BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 34

STUDY OF THE RISK FOR ACCIDENTS AND THE RELATED ENVIRONMENTAL HAZARDS FROM THE TRANSPORTATION OF CHEMICALS BY TANKERS IN THE BALTIC SEA AREA

BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
– HELSINKI COMMISSION –

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STUDY OF THE RISK FOR ACCIDENTS AND THE RELATED ENVIRONMENTAL HAZARDS FROM THE TRANSPORTATION OF CHEMICALS BY TANKERS IN THE BALTIC SEA AREA

Report on a study of the transportation pattern for chemicals in
the Baltic Sea Area and the related hazards for the marine environment,
carried out under the auspices of the Combatting Committee
of the Commission in 1987 to 1989

BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
– HELSINKI COMMISSION –
May 1990

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PREFACE

Within the framework of the Baltic Marine Environment Protection Commission - Helsinki Commission - a Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area has been prepared in accordance with the decision by the Commission. Sweden has acted as Lead Country in the preparation of this Proceeding and the preparatory work has been done by Dr Björn Looström, Swedish Coast Guard, and Mr Börje Stenstrdm. 3K Engineering AB, Sweden.

The contents of this Proceeding has been considered by the ad hoc Working Group on Combatting Spfflages of Harmful Substances other than Oil (CC CHEM) of the Baltic Marine Environment Protection Commission - Helsinki Commission - under the chairmanship of Captain Klaus Schroh, Sonderstelle des Bundes für Ölunfälle See/Küste, Federal Republic of Germany.

The publication has been finally edited by Capt. Klaus Schroh. Dr Björn Looström and Mr Börje Stenstrdm.

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STUDY OF THE RISK FOR ACCIDENTS AND THE RELATED ENVIRONMENTAL HAZARDS FROM THE TRANSPORTATION OF CHEMICALS BY TANKERS IN THE BALTIC SEA AREA

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STUDY OF THE RISK FOR ACCIDENTS AND THE RELATED ENVIRONMENTAL HAZARDS FROM THE TRANSPORTATION OF CHEMICALS BY TANKERS IN THE BALTIC SEA AREA.

1. Background.

The study presented in this document has been conducted to identify the transportation patterns for chemicals carried in bulk in the Baltic Sea Area and the related risks for outflow and potential hazards to the marine environment. The study has been performed under the auspices of the Combatting Committee of the Helsinki Commission in close cooperation between all the Baltic Sea States and forms part of a joint work In development of necessary response methods for chemical spills in the Baltic Sea Area. The work has included a thorough collection of transportation data for chemicals in bulk in all Baltic Sea ports during the entire year of 1987 and elaboration of these data for the development of transportation patterns. Information about applicable ship standard and the related accident risks has been applied to the transportation pattern, enabling estimation of the expected rate of accidents with oufflow and their geographical distribution, the size of the significant oufflow, the substances likely to constitute the highest risk for accidental outflow and the related hazard to the marine environment.

The safety standard for transportation of chemicals in bulk IS regulated internationally by requirements specified in the “International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk” and the “International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk” (the IBC Code - and its predecessor the BCH Code - and the IGC Code respectively), both being parts of the “International Convention for the Safety of Life at Sea" (the SOLAS Convention). The transportation of liquid chemicals in bulk is additionally regulated by Annex II of the MARPOL Convention in technical and operational aspects related to marine pollution.

The IBC/BCH Codes specify a minimum ship standard for the carriage of chemicals, determined from transportation safety aspects. Chemical tankers are broadly divided in three classes based their structural integrity, ships of types 1, 2 and 3. Type 3 ships are single skin tankers with a certain survivability standard (higher than for oil tankers), type 2 ships are double skin tankers and type 1 ships are double skin tankers with higher cargo tank Integrity requirements than in type 2 ships.

From the point of view of hazards to the marine environment, chemicals are divided in the MARPOL Convention into Categories A, B, C and D. Category A contains the chemicals being most harmful to human life and the marine environment and Category D those chemicals which pose only a limited threat. Chemicals which are considered harmless to the marine environment if released in small quantities from normal ship operations are identified in a separate list, referred to as Appendix III of Annex II of MARPOL. Also these "harmless" chemicals may, however, cause harm to the marine environment if relesed in larger quantities as a result of an accident and are therefore included in this study of the accidental hazards.

Liquid chemicals carried in packaged form are not included in this study, nor solid chemical substances carried in bulk or in packaged form.

This report describes briefly the results of the investigations and the model used for the calculation of accidental risks and and the related oufflow of chemicals.

2. The Transportation Pattern.

Hazardous chemicals in the form of liquids and liquefied gases are transported by tankers and gas carriers in the Baltic Sea Area in national trade, in trade between the coastal states and to/from areas outside of the Baltic Sea. The main stream of transportation enters or leaves the Baltic Sea via the Kiel Canal and diverts in north-easterly direction into one main path to the Gulf of Finland and one along the Swedish east coast. A second main stream of lesser magnitude enters the area from the North Sea via the Sound and the Danish Belts.

The general transportation pattern which is linking the various port areas together and which has been used for identification of the intensity of the transportation activities in various parts of the Baltic Sea is illustrated in Figure 1. The transportation patterns have not been related to Individual ports but to 15 national or geographical port areas, identified in the figure. 24 route segments link the port areas together to form the predominant shipping routes.

The shipment patterns between the identified geographical port areas have been developed without regard to the direction of the shipments, i.e. regardless of whether the chemicals are being shipped inbound to or outbound from the area in question.

The amount of chemicals carried per year within the Baltic Sea Area, as estimated from the 1987 statistics, totals about 5.8 million tons of liquid chemicals and about 2.9 million tons of gases. An overview of the shipment quantities, divided in MARPOL categories, number of shipments and number of individual chemicals, is shown in Table 1.

The total transportation volume for chemicals of categories A to D equivalents about 2,400 million tonmiles, distributed over about 1.1 million shipmiles of loaded passages. This corresponds as an average to about 12 loaded chemical tankers being enroute in the Baltic Sea Area at any time. For the transportation of gases the equivalent numbers are about 800 million tonmiles, distributed over about 300,000 shipmiles, corresponding to 3 to 4 loaded gas carriers always being enroute In the Baltic Sea Area.

The information about shipments of chemicals in all ports has been analysed and been allocated to the route network. The chemicals shipped on each route segment have been identified in respect of type, quantities, number of shipments and ship type. The general transportation pattern thus derived is fflustrated in the charts in Figures 2 to 8, illustrating the shipment patterns for chemicals of categories A, B, C and D, substances belonging to Appendix III of Annex II of MARPOL and gases.

Table 2 shows a summary of all chemicals reported to have been shipped, listed per MARPOL category. Chemicals, which have not been categorized at the point in time when this study was made, have been allocated to the most likely category in order to enable development of transportation and risk patterns. Such assumed categorizations are shown in the table by placement of the category letter within brackets. These assumed categorizations are made for the said purpose only and must not be taken as valid guidance to applicable transportation requirements.

3. The Accident Risk for Chemical Tankers.

The types of accidents resulting in outflow from chemical tankers in the Baltic Sea area are mainly groundings and collisions. Based on information derived from current national and international accident statistics and correlated with studies performed at the Helsinki University of Technology, the adjusted statistical risk for a grounding accident with outflow of cargo from a single bottom chemical tanker has been calculated to be 25 in 100,000 voyages in the area and the risk for a collision with outflow from a tanker with single side plating has been calculated to be 5 in 100,000 voyages. The risk for total loss of a chemical tanker is generally associated with collision damage with resulting flooding beyond the SOLAS survivability requirements. The risk for such an accident is estimated to be about 1 per 1,000,000 voyages.

These basic risk factors are related to single skin tankers. In order to account for the reduced risk for outflow from a type 2 or other double skin tanker, correction factors for the likely possibility of a rupture reaching the inner tank enclosure have been incorporated in the outflow calculations.

The estimated rate of groundings and collisions with outflow from single skin chemical tankers is consistent with the current accident rate for oil tankers in the Baltic Sea, showing an average of about 35 accidents with outflow in 100,000 voyages. When comparing the rate with international statistics for severe oil tanker grounding and collision accidents, the calculated grounding rate turns out about twice as high as the world-wide one. The risk for collision is correspondingly lower in the Baltic Sea than in world-wide operations. The higher grounding rate in the Baltic Sea should be regarded in light of the fact that tankers in the area operate on short voyages and spend a major portion of the tune in waters with navigational risks whereas tankers in world-wide operation generally spend most of the time in open waters.

A voyage will comprise several route segments as identified in Figure 1. Considering the average length of a voyage. the abovementioned combined risk factor of 30 per 100,000 voyages for a type 3 ship and a corresponding risk factor of about 4 per 100,000 voyages for a type 2 (double skin) ship has been approximately divided in nominal risk factors per route segment as follows:

Risk Factor for Oufflow per 100,000 Voyages

	ship type2	ship type3
- an average voyage in the Baltic Sea Area	4	30
- a route segment including a difficult port entry	1.3	10
- a route segment including an average port entry	0.8	6
- a route segment in the open sea	0.4	3

These nominal risk factors per route segment have been elaborated in order to enable an estimate of the likely distribution of accidents on different parts of the transportation network.

The carriage requirements for liquid chemicals are defined in the IBC and BCH Codes, specifying, when applicable, type 2 or type 3 chemical tankers. No chemicals known to be carried in the Baltic Sea require containment in type 1 ship. Analysis of actual shipping information shows that tankers to type 2 standard, i.e. tankers with double bottom and double sides, are used in the carriage of chemicals to a larger extent than that required by the Codes.

The ship type requirements, supplemented with available information about the actual shipping standard, have been applied together with the above mentioned nominal risk factors to the number of shipments on each route segment. The adding up of the total risk for accidents with outflow over the entire transportation network in the Baltic Sea **Area** indicates for Category **A** to D substances a risk rate for such accidents of 35 cases in 100 years, i.e. about one in every three years, The vast majority of these calculated oufflow cases are related to the shipment of Category C and D chemicals and the calculated accident rates for Category A and B chemicals are only 1 and 3 respectively in 100 years.

During the nine years in which the Helsinki Convention has been in force no serious chemical tanker accident is known to have occurred in the Baltic Sea. This may indicate that the calculated risks are somewhat on the conservative side but the information available from past shipping activities is not detailed enough for any valid conclusions to be drawn in this respect.

4. outflow of cargo.

In case of an accident of such severity that it results in outflow of cargo, a number of cargo tanks may leak. A portion of the tank content will then escape into the sea, the amount depending on the type of damage, the vessel's loading condition and the properties of the cargo.

4.1 Groundings.

In case of a grounding, illustrated in Figure 9, the tanks will be ruptured in the bottom and some cargo will escape as the cargo of a loaded tanker is generally excerting a hydrostatic overpressure on the tank bottom relative to the outside sea water pressure. This overpressure is, as a rough average, equivalent to a liquid column of about 1/8 of the tank depth in a tanker, fully loaded with a cargo lighter than water. This fraction of the tank content will therefore escape before equilibrium is reached. The fraction may be increased to double that value to take into account partly loaded ships with increased freeboard and the pumping effect of waves and swells around the grounded vessel. A total of 2/8 of the content in each cargo tank having been ruptured in the bottom should therefore be regarded as being lost.

In case of a double bottom ship the cargo is located somewhat higher up relative to the outside sea level and a total of 3/8 of the content of a leaking tank should be regarded as being lost in the rare case of damage to the tank inner bottom. In case of cargoes heavier than water or highly soluble, the entire content of a leaking tank will flow out following a grounding.

The number of cargo tanks ruptured in groundings with penetration of the outer skin is, as derived from available statistics, as an average 2.7 tanks in case of single bottom and a corresponding value of 0.33 tanks in case of double bottom. This means that double bottom tankers are sustaining damage causing outflow of cargo about eight times less frequent than single bottom tankers. The average tanker engaged in Baltic Sea trade has been estimated to have 16 cargo tanks.

The amount of a cargo parcel escaping in case of the statistical grounding accident is then, as shown in Figure 9:

single bottom, cargo lighter than water and insoluble, 1/24,
single bottom, cargo heavier than water or soluble, 1/6,
double bottom, cargo lighter than water and insoluble 1/130,
double bottom, cargo heavier than water or soluble, 1/50.

These fraction factors indicate the portion of a cargo that will escape in an average accident with bottom plating damage. resulting in leakage. The factors for double bottom tankers do take into account the fact that groundings with outflow occur about eight times less frequent with such tankers.

4.2 Collisions.

In case of **collision, illustrated** in **Figure** 10, the damage will **normally** first occur above the waterline and, when more serious, extend further down. In some cases a bulbous bow may complicate the rupture. If the damage is limited to the side above the waterline, only the cargo located above the lower edge of the damage **will** escape. In case of damage below the waterline, water will **fill** the tank and lift all cargo out in case of cargo lighter than water or soluble but in case of a cargo, insoluble and heavier than water, only the portion located above the lower edge of the damage **will** escape.

In the average collision with outflow **from** a single side tanker, only one tank will be ruptured, unless the damage occurs at a transverse bulkhead. The damage will, as estimated from available statistics, be limited to the side above the water level in about 80 per cent of the collisions. The height of the damage has been assumed to be **2/8** of the tank depth in case of damage above the waterline and **4/8** of the tank depth in case of a more severe damage. The amount of cargo then escaping, **from** a single side tanker, will be:

cargo lighter than water or soluble,	**1/40**
cargo heavier than water and insoluble,	**1/54.**

In case of double side plating, **only** about 20 per cent of the cases will involve damage to the inner bulkhead and 20 per cent of these may extend below the waterline. The statistical ouflow portion in this case will then be:

cargo lighter than water or soluble,	**1/200**
cargo heavier than water and insoluble,	I/270.

In the same way as for groundings, these ouflow factors do, for type 2 vessels, take into account a different extent of damage as well as a different frequency of occurrence.

4.3 Combined ouflow factors.

Taking into account the relative frequencies of groundings and collisions and including total losses, the outflow ratios can be weighted together to represent an average accidental oufflow factor, relevant for the spectrum and frequency of accidents occurring in the Baltic Sea Area. In case of sinking of the vessel it has been assumed that one fourth of the cargo will escape into the sea. These weighted factors, rounded off, will then be:

type 2 ship, cargo lighter than water and insoluble, 1/ 120,
type 2 ship, cargo heavier than water or soluble, 1/60,
type 3 ship, cargo lighter than water and insoluble, 1/25,
type 3 ship, cargo heavier than water or soluble, 1/6.

For cargoes which are carried both in type 2 and in type 3 ships an average outflow factor may be used, taken as 1/40 for chemicals lighter than water and insoluble and 1/ 12 for cargoes heavier than water or soluble.

These oufflow factors are weighted with regard to the frequency of groundings and collisions and the reported extent of damage in different types of accidents. They are related to the frequency of accidents resulting in rupture of the outer skin and do take into account the reduced frequency of outflows of cargo applicable to type 2 ships by showing reduced numerical values of the factor for such ships.

The development of such combined outflow factors naturally involves compromises. In weighing the separate factors together it is not practicable to take into account, for instance, the likely fact that the mix of groundings and collisions is different on different route segments, in particular route segments on the open sea compared to route segments involving habour and archipelago areas. Considering the many uncontrollable variables involved it seems, however, practical to use these simplified combined factors in making general estimates of the likely oufflow from accidents with chemical tankers.

5. Geographical Distribution of the Risk for Outflows.

An outflow factor in accordance with the above summary has been assigned to each chemical, taking into account the characteristics of the chemical, the ship type requirements according to the IBC or BCH Codes and any additional information available, indicating actual shipment in ships of a higher standard than the Code minimum requirement.

These outflow factors have been applied in the calculation of the potential risk for outflow of the substance. The outflow factor multiplied by the relevant accident risk factor for a Baltic Sea voyage or for a route segment and by the quantity of a chemical shipped on the route will show the expected statistical outflow for that chemical during that time period. This calculation has been made for each route segment and each chemical, using the relevant information about quantities, accident risk factors and outflow factors.

The figures so derived can be used for determining the individual chemicals most likely to cause outflow in any one part of the route network and can be added up per MARPOL category to illustrate the calculated risk for outflow, divided on categories and geographical areas.

By multiplication of the number of shipments on any route segment by the applicable accident risk factor and taking into account the fraction of the shipments being carried in type 2 ships, the likely number of accidents will be obtained. The likely total number of accidents within the Baltic Sea Area with outflow of chemicals of categories A, B, C and D together has been calculated in this way to be 35 in 100 years, comprising statistically 1 accident involving Category A, 3 involving

Category B, 14 involving Category C and 17 accidents involving Category D cargoes. The geographical distribution of the accident risk, expressed as likely number of ouflows in 100 years, is illustrated in Figure 11. It may be noted that, in case all shipments were made to the minimum standard prescribed by the Codes, the number of outflow cases would have been about twice as high.

The above calculations are related to the shipment of harmful substances of MARPOL Categories A to D. Additionally, the transportation of chemicals belonging to Appendix III of Annex II may pose a risk to the marine environment. The probable frequency of accidents with ouflow of Appendix III substances has similarily been calculated as 15 cases in 100 years.

The steps used in the calculations of the accident risk and the likely outflow on each route segment and for each chemical are also illustrated in Figure 12.

6. Significant Accidental Outflow Quantities.

The outflow quantity of cargo in case of an accident depends on many parameters, including the severity of the accident, the size of the vessel and the properties of the cargo. The average quantity expected to escape in the nominal accident can be estimated, taking into account the average size of a parcel of cargo of the chemical or the category of chemicals in question and the applicable outflow factor. Study of the characteristics of the tankers typically engaged in the carriage of chemicals of different categories has led to a set of estimates summarized in the table below. The table gives a general overview of the likely outflow scenarios and does not take into account all the details and variations that may occur in the actual transportation pattern.

Category	Tank size, m3 average	Tank size, m3 range	Tanks leaking average	Tanks leaking range	Outflow, tons average	Outflow, tons range	Frequency per 100 yrs
Gas	1000	400-4000	1	1	1000	400-4000	15
A	300	200-500	1	1-5	300	200-1500	17
D	300	200-500	1	1-5	400	100-1000	14
C	400	200-400	1	1-5	300	100-1200	3
B	200	200-500	1	1-3	100	50-800	1
App	300	100-300	1	1-3	150	25-600	1

7 Hazards to the Marine Environment.

The oufflow of chemicals of different types do represent different hazards to the marine environment. When the potential outflow of chemicals of different categories has been computed, the hazards therefrom may be illustrated by applying relevant hazard factors to the different substances. The approach accepted by IMO when mixtures of chemicals are considered is to apply a hazard factor of 1000 to Category A substances, 100 to B, 10 to C and 1 to Category D substances. Having applied these factors to the calculated potential outflow quantities of each category on each route segment, the values may be added up to show a total environmental hazard number per route segment and a total environmental hazard number per category of chemicals. Table 3 illustrates these calculated environmental hazard numbers for each category of chemicals on each one of the route segments identified in Figure 1. The magnitude and the distribution of the environmental hazards is also illustrated by the shade pattern on each one of the maps shown in Figures 2 - 7.

As becomes clear from Table 3, the transportation of Category A substances account for the largest fraction of the total environmental hazard, followed by Category B. If transportation were made strictly to Code minimum standard, Category B would, however, account for the highest environmental hazard number, followed by Category A. It also becomes clear from Table 3 that the highest risk area is the south-west part of the Baltic Sea, including the Kiel Canal approach. This area accounts for about 40 per cent of the total calculated number of accidents and outflow of cargo and about 50 per cent of the total environmental hazard, expressed in hazard numbers calculated as described above. These calculations are based on nominal assumptions and conditions. Local navigational conditions have not been evaluated in depth in this study and the calculations therefore do not take into account safety enhancing arrangements such as traffic service and control systems.

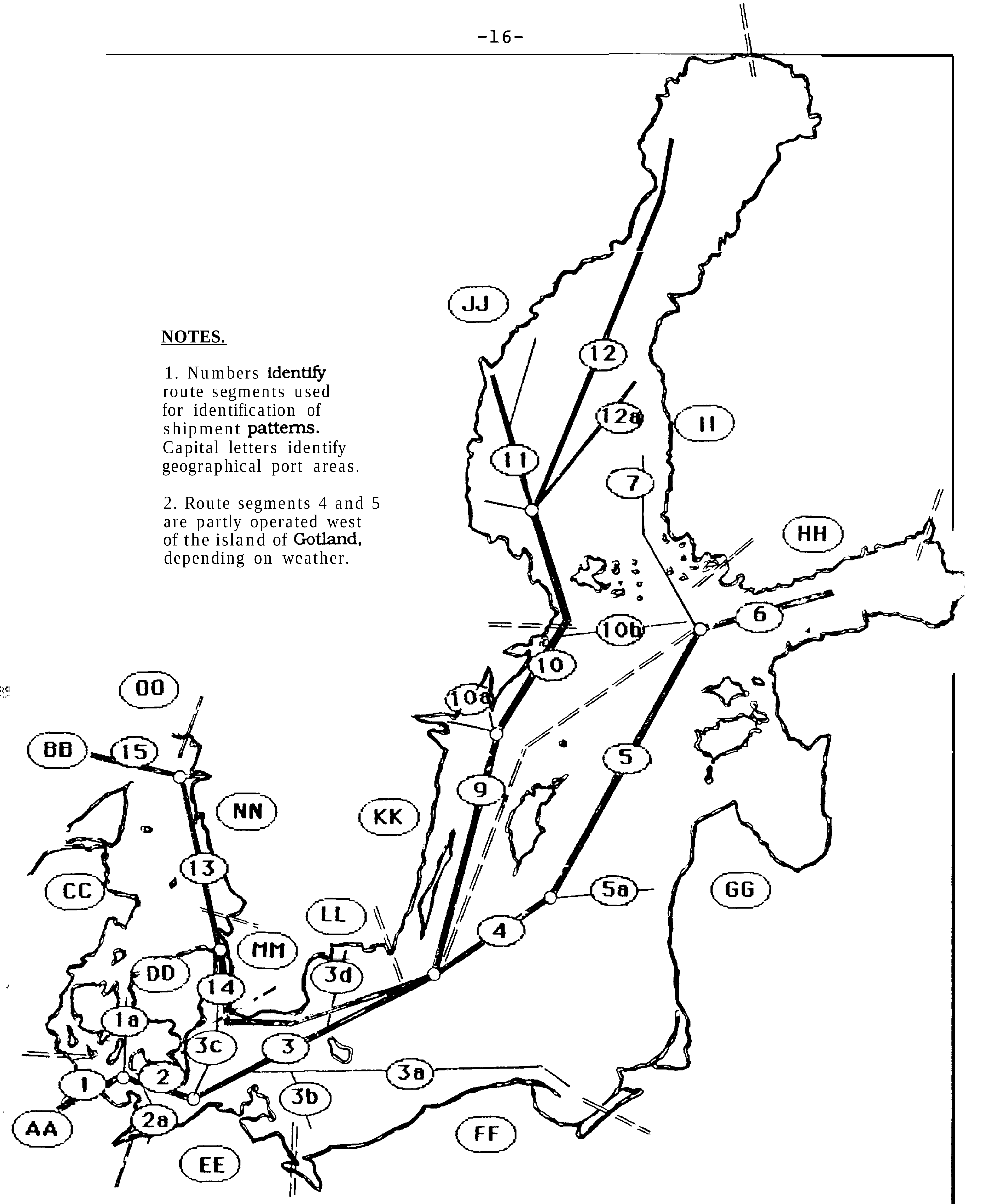
The transportation patterns and the related accidental and environmental risks described in this paper are based on information available at the time of development of Volume III of the HELCOM Manual on Co-operation in Combatting Marine Pollution, dealing with response to chemical spffls from tankers. The transportation patterns and the spectrum of chemicals carried may change by time as well as the standard of the tankers engaged in the trade. The study is believed to illustrate in rather accurate terms the situation in the current time period but the information may need to be updated and reviewed at intervals of, suggestedly, five years.

LIST OF FIGURES AND TABLES. Page

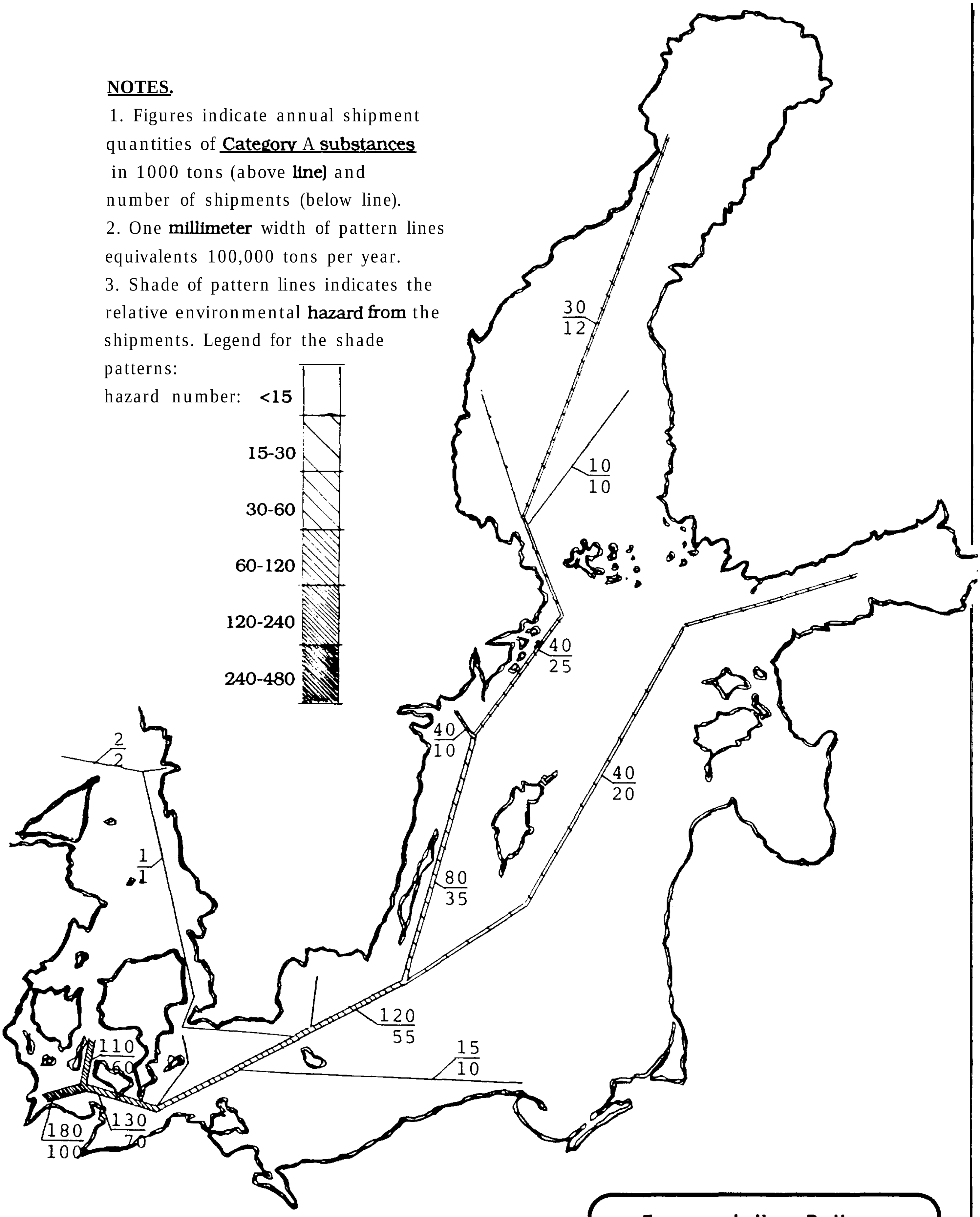
NOTES.

1. Numbers identify route segments used for identification of shipment patterns. Capital letters identify geographical port areas.

2. Route segments 4 and 5 are partly operated west of the island of Gotland, depending on weather.



Transportation Route System
Figure 1



Transportation Pattern for Category A Substances Figure 2

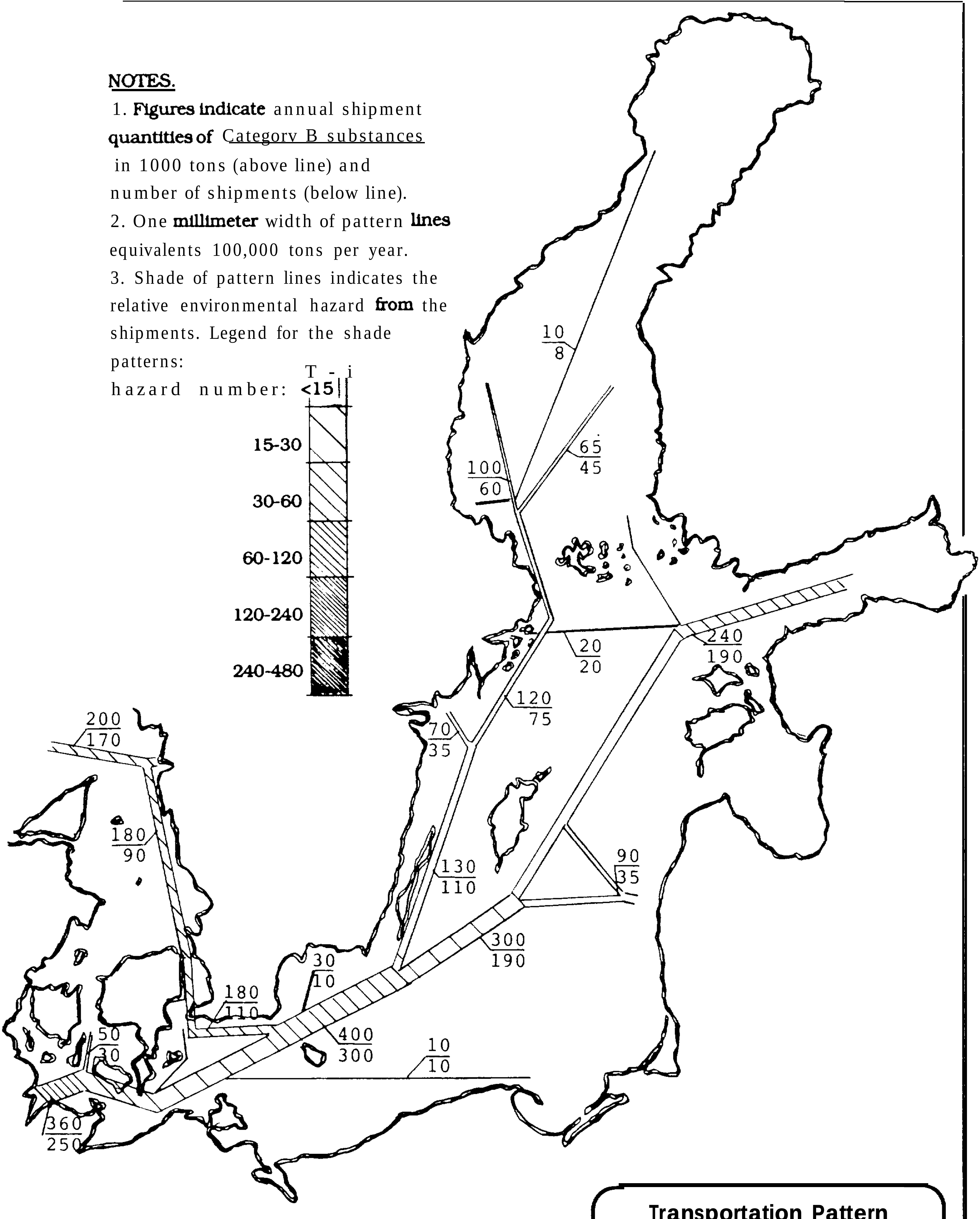
NOTES.

1. Figures indicate annual shipment quantities of Categorv B substances in 1000 tons (above line) and number of shipments (below line).

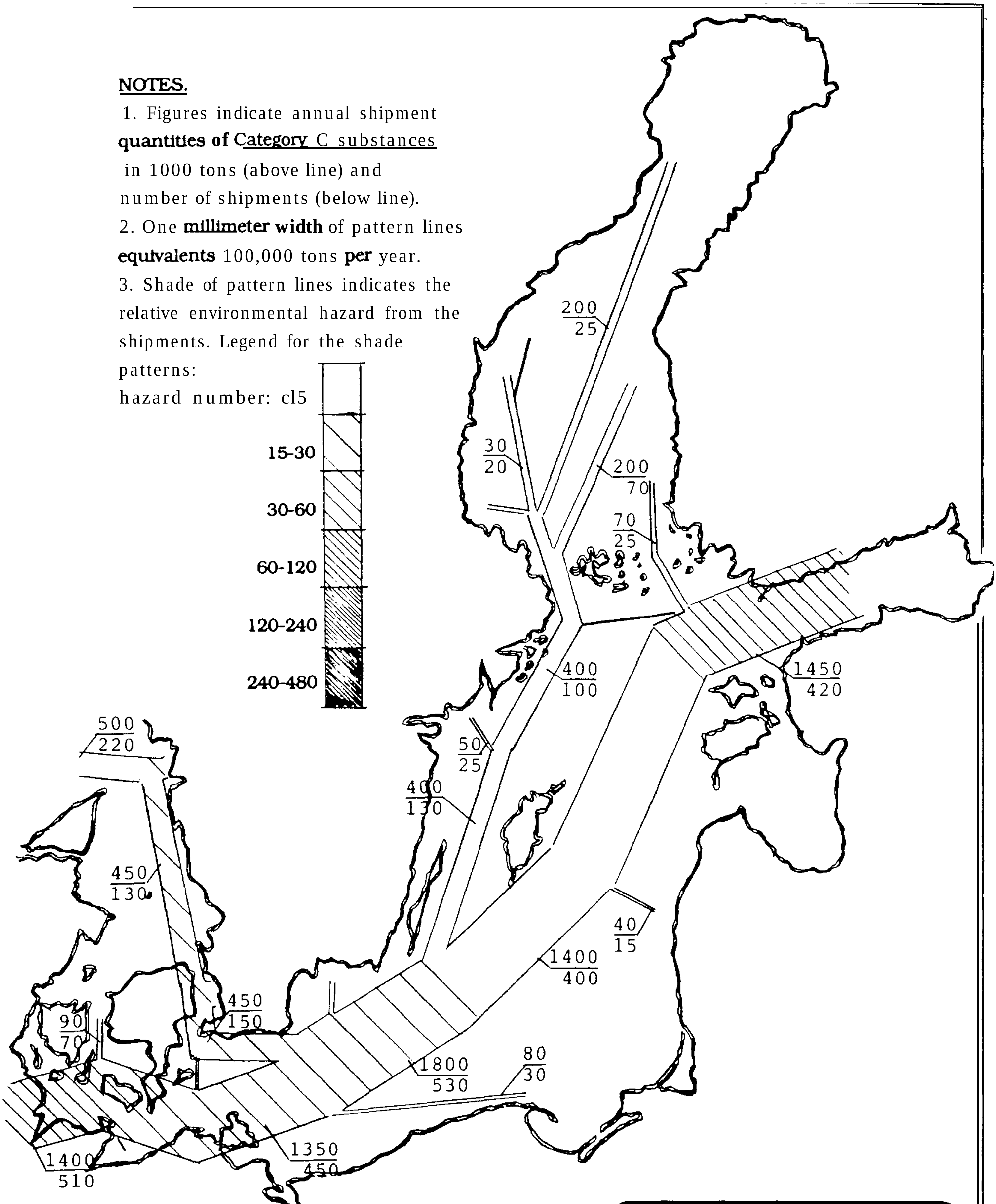
2. One millimeter width of pattern lines equivalents 100,000 tons per year.

3. Shade of pattern lines indicates the relative environmental hazard from the shipments. Legend for the shade patterns:

hazard number: <15



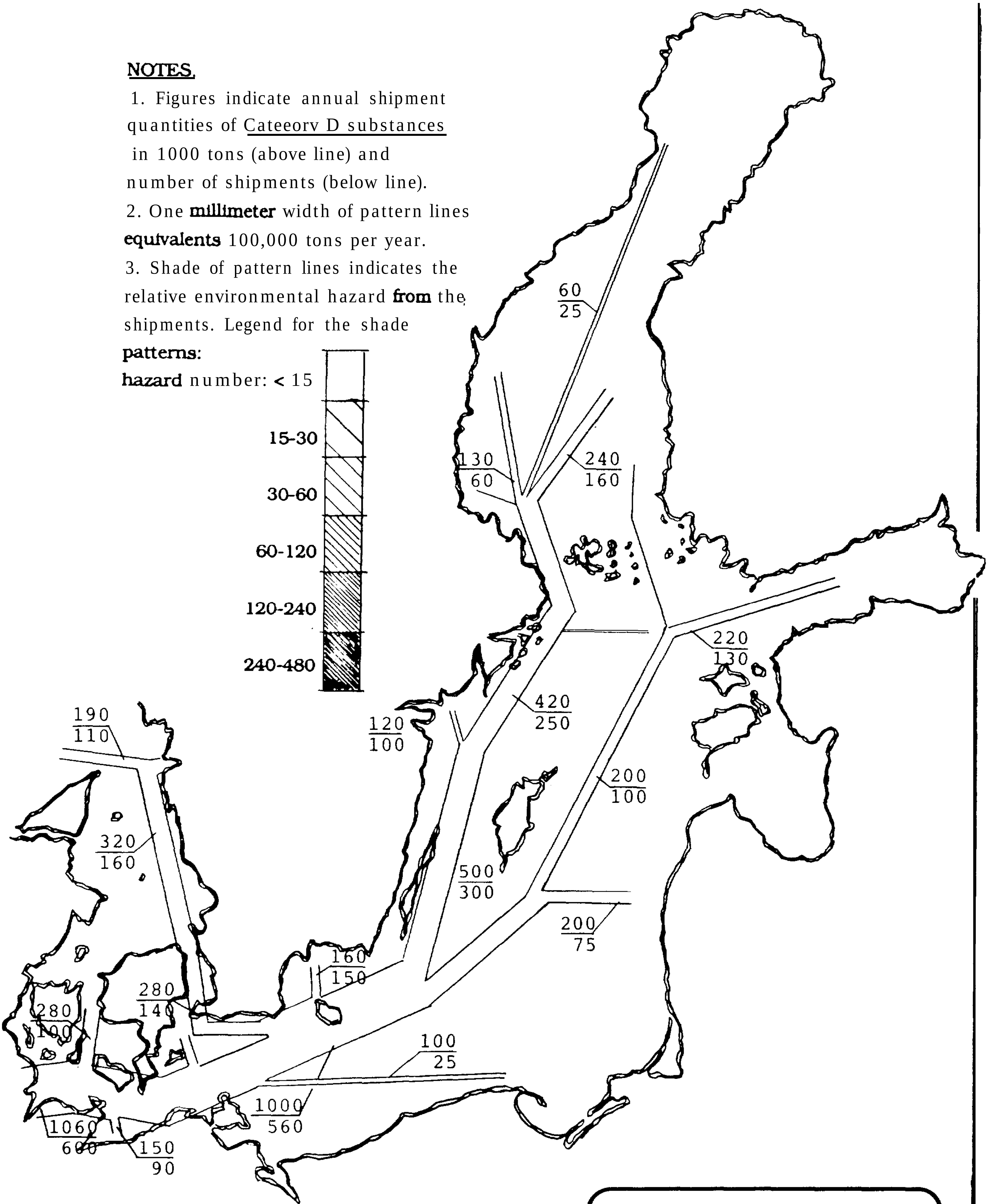
Transportation Pattern for Category B Substances Figure 3



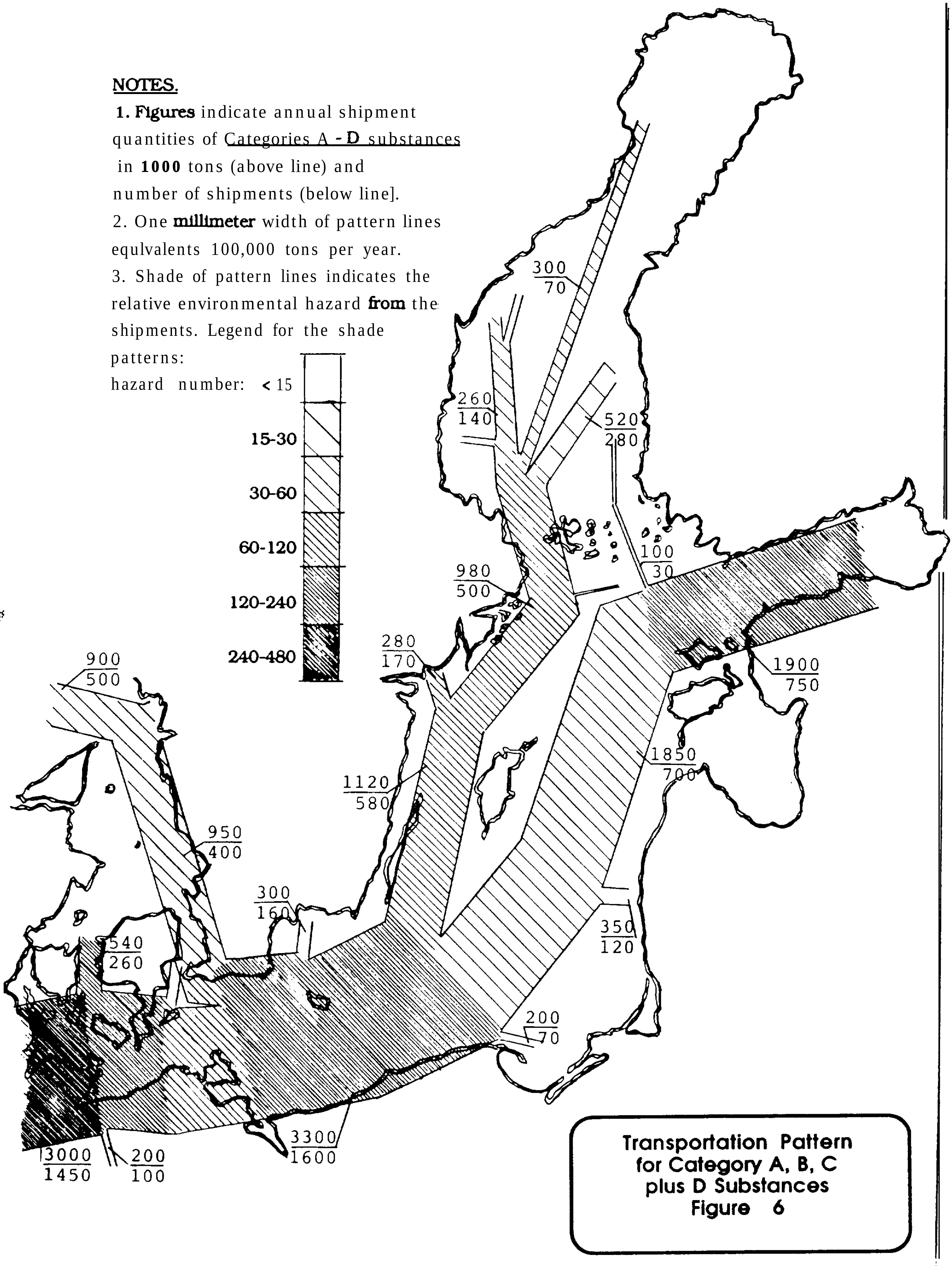
Transportation Pattern for Category C Substances Figure 4

NOTES.

1. Figures indicate annual shipment quantities of <u>Cateeorv D substances</u> in 1000 tons (above line) and number of shipments (below line).
2. One **millimeter** width of pattern lines **equivalents** 100,000 tons per year.
3. Shade of pattern lines indicates the relative environmental hazard **from** the shipments. Legend for the shade **patterns:**



Transportation Pattern for Category D Substances Figure 5

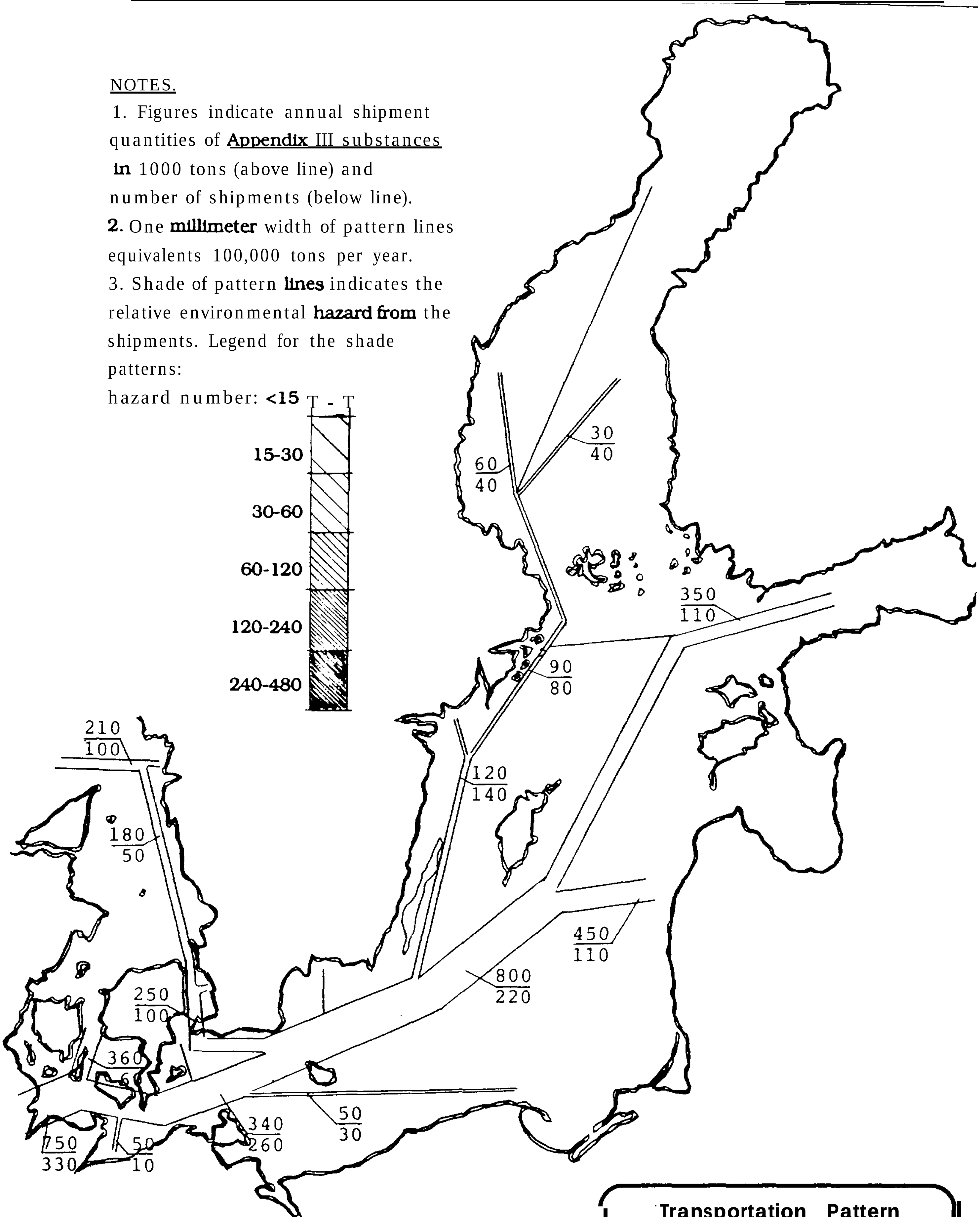


Transportation Pattern for Category A, B, C plus D Substances
Figure 6

NOTES.

1. Figures indicate annual shipment quantities of Appendix III substances in 1000 tons (above line) and number of shipments (below line).
2. One millimeter width of pattern lines equivalents 100,000 tons per year.
3. Shade of pattern lines indicates the relative environmental hazard from the shipments. Legend for the shade patterns:

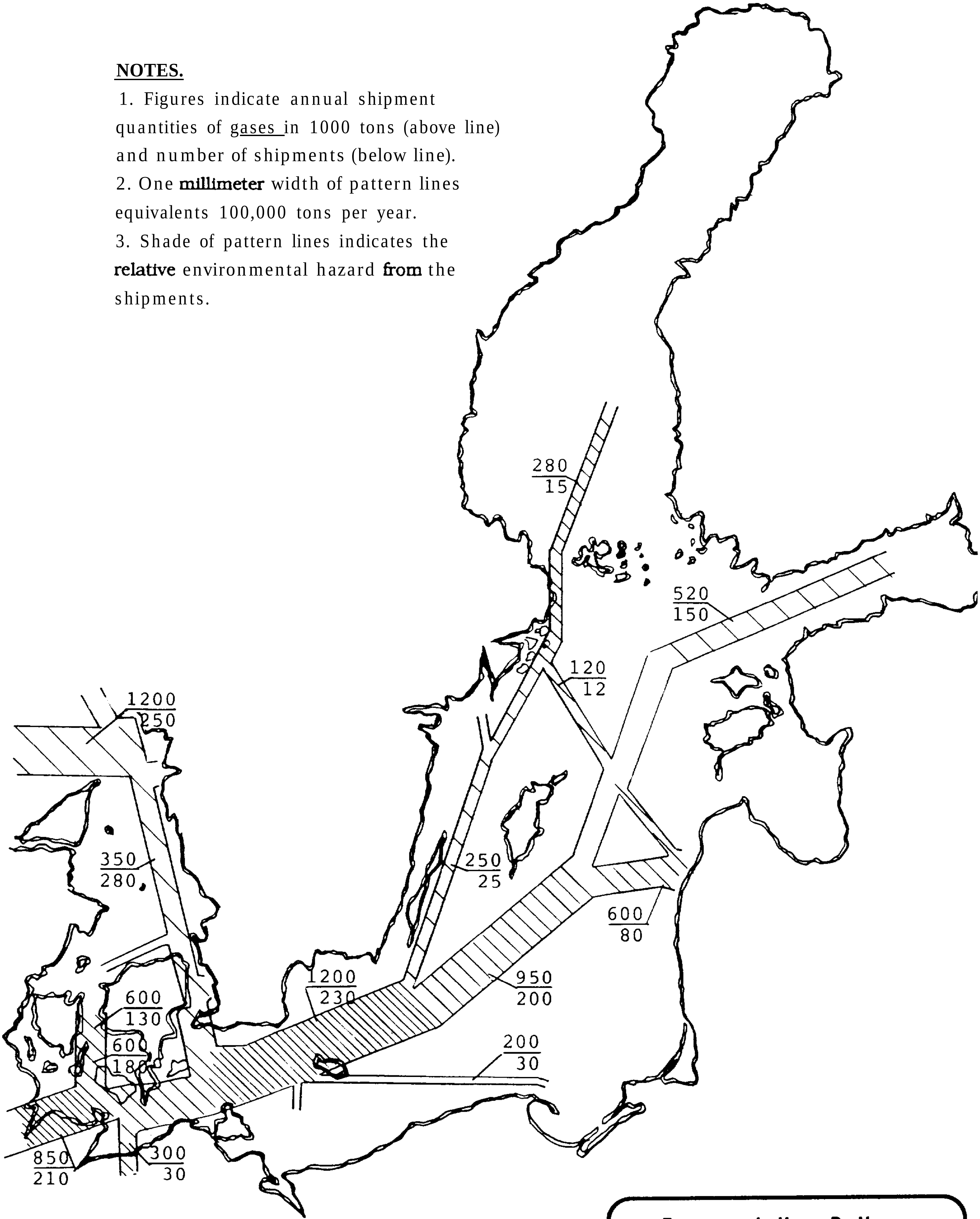
hazard number: <15



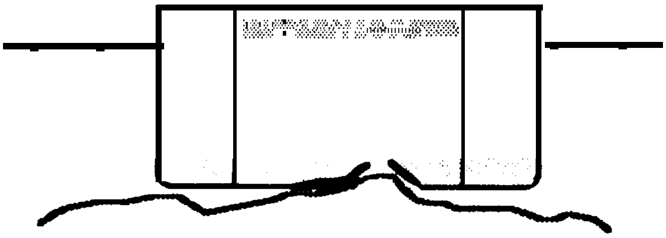
Transportation Pattern for Appendix III Substances
Figure 7

NOTES.

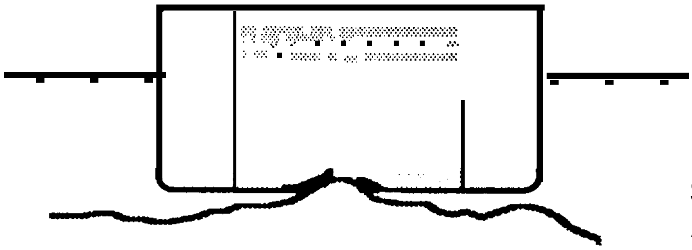
1. Figures indicate annual shipment quantities of <u>gases</u> in 1000 tons (above line) and number of shipments (below line).
2. One millimeter width of pattern lines equivalents 100,000 tons per year.
3. Shade of pattern lines indicates the relative environmental hazard from the shipments.



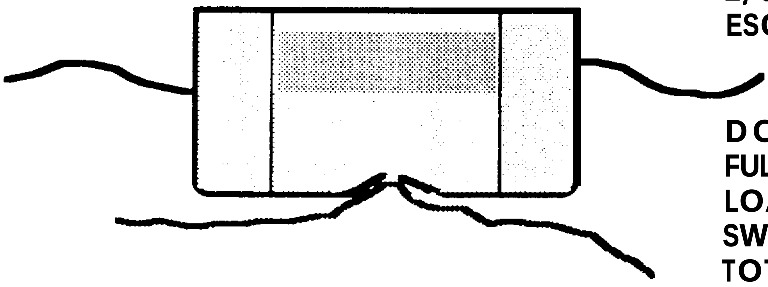
Transportation Pattern for Gases
Figure 8



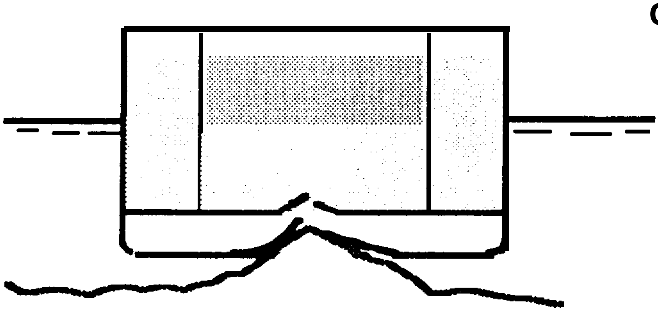
SINGLE BOTTOM TANKER,
FULLY LOADED,
1/8 OF TANK CONTENT
ESCAPING IF LIGHTER
THAN WATER



SINGLE BOIIOM TANKER,
PART LOADED,
2/8 OF TANK CONTENT
ESCAPING



SINGLE BOTTOM TANKER,
ACTION BY SWELL AND
WAVES,
2/8 OF TANK CONTENT
ESCAPING



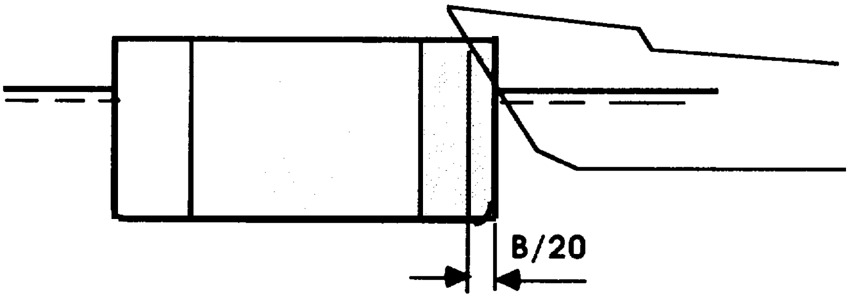
DOUBLE BOTTOM TANKER,
FULLY LOADED + PART
LOAD CONTRIBUTIONS +
SWELL CONTRIBUTIONS,
TOTALLY 3/8 OF TANK
CONTENT ESCAPING

AVERAGE EXTENT OF DAMAGE IN SINGLE BOTTOM
TANKER = 2.7 TANKS OUT OF 16.
IN DOUBLE BOTTOM TANKER= 0.33 TANKS OUT OF 16.

OUTFLOW PORTION IN SINGLE BOTTOM TANKER,
CARGO LIGHTER THAN WATER = 2.7/16*2/8 = ...1/24
CARGO HEAVIER THAN WATER OR HIGHLY
SOLUBLE = 2.7/16 *8/8= 1/6

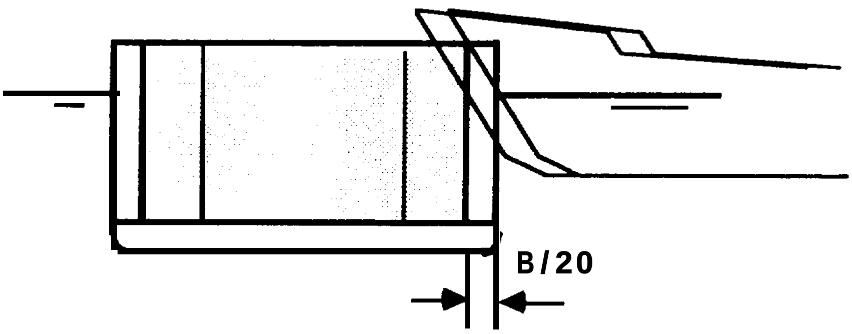
OUTFLOW PORTION IN DOUBLE BOTTOM TANKER,
CARGO LIGHTER THAN WATER = 0.33/16*3/8 =..... 1/130
CARGO HEAVIER THAN WATER OR HIGHLY
SOLUBLE = 0.33/16*8/8 = ... 1/50

Outflow at Groundings
Figure 9



AVERAGE COLLISION DAMAGE TO A SINGLE SIDE TANKER (TYPE 3):
NUMBER OF TANKS PENETRATED= 1
DAMAGE ONLY ABOVE WATER LINE IN 80% OF ALL CASES
DAMAGE BELOW WATER LINE IN 20 % OF ALL CASES

PORTION OF CARGO ESCAPING IF LIGHTER THAN
WATER = .8*1/16*2/8+.2*1/16*8/8=......................1/40
IF HEAVIER THAN
WATER = .8*1/16*2/8+.2*1/16*4/8=......................1/54



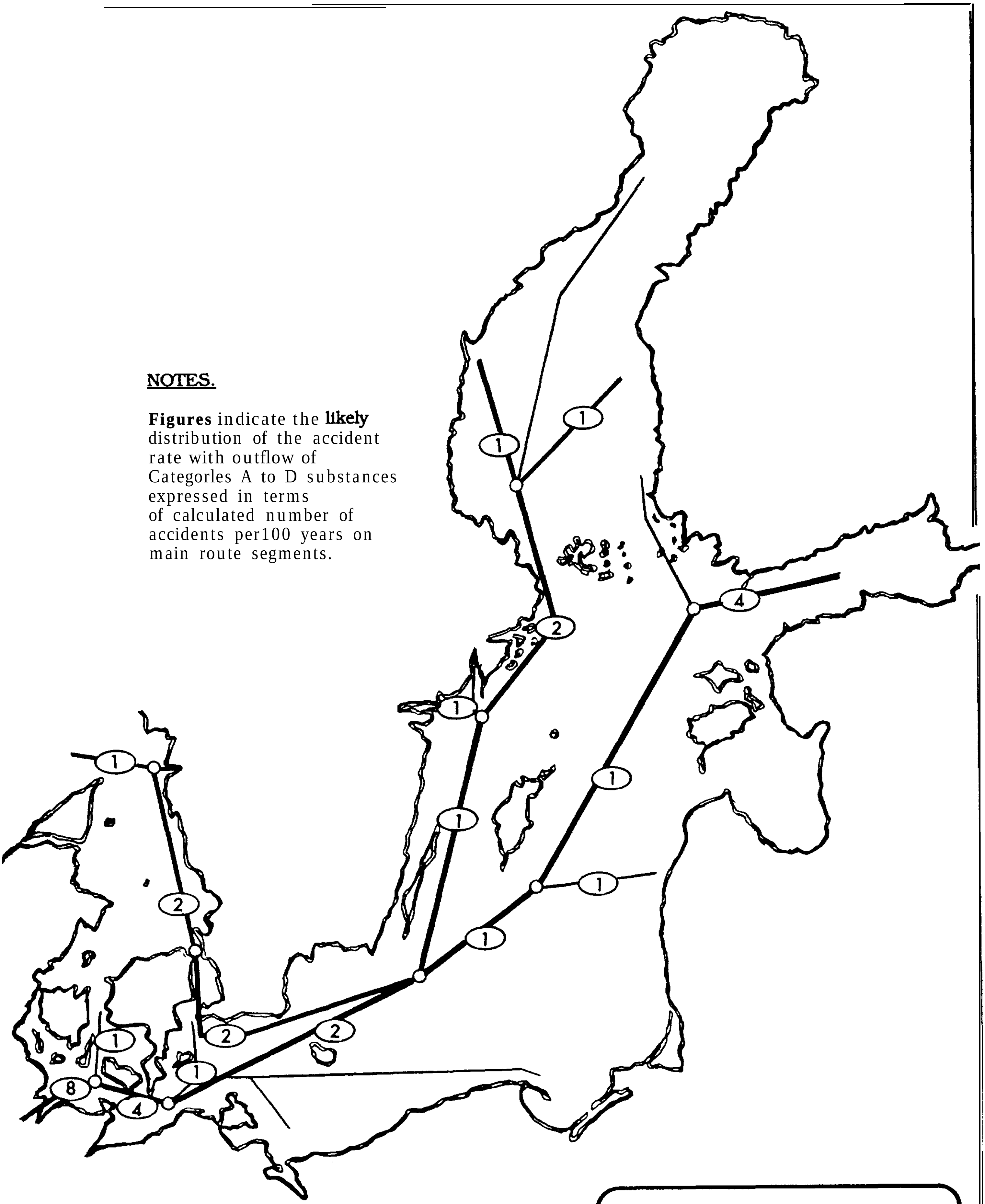
AVERAGE COLLISION DAMAGE TO A DOUBLE SIDE TANKER (TYPE 2):
NUMBER OF TANKS PENETRATED= 1
DAMAGE TO CARGO TANKS (>B/20) IN 20% OF ALL CASES
DAMAGE EXTENDING BELOW WATER LINE IN 20 % OF CARGO TANK DAMAGE CASES

PORTION OF CARGO ESCAPING IF LIGHTER THAN
WATER =(.2*.8*2/8+.2*.2*8/8)*1/16= 1/200
IF HEAVIER THAN
WATER = (.2*.8*2/8+.2*.2*4/8)*1/16=..................1/270

Outflow at Collisions
Figure 10

NOTES.

Figures indicate the **likely** distribution of the accident rate with outflow of Categorles A to D substances expressed in terms of calculated number of accidents per100 years on main route segments.



Geographical Distribution of Calculated Ou:!lows Figure 11

OUTFLOW CALCULATION MODEL

Quantity of a substance, carried on a route segment	Q
Accidental oufflow factor, ship type and cargo property related	δ
Rate of accidents with oufflow on route segment	σ
Environmental hazard number	η
Calculated statistical outflow per substance on a route segment	$\sigma \cdot \delta \cdot Q$
Total calculated outflow per category on a route segment (sum of all shipments of the same category)	$\Sigma \sigma \cdot \delta \cdot Q$
Total environmental hazard number per category on a route segment	$\eta \cdot \Sigma \sigma \cdot \delta \cdot Q$
Number of shipments per category on a route segment	N = Ntype 2 + Ntype3
Number of accidents with outflow per category on a route segment	M = σ/8* Ntype2 + σ*Ntype3
Number of accidents with outflow on a route segment (sum of M values for all categories)	CM

NOTE. In the way the model has been applied in the calculations, the accidental oufflow factor for type 2 ships takes into account the reduced frequency of outflows from this ship type and this factor must then be used in combination with the nominal accident rate, as applicable to single skin tankers, when the statistical outflow quantities are calculated. When the number of accidents are calculated, the rate of accident factor must be reduced by a factor of 8 for theaumber of shipments made in type 2 ships.

Outflow Calculation Model
Figure 12

TABLE 1
OVERVIEW OF THE TRANSPORTATION OF CHEMICALS IN THE BALTIC SEA AREA

Category of chemical	Number of chemicals in category	Quantity shipped, tons/year	Number of shipments per year
Category A	12	200000	120
Category B	29	700000	500
Category C	37	2200000	850
Category D	44	1700000	1000
Sum Cat A-D	122	4800000	2470
Appendix III	14	1000000	500
Gases	9	2900000	1000
TOTAL	145	8700000	3970

TABLE 2
SUMMARY OF CHEMICALS TRANSPORTED IN THE BALTIC SEA

SUBSTANCE LISTING BY CATEGORY	UN-NO	CATE-GORY	QUANTITY TONS	NO. OF SHIPMENTS
CATEGORY A		A	198171	117
coal tar	1999	A	153957	77
creosote	1334	A	22797	8
alpha-methykyrene	2303	A	9592	10
acetone cyanohydrine	1541	A	3590	3
naphtalene	2304	A	2646	3
TML/TEL	1649	A	1554	6
butyl toluene	2667	A	1400	1
butyl benzyl phtalate		A	1299	3
vinyl toluene	2618	A	475	1
solvents, cat A		A	466	3
ethyl acrylate	1917	A	200	1
dibutyl phtalate		A	195	1
CATEGORY B		B	707024	497
styrene monomer	2055	B	110472	73
ethylene dichloride	1184	B	92768	40
coal tar naphta solvent	2553	B	87313	12
phenol	2312	B	78700	65
acrylonitrile	1093	B	69221	30
tall oil		B	69118	47
white spirit	1300	B	63831	57
butyraldehyde	1129	B	33811	13
carbon tetracloride	1846	B	19000	1
solvents, cat B		B	17614	70
chlorobenzene	1134	B	12953	12

isopropylbenzene	1918	B	12060	6
turpentine	1299	B	9534	14
trichloroethylene	1710	B	5774	6
lub oil additives		(B)	5347	12
nonene	1257	B	4700	9
trimethylbenzene	2325	B	3964	8
butyl acrylate	2348	B	2540	7
isodecyl alcohol		(B)	2440	5
trichloroethane	2831	B	1350	2
tetrachloroethane	1702	B	1036	1
crotonaldehyde	1143	B	1030	1
pinene	2368	B	898	3
propylene dichloride	1279	B	850	1
tetrachloroethylene	1897	(B)	700	2
CATEGORYC		C	2226483	829
pyrolysis gasoline		(C)	477376	57
sulphuricacid	1830	C	472164	73
xylene	1307	C	409695	186
benzene/toluene/xylene mixture		(C)	345243	70
benzene	1114	C	90130	31
nitric acid	2031	C	74510	36
ethyl hexanol		(C)	63782	60
fluosilicic acid	1778	(C)	43844	24
pyrolysis waste mixtures		(C)	39537	14
toluene	1294	C	37382	28
aniline	1574	C	31039	27
benzine, aromat	1115	(C)	22799	9
potassium hydroxide solution	1814	C	20282	18
vinyl acetate	1301	c	16019	28
tall oil fatty acid		C	10979	9
solvents, cat C		C	10801	43
hexane	1208	C	8425	19
butyl acetate	1123	C	8101	22
ethylbenzene	1175	c	7910	4
octanol	1986	C	7120	13
cyclohexane	1145	c	6573	7
toluene diioscyanate	2078	C	4180	1
dipentene	2052	C	3112	7
heptane	1206	C	2890	11
ethylenediamine	1604	C	2656	8
ammonia aqueous	2672	C	2485	10
2-ethoxyethyl acetate	1172	C	1666	2
1,3-pentadiene		C	1206	1
sodium borohydride		C	1198	4
formaldehyde	1198	C	1000	1
propylamine	1277	c	1000	1
nonyl alcohol		C	679	3
amyl acetate	1104	C	436	1
methylamyl alcohol	2053	C	264	1
CATEGORY D		D	1696271	985
sodium hydroxide solution	1824	D	703957	279
phosphoric acid	1805	D	427977	100
vegetable oils		D	172538	202
methyl tert-butyl ether	2398	D	98490	52
ethylene glycol		D	43743)	66)

latex		D	394131	44
acetic acid	2785	D	32676	3(
methyl ethyl ketone	119:	D	26540	27
dichloromethane	159:	D	24223	14
formic acid	1775	D	20804	24
cakium chloride solution		(D)	18165	18
ethyl acetate	117:	D	17983	3;
cyclohexanone	1915	D	10980	11
urea, ammonium nitrate solution		D	10100	1
fatty acids		D	9935	9
methyi propyl ketone	1245	D	7408	:
2-ethoxyethanol	1171	D	7235	7
fish oil		D	5822	5
sodium hydroxide solution, spent		D	3926	4
methyl methacrylate	1247	D	2260	6
propionic acid	1848	D	2189	4
diisodecyl phtalate		D	1704	8
ethyl propionate	1195	D	1651	1
pyridine	1282	D	1100	1
ethyfene glycol acetate		D	931	8
diethyleneglycol iso-butyl ether		D	915	1
methyi isobutyl ketone	1245	D	571	5
ethylene glycol methyl ether	1188	D	525	1
aminoethyiethanolamine		D	510	2
2-ethylhexanoic acid		D	444	1
acetic an hydride	1715	D	397	1
amyl alcohol	1105	D	382	1
ethanolamine	2491	D	284	1
hexanol	2282	D	209	1
propylene glycol methyi ether		D	180	3
butylene glycal		D	104	1
APPENDIX III SUBSTANCES		App III	1045218	499
methyi alcohol	1230	App III	747545	175
ethyl alcohol	1 170	App III	96924	88
butyl alcohol	1 1 20	App III	54695	35
acetone	1090	App III	54307	45
isobutyl alcohol	1212	App III	27960	18
isopropylalcohol	1219	App III	23188	61
glycerine		App III	16946	21
dioctyl phtalate		App III	14026	24
propylene glycol		App III	7259	14
paraffin wax		App III	875	1
vegetable protein solution		App III	750	1
diethylene glycol		App III	639	3
ethylene glycol butyl ether	2369	App III	104	1
GASES		gas	2845921	962
ammonia	1005	gas	1427274	294
propane	1978	gas	703630	422
butane	1011	gas	243232	5c
propylene	1077	gas	210329	71
vinyl chloride	1086	gas	110071	46
butadiene	1010	gas	90772	51
ethylene	1038	gas	56883	2A
LPG	1075	gas	2570	2
ethyl chloride	1037	gas	1160	1

TABLE 3
TRANSPORTATION PATTERN AND ENVIRONMENTAL HAZARD NUMBERS

ROUTE SEG-MENT NUMBER	NOMINAL ACCIDENT RATE PER ROUTE SEGMENT IN 100000 VOYAGES	QUANTITIES SHIPPED PER MARPOL CATEGORY, 1000 TONS PER YEAR					CALCULATED ACCIDENT RATE IN 100 YEARS, PER CATEGORY AND ROUTE SEGMENT					HAZARD NUMBER PER CATEGORY AND ROUTE SEGMENT				
		A	B	C	D	SUM	A	B	C	D	SUM	A	B	C	D	SUN
1	10	175	360	1398	1061	2994	,3	,6	2,7	3,9	8	280	70	49	6	405
1-a	10	111	50	93	281	535	,2	,1	,2	1,0	1	180	10	4	1	195
2	6	116	311	1375	1001	280:	,1	,3	1,6	2,2	A	110	40	28	3	181
2-a	6	0	6	3	153	162	,0	,0	,0	,4	C	0	0	0	1	1
3	3	110	284	1355	743	2492	,1	,2	,8	,8	2	50	20	14	1	85
3-a	6	3	8	65	94	17c	,0	,0	,1	,2	C	3	0	2	0	5
3-b	6	6	0	0	12	18	,0	,0	,0	,0	C	7	0	0	0	7
3-c	10	2	14	91	148	255	,0	,0	,2	,6	1	2	0	3	1	6
3-d	6	1	27	0	163	302	,0	,0	,0	,3	C	0	0	0	0	c
4	3	32	283	1393	399	2107	,0	,2	,7	,5	1	10	20	13	1	44
5	3	32	194	1419	198	1843	,0	,1	,7	,3	1	10	10	13	0	33
5-a	6	0	89	35	204	328	,0	,1	,1	,4	1	0	10	1	1	12
6	10	32	230	1425	220	1907	,1	,3	2,4	,9	4	50	40	44	1	135
7	10	0	2	69	4	75	,0	,0	,2	,0	0	0	0	3	0	3
9	3	77	151	389	504	1121	,0	,1	,3	,6	1	40	10	5	1	56
10	6	40	124	395	410	969	,0	,1	,6	,9	2	40	10	11	1	62
10-a	10	38	68	49	117	272	,1	,1	,1	,5	1	60	10	2	1	73
10-b	6	0	21	4	21	46	,0	,0	,0	,1	0	0	0	0	0	0
11	6	30	103	32	125	290	,0	,1	,3	,4	1	30	10	6	1	47
12	6	30	10	190	62	292	,0	,0	,3	,0	0	30	0	5	0	35
12-a	6	10	63	208	240	521	,0	,1	,3	,5	1	10	10	6	1	27
13	10	1	167	437	322	927	,0	,3	,8	1,3	2	0	30	14	2	46
14	10	1	173	432	282	888	,0	,3	,8	1,0	2	0	30	14	1	45
15	6	2	207	472	185	866	,0	,2	,5	,4	1	0	20	9	1	30
TOTAL/							,9	2,9	13,8	17,1	35	912	350	249	24	1535

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BALTIC SEA ENVIRONMENT
PROCEEDINGS No. 34

STUDY OF THE RISK FOR ACCIDENTS AND THE RELATED ENVIRONMENTAL HAZARDS
FROM THE TRANSPORTATION OF CHEMICALS IN THE BALTIC SEA AREA

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