Is Artificial Rainmaking a Solution to Drought?

by A M Choudhury

THE earth's atmosphere always contains some amount of water vapour which does not exceed 4% of the total volume of the air. The amount of water substance in a vertical air column is usually of the order of two to three grams for a square centimetre. At a given temperature, a given mass of air has a definite capacity for holding water vapour. If the temperature decreases, the capacity of the air for holding the water vapour also decreases. In the case of dry air, the temperature decreases with height by about 1°C per 100 metres. In the case of moist air, however, this value could be 1/2°C per hundred metre rise. If air containing water vapour is forced to rise in the atmosphere as a result of convection, orographic uplift or the large scale motions associated with cyclonic storms, it will expand and the temperature of the air will therefore fall and eventually may fall to the point where the water vapour contained in it is sufficient to saturate the air. Condensation of the water vapour will take place if there is a further cooling of the air and consequently cloud will form. Unsaturated air can be brought to saturation either by adding water vapour or by cooling the air.

The condensation of water vapour in the atmosphere always occurs on small particles called condensation nuclei which exist in air in varying concentrations. These particles provide a centre around which the water vapour may rapidly condense. Larger particles are more efficient in this respect than the smaller ones and under the same environmental conditions those particles that are soluble in water produce larger droplets than do insoluble particles. Over land, there are about 1000-100,000 particles in every cubic centimeter of air and over ocean, their numbers vary from 100-1000 per cc. Their sizes vary from 10^{-7} cm to 10^{-3} cm in radius.

If the atmosphere were entirely free of foreign particles and ions (condensation nuclei), air would have become supersaturated by a factor of seven (7) without being condensed. However, because of the presence of condensation of nuclei, water vapour may condense when the air is very slightly supersaturated or even slightly undersaturated. A droplet of radius one ten-millionth of a centimetre (10^{-7} cm) requires a supersaturation of 223% to persist while droplets of radius greater than 10^{-5} cm require supersaturation of less than 1%. There are far more particles in the air than are needed as condensation nuclei in clouds and as a result condensation always occurs on the larger particles.

A cloud which is not producing rain contains about 100 droplets in every cubic centimetre and the average radius of these droplets is 10 microns. But the rain producing cloud consists of drops that are one millimetre in radius that is one thousand microns. In order that these droplets develop into some of the rain drops, they must increase in radius by one hundred times which correspond to an increase in volume by a million fold. The main difference between cloud and precipitation is the particle size. How the cloud drop particles grow more than one million times in size to form precipitation particles is the basic problem in cloud physics.

It has been observed that clouds at temperature considerably below 0°C consist of liquid drops rather than ice crystals. The reason is that the process of ice formation whether by freezing of liquid drops or condensation of vapour directly into ice crystals, also requires nucleation. The nuclei of ice formation whether in the liquid or from the vapour take effect considerably below 0°C. For water to freeze, molecules in the liquid state, which exist to a large degree in random positions, must align themselves into definite crystallographic positions appropriate to the ice lattice. Thus clouds form ordinarily first as liquid drops even at temperatures of -15°C or lower. When the temperature is sufficiently low, ice crystals occur and once they are present in sufficient concentrations the entire cloud tends to be transformed into ice crystals. The equilibrium vapour pressure over ice is less than that of liquid water at temperature below 0°C and consequently ice crystals can grow in an air unsaturated with respect to liquid water. For example at -20°C, ice crystals grow if the humidity exceeds 82%, at 40°C if it exceeds 68%.

Theory of natural rain

Collision and Coalescence Process: Those cloud droplets that grow by condensation to a size which is somewhat larger than the average will fall through a cloud with speeds greater than those of the smaller droplet. As a result the larger droplets may collide and coalesce with some of the smaller droplets lying in their paths. In this way the larger droplets in a cloud tend to increase in size fairly rapidly and on emerging from the base of the cloud may be sufficiently large to reach the ground as raindrops without being evaporated in the air. The production of rain drops in this way is known as collision and coalescence process of rain formation. The larger drop in the air must exceed some minimum size before this process can proceed at any significant rate. It has been found that this critical size is about 20 micron in radius. Rain from clouds with temperature greater than 0°C occurs due to this process and this is frequently referred to as warm rain process. Apart from the condensation nuclei and critical size, electric fields and electric charges also have influence on coalescence. However, critical values of the parameters controlling the rate of development of rain have not yet been determined.

Bergerson-Findesen Process: This process postulates that for the formation of rain, a mixed cloud consisting of water drops and ice crystals are necessary. It is known that water vapour pressure over ice is less than that over water for a given temperature. Hence if both phases are present side by side in a cloud ice crystals grow at the expense of supercooled drops because of the vapour pressure gradient between the drops and ice crystals. This vapour pressure difference between the ice crystals and water drops is very much greater than the vapour pressure difference between water drops and the environment. For example, at a temperature of -10°C, this is greater by a factor of 100 and so the ice crystals take up by condensation so much moisture that the droplets start to evaporate. Consequently, they begin soon to fall faster than the remaining cloud droplets and begin to collect these all the way taking advantage of the vapour pressure difference.

The latter process may initiate the former and the two acting together can readily lead to the formation of rain in subfreezing clouds. In clouds with temperature greater than 0°C, process one could be alone the activating process.

The fact that supercooled clouds are a common occurrence at temperatures above -20°C with the implication that ice forming nuclei are deficient in the atmosphere, the possibility arose that supply of artificial nuclei could induce artificial rain.

Bangladesh is facing a terrible drought situation currently and drought is quite a common experience in Bangladesh and in many other countries. The history of artificial rainmaking goes back to 1946 when Vincent Schaefer of USA discovered the general principles. During the last 40 years cloud-seeding activities have stirred the imagination of scientists all over the world. If this could be carried out in an operational manner, mankind could have solved the problems of drought which threatens many parts of the globe with famine.

Artificial rain making

Attempts to increase rain by lighting of fires, the firing of cannons, production of electric discharges by kites, firing of guns and rockets, ringing of church bells and by prayer have long been practised by man from time immemorial. However, in recent times, methods are being practised based on physical processes of rain formation such as the fact that suitable cloud may be made to release their precipitation by introducing artificial nuclei. The possibility of extending this technique to produce economically increases of rainfall has created a good deal of interest and lot of controversy. Modern rain making experiments are based on three main assumptions:

i) That either the presence of ice crystals in a supercooled cloud is necessary to release snow and rain by Bergeron-Findesen process or the presence of comparatively large water droplets to initiate the collision and coalescence process.

ii) That some clouds precipitate inefficiently or not at all because these agents are naturally deficient.

iii) That this deficiency can be remedied by seeding the clouds artificially with either solid carbon dioxide (dry ice) or silver iodide to produce ice crystals or by introducing water droplets or large hygroscopic nuclei.

In general, the energy involved in influencing the amount of precipitation by changing the atmospheric flow patterns which determines the amount of moisture being fed into the system and control the cloud forming processes is so large that it is not economically feasible to introduce similar amounts of energy to alter them artificially. However, there appear to be circumstances when small amounts of energy applied at the right time and place may produce the desired result.

In 1946 Vincent Schaefer of General Electric Company while working with clouds in a food freezer dry ice created several millions of ice crystal embryos (ice nuclei) in a supercooled cloud of -40°C. Schaefer made the first field trial on 13 November 1946 when 3lb of crusted dry ice was dropped along a line of 3 miles into an altocumulus deck whose temperature was about -20°C by an aircraft. This and similar other experiments demonstrated that large areas of supercooled stratiform cloud were converted into ice cloud by seeding. Shortly afterwards Bernard Vonnegut found that silver iodide was also an effective nucleating agent with a threshold of -4°C. One gram of silver iodide can produce 10^{15} number of nuclei by vapourizing an acetone solution of silver iodide in a hot flame. Then started the history of artificial rain making experiments. Dry ice has to be used for seeding from aeroplanes and hence it is very costly. On the other hand, silver iodide could be sprayed from the ground by using silver iodide generators. However, silver iodide particles are subject to photolytic action in sunlight and its efficiency is reduced to one tenth after half an hour of exposure. Silver iodide has arrangements of molecules similar to that of ice in at least one crystallographic plane and hence it serves as ice nucleus.

Evaluation of seeding experiments

It has been established that artificial seeding of certain types of clouds can modify their structure and in some cases can initiate and increase precipitation. The primary goal in seeding experiments is to demonstrate that an increase in precipitation has taken place as a result of the seeding over the area under investigation. This must be done using standard statistical techniques for convincing demonstration of success. In most of the early experiments and operations by commercial firms rigorous standards of statistical validity were not maintained. As a result, even though there was demonstration of positive indication of increase of rain as a result of these experiments and operations, a definite statement could not be made. One of the difficulties which contribute to this uncertainty is that the quantity of precipitation is governed not only by the microphysics of individual clouds but also by the dynamic processes involved in the large scale circulations. Question whether the observed change was the direct and immediate consequence of the treatment or would have occurred without it is difficult to answer, because the latter quantity can not be known. Hence it is necessary to turn to statistical procedure to evaluate the effects.

The estimation of precipitation which would have fallen in the absence of seeding in much harder than measuring the amount which did fall. Because of the large variability of the amounts of precipitation from year to year, climatological normals for comparisons cannot be used. Target-control area regression is one of the predictive devices used for this purpose. In this procedure an area near the target and otherwise resembling it as much as possible in selected for comparison. It is assumed that natural variation of prescription at the control area be closely similar to those at the target area, so that the amount which would have fallen at the target in the absence of seeding can be estimated from the precipitation which fell at the control area during the period of seeding. It is further assumed that seeding does not spread into the control area to contaminate it.

Since the discovery of seeding effect, numerous cloud seeding experiments have been carried out over the last four decades in different parts of the globe with a view to increase rainfall by seeding clouds with solid ice or silver iodide. But with the exception of Israel experiment, there is little convincing evidence that seeding clouds with artificial nuclei induce economically significant increases in precipitation that can be distinguished from natural variation of rainfall. However, in recent years, a number of long-term national experiments have been conducted based on statistical designs incorporating randomization between target and control areas and seeded and unseeded periods under the supervision of reputably scientists experienced in the field of cloud physics and cloud seeding. In some cases a consistent decrease of rainfall has been noticed as a result of seeding. However, cloud seeding activities have stirred the imagination of scientists all the world over and a great deal of progress has been made in cloud physics.

(The writer is, director, Bangladesh Space Research and Remote Sensing Organisation (SPARSO).)

Village Guards Reduce Poaching in Namibia

by Sandra Mbanefo

ELIAS Hambo is a quiet man, a frequent traveller through Damaraland's soulful, desert landscape. He drives along windswept trails, invisible to the inexperienced eye. His black hair has turned a fine shade of dusty grey as a whirling cloud of sand follows his Landrover like a faithful shadow.

Mr Hambo is delivering monthly rations to community game guards living in some of northern Namibia's remotest areas. He has been senior field officer of a WWF Wide Fund for Nature project in Damaraland and Kaokoland (together called Kaokoveld) for nine years. His truck is laden with bags of ground maize, flour, and sugar, boxes of tea, bars of soap, and bottles of cooking oil. Four villagers sit squeezed in between supplies son the back, hitching a ride to a desert valley just beyond.

Damaraland and Kaokoland were created in the early 1960s as black homelands for the Damara, Herero and Himba peoples. The new territory was carved out of existing tribal reserves, white commercial farms and land de-gazetted from Etosha National Park.

For more than 1000 years, people shared this land with their livestock and wildlife, including the desert elephant (Loxodanta African) and black rhino (Diceros bicornis bicornis). However new farming practices and a changing political climate began to disturb this peaceful co-existence. Military conflict also contributed to instability and a proliferation of guns in Kaokoland.

By the 1970s, the hunt for rhino horn and ivory began in earnest. With poverty in the homelands, horn traders found people to track down northern Namibia's unique black rhinos which are specially adapted to the desert.

"In the olden days, my people only hunted kudu, gemsbok, springbok and zebra for food," Mr Hambo recounts. "The people didn't hunt elephant or rhino because they weren't eaten. That type of hunting came with the white people, who wanted horn and brought money, ammunition and rifles."

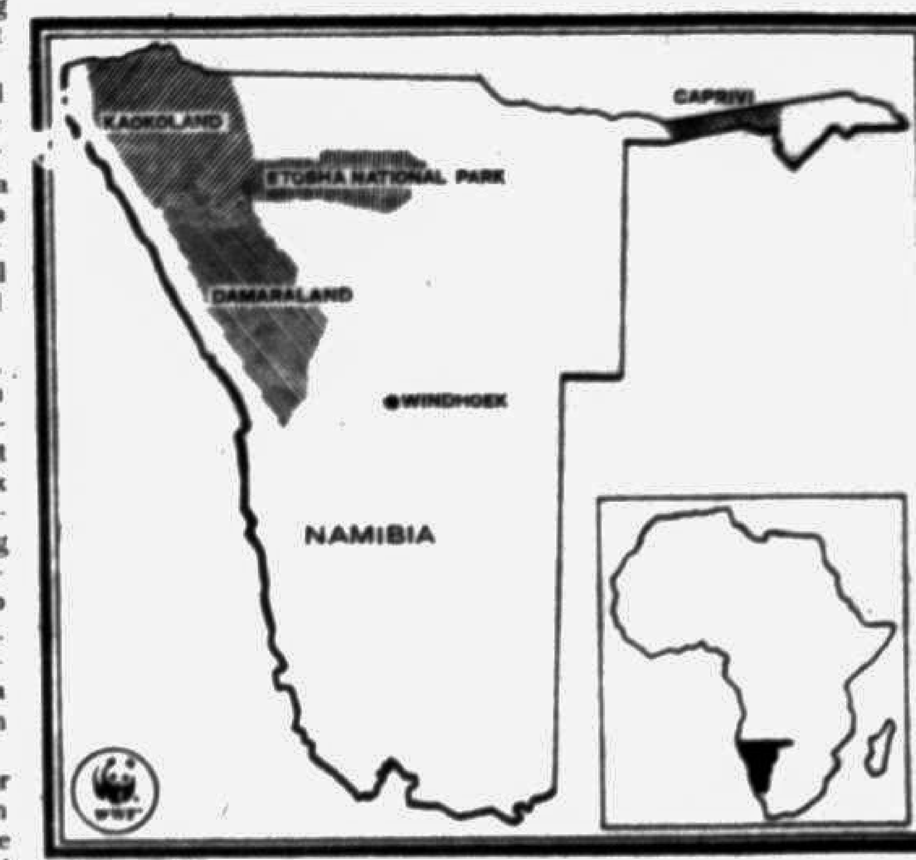
By the early 1980s, rhino and elephant poaching became so rampant that carcasses dotting the desert landscape became almost a daily sight. The elephant population fell from over 1,000 to 250, and the rhino population decreased from an estimated 250 in 1970, to 60.

It became obvious that government anti-poaching units were not enough to solve the problem. Local people had to somehow become involved in stopping the poaching.

At the time, Mr Hambo was working in Etosha National Park with a conservator called Garth Owen-Smith. In 1982, they left their jobs and with the help of another conservator, Chris Eyre, started a new system of wildlife protection.

"The majority of local communities were as concerned as we were about the poaching," Mr Owen-Smith remembers. "But they felt powerless because the wildlife seemed to belong to the government."

With initial funding from the Endangered Wildlife Trust and later WWF, Mr Owen-Smith set up a community-based conservation project. After months of village meetings — with Mr Hambo acting as interpreter and project spokesperson — local communities decided to join the conservation effort by appointing their own game guards.



Damaraland and Kaokoland (Kaokoveld), northern Namibia

Most of the guard chosen were ex-hunters, known for their skill in tracking animals. They monitor wildlife and report poaching incidents to natures conservation officials.

Most importantly, they provide a mechanism for local people to share responsibility for the wildlife in their area.

Being expert trackers, they could follow weeks-old spoor. In many case, poachers were apprehended a long time after poaching incidents, simply by the game guards' skilful tracking. From 1983 to 1984 illegal hunting virtually came to a stoop in all the areas where there were game guards.

"Western conservation policies failed because they addressed wildlife without integrating the people of Africa in the conservation movement," Mr Owen-Smith says. "Any management plan must be drawn up together with the local people."

As a direct result of community participation in Kaokoland, animal population are growing. In the last ten years, elephant numbers have increased from 250 to an estimated 350, rhinos have increased from 60 to 100, springbok from 1,000 to 7,000, gemsbok from 400 to 1,800 zebra from 560 to 2,200 and giraffe from 232 to 3000.

Today there are 30 community game guards in northern Namibia's Kaokoland; the project recently expounded to East Caprivi where 15 community game guards have been appointed by local communities.

Because they live in remote areas, their salary consists of both money and supplies. Mr Hambo distributes their supplies each month and collects their wildlife monitoring reports.

After hours of driving, Mr Hambo's Landrover comes to a halt on a rocky mountainside. A small herd of goats flees up the hill, away from a family settlement of three round dung huts. Mr Hambo jumps out of the jeep, and greets Salmon Karutjaiva, a community game guard.

They unload the supplies before finding some shade in which to hold their meeting. Mr Karutjaiva gives his monthly report: he sighted 7 elephants, 40 gemsbok, 20 springbok and several lions. He also saw a male and female rhino; the cow is pregnant and due to give birth any day. Finally, four people moved in to the area, and have started a settlement close by.

— WWF Features

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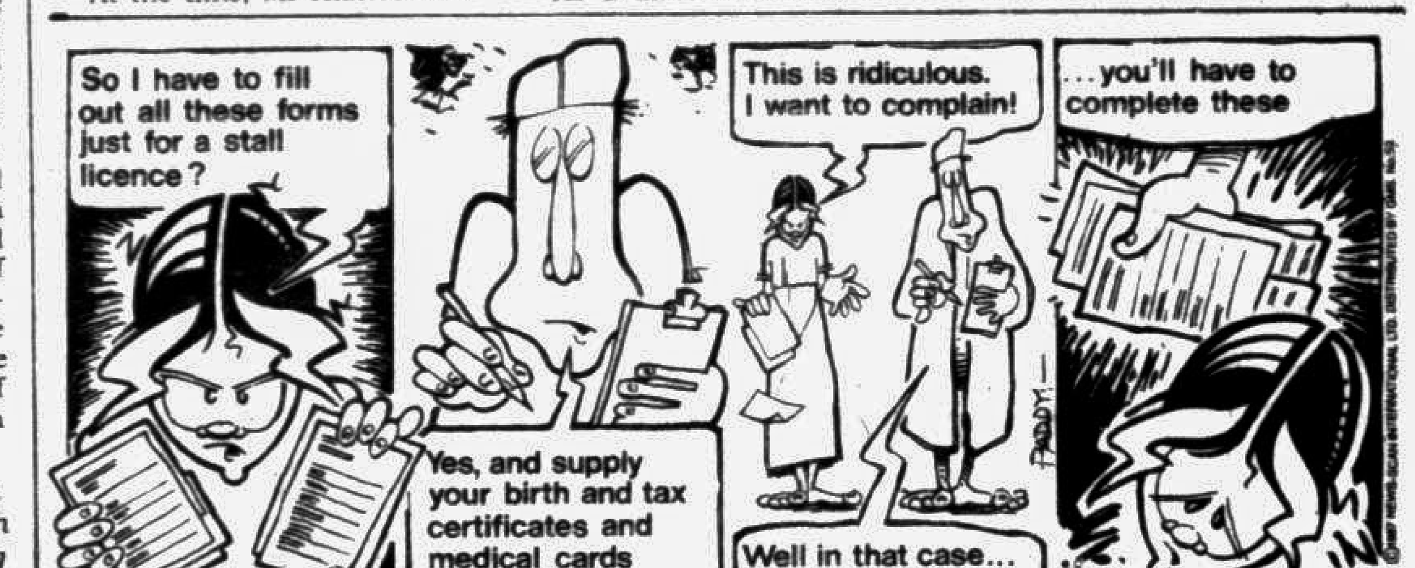


Indians Seek to Block Quebec's Patriotic Project

Clyde Sanger writes from Ottawa

A river which few people have ever seen may become a strong influence on whether the French-speaking province of Quebec and its seven million people split from the rest of Canada.

The Great Whale River runs into Hudson Bay about 1,200 kilometres north of Montreal, the provincial capital. It is part of several river systems that have long been the hunting and fishing grounds of Cree Indians who number some 10,000 in this area.

It is also the site of a hydro-electric project that the Quebec Premier, Robert Bourassa, has called "the project of the century" — a three-stage plan he initiated during his first term as premier in the early Seventies.

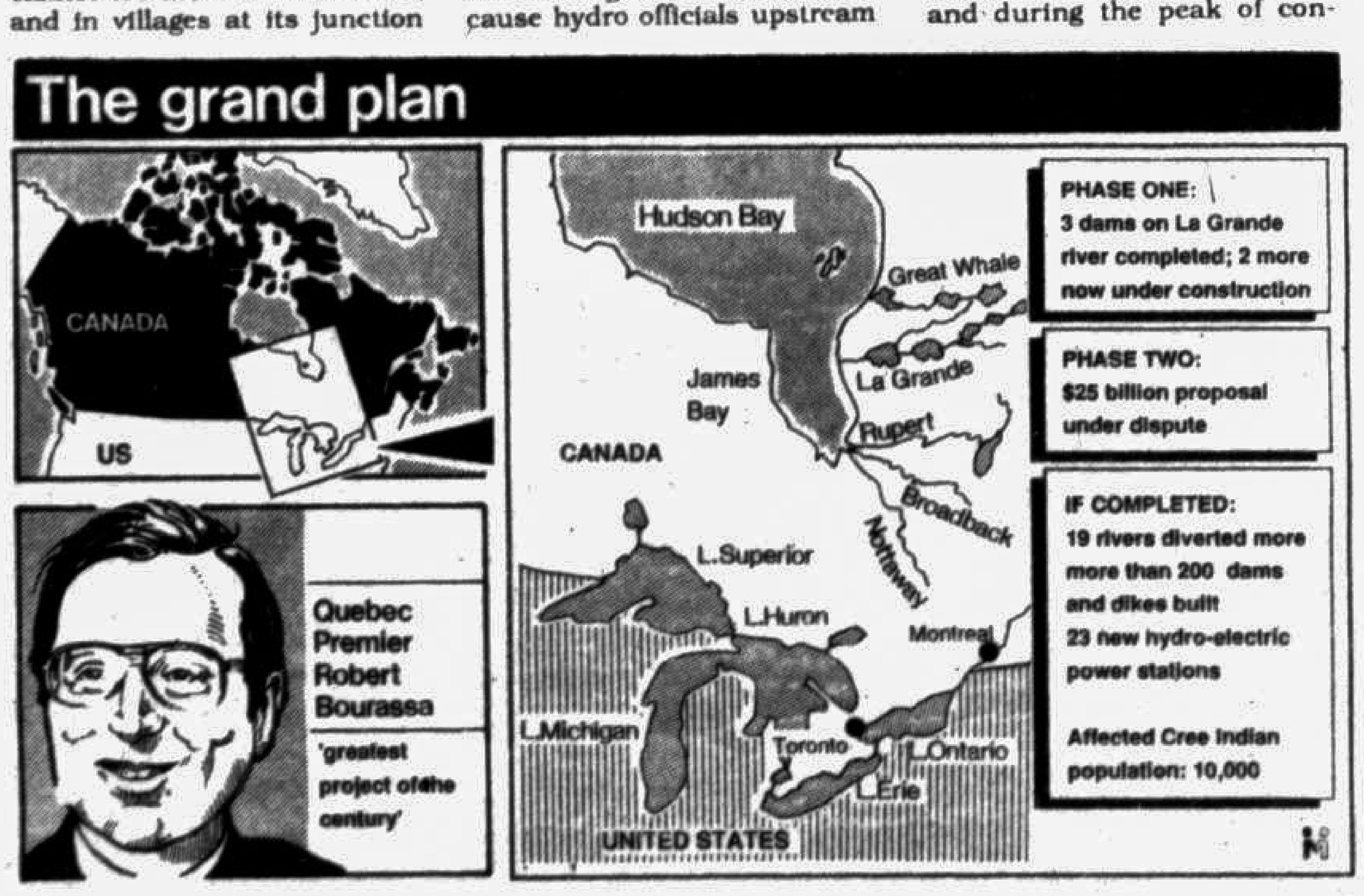
If completed, an area of land the size of Germany will be affected by the diversion of 19 rivers, the building of more than 200 dams and dikes and the construction of 23 hydro-electric power stations. The plan is to sell electricity to the United States.

The Cree people are determined to stop it. They accepted construction of the first phase after the courts awarded them Can$250 million. But they have since suffered a series of ill-effects and say that no amount of money as compensation will win their support for the two later stages, one on the Great Whale River, the other on the Nottaway, Rupert and Broadback rivers.

Because of phase I, mercury poisoning has become a serious problem. Trees drowned in huge reservoirs created by four dams on La Grande River have produced bacteria that leach the mercury out of the rocks and into the food chain. Today the Cree cannot eat the fish in the river, and in villages at its junction with James Bay as many as one third of the people have high levels of mercury in their bodies.

As well, the dams have altered the seasonal flow of rivers, endangering the movement of wildlife. In 1984 about 5,000 caribou on their annual migration drowned because hydro officials upstream had let the Caniapiscau river rise to abnormal levels.

Robert Bourassa may regret these environmental Problems, but more important are the enormous economic benefits he sees flowing from the James Bay project. The first stage now produces more than 10,000 megawatts of power and during the peak of construction in 1978 provided jobs for 18,000 Quebeckers.



After these jobs were gone, several aluminium plants and other factories were set up using the new hydro power. For Quebec nationalists, Hydro Quebec symbolises their political and economic power, is a tribute to their engineering skills and proof that English-speaking businessmen no longer run the Quebec economy.

For Robert Bourassa, an economist by training, the James Bay project seems to have become an obsession. After nine years out of office he became premier again in 1985 by promising to cut unemployment. The James Bay II complex on the Great Whale was Bourassa's means of "putting Quebec back to work".

He had just written a book called Power from the North explaining in detail how the United States was running out of coal and would buy billions of dollars worth of Quebec's hydro power.

The figures involved are sky-high. James Bay I, originally projected to cost $3.5 billion, eventually jumped to $14 billion. James Bay II is costed officially at $12.7 billion, but may well rise to $20 billion. Earlier this year deals he believed he had made with Vermont and New York states amounted to $25 billion to supply 1,450 megawatts of power until the year 2022.

This time though, the Cree took their own initiatives early. With Inuit (Eskimo) companions, they paddled canoes down to New York in April 1990 to dramatise their protests.

The James Bay hydro-electric project in northern Canada is said to be a critical investment for the province of Quebec, where talk of separation is still on the boil. It is a matter of economic independence and pride for Quebeckers, but for Cree Indians who hunt and fish in the area, it has meant disaster. They are fighting the construction of the project's second phase and, reports Gemini News Service, they have gained the support of many Americans who were supposed to buy the electricity.

This month a Cree delegation is in Geneva, telling the UN Working Group on Indigenous Populations that if Quebec declares itself independent of Canada, the Cree of James Bay will declare their own independence from Quebec, in effect claiming the whole northern half of the province.

A month earlier, 100 unarmed Cree had formed a barricade at a small airport and chased away with goose-calls and shouts a party of Hydro Quebec officials who had flown up to hold hearings into the Great Whale project.

These moves have had a sharp effect. American environmental bodies, notably the National Audobon Society, have backed the Crees' stand arguing that their lands are the northern equivalent of tropical rainforests and an irreplaceable sanctuary of wildlife.

This month American politicians including New York mayor David Dinkins, have voiced concern about the hydro deal with Bourassa and about native rights.

Bourassa exploded in frustration. 'There are seven million Quebeckers on this land, in Canada, who need this project. The natives blocked ratification of the Meech Lake Accord. Now should they block Great Whale?"

Last summer a native Canadian blocked the passage of the Meech Lake Accord, a constitutional agreement between Quebec and the rest of Canada, because it did not acknowledge native rights.

The federal government has tiptoed around the issue. Last month Environment Minister Jean Charest announced it would do a full social and economic study of the impact of the Great Whale project, lasting about two years. But it has not tried blocking construction of 575 kilometres of access roads or the building of three airports due to start shortly.

Charest, himself a Quebecker like Prime Minister Brian Mulroney, was attacked by an opposition critic as "deceptive and totally lacking in courage." Critics believe that once some $750 million has been spent on these preliminary works.

Except possibly the Cree people. A referendum on Quebec sovereignty is due by October 1992, unless Ottawa and the other nine provinces produce a better constitutional deal for Quebec than the Meech Lake Accord that collapsed last year.

(Clyde Sanger, an author and journalist who has worked in Britain, Africa and at the UN, has lived in Canada since 1967.)