The Economic Effects of Urbanization on the Crushed Stone Industry in the Rural Municipality of Rockwood, Manitoba

By

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ABSTRACT

Economically, a quarry operation has a greater competitive advantage over its rival firms the closer it locates to the urban market. However, an active quarry operation typically generates environmental disamenities and when placed in an urban - suburban setting, it causes serious land use conflicts. The residents' desire for a clean environment and peaceful surroundings comes into conflict with quarry activity. Over time, the residents demand the local municipal government to control active quarry operations, who in turn may establish zoning ordinances. This action restricts the productive capacity of the industry, which causes an increase in production costs. As the conflict escalates, the quarry operator, for economic reasons, is encouraged to locate further from the urban - suburban setting. This practicum has analysed this type of land use conflict between the local residents of Rockwood Municipality, Manitoba and the quarry industry, and has estimated the relocation costs at selected deposits near Winnipeg.

In June 1979, Clean Environment Commission public hearings, under the authority of the Clean Environment Act, were held to prescribe limits on discharge of contaminants into the environment from crushed stone quarries located in Rockwood Municipality. As a result of these hearings, emission standards on all phases of production were established on all active quarries in Rockwood Municipality.

As land use competition increases and land use conflicts escalate between active quarry operations and residents, there will be an increased pressure for the crushed stone industry to relocate outside the urban

setting causing an increased delivered price. If mining is unduly restricted before depletion of the mineral resource due to local environmental concerns, there will be a cost to society. The focus of the research was to estimate the increased delivered price that would occur if the crushed stone industry were forced to relocate at the next closest deposit outside the urban fringe.

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CHAPTER 1.0

INTRODUCTION

1.1 PROBLEM STATEMENT

Crushed stone resources are important because they are an essential ingredient in most construction-related activities, and consequently this high-bulk/low-value commodity replaces more expensive materials in structures, such as wood and steel. This resource is significant because under present engineering technology, no suitable substitute is available for many end uses. Crushed stone is a non-renewable resource whose delivered price is extremely sensitive to transportation costs. The availability of crushed stone resources at reasonable delivered prices can act as a constraint to future construction activities.

During the past decade, urban encroachment has significantly decreased the supply of both high-quality sand and gravel and crushed stone resources to Winnipeg. The Birds Hill region, northeast of Winnipeg, presently supplies the city with approximately 3,000,000 tonnes of sand and gravel, whereas Rockwood Municipality (see Figure 1.1) supplies approximately 1,000,000 tonnes of crushed stone annually. Delivered prices of sand and gravel resources from the Birds Hill area may increase significantly because:

(1) of land use pressure caused by urban encroachment;

(2) the Birds Hill area has supported gravel extraction for many years and, consequently, high-quality resources above the water table are near depletion; and

(3) present mining methods necessitate extraction of gravel below the water table resulting in increased extraction costs.

Sand and gravel and crushed stone may be utilized interchangeably when their quality and respective prices are competitive.

Because the demand for both sand and gravel and crushed stone resources is highly inelastic (Bronitsky, 1973), a large percentage change in delivered price will not cause a large percentage change in quantity demanded. Also, even in times of economic constraint, the demand for crushed stone is significant because for many end uses there is imperfect substitutability (see Table 1.1). These factors have caused Rockwood Municipality to become much more significant in terms of its potential to supply Winnipeg with crushed stone in the future.

The extraction process of crushed stone resources include many environmentally disruptive activities. Residents located near active quarries and along transportation routes are subjected to increased levels of noise, dust, blasting, increased local truck traffic, increased potential for groundwater contamination, and unattractive sights. These environmental disamenities are all by-products of an active quarry operation.

The environmental disamenities noted above can agitate serious land use conflicts between local quarry operations and local residents. The residents' desire to avoid the environmental disamenities associated with active quarry operations cause local residents to increase political pressure to control active quarry operations through zoning ordinances that restrict or prohibit the industry. A reduction in the productive capacity of the crushed stone industry results, and an increase in production costs occurs because the quarry operators are forced to adapt to environmental regulations. Eventually, the resulting land use conflict forces the industry to locate in regions outside the urban setting causing the increased distance for crushed stone transportation. Bronitsky (1973) concluded that a distance of 33 kilometres generally doubles the delivered price of crushed stone, and that the relative contribution of transportation costs to total delivered costs increases with increasing urbanization effects.

In 1979, the Manitoba Clean Environment Commission, under authority of the Clean Environment Act, held public hearings in order to establish environmental regulations controlling active quarry operations in Rockwood Municipality. These public hearings were conducted as a result of agitation of the local residents towards the environmental disamenities of active quarry operations. Emission standards on all phases of production were established on all active quarries in Rockwood Municipality as a result of these environmental hearings. Consequently, in time the quarry operators may be forced to adapt to stricter environmental regulations or be zoned out of the municipality.

BACKGROUND

1.2 URBANITE MIGRATION

1.2.1 Urban to Rural Migration

Since World War II, a reverse population movement from Winnipeg to an area approximately 80 kilometres from the city has occurred (Manitoba Department of Municipal Affairs, 1974). Many of the new rural residents are young families seeking the amenities of country life. The Manitoba Department of Municipal Affairs (1974) has conducted several studies concerning rural residential values in Rockwood Municipality and adjacent areas. The studies concluded that the exurbanites who wanted to reside in rural areas were seeking:

(1) a less crowded environment;
(2) an attractive landscape;
(3) a desire to keep animals;
(4) larger lot sizes; and
(5) a clean environment.

Also, the Manitoba Department of Municipal Affairs concluded that values of privacy, rural lifestyle, and aesthetic appeal prevailed over economic factors as the features which attracted the exurbanite from Winnipeg to rural areas.

Since 1961, the number of exurbanites located in Rockwood Municipality has been increasing. The ten-year population growth rate from 1961 to 1971 was approximately 13 percent (Manitoba Department of Municipal Affairs, 1974). Recent building activity in Rockwood Municipality indicates that this growth rate is being maintained (Manitoba Department of Municipal Affairs, 1974). In comparison, the farm population decreased by 1 percent over the same period.

1.2.2 Land Use in Rockwood Municality

The Manitoba Department of Municipal Affairs determined that agriculture constituted the means and livelihood and way of life of 48 percent of Rockwood Municipality's population. In addition, the municipality possesses an agricultural service industry, aggregate mining, a site for the federal penitentiary, and satellite towns for people working in Winnipeg.

ECONOMICS

1.3 ECONOMICS OF QUARRY PRODUCTION

1.3.1 Demand for Crushed Stone

Underwood, McLellan and Associates (1976) concluded that the Winnipeg region will consume a cumulative total of 24 million tonnes of crushed dolomite between 1976 and 1996. The rock will be used primarily for road construction and maintenance in Rockwood Municipality and Winnipeg as well as for house construction in Winnipeg (see Table 1.1).

The demand for crushed stone is tied closely to activity in the construction industry. Bronitsky (1973) concluded that the demand for new structures is positively inelastic and the demand for roads and streets even more so. Generally, about 50 percent of the crushed stone demand in Manitoba originates in highway and street

TABLE 1.1

END USES OF CRUSHED STONE IN MANITOBA

CONSTRUCTION TYPE	END USE
Road Construction	Subbase Base Traffic (surface) gravel Shoulders Maintenance (pit run) Ice control
Concrete Aggregate	Road surface Dams Foundations Building Ready mix Sidewalks Precast blocks, tiles Mortar Grout
Asphalt Aggregate	Road surfacing Parking lots
Railway Construction	Subbase Ballast
Fill	Sewer and water pipe bedding Septic field construction Rip-rap Dam construction

construction (Underwood, McLellan and Associates, 1976). Bronitsky (1973) suggested that this construction category is dependent upon the availability of public funds, and has been unresponsive to changes in construction costs.

1.3.2 Supply of Crushed Stone

Two large areas of shallow bedrock of the Gunton Member of the Ordovician Stony Mountain Formation occur within Rockwood Municipality. Both areas contain millions of tonnes of quality dolomite which can be easily removed. However, the supply of crushed dolomite available for removal is decreasing substantially every year because local residents are building structures on top of or near these reserves (Bannatyne, 1981, Personal Communication).

1.3.3 Location Theory of Aggregate Industry

The economic value of a quarry deposit is dependent upon several factors, such as:

(1) access to market,
(2) quality and quantity of stone of deposit,
(3) level of construction activity,
(4) distance from market, and
(5) municipal zoning legislation.

During 1981, Rockwood Municipality had six quarry operations, which were:

(1) Standard Limestone Quarries Ltd. (N½ 33-13-2E),
(2) Riverside Gravel Co. (l.s. 14-14-13-2E),
(3) B.A. Construction Ltd. (NE¼ 33-13-2E),

(4) City of Winnipeg Primary Materials Section (Sec. 11, 12, 14-13-2E),

(5) General Stone Company Limited (l.s. 3-5-14-2E), and

(6) Bison Rock Products Ltd. (SW¼ 13-12-2E).

1.3.4 Production Technology

Aggregate mining is characterized by the removal of the material from open pits called quarries. The rock is blasted into relatively large pieces from the parent rock, crushed into smaller pieces, and stockpiled. The process of rock crushing requires processing plants, which operate at the quarry location. All of the crushed stone produced in Rockwood Municipality is transported to market by truck.

LAND USE CONFLICTS

1.4 CONFLICT BETWEEN QUARRY OPERATORS AND ROCKWOOD MUNICIPALITY RESIDENTS

In June 1979, Clean Environment Commission public hearings were held to prescribe limits on discharge of emission of contaminants into the environment from crushed stone quarries located in Rockwood Municipality. These hearings were conducted as a result of several complaints regarding environmental disamenities associated with active quarry operations to various government agencies. The residents near active quarries demanded quarry standards from both the Municipal and Provincial Governments. The complaints stated that:

(1) local quarry operators were using excessive blasting at all hours of the day;

(2) trucks were raising dust when hauling stone over a gravel road;

(3) derelict quarries were an eyesore,

(4) devaluation of property occurred,

(5) physical damage to their homes due to shock waves from excessive blasting was alleged to have occurred,

(6) reclamation of consumed land was not undertaken or planned, and

(7) water pollution and disruption of underground streams could occur.

Consequently, in June 1979, the Manitoba Clean Environment Commission established limits on all phases of processing of crushed stone on all active quarries within Rockwood Municipality.

1.5 RESEARCH OBJECTIVES

As land use competition increases and land use conflicts between active quarry operations and residents escalate, there will be an increased pressure for the crushed stone industry to relocate outside the urban setting causing an increased delivered price. If mining is unduly restricted before depletion of the mineral resource due to local environmental concerns, there will be a cost to society. The focus of the research was to estimate the increased delivered price that would occur if the crushed stone industry were forced to relocate at the next closest deposit outside the urban fringe.

1.5.1 Objective #1

The first objective was to estimate the increase in delivered price of crushed stone from selected deposits near Winnipeg, that is, to develop an economic model that would aid in predicting an increase in delivered price of crushed stone if the industry were forced to relocate at selected deposits.

1.5.2 Objective #2

The second objective was to delineate the causes of land use conflicts and outline potential effects of these land use conflicts on the crushed stone industry.

1.6 RESEARCH METHODS

The collection of data was aimed at estimating the delivered price of crushed stone from selected deposits near Winnipeg. The methods utilized are outlined in the sequence below.

1.6.1 Method for Objective #1

The first objective was to estimate the increase in delivered price of crushed stone from selected deposits near Winnipeg. This task was implemented by the following methods:

(1) GEOLOGICAL INVENTORY:

The selection of potential crushed stone deposits was based on geological mapping conducted by Mr. B. Bannatyne and Mr. C.W. Jones during the summers of 1979 and 1980. This mapping program included outlining:

- overburden thickness;
- geological formations including geological contacts;
- past and present quarry locations; and
- historical end uses of resource.

(2) ENGINEERING INVENTORY:

An extensive literature review was conducted to delineate the engineering properties of bedrock suitable for crushed stone as well as the appropriate engineering tests including specifications which determine potential quality. The literature review included outlining:

- engineering specifications of bedrock for various potential end uses;
- engineering properties of bedrock; and
- engineering tests and results which have been conducted on bedrock formations in Rockwood Municipality.

The data generated from the geological and engineering inventories were used to define potential crushed stone deposits as well as the general quality of bedrock for various end uses.

(3) PERSONAL INTERVIEW OF ACTIVE QUARRY OPERATORS:

A personal interview of active quarry operators was conducted to estimate the average delivered price of crushed stone to Winnipeg. The interview included obtaining information on the following items:

- production costs[1] for producing crushed stone;
- transportation costs[2] for transporting crushed stone to market;
- general concerns of industry towards environmental problems; and
- engineering specifications of crushed stone samples from active quarries.

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[1] The figures for production costs supplied by the various producers are confidential. The average estimated stockpile cost to produce a tonne of crushed stone is $3.15 in 1981 constant dollars.

[2] The transportation costs were estimated to be $0.075 per tonne-kilometre.

(4) ESTIMATED DELIVERED PRICE OF CRUSHED STONE PER TONNE:

The delivered price of crushed stone was estimated by considering two factors, that is:

- an average stockpile price was estimated per tonne for active quarries by averaging the production costs of each quarry; and
- the transportation cost to Winnipeg was calculated by considering the cost per tonne as well as the least cost distance calculation[3] per tonne.

(5) ESTIMATED DEMAND FOR CRUSHED STONE IN WINNIPEG BETWEEN 1981 AND 1996:

A scenario for predicting the expected future demand for crushed stone in Winnipeg was conducted by Underwood, McLellan and Associates (1976). This scenario was utilized in this study to estimate the future production of crushed stone near Winnipeg. Also, to account for an increase or decrease in economic activity, alternate scenarios of 220,000 tonnes above and below the expected value were prepared. The scenarios were utilized to calculate the total dollar value of crushed stone delivered to Winnipeg from each selected deposit.

The base forecast demand for crushed stone was tested for period between 1976 and 1980. These figures were obtained by production figures[4] recorded by the Manitoba Department of

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[3] The least cost distance for crushed stone transportation to Winnipeg is the shortest possible route taken.

[4] The demand for crushed stone in the Winnipeg Region was within 200,000 tonnes of the prediction for each of the years between 1976 and 1981.

Energy and Mines, Mineral Resources Division. The base forecast and alternate scenarios #1 and #2 were applied to the selected deposits and consequently an increase in total cost of producing crushed stone at each deposit was calculated.

1.6.2 Method for Objective #2

The second objective was to delineate the causes of land use conflicts and outline the potential effects of these land use conflicts on the crushed stone industry. This task was implemented by reviewing the literature related to economics of the crushed stone industry and related environmental concerns.

1.7 THE DELIMITATIONS

The study will examine only those land use conflicts which exist between rural residents of Rockwood Municipality and the active quarry operators.

The study will examine the crushed stone industry only, and will not consider the sand and gravel industry.

The study will limit the market for crushed stone to Winnipeg and Rockwood Municipality.

The study will not examine areas greater than 3 metres of overburden for delineating bedrock deposits.

The study will estimate the increase in costs for relocating the crushed stone industry in constant 1981 dollars.

1.8 THE ASSUMPTIONS

1.8.1 Assumption #1

The first assumption is that the City of Winnipeg will continue to use crushed dolomite for construction purposes.

1.8.2 Assumption #2

The second assumption is that the production technology of the crushed stone industry will remain constant, and that no alternative substitute for aggregate is available in the Winnipeg Region.

1.8.3 Assumption #3

The third assumption is that the demand for crushed stone will follow the demand scenario prepared by Underwood, McLellan and Associates (1976) for the planning period between 1981 and 1996.

1.8.4 Assumption #4

The fourth assumption is that land use conflicts will have an effect on the productive capacity of quarry operators in Rockwood Municipality.

1.9 SUMMARY

Chapter 1 of this study has developed the framework for the land use conflict between the rural residents of Rockwood Municipality and the quarry operators. To aid in the resolution of this conflict, Chapter 2 will review the related literature concerning:

(1) bedrock geology in Rockwood Municipality;

(2) economics of the crushed stone industry in Rockwood Municipality;

(3) causes and effects of urban to rural migration of residents from Winnipeg to Rockwood Municipality;

(4) environmental impact of quarry operations in Rockwood Municipality; and

(5) the institutional framework of the problem.

CHAPTER 2.0

REVIEW OF RELATED LITERATURE

2.1 PREAMBLE

The focus of this literature review was to:

(1) outline studies which were related to the problem;

(2) evaluate methods former researchers used to solve similar problems; and

(3) examine data that are pertinent to the purposes of this practicum.

2.2 RESOURCE MANAGEMENT: AN OVERVIEW

Resource management is a complex decision-making process ideally involving inventory, assessment, goal formulation, policies, programs, legislation, administration and managerial strategies (Krueger and Mitchell, 1977). The considerations involved in the decision-making process are both numerous and complex. For example, knowledge is required about individual aspects as well as the manner in which they interact. For a given resource management problem, this framework helps to identify areas in which understanding is needed as well as where information is either adequate, inadequate, or totally lacking (Krueger and Mitchell, 1977).

2.2.1 Administration of Aggregate Resource Management

Manitoba provincial support for aggregate resource management is highlighted by the recent adoption on an interim basis of a set of Provincial Land Use Policies in November 1980, one of which concerns itself with the protection of aggregate. Land Policy #13 states "high-quality aggregate should be protected from surface land uses that would interfere with its future exploitation" (see Appendix 1 for Land Policy #13). The mandate for this policy is to ensure aggregate resources for future construction activities as well as to provide Manitoba with a rational policy for the allocation of land to meet social and economic needs (Province of Manitoba, June 1978).

2.2.2 Aggregate Planning in Rockwood Municipality

The Planning Act and the coordinated role of the Department of Municipal Affairs provides an administrative framework which facilitates provincial technical input into regional planning, while maintaining the decision-making authority at the municipal level (Ringrose and Large, 1979). For example, in 1979, the Mineral Resources Division of the Manitoba Department of Mines, Natural Resources, and Environment implemented a program to outline and evaluate dolomite resources in Rockwood Municipality. The mandate of this program was to ensure that reserves of crushed stone are available for future extraction for both Winnipeg and Rockwood Municipality, and to provide Rockwood Municipality with rational resource policies. Through the coordination of the Planning Act and the Department of Municipal Affairs, the technical data compiled were incorporated into the Rockwood Municipality Development Plan. Consequently, through the planning process, areas of high-quality dolomite are zoned for future mining.

2.2.3 Statutory Support for Aggregate Resource Management

Statutory support for the objectives of Land Policy 13 is embodied in the Mines Act: "The Minister may withdraw any lands or mining rights or any mining right, the property of the Crown, from prospecting and staking out and from lease" (Section 6(1), the Mines Act). This ensures that no single operator can control a valuable mineral deposit on Crown land. The Manitoba Department of Highways utilizes this option to protect supplies of crushed stone for future public work projects. In addition, statutory support for the objectives of Policy #13 is Quarry Minerals Regulation (Manitoba Regulation 226/76). This regulation places rehabilitation requirements on gravel pits and quarry operations.

GEOLOGY

2.3 BEDROCK GEOLOGICAL STUDIES OF MANITOBA

2.3.1 Regional Geology of Manitoba

The regional bedrock geology of southern Manitoba was initially mapped by Tyrrell (1892) of the Geological Survey of Canada. Tyrrell (1892) mapped the Silurian bedrock that outcrops on the northeast shore of Lake Winnipegosis and the Silurian sections exposed near Grand Rapids. The Ordovician stratigraphy on the west shore and islands of Lake Winnipeg was mapped by Tyrrell and Dowling (1900). These reports contain detailed descriptions of measured sections as well as faunal lists of the many Ordovician and Silurian fossils.

2.3.2 Economic Geology in Southern Manitoba

Economic geology studies were undertaken by Wells (1905), Parks (1914), Wallace and Greer (1927), and Goudge (1933, 1944). These studies provide an economic assessment of potential end uses of the

Silurian and Ordovician bedrock in Manitoba as well as outlined the engineering specifications for many end uses. For example, Wells (1905) examined the different potential industrial uses that both high-calcium limestone and a high-quality dolomite have. Parks (1916) and Goudge (1933, 1944) examined the potential end uses that the different geological formations have for construction materials, such as crushed stone for highway development and for building and ornamental stone.

2.3.3 Stratigraphic Studies of the Southern Interlake, Manitoba

Baillie (1950, 1952) mapped the Silurian and Ordovician formations in southern Manitoba on a regional scale. These studies include stratigraphic sections of the different quarries, outcrop locations, faunal lists and localities, and most significantly a classification scheme of the Ordovician and Silurian formations into the different members. In addition, regional stratigraphic studies by Stearn (1956), Cowan (1978), Wallace (1978), and Bannatyne and Jones (1979) have been completed. The most detailed mapping of the regional bedrock was by Bannatyne and Jones (1979).

2.3.4 Regional Geology of Rockwood Municipality

Geological mapping at a scale of 1:50 000 was completed by Bannatyne and Jones (1979). The mapping included depth to bedrock maps, and bedrock elevation maps with the geological formational contacts included. These maps were utilized as a guideline to determine potentially favourable quarry deposits within the municipality for land use planning purposes. In addition, James F. MacLaren Ltd. (1980) mapped the surficial as well as the regional bedrock geology of Rockwood Municipality. This study outlines the engineering requirements of bedrock for various end uses and delineates the potential quality of bedrock formations in Rockwood Municipality.

ECONOMICS

2.4 ECONOMICS OF CRUSHED STONE

2.4.1 Benefits of Mineral Resources

Minerals and mineral processing industry are a fundamental component of Canada's material and economic base. However, most Canadians are not aware of the role in our economy and of the contribution made by minerals to the growth of the nation's wealth. With respect to both crushed stone and sand and gravel, this resource can be utilized to build Canadian cities, and to rehabilitate these cities as the need arises.

2.4.2 Aggregate Substitution

Crushed stone and sand and gravel can be used interchangeably when their respective prices are competitive, and when there is complete substitute ability (Canadian Transport Commission, 1978). Furthermore, in areas where both are abundant, and in cases where both can be used alternatively, sand and gravel are generally produced because of lower production costs (Canadian Transport Commission, 1978). In the periphery of Winnipeg, quality sand and gravel is extracted from the Birds Hill area, while crushed stone is quarried in Rockwood Municipality. However, high-quality sand and gravel available above the water table in the Birds Hill area is expected to be near depletion during the mid-1980's (Underwood, McLellan and Associates, 1976). Consequently, crushed stone production from Rockwood Municipality will become an attractive source of construction materials in the near future.

2.4.3 Demand for Crushed Stone

The quantity of crushed stone demanded is closely related to activity in the construction industry, which, in fact, depends upon economic conditions. Similarly, because of the limited number of end uses, the demand for aggregate is highly inelastic (Bronitsky, 1973).

Underwood, McLellan and Associates (1976) and Barto and Vogel (1978) have estimated the demand for crushed stone in Manitoba. The Underwood, McLellan and Associates (1976) study estimated the demand for both crushed dolomite and sand and gravel in the Winnipeg region whereas the study by Barto and Vogel predicted the provincial demand for crushed dolomite.

2.4.4 Supply of Crushed Stone

Underwood, McLellan and Associates Limited (1976) and James F. McLaren Ltd. (1980) have completed studies on the available supply of crushed stone for construction activities in Rockwood Municipality. Underwood, McLellan (1976) calculated that Rockwood Municipality has 54 million tonnes of dolomite available under 3 metres of overburden. However, these studies do not consider the effect of urban sterilization of the quarry industry caused by land use conflicts. Consequently, the supply calculations should only be considered as potential resources.

2.4.5 Effect of Urbanization on Stone Industry

Bronitsky (1973), the Municipal Planning Branch (1975), Stonehouse (1978), and Bannatyne (1981) have all concluded that urbanization affects the productive capacity of the stone industry by building structures on top of high-quality reserves or by zoning legislation that restricts the industry. Bronitsky (1973) determined that this results because of the residents' desire to avoid the environmental disamenities associated with quarrying.

The Municipal Planning Branch (1975) has concluded that a large portion of the Rural Municipality of Rockwood contains potential sources of stone and gravel. A number of quarries have been in operation for years supplying the construction industry of Winnipeg. Because transportation costs represent such a high proportion of the total per unit weight cost of construction materials, the crushed stone industry must operate in close proximity to its market, the region and Winnipeg. These deposits of industrial minerals are of concern from a planning standpoint for two major reasons:

1. The quarries are valuable natural resources and should be protected from the influx of residential and other urban land uses.
2. Because mineral extraction activities are a potential hazard and a nuisance to adjacent residents, as has occurred in the past with respect to noise and dust, the disruption of road surfaces by trucks requiring municipal maintenance and unstable, unsightly pits, regulations should be adopted to govern their operation (Department of Municipal Affairs, 1975).

LAND USE CONFLICTS

2.5 QUALITY LAND: A SCARCE RESOURCE

Found (1974) suggested man's main purpose for using land is to gain some sort of satisfaction, such as earning an income or providing recreation. Found (1974) determined the value accrued to land is dependent upon two factors, that is, the contribution which land makes in the production process, and the price which one receives from the sale of one's land. These factors are strongly interdependent, and determine the value accrued to a parcel of land. Because land is a finite resource, the demands for goods and services provided by quality land can be numerous. Consequently, conflicts of land use originate because of the numerous competing uses for a finite land resource.

2.5.1 Land Use Policies in Winnipeg Region

The Municipal Planning Branch has undertaken many studies evaluating land use and potential land use conflicts in the Winnipeg region (See Bibliography). These studies were undertaken to establish a set of policies relating primarily to the physical accommodation of development within a 50- to 100-kilometre radius of Winnipeg (Manitoba Department of Municipal Affairs, 1977). The Manitoba Department of Municipal Affairs suggested these policies should satisfy both amenity and development values as well as optimize the development pattern within the context of competing land uses, resource base utilization, and environmental quality.

The studies undertaken by the Municipal Planning Branch outline the significant impact that land use conflicts may have on the quality of life in the Winnipeg region, including Rockwood Municipality. In addition, these studies contain much information concerning the identity, value structure, and concerns of the rural residents. Furthermore, many of these studies utilized an analytical survey method to obtain the data, and consequently, were of aid in the development of this study.

ENVIRONMENTAL EFFECTS OF QUARRYING

2.6 ENVIRONMENTAL IMPACT OF QUARRYING

Environmental impact assessment is a technique used to evaluate the effects of man's actions on the biosphere considering the ecological impacts and the economic costs and benefits. This type of analysis can be used to evaluate the environmental impacts associated with a large variety of activities at each of the local, regional, and global scales, and finds application in several fields, including engineering and urban and regional planning, as well as in fields which are oriented specifically to environmental analysis (Ripley et al., 1978).

There are several environmental hazards that can be accrued to surface mining operations. Factors such as noise, air pollution, groundwater contamination, and aesthetic pollution are the most significant.

2.6.1 Impact of Blasting in Rockwood Municipality

When blasting operations are undertaken in a settled area, the occupants of the surrounding buildings often become aware of the accompanying ground vibrations. They notice for the first time certain cracks in their walls and foundations, and inevitably infer that the cracks were caused by the blasting. Usually they are mistaken, misled by the fact that the threshold of human perception of vibration is far below the threshold of structural damage; the cracks produced by the settlement or shrinkage of materials have been there unnoticed for years (Northwood and Crawford, 1965).

During 1979, complaints regarding the blasting operations by local quarry operators in Rockwood Municipality were received by the Clean Environment Commission. Factors such as sound emission and vibration were the major concerns. The Clean Environment Commission (1979) found that sound and vibration levels were extremely variable, and that higher blasting levels may have occurred from improper blasting procedures.

2.6.2 Particulate Emission in Rockwood Municipality

The Clean Environment Commission (1979) concluded that since quarry process equipment, stockpiles, and most activities are located within the quarry, particulate emissions are minimal. The Commission (1979) indicated, however, on occasion considerable amounts of dust are produced by truck traffic on the access road and the municipal road leading to Provincial Highway #7.

2.6.3 Groundwater Contamination in Rockwood Municipality

The bedrock geology within Rockwood Municipality is composed of carbonate rock that constitutes an extensive aquifer. Contamination of high-quality groundwater may occur because the carbonate rock is near surface, and in many places, seepage from waste disposal or septic fields could readily percolate to the water table (Manitoba Department of Municipal Affairs, 1973). The potential for groundwater contamination can at best be minimized by eliminating any spills or discharges of refuse, petroleum wastes or sanitary wastes to exposed groundwater or to soils in areas where such discharge might contaminate groundwater (Clean Environment Commission, 1979).

2.6.4 Noise Pollution in Rockwood Municipality

The amount of noise generated, like GNP, is often a rough yardstick of economic progress. However, for many, the cliché of the hustle and bustle of city life no longer invokes the image of an area of thriving, throbbing, economic activity, but rather an ear-shattering experience. For example, prolonged exposure to sound levels greater than 85 to 90 decibels results in permanent hearing damage (Seneca and Taussig, 1979). Consequently, heavy truck traffic at a distance of 15.2 metres can cause hearing damage for up to 8 hours (Seneca and Taussig, 1979). In Rockwood Municipality, complaints regarding sound emision from both quarry operations and truck transportation along Provincial Highway #7 were received by the Clean Environment Commission in 1979 (Clean Environment Commission, 1979).

2.6.5 Aesthetic Pollution in Rockwood Municipality

Rockwood Municipality has several derelict abandoned quarries within its borders. These abandoned quarries are a result of several years of unmanaged control. Consequently, large areas around urban centres such as Stonewall and Stony Mountain remain in a derelict condition.

2.7 RESOLUTION OF LAND CONFLICT IN ROCKWOOD MUNICIPALITY

Urban expansion of Winnipeg has proceeded so rapidly that many aggregate deposits in Rockwood Municipality have been built over before they could be extracted. Furthermore, the crushed stone industy may be sterilized by proximity to residential development where the homeowners' objections may block the granting of extraction permits. Consequently, a resolution to the problem is necessary for the survival of the crushed stone industry in Rockwood Municipality.

Bronitsky (1973) and Hamilton (1980) both concluded that sequential land use planning based on resource inventory may be the most appropriate vehicle to resolve this type of conflict. In this process, the crushed stone would be removed prior to issuance of permission to subdivide. In addition, the quarry operator would have to guarantee rehabilitation of consumed land. Hamilton (1980) suggested that separating extraction and residential development will eliminate most of the conflict.

Hamilton (1980) suggested several methods in which active quarry sites can be made more socially acceptable:

(1) The visual aspect can be removed by screening with trees, shrubs, or earth embankments which also reduce dust and noise pollution.

(2) Parts of the site from which crushed stone is removed can be promptly rehabilitated using the same equipment.

(3) The rehabilitation plan should be finalized before site development begins.

(4) Worked-out quarries can be utilized for landfill sites.

(5) Quarries can be converted into recreational facilities.

In addition, Bronitsky (1973) suggested several methods in which the environmental impact of quarrying could be minimized:

(1) A more sophisticated approach in community relations between quarry operators and local residents could be developed.

(2) Public relations should be directed towards educating the public about the importance of crushed stone to regional economies.

(3) The quarry operators should post a bond which would guarantee rehabilitation.

(4) Regional planners with decision-making power should become informed and active in locational problems of the aggregate industry.

(5) A regional "land bank" for future aggregate operations should be created.

2.8 SUMMARY

Chapter 2 has reviewed the related literature concerning the effects that land use conflicts may have on the productive capacity of the crushed stone industry in Rockwood Municipality. The literature emphasized two major concerns, which are:

(1) Urbanization effects reduce the productive capacity of the crushed stone industry by building structures on top of reserves or by zoning legislation that prohibits the industry.

(2) The Rockwood Municipality residents' desire to avoid the environmental disamenities associated with quarrying occurred because of:

- excessive blasting at all hours;

- increased local truck traffic;
- derelict quarries are an eyesore;
- devaluation of property;
- physical damage to their homes; and
- potential water pollution.

Chapter 3 will discuss the history of exploration and development of the crushed stone industry in the Winnipeg Region including production technology.

CHAPTER 3.0

HISTORY OF EXPLORATION AND DEVELOPMENT OF THE CRUSHED STONE INDUSTRY INCLUDING PRODUCTION TECHNOLOGY

3.1 PREAMBLE

The primary objective of this chapter was to develop a historical perspective in order to determine present and future market conditions of the crushed stone industry for the Winnipeg market. This chapter will identify the past as well as present producers of crushed stone, and provide the preliminary economic statistics in order to develop an economic framework.

3.2 PAST PRODUCERS OF CRUSHED STONE

Quarrying of crushed stone, primarily for construction purposes in the Winnipeg market, was initiated in 1880 when John Gunn and Sons of Winnipeg opened a small stone quarry in sec. 30-13-2E (See Table 3.1). The quarried stone was utilized for both crushed stone and rubble, and was consumed both locally and in Winnipeg. Later in 1882, both Enoch Williams and Andy Patterson started small stone quarries in sec. 36-13-1E and sec. 31-13-2E at Stonewall. These quarries produced crushed stone for local construction activity.

By 1907, five quarries were in operation around Stony Mountain (see Table 3.1), and an additional two quarries were in production near Gunton. These quarries all produced crushed stone for local construction purposes.

In 1910, the Winnipeg Supply and Fuel Company purchased Patterson's property as well as bought former quarry properties located at W½-36-13-1E and sec. 36-13-1E. These quarry properties were used intermittently until 1967 for both crushed stone and lime. In addition, Winnipeg Supply and Fuel Company Limited opened a quarry located at sec. 32-13-2E in 1957. The stone was used for lime; however, production ceased around 1970.

During 1916, Manitoba Quarries Limited produced crushed stone from both the old Gunn quarry and from another quarry located in sec. 36-13-1E. Furthermore, the company produced crushed stone from a quarry located near Gunton. Prior to 1927, these quarries ceased production.

Additional quarries were operated in Rockwood Municipality by Gillis Quarries Company Limited in 1940 as well as by Building Products and Concrete Limited in 1963 (see Table 3.1). These quarries were primarily used for crushed stone and lime.

3.3 ACTIVE QUARRIES IN STUDY AREA

3.3.1 City of Winnipeg Primary Materials Section

Dolomite of the Gunton and Penitentiary Members of the Ordovician Stony Mountain Formation was quarried by the City of Winnipeg to be used for both crushed stone and concrete aggregate. The quarry operation commenced in 1905 after the City of Winnipeg decided to dismantle the former quarry operation located at Little Stony Mountain and move the plant to l.s. 2 and 3-14-13-2E.

By 1913, the quarry measured 450 metres long by 50 metres wide by 4 metres deep and produced an annual total of about 50,000 cubic metres of crushed stone. The crushed stone processing involved the drilling of holes 6 metres deep by 1.2 metres back from the quarry face and 1.2 to 1.5 metres apart using dynamite to blow the entire face to the floor. The rock was crushed and stockpiled for use on city streets.

In 1927, the quarry was 245 cubic metres by 4.2 metres deep and produced an average daily total of 1025 cubic metres crushed stone. The quarry produced crushed stone for city streets as well as supplied C.P.R. with rubble. Around 1944, the City of Winnipeg acquired the former Gunn quarry located at l.s. 14-11-13-2E. This quarry commenced operation around 1944 and produced crushed stone for concrete aggregate, mastic pavements, asphalt filler, and for use as tennis court dressing.

By 1979, the quarry operations extended onto sec. 11, 12, 14-13-2E producing an annual total of 165,000 tonnes (Manitoba Clean Environment Commission, 1979). Presently, crushed stone processing involves the:

(1) stripping of overburden,
(2) drilling and blasting of bedrock,
(3) primary and secondary crushing,
(4) screening, and
(5) stockpiling.

The processing equipment for this operation is located outside the quarry; however, the stockpile is located west of the quarry. The product is transported via Provincial Highway #7 for consumption in Winnipeg.

3.3.2 Standard Limestone Quarries Limited

Dolomite of the Gunton Member of the Ordovician Stony Mountain Formation is quarried by Standard Limestone Quarries Limited. The operation commenced in 1961 on the N½-33-13-2E.

In 1979, the quarry operation produced 495,000 tonnes per year (Manitoba Clean Environment Commission, 1979), and crushed stone five days per week. The processing of crushed stone at this locality involves the:

(1) removal of overburden,

(2) drilling and blasting of bedrock,

(3) primary and secondary crushing,

(4) screening, and

(5) stockpiling.

The processing equipment was located on the quarry floor approximately twelve metres below grade (Manitoba Clean Environment Commission, 1979).

3.3.3 B.A.C.M. Construction Limited

In 1967, dolomite of the Gunton Member of the Ordovician Stony Mountain Formation was quarried by Tallman Gravel and Sand Supply Limited[5] to be used for crushed stone. This quarry operation, located on the NE¼-33-13-2E, became inactive as of 1967 and was subsequently reopened by B.A.C.M. Construction Limited in 1977.

In 1979, the quarry produced 165,000 tonnes of crushed stone per year (Manitoba Clean Environment Commission, 1979) and crushed stone five days per week. Processing operations at this locality included:

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[5] Tallman Gravel and Sand Supply Limited later became a subsidiary of B.A.C.M. Construction Limited.

(1) overburden removal,

(2) drilling and blasting,

(3) primary and secondary crushing,

(4) screening, and

(5) stockpiling.

The processing equipment was located at the base of the quarry.

3.3.4 General Stone Company Limited

Dolomite of the Gunton Member of the Ordovician Stony Mountain Formation was quarried by General Stone Company Limited for crushed stone. The quarry is located on l.s. 3-5-14-2E and production commenced in October 1976. The crushed rock was transported via truck to Winnipeg for concrete aggregate as well as for local construction purposes.

3.3.5 Riverside Construction Company Limited

In 1978, dolomite of the Gunton Member of the Ordovician Stony Mountain Formation was quarried by Riverside Gravel Company Ltd. for crushed stone. The quarry is located on l.s. 7-33-13-2E, and produced an annual total of 33,000 tonnes (Manitoba Clean Environment Commission, 1979). The processing equipment was located at the base of the quarry.

3.3.6 Bison Rock Products Limited

Dolomite of the Gunton Member of the Ordovician Stony Mountain Formation was quarried by Bison Rock Products Limited for crushed stone. Production commenced in 1978 on the SW¼-13-12-2E. The crushed stone was transported via truck for consumption in Winnipeg.

TABLE 3.1

PAST PRODUCERS OF CRUSHED STONE IN WINNIPEG REGION[6]

OPERATOR	LOCATION	YEAR(S) IN OPERATION	STONE USE
John Gunn	sec. 30-13-2E	1880-1905	Crushed stone
Enoch Williams	sec. 36-13-1E sec. 31-13-2E	1882-1905	Crushed stone
Andy Patterson	sec. 31-13-2E	1882-1910	Crushed stone
John Gunn & Sons	l.s. 14-11-13-2E	1900-1905	Rubble, crushed stone
Peter Irwin & Sons	W½-36-13-2E	1905-1907	Crushed stone
J.W. Fullbrook	sec. 36-13-2E	1905-1907	Lime, crushed stone
Enoch Williams	l.s. 6-28-15-2E	1905-1914	Crushed stone
Winnipeg Supply and Fuel Co. Ltd.	sec. 36-13-2E	1905-1967	Rubble, crushed stone
City of Winnipeg	l.s. 2, 3-14-13-2E	1905-1981[7]	Crushed stone
John Gunn	l.s. 7-28-15-2E	1906-1914	Crushed stone, lime, building stone
Manitoba Quarries Ltd.	l.s. 6, 7-28-15-2E	1916-1917	Crushed stone
Winnipeg Supply and Fuel Co. Ltd.	l.s. 2-4-14-2E	1916-1916	Crushed stone, lime
Gillis Quarries Ltd.	l.s. 2-4-14-2E	1944-1944	Crushed stone
Winnipeg Supply and Fuel Co. Ltd.	l.s. 13, 14-32-13-2E	1957-1967	Lime
Building Products and Concrete Supply Ltd.	sec. 28-15-2E	1963-1963	Crushed stone
Kleysen Cartage Co. Ltd.	l.s. 7-33-13-2E	1968-1969	Crushed stone

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[6] The total production years for many of the quarries listed are not known exactly.

[7] Still active.

TABLE 3.2

ACTIVE PRODUCERS OF CRUSHED STONE
IN ROCKWOOD MUNICIPALITY

OPERATOR	LOCATION	YEAR STARTED	STONE USE
City of Winnipeg Primary Materials Section	l.s. 2, 3-14-13-2E and l.s. 14-11-13-2E	1905	Crushed stone, concrete aggregate
Standard Limestone Quarries Ltd.	N½-33-13-2E	1961	Crushed stone
B.A.C.M. Industries Ltd.	NE¼-33-13-2E	1963	Crushed stone, concrete aggregate
General Stone Quarries Ltd.	l.s. 3-5-14-2E	1976	Crushed stone
Riverside Gravel Company Ltd.	l.s. 7-33-13-2E	1978	Crushed stone
Bison Rock Products Ltd.	SW¼-13-12-2E	1978	Crushed stone

3.4 PRODUCTION TECHNOLOGY OF THE CRUSHED STONE INDUSTRY

This section will describe the processing methods utilized by the crushed stone industry in order to outline the factors of production which cause a variability in unit extraction costs between deposits. This analysis includes a breakdown of production methods, and the important economic considerations in each process.

3.4.1 Overburden Removal

The quantity of overburden overlying bedrock is an important economic consideration. The stripping of overburden is usually carried out in two separate operations (Goldbeck, 1954). A front-end loader is utilized to remove the upper 2 metres of overburden, whereas the lower metre may be removed by a scraper. The overburden is stockpiled, and can be utilized for fill or as a berm to decrease visual blight.

3.4.2 Drilling and Blasting

The economics of drilling and blasting in a quarry operation as well as the procedure utilized are controlled by the hardness and abrasiveness of the rock (McLean and Gribble, 1978). There are three main stages in excavating rock by explosive and reducing it to manageable sized pieces, that is:

(1) drilling of the bedrock,
(2) blasting, and
(3) secondary blasting.

McLean and Gribble (1978) concluded that the particular drilling technique applied, including type of explosive and spacing pattern, depends upon:

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8. For this study, the economic limit of overburden overlying a deposit has been defined as 3 metres.

9. The abrasiveness of a rock is a measure of how rapidly drill bits are worn down, and it correlates with the type of mineralogy and grain size. The most abrasive dolomite contains a high content of silica.

(1) Type of rock - Soft sedimentary layers require low-density, low-strength explosives;

(2) The degree of fragmentation required, particularly in quarry work where the rock must be suitable for loading and crushing machinery;

(3) The shot hole conditions, which may be wet or dry. If the shot hole is partially filled with water, a water-resistant type of explosive is used until the charge column has been brought above the water line; and

(4) The size of the shot hole - 105 mm is common in quarry operations.

Blasting is implemented by charging the shot hole with gelignite at the bottom and priming this charge with a detonator. A low-velocity explosive, such as ammonium nitrate mixed with diesel oil (ANFO), is usually poured on top of the high-velocity explosive to within approximately 3 metres of the top (McLean and Gribble, 1978). The remaining portion is filled with sand or other fine material. The ammonium nitrate is exploded by detonation of the sensitive gelignite.

Secondary blasting is used to break up larger blocks produced by the initial blast (McLean and Gribble, 1978). In secondary blasting, the charge is attached to the block by clay and exploded.

3.4.3 Crushing and Screening

The objective of crushing is to crush the rock into manageable size pieces that will fulfill the engineering specifications for desired end use for a given project. The type as well as size specification of crushed stone are directly related to the intended end use for the stone. For instance, different quality of limestone as well as size specification are required for crushed stone consumed in road construction in contrast to crushed stone used for concrete aggregate.

Jaw crushers of the Blake type and gyratory crushers are used for primary crushing. The jaw crusher consists of an immovable and movable jaw lined with interchangeable, generally corrugated, wear-resistant lining plates (Krynine and Judd, 1957). The movable jaw rotates about a horizontal axis in a pendulum action and crushes the stone material by striking the immovable jaw.

The gyratory crusher consists of a concave hopper in which a stout vertical shaft is suspended at the top (Krynine and Judd, 1957). The shaft operates on a kind of pendulum which describes a small circle at the bottom of the hopper. The shaft carries a renewable crushing head, and the hopper is lined with renewable chilled-iron or steel staves.

Vibrating screens are utilized to separate the crushed stone into separate size specifications required for different engineering projects. For efficient screening to specification size, each crushed particle must come into contact with the screen cloth at some point in time. If not, the screener may become clogged.

3.4.4 Stockpiles

To provide for variations for different sizes of stone required, stockpiles of material which contain varying specification sizes are required. Consequently, circular stockpiles are built up near the quarry.

3.5 SUMMARY

Chapter 3 has outlined the history of exploration and development of the crushed stone industry near Winnipeg. Chapter 4 will delineate the bedrock geology in Rockwood Municipality and adjacent areas, and describe the engineering properties of crushed stone.

CHAPTER 4.0

ENGINEERING AND GEOLOGICAL PROPERTIES OF CRUSHED STONE

4.1 PREAMBLE

This chapter's objective was to outline the engineering and geological properties of crushed stone that influence the potential end use. The analysis included outlining the factors that determine the physical and chemical durability of crushed stone as well as the geological properties of the Silurian and Ordovician bedrock formations in the study area. In addition, the physical properties, depositional and postdepositional processes that have altered the dolomitic bedrock will be discussed.

4.2 REGIONAL GEOLOGY

A succession of Paleozoic carbonates overlies the basement Precambrian granites of Archean age within the study area. These sedimentary formations generally strike in a north-south direction, and dip gently to the west. The carbonate bedrock generally is composed of dolomite to dolomitic limestone that contain minor quantities of argillaceous and arenaceous material.

4.3 ORDOVICIAN STRATIGRAPHY

The Ordovician stratigraphy consists of the Stony Mountain Formation and the upper part of the Red River Formation (see Table 4.1). The Red River Formation has been subdivided into the Selkirk Member and the Fort Garry Member, which, in turn, are overlain by the Ordovician Stony Mountain Formation. The Stony Mountain Formation has been subdivided into

TABLE 4.1

GEOLOGICAL FORMATIONS WITHIN ROCKWOOD MUNICIPALITY

		END USE
PALEOZOIC SILURIAN A INTERLAKE GROUP:	dolomite, aphanitic, stromatolitic fragmental, fossiliferous; thin argillaceous and arenaceous marker bed	
ORDOVICIAN AND SILURIAN B STONEWALL FORMATION:	dolomite, finely crystalline to aphanitic; reefoid in part; slightly mottled in part; arenaceous and argillaceous marker bed near middle	lime, crushed stone, rubble, dimension stone
ORDOVICIAN STONY MOUNTAIN FORMATION C WILLIAMS MEMBER:	dolomite, arenaceous and argillaceous	
D GUNTON MEMBER:	dolomite, mottled buff and grey; slight but variable argillaceous content	rubble, crushed stone, lime, building stone
E PENITENTIARY MEMBER:	dolomite, argillaceous, vuggy, fossiliferous	crushed stone
F GUNN MEMBER:	calcareous shale, red and purple, fossiliferous; thin limestone interbeds	
RED RIVER FORMATION G FORT GARRY MEMBER:		
Upper part:	dolomite, in part cherty; limestone beds of variable thickness near base and at top of subunit	
Lower part:	dolomite, aphanitic; marker bed of intraformational breccia at top of subunit	
H SELKIRK MEMBER:	dolomitic limestone, mottled, fossiliferous; upper limestone layer with abundant chert nodules	

Source: Bannatyne and Jones (1979)

four members: the Gunn Member, Penitentiary Member, Gunton Member, and the Williams Member.

4.3.1 Red River Formation

4.3.1.1 Selkirk Member

The Selkirk Member of the Ordovician Red River Formation consists predominantly of yellowish grey, pale yellowish brown mottled dolomitic limestone. The upper portion of the member includes a limestone bed with abundant chert nodules. Deposition of the Selkirk Member occurred in a shallow water, marine, low-energy infratidal environment (Cowan, 1978).

4.3.1.2 Fort Garry Member

The Fort Garry Member of the Ordovician Red River Formation has been subdivided into an upper and lower unit separated by a thin marker bed of intraformational breccia at the top of the basal subunit.

The basal unit, approximately 30 metres thick, consists of dense grey and red lithographic dolomite that contains minor interbedded fine to medium crystalline dolomite (Cowan, 1978). The dolomite is often structureless; however, laminar and nodular bedding is present. Cowan (1978) suggested the end of Selkirk deposition was marked by a regression of a shallow sea, followed by an alternating intertidal and supratidal environment, in which the interbedded massive and laminar carbonates of the basal unit of the Fort Garry Member were deposited.

The upper unit consists of light grey to white dolomite that contains chert nodules. The lower portion of the upper unit of the Fort Garry Member contains two limestone beds of variable thickness. Wallace (1979) concluded that the Upper Fort Garry Member was deposited in a clean carbonate tidal flat setting which kept pace with minor transgressive fluctuations.

4.3.2 Stony Mountain Formation

4.3.2.1 Gunn Member

The Gunn Member of the Ordovician Stony Mountain Formation is composed of an interbedded red and purple, argillaceous, fossiliferous dolomite that contains thin limestone interbeds. The beds vary in thickness from 2.5 to 7.5 centimetres. Deposition of the Gunn Member was initiated by a sudden influx of terrigenous detritus which was deposited in a shallow infratidal environment (Roehl, 1967). Cowan (1978) suggested that extensive postdepositional reworking of the sediment occurred by burrowing organisms, which, in part, can be seen by the numerous tubular structures which are located in thin limestone interbeds.

4.3.2.2 Penitentiary Member

The Penitentiary Member of the Ordovician Stony Mountain Formation consists predominantly of red and green argillaceous, sublithographic to finely crystalline dolomite which contains interbedded calcitic dolomite (Cowan, 1978). Cowan (1978) concluded that the infilled tubular structures which are present in the dolomite were primarily the result of worm burrowing.

Wallace (1979) suggested that the Penitentiary Member represents a continuation of marine conditions which were initiated in Gunn time; however, the steady decline in the quantity of terrigenous material during Penitentiary time indicates a change in circulation pattern occurred or the source of terrigenous material was depleted.

4.3.2.3 Gunton Member

The Gunton Member of the Ordovician Stony Mountain Formation consists of a sublithographic to finely crystalline dolomite that displays considerable variation in both structure and texture (Cowan, 1978). The lower two-thirds of the member consists of dense, light grey, massive, sublithographic dolomite with minor intervals of laminar and nodular bedding, whereas the upper one-third consists of both vuggy and intraclastic, sublithographic to finely crystalline dolomite (Cowan, 1978).

Wallace (1979) suggested that Gunton time was characterized by shallow subtidal sedimentation in which prograding tidal flats developed along with laterally equivalent subtidal marine deposits. The basal contact of the Gunton Member was interpreted by Wallace (1979) to represent an erosional surface which resulted with the regression of the seas at the end of Penitentiary time.

4.3.2.4 Williams Member

The Williams Member of the Ordovician Stony Mountain Formation consists of an interbedded, arenaceous, argillaceous, sublithographic dolomite and shale (Cowan, 1978). The dolomite is usually thick-bedded, but in places is thinly bedded and intraclastic. The sand grains in both the dolomite and shale are disseminated, quartzose, well-rounded and frosted (Cowan, 1978).

Wallace (1979) concluded that the Williams Member was a shallow marine carbonate deposit bounded by erosional surfaces. Sedimentation throughout Williams time was characterized by a constant influx of large amounts of terrigenous material (clay and sand constituents inhibit faunal development), and two distinctly different depositional environments. The lower Williams deposition is postulated by Wallace (1979) to have taken place in a moderately high-energy beach environment characterized by shallow subtidal to low-intertidal deposits. The upper Williams Member gradationally overlies the lower Williams Member and has been interpreted to represent a low-energy shallow marine environment.

4.4 ORDOVICIAN AND SILURIAN

4.4.1 Stonewall Formation

Cowan (1978) subdivided the Stonewall Formation into two units with different lithologies. The Lower Stonewall consists of a light yellowish grey, slightly mottled, fossiliferous, vuggy, finely crystalline dolomite. Some subrounded to subangular cobble to fine sand-sized intraclastic dolomite is interbedded with the fossiliferous dolomite (Cowan, 1978). The basal portion of this unit contains dense interbeds of red and green, argillaceous, nodular dolomite overlying the lower pale yellowish brown, fossiliferous dolomite.

The Upper Stonewall consists of a dense, light grey, finely crystalline to sublithographic dolomite. The greater portion of the unit is structureless, although some sections display laminar bedding (Cowan, 1978).

Cowan (1978) suggested that the Stonewall deposition began with the transgression of the sea and establishment of a shallow infratidal environment in which tabulate corals and brachiopods flourished. Subsequent regression of the sea resulted in deposition of windblown sand, illitic clays, brecciated dolomite and carbonate mud in a shallow marine to terrestrial environment.

4.5 SILURIAN STRATIGRAPHY OF ROCKWOOD MUNICIPALITY

4.5.1 Interlake Group

The Silurian Interlake Group generally consists of a light yellowish grey aphanitic dolomite that contains many varieties of fossils, and in places is fragmental. The Silurian Interlake Group contains thin argillaceous and arenaceous marker beds.

The sedimentation of the Silurian Interlake Group occurred in alternating regressive and transgressive shallow marine conditions.

4.6 ENGINEERING PROPERTIES OF CRUSHED STONE

Crushed stone generally can occupy approximately 70 percent to 80 percent of the volume of concrete, and, therefore, can be expected to have an important influence on the concrete's physical properties (Mindess and

Young, 1981). In addition to their use as an economical filler, crushed stone generally provide concrete with improved dimensional stability and wear resistance. Crushed stone should be hard and strong as well as free of undesirable impurities, such as silt, clay, dirt or organic material (Mindess and Young, 1981). A soft, vuggy rock can limit the strength and wear resistance, and in addition may also break down during mixing and adversely affect workability by increasing the quantity of fines. Furthermore, rocks that tend to fracture easily along joint or bedding planes can also limit the strength and wear resistance. Consequently, bedrock containing a high content of impurities or is soft and porous should not be utilized as a construction material.

The quality of crushed stone is dependent upon its ability to resist both chemical and physical weathering. Highly porous rock, which may be broken down easily, or those which may swell when saturated all indicate a product which is easily deteriorated by weathering. The crushed stone may induce a weak bond in the concrete and subsequently may induce cracking or spalling of the concrete.

4.7. FACTORS AFFECTING ENGINEERING SERVICE OF ROCK

4.7.1 Physical Durability of Rock

Crushed stone is determined to be unsound if volume changes that accompany environmental changes lead to deterioration of concrete (Mindess and Young, 1981). Consequently, if rock pores or vugs are completely saturated with moisture and freezing occurs, a cracking of the rock may result because of induced tensile stresses within the rock. However, the degree of saturation in most rocks is usually less than 100 percent. Therefore, frost action will cause cracking only when there is not enough space within the pores to permit the freezing water to expand.

Cyclical heating as a result of high temperatures and subsequent cooling may cause the physical disintegration of a rock, particularly if the constituent mineral is calcite (Krynine and Judd, 1957). When heated, a calcite crystal will expand along the direction of one crystallographic axis and contract in a direction perpendicular to that axis. Consequently, these differences cause irreversible sliding of the crystals and result in an increase in volume due to differential thermal expansion of tightly-knit calcite crystals.

4.7.2 Shape and Texture of Crushed Stone

The shape of natural rock fragments is dependent upon the presence and spacing of natural partings such as cleavage planes in minerals and joints in rocks. If natural parting planes are absent or few, the probability of breaking into equidimensional particles in all directions is equal. Dolomite, for example, has no easy cleavage and when broken or crushed will produce an angular rock with a rough surface texture.

Crushed stone shape and texture affect the workability of fresh concrete through their influence on cement paste requirements (Mindess and Young, 1981). Sufficient paste is required to coat the aggregate and to provide lubrication to decrease interactions between aggregate particles during mixing. Consequently, the surface texture of crushed stone is important for workability because a rough surface requires more lubrication for movement. Mindess and Young (1981) concluded that the ideal aggregate particle is one that is close to spherical in shape with a relatively smooth surface.

4.7.3 Porosity of Aggregate

The number of pores in an aggregate particle directly influence the freezing and thawing durability, strength, elasticity, abrasion resistance, specific gravity, rate of chemical alteration and bond characteristics (Krynine and Judd, 1957).

4.7.4 Chemical Durability of Aggregate

Most chemical durability problems result from a reaction between reactive silica in aggregates and alkalis contained in the cement (Mindess and Young, 1981). The most familiar problem is the alkali-aggregate reaction which may cause extensive map cracking or pattern cracking. Research undertaken by Stanton (1940) suggested that the factors that controlled the alkali-aggregate expansion were:

(1) nature of reactive silica,
(2) amount of reactive silica,
(3) particle size of reactive material,
(4) amount of available alkali, and
(5) amount of available moisture.

Experimental evidence by Diamond (1976) outlined four distinct processes for the alkali-aggregate reaction to occur:

(1) initial alkaline depolymerization and dissolution of reactive silica;
(2) formation of a hydrous alkali silicate gel;
(3) attraction of water by the gel; and
(4) formation of a fluid sol.

Furthermore, Diamond (1976) suggested that this process destroys the integrity of the aggregate particle. The reaction does not necessarily take place from the outside inward, but may proceed throughout the reactive silica particle, depending upon its structure. However, the gel has the ability to imbibe considerable amounts of water, which is accompanied by a volume expansion (Mindess and Young, 1981). If this expansion is sufficient, the resulting stress will crack the weakened aggregate and surrounding paste.

A second process involving alkali-carbonate reaction may cause deleterious expansion (Mindess and Young, 1981). The rocks concerned are dolomitic limestones (Mg,Ca/$CaCo_3$) containing some clay, but not all rocks of this type cause deleterious expansions. Mindess and Young (1981) concluded that expansive rocks have the following features:

(1) very fine grained dolomite,

(2) considerable amounts of fine grained calcite,

(3) abundant interstitial clay, and

(4) the dolomite and calcite crystals are evenly dispersed in a clay matrix.

Periodically, other kinds of chemical distress occur. For example, iron pyrites (FeS) may react expansively in the presence of calcium hydroxide to form ferrous sulphate and ultimately ferric hydroxide (Mindess and Young, 1981). This reaction may cause popouts and staining. In addition, small quantities of zinc and lead are occasionally found in aggregate deposits and may greatly delay settling and early hardening of the concrete.

4.8 ENGINEERING PROPERTIES OF BEDROCK FORMATIONS IN THE WINNIPEG REGION

The primary objective of this section was to delineate as well as discuss the engineering tests that are required to evaluate the suitability of a crushed stone deposit for construction materials. Furthermore, this section will classify each of the geologic bedrock formations based on suitability for construction purposes as well as delineate published results of the engineering tests needed to define quality.

4.8.1 Aggregate Resistance to Abrasion Test

The aggregate abrasion resistance test measures the resistance to surface wear by abrasion, and subsequently, the lower the value, the greater the resistance (McLean and Gribble, 1979). The physical requirements of bedrock for various crushed stone uses are given in Table 4.2.

TABLE 4.2

PHYSICAL REQUIREMENTS OF
LOS ANGELES ABRASION (% LOSS)

SPECIFICATION

END USE	Base Course Class A	Traffic Type A	Bituminous Class A	Concrete Coarse I
	60	35	35	40

MacLaren (1980)

4.8.2 Frost Resistance Test

The frost resistance or soundness test is a measure of the resistance of a sample to disintegration by physical weathering processes produced primarily by frost action. The test is simulated by soaking the crushed stone in a saturated solution of sodium or magnesium sulphate and subsequently drying the samples in an oven (Mindess and Young, 1981). Furthermore, the cycle is repeated five times and subsequently the percentage weight loss is calculated (MacLaren, 1980). The crystallization of the salt in the pores is assumed to simulate the disruption of the crushed stone.

TABLE 4.3

PHYSICAL REQUIREMENTS OF
SODIUM SULPHATE SOUNDNESS (% LOSS)

SPECIFICATION

END USE	Base Course		Bituminous	Concrete	
	Fine	Coarse	Class A	Fine	Coarse
	16	12	12	16	12

MacLaren (1980)

4.8.3 Crushing Strength Test

The crushing strength value measures the resistance of a crushed stone to crushing under a gradually applied compressive load (McLean and Gribble, 1979). The determination of the strength is usually carried out on solid rock material. Generally, the larger the value, the more suitable the rock is for construction purposes.

4.8.4 Insoluble Residue Test

The insoluble residue test is a measure of the percentage of silica and other insoluble material such as clay and silt contained in the dolomite bedrock. The test is implemented by digesting the samples in perchloric acid and subsequently filtering and weighing these samples. Generally, the greater the percentage of insoluble material contained in a sample, the less desirable the rock is for construction purposes.

4.9 SUITABILITY OF BEDROCK FORMATIONS FOR CRUSHED STONE PRODUCTION

The objective of this section is to provide, in a general framework, the suitability of each bedrock formation in the study area as to potential end use. This analysis included delineating the published engineering specifications for each bedrock formation (see Table 4.4) and defining each bedrock formation for potential quality.

TABLE 4.4

ENGINEERING PROPERTIES OF BEDROCK IN STUDY AREA

Geologic Formation	Member	Abrasion Resistance (% Loss)	Frost Resistance (% Loss)				Crushing Strength (kg/cm)	Insoluble Residue
			1/2"-3/8"	3/4"-1/2"	1¼"-3/4"			
Ordovician Red River	Selkirk	41.2[11], 51.1[11] 48.4[11]	8.0[11], 8.0[11] 3.5[11]	8.3[11], 10.4[11] 12.2[11]	16.8[11], 18.6[11] 21.3[11]		353.6[13]	2.0[14]
Ordovician Red River	Fort Garry Lower	44.6[12], 32.5[11]	34.2[11]	27.2[11]	23.8[11]	12.1 (fine)[12] 4.1 (coarse)[12]	619.0[13]	15.4[14]
	Fort Garry Upper	28.8[12], 32.7[11]	30.7[11]	19.8[11]	15.3[11]	1.8 (fine)[12] 12.7 (coarse)[12]	1091.6[13]	5.9[14]
Ordovician Stony Mountain	Gunn						292.8[13]	8.0 to[10,14] 25.0
Ordovician Stony Mountain	Penitentiary	58.0[11]	100[11]	100[11]	100[11]			8.0 to[10,14] 25.0
Ordovician Stony Mountain	Gunton	27.7[12], 27.5[11] 29.3[11], 30.3[11]	27.0[11], 20.9[11] 8.5[11], 15.0[11]	16.5[11], 5.2[11] 13.3[11], 10.3[11]	17.1[11], 4.5[11] 12.7[11], 9.6[11]	21.1 (fine)[12] 15.6 (coarse)[12]	933.3[13]	0.46 to[10,14] 11.48
Ordovician Stony Mountain	Williams						349.2[13]	5.6 to[10,14] 36.95
Ordovician Stonewall		29.2[12], 27.0[11] 23.8[11]	22.9[11] 16.2[11]	10.9[11] 6.6[11]	10.8[11] 6.4[11]	2.1 (fine)[12] 15.6 (coarse)[12]	349.2[13]	0.38 to[14] 7.31
Silurian Interlake Group		31.8[12], 33.0[12] 36.4[11], 33.5[11]	26.9[11] 29.9[11]	11.6[11] 17.1[11]	9.7[11] 7.9[11]	17.7 (fine)[12] 1.9 (fine)[12] 20.6 (coarse)[12]	347.0[13]	5.9 to[10] 15.4

10. Cowan. J. 1978. Ordovician and Silurian Stratigraphy of the Interlake Area, Manitoba. Unpublished M.Sc. thesis, University of Manitoba.

11. Jones, C.W. and B.B. Bannatyne. 1982. Evaluation of Bedrock Aggregates in Manitoba. "Report of Field Activities", Manitoba Department of Energy and Mines, Winnipeg.

12. James F. MacLaren Limited. 1980. Mineral Aggregate Study of the Southern Interlake Region. Report submitted to Manitoba Department of Energy and Mines, Winnipeg.

13. Oosterveen, J. 1981. A Preliminary Study of the Engineering Properties of Ordovician and Silurian Limestones of Southern Interlake, Manitoba. Unpublished B.Sc. thesis, University of Manitoba.

14. Wallace, G. 1978. Ordovician Stratigraphy of the Southern Interlake, Manitoba. Unpublished M.Sc. thesis, University of Manitoba.

4.9.1 Economic Evaluation of Aggregate

The suitability of bedrock for aggregate production has been assessed by the Manitoba Department of Energy and Mines (1981). This classification only determines the potential quality of the bedrock, and consequently when delineating areas of reserves of stone further testing should be implemented.

TABLE 4.5

SUITABILITY OF BEDROCK FOR AGGREGATE PRODUCTION

FORMATION	MEMBER	POTENTIAL AGGREGATE QUALITY
Interlake Group		High
Stonewall		High
Stony Mountain	Williams	Low
	Gunton	High
	Penitentiary	Medium
	Gunn	Low
Red River	Fort Garry (Upper)	Medium-High
	Fort Garry (Lower)	Medium
	Selkirk	Low

Source: Manitoba Department of Energy and Mines (1981)

4.10 SUMMARY

Chapter 4 has summarized the engineering specifications and geological properties of bedrock required for crushed stone production. This perspective aided in locating potential deposits for future extraction.

CHAPTER 5.0

ECONOMICS OF THE CRUSHED STONE INDUSTRY

5.1 PREAMBLE

The objective of this chapter was to estimate the economic costs of relocating the crushed stone industry at selected deposits near Winnipeg. This analysis included:

(1) an assessment of the potential supply of crushed stone available;

(2) an economic scenario to predict the future demand of crushed stone;

(3) an assessment of the increased delivered price of crushed stone through relocation of the industry; and

(4) an overview of the impact of land use conflicts on the economics of the crushed stone industry.

5.2 SUPPLY OF CRUSHED STONE IN STUDY AREA

The Manitoba Department of Energy and Mines has been actively involved in regional land use planning in order to protect high-quality crushed stone deposits. The program involves that selected high-potential aggregate resources[15] be incorporated into the long-run development plan for rural municipalities. Otherwise, sharp price increases caused by resource scarcity may occur, which in the long run may act as a constraint

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15. This study utilized the deposits which were recommended for future development in the Southern Interlake Development Plan.

to future economic growth. This study utilized these selected deposits as the potential supply for future crushed stone production, and has defined each major deposit as a zone[16] (see Table 5.1).

5.2.1 Estimated Supply of Selected Deposits

The supply of crushed stone available in each selected zone (see Map 1 in Appendix IV) is an estimate of the potential resources available in tonnes. The estimated reserve calculation involved multiplying the average bedrock stratigraphic thickness by the surficial area, and was recorded in potential tonnes available (see Table 5.2). In addition, reserve estimates are based on potential quality, that is, areas which have a high potential for crushed stone production.

5.3 DEMAND FOR CRUSHED STONE IN WINNIPEG REGION

The demand for crushed stone in the Winnipeg Region is tied closely to activity in the construction sector. This type of relationship between an input and output of a final product is referred to as derived demand, where the crushed stone is directly consumed in construction related activities (Bronitsky, 1973). Consequently, the demand for crushed stone is a function of end use (see Table 5.3), where the product should possess a low value.

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16. Selected deposits in Rockwood Municipality and adjacent areas have been defined as potential zones for location of the crushed stone industry. This study calculated the increased delivered price of relocating the industry at selected deposits.

TABLE 5.1

AVERAGE THICKNESS OF BEDROCK FORMATIONS IN SELECTED SUPPLY AREAS FOR CRUSHED STONE IN THE WINNIPEG REGION

DEPOSIT	MUNICIPALITY	GEOLOGICAL FORMATION	GENERALIZED QUALITY	AVERAGE THICKNESS (IN METRES)
Little Mountain	Rosser	Ordovician Stony Mountain Formation; Gunton Member	High	4.5
Lilyfield	Rosser	Ordovician Stony Mountain Formation; Gunton Member	High	3.6
Stony Mountain	Rockwood	Ordovician Stony Mountain Formation; Gunton Member	High	3.6
Stonewall South East	Rockwood	Ordovician Stony Mountain Formation; Gunton Member	High	6.1
Stonewall North East	Rockwood	Ordovician Stony Mountain Formation; Gunton Member	High	6.1
Gunton	Rockwood	Ordovician Stony Mountain Formation; Gunton Member	High	7.6
Mulder	St. Andrews	Ordovician Red River Formation; Fort Garry Member	Medium to High	3.9[17]
Inwood	Woodlands	Silurian Interlake Group; Inwood Formation	High	7.6

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[17] Only 3.9 metres of the bedrock formation is above the water table. Consequently, extraction costs increase significantly because the quarry must be pumped dry before the stone can be removed.

TABLE 5.2

ESTIMATED RESOURCES[18] OF CRUSHED STONE IN STUDY AREA

(in tonnes)

DEPOSIT	ZONE	DISTANCE (in km)	ESTIMATED POTENTIAL RESOURCES	ESTIMATED CONSUMED RESOURCES	ESTIMATED TOTAL REMAINING
Little Mountain	1	5	23,262,000	564,000	22,698,000
Lilyfield	2	15	22,843,000	759,000	22,084,000
Stony Mountain	3	19	10,468,000	5,790,000	4,678,000
Stonewall South East	4	24	11,186,000	None	11,186,000
Stonewall North East	5	29	247,049,000	5,165,000	241,884,000
Mulder	6	32	11,683,000	310,000	11,373,000
Gunton	7	40	57,663,000	1,559,000	56,104,000
Inwood	8	74	1,261,905,000	3,400,000	1,258,505,000
TOTAL			1,646,059,000	17,547,000	1,628,512,000

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[18] The resource estimates are maximum potential resources. Substantial quantities of potential reserves have been sterilized through urban encroachment, for example, in areas such as Stony Mountain.

TABLE 5.3

FINAL END USE OF CRUSHED STONE IN MANITOBA IN 1973
(in tonnes)

USE	TONNES	PERCENT ALLOCATED TO EACH SECTOR
Residential	210,378	13.9
Non-Residential	110,984	7.3
Road Construction	659,011	43.5
Other Engineering	152,138	10.0
Exported and Unallocated	384,081	25.3
TOTAL	1,516,592	100.0

Source: Underwood, McLellan and Associates (1976)

Bronitsky (1973) suggested that in the short term, the demand for crushed stone is highly inelastic because there is little opportunity to alter the material requirements of a project. This factor depends upon technical substitutability of other commodities for crushed stone. However, Bronitsky (1973) suggested that the demand for crushed stone, in the long run, is less inelastic. For example, a contractor may choose between structural steel and reinforced concrete based on economics of using these two construction materials.

5.3.1 Effect of Economic Growth on the Crushed Stone Industry in Winnipeg Region

Underwood, McLellan and Associates (1976) concluded that the demand for crushed stone in the Winnipeg Region will increase slightly[19] between 1976 and 1996 (see Table 5.4). Furthermore, the Province of Ontario (1980) concluded that in times of static economic

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[19] The economic demand model is based on a slight increase in yearly economic growth over the forecast period.

growth, there is significant construction activity and, as a result, a significant demand for crushed stone. The end use of crushed stone can be utilized for replacement renewal as well as rebuilding of existing structures. Furthermore, there are certain end uses in which technical substitution for crushed stone is impossible even in the long run (Bronitsky, 1973), for example, the use of crushed stone as a subbase under pavement and fill around structures wherever good drainage is required.

5.3.2 Forecast of Demand for Crushed Stone in Winnipeg Region

The demand for crushed stone in the Winnipeg Region is variable from year to year depending upon activity in the construction sector. Historical evidence of demand figures[20] displays variability of demand between 0 tonnes to 200,000 tonnes above or below the expected value. Consequently, in order to evaluate the variable effect of either an increase or decrease in quantity demanded in the long run, alternate forecasts A[21] and B[22] were prepared (see Table 5.4).

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[20] The variability between the expected demand and actual demand was calculated between 1976 and 1980.

[21] During 1981, speculation concerning the development of the Alcan aluminium plant occurred. This project would consume considerable quantities of crushed stone in the short term, and increase demand slightly in the long run due to infrastructure.

[22] The effect of high interest rates on the construction industry was notable during the forecast years of 1981 and 1982. During this period, a slight decrease in construction activity occurred.

TABLE 5.4

DEMAND FOR CRUSHED STONE IN WINNIPEG REGION
1981 - 1996
(in tonnes)

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DEMAND	DEMAND	DEMAND
1981	1,309,000	1,529,000	1,089,000
1982	1,342,000	1,562,000	1,122,000
1983	1,375,000	1,595,000	1,155,000
1984	1,410,200	1,632,400	1,190,200
1985	1,444,300	1,664,300	1,224,300
1986	1,479,500	1,699,500	1,259,500
1987	1,485,000	1,705,000	1,265,000
1988	1,490,500	1,710,500	1,270,500
1989	1,499,300	1,719,300	1,279,000
1990	1,507,000	1,727,000	1,287,000
1991	1,516,900	1,736,900	1,296,900
1992	1,553,200	1,773,200	1,333,200
1993	1,591,700	1,811,700	1,371,700
1994	1,629,100	1,849,100	1,409,100
1995	1,668,700	1,888,700	1,448,700
1996	1,712,700	1,932,700	1,492,700
TOTAL	24,014,100	27,534,100	20,494,100

Source: Underwood, McLellan and Associates (1976)

5.4 ECONOMIC COST ESTIMATION OF RELOCATING THE CRUSHED STONE INDUSTRY AT SELECTED DEPOSITS NEAR WINNIPEG

The market structure of the crushed stone industry, by economic definition, is an oligopoly in nature (Bronitsky, 1973). This type of market behavior is characterized by concluding that each firm recognizes that its best choice depends upon the alternative choices made by its rival firms. That is, the firm recognizes its decisions depend upon the assumptions it makes about rival decisions and reactions (Bronitsky, 1973). These factors are notable in determining the market share of each firm.

The price of crushed stone is a function of the competition's selling price, therefore, each producer's price is constrained by each seller of crushed stone. Bronitsky (1973) concluded that it is reasonable to assume an average industry price based on these factors. For example, if Firm 1 raises the price while the competition holds its price constant, the quantity demanded will fall much more sharply than if all sellers matched his price increase.

5.4.1 Extraction Costs

Unit extraction costs per tonne were surveyed for each producer in Rockwood Municipality. These costs represent stockpile prices and processing costs.

The average stockpile price was estimated by utilizing the following formula:

$$X = \frac{(P_1)\ (Q_1) + (P_2)\ (Q_2) + (P_3)\ (Q_3)}{N}$$[23]

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[23] This method of price estimation accommodates economies of scale. Each producer is classified according to a large, intermediate or small producer. That is:

(1) a large producer produces more than 300,000 tonnes;
(2) an intermediate producer produces between 100,000 and 300,000 tonnes; and
(3) a small producer produces less than 100,000 tonnes.

The variables denoted by P represent the average cost of producing a tonne of crushed stone, and include all extraction and processing costs at the quarry site. The variable N represents the average production of crushed stone in Rockwood Municipality between 1976 and 1981. The average cost of producing a tonne of crushed stone was estimated to be $3.15 in 1981 constant dollars.

5.4.2 Transportation Costs

Crushed stone is transported to Winnipeg from Rockwood Municipality by truck via Provincial Highway #7. The transportation costs are a function of distance and are important in calculating the delivered price of crushed stone. Crushed stone, in recent years, has tended to be produced at relatively low-cost production sites near urban markets. However, during the past decade, competing land uses, depletion of existing reserves and environmental restrictions have caused new quarry operations to locate further from local markets. This factor is notable because of the increase in delivered price directly related to increased transportation costs (see Table 5.5).

TABLE 5.5

ESTIMATED COST OF TRANSPORTING A TONNE
OF CRUSHED STONE FROM SELECTED DEPOSITS TO WINNIPEG
(in 1981 constant dollars)

DEPOSIT	DISTANCE (in km)	TRANSPORTATION COST (per tonne)
Little Mountain	5	$0.37
Stony Mountain	19	$1.42
Stonewall North East	24	$1.80
Stonewall South East	29	$2.10
Mulder	32	$2.40
Gunton	42	$3.15
Inwood	74	$5.55

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24. Transportation cost per tonne was estimated to be $.075 per tonne/kilometre.

5.4.3 Economic Model

The cost of producing a tonne of crushed stone was estimated to be $3.15 per tonne, and the transportation cost of delivering a tonne of crushed stone to Winnipeg was estimated to be $.075 per tonne kilometre (see Appendix II). These cost figures were applied to the demand model developed in Section 5.3, and were utilized in order to estimate the relocation costs at selected deposits (see Appendix III).

The scenario developed in Appendix III includes the base forecast prepared by Underwood, McLellan and Associates (1976) as well as Alternate Scenario I and Alternate Scenario II. Alternate Scenario I provides for an estimation of relocation costs if an increase in demand occurred as a result of an increase in economic activity. Scenario II predicts the relocation costs in a climate of decreased economic activity resulting in a decreased demand for crushed stone.

The cumulative total cost for relocating at each selected deposit is noted in Table 5.6. An example of the increased cost to society if the industry were required to relocate due to local environmental concerns is given below. If the industry had to relocate from Stony Mountain (Zone 2) to Stonewall Southeast (Zone 4), the crushed stone would have to be transported an additional 10 kilometres resulting in an additional cost of $0.75 per

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25. In Rockwood Municipality, quarry operations are located at more than one deposit. In this analysis, all operations are located at each deposit simultaneously and the cost of relocating the industry was calculated.

tonne. The additional cost to society would be $16,089,459 by utilizing the Base Forecast. If the scenario were applied to Alternate Forecasts A or B, the increased cost would be $19,449,321 or $13,812,521 respectively.

TABLE 5.6

ESTIMATED CUMULATIVE TOTAL DELIVERED PRICE FOR CRUSHED STONE AT EACH SELECTED ZONE BETWEEN 1981 AND 1996 (in 1981 constant dollars)

ZONE	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
1	84,769,773	97,097,239	72,343,114
2	102,780,336	116,855,364	87,713,464
3	109,984,578	121,116,254	93,861,604
4	118,869,795	136,304,685	101,525,985
5	127,995,153	146,768,479	109,231,954
6	133,278,255	152,826,465	113,740,590
7	151,288,830	173,409,390	129,110,940
8	208,922,670	239,565,810	178,296,060

The cumulative marginal cost for relocating the industry is noted in Table 5.7. This table delineates the additional estimated cumulative economic costs that would be realized by relocation of the industry. This estimate of the increased delivered price of crushed stone is a function of the additional costs of transporting the product to Winnipeg. The cost estimates are projected between 1981 and 1996, and are calculated in 1981 constant dollars.

TABLE 5.7

CUMULATIVE MARGINAL COST FOR RELOCATING THE CRUSHED STONE INDUSTRY AT EACH SELECTED ZONE BETWEEN 1981 AND 1996 (in 1981 constant dollars)

ZONE	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
1	18,010,563	19,758,125	15,370,350
2	7,204,242	4,260,890	10,927,541
3	8,885,217	15,188,431	7,664,381
4	9,125,358	10,463,794	7,705,969
5	5,283,102	6,057,986	4,508,636
6	18,010,275	20,582,925	15,370,350
7	57,633,840	66,156,420	49,185,120
8			

The estimated increase in marginal cost per year is noted in Table 5.8. This table outlines the additional costs per year of relocating the industry.

TABLE 5.8

ESTIMATED AVERAGE MARGINAL COST OF RELOCATING THE CRUSHED STONE INDUSTRY (PER YEAR)

(in constant 1981 dollars)

ZONE	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
1	1,200,704	1,317,208	1,024,690
2	480,283	284,059	728,502
3	560,329	1,012,562	510,958
4	608,357	697,586	513,731
5	352,207	403,865	300,578
6	1,200,705	1,372,195	1,024,690
7	3,842,256	4,410,428	3,279,008
8			

5.5 DISCUSSION

A quarry operation has an increased competitive advantage over its rival firms the closer it locates to the market it serves. Also, in terms of resource allocation in production, a quarry is more economically efficient the closer it is located to construction related activities. When an active quarry operation locates in a suburban setting, however. conflicts of land use occur between active quarry operations and local residents. The environmental disamenities associated with active quarry operations, such as:

(1) excessive blasting,

(2) increased local truck traffic,

(3) increased dust levels,

(4) devaluation of property, and

(5) increased groundwater pollution hazard

come into conflict with rural residential values of privacy, attractive landscapes, and a clean environment. In time, as the conflict escalates, the local residents place political pressure on the local municipal council and provincial government to control quarry activity through zoning ordinances that restrict production. This action restricts the productive capacity of the quarry operation, which is economically encouraged to relocate further from the urban - suburban setting. Logically, an increased delivered price of crushed stone will result from increased transportation costs.

In 1979, Clean Environment Commission public hearings were held under the authority of the Clean Environment Act to establish limits on all phases of production on crushed stone quarries located in Rockwood Municipality. These hearings were conducted as a result of several complaints concerning the environmental disamenities associated with active quarry operations.

5.5.1 Impact of Zoning Regulations on the Production of Crushed Stone in Rockwood Municipality

As noted previously, land use conflicts between active quarry operations and local residents can lead to zoning restrictions placed upon the industry. These regulations may control the:

(1) location of quarry operations,

(2) transportation routes,

(3) air and water pollution emissions,

(4) operating hours,

(5) noise levels,

(6) blasting, and

(7) other operating procedures.

Consequently, these environmental problems noted lead to zoning restrictions that either reduce the productive capacity of the industry or sterilize the industry completely. As urbanization effects increase, transportation distances become longer and the average delivered price of crushed stone increases. As the delivered price increases, consumers may look for means of reducing costs through economic substitution of other building materials. One notable concern towards increased delivered price is that the public sector is the largest consumer of crushed stone (see Table 5.3), for example in road construction, and has been notoriously unresponsive to increases in construction costs (Bronitsky, 1973). It is in the public interest to maintain an adequate supply of high-quality crushed stone near major construction projects.

5.5.2 Effect of Land Use Conflicts on the Delivered Price of Crushed Stone in Rockwood Municipality

Of notable importance in construction related activities, logically, is the delivered price of aggregate. Because aggregates are directly consumed in essential construction activities, such as concrete production, asphalt surfacing, and fill, their delivered price varies for each job, depending upon the distance from the quarry and resulting transportation costs, as well as the initial production cost at the stockpile.

In locating a site for a quarry, the following factors were considered in this study:

(1) supply available, and

(2) distance from market.

These factors will be discussed in relation to the crushed stone industry located in Rockwood Municipality.

SUPPLY

The quality of crushed stone available to the Winnipeg market was previously discussed in Chapter 4, whereas the estimated potential supply of crushed stone was outlined in Section 5.2. The primary source of bedrock available for most end uses is the Gunton Member of the Ordovician Stony Mountain Formation as well as the Ordovician Stonewall Formation. Crushed stone is a non-renewable resource and is fixed in terms of quality and supply. As urban encroachment occurs, the potential supply of crushed stone available decreases near urban markets. This could, in the long run, lead to serious shortages of high-quality crushed stone near Winnipeg.

TRANSPORTATION COSTS

Crushed stone is a high-bulk/low-value commodity that must be transported from the quarry to the construction site. Bronitsky (1973) estimated that shipment by truck over a distance of 32 kilometres generally doubles the delivered cost of crushed stone. This factor makes crushed stone the most sensitive of any mineral to shipping distances.

Transportation costs have two pronounced effects on the economics of crushed stone (Bronitsky, 1973). Mineral aggregates are produced and consumed in local regional markets which are insulated by prohibitive shipping costs to the demand and supply conditions in other regional markets. Consequently, the industry must compete primarily on a local scale.

The second effect of relatively high transportation costs is the effect on scaled economics and an understanding of why over 80 percent of the industry can survive at production levels which are economically inefficient (Bronitsky, 1973). Therefore, the industry locally will experience large differences in quantities produced between operators.

In Winnipeg, the crushed stone companies which supply the local market are located within a distance of 33 kilometres. The product is transported by truck via Provincial Highway #7 to Winnipeg.

The increase in delivered price resulting from increased transportation distances were calculated in Appendix II. This increase in price was estimated to show the potential impact if urban encroachment were to encourage the industry to relocate in areas outside the urban - suburban setting.

5.6 SUMMARY

The Winnipeg market has sufficient reserves of quality bedrock for crushed stone production to meet the anticipated demand over the next twenty years. However, sharp price increases for this commodity may be experienced through increased transportation costs which are the result of:

(1) depletion of reserves close to Winnipeg;

(2) increased land costs caused by competing land uses;

(3) higher energy costs;

(4) zoning regulations which may be imposed upon the quarry operators;

(5) supply restrictions based on quality of bedrock geology; and

(6) urban encroachment.

The important economic condition is not the total estimated reserves available to the market, but rather the delivered price at which this resource can be made available. Paradoxically, the basic raw materials which our civilization utilizes for building and maintenance are not given much importance or significance. The consequence of sharp price increases in this basic commodity may be future constraints to economic growth.

CHAPTER 6.0

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This practicum has outlined the economic effects of urbanization on the crushed stone industry. Two general processes of urbanization restrict the productive capacity of the industry, that is, by building overtop of high-quality deposits or by zoning ordinances that restrict the industry. The economic effect of this problem is that the industry must locate further from the market causing an increased delivered price through increased transportation costs.

It has been the objective of this practicum to develop an economic model that would aid in predicting the increased delivered price of crushed stone, in 1981 constant dollars, that would occur if the quarry operations were forced to relocate at the next closest deposit outside the zone of urban influence. The study methods included:

(1) geological mapping and defining potential quarry locations;

(2) an extensive literature review to aid in delineating the engineering properties of crushed stone; and

(3) a personal interview of quarry operators to collect economic information concerning production and transportation costs.

The data collected from the above noted tasks were incorporated into an economic model that predicts the increased delivered price of crushed stone between 1981 and 1996 if the industry were to relocate at the next closest deposit.

The literature has shown that when an active quarry operation locates near rural residential homes, conflicts of land use will occur. The environmental disamenities associated with active quarry operations, for example increased noise, dust, local truck traffic, blasting, and an increased potential for groundwater contamination, cause serious land use conflicts. The residents' desire for a clean environment and peaceful surroundings comes into conflict with quarry activity. Over time, as the land use conflict escalates, the residents increase political pressure to both the municipal council and provincial government to control quarry activity. This process typically leads to zoning ordinances that restrict or prohibit the industry (Bronitsky, 1973). The end result is an increase in production costs as the industry is required to adapt to environmental regulations.

In June 1979, Clean Environment Commission public hearings, under the authority of the Clean Environment Act, were held to prescribe limits on emission of contaminants into the environment from crushed stone quarries in Rockwood Municipality. These hearings were conducted as a result of several complaints regarding the environmental disamenities associated with active quarry operations to various government agencies. The residents located near active quarry operations demanded that restrictions be placed on production processes of the crushed stone operation by both the Municipal and Provincial Governments.

If mining is unduly restricted before depletion of the mineral resource due to local environmental concerns, there will be a cost to society. The focus of the research was to estimate the delivered price that would occur if the crushed stone industry were forced to relocate at the next closest deposit outside the zone of urban influence. This research is significant because as land use competition increases and future land use conflicts between active quarry operations and residents escalate, there will be an increased pressure for the crushed stone industry to relocate outside the urban setting causing an increased delivered price.

The conflict described in this practicum is typical of the general conflict facing society, that is, between economic growth and environmental amenities. High economic growth rates achieved over the past three decades have seen significant environmental tradeoffs in order to sustain growth levels. These tradeoffs have included the losses of valuable air, land and water resources.

6.2 RECOMMENDATIONS

This practicum recommends that the Manitoba Department of Municipal Affairs, Municipal Planning Branch enforce Provincial Land Use Policy #13, Manitoba Regulation 217/80 of the Planning Act. The Provincial Land Use Policy #13 states that economically valuable aggregate and quarry mineral deposits should be protected from surface land uses that would interfere with their ongoing and future exploitation. Through the Manitoba provincial planning process, under the authority of the Planning Act, the issues and concerns raised by this practicum can be addressed.

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APPENDIX I

MANITOBA PROVINCIAL LAND USE POLICY #13

POLICY #13

ECONOMICALLY VALUABLE AGGREGATE AND QUARRY MINERAL DEPOSITS SHOULD BE PROTECTED FROM SURFACE LAND USES THAT WOULD INTERFERE WITH THEIR ONGOING AND FUTURE EXPLOITATION.

A. Policy Objectives

The objectives of this Policy are:

(a) To protect aggregate and quarry mineral resources for future construction and development in the Province.

(b) To ensure that materials are available to support local and provincial construction needs and industrial minerals production at a reasonable cost.

(c) To ensure that pit and quarry operations are reasonably compatible with adjacent land uses.

(d) To integrate aggregate and quarry mineral extraction into the overall land use planning process by allocating areas specifically for extraction and by assuming that as the economic climate changes so areas allocated to resource extraction will also change.

(e) To pursue sequential land use practices such that on a known deposit (i) a non-conflicting land use is applied to the surface of the deposit prior to mineral extraction, and (ii) the land is returned to a practical and compatible use once extraction has ceased.

B. Policy Application

Deposits of sand and gravel and near-surface limestone which are in demand as construction materials by industry, local communities or government departments and agencies, should be protected. In certain parts of the Province such minerals as bentonite, shale, gypsum, high calcium limestone, silica sand and other quarry minerals should also be protected to ensure a supply of these materials to industrial mineral related industries. These include both surface deposits and shallow subsurface deposits overlain by till or clay.

For the purpose of this Policy:

(a) Conflicting land uses include residential subdivision lots, highways or utility corridors. Such development should be deferred until the mineral is extracted and the site rehabilitated.

(b) Marginally conflicting land uses include the incorporation of aggregate and quarry mineral deposits into a Provincial or National Park, a Wildlife Management Area, a Community Pasture or a Provincial Forest or the establishment of a garbage dump on part of a deposit. In these cases, mineral extraction can take place alongside the alternative land use, provided that agreement is reached between the two concerns, to ensure optimal utilization of all resources involved.

(c) Non-conflicting land uses include recreation outside of Provincial Parks, low value timber stands, general agricultural practices and temporary occupation, such as trailer parks or parking lots. Pit and quarry operations can develop in these areas whenever such activities become economically feasible.

In some areas aggregate or quarry mineral extraction should be recognized as a primary land use. In other areas a marginal or non-conflicting land use may be permitted providing that it could later be converted to a gravel or mineral extraction operation.

In order to indicate areas where conflicting land uses should be disallowed, the Mineral Resources Division is in the process of producing aggregate and quarry mineral resource maps for certain regions of the Province. These will take the form of "Stop – Caution – Go" maps. "Stop" indicates valuable deposits upon which no conflicting land use should be allowed. "Caution" denotes a deposit whose full potential is not proven or whose quality is not high but which has been recognized as of value to the region. Deposits with a status of "Caution" may be designated for a conflicting land use, after local needs have been scrutinized. "Go" denotes a deposit of no present recognized value as an aggregate or quarry mineral source. Periodic revision to the "Stop – Caution – Go" status of deposits will reflect continuing exploration and changing economic conditions. It is understood that the maps will be subject to approval by the Provincial Land Use Committee.

The rehabilitation of pits and quarries on both Crown and private land is governed by Regulation under The Mines Act. The rehabilitation takes place in accordance with an approved plan. Concensus for the plan is derived from concerned Municipal and Provincial agencies. The Mineral Resources Division requires such plans from all commercial operators.

Following mineral exploitation and rehabilitation, the land can be restored t(some compatible use.

C. Definitions

For the purpose of this Policy:

(a) "Aggregate" means sand, gravel, or both, or crushed rock.

(b) "Economically Valuable Aggregate and Quarry Mineral Deposits" means those areas of aggregate and quarry mineral resource which have a high potential for extraction based on supply and demand projected over 25 years.

(c) "Quarry Minerals" means those minerals obtained by quarrying, including shale, kaolin, bentonite, gypsum, clay, silica-rich sand, peat, salt, coal, and rock or stone used for any purpose other than as a source of metal, asbestos, potash, oil and natural gas.

APPENDIX II

ESTIMATED DELIVERED PRICE OF CRUSHED STONE PER TONNE/KILOMETRE

Estimated Stockpile Cost	Distance in Kilometers	Transportation Cost	Total Delivery Cost
3.15	1	0.075	3.23
3.15	2	0.150	3.30
3.15	3	0.225	3.38
3.15	4	0.300	3.45
3.15	5	0.375	3.53
3.15	6	0.450	3.60
3.15	7	0.525	3.68
3.15	8	0.600	3.75
3.15	9	0.675	3.83
3.15	10	0.750	3.90
3.15	11	0.825	3.98
3.15	12	0.900	4.05
3.15	13	0.975	4.13
3.15	14	1.050	4.20
3.15	15	1.125	4.28
3.15	16	1.120	4.35
3.15	17	1.275	4.43
3.15	18	1.350	4.50
3.15	19	1.425	4.58
3.15	20	1.500	4.65
3.15	21	1.575	4.73
3.15	22	1.650	4.80
3.15	23	1.725	4.88
3.15	24	1.800	4.95
3.15	25	1.875	5.03
3.15	26	1.950	5.10
3.15	27	2.025	5.18
3.15	28	2.100	5.25
3.15	29	2.175	5.33
3.15	30	2.250	5.40
3.15	31	2.325	5.48
3.15	32	2.400	5.55
3.15	33	2.475	5.63
3.15	34	2.550	5.70
3.15	35	2.625	5.78
3.15	36	2.700	5.85
3.15	37	2.775	5.93
3.15	38	2.850	6.00
3.15	39	2.925	6.08
3.15	40	3.000	6.15
3.15	41	3.075	6.23
3.15	42	3.150	6.30
3.15	43	3.225	6.38
3.15	44	3.330	6.45
3.15	45	3.375	6.53
3.15	46	3.450	6.60
3.15	47	3.525	6.67
3.15	48	3.600	6.75
3.15	49	3.675	6.83
3.15	50	3.750	6.90

Estimated Stockpile Cost	Distance in Kilcmeters	Transportation Cost	Total Delivery Cost
3.15	51	3.825	6.98
3.15	52	3.900	7.05
3.15	53	3.975	7.13
3.15	54	4.050	7.20
3.15	55	4.125	7.28
3.15	56	4.200	7.35
3.15	57	4.275	7.43
3.15	58	4.350	7.50
3.15	59	4.425	7.58
3.15	60	4.500	7.65
3.15	61	4.575	7.73
3.15	62	4.650	7.80
3.15	63	4.725	7.88
3.15	64	4.800	7.95
3.15	65	4.875	8.03
3.15	66	4.950	8.10
3.15	67	5.025	8.18
3.15	68	5.100	8.25
3.15	69	5.175	8.33
3.15	70	5.250	8.40
3.15	71	5.325	8.48
3.15	72	5.400	8.55
3.15	73	5.475	8.63
3.15	74	5.550	8.70
3.15	75	5.625	8.78
3.15	76	5.700	8.85
3.15	77	5.775	8.93
3.15	78	5.850	9.00
3.15	79	5.925	9.08
3.15	80	6.000	9.15
3.15	81	6.075	9.23
3.15	82	6.150	9.30
3.15	83	6.225	9.38
3.15	84	6.300	9.45
3.15	85	6.375	9.53
3.15	86	6.450	9.60
3.15	87	6.525	9.68
3.15	88	6.600	9.75
3.15	89	6.675	9.83
3.15	90	6.750	9.90
3.15	91	6.825	9.98
3.15	92	6.900	10.05
3.15	93	6.975	10.13
3.15	94	7.050	10.20
3.15	95	7.125	10.28
3.15	96	7.200	10.35
3.15	97	7.275	10.43
3.15	98	7.350	10.50
3.15	99	7.425	10.58
3.15	100	7.500	10.65

APPENDIX III

ESTIMATED DELIVERED PRICE OF CRUSHED STONE TO WINNIPEG BETWEEN 1981 AND 1996

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 1

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	4,620,770	5,397,370	3,844,170
1982	4,737,260	5,513,860	3,960,660
1983	4,853,750	5,630,350	4,077,150
1984	4,978,006	5,762,372	4,201,406
1985	5,098,379	5,874,979	4,321,779
1986	5 222,635	5,893,335	4,446,035
1987	5,242,050	6,018,650	4,465,450
1988	5,261,465	6,038,065	4,484,865
1989	5,292,529	6,069,129	4,514,870
1990	5,319,710	6,096,310	4,543,110
1991	5,354,657	6,131,257	4,578,057
1992	5,482 796	5,259,396	4,706,196
1993	5,618,701	6,395,301	4,842,101
1994	5,750,723	6,527,323	4,974,123
1995	5,890,511	6,667,111	5,113,911
1996	6,045,831	6,822,431	5,269,231
TOTAL	84,769,773	97,097,239	72,343,114

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 2

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	5,602,520	6,544,120	4,660,920
1982	5,743,760	6,685,360	4,802,160
1983	5,885,000	6,826,600	4,943,400
1984	6,035,656	6,986,672	5,094,056
1985	6,181,604	7,123,204	5,240,004
1986	6,332,260	7,273,860	5,390,660
1987	6,355,800	7,297,400	5,414,200
1988	6,379,340	7,320,940	5,437,740
1989	6,417,004	7,358,604	5,474,120
1990	6,449,960	7,391,560	5,508,350
1991	6,492,332	7,433,932	5,550,732
1992	6,647,696	7,589,296	5,706,096
1993	6,812,476	7,754,076	5,870,876
1994	6,972,548	7,914,148	6,030,948
1995	7,142,036	8,083,636	6,200,436
1996	7,330,356	8,271,956	6,388,756
TOTAL	102,780,336	116,855,364	87,713,464

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 3

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	5,995,220	7,002,820	4,987,620
1982	6,146,360	7,153,960	5,138,760
1983	6,297,500	7,305,100	5,289,900
1984	6,458,716	7,476,392	5,451,116
1985	6,615,894	7,622,494	5,607,294
1986	6,776,110	7,703,710	5,768,510
1987	6,801,300	7,808,900	5,793,700
1988	6,826,490	7,834,090	5,818,890
1989	6,866,794	7,874,394	5,857,820
1990	6,902,060	7,909,660	5,894,460
1991	6,947,402	7,955,002	5,939,802
1992	7,113,656	8,121,256	6,106,056
1993	7.289,986	8,297,586	6,282,386
1994	7,461,278	8,468,878	6,453,678
1995	7,642,646	8,650,246	6,635,046
1996	7,844,166	8,851,766	6,836,566
TOTAL	102,780,336	126,116,254	93,861,604

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 4

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	6,479,550	7,568,550	5,390,550
1982	6,642,900	7,731,900	5,553,900
1983	6,806,250	7,895,250	5,717,250
1984	6,980,490	8,080,380	5,891,490
1985	7,149,285	8,238,285	6,060,285
1986	7,323,525	8,412,525	6,234,525
1987	7,350,750	8,439,750	6,261,750
1988	7,377,975	8,466,975	6,288,975
1989	7,421,535	8,510,535	6,331,050
1990	7,459,650	8,548,650	6,370,650
1991	7,508,655	8,597,655	6,419,655
1992	7,688,340	8,777,340	6,599,340
1993	7,878,915	8,967,915	6,789,915
1994	8,064,045	9,153,045	6,975,045
1995	8,260,065	9,349,065	7,181,065
1996	8,477,865	9,566,865	7,388,865
TOTAL	118,869,795	136,304,685	101,525,985

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 5

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	6,976,970	8,149,510	5,804,370
1982	7,152,860	8,325,460	5,980,260
1983	7,328,750	8,501,350	6,156,150
1984	7,516,366	8,700,692	6,343,766
1985	7,698,119	8,870,719	6,525,519
1986	7,885,735	9,058,335	6,713,135
1987	7,915,050	9,087,650	6,742,450
1988	7,944,365	9,116,965	6,771,765
1989	7,991,269	9,163,869	6,817,070
1990	8,032,310	9,204,910	6,859,710
1991	8,085,077	9,257,677	6,912,477
1992	8,278,556	9,451,156	7,105,956
1993	8,483,761	9,656,361	7,311,161
1994	8,683,103	9,855,703	7,510,503
1995	8,894,171	10,066,771	7,721,571
1996	9,128,691	10,301,291	7,956,091
TOTAL	127,995,153	146,768,479	109,231,954

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 6

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	7,264,950	8,485,950	6,043,950
1982	7,448,100	8,669,100	6,227,100
1983	7,631,250	8,852,250	6,410,250
1984	7,826,610	9,059,820	6,605,610
1985	8,015,865	9,236,865	6,794,865
1986	8,211,225	9,432,225	6,990,225
1987	8,241,750	9,462,750	7,020,750
1988	8,272,275	9,493,275	7,051,275
1989	8,321,115	9,542,115	7,098,450
1990	8,363,850	9,584,850	7,142,850
1991	8,418,795	9,639,795	7,197,795
1992	8,620,260	9,841,260	7,399,260
1993	8,833,935	10,054,935	7,612,935
1994	9,041,505	10,262,505	7,820,505
1995	9,261,285	10,482,285	8,080,285
1996	9,505,485	10,726,485	8,284,485
TOTAL	133,278,255	152,826,465	113,740,590

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 7

	BASE FORECAST	ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	8,246,700	9,632,700	6,860,700
1982	8,454,600	9,840,600	7,068,600
1983	8,662,500	10,048,500	7,276,500
1984	8,884,260	10,284,120	7,498,260
1985	9,099,090	10,485,090	7,713,090
1986	9,320,850	10,706,850	7,934,850
1987	9,355,500	10,741,500	7,969,500
1988	9,390,150	10,776,150	8,004,150
1989	9,445,590	10,831,590	8,057,700
1990	9,494,100	10,880,100	8,109,100
1991	9,556,470	10,942,470	8,170,470
1992	9,785,160	11,171,160	8,399,160
1993	10,027,710	11,413,710	8,641,710
1994	10,263,330	11,649,330	8,877,330
1995	10,512,810	11,898,810	9,126,810
1996	10,790,010	12,176,010	9,404,010
TOTAL	151,288,830	173,409,390	129,110,940

ESTIMATED DELIVERED PRICE FOR CRUSHED STONE IN WINNIPEG REGION

1981 - 1996

ZONE 8

BASE FORECAST		ALTERNATE FORECAST A	ALTERNATE FORECAST B
YEAR	DELIVERED PRICE	DELIVERED PRICE	DELIVERED PRICE
1981	11,388,300	13,302,300	9,474,300
1982	11,675,400	13,589,400	9,761,400
1983	11,962,500	13,876,500	10,048,500
1984	12,268,740	14,201,880	10,354,740
1985	12,565,410	14,479,410	10,651,410
1986	12,871,650	14,785,650	10,957,650
1987	12,919,500	14,833,500	11,005,500
1988	12,967,350	14,881,350	11,053,350
1989	13,043,910	14,957,910	11,127,300
1990	13,110,900	15,024,900	11,196,900
1991	13,197,030	15,111,030	11,283,030
1992	13,512,840	15,426,840	11,598,840
1993	13,847,790	15,761,790	11,933,790
1994	14,173,170	16,087,170	12,259,270
1995	14,517,690	16,431,690	12,603,690
1996	14,900,490	16,814,490	12,986,490
TOTAL	208,922,670	239,565,810	178,296,060

APPENDIX IV

POTENTIAL DEPOSITS OF CRUSHED STONE
IN THE WINNIPEG REGION