WASTE HEAT UTILIZATION

FEASIBILITY STUDY

Old Crow, Y.T.

Prepared for:

Old Crow Band

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With a contribution from:

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of Energy, Mines and Resources Canada

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Executive Summary

In the community of Old Crow, in the Northern Yukon, the Loucheux people have lived for hundreds of years. Over the last century, the people have been introduced to countless new foods, materials, and technologies. Some of these have been responsible for cultural conflict, and some have been of enormous advantage.

The people of Old Crow are presently examining methods of incorporating some of the new technologies into ventures which compliment and assist the new lifestyles in the community as well as the traditional ways.

In the interest of maximizing the benefits of energy and resources available to the community, the Old Crow Band obtained funding for a study to assess waste heat potential for greenhousing in Old Crow.

This study has been conducted through Phase 1 funding from the Energy, Mines, and Resources Canada (EMR), Remote Community Demonstration Program (RCDP). This report documents the Stage 1 requirements of the study to assess the feasibility of utilizing waste heat from the diesel electric plant for a food production facility.

The results of the Stage 1 study conclude that it is feasible and appropriate to utilize waste heat from the generators in Old Crow for an integrated food production facility. Based upon a preliminary evaluation of the technical, economic, and social factors involved, such a project appears to offer several significant advantages to the community.

The implementation of an integrated food production facility offers training and employment opportunities for the community. Local employment and the purchase of local materials for facility construction, fertilizer and feed, could also increase the cash flow in the community. In addition, the facility could offer a unique opportunity to conduct community based information transfer programs, and valuable research into successful food-production techniques in the far North.

Training will be an essential part of project development to prepare selected trainees with operational and managerial skills required for the facility.

A significant component of the Stage 1 study contained in this report is the evaluation of economic factors which will determine the extent of project implementation. The economic feasibility of this project is outlined below.

The following table summarizes estimated capital costs and one year operating costs for a waste heat recovery and distribution system, and a food production facility in Old Crow.

These calculations represent preliminary approximations based on standard systems and northern designs. Circumstances specific to final design may significantly affect the costs of buildings, equipment, and installation in Old Crow. These data are provided only as the basis for further study.

ECONOMIC SUMMARY
WASTE HEAT RECOVERY, DISTRICT HEATING SYSTEM AND
FOOD PRODUCTION FACILITY: OLD CROW, YUKON

	Waste Heat Recovery and Distribution	Greenhouse and Garden Operation	Poultry and Egg Operation	Ancillary Space
CAPITAL COSTS				
Building cost @ $90/sq ft		36,000	36,000	63,000
Area (sq ft)		400	400	700
Equipment cost	340,668	30,150	5,400	1,000
Total	340,668	66,150	41,400	64,000
Cost/square foot (avg $120)		165	104	91
REVENUE	67,860	40,111	14,000	
ANNUAL OPERATING EXPENSES	4,620	6,389	7,837	
ANNUAL LABOUR EXPENSES	5,600	21,500	6,163	
REVENUE - OPERATING COSTS	$57,640	$12,222	$0	$0

SIMPLE PAYBACK on TOTALPROJECT (yrs): 7

PROJECT SUMMARY

REVENUE	$121,971
CAPITAL	$512,218
OPERATION	$18,846
LABOUR	$33,263
TRAINING	$100,000

The results of this Stage 1 study strongly favor more detailed investigation into the development of a waste heat recovery system and a food-production facility in Old Crow. It is recommended that the project proceed with the tasks outlined in the proposal for the second stage of this study.

ÉTUDE DE FAISABILITÉ CONCERNANT L'UTILISATION DE REJETS THERMIQUES

OLD CROW (YUKON)

Résumé

Les Loucheux vivent depuis des siècles dans la collectivité de Old Crow, dans le nord du Yukon. Au cours du vingtième siècle, ils se sont vus présenter un nombre incalculable de matériaux, de techniques et d'aliments nouveaux. Certaines de ces nouveautés ont été à l'origine de conflits culturels et d'autres ont été très bénéfiques.

Les habitants de Old Crow procèdent actuellement à l'examen de méthodes qui leur permettraient d'incorporer certaines techniques nouvelles dans des entreprises qui appuient et encouragent l'implantation de nouveaux genres de vie dans la collectivité, ainsi que l'utilisation des méthodes traditionnelles.

Afin de maximiser les avantages pouvant être tirés de l'énergie et des ressources disponibles dans la collectivité, la bande de Old Crow a obtenu une aide financière en vertu du Programme de démonstration dans les collectivités éloignées d'Énergie, Mines et Ressources Canada, pour que soit menée une étude ayant pour but d'évaluer la possibilité d'utiliser des rejets thermiques aux fins de culture en serres à Old Crow.

Le présent rapport des conclusions tirées de la phase 1 de l'étude visant à évaluer la possibilité d'utiliser les rejets thermiques de la centrale électrique alimentée au combustible diesel pour faire fonctionner une usine de produits alimentaires et la possibilité de se servir d'une partie des rejets thermiques pour exploiter un digesteur anaérobie d'effluents urbains. Les résultats montrent qu'il est possible et à propos d'utiliser les rejets thermiques des génératrices pour faire fonctionner une usine intégrée de produits alimentaires à Old Crow. Suite à une évaluation préliminaire des facteurs techniques, sociaux et économiques impliqués, un projet de ce genre semble offrir plusieurs avantages dignes de mention pour les habitants de la collectivité. L'étude exécutée par N.A. Jacobsen, ingénieur civil et expert-conseil de Whitehorse, indique que, bien qu'un digesteur anaérobie à forte charge conçu pour les effluents urbains soit réalisable à Old Crow, il ne serait pas rentable ni souhaitable.

La mise en service d'une usine intégrée de produits alimentaires représente des occasions d'emploi et de formation pour les habitants de la collectivité. La création d'emplois dans la localité et l'achat sur place des matériaux de construction, des fertilisants et de la nourriture pour les animaux pourraient aussi augmenter la capacité d'autofinancement dans la collectivité. De plus, ce serait là une occasion unique de lancer des programmes de transfert d'information et d'exécuter des recherches concernant des techniques de production alimentaire efficaces dans le Grand nord.

Le projet comprendra une étape de formation afin de préparer les candidats choisis en fonction de leurs aptitudes à exploiter et à gérer l'usine.

Parmi les éléments importants de la phase 1 de l'étude, citons l'évaluation des facteurs économiques, laquelle déterminera la portée de la mise en oeuvre du projet. La faisabilité économique de ce projet est exposée brièvement ci-après.

Le tableau ci-dessous résume les coûts d'exploitation d'une année et les coûts en capital, tels qu'estimés pour un système de récupération et de distribution de rejets thermiques et une usine de produits alimentaires à Old Crow.

Ces calculs représentent des approximations préliminaires établies en fonction de systèmes courants et de modèles spécialement conçus pour le Nord. Il se peut que des circonstances particulières à la conception définitive aient un effet considérable sur les coûts des édifices, du matériel et de l'installation à Old Crow. Ces données sont fournies uniquement à titre de point de départ pour des études ultérieures.

Les résultats de la phase 1 de l'étude montrent clairement qu'il faudrait exécuter des études plus détaillées en ce qui concerne la mise au point d'un système de récupération des rejets thermiques et d'une usine de produits alimentaires à Old Crow. Il est recommandé que les responsables du projet mettent en marche les activités mentionnées de la proposition décrivant la deuxième phase de l'étude.

Cette étude a été réalisée pour la collectivité de Old Crow par Arctech Community Energy Research Associates.

RÉSUMÉ ÉCONOMIQUE
SYSTÈME DE RÉCUPÉRATION DE REJETS THERMIQUES ET DE CHAUFFAGE URBAIN, ET USINE DE PRODUITS ALIMENTAIRES OLD CROW (YUKON)

	Récupération et distribution de rejets thermiques	Exploitation d'une serre et d'un jardin	Exploitation d'un élevage de volailles et d'une usine de traitement d'oeufs	Espace auxiliaire
COÛTS EN CAPITAL				
Coût de construction, à 90 $ le pi carré		36,000 $	36,000 $	63,000 $
Superficie (en pieds carrés)		400	400	700
Coût du matériel	340,668 $	30,150 $	5,400 $	1,000 $
Total	340,668 $	66,150 $	41,400 $	64,000 $
Coût du pied carré (en moyenne 120 $)		165 $	104 $	91 $
REVENU	67,860 $	40,111 $	14,000 $	
DÉPENSES D'EXPLOITATION ANNUELLES	4,620 $	6,389 $	7,837 $	
FRAIS DE MAIN-D'OEUVRE ANNUELS	5,600 $	21,500 $	6,163 $	
REVENUS MOINS COÛTS D'EXPLOITATION	57,640 $	12,222 $	0 $	0 $

DÉLAI D'AMORTISSEMENT POUR L'ENSEMBLE DU PROJET, SANS TENIR COMPTE DE L'INFLATION, en années (excluant les coûts de la formation): 7

RÉSUMÉ DU PROJET

REVENUS	121,971 $
CAPITAL	512,218 $
EXPLOITATION	18,846 $
MAIN-D'OEUVRE	33,263 $
FORMATION	100,000 $

1.0 Introduction

This report documents the results of a study to evaluate the opportunities for recovering and utilizing waste heat from the Yukon Electrical Company Ltd. diesel-fueled electricity generator at Old Crow, Yukon. Arctech Community Energy Research Associates has been contracted by the Old Crow Indian Band to assess the technical, social, and economic factors which would determine the feasibility of using this energy resource for the benefit of the community. This study is funded through an agreement between the Old Crow Indian Band and the Government of Canada, Energy Mines and Resources (EMR), Remote Community Demonstration Program (RCDP).

Through initial discussions with the Chief and Council it was determined that the community could benefit significantly if the recoverable waste heat was utilized for facilities to produce locally grown vegetables, poultry and eggs. As well, it was suggested that the recurrent problems associated with the disposal of sewage be addressed by evaluating the potential of using a portion of the waste heat for an anaerobic digester. The feasibility of a digester to treat sewage from the community and waste material produced by the greenhouse and poultry house has been assessed.

To insure that this study meets the needs of the people of Old Crow, the study team has spent a total of more than fourteen person weeks living in the community. During this time, the study team has had the opportunity to discuss the project with many community members of all ages. Visiting with the people of Old Crow has given the study team a better understanding of: what the people want; the level of community interest; the requirements of training programs to further develop this interest; the experience of community members in growing vegetables and raising chickens; and the extent to which the experience of other projects of a similar nature can be applied in Old Crow.

The valuable information gained during the community visits has been combined with technical and economic evaluations. The technical and economic evaluations are based on information from food production and waste heat recovery projects in Canada and Alaska, and discussions with other knowledgeable persons in the Yukon. This report provides the Old Crow Band with the information they need to decide how to best develop the available waste heat resource for the long term benefit of the community.

2.0 Community Profile

Old Crow is the only permanent community in the Yukon which is accessible only by air or water. This situation creates two unique perspectives:

> of the Outside, by the people of Old Crow,
> and of Old Crow, by the people Outside.

For the awareness of the Outside reader, it is essential to provide the information in this report within a context of the current, historical, and geographical background of the community.

2.1 General Description

Old Crow, the northernmost settlement in the Yukon, is north of the Arctic Circle at 67.6 deg N and 139.8 deg W. The community is sited on a river terrace on the north bank of the Porcupine River, immediately downstream of where the Old Crow River flows into the Porcupine from the north. The village is bounded on the east and west by peat plateaus and on the north and northwest by an area of high ground known as Old Crow Mountain which rises to approximately 700 metres above sea level.

The settlement area, which extends for about 1000 metres along the river at an elevation of approximately 250 metres above sea level is relatively flat, within a maximum relief of three metres. The eastern and western edges of the terrace are lower and subject to periodic flooding. Because the Old Crow region is within the zone of continuous permafrost, meltwater and precipitation collect in localized depressions throughout the village. Typical soils consist of frozen silts, sand and gravels overlain by ice-rich silt and peat.

In the community area, white or black spruce are the dominant vegetation in undisturbed areas. Where groundwater is plentiful, thick willow dominates. Paper birch and aspen are also common in small, widely distributed stands.

Log buildings dominate the architectural style of the community. In recent years, house construction in Old Crow has developed an integration of the log building with insulation levels suited to the rigors of the northern climate.

2.2 Climate

Old Crow, located approximately 120 kilometres north of the Arctic Circle, has a climate significantly colder than the southern parts of the Yukon.

On the basis of records taken at Old Crow since the late 1960's, a generalized sense of the climate can be gained. (All temperatures are in degrees C) Heating demand (ref 18 deg C) is an annual average of 10,207 degree days; agricultural potential as measured by growing degree days (ref 5 deg C) averages only 695. By comparison, Whitehorse has a heating demand of 6,894 degree days and an agricultural potential of 959 growing degree days. Haines Junction, the location of an Agriculture Canada Research Station, has only 680 growing degree days. However, the growing degree days at Haines occur between April and October, while the outdoor growing season at Old Crow occurs between May and September. Outdoor gardening in Old Crow is further limited by the cold ground temperatures of the permafrost and the fact that freezing temperatures can occur during any month.

Recorded temperatures at Old Crow have been as high as 32.8 in August and as low as -59.4 in January. Extreme minimum temperatures in June, July and August have been -8.3, -2.5 and -5.0 respectively. Average daily temperatures range from 14.2 in July to -33.1 in January.

Annual precipitation in Old Crow averages 215 mm, with about half of the total precipitation in the form of snow. On the average, there are 64 days per year with precipitation: 24 days with rain and 37 days with snowfall. For the period of climatic averaging ending in 1980 as published by the Atmospheric Environment Services, only July and August had days without snowfall. However this year (1984) snowfall occurred on two separate occasions in August.

The prevailing winds in Old Crow are from the northeast during cold weather and from the west during warmer weather. The average wind velocity is about 8 km/hr, with December and January having means near 4 km/hr, and August near 12 km/hr. The wind blows almost continuously in Old Crow. Frequent cloud cover is caused mainly by the Old Crow Mountains to the northwest, and the Keele Range mountains to the southwest.

The climate of Old Crow can be generalized as harsh and extremely variable.

2.3 The People

The Old Crow region has been continuously inhabited for at least 30,000 years as suggested by archaeological evidence. This region is one of the few areas in Canada which was not covered by ice during the last glaciation. The Old Crow site is a good fishing area near major caribou migration routes and had been a traditional gathering place for families using the Porcupine River for travel. Until the 1950's, the people wintered in small camps along the Porcupine River. About this time, a federal day school was built and Old Crow became a year round centre of regional activity.

The present population of approximately 250 people is predominately Loucheux, with strong nomadic traditions. Most people maintain the traditional livelihood of hunting, trapping and fishing on a full or part time basis. The annual salmon harvest on the Porcupine River is a major activity for many families.

Hunting and the sharing of fish and game is a tradition of the people. The spring and fall harvest of the migrating Porcupine caribou herd provides a major source of food. Some moose are also harvested.

In keeping with another tradition, most of the people move camp to Old Crow Flats by April and many stay until June. Several thousand muskrats are harvested annually on the flats during this "ratting season". Muskrats are harvested for their pelts, and while they are on the flats muskrats also contribute to the diet of the people. This yearly movement of the people to Old Crow Flats is a significant event in Old Crow.

Many people in the community combine the traditional livelihood with employment from various sources including the federal and territorial governments, the Band, the Co-op store, Trans North Air, and Yukon Electric. Nearly all employment in Old Crow is for the provision of community services.

The challenges and opportunities found in Old Crow are typical of most northern communities.

2.4 Energy Use

The recent "Overview Study of the Potential for Yukon Communities to Reduce Their Dependence on Oil", funded by Energy Mines & Resources, determined that the people of Old Crow maintain one of the lowest percapita energy demands for heating fuel and electricity in the Yukon. Elsa, Pelly, and Tagish- Marsh Lake are the only Yukon Communities which use less energy per person than Old Crow. This is influenced by the high cost of energy in Old Crow, the modest size of most dwellings, and a significantly smaller commercial sector than most Yukon communities.

The primary source of energy in Old Crow is wood. Approximately 1000 cords (14000 Gigajoules) per year are used by the community. Spruce is the fuel wood used most often. While most of the spruce trees in the Old Crow area range in size up to 200 mm (8 in) diameter, a number of logs as large as 500 mm (20 in) diameter at the butt were seen in the community wood pile.

Nearly all dwellings use wood for space heat and domestic hot water; the average household uses 10 cords per year. The school uses about 150 cords (2100 gigajoules) per year in a central boiler. Domestic hot water in the school for showers and sinks is heated with electricity. Electricity used for hot water heating in the school is estimated at 46,000 kilowatt hours (165 Gigajoules) per year, and amounts to 30% of the school's annual electricity consumption.

The second largest energy source in the community is diesel fuel for the generator. In 1983 the generator consumed 301,649 litres (11,357 Gigajoules) to produce 786,700 kilowatt hours (2831 Gigajoules) of electricity. This summary is based on data provided by Yukon Electrical Company Ltd. These data indicate that the generator operated at an efficiency of 25% for conversion of fuel energy to electrical energy.

The third largest energy source in the community is fuel oil for heating government and commercial buildings. Based on available data, this amounts to approximately 150,000 litres (5650 Gigajoules) per year. A cursory survey of oil heated buildings in the community indicates that all of these buildings have a very high potential for cost effective energy conserving retrofits.

Based on data collected for this study, 1984 fuel oil costs vary from \$0.70 to \$0.85 per litre (\$18.60 to \$22.60 per Gigajoule). Electricity costs are presently set by YECL at \$0.384 per kilowatt hour (\$106.67 per Gigajoule) for residential and, \$0.488 per kilowatt hour (\$135.56 per Gigajoule) for general service accounts. Residential customers benefit from the federal government subsidy which charges the first 700 kilowatt hours per month at the Whitehorse rate of \$0.072 per kilowatt hour. Very few residential customers in Old Crow use more than 700 kilowatt hours per month.

3.0 Waste Heat Production

In most Northern communities waste heat is produced when fuel is burned to generate electricity. The energy situation in Old Crow is similar to most remote Northern communities. The electricity needed to meet the basic requirements of power and light is supplied by engines which burn diesel fuel. These engines turn generators to produce electricity. Power-producing units such as these are typically called "generators".

Diesel fuel is expensive, and even more expensive when it must be shipped into the community by air. Although electrical service provided by large, community-sized, diesel-fueled generators is quite reliable, it is usually four to six times more expensive than electricity produced by hydroelectric dams. One reason for the high price of electricity is the expensive fuel. Another reason is that a diesel-fueled generator is at best, only thirty percent efficient for producing electricity.

Most gasoline or diesel fueled engines are only twenty five to thirty percent efficient. This "efficiency" is demonstrated by the following example. If you put four gallons of gasoline in a snowmobile, one gallon makes the machine go, the other three gallons make heat. Usually the heat that an engine produces is wasted; in the case of a snowmobile, some of this heat warms the driver, and the rest is lost.

Similarly, in the case of the diesel generator, this "waste heat" is usually lost. In 1983, the generator at Old Crow operated at an efficiency of 25%. For every four litres of fuel that the engine burned, only one litre produced electricity, the other three litres produced heat. This heat is presently wasted, because it either goes up the stack or out through the radiator.

In recent times, high fuel prices have provided northern communities in Alaska and Canada with a cost-effective opportunity to recover much of this waste heat for use in the community.

3.1 Waste Heat Recovery

To provide the community of Old Crow with current information on waste heat recovery, reports on the operation of waste heat recovery systems in Alaska and the Northwest Territories were reviewed. As well, visits were made to a number of generator units in the Yukon which are using waste heat recovery systems.

3.1.1 Engine Coolant Heat Recovery

The simplest form of waste heat recovery can be used where the generator is located in a building such as a shop or garage. For example, at the Eagle Plains Lodge, the system recovers the wasted heat from the engine coolant radiator or "water jacket" by reversing the radiator fan so that in winter, the fan draws cold outside air across the radiator. This cools the radiator and warms the air, which is then used to heat the building.

In a 1983 letter to the Government of the Northwest Territories, Mr. D. I. McGuinness, Engineering Manager for the Northern Canada Power Commission (NCPC) states that many of their northern plants are equipped with water jacket heat recovery systems. These heat recovery systems provide heat for the plant garage or warehouse buildings. Several of these systems have been in operation for 10-20 years with good success. NCPC designers and engineers like jacket heat recovery as it absorbs machinery heat which would otherwise have to be directed to the radiators and cooled by operating radiator fans. Since about 5 h.p. of electric motor fan power is required for every 300 kW of engine generated power, this wasted fan energy can be saved to the cost benefit of NCPC.

Another method of recovering waste heat is to locate the radiator in a building adjacent to the generator. The heat from the radiator is used to heat the other building. However, there are several factors which may cause problems in such a system. If any difficulties occur in the transmission line between the generator and the radiator, the entire power system in the community could be affected. Because of the danger of system shutdown, these systems are not considered reliable for unattended operation.

There is a simple way to insure safe and reliable operation of a waste heat recovery system, so that the electrical service is not affected by difficulties with the waste heat recovery system. This system uses a "heat exchanger" to transfer the heat from the engine coolant loop into a "district heating" loop which services the community. The heat transfer fluid in the district heating loop is a water and antifreeze mixture similar to the coolant fluid. With this method of heat recovery, electricity production is not compromised; only the heat, not the coolant fluid, is transferred into another system.

A basic district heating system consists of a main loop which circulates the heat through a "feed" leg to "end use" locations in the community. At each end use point, branch lines transfer heat from the mains to a heat exchanger in the building. The heat is extracted to warm the building or to provide domestic hot water. The heat transfer fluid, now cooled, is returned by a second branch line to the "return" leg of the main loop. From there, the fluid circulates back to the heat exchanger in the generator building, where it is reheated, and the process is repeated. Many end use points, each with their own feed and return branch lines can be serviced by one main loop of a district heating system.

The advantage with heat-exchanged engine coolant heat recovery is that the district heating system utilizes whatever heat it requires, and the existing cooling system will continue to dissipate any unused heat.

3.1.2 Exhaust Gas Heat Recovery

An engine rejects about the same amount of heat in the form of hot exhaust gases as it does through the radiator. Exhaust heat recovery units called "exhaust boilers" are used in some installations to increase the amount of recoverable heat. Exhaust gas heat exchangers are more expensive per unit of heat recovered than coolant fluid heat exchangers. Temperature differentials in exhaust boilers can be as high as 555 deg C (1000 deg F), therefore they are made of high temperature stainless steel to withstand the high temperatures and potentially high pressures if steam were accidentally produced.

Exhaust boilers are also subject to "sooting up" from unburned fuel, which lowers the efficiency. As compared with coolant heat exchangers, exhaust boilers may have a useful lifetime as short as 5 years, while coolant heat exchangers usually last for more than 20 years. Facilities where exhaust boilers are used have indicated that most system problems relate to the exhaust boiler, and that frequent attention to system monitoring is required. For these reasons, the use of exhaust boilers is not recommended for generators which run unattended for most of the time. The use of an engine coolant heat recovery system does not prevent the addition of an exhaust boiler at a later time.

3.2 Waste Heat Availability

The total amount of waste heat available at the generator is determined from generator output and specifications as provided by the engine manufacturers and the utility company.

3.2.1 Electricity Generating Units at Old Crow

Data for the three generators in Old Crow, as provided by YECL and Finning Tractor and Equipment Co., are shown in Table 3.2.1.A below. This table shows maximum heat rejection to engine coolant and exhaust gases at the full operating capacity of the generator.

TABLE 3.2.1.A
GENERATING UNITS, FULL LOAD CAPACITIES & MAXIMUM HEAT REJECTION
YUKON ELECTRICAL COMPANY LTD.
OLD CROW YUKON

C.U.L. UNIT NUMBER	ENGINE MFG & MODEL	PRIME POWER kW	HEAT REJECTION ENGINE COOLANT BTU/min	BTU/hr	kW	HEAT REJECTION STACK GASES BTU/min	BTU/hr	kW
8	CAT D353	200	10987	659232	193	11225	673547	197
186	CAT D3306	150	6824	409440	120	10521	631260	185
230	CAT D3408	220	8815	528900	155	13592	815520	239

Under normal operating conditions, generators seldom operate at full load and maximum efficiency. For example, at Old Crow, the maximum peak demand occurs during November or December, and has been as low as 172 kW, and as high as 180 kW during the last three years.

It can be assumed that both electrical power demand and electricity use in Old Crow will increase in the future. Therefore, the size of the waste heat recovery equipment is determined by the heat rejection characteristics in the range between historic peak load and maximum generating capacity.

Information on electricity generation, fuel used, and generator efficiency were provided by the Yukon Electrical Company (YECL) for the period of 1981 to present.

3.2.2 Electricity Generation

Table 3.2.2.A shows electrical generation for the last three years in Old Crow. The table shows total generation for each month, as well as total, minimum, average, and maximum generation per month for each year. The monthly generation figures are averaged to provide generation data for a typical year. Average power in kilowatts is shown for each month of the typical year.

TABLE 3.2.2.A
ELECTRICITY GENERATION
OLD CROW, YUKON

	ELECTRICITY GENERATION MWh/month			AVERAGE YEAR	
	81-82	82-83	83-84	MWh/month	AVG kW
APR	57	43	65	55	77
MAY	46	39	61	49	65
JUN	50	55	37	47	65
JLY	49	37	47	44	59
AUG	50	55	41	49	65
SEP	56	43	46	49	67
OCT	83	61	66	70	94
NOV	82	86	68	78	109
DEC	91	68	108	89	120
JAN	73	96	62	77	104
FEB	69	77	78	75	110
MAR	62	75	82	73	98
TOTAL	768	734	761	754	
MINIMUM	46	37	37	44	59
AVERAGE	64	61	63	63	86
MAXIMUM	91	96	108	89	120
PEAK kW	180	176	172		180
EFFICIENCY %	28	26	25	26	
kWh/litre	2.88	2.76	2.61	2.75	

The electrical generation data and generation efficiency was used to calculate fuel input per month assuming a constant efficiency throughout the year.

3.2.3 Fuel Input to Generators

Table 3.2.3.A shows generator fuel input in Gigajoules per month at an assumed fuel energy content of 37.65 megajoules per litre. Yearly totals and monthly minimum, average, and maximum values are calculated from monthly electricity generation values, using the efficiencies tabulated for each year. From these data, an average fuel energy input to the generators is computed for each month of a typical year. Average input in kilowatts is shown for each month of the typical year.

TABLE 3.2.3.A
FUEL CONSUMPTION FOR ELECTRICITY GENERATION
OLD CROW, YUKON

	GENERATOR FUEL GIGAJOULES/month	(37.65 MJ/litre)		AVERAGE YEAR	
	81-82	82-83	83-84	GJ/month	AVG kW
APR	747	587	940	758	292
MAY	603	527	878	669	250
JUN	648	748	528	641	247
JLY	645	500	673	606	226
AUG	653	754	589	665	248
SEP	731	590	670	664	256
OCT	1085	830	959	958	358
NOV	1064	1169	976	1070	413
DEC	1186	926	1563	1225	457
JAN	999	1386	818	1068	399
FEB	945	1117	1018	1027	421
MAR	841	1078	1081	1000	373
TOTAL	10149	10212	10692	10351	
MINIMUM	603	500	528	606	226
AVERAGE	846	851	891	863	328
MAXIMUM	1186	1386	1563	1225	457

The average year Gigajoules per month is used to calculate the average recoverable waste heat for evaluating distribution potential.

3.2.4 Recoverable Waste Heat

Based upon studies of installations in Canada and Alaska, it has been determined that the amount of heat which is economically recoverable is usually 24% of the fuel energy input for engine coolant heat recovery, and 16% of the fuel energy input for exhaust gas heat recovery. The fuel input data in gigajoules per month and these recovery rates were used to determine recoverable engine coolant heat and exhaust gas heat.

Table 3.2.4.A shows average recoverable waste heat for each month of a typical year. The table shows gigajoules per month, megajoules per average day, average kilowatts, and megajoules per degree day.

TABLE 3.2.4.A
RECOVERABLE WASTE HEAT
OLD CROW, YUKON

	ENGINE COOLANT HEAT RECOVERY @ 24% OF FUEL GJ				EXHAUST GAS HEAT RECOVERY @ 16% OF FUEL GJ			
	GJ/mo	MJ/DAY	AVG kW	MJ/DDY	GJ/mo	MJ/DAY	AVG kW	MJ/DDY
APR	182	6064	70	208	121	4043	47	138
MAY	161	5182	60	316	107	3455	40	211
JUN	154	5132	59	837	103	3421	40	558
JLY	145	4691	54	1279	97	3127	36	853
AUG	160	5150	60	636	106	3433	40	424
SEP	159	5310	61	345	106	3540	41	230
OCT	230	7417	86	263	153	4945	57	175
NOV	257	8558	99	211	171	5705	66	141
DEC	294	9484	110	216	196	6323	73	144
JAN	256	8267	96	157	171	5512	64	104
FEB	246	8722	101	193	164	5814	67	129
MAR	240	7742	90	193	160	5161	60	128
TOTAL	2484			4852	1656			3235
MINIMUM	145	4691	54	157	97	3127	36	104
AVERAGE	207	6810	79	404	138	4540	53	270
MAXIMUM	294	9484	110	1279	196	6323	73	853

To determine waste heat available to meet a building space heating load, the amount of heat available must be evaluated as a function of climate.

Monthly heating degree days for the period 1981 to present, computed from monthly temperature data provided by Atmospheric Environment Services (AES), are shown in Table 3.2.4.B below. The average year degree day data were used to compute the recoverable heat availability in Megajoules per degree day shown in Table 3.2.4.A above.

TABLE 3.2.4.B
CLIMATE: HEATING DEGREE DAYS
OLD CROW, YUKON

	HEATING DEGREE DAYS ref: 18 degrees C 81-82	82-83	83-84	AVERAGE
APR	849	897	882	876
MAY	375	521	629	508
JUN	207	183	162	184
JLY	164	78	99	114
AUG	273	260	220	251
SEP	474	369	543	462
OCT	784	921	921	875
NOV	1146	1311	1191	1216
DEC	1231	1283	1566	1360
JAN		1727	1547	1637
FEB	1271	1170	1393	1278
MAR	1215	1318	1206	1246
TOTAL	7990	10037	10358	10007
MINIMUM	164	78	99	114
AVERAGE	726	836	863	834
MAXIMUM		1727	1566	1637

The heating degree day data are also used to compute monthly heating load for buildings when the annual fuel input can be estimated. The results are then used to assess distribution potential for a district heating system.

3.2.5 District Heating Potential

In a coolant-fluid heat recovery and distribution system, the heat rejected by the engine coolant takes three paths. The first path is the route taken by the heat which never makes it across the heat exchanger. As the heat is transferred from the engine cooling loop to the district heating loop, not all of the heat can be transferred across the heat exchanger. However, heat exchanger efficiencies as high as 95% can be achieved.

The other two paths taken by the heat follow the district heating loop; most of the heat will be distributed to the buildings, and some of the heat will escape through the pipe insulation. When a district heating loop is designed for permafrost regions, high levels of insulation are chosen for the pipe to minimize this heat path to less than 10% of the total heat available in the district heating loop at the heat exchanger. The remaining energy is available to meet heating loads such as building space heating and domestic hot water (DHW), or returned to the heat exchanger. The operation of the terminal equipment at each end use point is automatic; in conjunction with the existing heating equipment.

Table 3.2.5.A shows District Heating Potential as a function of available heat from engine coolant and heating loads from a number of community buildings. The heating loads are based on annual fuel use for existing buildings and design calculations for proposed buildings. These data are used to estimate the distributable heat for average days of average months of a typical year in Old Crow. The extent to which the available waste heat is used will determine the economic feasibility of system operation.

TABLE 3.2.5.A

DISTRICT HEATING POTENTIAL & SYSTEM UTILIZATION FOR ENGINE COOLANT HEAT RECOVERY

OLD CROW, YUKON

	DEGREE DAYS 81-84 AVERAGE	AVAILABLE COOLANT HEAT AVG MJ/DAY	FOOD PRODUCTION FACILITY AVG MJ/DAY	SCHOOL DHW AVG MJ/DAY	PROP WELL HOUSE AVG MJ/DAY	NHW STATION AVG MJ/DAY	RCMP STATION AVG MJ/DAY
APR	876	6064	146	454	76	1698	3715
MAY	508	5182	47	454	52	954	2086
JUN	184	5132	3	454	32	357	780
JLY	114	4691	0	454	24	213	466
AUG	251	5150	11	454	30	471	1030
SEP	462	5310	91	454	49	896	1959
OCT	875	7417	304	454	75	1642	3592
NOV	1216	8558	602	454	110	2357	5157
DEC	1360	9484	728	454	140	2551	5581
JAN	1637	8267	776	454	155	3071	6717
FEB	1278	8722	575	454	127	2631	5755
MAR	1246	7742	325	454	108	2338	5114
TOTAL	10007						
MINIMUM	114	4691	0	454	24	213	466
AVERAGE	834	6810	301	454	82	1598	3496
MAXIMUM	1637	9484	776	454	155	3071	6717

PERCENT OF SYSTEM UTILIZATION	FOOD PRODUCTION FACILITY (FPF) %	FPF + SCHOOL DHW %	FPF + SCH DHW + WELL HSE %	FPF + SCH DHW + WELL HSE + NHW %	FPF + SCH DHW + WELL HSE + NHW + RCMP %	NON-UTILIZED RESIDUAL HEAT %	AVG MJ/DAY	GJ/MONTH
APR	2	10	11	39	100	0	0	0
MAY	1	10	11	29	69	31	1589	49
JUN	0	9	10	16	32	68	3506	105
JLY	0	10	10	15	25	75	3533	110
AUG	0	9	10	19	39	61	3154	98
SEP	2	10	11	28	65	35	1861	56
OCT	4	10	11	33	82	18	1350	42
NOV	7	12	14	41	100	0	0	0
DEC	8	12	14	41	100	0	0	0
JAN	9	15	17	54	100	0	0	0
FEB	7	12	13	43	100	0	0	0
MAR	4	10	11	42	100	0	0	0
MINIMUM	0	9	10	15	25	0		0
AVERAGE	4	11	12	33	76	24		38
MAXIMUM	9	15	17	54	100	75	3533	110

TOTAL RESIDUAL:459GJ   TOTALAVAILABLE:2484GJ   ANNUAL AVG UTILIZATION: 82%

POTENTIALFUELOIL DISPLACEMENT: 66,972 litres, currentvalue: $50,229

The Food Production Facility can be expected to use only an average of 4% of the available heat. Therefore additional options for the use of recoverable heat have been analyzed as shown in Table 3.2.5.A above. The second option meets the heating requirements of the Food Production Facility and the Domestic Hot Water at the School, and utilizes an average 10% of the available heat.

The third option meets the heating requirements of the Food Production Facility, the Domestic Hot Water at the School, and the heating requirements of a Well House for the community well. This option utilizes an average 11% of the available heat. The connection to a well house will also provide for the economic distribution of freeze protected water in a pipe bundled with the district heating loop.

The fourth option meets the heating requirements of the Food Production Facility, the Domestic Hot Water at the School, a Well House, and the average space heat and DHW load of the Health Nurse Station. This option utilizes an average 33% of the available heat.

To maximize district heating system economics, all available waste heat should be used. Since the fourth option leaves two thirds of the heat not utilized, a fifth option was chosen to incorporate the RCMP Station with the other buildings serviced in option four. Although the district heating system cannot be expected to provide all of the heat requirements of the RCMP Station, all residual heat can be used to provide 100% utilization of the system for six months of the year.

This last option uses 81% of the average available waste heat from the engine coolant during a typical year. The residual 19% would be available during the months of May to October and could be used to provide soil warming and frost protection for the Food Production Facility gardens. As well this residual heat could be used to heat a Summer Season Pool in the community. With district heating branch lines to the RCMP Station, an extension to the hockey rink area for the Summer Pool would be economically feasible, and could possibly provide for 100% annual heat recovery system utilization.

Under normal operating conditions, the available heat and the heating demand will vary from day to day, and at different times throughout the day. Electricity demand is usually greater during the day than at night, while heating demand is usually greater during the night than during the day. For this reason, the heat distribution to individual loads is sized to provide maximum heat utilization at an average base load, with extreme conditions met by the existing heating systems of serviced buildings.

This study concludes that engine coolant heat recovery from the diesel generators at Old Crow can provide sufficient recoverable waste heat to meet all of the heating needs of the food production facility. At all times there will be a variable quantity of surplus heat not required by the food production facility. This heat can be used to meet a portion of the space heating or DHW demand of other buildings in the community. This greater system utilization will significantly enhance the economic feasibility of the proposed waste heat recovery system.

It is recommended that the generator output at Old Crow be monitored on at least an hourly basis during the months of November and December 1984, to determine the average day load cycling. These data will be required to determine design parameters if more detailed evaluations of recovery system feasibility are required.

4.0 Northern Horticulture

Successful horticultural operations in the form of outdoor gardening and greenhousing have been achieved by many growers in northern Canada and Alaska.

A community greenhouse and garden facility for vegetable production has been suggested by the Old Crow Band as one means of utilizing some of the recoverable waste heat from the diesel electric plant.

This section of the report addresses the benefits and limitations of a greenhouse and garden in Old Crow by examining the technical and economic factors of operating such a facility.

The costs associated with the economics section are based upon data collected during the initial community visit to Old Crow in April, 1984, and greenhouse production data obtained from Yukon producers and other greenhouse/garden operations in Canada and Alaska. For the purpose of discussion, it is assumed that quoted costs are subject to change at a rate comparable to the rate of change of other economic factors in Old Crow.

If the feasibility of a greenhouse/garden operation is based upon economic factors alone, then the cost of local production cannot exceed the revenue from vegetable sales. However, if other considerations indicate that locally produced vegetables will have greater appeal in the community, then these factors must also be examined. For example, in Whitehorse, consumers are willing to pay higher prices for farm fresh eggs than for imported eggs.

Such factors as vegetable quality, as well as the sense of local self-sufficiency, must also be considered. There may also be advantages in establishing greater levels of community control over the production of vegetables available in the community.

4.1 Yukon Horticultural Experience

To obtain a sampling of the collective Yukon experience in horticulture, vegetable growers from the Atlin Road, to Mayo and Dawson were visited. This sampling ranged from family scale operations through to commercial-scale garden and greenhouse production. The information gathered in conversations with the growers was used to assess common methods for improving the success of crops and avoiding crop failure. Accurate records of vegetables harvested are not often kept, but the gardeners can usually estimate the amount which they produce each year.

4.1.1 Gardening Experience in Old Crow

During the April visit to Old Crow, discussions with individual community residents assessed historic and present levels of experience in gardening in the Old Crow area. Types of crops grown, which crops were successful and not successful, and techniques used for local horticulture were discussed. The information gained in these discussion was combined with other Yukon experience.

Several people in Old Crow have previous experience with vegetable gardening. Stories were told of trappers who lived up-river from the community. They sometimes planted rutabagas, cabbages, and other cold season crops before they left to sell their furs. The gardens took care of themselves, and when the trappers returned, the produce was ready for harvest.

The Catholic priests had a successful garden plot in front of the church. Other residents told of various people who have had garden plots in and around the community.

Many of these one-time gardeners still live in town, however this practice has not been passed down to the younger people as a traditional means of obtaining food.

There are presently outdoor gardens at the Nursing Station, Steven Frost's house and the Anglican Rectory. Steven Frost has two gardens. One garden consists of "raised" beds, for potatoes. The potatoes are hardy and vigorous, and their development equals those grown in the southern Yukon.

The ground-level bed is doing reasonably well, considering the cold temperatures in Old Crow this summer. Crops in this garden include spinach, lettuce, radishes and beets.

The Anglican Minister has planted his "raised bed" garden in an unused river boat. The garden is flourishing and his carrots are, if one can judge by occasional carrot tops on the street, much relished by the children.

Inspection of these sites indicates that the plants are growing well. With a small amount of additional care, productivity can be increased. The most important improvements relate to "soil preparation", and include fertilization, using "raised bed" techniques to keep the plant roots warmer, and pest control. The need for soil improvement here is typical of many garden locations in the Yukon.

4.1.2 Greenhousing Experience in Old Crow

During the 1940's, the Mounted Police detachment operated a greenhouse in Old Crow for the benefit of it's members and undoubtedly the community. There are some pictures of the greenhouse in the Old Crow museum. Unfortunately, the pictures do not show it in the summer, nor is the whole building visible, however, it appears to be at least eight feet wide and longer than it is wide. The growing beds were fertilized with the contents of caribou stomachs. The stomachs were removed from animals harvested for meat. The stomachs were allowed to freeze then transported to the greenhouse where the contents were spread on the growing beds.

Five greenhouses were in operation in the community this summer; one at the School one at the Nursing Station, one at the Old Catholic Church, one behind the Co-op store, and the fifth at Johnnie Abel's residence.

Due to a late start in planting, and a very cold summer season, many plants did not survive, and production in all the greenhouses was quite low. Tomato, cucumber, and zucchini plants all successfully set fruit in the school greenhouse from seedlings started in Whitehorse and taken to Old Crow.

With an earlier start, better protection from frost, regular watering, and some training for the gardeners, the harvest would improve considerably.

4.2 Northern Gardening

Vegetable production in the north offers many challenges to the gardener. Short growing seasons, high risk of frost, and low soil temperatures are three major hurdles which the northern gardener must overcome. On the other hand, the long days of summer provide plants with much more sunshine per day than they can obtain in the south.

The most successful outdoor gardens in northern regions employ the use of many cold climate horticultural techniques. Such techniques include planting in raised beds, providing frost and wind protection, selecting frost tolerant crops, and the use of "bedding plants" to give the crop a head start on the short season.

If a gardener can get an early start by raising ground temperatures, and protect the plants from frost, then fantastic yields can be obtained. Alaskan experience with two foot wide cabbage heads is not uncommon.

The following sections address the factors which should be considered in planning an outdoor vegetable garden in the north.

4.2.1 Soil Bed Gardening

The major problem faced by many Yukon gardeners is poor soil conditions. There are several common practices for improving these conditions. Addition of organic material, fertilization, warming of the soil bed area, providing good drainage, controlling pests (especially rodents), and irrigation will make the soil more productive.

Heavy clay soils and coarse sandy soils generally require the addition of an organic material, such as peat moss or manure, to lighten the soil and improve it's ability to retain moisture. Manures have an additional benefit of adding nutrients to the soil which are necessary for plant growth. Locally produced animal manures and peat moss, if available, are the favored choice of Yukon growers, with chicken manure being the most concentrated source of plant nutrients.

4.2.2 Fertilizers

Fertilizers are often used to augment the nutrient content of manures. Many experienced gardeners tend to apply fertilizers according to the directions on the bag or box, or by "feel". A few gardeners obtain a soils analysis and follow the resulting recommendations.

4.2.3 Irrigation

Irrigation is a major problem for those who are gardening away from lakes and streams. Much of the Yukon suffers from a lack of rain, and access to well water can be very costly. Water for irrigation is often hauled to these sites at great expense to the gardener. Mulching with plastic and other materials is often used to retard evaporation of soil moisture.

4.2.4 Pests

Animals and insects are sometimes responsible for serious losses in northern vegetable gardens. These invaders are usually referred to as "pests".

There are several effective means of reducing the damage caused by these pests. Fences, poison, traps and shot-guns are the usual methods employed for pest control, with some gardeners employing only non-violent and organic remedies. In general, the most damaging pests seem to be rodents, which can be effectively controlled with a good fence.

4.2.5 Crop Varieties

The varieties best grown outside can be categorized as those which have a "final" harvest period, and can withstand the rigors of the outdoor climate. This is the case with vegetables like carrots, which require a long time to grow. Once they are harvested, a new crop has to be planted in the space, then another period of growth is required before the second crop can be harvested. The short growing season may limit "double cropping" of some vegetables.

Crops such as turnips, potatoes, beets, broccoli, chard, spinach, radishes, carrots and lettuce are successfully grown in outdoor gardens throughout the Yukon. Crops such as tomatoes, and cucumbers on the other hand, produce continuously over a long period, thus making better use of high cost greenhouse space. Lettuce can be grown outdoors in the summer, and in the greenhouse during the rest of the year.

It is advisable to produce a mixture of different vegetables. This method of "mixed production" is not the most "efficient" way to grow, however, it is good insurance against a total failure of the crop, since some varieties are bound to survive conditions which would decimate others. The most efficient method of production is to grow only one or two of the highest yielding types of vegetables, however, depending upon the circumstances and the market, variety may be a more important consideration than yield.

The majority of vegetable crops are harvestable over a four week period. Some varieties, such as lettuce, mature in a short length of time, and are harvestable over a long period. There are two options available to deal with an excess of a particular crop that may result from that variety being harvested all at one time. They can be stored for sale over an extended period, or shipped to other markets.

4.2.6 Frost Protection

In Northern areas like Old Crow, with short growing seasons and a risk of frost in all summer months, it is necessary to implement some method of frost protection for frost susceptible vegetables.

Two methods of frost protection can be used, low cost plastic crop shelters and mist spray irrigation for periods of low temperature. Each have advantages and disadvantages over the other. A plastic shelter will raise the overall temperature of the growing area and soil bed thus supporting higher yields. The spray irrigation method has a lower initial and maintenance cost and is not susceptible to wind damage. Spray irrigation is, however, susceptible to power and water supply failure.

Cool soil temperatures have eliminated all but the most inventive and persistent growers from much of the Yukon. Those who persist swear by a number of proven methods. The use of plastic mulch (a sheet of plastic spread over the growing area which traps the heat like a greenhouse) is widespread, especially in the spring. Gardeners have been successful using both clear and black plastic mulches. Another common practice is to grow the more delicate vegetables in raised beds, cold frames, or "seasonal" greenhouses.

Some crops which can be grown outside more economically than in a greenhouse are "frost tolerant" varieties, such as broccoli, which will not be damaged by minor frosts. These varieties do not require protection.

4.3 Northern Greenhousing

Many crops which cannot be grown outside in the north can be successfully produced in a greenhouse. Appropriate northern greenhouse designs are characterized by a south wall of windows to let in the sunshine, and an insulated north wall to keep out the cold. The plants are grown on benches or on the floor. Greenhouses may be either free-standing structures, or they may be constructed as an addition to an existing structure.

The advantage of greenhousing is that the windows provide protection from the weather, while allowing the penetration of sunlight essential to plant growth. The gardener has better control over the environment, and can easily provide the plants with a regulated supply of water and nutrients.

In conventional greenhouses, there are many materials which are used as a "media" to support the roots of the plants. Local soil can be used, however, many of the difficulties associated with outdoor gardening, such as soil quality, proper fertilization, and weed control, are similar in greenhouses when soil is used.

4.3.1 Temperature Requirements

Most vegetables will produce well in temperatures between 10 deg. C (50 deg. F) and 32 deg. C (90 deg. F). Temperatures above or below this range may cause stress in the plants, reducing their ability to perform efficiently. In the case of many varieties of fruiting vegetables, such as tomatoes, night time temperatures below 10 deg. C will prevent the flowers from "setting" fruit. Leafy vegetables, such as lettuce prefer lower temperatures. Temperatures above 23 deg. C may cause them to bolt and "go to seed" prematurely.

Fruiting plants need a night-time reduction in temperature to trigger the change from the day-time phase of vegetative production into the night-time phase of producing reproductive tissue.

For greenhouse operation, an ideal day-time temperature is between 18 deg. C and 25 deg. C. An ideal night-time temperature is 5 deg. C below the day-time temperature, but should never be lower than 10 deg. C.

4.3.2 Ventilation Requirements

Greenhouses require ventilation to provide two primary functions: cooling, and supplying fresh air.

Cooling is required during times when the heat produced by the sun shining in through the windows causes the temperature to rise above the desirable limits. This temperature rise may also occur because of the heat given off by any supplementary lighting or other electrical equipment.

Plants require copious amounts of carbon dioxide for the process of photosynthesis. A ventilation rate of 1/2 air change per hour (30 litres/sec or 60 cfm) in the greenhouse will be required during the day light hours to provide adequate levels of carbon dioxide.

4.3.3 Lighting Requirements

Light plays an essential role in providing the energy required for plant growth. During the summer, all of the light requirements of the plants can be provided by the sun. During fall, winter, and spring, a supplemental light source will be required. For proper growth, artificial lighting should closely resemble sunlight, both in intensity and colour.

It is estimated that the electrical load from the artificial light will be 500 watts per square meter. Table 4.3.3.A summarizes the lighting requirements during the year in hours per month (hrs/month).

Table 4.3.3.A

SUPPLEMENTARY LIGHTING REQUIREMENTS

MONTH	hrs/month
January	244
February	118
March	0
April	0
May	0
June	0
July	0
August	0
September	0
October	118
November	244
December	372
Total/year	1096

4.3.4 Hydroponics

Some Yukon greenhouse growers are turning to an ancient method of gardening used by the Aztec Indians of Mexico to reduce the amount of work and minimize many of the problems of soil bed greenhousing. "Hydroponics" is a method of growing plants in a sterile medium (gravel, sand, vermiculite, plastic, etc.) and using water to carry the nutrients (fertilizer) to the plants. This method eliminates problems associated with improving poor soils.

The simplest hydroponic system involves a growing bed filled with fine (about half inch) gravel, in which the vegetable seedlings are planted. The bed has a waterproof seal so it will not leak. The bed should be about six inches deep, and have a drain at one end. The drain empties into a barrel which contains a solution of water and fertilizer. A pump sits in the bottom of the barrel. The pump is turned on and off three times a day (usually by an automatic timer) for about half an hour each time. This pushes the solution to the gravel bed, and feeds the plants. The solution then drains back down into a barrel.

The "Feasibility Study of an Arctic Food Producing Facility": by The Defense and Civil Institute of Environmental Medicine (DCIEM) lists the following advantages to hydroponic gardening:

- transplanting without "seedling shock"
- no waterlogging
- less weeds using sterile media
- faster plant growth
- potential for higher yields of uniform crop
- reduced growth area for the same yield
- out-of-season crop production
- conservation of water and nutrients
- utilization of normally unproductive areas
- less manual labour

From the experience of Yukon hydroponic growers, the following advantages can be added to the list above:

- less "pests" (insects, rodents,etc)
- good quality soil is not a requirement
- less technical training required to operate

It is technically feasible for a hydroponic greenhouse to supply the community of Old Crow with many of the vegetables now available in the Co-op, such as tomatoes, peppers, cucumbers, and lettuce. The economics of this operation are discussed in Section 7.2.3.

4.3.5 Greenhouse Modules

The DCIEM Arctic Food Producing Facility has been used as a production model for this analysis. The Arctic Facility is a modular hydroponic growing unit sized to provide sufficient tomatoes, cucumbers and lettuce for 100 military personnel in isolated Arctic locations, such as Alert, NWT. Production figures from the Arctic facility have been used in the economic analysis for the Old Crow Greenhouse. These figures are summarized in Table 4.3.5.A.

The figures in the table represent quantities which can be simultaniously produced in a growing bed area of 15.6 square meters (168 square feet). Table 4.3.5.A shows production rates for a twelve month and a nine month production season.

TABLE 4.3.5.A

PRODUCTION ESTIMATES

DCIEM, ARCTIC FOOD PRODUCING MODULE

CROP	12 MONTH PRODUCTION	9 MONTH PRODUCTION
Tomatoes	1092 lbs	819 lbs
Cucumbers	316 lbs	237 lbs
Lettuce	180 lbs	135 lbs

The evaluation of a greenhouse facility for Old Crow also includes a nine month production season and a twelve month production season.

In the nine month season the greenhouse would be operated from February through October, for fruiting vegetables such as tomato and pepper. For the months of November, December and January, the greenhouse would produce lettuce and other greens which can be produced at lower light levels. The limited amount of natural light available to the plants during these dark months would necessitate the use of expensive supplementary lighting for healthy plant growth.

The twelve month operation assumes that the facility would be operated year round. There would be sufficient heat available from the waste heat delivery system to operate the facility during this time. However, given the high cost of electricity in this community it may not be economical to operate the greenhouse on a twelve months basis, since the fruiting vegetables require high light levels to produce fruit.

To determine the size required for the facility to meet the demand in Old Crow, Table 4.3.5.B compares the consumer demand for fresh salad vegetables in Old Crow to the production estimates for the Arctic Module.

The table shows that a twelve month operation in Old Crow would require three modules to supply the requirements of the community for the crops shown.

To produce these quantities, some adjustments would be required in the growing patterns used in the Arctic Facility as this would provide too much of some crops and not enough of others at different times of the year.

If the Old Crow facility is operated on a nine month schedule, it would require four of the modules to meet the needs of the community. Similar adjustments to the growing patterns would have to be made with the nine month schedule to meet the demand in Old Crow.

TABLE 4.3.5.B

CROP	CONSUMER DEMAND	12 MONTHS PRODUCTION		9 MONTH PRODUCTION	
	lbs/yr	lbs/yr 1 module	lbs/yr 3 modules	lbs/yr 1 module	lbs/yr 4 modules
Tomatoes	2402	1092	3276	819	3276
Cucumbers	858	316	948	237	948
Lettuce	2400	180	540	135	540

4.3.6 Bedding Plants

One means commonly employed by commercial growers to make their greenhouses more profitable is the raising of bedding plants. Bedding plants are are started in the greenhouse, and transplanted outside when they are large enough to withstand the rigours of the outdoor climate. Most varieties cannot be transplanted until all danger of frost is past, however some, such as broccoli and cauliflower, will withstand frost.

Both frost-hardy and frost-susceptible vegetables benefit from this practice because it reduces the growing period necessary in the outdoor garden by several weeks. This makes it possible to grow many crops in areas which would otherwise be unsuitable.

Most commercial operators raise bedding plants primarily to sell to gardeners. In the case of Old Crow there may only be a very small market for bedding plants. The value of this crop is in the savings to the outdoor garden section rather than as a cash revenue crop. The outdoor garden section of the food production facility will depend on the use of bedding plants.

5.0 Poultry

A community poultry facility for egg production has been suggested by the Old Crow Band as one means of utilizing some of the recoverable waste heat from the diesel electric plant.

This section of the report addresses the benefits and limitations of a poultry house in Old Crow by examining technical and economic considerations of operating such a facility.

The costs associated with the economics section are based upon data collected during the initial community visit to Old Crow in April 1984, and poultry/egg production data obtained from Yukon producers. For the purposes of discussion, it is assumed that quoted costs are subject to change at a rate comparable to the rate of change of other economic factors in Old Crow.

If the feasibility of an egg production facility in Old Crow is based upon economic parameters alone, then the cost of local production cannot exceed the revenue from egg sales. However, if other considerations indicate that locally produced eggs will have greater appeal in the community, then these factors must also be examined. For example, in Whitehorse, consumers are willing to pay more for a dozen farm fresh eggs than a dozen imported eggs. Such factors as egg quality, as well as the sense of local self-sufficiency, must also be considered. There may also be advantages in establishing greater levels of community control over the production of eggs and poultry available in the community.

5.1 Yukon Poultry and Egg Production Experience

There are numerous poultry/egg operations throughout the Yukon. Flocks as large as 100 hens are fairly common in rural areas. If the eggs are sold, these operations are generally within reasonable transportation distance of marketing centres.

Several of these operations were visited during this study to obtain information on egg production, feeding practices, and other requirements of the laying flock.

Most operators have very simple, well-designed facilities. They generally feed the hens a combination of commercial and local feed, and follow sensible sanitation and culling procedures. These practices result in healthy flocks, with good egg quality and production, and a low incidence of disease.

Prices for a dozen farm fresh eggs vary from operator to operator, however, a dozen farm fresh eggs generally retail for more than imported eggs.

Based upon conversations with Yukon operators, a flock of one hundred egg-laying hens in a well-organized and well equipped facility can easily be operated by one experienced person on a part-time basis. Daily tasks include providing feed, water, additional litter, egg-gathering, and checking the birds for healthy appearance and behavior.

5.1.1 Previous and Current Experience in Old Crow

A management resource capable of handling a small "family size" flock of egg-laying hens already exists in Old Crow. Steven Frost has been managing a small poultry operation for the last three years.

The shelter presently in use as a poultry house is a temporary structure, and is not equipped with electricity. Consequently, water and feed are distributed by hand, and the facility uses only natural lighting and ventilation. This operation is managed by one person on a part-time basis, and has successfully produced enough eggs for the family.

An inspection of this facility indicates that the chickens are healthy and comfortable. With improved facilities and equipment, it is expected that local production could be further expanded to meet the needs of a greater portion of the community.

5.2 Egg Production

Poultry varieties which have been bred for egg-production are available in the Yukon, or through hatcheries in the south. Some Yukon poultry flock operators bring each flock into their facility as day-old chicks. Other flock operators do not purchase the pullets until they are ready to produce eggs at approximately 20 weeks. The decision varies from operator to operator, and depends upon several factors:

1. Hatcheries often have an age limit for raising the chicks, as they want to optimize space utilization, and the pullets require more space and feed as they grow larger.

2. Travel conditions may not favor the transport of very young chicks. If the method of transport is long and rough, it may injure the chicks.

3. The cost of raising chicks to productive age depends upon the facilities available. The optimum age to bring in a flock will depend upon the difference in cost per bird plus shipping charges for heavier birds, compared to the cost of bringing in enough feed to raise the flock to production. As well, heating equipment and additional observation of the chicks are required to insure their health, and to watch for any signs of weakness or disease.

For a poultry operation in Old Crow, this decision will depend largely on the third consideration, as the shipping costs for feed from Whitehorse nearly double the value per kilogram. The following sections outline the factors which must be considered when deciding on the most economical age to bring the chickens into a poultry facility in Old Crow.

5.2.1 Space Requirements

A poultry facility should provide .1 to .2 square metres (2-3 square feet) of floor space for each laying hen. A flock of one hundred hens needs about twenty square metres (200 square feet) of floor space to move freely in. The space must be well arranged to provide adequate access to feed, light, and heat, without being subject to drafts.

In addition to the floor space, the hens need nesting and roosting space. The nests should be constructed so that the interior of the nesting box is dark. This will aid in egg production, and reduce egg pecking. Roosts made of wooden slats are provided for the birds to perch on. They are used for resting and sleeping, as chickens do not like to sleep on the floor.

5.2.2 Temperature Requirements

Facilities for egg-laying hens should be kept between 15.5 and 18.3 degrees C. (50 and 65 degrees F.). The published limits of temperature range for hens are from 7 to 27 degrees C. (45 to 80 degrees F.). Yukon operators find that the chickens will generally spend time outside, regardless of temperature, unless there is snow on the ground.

Observing the behavior of the chickens is a good indication of assessing whether temperatures are within a comfortable range for them. If it is too warm, the chickens will attempt to get as far away from the heat source as possible, usually gathering close to a draft. If it is too cold, they will huddle together trying to stay warm.

5.2.3 Feed Requirements

Feed rations for commercial egg production facilities are sold as a pelletized preparation containing 15-17% protein and essential vitamins and nutrients. Alberta Agriculture estimates a requirement of 12 kg. (25 lbs.) of feed per 100 hens per day during the laying period. This represents 0.84 kg of feed per hen per week.

With a well balanced diet, and a clean, healthy environment, chickens can gain one pound for every two pounds of feed up to the age of about 16 weeks. Commercially produced chicken feed or "poultry ration" adequately meets the dietary requirements for chickens.

Feed must always be available to chickens. A "feeder" is set up in such a way that it is easily accessible, and raised up off the floor so the chicks can not get into it or spill the feed. Hanging feeders are recommended over trough-type feeders. Feeders are generally hung so that the feed is at approximately the same level as the backs of the chickens. This reduces spillage, and helps to keep the feed clean.

A constant supply of clean water is essential for proper growth of the hens and production of eggs. The warmer the air temperature, the more water the birds will need to maintain their body systems. Clean water must be available to the birds at all times.

It is possible to locally produce the components for poultry ration which meets all of the protein and nutrient requirements. However, for simplifying start-up of a new operation, commercial feeds have several advantages. For example, it is simpler to monitor the actual cost of producing eggs using commercial feed. Commercial feeds are readily available at a cost of $.77/ kg. including shipping from Whitehorse to Old Crow.

Although they contain all the necessary nutrients for chickens, the commercial feeds may be supplemented with vegetable, meat, and fish scraps as desired. In the experience of Yukon producers, green vegetable material improves the quality and flavour of the eggs. However, supplemental feeds should be tested on a few birds prior to giving a new feed to an entire flock. For example, feeding fish to laying hens may result in the eggs having a fishy flavour.

Commercial rations can be blended with locally available feed, such as fish or meat meal and green plant material, to reduce the amount of commercial ration required. The source and quality of the protein will affect the overall strength and vitality of the chickens. Many Yukon operators believe that variety in feed sources aids in the development of stronger, healthier birds and eggs than those which are fed exclusively on commercial feed.

To insure the production of healthy eggs with shells hard enough to withstand handling, the chickens are supplied with a source of calcium, such as oyster shell, bone meal, or ground eggshells. Full calcium requirements are included with many commercial feed rations, however, additional calcium is available through feed distributors in Whitehorse.

5.2.4 Lighting Requirements

A facility for egg-laying hens should provide plenty of fresh warm air, as the birds are particularly sensitive to cold air and drafts.

Both light and darkness are critical factors in an egg production facility. Egg-laying chickens require between fourteen and sixteen hours of light per day for maximum production, and complete darkness for a period of approximately six hours per day. In the winter, when sunlight is not available for this length of time each day, Michigan State University Extension Services recommends supplemental lighting at a density of one 40 watt bulb per 100 square feet of floor area. Yukon experience indicates that one 40 watt bulb may be enough for up to two hundred square feet (one hundred birds). These lights can easily be turned off and on by an automatic timer.

A common complaint from egg producers is that chickens sometimes develop a habit of eating eggs, or pecking and injuring other chickens. This undesirable condition is called "cannibalism". It is prevalent among some breeds, and difficult to control once started.

Although cannibalism can also be caused by other stress conditions, reducing the light intensity will reduce the incidence of cannibalism. Millers Hatcheries in Edmonton recommends the use of red lamps as a method of reducing light intensity if cannibalism becomes a problem.

5.2.5 Ventilation Requirements

Adequate ventilation in the poultry house is very important, as it helps to reduce the build-up of moisture, heat, and odors. Ventilation is used to maintain an environment with a temperature range between 7 and 27 degrees C, and a relative humidity range between 50% and 75%. Ventilation also helps to keep the birds healthy and resistant to disease.

Reliable ventilation can be provided by fans controlled by relative humidity and temperature. The University of Alaska recommends a minimum of half a cubic foot per minute (cfm) (0.23 litres/sec) per bird. This is increased to 3 cfm (1.4 litres/sec) per bird during winter operation and 5 cfm (2.3 litres/sec) per bird during summer operation to control humidity and temperature.

In general, a colder climate reduces the chance of overheating, so the ventilation rate may be decreased, however, cold incoming air must be mixed with warm air before it reaches the chickens, so they will not be exposed to cold drafts.

6.0 Food Production Facility

There are many factors which determine the success of producing food in the north. In considering these factors, there are several potential advantages to combining the operation of a greenhouse, a poultry house, and an outdoor garden into a single integrated facility. By centralizing the food producing operations, the facility can make use of the same building, as well as shared heating and utilities.

The requirements for greenhousing and gardening are more stringent than those for a poultry operation. Aside from heat and power, the only additional requirement for a poultry facility is access to a "free range" area for the hens.

The following section discusses the specific requirements for siting a food production facility in Old Crow.

6.1 Facility Siting Requirements

The selection of a suitable site is an important factor in ensuring the success of the food production facility and the garden. Several locations in the community, mainly vacant lots, and the areas surrounding some of the houses, were examined during the community visits to determine their suitability for a food production facility.

Siting factors considered in this study include visibility, accessibility, security, solar exposure and weather protection, and suitability of soil conditions.

6.1.1 Visibility

The food production facility should be located in a convenient and accessible place for the people, preferably along the main road. If the facility is located in a well-travelled location, it will promote general interest and a sense of association with the project. This would facilitate the promotion of visits to the facility for meetings, training sessions, research, and a general interest in agricultural activities.

6.1.2 Access and Availability

Site investigations examined the suitability of various potential sites for services such as road, power, water, and waste heat from the diesel generator.

Road access is necessary for the delivery of construction and operating supplies. During winter harvest in the facility, produce will have to be moved to the retail outlet in a heated vehicle to prevent spoilage by freezing. For this reason, it is important to insure that the road access will not become blocked with snow.

Electrical service should be readily available, as there would be a considerable cost for constructing power supply lines to service the site.

Water delivery within the community is effected by tanker truck. If the water which is critical for irrigation of summer gardens depended upon this delivery method, it would add a considerable operating expense to the project. The site therefore, should either be close to an alternate source of summer irrigation water, or located to facilitate the incorporation of a water line from the community well to the greenhouse. Our investigation indicates that there is ample water available from the well to meet the requirements of the facility without limiting the supply available to the community.

Selecting a suitable site for the facility is influenced by its closeness to the diesel plant, to ensure effective transfer of heat from the plant to the facility. The farther the heat is moved from the diesel plant, the more heat will be lost before it reaches the building, and the greater will be the delivery cost. Based upon other successful waste heat recovery systems, the facility should be located within one kilometre of the diesel plant. Several potential sites, within practical servicing distance, were investigated during community visits in April and August.

To determine the availability of potential sites, a search of land titles and leases in Old Crow was conducted. Further investigation also considered the disposition of the community toward available potential sites in the community, and an assessment of recent land use planning studies.

6.1.3 Security

During the August visit it was noted that two, four, six and eight legged pests were a problem in most of the local gardens and poultry operations. All of the incidents were a result of curiosity and feeding urges. None were of a malicious nature. Site evaluations and facility design must consider possible means of eliminating or reducing the impact of this problem. Capital costs for the facility will have to include adequate fencing, and operational costs will include some means of insect and rodent control.

6.1.4 Solar Exposure

Adequate light is very important for plant growth. Therefore, the site should have good uninhibited exposure to the sun in a general southerly direction. It is best if the garden area slopes slightly to the south, so that the sun's rays strike the soil more directly, and more of the energy is absorbed by the earth. This will raise soil temperatures and increase production.

It is important to consider future construction plans, which may reduce the amount of sunlight available to the site. Locating the facility in a site which is not planned for other facilities will ensure that no future construction will shade the growing areas from the sun.

6.1.5 Weather Protection

The primary retardent to vegetable growth in northern locations is the low temperature of the growing bed and surrounding air. Siting of any horticultural venture must consider ways of increasing the temperature of the area with a minimum of cost and effort. The site should slope to the south, be unshaded to the south and be protected by natural barriers on all sides, especially the sides open to prevailing winds.

6.1.6 Soil Conditions

Suitability of soil conditions must be considered for both facility siting and garden siting.

In Old Crow, where permafrost in some areas is very close to the surface, site investigations should consider areas where the permafrost has been degraded to a substantial depth. This will allow increased summer soil temperatures in the garden area, and facilitate improved drainage. It will also reduce the cost of foundation construction for the facility, and reduce the possibility of future problems with permafrost degradation.

An important function of soil is to provide a media which gives plant roots access to nutrients, air and water in order to sustain healthy vigorous growth. The soil must be well-drained and friable (loose) to allow uptake of nutrients, and to provide room for growth. If any of these conditions are lacking, the result will show in reduced production.

Vegetables grow best if water is available to the roots, but they do not like to have their roots constantly wet. Because of this, adequate drainage is another very important factor in selecting a garden site. Much of the community suffers from poor drainage of surface water, especially in the spring and fall. This is a result in part from soil types and in part from the presence of permafrost which blocks drainage to the deep earth.

To determine the feasibility of outside soil gardening, several soil samples from Old Crow were tested by a laboratory in Alberta. The results of the analysis are discussed in the Section 6.2.1.

6.2 Facility Site Investigations

The ideal location for the food production facility would maximize all the desirable features of a site as described above.

Vacant land within the community was inspected and assessed for it's ability to meet the requirements for a food production facility. The criteria used was that the site should; be visible to a large percentage of the community, be easily to access, afford a good potential for security of the crops, have good exposure to the sun through a long season, be protected from wind, and have suitable soil conditions or at least ones which could be improved to a satisfactory level with a minimum of expense and labour.

The site which best meets these ideal criteria is located between the residence of the Donald Frost Family and the National Health and Welfare Nursing Station on the south side of the road to the airport. This is a high-profile area, on the main thoroughfare between the residential sections of the community and the airport, school, and Co-op Store.

An existing road and electrical power lines provide access to the site. The proximity of the river provides an alternate source of irrigation water and precludes any future building to the south. Water could also be conveniently piped to the site from the well with the waste heat delivery system.

The site is located on a high bank overlooking the Porcupine River in an area with good drainage. The site is higher than areas which have been subject to flooding in the past. The bank is not subject to river erosion or slumping. The soil is a sandy silt with some clay to at least 4.8 meters. Permafrost in the area has been degraded to a depth of one metre.

This area has a cleared plot, surrounded by trees, with tall spruce to the west, north and east, and low willows to the south. The trees on the east side are located east of the Frost Residence, however, they would still afford some protection from easterly winds.

A garden plot of approximately 0.2 hectares (1/2 acre) would be sufficient to produce the crop that is required in Old Crow. Adjacent to the proposed food production facility site is a tract of land large enough for a garden that could grow all the outdoor varieties of vegetable required to meet the needs of the community. Gardening has been successfully done in the immediate area by Catholic priests and local residents. The site is well sheltered to the north and west by trees and bushes. The soil is well drained silt and clay.

There will be ample area on this site for the proposed facility building, the garden plot and an outside range area for the chickens. The two small buildings which occupy the site would not interfere with the use of the site for a food production facility, as they are located near the perimeter of the lot.

This site encompasses portions of two lots. The Old Crow Co-op leases one lot from Canada. The other is titled to the Catholic Church. These groups will have to be approached to determine their interest in the lands.

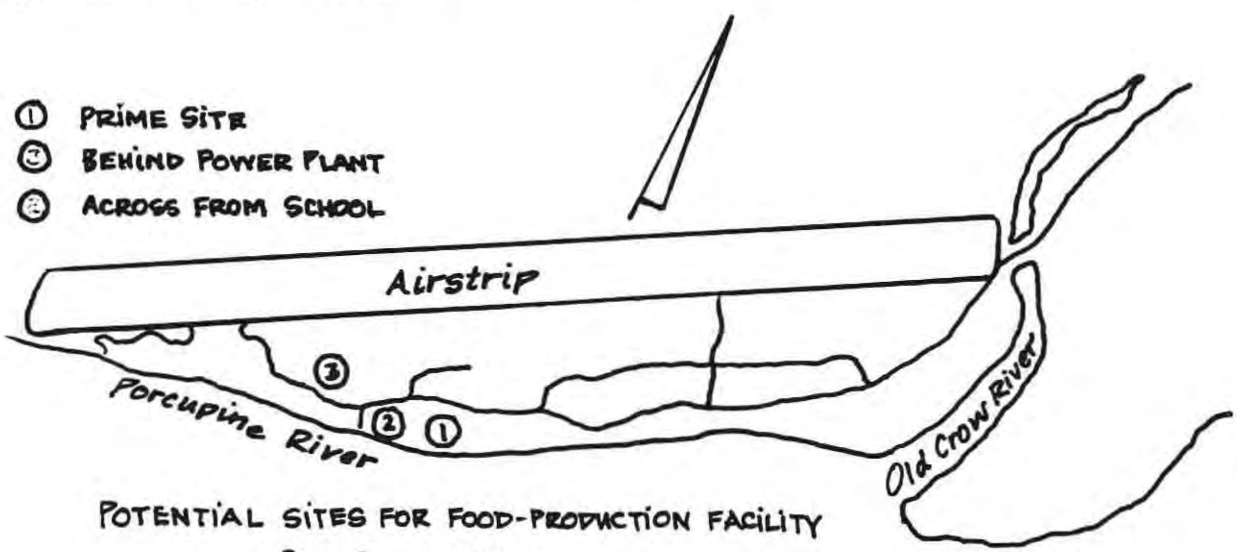
Several other areas in the community were evaluated for their potential as suitable locations for the food production facility. Comments on these sites are discussed below.

The area to the northeast of the diesel plant was assessed to determine its suitability for the facility site. This area is low, wet and covered by a thick stand of spruce trees. It has no road or power access at the present time. Any construction in this location will require clearing of the site and installation of additional power poles to access the site. This location appeared to be unsuitable for a food-production facility, as the area is mainly "industrial", and there is constant noise from the generator close by.

The site across from the school, on the south side of the road to the airport, is easily accessible and would require no additional delivery of services. There are two cold storage buildings located on the site. This area is used for storing the winter wood supply for the school.

The site is exposed to the wind and subject to periodic flooding of the Porcupine River. Much of it has been back filled with gravel which would reduce gardening potential, and because of the long narrow shape of the lot it would be difficult to utilize the area to provide a garden plot and area for chicken range.

Since the school property is the only land in the area which has been recently surveyed, it is difficult to determine the actual size of the site. There is no record of the YECL site survey. This information will be required for the completion of Phase Two of this study if this site is given further consideration for the food production facility. At the same time, the school storage buildings should be examined for possible relocation.



POTENTIAL SITES FOR FOOD-PRODUCTION FACILITY
OLD CROW, YUKON

6.2.1 Soil Analysis

During the April visit to the community, soil samples were taken from six locations for laboratory testing. Samples were taken from the following locations; the east end of the airport runway, the northeast school yard, the soil beds in the Co-op greenhouse, the north side of House #77, the nursing station greenhouse, and the garden at Steven Frost's house.

Samples were taken to a depth of four to six inches in early spring, when the ground was still frozen below this level. Soil test results from the Alberta Agriculture laboratory in Edmonton are summarized in Table 6.2.1.A.

Table 6.2.1.A

SOIL TEST RESULTS FOR OLD CROW, YUKON

LOCATION OF SAMPLE	AVAILABLE NUTRIENTS (in lbs/acre) N	P	K	pH	SALTS (in mmhos) TDS	NA	SO4	O.M.	FREE LIME	TEXTURE
East end airstrip	8 L	7 L	138 M	6.4	0.4	L-	---	M	--	MEDIUM loam-clay loam
School yard	100+ VH	6 L	216 M	6.5	2.3	L	M	M	--	FINE silt-silt loam silty clay loam
Co-op green house	(Note:results in ppm) 18(NH3) 6(NO3)	3 L	44 L	5.7	---	66	37.6			sand & peat
House #77	100+ VH	200+ VH	1220 VH	7.1	2.3	H+	L	M	L	MEDIUM Loam-clay loam
Nursing Station garden	7 L	34 M	212 M	7.6	0.5	L-	--	M	M-	FINE silt-silt loam silty clay loam
Steven Frost's garden	7 L	120 H	234 M	7.1	0.7	M+	--	M	--	MEDIUM loam-clay loam sandy clay loam

LEGEND:
L is low
M is medium
H is high
VH is very high
ppm is parts per million
O.M. is Organic Matter

The results of the soils analyses show favorable levels of required nutrients for vegetable gardening in most locations. Three of the samples have good texture and contain adequate nutrients. Two samples are composed of a heavy sandy clay loam, and require the addition of an organic material such as peat moss to lighten the soil. The remaining locations require very little improvement, and could support some crops without fertilization.

For all of the sampling locations, the addition of the recommended amounts of fertilizer would further improve the soil. Copies of the soils analyses results and recommended fertilizer supplements are included as Appendix A.

7.0 Economic Assessment

If the application of a technology has been evaluated as "appropriate" in a technical and social context, then the decisions for project implementation will primarily depend on economic factors. The introduction of any relatively new commercial venture in a small community must be proportioned to the available experience and resources in that community. These factors have been considered in examining the optimum size and capacity for the Food Production Facility in Old Crow, and are reflected in the limits of the economic analysis.

The preliminary assessment of the economic feasibility of waste heat recovery and distribution in the community of Old Crow has been developed from data obtained from other similar projects. The preliminary assessment of the Food Production Facility economics is based on information obtained from similar operations, and the availability of waste heat in Old Crow.

Where possible, cost estimates are based on the current value of similar projects in Old Crow. For example, the Food Production Facility building design would be architecturally compatible with existing buildings and would utilize local labour for construction. Therefore the cost of the basic building is estimated from current Old Crow costs per unit area.

In other cases, such as operating costs for greenhousing, gardening and poultry, the study team has used Yukon experience wherever possible to develop initial estimates which are then modified for conditions specific to Old Crow.

7.1 Waste Heat Recovery and Distribution

In the case of waste heat recovery and distribution, each application is unique. The study team has visited installations, and initiated discussions with system operators and designers in the Yukon, Northwest Territories, and Alaska. As well, the current literature on northern systems design and operation have been reviewed and correlated. Two basic conclusions have emerged from this research: costs for waste heat recovery and distribution systems vary widely as a function of design, materials, location, and other factors, and that simple systems, with a minimum number of moving components are usually more cost effective and reliable. The economic analysis detailed below is based on a preliminary recovery system design supplied by YECL, with the addition of one heat exchanger for each engine. If further study, as recommended, determines that the daily variation of available heat is out of phase with daily fluctuation of heating load, then thermal storage buffering will have to be included.

In Table 7.1.A below, cost estimates have been developed for the waste heat recovery and distribution options discussed and analyzed in section 3.2.5.

TABLE 7.1.A
PRELIMINARY ECONOMIC ANALYSIS
ENGINE COOLANT HEAT RECOVERY & DISTRICT HEATING SYSTEM
OLD CROW, YUKON

	GENERATOR BLDG & MAINS	FOOD PRODUCTN FACILITY	SCHOOL DHW	PROP WELL HOUSE	NHW STATION	RCMP STATION	OTHER MAY-OCT
HEAT RECOVERY EQUIPMENT							
RECOVERY CAPACITY (kW)	150						
INSTALLED COST	$84,667						
MAINS LENGTH (metres)	225						
PIPE SIZE (mm)	75						
INSTALLED COST	$62,550						
BRANCH LINES (metres)		90	5	50	51	280	60
PIPE SIZE (mm)		25	18	25	40	51	32
INSTALLED COST		$16,200	$825	$9,000	$10,710	$64,400	$11,820
TERMINAL EQUIPMENT							
HEAT EXCH (SPHT)(kW)		15		5	45	55	25
HEAT EXCH (DHW)(kW)		3	12		5	5	
INSTALLED COST		$4,200	$2,800	$1,167	$11,667	$14,000	$5,833
MONITORING & CONTROLS							
INSTALLED COST	$4,500	$900	$50	$500	$510	$2,800	$600
ENGINEERING	$15,172	$2,130	$368	$1,067	$2,289	$8,120	$1,825
TOTAL COSTS	$166,888	$23,430	$4,043	$11,733	$25,175	$89,320	$20,079

DISTRICT HEATING SYSTEM OPTIONS:	(1) FOOD PRODUCTION FACILITY (FPF)	(2) FPF + SCHOOL DHW	(3) FPF + SCH DHW + WELL HSE	(4) FPF + SCH DHW + WELL HSE + NHW	(5) FPF + SCH DHW + WELL HSE + NHW + RCMP	(6) ADD MAY-OCT USE
CAPITAL COST						
HEAT RECOVERY & DISTRIBUTION	$190,318	$194,361	$206,094	$231,270	$320,590	$340,668
OPERATING COSTS (annual O&M)	$5,710	$5,831	$6,183	$6,938	$9,618	$10,220
AVERAGE % UTILIZATION	4	11	12	33	76	100
FUEL OIL DISPLACEMENT SPHT (litres)	2435	7100	7836	22022	50079	65976
FUEL OIL DISPLACEMENT DHW (litres)	1169	19829	19829	22166	24504	24504
VALUE @ $0.75/litre	$2,703	$20,197	$20,749	$33,141	$55,937	$67,860
SIMPLE PAYBACK (years)	-63	14	14	9	7	6

For this preliminary economic analysis, economic factors based on $/kW of installed heat recovery capacity, $/metre of installed heat transmission pipe, and $/kW of installed terminal heat distribution, have been developed from a review of existing, northern, waste heat recovery projects.

These economic factors have been used in the analysis to compute cost estimates of installed capacity. The analysis includes the generator building heat recovery equipment, the main distribution pipe and fittings, and heat transfer terminal equipment for each end use point. In the upper section of the table, these costs are assessed and totaled for each potential end use point as discussed in section 3.2.5.

The bottom section of the table provides an economic summary and simple payback analysis for each district heating system option. The fuel oil displacement value used for the payback analysis is computed from average percent utilization and recoverable engine coolant heat, as calculated for each district heating option, in Table 3.2.5.A above. The space heat (SPHT) fuel oil displacement is calculated as the litres equivalent of distributed heat at 37.65 Megajoules/litre. The calculations are not adjusted for furnace efficiency, and are therefore conservative estimates of actual fuel oil replacement. In the case of domestic hot water (DHW) fuel oil replacement, to be consistant with the space heating fuel replacement, the amount of fuel which would be burned in the generator to produce the electricity used for DHW is calculated. The current value of $0.75 per litre is used to estimate a dollar value of the total oil replacement. In the case of the school DHW, the value of the electricity displaced is $22,448 at current electricity rates. The value of the generator fuel displaced is $13,995. The economics based on fuel displacement are therefore conservative.

The base option supplies the Food Production Facility with all requirements for space heating and domestic hot water. The negative figure in the simple payback indicates that this option is not economically feasible. With the integration of the school DHW load and a wellhouse, the economic payback becomes 14 years. Option four, which integrates the Health Station, reduces the payback to 9 years. By extending the system to the RCMP Station, and achieving total heat utilization for the six months of winter, the system payback can be further reduced to 7 years with option five. The sixth option would utilize available heat from May to October. Economics for this option are based on a short extension of the heating system from the RCMP to a location suitable for a Summer pool. If total utilization of recoverable waste heat can be achieved, then the waste heat recovery and distribution system can reach payback in 6 years.

These calculations represent preliminary approximations based on standard systems. Circumstances specific to final system design may significantly affect the cost of equipment and installation in Old Crow. These data are provided only as the basis for decisions for further study.

7.2 Economic Assesment of Greenhouse & Garden Sections

Economically it is impractical to consider growing all of the vegetables required by the people of Old Crow in the greenhouse facility. Many varieties, such as broccoli and carrots can be more economically grown outside during the summer. The varieties best grown outside can be categorized as those which have a final harvest period. This is the case with vegetables like carrots. They require a long time to grow. When harvested, a new crop has to be planted in the space, then another period of growth is required before the second crop can be harvested. Crops like tomatoes on the other hand produce continuously over a long period thus making better use of high cost greenhouse space.

In Northern areas like Old Crow, with short growing seasons and a risk of frost in all summer months, it is necessary to implement some method of frost protection for frost susceptible vegetables. One economical method of doing this is to cover the vegetables with a low cost polyethylene shelter supported on polyethylene pipe.

A second category of crops which can be grown outside more economically than in a greenhouse are "frost tolerant" vegetables which will not be damaged by minor frosts, such as broccoli. These varieties do not require protection.

Therefore, two types of vegetable production are being considered in the economic analysis; section 7.2.3 examines greenhouse vegetable production, and,section 7.2.4 examine outside gardening with low cost frost protection for frost susceptible varieties.

7.2.1 Market Survey

Information on present and future market potential of fresh vegetables in Old Crow was provided by the Co-op Manager, Ray Lahti, and past Co-op manager, Dave Webster. The information they provided was used to tabulate retail sales information shown in Table 7.2.1.A.

They both indicated that locally produced vegetables would have good sale potential in the store and would be an improvement over the quality of the vegetables that are now provided to the consumer. Their positive reaction was echoed by every individual in Old Crow with whom the project was discussed.

TABLE 7.2.1.A

RETAIL VALUE

OF

PRODUCE

Vegetable	lbs/wk	$/lb
Broccoli	23	1.59
Cabbage	35	1.54
Carrots	50	1.09
Cauliflower	23	3.50
Celery	25	1.88
Cucumber	25	1.78
Green Peppers	30	1.54
Lettuce	30	2.43
Onions	25	1.20
Potatoes	150	1.79
Tomatoes	70	1.89
Turnips	25	1.62

Co-op wholesale purchases are shown in lbs/wk (pounds per week). These figures are based on the average quantities of fresh vegetables that were purchased by the co-op from their distributor in Whitehorse for shipment to Old Crow.

The shelf price shown in $/lb (Dollars per pound) is the Co-op price at the time of survey.

In addition to the items listed in table 5.6.A, the Co-op manager advised that there was also a potential market for other crops, such as strawberries, spinach, radishes, and flowers.

During the August visit to the community, an Indian Affairs advisor working at the Old Crow Co-op reported that up to 50% of many varieties of fresh vegetables presently brought into the store are thrown out because the quality has deteriorated so much in transit that people will not buy them. Higher throw away, or "cull", rates are encountered with more perishable vegetables such as lettuce and tomatoes. Lower cull rates are experienced with vegetables such as potatoes and turnips which store well. Discussions with retail produce managers in the Yukon indicates that a cull rate of 10 to 15% for all vegetables is normal.

Vegetables produced in the community could be delivered to the Co-op in a "fresh from the garden condition". This will eliminate much of the waste. The increase in the quality of produce can also be expected to encourage an increase in sales.

Table 7.2.1.B shows the quantities of locally produced vegetables required to meet the present demand in Old Crow. This table assumes that vegetables produced locally would not be subject to the high cull rate presently being experienced. A cull rate of 10% has been assumed for all local produce. This is consistent with information supplied by produce managers.

To determine the volume required to displace the import of each variety of vegetable sold a graduated cull rate has been applied.

Those vegetables having a high cull rate will need to be replaced with fewer locally produced vegetables than those with lower cull rates. For example, tomatoes, with a cull rate of about 50%, could be replaced with nearly half as many locally produced tomatoes.

The total annual volume of vegetables presently sold through the Co-op is shown in the column headed "IMPORTED" and divided into pounds per year (lbs/yr), and dollars per year ($/yr).

The "LOCAL SUPPLY" column lists the quantity of locally produced vegetables required in lbs/yr and $/yr. This includes an assumed 10% increase in demand for vegetables resulting from the improved quality and a 10% cull rate.

Table 7.2.1.B

PRODUCE REQUIRED

TO

MEET CONSUMER DEMAND

	IMPORTED	LOCAL SUPPLY
VEGETABLE	lbs/YR	lbs/yr
Broccoli	1196	1076
Cabbage	1820	1638
Carrots	2600	2808
Cauliflower	1196	1076
Celery	1300	780
Cucumber	1300	780
Green Peppers	1560	936
Lettuce	1560	936
Onions	1300	1404
Potatoes	7800	8424
Tomatoes	3640	2184
Turnips	1300	1404
Total	26572	23447

7.2.1.1 Pricing Strategy

There are three methods of establishing the market value of a product. One method is to establish the value by calculating all the costs involved in producing, marketing, and delivering the product to the consumer, then add on a percentage for profit. Another method is to assess the maximum price which the market will bear. Above this price sales will drop off sharply. The third method is to find out at what price a product is presently being sold in the community and evaluate whether you can sell your product at that price and still meet production expenses and make a profit.

For the purposes of this economic evaluation, the third method will be used to establish the value of produce from the food production facility. This method has been chosen because the Co-op's pricing structure is acceptable to the community and provides sufficient information for the analysis.

The Co-op's pricing policy at the time of survey is to price vegetables based on the wholesale price, plus 35% mark-up plus the cost of freight. In setting this policy, the Co-op had recognized the need of the community for this commodity and used a pricing structure that would keep the price as low as possible. In doing so, the Co-op put themselves in a position of having to subsidize the sale of some vegetables with profits from other sales. With the heavy spoilage rate of fresh produce (up to 50% on some varieties), the 35% mark-up on the vegetables which were sold may not be sufficient to cover the losses on those that are thrown out.

7.2.2 Value Of Vegetable Production

It is assumed that the products of the facility will be sold to the Co-op. Therefore, Co-op's costs are considered to be the maximum value for locally produced vegetables. However, a slightly higher price would not present an economic hardship for the community, because the consumer would still be getting better value for their money. A lower price could be used if it can be proven to be profitable.

Table 7.2.2.A shows the real costs to the Co-op of the produce they sell.

TABLE 7.2.2.A

SHELF VALUE

OF PRODUCE

VEGETABLE	SALES PRICE $/lb	CO-OP COST $/lb	VOLUME ORDERED lbs/yr	CO-OP COST $/yr
Broccoli	1.59	1.58	1196	1885
Cabbage	1.54	1.54	1820	2795
Carrots	1.09	1.03	2600	2677
Cauliflower	3.50	3.13	1196	3741
Celery	1.88	2.17	1300	2827
Cucumber	1.78	2.08	1300	2700
Green Peppers	1.54	1.84	1560	2875
Lettuce	2.43	2.71	1560	4228
Onions	1.20	1.11	1300	1441
Potatoes	1.79	1.53	7800	11935
Tomatoes	1.89	2.18	3640	7950
Turnips	1.62	1.92	1300	2497
Total			26572	47550

The $/lb values shown have been calculated for each pound of each variety of vegetable shown considering all the costs involved in putting that commodity on the shelf. The value is derived from the Wholesale price plus all the costs incurred by the Co-op, i.e., an average of $0.65/lb freight to Old Crow airport, plus $0.07/lb local freight, plus the cull rate.

These figures should be considered as the lowest value of local produce. It is hard to place an upper limit on the value. To quote the Indian Affairs advisor to the Co-op,"good produce can be sold at almost any price, poor produce cannot be sold at any price".

The volume ordered is total quantity of each variety imported by the Co-op.

The last column shows the total cost per year of each vegetable to the co-op.

7.2.3 Greenhouse Operation

Table 7.2.3.A shows costs associated with the construction and operation of the facility. The table is divided into CASE ONE and CASE TWO.

CASE ONE examines the economics of operating the greenhouse with mature plants producing through a 12 month season using supplementary lighting as required, to sustain maximum production.

CASE TWO examines the economics of operating the greenhouse with mature plants producing through a 9 month season with the balance of the year being devoted to producing crops requiring low light levels, which could be sold to the Co-op or fed to the chickens depending on demand, preparing the greenhouse for the next season, training, record keeping, and starting bedding plants for use in the greenhouse in the next season.

For the purposes of comparison, estimates are shown for one, two, and three DCIEM sized production modules for CASE ONE and one, two, and four production modules for CASE TWO.

TABLE 7.2.3.A

ECONOMIC ANALYSIS FOR FOOD PRODUCTION FACILITY

GREENHOUSE SECTION

	CASE 1			CASE 2		
	1 2	3		1	2	4
CAPITAL COSTS	MODULE	MODULE	MODULE	MODULE	MODULE	MODULE
Construction Costs	18000	36000	54000	18000	36000	72000
Ventilation	1000	2000	3000	1000	2000	4000
Supplemental lighting equip.	7700	15400	23100	7700	15400	30800
Hydroponic equipment	2000	4000	6000	2000	4000	8000
Misc. controls	800	1600	2400	800	1600	3200
Total:	29500	59000	88500	29500	59000	118000
OPERATING COSTS						
Seeds & Fertilizer	210	420	630	158	315	630
Misc. Supplies	50	100	150	38	75	150
Power	4894	9788	14682	2108	4216	8432
Repairs & Maintenance	200	400	600	150	300	600
Local freight	111	222	333	83	167	333
Labour	4000	6000	8000	3000	4500	7500
Total:	9465	16930	24395	5536	9573	17645
REVENUE						
Vegetable sales	4910	9819	14878	3720	7439	14878
Revenue less operating costs	-4555	-7111	-9517	-1817	-2134	-2767

A building cost of $840.00 per square meter ($90.00 per square foot) has been used for building costs in Old Crow. This figure was provided by the Bands Housing Construction Project Manager for building costs in Old Crow. Construction costs for each greenhouse module are based on a floor area of 18.2 square meters (200 square feet). This is sufficient to provide a net growing bed area of 15.6 square metres (168 square feet), which is equal to the model DCIEM unit.

All other capital expenses include labour, material and shipping required to provide a finished product ready for use in the greenhouse. The cost of the heating system is incorporated in the terminal costs of the District Heating System.

Operating expenses listed include material and shipping. Labour is listed as a single item and includes the cost of labour to do all the work required for the day-to-day operation of the greenhouse including setting up, starting seedlings, planting, weeding, transplanting, fertilizing, harvesting, weighing of produce, keeping of production records, and transporting of produce to the Co-op.

Revenue from sales assume that all the produce is sold to the Co-op at the present Co-op cost. Volume of sales are based on the quantity of produce required to displace the imported produce.

If the crop values from Table 7.2.2.A are compared to the cost of operation from Table 7.2.3.A, it can be seen that such an operation would not be profitable.

To make the economics of operating the facility more attractive, other means of increasing the value of goods produced in the greenhouse must be considered.

CASE 2 considers the use of part of the greenhouse section for the production of bedding plants. This is a common strategy employed by commercial operators to increase revenue during the "off-season".

Table 7.2.3.B summarizes the economics of bedding plant production in Old Crow. Although a definite interest has been indicated by many people, it is not possible to assess a demand for bedding plants from the community. Therefore, adequate quantities of bedding plants only to meet the requirements of the facility garden have been considered.

TABLE 7.2.3.B

ECONOMIC EVALUATION BEDDING PLANT OPERATION

Costs	local production		buy from Whitehorse
CAPITAL EXPENDITURES			
Bedding flats	250		
Misc. supplies	25		25
Utensils	50		50
TOTAL	$325		$75
ANNUAL OPERATING EXPENDITURES			
Potting soil	local n/c		
Peat moss	local n/c		
Fertilizer	50		
Seeds	75		
Seed potatoes	75		75
Jiffy pots	styro cup n/c		
Bedding plants			656
Freight	50		800
Labour	1000		300
TOTAL	1250		$1831
COST TO PURCHASE BEDDING PLANTS		1831	
ANNUAL PRODUCTION COSTS		1250	
NET SAVINGS		561	

Capital expenses include the tools and "flats" needed for producing bedding plants. Costs shown include purchase, freight, and labour required to prepare each item for use in the operation.

Operating expenses listed include material and shipping. Labour is listed as a single item and includes the cost of labour to do all the work required to produce bedding plants including acquiring local soil and peat moss and sterilizing, setting up, starting seedlings, planting, thinning, weeding, fertilizing, and keeping of production records.

If bedding plants are not grown in the greenhouse then they must be purchased. The average Whitehorse costs for bedding plants is 65 cents each for vegetables and 25 cents for flowers. About 1200 plants would be required to supply the garden. By growing bedding plants locally in the food production facility, a net savings of $561.00 can be achieved in the overall economics of the greenhouse operation.

Bedding plants produced in Whitehorse could be shipped to Old Crow by charter under specifically controlled environmental conditions. Special arrangements would have to be made, as the only scheduled airline presently servicing this community from Whitehorse does not guarantee delivery of perishable items.

In both cases examined for the greenhouse, there is a net loss over a one year period. If the $561.00 savings is deducted from the losses in CASE 2, there is still a net loss.

CASE 2 also allows for the production of chicken feed during the "off-season". Cull, trimmings and scraps from the greenhouse could also be fed to the chickens. It is estimated that the value of chicken feed and scraps to the chicken section of the facility would approximate the deficit provided the two facilities were matched in size.

In conclusion, CASE TWO, with the inclusion of facilities for the production of bedding plants and chicken feed, should be pursued in future analysis.

7.2.4 Garden Operation

The present shelf value of the vegetables that could be raised in an outside garden for sale to the Old Crow Co-op are in excess of $32,000. Therefore, it makes good economic sense to investigate the feasibility of gardening in Old Crow. Gardening has proven that it can be successful accomplished, both in Old Crow and in similar Northern communities.

The outside garden operation is the least capital intensive and most labour intensive of all the sectors in the food production facility. It also offers the greatest possibilities for making the entire facility economically self-sustaining.

Plastic crop shelters can be built for $5.00 per square meter (50 cents/sq. ft). Much of the cost of spray irrigation is carried in the cost of normal irrigating equipment for the garden. In addition to this equipment, the spray system would require temperature sensors to activate the spray system when the temperature drops below a predetermined level. Thermostats and valves for a system of this size would cost approximately $300.

Many of the root crops could be frozen or stored by other methods. Those varieties which cannot be stored could be shipped to another community for sale, such as Inuvik.

Table 7.2.4.A shows an economic analysis for the outside garden.

TABLE 7.2.4.A

ECONOMIC ANALYSIS - OUTSIDE GARDEN

CAPITAL EXPENSES	
Building poly crop shelter	3225
Building raised beds	1600
Roto tiller	1200
Mulch shredder	600
Misc. tools & equip.	200
Total	6825
ANNUAL OPERATING EXPENSES	
Replace poly on crop shelter	216
Fertilizer	800
Tools	50
Labour	16000
Total	17066
REVENUE FROM SALES	32672
Net Profit	15606

Capital expenses include labour, material and shipping required to provide a finished product ready for use in the garden. The cost of the mulch shredder has been shared on a 50-50 basis with the chicken section of the facility.

Operating expenses listed include material and shipping. Labour is listed as a single item and includes the cost of labour to do all the work required for the setting up, planting, weeding, transplanting, fertilizing, harvesting, weighing of produce, and keeping of production records.

Revenue from sales assume that all the produce is sold to the Co-op at the present Co-op cost. Volume of sales are based on the quantity of produce required to displace the imported produce.

7.2.5 Export Potential

Production levels from the outside garden have been studied at the rate required to produce all the vegetables required by the community. The garden area required to support these production levels is available. However, because of the short growing season, it will be impossible to stagger harvest dates to provide a continuous supply of vegetables from the outside garden.

Export to Inuvik has been examined as a possible market. Since Inuvik presently imports most of their vegetables from the south it can be assumed that they would look favourably on surplus produce from Old Crow.

The Co-op has investigated the feasibility of making their wholesale purchases through an Inuvik wholesaler. Their research indicated that the wholesale prices for produce in Inuvik are 10% higher than their present costs to purchase vegetables in Whitehorse and ship them to Inuvik. This would allow a 10% mark up on produce shipped to Inuvik for sale.

A further point to consider is that the cost of culled produce is normally born by the consumer and not by the vendor. The tables previously produced for this economic analysis placed the burden of culled vegetables on the Food Production Facility in an effort to equate the Co-op's present costs for produce. However, this would not be the case when considering export to Inuvik, where retailers are already absorbing a 10% cull rate. This would, in effect, result in another 10% increase in the value of the produce exported.

The only additional cost that would apply to export of surplus produce is freight. Since the Co-op regularly charters aircraft from Inuvik to bring in supplies surplus produce could be sent out on the back-haul at no additional cost.

In conclusion, produce for export has a 20% higher value in Inuvik than it does in Old Crow, and there are no additional costs associated with export.

7.2.6 Summary of Greenhouse and Garden Economics

Table 7.2.6.A summarizes the economics for the greenhouse and garden sections. Costs and revenues are based on the Case 2 scenario with the greenhouse being 37 square meters (400 square feet) in area.

TABLE 7.2.6.A

SUMMARY

OF

ECONOMIC EVALUATIONS

GREENHOUSE & GARDEN SECTIONS

	REVENUES	
Greenhouse Produce	7439	
Garden Produce	32672	
Total	40111	
	OPERATING COSTS	CAPITAL COSTS
Greenhouse	9573	59000
Bedding Plants	1250	325
Garden	17066	6225
Total	27889	65550
Excess of sales over costs	12222	
Simple payback on Capital Investment in years		5.36

LABOUR SUMMARY

Greenhouse	4500
Bedding plants	1000
Garden	16000
Total	21500

Revenues are shown to include the sale of greenhouse and garden produce. Revenue from the bedding plant operation has not been indicated because that revenue is a savings to the operation which reduces the operating cost of the outdoor garden but it does not generate revenue to the facility.

Operating costs include all cost for the day to day operation of each part of this section of the facility, including: labour for operation, maintenance, administration, and record keeping, and the cost of supplies and services.

The calculation of pay back on the capital investment has used the simple pay-back method of dividing the total capital costs of the operation by the excess of sales over operating cost.

A LABOUR SUMMARY has been incorporated into the table to itemize the labour component of each part of this operation. The labour rate has been assumed to be paid at the rate of $10.00 per hour.

7.3 Economic Assessment of Egg and Poultry Production in Old Crow

There are many choices open to the operator of a poultry facility which determine the economic success of the operation. The discussion on Egg Production in Section 5.2 presents many factors to evaluate in an economic analysis. This section evaluates a number of potential egg production options for the community of Old Crow.

7.3.1 Market Survey

According to information provided by the Co-op manager, the Old Crow Co-op supplies eggs to the community at the rate of 150 to 180 dozen per week. Assuming a population of 250 people in Old Crow, this is equivalent to an average of 8 eggs per person per week. This demand indicates a market large enough to consider egg production in the community.

At the time of the April community visit, eggs were sold at a price of $2.75 per dozen. This represent an annual egg revenue of $21,450 to $25,740.

Chicken is sold as packaged frozen drumsticks, legs, breasts, and whole chicken at a whole chicken price of $6.15 per kilogram. According to the previous Co-op manager, approximately 140 kilograms of chicken per week are sold by the Co-op. This represents an annual chicken revenue of nearly $45,000.

7.3.2 Egg and Broiler Production

The following section examines the economic feasibility of a poultry operation in Old Crow. Two operating scenarios for egg production and one scenario for broiler production are discussed.

Table 7.3.2.A shows the parameters and assumptions which were used to calculate operating costs for the poultry facility. Two cases are shown, with Case 1 showing costs for 100% imported feed, and Case 2 showing costs associated with providing 50% of the feed requirements locally.

TABLE 7.3.2.A

POULTRY OPERATION ECONOMIC ASSESSMENT

	CASE 1	CASE 2
$/chick @ 4 wks (Old Crow)	3.51	3.51
$/hen @ 20 wks (Old Crow):	11.03	11.03
$/kg feed:	.77	.77
kg feed/bird/wk:	.84	.42 + .42 LOCAL FEED
eggs/hen/year:	240	240
$/dozen eggs:	2.75	3.25 INCREASE COST PER DOZEN
kg/avg.broiler (12 wks):	1.50	1.50
$/kg chicken:	6.15	6.15

Costs for chicks and hens include price per bird plus freight from Edmonton to Old Crow. Feed costs for imported pelletized ration are based on cost per kilogram in Whitehorse plus shipping via fourth class mail to Old Crow. Feeding requirements (kg/bird/wk) and number of eggs produced annually by each hen (eggs/hen/year) are based on data from Alberta Agriculture.

In addition to the different assumptions for feed, CASE 1 uses the current shelf price for a dozen eggs in Old Crow. CASE 2 uses a price of $3.25 per dozen, which corresponds with the incremental cost of farm-fresh eggs in Whitehorse. Increasing the cost per dozen eggs from $2.75 to $3.25 amounts to an additional $19 per week revenue for 100 hens. The cost of broiler chicken is based upon estimated price per kilogram and average broiler size for whole frozen chicken in Old Crow.

Table 7.3.2.B shows CASE 1 and CASE 2 weekly egg production figures for increasing flock sizes from 25 to 400 laying hens. Revenues and costs for the table on a "per bird" basis can easily be determined using the column for 100 birds, and dividing all figures by 100.

TABLE 7.3.2.B

WEEKLY EGG PRODUCTION

	CASE 1					CASE 2				
# hens:	25	50	100	200	400	25	50	100	200	400
kg/wk feed:	21	42	84	168	336	11	21	42	84	168
$/wk feed:	16	33	65	130	260	12	25	49	99	197
# eggs/wk:	115	231	462	923	1846	115	231	462	923	1846
doz eggs/wk:	10	19	38	77	154	10	19	38	77	154
$/wk egg revenue:	26	53	106	212	423	31	63	125	250	500

The next three tables show estimated annual operating costs for the facility. Three scenarios are presented with the difference between operating costs and revenues along the bottom row of each section. The three scenarios are: egg production with birds brought in at laying age of 20 weeks, egg production with birds brought in at 4 weeks and raised to laying age in the facility, and broiler production, with pullets harvested at 12 weeks.

For CASE 1, the hens are fed entirely on imported pelletized laying ration. For CASE 2, half the feed requirements are supplied by local sources. Local feed is assigned a "dry weight" value equal to the cost per kilogram of laying ration in Whitehorse.

Table 7.3.2.C examines the costs associated with bringing "ready to lay" hens into Old Crow at 20 weeks. The CASE 1 operation (100% imported feed) shows a net revenue of $1516 for every hundred birds, or $15.16 per bird. CASE 2 (50% local feed) shows a net revenue of $33.33 per bird.

TABLE 7.3.2.C

Scenario 1: YEARLY EGG PRODUCTION AND CHICKEN HARVEST - start w/ hens @ 20 wks

	CASE 1					CASE 2				
# hens:	25	50	100	200	400	25	50	100	200	400
$ hens @ 20 wks:	276	552	1103	2207	4414	276	552	1103	2207	4414
feed (kg):	1092	2184	4368	8736	17472	546	1092	2184	4368	8736
$/yr feed:	845	1690	3381	6762	13523	641	1282	2564	5128	10256
chicken harvest $:	125	250	500	1000	2000	125	250	500	1000	2000
$/yr eggs rvnu:	1375	2750	5500	11000	22000	1625	3250	6500	13000	26000
revenue - cost/yr =	379	758	1516	3032	6063	833	1666	3333	6665	13330
net revenue per hen=			$15.16					$33.33		

Table 7.3.2.D assumes that chicks are brought in at the age of 4 weeks, and brought up to laying age of 20 weeks at the facility in Old Crow. The CASE 1 operation shows a net revenue of $12.27 on each bird, and CASE 2 has a net revenue of $32.96 per bird.

TABLE 7.3.2.D

Scenario 2: YEARLY EGG PRODUCTION AND CHICKEN HARVEST - start w/chicks @ 4 wks

	CASE 1					CASE 2				
# hens:	25	50	100	200	400	25	50	100	200	400
$ chicks @ 4 wks:	88	176	351	703	1406	88	176	351	703	1406
feed (kg):	1428	2856	5712	11424	22848	714	1428	2856	5712	11424
$/yr feed&ship:	1105	2211	4421	8842	17684	838	1676	3353	6706	13412
chicken harvest $:	125	250	500	1000	2000	125	250	500	1000	2000
$/yr eggs rvnu:	1375	2750	5500	11000	22000	1625	3250	6500	13000	26000
revenue - cost/yr =	307	614	1227	2455	4910	824	1648	3296	6591	13182
net revenue per hen=			$12.27					$32.96E		

From these three tables, it appears that the most optimistic scenario from an economic standpoint is to bring in hens at 20 weeks and provide 50% of the feed from local sources. Reduced feed costs combined with a price of $3.25 per dozen eggs shows the most favorable results.

The worst economic case is bringing in the chicks at 4 weeks, feeding them 100% imported feed, and selling the eggs at the current price per dozen.

Table 7.3.2.E presents costs for growing chicken for meat in Old Crow, where chicks are brought in at 4 weeks, and harvested at 12 weeks. The table assumes four production cycles per year. Chicken harvest values are based upon the current price per kilogram for chicken in Old Crow. CASE 1 is a losing proposition, showing an annual deficit of $2.09 per bird. CASE 2 shows a net revenue of $1.81 per bird.

TABLE 7.3.2.E

Scenario 3: ANNUAL BROILER PRODUCTION

	CASE 1					CASE 2				
# birds per cycle:	25	50	100	200	400	25	50	100	200	400
$ chicks:	351	703	1406	2812	5624	351	703	1406	2812	5624
grower feed (kg):	1008	2016	4032	8064	16128	504	1008	2016	4032	8064
cost of feed:	780	1560	3121	6242	12483	390	780	1560	3121	6242
chicken harvest $:	923	1845	3690	7380	14760	923	1845	3690	7380	14760
revenue - cost/yr =	-209	-418	-837	-1673	-3347	181	362	724	1447	2895
net revenue/bird=	$-2.09					$1.81				

For all scenarios, management of the facility was assumed to be similar to most "family scale" operations, in which labour is not considered as part of the operating expenses. The net profit represents the value of the labour required for operation of the facility. This value will fluctuate, depending upon several factors, particularly the efficiency of operation. Labour has therefore been excluded from the calculations, and wages are based on annual net revenue.

7.3.3 Export Potential

The average production of dual-purpose laying hens is 240 eggs per bird per year. Using this figure, and the consumption rates from the market survey above, the community of Old Crow would require close to five hundred birds to supply their maximum weekly demand.

Old Crow may wish to consider an expanded facility proportioned to an export market when they have established an operation which adequately meets the needs of their own community.

7.3.4 Capital and Operating Costs of Poultry Facility

Table 7.3.4.A shows capital costs and one year operating costs for increasing flock sizes from 25 to 400 hens. Capital costs for the building are based upon the current construction costs ($/sq ft) in Old Crow. Costs for ventilation equipment, poultry equipment and controls are estimated from data collected during the study. One year operating costs are based on the most profitable scenario as developed in the sections above. Annual labour costs are assumed to equal the difference between revenue and operating costs.

TABLE 7.3.4.A
CAPITAL COSTS - POULTRY FACILITY

Number of chickens:	25	50	100	200	400
Building Cost @ $90/sq ft	4,500	9,000	18,000	36,000	72,000
Ventilation Equip	125	250	500	1,000	2,000
Poultry Equipment	1,250	1,500	2,000	3,000	5,000
Controls	800	800	800	800	800
Feed grinder	600	600	600	600	600
Total	7,275	12,150	21,900	41,400	80,400
Area (sq ft)	50	100	200	400	800
Cost/square foot	146	122	110	104	101
ONE YEAR OPERATING EXPENSES					
Hens at 20 weeks	276	552	1,104	2,208	4,416
Local feed	218	437	874	1,747	3,494
Imported feed + shpg	420	841	1,682	3,363	6,727
Misc Supplies	15	30	60	120	240
Light	15	29	58	116	233
Ventilation	35	71	141	282	564
Total	980	1,959	3,919	7,837	15,674
REVENUE					
Eggs	1,625	3,250	6,500	13,000	26,000
Chickens	125	250	500	1,000	2,000
Total	1,750	3,500	7,000	14,000	28,000
LABOUR COST					
Revenue - Operating Cost	770	1,541	3,081	6,163	12,326

To optimize labour requirements for the facility, the annual net revenue of $6163 for a flock size of 200 hens has the best potential for realistic one-person facility management. Based on egg-production estimates, this flock size should meet half the present community egg requirements. A poultry module size of approximately 40 square metres (400 sq ft) would provide ample space for a 200 hen flock.

8.0 Training Requirements

An initial evaluation of training requirements for the operation of the waste heat recovery and distribution system, and for the food production facility have been assessed during Stage 1.

The people of Old Crow have not yet had the opportunity to learn all of the skills and techniques associated with district heating and food production. However, several people in Old Crow have a wealth of experience relating to these areas. Their experience would contribute a valuable component to a training program.

This study has determined that the availability of on-site training and skills upgrading is the critical component in the success of this project.

To ensure continuity of facilities operation, two persons (as a minimum) should be trained for each functional position to be further defined in Stage 2.

Curriculum development should integrate guest lectures and educational material from recognized institutions in the south, to provide a framework for eventual certification of trainees.

8.1 Waste Heat Recovery & District Heating System

The waste heat recovery and distribution system has similar operating characteristics to the school heating system. Training would expand the skills presently used to operate the heating system at the school. A training program would be designed to further develop these existing skills for an additional area of application.

Components of the training program for management and operation of the WHR and distribution system should include:

Equipmentoperation
Heat Recovery and Distribution System Maintenance
Ordering procedures for expendable supplies
Daily records and system monitoring
Observational records and monthly reports

8.2 Food Production Facility

The Loucheux people are keenly observant of seasonal climate changes and the ways of the land. With a well equipped food production facility and a training program developed specifically to meet their requirements, the people in Old Crow could specialize and adapt these traditional observational skills to successful horticulture and poultry raising.

Components of the training program for vegetable production management and operation should include:

Management Decision Making
Equipmentoperation& maintenance
Facility sanitation
Ordering procedures for seeds
Planting & Cultivation
Soil bed & Hydroponics techniques
Ordering procedures for expendable supplies
Transplanting seedlings
Plant nutrition
Fertilization and watering requirements
Fertilizer records
Crop harvest and transport to market
Crop production records
Crop rotation
Observational records and monthly reports

Components of the training program for management and operation of the poultry and egg production facility should include:

Management Decision Making
Equipmentoperation& maintenance
Facility sanitation
Ordering procedures for birds and feed
Ordering procedures for expendable supplies
Feeding and watering requirements
Feed records
Egg gathering and transport to market
Daily production records
Flock rotation
Observational records and monthly reports

9.0 Economic Summary

Table 9.0.A summarizes estimated capital costs and one year operating costs for the waste heat recovery and distribution system, and the food production facility.

TABLE 9.0.A
ECONOMIC SUMMARY
WASTE HEAT RECOVERY AND DISTRICT HEATING SYSTEM &
FOOD PRODUCTION FACILITY
OLD CROW, YUKON

	Waste Heat Recovery and Distribution	Greenhouse and Garden Operation	Poultry and Egg Operation	Ancillary Space
CAPITAL COSTS				
Building cost @ $90/sq ft		$36,000	$36,000	$63,000
Area (sq ft)		400	400	700
Equipment cost	$340,668	$30,150	$5,400	$1,000
Total	$340,668	$66,150	$41,400	$64,000
Cost/square foot (avg $120)		$165	$104	$91
REVENUE	$67,860	$40,111	$14,000	
ANNUAL OPERATING EXPENSES	$4,620	$6,389	$7,837	
ANNUAL LABOUR EXPENSES	$5,600	$21,500	$6,163	
REVENUE - OPERATING COSTS	$57,640	$12,222	$0	$0

SIMPLE PAYBACK on TOTAL PROJECT (years) 7

PROJECT SUMMARY

REVENUE	$121,971
CAPITAL	$512,218
OPERATION	$18,846
LABOUR	$33,263
TRAINING	$100,000

These calculations represent preliminary approximations based on standard systems and northern designs. Circumstances specific to final system design may significantly affect the cost of buildings, equipment, and installation in Old Crow. These data are provided only as the basis for decisions for further study.

Capital costs for the waste heat recovery and distribution (district heating) system are based upon the design configuration with the highest annual system utilization.

Capital costs of the food production facility assume a building area of 144 square metres. The dimensions are based upon the required area for a greenhouse and poultry operation to meet half the present demand for vegetables and eggs in Old Crow, plus ancillary space.

The design includes 37 square metres (400 sq ft) of greenhouse, 37 square metres (400 sq ft) of poultry house, and an ancillary space of 70 square metres, including training and office space, mechanical equipment, tools, supplies and materials storage.

Total capital cost of the project is estimated at $512,218.

The revenue for the district heating system of $67,860 is based on estimated fuel oil displacement and is expressed as "oil equivalent" dollars. This is calculated on the present cost per litre of fuel oil in Old Crow.

The $54,111 revenue for the food production facility is based on the total sales of vegetables and eggs, and is calculated on the best case scenarios for both operations, as detailed in Sections 7.2.6 and 7.3.4 respectively.

One year of operating costs and potential revenues for the district heating system and the food production facility are also summarized on the table.

Operating costs for the district heating system include materials required for maintenance of the system and the cost of pumping power.

Operating costs for the greenhouse and garden include power for lighting, operation of heating and food production equipment, and materials for maintenance of the facility.

Operating costs for the poultry house include power for lighting, operation of heating and ventilating equipment, feed, and supplies.

Total annual operating costs for the project are estimated at $19,336.

Labour costs for the district heating system are $5600, based on the time required for preventative and regular scheduled maintenance, servicing, monitoring, and report preparation.

Labour costs for the greenhouse/garden operation are $21,500. This includes all labour requirements for day-to-day operation of the facility, as well as regular maintenance, record keeping and report preparation.

Labour costs are based on estimated number of person hours required at $10 per hour. The remaining balance of $9113 represents profit.

Labour costs of $6163 for the poultry operation are based on estimated number of person hours required for day-to-day operation of the facility, as well as regular maintenance, record keeping and report preparation.

For the poultry facility, the difference between revenue and operating costs is the value assigned to labour. This is a "floating" value, which may fluctuate directly proportional to an increase or decrease in revenues or operating costs.

Total value of the labour component is $32,773. This corresponds to 410 person days at a rate of $10 per hour for an eight hour day. It is recognized that the nature of the work involved may not conform to an eight hour day schedule, or provide full-time employment to the individuals involved.

Training costs of $100,000 are estimated to cover the cost of instructional fees, travel expenses, and training materials for the first year of operation.

A simple payback of 7 years is calculated for the total project. The balance on the project indicates a substantial annual net revenue.

10.0 Conclusions

The results of the Stage 1 study conclude that it is feasible and appropriate to utilize waste heat from the diesel-electric generating plant in Old Crow for an integrated food production facility. Based upon a preliminary evaluation of the technical, economic, and social factors involved, such a project appears to offer several significant advantages to the community.

An initial examination of the proposed facility indicates that an integrated food-production facility consisting of a greenhouse, a garden, and a poultry house is feasible, provided that all three components are implemented.

A number of factors become economical for commercial scale production when the three components are combined into a single facility. For example, a combined facility shares the capital costs of building construction and utilities.

The implementation of an integrated food production facility offers training and employment opportunities for the community. Local employment and the purchase of local materials for facility construction, fertilizer and feed, could also provide a mechanism for increasing the cash flow in the community. In addition, the facility could offer a unique opportunity to conduct community based information transfer programs, and valuable research into successful food-production techniques in the far North.

11.0 Recommendations

Based on the conclusions of Stage 1 investigations, it is recommended that the Study proceed with the tasks outlined in the proposal for Stage 2, relating to waste heat recovery and food production in Old Crow. The following recommendations identify the areas of further work required to complete the feasibility study. It should be recognized that some of these recommendations are outside the scope of the Terms of Reference for the Stage 2 component of the study.

11.1 Waste Heat Recovery Recommendations

From the results of this study, it is concluded that there is ample waste heat available to maintain a food production facility. It is recommended that further investigation examine the potential for distribution of surplus heat to other users in the community. Other potential uses may include; domestic hot water for the school, space heating for a water delivery point, and supplemental space heating for other buildings in the community which are presently heated with oil.

Energy conservation retrofit of buildings receiving supplementary heat should be evaluated. Conservation plays an important role by increasing the waste heat contribution to the space heating and hot water requirements.

An integrated application of waste heat utilization and energy conservation retrofit of buildings will maximize the number of community buildings which can benefit from the waste heat.

It is recommended that design development focus on waste heat recovery from the engine coolant on all generators in the YECL facility. It is further recommended that the waste heat distribution system be designed to carry all waste heat presently available, and to accommodate future expansion of the system.

It is recommended that the variations in electricity generation during typical winter days be monitored with a chart recorder, by Yukon Electrical Company Ltd., during the November 1984 to January 1985 period, to provide necessary data for engineering design of the heat recovery system.

In addition, the study should examine the feasibility of coaxial delivery of water with the waste heat distribution system.

11.2 Food Production Facility Recommendations

It is recommended that further study examine the specific requirements for a food production facility designed to meet at least half of the present community requirements for produce and eggs.

It is recommended that availability of the prime site be investigated to determine if it may be used by the community for this purpose.

It is recommended that cost estimates for the facility maximize the use of local labour and materials.

It is also recommended that facility design development include a minimum of 200 square feet within the food production building for training sessions, meetings, and other community activities related to food production.

11.2.1 Greenhouse Recommendations

Results of this Stage 1 report strongly favor further investigation into the development of hydroponic greenhousing techniques for Old Crow. Hydroponic methodology, planting schedules, suitable crop varieties and market demand should receive more detailed evaluation.

It is recommended that further study proceed with a design concept for a 400 square foot greenhouse section in the food-production facility. This floor area would accommodate enough vegetables to replace half the community's present requirements.

11.2.2 Outside Garden Recommendations

The results of this study indicate the success of raised bed gardening in cold climates. It is recommended that proven techniques for increasing soil fertility and plant productivity in raised outside beds be addressed in further study.

The study has concluded that there will be a surplus of waste heat available from the generators from May to October. It is recommended that attention be given to using some of this heat to protect frost susceptible varieties, which could be grown in outside beds enclosed by a low-cost, low-maintenance shelter.

11.3 Poultry Recommendations

It is recommended that the study proceed with a design concept for a 400 square foot poultry house section in the food-production facility. This area would accommodate enough hens to produce half the community's present demand for eggs.

Although egg production is feasible for Old Crow, it is evident from the Stage 1 study that the economics of poultry raising are significantly affected by the percentage of feed requirements which can be met with local resources.

Further study should provide information on acquisition and value of local materials for feed and litter, breed selection, production scheduling, egg marketing in the community, and utilization of manure for garden fertilization.

With the potential economic advantage of providing local material for feed, the economics of broiler production may be favorable. Further study should examine the economics of broiler production as a component of the food production facility.

11.4 Training Recommendations

Training will be an essential part of project development to prepare selected trainees with operational and managerial skills required for the waste heat and food production facility.

It is recommended that the level of community interest in training be further investigated. Continued support of the study from the Old Crow Band indicates their interest in effective training approaches to develop the energy component of community planning. Training could include energy management workshops on current appropriate energy technologies and energy planning for interested community members.

It is recommended that further study delineate training requirements and delivery approaches which would be compatible with the community.

It is also recommended that training investigations include the feasibility of linking training programs in Old Crow with certifiable programs from other institutions.

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APPENDIX A

SOIL ANALYSIS

OLD CROW, YUKON

AGRICULTURE
Alberta Tree Nursery and
Horticulture Centre

RR6, Edmonton, Alberta, Canada T5B 4K3 403/973-3351

May 29, 1984

Ingrid Taggart
Decora Landscaping Ltd.
105 Granite Road
WHITEHORSE, Yukon Territory
Y1A 2C6

Dear Ms. Taggart:

Re: Soil Test Results

Below are the recommendations for each soil tested:

#84027 AIRSTRIP	Lawn - topsoil, uncultivated		
	0-0-60	x 4 lb./1000 ft.^{2}	spring
	11-48-0	x 5 lb./1000 ft.^{2}	spring
	34-0-0	x 4 lb./1000 ft.^{2}	mid July
	16-20-0	x 6 lb./1000 ft.^{2}	every spring and summer starting next year.
#84028 SCHOOLYARD	Lawn - topsoil		
	11-48-0	x 5 lb./1000 ft.^{2}	late May
	11-48-0	x 2 lb./1000 ft.^{2}	mid July
	16-20-0	x 6 lb./1000 ft.^{2}	every spring and summer starting next year.

#84030 Vegetables - potatoes

#77

- all nutrients excessive, no fertilizers required
- sodium levels too high, do not use soft water to irrigate
- increase organic matter by incorporating 2 inch peat moss to 6 inches deep
- do not use lime.

#84031 Vegetables - potatoes

NURSING STATION

11-48-0 x 5 lb./1000 $ft.^2$
21-0-0 x 4 lb./1000 $ft.^2$
Peat Moss 2 inches

-broadcast and incorporate to 6 inches before planting.

-do not use lime.

#84032 Vegetables - mixed

STEVEN FROST GARDEN.

21-0-0 x 5 lb./1000 $ft.^2$

-sodium levels getting high, check irrigation water quality.
-increase organic matter.

These recommendations are based on central Alberta soils and climatic conditions and may not apply to those conditions found in the Yukon. First hand experience is required.

Yours very truly

L. Eckberg

L. ECKBERG, P.Ag.
Horticulture Technician

LE/pf
Att'd.
cc: J. Carson
Report No.: D11686

SOIL TEST REPORT FOR GARDEN AND LAWN

FOR OFFICE USE

REPORT NO. D . . . . 11686 . . . . DATE . . . . . . May 24, 1984 . . . .

RECEIPT NO. SF . . . . 23021 . . . .

Alberta AGRICULTURE
SOIL & FEED TESTING LAB.
BOX 8070, EDMONTON, ALBERTA
T6H 4P2

NAME: . . . . Ingrid Taggart, Decora Landscaping Ltd., ...

ADDRESS: . . . 105 Gramte Road, ...

. . . . Whitehorse, Y.T. . . . TIA 2C6 . . . .

SOIL TEST RESULTS*

Lab. No.	Sender's No.	Available Nutrients (lb/acre) Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)	Soil Reaction (pH)	Salts Total (mmhos)	Sodium (Na)	Sulphate (SO_4)	Organic Matter	Free Lime	Texture
406	84027	8	7	138	-	6.4	0.4	L-	-	M	-	3
407	84028	100+	6	216	-	6.5	2.3	L	M	M	-	4
	84029	see greenhouse										
408	84030	100+	200+	1220	-	7.1	2.3	H+	L	M	L	3
409	84031	7	34	212	-	7.6	0.5	L-	-	M	M-	4
410	84032	7	120	234	-	7.1	0.7	M+	-	M	-	3

See reverse side of report for general interpretation of results.

conductivity ↑ ↑ H_2O source? needs testing.

FERTILIZER RECOMMENDATIONS

Lab. No.	Sender's No.	FERTILIZER Formulation	Amount (lb. per 1000 sq. ft.)	Method and Time of Application
406	Lawn			

SPECIAL REMARKS

A. Specific comments and further information regarding your soil test results are given on attached page.

B. The sections below marked with an [X] provide further information concerning your soil sample(s) or test results.

[ ] The soil test(s) do not reveal an explanation for your problem. See "Additional Comments" on the back of this report.

[ ] FOR BEST RESULTS FROM FERTILIZERS:

(a) If fertilizer is broadcast on the surface of a garden, it should be worked into the soil prior to seeding or planting.

(b) Spread fertilizer uniformly to avoid excessive amounts in certain spots and deficiencies in others.

(c) Apply fertilizers when grass or plants are dry. Avoid placing on the leaves of broad leaf plants or in direct contact with the seed or young seedlings. Watering following fertilization helps reduce the risk of burning. DO NOT apply fertilizer immediately after watering or rain.

(d) When side dressing garden crops, place fertilizer 2 inches to the side and one inch below the seed.

[ ] THE ORGANIC MATTER level of your soil sample no. . . . . is low. The organic matter content may be increased by mixing compost, peat or manure with the soil. Addition of such organic materials is very important for garden soils in order to maintain favorable physical condition and productivity.

[ ] You have a SALT PROBLEM (often called alkali) in sample no. . . . . This is shown by the conductivity value and/or the sulfate level. See the comments on the back of this report.

[ ] The FREE LIME (calcium carbonate) content of your soil is:

. . . . low . . . . medium . . . . high . . . . very high.

The presence of excessive amounts of free lime in the soil is not desirable. See comments on the back of this report.

[ ] The REACTION (pH) of your soil sample . . . . is:

. . . . moderately acid . . . . strongly acid . . . . extremely acid.

An explanation of this soil condition and possible corrective action is given on reverse side of this report and in attached leaflets.

ENCLOSED LEAFLETS: . . . .

RECOMMENDED BY: . . . . DATE: . . . .

Alberta

AGRICULTURAL SOIL AND FEED TESTING LABORATORY
O.S. Longman Bldg. 6909 - 116 St., Edmonton, Alberta T6H 4P2
Telephone: 436-9150
Rite No.: 427-6362

Information Sheet for Farm Soils

FOR OFFICE USE ONLY

B		
Regular	× $10.00 =	
Lime Requirement Only	× $ 5.00 =	
Special		
Lime Requirement	× $ 2.00 =	
Organic Matter	× $ 2.00 =	
DTPA Extractable	× $ 2.00 =	
Other	× $ =	
TOTAL		
PAID		
BALANCE DUE		
RECEIPT NO.		

NAME: Ag. Canada (Please print)
ADDRESS: Box 2703
CITY OR TOWN: Whitehorse Y.T. POSTAL CODE Y1A 2C6
PHONE NO. 667-5272

County No. ______ or M.D. No. ______ or I.D. No. ______
District Agriculturist Office at ______
Date Sampled May 1984

Have you soil tested any of your fields before with this laboratory? Yes ☐ No ☐

PLEASE READ SAMPLING INSTRUCTIONS ON THE REVERSE SIDE
A DUPLICATE COPY OF THIS SHEET SHOULD BE KEPT FOR YOUR RECORDS
PLEASE PRINT CLEARLY AND PROVIDE ALL INFORMATION POSSIBLE

SOIL & CROP INFORMATION / **SOIL & CROP HISTORY**

For Lab. Use Only	Sample and Box Number	Sample Depth (inches)	Crop To Be Grown: Crop	Per cent Legume (if Forage)	Is This Irrigated Land	No. of Places Sampled	Field Size	Legal Location (QR / SEC / TWP / RGE / W of)	Was Fertilizer applied before sampling	Cropping History of Field: Last Crop Grown or Fallow / Previous Year Crop or Fallow	Per cent Legume (if Forage)	Crop Yield bu/acre or tons/acre	Fertilizer Applied With Last Crop Only: Analysis / Rate (lbs./ac.)	Damage to Last Crop: Amount (Please circle)	Damage to Last Crop: Cause (Please circle)	Time of Plow Down (please circle) (Fill in only when Forage with more than 25% Legume or Manure is Plowed Down)	Rate of Manure Applied	Analysis Requested (See back of Sheet)
SAMPLE ENTRY ONLY	1	0-6 ☑ 6-12 ☑ 12-24 ☑	Barley		Yes ☐ No ☑	20	60 acres	SW 6 50 13 4	Yes ☑ No ☐ Analysis 34-0-0 150 lb/ac	1982 Grass-Legume / 1981 Oats	30	2 / 50	Broadcast: 34-0-0 150 lbs. Drilled: 11-48-0 60 lbs.	1-None (2-Light) 3-Medium 4-Heavy	(1-Too Dry) 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) (3-Late (after Sept. 1))	10 tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___
108	84030	0-6 ☑ 6-12 ☐ 12-24 ☐	vegetables #77 behind ~~[illegible]~~		Yes ☑ No ☐				Yes ☐ No ☑ Analysis	1983 potatoes / 19..		/	Broadcast: / Drilled:	1-None (2-Light) 3-Medium 4-Heavy	1-Too Dry 2-Too Wet 3-Weeds, Pests (4-Hail, Frost) 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) 3-Late (after Sept. 1)	tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___
109	84031	0-6 ☑ 6-12 ☐ 12-24 ☐	vegetables nursing station		Yes ☑ No ☐				Yes ☐ No ☑ Analysis	1983 potatoes / 19..			Broadcast: / Drilled:	(1-None) 2-Light 3-Medium 4-Heavy	1-Too Dry 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) 3-Late (after Sept. 1)	tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___
110	84032	0-6 ☑ 6-12 ☐ 12-24 ☐	vegetables Stephens house		Yes ☐ No ☐				Yes ☑ No ☐ Analysis	1983 mixed / 19..			Broadcast: / Drilled:	(1-None) 2-Light 3-Medium 4-Heavy	1-Too Dry 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) 3-Late (after Sept. 1)	5 tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___

If you wish a copy of your soil test report to be forwarded to a fertilizer company, please specify the company name and dealer number ....

OTHER INFORMATION OR SPECIAL CONCERNS SHOULD BE NOTED ON A SEPARATE SHEET OF PAPER: e.g. Factors affecting crop, special problems, etc.

Alberta

INGRID TAGGART

AGRICULTURAL SOIL AND FEED TESTING LABORATORY
O.S. Longman Bldg. 6909 - 116 St., Edmonton, Alberta T6H 4P2
Telephone: 436-9150
Rite No.: 427-6362

RECEIVED
MAY 17 1984
A.S.F.T.L.

Information Sheet for Farm Soils

NAME: ~~Ag. Canada~~ DECORA LANDSCAPING LTD.

ADDRESS: ~~Box 2703~~ (Please print) 105 GRANITE ROAD, WHITEHORSE

CITY OR TOWN: ~~Whitehorse Y.T.~~ POSTAL CODE ~~Y1A 2C6~~

PHONE NO. 667-5272

County No. ______ or M.D. No. ______ or I.D. No. ______

District Agriculturist Office at ______

Date Sampled May 84.

Have you soil tested any of your fields before with this laboratory? Yes ☐ No ☐

PLEASE READ SAMPLING INSTRUCTIONS ON THE REVERSE SIDE
A DUPLICATE COPY OF THIS SHEET SHOULD BE KEPT FOR YOUR RECORDS
PLEASE PRINT CLEARLY AND PROVIDE ALL INFORMATION POSSIBLE

FOR OFFICE USE ONLY

D 11686

.... Regular × $10.00 = ...
.... Lime Requirement Only × $ 5.00 = ...

Special
.... Lime Requirement × $ 2.00 = ...
.... Organic Matter × $ 2.00 = ...
.... DTPA Extractable × $ 2.00 = ...
.... Other × $ = ...

10 - GHSE TOTAL
PAID (60CK)
BALANCE DUE ....
RECEIPT NO. 23021

SOIL & CROP INFORMATION / SOIL & CROP HISTORY

For Lab. Use Only	Sample and Box Number	Sample Depth (inches)	Crop To Be Grown: Crop	Per cent Legume (if Forage)	Is This Irrigated Land	No. of Places Sampled	Field Size	Was Fertilizer applied before sampling	Cropping History of Field: Last Crop Grown or Fallow / Previous Year Crop or Fallow	Per cent Legume (if Forage)	Crop Yield bu/acre or tons acre	Fertilizer Applied With Last Crop Only: Analysis, Rate (lbs./ac.)	Damage to Last Crop: Amount (Please circle)	Cause (Please circle)	Fill in only when Forage with more than 25% Legume or Manure is Plowed Down: Time of Plow Down (please circle)	Analysis Requested (See back of Sheet)
EXAMPLE ENTRY ONLY	1	0-6 ☑ 6-12 ☑ 12-24 ☑	Barley; LEGAL LOCATION: SW 6 50 13 4 (QR SEC TWP RGE W of)		Yes ☐ No ☑	20	60 acres	Yes ☑ No ☐ Analysis 34-0-0 150 lb./ac	1982 Grass-Legume; 1981 Oats	30	2; 50	Broadcast: 34-0-0 150 lbs. Drilled: 11-48-0 60 lbs.	1-None (2)-Light 3-Medium 4-Heavy	(1)-Too Dry 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) (3)-Late (after Sept. 1); Rate of Manure Applied 10 tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___
06	84027	0-6 ☑ 6-12 ☐ 12-24 ☐	lawn (top soil) Quistip; LEGAL LOCATION: (QR SEC TWP RGE W of)		Yes ☐ No ☑			Yes ☐ No ☑ Analysis	1983 uncultivated; 19..			Broadcast: / Drilled:	1-None 2-Light 3-Medium 4-Heavy	1-Too Dry 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) 3-Late (after Sept. 1); Rate of Manure Applied ___ tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___
07	84028	0-6 ☑ 6-12 ☐ 12-24 ☐	lawn (top soil) Echinf Echiff.; LEGAL LOCATION: (QR SEC TWP RGE W of)		Yes ☐ No ☑			Yes ☐ No ☑ Analysis	1983 uncultivated; 19...			Broadcast: / Drilled:	1-None 2-Light 3-Medium 4-Heavy	1-Too Dry 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) 3-Late (after Sept. 1); Rate of Manure Applied ___ tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___
008	84029	0-6 ☑ 12-24 ☐	greenhouse; LEGAL LOCATION: (QR SEC TWP RGE W of)		Yes ☑ No ☐			Yes ☐ No ☑ Analysis	1983 vegetables; 19....			Broadcast Drilled	1-None 2-Light 3-Medium 4-Heavy	1-Too Dry 2-Too Wet 3-Weeds, Pests 4-Hail, Frost 5-Salts	1-Early (before June 30) 2-Midseason (June 30-Aug. 30) 3-Late (after Sept. 1); Rate of Manure Applied ___ tons/acre	Regular ✓ Lime Requirement ___ Other (Specify) ___

C-2205 #104

If you wish a copy of your soil test report to be forwarded to a fertilizer company, please specify the company name and dealer number AG CANADA BOX 2703 WHITEHORSE YT. Y1A 2C6

OTHER INFORMATION OR SPECIAL CONCERNS SHOULD BE NOTED ON A SEPARATE SHEET OF PAPER: e.g. Factors affecting crop, special problems, etc.
Send copy of results & recommendation to Box 2703

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Alberta
AGRICULTURE

AGRICULTURAL SOIL AND FEED TESTING LABORATORY

9th Floor O.S. Longman Building
6909 - 116 Street, Edmonton, Alberta, T6H 4P2
Lab. Analysis (403) 427-6361
436-9150

GREENHOUSE SOIL TEST REPORT

Submitter: Ingrid/Taggart/Decora Landscaping Ltd.,
105 Gramte Road
Whitehorse, Alberta

Phone:

REPORT NO. C-2205

Date Sample Received May 17, 1984

Date Analysis Completed May 22, 1984

Receipt No. SF 23021 $60.00)10. for 1 samples

ANALYTICAL RESULTS (All results in Parts Per Million extractable, for pH, texture and E.C. see reverse)

LABORATORY NUMBER	GROWER'S SAMPLE NUMBER	Ammonium N	Nitrate - N	Phosphorus P	Potassium K	Sodium Na	Calcium Ca	Magnesium Mg	Chloride Cl	Sulfates S	Nitrites NO_2	pH	Electrical Conductivity E.C.	Texture
104	84029	18	6	3	44	66	606	192	-	37.6	-	5.7	0.7	7
		Recommendations:												
		Recommendations:												
		Recommendations:												
NUTRIENT SUFFICIENCY RANGE IN GROWING MEDIA	*Acetic Acid	0-20	25-75	25-50	150-300	0-30	500-1000	150-300	0-30	30-60	Nil	5.5 6.9	0.8-3.0	
	WATER EXTRACT	0-20	35-180	5-50	35-300	0-30	60-400	30-200	0-30	30-60	Nil	5.5 6.9	0.8-3.0	

Special Comments

~~behind house~~ Janu
~~stayed in~~.
coop greenhouse

*Agricultural Soil & Feed Testing Laboratory using Acetic Acid Extract
Water Extract given for Information Only.

Recommendation by______________ Date__________

Greenhouse Crop Specialist
Alberta Horticultural Research Center
Brooks, Alberta (403) 362-3391

HOW TO INTERPRET SOIL TEST DATA FOR GARDENS AND LAWNS

The following information is to help you to understand the results of your soil tests and recommendations.

NITROGEN, PHOSPHORUS, POTASSIUM AND SULPHUR when needed can be supplied in the form of manufactured or natural fertilizers, eg. manure or compost. See how your soil tests compare with the following general guidelines.

	Very Low	Medium	Very High
Nitrogen	less than 15 lb/acre	30 – 60 lb/acre	over 100 lb/acre
Phosphorus	less than 10 lb/acre	20 – 50 lb/acre	over 150 lb/acre
Potassium	less than 50 lb/acre	150 – 300 lb/acre	over 800 lb/acre

When the soil tests are very low to medium, then fertilizer recommendations are made to raise and balance plant nutrient levels. If high tests are obtained for all nutrients, then no fertilizer is required. Very high tests indicate possible over fertilization or adverse soil conditions affecting plant growth.

SOIL REACTION is a test which indicates whether the soil is acidic or alkaline. Most garden plants and lawn grasses grow best at a pH of 5.8 to 7.3. If the test is within this range, there is no need for correction. An acid soil condition (pH less than 5.5) can seriously harm growth of most plants. Soils with **Free Lime** usually have an alkaline reaction (pH of 7.5 – 8.5) and these soils may have low amounts or availability of some nutrients. When a soil shows the presence of free lime, this may indicate a greater need for a phosphorus fertilizer. If a nitrogen fertilizer is used on these soils, ammonium sulfate (21-0-0) is suggested in place of ammonium nitrate (34-0-0) because of its greater acidifying effect. The application of manure or acidic peat on alkaline soils may also be beneficial.

FREE SALTS: The total amount and kinds of salts in soil can affect plant growth. See how your soil and test results compare with the following guidelines:

	Low	Medium	High	Very High
Total Salts (mmhos)	0 – 0.5	0.5 – 3.0	3 – 8	over 8
Sulphates and Sodium	L	M	H	H+

If the tests are high, crop production may be retarded. **SULPHATES** and **SODIUM** are measured to determine specific kinds of salts present in saline soil samples. Leaching, with heavy applications of water, addition of organic matter and selection of salt tolerant crops are recommended if soluble salts are present in very high amounts.

ORGANIC MATTER: The organic matter or humus content of the soil is one of the most important factors affecting the physical condition or tilth of soil. Organic matter serves as a storehouse for plant nutrients, particularly nitrogen; it has a marked beneficial effect on the physical properties of soils; and it is the major food supply for microorganisms, nature's busiest helpers in the soil.

ADDITIONAL COMMENTS: A soil test is not the answer to all garden problems. If you are having trouble with your crops, or plants, and the test did not expose the cause of the trouble, better look elsewhere. Look for disease or insect damage. How is soil drainage? Are you using recommended varieties? Are your crops too close to shade trees? Are you over-watering? Are you planting properly and at the right time? These are examples of trouble which soil tests will not reveal.

COMMENTS RE:

(a) SOIL TEST RESULTS

Electrical Conductivity - Soluble salts are measured on a 2:1 water: soil extract by the flow of electrical current. The electrical conductivity is reported on a saturated paste basis in millimhos per centimeter.

Texture Codes 1. Very Coarse (Sand & Loamy Sand); 2. Coarse (Sandy Loam); 3. Medium (Loam, Clay Loam, Sandy Clay Loam, Sandy Clay); 4. Fine (Silt, Silt Loam, Silty Clay Loam); 5. Very Fine (Clay, Heavy Clay, Silty Clay); 6. Organic. Artificial Mixes 7. Sand & Peat; 8. Perlite & Peat; 9. Perlite & Sand; 10. Triple Mix - Sand, Peat, Soil or Perlite, Sand Soil.

(b) RECOMMENDATIONS

1. Lime may be recommended for two reasons:
   (a) to correct an acid reaction.
   (b) to assist in removing excess potassium or sodium.

2. Sulfur is recommended to correct an alkaline reaction. It is slow acting but effective. It also serves as a source of sulfates.

3. Leaching is recommended to remove excess amounts of nutrient elements and salts. Leaching is generally used to remove all the nitrates and therefore an application of ammonium nitrate is recommended following leaching. Leaching is accomplished in the same manner as watering except that larger amounts of water are applied. The area to be leached should be watered in the usual manner first, and then continually rewatered until the desired amount of water has been applied. It is most effective if the leaching process is done in two stages spaced about two hours apart, i.e.: apply one half the recommended rate of water, wait two hours, then apply the remaining amount of water. Leaching of ground beds is often not practical unless excellent drainage has been provided.

4. Where leaching is impractical the incorporation of peat or similar organic matter with the soil will help alleveiate a high salts problem.

SOLUBILITY OF FERTILIZERS IN COLD AND HOT WATER

		SOLUBILITY	
		g PER 100cc WATER	
FERTILIZER	GRADE	COLD	HOT
AMMONIUM NITRATE	34-0-0	118.3 (0)	871.0 (100)
AMMONIUM SULPHATE	21-0-0 (24S)	70.6 (0)	103.8 (100)
CALCIUM NITRATE	15.5-0-0 (24% CaO)	102.5 (0)	376.0 (100)
UREA	46-0-0	78.0	
MONOAMMONIUM PHOSPHATE	11-48-0	22.7 (0)	173.2 (100)
DIAMMONIUM PHOSPHATE	18-46-0	57.5 (0)	106.0 (70)
POTASSIUM CARBONATE		112.0 (20)	156.0 (100)
POTASSIUM CHLORIDE	0-0-62	34.7 (20)	56.7 (100)
POTASSIUM NITRATE	13-0-44	13.3 (0)	247.0 (100)
POTASSIUM SULPHATE	0-0-50	12.0 (25)	24.0 (100)
POTASSIUM OTHOPHOSPHATE		90.0	(20)
MONOPOTASSIUM PHOSPHATE		167.0	(20)
MAGNESIUM SULPHATE		26.0 (0)	73.8 (100)
SODIUM BORATE (BORAX)		1.6 (10)	14.2 (55)
SOLUBOR		4.5 (10)	32.0 (50)
COPPER SULPHATE		31.6 (0)	203.3 (100)
MANGANESE SULPHATE		105.3 (0)	111.2 (54)
FERROUS SULPHATE		15.6	48.6 (50)
SODIUM MOLYBDATE		56.2 (0)	115.5 (100)

The figures in parentheses are the temperatures (°C) at which the solubilities were determined.

USEFUL MEASUREMENTS

1 Imperial Gallon=4 quarts=8 pints=160 fluid ounces =10 pounds of water=approximately 1.2 U.S. gallons
1 U.S. gallon=.8345 or approximately 5/6 Imperial gallon
1 Imperial pint=20 fluid ounces
1 U.S. pint=16 fluid ounces
1 pound=16 ounces
1 tablespoon=3 teaspoons
2 tablespoons=3 fluid ounce
1 gallon in 1,000,000 gallons of water. 1 ppm (part per million)

1 pound in 100,000 gallons of water=1 ppm (parts per million)
1 yard=3 feet=36 inches
1 foot=12 inches
1 acre=approximately 209 by 209 feet=43,560 square feet
1 square yard=9 square feet
1 square foot=144 square inches

APPENDIX B

FEASIBILITY STUDY FOR AN ANAEROBIC SEWAGE DIGESTOR OLD CROW, YUKON

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Name	Symbol
area	A
carbon dioxide	CO_2
chemical oxygen demand	COD
coefficient of transmission (1/RSI)	U
hydraulic detention time	HDT
kilowatt hour	kWh
litre	L
litres per capita per day	lpcd
mega joules	MJ
methane	CH_4
metre	m
miligrams per litre	mg/L
nitrogen	N
pnosphorous	PO_4
thermal resistance (metric)	RSI
watt	W
watts per degree Celsius	$W/^oC$

SUMMARY

This study was carried out to examine the feasibility and cost effectiveness of an anaerobic sewage digester to serve the community of Old Crow. The major components of the work included investigation and applicability of current anaerobic sewage treatment, design criteria, technical and design construction considerations, as well as the economic, technical, cultural and operational feasibility of operating such a facility in Old Crow in conjunction with a greenhouse facility. Also examined were the benefits which could be derived from the by-products of the treatment process such as biogas as an energy source and stabilized sludge for fertilizer and the possibility of using waste heat from the diesel generating plant to maintain temperatures in the treatment facility.

The study results indicate that although a high-rate anaerobic plant is feasible for Old Crow it is not considered to be cost effective or desirable for a number of reasons as follows:

(1) The digester will not be capable of producing sufficient biogas as an energy form to meet the yearly heat requirements of the digester facility. This is essentially due to climatic factors.

(2) It is not cost effective to use waste heat from the diesel plant facility. This is because the digester would have to be positioned where it will be safe (for public health and environmental reasons) to discharge relatively high strength effluent to the Porcupine River. Ideally this location would be at the present lagoon site which is too far distant from the diesel plant to consider transfer of waste heat through underground lines.

(3) The digester facilities will operate best with feed materials of relatively high strength sewage such as sewage bags slightly

diluted with pumpout wastes. Since bagged sewage will likely be gradually phased out as more pumpout tanks are installed, the sewage will probably not be of sufficient strength, and will be in too great a volume to allow a biogenerator to operate efficiently.

(4) Social acceptance of a sewage digester in Old Crow may be difficult to achieve.

(5) Proper operation and maintenance of such a facility in Old Crow will be a problem due to the remoteness of Old Crow and difficulties in maintaining specially skilled operators.

(6) As a system for treating sewage, an anaerobic digester will be very costly to construct and maintain and is not considered cost effective when compared to a simple sewage lagoon treatment system.

In general, the concept of providing an anaerobic sewage digester in Old Crow is not considered cost effective or desirable and it would provide no significant benefits to the community either in terms of by-products of the treatment facility or for public health and environmental reasons.

1.0 INTRODUCTION

This study examines the feasibility and cost effectiveness of providing an anaerobic sewage digester for the community of Old Crow. A major component in the study is to investigate the feasibility of designing and operating the facility to produce methane gas as a supplemental energy source for heating a greenhouse operation, the sewage digester facility and the possibility of using any excess gas to generate electricity for input into the electrical grid.

More specifically, the study includes examination of the following:

- availability and applicability of current sewage digester technology;
- technical, economic and cultural feasibility of applying this technology to Old Crow;
- design requirements to utilize waste heat from the diesel-electric generating facility for maintaining environmental requirements of the digester;
- technical, social and health aspects relating to the input and pretreatment of raw materials for the digester;
- risks and benefits of the potential utilization of sewage digester by-products in the community;
- training requirements for digester facility operation.

The study also discusses the overall sewage collection and disposal system, associated problems and suggestions for improvements to the present system.

2.0 BACKGROUND

The present sewage collection system in Old Crow consists of sewage pumpout from a number of establishments as follows:

- School and Teacherage
- R.C.M.P. Detachment
- Nursing Station
- Co-op
- Airport Building
- Band Office
- Five residences

The Band has a service contract with the Y.T.G. to collect the sewage and discharge it to the sewage lagoon located west of the airstrip. The sewage collected per week from the 6,000 gal holding tank at the school is estimated at 10 - 12,000 gal per week (45,460 - 54,552 L per week). The sewage volume collected from the other buildings having holding tanks is estimated at 20,000 - 30,000 L per week, giving a total of about 65,000 - 85,000 L per week.

There are four new band houses that have been recently constructed and are also equipped with holding tanks which are soon expected to be used on a continuous basis.

The remainder of the community uses earth privies and bucket toilets. Bagged sewage is collected and disposed of at a pit in the garbage dump area west of the airstrip. In general, the dump area appears to be maintained fairly well with proper segregation of bagged sewage, household garbage and non-burnables into separate areas. The liquid sewage from holding tanks is discharged into the nearby sewage lagoon.

A well located adjacent to the river and opposite the school supplies potable water for the community. It is pumped to the school and the remainder of the community is served by truck delivery.

Since the EPEC Community Development Study in 1980, the new well supply has been developed and the waste disposal area has been improved. Essentially, the level of water and sanitation facilities in the community has improved very little over the years. The main concerns are public health related and include the following:

- poor water delivery facilities;
- bagged sewage system (public health and nuisance problems);
- sewage collection facilities are inadequate;
- drainage is poor throughout the community;
- poor housing and inadequate or non-existant plumbing in most homes.

The purpose of this study is to examine the feasibility of a sewage digester for the community. If feasible, it could provide benefits to the community in terms of:

- providing a safe disposal and treatment method for climatic sewage including bagged and pumpout sewage;
- providing methane gas as a fuel for supplementing the heating requirements for the community greenhouse and digester;
- providing fertilizer for growing vegetable crops.

3.0 ANAEROBIC SEWAGE TREATMENT

Anaerobic sewage treatment, or anaerobic digestion, is the controlled breakdown of organic matter in the absence of oxygen. It is a biological process involving 2 stages of activity. The first stage involves bacteria which convert fats, carbohydrates and proteins in the sewage or manure into simple organic acids such as acetic and propionic acid. The "acid-forming" bacteria produce rapidly and are relatively insensitive to changes in the environment. The second stage of the process involves the transformation of acids to methane and carbon dioxide commonly called "biogas". In this step, the bacteria (called methane-formers or methanogens) are very sensitive to temperature, toxic substances, pH, etc., and require a special environment to function properly. They also grow slowly and are few in number. FIGURE 3.1 shows the anaerobic disgestion process in a simplified manner.

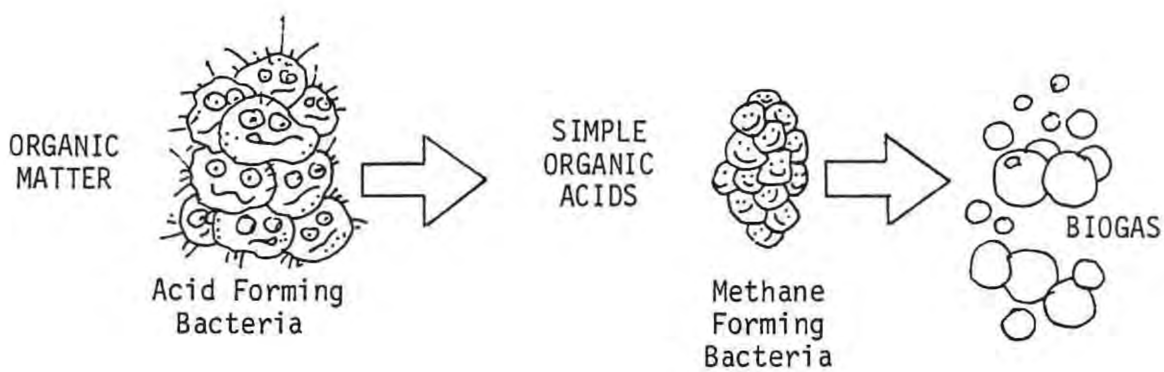

FIGURE 3.1 - ANAEROBIC DIGESTION PROCESS - (SIMPLIFIED)

The acid-forming bacteria and the methane-forming bacteria live and function together in the anaerobic digestion process to breakdown organic matter and form biogas. The conditions necessary for biogas production occur naturally in nature and is observed in places like swamps. Over the years, man has used this natural process to meet his own needs, both for the treatment of wastes and for the production of gas as a fuel.

Biogas contains 60 - 75% methane with the remaining portion of the gas comprising mostly carbon dioxide, with water vapour and traces of other gases such as hydrogen, ammonia and hydrogen sulphide. The energy content of biogas as compared to other fuels is shown in TABLE 3.1. The presence of CO_2 in biogas reduces its energy content somewhat and makes biogas storage more expensive than if only pure CH_4 (methane) were being stored. This reduced content also lessens the power output of engines which use biogas and requires increased flow in gas burner applications. Hydrogen sulphide is a undesirable impurity in biogas because it gives an unpleasant odour and is corrosive to mechanical equipment.

TABLE 3.1 - ENERGY CONTENT OF VARIOUS FUELS

FUEL	MJ/m^3
Coal Gas	16.7 - 18.5
Biogas	20 - 26
Methane	33.2 - 39.6
Gasoline	34.8
Diesel Fuel	38.7
Natural Gas	38.9 - 81.4
Propane	81.4 - 96.2
Butane	107.3 - 125.8

Anaerobic digesters have been used for many decades throughout the world, particularly in warmer climates, to treat organic wastes. The size of the treatment units vary from small, single farm or family units to large systems that form an integral part of sewage treatment plants serving cities. There are many thousands of such units in India, Pakistan, Philippines, Japan and Korea, which are used for small, individual farming units and communities. The plants are often called "Gobar Plants" and produce gas which is used for heating and cooking.

In the larger plants, the system is generally used to heat the treatment plant facility.

Biogas production is considered optimal at about 35°C although the digestion process will occur between the range of 10° to 70°C. The efficiency of the system and subsequent gas production drops markedly with lower operating temperatures. Recent studies by Pyke, Heinke and Prasad [9,11] indicate that the practical lower temperature limit for treating black water waste using the anaerobic filter process is about 25°C. The amount of methane that can be produced from human sewage waste is 0.02 - 0.03 m^3/day/person.

The conventional method of anaerobic digestion involves the addition of an organic waste slurry into an airtight containment vessel called the digester. Heat is often added and a mixing device is provided, both which improve the efficiency of the process. Detention times are generally 20 - 40 days. 80 - 90% of a waste's biodegradable organic portion can be effectively stabilized by anaerobic digestion. The resultant residue is rich in nutrients and an excellent fertilizer. Since the process is very effective in inactivating pathogenic organisms, the residue is considered safe for disposal onto the land.

In the past few years, with the emphasis on economic, environment and energy considerations, there has been a surge in research involving anaerobic treatment technologies. Worldwide interest over the past decade has led to the development of high-rate anaerobic digestion processes. These processes are based on much higher micro-organism - to - waste contact efficiency and biomass retention. This means that good waste stabilization and treatment can be obtained with detention times as low as 12 to 24 hours as compared with 30 days with the conventional methods. Some of these advanced anaerobic reactors include the anaerobic filter, upflow sludge bed reactor, fluidized and expanded bed reactor, downflow stationary fixed film reactor and the anaerobic contact process. High rate processes have yet to obtain wide spread use. However, several full-scale high-rate anaerobic systems are now being marketed and a number of installations are now operating satisfactorily to treat a variety of organic wastes. Recent studies have shown that such a process may be suitable for northern applications involving treatment of moderately concentrated wastes such as pumpout sewage, bagged sewage or combinations thereof. At present however, the author is not aware of any installations at this time that are treating domestic sewage directly. The high rate systems now being used are treating high strength, soluble process wastes from various types of industrial and commercial operations.

Of the anaerobic processes, the anaerobic filter has received considerable attention and studies have shown it to be applicable for treating a variety of wastewater types. Based on present technology, Pyke[11], suggests that the anaerobic filter process is the preferred system to consider for northern applications using medium strength sewage. In this process, the biomass - to - waste contact is dependent on the passage of waste over stationary films of biomass attached to a fixed support media and through suspended biomass developed within the media and void spaces in the reactor. Various types of support media may be used such as plastic or ceramic rings and crushed rock. The main advantage with this process, as with other high-rate systems, is that the biomass or microorganisms that are responsible for stabilizing the organics are retained on the media. In conventional systems, long retention times (30 - 40 days) were required for stabilization due to the slow growth rate of the biomass. However, with the high rate process, after an initial start-up time and acclimatization period of about 30 days, the HDT can be set at a few days and still provide a level of treatment and unit gas production that is similar to the conventional long retention system.

A schematic diagram showing an anaerobic filter is show in FIGURE 3.2.

Some of the advantages of anaerobic sewage treatment are as follows:

- very low production of biological solids;
- high degree of waste stabilization, high treatment efficiency;

- production of methane gas and fertilizer;
- capital costs are relatively low for high rate process;
- relatively low operating costs compared to other forms of mechanical treatment;
- low nutrient requirements.

Some disadvantages are as follows:

- high optimum operating temperatures limit attractive treatment installations to warm waste waters of 25^{o}C or more;
- methane forming bacteria are sensitive to pH, organic loading rates, temperature and toxic substances;
- slow growth rate of methane bacteria requires long biomass retention times.

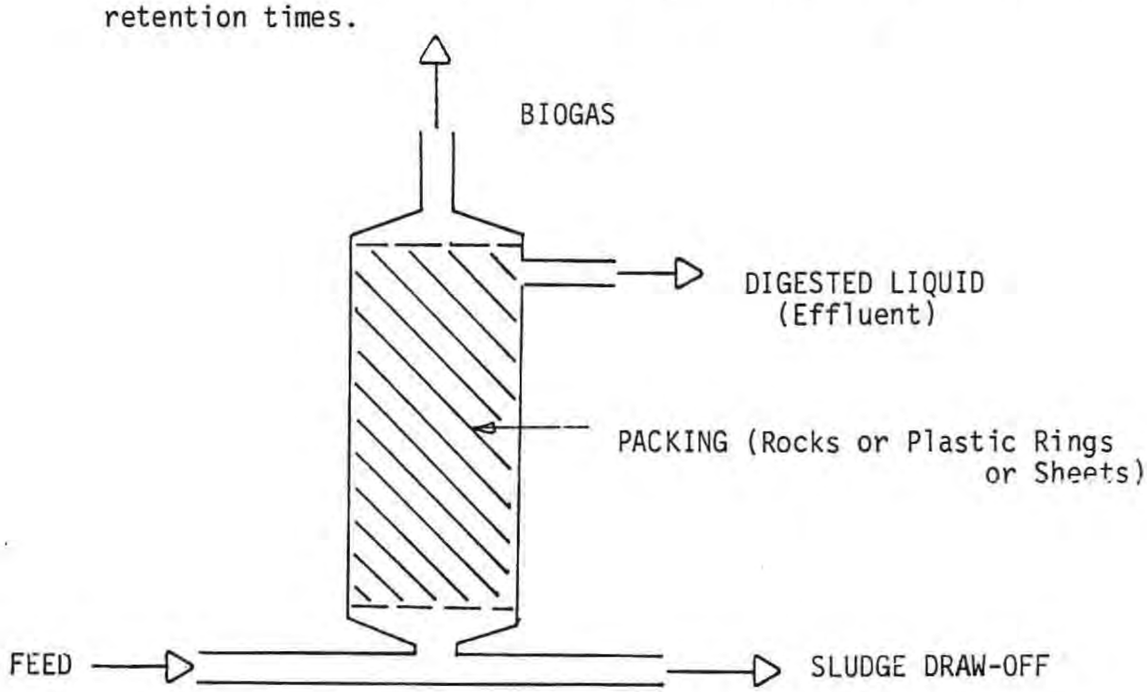

FIGURE 3.2 - ANAEROBIC FILTER - (SCHEMATIC)

Anaerobic sewage digesters have not yet been used in the north. The main factors prohibiting their use include cold climate which can result in high costs and other associated problems in maintaining the optimum operating temperatures; and the remoteness of communities which have poor services and lack of skilled labour for operating such facilities. Also, when considering anaerobic digestion as an alternative specifically for treating sewage prior to discharge, they have not been considered cost effective when compared to sewage lagoons, for example.

4.0 DESIGN CRITERIA

4.1 Population

The January 1984 population of Old Crow was 217 according to Yukon Government Economic Research and Planning. In EPEC's 1981 Community Development Study, a projected population of 240 people was used for planning purposes over the next decade. For the purposes of this study, a design figure of 270 persons will be used as per Stanley Associates Water and Sewer Utility Improvements Study (1984).

4.2 Sewage Strengths and Volumes

Sewage strengths characteristics will vary depending on the method of sewage collection employed. As discussed earlier, the community is essentially on the honey bag system with a few buildings on the pumpout system. The following table summarizes the characteristics of human wastes from honey bags and from black water wastes. These figures will be used when considering options for sewage treatment methods.

TABLE 4.1 - CHARACTERISTICS OF HUMAN WASTES (9)

	Honey-Bag Waste		Black Water Waste*	
Parameter	Average	Range	Average	Range
Volume (L/person/day)	1.3	-	8.5	-
pH	-	8.6-8.9	-	7.85-8.40
Alkalinity (mg/L)	14 900	11 900- 17 000	1947	1800 - 2280
Total solids (mg/L)	78 140	65 990- 85 030	8957	7800 -12 200
Volatile solids (% of total solids)	77.53	71.53-80.18	72.6	70.8-76.0
Dissolved solids (mg/L)	39 290	32 500- 53 620	-	-
COD (mg/L)	110 360	80 750-134 820	10 210	8400 -18 180
Supernatant COD (mg/L)	48 510	39 980- 61 280	5060	3780 - 7000
TKN (mg/L)**	8070	7280- 9520	830	790 - 1040
N in NH_3 (mg/L)	3920	3470- 4060	555	520 - 590
Organic N (mg/L)	4150	3696- 5520	285	270 - 450
Phosphorus (PO_4) (mg/L)	3730	3400- 4250	-	-
Volatile acids (mg/L)	2490	2300- 2670	1504	1080 - 1870

*Toilet Waste diluted by about 1L per flush.

** TKN = total Kjeldahl nitrogen

Sewage strengths from pumpout wastes are estimated as follows for a trucked water supply and sewage disposal system.

TABLE 4.2 - CHARACTERISTICS OF PUMPOUT WASTES

PARAMETER	RANGE
Volume (lpcd)	25
pH	8.6-8.9
Total Solids (mg/L)	1211
BOD_5 (mg/L)	1011
COD (mg/L)	1300
Nitrogen (N) (mg/L)	177
Phosphorous (PO_4) (mg/L)	33

The overall sewage strengths and volumes that will be generated from the community cannot be accurately determined at this time due to the combined sewage bag and pumpout waste systems.

At present, the community and supporting agencies such as Indian and Inuit Affairs, Department of National Health and Welfare and Y.T.G. are favouring the increased use of trucked water delivery and trucked sewage pickup. A recent report entitled "Old Crow Water and Sewer Utility Improvements Study" by Stanley Associates Engineering Ltd., recommends the use of a trucked system for both water delivery and liquid sewage pickup. In the author's opinion, this is the most logical, practical and cost effective step towards improving the level of sanitation in the community. There is some level of uncertainty as to when the bagged sewage system will be eliminated completely, since the program will likely be phased over a number of years. Nonetheless, the direction of the community appears to be established. Accordingly, as more sewage holding tanks are installed and come on stream, the sewage volumes will increase and sewage strengths will become more dilute.

5.0 TECHNICAL AND DESIGN CONSIDERATIONS

5.1 System Components

In the author's opinion and based on current technology, it appears that the anaerobic filter process or some other high rate process should be considered in this study. A conventional long retention system would require a large digester volume (100 - 300 m^3 - depending on sewage volumes) and associated costs as well as excessive heating requirements when compared to a high-rate process. The following design parameters will be used for this analysis.

HDT (hydraulic detention time)	5 days
Operating temperature	35^oC
Loading rate	1 kg COD/m^3/day
COD removal efficiency	80%

A separate building will be required to house the digester and related facilities. This facility would generally include:

- holding tank for collected sewage (required to heat sewage and hold prior to charging vessel);
- waste charging system (trash or hydraulic ram pump);
- digester vessel (concrete or fibreglass-insulated);
- heating system (a system of heating coils within vessel to maintain optimum operating temperatures);
- gas removal and storage system;
- gas utilization system (gas furnace);
- sludge removal system;
- effluent removal system.

5.2 Vessel Sizing

The anaerobic treatment process is best suited for relatively high and medium strength wastes which have a COD of 3,000 - 10,000 mg/L. The present sewage bag wastes, combined with the present pumpout wastes, would likely produce a feed solution which will be amenable to an efficient anaerobic treatment system. However, if the community is serviced entirely with pumpout systems, it is unlikely that the system will be efficient. Another option would be to install 2 holding tanks in each home; one for toilet wastes from low flush toilets and the other to collect greywater. The toilet wastes could be fed into the digester while the greywater would be discharged to the sewage lagoon.

Without discussing sewage collection alternatives in any detail at this time, it is assumed that in order for the anaerobic process to be considered for Old Crow, the entire collection system and methods must be geared to accommodate the facility.

Assuming that all of the sewage wastes from the community will be fed into the digester, the daily input of COD would be about 23 kg/day based on a population of 270 persons.

In Arctech's Waste Heat Utilization study, the possibility of raising chickens is discussed and it is assumed that the manure plus litter from this facility would also be fed into the digester. The study examines the operation for 25, 50, 100 and 200 chickens. Since chicken wastes will be a relatively small contribution to the facility, 200 chickens will be used to determine design loading rates. This would provide a daily input of about 85 litres of manure and bedding with about 3 kg COD contribution per day. The total COD contribution per day could be a maximum of 26 kg per day. Using a loading rate of 1 kg COD/m^3 per day, a digester volume of about 26 m^3 would be required. The volumetric loading of black water would be about 6,300 L/day or 23 Lpcd.

With a daily input of 26 kg COD/day and an 80% efficiency removal rate for COD, a daily production rate of 7,280 L/day of methane could be realized. This assumes that 0.35 L of methane is produced for every gram of COD that is removed. This equates to about 270 MJ of energy produced per day.

5.3 Biogas Utilization

It must be assumed that at some periods of time, the digester facility will require a separate heat source to maintain optimum operating temperatures during start-up and when the system is not functioning properly. When the digester is operating satisfactorily, it is expected that the biogas produced will be utilized to produce heat for the facility. The most efficient way to provide this would be by feeding the biogas directly to a gas furnace located in the facility. The furnace would be used to maintain the heat requirements of the digester and the building.

5.4 Energy Requirements

In order to house the digester and related facilities, a building with dimensions of about 8m x 8m x 4m will be required. Within the building will be the digester vessel having dimension of about 3.5 m radius and 3 m high (cylindrical). The vessel will have a relatively constant heat input requirements of 35°C relative to the inside of the building. The heat requirements for the building will vary, depending on the time of year. The following assumptions and heat loss calculation are presented:

Digester Vessel:

Surface Area ($30m^3$ cylindrical vessel)	54 m^2
RSI (0.1 m conc & 0.075 m insulation)	2.26
UA	24 W/C^o
ΔT ($35^oC - 20^oC$)	15^oC
Annual heat loss (UAΔT)	3,154 kWh

Digester Building:

Surface Area (8m x 8m x 4m high bldg)	256 m^2
RSI (Assume all surfaces @ RSI 10.6)	10.6
UA	24 W/C^o
Infiltration and miscellaneous heat losses	10 W/C^o
Annual degree days	10,200
Annual heat loss (UAΔT)	8,323 kWh

This assumes that during the winter months, the sewage will be delivered to the building at approximately 20^oC. If frozen sewage bags are taken to the facility, there will be an additional heat requirement to bring the sewage to room temperature in the holding tank prior to feeding the digester.

The total yearly heat loss would be in the order of 11,500 kWh. The energy generated from biogas, assuming continuous operation at the design loadings, is 270 MJ/day or 98,550 MJ/year or 27,375 kWh/year.

However, it is unlikely that the digester will ever operate at optimum output of biogas continuously. Assuming that the digester operates at 80% overall efficiency, the yearly available energy would be reduced to about 21,900 kWh/year. Also, the sewage load for the first few years will be less than the ultimate design load of 26 m^3 COD/day. Given the present population and uncertainty regarding the chicken operation, for design calculations it is assumed that only 70% of the ultimate design load of sewage will be available, at least for the first 10 years. This reduces the initial available yearly energy from biogas from 21,900 to 15,300 kWh/year or 42 kWh/day average. However, for the purposes of design we will assume the maximum load at this time. With an energy transfer efficiency of 60% after converting the biogas into heat energy, the actual available heat input available is reduced to 9,198 kWh/year or about 25 kWh/day average.

The daily heat loss from the digester vessel should remain constant at about 9 kWh/day. The heat loss from the building will be greatest during the coldest winter days and is estimated as follows:

UA (total)	34 W/C^{o}
ΔT (20^{o}C - (-45^{o}C))	65^{o}
Maximum daily heat loss (UAΔT)	53 kWh

With the heat loss from the vessel, the maximum daily heat requirement will be about 62 kWh. With only 25 kWh/day provided from the biogas generating facility there will be just barely enough energy available to heat the digester vessel and certainly not the building during the coldest days.

During the warmest summer months the daily heat requirements for the facility will probably range from 10 to 18 kWh. Accordingly, there may be some periods during the summer when the facility will be capable of sustaining itself, insofar as heat requirements are concerned.

Accordingly, in order to maintain the facility, an additional heat source will be required, probably for 70 - 80% of the year. There will be so little energy available from excess biogas production in the summer to consider it for use elsewhere.

5.5 Location

Ideally, the digester facility should be located near the diesel power generating facilities in the community such that waste heat could be readily utilized when required. However, this will not likely be possible for environmental and public health reasons. The effluent from the digester, although treated, will be relatively high in organics, likely in excess of 500 mg/L COD, depending on the strength of influent and other factors. This is about 5 times higher than the level of organics that is in the raw sewage in the City of Whitehorse system. Accordingly, such a quality of sewage effluent should not be discharged directly into the Porcupine River adjacent to the community since it could cause contamination of the shoreline and public health concerns.

The ideal location for the facility would be near the sewage lagoon where the effluent would under go further oxidation after digestion. The lagoon would also accept the sewage effluent during periods of shutdown or when the digester is not functioning properly.

One of the considerations in this study was to use waste heat from the diesel generating facilities to maintain digester facility temperatures. In order to do this, a buried, insulated, hot water line would have to run about 1000 m from the plant to the lagoon. This is not considered cost effective given the capital costs for such a utility and the heat losses which would be encountered in such a long run.

Although one could consider other digester locations somewhat closer to the diesel plant and downstream from the community, it is doubtful that environmental legislation would allow direct discharge of digester effluent directly into the river without further stabilization or treatment.

Based on the foregoing, utilization of waste heat from the diesel plant to serve the digester facility is not considered cost effective.

6.0 CULTURAL CONSIDERATIONS

6.1 Training Requirements

The operation and maintenance of an anaerobic digester requires personnel specifically trained for such a job. The biological treatment process is very sensitive to changes in temperature, shock loadings and toxic substances. Although the mechanics of the system are relatively straightforward, the system requires constant maintenance and control. At least 2 persons would require specialized training in this regard. This would require technical training and on-site supervision for the selected Old Crow residents for a substantial period of time.

6.2 Operation and Maintenance

Due to the location of Old Crow, when breakdowns in the facility occur, repair or replacements parts will be difficult to obtain readily. This is a common problem with the use of mechanical systems in the north. Problems associated with operation and maintenance are probably the most significant reasons why sewage treatment systems involving any degree of mechanism or sophistication do not work well in the north.

6.3 Benefits and Risks to Community

The benefits to the community of Old Crow from the operation of a biogenerator can be summed up as follows:

- provision of local employment for operation and maintenance of digester;

- stabilized sludge from the digester operation is an excellent fertilizer and could be used for vegetable crops.

From earlier dicussions in Section 5, it does not appear that the community will benefit from biogas generation since it is likely that there will not be any excess gas available after the heating requirements of the digester are met, except perhaps for short periods in the summer.

The only risks that are foreseeable with the sewage digester are connected directly with the facility itself and biogas operation. Because the ignition energy for methane is very low, any spark or open flame will ignite biogas within the explosive concentration limits. While the levels of risk from explosion, toxity or asphyxiation are probably low with a well designed system, the hazards do exist, and must be taken into account.

6.4 Social Acceptability

The concept of sewage digestion and the principles of anaerobic digestion are not understood well by the people of Old Crow or by most people for that matter. Traditionally, sewage has not been considered by natives as something that could be used to benefit them directly (ie. biogas or fertilizer). Most residents of Old Crow have never experienced farming or vegetable gardening techniques and therefore cannot be expected to have an appreciation for the use of organic fertilizers to enhance production. That is not to say that such concepts cannot be learned, but it may take time. A greenhouse facility would help to develop an awareness of the used fertilizers and therefore the value of the digester and its by-products.

If the biogas facility concept for Old Crow was to develop further, it would be worthwhile to spend some time explaining the concepts of anaerobic treatment to them to develop an awareness. The acceptance of the facility by the residents would be essential prior to proceeding further with the program.

7.0 COSTS

Very few high-rate sewage digester systems are in operation at the present time in Canada and the U.S. Most of them are used to treat high strength industrial and agricultural wastes. At the time of this writing, the author has not yet received accurate information on costing for constructing a high rate digester and related facilities in Old Crow. Attempts have been made to contact suppliers of off-the-shelf type systems which may be appropriate for Old Crow. This costing information is forthcoming. Nonethless, based on available data and information, a rough estimate of costs to construct the sewage treatment facilities including the building and related works is expected to be in the order of $400,000 to $500,000. It should be pointed out here, that the digester will not replace the need for a sewage lagoon or other forms of treatment. It is felt that the sewage lagoon would still be the most practical way to provide final treatment for the digester effluent prior to discharge to the Porcupine River. In addition to the capital costs, the operation and maintenance costs will be extremely high particularly considering that boilers or some other form of heat source will be required to maintain digester temperatures on a year round basis. Given the requirement for skilled plant operators, continuous maintenance and fuel requirements, the yearly O & M costs could be in the order of $150,000 - $200,000 per year for operation of the digester facility only.

If the digester were located near the diesel plant in order to utilize waste heat, the plant effluent would have to be treated prior to discharge into the Porcupine River. The most cost effective method for treatment would be with the use of the sewage lagoon west of the community. The yearly O & M costs for trucking the digester effluent to the sewage lagoon are estimated at $30,000 - $50,000.

Based on other considerations as discussed in Section 8.0, it does not appear that the system will be cost effective nor desirable for Old Crow at this time. Accordingly, it may not be necessary to proceed further with the cost effective analysis.

8.0 DISCUSSION AND CONCLUSIONS

The objective of this study was to examine the feasibility and cost effectiveness of operating and maintaining a sewage digester at Old Crow. From a technical point of view, the project is feasible. High-rate anaerobic treatment technology is available which could be applied to the Old Crow situation. However, there are a number of other important factors which, in the author's opinion, do not make the project appear very attractive for the community at this time. The major drawbacks are outlined as follows:

(1) Due to the cold climate in Old Crow, the digester will not be capable of producing sufficient biogas as an energy form to heat treatment facilities on a year-round basis. This means that in order for the facility to operate, boilers or some other heating facility will be required to maintain the required temperatures. Accordingly, rather than providing an additional or alternate energy source for the community, it will cause a drain on existing energy sources, whether in the form of oil or wood.

(2) In the beginning, the concept of a biogenerator appeared to be worthwhile investigating, particularly with the diesel generating plant to supplement the anaerobic facility heat requirements. In order for this to be effective, the anaerobic digester should be reasonably close to the generating plant. Unfortunately, due to the nature of the plant effluent, it can not be discharged directly to the river. In order for the digester to be located close to the diesel plant, post treatment of the effluent would be required or the effluent would have to be re-trucked to the sewage lagoon. Neither of these alternatives are considered to be worthwhile considering further for reasons of costs.

The plant would be best located near the sewage lagoon. In such a case there will be major heat losses and high costs involved with transferring heat through hot water lines over such a long distance

(1,000 m). Accordingly, there does not appear to be a practical and cost effective way of utilizing diesel generated waste heat for the treatment plant.

(3) In order for a high-rate anaerobic digester to work efficiently and to provide a cost effective operation, the feed material should be moderate to high strength sewage, in the order of 3,000 mg/L or higher COD. Diluted bagged sewage would probably be ideal as a digester feed solution.

However, when improvements in the water and sanitation system occur in the community, bagged sewage will likely be phased out as more and more pumpout systems are installed with new housing facilities. The normal pumout sewage which includes both grey and blackwater, would be weaker in strength and be in higher volumes. This would necessitate pretreatment (settling facilities) prior to digestion which would be very costly.

Alternatively, each home could be equipped with 2 holding tanks, one for greywater for lagoon disposal and one for blackwater for digester treatment. If the biogenerator was a viable alternative for Old Crow, this concept could be considered further. However, in light of other factors, it does not seem worthwhile at this time.

(4) From a cultural and social viewpoint, the concept of a sewage digester for Old Crow should be questioned. Social acceptance of the facility may be difficult to achieve.

(5) Operation and maintenance of the facility will be a problem. Specially trained personnel will be required to run the facility and due to the sensitive nature of the treatment process, problems in maintaining an efficient operation will likely occur from time to time; particularly in such a remote location.

(6) When considering the digester facility as a treatment system for domestic sewage, it is not cost effective when compared to a sewage lagoon treatment system. Also, there are no environmental or public health considerations that would make it more attractive.

Regarding the servicing infrastructure, the focus of attention should be placed on improving the level of sanitation in Old Crow. The concerns and suggested direction are outlined in EPEC's 1980 Community Development Study. The author supports the conclusions, observations and recommendations made in Stanley Associates 1984 report entitled "Old Crow Water and Sewer Utility Improvements Study". These include recommendations made towards implementation of a trucked water delivery and sewage collection system. Add-on washrooms are felt to be a good method of improving the level of sanitation within the community. However, they should only be constructed on houses which are well constructed and insulated and which have a reasonable remaining life span. A program of new housing construction should continue and the buildings should be equipped with a plumbing system and holding tanks that are compatible with the overall trucked systems.

A major problem in Old Crow which has persisted for years, is poor drainage. Due to the low-lying nature of the community and permafrost, standing water persists throughout most of the summer. These ponds around homes contain feces from sewage bags and animals and in one sense are not all that dissimilar from small sewage lagoons. The public health and nuisance problems associated with lack of drainage in the community are obvious. Gravel sources are available nearby which could be used to raise the ground levels around buildings and on roadways. Many of the buildings would have to be raised. A system of culverts and possibly drainage ditches should be incorporated into the project.

Although some of the above discussions do not pertain directly to the study terms of reference, they required addressing due to the connection of the sewage collection system to the treatment facility.

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