

APPENDIX G ACCESS CHANNEL DESIGN

APPENDIX G ACCESS CHANNEL DESIGN

G.1 First Time Ship Handling Simulation

G.1.1 Maneuvering Equation of Motion

The mathematical model of the ship maneuvering that is employed within the simulation system can be classified as a modular type one. The modular means the total force acting on the ship is expressed as a sum of components of forces acting on the parts of the ship. The model is based on the published results of research conducted in Japan within the MMG (Mathematical Modeling Grouped) and the MSS (Model for Slow and Shallow Motions) projects. The data for the model comes from the database developed and maintained by Japan Marine Science Inc. The following forces are modeled in the system:

- Hull force, propeller force, rudder force, tugboat force (Side thruster force);
- Wind force, wave force, tidal current force;

The effects of restricted water depth are included into the models of hydrodynamic forces.

The motion of ship's engine, rudder position and tugboat's Z-propeller are also modeled using specific dynamic equations. The ship maneuvering motion has 3 degrees of freedom (DOF) and the computed motions are surge, sway and yaw.

G.1.2 Simulation System

The fast time ship handling simulation is a numerical ship handling simulation conducted with an automatic controller replacing the human navigator. It is to provide the data about limited in scope behavior of the man-machine-environment system under designed conditions and constraints. The simulation system used for the fast time ship-handling simulation consists of the following components.

- a) Motion computing system, which is a system implementing the mathematical models of the simulation system.
- b) Automatic controller, which is a system that realizes some control strategy.
- c) Simulated control input system, which is a system that connects the automatic controller and the motion computing system.
- d) Output system, which is a system that records the simulation state.

The mathematical model of the ship maneuvering that is employed within the simulation system can be classified as a modular type one. The modular means the total force acting on the ship is expressed as a sum of components forces acting on the parts of the ship. The model is based on the published results of researches conducted in Japan within the MMG (Mathematical Modeling Grouped) and the MSS (Model for Slow and Shallow Motions) projects. The following forces are modeled in the system:

- Hull force, propeller force, rudder force, tugboat force (Side thruster force)
- Wind force, wave force, tidal current force.

The effects of restricted water depth are included into the models of hydrodynamic forces. The power of ships engine, rudder position and tugboats Z-propeller are also modeled using specific dynamic equations. Figure G.1.1 shows the modeling process and the mathematical model.

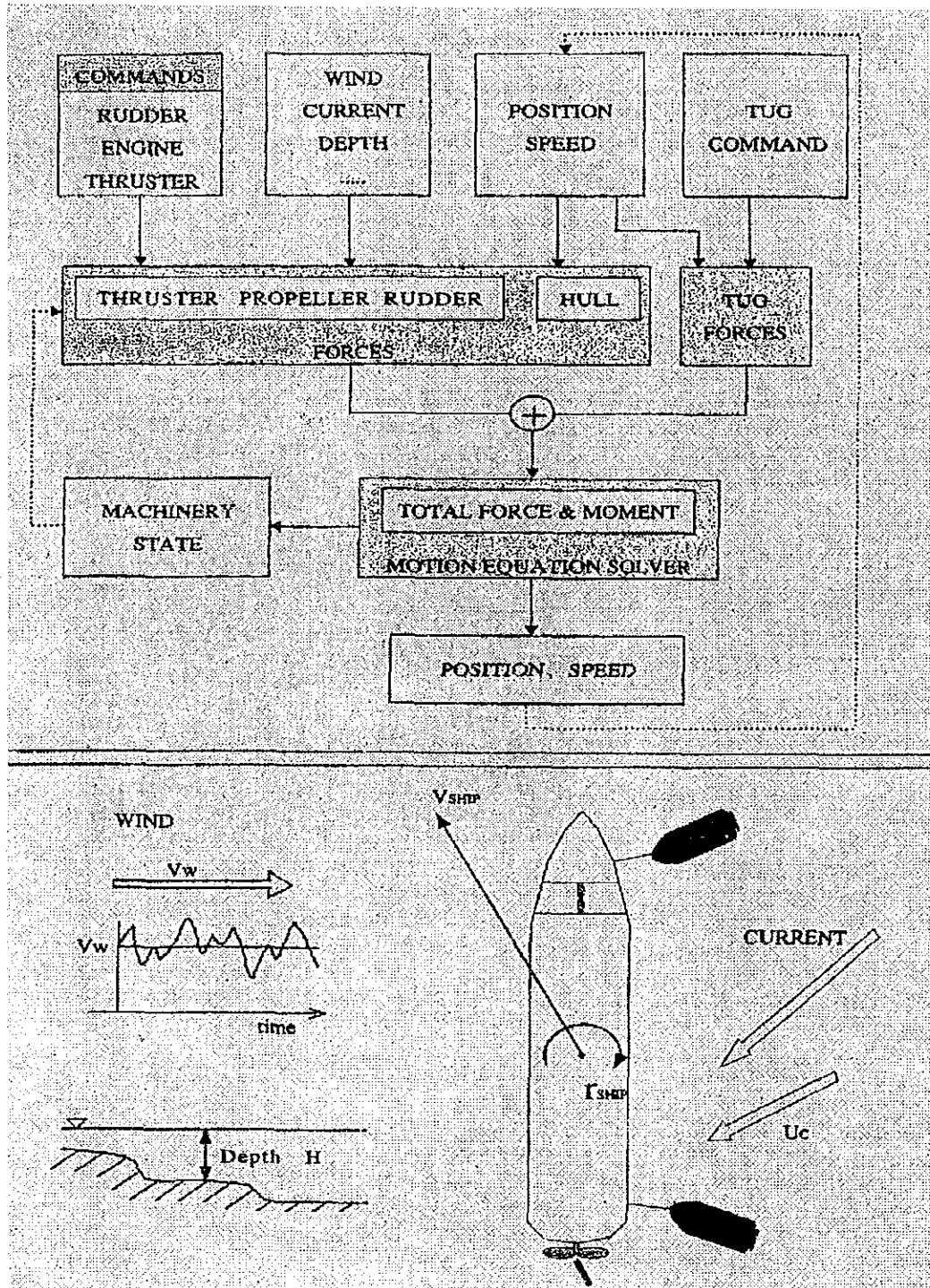


Figure G.1.1 Modeling Process and Mathematical Model

G.1.3 Model of Wind and Tidal Current Condition

Wind and tidal current condition were determined according to the survey data. Their predominant directions were taken into consideration.

G.1.4 Ship Used for the Fast Time Ship-handling Simulation

Table G.1.1 shows the principal particulars of the ship which is used for the ship-handling simulation model.

Table G.1.1 Ship's Principal Particulars

LOA	292.15 m	
LPP	273.00 m	
Breadth	32.26 m	
Depth	21.20 m	
DWT	59,418MT	
Condition	Full load	Half load
Draft	13.00 m	11.00 m
Displacement	78,722 mt	63,350 mt
Project area	Front	1,000 m ²
	Side	5,300 m ²
Speed	Full	knots
	Half	9.3 knots
	Slow	7.5 knots
	D.Slow	6.5 knots
		1,060 m ²
		5,870 m ²
		knots
		9.5 knots
		7.7 knots
		6.7 knots

Figure G.1.2 shows a photograph of the ship and Figures G.1.3 and G.1.4 shows the trajectory and the time history of turning maneuver in shallow and deep sea obtained through the simulation.

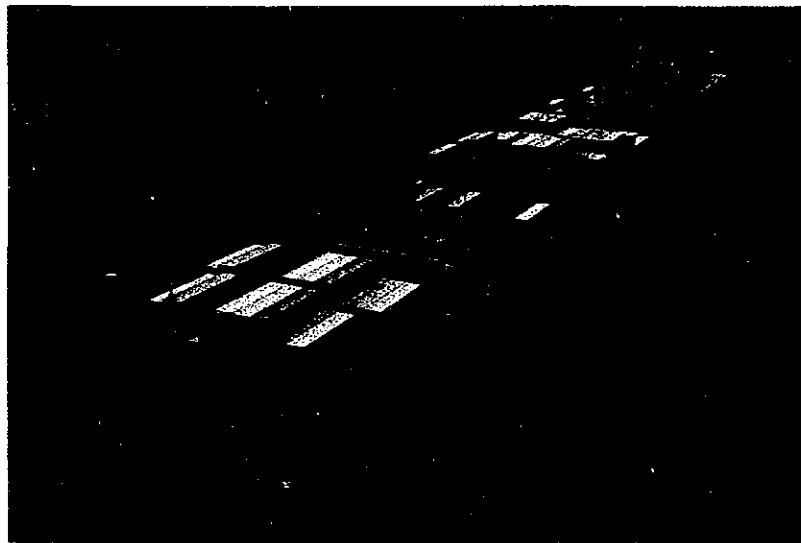


Figure G.1.2 Photograph of the Ship

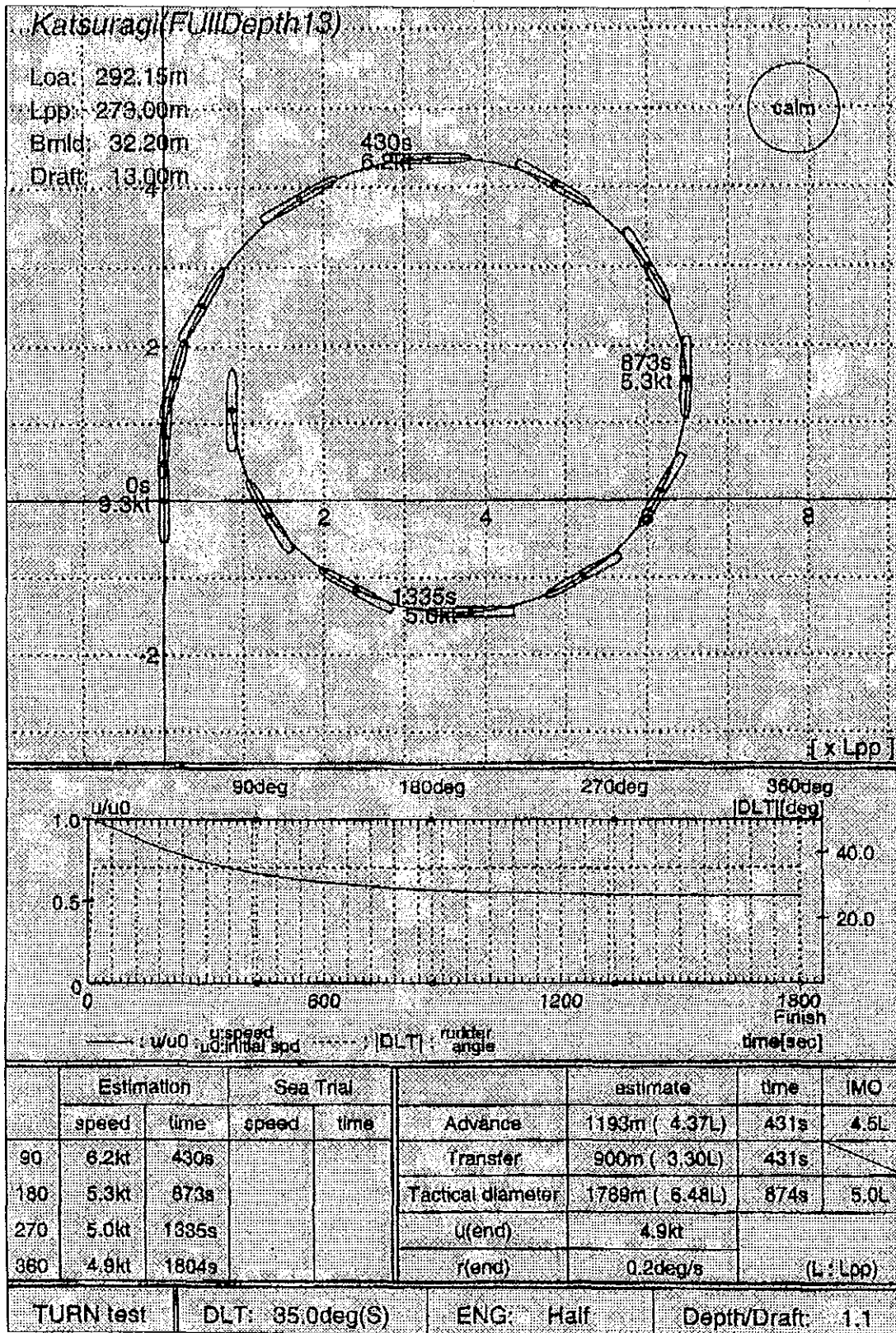


Figure G.13 Trajectory of the Ship (Shallow Sea)

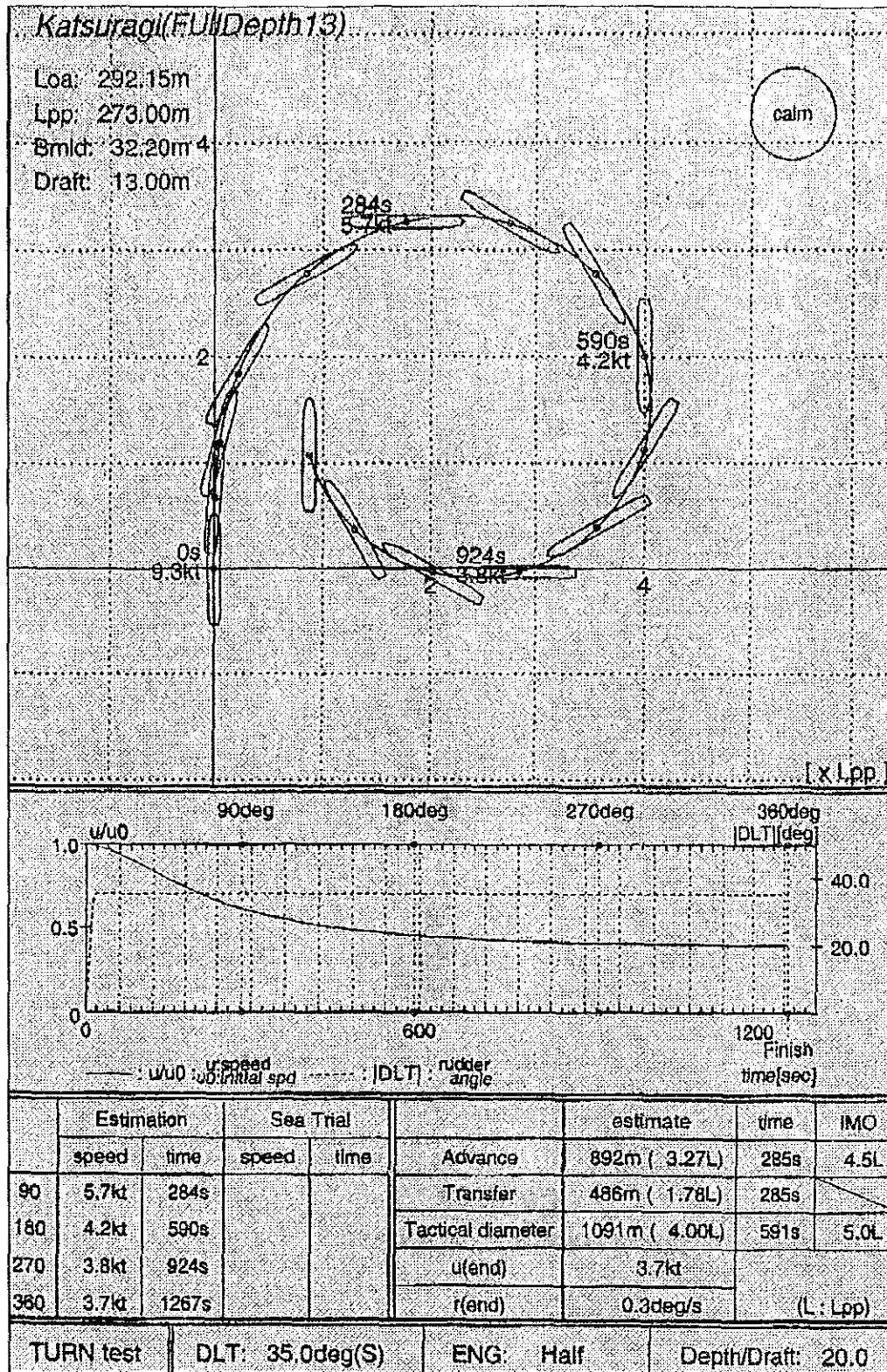


Figure G.1.4 Trajectory of the Ship (Deep Water)

Figure G.1.5 shows the wind and current directions used in the simulations of track keeping maneuver. Wind direction varied from 0 to 315 degrees (With a step of 45 degrees) and wind velocity varied from 12 m/sec. to 15 m/sec.

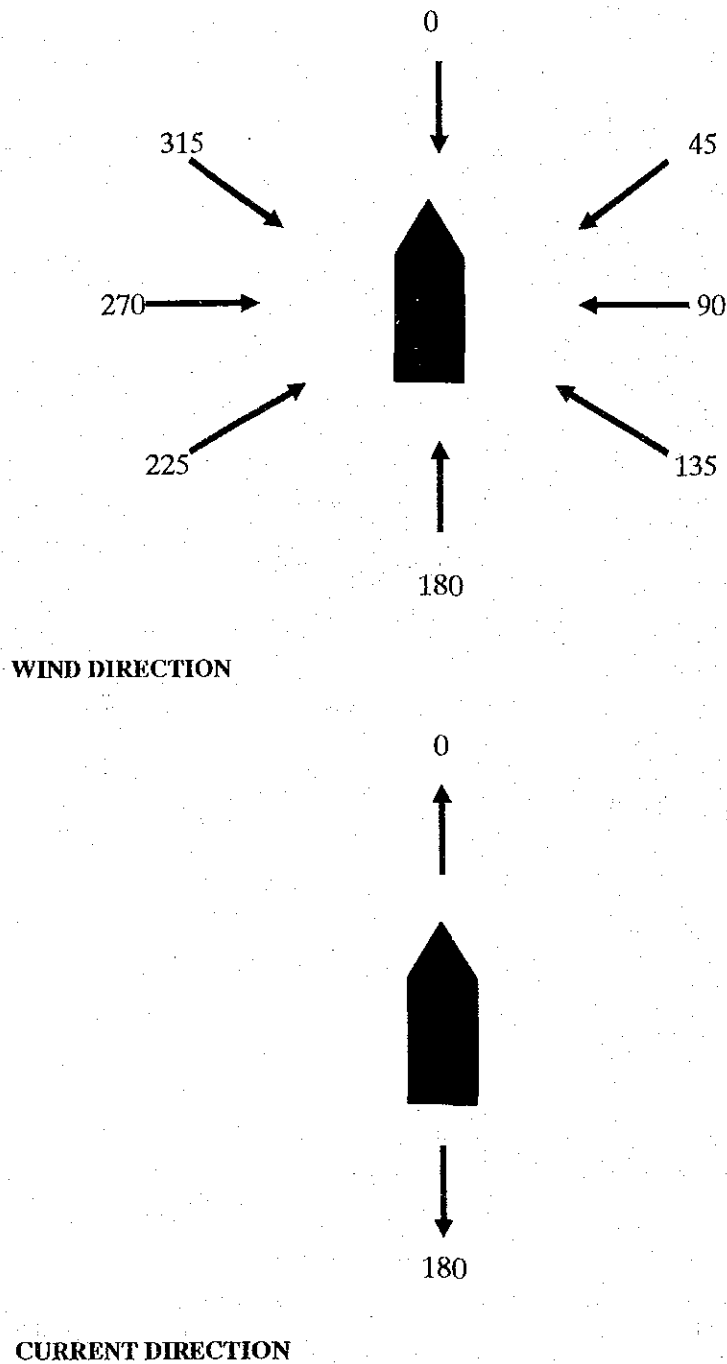


Figure G.1.5 Wind and Current Directions Used in the Simulations of Track Keeping Maneuver

Figure G.1.6 shows the arrangement of the tugboats during the simulation. Wind direction varied from 0 to 315 degrees (With a step of 45 degrees). Two (2) tidal current directions (follow and against) were used in the simulation. Figure G.1.7 shows the wind and current directions used in the simulations of turning with tugboats assistance.

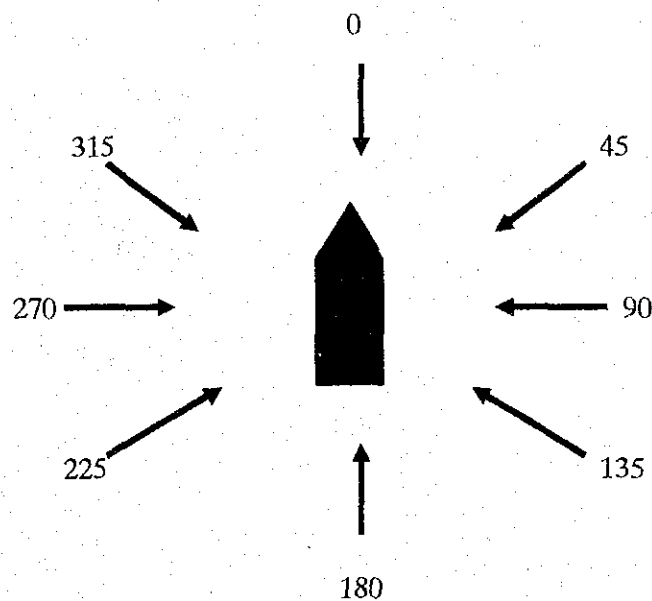


Figure G.1.6 Wind Directions Used in the Simulations During the Simulations of Turning

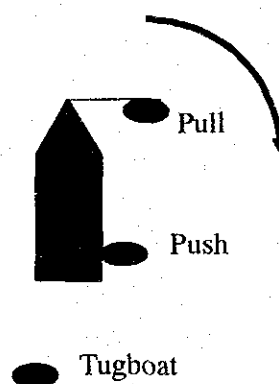


Figure G.1.7 Tugboats Arrangement During the Simulations of Turning

G.2 Fast Time Ship Handling Simulation Result

Simulation studies are performed for the cases as listed below:

Table G.2.1 Channel Navigation

Condition	Ship's speed	Wind		Current	
		Direction	Velocity (m/s)	Direction	Velocity (knot)
Full load	*Half & Slow	All direction	12	Follow & Against	1
Full load	*Half & Slow	All direction	12	Follow & Against	2
Full load	*Half & Slow	All direction	12	Follow & Against	3
Full load	*Half & Slow	All direction	12	Follow & Against	1,2,3
Full load	*Half & Slow	All direction	15	Follow & Against	1
Full load	*Half & Slow	All direction	15	Follow & Against	2
Full load	*Half & Slow	All direction	15	Follow & Against	3
Full load	*Half & Slow	All direction	15	Follow & Against	1,2,3
Full load	*Half & Slow	North	12	Follow	2
Full load	*Half & Slow	NE	12	Follow	2
Full load	*Half & Slow	East	12	Follow	2
Full load	*Half & Slow	SE	12	Follow	2
Full load	*Half & Slow	South	12	Follow	2
Full load	*Half & Slow	SW	12	Follow	2
Full load	*Half & Slow	West	12	Follow	2
Full load	*Half & Slow	NW	12	Follow	2
*Full load	*Half & Slow	All direction	12	Follow & Against	2
*Full load	*Half & Slow	All direction	12	Follow & Against	2

[Note (*) Enlarged figure, Half Speed: Outer Channel, Slow Speed: Inner Channel]

Table G.2.2 Turning with Tugboat

Condition	Ship's speed	Wind		Current	
		Direction	Velocity (m/s)	Direction	Velocity (knot)
Full load	-	All direction	12	Follow	2
Full load	-	All direction	12	Against	2
Full load	-	All direction	15	Follow	2
Full load	-	All direction	15	Against	2
Half load	-	All direction	12	Follow	2
Half load	-	All direction	12	Against	2
Half load	-	All direction	12	Follow	2
Half load	-	All direction	12	Against	2
Full load	-	North	12	Against	2
Full load	-	NE	12	Against	2
Full load	-	East	12	Against	2
Full load	-	SE	12	Against	2
Full load	-	South	12	Against	2
Full load	-	SW	12	Against	2
Full load	-	West	12	Against	2
Full load	-	NW	12	Against	2
Full load	-	North	12	Follow	2
Full load	-	NE	12	Follow	2
Full load	-	East	12	Follow	2
Full load	-	SE	12	Follow	2
Full load	-	South	12	Follow	2
Full load	-	SW	12	Follow	2
Full load	-	West	12	Follow	2
Full load	-	NW	12	Follow	2

The results of simulation showing the cases of channel deviation are presented in Tables G.2.3 to G.2.6.

Table G.2.3 Matrix of Results of Ship Deviated from the Channel – Full Load

Load condition	Draft condition	Sip's speed
Full load	13.0m	Slow and Half

Wind Velocity: 12m/s						Wind Velocity: 15m/s					
Current follow			Current against			Current follow			Current against		
C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.
1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No
1	<NE>	No	1	<NE>	No	1	<NE>	No	1	<NE>	No
1	<E>	No	1	<E>	No	1	<E>	No	1	<E>	No
1	<SE>	No	1	<SE>	No	1	<SE>	No	1	<SE>	No
1	<S>	No	1	<S>	No	1	<S>	No	1	<S>	No
1	<SW>	No	1	<SW>	No	1	<SW>	No	1	<SW>	No
1	<W>	No	1	<W>	No	1	<W>	No	1	<W>	No
1	<NW>	No	1	<NW>	No	1	<NW>	No	1	<NW>	No
2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No
2	<NE>	No	2	<NE>	No	2	<NE>	No	2	<NE>	No
2	<E>	No	2	<E>	No	2	<E>	No	2	<E>	No
2	<SE>	No	2	<SE>	No	2	<SE>	No	2	<SE>	No
2	<S>	No	2	<S>	No	2	<S>	Yes	2	<S>	No
2	<SW>	No	2	<SW>	No	2	<SW>	Yes	2	<SW>	No
2	<W>	No	2	<W>	No	2	<W>	Yes	2	<W>	No
2	<NW>	No	2	<NW>	No	2	<NW>	No	2	<NW>	No
3 Knot	<N>	Yes	3 Knot	<N>	No	3 Knot	<N>	Yes	3 Knot	<N>	No
3	<NE>	No	3	<NE>	No	3	<NE>	No	3	<NE>	No
3	<E>	No	3	<E>	No	3	<E>	No	3	<E>	No
3	<SE>	Yes	3	<SE>	No	3	<SE>	Yes	3	<SE>	No
3	<S>	Yes	3	<S>	No	3	<S>	Yes	3	<S>	No
3	<SW>	Yes	3	<SW>	No	3	<SW>	Yes	3	<SW>	No
3	<W>	Yes	3	<W>	No	3	<W>	Yes	3	<W>	No
3	<NW>	Yes	3	<NW>	No	3	<NW>	Yes	3	<NW>	No

[Note: C.V: Current Velocity, W.D: Wind Direction, Dev.: Deviation]

Table G.2.4 Matrix of Results of Ship Deviated from the Channel – Half Load

Load condition	Draft condition	Sip's speed
Half load	11.0m	Slow and Half

Wind Velocity: 12m/s						Wind Velocity: 15m/s					
Current follow			Current against			Current follow			Current against		
C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.
1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No
1	<NE>	No	1	<NE>	No	1	<NE>	No	1	<NE>	No
1	<E>	No	1	<E>	No	1	<E>	No	1	<E>	No
1	<SE>	No	1	<SE>	No	1	<SE>	No	1	<SE>	No
1	<S>	No	1	<S>	No	1	<S>	No	1	<S>	No
1	<SW>	No	1	<SW>	No	1	<SW>	No	1	<SW>	No
1	<W>	No	1	<W>	No	1	<W>	No	1	<W>	No
1	<NW>	No	1	<NW>	No	1	<NW>	No	1	<NW>	No
2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No
2	<NE>	No	2	<NE>	No	2	<NE>	No	2	<NE>	No
2	<E>	No	2	<E>	No	2	<E>	No	2	<E>	No
2	<SE>	No	2	<SE>	No	2	<SE>	No	2	<SE>	No
2	<S>	No	2	<S>	No	2	<S>	Yes	2	<S>	No
2	<SW>	No	2	<SW>	No	2	<SW>	Yes	2	<SW>	No
2	<W>	No	2	<W>	No	2	<W>	Yes	2	<W>	No
2	<NW>	No	2	<NW>	No	2	<NW>	No	2	<NW>	No
3 Knot	<N>	Yes	3 Knot	<N>	No	3 Knot	<N>	Yes	3 Knot	<N>	No
3	<NE>	No	3	<NE>	No	3	<NE>	No	3	<NE>	No
3	<E>	No	3	<E>	No	3	<E>	No	3	<E>	No
3	<SE>	Yes	3	<SE>	No	3	<SE>	Yes	3	<SE>	No
3	<S>	Yes	3	<S>	No	3	<S>	Yes	3	<S>	No
3	<SW>	Yes	3	<SW>	No	3	<SW>	Yes	3	<SW>	No
3	<W>	Yes	3	<W>	No	3	<W>	Yes	3	<W>	No
3	<NW>	Yes	3	<NW>	No	3	<NW>	Yes	3	<NW>	No

[Note: C.V: Current Velocity, W.D: Wind Direction, Dev.: Deviation]

Table G.2.5 Matrix of Results of Ship Deviated from the Turning Basin – Full Load

Load condition			Draft condition			Ship's speed					
Full load			13.0m								
Wind Velocity: 12m/s						Wind Velocity: 15m/s					
Current follow			Current against			Current follow			Current against		
C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.
1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No
1	<NE>	No	1	<NE>	No	1	<NE>	No	1	<NE>	No
1	<E>	No	1	<E>	No	1	<E>	No	1	<E>	No
1	<SE>	No	1	<SE>	No	1	<SE>	No	1	<SE>	No
1	<S>	No	1	<S>	No	1	<S>	No	1	<S>	No
1	<SW>	No	1	<SW>	No	1	<SW>	No	1	<SW>	No
1	<W>	No	1	<W>	No	1	<W>	No	1	<W>	No
1	<NW>	No	1	<NW>	No	1	<NW>	No	1	<NW>	No
2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No
2	<NE>	No	2	<NE>	No	2	<NE>	No	2	<NE>	No
2	<E>	No	2	<E>	No	2	<E>	No	2	<E>	No
2	<SE>	No	2	<SE>	No	2	<SE>	No	2	<SE>	No
2	<S>	No	2	<S>	No	2	<S>	No	2	<S>	No
2	<SW>	No	2	<SW>	No	2	<SW>	No	2	<SW>	No
2	<W>	No	2	<W>	No	2	<W>	No	2	<W>	No
2	<NW>	No	2	<NW>	No	2	<NW>	No	2	<NW>	No
3 Knot	<N>	Yes	3 Knot	<N>	Yes	3 Knot	<N>	Yes	3 Knot	<N>	Yes
3	<NE>	Yes	3	<NE>	Yes	3	<NE>	Yes	3	<NE>	Yes
3	<E>	Yes	3	<E>	Yes	3	<E>	Yes	3	<E>	Yes
3	<SE>	Yes	3	<SE>	Yes	3	<SE>	Yes	3	<SE>	Yes
3	<S>	Yes	3	<S>	Yes	3	<S>	Yes	3	<S>	Yes
3	<SW>	Yes	3	<SW>	Yes	3	<SW>	Yes	3	<SW>	Yes
3	<W>	Yes	3	<W>	Yes	3	<W>	Yes	3	<W>	Yes
3	<NW>	Yes	3	<NW>	Yes	3	<NW>	Yes	3	<NW>	Yes

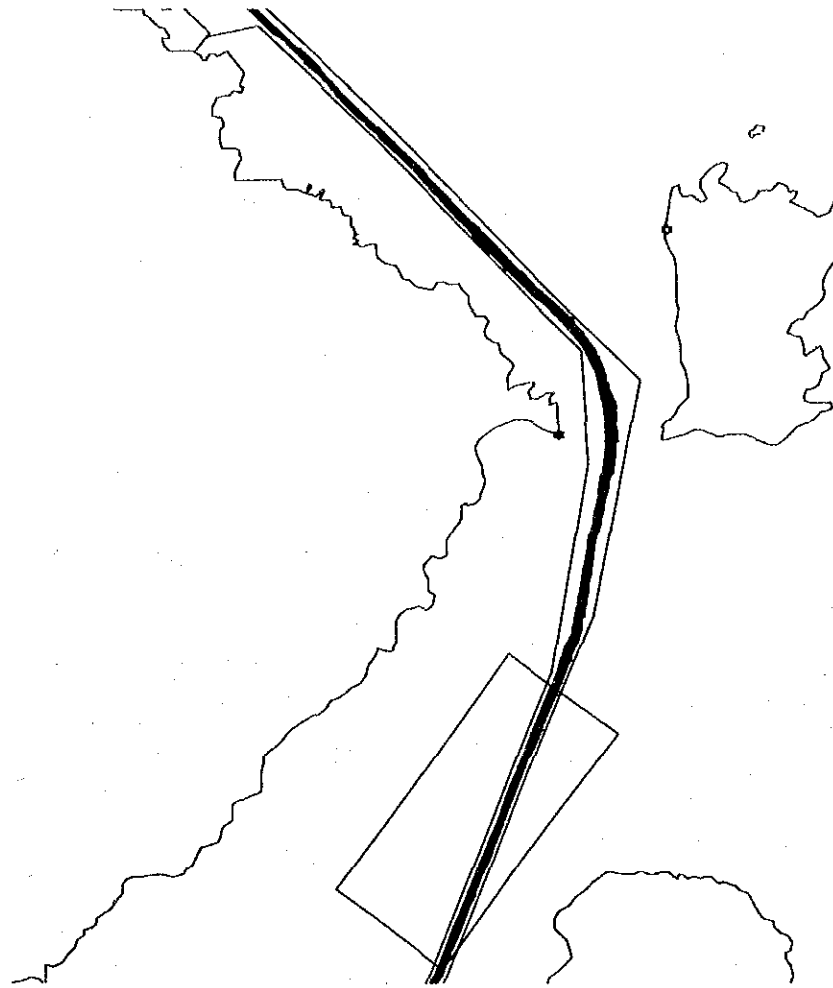
[Note: C.V: Current Velocity, W.D: Wind Direction, Dev.: Deviation]

Table G.2.6 Matrix of Results of Ship Deviated from the Turning Basin – Half Load

Load condition	Draft condition	Sip's speed
Half load	11.0m	

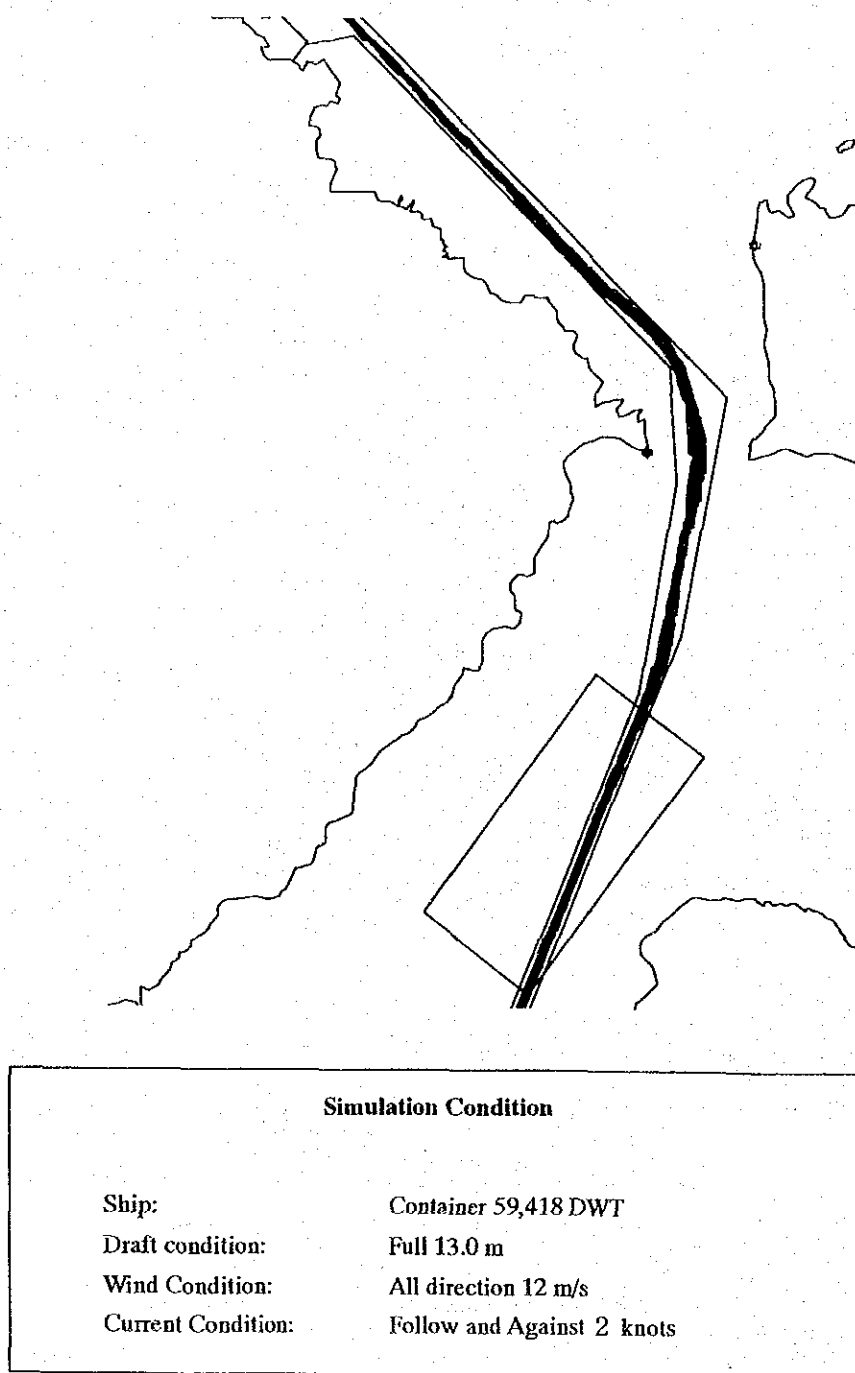
Wind Velocity: 12m/s						Wind Velocity: 15m/s					
Current follow			Current against			Current follow			Current against		
C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.	C.V.	W.D	Dev.
1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No	1 Knot	<N>	No
1	<NE>	No	1	<NE>	No	1	<NE>	No	1	<NE>	No
1	<E>	No	1	<E>	No	1	<E>	No	1	<E>	No
1	<SE>	No	1	<SE>	No	1	<SE>	No	1	<SE>	No
1	<S>	No	1	<S>	No	1	<S>	No	1	<S>	No
1	<SW>	No	1	<SW>	No	1	<SW>	No	1	<SW>	No
1	<W>	No	1	<W>	No	1	<W>	No	1	<W>	No
1	<NW>	No	1	<NW>	No	1	<NW>	No	1	<NW>	No
2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No	2 Knot	<N>	No
2	<NE>	No	2	<NE>	No	2	<NE>	No	2	<NE>	No
2	<E>	No	2	<E>	No	2	<E>	No	2	<E>	No
2	<SE>	No	2	<SE>	No	2	<SE>	No	2	<SE>	No
2	<S>	No	2	<S>	No	2	<S>	No	2	<S>	No
2	<SW>	No	2	<SW>	No	2	<SW>	No	2	<SW>	No
2	<W>	No	2	<W>	No	2	<W>	No	2	<W>	No
2	<NW>	No	2	<NW>	No	2	<NW>	No	2	<NW>	No
3 Knot	<N>	Yes	3 Knot	<N>	Yes	3 Knot	<N>	Yes	3 Knot	<N>	Yes
3	<NE>	Yes	3	<NE>	Yes	3	<NE>	Yes	3	<NE>	Yes
3	<E>	Yes	3	<E>	Yes	3	<E>	Yes	3	<E>	Yes
3	<SE>	Yes	3	<SE>	Yes	3	<SE>	Yes	3	<SE>	Yes
3	<S>	Yes	3	<S>	Yes	3	<S>	Yes	3	<S>	Yes
3	<SW>	Yes	3	<SW>	Yes	3	<SW>	Yes	3	<SW>	Yes
3	<W>	Yes	3	<W>	Yes	3	<W>	Yes	3	<W>	Yes
3	<NW>	Yes	3	<NW>	Yes	3	<NW>	Yes	3	<NW>	Yes

[Note: C.V: Current Velocity, W.D: Wind Direction, Dev.: Deviation]



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 12 m/s
Current Condition:	Follow and Against 1 knot

**Figure G.2.1 Channel Navigation - Full Draft, All Directions 12 m/s,
Follow and Against, 1 Knot**



**Figure G.2.2 Channel Navigation - Full Draft, All Directions 12 m/s,
Follow and Against, 2 Knots**

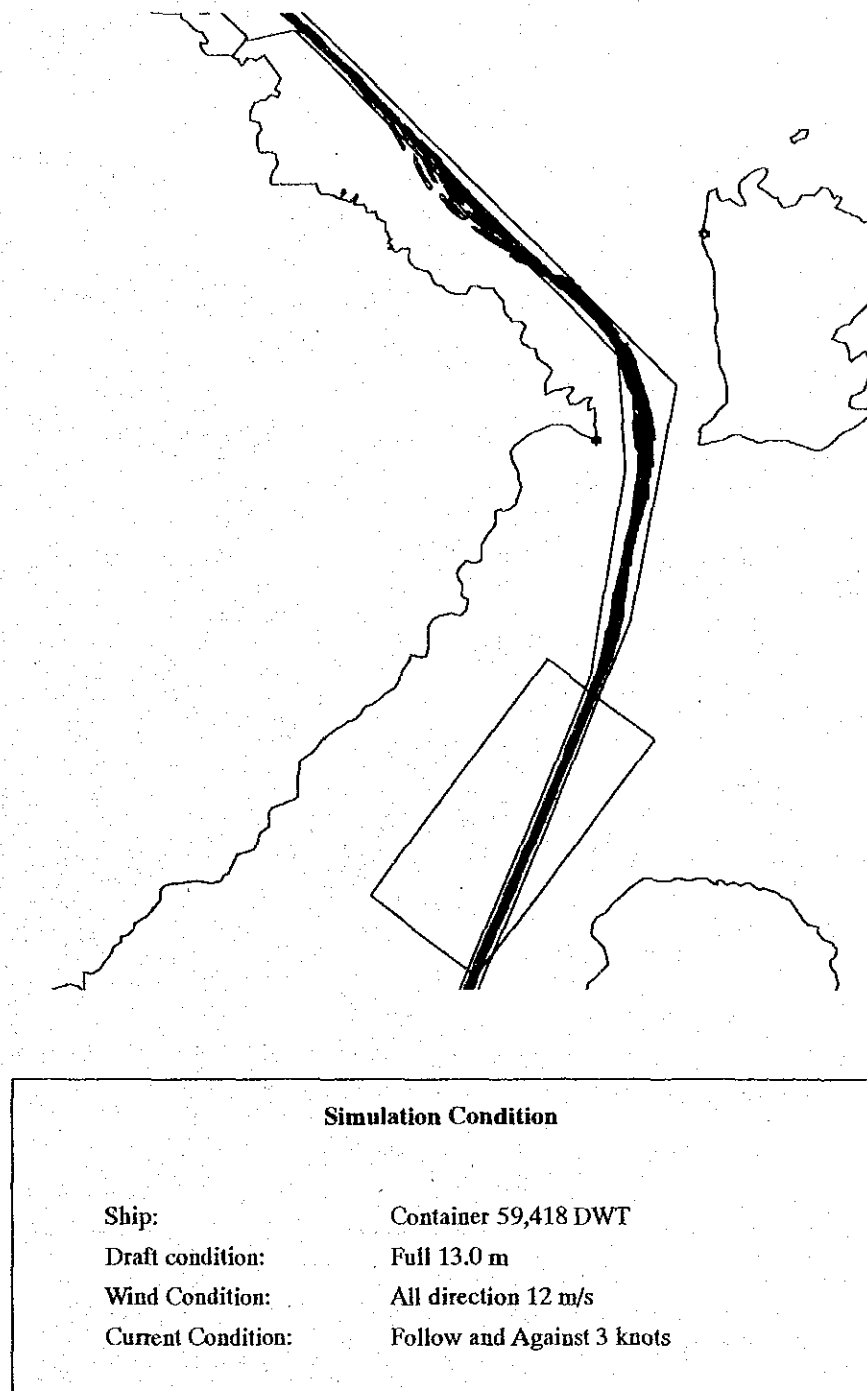
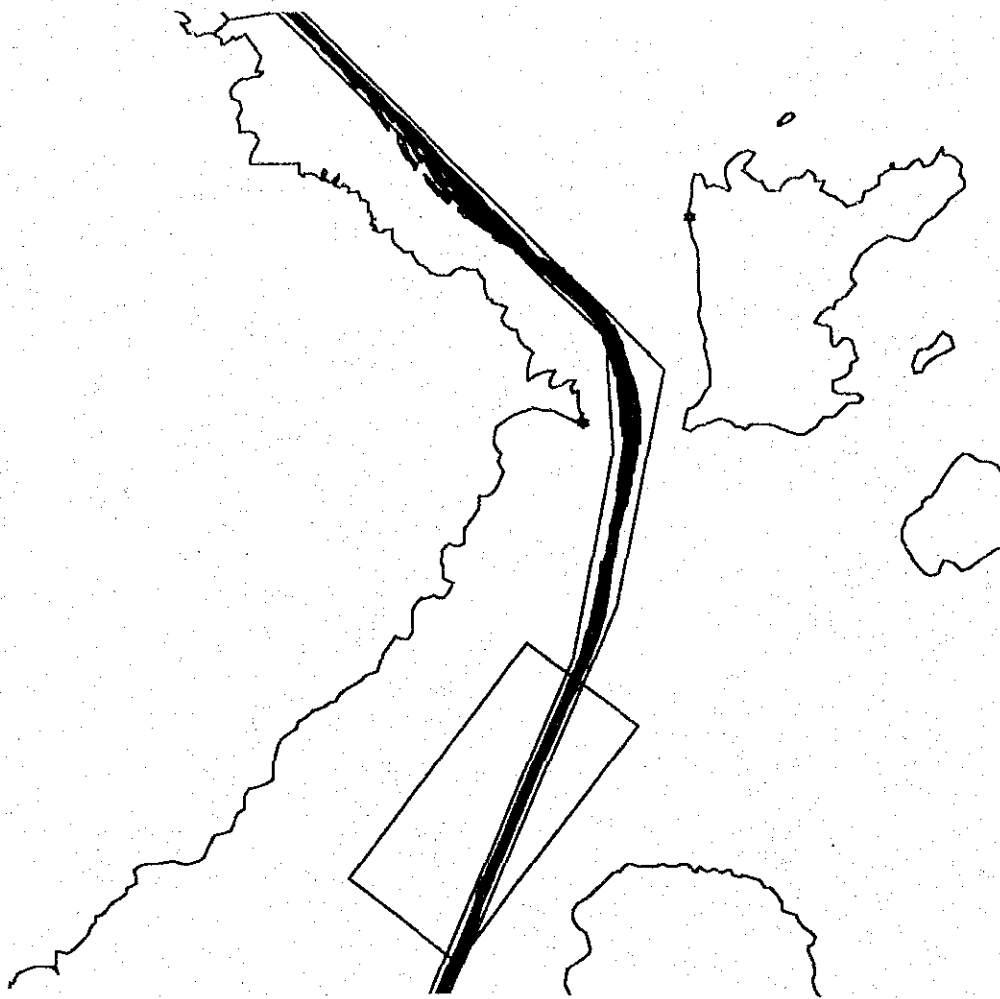


Figure G.2.3 Channel Navigation - Full Draft, All Directions 12 m/s, Follow and Against, 3 Knots



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 12 m/s
Current Condition:	Follow and Against 1-3 knots

**Figure G.2.4 Channel Navigation - Full Draft, All Directions 12 m/s,
Follow and Against, 1-3 Knots**

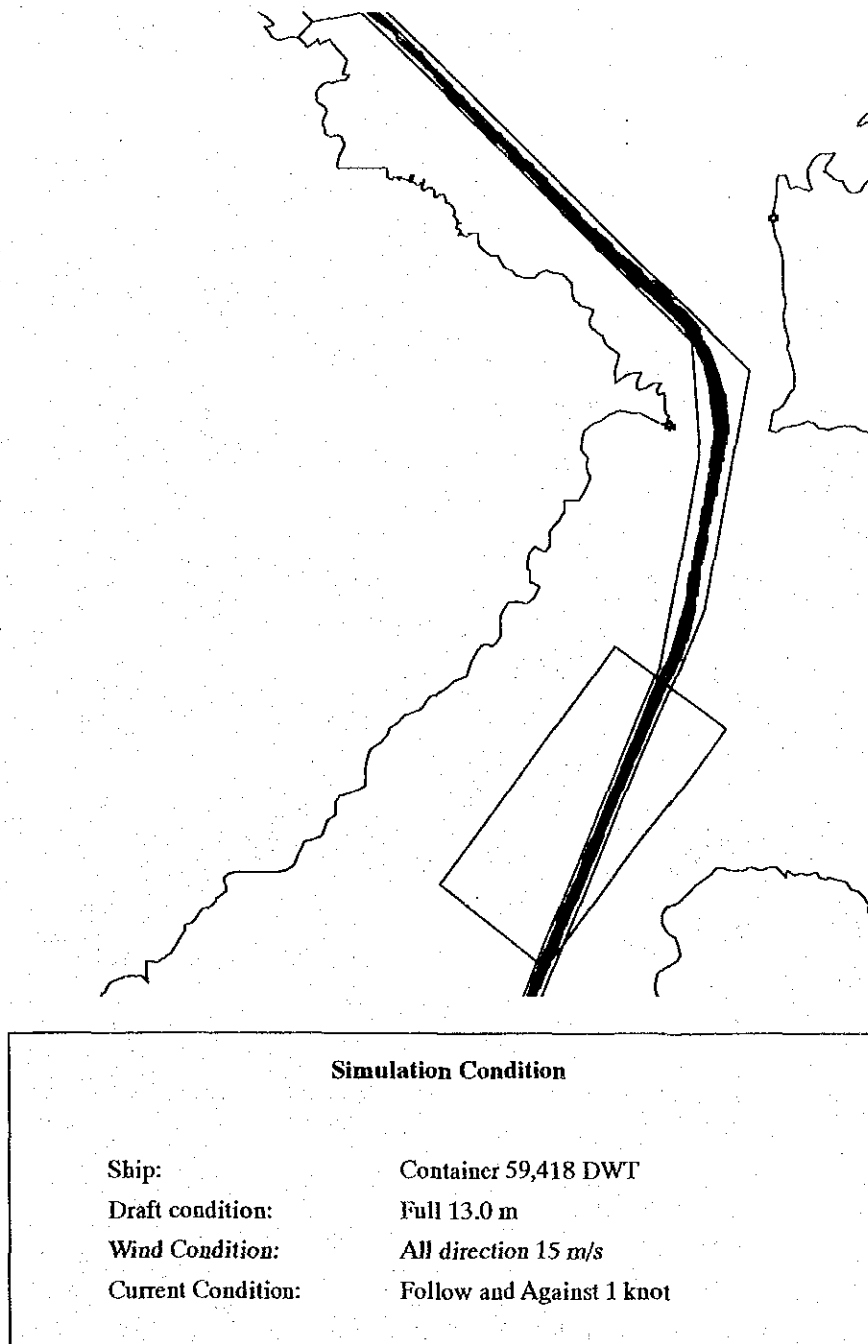
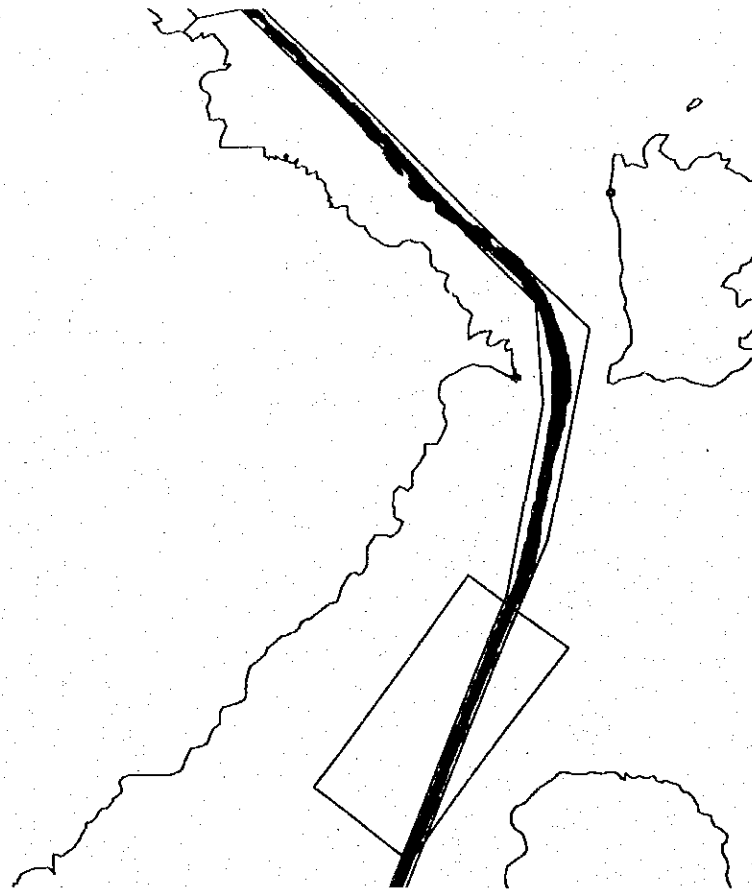
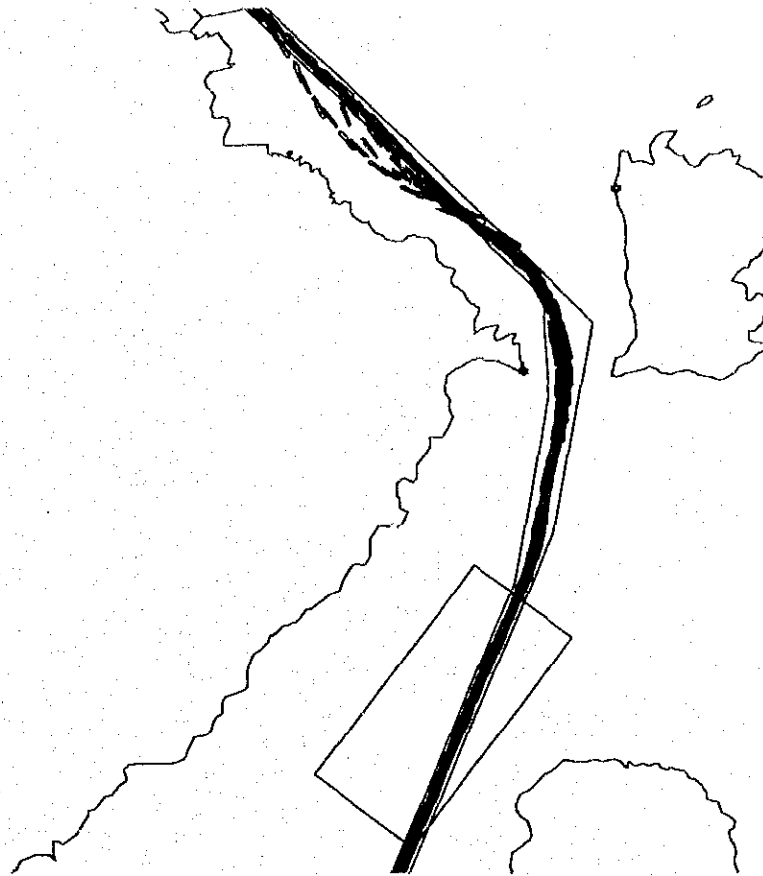


Figure G.2.5 Channel Navigation - Full Draft, All Directions 15 m/s, Follow and Against, 1 Knot



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 15 m/s
Current Condition:	Follow and Against 2 knots

Figure G.2.6 Channel Navigation - Full Draft, All Directions 15 m/s, Follow and Against, 2 Knots



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 15 m/s
Current Condition:	Follow and Against 3 knots

**Figure G.2.7 Channel Navigation - Full Draft, All Directions 15 m/s,
Follow and Against, 3 Knots**

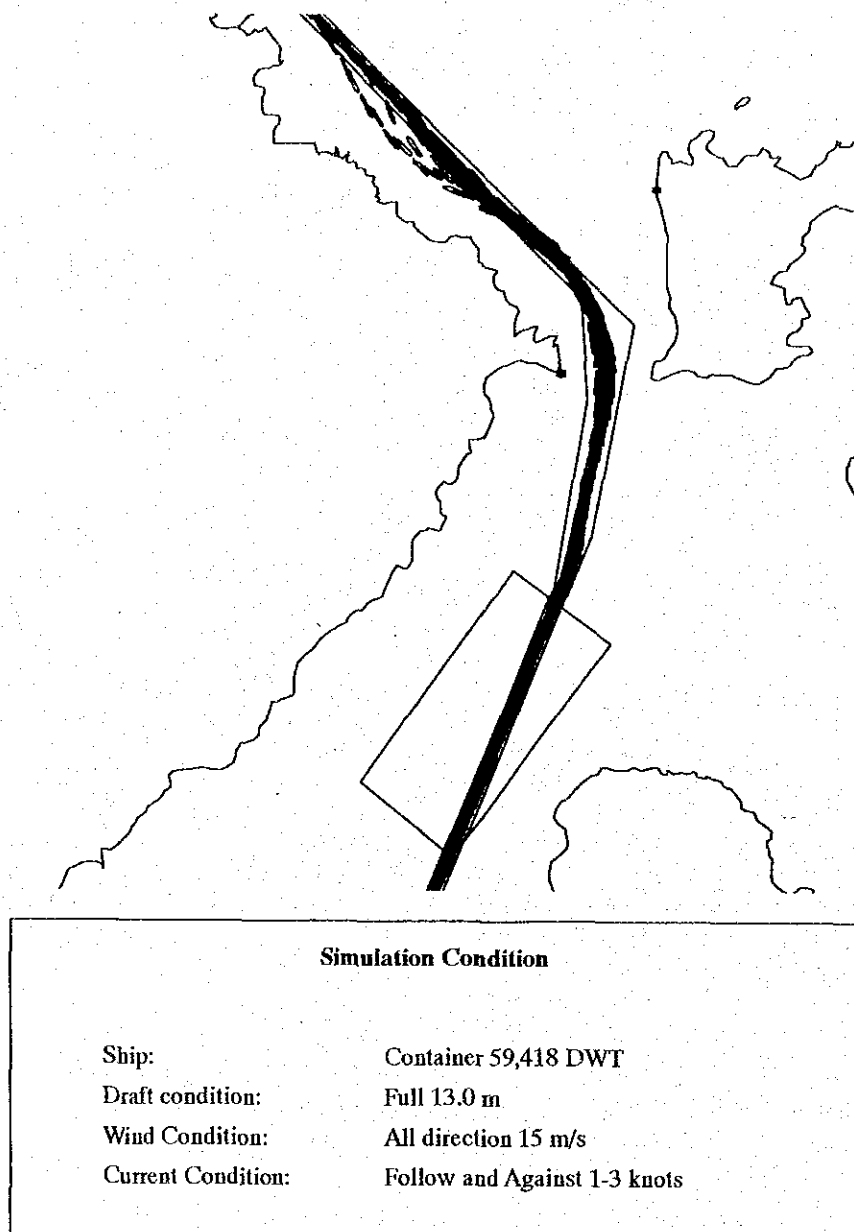


Figure G.2.8 Channel Navigation - Full Draft, All Directions 15 m/s, Follow and Against, 1-3 Knots

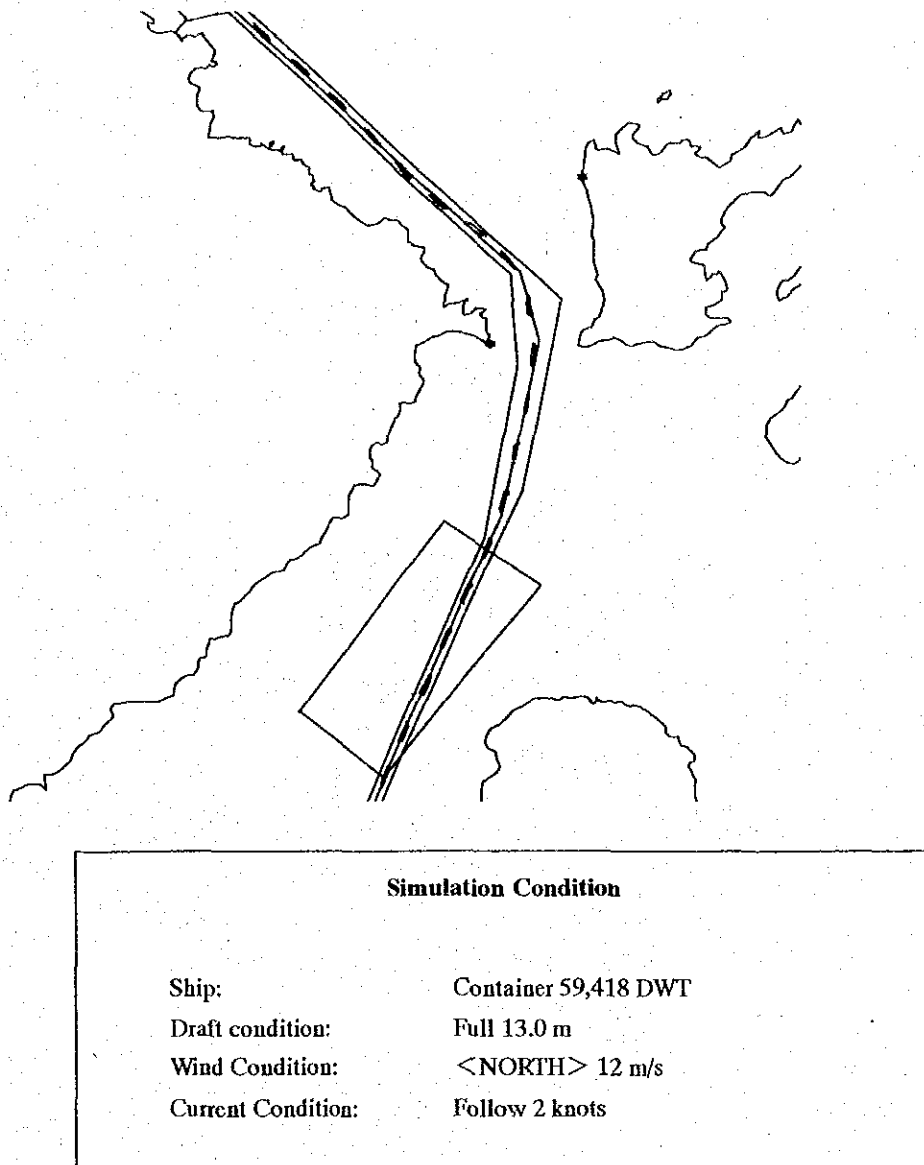
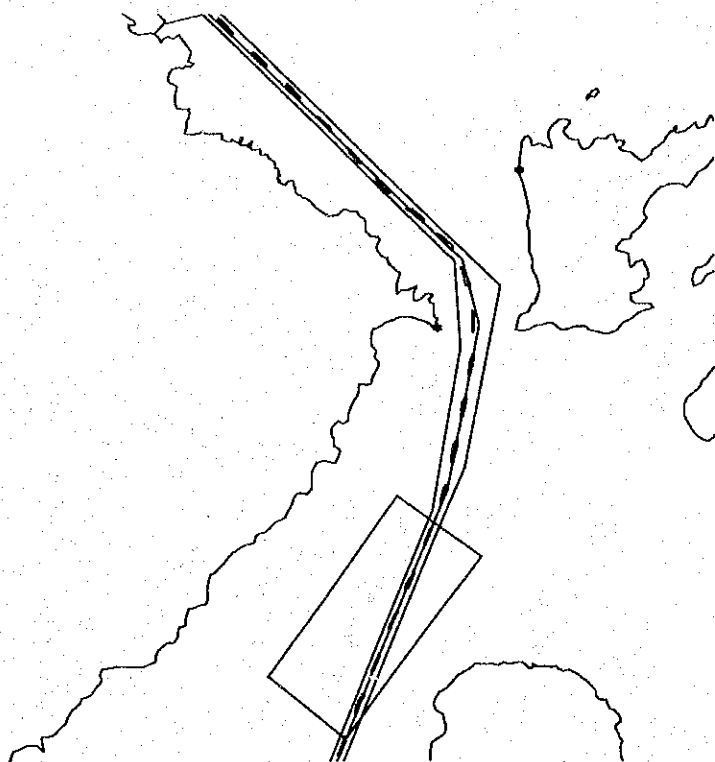
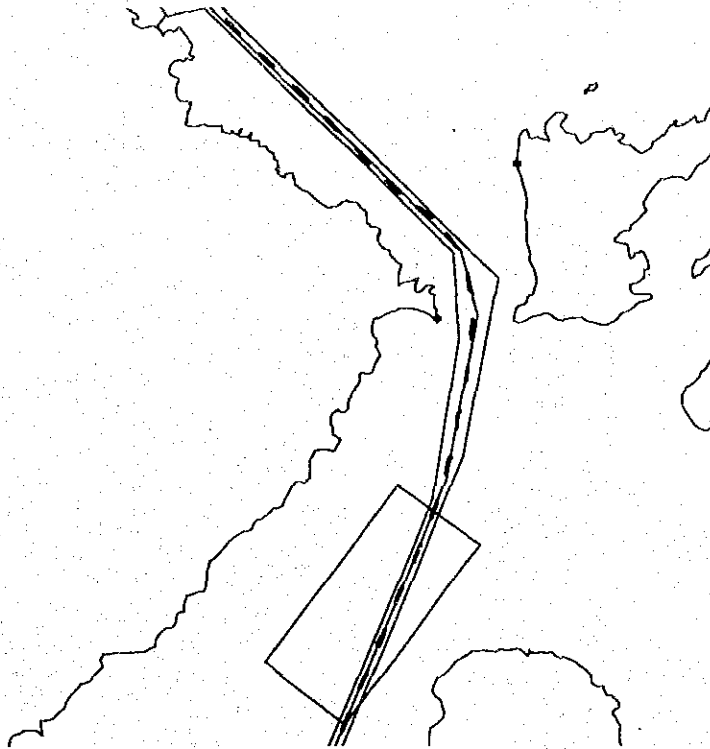


Figure G.2.9 Channel Navigation - Full Draft, North Wind 12 m/s, Follow, 2 Knots



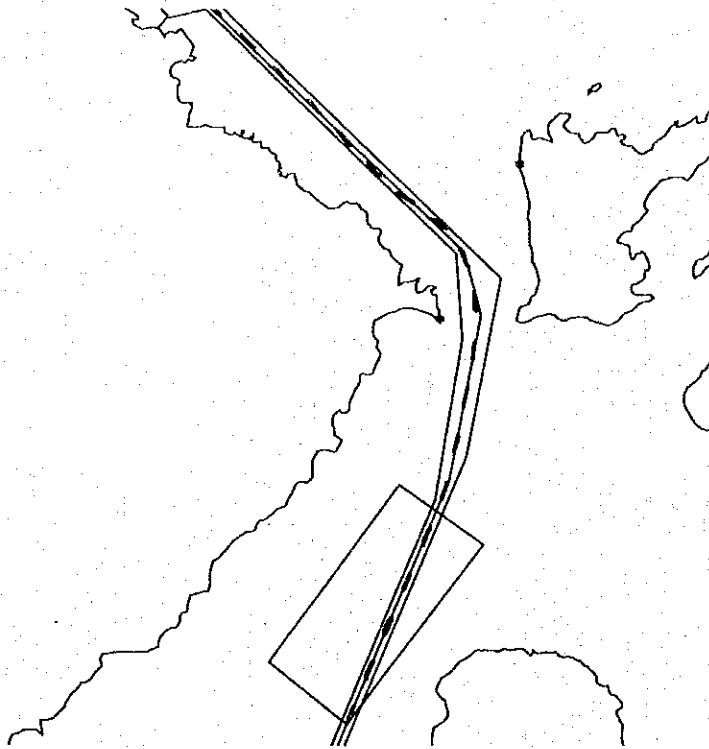
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NE> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.10 Channel Navigation - Full Draft, North East Wind 12 m/s,
Follow, 2 Knots**



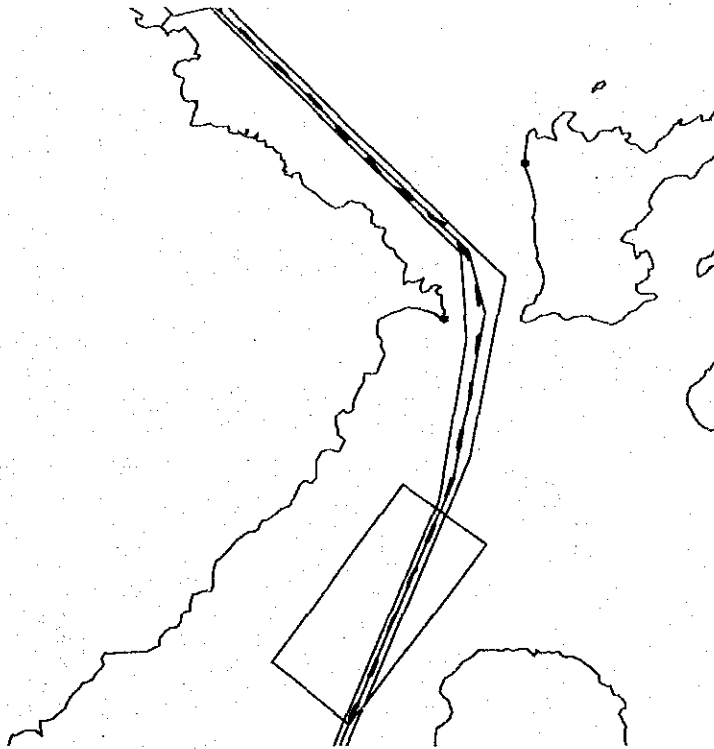
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<EAST> 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.11 Channel Navigation - Full Draft, East Wind 12 m/s, Follow, 2 Knots



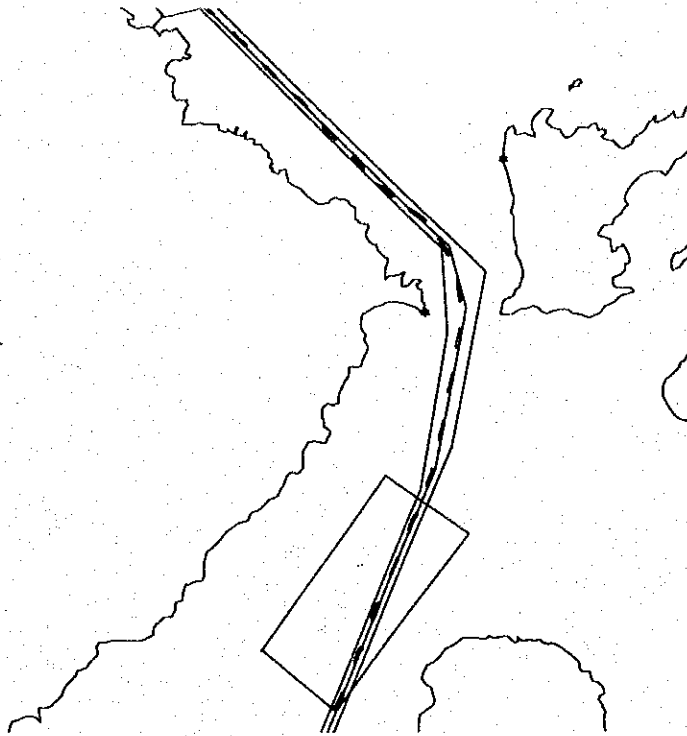
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SE> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.12 Channel Navigation - Full Draft, South East Wind 12 m/s,
Follow, 2 Knots**



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SOUTH> 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.13 Channel Navigation - Full Draft, South Wind 12 m/s, Follow, 2 Knots



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SW> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.14 Channel Navigation - Full Draft, South West Wind 12 m/s,
Follow, 2 Knots**

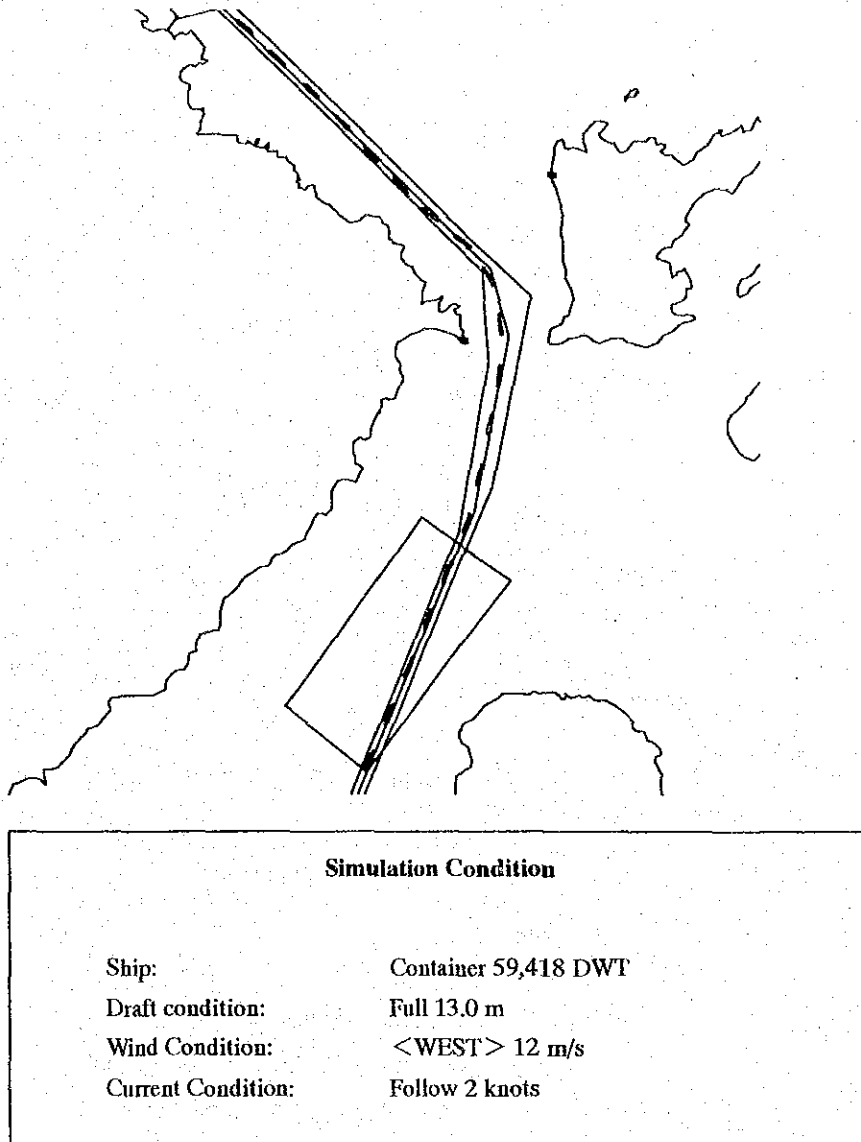
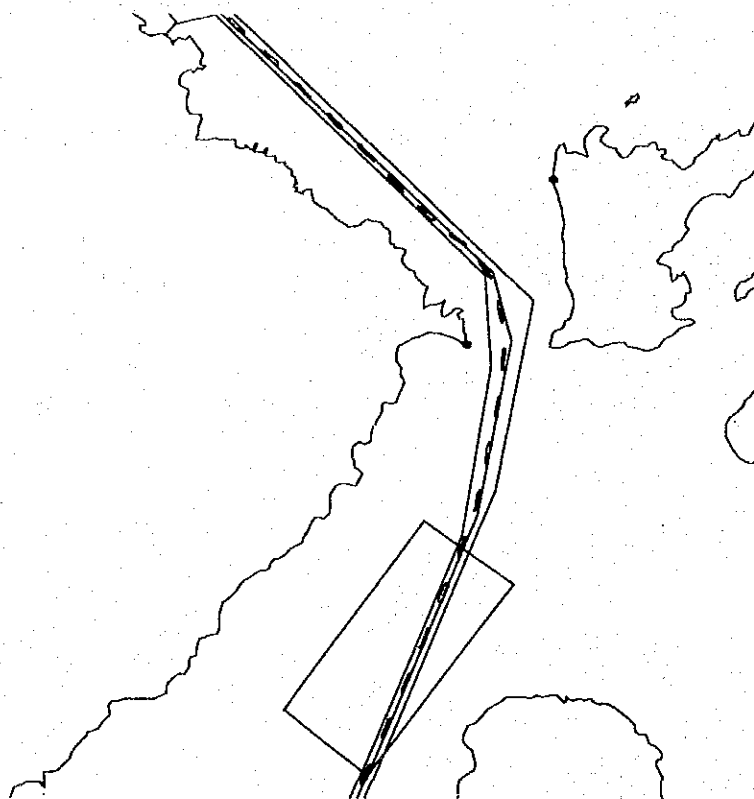
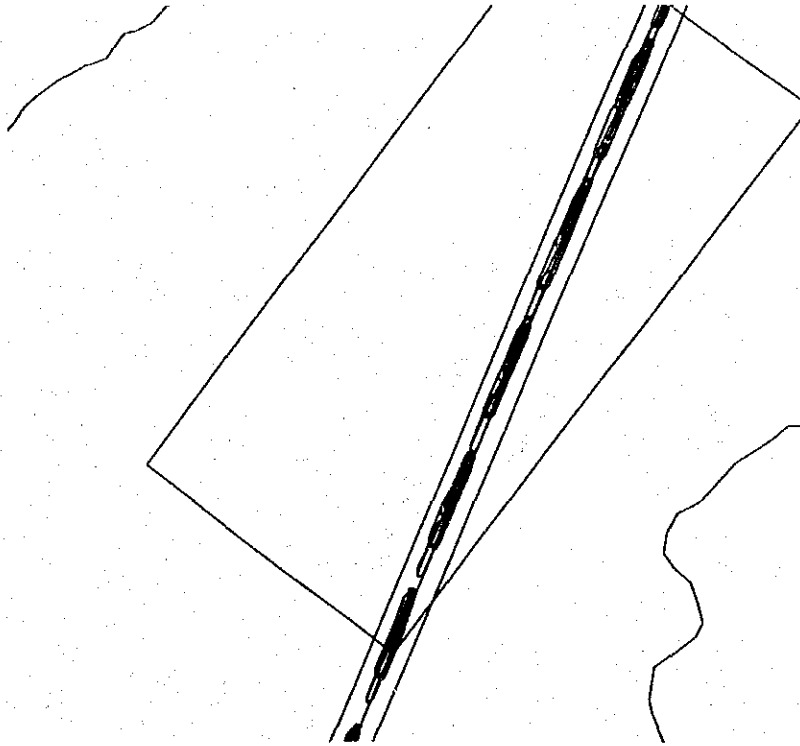


Figure G.2.15 Channel Navigation - Full Draft, West Wind 12 m/s, Follow, 2 Knots



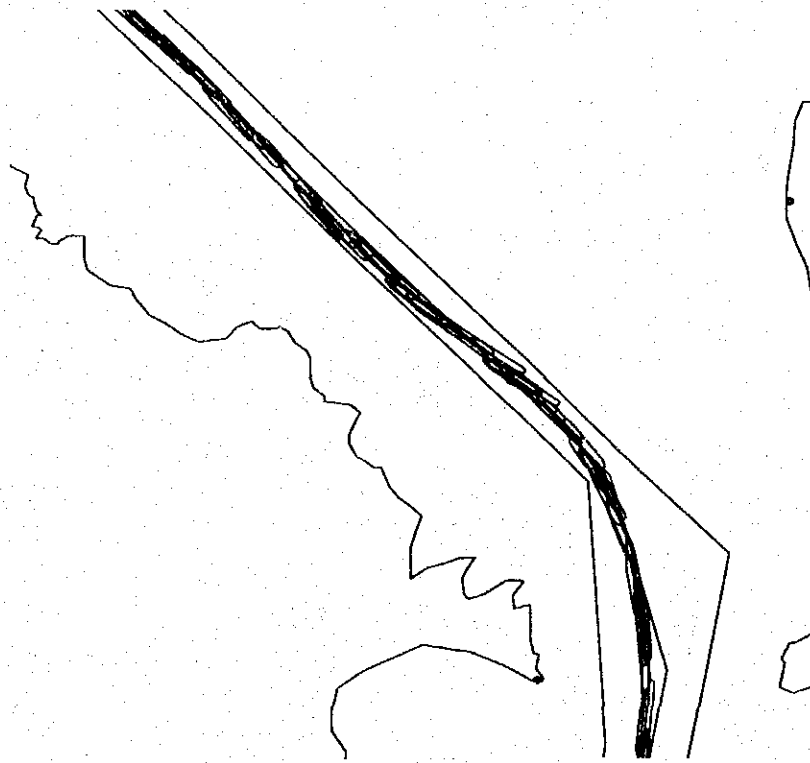
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NW> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.16 Channel Navigation - Full Draft, North West Wind 12 m/s,
Follow, 2 Knots**



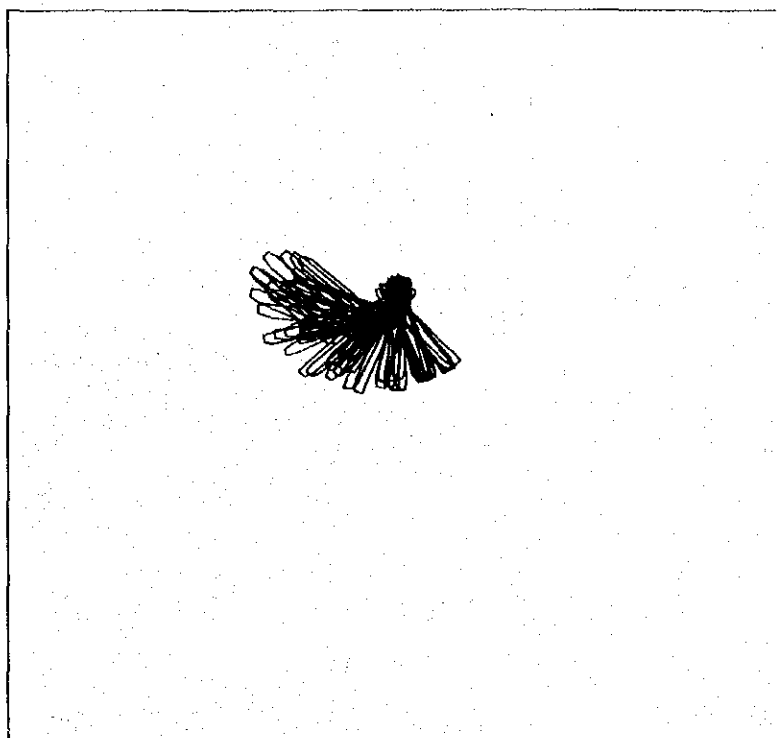
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.17 Channel Navigation - Full Draft, All Directions 12 m/s,
Follow, 2 Knots**



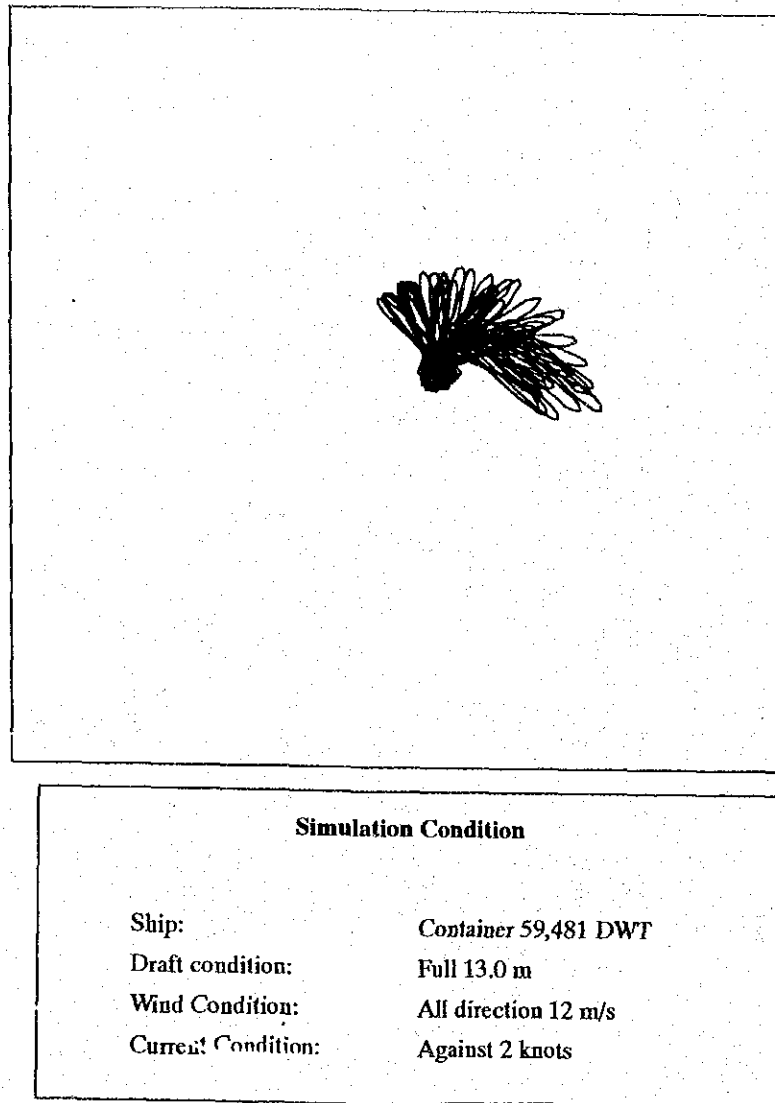
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.18 Channel Navigation - Full Draft, All Directions 12 m/s, Follow, 2 Knots

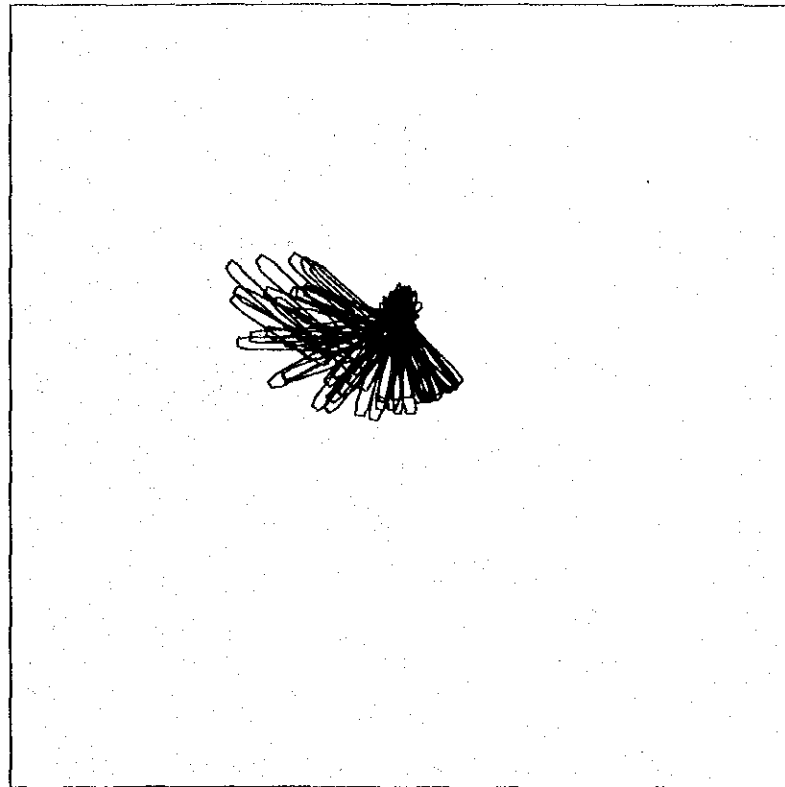


Simulation Condition	
Ship:	Container 59,4818 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.19 Turning with Tugboat – Full Draft, All Directions 12 m/s, Follow 2 Knots



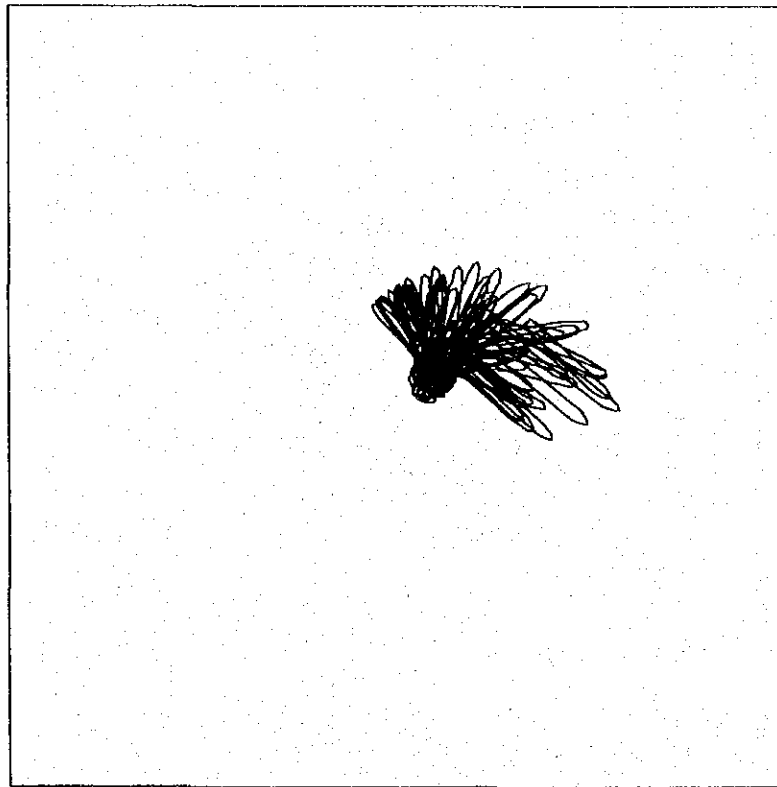
**Figure G.2.20 Turning with Tugboat – Full Draft, All Directions 12 m/s,
Against 2 Knots**



Simulation Condition

Ship:	Container 59,481 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 15 m/s
Current Condition:	Follow 2 knots

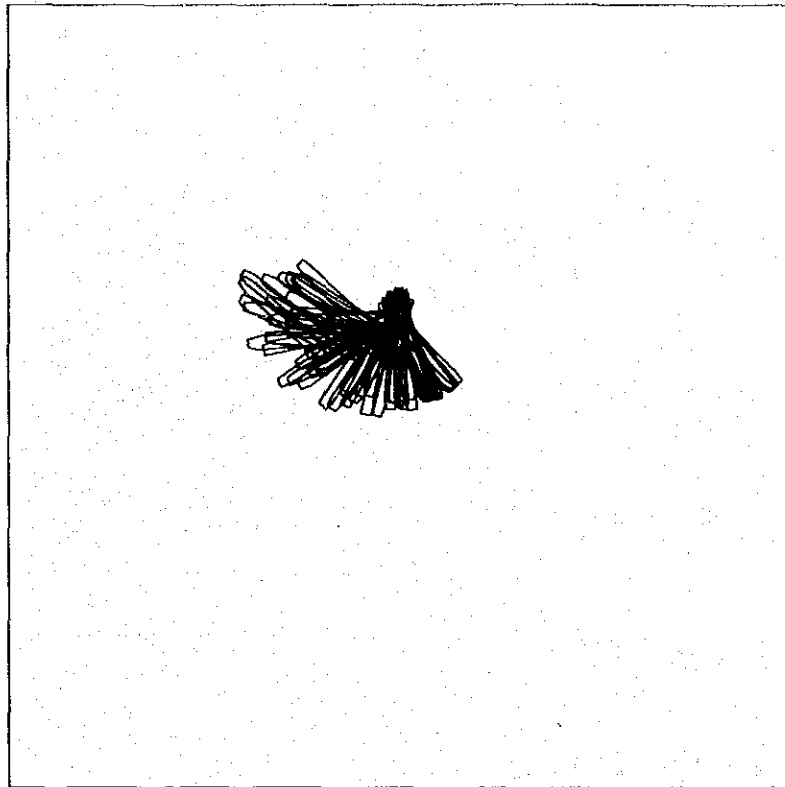
Figure G.2.21 Turning with Tugboat – Full Draft, All Directions 15 m/s, Follow 2 Knots



Simulation Condition

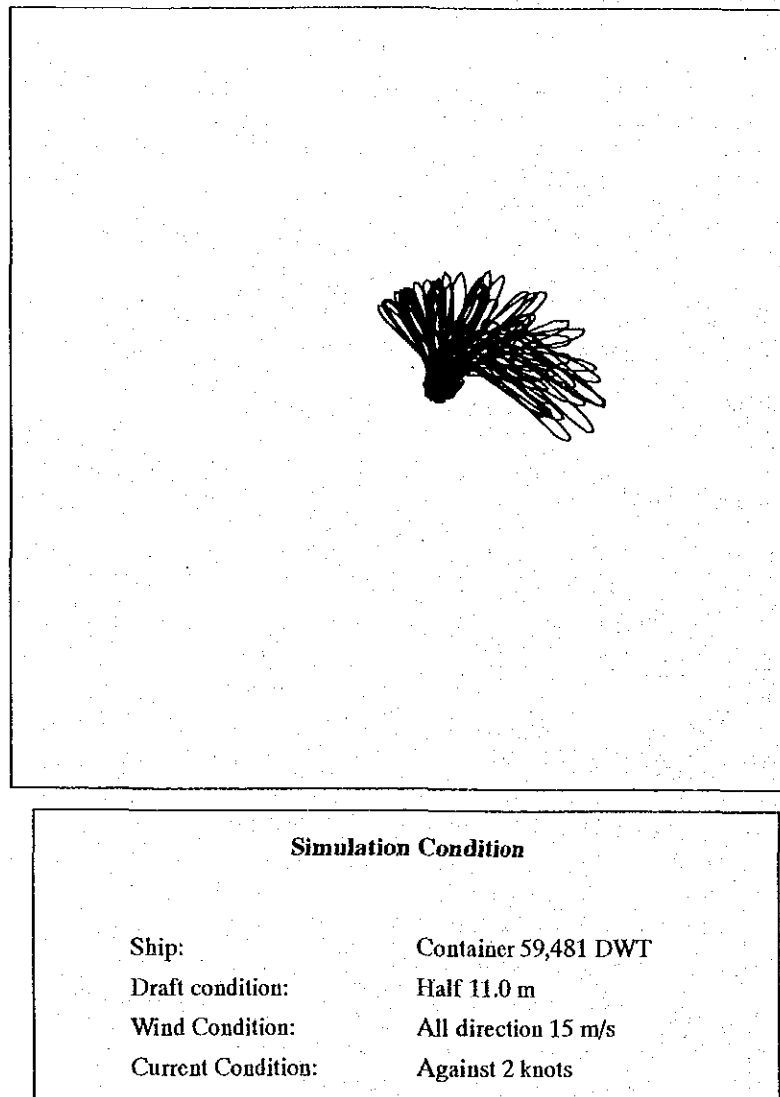
Ship:	Container 59,4818 DWT
Draft condition:	Full 13.0 m
Wind Condition:	All direction 15 m/s
Current Condition:	Against 2 knots

**Figure G.2.22 Turning with Tugboat – Full Draft, All Directions 15 m/s,
Against 2 Knots**

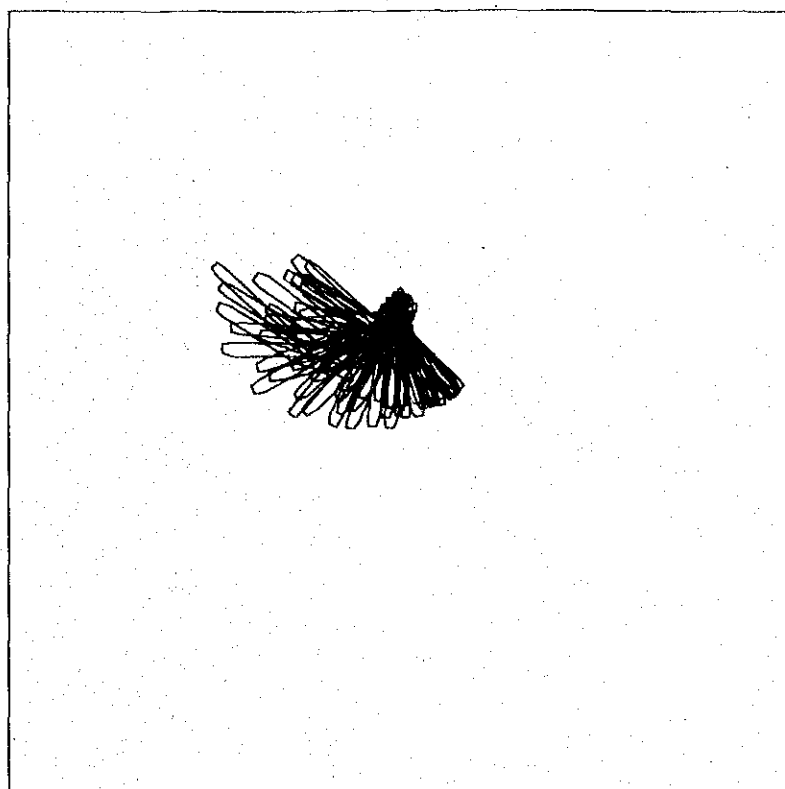


Simulation Condition	
Ship:	Container 59,481 DWT
Draft condition:	Half 11.0 m
Wind Condition:	All direction 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.23 Turning with Tugboat – Half Draft, All Directions 12 m/s, Follow 2 Knots



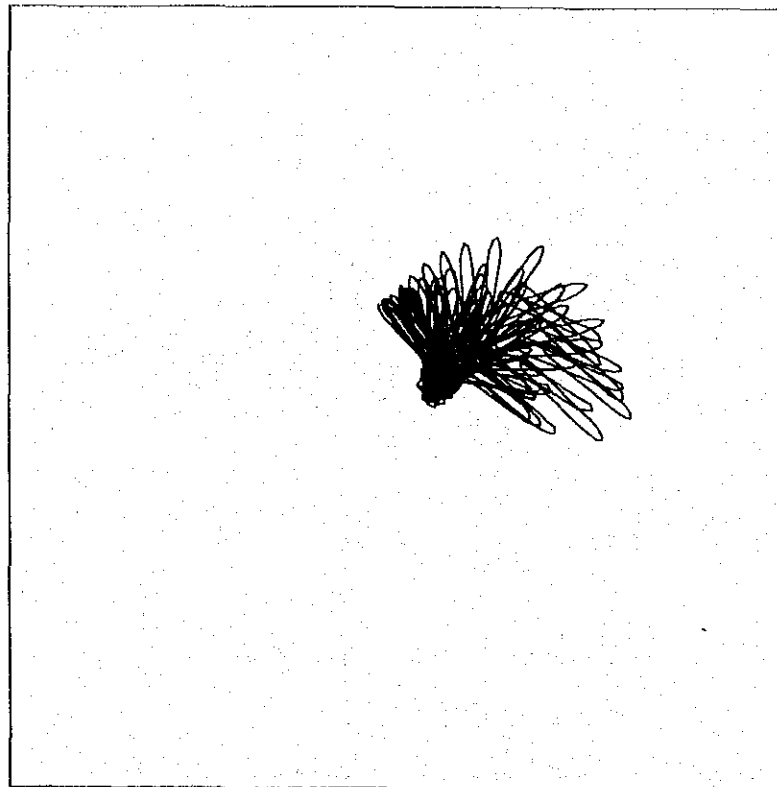
**Figure G.2.24 Turning with Tugboat – Half Draft, All Directions 15 m/s,
Against 2 Knots**



Simulation Condition

Ship:	Container 59,481 DWT
Draft condition:	Half 11.0 m
Wind Condition:	All direction 15 m/s
Current Condition:	Follow 2 knots

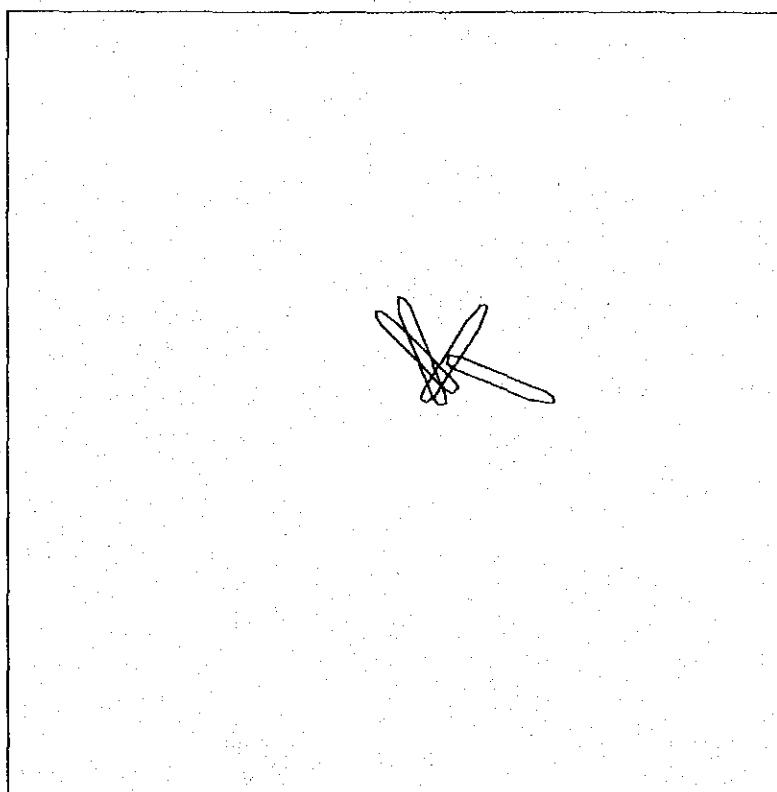
Figure G.2.25 Turning with Tugboat – Half Draft, All Directions 15 m/s, Follow 2 Knots



Simulation Condition

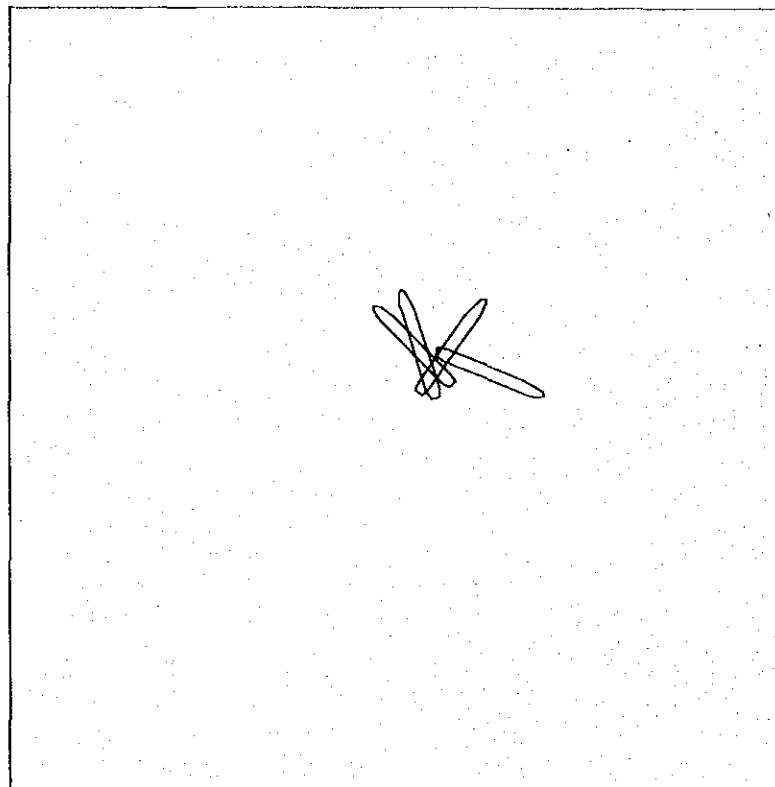
Ship:	Container 59,481 DWT
Draft condition:	Half 11.0 m
Wind Condition:	All direction 15 m/s
Current Condition:	Against 2 knots

**Figure G.2.26 Turning with Tugboat – Half Draft, All Directions 15 m/s,
Against 2 Knots**



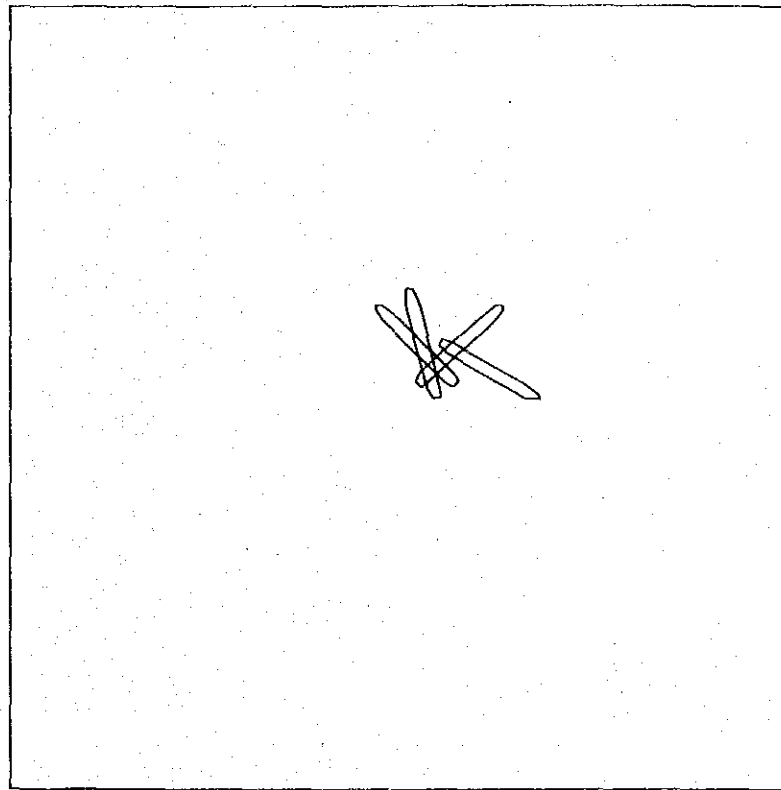
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NORTH> 12 m/s
Current Condition:	Against 2 knots

Figure G.2.27 Turning with Tugboat – Full Draft, North Wind 12 m/s, Against 2 Knots



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NE> 12 m/s
Current Condition:	Against 2 knots

**Figure G.2.28 Turning with Tugboat – Full Draft, North East Wind 12 m/s,
Against 2 Knots**



Simulation Condition

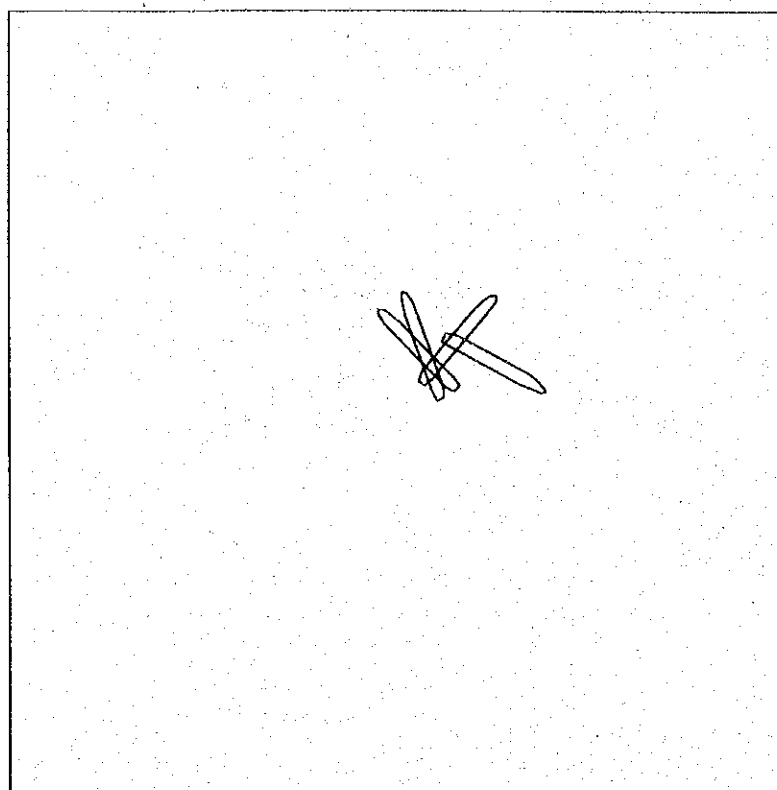
Ship: Container 59,418DWT

Draft condition: Full 13.0m

Wind Condition: <EAST> 12 m/s

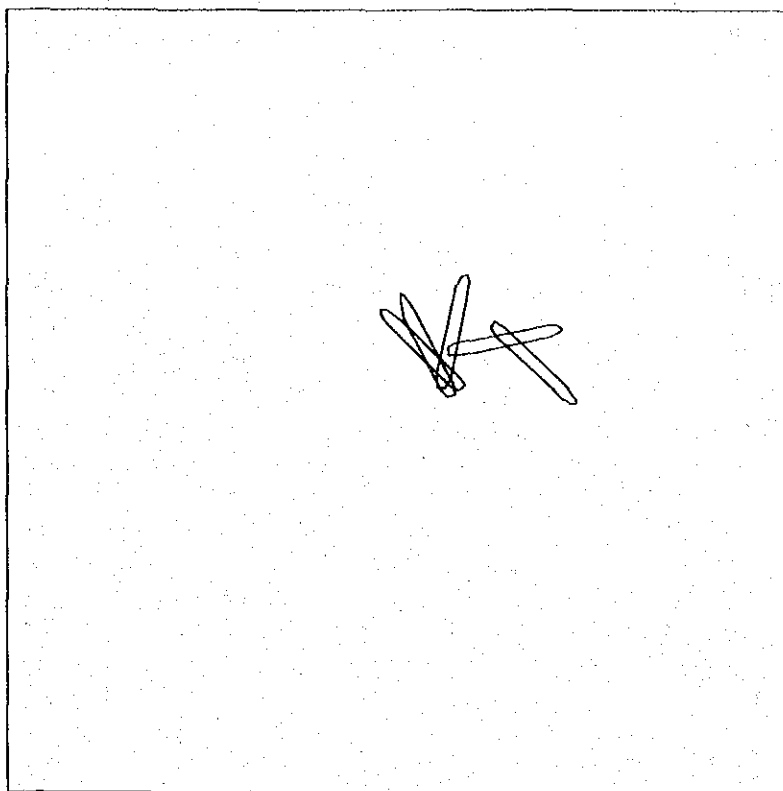
Current Condition: Against 2 knots

**Figure G.2.29 Turning with Tugboat – Full Draft, East Wind 12 m/s,
Against 2 Knots**



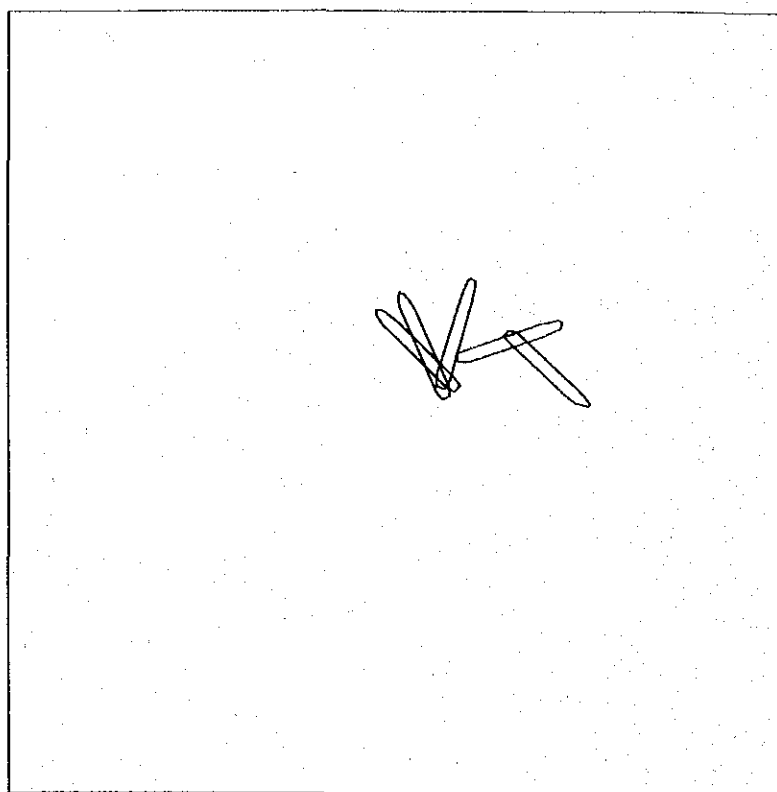
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SE> 12 m/s
Current Condition:	Against 2 knots

**Figure G.2.30 Turning with Tugboat – Full Draft, South East Wind 12 m/s,
Against 2 Knots**



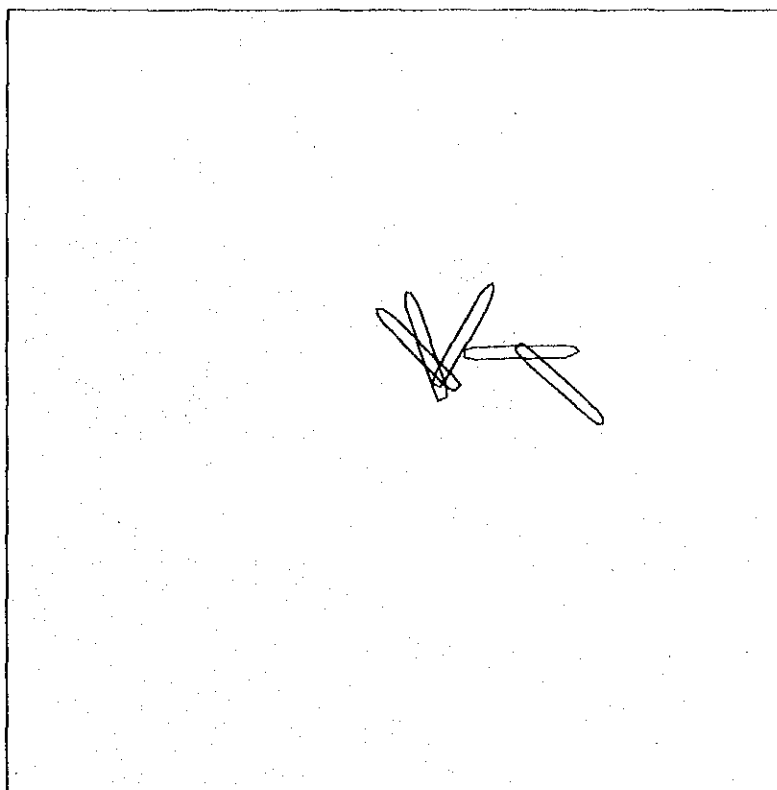
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SOUTH> 12 m/s
Current Condition:	Against 2 knots

Figure G.2.31 Turning with Tugboat – Full Draft, South Wind 12 m/s, Against 2 Knots



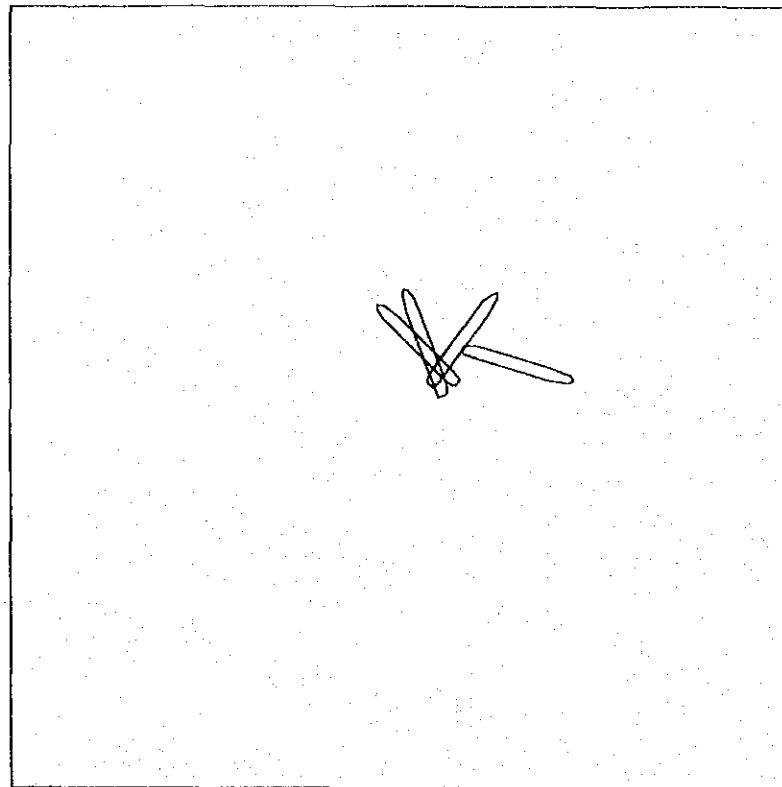
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SW> 12 m/s
Current Condition:	Against 2 knots

**Figure G.2.32 Turning with Tugboat – Full Draft, South West Wind 12 m/s,
Against 2 Knots**



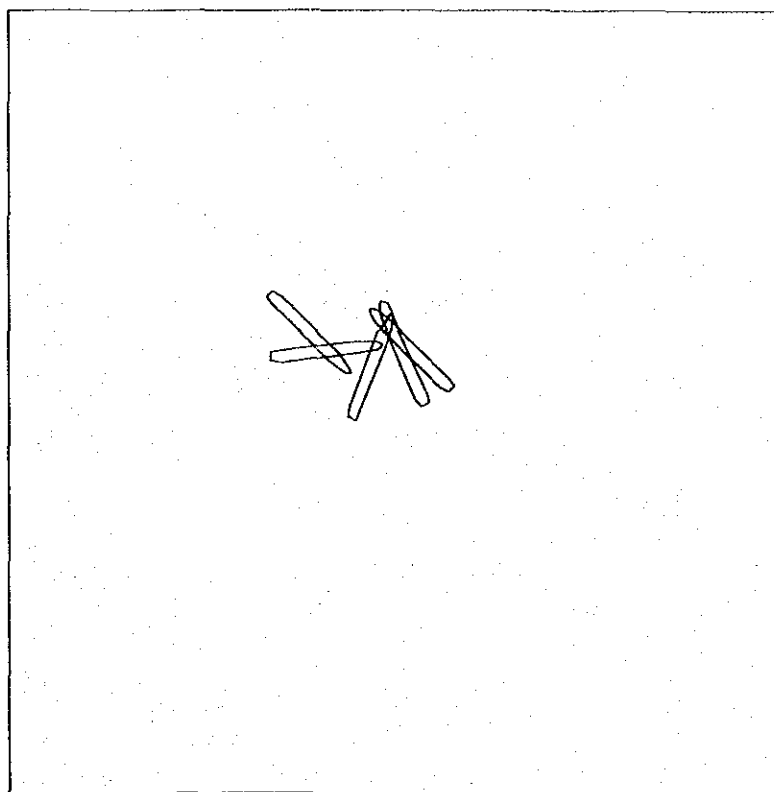
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<WEST> 12 m/s
Current Condition:	Against 2 knots

**Figure G.2.33 Turning with Tugboat – Full Draft, West Wind 12 m/s,
Against 2 Knots**



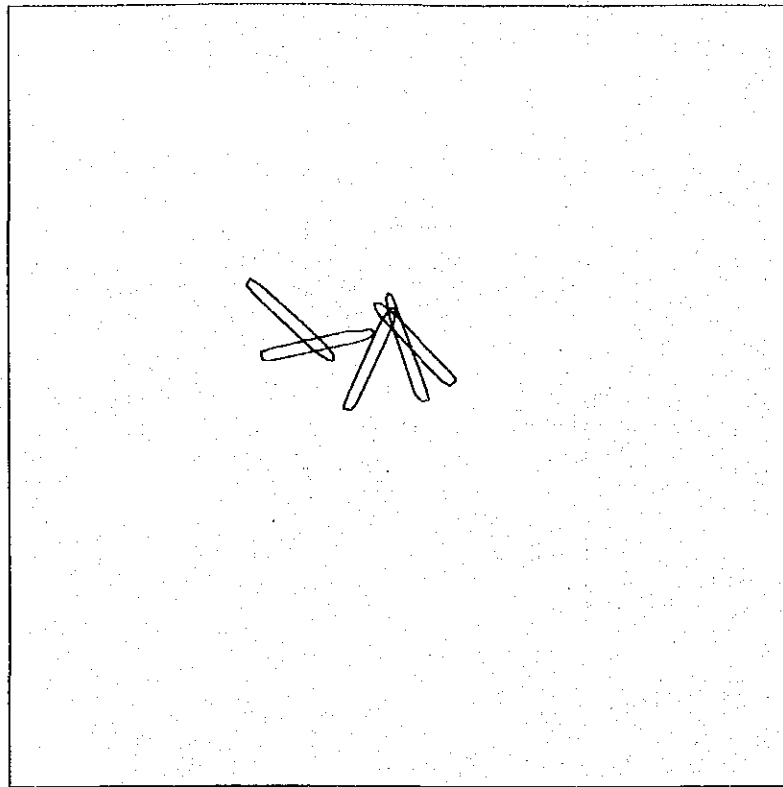
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NW> 12 m/s
Current Condition:	Against 2 knots

**Figure G.2.34 Turning with Tugboat – Full Draft, North West 12 m/s,
Against 2 Knots**



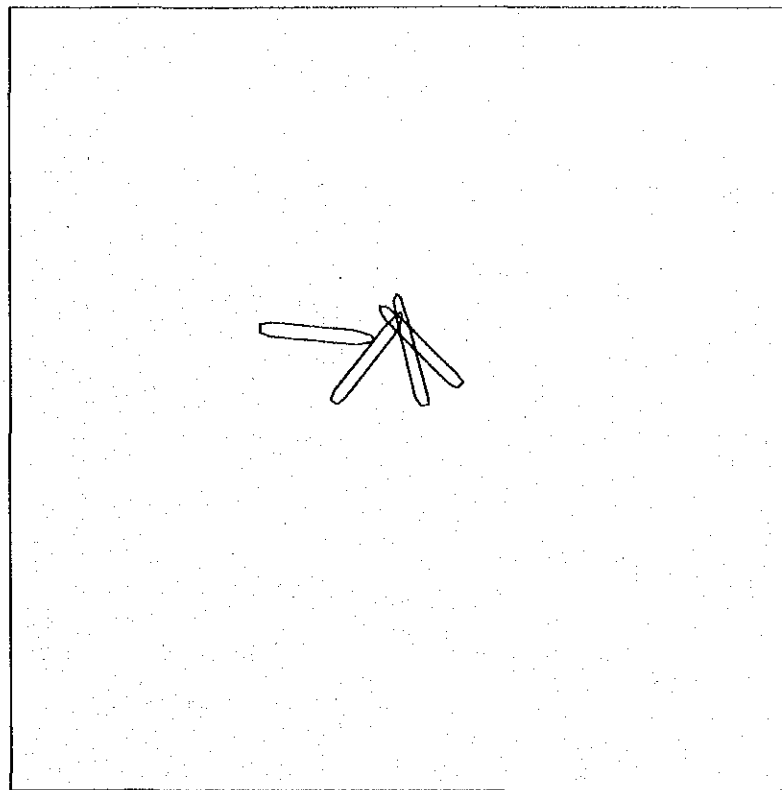
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NORTH> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.35 Turning with Tugboat – Full Draft, North Wind 12 m/s,
Follow 2 Knots**



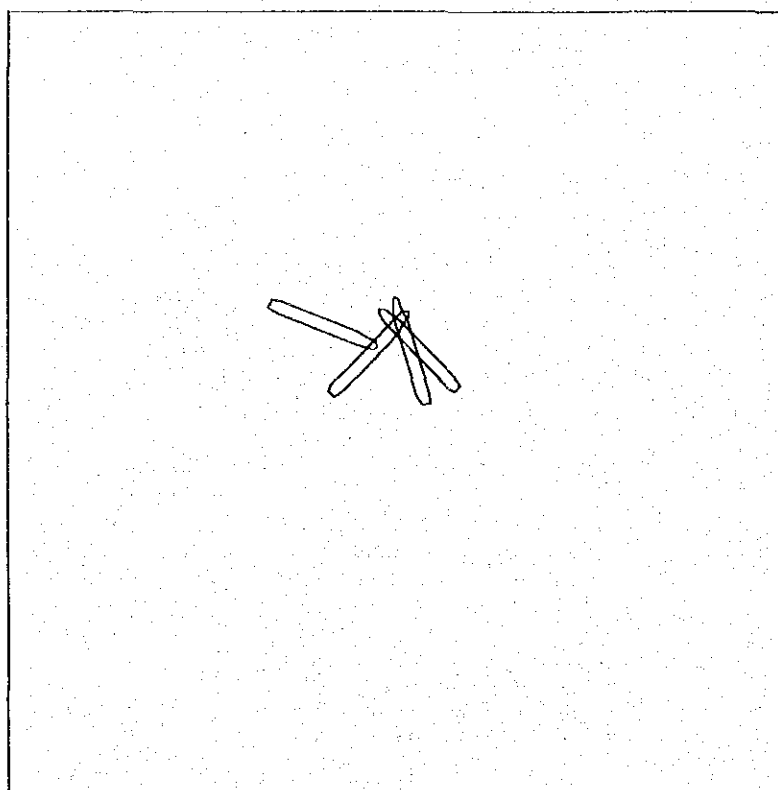
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NE> 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.36 Turning with Tugboat – Full Draft, North East 12 m/s, Follow 2 Knots



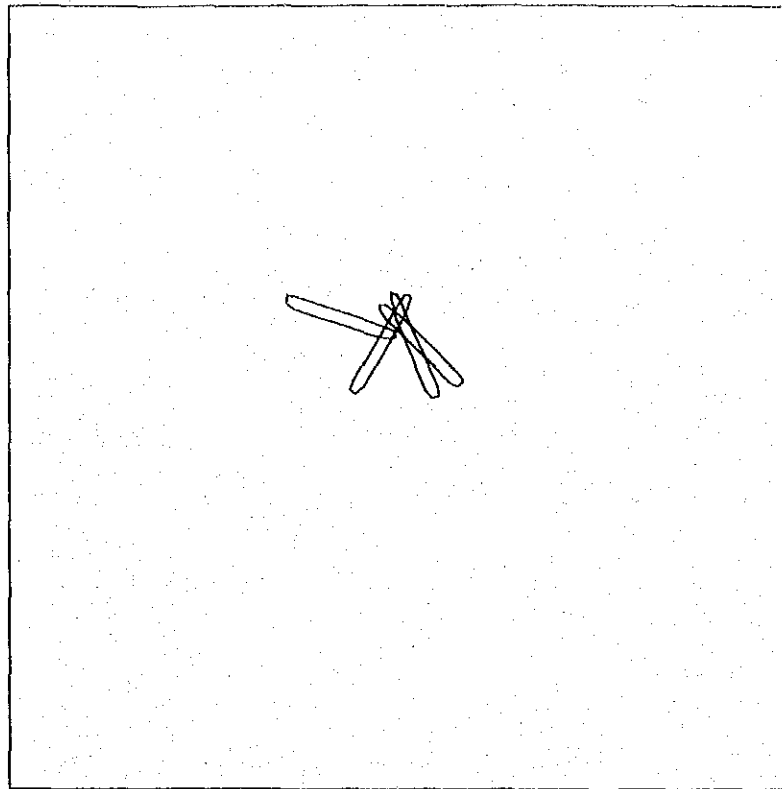
Simulation Condition	
Ship:	Container 59,418DWT
Draft condition:	Full 13.0 m
Wind Condition:	<EAST> 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.37 Turning with Tugboat – Full Draft, East Wind 12 m/s, Follow 2 Knots



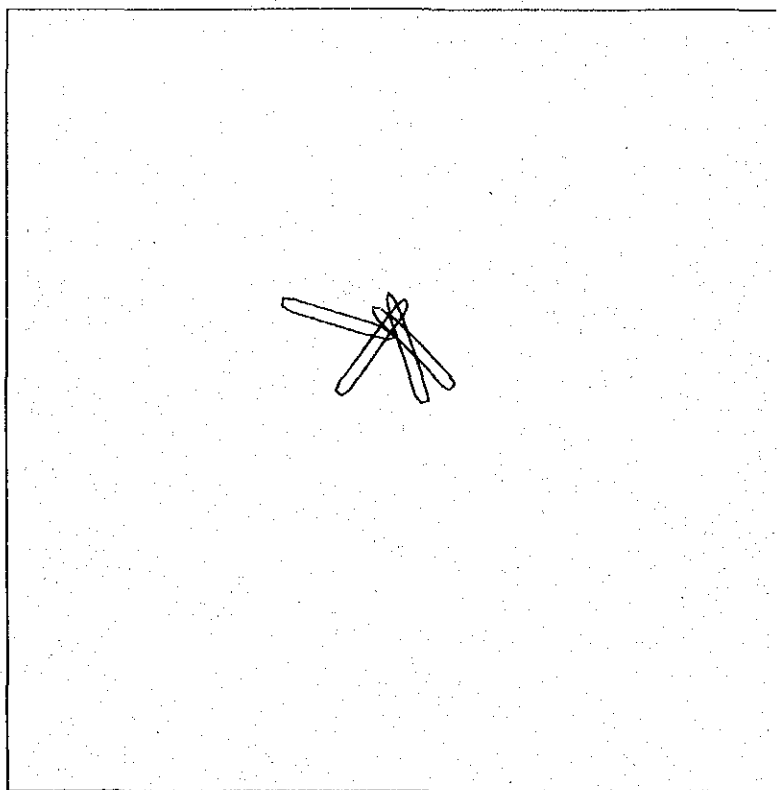
Simulation Condition	
Ship:	Container 59,418DWT
Draft condition:	Full 13.0m
Wind Condition:	<SE> 12 m/s
Current Condition:	Follow 2 knots

Figure G.2.38 Turning with Tugboat – Full Draft, South East Wind 12 m/s, Follow 2 Knots



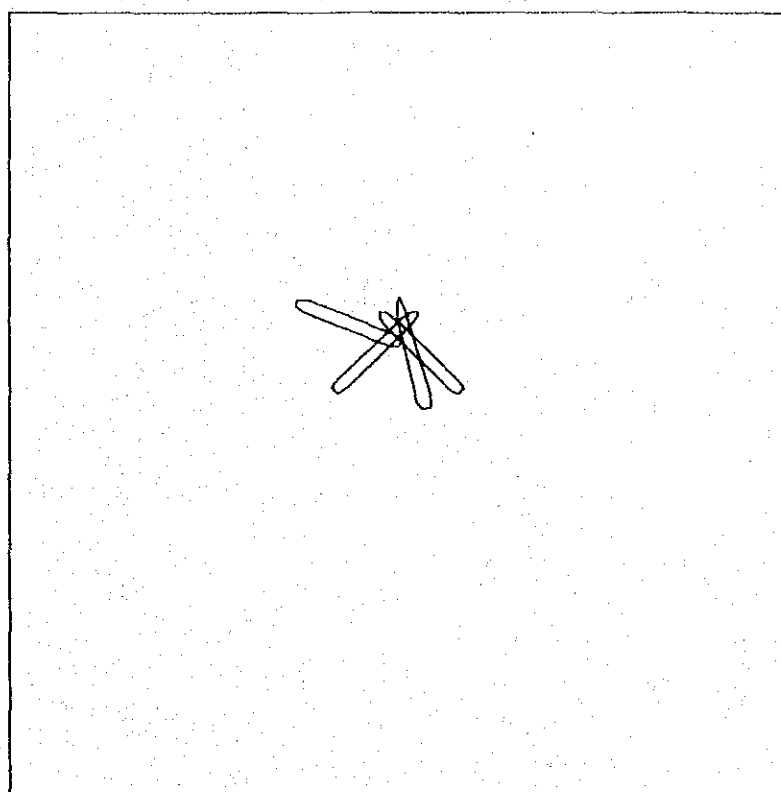
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SOUTH> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.39 Turning with Tugboat – Full Draft, South Wind 12 m/s,
Follow 2 Knots**



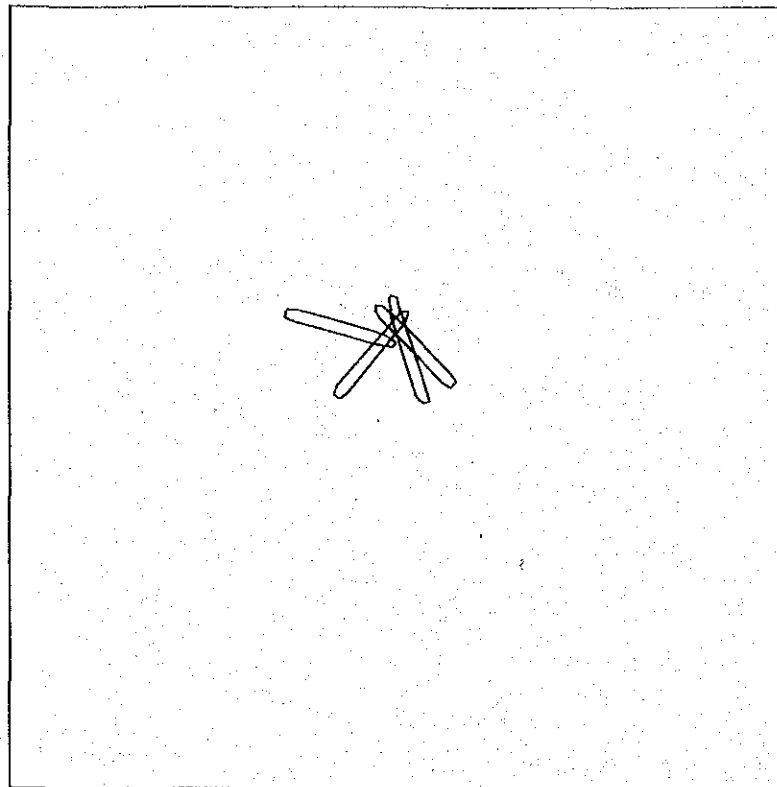
Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<SW> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.40 Turning with Tugboat – Full Draft, South West Wind 12 m/s,
Follow 2 Knots**



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<WEST> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.41 Turning with Tugboat – Full Draft, West Wind 12 m/s,
Follow 2 Knots**



Simulation Condition	
Ship:	Container 59,418 DWT
Draft condition:	Full 13.0 m
Wind Condition:	<NW> 12 m/s
Current Condition:	Follow 2 knots

**Figure G.2.42 Turning with Tugboat – Full Draft, North West Wind 12 m/s,
Follow 2 Knots**

G3 Operation Manual for Ships calling La Unión Port and Navigation Controls Officer

This manual is prepared for convenience of ships to call the port and all ships are requested to observe the contents in this manual for safe operation.

The manual is to be revised by new learned knowledge and also change of circumstance.

G3.1 Operational Criteria

The following criteria are introduced to maintain safe navigation in the channel for calling ships according to the result of ship handling simulation.

Natural condition	Outer channel	Inner channel
Wind velocity	12 m/s	12 m/s
Current velocity	2 knots	2 knots
Wave height	1.5 m	1.0 m
Visibility	3 miles	3 miles

G3.2 Ship's Course in the Channel of Inbound and Outbound Ship

Basic courses of inbound and outbound ships are considered as follows:

Total distance between the channel entrance and turning basin entrance is around 12.08 miles.

(1) Inbound Ship

Point	Course	Distance	Remarks
Channel Entrance			2 Entrance Buoys, Pilot on Board
	<022>	7.56 miles	Heading on Light House
Punta Negra			Alter Course (11 degrees)
	<011>	1.30 miles	
Punta Los Negritos			Alter Course (23 degrees)
	<338>	0.50 miles	
Punta Los Negritos			Alter Course (24 degrees)
	<314>	2.72 miles	
Basin Entrance			

(2) Outbound Ship

Point	Course	Distance	Remarks
Basin Entrance			
	<134>	2.72 miles	Heading on Light House
Punta Los Negritos			Alter Course (24 degrees)
	<158>	0.50 miles	
Punta Los Negritos			Alter Course (23 degrees)
	<191>	1.30 miles	
Punta Los Negra			Alter Course (11 degrees)
	<202>	7.56 miles	Pilot Disembark
Channel Entrance			2 Entrance Buoys

G.3.3 Maneuver of Ship

Recommended maneuvers of inbound and outbound ships are as follows:

Course for channel navigation is shown in Figure G.3.1.

(1) Inbound Ship

- 1) When approaching to the pilot station at the entrance of the channel, a ship keeps her course on <022> at speed of 6-7 knots and pick up a pilot on her leeward side depending on wave and wind direction.
- 2) After picking up the pilot, a ship increase her speed up to about 9 knots and keeps her heading on course of <022> to the light house at Punta Los Negritos, which is placed as the mark for inbound ship.
- 3) Before passing Punta Negra on her port side, she changes her course to <011> to pass the bend area between Punta Los Negritos and Punta Chiquirin.
- 4) When passing off Punta Chiquirin on her port side, a ship begins turning to port and proceeds to the inner channel. Precaution should be taken into account for keeping her on the course line to the inner channel without over-run. Depending on the current velocity, especially when in follow direction current, her speed should be adjusted.
- 5) After finishing turning, she sets her course on <314> in the inner channel, She should be kept in the middle of the channel as close as possible. In the inner channel no heading mark is available therefore positioning by observation of buoys should be done as much as possible.

Ship's speed is reduced according to the distance to the entrance of turning basin and is adjusted to be about 3 knots when a ship arrives at the entrance.

- 6) Two tugboats are made fast by the time when passing through the entrance of turning basin with tugboat lines.
- 7) She proceeds to the position of 2-3 times of her breadth from the berth and stops her movement in the position.
- 8) Swing her round and place her parallel to the berth and then push her to the berth slowly with tug assistance. At the final stage a lateral speed of a ship should be less than 10 cm/s.
- 9) Back spring line should be made fast to control her headway at first.
- 10) She should be moored according to the recommended mooring arrangement.

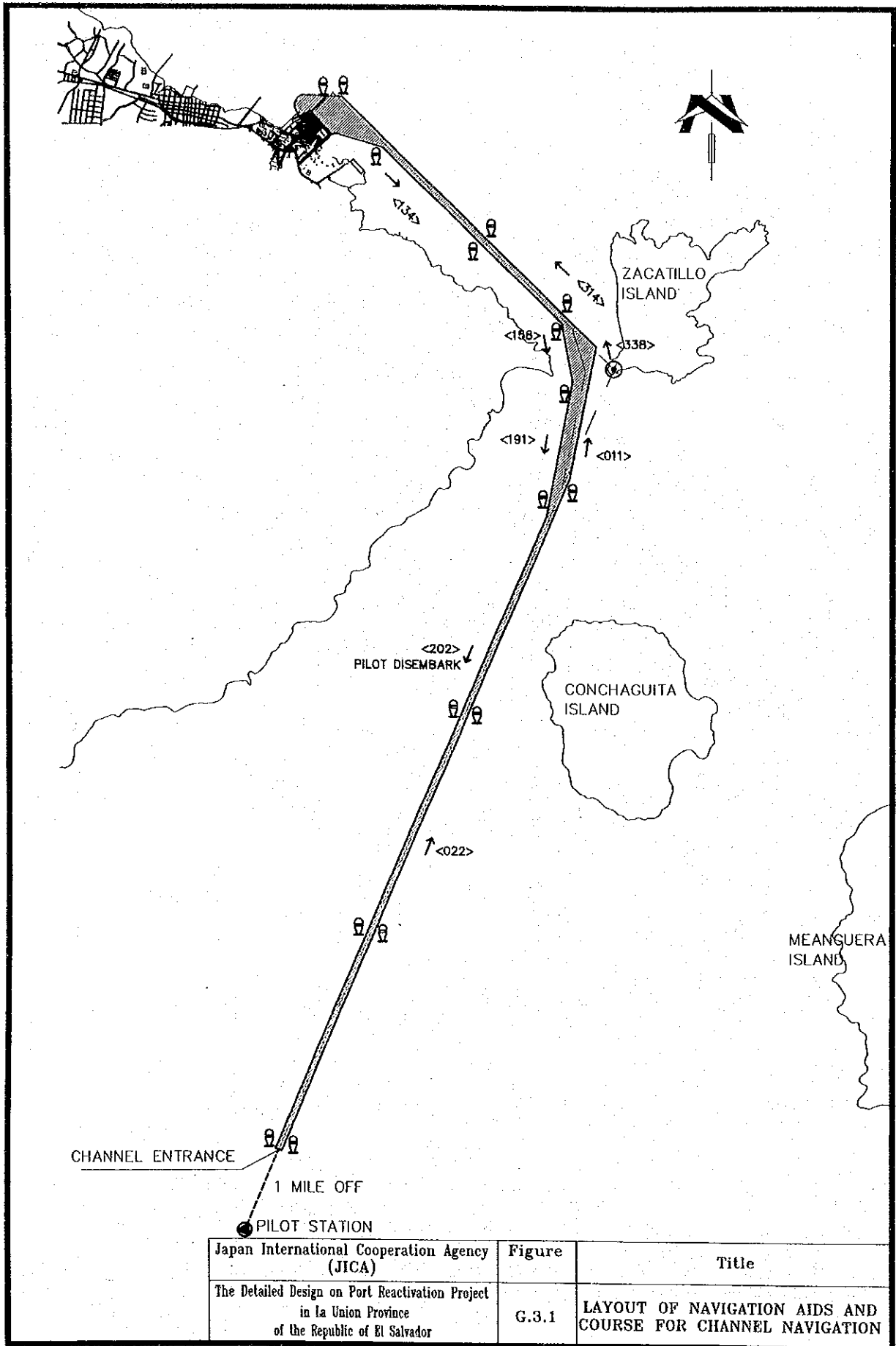
(2) Inbound Ship

- 1) Confirm single up of mooring lines and making fast of tugboat lines on her fore and aft.

- 2) Pull out her with two tugboats slowly. The direction of movement is considered depending on the current direction.
- 3) When a ship clears the berth with enough distance, commence to swing her round.
- 4) The direction of turning is decided according to the current and wind direction. Proper care should be taken against ship's drift and turning should be done at the center of the turning basin.
- 5) Finishing turning and put her heading to the entrance of the inner channel, she starts propelling and proceeds with tugboat assistance.
- 6) When she enters in the channel and set her course on <134>, two tugboats are dismissed.
- 7) To keep her in the center of the channel without drifting, she needs an effective rudder force therefore proper speed (about 7-9 knots) should be needed. The lighthouse at Punta Los Negritos is a heading mark of her.
- 8) Passing light buoy located at the Norse side of Punta Chiquirín on her starboard side, she begins turn to starboard and sets her on the next course <191> and proceeds to the outer channel.
- 9) Passing at the buoy located at East side of Punta Negra, a ship change course to <202> and enter into the outer channel.
- 10) Reduce her speed to about 6knots to disembark the pilot.
- 11) Passing Punta La Pelona of Isla Conchaguita, the pilot disembarks her and the captain keeps her course on <202> by observation of buoys.

G3.4 Navigation Aids

Navigation aids along the outer and inner channel including lighthouse and light buoys are arranged shown in Figure G.3.1.



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	G.3.1	LAYOUT OF NAVIGATION AIDS AND COURSE FOR CHANNEL NAVIGATION

G.3.5 Communications

Vessel traffic service is introduced for calling ships. The navigation control officer keeps communication with ships in the vicinity of the port by VHF radio, and also collects information of a ship movement through AIS receiver.

The control center receives Estimated Time of Arrival (ETA) from calling ships and Estimated Time of Departure (ETD) from leaving ships and arranges a pilot and tug boats

The navigation officer control gives the clearance of entering the channel and leaving the port. Ships should keep listening VHF radio on ch.16 and call the control center when she enters in to the communication area.

G.3.6 Pilot

Pilot is compulsory for foreign ships and is available 24 hours.

A ship approaching to the port should contact with the navigation control officer by VHF radio and gives ETA pilot station. Pilot ladder shall be prepared on the leeward side of wave direction.

The pilot station is 1 mile of the entrance of outer channel. The pilot embarks at the pilot station on arrival and disembarks at Punta La Pelona of Isla Conchagueta.

The pilot comes along side a ship by tugboat and embarks on board.

G.3.7 Waiting Anchorage

The existing anchorage lays in NW of Isla Conchagueta, which is marked in the chart. The minimum depth of the anchorage is 11.9 m. Therefore ships with draft of over than 11 m should not anchor in this area.

New waiting anchorage for ships with deep draft over than 11m is placed in the area with 18 m depth of water between SW of Isla Meanguera.

This new anchorage faces to open sea and a ship will be effected by swell very much. A ship should pay attention to wind and wave condition to protect dragging anchor while stays in this anchorage.

G.3.8 Tugboat

Two tugboats with capacity of 3,600 HP will be arranged to assist berthing and unberthing operations. A tugboat has a function of transportation of pilot to and from a ship. A tugboat has own lines to be used for making fast a ship.

G.3.9 Charts

El Salvador chart (SAL CH.5, CH.6), U.S. Chart (DA 21521, 21529) and B.A. chart (1960) are available for channel navigation and port entry. Those charts should be corrected or revised properly according to alteration of port facilities.

G.3.10 Berth Arrangement and Mooring Arrangement

A container berth with length of 340 m, multi-purpose berth with length of 220 m and passenger dolphin berth with length of 240 m are arranged to accept ships.

A moored ships are recommended to make fast all lines as tight as possible against strong current in the berthing basin all the time while she stays. Tugboats are available in the case of emergency such as the accident of breaking of mooring lines.

At least 4 head/stern lines and 2 fore /back spring lines are requested for moored car carrier and bulk ship.

G.4 Vessel Traffic Service

Vessel traffic service is introduced for safe and effective port operation.

The system is consisted of VHF (Very high frequency) radio, AIS (Automatic Identification System) and Personal computer.

G.4.1 Block Diagram of System

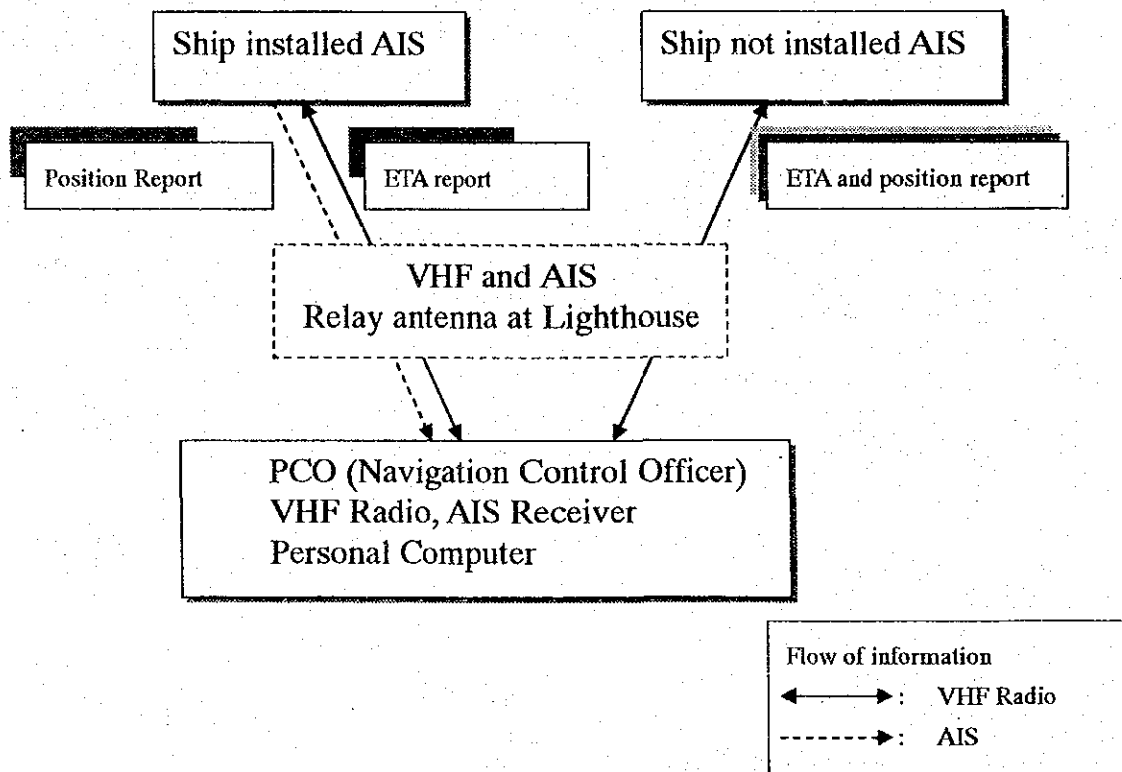


Figure G.4.1 Block Diagram of System

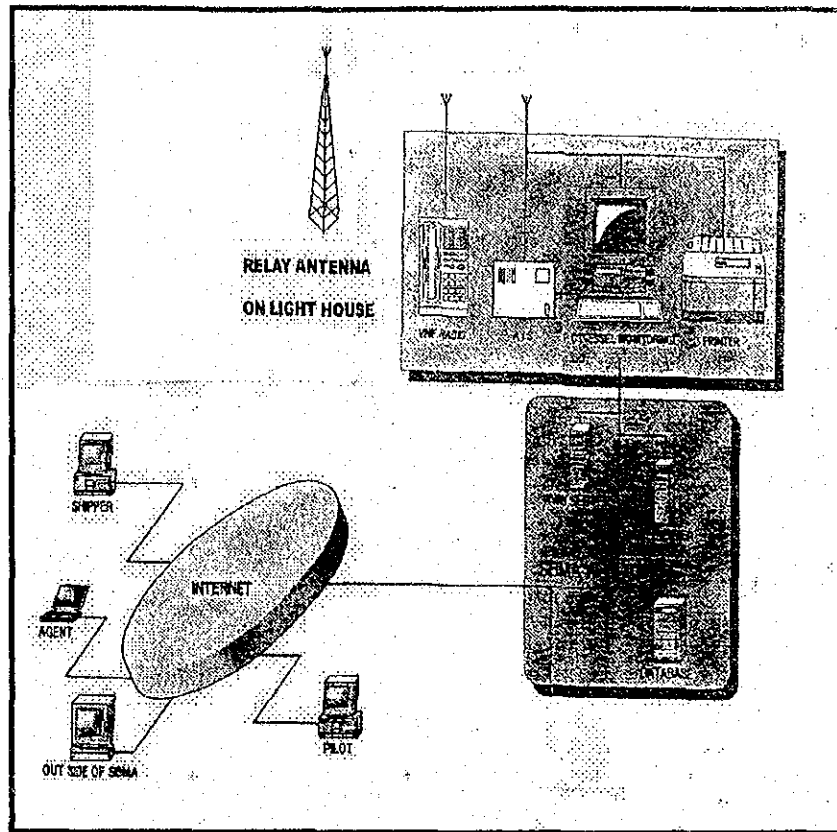


Figure G.4.2 Image of VTS System

G.4.2 Contents of Information

The following information is transmitted between a ship and Navigation Control Officer.

- 1) VHF Radio
 - a) From a ship
 - ETA at pilot station, ETD
 - Ship's particulars
 - Ship's position
 - b) From the Navigation Control Officer
 - Nautical condition
 - Berth information
 - Channel traffic information
 - Pilot information
 - Clearance of channel navigation
- 2) AIS
 - a) From a ship
 - Ship's position
 - Ship's movement (course, speed, status, ship's particulars, etc.)

G.4.3 Function of Navigation Control Officer (NCO)

The NCO controls the traffic of the channel and manages berth allotment.

NCO arranges channel traffic according to ETA, which is given to the NCO from calling ships and ETD from ships in port.

All information is taken into the PC and real time ships position from AIS is displayed on the personal computer display. A position, which is given from ships not installed with AIS by VHF radio, are put in to personal computer as a data and is displayed at some interval.

The officer gives current natural sea and weather condition such as wind, wave, tide, current and also the condition of navigation aids especially when the light house and light buoy are not in good condition for safe navigation.

The VTS is maintained through day and night for ships calling this port.

G.4.4 Traffic Pattern

The port has 3 berths to be used for large ships.

Four traffic pattern of arrival and departure are expected as follows:

Pattern	Berth condition	Operation
1	No berth is occupied	Arrival-Arrival-Arrival
2	One berth is occupied	Arrival-Arrival-Departure
		Arrival-Departure-Arrival
		Departure-Arrival-Arrival
3	Two berths are occupied	Arrival-Departure-Departure
		Departure-Arrival-Departure
		Departure-Departure-Arrival
4	All berths are occupied	Departure-Departure-Departure

The above patterns happen independently in the port operation.

The pilot and a tugboat, which is used for transportation of the pilot, attend a ship at the same time and their number is limited, therefore the channel navigation is limited by operation pattern as follows:

- 1) When a ship arrives at the port, the pilot and a tugboat come and meet a ship at the pilot station off the outer channel, and return to the port. In this case it takes about 1.5 hours for one-way trip and 3 hours for round trip.
- 2) When two ships arrives at the port, 2nd ship has to wait for the pilot at outer anchorage, in this case minimum 3.0 hours are necessary to take the pilot.
- 3) When a ship departs from the port and the other ship arrives, waiting time of arrival ship for the pilot is a little because the pilot disembarks the departure ship and moves to arrival ship directly at the pilot station.

When a ship arrives and the other ship departs from the port, the situation is similar to the above; the pilot moves to a departure ship after making fast an arrival ship to the berth directly.

- 4) When a ship departs from the port, the pilot and a tugboat attend a ship to the outer channel and return to the port. In this case it takes about 0.8 hour for one-way trip and 1.6 hours for round trip.
- 5) When two ships depart from the port, 2nd ship has to wait for the pilot at the berth, in this case minimum 1.6 hour necessary to take the pilot.

G.4.5 One Way Access Channel Width by PIANC

	CNTR ship			BUKL ship			Remarks
	Vessel speed	Outer	Inner	Vessel speed	Outer	Inner	
(a)Vessel speed	moderate.	0.0	0.0	moderate	0.0	0.0	In:5-7, Out:7-9 knots
(b)Prevailing cross wind	moderate.	0.4	0.4	moderate	0.4	0.5	Chubascos
(c)Prevailing cross current	moderate.	0.2	0.1	moderate	0.2	0.1	
(d)Prevailing long. current	moderate.	0.1	0.2	moderate	0.1	0.2	
(e)Hs and λ	moderate.	1.0	0.5	moderate	1.0	0.5	H1/3: 2m
(f)Aids to navigation		0.1	0.1		0.1	0.1	Good
(g)Bottom surface		0.1	0.1		0.1	0.1	<1.5d, soft
(h)Depth of water		0.2	0.4		0.2	0.4	<1.25d, In <1.15d
(i) Cargo hazard level		0.0	0.0		0.0	0.0	
Width(wi)		2.1	1.8		2.1	1.9	
Width(bm)		1.3	1.3		1.5	1.8	C:good, B:moderate and poor
Width(br)	moderate.	0.5	0.50	moderate	0.5	0.50	Out:slop., In:steep
Width(bg)	moderate.	0.5	0.50	moderate	0.5	0.50	Out:slop., In:steep
Total width(B)		4.4	4.1		4.6	4.7	
Ship's breadth(m)		32.2	32.2		32.2	32.2	
Channel Width(m)		142	132		148	151	