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these parties  
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**MEMORANDUM OF AGREEMENT.**

March 5, 1991

This agreement is binding between Giant Yellowknife Mines Limited (Giant), Environmental Protection Services (EPS) and Pollution Control Division/Renewable Resources (PCD), Government of the Northwest Territories.

The parties agree to share equally in the costs of Western Research - Calgary, for Sulphur Dioxide Monitoring Stations and the sampling therein. The samples will be taken over approximately a 12 month period on a monthly basis by Giant personnel and analysed by Western Research. The total estimated costs for the project are approximately \$2,630, excluding freight, GST, set up, monitoring, and interpretation which are covered by Giant.

Giant agrees to provide PCD and EPS with access to analysis results as they become available. Each party will advise the other if any part or whole of the reported analysis is distributed outside the respective group.

Each party agrees to cover \$2,630 as their contribution to the project. EPS and PCD will each be invoiced for \$1,315 as of April 1, 1991, and the remaining \$1,315 as of September 1, 1991, which is the final month of the project.

Signed in agreement this 15th day of April, 1991 in Yellowknife, Northwest Territories.

Laura Johnston

Signature

Environmental Protection Services

Errol Regan

Signature

Pollution Control

D. Halversen

Signature

Giant Yellowknife Mines Ltd.

LAURA JOHNSTON

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Errol Regan

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G. Halversen

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April 15/91

Table 2 Lead canister network results expressed as total sulphur on  $SO_2$  eq. ng/day/100 cm<sup>2</sup>

| Stn              | Dir | Dist (m) | Oct  | Nov  | Dec  | Jan  | Feb  | March | April | May                        | June | July | Aug  | Sept | Oct  |
|------------------|-----|----------|------|------|------|------|------|-------|-------|----------------------------|------|------|------|------|------|
| 1                | N   | 1.5      | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01  | 0.01  | 0.01                       | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 2                | N   | 2.5      | 0.03 | 0.01 | 0.02 | 0.02 | 0.01 | 0.05  | 0.01  | 0.03                       | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 3                | N   | 4.0      | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05  | 0.01  | 0.01                       | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 4                | ESE | 0.7      | 0.03 | 0.01 | 0.02 | 0.02 | 0.03 | 0.01  | 0.01  | 0.01                       | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 5                | EE  | 0.7      | 1.15 | 0.45 | 1.90 | 0.34 | 0.95 | 0.52  | 0.02  | 0.04                       | 1.06 | 0.01 | 0.01 | 0.01 | 0.01 |
| 6                | S   | 1.0      | 0.24 | 0.13 | 0.12 | 0.06 | 0.07 | 0.03  | 0.01  | 0.01                       | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 7                | S   | 0.5      | 2.10 | 0.54 | 0.02 | 0.01 | 0.18 | 0.13  | 0.14  | 0.33                       | 0.70 | 0.01 | 0.01 | 0.01 | 0.01 |
| 8                | SW  | 0.7      | 0.54 | 0.25 | 0.02 | 0.02 | 0.02 | 0.16  | 0.25  | 0.50                       | 0.80 | 0.01 | 0.01 | 0.01 | 0.01 |
| 9                | SSW | 1.4      | 0.30 | 0.25 | 0.01 | 0.02 | 0.02 | 0.04  | 0.18  | 0.22                       | 0.18 | 0.01 | 0.01 | 0.01 | 0.01 |
| 10               | SW  | 0.4      | 0.41 | 0.02 | 0.02 | 0.02 | 0.02 | 0.12  | 0.01  | 0.03                       | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 |
| 11               | WSW | 0.3      | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.13  | 0.12  | 0.33                       | 0.15 | 0.01 | 0.01 | 0.01 | 0.01 |
| 12               | N   | 0.2      | 0.11 | 0.01 | 0.02 | 0.02 | 0.01 | 0.05  | 0.07  | 0.11                       | 0.10 | 0.01 | 0.01 | 0.01 | 0.01 |
| 13               | S   | 1.7      | 0.47 | 0.15 | 0.02 | 0.01 | 0.03 | 0.13  | 0.21  | 0.15                       | 0.10 | 0.01 | 0.01 | 0.01 | 0.01 |
| 14               | E   | 0.1      | 0.01 | 0.02 | 0.02 | 0.02 | 0.04 | 0.07  | 0.02  | 0.04                       | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 |
| 15               | S   | 0.1      | 0.18 | 0.01 | 0.02 | 0.02 | 0.02 | 0.11  | 0.11  | 0.13                       | 0.15 | 0.01 | 0.01 | 0.01 | 0.01 |
| 16               | SSW | 0.2      | 0.21 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03  | 0.04  | 0.15                       | 0.43 | 0.01 | 0.01 | 0.01 | 0.01 |
| 17               | W   | 0.2      | 0.30 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05  | 0.02  | station destroyed by flood |      |      |      |      |      |
| Monthly averages |     |          | 0.40 | 0.12 | 0.13 | 0.02 | 0.12 | 0.11  | 0.14  | 0.20                       | 0.32 | 0.07 | 0.11 | 0.01 | 0.01 |

## What are air quality objectives?

An air quality objective is a statement of the concentration of an air pollutant and the length of time of exposure to it, which, if not exceeded, affords a specified degree of protection to animals, plants, and materials. Objectives are generally set to cover both short- and long-term exposure to air pollutants. Pollution control agencies routinely monitor the levels of air pollutants and compare the levels with the air quality objectives to determine their progress in securing and maintaining the best possible air quality for the public. The federal government sets national ambient air quality objectives on the basis of recommendations from the Federal-Provincial Advisory Committee on Air Quality. Provincial governments have the option of adopting these either as objectives or as enforceable standards in their jurisdictions.

Canada has a unique three-tiered system of national air quality objectives, which arose from the recognition that, in a country as large as Canada, the need for objectives varied across the country. By setting objectives at what are called the maximum tolerable, maximum acceptable, and maximum desirable levels, three ranges of air quality were established to meet these needs (Federal-Provincial Committee on Air Pollution 1976):

- The *maximum desirable level* is the long-term goal for air quality and provides a basis for an antidegradation policy\* for unpolluted parts of the country and for the continuing development of control technology.
- The *maximum acceptable level* is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, and personal comfort and well-being.
- The *maximum tolerable level* denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general population.

A review of these objectives and of the need for objectives for other pollutants is under way by the Federal-Provincial Advisory Committee on Air Quality.

These ranges reflect the reality of air quality in Canada. For example, there are parts of the country

## Canada's three-tiered system of air quality objectives

High  
pollutant  
levels

\_\_\_\_\_ maximum tolerable level

Tolerable range  
of air quality

\_\_\_\_\_ maximum acceptable level

Acceptable range  
of air quality

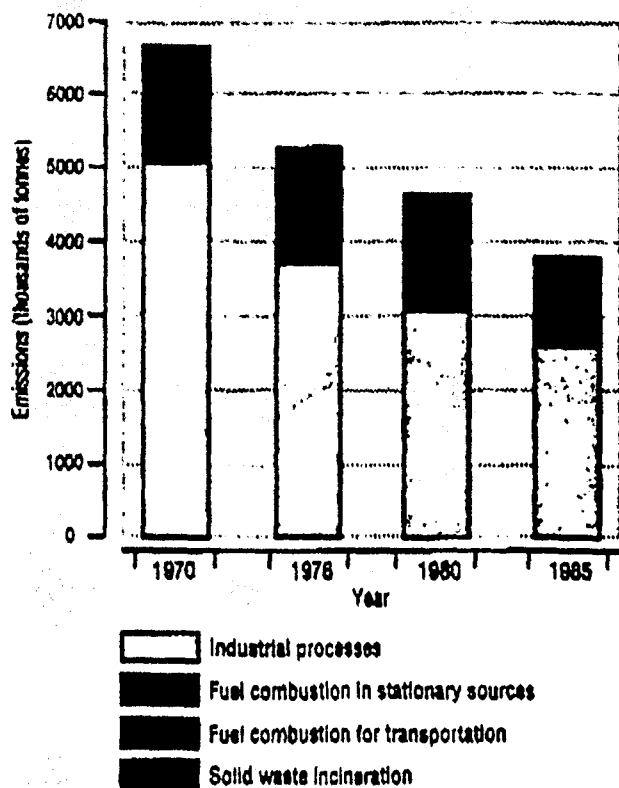
\_\_\_\_\_ maximum desirable level

Low  
pollutant  
levels

where the levels of the common air pollutants are extremely low. A reasonable goal for these areas is to maintain air quality within the desirable range and prevent any deterioration in quality. However, there are other more densely populated parts of the country where there are significant emissions of the common air pollutants and where air quality usually falls within the acceptable range. Under these circumstances, for example, a reasonable short-term goal might be to keep within the acceptable range of air quality, avert any trends toward more-polluted air, and work to improve air quality over the long term. When pollutant concentrations are below the maximum acceptable level, there is, by definition, adequate protection for the most sensitive persons and parts of the environment. The tolerable range of air quality was defined to accommodate situations where there was more-severe air pollution, but of an episodic nature, which may require extraordinary control measures. Most provincial governments have adopted the national ambient air quality objectives in whole or in part for use in the provinces. Air quality requirements in Canada are comparable with those in use in many other parts of the world.

\* This is a policy of not allowing the quality of unpolluted air to deteriorate even though there might be apparent leeway to do so without demonstrable effects.

Figure 8  
Sulphur dioxide emissions in Canada, 1970-1985



Source: Environment Canada 1986; Vana 1989.

sites in the Prairie provinces, the fine fraction was usually less than 40% of the inhalable particles.

The levels of inhalable particles measured in Canada are below the recently introduced US air quality standards for this size of particle, set at  $150 \mu\text{g}/\text{m}^3$  for exposure over one hour and  $50 \mu\text{g}/\text{m}^3$  for exposure over one year (US Environmental Protection Agency 1987). Canadian air quality objectives for inhalable particulate matter are being developed.

## Sulphur dioxide

About 70% of total sulphur dioxide emissions in 1985 in Canada came from industrial processes—69% of this was from copper, nickel, lead, zinc, gold, and aluminum production, and a further 21% was from oil and natural gas recovery and processing. Fuel combustion, mainly by power

## Air quality objectives for sulphur dioxide

| Exposure period | Maximum desirable concentration (ppb) | Maximum acceptable concentration (ppb) | Maximum tolerable concentration (ppb) |
|-----------------|---------------------------------------|--|---------------------------------------|
| One hour        | 170                                   | 340                                    | —                                     |
| 24 hours        | 60                                    | 110                                    | 310                                   |

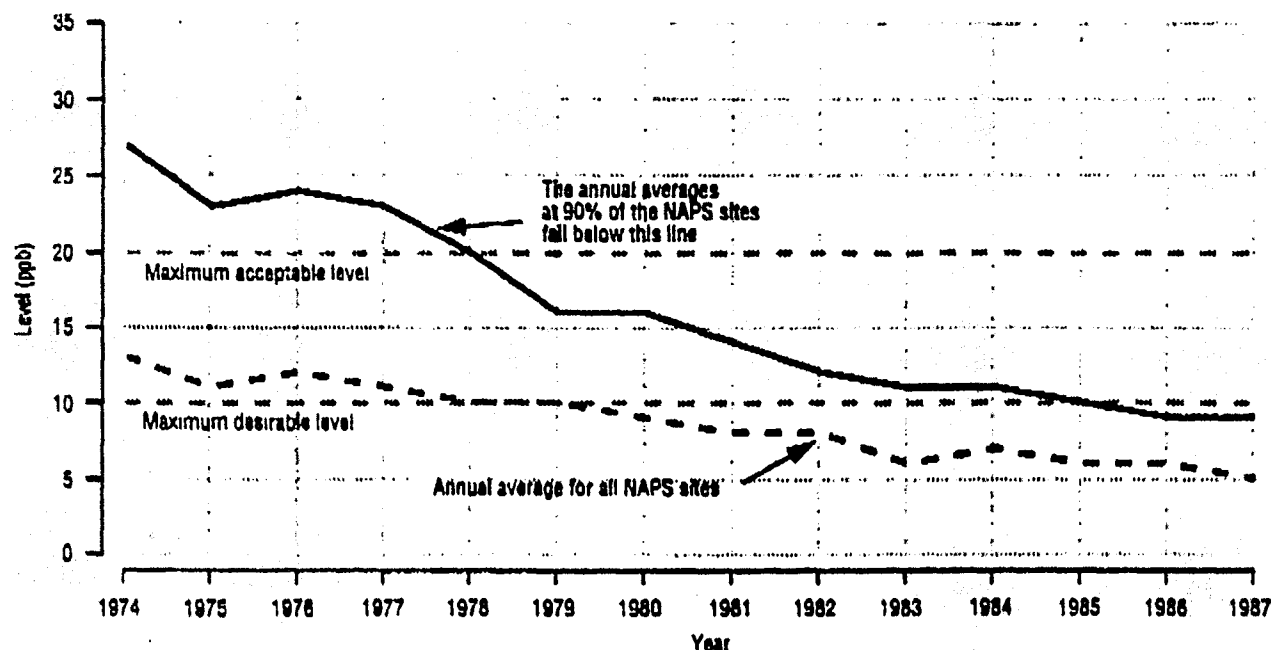
plants and industries, accounted for 28% of total Canadian emissions of sulphur dioxide. Between 1970 and 1985, sulphur dioxide emissions declined by almost 45% (Figure 8), mainly because of modifications to industrial processes and technology, the capture and use of sulphur dioxide to make commercially useful sulphuric acid, and the increased use of low-sulphur fuels (Paine 1989).

Environmental levels of sulphur dioxide can adversely affect both human health and vegetation. In epidemiological and laboratory-controlled human health studies, effects on the lung and the induction of chronic lung disease have been recorded. Although no clear threshold has been identified, short-term exposures to sulphur dioxide at concentrations of up to 1 ppm have not induced severe or irreversible effects; however, significant reductions in lung function have been observed in healthy exercising adults after exposure to this level (Kirkpatrick *et al.* 1982; Stacy *et al.* 1983; Linn *et al.* 1985). Mild respiratory symptoms related to airway dysfunction and transient bronchoconstriction have also been observed in exercising asthmatic subjects (Schachter *et al.* 1984; Wisek and Schachter 1985).

In epidemiological studies, short-term exposures to sulphur dioxide that lasted a day or so have been correlated with deaths, although there was concomitant exposure to high particulate levels during these pollution episodes (Martin 1964; Ellison and Waller 1978). Long-term or chronic exposures to levels of up to 50 ppb of sulphur dioxide induced respiratory symptoms and disease (coughs and bronchitis), especially in young children (Dodge 1983) and smokers (Sawicki 1969).

The earliest sign of injury to vegetation is damage to foliage; other plant parts appear to be more resistant. The eastern white pine is a particularly sensitive species, showing signs of acute injury in a matter of hours at a sulphur dioxide concentration in air as low as 25–30 ppb. Many plant species are damaged within hours when exposed to a sulphur dioxide concentration between 100 and 1000 ppb, whereas some hardier plant species show acute damage only above 1 ppm (Federal-Provincial Advisory Committee on Air Quality 1987a).

Figure 9  
Trends in ambient air levels of sulphur dioxide in Canada, 1974-1987



Source: Environment Canada 1987, 1988.

Long-term injury to vegetation, usually observed as a yellowing of foliage, is generally assessed in terms of the average concentration of sulphur dioxide to which a plant is exposed over the growing season or over a one-year period, because sulphur dioxide concentrations can be quite variable from day to day. The response observed in plants is also strongly influenced by such environmental factors as sun, rain, wind, and drought. Studies of chronic forest damage suggest that effects are prominent when the average sulphur dioxide concentration is about 17 ppb but slight when the concentration is 8 ppb. Lichen species diversity and abundance are affected at 15-20 ppb.

The recommended air quality objectives (Federal-Provincial Committee on Air Pollution 1976) were based on both human health effects and effects on vegetation. The maximum acceptable limits for a one-hour, 24-hour, and annual average were 340, 110, and 20 ppb, respectively; maximum desirable limits were 170, 60, and 10 ppb for the same time periods. These levels were retained following a review of the more recent literature (Federal-Provincial Advisory Committee on Air Quality 1987a).

In urban areas of Canada, the annual average level of sulphur dioxide measured at NAPS monitoring sites decreased by 54% between 1974 and 1986—from 13 ppb to

6 ppb—and the annual average levels at 90% of the NAPS monitoring sites are now well below the maximum desirable level annual air quality objective of 10 ppb (Figure 9) (Environment Canada 1987, 1988). In 1986, the one-hour maximum desirable level objective of 170 ppb was met or bettered 99.9% of the time at 93% of the NAPS monitoring sites. Monitoring sites in Montreal, Quebec City, Rouyn, Trois-Rivières, Shawinigan, and Sudbury all recorded hourly average sulphur dioxide concentrations that exceeded the maximum acceptable level one-hour air quality objective of 340 ppb, but in all cases the objective was exceeded less than 1% of the time. At all but the Quebec City, Rouyn, and Shawinigan sites, however, the 24-hour maximum acceptable level air quality objective of 110 ppb was not exceeded in 1986. The 24-hour maximum tolerable level was exceeded 12 times in Quebec City in 1986 (Environment Canada 1988).

### Carbon monoxide

Any combustion process where carbon-containing organic material is burned without sufficient oxygen will produce carbon monoxide. Motor vehicles, especially poorly tuned ones, are a major source of carbon monoxide