Environment Canada
Environmental Protection Service

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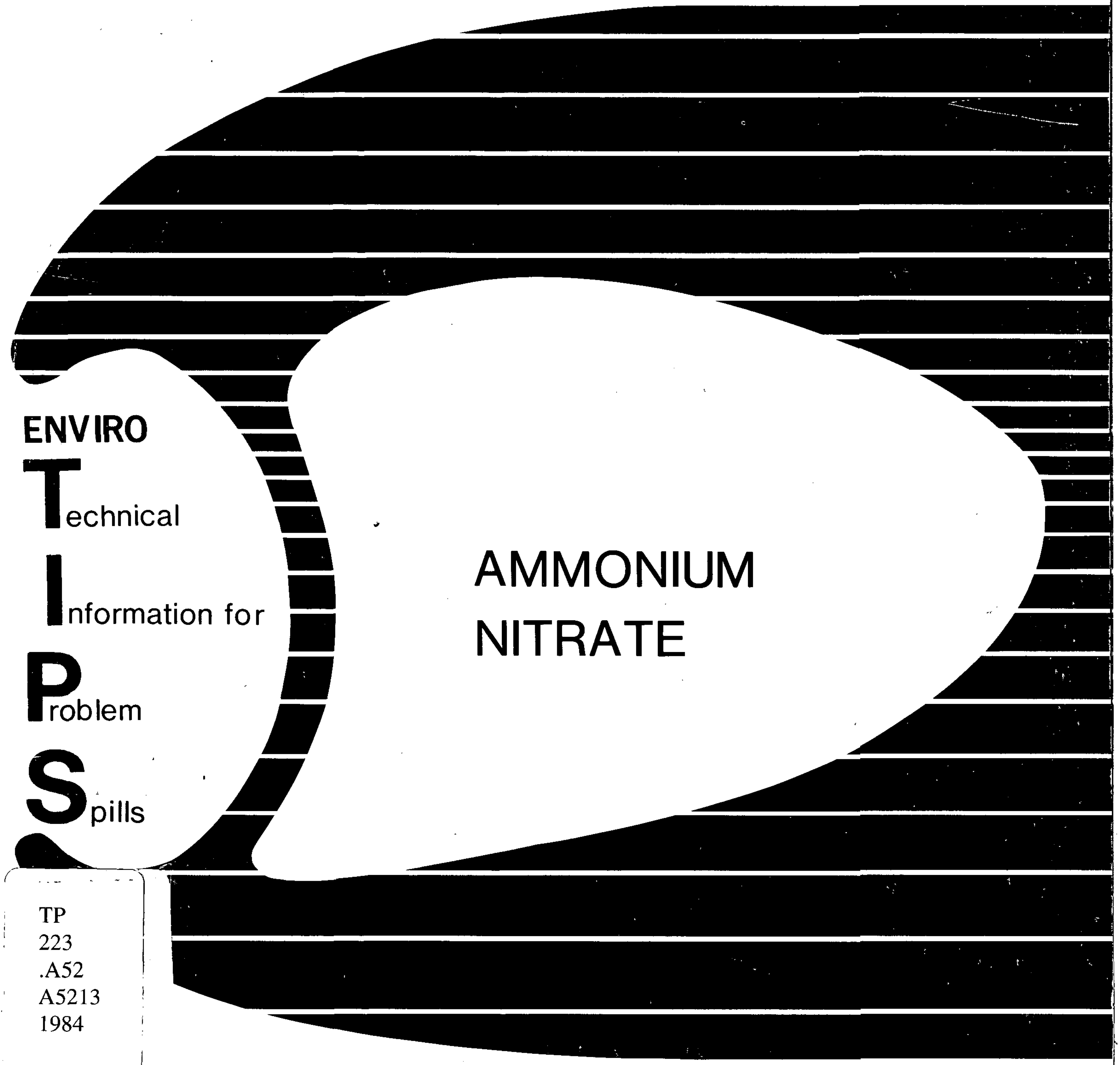

ENVIRO
Technical Information for Problem Spills

AMMONIUM NITRATE

June 1984

Canada

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals provide detailed information on chemical substances. This information is intended to assist the reader in designing countermeasures for spills and to assess their impact on the environment. The manual has been reviewed by the Environmental Protection Programs Directorate, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

AMMONIUM NITRATE

TECHNICAL INFORMATION FOR PROBLEM SPILLS

Technical Services Branch
Environmental Protection Programs Directorate
Environmental Protection Service
Ottawa, Ontario

June 1984

N° de cat. En 48-10/13-1984E
ISBN 0-662-13354-4
BEAUREGARD PRESS LIMITED

FOREWORD

The Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals that are spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of EnviroTIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that they are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review. The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation, and Waterloo Engineering Limited.

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1 SUMMARY

AMMONIUM NITRATE (NH_4NO_3)

White to light gray solid granules with no odour

SYNONYMS

Nitram, Ammonium Salt of Nitrate Acid, Nitrate of Ammonia, German Saltpeter, Norway Saltpeter

IDENTIFICATION NUMBERS

UN No. 0222 (explosive, more than 0.2 percent combustibles), 1942 (oxidizer, not more than 0.2 percent combustibles), 2072 (oxidizer, ammonium nitrate fertilizer), 0223 (explosive, greater amounts of combustibles), 2067 (oxidizer, ammonium nitrate fertilizers, type A, not more than 0.2 percent combustibles, 79 percent NH_4NO_3), 2068 (oxidizer, ammonium nitrate fertilizer, type A, 80 to 90 percent NH_4NO_3), 2069 (oxidizer, ammonium nitrate fertilizers, type A, 45 to 70 percent NH_4NO_3), 2070 (oxidizer, ammonium nitrate fertilizers, type A, 70 to 90 percent NH_4NO_3), 2071 (no label, ammonium nitrate fertilizers, type B, fertilizer mixture <70 percent NH_4NO_3, <0.4 percent combustibles), 2426 (oxidizer, solution with not less than 15 percent water); CAS No. 6484-52-2; OHM-TADS No. 7216588; STCC No. 4918310-12 (solid), 4918774 (solution)

GRADES & PURITIES

Fertilizer grade: solid (prills) 95 to 99 percent NH_4NO_3 (33 to 35 percent N)

Solution: <40 percent NH_4NO_3, 50 percent NH_4NO_3, 83 percent NH_4NO_3

Explosive grade: solid (prills) 95 to 97 percent NH_4NO_3

IMMEDIATE CONCERNS

Fire: Not flammable, but may decompose or explode under high temperature or shock

Human Health: Slightly toxic by ingestion

Environment: Harmful to aquatic life in high concentrations

PHYSICAL PROPERTY DATA

State (15°C, 1 atm): solid
Boiling Point: decomposes
Melting Point: 169.6°C
Density: 1.725 g/cm^3
Solubility (in water): 118 g/100 mL (0°C)
Behaviour (in water): sinks and mixes
Odour Threshold: odourless

ENVIRONMENTAL CONCERNS

Ammonium nitrate is a nutrient. Spills may cause massive algal blooms in static waters and affect local species population balance in the aquatic environment. There is no bioaccumulation or food chain contamination potential.

HUMAN HEALTH

No TLV or IDLH established.

Exposure Effects

Inhalation: Dust is irritating to eyes and mucous membranes. If inhaled, causes coughing or difficult breathing. Toxic nitrogen oxides, due to decomposition of material at high temperature, can quickly cause acute respiratory problems

Contact: Contact with skin and eyes causes irritation

Ingestion: Causes nausea, hypertension and, in the case of massive doses, death.

IMMEDIATE ACTION

Spill Control

Restrict access to spill site. Issue warning: "OXIDIZER". Call fire department and notify manufacturer. Stop the flow and contain spill, if safe to do so. Keep contaminated water from entering sewers or watercourses.

Fire Control

Not flammable, but may decompose or explode when heated. Use flooding amounts of water to extinguish. Cool fire-exposed containers with water.

COUNTERMEASURES

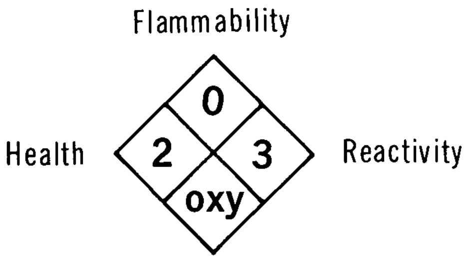
Emergency Control Procedures in/on

Soil: Construct barriers to contain runoff from water application. Remove material by manual or mechanical means

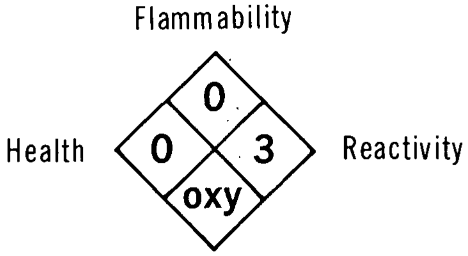
Water: Contain by damming, water diversion or natural barriers. Dredge or vacuum pump to remove undissolved material, if possible. Dilute or treat contaminated water or use as a fertilizer

NFPA HAZARD CLASSIFICATION

FIRE



NON-FIRE



2 PHYSICAL AND CHEMICAL DATA

Physical State Properties

Appearance	Transparent to white or grey granules (Merck 1983)
Usual shipping states	Solid or Liquid (solutions) (CCD 1977)
Physical state at 15°C, 1 atm	Solid
Melting point	169.6°C (CRC 1980; Ullmann 1975)
Boiling point	Solid decomposes before boiling (Dupont MSDS 1980)
Decomposition temperature	302°C (NFPA 1978)

Densities

Density	Solid: 1.725 g/cm^3 (20°C) (Ullmann 1975) Solution: 1.2250 g/cm^3 (20°C) (50 percent solution) (Ullmann 1975)
Specific gravity	1.725 (25°C) (CRC 1980)
Bulk density	0.88 to 0.95 g/cm^3 (high density, fertilizer grade) (CCPA 1982) 0.72 to 0.80 g/cm^3 (low density, explosive grade) (CCPA 1982)

Fire Properties

Flammability	Nonflammable oxidizing agent that supports combustion (NFPA 1978)
Upper and lower explosive limits	All concentrations of ammonium nitrate are stable at temperatures less than the melting point in the absence of organic matter (Kirk-Othmer 1980)
Decomposition temperature	302°C (NFPA 1978) > 250°C (PB 81-152928)
Decomposition products	Water, nitrogen, oxygen and nitrogen oxides (e.g., nitrous oxide) (Ullmann 1975)
Behaviour in a fire	Heating may result in detonation (Dupont MSDS 1980)
Explosiveness	Capable of undergoing detonation if heated under confinement that permits high pressure buildup or if subjected to strong shocks (NFPA 1978)

Heat of explosion	1,620 kJ/kg (Ullmann 1975) 1,601 kJ/kg (Meyer 1977)
Volume of detonation gases	980 L/kg (Meyer 1977)
Detonation velocity	2.7 km/s (Kirk-Othmer 1980; Meyer 1977)
Impact sensitivity	47 Nm - no reaction (Meyer 1977)
Specific energy	530 kJ/kg (Ullmann 1975)
Lead block test	180 cm^3/kg (a measure of the deformation in lead when 10 g exploded) (Ullmann 1975; Meyer 1977)

Other Properties

Molecular weight of pure substance	80.04 (CRC 1980)
Constituent components of typical commercial grade	Fertilizer grade: > 95 percent ammonium nitrate, < 5 percent moisture, clay, etc., Explosive Grade: > 95 percent ammonium nitrate, < 5 percent organics, etc. (Ullmann 1975; Kirk-Othmer 1980)
Hygroscopicity	Very hygroscopic (Merck 1983)
Vapour pressure	1.5 kPa (saturated solution at 20°C) (Kirk-Othmer 1980) 10 kPa (10 percent solution at 50°C) (Ullmann 1975)
Latent heat of fusion	6.110 kJ/mole (at melting point) (Perry 1973)
Latent heat of sublimation	174.5 kJ/mole (20°C) (Kirk-Othmer 1980)
Heat of formation	Crystal: -339.9 kJ/mole (25°C) (Lange's Handbook 1979) Aqueous: -364 kJ/mole (25°C) (Kirk-Othmer 1980) -339.9 kJ/mole (25°C) (Bailar 1973)
Heat of solution	-27.1 kJ/mole (infinite dilution) (18°C) (Perry 1973) -26.4 kJ/mole (infinite dilution) (20°C) (Ullmann 1975) 16.75 kJ/mole (integral of 1 mole to saturation) (Ullmann 1975)
Heat capacity constant pressure (C_p)	Solid: 139 J/(mole•°C) (25°C) (Lange's Handbook 1979) 136.2 J/(mole•°C) (25°C) (Kirk-Othmer 1980; Ullmann 1975) Solution: 204.0 J/(mole•°C) (18-50°C) (64 percent solution) (Kirk-Othmer 1980)

Coefficient of thermal expansion	9.82×10^{-4}/°C (20°C) 9.20×10^{-4}/°C (0°C) 11.13×10^{-4}/°C (100°C) (Kirk-Othmer 1978)
pH of aqueous solution	5.43 (0.1 M solution) (Merck 1983)
Eutectic compositions	41.2 percent aqueous solution (f.p. -17.35°C) (Lange's Handbook 1979)
Entropy	Crystal: 151.1 J/(mole•°C) (Bailar 1973) Aqueous: 259.8 J/(mole•°C) (Bailar 1973)

Solubility

In water	118 g/100 mL (0°C) 187 g/100 mL (20°C) 843 g/100 mL (100°C) (Kirk-Othmer 1980)
In other common materials	Ethanol: 3.8 g/100 mL (20°C) (CRC 1980) Methanol: 17.1 g/100 mL (20°C) (CRC 1980) Soluble in acetone and ammonia Insoluble in diethyl ether (CRC 1980)

General Discussion on Chemical Properties and Behaviour

Solid ammonium nitrate occurs in five different crystalline forms (Kirk-Othmer 1980; Ullmann 1975):

Geometry	Temperature Range (°C)
Cubic	125.2 to 169.6
Tetragonal	84.2 to 125.2
Rhombic	32.1 to 84.2
Rhombic	-18 to 32.1
Tetragonal	less than -18

The transition at 84.2°C (tetragonal to rhombic) is of particular interest because of the sudden expansion shown by the crystals during the cooling through this point. The 32.1°C transition is felt to be important because of the closeness to normal storage temperatures, although no documentation has been found on expansion/contraction at this point.

Concern of the explosive nature of ammonium nitrate has existed for a number of years. Ammonium nitrate decomposes at 200 to 260°C by the following reaction (Kirk-Othmer 1980; Ullmann 1975):

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

This reaction is not explosive and has an enthalpy of -37.3 kJ/mole. The explosive reaction is thought to be either:

$2NH_4NO_3 \rightarrow 2N_2 + 4H_2O + O_2$ or
$4NH_4NO_3 \rightarrow 3N_2 + 2NO_2 + 8H_2O$

The enthalpy of reaction for the latter is -103 kJ/mole (Ullmann 1975). One reference indicated that the first reaction is more likely at temperatures greater than 300°C and the latter is more likely at temperatures under 300°C (Bailar 1973).

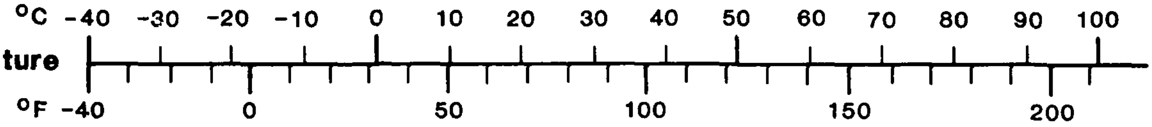
Explosive-grade ammonium nitrate is prepared from low-density solid mixed with carbon carriers such as wood or oils, catalysts such as aluminum powder, and water desensitization agents and sensitizers such as TNT. The catalysts and sensitizers may be added just before use to allow for safe transportation.

Fertilizer-grade ammonium nitrate has exploded on a number of occasions. These incidents can be attributed to a number of factors (Kirk-Othmer 1980; NFPA 1978; Ullmann 1975; Bailar 1973):

a) high temperatures (above 250°C);
b) high pressures;
c) shock (such as another explosion);
d) contamination by organic or carbon-containing materials;
e) presence of catalytic contaminants such as chlorides, chromium, cobalt, copper; and
f) ammonium nitrate itself being in a "dry" state or containing little moisture.

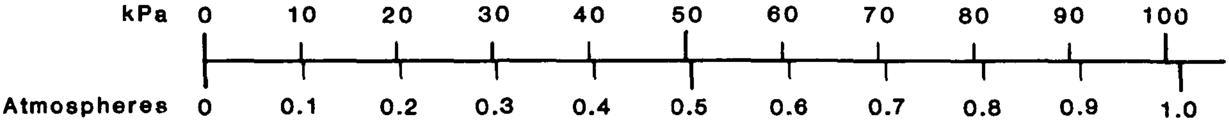
CONVERSION NOMOGRAMS

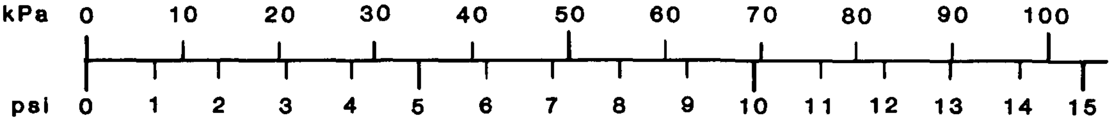
Temperature

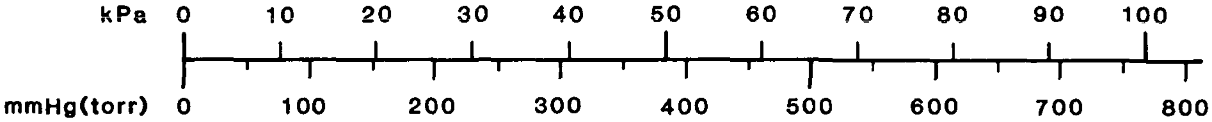


Pressure

1 kPa = 1,000 Pa







Viscosity

Dynamic 1 Pa·s = 1,000 centipoise (cP)

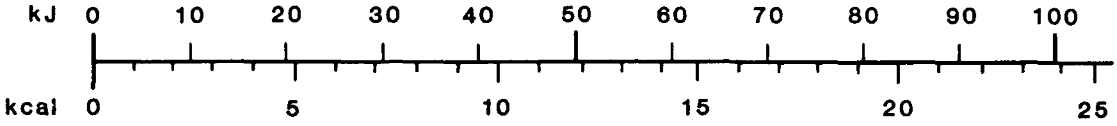
Kinematic 1 m^2/s = 1,000,000 centistokes (cSt)

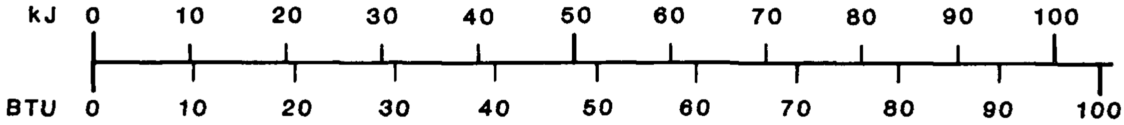
Concentration (in water)

1 ppm ≅ 1 mg/L

Energy (heat)

1 kJ = 1,000 J





Density

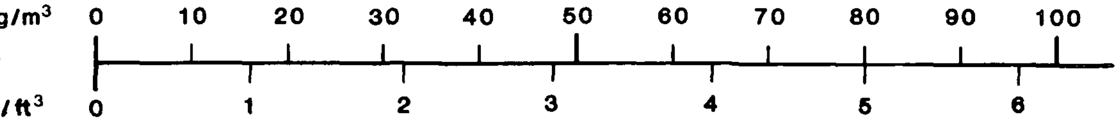


FIGURE 1

AMMONIUM NITRATE

SOLUBILITY IN WATER vs TEMPERATURE

Reference: KIRK-OTHMER 1980

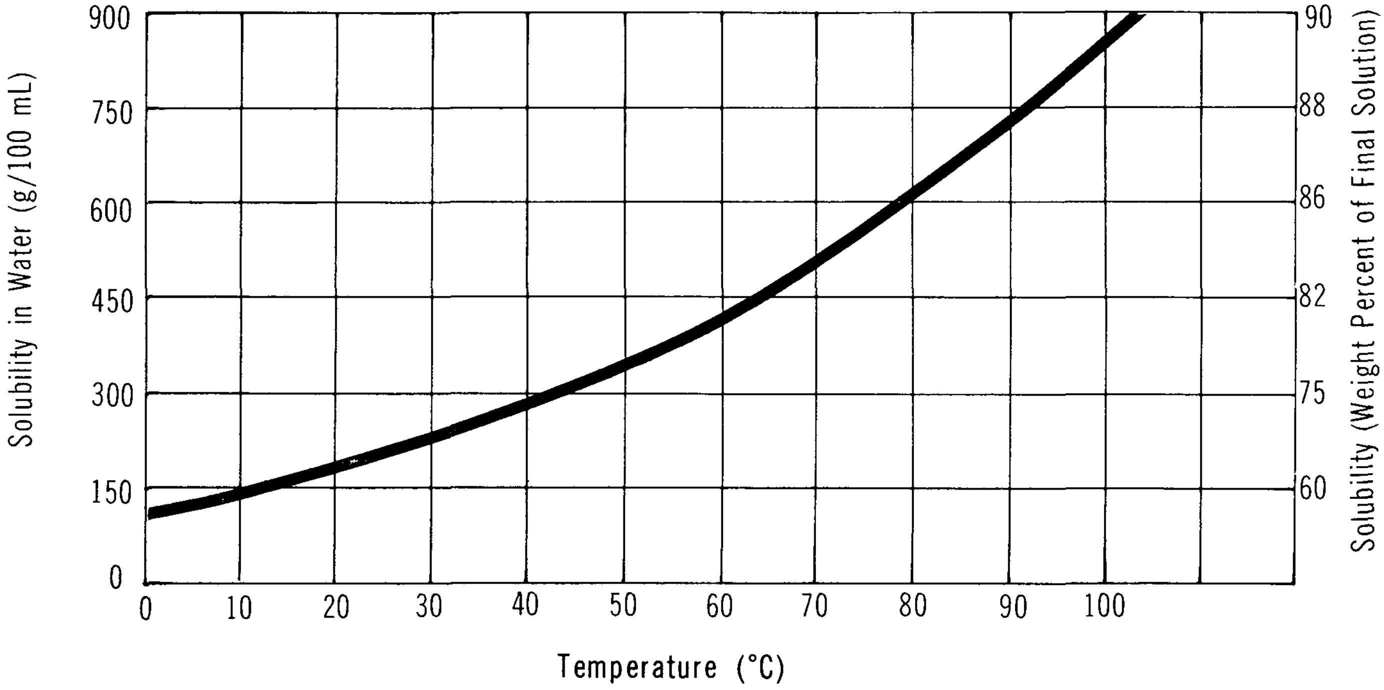
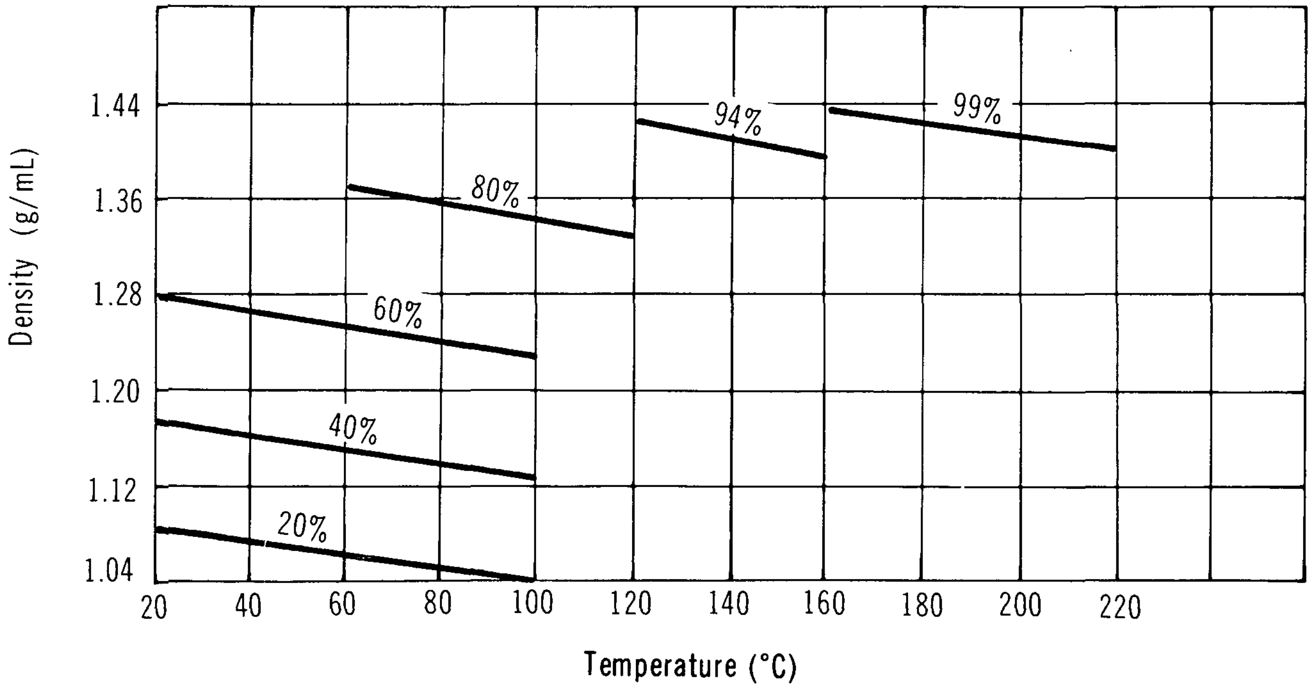


FIGURE 2

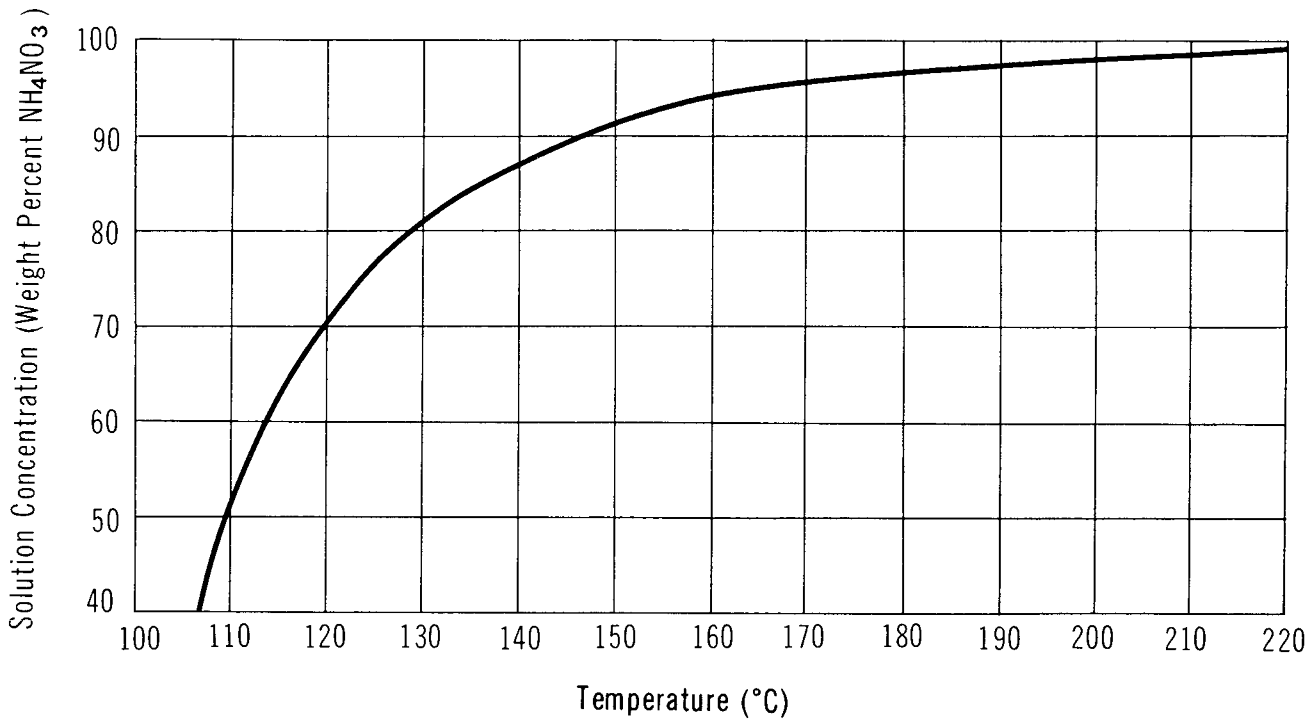
AMMONIUM NITRATE

DENSITY OF SOLUTIONS

Reference: ULLMANN 1975



BOILING POINT OF SOLUTIONS



3 COMMERCE AND PRODUCTION

3.1 Grades, Purities (Kirk-Othmer 1980; Corpus 1984; PB 81-152928)

Ammonium nitrate is available in two general grades: fertilizer and explosive. Fertilizer-grade is the most common, accounting for 79 percent of the domestic demand in 1982. Fertilizer-grade contains 95 percent or greater ammonium nitrate and is made of high-density prills. Most fertilizer-grade ammonium nitrate is sold in solid form as prills or granular material. It is also available in aqueous solutions of strengths up to 40 percent and is occasionally transported in solutions up to 83 percent. Fertilizer-grade material is often sold by the percentage of nitrogen (35 percent nitrogen = 100 percent ammonium nitrate). Explosive-grade ammonium nitrate contains 95 percent or greater ammonium nitrate and is made of low-density prills. It is formulated with carbon carriers such as wood or oils, water desensitization agents, catalysts such as aluminum powder, and sensitizers such as TNT. The latter two ingredients may be omitted for transport to render the material stable.

3.2 Domestic Manufacturers (Scott 1979; CCPA 1981; CBG 1980)

These are corporate headquarters' addresses and are not intended as spill response contacts.

C-I-L Inc.
90 Sheppard Avenue East
North York, Ontario
M2N 6H2
(416) 229-7000

Cominco
200 Granville Street
Vancouver, British Columbia
V6C 2R2
(604) 682-0611

Cyanamid Canada Inc.
2255 Sheppard Avenue East
Willowdale, Ontario
M2J 4Y5
(416) 498-9405

Dupont Canada Inc.
555 Dorchester Boulevard West
P.O. Box 6000
Montreal, Quebec
H3C 2V1
(514) 861-3861

Esso Chemical Canada
2300 Yonge Street
Toronto, Ontario
M5W 1K3
(416) 488-6600

Nitrochem Inc.
Suite 800
2055 Peel Street
Montreal, Quebec
H3A 1V4
(514) 849-9222

Simplot Chemical Co. Ltd.
P.O. Box 940
Brandon, Manitoba
R7A 6A1
(204) 728-5701

Western Co-Operative Fertilizers
11111 Barlow Tr. S.E.
P.O. Box 2500
Calgary, Alberta
T2P 2N1
(403) 279-4421

3.3 **Other Suppliers** (Corpus 1984; Scott 1979)

U.S. Steel International of Canada Ltd.
7 King Street East
Toronto, Ontario
M5C 1A8
(416) 364-6291

United Cooperatives of Ontario
151 City Centre Drive
Mississauga, Ontario
L5B 1M7
(416) 270-3560

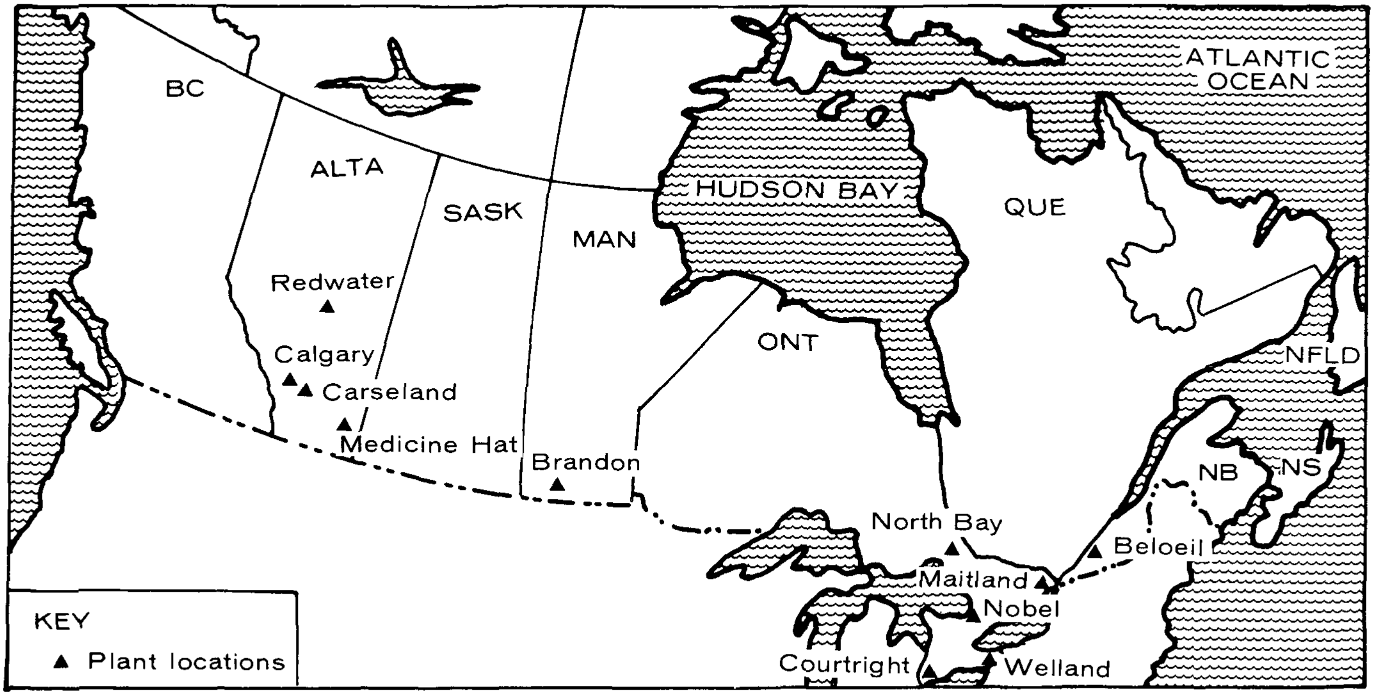
3.4 Major Transportation Routes

Current Canadian production of ammonium nitrate is located in Quebec, Ontario, Manitoba and Alberta. Major plants are in Niagara Falls, near Sarnia, Ontario; near Winnipeg, Manitoba; and in Southern Alberta. These are shown in Figure 4. Transportation of ammonium nitrate is universal across Canada.

FIGURE 4

AMMONIUM NITRATE

CANADIAN PRODUCERS



3.5 **Production Level** (Corpus 1984)

Company, Plant Location	Nameplate Capacity kilotonnes/yr (1982)
C-I-L, Beloeil Que.	65
C-I-L, Nobel, Ont.	20
C-I-L, Courtright, Ont.	145
C-I-L, Carseland, Alta.	225
Cominco, Calgary, Alta.	20
Cyanamid Canada, Niagara Falls, Ont.	200
Dupont Canada, North Bay, Ont.	25
Esso Chemical Canada, Redwater, Alta.	210
Nitrochem, Maitland, Ont.	170
Simplot Chemical, Brandon, Man.	135
Western Cooperative Fertilizers, Calgary, Alta.	77
Western Cooperative Fertilizers, Medicine Hat, Alta.	60
TOTAL	1,352
Domestic Production (1982)	1,200
Imports (1982)	10
TOTAL SUPPLY	1,210

3.6 The Manufacture of Ammonium Nitrate

3.6.1 General. Ammonium nitrate is manufactured in Canada by neutralizing nitric acid with ammonia.

3.6.2 Manufacturing Process (CCPA 1982; Kirk-Othmer 1980). Nitric acid in 55 to 60 percent concentration is reacted with ammonia gas in a stainless steel vessel known as a neutralizer under controlled pressure and temperature. The neutralizer can be operated under pressure or at atmospheric pressure, depending upon different process designs. The heat of the reaction raises the temperature of the mixture, causing the water to evaporate, concentrating the mixture to 80 to 85 percent ammonium nitrate solids. The overall reaction is

$$NH_3\ (g) + NNO_3\ (aq) \rightarrow NH_4NO_3\ (aq)$$

Overheating in the neutralizer must be avoided; a high temperature trip system to shut off the feed to the neutralizer is usually provided.

Ammonium nitrate prills are produced by first concentrating the solution by vacuum or falling film evaporator. The concentrated liquor is then sprayed into a prill tower to form the solid. After drying, cooling and screening, an anticaking agent such as clay or diatomaceous earth is added on the prill surface.

3.7 **Major Uses in Canada** (Corpus 1984)

Ammonium nitrate is used in direct soil application, fertilizer mixtures, and explosives. In 1982, 54 percent of domestic demand was sold for direct soil application, 25 percent for formulation of other fertilizers, and 21 percent for explosives. In the same year, 39 percent of the total domestic demand was exported.

3.8 **Major Buyers in Canada** (CBG 1980; Corpus 1984)

Agricultural Chemicals, London, Ont.
Alberta Wheat Pool, Edmonton, Alta.
Cargil Grain, Winnipeg, Man.
Coopératives Fédérées du Québec, Montréal, Qué.
Dupont Canada, North Bay, Ont.
Manitoba Pool Elevators, Winnipeg, Man.
Saskatchewan Wheat Pool, Regina, Sask.
Swift Chemical, Toronto, Ont.
United Cooperatives of Ontario, Mississauga, Ont.
United Grain Growers, Winnipeg, Man.
Winfield Chemical, Woodstock, N.B.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation

4.1.1 Bulk Shipment. Bulk shipment of ammonium nitrate (fertilizer-grade) is primarily by truck (open dump type) and by train (box car).

4.1.2 Packaging and Transport

Most ammonium nitrate fertilizer is packaged and transported in either multi-wall paper bags or in plastic bags. The most common weight of these bags is 27 kg (60 lb.), with a range of 23 to 50 kg (50 to 110 lb.). Table 2 provides details of available packaging modes. In the USA, it is estimated that 72 percent of the material is transported by truck and 28 percent by rail (PB 271984; DPIMR 1982). The situation is expected to be similar in Canada.

Ammonium nitrate, especially that which is not coated, agglomerates and cakes in contact with moisture; in packaging, emphasis is therefore placed on protection from moisture.

Solutions are occasionally transported by tank truck or car. Solution strengths vary from <40 to 83 percent.

4.2 Compatibility with Materials of Construction

The compatibility of ammonium nitrate solid and solutions with materials of construction is indicated in Table 3. The unbracketed abbreviations are described in Table 4. The rating system is briefly described below:

Recommended: This material will perform satisfactorily in the given application.

Conditional: Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.

Not Recommended: Material will be severely affected in this application and should not be used.

TABLE 2 PACKAGING REQUIREMENTS FOR AMMONIUM NITRATE (RTDCR 1974)

	Packaging Type
FERTILIZERS (oxidizers or no label)	
Mixed fertilizers or ammonium nitrate with approved coating	- Burlap bags less than 91 kg (200 lb.)
	*- Multi-wall paper bags of at least 4-ply construction including a moisture-barrier ply, less than 50 kg (110 lb.) net weight
	- Multi-wall paper bags similar to above but of 3-ply construction, less than 36 kg (80 lb.) net weight
	* - Specification 44P, all plastic bags not over 37 kg (81 lb.)
	- Bulk in tightly closed freight cars
Ammonium nitrate and that organically coated	- Wooden or fibreboard boxes with glass, metal or other inside container
	- Metal or fibre drums
	- Metal kegs or barrels
	- Metal cans
Solutions	- Specifications 6A, 6B, 6C metal barrels or drums
	- Specification 17C, 17E, 17H, 37A, 37B metal drums (single trip)
	- Specification 12B, fibreboard boxes with inside container
	- Train tank car - e.g., 111A60ALW1, 111A100ALW or 103ALW
	- Truck tank vehicle
EXPLOSIVE GRADE (as low explosives)	- Specification 10B wooden barrels or kegs not over 91 kg (200 lb.) gross weight
	- Specification 13 metal kegs not less than 178 mm (7 in.) long, 3 to 68 kg (6.25 to 150 lb.)
	- Specification 14, 15A or 16A wooden boxes with inside containers of metal kegs (Spec. 13) or fibre or metal containers not over 0.7 kg (1.5 lb.) capacity each or cotton bags not over 11 kg (25 lb.) capacity each

TABLE 2 PACKAGING REQUIREMENTS FOR AMMONIUM NITRATE (RTDCR 1974) (Cont'd)

	Packaging Type
EXPLOSIVE GRADE (Cont'd)	- Specifications 14, 15A or 16A wooden boxes with strong paper bags of capacity not exceeding 11 kg (25 lb.) - Specifications 12H, 23F or 23H fibreboard boxes with inside cylindrical fibre containers not over 127 mm (5 in.) in diameter and not over 457 mm (18 in.) long with paraffin coating - Specifications 12H, 23F or 23H fibreboard boxes with inside containers of strong paper not exceeding 11 kg (25 lb.) - Specification 15A wooden boxes lined according to Specification 2L

* Indicates most common packaging modes

TABLE 3 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings		23	ABS (DPPED 1967)		
		49	PE (DPPED 1967)		
		60	PVC I PVC II (DPPED 1967)		
	Saturated	66	PVDC (DCRG 1978)		
	Saturated	79	PP (DCRG 1978)		
	Saturated	121	Chlorinated Polyether (DCRG 1978)		
	Saturated	135	PVDF (DCRG 1978)		

TABLE 3 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

Application	Chemical Conc.	Chemical Temp. (°C)	Material of Construction: Recommended	Conditional	Not Recommended
1. Pipes and Fittings (Cont'd)		To operating limit of material	PVC I ABS PE (MWPP 1978)		
2. Valves	All	21, boiling	SS 316 SSJ-20 (JSSV 1979)		
	Saturated	66	CI lined with PVDC (DCRG 1978)		
	Saturated	79	CI lined with PP		
	Saturated	121	CI lined with Chlorinated Polyether (DCRG 1978)		
3. Pumps	All	93	GRP with FPM "O" ring		
	Aqueous Solution		All Iron SS 304 SS 316 High Silicon Cast Iron Monel (HIS 1969)		
4. Others	Saturated	60	uPVC PE PP POM NR NBR IIR EPDM CR FPM CSM (GF)		

TABLE 3 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

Application	Chemical		Material of Construction		
	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
4. Others (Cont'd)		60	PVC (TPS 1978)		
	Saturated	80	PP IIR EPDM CR FPM CSM (GF)	PE POM NBR (GF)	uPVC NR (GF)
	Saturated	82	PP (TPS 1978)		
	Saturated	85	CPVC (TPS 1978)		
	Saturated	100	IIR EPDM CR, FPM CSM (GF)	PP (GF)	uPVC PE POM, NR NBR (GF)
	Saturated	Boiling	SS 302 SS 304 SS 316 SS 430 (ASS) NR* SBR, CR NBR* IIR, CSM EPDM (GPP)	SS 410 (ASS)	Copper Copper Alloys (Kirk-Othmer 1980)
	10 to 50 and 100%	24 to 100	Glass (CDS 1967)		
	60 to 90%	100	Glass (CDS 1967)		
	10 to 50 and 100%	24			Concrete (CDS 1967)
	100%	24			Wood (CDS 1967)

*This material has been given a lower rating in a similar application by another reference.

TABLE 4 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
CI	Cast Iron
	Cast Iron, High Silicone
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene)
CSM	Chlorosulphonated Polyethylene (Hypalon)
	Copper
EPDM	Ethylene Propylene Rubber
FPM	Fluorine Rubber (Viton)
GRP	Glass Reinforced Vinyl Ester
	Glass
	Iron
IIR	Isobutylene/Isoprene (Butyl) Rubber
NBR	Acrylonitrile/Butadiene (Nitrile, Buna N) Rubber
NR	Natural Rubber
	Nickel-Copper Alloy (Monel)
PE	Polyethylene
POM	Polyoxymethylene
PP	Polypropylene
PVC (followed by grade if any)	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PVDF	Polyvinylidene Fluoride
SBR	Styrene/Butadiene (GR-5, Buna S) Rubber
SS (followed by grade)	Stainless Steel
uPVC	Unplasticized Polyvinyl Chloride

5 CONTAMINANT TRANSPORT

5.1 General Summary

Ammonium nitrate is primarily transported as a solid, in granular (prill) form, or occasionnally as an aqueous solution. When spilled in water, all forms will dissolve rapidly. When spilled on soil, the liquid forms will spread on the surface and penetrate into the soil at a rate dependent on the soil type and its water content. Movement of ammonium nitrate toward the water table may be an environmental problem.

Because ammonium nitrate is essentially nonvolatile, vapour dispersion in air is not a problem. Dust may be a problem in certain situations.

Factors considered for the movement of an ammonium nitrate spill in water and soil are as follows:

Contaminant Transport
- Leak or spill
  - Rate of discharge
  - Percent remaining
- Water
  - Diffusion rate
- Soil
  - Depth and time of penetration

It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different, and to some extent inconsistent. This approach allows comparison between chemicals as similar assumptions have been made for each chemical.

5.2 Leak Nomograms

5.2.1 Introduction. Ammonium nitrate is transported primarily as a solid or occasionnally as an aqueous solution. In aqueous form, ammonium nitrate could be transported in a railway tank car. While the capacities of the tank cars vary widely, one tank car (capacity 80 000 L) has been chosen for development of the leak nomograms throughout the EnviroTIPS series to allow for comparison among the various substances.

If a tank car loaded with dilute aqueous solution is punctured on the bottom, all of the contents will drain out by gravity. Higher concentrations of ammonium nitrate solution are highly viscous or solid at normal temperatures; they will not drain by gravity unless the temperature is elevated.

The aim of the nomograms is to provide a simple means to obtain the time history of the conditions in the tank car and the leak rate of the liquid. Because of the low volatility of ammonium nitrate solution and the fact that tank cars are not pressurized, no leak nomograms have been prepared for vapour release from a puncture in the top of the tank.

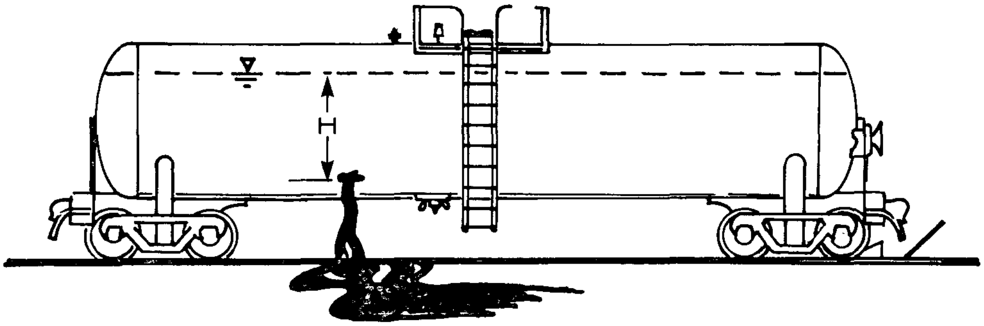


FIGURE 5 TANK CAR WITH PUNCTURE HOLE IN BOTTOM

5.2.2 Nomograms.

5.2.2.1 Figure 6: Percent remaining versus time. Figure 6 provides a means of estimating the percent of liquid remaining in the standard tank car after the time of puncture for a number of different hole diameters. The hole diameter is actually an equivalent diameter and can be applied to a noncircular puncture.

The standard tank car (2.75 m ⌀ x 13.4 m long) is assumed to be initially full (at t=0) with a volume of about 80 000 L of ammonium nitrate solution. The amount remaining at any time (t) is not only a function of the discharge rate over time, but also of the size and shape of the tank car.

5.2.2.2 Figure 7: Discharge rate versus time. Figure 7 provides a means of estimating the instantaneous discharge rate (L/s) at any time (t) after the time of puncture for a number of equivalent hole diameters. The nomogram is only applicable to the standard tank car size with an initial volume of 80 000 L.

FIGURE 6

AMMONIUM NITRATE

PERCENT REMAINING VS TIME

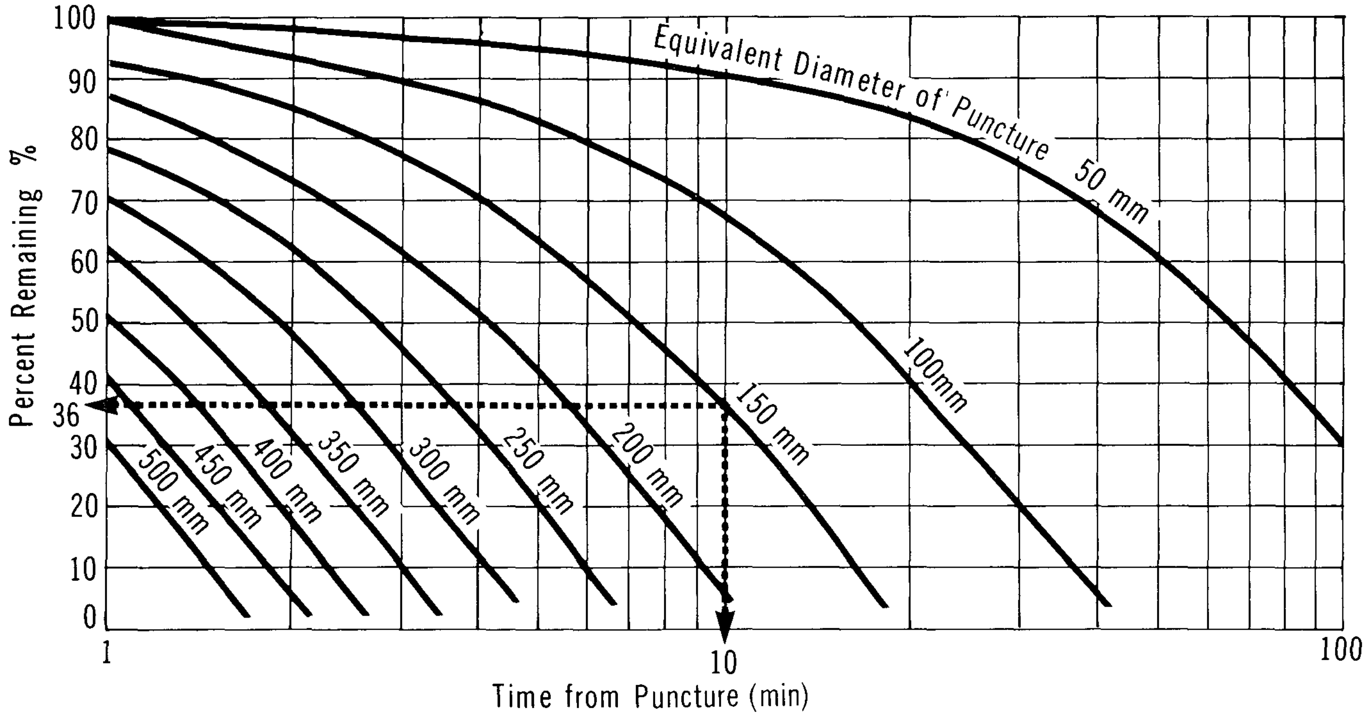
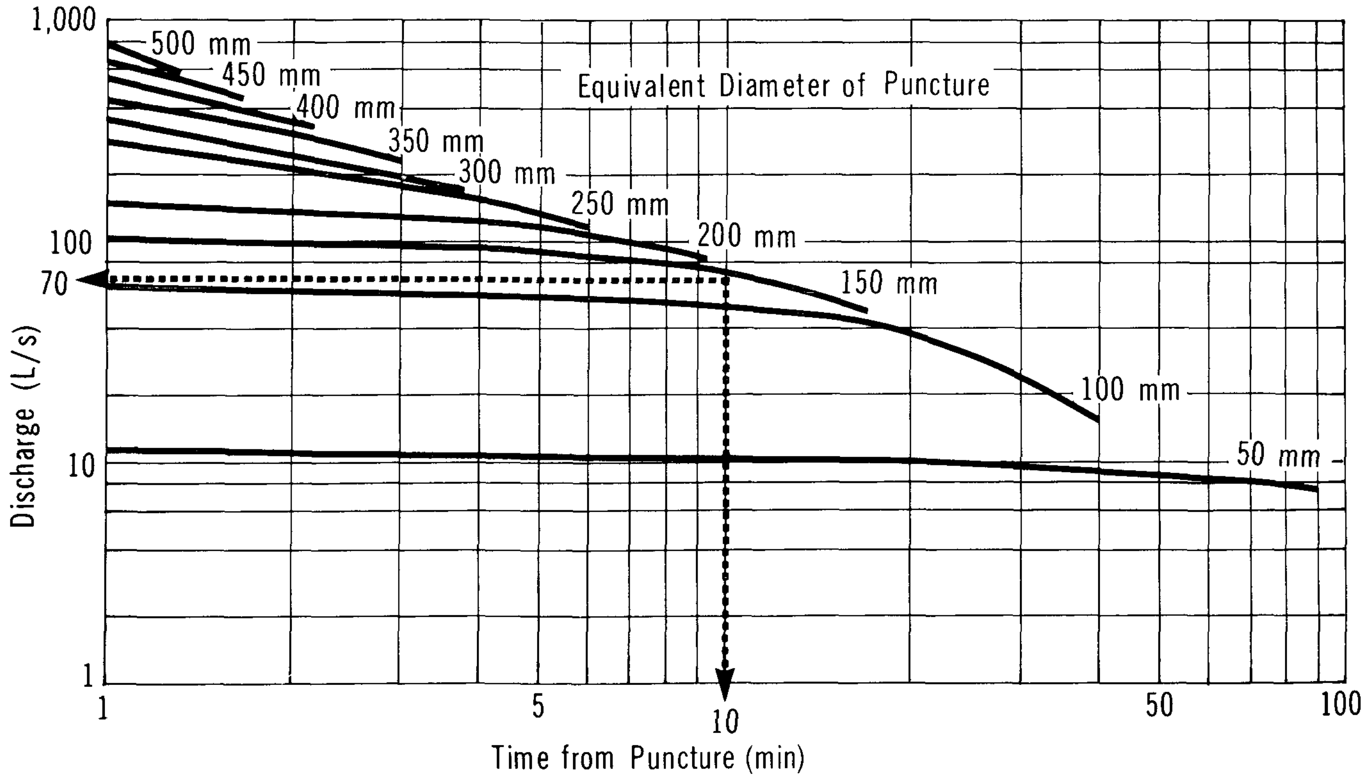


FIGURE 7

AMMONIUM NITRATE

DISCHARGE RATE VS TIME



5.2.3 Sample Calculations.

i) Problem A

The standard tank car (2.75 m ∅ x 13.4 m long) filled with a 30 percent aqueous solution of ammonium nitrate has been punctured on the bottom. The equivalent diameter of the hole is 150 mm. What percent of the initial 80 000 L remains after 10 minutes?

Solution to Problem A

- Use Figure 6
- With t=10 min and d=150 mm, the amount remaining is about 36 percent or 28,800 L

ii) Problem B

With the same conditions as Problem A, what is the instantaneous discharge rate from the tank 10 minutes after the accident?

Solution to Problem B

- Use Figure 7
- With t=10 min and d=150 mm, the instantaneous discharge rate (q) = 70 L/s

5.3 Dispersion in Air

Because ammonium nitrate is nonvolatile, there is no significant potential for vapour dispersion in air. Dusting may occur in certain spill situations, but because of the many variables involved this phenomenon is not modelled here.

5.4 Behaviour in Water

5.4.1 Introduction. When spilled on a water surface, ammonium nitrate will dissolve rapidly. Mixing takes place and the spill is diluted. This mixing can generally be described by classical diffusion equations with one or more diffusion coefficients. In rivers, the principal mixing agent is stream turbulence, while in calm water mixing takes place by molecular diffusion.

To estimate the pollutant concentration in a river downstream from a spill, the turbulent diffusion has been modelled. The model employed is strictly applicable to neutrally buoyant liquids and solids that dissolve in water. As ammonium nitrate is denser than water, the maximum concentration would be expected near the bottom in the first hours after a spill.

The one-dimensional model uses an idealized rectangular channel section and assumes a uniform concentration of the pollutant throughout the section. Obviously, this applies only to points sufficiently far downstream of the spill where mixing and dilution have distributed the pollutant across the entire river channel. The model is applicable to rivers where the ratio of width to depth is less than 100 ($W/d < 100$) and assumes a Manning's roughness coefficient of 0.03. Details of the model are outlined in the Introduction Manual.

No modelling has been carried out for molecular diffusion in still water. Rather, nomograms have been prepared to define the hazard zone and the average concentration within the hazard zone as a function of spill size, but independent of time.

5.4.2 Nomograms. The following nomograms are presented to calculate pollutant concentrations in non-tidal rivers and in lakes (still water).

Non-tidal Rivers

Figure 9: time versus distance for a range of average stream velocities
Figure 10: hydraulic radius versus channel width for a range of stream depths
Figure 11: diffusion coefficient versus hydraulic radius for a range of average stream velocities
Figure 12: alpha* versus diffusion coefficient for various time intervals
Figure 13: alpha versus delta* for a range of spill sizes
Figure 14: maximum concentration versus delta for a range of river cross-sectional areas

Lakes or Still Water Bodies

Figure 15: volume versus radius for the hazard zone for a range of lake depths
Figure 16: average concentration versus volume for the hazard zone for a range of spill sizes

The flowchart in Figure 8 outlines the steps required to estimate downstream concentration after a spill and identifies the nomograms to be used. These nomograms (Figures 9 through 14) are described in the following sub-sections.

5.4.2.1 Nomograms for non-tidal rivers.

Figure 9: Time versus distance. Figure 9 presents a simple relationship between average stream velocity, time, and distance. Using an estimate of average

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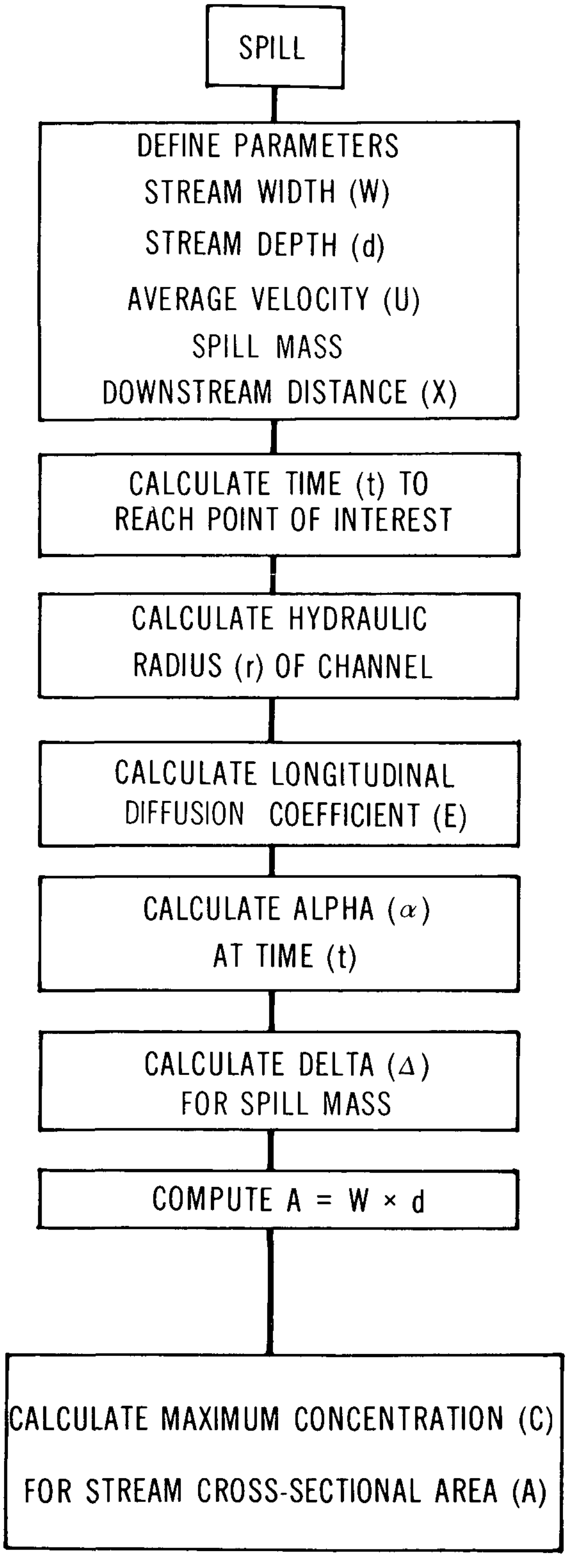
* Alpha and delta are conversion factors only and are of no significance other than to facilitate calculation of downstream concentration.

FLOW CHART TO DETERMINE POLLUTANT CONCENTRATION IN NON-TIDAL RIVERS



Step 1: Observed or Estimated

$W =$ ________ m

$d =$ ________ m

$U =$ ________ m/s

MASS = ________ tonnes

$X =$ ________ m

Step 2: Use Figure 9

$t =$ ________ minutes

Step 3: Use Figure 10

$r =$ ________ m

Step 4: Use Figure 11

$E =$ ________ m^2/s

Step 5: Use Figure 12

$\alpha =$ ________

Step 6: Use Figure 13

$\Delta =$ ________

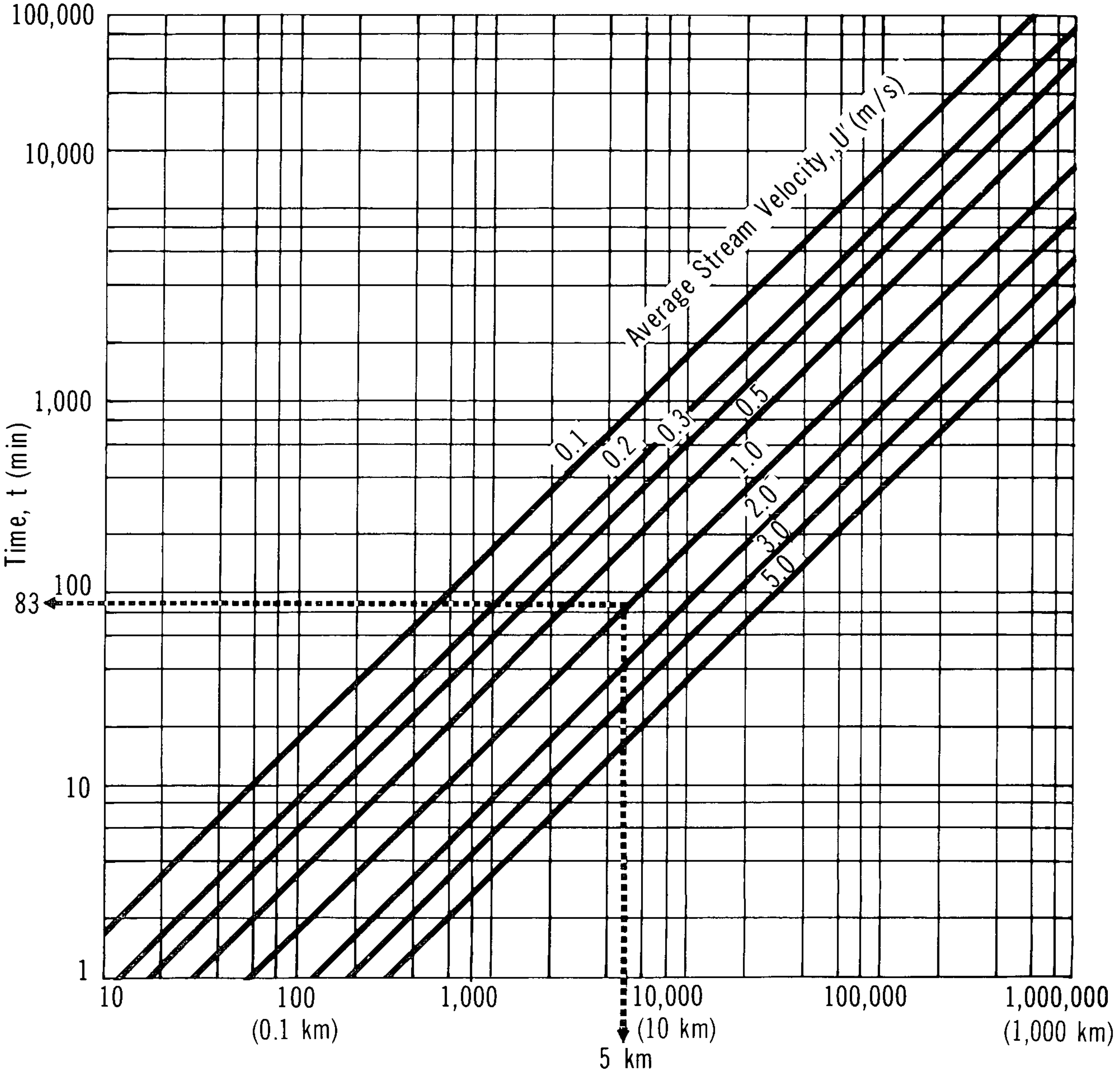
Step 7: Compute stream cross-sectional Area (A)

$A = W \times d$ ______ m^2

Step 8: Use Figure 14

$C =$ ________ ppm

TIME vs DISTANCE



stream velocity (U), the time (t) to reach any point of interest, at some distance (X) downstream of the spill, can be readily obtained from Figure 9.

Figure 10: Hydraulic radius versus channel width. The model used to estimate downstream pollutant concentration is based on an idealized rectangular channel of width (W) and depth (d). The hydraulic radius (r) for the channel is required in order to estimate the turbulent diffusion coefficient (E). The hydraulic radius (r) is defined as the stream cross-sectional area (A) divided by the wetted perimeter (P). Figure 10 is a nomogram for computation of the hydraulic radius (r) using the width and depth of the idealized river cross-section.

Figure 11: Diffusion coefficient versus hydraulic radius. Figure 11 permits calculation of the longitudinal diffusion coefficient (E), knowing the hydraulic radius (r) from Figure 10 and the average stream velocity (U).

Figure 12: Alpha versus diffusion coefficient. Figure 12 is used to estimate a conversion factor, alpha (α), which is a function of the diffusion coefficient (E) and the time (t) to reach the point of interest downstream of the spill.

Figure 13: Alpha versus delta. A second conversion factor, delta (Δ), must be estimated from Figure 13 to allow determination of the pollutant concentration at the point of interest. Delta (Δ) is a function of alpha (α) and the spill size.

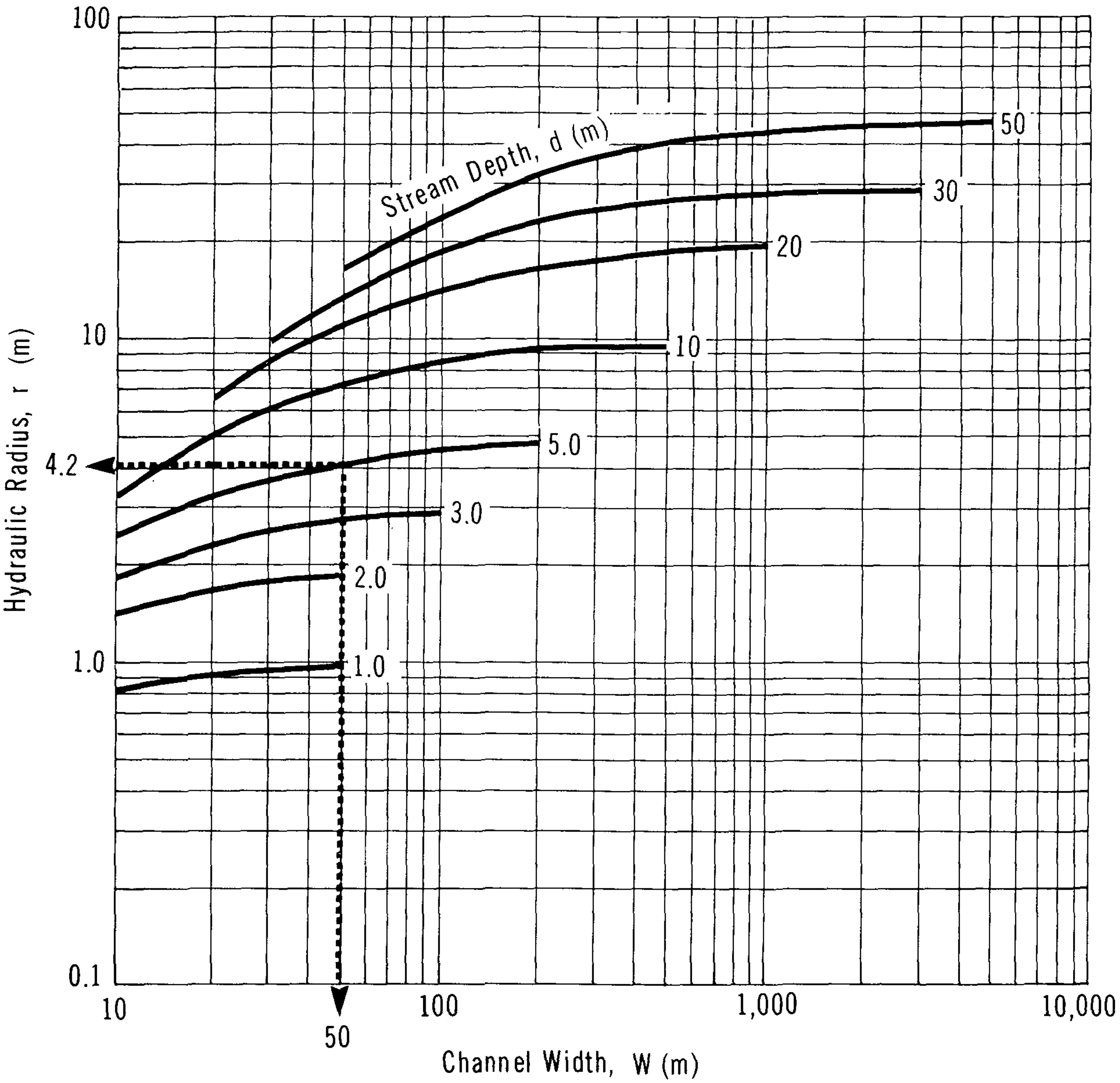
Figure 14: Maximum concentration versus delta. Figure 14 represents the final step for calculation of the maximum downstream pollutant concentration (C) at the point of interest. Using the factor delta (Δ) and knowing the stream cross-sectional area (A), the concentration (C) is readily obtained from the nomogram. The value obtained from Figure 14 applies to neutrally buoyant liquids or solids and will vary somewhat for other pollutants which are heavier or lighter than water.

5.4.2.2 Nomograms for lakes or still water bodies.

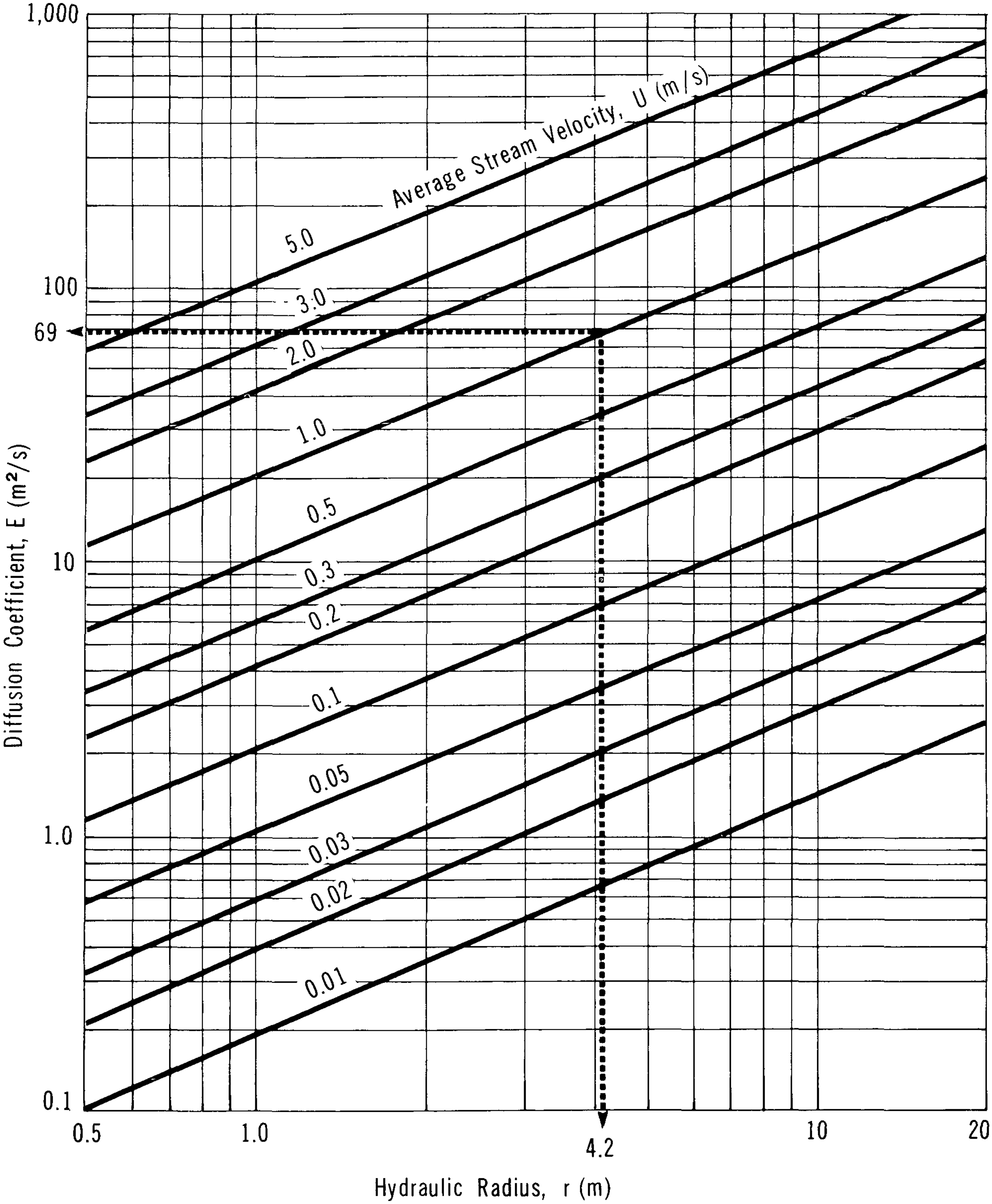
Figure 15: Volume versus radius. The spill of a neutrally buoyant liquid in a lake in the absence of wind and current has been idealized as a cylinder of radius (r) and length (d), equivalent to the depth of the lake at the point of spill. The volume of water in the cylinder can be obtained from Figure 15. The radius (r) represents the distance from the spill to the point of interest.

Figure 16: Average concentration versus volume. For a known volume of water (within the idealized cylinder of radius (r) and length (d)), the average concentration

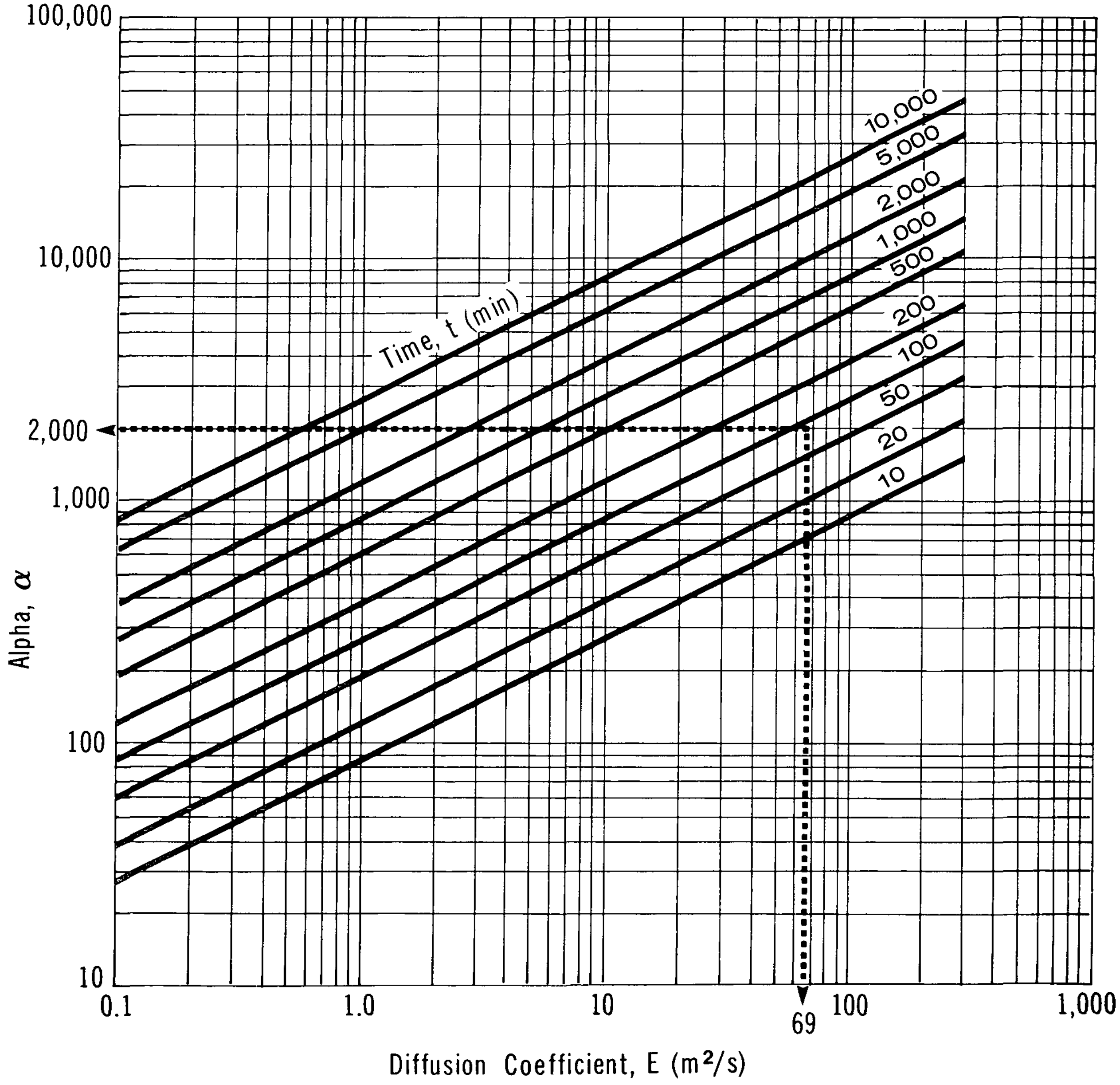
HYDRAULIC RADIUS VS CHANNEL WIDTH



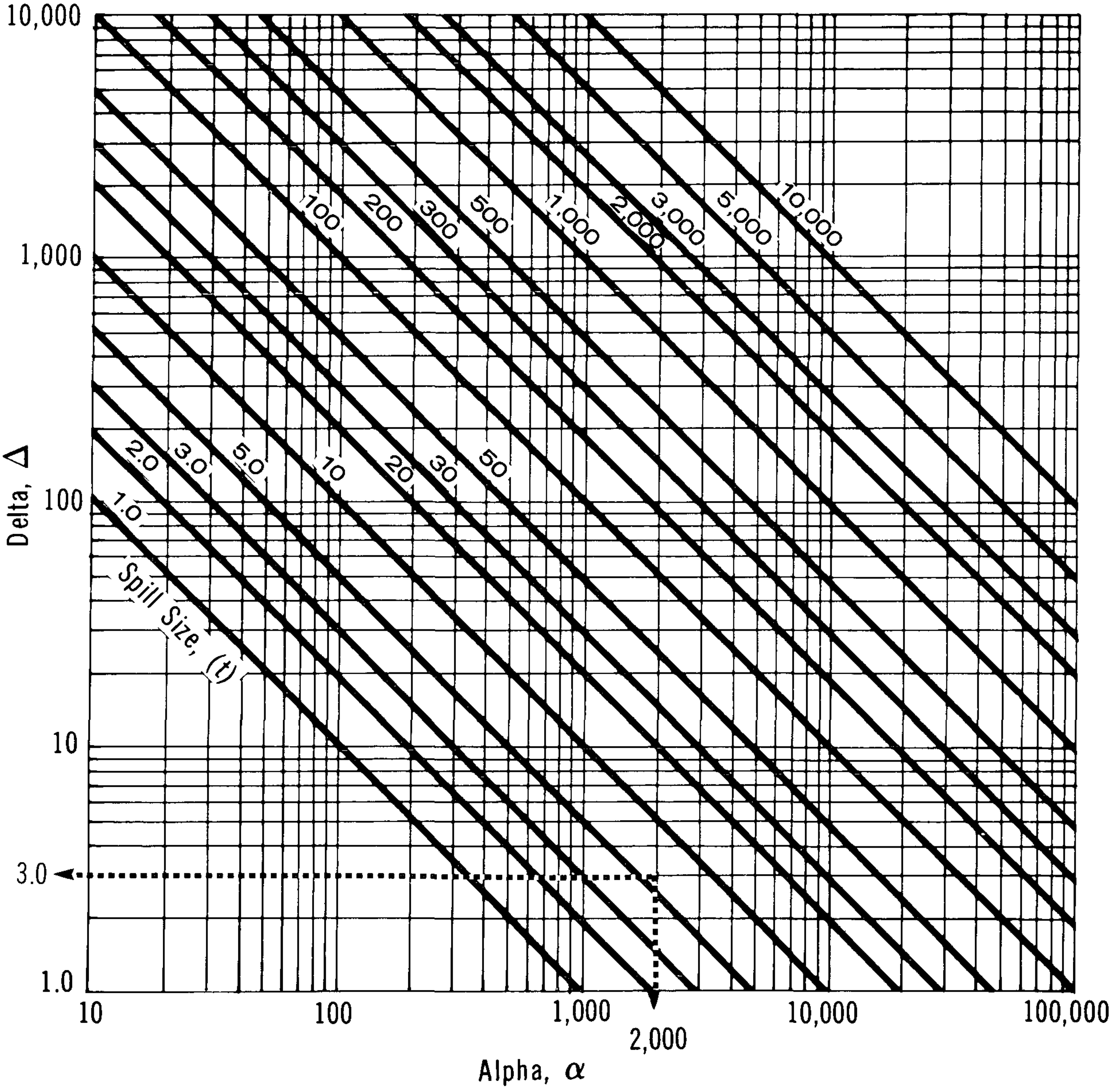
DIFFUSION COEFFICIENT VS HYDRAULIC RADIUS



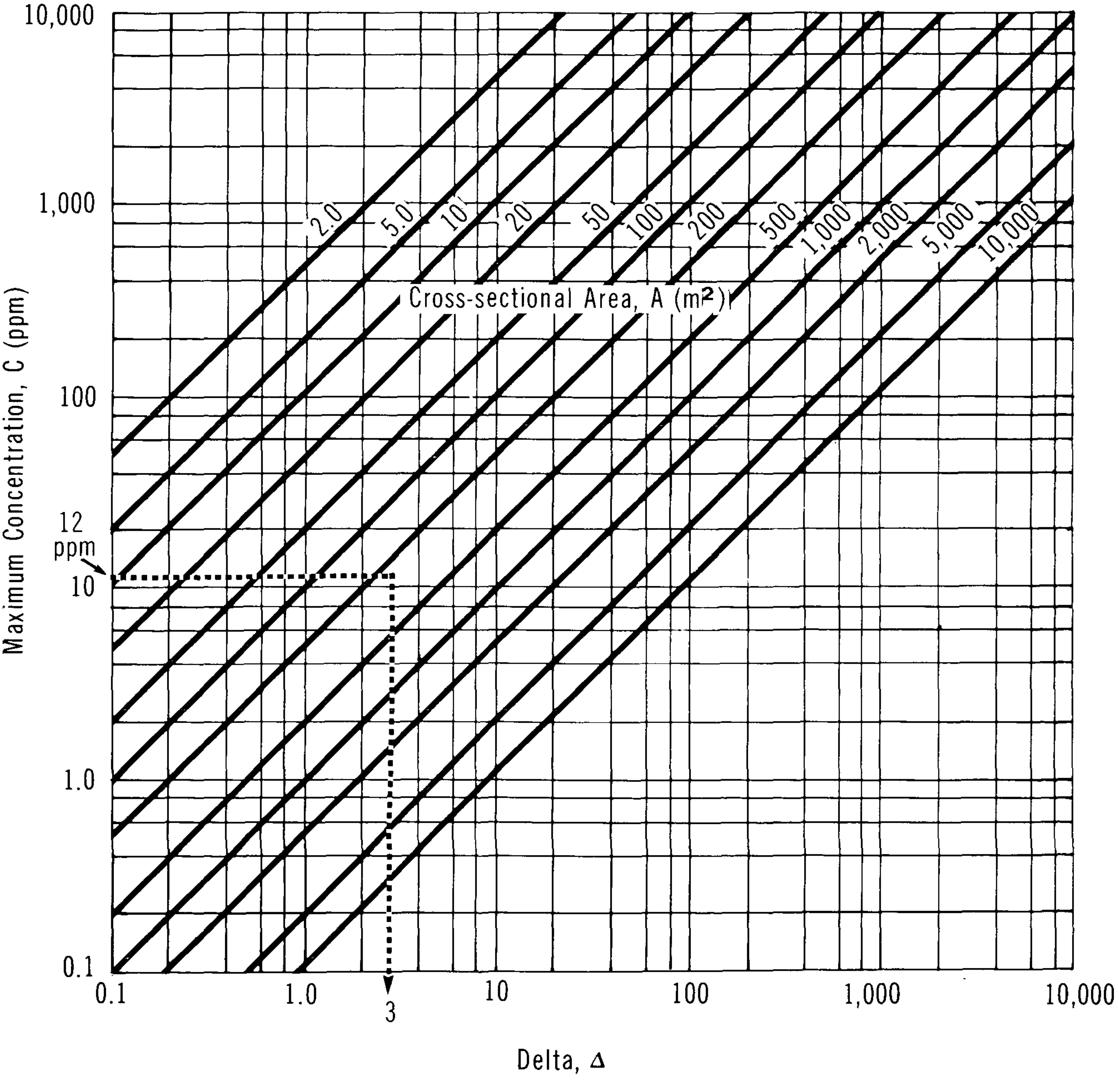
ALPHA vs DIFFUSION COEFFICIENT



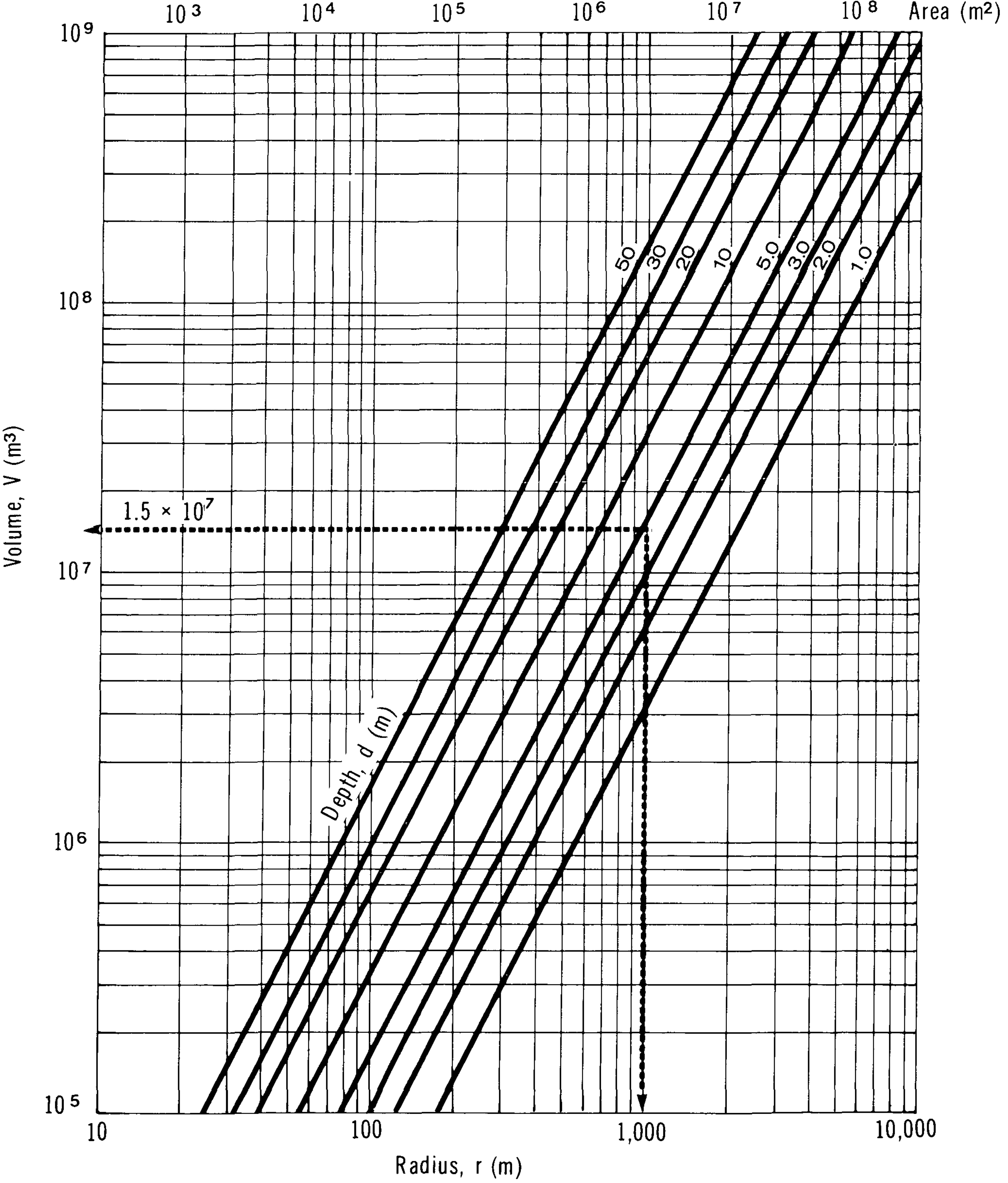
ALPHA vs DELTA



MAXIMUM CONCENTRATION vs DELTA

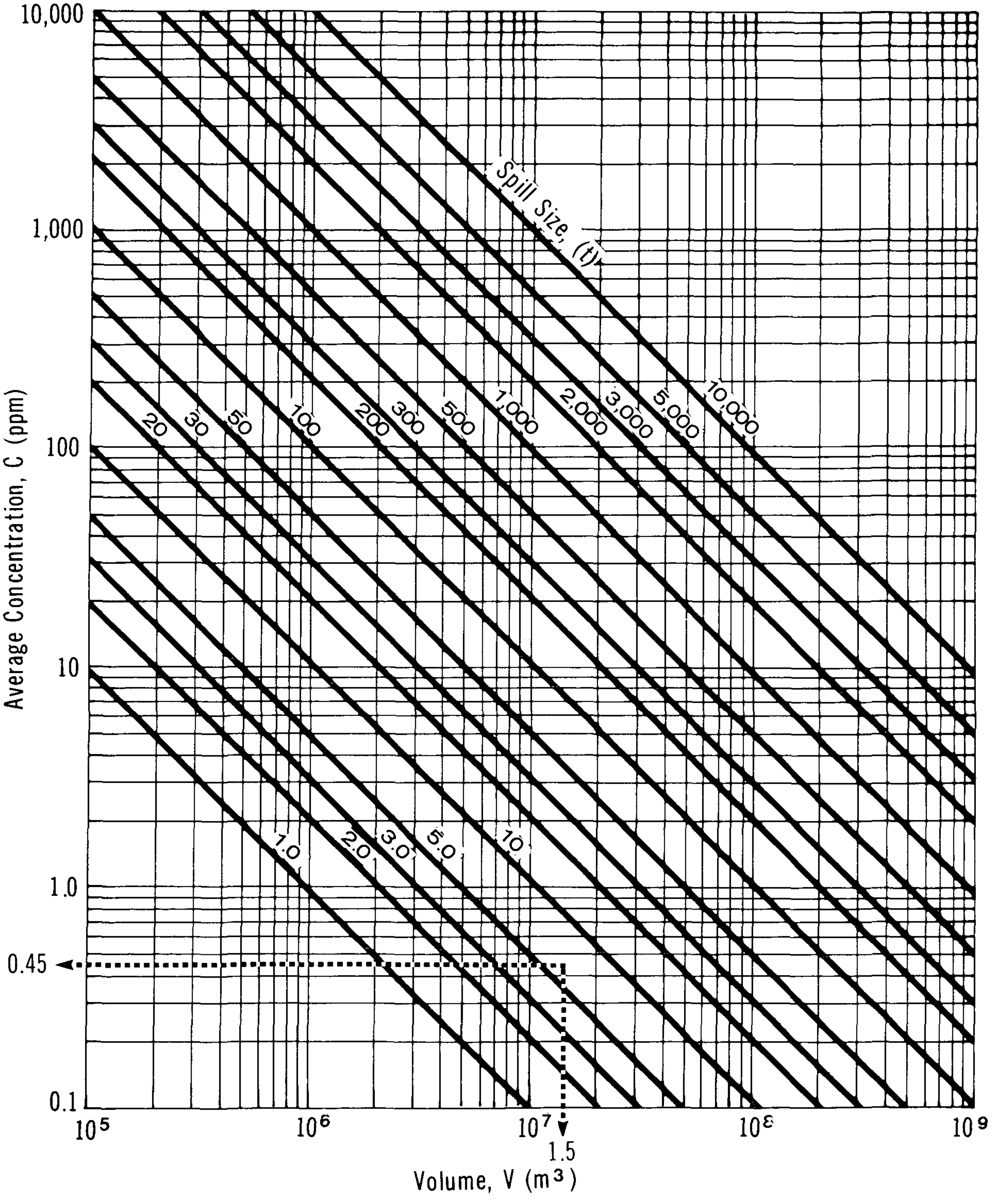


VOLUME vs RADIUS



AMMONIUM NITRATE

AVERAGE CONCENTRATION vs VOLUME



of pollutant (C) can be obtained from Figure 16 for a known mass of spill. This assumes the pollutant is spread evenly throughout the cylinder. For pollutants that are more or less dense than water, the actual concentration at the bottom would be higher or lower, respectively.

5.4.3 Sample Calculations.

5.4.3.1 Pollutant concentration in non-tidal rivers. A 20 tonne spill of 30 percent ammonium nitrate solution has occurred in a river. The stream width is 50 m and the stream depth is 5 m. The average stream velocity is estimated at 1 m/s. What is the maximum concentration expected at a water intake located 5 km downstream?

Solution

Step 1: Define parameters

- W = 50 m
- d = 5 m
- U = 1 m/s
- spill mass = 20 tonnes of 30 percent solution, equivalent to 6 tonnes of 100 percent ammonium nitrate

Step 2: Calculate time to reach point of interest

- Use Figure 9
- With X = 5,000 m and U = 1 m/s, t = 83 min

Step 3: Calculate hydraulic radius (r)

- Use Figure 10
- With W = 50 m and d = 5 m, r = 4.2 m

Step 4: Calculate longitudinal diffusion coefficient (E)

- Use Figure 11
- With r = 4.2 m and U = 1 m/s, E = 69 m^2/s

Step 5: Calculate alpha (α)

- Use Figure 12
- With E = 69 m^2/s and t = 83 min, α = 2,000

Step 6: Calculate delta (Δ)

- Use Figure 13

- With alpha (α) = 2,000 and spill mass = 6 tonnes, delta (Δ) = 3

Step 7: Compute stream cross-sectional area (A)

- $A = W \times d = 50 \times 5 = 250\ m^2$

Step 8: Calculate maximum concentration (C) at point of interest

- Use Figure 14
- With $\Delta = 3$ and $A = 250\ m^2$, $C = 12$ ppm

5.4.3.2 Average pollutant concentration in lakes or still water bodies. A 20 tonne spill of 30 percent ammonium nitrate solution has occurred in a lake. The point of interest is located on the shore approximately 1,000 m from the spill. The average depth between the spill site and the point of interest is 5 m. What is the average concentration which could be expected?

Solution

Step 1: Define parameters

- $d = 5$ m
- $r = 1,000$ m
- spill mass = 6 tonnes (equivalent)

Step 2: Determine the volume of water available for dilution or

- Use Figure 15
- With r = 1,000 m, d = 5 m, the volume is approximately $1.5 \times 10^7\ m^3$

Step 3: Determine the average concentration

- Use Figure 16
- With $V = 1.5 \times 10^7\ m^3$ and spill mass = 6 tonnes, the average concentration is 0.45 ppm

5.5 Subsurface Behaviour: Penetration into Soil

5.5.1 Mechanisms. The principles of contaminant transport in soil and their application to this work are presented in the Introduction Manual. Special considerations related to the spill of ammonium nitrate onto soil and its movement downward through the soil are presented here.

Ammonium nitrate is generally shipped and stored in solid form. Thus, when spilled, aside from the explosion hazard, minimum groundwater pollution potential exists provided that the soil is dry and cleanup is completed prior to any precipitation occurring.

Ammonium nitrate is quite soluble in water (187 g/100 mL at 20°C). Thus, if precipitation occurs prior to cleanup or if water is used to disperse the spilled chemical, the solution of NH_4NO_3 produced can infiltrate the soil and migrate downward toward the groundwater system.

For this work, the soils have been assumed to be at field capacity (the maximum water the soil can hold, after the excess water has been drained). This situation provides very little interstitial water to dilute the chemical during transport or to impede its downward movement and thus represents "worst case" analysis.

Upon reaching the groundwater table, the contaminant will continue to move, now in the direction of groundwater flow. A contaminated plume will be produced, with diffusion and dispersion serving to reduce the concentration somewhat. This is shown schematically in Figure 17.

5.5.2 Equations Describing Ammonium Nitrate Movement into Soil. The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table have been described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.5.3 Saturated Hydraulic Conductivity of Ammonium Nitrate in Soil. The saturated hydraulic conductivity (K_o), in m/s, is given by:

$$K_o = \frac{(\rho g)k}{\mu}$$

where: k = intrinsic permeability of the soil (m^2)

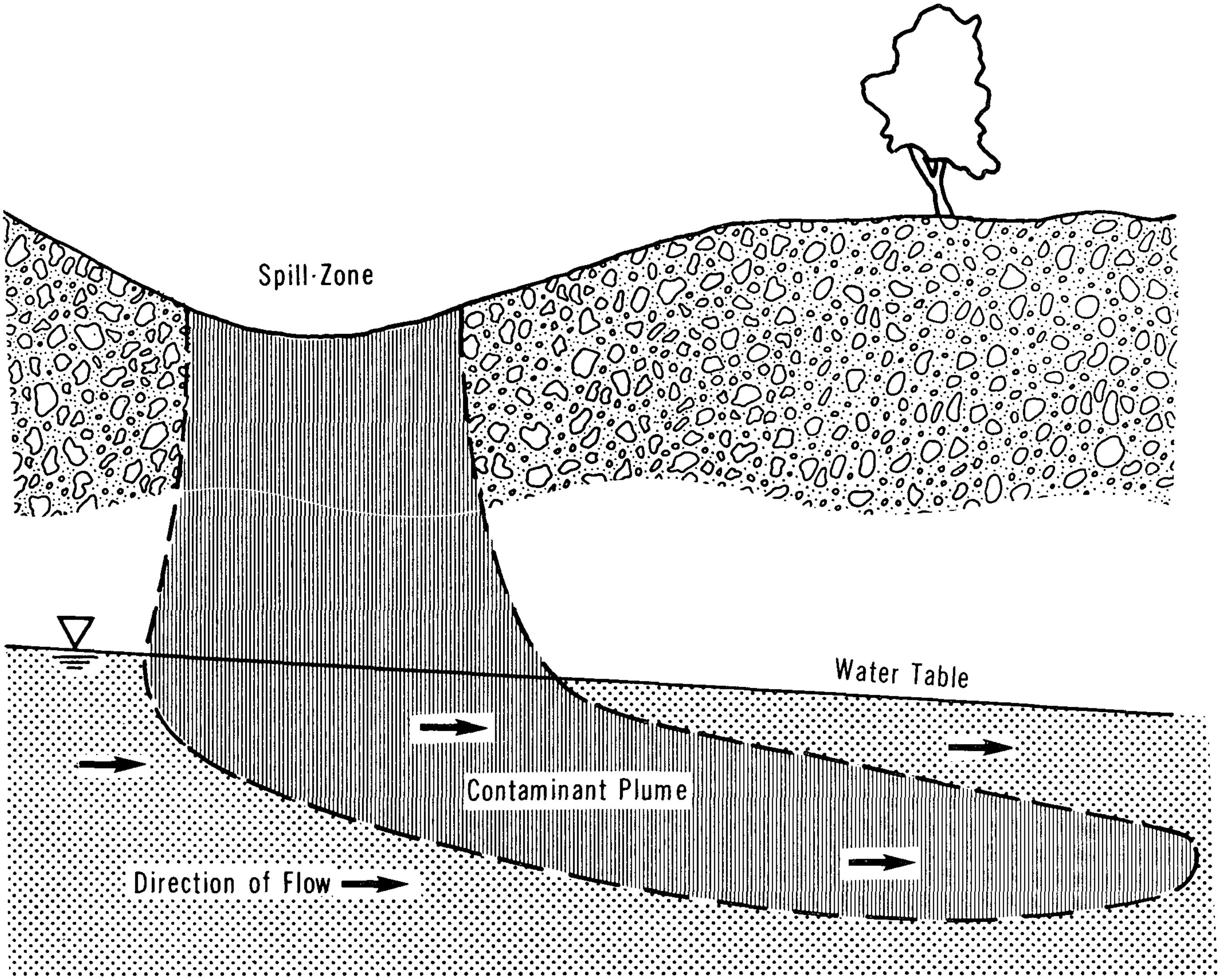
ρ = mass density of the fluid (kg/m^3)

μ = absolute viscosity of the fluid (Pa•s)

g = acceleration due to gravity = 9.81 m/s^2

The fluids involved are 30 percent ammonium nitrate by weight (representing a strong solution), and water. The water calculations represent the extreme as the solution is diluted.

SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand

–Porosity (n) = 0.35

–Intrinsic Permeability (k) = 10^{-9} m^2

–Field Capacity (θ_{fc}) = 0.075

Property	30% NH_4NO_3 20°C	30% NH_4NO_3 4°C	Water 20°C
Mass density (ρ), kg/m^3	1,128	1,132	998
Absolute viscosity (μ), Pa·s	2.8×10^{-3}	4.5×10^{-3}	1.0×10^{-3}
Saturated hydraulic conductivity (K_o), m/s	$(0.39 \times 10^7)k$	$(0.25 \times 10^7)k$	$(0.98 \times 10^7)k$

5.5.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

Property	Soil Type: Coarse Sand	Silty Sand	Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45

5.5.5 Penetration Nomograms. Nomograms for the penetration of ammonium nitrate into the unsaturated zone above the groundwater table were prepared for each soil. They present penetration time (t_p) plotted against depth of penetration (B). Because of the methods and assumptions used, the penetration depth should be considered as a maximum depth in time t_p.

A flowchart for the use of the nomograms is presented in Figure 18. The nomograms are presented as Figures 19, 20 and 21.

The water line on the nomograms represents the maximum penetration of water at 20°C in time t_p. It is a limiting condition as the solution becomes diluted with water.

5.5.6 Sample Calculation. A 20 tonne spill of ammonium nitrate has occurred on silty sand. The temperature is 20°C; the spill radius is 8.6 m. Rainfall occurs during cleanup. Calculate the depth of penetration 10 days after the rainfall.

FIGURE 18

FLOWCHART FOR NOMOGRAM USE

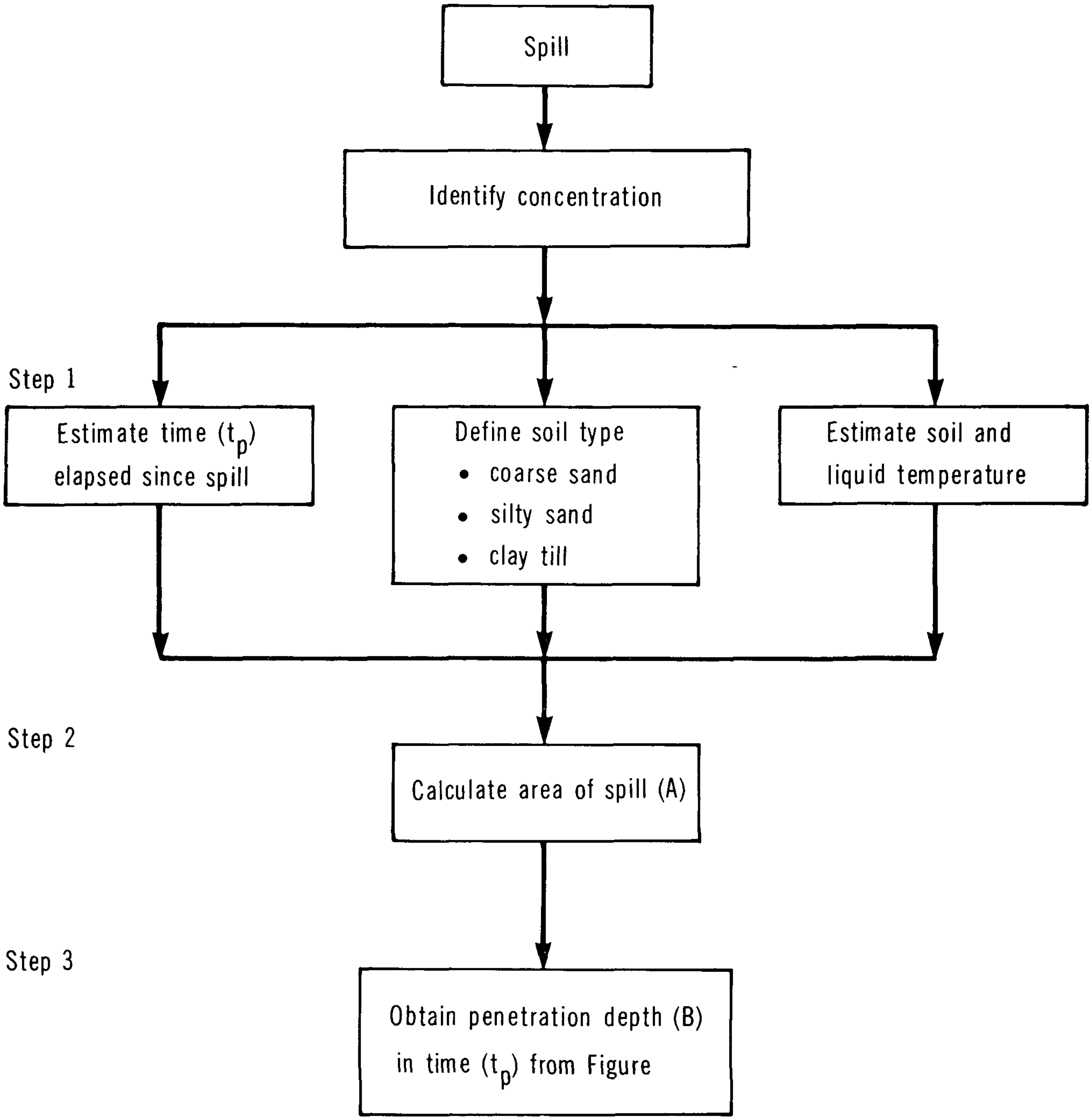
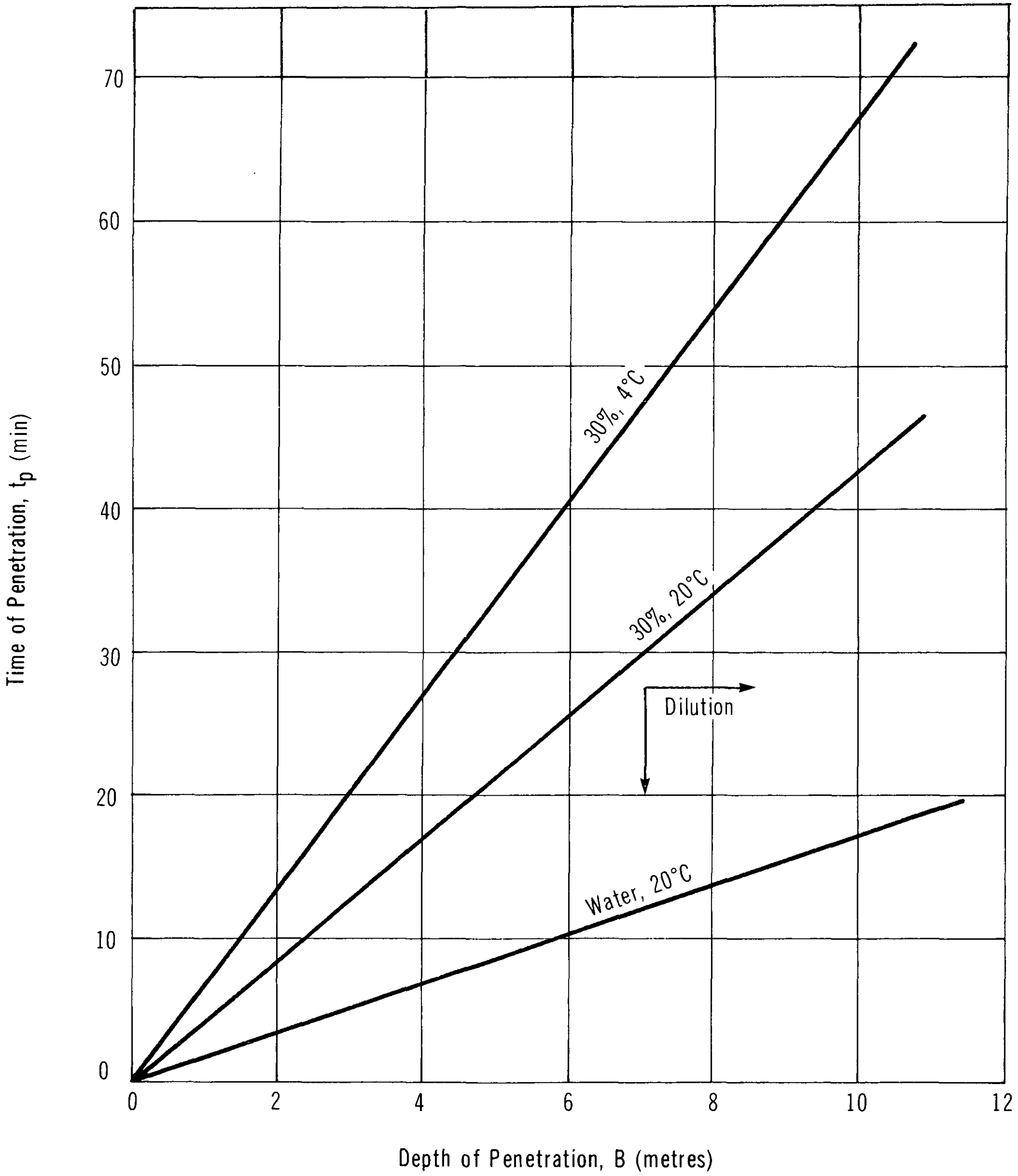


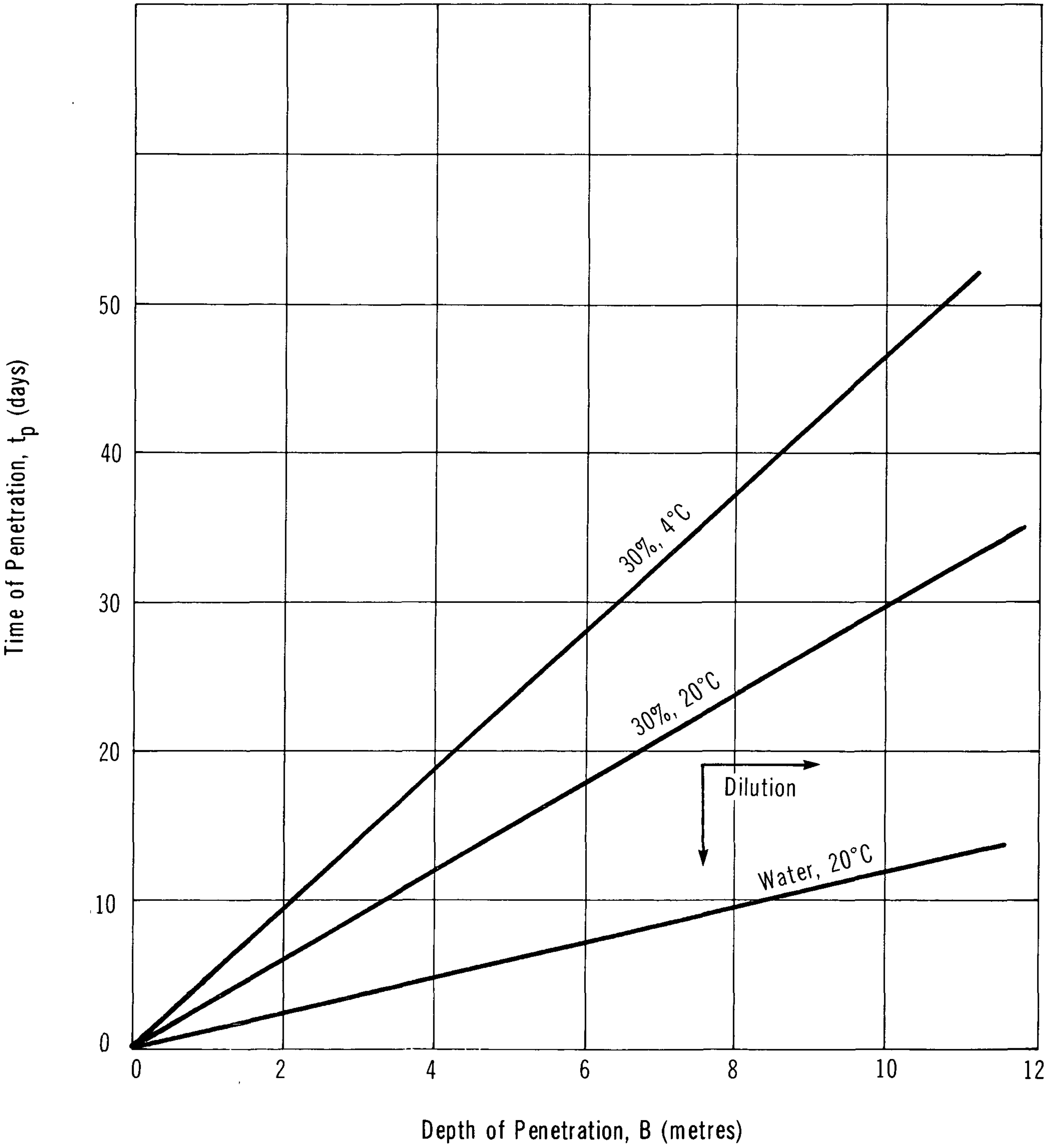
FIGURE 19

AMMONIUM NITRATE

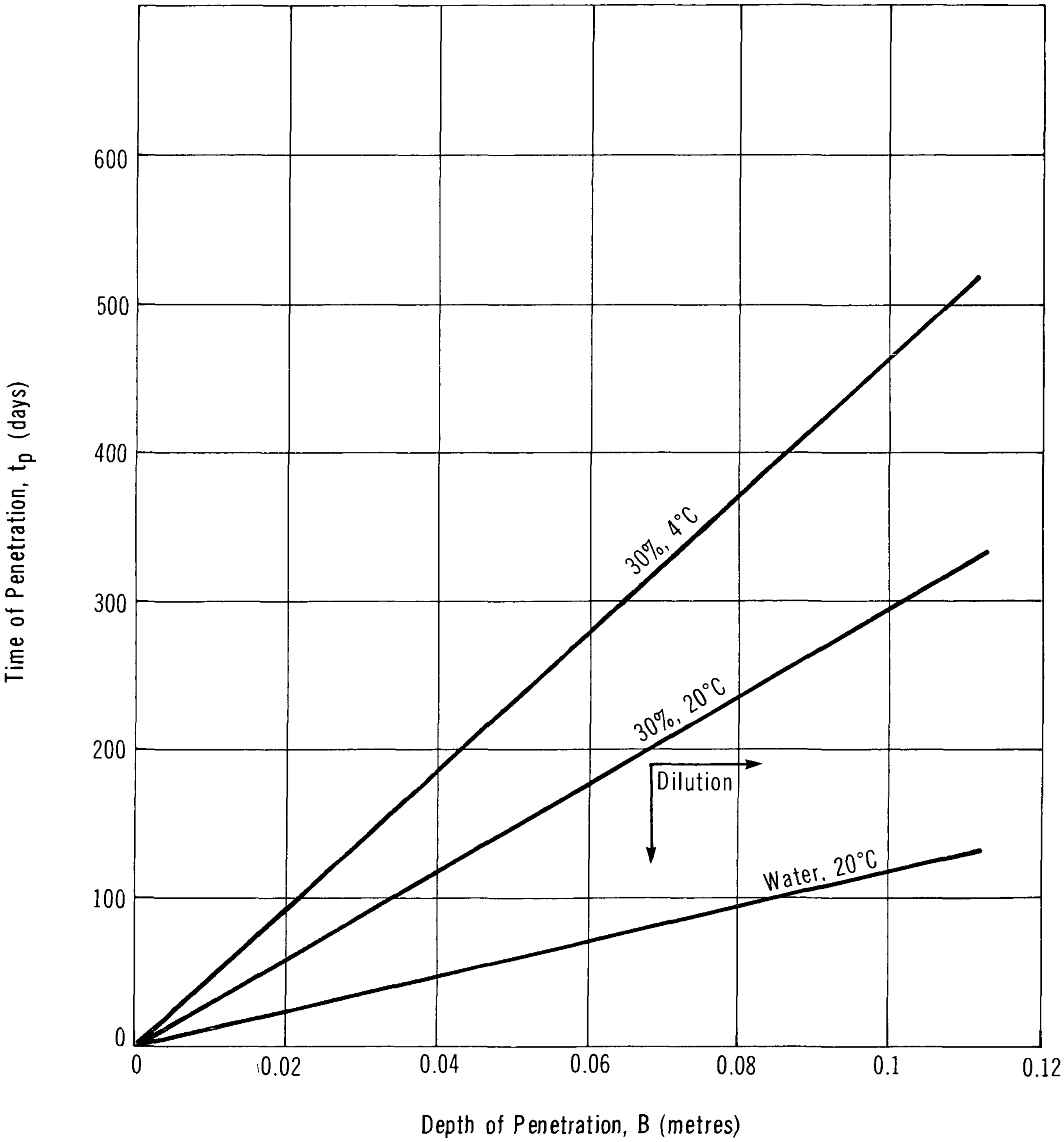
PENETRATION IN COARSE SAND



PENETRATION IN SILTY SAND



PENETRATION IN CLAY TILL



Solution

Step 1: Define parameters

- Mass spilled = 20,000 kg (20 tonnes)
- T = 20°C
- $r = 8.6$ m
- Soil = silty sand
- Groundwater table depth (d) = 13 m
- Time since spill (t_p) = 10 days

Step 2: Calculate area of spill

- $A = \pi r^2 = 232 \text{ m}^2$

Step 3: Estimate depth of penetration (B) at time (t_p)

- For silty sand at $t_p = 10$ days
- From Figure 20, the penetration depth is:

30%	Dilute (water, worst condition)
B = 3.4 m	B = 8.4 m

- Groundwater table has not been reached in this time

6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Water. A drinking water guideline of 10 mg/L of nitrate nitrogen has been proposed for Canada (Guidelines/Canadian/Water 1978; Water Management Goals 1978). The guideline for unionized ammonia is 0.02 mg/L; this corresponds roughly to an ammonia content of 0.5 mg/L at 20°C and pH 7, 0.5 mg/L at pH 8, and 0.07 mg/L at pH 9 (Water Management Goals 1978).

The current U.S. drinking water criterion is 10 mg/L nitrate nitrogen (QCFW 1974); 5 mg/L has been proposed as a limit (OHM-TADS 1981; O.I. 1970).

A limit of 100 mg/L nitrate nitrogen is suggested for livestock watering (Guidelines/Canadian/Water 1978). Nitrate standards for drinking water in other countries include: World Health Organization, 30 mg/L; Sweden, 30 mg/L; France, 40 mg/L (Jorgensen 1979).

6.1.2 Air. Ammonium nitrate dust levels are not regulated (ammonium nitrate is not volatile and thus vapour would be highly unlikely).

6.2 Aquatic Toxicity

6.2.1 U.S. Toxicity Rating. Ammonium nitrate has been assigned a TL_m 96 (4-day median toxicity rating) of 100 to 10 mg/L (RTECS 1979).

6.2.2 Measured Toxicities.

6.2.2.1 Freshwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Kill Data					
800	3.9	Bluegill	killed	tap water	WQC 1963
800	384	Bluegill	killed	distilled	OHM-TADS 1981
454	90	Goldfish	killed	distilled	WQC 1963
0.5 ppm (as free NH_3)	TNS	All species	threshold	-	DPIMR 1982

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Toxicity Studies					
3.4 (as ammonium salt)	96	Bluegill	LC_{LO}	static	WQC 1971
1,310 (as nitrate)	96	Chinook salmon	LC_{50}	freshwater	QCFW 1976
1,080 (as nitrate)	7 day	Chinook salmon	LC_{50}	freshwater	QCFW 1976
1,360 (as nitrate)	96	Rainbow trout	LC_{50}	-	QCFW 1976
1,060 (as nitrate)	7 day	Rainbow trout	LC_{50}	-	QCFW 1976
2,000 (as nitrate) from sodium	96	Bluegill	LC_{50}	-	QCFW 1976
420 (as nitrate) from potassium	96	Bluegill	LC_{50}	-	QCFW 1976
400 (as nitrate)	TNS	Largemouth bass, Channel catfish	No effect	-	QCFW 1976
1.6 (as nitrate)	24	Fingerling rainbow trout	LC_{50}	-	QCFW 1976
2,030 (as nitrate)	1.5	Minnows (*Phoxinus laevis*)	LC_{50}	-	QCFW 1976
1.6 (as nitrate)	24	Mosquito fish	LC_{50}	-	QCFW 1976
1.5 (as nitrate)	48	Mosquito fish	LC_{50}	-	QCFW 1976
0.19 to 0.39 (as nitrate)	96	4 sizes of rainbow trout	LC_{50}	hard water pH 8 to 9	QCFW 1976
0.14 to 0.15 (as nitrate)	8 days	12 gram rainbow trout	LC_{50}	flow through, hard water	QCFW 1976

Conc. (mg/L)	Time (hours)	Species	Result	Reference
Plants				
13.2 to 15.9 (as NH_4)	TNS	Eurasian water-milfoil	IL_{50}, stem length	Stanley 1974
16.2 (as NH_4)	TNS	Eurasian water-milfoil	root length altered	OHM-TADS 1981

6.2.2.2 Saltwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Toxicity					
990 (as nitrate)	96	Chinook salmon	LC_{50}	15 °/₀₀ salinity	QCFW 1976
900 (as nitrate)	7 day	Chinook salmon	LC_{50}	15 °/₀₀ salinity	QCFW 1976

6.3 Toxicity to Other Biota

6.3.1 Livestock.

Conc. (mg/kg)	Species	Result	Reference
2,000	Sheep	single oral dose; death in 12 h to 17 d	Clarke 1975
500 (repeated oral dose for 10 days)	Sheep	no visible effects	Clarke 1975

Fertilizers containing ammonium nitrate can cause illness in poultry (Clarke 1975); 400 mg/L has been suggested as toxic limit for livestock (Todd 1970).

6.3.2 Plant.

Conc. (mg/L)	Time (hours)	Species	Result	Conditions	Reference
15	40	Fungus (*Aspergillus niger*)	LD_{50}	36°C	Nowasielski 1971

6.4 Effect Studies

pH and water hardness are important in determining toxicity. Spills may cause massive algal blooms in static waters (OHM-TADS 1981). It is concluded that levels of nitrate nitrogen below 90 mg/L in water would have no effect and that a level of 5 mg/L (as nitrate) would be safe for warm water fish; as the nitrate appears to affect saltwater species more, a nitrate nitrogen limit of 0.06 mg/L would be safe for salmonid species (OCFW 1976).

6.5 Degradation

Ammonium nitrate will be taken up by bacteria. Nitrate ions are more persistent in water than are ammonium ions; nitrate degradation is fastest in anaerobic conditions (OHM-TADS 1981).

6.6 Long-term Fate and Effects

Because of its nutrient value, ammonium nitrate spills may affect local species population balances. There is no bioaccumulation or food chain contamination potential.

7 HUMAN HEALTH

There is a limited amount of information in the published literature concerning the toxicological effects of test animal and human exposures to ammonium nitrate. Incidents of infant sickness and death from high nitrate levels in drinking water have been reported (QCFW 1976). There is no information available to date on the effects of ammonium nitrate on reproduction, nor its mutagenicity or carcinogenicity. Ammonium nitrate is a nonvolatile solid, thus limiting routes of exposure.

Ammonium nitrate has been reported in the EPA TSCA inventory. The data summarized here are representative of information in the literature.

The toxicological data summarized here have been extracted from reliable standard reference sources. Only acute (short-term) exposure data are given for nonhuman mammalian species, to support interpretation of the human data where appropriate.

7.1 Recommended Exposure Limits

The basis for exposure standards for ammonium nitrate was not specified in the literature. Standards listed here are provisional; they do not pertain to ammonium nitrate unless present in the form of a dust.

Canadian provincial guidelines generally are similar to those of the USA-ACGIH, unless indicated otherwise.

Guideline (Time)	Origin	Recommended Level	Reference
Time-weighted Averages (TWA)			
Nuisance particulates (respirable)	USA-ACGIH	5 mg/m^3	TLV 1983
Provisional limit	USA-EPA, suggested	0.05 mg/m^3	GE 1981
Short-term Exposure Limits (STEL)	No data		
Other Human Toxicities			
Acute body contact exposure limit	-	1 ppm (in water)	AAR 1981

7.2 Irritation Data

7.2.1 Skin Contact. Ammonium nitrate is irritating to the skin on contact, and may cause burns (AAR 1981). There is no information on the effects of specific exposure levels on the skin.

7.2.2 Eye Contact. Ammonium nitrate is irritating to the eye on contact, and may cause burns (AAR 1981). There is no information on the effects of specific exposure levels on the eyes (AAR 1981).

7.3 Threshold Perception Properties

7.3.1 Odour. Ammonium nitrate is odourless.

7.3.2 Taste. No data.

7.4 Toxicity Exposures/Studies

7.4.1 Ingestion.

Exposure Level (and Duration)	Effects	Reference
Acute Exposure		
SPECIES: Human		
105 mg/L (as nitrate) (<3.7 mg/kg/d) in drinking water	Increase in reaction time in children, possible CNS effects	WQCB 1971
> 100 mg/L (as nitrate ion) in drinking water	Alimentary methemoglobinemia	WQCB 1971
>50 mg/L (as nitrate ion) in drinking water	Methemoglobinemia causing hypoxia, found in infants, school children and adults	WQCB 1971
> 45 mg/L (as nitrate ion) in drinking water	Methemoglobinemia in infants; over 3 year period, 139 cases of nitrate poisoning with 14 deaths	WQCB 1971
SPECIES: Rat		
4,500 mg/Kg	LD_{50}	AAR 1981

Exposure Level (and Duration)	Effects	Reference
SPECIES: Dog		
22.13 to 110.17 mg/L (as nitrate) (1.0-5.1 mg/kg/d) in drinking water	Methemoglobinemia in half of the animals	WQCB 1971

7.5 Symptoms of Exposure

General symptoms of exposure found in most information sources have not been specifically referenced. Only those of a more specific or unusual nature have their sources indicated.

7.5.1 Inhalation of Dust.

1. Irritating to mucous membranes of the respiratory tract.
2. Urination and acid urine (CHRIS 1978).
3. Severe lung congestion, coughing and difficult breathing (AAR 1981).
4. Large amounts cause systemic acidosis and abnormal hemoglobin (CHRIS 1978).

7.5.2 Ingestion.

1. Nausea and vomiting (TDB (on-line) 1981).
2. Diarrhea (TDB (on-line) 1981).
3. Hypertension.
4. Urination and acid urine (AAR 1981).
5. Large amounts may cause systemic acidosis and abnormal hemoglobin (CHRIS 1978).
6. Methemoglobinemia (QCFW 1976; WQCB 1971).

7.5.3 Skin Contact.

1. Irritation (CHRIS 1978).
2. Burns (AAR 1981).

7.5.4 Eye Contact.

1. Irritation (CHRIS 1978).
2. Burns (AAR 1981).

7.6 Human Toxicity to Decay or Combustion Products

Ammonium nitrate is sometimes used in the manufacture of explosives. It is capable of undergoing detonation if heated under confinement that permits high pressure buildup, or if subjected to strong shocks (Strehlow 1981). It explodes more readily if contaminated with organics. Combustion products include oxides of nitrogen (nitric oxide and nitrogen dioxide) (Kirk-Othmer 1980).

7.6.1 Nitric Oxide and Nitrogen Dioxide. Nitric oxide is a colourless gas with a sharp, sweet odour (NIOSH Guide 1978). It is converted spontaneously in air to nitrogen dioxide; hence, some of the latter gas is invariably present whenever nitric oxide is found in the air. At concentrations below 50 ppm, the reaction is slow; substantial concentrations of nitric oxide may frequently occur with negligible quantities of nitrogen dioxide. The chief toxic effect of nitric oxide has been ascribed to the formation of methemoglobin and subsequent action on the central nervous system. Information available on the mechanism of nitric oxide intoxication suggests that, in mixtures with carbon monoxide as well as nitrogen dioxide, additive effects should be assumed (Doc. TLV 1981). The TLV® for nitric oxide is 25 ppm (8 h-TWA) and the STEL is 35 ppm (TLV 1983).

Nitrogen dioxide is a reddish-brown gas at higher temperatures; its boiling point is 21°C. Many deaths from pulmonary edema induced by the inhalation of high concentrations of nitrogen dioxide have been reported. Lung effects, including bronchitis and emphysema and marked decrease to resistance to infection, have been reported from chronic NO_2 exposures (Doc. TLV 1981). The TLV® for nitrogen dioxide is 3 ppm (8 h-TWA), while the STEL is 5 ppm (TLV 1983).

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of Ammonium Nitrate with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
GENERAL														
Heat			X					X					Pure substance is difficult to detonate. Contaminated ammonium nitrate detonates more readily. When heated to decomposition emits nitrogen oxides	Sax 1979
SPECIFIC CHEMICALS														
Acetic Acid		X											Concentrated mixtures ignite on warming	Bretherick 1979
Aluminum Powder			X										Can be explosive with aluminum powder especially if organics present	NFPA 1978
Ammonium Chloride						X		X					Decomposes, gases liberated contain chlorine	NFPA 1978

8.1 Compatibility of Ammonium Nitrate with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Carbon			X										Explosions may occur when heated	NFPA 1978
Charcoal and Metal Oxides		X											Ignites at 80 to 120°C	Bretherick 1979
Copper Iron (II) Sulphide			X										Reacts explosively on contact	Bretherick 1979
Cyanoguanidine			X										Mixture is detonatable	Bretherick 1979
Phosphorus			X										White or yellow phosphorus and ammonium nitrate can be exploded by percussion	NFPA 1978
Potassium and Ammonium Sulphate			X										Mixture explodes on contact with potassium	Bretherick 1979
Potassium Nitrate		X											Incandesces on contact	Bretherick 1979
Potassium Permanganate	X		X			X							Explosion due to formation and decomposition of ammonium permanganate	Bretherick 1979
Sodium			X										Forms explosive disodium nitrite	Bretherick 1979; NFPA 1978

8.1 Compatibility of Ammonium Nitrate with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Sodium Hypochlorite						X							Decomposes the hypochlorite rapidly	NFPA 1978
Sodium Perchlorate			X										Mixture is used as an explosive	NFPA 1978
Sulphur		X	X										Mixture can be exploded by shock	Bretherick 1979
Urea			X										Explosion on mixing - cause unknown	Bretherick 1979
Zinc (powder)			X								X		Reacts violently after mixing if moisture present, zinc powder may catalyze explosion if other reactants, e.g. chlorides, also present	NFPA 1978
<u>CHEMICAL GROUPS</u>														
Alkali Metals			X										May form explosive alkali hyponitrites	Bretherick 1979
Chlorides						X		X					May catalyse decomposition with release of toxic gases including chlorine	NFPA 1978; Bretherick 1979

8.1 Compatibility of Ammonium Nitrate with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Chloride Salts			X			X				X				Bretherick 1979
Fertilizer Materials		X											May ignite at >90°C due to free acid in the fertilizer	Bretherick 1979
Metals, powdered		X	X										Finely divided metals can catalyze a fire or an explosion especially if organics present. Known reactions include those with zinc, cadmium, copper, magnesium, lead, cobalt, nickel, bismuth chromium and antimony	NFPA 1978; Bretherick 1979
Metal Salts						X							Decompose	Bretherick 1979
Organic Matter		X											Organic matter may cause self-detonation	NFPA 1978
Organic Fuels			X										Ease of detonation of ammonium nitrate is greater when 2-4% oil is present	Bretherick 1979

8.1 Compatibility of Ammonium Nitrate with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Hydrocarbon Oils			X										Hydrocarbon oils can render mixture detonatable	Bretherick 1979
Oxidizing Agents			X			X								EPA 600/2-80-076
Polymerizable Compounds		X	X											EPA 600/2-80-076
Reducing Agents											X			EPA 600/2-80-076

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a literature review. To avoid any deviation from the intended meaning, the wording of the original source has been presented essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. It is recognized that countermeasures vary from situation to situation and thus what may be incorrect for one situation is in fact correct for another. These procedures should not be considered as Environment Canada's recommendations.

9.1.1 Fire Concerns. Ammonium nitrate is an oxidizing agent which supports combustion. It is capable of undergoing detonation if heated under confinement that permits high pressure buildup, or if subjected to strong shocks such as those from an explosion. Organic and other easily oxidizable matter can sensitize it to a more readily explodable state. Ammonium nitrate melts at 169°C with slow decomposition; near 301°C, the decomposition accelerates with sudden rushes of light-brown to orange-copper-coloured fumes, indicating the formation of toxic nitrogen oxides, with the possibility that the decomposition may become explosive. Self-ignition of mixtures of ammonium nitrate with easily oxidizable organic materials or easily oxidizable, finely divided metals may take place at moderately elevated temperatures (NFPA 1978). If the product is molten, it should not be confined as it could detonate (CCPA 1982).

9.1.2 Fire Extinguishing Agents. Use flooding amounts of water in early stages of fire. When large quantities of ammonium nitrate are involved in advanced or massive fires, control efforts should be confined to protecting exposures; firefighting personnel should secure hose nozzles in fixed position or set up unmanned portable or fixed turrets and then withdraw to a safe location. Exercise extreme caution in application of water on fused or molten material to avoid eruptive scattering and spread of fire. As toxic nitrate oxides may be present, fires should be approached from upwind (NFPA 1978).

Small fires: Dry chemical, CO_2, water spray or foam.
Large fires: Flooding amounts of water initially. After control is achieved, other agents may be used.

Do not move cargo or vehicle if cargo has been exposed to heat. Use water spray to cool containers involved in a fire to prevent rupture (ERG 1980).

9.1.3 Spill Actions.

9.1.3.1 General. Stop or reduce discharge of material if this can be done without risk. Eliminate sources of heat. If material is hot or molten, treat as an explosive potential (GE 1981).

9.1.3.2 Spills on land. Contain if necessary by forming mechanical barriers to prevent spreading and shovel spilled material into containers for disposal (EPA 670/2-75-042; GE 1981). As ammonium nitrate is a fertilizer, small residual amounts will not harm land.

9.1.4 Cleanup and Treatment.

9.1.4.1 Spills on land. Clean up major amounts using mechanical means. Residual amounts will act as a fertilizer. If mechanical cleanup cannot remove the majority of the material, it should be spread out or diluted using large amounts of water. Excessive amounts of ammonium nitrate will harm vegetation.

9.1.4.2 Spills in water. Recover any undissolved material. Dissolved material may be treated in a number of ways. Activated carbon can be applied, at 10 percent the spill amount, over the region occupied by 10 mg/L or greater concentrations (EPA 670/2-75-042). Natural zeolites and clinoptilolite have been recommended as in situ sorbents to selectively hold ammonium ions (OHM-TADS 1981; DPIMR 1982). Amberlite IRA 400 should also be considered (CG-D-38-76). Large concentrations in water should be dealt with by removing the water or diluting to lesser concentrations.

9.1.4.3 General. Contaminated solid or liquid material can be disposed of by using as a fertilizer - on agricultural lands as an example. For treatment of contaminated water that cannot be used as a fertilizer, gravity separation of solids followed by neutralization with either hydrochloric or sulphuric acid is recommended. The neutralized water may then be passed through dual-media filtration and ion exchange resins prior to final neutralization with sodium hydroxide (pH 7.0). The waste water from backwash of the filtration unit is returned to the gravity separator (EPA 600/2-77-227).

9.1.5 Disposal. Most waste material can be used as a fertilizer provided that it does not contain contaminants of environmental concern. Waste ammonium nitrate must never be discharged directly into sewers or surface waters. If incinerated, scrubbers are required for NO_2 and oxidation or reduction process for NO (GE 1981).

9.1.6 Protective Measures. For entry into a situation where the spilled material and its characteristics are unknown, self-contained breathing apparatus and a totally encapsulated chemical suit should be worn.

If the spilled material is known to be ammonium nitrate:

- Dust respirators, rubber gloves and chemical safety goggles may be worn to minimize exposure and skin contact (GE 1981).
- Protective clothing and self-contained breathing apparatus should be worn if the material is involved in a fire (OHM-TADS 1981).
- Butyl and cloropel have been recommended as chemical suit materials (excellent resistance) for protection against ammonium nitrate (EE-20).

9.1.7 Storage Precautions. Protect containers against physical damage. Store in well-ventilated buildings, preferably of noncombustible construction and equipped with automatic sprinkler protection. Floor drains and recesses should be plugged or eliminated to prevent entrapment of flowing molten nitrate during fire. Separate from all organic materials or other contaminating substances such as flammable liquids, acids, corrosive liquids, organic chemicals, chlorates, sulphur and finely divided metals or charcoal, coke, cork and sawdust (NFPA 1978).

10 PREVIOUS SPILL EXPERIENCE

This section contains information on previous spill experience which will be useful to readers in understanding spill response and countermeasures. Only those which meet the criterion are included, and thus, the number of experiences is not an indication of the problems or frequency of spillage. As technology in spill control advances, this section will be updated in future manual revisions to include the most useful information.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals is as follows.

Methods have been documented here for the analysis of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g., commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Method for the Detection of Ammonium Nitrate Particulate Matter in Air

11.1.1 Ion Chromatography (Dionex 1978). A range of 0.1 to 25.4 ppm nitrate in the extract may be determined using ion chromatography. This is equivalent to between 28 and 7,055 $\mu g/m^3$, or 0.01 to 2.16 ppm in air.

A known volume of air is drawn through a 37 mm diameter cellulose ester filter of 0.8 µm pore size. A sample size of 90 L is recommended at a flow rate between 1.5 and 2.0 L/min. The sample filter is transferred to a 60 mL container with tweezers and extracted with 25 mL distilled water by gentle swirling. An aliquot is then injected into a suitable ion chromatograph and the retention time and peak height noted. The nitrate is determined using a standard curve. Typical operating conditions for the ion chromatograph are: 3.1 mL/min eluent flow rate, ambient column temperature, standard eluent which is 0.003 M sodium bicarbonate and 0.0024 M sodium carbonate; 100 µL sample loop, conductivity meter setting at 10 µMHO full scale, and a chart speed of 40 cm/h. It should also be noted that a dual-pen linear chart recorder is recommended to be used to obtain the chromatograms.

11.2 Qualitative Method for the Detection of Ammonium Nitrate Particulate Matter in Air

The sample is collected as in Section 11.1.1. A 1 mL volume of sample is placed in a test tube and acidified with 3 M sulphuric acid added drop-wise. Drop-wise addition of 0.05 M silver perchlorate is continued with stirring until precipitation is complete. A 3 mL volume of freshly prepared 1 M ferrous sulphate solution is added and the mixture centrifuged if any precipitate forms. The clear solution is decanted into a large 15 cm test tube and water-cooled. Concentrated sulphuric acid is added slowly to the solution down the test tube side, while the test tube is held at an angle. Sufficient sulphuric acid is added to give approximately a 2.5 cm layer at the bottom of the test tube. A brown ring indicates the presence of nitrate (Welcher 1955).

11.3 Quantitative Method for the Detection of Ammonium Nitrate in Water

11.3.1 Ion Chromatography (Dionex 1978). A range of 0.1 to 25.4 ppm nitrate in water may be determined by ion chromatography.

A minimum volume of 2 L of representative sample is collected in an appropriate container. If the sample is visibly turbid, pre-filtering is recommended prior to injection into the ion chromatograph. The range of sample concentrations can be varied by dilution of the sample. An aliquot is then injected into a suitable ion chromatograph and the retention time and peak height noted. The nitrate is determined using retention times and peak heights as well as a standard curve. Typical operating conditions for the ion chromatograph are: 3.1 mL/min eluent flow rate, ambient column temperature, standard eluent which is 0.003 M sodium bicarbonate and 0.0024 M sodium carbonate, 100 µL sample loop, conductivity meter setting at 10 µMHO full scale, and a chart speed of 40 cm/h. It should also be noted that a dual-pen linear chart recorder is recommended to be used to obtain the chromatograms.

11.4 Qualitative Method for the Detection of Ammonium Nitrate in Water

The sample is collected as in Section 11.3.1. A 1 mL volume of sample is placed in a test tube and acidified with 3 M sulphuric acid, added drop-wise. Addition of 0.5 M silver perchlorate is continued with stirring until precipitation is complete. A 3 mL volume of freshly prepared 1 M ferrous sulphate solution is added and the mixture centrifuged if any precipitate forms. The clear solution is decanted into a large 15 cm. test tube and water-cooled. Concentrated sulphuric acid is added slowly to the solution down the side of the test tube, while the test tube is held at an angle. Sufficient sulphuric acid is added to give approximately a 2.5 cm layer at the bottom of the test tube. A brown ring indicates the presence of nitrate (Welcher 1955).

11.5 Quantitative Method for the Detection of Ammonium Nitrate in Soil

11.5.1 Titrimetric (Hesse 1972). A variable range depending on the aliquot of extract used of ammonium nitrate in soil may be determined by steam distillation followed by titration.

A 5 g sample of 2 mm (sieve-size) soil is shaken for 60 min with 50 mL of 2 M potassium chloride solution. The solution should be boiled for 15 min with solid magnesium oxide to remove any ammonia, cooled, filtered, and then diluted to 50 mL. A suitable aliquot of extract is transferred to a distillation flask. A boric acid solution is prepared by dissolving 20 g boric acid in 900 mL water and adding 20 mL mixed indicator. The indicator is prepared by dissolving 0.1 g bromocresol green and 0.07 g methyl red in 100 mL ethanol. Sodium hydroxide (0.1 M) is added drop-wise until a reddish-purple colour is obtained. The volume is taken to 1 L. A 5 mL aliquot of the boric acid solution is transferred to a suitable conical flask beneath the condenser which is attached to the distillation flask. A 0.5 g mass of magnesium oxide is added to the sample extract and the flask stoppered. The contents are steam-distilled into the boric acid solution. A 35 mL volume of distillate should be collected and discarded. A 1 mL volume of 2 percent aqueous sulphamic acid is added and the solution swirled. A 0.2 g mass of Devarda's alloy is added to the distillation flask. Devarda's alloy is prepared by combining 50 g copper, 45 g aluminum, and 5 g zinc. The contents are steam-distilled into a fresh 5 mL portion of boric acid solution. A 30 mL volume of distillate is collected and titrated with standardized hydrochloric acid. It should be noted that all nitrates are indicated and thus the result is essentially total nitrates in the soil.

11.6 Qualitative Method for the Detection of Ammonium Nitrate in Soil

A 1 mL volume of extract (Section 11.5.1) is placed in a test tube and acidified with the drop-wise addition of 3 M sulphuric acid. Drop-wise addition of 0.5 M silver perchlorate is continued with stirring until precipitation is complete. A 3 mL volume of freshly prepared 1 M ferrous sulphate solution is added and the mixture centrifuged if any precipitate forms. The clear solution is decanted into a large 15 cm test tube and water-cooled. Concentrated sulphuric acid is added slowly to the solution down the test tube side, while the test tube is held at an angle. Sufficient sulphuric acid is added to give approximately a 2.5 cm layer at the bottom of the test tube. A brown ring indicates the presence of nitrate (Welcher 1955).

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EnviroTIPS

Common Abbreviations

BOD	biological oxygen demand
b.p.	boiling point
CC	closed cup
cm	centimetre
CMD	count median diameter
COD	chemical oxygen demand
conc.	concentration
c.t.	critical temperature
eV	electron volt
g	gram
ha	hectare
Hg	mercury
IDLH	immediately dangerous to life and health
Imp. gal.	imperial gallon
in.	inch
J	joule
kg	kilogram
kJ	kilojoule
km	kilometre
kPa	kilopascal
kt	kilotonne
L	litre
lb.	pound
LC_{50}	lethal concentration fifty
LC_{LO}	lethal concentration low
LD_{50}	lethal dose fifty
LD_{LO}	lethal dose low
LEL	lower explosive limit
LFL	lower flammability limit
m	metre
m	meta
M	molar
MAC	maximum acceptable concentration
max	maximum
mg	milligram
MIC	maximum immision concentration
min	minute or minimum
mm	millimetre
µg	microgram
µm	micrometre
°Be	degrees Baumé (density)

MMAD	mass median aerodynamic diameter
MMD	mass median diameter
m.p.	melting point
MW	molecular weight
N	newton
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
o	ortho
OC	open cup
p	para
P_c	critical pressure
PEL	permissible exposure level
pH	measure of acidity/alkalinity
ppb	parts per billion
ppm	parts per million
P_s	standard pressure
psi	pounds per square inch
s	second
STEL	short-term exposure limit
STIL	short-term inhalation limit
T_c	critical temperature
TC_{LO}	toxic concentration low
T_d	decomposition temperature
TD_{LO}	toxic dose low
TL_m	median tolerance limit
TLV	Threshold Limit Value
T_s	standard temperature
TWA	time weighted average
UEL	upper explosive limit
UFL	upper flammability limit
VMD	volume mean diameter
v/v	volume per volume
w/w	weight per weight