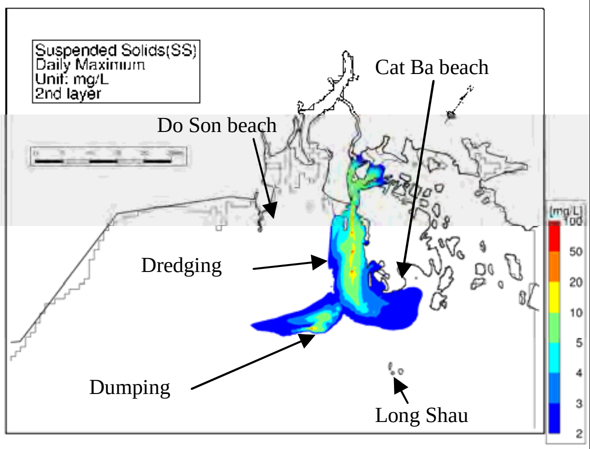
<table>
<tr><th>Case 12 (without silt curtain)</th><th>Case 13 (without silt curtain)</th></tr>
<tr><td>(Offshore dumping)



● : Load generation point</td><td>(Dumping at SDV)



● : Load generation point</td></tr>
<tr><td>Upper layer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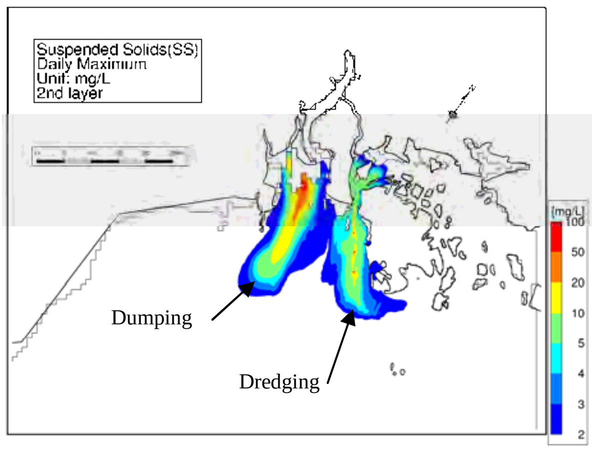
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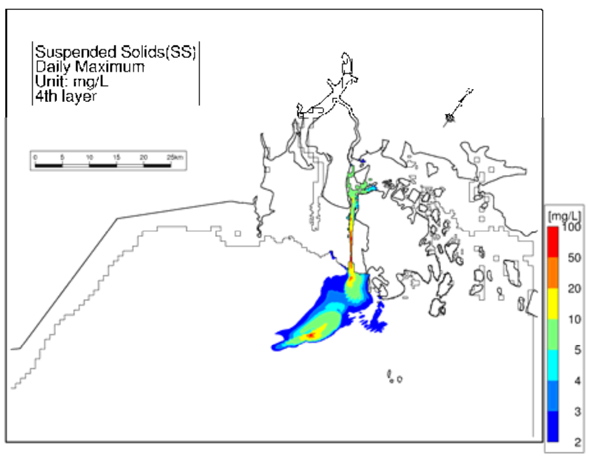
<tr><td>Lower layer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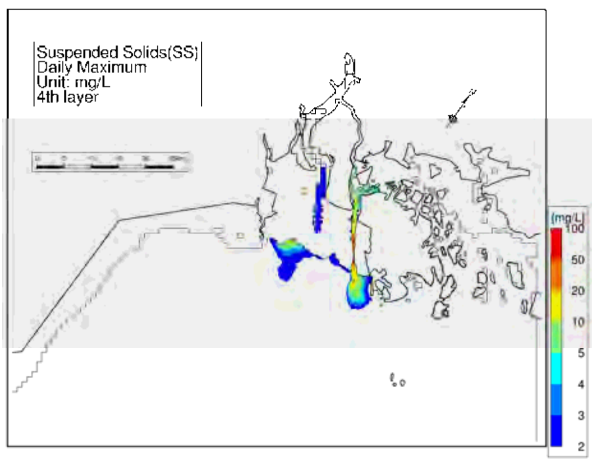
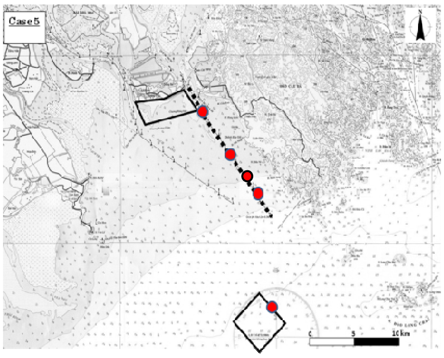
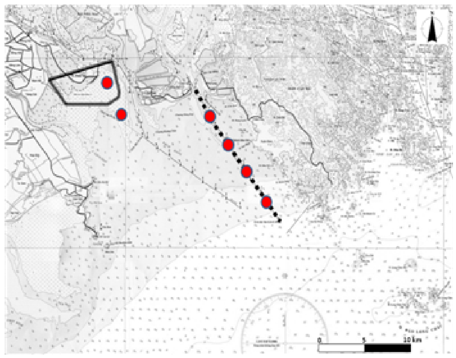
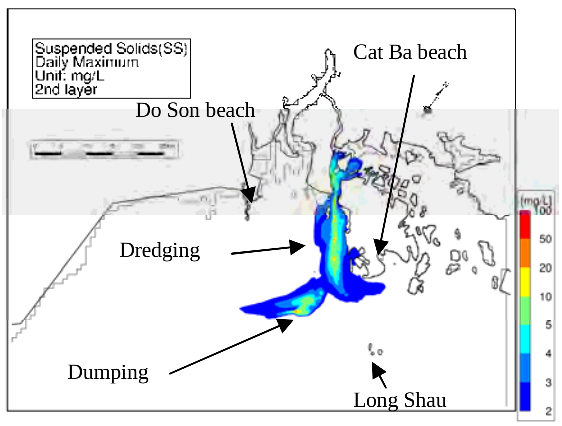

</td></tr>
</table>

Figure 12 Simulation result (Case12 and Case 13: large domain, daily maximum)

<table>
<tr><td>Case 15 (with silt curtain for dredging)</td><td>Case 16 (with silt curtain for dredging, dumping basin and drainage effluent outlet from embankment)</td></tr>
<tr><td>(Offshore dumping)

● : Load generation point</td><td>(Dumping at SDV)

● : Load generation point</td></tr>
<tr><td>(Upper layer)

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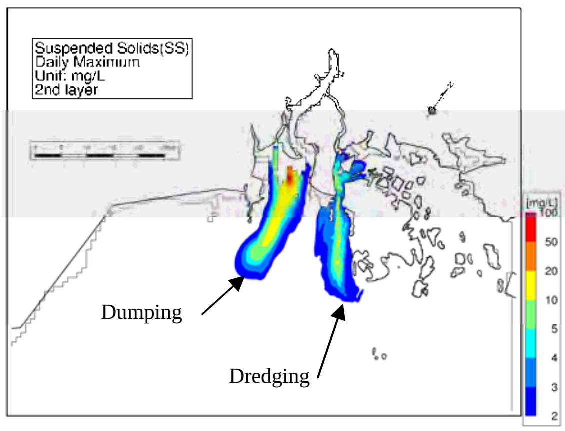
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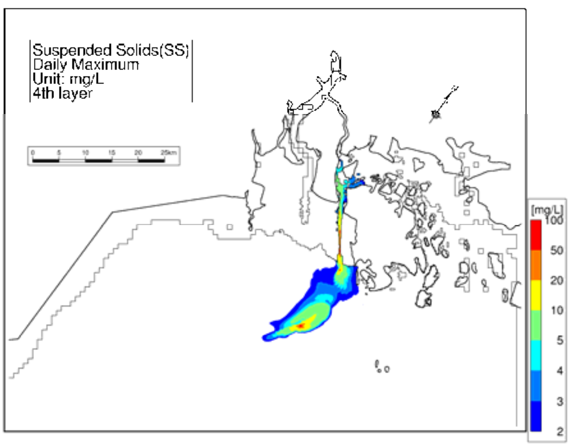
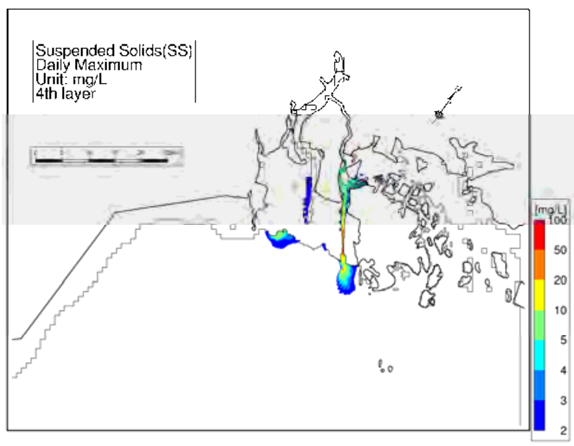
<tr><td>(Lower layer)

</td><td>(Lower layer)

</td></tr>
</table>

Figure 13 Simulation result (Case 15 and Case 16: large domain, daily maximum)

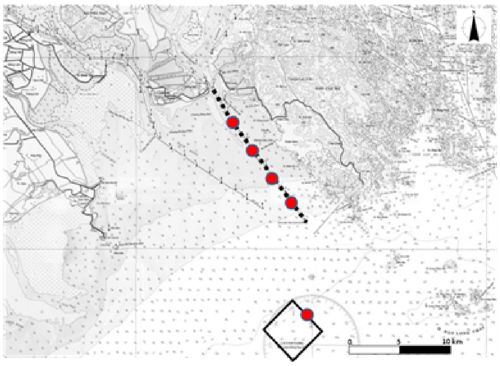
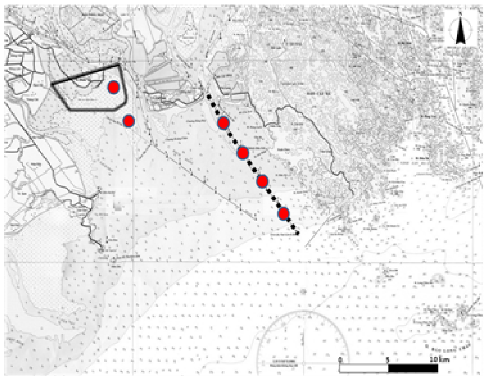
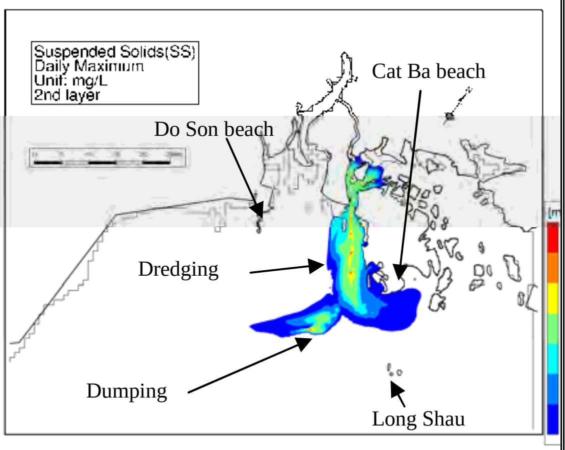
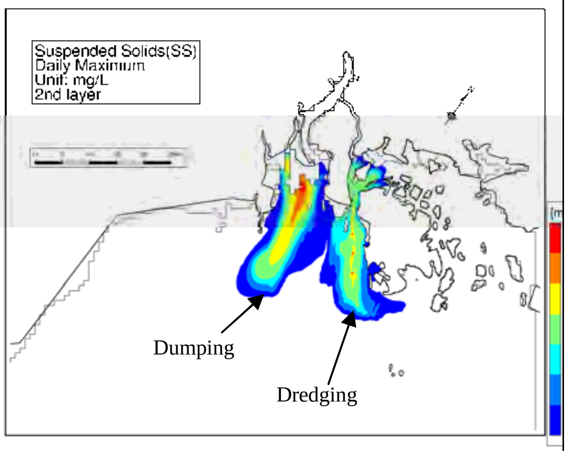
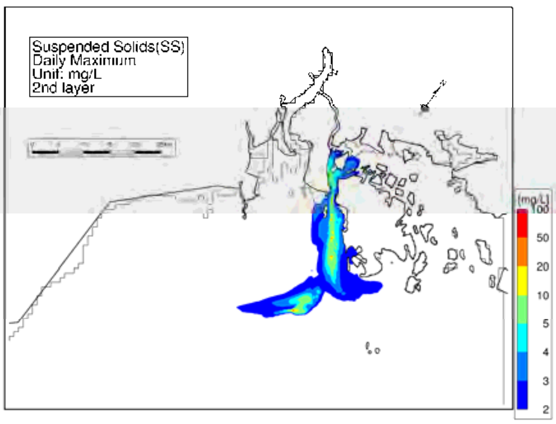
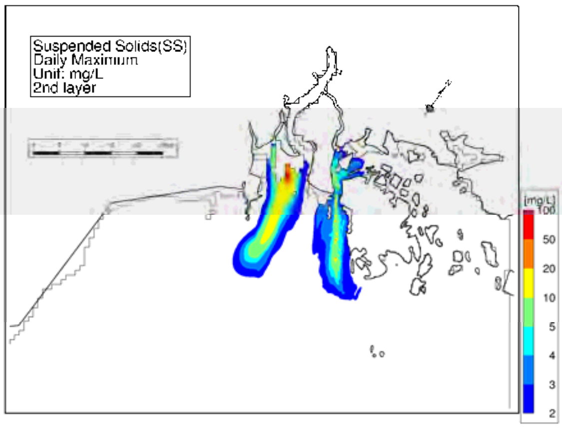
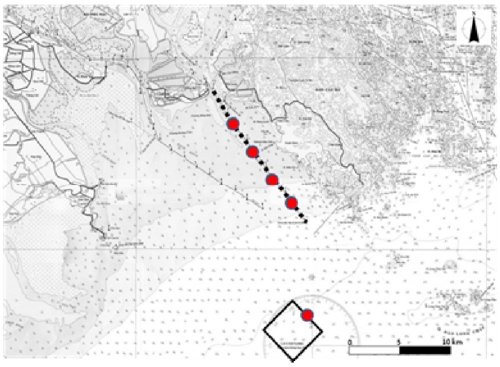
<table>
<tr><th></th><th>Case 12 and 15</th><th>Case 13 and 16</th></tr>
<tr><td></td><td>(Offshore dumping)

● :Load generation point</td><td>(Dumping at SDV)

● : Load generation point</td></tr>
<tr><td>without silt curtain</td><td>Case 12 (Upper layer)

</td><td>Case 13 (Upper layer)

</td></tr>
<tr><td>with silt curtain</td><td>Case 15 (Upper layer)

</td><td>Case 16 (Upper Layer)

</td></tr>
</table>

Figure 14 Simulation result (Case 12 and 15, Case 13 and 16: Upper layer, large domain, daily maximum)

Case 12 and 15

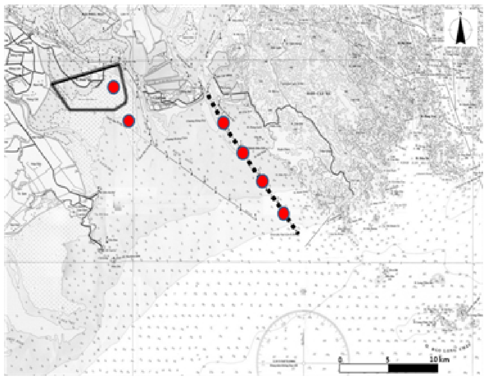
(Offshore dumping)



●:Load generation point

Case 13 and 16

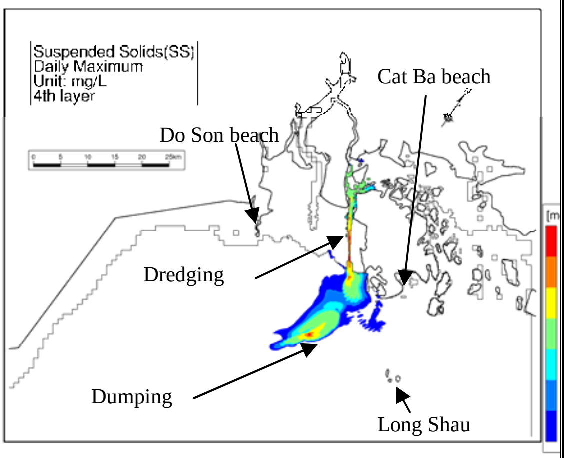
(Dumping at SDV)



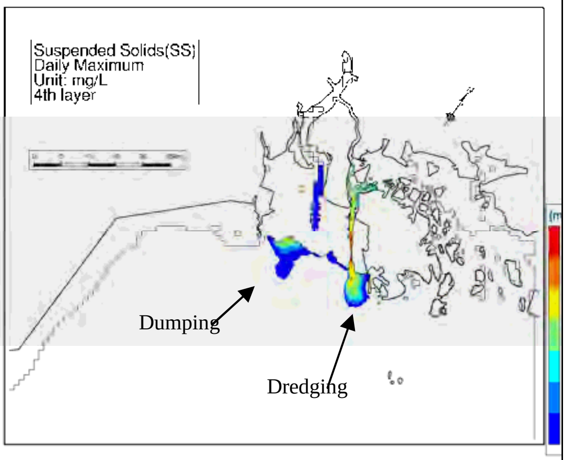
● : Load generation point

without silt curtain

Case 12 (Lower layer)

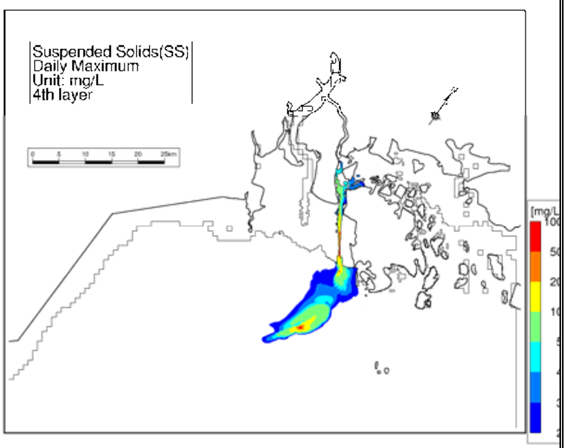


Case 13 (Lower layer)



with silt curtain

Case 15 (Lower layer)



Case 16 (Lower Layer)

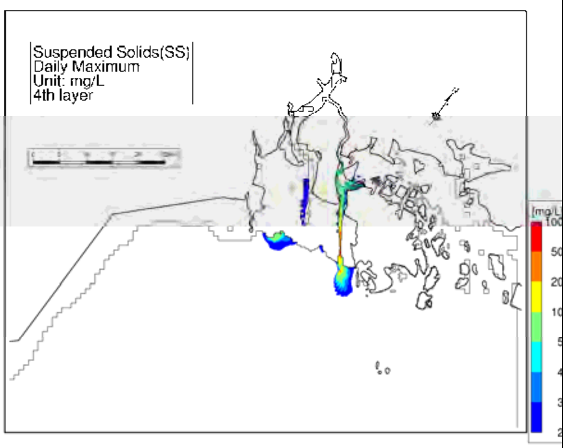


Figure 15 Simulation result (Case 12 and 15, Case 13 and 16: Lower layer, large domain, daily maximum)

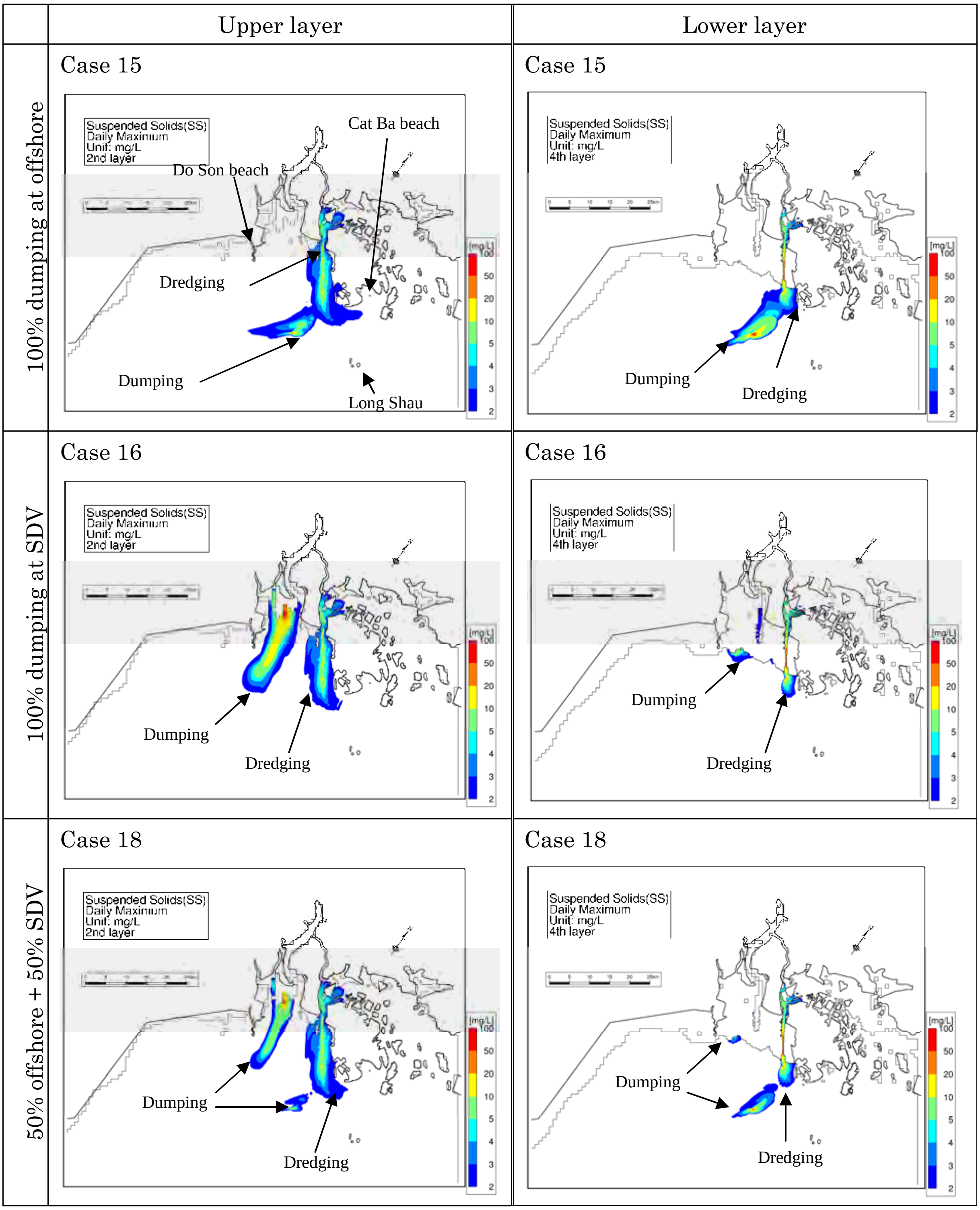


Figure 16 Simulation result (Case 15, Case 16 and Case 18: large domain, daily maximum)

4-3. Impact to the Environment

Comparative summary of the environmental impact assessment for SS dispersion between near-shore (SDV) and offshore dumping without SS control measures are shown in ***Table 7***.

Table 7 Summary of environmental impact assessment

Type of impact		Near-shore (SDV)	Offshore
Natural environment	Impact on water quality (i.e. SS)	- The upper layer SS dispersion range was more extensive compared to offshore dumping. - The upper layer SS concentration was significantly higher compared to offshore dumping. - Near-shore dumping may result in a maximum ten-fold increase in SS concentration from current levels.	- The upper layer SS dispersion range was less extensive compared to near-shore dumping. - The upper layer SS concentration was significantly lower compared to near-shore dumping.
Biological environment	Impacts by loss of existing benthic habitat	- The diversity and abundance of marine organisms were higher compared to offshore dumping area. - The near-shore area probably functions as a nursery ground for various species. - The near-shore area probably supports two fish species listed under Vietnam Red Book.	- The diversity and abundance of marine organisms were lower compared to near-shore dumping area. - No significant ecological function was identified. - No endangered species was identified.
	Impacts by SS dispersion	- Impacts on marine organisms will be greater compared to offshore dumping, as SS dispersion was predicted to be more significant than offshore dumping.	- Hard corals in Cat Ba Island and Long Chau Islands are unlikely to be affected from SS dispersion. - Impacts of SS dispersion on marine organisms will be less than near-shore dumping, as SS dispersion was predicted to be less significant than near-shore dumping.
Social environment	Impacts by loss of existing fishing area & SS dispersion	- PAHs by loss of fishing area and SS dispersion would be all existing/conventional occupations depending on sea water. - Impact on tourism//beach resorts would be moderate at Do Son beaches while it would be great in Cat Ba beaches unless proper monitoring is considered.. - Detailed social condition near SDV is not available at moment. Further survey and assess will be necessary if dumping at SDV is chosen.	- PAHs by loss of fishing area and SS dispersion would be limited to offshore fishing households. - Impact on tourism//beach resort would be negligible or minimal.
Conclusion	Without SS control measures, either near-shore (SDV) or offshore dumping would cause impacts on natural, biological, and social environment. However, considering the environmental sustainability and avoidance and minimization of unnecessary environmental impacts, **offshore dumping** is the preferable option without SS control measures. Due to the higher extent of negative impacts, SS control measures for near-shore		

<table>
<tr><th>Type of impact</th><th>Near-shore (SDV)</th><th>Offshore</th></tr>
<tr><td></td><td colspan="2">dumping would be technically difficult and costly to minimize and compensate the damages.

Therefore, it is recommendable to dispose the dredged sediment at the offshore dumping site. Even with the offshore dumping, it is still required to apply SS control measures for dredging activity to minimize the impacts with effective, economical, and practical measures.</td></tr>
</table>

5. Mitigation Measures and Monitoring

5-1. Mitigation Measures

Recommended mitigation measures are summarized in ***Table 8***.

Table 8 Recommended mitigation measures

Phase	Category	Impact factor	Mitigation measure	Implementing organization	Cost (USD)
Pre-Construction phase	Social environment	Land acquisition (if any)	Acquisition/compensation & IRP[5] by Land law And/or Career change program or IRP by DCEZ'[6] safety guard policy	District PC	Shall be defined by the District PC for the DCEZ's safety guard policies
		Loss of fisheries ground	Career change program or IRP by DCEZ' safety guard policy		
		Aquaculture	Inventory survey	Construction contractor	
Construction phase	Natural environment	Dust	Water spray, etc.	Construction contractor	-
		Noise/Vibration	Securing distance	Construction contractor	-
		Suspended solid	Silt curtain Overflow prohibition	Construction contractor	2,300,000/3years (for dredging and sensitive area) 8,750,000/3years (for SDV)
		Sediment degradation	Silt curtain	Construction contractor	
	Biological environment	Impact on hard corals and other marine organism due to SS dispersion from dredging and dumping activities	- Prohibition of overflow from dredger. - Installation of silt curtain around the dumping site - Implementation of reactive monitoring	Construction contractor	Refer to the cost above.
	Social environment	Degradation of water quality by SS for salt/aquaculture/beach resorts/fishery	DCEZ' safety guard policy (career change program or other mitigation/compensation measures)	District PC	Shall be defined by District PC for the DCEZ's safety guard policies.
Operation phase	Natural environment	Dust, Exhaust gas	Water spray High-combustion-efficiency engine	Operator	-

[5] IRP: Income Restpration Plan

[6] DCEZ: Dinh Vu-Cat Hai Economic Zone

Phase	Category	Impact factor	Mitigation measure	Implementing organization	Cost (USD)
		Noise/Vibration	Monitoring, Interview	Operator	3,000/year
		Discharged water	Discharge water management	Operator	-
		Ballast water	Offshore replacement	Operator	-
		Antifouling paint, Sediment quality	Regular monitoring	Project owner	37,500/year
	Biological environment	Any of impacts in Natural environment	Any of measures in Natural environment	Operator	Refer to the cost above.
	Social environment	Oil Spill Accident	- Capacity development of authority's disaster management skills - Preparation of disaster management materials and implementation structure	Lach Huyen Gateway Port Authority	Shall be defined by Lach Huyen Gateway Port Authority

5-2. Monitoring Plan

Recommended environmental monitoring plans are summarized in ***Table 9***.

Table 9 Recommended environmental monitoring plan

Phase	Category	Impact factor	Monitoring method	Implementing organization	Cost (USD)
Pre-Construction phase	Social environment	Land acquisition	2 time/year Standard methods for involuntary resettlement monitoring	District PC (legally responsible) with Collaboration of MPMU2	- Mandatory cost shall be defined by District PC - MPMU2's monitoring cost shall be 50,000/year
		Clearance of construction area (port & dumping site)	2 time/year Standard methods for involuntary resettlement monitoring		
Construction phase	Natural environment	Air quality, Noise, Vibration	1 time/month	Construction contractor	9,160/3years
		Suspended solid	Daily	Construction contractor	9,400/ 3years
		General environment	4 times/year	Project owner	375,000/year
	Biological environment	Impact on hard corals and other marine organism due to SS dispersion from dredging and dumping activities	**[Water quality monitoring]** - Daily monitoring of turbidity/SS levels at environmentally sensitive sites (3 sites) **[Coral health monitoring]** - Monthly monitoring of coral health at 2 hard coral sites (Cat Ba Island and Long Chau Island)	Construction contractor	130,000/3 years
		Impact on demersal fish/macro zoo benthos due to construction works	**[Demersal fish/macro zoobenthos monitoring]** - Seasonal monitoring of fish/macro zoo benthos status through trawling survey	Project owner	The cost is included in the cost for General environment of natural environment.
	Social environment	Degradation of water quality by SS for salt/aquaculture/ beach resorts/fishery	2 time/year Standard methods for involuntary resettlement monitoring	District PC (legally responsible) with Collaboration of MPMU2	- Mandatory cost shall be defined by District PC - MPMU2's monitoring

Phase	Category	Impact factor	Monitoring method	Implementing organization	Cost (USD)
					cost shall be 50,000/year including follow-up monitoring for pre-construction
Operation phase	Natural environment Biological environment	General environment	2 times/year	Project owner	187,500/year
	Social environment	Follow-up monitoring for PAP	2 time/year Standard methods for involuntary resettlement monitoring	District PC (legally responsible) with Collaboration of the LH Gateway Port Authority	- Mandatory cost shall be defined by District PC - Port Authority's monitoring cost shall be 50,000/year

6. Conclusions and Recommendations

Based on the study of present natural, biological and social conditions and study of SS dispersion caused by dredging/dumping activities using simulation models, this study concludes and recommends as follows:

- The near-shore area is more environmentally sensitive being affected by river water flow.
- The near-shore area is likely to have greater ecological values than the offshore area. Hence impacts of benthic habitat loss through dumping activities will be more significant with near-shore dumping.
- Near-shore dumping may cause more significant impacts on conventional occupations depending on seawater, led by the loss of fishing area and degradation of productivities by higher SS concentration.
- Near-shore dumping may cause more significant impacts on coastal tourism especially during the beaching seasons led by the degradation of beaching attractiveness by higher SS concentration.
- According to the simulation results, biological and socially sensitive area such as Ha Long Bay, Cat Ba beach area, Do Son beach area, Long Chau Islands will not be affected directly by offshore dumping, however the SS dispersion by dumping at SDV might reach to Do Son beach area.
- Based on the findings listed above, offshore dumping is preferable.
- By the combination of dumping at different location, such as 50% of dumping at offshore and 50% of dumping at SDV, the affected area will be broader than that by dumping at single location.
- Countermeasures to SS dispersion such as silt protector/curtain will effectively work to reduce the impact by dredging/dumping activities.
- Past studies indicate that dumped sediment at offshore site is unlikely stirred up with normal seastate.
- Even though offshore dumping is likely to have naturally, biologically and socially less impact, continuous monitoring and measures to control SS generation/dispersion during the construction phase are highly recommended.