

AGGREGATE RESOURCES, LAND USE AND POLICY ON THE LOWER MAINLAND OF
BRITISH COLUMBIA

by,

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ABSTRACT

This thesis studies the aggregate industry of the Lower Mainland of British Columbia. It updates previous market and industry studies by C.D. Taylor (Simon Fraser University, 1989) and D. Smith (Thurber Consultants, 1989). Aggregate recycling in the Lower Mainland is also examined. Land use issues and legislation pertaining to the sand and gravel industry is also discussed as is a detailed analysis and legal history of soil removal bylaws in the region.

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1. INTRODUCTION

This thesis seeks to convey to the reader an appreciation of the value of sand and gravel resources to the Lower Mainland of British Columbia. Despite an abundance of sand and gravel throughout the Lower Mainland, only a fraction of the total amount can be considered economic. This is demonstrated through a review of the processes involved in the formation of sand and gravel deposits. In addition, aggregate material quality further limits the available resource. An aggregate with unique properties for use in a specific application can be a rare and relatively valuable commodity. Aggregate material properties are examined as are the material requirements of aggregate end use applications. The aggregate market for the Lower Mainland of British Columbia is examined with respect to supply and demand and includes an analysis of recycled aggregate and its potential.

Aggregate is a fundamental component of construction. As the population of the Lower Mainland of British Columbia grows, and extends into the Fraser Valley, considerable quantities of aggregate are required for roads, housing, and associated infrastructure. Local topography and glacial events combined to give the Lower Mainland an extensive supply of sand and gravel. Numerous areas contain aggregate resources of good economic potential. The rapid expansion of the population, however, threatens the supply of aggregate not only by consumption, but by the sterilization of areas containing proven and potential resources. Pressure is brought to bear by local communities to shut down existing operations prior to the end of the economic life of the resource. Land with good

aggregate potential is developed for other more politically popular purposes. Other aggregate resources are made inaccessible by the Agricultural Land Reserve.

A number of public benefits are generated by the production of aggregate. The sterilization of a resource, or the premature closure of a pit results causes these benefits to be forgone. Matysek (1995) notes that 4000-5000 people are directly employed in the aggregate industry in British Columbia. Including transportation, the market value of aggregate production in B.C. is estimated to be \$370 million (Smith, 1990). Indirectly, many other people such as those in the construction industry enjoy the benefits from aggregate production. The B.C. Road Builders and Heavy Construction Association estimated the value of its members' work to be about \$500 million annually (D. Smith, 1990). The public also benefits from the production of aggregate through resource rents paid by aggregate operations to various levels of government. In 1986, the Ministry of Crown Lands royalty, generated approximately \$1 million of which \$550,000 was derived from the Lower Mainland (Smith, 1990). This represents only one of a number of taxes paid to municipal, provincial and federal governments by aggregate producers which, theoretically, benefits the public.

Despite the value of aggregate and its fundamental importance, no individual government agency is responsible for the administration and development of aggregate resources. Numerous government bodies claim benefits from aggregate development in the form of regulatory fees and other royalties yet none claim any

responsibility to ensure the orderly development or long term supply of the resource. In other instances parochial interests view aggregate operations as a nuisance and ban development. Without an advocate in government there can be no assurance of responsible management of a valuable public resource.

The state of California is an example of an area where predicted shortages of aggregate has led to specific government action to identify and preserve resources. The province of Ontario has tried to strategically develop aggregate resources through land use planning since the early 1970s. In both instances, sequential land use, where aggregate extraction is only the first step in the land use process, has been demonstrated to be a method by which aggregate resources can be developed.

In British Columbia, poorly defined property rights have led to conflicts over land use and the right to extract benefits. Legal challenges to the soil removal by-laws of the Lower Mainland provide an example of how municipalities utilized their right to regulate excavations within their boundaries, to create a tool for land use planning and the generation of revenue.

In this text, after having defined aggregates and their geological sources, they are situated in the general framework of B.C.. To do this, the Lower Mainland is used to illustrate economic characteristics such as supply, demand, price, transportation, and recycling. It is used to analyze the legislative procedures that regulate the

permitting and commercialization of aggregates. Suggestions of how the management system can be improved are provided.

2. AGGREGATE SOURCES

Aggregate may be sourced from either sand and gravel or solid stone deposits. In the case of sand and gravel, the raw material may be either used in its natural state or further processed by crushing, screening or washing. Gravel extracted in its natural state is the product of erosion and therefore contains rounded particles with smooth edges. Stone deposits are mined by drilling and blasting. The material is then crushed and screened to a desired size. The end product tends to be more uniform than natural gravel with more angular shapes and sharp edges.

Although sand and gravel accumulations are relatively common, economic, exploitable sand and gravel deposits are not. Economic sand and gravel deposits must be well sorted and free of deleterious materials. This requires a very specific pattern of erosion and deposition. The source rock from which the sediments are eroded must be competent and free of reactive, soft minerals. Deposits must be conveniently located to their market. Unfortunately as suitable aggregate material provides excellent drainage for housing development, conveniently located deposits are rapidly sterilized by urban growth. The depositional environment suitable for economic sand and gravel deposits also often provides ideal agricultural land. These areas are reserved for agricultural purposes (in the Agricultural Land Reserve) and are difficult to develop for aggregate.

2.1 SAND AND GRAVEL SOURCES

Sand and gravel are formed by the erosion of solid rock and the subsequent transportation, abrasion and deposition of the particles. The mechanisms of transportation and deposition are by the actions of ice, water or wind.

2.1.1 Glacial Deposits

Many of the economic sand and gravel deposits in North America (particularly in the northern United States and Canada) are the result of alpine or continental glaciation.

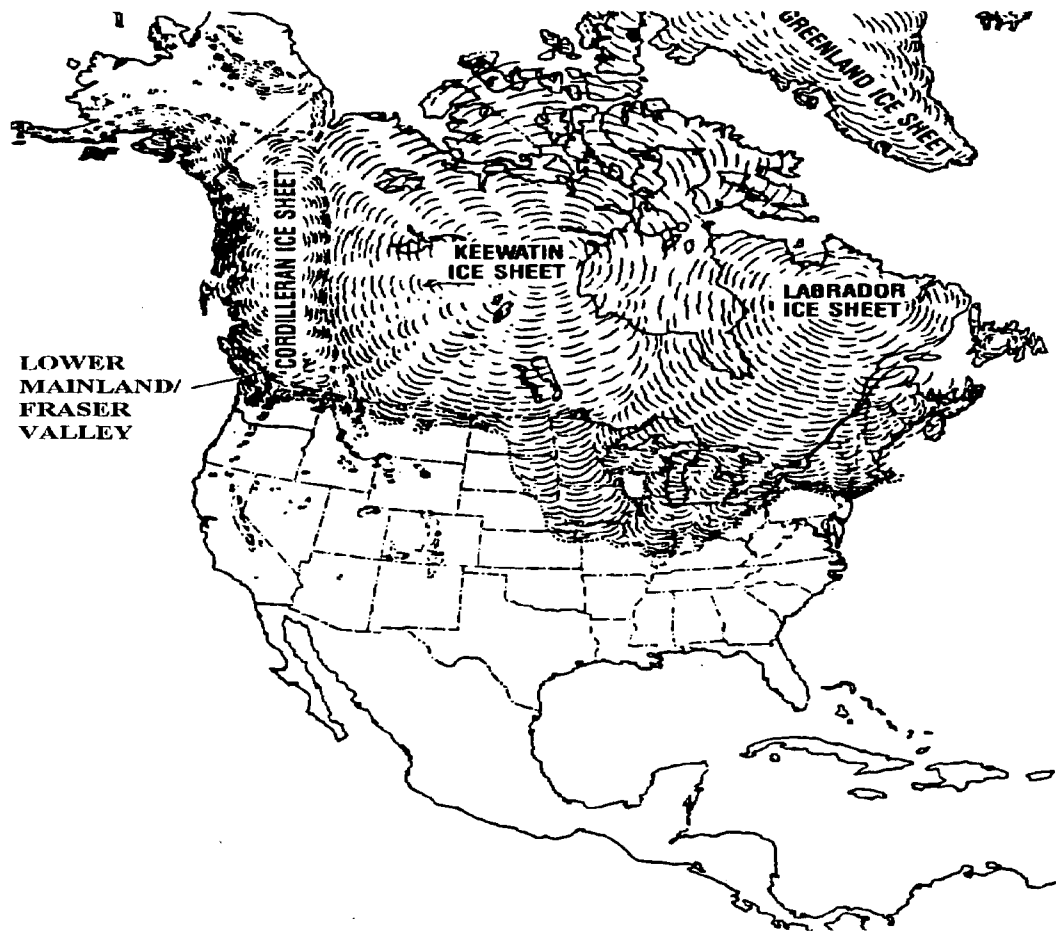


Figure 2-1: Extent of Continental Glaciation
(adapted from the Aggregate Handbook, 1991)

The quality and type of sand and gravel deposited by a glacier depends largely on the method by which the original rock was eroded, transported and deposited. This in turn is dependent on the movement mechanism employed by the eroding glacier.

2.1.1.1 Glacial Movement

A glacier moves in response to gravity and as a result of the great mass of ice accumulated within the glacier. The mechanisms by which this movement takes place are caused by the unique properties of ice when under high pressures (Kehew, 1988). The first movement mechanism is a result of the visco-plastic properties of ice when subject to pressures greater than 100 kPa. When sufficient pressure is generated, ice near the bed/glacier interface acts as a visco-plastic fluid and deforms plastically. The movement of ice at the bed/glacier interface is restricted by material from the bed which limits movement. As the distance from the bed increases however, less resistance is felt which allows the ice to flow more rapidly. The velocity of flow within the ice reaches a maximum, and as the distance increases above the ice/bed interface a corresponding decrease in the overlying ice mass causes the pressure to drop below 100 kPa. Below this pressure the ice ceases to flow plastically. The result is that cracks (crevasses) appear in the upper regions of the glacier perpendicular to the direction of movement.

The second movement mechanism is the result of a thin, lubricating layer of water between the glacier and the bed (Kehew, 1988). The water layer can be caused by: (1) the insulating ability of the glacier which traps geothermal heat and partially melts the glacier; (2) the tendency of the freezing point of water to drop under

high pressure. The pressure of the glacier causes the water at the interface to remain in liquid form; and (3) movement of the glacier along the rock bed creates friction and therefore heat which can melt enough ice to provide a lubricating layer.

Glaciers can therefore be categorized by their movement mechanism: cold based (in which no water is present beneath the glacier); and wet based (in which water contributes to movement). Cold based glaciers are unable to generate sufficient pressure to reduce their basal freezing point and so remain frozen to their beds. Wet based glaciers may move on a layer of water above their beds. Typically basal sliding comprises between 10-25% of the total velocity of a wet based glacier (the balance being visco-plastic flow). Glaciers intermediate to these two movement mechanisms are common with some regions wet based and others cold based. Often glaciers are frozen at their terminus but wet based beneath their interior.

2.1.1.2 Erosion

Erosion and the ultimate deposition of sand and gravel is the result of glacial movement. Although the quantity and types of material collected in glacial erosion is a result of many complex factors, the methods by which the material is collected are few and well understood. Wet based glaciers can often be detected by the striations or grooves left in the bedrock following the glaciers movement. This is an indication of *abrasion*. Abrasion is an erosional process in which collected materials within the glacier are dragged along the bedrock as the glacier moves. Striations can range in size from small scratches to gouges of 1 meter in depth and width that can be traced for kilometers. In the context of sand and gravel deposits,

the abrasion process acts to break up and abrade large boulders collected by the glacier into finer particles. Abrasion does not occur as a result of cold based movement.

Large rock particles are collected by an erosional process known as *plucking*.

When glacial movement is impeded by an obstacle, pressure increases on the up-glacier side of the obstacle as the ice contracts. This additional pressure lowers the melting temperature of the ice, causing additional melting on the up-glacier side of the obstacle. The water then flows around the obstacle and into any cracks within the obstacle. It then re-freezes as a result of the reduction in pressure beyond the up-glacier face of the obstacle. This weakens the rock-mass and allows rock fragments to be broken off by glacial movement beyond the face of the obstacle.

Large scale erosion takes place due to *ice thrusting* at the margin of a glacier, particularly if the margins are frozen to their beds. Rock is sheared off below the bed and carried up into the ice along shear planes that develop at glacial margins from the visco-plastic flow regime common to cold based glacial movement. This erosional process can pick up slabs tens of meters thick and kilometers in length.

2.1.1.3 Deposition

Deposition of sand and gravel from a glacier can occur in a number of ways.

Broadly speaking however, these methods of deposition can be broken down into two categories: material deposited directly from ice, and material deposited by water flowing from the glacier. *Till*, or material deposited directly from ice, is not

subject to any sorting mechanism and therefore contains material sizes ranging from silt and clay to large boulders. As a result these deposits tend to be uneconomic. *Basal till* is material which is removed by friction from the lower layers of wet based, sliding glaciers. *Ablation till* results from debris accumulated at the glacier surface by thrusting or upward trending glacial flow patterns. As the glacier retreats, this accumulated material is deposited as the ice melts away beneath.

During high summer temperatures or during glacial retreat, water forms from glacial melting forming proglacial lakes at the terminus and streams within and below the glacier. Water flowing from ice in glaciers can act to sort eroded material, and deposits the sand and gravel according to size.

Ice-contact stratified drift deposits are made up of material stratified and deposited by meltwater in contact with ice. Some land forms which can result in economic sand and gravel resources are:

- *Eskers*: long sinuous land forms that were the result of stream channels formed under or on ice sheets. Eskers can range in size from 300 feet to 300 miles in length and can reach 600 feet in height. Although the contained material can be poorly sorted, eskers can often be economic sources of sand and gravel.
- *Kames*: irregular accumulations of sand and gravel formed by water running alongside, within, or on ice. A kame may form a shoulder along a valley in which the ice lay, or may form a hill where sand and gravel happened to accumulate within the ice.

Glacial outwash deposits are coarse sediments deposited by meltwater in outwash plains or valley trains. In flat areas, outwash material spreads to form outwash plains covered with a thin layer of sand and gravel. In valleys, or major stream channels that carried glacial meltwater, thick beds of coarse material are often found that can represent significant, economic sand and gravel deposits.

Glacial lacustrine sediments, or deposits of glacial lakes, contain primarily fine silts however significant gravel deposits can accumulate in deltas and fans associated with the lake.

Moraines formed by either continental or valley glaciation are also good sources of sand and gravel (Aggregate Handbook, 1991). Continental terminal moraines were formed at the limit of glacial advance and are deposited as the glacier retreats.

Alpine glaciers form smaller terminal and lateral moraines which tend to be bouldery and poorly sorted. Continental terminal moraines however are often major economic sources of aggregate material.

2.1.2 Marine Deposits

Water transported deposits are formed where a change in the transportation capacity of a body of water causes heavier material to drop out of the flow. As the carrying capacity of all but the strongest flows does not come anywhere near the capacity required to carry substantial quantities of gravel, these deposits are primarily made up of sand and silt. Stream channels with sufficient energy to

transport gravel tend to form sand and gravel deposits in deltas where the streams enter larger bodies of water. If strong tidal action is present, sand and gravel may be transported and concentrated by tidal action in beach and bar forms. In *lacustrine* (lake) environments where no tidal action serves to redistribute sand and gravel, deposits remain concentrated in deltas at stream mouths where the material can be well stratified.

Fluvial (stream) environments are commonly of high enough energy to transport sand and gravel and will form deposits on stream and river beds, and banks; wherever the energy becomes insufficient to carry the material. In arid regions, economic sand and gravel deposits are often found in alluvial fans. Intermittent high energy water flows concentrate alluvium where the streams or canyons widens.

2.1.3 Wind Blown (Eolian) Deposits

Eolian deposits consist of materials of too fine a texture to represent potential aggregate deposits. They will therefore not be discussed.

2.2 STONE DEPOSITS

Stone deposits can be classified into three types: sedimentary, igneous, and metamorphic.

2.2.1 Sedimentary

Sedimentary rocks are formed by the consolidation of sediments by chemical, biochemical, or mechanical processes. Limestone and dolomite are chemically or biochemically consolidated sediments of the shells of marine animals and plants. These rocks make up a large proportion (71%) of crushed stone produced in the United States (Langer and Glanzman, 1993). Of other sedimentary rocks, only a very hard, dense sandstone is suitable for a source of crushed rock, and then only if no other source of aggregate is available.

2.2.2 Igneous

Igneous rocks are formed by the solidification of magma. Intrusive igneous rocks harden at depth and tend to have a coarse mineral structure as a result of their slower rate of cooling. Extrusive rocks cooled quickly at or near the earth's surface and therefore tend to have a more fine grained texture.

Of the igneous rocks, granite and diabase (known as traprock) make up 14% and 8% (respectively) of crushed stone production in the United States (Langer and Glanzman, 1993). Although granite describes a very specific rock, in the aggregate industry, granite is a catch-all term for coarse grained, light coloured, igneous, intrusive rock such as syenite, and diorite. In some cases it refers to metamorphic equivalents such as syenite gneiss. Diabase or traprock is primarily basalt or gabbro, both fine grained, dark rocks.

2.2.3 Metamorphic

Metamorphic rocks are formed when existing rocks are subject to sufficiently high temperatures and pressures. These conditions can cause minerals within the rock to recrystallize into new minerals and form new rocks. Marble, gneiss and quartzite are the most common metamorphic rock types which are considered suitable for aggregate production. Together they accounted for approximately 7% of crushed stone production in the United States (Langer and Glanzman, 1993).

3. AGGREGATE PROPERTIES

Aggregate use applications require specific aggregate characteristics which can vary from one application to another. What may be a desirable characteristic of an aggregate in Portland cement concrete (pcc) may be an undesirable or unimportant feature of a good road base aggregate. A list of physical, chemical, and mechanical qualities is used to rate aggregate particles. The aggregate material can then be evaluated in the context of each specific end use.

Although there are many different criteria on which aggregate materials can be judged, Marek (1991), and Mielenz (1966) provide descriptions of fundamental aggregate evaluation which are summarized in the following sections.

3.1 PHYSICAL PROPERTIES

Physical properties provide descriptions of the fundamental aspects of an aggregate particle that relate to a particle's length, mass and appearance. Not all properties are critical to performance in all applications.

Particle Shape: Particles can be described as being cubical, blade, disk, or rod shaped. Particle edges can be rounded or angular. Generally the most stability is provided by cubic, angular particles. This shape allows particles to interlock with one another, an important characteristic in applications such as in unbound road base or in asphaltic surfaces. In pcc, shape is less important as the water/cement

ratio can be adjusted to provide strength. Angular particles provide better skid resistance in road surfaces but increase rolling resistance and tire wear.

Maximum Particle Size: Maximum particle size refers to the largest mesh opening size through which 100% of the material will pass. Material in a road surface with particles larger than 1/2 inch will decrease the incidence of skidding, particularly for vehicles traveling at high speeds. Noise, rolling resistance and tire wear are all increased as a result of the presence of +1/2 inch material in a road surface. Larger particle sizes also increase the difficulty of handling and applying the aggregate material.

Surface Texture: Surface texture refers to the smoothness or roughness of a particle's surface. Rough particle surfaces are generally preferable although not essential in most applications. The strength of asphalt is increased by rough material. Particle roughness allows for better unbound aggregate stability in road base applications by increasing the interparticle friction thereby allowing the particles to interlock with more strength. Rough particles in a road surface increase friction coefficient of tire to road surface contact. In pcc applications particle roughness is less important as the overall strength of the cement is adjusted through the water/cement ratio.

Pore Structure: Pore structure describes the void space or cavities within the aggregate particles. Impermeable pores are isolated, enclosed cavities within the particle, while permeable cavities are open to the surface of the particle and may

interconnect with other pores. Aggregate particles with a large amount of permeable, interconnected pores are undesirable, as the end product will be highly susceptible to moisture related deterioration (such as freeze/thaw and wetting/drying). In addition, greater amounts of binder will be consumed in the void spaces adding to the cost. Conversely, surface pores can be beneficial in adding to the material roughness. Moisture absorbed into permeable material in pcc applications can act to improve curing conditions.

Absorption: Absorption describes the ability of an aggregate material to absorb water. This can range from 0% to 30% of the dry aggregate weight. High absorption can increase the rate of particle deterioration and add to costs due to increased binder/water requirements (as described in the section on aggregate pore structure). Lower absorption is preferable with a rating of approximately 1% generally being considered acceptable for most applications (Marek, 1991).

Porosity: Porosity represents the amount of void space within a material. Porosity influences material strength, elasticity, absorption, permeability, durability, and density. Igneous and metamorphic rocks generally have a lower permeability and greater density than sedimentary rocks. This is primarily due to their lower porosity. The desirability of a porous rock hinges on the interconnectedness or permeability of the rock. Porous but impermeable rocks can be of use particularly in applications where a light weight aggregate is required.

Permeability: Permeability relates to the ease with which water may move through the rock. High permeability is an undesirable characteristic in aggregate particles.

Particle Grading: Particle grading describes the distribution of sizes of particles in a volume of aggregate. A well graded mixture would possess a representation of a wide variety of sizes while a poorly graded mixture would possess only one size of particle. Well graded aggregate tends to increase the strength and workability in concrete applications.

Thermal Volume Change: This characteristic describes the change in particle dimensions in response to temperature variations. As particles may expand at different rates in different directions, a volumetric expansion coefficient is used. An even rate of expansion at all temperatures and in all directions is a characteristic of good aggregate material. In pcc applications an aggregate's thermal expansion should closely match that of the cement. Otherwise a less rigid binder should be used.

Thermal Conductivity: This characteristic describes the ability of an aggregate particle to transmit heat. A low thermal conductivity reduces frost penetration while a high conductivity resists the build up of stress within the pavement structure due to temperature differentials.

Integrity During Heating: This describes an aggregate particles ability to maintain its valuable qualities during heating. This characteristic is primarily of interest in

hot-mix asphalt applications in which the aggregate is heated to temperatures ranging from 175 to 200 C.

Electrical Conductivity: Electrical conductivity, the degree to which an aggregate can transmit electricity is of particular importance in pavement surface applications. Vehicles moving on a pavement create a static charge by their movement as well as through the friction between the tires and the road. The aggregate should conduct the electricity through the surface and prevent any static build up on the road surface.

Visual Characteristics: Reflection, glare, and colour are all important visual characteristics which are considered when determining the materials acceptability. Reflection is defined as the returning of light waves by the material toward the light source. A high reflectivity allows a road surface to be more easily defined by a driver both in light and in darkness. Glare defines a reflection of a strong, dazzling light from a surface. While a road surface should have high reflectivity, it should not produce glare conditions. Aggregate colour is considered to avoid highly contrasting (i.e. black and white) particles in a road surface which may be distracting and contribute to driver fatigue. In structural applications, colour may be considered for aesthetic purposes.

Wetting and Drying Characteristics: Wetting and drying can cause aggregate material to swell and contract. Over many wetting/drying cycles the material may begin to deteriorate. Consequently the resistance is evaluated, along with the overall volumetric change in response to wetting/drying cycles. Aggregate with

less resistance to wetting/drying may be used in applications where it is sealed with an impervious binding agent such as asphalt. Unbound road base should exhibit both a strong resistance and little volume change in response to fluctuations in surrounding moisture.

Freeze/Thaw Resistance: Moisture present within aggregate particles, when frozen, can expand to fracture the particle. Aggregate material to be used in areas where it will be subject to freezing temperatures must be capable of withstanding these conditions. Freeze/thaw resistance is influenced by pore size, volume, and pore accessibility within the particle.

Deleterious Substances: Aggregate materials must have minimal amounts of deleterious substances such as: soft and/or weak materials, reactive materials, organic materials, and clay coatings.

3.2 CHEMICAL PROPERTIES

Chemical properties relate to an aggregate particle's chemical nature and describes the type of transformations the particle may undergo due to: reactions within the particle resulting from the particle's internal chemical composition , or; chemical reactions brought about by external chemical processes.

Solubility: Solubility of aggregate particles addresses the tendency of a substance in the aggregate particle to dissolve in the presence of moisture. Limestone and other carbonate rocks will dissolve when exposed to slightly acidic water.

Slaking: Slaking occurs when water destroys the interparticle attraction in aggregate materials causing the rocks to break apart and crumble. Clay and shale are particularly susceptible to slaking under moist conditions. Their presence considerably detracts from an aggregate's quality.

Base Exchange: Base exchange describes the substitution of cations on the surface of aggregate particles. This exchange may release alkalis from clays adsorbed onto the aggregate. These alkalis may react detrimentally with binding agents used with the aggregate.

Surface Charge: The surface charge on an aggregate particle influences the ability of a binder to adhere to the particle surface.

Coatings: Materials covering the aggregate particles such as salt, dust or clay may be deleterious to the aggregate's end use application. Benign coatings which are firmly affixed may be acceptable.

Chemical Resistance: This describes a material's resistance to deterioration from exposure to any chemical which may be encountered in the aggregate application (i.e. road salt).

Chemical Reactivity: This characteristic examines a material's compatibility with any binder with which it may be mixed. Chemicals contained in either the binder or minerals within the aggregate particle may react adversely with one another.

Oxidation and Hydration Reactivity: Reactions with oxygen (oxidation) can cause particle deterioration and surface staining. Reactions with water (hydration) may cause particles to swell resulting in popouts.

Organic Material Reactivity: The presence of organic material may cause an adverse reaction with the binder.

Chloride Content: Chloride ions exist in varying amounts in aggregate materials. Should this concentration be too large, the chloride ions could contribute to corrosion in iron materials used in association with the aggregate (rebar, structural steel etc.). As corrosion causes an increase in volume of the corroded material, this reaction may increase internal stresses, weakening the structure.

3.3 MECHANICAL PROPERTIES

Mechanical properties describe the physical behavior of an aggregate material when exposed to specific conditions.

Particle Strength: This characteristic concerns the tensile and compressive strength of an aggregate particle. This property can vary quite considerably between particles, particularly in the case of sand and gravel based aggregate.

Mass Stability: This property is related to grading, shape, surface texture and binder properties. Mass stability concerns the ability of an aggregate mass to remain stable under loading.

Wear Resistance: Wear resistance describes a material's ability to resist abrasion. This characteristic is of particular concern in road surface applications. A good material will wear unevenly and resist polishing (a quality dependent on the mineral types present in the particle).

Resistance to Degradation: While wear resistance describes the abrasion of aggregate materials by external objects (tires, shoes, etc.), degradation includes the autogenous abrasion caused by abraded aggregate fragments. As an example, movement within a pavement structure is caused by the loading and unloading forces on the surface and results in aggregate particles abrading in an autogenous manner. In these instances the products of abrasion are not removed but instead remain as a part of the structure. Resistance to degradation concerns a structure's

ability to withstand this action. Other examples of processes which may result in particle degradation are asphalt and concrete mixing, and application, and asphalt compaction.

Particle Shape of Abraded Fragments: Degradation (as described above) may not necessarily be detrimental, depending largely on the shape of the particle fragments. Particles which abrade to jagged fragments may maintain or enhance characteristics such as surface friction, roughness and particle shape. Rounded fragments can result in the reduction of some of these characteristics.

Particle Stress Characteristics: Particle Stiffness, Resilient Modulus, and Particle Strength are all mechanical properties which concern the aggregate particles behavior when subject to stress. Figure 3.1 illustrates a cube of rock loaded vertically by a stress, σ_z .

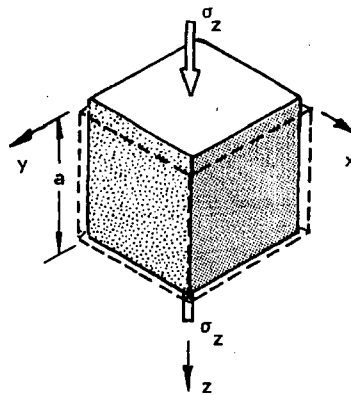


Figure 3-1: Illustration of Rock Behavior Under Stress
(Hoek and Brown, 1980)

If the rock is free to expand laterally and behaves elastically (as most hard rocks do at stress levels below their compressive strengths (Hoek and Brown, 1980)), the rock will decrease in vertical extent by w and increase in lateral dimensions by an amount $u = v$. The strain is given by the deformation per unit length: vertically, $\epsilon_z = \sigma_z / E$; and laterally, $\epsilon_x = -u/a$. The lateral deformation is related to the vertical stress by $\epsilon_x = -\nu \sigma_z / E$. Young's Modulus is represented by E and ν represents Poisson's Ratio. Both of these are elastic constants which describe a rock's behavior under stress (Hoek and Brown, 1980).

Particle stiffness reflects an aggregate's resistance to deformation. This characteristic is usually indicated by a high modulus of elasticity (E). Stiff materials, although strong, tend to be brittle. Nevertheless an unyielding, stiff aggregate is desirable in most applications. One exception is in pcc where an overly stiff particle may cause micro-cracking during curing of the mixture or during the plastic shrinkage stage of the hydration process.

The resilient modulus used in the aggregate industry is very similar to Young's Modulus and reflects the resilience of an aggregate material by applying repeated axial loads to a material sample and measuring the recoverable (elastic) strain. The resilient modulus results from the division of the applied repeated axial deviator stress by the recoverable strain.

3.4 ROCK PROPERTIES

Aggregate properties are heavily reliant on their source rock. In the case of crushed rock, the deposit generally consists of only one rock type. Knowledge of the performance characteristics of the source rock allows for an accurate prediction of the performance of the produced aggregate. Sand and gravel deposits are accumulations of durable rock grains and fragments. While sand and gravel sourced aggregate tends to be less uniform in quality, a knowledge of the contained particles will allow for an estimation of aggregate performance. The following table lists various characteristics of common rock types used in aggregate production.

Table 3-1: Typical Physical Properties of Common Aggregate

PROPERTY	GRANITE	LIMESTONE	QUARTZITE	SANDSTONE
Unit Weight (kg/m³)	2595 - 2755	1875-2800	2640-2725	1910-2690
Compressive Strength (MPa)	35-460	18-195	110-310	35-140
Tensile Strength (MPa)	2.9-4.9	2.9-5.9	N.A.	1.0-2.9
Shear Strength (MPa)	25.5-33.1	5.5-24.8	N.A.	2.0-20.6
Modulus of Rupture (MPa)	9.5-38.3	3.4-13.8	N.A.	4.8-15.9
Modulus of Elasticity	31000-60000	29600-60000	N.A.	15900-74500
Water Absorption (% by weight)	0.07-0.30	0.50-24.0	0.10-2.0	2.0-12.0
Avg. Porosity (%)	0.4-3.8	1.1-31.0	1.5-1.9	1.9-27.3
Linear Expansion (*10⁻⁶ in/in/C)	1.8-11.9	0.9-12.2	7.0-13.1	4.3-13.9
Specific Gravity	2.6-2.76	1.88-2.8	2.64-2.72	1.9-2.7

Adapted from The Aggregate Handbook (1991); National Stone Association.

4. AGGREGATE USES

In 1993 sand and gravel in Western Canada (western provinces) was consumed in the following applications (Irvine and Vagt, 1995):

- road bed and surfacing (60%);
- concrete aggregate (13%);
- asphalt aggregate (7%);
- fill material (6%);
- other uses including railroad ballast, ice control, mortar sand, backfill and miscellaneous (14%).

For comparisson, aggregate was consumed in the following applications in 1987 (Vagt, 1988).

- roads (70%)
- concrete (9.9%)
- asphalt (8.2%)
- fill (7.7%)
- other uses (4.2%)

4.1 Road Base Applications and Specifications

Road base applications include the base, sub-base course, and subgrade. The base course supports vehicular loads, provides drainage, resists frost action, and must be suitable for surfacing. Base material calls for highly stable, graded, crushed gravel or stone. The sub-base course performs similar functions to the base course.

Aggregate performance in this layer is less critical so a lower quality aggregate

may be used (Ontario Ministry of Natural Resources, 1992). The subgrade provides the foundation for the road structure. Generally material grading from sand to sand and gravel may be used.

Pavement structures can be divided into two categories, flexible and rigid, depending upon the manner in which the supported load is transferred to the subgrade. Flexible pavements are constructed with thin layers of wearing and binder course over the base and sub-base course which in turn rests upon the compacted sub-grade. Flexible pavements transfer the vehicular load through the surface to the base and sub-base which act to reduce the stress intensity as the load passes through successive layers. To provide this support the base and sub-base must be stable. A lack of lateral stability in these layers results in pavement distress and eventual longitudinal cracking of the surface.

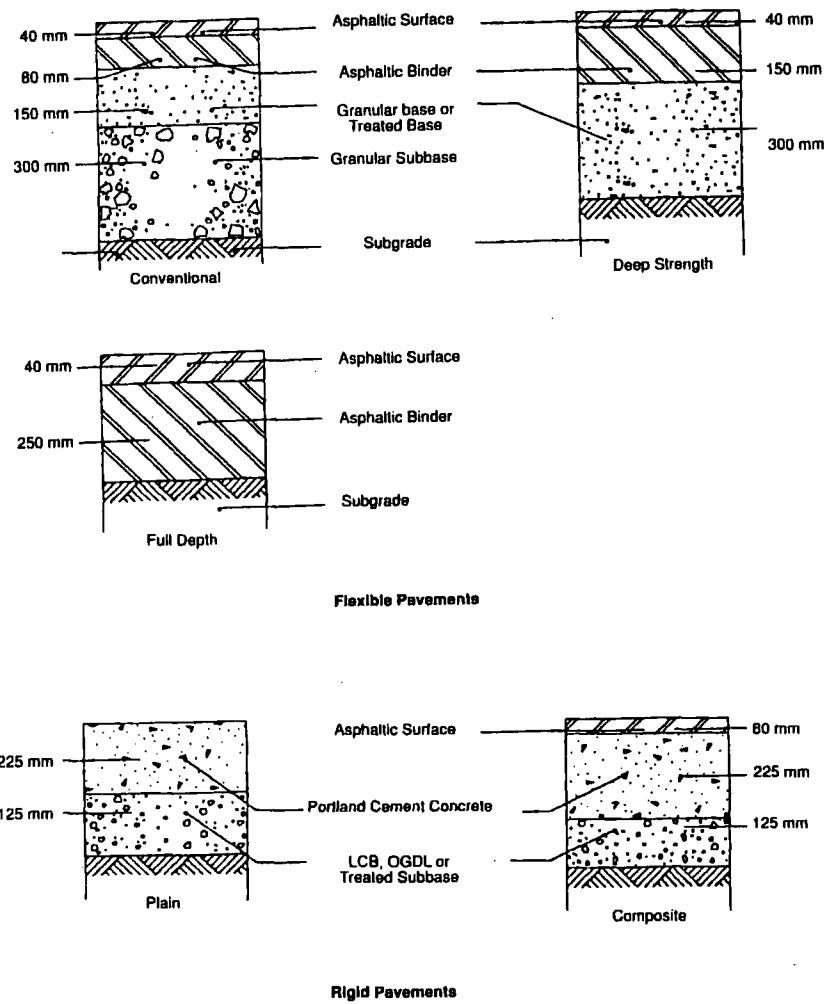


Figure 4-1: Road Type Sections (Ontario Ministry of Natural Resources)

To support vehicular loads, rigid pavements rely on the beam action of a stiff pcc slab. The slab acts to distribute the load to the sub-base layer below. The stiffness of the slab acts to distribute the load evenly through out the sub-base. A thin layer of aggregate base may be added between the pcc surface and the sub-grade to aid in drainage and to minimize pumping. Pumping occurs as a result of a saturated sub-grade layer forming a slurry of fines at its surface. When the pcc surface is loaded the slurry is “pumped” through surface cracks or joints. A sufficiently permeable base will prevent the saturation of the sub-base and, in addition, will protect the surface from frost action in the sub-grade (Marek, 1991). In comparison with flexible pavement structures, in rigid pavements, the load supporting duty of the base and sub-base is secondary to providing drainage.

Although the most noticeable damage caused by frost to roadways is on the road surface, the damage is initiated in the road base and sub-base layers. It is in these areas where frost resistance must be designed into the road structure. Frost damage occurs in two ways. First, ice lenses form in the base or sub-base layers causing the over-lying layers to rise. If the lense is of sufficient size, the road surface may crack. Secondly, during spring thaw as the lense melts, fine, unbound material is washed out of the supporting layers causing the road to settle unevenly (differential settling), again with the potential of causing the road surface to crack. A damaged road surface will allow moisture to penetrate into the road base which will potentially cause larger or more numerous ice lenses to form the following winter.

Frost damage requires (1) a source of moisture, (2) inadequate drainage, and (3) freezing temperatures. While little can be done to avoid freezing temperatures, roads built in areas of high moisture can be designed to minimize frost action. Frost related surface cracking has been found to be almost directly proportional to fines content of the base and sub-base materials (Thompson, 1991). Particularly susceptible to frost damage are roads with sub-bases with a high silt or clay content. Aggregate materials of less than 8% of -74 μ material should not be frost active, however aggregate with a 5 to 6% fines content is preferable (Thompson, 1991). The B.C. MoTH requires that all base and sub-base aggregates be of less than 5% passing -74 μ (Standard Specifications for Highway Construction sections 202.02.02, 202.02.03).

Stability of road base is an important factor road construction particularly in flexible pavement applications. Stability of an unbound base is increased by using aggregate with: (1) angular particle shape, (2) rough surface texture (3) dense grading.

Angular particles interlock with one another more easily and rough particle surfaces inhibit movement. A more stable road base is the result. Equidimensional particle shapes are also preferable due to the strength advantage these shapes enjoy over elongated particles.

While (1) and (2) are readily obtainable through selection of suitable material, achieving a maximum density requires that permeability and load capacity be

reduced. Maximum stability is achieved when the fines content is sufficient to fill the voids between aggregate particles. For this to occur the fines content is typically between 7 to 10% of -74 μ material. As noted, a fines content above 5% may lead to permeability and frost problems in colder climates. Excessive fines also reduce the load carrying capacity of an aggregate base (Marek, 1991). To achieve a compromise between stability and frost resistance, base and sub-base materials may be combined with a binder. The three major material groups of additives are: portland cement; asphalts; and others (flyash/lime, calcium chloride, lignosulphonate, etc.). Cement treatments involve the addition of between 5-14% concrete. Asphalt treated bases contains approximately 3 to 3.5% asphalt and is applied with an asphalt spreader. Flyash/lime and other similar treatments are more common in subgrade treatment where they act to penetrate voids and resist saturation. These solutions greatly increase the road construction costs.

4.1.1 Asphalt

Asphalt is predominantly made up of bitumens which occur in nature or are obtained during petroleum refining. It is used to bind aggregate particles into a plastic, dense material used in applications such as in road surfacing. Asphalt may be applied as a "Hot-Mix" in which the aggregate is dried, heated and mixed with heated asphalt cement. The mixture is then applied and compacted at a temperature of between 125-135 C providing a durable, deformation resistant, fatigue resistant pavement surface.

Asphaltic surfaces are used in both rigid and flexible pavements. These surfaces directly support the vehicular load and must consist of dense, highly stable, durable, materials with good frictional properties.

Flexible pavements contain a binder course of a lower quality Hot-Mix. This layer is critical to the overall pavement structure's strength. It supports the wearing surface loads and distributes it to the base layers below. It must have good elastic stiffness and resist cracking and rutting.

Aggregate comprises 80% of an asphaltic mixture (by weight). As a result the overall quality of the aggregate is reflected in the quality of the asphaltic mixture. Nevertheless, the aggregate must be suited to asphaltic applications. Unsuitable aggregate will be stripped of its asphalt coating, diminishing the asphalt strength and stability. Critical aggregate performance characteristics are: particle shape; strength/grading; and surface qualities including texture, coatings and charge (Marek, 1991).

Asphalt aggregate particles must be angular, equidimensional (preferably) cubical particles. Angular particles tend to interlock and resist interparticle movement better than rounded particles. The overall strength of asphaltic pavements relies in a large part on material stability. Particle interlock can be as important as individual particle strength to the strength of a pavement. Consequently the use of natural (i.e. rounded) materials is very much restricted in asphalt applications. Rounded, natural sand and gravel material should first be crushed before use. If

rounded material must be used, 40% of +5mm material should have at least one fractured face (Marek, 1991). The addition of crushed, fine material to an asphalt mixture greatly increases asphalt stability. Non cubical, long, thin particles, while angular tend to break more easily and are therefore undesirable.

Very little stability in asphalt is provided by the binder. Aggregate in asphalt must have sufficient strength to support vehicle loads, particularly in wearing course applications. Dense grading also assists in providing support. If an aggregate material possessing lower strength must be used, dense gradings may compensate somewhat. Although theoretically the maximum strength is obtained with maximum density, some allowance must be made for penetration of the asphalt binder. In asphalt base course applications, a more open grade is used with fewer fines and larger particles.

The ability of an asphalt cement to bind aggregate is greatly influenced by the surface characteristics of the individual particles. A desirable surface texture is often a compromise between coatability and adhesion. To perform properly an asphalt binder should adequately coat and adhere to each particle. Particles possessing rough surfaces are more difficult to coat but tend to adhere more readily to the asphalt. Any surface coating (such as clay, silt etc.) will diminish the coatability of the particle. In some cases, the coating may react deleteriously with the asphalt mixture. Clay and other coating should be removed by washing at the production site prior to mixing. Limestone and dolomite aggregates are basic and will repel water while granite and quartzite are acidic and will attract it. Overall, a

hydrophobic particle surface is more desirable for its water repellent qualities. In either case the asphalt mixture should be matched to the surface charge of the particle (one can choose between cationic and anionic asphalt mixtures).

4.1.1.1 Tire wear on pcc and asphalt surfaces

Tire wear is substantially increased on pcc surfaces in comparison with tire wear on asphaltic surfaces. Research by the Pirelli-Armstrong Tyre Corporation indicates that tire wear is caused by abrasion which occurs due to uneven, erratic movement of the tire body. Each impact with a pavement joint on a pcc surfaces causes an alteration in tire rotation which causes erratic motion. The resulting abrasion is increased if a tire is bounced off the ground (Anonymous, 1992).

4.1.2 Concrete

Concrete is a composite material consisting of a mixture of water, cement and particles of fine and coarse aggregate. Concrete may be used in roads or as a structural material. As opposed to other aggregate applications, concrete is unique in that the cement used to bind the aggregate provides a significant proportion of the structural strength and stability of the product. Consequently many of characteristics desirable in unbound and asphalt applications are less important in concrete products. Important factors in concrete performance include:

- workability - the material must be placed without segregation or bleeding;
- curing rate - the material must harden within a reasonable time to allow earliest use;

- strength - concrete must develop adequate strength for the application and do so in a timely manner;
- durability - the concrete must withstand the demands of its specific application in addition to environmental stresses (such as freeze thaw cycles, salt exposure, acid rain, etc.);
- volume stability - material volume should remain within limits during curing and service life.

Workability and Curing Rate: These are characteristics which are highly dependent on the water/cement ratio in addition to the quantity and size of aggregate used. As such, the quality of the end product is largely controlled by the mix rather than the particle qualities. While an optimum aggregate can be selected, this can be expensive. It is often more economic to adjust other parameters to compensate for any shortcomings in a lower cost aggregate. Particle shape can have some influence on workability: angular particles require more mortar than do rounded particles to achieve the same workability. As particle interlock is of little importance in concrete, rounded particles are preferable.

Strength: As previously mentioned, concrete derives a significant portion of its strength from the cement binder. In low and medium strength concretes, aggregates are used as filler to reduce the quantity of cement required. The water cement ratio can be altered to increase the product strength. In high strength concrete, however, both a high mortar (cement) strength and a high aggregate strength are required. The particle surface texture can also influence strength. In

low and medium strength concretes, while a rough surface texture will increase the strength of the particle/grout bond, this is not considered essential to product performance. In high strength applications this bonding is essential necessitating the use of particles with rough surfaces.

Durability: Concrete durability is influenced more by the quantity of freeze thaw cycles encountered than by the magnitude of the temperature fluctuations involved. Aggregate resistance to freeze/thaw damage is related to the number and accessibility of pores in the aggregate particles.

Undesirable materials within concrete can significantly harm the strength and durability of concrete. Minerals either more susceptible to weathering or containing chemicals capable of harmfully reacting with the cement, can seriously harm the strength and durability of concrete. Shale, chert, and argillaceous limestone or sandstone can physically harm concrete products. Alkali-silica and alkali-carbonate reactions are potentially harmful aggregate-binder reactions causing expansion within the concrete. Alkali-silica reactions are by far the more common as many acidic, igneous rocks are potentially reactive. Highly reactive aggregate content must be kept below 5% in concrete products (Marek, 1991).

Volume Stability: Computability between binder and aggregate in terms of thermally induced volumetric expansion is essential to concrete strength and durability.

4.2 TESTING AND STANDARDS

To adequately judge aggregate quality, numerous tests have been developed. The Aggregate Handbook lists 70 different aggregate testing procedures recognized by the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO). The BCMoTH employs the following tests on aggregate to be used on Provincially managed road projects (BCMoTH Standard Specifications 202.04.02, 1995):

- BCH I-1, Sieve Analysis of Aggregates;
- BCH I-2, Wash Test of Aggregates;
- BCH I-5, Soundness of Aggregates by use of Magnesium Sulphate;
- BCH I-8, Sand Equivalent;
- BCH I-9, Degradation;
- BCH I-12, Plastic Limit Determination;
- BCH I-13; Fracture Count on Course Aggregate;
- BCH I-17; Petrographic Test.

BCH I-1 and I-2 are a method of size analysis. The material is screened over a number of sieves. Wet screening is employed in the smaller size range to improve screening efficiency. The mass percent of material passing is charted versus the log of the sieve size and a gradation curve is established. Suitable aggregate materials must fall within specific limits with respect to the mass of material in each size range.

BCH I-5 (Soundness) corresponds to the ASTM C 88 Sulphate Soundness test. This test provides a general index of aggregate quality and an estimate of the

material's resistance to weathering. As the precision of the test is poor it should not, in itself, be used as a basis for excluding certain aggregates (Marek, 1991). In this test the specimens are washed, dried and separated into various size classifications. The material is then exposed to a magnesium sulphate solution at a temperature of 25 C for 16 to 18 hours. The material is then briefly allowed to drain before being dried in an oven. This is typically repeated for 5 cycles. The salt solution penetrates pore spaces in the aggregate. When dried, the salts precipitate inside the aggregate and, upon rehydrating, exert internal pressures similar to those caused by freezing water. The material is again sieved and a weighted average loss per size fraction is calculated. The BCMoTH considers a material unsatisfactory if, after 5 cycles, losses exceed 20% for coarse aggregates and 25% for fines.

BCH-I8 (Sand Equivalent Test) is equivalent to ASTM D 2419 and tests the relative proportion of plastic fines and dust to sand size particles in -5 mm material. In this test a specific quantity of fine aggregate is combined with a flocculant in a graduated cylinder. The material is well irrigated to remove particle coatings and allowed to separate. The plastic fines are forced to remain in suspension while the more desirable fine material is allowed to settle. The height of the settled material is then compared to the height of plastic fines and reported as a sand equivalent percentage. This test indicates the relative quantity of undesirable plastic fines in a quantity of fine aggregate. BCMoTH calls for sand equivalent values of not less than:

- 40 for 25 mm and 50 mm base course aggregates;
- 30 for 75 mm base course aggregate;

- 20 for sub base aggregate and surfacing aggregate.

BCH I-9 (Degradation) is known as the Washington State Degradation Test. No ASTM standard exists for this test. The test involves the autogenous abrasion of pre-classified aggregate material immersed in water. The material is abraded for a specific number of cycles and then re-screened. Material passing the screen is weighed and reported as a percentage of the original total material mass. The MoTH standard requires that a maximum degradation factor of 35 is required. The test is reported to be accurate in reproducibility for more competent aggregate. Degradation factors of around 10 are reproduced over several trials to ± 2 . Less competent aggregate produces wildly unpredictable results when the same material is re-tested. As a result the ASTM refused to recognize this test. The BCMoTH is now likely to employ the Micro-Deval test which is widely used in eastern Canada and has been extensively tested in Ontario. Micro-Deval testing involves placing a specific quantity of sized aggregate material (which has been soaked in water for 24 hours) with a volume of water and specific ball charge into a grinding mill and comminuting at 100 rpm for 2 hours. The resulting abraded material passing a given screen size is expressed as percentage of the original material mass. Aggregate having a loss of less than 40% has been found adequate for road base while a loss of less than 10% is preferable for pcc applications.

BCH I-12 (Plastic Limit Determination) corresponds to ASTM D-424. A -0.414 mm sample is used to determine the minimum water content at which a material remains cohesive. An additional test is performed to determine the water content at

which point a substance passes from a plastic to a liquid. The difference between the plastic and liquid limits is termed the plasticity index. The BCMoTH requires a high fines surfacing aggregate to have a maximum plasticity index of 6.

BCH I-13 (Fracture Count) is another non-ASTM recognized test. The BCMoTH requires that coarse aggregate possess a minimum of 50% fracture surfaces.

Aggregate with a lower fracture count must be re-crushed to the next smaller size until it meets the minimum requirement.

BCH I-17 (Petrographic Test) is a subjective analysis of an aggregate's quality and an attempt to quantify its properties. Any aggregate failing BCH I-5, I-8, or I-9 are examined under I-17 to determine the reason for failure. Simple, subjective testing is carried out on the material in the physical, chemical and mechanical categories listed in chapter 2. The aggregate is rated on the percentage of good, fair, poor, and deleterious content. These ratings are then combined to provide an index of petrographic quality. In some cases petrographic examination may reveal that chemical or physical treatment may be possible to upgrade the materials rating.

Los Angeles Degradation Test (ASTM C 131): The Los Angeles Abrasion Test employs a tumbling mill to evaluate a material's quality. The sample is first washed and oven dried. It is then separated into individual size fractions and recombined in size proportions corresponding to a specified grading. The recombined sample is then placed in a tumbling mill with a ball charge and rotated for 500 revolutions.

The material is then sieved dry over a number 12 sieve. The quantity passing this is then measured and listed as “percent loss”. This test, designed in the mid 1920s is decreasing in popularity. The ASTM cautions that this test should only be used to indicate the relative quality of aggregate material from sources having similar mineral composition and can not be used to compare materials of different origin, composition or structure (Marek, 1991).

5. AGGREGATE SOURCES FOR THE LOWER MAINLAND OF BRITISH COLUMBIA

Glacial activity and the resulting sand and gravel deposition in the Fraser Valley and Lower Mainland have been extensively studied and detailed by numerous authors over the past 45 years. Hora and Basham (1980) and Bobrowsky (1995) describe this event with specific reference to the deposition of economic deposits of sand and gravel. Hora and Basham's (1980) geological summary of the local deposits provides a good (if now dated) description of locations and qualities. The study does however note that :

"Gaps exist in our knowledge of the sand and gravel deposits in the region.

The extent of some important deposits, most notably in the Coquitlam valley, is not sufficiently known, and should be defined and the nature of the resources evaluated."

Although the Geological Survey Branch of the BC MoEMPR has proposed a sand and gravel inventory be conducted (1995) which would include current and exhausted pits, potential deposits as well as material quantity and quality, at the time of this thesis the Lower Mainland had not been examined. Some detailed studies have been carried out in specific areas. Thurber Consultants' (Smith and Hungr, 1985) Westwood Plateau Area Escarpment Sand and Gravel Study is one such example. Pit operators too, have extensive local geological knowledge with respect to available tonnage and quality. Unfortunately, little of this knowledge is recorded. The findings of these studies are summarized in the following section.

Sand and gravel resources of the Lower Mainland are believed to have originally have been deposited during various episodes of Wisconsinian (25000 - 10000 years ago) glaciation. Major glaciation/de-glaciation cycles during the quaternary period were accompanied by severe changes in sea level as well as the isostatic depression of the land surface. At times, parts of the Lower Mainland were up to 200m below sea level. In the Fraser Valley, glacial advances resulted in substantial quantities of sand and gravel forming in front of the glacier. Subsequent glacial retreats resulted in further deposition as the ice melted. As the Fraser Valley is contained to the north and south by mountains, the terminus of the ice sheet covering the Fraser Lowlands was periodically in water. Tidal action combined with the varying sea levels and served to widely distribute the sand and gravel throughout the Fraser Valley and Lower Mainland. As a result the Lower Mainland hosts many sand and gravel deposits of up to several meters in thickness at elevations ranging from 0 to 200 meters (Hora and Basham, 1980).

The most important economic deposits associated with the period of Fraser Glaciation are the Sumas, Capilano, Fort Langley, and Vashon sediments. Some of the largest economic accumulations are found in North Vancouver, Langley, Abbotsford, and the Coquitlam Valley and Chilliwack River areas. Beyond the Lower Mainland, large deposits are found near Sechelt and in Jervis Inlet.

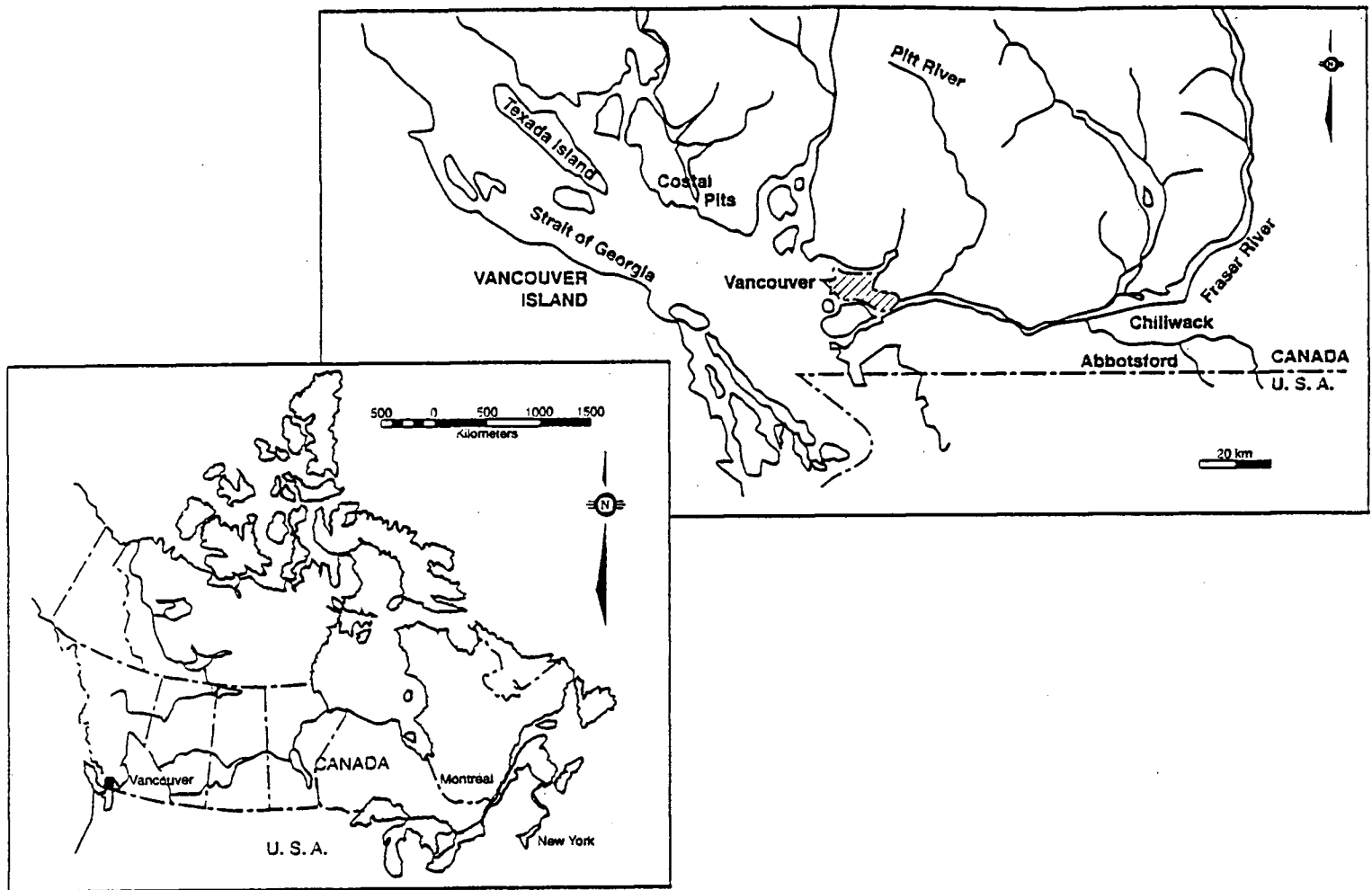


Figure 5-1: The Lower Mainland of British Columbia

Large Capilano deposits located in North Vancouver have been sterilized by urban development. The District of Kent contains some remnants of Sumas sediments. Deposits can range from 10 to 20 meters thick and tend to have a high sand content. The Chilliwack area is located where the Fraser Valley widens into the Fraser Lowlands. This widening lowers the river's carrying capacity and caused the heavier sand and gravel particles to settle. The deposits in this area are Salish, post-glacial, alluvial gravels of between 5 and 10 meters in thickness. Hora and Basham (1980) identified deposits of Sumas Drift of up to 20 meters in thickness in the Chilliwack River Valley and another 50 meter thick deposit (which was at

the time being developed by the MoTH) between Cultus Lake and the Canada-US border. The Abbotsford/Matsqui district contain Sumas Drift deposits and range in thickness from 10 to 50 meters. The deposits are, in some areas, small alluvial fans. The glaciofluvial and ice contact deposits in the Matsqui area are particularly extensive but often extend below the water table which limits their availability for development. Mission contains glaciofluvial and ice-contact deposits of Sumas drift. The deposits are limited in extent but can range up to 50 meters in thickness. As they are often located in steeply sloping terrain, their development as economic aggregate sources can be influenced by overburden removal and slope stability complications. Deposits in the Maple Ridge area include Vashon drift, Sumas, Fort Langley, and Salish formations. Deposits can range in thickness up to 20 meters. Langley contains both Fort Langley and Sumas formations. The Fort Langley deposits are up to 45 meters thick with layers of silt and clay. The Sumas drift deposits can reach 50 meters in thickness and can extend below the water table. The Coquitlam valley deposits are of great economic importance. Gravels can reach 150 meters in thickness and were deposited during several glacial advances and retreats. Quadra, and Highbury deposits are represented in Coquitlam and are overlain by Vashon till. Valuable fossil materials have been found in these sediments. These deposits are contained in steep topography with deep overburden which can complicate extraction. Capilano sediments on the south-western BC coast and on Vancouver Island can reach 65 meters in thickness. Current reserves of these deposits on BC's Sunshine Coast (Sechelt, Jervis Inlet etc.) are believed

to be extensive and will represent a growing proportion of the Lower Mainland aggregate reserve.

5.1 SUPPLY

Supply can be divided into three separate categories: conventional, marine and recycled. In terms of tonnage the final two, marine and recycled aggregate, are of marginal importance.

5.1.1 Conventional Aggregate Sources

The supply of aggregate for the Lower Mainland comes from the following locations (Irvine, 1995):

- coastal pits on tidewater - 8 million tonnes
- north side of the Fraser River - 4 million tonnes
- Matsqui/Abbotsford and Chilliwack - 4 million tonnes
- Fraser River - 4 million tonnes
- Quarries on Texada Island - 1 million tonnes per year
- Imports from the United States - 1 million tonnes per year

Coastal and tidal pits tend to be much larger in size allowing economies of scale.

As many aggregate production centers have moved further up the Fraser Valley away from the core of Vancouver, barged aggregate from areas such as Sechelt and Jervis Inlet has become more competitive. Transportation costs for this product include a 50-150 km barge journey as well as the cost to load and unload the product. The material must then be trucked to the customer's site or transfer depot. Coastal reserves are thought to be extensive. Although some deposits in Howe Sound have been depleted, 50% of the deltaic deposits located in Sechelt and Jervis Inlets have not been explored or developed (Hora, 1995). Crushed stone from Texada Island is also barged to the Lower Mainland. The crushed granite is a

byproduct of a limestone mine. Sand and gravel production north of the Fraser is limited by the amount of overburden and availability of land. Although reserves are extensive, they are often poorly sorted. Production south of the Fraser is diminishing. Most deposits are expected to be exhausted within 5 - 10 years with no new production anticipated (Irvine, 1995). Deposits in this area tend to be flat lying, well sorted and extensive. Most of these deposits outside of city limits are within the Agricultural Land Reserve and therefore off limits to large scale development. Fraser River production is limited by annual replacement of material (see Marine Extraction below). Deposits in the Matsqui/Abbotsford area are considered extensive but limited by quality considerations and land availability.

The exact number of gravel pits in British Columbia is not known. The BC MEMPR estimates that 6000 pits exist in the province of which 2600 are active. The largest producer and consumer of aggregate in the province is the BC MoTH which estimates that they hold tenure (of various forms) over approximately 3000 gravel pits throughout the province (Lee, 1995).

5.1.2 Marine Extraction

Marine dredging of aggregate materials provides an alternative to conventional extraction. In regions of the world where conventional sources have become scarce, marine dredging has become a large source of aggregate. Britain and Japan extract (respectively) 18 million tonnes and 75 million tonnes annually accounting together for 75% of the world's marine production. As land based aggregate resources are exhausted or sterilized on the United States' east coast, the US

Atlantic Continental Shelf (which contains an estimated $2.4 \times 10^{12} \text{ m}^3$ resource) will likely be dredged for its aggregate.

Marine mining would presumably lower the cost of aggregate for areas in close proximity to the operation. Environmentally, marine dredging is more visually appealing to observers than are gravel pits and quarries. The resulting excavation is not as apparent and therefore not as likely to offend the local population. Marine mining also yields very large quantities of material over a very small areas of coastline. Zones of disturbance can therefore be limited.

Although studies have shown marine dredging to have no long term detrimental effects on fish stocks (Hurme and Pullen, 1988; Jokiel, 1989, Oulasvirta and Lehtonen, 1990) dredging does temporarily modify the ecosystem. It can also cause turbidity plumes, navigational hazards and irregular sea beds. Beaches - a source of considerable revenue in some locations - can be altered by marine mining.

5.1.2.1 Marine aggregate extraction in the Lower Mainland/Fraser Valley

In a local context marine dredging takes place on the lower mainland in the Fraser River. The lower Fraser has formed a broad wandering gravel bed channel 50 km long between Laidlaw (near Hope) and Sumas Mountain. In the past, considerable dredging was carried out during low flows on the Fraser. An estimated 2.2 million m^3 of gravel sized material was removed annually between 1973 and 1987 (Northwest Hydraulic Consultants Report [NHC], 1989). Extraction was

suspended in 1988 due to degradation of spawning beds, sedimentation affecting fisheries and erosion of flood control dikes. Currently, on an annual basis, 1.2 million cubic meters of sand and gravel is removed for maintenance with up to an additional 2 million cubic meters (total 3 million) excavated as borrowed and maintenance material. The majority of the material is removed from the South Arm of the Fraser. The North Arm's flow is diminishing and so the Fraser River Harbour Commission (FRHC-the federal government agency with jurisdiction over the river from the mouth to Kanaka Creek) has suspended dredging. A further 100,000 cubic meters year is extracted on occasion from the upper reaches of the river. The B.C. Ministry of Crown Lands has jurisdiction over dredging in areas beyond Kanaka Creek. In addition, any instream mining requires permission from the Federal Department of Fisheries and Oceans (DFO).

The annual suspended load and bed load in the Fraser River in the Agassiz area has been calculated to average 17.5 million tonnes/year. Approximately 35% of the load is sand with the balance being silt or clay. The gravel bed load has averaged 175,000 tonnes/year reaching highs of 500,000 tonnes per year during high annual flows (NHC, 1989)

The FRHC grants licenses to private companies to dredge up to a given limit of material. The Provincial Government earns a royalty of \$1.50 per cubic meter removed. Other than the FRHC, Fisheries and Oceans Canada, Public Works Canada, and the Canadian Coast Guard all monitor the effects of sand and gravel removal.

In 1989 in response to a MoTH request to extract gravel, the DFO contracted a study to examine the potential for gravel removal from islands and sand bars in the Fraser River. A number of sites were identified where scalping may take place without harmful environmental effects. In some instances areas were identified where salmon habitats could be enhanced by excavation. Currently 500,000 cubic meters of Fraser River material is being tendered by Crown Lands (Foster Bar). Two other operations remove gravel from the Fraser near Chilliwack but have been "grandfathered" and their license will not be renewed following closure. All of these operations involve scalping rather than dredging.

Given the potential harmful effects of marine mining, whether real or perceived, the current political atmosphere with respect to fisheries makes large scale dredging doubtful. After all, the idea behind multiple land use is to reduce land use conflicts. With the drastic reductions in the salmon fishery currently underway even the Fraser River extraction programs may well be threatened.

Although a great deal of material is removed from the Fraser, much of it is sand and of limited use in construction. Currently, demand exists for dredged material in the construction of the Vancouver International Airport terminal and runway which are conveniently located at the mouth of the North Fraser. Once this project is completed it is doubtful that a market can be found for such large quantities of sand.

5.1.3 Recycled Aggregate

Recycling aggregate involves reprocessing old waste aggregate into a material which can be used in a new application. The benefits of aggregate recycling are many. First the recycler earns profits from selling the recycled material. In addition the recycler can charge a fee for receiving waste. Second the construction company saves in transportation costs as trucks can be used to haul away waste as well as to pick up fresh material. Costly empty haul-back time can be avoided. In addition, recycling facilities are often much closer to urban centers than sand and gravel pits which reduces travel time. Thirdly, consumers can benefit through lower cost recycled material. A fourth benefit can be seen in reducing the quantity of waste going to land-fill sites.

There are few negative effects from aggregate recycling. Recycling facilities are typically small in size. No permanent change is caused to the operating site and the equipment itself is highly mobile so when operations cease, little rehabilitation should be required. There is no blasting of rock and the equipment is small in scale so operating noise is limited. The only major drawback is truck traffic to and from the site but this can be limited by locating recycling facilities away from residential areas.

Recycled aggregate is produced by crushing and grinding waste construction and road materials. The sources therefore for recycled aggregates are anywhere waste construction or road materials are produced. Large urban areas, particularly those

enjoying a large amount of growth are typically large generators of aggregate waste.

In 1991 demolition, land clearing, and construction waste accounted for 36% of the total waste generated (GVRD Technical Memorandum 4, "DLC Transfer And Disposal", June 1993) in the Greater Vancouver Regional District (GVRD).

Aggregate waste is produced during: demolition or renovation of structures or; road construction or repair work. Of these activities road repair and construction generates the cleanest waste - typically asphalt. Demolition or renovation of structures can often produce "unclean" waste which contains rebar or other undesirable materials which may either damage the recycling equipment, or somehow harm the quality of the recycled product. Although rebar may be extracted from the recycling circuit with magnets, it is preferred if rebar is removed at the demolition site rather than by the recycler. It is common for recyclers to charge an extra dumping fee (often substantial) if a large amount of rebar is contained in a load of waste. Other undesirable contaminants such as wood, brick, or glass are also heavily penalized if disposed of at a recycling site.

In 1991, 420,000 tonnes of waste concrete and asphalt were produced (GVRD Technical Memorandum 4, "DLC Transfer And Disposal", June 1993). Of total demolition waste in 1991, 58% was residential in origin while 42% was commercial (GVRD, 1993). Of these quantities both residential and commercial waste averaged 3.2% reinforced concrete and 15% non-reinforced concrete

(GVRD, 1993). Residential waste contained 6.7% asphalt while commercial waste contained 3.8% asphalt (GVRD, 1993).

Recycling of waste concrete and asphalt is dealt with in more detail in chapters 6.

5.2 DEMAND

As the population of the Lower Mainland continues to grow, enormous quantities of building materials are consumed. Of these materials aggregate is perhaps the most fundamental to the construction industry. It is difficult to imagine any road or structure being built without concrete, sand, or gravel. A standard highway consumes aggregate at the rate of 12000 tonnes/lane-km (Langer and Glanzman, 1993). A house with associated infrastructure uses 300 tonnes of aggregate.

There are 65000 km of public roads within the province of BC, 45000 km of which are provincial highways (Lee, 1995). Mountainous terrain is common in the province as are multiple freeze-thaw cycles and heavy precipitation (particularly on the Lower Mainland), each of which can cause damage to roads and resulting in frequent maintenance. The BC Ministry of Transportation and Highways (MoTH) estimates that roughly 5 million tonnes of aggregate per year is required for maintenance of existing roads. During periods of highway building, such as during the Coquihalla project in the mid 1980s, MoTH annual consumption can reach 20 million tonnes of aggregate (Lee, 1995).

Between 1980 and 1988, British Columbians consumed an average of 14.8 tonnes of aggregate per capita, per annum (Martin, 1993). In 1994 the B.C. Ministry of Energy Mines and Petroleum Resources (MEMPR) estimates that 41,837,000 tonnes of aggregate were produced province wide of which roughly half (21,000,000 tonnes) was consumed in the Lower Mainland. Other estimates for Lower Mainland consumption range as high as 30,000,000 tonnes per year.

A number of attempts have been made at forecasting aggregate demand on the Lower Mainland. These have included: (1) Silverston and Carson (1974); (2) Hora and Basham (1981); and (3) Taylor (1989). Currently an attempt at forecasting is being organized by the MEMPR.

Indicators used for prediction in the previous studies have included historical consumption (1 and 2), per capita income (1, 2, and 3), gross provincial product (3) and population (3). Other studies in Ontario (Gartner Lee Associates and Procter & Redfern (1977); Peat, Marwick and Partners with M.M. Dillon Ltd. (1980)) have concluded that much of the variation in the demand for aggregate is a function of government spending and policy. A proportion of the market exists independent of economic growth and demand remains in this area despite periods of little or no growth. Poulin (1995) lists gross national product, population levels, and interest rates as important factors in demand forecasting.

As aggregate is fundamental to any construction project, aggregate demand is a function of construction activity. Construction activity can be influenced by factors such as interest rates and demand for roads and housing. As noted above these factors can be traced and used in forecasting. A large portion of aggregate consumption is generated by activity in the private sector in construction projects. This activity tends to reflect the economic climate at the time of project initiation. Consequently a favourable economic environment will result in increased aggregate demand and can be predicted by the above noted factors. Government initiated projects however are less predictable. Public works projects - traditionally large consumers of building materials - are often initiated by governments in less favourable economic times in an attempt to "jump start" local economies. These events cannot be anticipated by examining traditional market indicators. It is not uncommon for governments nearing the end of their term of office to initiate large infrastructure projects. Projects such as the Coquihalla and Island highways are all recent examples of government initiated projects which increased MoTH consumption alone to more than 20 million tonnes (Lee, 1995).

Despite the several forecast attempts, an accurate model remains elusive. Fundamental to the problem of forecasting is a lack of accurate production and consumption information. Government statistics on aggregate consumption are typically between 6 to 10 million tonnes per annum lower than industry estimates. Industry representatives cite numerous cases of under reporting of production statistics to support their figures. Some confusion also exists as to what constitutes

commercial aggregate production. Without accurate historical statistics and a method of ensuring the accuracy of current information it is unlikely that any future forecasting attempts will meet with success.

5.3 PRICE

In constant dollar terms, very little has changed with respect to aggregate prices.

Taylor (1981) discovered that the relative price of aggregate had in fact decreased since the early 1960s. It is important to note that these prices are FOB. Actual customer costs could well be higher as a result of greater shipping distances.

5.3.1 Elasticity

Elasticity measures the response of the quantity demanded or supplied resulting from a change in price. A commodity described as elastic, should its price increase, will experience a decrease in demand, exerting pressure to return the price to its original level. Consumers faced with an increased price may reduce consumption or substitute another item. Aggregate is highly non-elastic in the short term (Poulin, 1995). Aggregate is a fundamental commodity to construction. It would be difficult in the short term to locate and produce a suitable less expensive substitute. While consumption can be reduced however, as aggregate costs typically make up a very small proportion of overall project costs, a price increase is unlikely to have any influence.

From a less theoretical standpoint however, it is difficult to reconcile the non-elastic nature of the aggregate market with the fact that there has been no real price increase in aggregate products in over 30 years. Surely given the fundamental nature of aggregate and the absolute necessity of its use, aggregate producers would be capable of demanding a higher price for their commodity.

The difficulty lies within the aggregate market itself and largely rests in the relative commonness of sand and gravel in the region. It is not difficult to find sand and gravel on the Lower Mainland or within the Fraser Valley. As a result there is fierce competition between established producers, whose occupation it is to extract, process and sell aggregate, and temporary producers who generate sand and gravel as a byproduct of their primary activity. Established producers face costs of production and are burdened with numerous other regulatory fees which must be covered by their product price. Temporary producers are less encumbered by regulations and their associated fees. As their sand and gravel is a byproduct of another activity, their production costs are nil. As an example, the construction of the Henderson Center in Coquitlam, located near the largest sand and gravel operations on the Lower Mainland, produced 50,000 m³ of sand and gravel which is currently being sold below market rates. The Allouette/Fraser Regional District recently completed a pipeline project and in the process excavated 50-60,000 m³ of sand. This material was sold at a price of \$0.50 m³ (the current retail price for sand is approximately \$3.00 m³). The prospect of selling the material both returns revenue to the project as well as saves the project operators from costly removal

fees. Neither of these projects are faced with reclamation expenses nor are they bound by MEMPR regulations in their extraction. Furthermore, in instances similar to the first example, the land has long since passed from provincial ownership meaning no royalty fees are paid: revenues on a commodity owned by the public are foregone. As there are very few production expenses, there is clearly little incentive to charge market value for the product.

A similar situation exists between established producers and the MoTH. The MoTH while not directly competing in the sale of materials can select to use materials taken from their own pits in highways contracts. As the MoTH estimates they have tenure over 3000 gravel pits throughout the province, they represent a significant force in the market. These pits are not subject to as demanding regulations as are commercial pits and are often in violation of the Mines Act. As a result they are not always faced with costs similar to commercial producers.

Although aggregate as a commodity is non-elastic the reality of the Lower Mainland aggregate market has prevented any significant increase in commodity prices. Non-commercial and government producers are able to circumvent or avoid many of the costly regulations which commercial producers face. Land developers produce gravel at no cost and are able to save disposal costs by selling sand and gravel at below market price. Commercial producers are therefore unable to take advantage of the non-elasticity of their product.

5.4 TRANSPORTATION

As aggregate is a bulk, low cost commodity, transportation charges often play the greatest role in determining the final product cost. Producers located near their market can enjoy a significant cost advantage. Aggregate production from the 2600 commercial pits in BC was valued at \$170 million in 1994. With transportation costs included this value rose to \$370 million (Matysek, 1995). Timely movement of products is equally important to producers and consumers. For most producers, areas available for inventoried stockpiles is very limited. Consumers are often on a fixed schedule and require precisely timed delivery. For these reasons large aggregate consumers such as ready-mix and asphalt producers locate themselves near sources of aggregate.

Transportation charges are highly variable and depend on such things as time, distance, availability of haulback, tonnage, frequency and availability of a carrier.

5.4.1 Barge

Barges are typically used for transportation of larger loads of aggregate from pits or quarries. Barges are shallow draft vessels and do not require deep water ports. Loading and unloading is easily accomplished by a role-on role-off method. For this reason many producers shipping from tidewater pits have established distribution terminals along the Fraser River and other waterfront locations. Loads can range from 1000 to 5000 tonnes. The cost of shipping from Sechelt to Vancouver (a popular route) is approximately \$2.00/tonne. Some larger aggregate

producing companies also operate barges and can gain a cost advantage by shipping within their own company. Hora (1986) lists 150 km as the maximum economic distance that aggregate can be barged.

5.4.2 Bulk Ocean Carriers

Bulk ocean carriers are large, ocean going vessels capable of carrying loads in the range of 45,000 tonnes of aggregate for distances of greater than 150 km. These ships require docking and port facilities similar to other large freight carrying vessels. No aggregate is transported in this fashion in British Columbia.

Transportation costs for the 1400 km Nova Scotia to New York City haul were approximately \$3.00 /tonne or \$0.002 per tonne kilometer (Taylor, 1989). These low shipping costs combined with a suitable backhaul allow aggregate to be shipped into the United States from as far away as Scotland.

5.4.3 Truck

Trucks offer the most flexible yet least efficient and most costly form of transportation. Freight charges are based on time therefore local traffic conditions have a considerable influence on costs. A very large variety of trucks and trailers exist each with different load capacities and costs. Generally speaking, a larger truck and trailer combination will have a lower per tonne cost. Charges can range from \$50 to \$85 per hour depending on the load transported. Virtually every tonne of delivered aggregate will have at some point been transported by a truck. Hora

(1986) determined the maximum supportable haulage distance for trucks to be 50 km.

5.4.4 Rail

Rail offers an attractive alternative to trucking for transporting large quantities of bulk materials over long distances. For aggregate however a number of factors require consideration. The aggregate industry in the United States makes considerable use of railways for aggregate haulage. In Canada the rail systems are much less extensive and a lack of competition between rail companies could conspire to keep haulage costs uneconomic. Both the customer and the producer must have convenient access to loading and unloading facilities; ideally the rails would run from the pit to the distribution terminal. Rail accessibility is grade dependent; mountainous areas are expensive to service. The rail company must be equipped with suitable rail cars. Loading and unloading times can vary between 100 tons/hour (the contents of one car) to 10,000 tons in 30 minutes depending on the equipment and methods used. The least efficient method requires a crane and clamshell, can be carried out virtually anywhere along the track, and is inexpensive. The most efficient method is highly inflexible with respect to location and requires a large investment in rail cars and materials handling equipment.

Only a small quantity of aggregate is believed to be moved by rail in the Lower Mainland. Taylor (1989) lists a rail haulage price of \$12 per tonne for a 160 km journey in southern Alberta (\$0.075 per tonne kilometer).

5.5 IMPORT/EXPORT

Sand and gravel moves both into and out of BC. The United States is the only market for BC's exported material and is the primary source of BC's sand and gravel. The Philippines has occasionally shipped sand and gravel into BC (463 tonnes in 1987 valued at \$5310.00) but this represented only 2% of total imports at the time (Statistics Canada, Catalogue 65-006).

There are currently no duties imposed on aggregate materials crossing the US-Canada border.

Imports into Canada from the US have fluctuated a great deal in the past but have averaged between 0.9 and 1 million tonnes per year (Statistics Canada, Catalogue 65-006). Imports of sand and gravel are typically the result of the large cement producers in the Lower Mainland shipping within their company from one of their Washington based pits.

Exports to the United States are small compared to the material flowing the other way but have climbed steadily throughout the past 15 years.

6. RECYCLED AGGREGATE ON THE LOWER MAINLAND

Conditions on the Lower Mainland favour aggregate recycling. As the population can only expand up the Fraser Valley, aggregate producing operations are driven further from the municipalities such as Vancouver. The nearest inland aggregate source to Vancouver is located 40 km away in the Coquitlam River Valley.

Unmined aggregate deposits located nearer to Vancouver have been sterilized by urban development. Vancouver must depend more heavily on barged aggregate which is shipped 100-150 km. Recycled aggregate operations can be located much more conveniently for use by the westernmost municipalities on the Lower Mainland. Reduced transportation costs can allow recycled aggregate to be sold at an overall lower price than conventional material. In some cases transportation savings can be further enhanced by using aggregate transporting trucks to haul back recyclable waste.

Recycling operations avoid paying many of the taxes and royalties imposed upon the conventional aggregate producers. Mining tax and royalties, Crown Land fees and royalties as well as soil removal fees are all forms of taxation payable by aggregate operations but not applicable to aggregate recyclers.

Environmental regulation of aggregate recycling is also reduced in comparison with the conventional industry. Sand and gravel and crushed stone operations must

prior to operation. To extract aggregate resources from lands in the Agricultural Land Reserve (ALR) conventional aggregate producers must show extraction will maintain or enhance the effected land. In comparison, aggregate recycling requires no environmental bond or reclamation plan. As the land upon which the recycling takes place is not harmed by the operation, it is not incompatible with agricultural land uses.

Recycling aggregate waste reduces demands on increasingly scarce landfills. Similar situations in Toronto and Los Angeles have resulted in the growth of recycled aggregate industries on a very large scale. Blue Diamond, one of several Los Angeles recycling companies, has an annual production capability of 2 million tons a year. Their portable recycling plants produce 300-400 tph (Zimmerman, 1991). In 1990, Toronto recycled 968,150 tonnes of concrete and 533,600 tonnes of asphalt (Ontario Ministry of Natural Resources, 1990). European cities have used recycling for many years in response to diminished fresh aggregate reserves and fewer landfill sites. Holland contains over forty aggregate recycling plants and has attempted to import demolition waste from England. All new German structural designs must include plans for demolition and recycling. In Britain, 10 million tonnes of building demolition waste and 8 million tonnes of road asphalt are recycled annually (Zimmermann, 1991).

The Greater Vancouver Regional District (GVRD) estimates that in 1991, demolition, land clearing and construction accounted for 36% of the total waste generated in the district. Of this amount, 420,000 tonnes of waste concrete and asphalt (aggregate waste) were produced (GVRD, 1993). Aggregate waste is produced during: demolition or renovation of structures or; road construction or repair work. Demolition or renovation of structures can often produce "unclean" waste which contains rebar or some other undesirable substance which may either damage the recycling equipment or somehow harm the quality of the recycled product. Although rebar can be removed with magnets during recycling it is preferred if it is removed at the demolition site rather than by the recycler. It is common for recyclers to charge an extra dumping fee (often substantial) if a large amount of rebar is contained in a load of waste. Other undesirable material such as wood, brick, or glass are also heavily penalized or refused outright at aggregate recycling facilities.

Road repair and demolition generates far fewer "unclean" substances with respect to the recycling process. Concrete, asphalt and road based materials can all be easily recrushed, screened and reused.

Of total demolition in 1991, 58% was residential in origin while 42% was commercial. Of these quantities both residential and commercial waste averaged

3.2% reinforced concrete (containing rebar) and 15% non-reinforced concrete.

Residential waste contained 6.7% asphalt while commercial waste contained 3.8% asphalt (GVRD, 1993).

For 1993 and 1994 the GVRD estimates that 417,900 tonnes and 550,415 tonnes (respectively) of aggregate waste were produced (personal communication, Marr, 1995). No statistics were available for these years concerning quantities of recycled material produced.

6.1 AGGREGATE RECYCLING OPERATIONS

Aggregate recycling has been carried out on the Lower Mainland since 1983. Since this time four principle recycling stations have opened and become established with a fifth opening periodically (figure 7-1). Another company now operates a portable crushing and screening facility which can be transported to demolition sites where concrete is recycled and either used on site or shipped elsewhere.

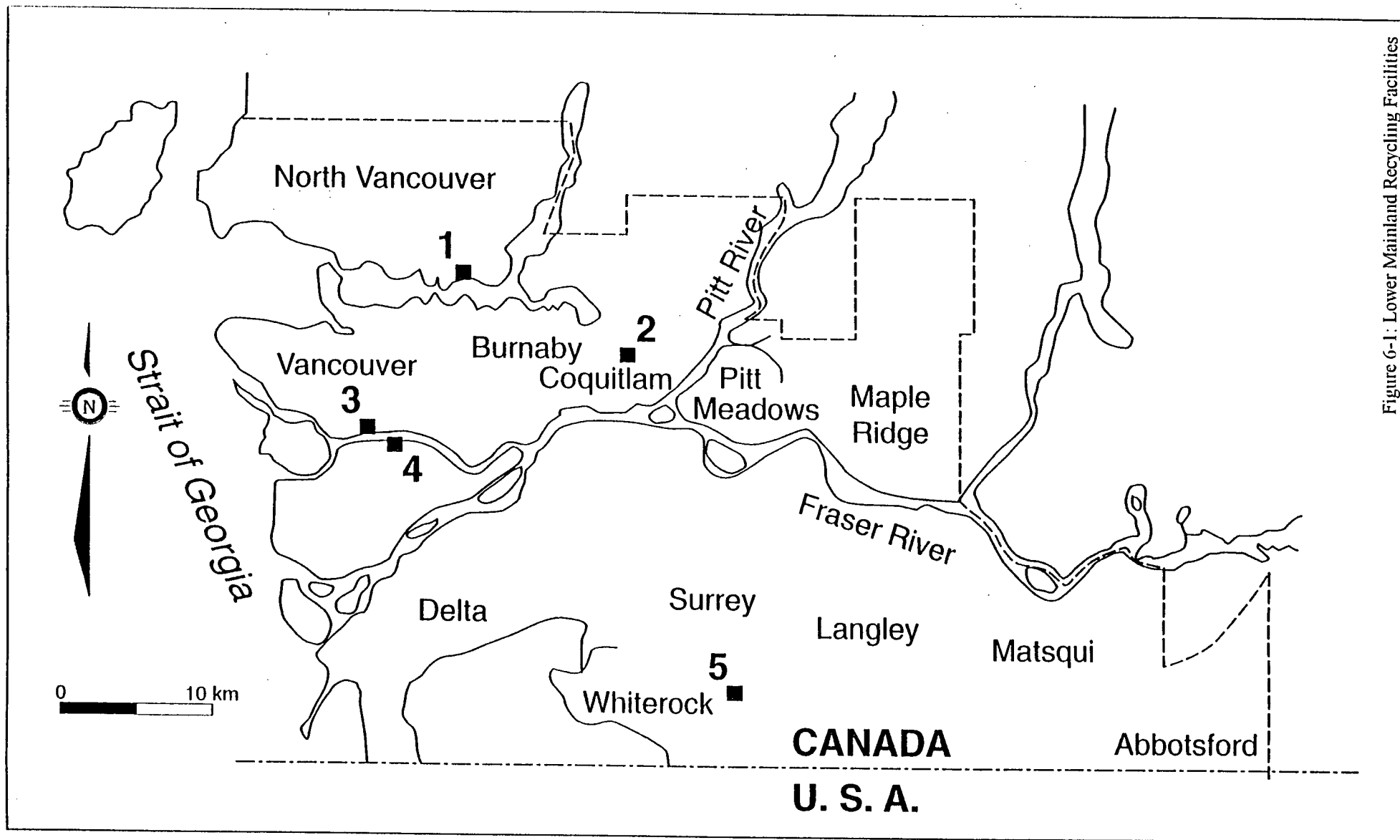


Figure 6-1: Lower Mainland Recycling Facilities

Lower Mainland Recycling (LMR) is located at 24th avenue and 192 street in South Surrey at the Surrey Municipal Pit. Until recently LMR also operated from a location at 19100 16th avenue (South Surrey) where conventional aggregate material was also available. This location has now been reclaimed and all recycling activity takes place at the 24th avenue location.

The LMR circuit consists of a 22X36 single Toggle Cedarapids jaw crusher which feeds a multi-decked vibrating screen in closed circuit with a 42X46 roll crusher. Despite the high costs associated with roll crusher operation (rollers wear quickly), LMR feel that their system gives superior control over undersize and therefore save money in the long term due to less over crushing. The tendency of the roll crusher to jam when fed long, thin, soft pieces of asphalt (which can pass uncrushed through the jaw crusher), has been overcome by a unique adaptation which allows the rolls to be quickly opened. This allows oversize to pass through the rolls and be re-circulated and slowly abraded to a more manageable size. The circuit is diesel powered, generates 350 kW/h and consumes 400 litres /day. LMR charges a \$2.00 tippage fee even for clean material. Additional fees are charged for disposal of unwanted materials including rebar which the LMR circuit is not equipped to easily remove. The major purchasers of LMR material are private contractors doing road repair and construction work for local municipalities. LMR reports positive feedback with respect to the performance of recycled aggregate.

RichVan holdings operates a recycling facility on River Road in Richmond and is well located to serve customers in that municipality as well as those in Vancouver via the Night Street Bridge. RichVan provides a wide variety of material sizes and composition. The circuit is comprised of a single toggle Cedarapids crusher feeding an impactor. The circuit is equipped with magnets to remove rebar, chains and other ferrous objects. These materials can then be recycled at a neighbouring metal recycling facility. Dumping of clean material is permitted free of charge and a penalty is imposed for undesirable waste. RichVan has a mobile rock breaker (Insley) that is capable of handling very large material. RichVan has been tested and approved for use by the Municipality of Richmond and, at the time of interview, was under consideration by the City of Vancouver.

Columbia Bitulithic operates an aggregate recycling facility on Mitchell Island in Richmond B.C.. An additional waste material receiving site is located in Coquitlam. From there waste is transferred to the Mitchell Island facility for recycling. The Company itself has been in existence in the Lower Mainland since 1910 and has grown into one of the Lower Mainland's, larger locally owned construction materials producers. Columbia Bitulithic has been recycling aggregate since 1983. The Columbia Bitulithic circuit is very similar to the RichVan circuit with a primary jaw crusher followed by vibrating screens in closed circuit with an impactor. The circuit is protected by a number of magnets to remove metal objects. In an effort to reduce the supply of waste, Columbia Bitulithic recently

initiated tippage fees of between \$25-\$75 per load of asphalt waste. Concrete waste is dumped free of charge. Due to the diversity of its operations, Columbia Bitulithic is the largest consumer of its recycled product. The Mitchell Island site provides both a supply of aggregate for Columbia Bitulithic's road building and construction projects as well as a location for waste disposal from demolition projects. The facility is convenient to Richmond, Burnaby and Vancouver. Facilities exist at the Richmond location for loading and unloading barges.

BA Blacktop operates a recycling facility in North Vancouver. BA is primarily a paving contracting company although they have been involved in recycling for more than 15 years. Although asphalt is the primary recycled material, BA has recently begun handling waste concrete for both Lafarge and Ocean Cement, two of the largest building material producers on the Lower Mainland. This is expected to increase the quantity of waste concrete being recycled. The bulk of recycled material produced by BA is used in their own road construction and repair contracts. BA reports recycled material as being superior to conventional aggregate in applications such as road grade material. Recycled asphalt maintains its cohesive qualities after the recycling process which allows it to resist the deleterious actions of water when the material is applied in wet conditions. The binder material which is also present in recycled asphalt acts to repel water which improves drainage.

The BA circuit consists of a 40X42 Traylor Bulldog jaw crusher that feeds material to a screen which in turn feeds oversize to a smaller Pioneer secondary jaw crusher, and undersize to a roll crusher. Each of these crushers is in closed circuit with the screen which allows material to be reduced over several passes until the desired product size is reached. The BA circuit equipped neither with a breaker nor with protective magnets. As BA primarily recycles asphalt, neither of these pieces of equipment were required. With the increase in waste concrete however, BA will consider purchasing the appropriate equipment. The BA circuit is capable of producing 800-1000 tonnes per day. An inexperienced crusher operator however can reduce production to 300-500 tonnes per day. Like Columbia Bitulithic, BA has been faced with an oversupply of incoming waste resulting in periodic tippage fees being imposed.

Eco Tech recycles concrete and asphalt in Coquitlam. No operational details were made available by Eco Tech for this report. Although the GVRD has reported Eco Tech to have been in continuous operation, a previous aggregate recycling survey (Martin, 1993) found that Eco Tech was not in operation and had opened and closed several times in the past. The Eco Tech recycling circuit is believed to be similar in production capabilities (by the GVRD) to other Lower Mainland aggregate recyclers.

Litchfield operates a portable recycling operation in the Lower Mainland. At the time of this report the portable crusher was in operation in East Vancouver at a warehouse demolition site. No operational details concerning the recycling operation were released by Litchfield. The circuit consists of a small primary jaw crusher which feeds an impactor. The material is then screened and sent to two stockpiles of oversize and undersize material. No recirculation of oversize material is present. The circuit has no apparent method of removing ferrous objects and no breaker is present indicating the waste material to be recycled must be carefully sorted. A brief survey of other demolition contractors within the Lower Mainland revealed no other companies that make use of portable recycling equipment.

6.2 RECYCLED AGGREGATE SOURCES

Although the recycled aggregate industry will never approach the size of the conventional aggregate industry, governmental estimates of the industry tend to underestimate the supply of waste generated. This fosters a belief that the industry has grown to its maximum size and further encouragements to recycle would lead to diminishing returns. In 1993 the GVRD along with the British Columbia Ministry of the Environment, Parks and Lands commissioned a study (quoted above) by CHM Hill Engineering entitled "Demolition/Landclearing/ Construction, Technical Memorandum 4." This study was based upon the GVRD's Waste Flow and Recycling Audit which visually surveyed the quantity and composition of demolition/landclearing/construction (DLC) waste at DLC landfills in the GVRD. Using this study, the GVRD estimated the annual quantity of aggregate waste

generated, - 420,000 tonnes - and the quantity recycled - 356,000 tonnes- or 85%.

Based on this figure the GVRD reported that ...”significant further recycling may be difficult to achieve.”

The report goes on to note the existing facilities for recycling as :

- B&A Blacktop
- Columbia Bitulithic
- Eco Recycling
- RichVan Holdings

(Note that Lower Mainland Recycling is not included although it was in operation at the time of the report). Each of these facilities is described as having a production capacity of “..between 800 and 1000 tonnes/day of concrete and asphalt.” If the GVRD’s figures are to be taken as correct, the 356,000 tonnes of annually recycled material would leave the four noted facilities operating at only 30% capacity (this figure would decrease further if Lower Mainland Recycling was included). With supplies at such low levels, it is unlikely that all of the facilities could have remained in operation since the reports release.

The report underestimated not only the quantity recycled but the quantity available for recycling. Not all aggregate waste goes to DLC landfill sites. As waste

concrete is an inert, stable material it is desirable as fill, particularly in reclamation projects. In addition, the report failed to account for mobile recycling carried out by companies such as Lichfield. The material in this instance would also not be recorded by the DLC survey either in its waste or recycled form. Paul Allard, of Columbia Bitulithic, and Dave Channell of BA Blacktop state that their operations have introduced tippage fees in an effort to reduce incoming waste.

6.3 RECYCLED AGGREGATE APPLICATIONS

The suitability of recycled aggregate as a substitute for conventional material is highly dependent on the specific application for which it is to be used. As aggregate materials typically represent only a very small proportion of over-all project costs, decisions concerning the use of recycled materials are rarely made on the basis of material costs. Although reserves of fresh aggregate near the Lower Mainland are diminishing, no serious material shortage exists. The use of recycled aggregate as a substitute cannot be attributed to a lack of conventional resources. The substitution of a recycled material over a fresh aggregate in a construction project depends more on product quality than on material cost advantages or availability. Before a recycled material will be used as a substitute, the user must be assured that the product will perform either as well as, or better than, a conventional product. Qualitatively, aggregate can only be as good as its source material. While conventional aggregate is usually sourced from material of a consistent quality, recycled aggregate can be made up of materials of variable

quality. Aggregate waste is inspected visually prior to being accepted for recycling. Qualitative testing can be carried out on recycled aggregate products, however, as source materials change with each truck load, it is difficult to describe the results of these tests as representative of overall recycled aggregate quality. Easily applicable standards which can be used to categorize recycled products by the quality of their source material could greatly increase their acceptance by consumers. Once qualitative concerns can be satisfied, other considerations such as cost and availability will influence the issue of substitutability.

When coarse, crushed concrete is substituted for coarse, fresh aggregate in concrete, the overall strength of the final product is reduced. When the fine portion of recycled, crushed concrete is used in concrete production, the workability is diminished (Ontario Ministry of Natural Resources, Feb. 1992). Recycled concrete can however be used in a utility concrete if additional Portland Cement is used. Recycled concrete, particularly when blended with recycled asphalt, can be a good substitute for conventional aggregate in road base and sub-base applications. Crushed concrete and asphalt, when used unbound in road base or road shoulders, tend to show superior cohesion and resistance to water. The US National Cooperative Highway Research Program found that aggregate particles made from crushed concrete have a good particle shape, high absorption, and a low specific gravity compared to conventional aggregate. Freeze-thaw resistance was also found to be greater in recycled aggregate. In unbound road base, waste concrete

particles were found to gain strength over time due to cementing action (Zimmerman, 1991). Waste asphalt can be combined with fresh asphalt and re-used. The City of Los Angeles has experimented successfully with 100 percent recycled asphalt as road surface (GVRD Technical Memorandum, 1993).

Despite the obvious suitability of recycled aggregate for applications such as in road base, resistance to the material has been encountered on the Lower Mainland by some producers (conversations, Gagno 1993; Schoeppe, 1993). Recycled aggregate is judged with suspicion by some contractors and municipalities. Qualitative testing also can discriminate unfairly against crushed concrete, particularly the Los Angeles Abrasion Test and the Degradation Test (see section 4.2 for procedures). These tests subject material samples to abrasion and measure the fine material resulting from this action. Crushed concrete particles typically are coated with mortar and grout which is easily abraded away, although the aggregate particles themselves may be quite sound. The large quantity of fines resulting from the test could conceivably cause a petrographically superior aggregate to be rated as unfit for a road base material. This problem was identified by the Ontario Ministry of Transport has found that with recycled aggregate, the Los Angeles Abrasion Test results show little correlation with actual field performance and has adopted the Micro-Deval Test (Ontario Ministry of Natural Resources, 1992). The B.C. MoTH, although still using the degradation test, intends to also employ the Micro-Deval Test.

6.4 RECYCLING POLICY

Although recycled aggregate can be partially substituted for conventional materials, the costs and benefits must be evaluated to determine if such a substitution is advantageous. Costs associated with conventional aggregate production are primarily associated with environmental disturbances caused in the extraction of the resource. Gravel pits and quarries permanently change the topography. While many examples exist of successful reclamation (including instances where the land was rehabilitated to a condition superior to that of its original state), current perceptions judge any disturbance of the environment to be negative. Aggregate production is often carried out on the periphery of urban centers. While demand can exist near the production center, in the Lower Mainland, the nearest aggregate producer is located 40 kilometers from the urban center of Vancouver. The costs of transportation of products through congested city streets include additional traffic, fuel consumption, vehicle emissions, and increased frequency of road repair (caused not only by gravel trucks but by all heavy traffic). Other negative consequences include local nuisances created by the operation itself such as noise from crushing and blasting, and dust.

Advantages to the use of recycled aggregate include:

- reduced consumption of conventional aggregate lowering the demand on local natural resources and the associated disturbances caused in their extraction.

- reduced demand on land fill sites for aggregate waste disposal
- shorter transportation distances (as recycling can be carried out at or near demolition sites) resulting in less truck traffic, lower fuel demand, fewer emissions, and less road damage
- more efficient transportation - as trucks carrying waste to the recycler can then be used to haul recycled product.

The social costs of recycled aggregate are few particularly in comparison with the conventional industry. Although the use of recycled aggregate reduces the consumption of conventional aggregate, the impact of aggregate recycling on conventional producers is likely to be insignificant. In France, the contribution of recycled materials in 1991 to the overall production of aggregate was roughly 3% (Anonymous, 1992). Conventional aggregate producers can also participate in the recycled market by operating recycling plants themselves. Problems such as dust and noise are common to both the recycled and conventional producers.

Recycling aggregate can be seen therefore to be an overall positive activity. As such, it is in the interests of the government to ensure that an optimal level of recycling is occurring. A number of policy alternatives are available to the government agencies to influence recycling. Attendants at an aggregate recycling seminar, when asked why they recycle, listed their reasons as: outside pressure; limited landfill access, increased disposal and transport cost and being required to

recycle (Prokopy, 1993). Policy alternatives that arise from these statements can be summarized as follows:

1. Recycling can be encouraged by increasing user fees for those seeking to dispose of recyclable material at land fills. Experience in Canada and the USA has shown that if consumers bear the cost of disposal, they have an incentive to recycle (Ezeala-Harrison, 1995)
2. Consumption of recycled products can be encouraged, thus increasing demand for recyclable material can be similarly increased.

From the perspective of the Lower Mainland, the first alternative is not, by itself, appropriate. The fact that recyclers charge dumping fees in an attempt to control incoming waste, suggests that insufficient capacity exists to handle available recyclable waste. Increased user fees at land-fills would result in corresponding increases in dumping fees at recycling facilities. While "polluter pay" principles can be an effective recycling policy tool, fees must be limited to prevent illegal dumping of waste to avoid onerous dumping fees. Before a policy of this type is implemented it would be necessary to ensure that (a) adequate recycling capacity exists and, (b) markets exists for recycled products. By increasing consumption of recycled products (option 2), particularly on government projects, demand for recycled waste can be increased. The current situation suggests that a market of suitable size has not developed to encourage increased recycling activities. Policies encouraging the use of recycled products wherever possible on government works

projects would serve to boost demand and encourage new recycling capacity to be added.

In 1994, the GVRD drafted the following policy proposals which may influence the recycled aggregate industry (Overview- The Recommended Solid Waste Strategy for the GVRD, draft, March 1994).

1. no new processing facilities are required for dry recyclables
2. processors required to obtain GVRD permits and report operating data.
3. weight based tipping fees instead of volume based fees (at land fills)
4. Increased separation of recyclables at DLC (demolition) sites

While the implementation of some of these policies will increase their knowledge, little is understood by regulating agencies of the recycled aggregate market.

Information regarding waste and recycling has been compiled by the GVRD but their information is clearly inaccurate (see section 7.2). This is illustrated by proposal 1. While a market for recycled aggregate products may not exist in at a scale which will consume all recyclable aggregate waste, currently there is clearly a lack of processing capacity. Proposals 2 and 3 will assist the GVRD in obtaining a more accurate picture of the quantities of waste being dumped and being recycled. Before a recycling policy can be implemented an accurate inventory of annual disposed quantities of recyclable building waste must be taken. Accurate data must also be gathered as to the processing capacity of the existing recyclers. Finally, this information should be reconciled with estimates of generated recyclable waste in the region. It should not be assumed that all recyclable waste is either recycled or

dumped in the locations monitored by the GVRD. Material recycled on site should be included in all surveys. Proposal 4 will increase the recyclability of waste and perhaps allow for more waste to be recycled. Without additional recycling capacity however, the clean aggregate waste will be dumped at a land fill.

7. LEGISLATION, PROPERTY RIGHTS AND LAND USE

Property right allocation is inextricably linked to resource and land use. Non existent or poorly defined property rights can lead to both conflicts between resource users as well as inefficiencies in the use of resources. These inefficiencies can have long term negative effects such as depletion or premature exhaustion of resources. The Lower Mainland of British Columbia, although blessed with a natural abundance of sand and gravel is in danger of losing much of its rich resource due to inadequate planning and policies which discourage efficient extraction. This chapter examines property rights in general followed by an examination of allocated rights in the sand and gravel industry and the effects of these allocations on resource use.

7.1 *PROPERTY RIGHTS*

Broadly speaking, property rights can be described as in Baker (1990) to outline:

1. who has the right to benefit from the resource;
2. who may control the resource and;
3. different uses to which the resources can be put.

Bromley (1991) describes property ownership as an entitlement to a non physical "stream of income or benefits which are derived from a physical or financial asset."

Property rights are therefore seen in this instance to allow the owner to control or consume these benefits.

These definitions fail to illustrate the responsibilities of ownership. Sinding (et al, 1995) provides an alternative view of property rights as the ownership of “residual decision rights and the allocation of residual returns.” The owner is free to use and enjoy the benefits of an asset but only within the rules and regulations laid out by the laws and contracts governing the asset. The owner must first satisfy these legal and contractual obligations before enjoying what is left (the residual benefits).

Property rights do not necessarily entitle the owner to free use of his or her asset. Rather they obligate the owner to fulfill certain responsibilities which restrict the extent to which the owner may use or enjoy his or her property.

As was noted by Randal (1987) “property rights specify both the proper relationships among people with respect to the use of things and the penalties for violating these proper relationships.” Without property rights (or without adequate property rights) this “proper” relationship remains undefined. In the absence of rights to ensure a future stream of benefits, an individual is unlikely to act to conserve the resource. Instead, the incentive is to maximize current individual benefits and consume as much as possible (Sinding (1995) illustrates this point with the example of the unregulated offshore fishery). The result is an inefficient squandering of resources in which no thought is given to future supplies. An often quoted example of this situation, Hardin’s 1968 ‘Tragedy of the

Commons”, describes the destruction of a common pasture by herdsmen; each determined to maximize his own herd’s consumption, oblivious to the damage being caused, not by his own individual behavior, but by the collective behavior of all of the herdsmen.

7.2 PROPERTY REGIMES

Property rights can be broadly divided into four categories: private, state, common, and open access. Crucial to the differentiation of the various regimes is the varying degree of control offered to the holder of the rights.

Open access property regimes are characterized by a lack of exclusivity of consumption. In addition no individual or group exerts control over the resource or property. Without either exclusivity or control it can be said that open access property regimes exist where there is an absence of property rights. This can result in irresponsible consumption and depletion of the resource (Sinding ,1995). This situation characterized the previously mentioned “Tragedy of the Commons”.

Private ownership entitles the possessor, whether an individual or a corporation, to enjoy their property to the exclusion of others. As was mentioned in the previous paragraph, property rights rarely give the owner total control and exclusivity to the resource and private property rights are no exception. Private ownership is better described as allowing exclusive consumption of *residual* benefits. Home ownership for example allows the owners to do whatever they wish with their property

provided they are not in violation of any Federal or Provincial law or any Municipal bylaw or zoning regulation (it is interesting to note that property rights are not constitutionally protected in Canada). Nevertheless even the illusion of private ownership tends to encourage the owners to consume more efficiently (Sinding, 1995) and take greater care in managing what they believe to be their property.

State property regimes exist when a resource is managed by a government. The government grants rights of consumption to individuals or groups in the forms of permits or licenses. While the holder of the property rights may be granted rights similar to those of private ownership, decisions made regarding the management of the property are made by the state, which often has interests other than in efficient, responsible development. The result can often resemble a form of an open access regime in which all parties involved in consumption assume no responsibility for conservation and seek only to maximize their personal consumption. A good illustration of this situation is British Columbia's salmon fishery. In this case, groups representing the different fishing interests each regularly petition the government to increase their share of the catch while blaming the other parties for declining stocks.

Common property regimes allow exclusivity and control over a resource to a group of individuals or corporations. Theoretically this allows a number of people

to share the benefits (again, residual) and responsibilities of ownership. As each member of the collective can expect to enjoy a portion of the generated benefits from the common property, the incentive to carefully manage the resource should be similar to that of a private regime. Unfortunately there are few true common property regimes in existence in modern society. The mechanisms (licensing etc.) required to identify members of the exclusive group virtually always requires some sort of government control. As the state typically assumes an inordinately greater share of control of the property, the collective's members assume less responsibility for properly managing the property. The result can be a combination of state and common property regimes.

With respect to aggregate resources, the property rights regime is somewhat confusing. A state regime exists, however, the number of bureaucratic organizations involved create an illusion of governmental open access.

7.3 INTEREST GROUPS AND PROPERTY RIGHTS

The lack of defined aggregate resource property rights in the province of British Columbia has resulted in a somewhat chaotic situation. While benefits are claimed by numerous interest groups only isolated, token efforts are made at managing the resource resulting in a loss of benefits for the actual resource owners, the citizens of the province.

A number of interest groups participate in the property rights process, each seeking to achieve their own agenda. Libecap (1989) identified three distinct groups as; private claimants, politicians and bureaucrats. Private claimants seek to obtain benefits from property ownership. These parties can include the actual owners of the asset or those who benefit indirectly from its use or non-use. Politicians have the power to change property rights allocations and to regulate the use and exploitation of assets. Politicians are motivated to maximize political gain and can be expected to act to achieve this goal. Bureaucrats, although empowered by politicians, can wield considerable influence in the decision making process. Bureaucrats, as with the other interest groups, act to further their own interests by expanding or maintaining jurisdictional turf or increasing operating budgets (Libecap, 1989; Sinding, 1994).

In the case of aggregate production, private claimants can be considered to be all groups interested in the development of a sand and gravel deposit or quarry. This includes the aggregate producers as well as those who would prefer to see the land used for other purposes (environmental, agricultural, industrial, or housing development). An interesting addition to this group are agencies such as the MoTH, the MoF, and municipal governments, each of which seeks to claim non-commercial, private ownership rights as government bodies. Politicians can be considered to be both incumbents and those seeking office, at the provincial and municipal levels. Bureaucrats involved with aggregate are numerous and are found

at the federal, provincial, regional and municipal levels. Government agencies with an interest in the aggregate industry include:

1. the BC Ministry of Crown Lands regulates and approves tenure on crown land.

Their authority is granted under the Land Act as well as the Mineral Tenure Act of 1988 (Chapter 5, part 1: Interpretation) which explicitly excluded aggregate materials from the definition of a mineral substance (which would have brought aggregate materials under the jurisdiction of the MoEMPR). Procedures for applying for tenure as well as types of tenure available are listed in section 5.5.1.

Crown Lands also receives a production based royalty for the extraction of aggregate materials as well as a Land Rent Fee; both payable by the leaseholder. The ministry is also responsible for marine extraction in the Fraser River from the upper reaches to Kanaka Creek.

2. the BC ministry of Energy Mines and Petroleum Resources is authorized by the Mines Act (Health, Safety and Reclamation Code) to inspect and/or approve pits on both crown and private land with respect to:
 - mining plans and operations,
 - reclamation plans,

- health and safety issues.
3. the BC ministry of the Environment is involved to oversee environmental concerns; pertinent legislation is found in the Environment Management Act, the Waste Management Act, the Water Act, the Wildlife Act, and the Federal Fisheries Act.
 4. the BC Ministry of Transport and Highways is the largest producer and consumer of aggregate in the province. They hold tenure over approximately 3000 gravel pits (Lee, 1995). Highways appraises sources and estimates reserves for its own use. This ministry is believed to have the most accurate and extensive inventory information in the province; superior, even to the Geological Survey branch of the MEMPR.
 5. the BC Ministry of Forests oversees sand and gravel mining in the province when the end use is for forestry related purposes.
 6. the BC Ministry of Finance is responsible for taxation of the aggregate industry under the Mining Tax Act.

7. the BC Agricultural Land commission which must approve the release of any land situated in the Agricultural Land Reserve. The Soil Conservation Act governs soil removal from reserve lands.
8. the BC Ministry of Municipal Affairs is responsible for the Municipal Act which authorizes municipal soil removal by-laws.
9. the Workers Compensation Board regulates health and safety matters under Bill C-70 (federal). In addition, the WCB monitors hazardous waste disposal to protect workers and to prevent contamination of aggregate products.
Adequate dust control is also a WCB concern.
10. the Federal Department of Fisheries and Oceans is through the Federal Fisheries Act wherever fish stocks may be affected.
11. Environment Canada is concerned with marine dredging under the Federal Fisheries Act (Gravel Removal Order).
12. the Canadian Coast Guard monitors marine extraction in the Fraser River under the Navigable Waters Act and has conducted a number of studies on the impacts of marine extraction.

13. Regional Districts have the authority to implement regulations influencing aggregate operations. The mining of sand and gravel is not considered a use of land for zoning purposes within the regional district, however the processing of the material is so considered. This essentially constitutes "a distinction without a difference" as aggregate production cannot exist without crushing, washing and screening.
14. Municipalities are authorized by the Municipal Act to regulate extraction through soil removal by-laws. Municipal zoning regulations influence sand and gravel operations.
15. the Fraser River Harbour Commission is responsible for the allocation and monitoring of marine extraction in the lower Fraser River from Kanaka Creek to the mouth of the river.

The competitors for ownership of sand and gravel are both determined and numerous. Excluding private claimants, at least 15 political bodies with an associated 15 bureaucratic groups can lay claim to at least a portion of the sand and gravel development rights in the Lower Mainland. As no single private, political, or bureaucratic organization can claim complete ownership or even a dominant position in the ownership of the resource, no individual or organization

has complete responsibility for resource management. Baker (1990) illustrates the consequences of multiple claims in the following passage:

“...Competing and changing claims for the rights to property frequently promote disputes for ownership and the benefit of resources. It is through the structure of property rights that society controls the use and management of natural resources, and the adaptation and reform of property rights is commonly used to resolve conflicting claims to the rights of those resources.”

At present the large number of competitors for ownership of aggregate resources has resulted in a number of conflicting claims. The Coopers and Lybrand study (1993) on Aggregate Pricing identified 20 contentious issues between the Ministry of Crown Lands and aggregate producers (this represents only two of the many competitors for ownership rights).

Other property issues illustrate the lack of defined rights for the resource. The Ministry of Crown Lands, on the public's behalf, claims ownership of aggregate resources located on public land in the province. The Ministry of Municipal Affairs under the Municipal Act gives the right to control aggregate production to specific Municipalities. Property rights are exercised by the Municipalities through zoning by-laws which may prohibit resource development, and soil removal fees (charged on public and private land). Although these fees are ostensibly used for road repair, evidence exists to show that collected funds are significantly in excess of what is required for this purpose. While no conflict exists between the involved

government ministries, the aggregate producers have vehemently contested the soil removal fees. Although Crown Lands is likely the predominant ministry with respect to aggregate resources on Crown Lands, its exclusivity to enjoyment of benefits is restricted by legislation such as the Municipal Act.

Section 2(4) of the Forest Practices Code of British Columbia Act allows the use and occupation of forested Crown land under the Coal Act, the Geothermal Resources Act, the Mineral Tenure Act, and the Petroleum and Natural Gas Act.

Clause 13 of the Forest Land Reserve Act controls the use of private forest reserve land and allows use or occupation authorized under the Coal Act, the Geothermal Resources Act, the Mineral Tenure Act, and the Petroleum and Natural Gas Act.

As neither of these Acts permits occupation or use under the Mines Act, the extraction of aggregate materials as a multiple or sequential land use for forested areas is not legally possible. While this is believed to be an oversight on the part of the political bodies involved in the drafting of the Act, it illustrates a lack of interest in the rational development of aggregate resources. As virtually every other natural resource interest is permitted under the two Acts by the benefit of being recognized by its own specific government ministry and legislation, perhaps the solution to aggregate resource use issues would be better resolved by an Aggregate Resources Act and a ministry with specific responsibility of managing the development and allocation of aggregate resources.

Despite the appearance of control and regulation by the Ministry of Crown Lands, the provinces aggregate resource is in a situation in which numerous government ministries (federal, provincial, regional and municipal), and private citizens (including aggregate producers, property developers and those seeking to block development) all seek to maximize their portion of ownership rights. Managing resources becomes an instrument to gain rights for bureaucrats. Private citizens are left without a clear policy to follow.

7.4 LAND USE STRATEGIES

Inevitably some type of aggregate resource management strategy will have to be implemented that will involve the provincial government. Continuation of the status quo could result in an eventually intolerable situation where the cost of mismanagement will become apparent by increasing aggregate prices and depleted aggregate reserves. The provincial government should become involved in the development process and initiate programs involving sequential and multiple land use.

7.4.1 Sequential Land Use

Sequential land use is a logical alternative and involves resource extraction before the land is removed from the mineral base and used for other purposes. This however requires planning of aggregate extraction and establishing a quarry permitting mechanism that can generate consensus. It is logical, in a resource

management framework, to plan a sequential development for aggregate removal prior to construction and urbanization. Planning should have as objectives (1) to regulate mining activity to prevent unacceptable environmental impacts, (2) to protect mineral deposits so that they can be mined to provide for future economic development and (3) to govern the sequential or post mining use of land for the purpose of compatibility with general land use plans (Thomson, 1980). This requires that accurate surveys identifying the location of deposits along with available tonnages, and material qualities be made available.

Sequential land use in the context of this paper concerns the extraction of sand and gravel only as the first step in the land use process. This provides for more efficient land use and encourages a more acceptable level of rehabilitation of the site following mining. A developer, rather than being concerned only with opening a sand and gravel pit, would submit a long range development plan for the area in which sand and gravel removal would only be the first step. As reclamation is more successful and less expensive if planned from the outset with specific goals in mind (Norman and Lingley, 1992), the property could be developed for agriculture, recreation or industrial use. Examples of this are as follows: south-east Florida where abandoned quarries are now waterfront property; south-western Pennsylvania where a housing development includes 300 houses, playgrounds, community buildings and a sewage treatment plant, all built on reclaimed land (Thompson 1980).

On the Lower Mainland, the best example of successful sequential land use is Coquitlam's Town Center Park. The 40 hectare (98 acre) park is situated on an old sand and gravel pit which had operated from the early 1920s until the 1970s. The park contains a number of playing fields, a stadium and Lafarge Lake, a man-made 2 hectare (5 acre) lake. The 70 hectare (172 acre) Central Fraser Valley Exhibition Park in Matsqui and the park adjacent to the Point Roberts border crossing are both on reclaimed land. Also sand and gravel extraction was used to enhance the agricultural ability of what is now a 100 acre corn and hay silage farm on 0 avenue and 256th street in Langley (Taylor, 1989).

A good example of sequential land use planning can be found in Southern Ontario. There the provincial government in 1986 with its Mineral Resources Policy required that local governments make every effort to reserve aggregate resources for future development rather than permit land usage that would preclude use as an aggregate source. This aggregate policy was formulated because of concern over whether adequate supplies of material would be available to major metropolitan areas if adjoining municipalities restricted development through zoning (Ontario Ministry of Natural Resources, 1992). The Ontario government has also had a detailed inventory of aggregate reserves prepared for most townships in southern Ontario. The inventory gives details on location, quality and quantity of reserves and is freely available to the public and to townships for planning purposes. The

government has also commissioned a study of aggregate reserves and transportation corridors in order to establish a long term plan for future supply.

In California the Surface Mining and Reclamation Act (SMARA) identifies and protects mineral resource areas of high land-use conflict and ensures reclamation of mined lands. The act gives powers of land use decision making to the local governments but allows the state government to prepare a detailed inventory of the states reserves. The state can then designate certain deposits as being "regionally or of statewide significance" and the local authorities may then use this information in their planning process. It is estimated that 50 billion tons of aggregate material have been identified as protected under SMARA since its inception in 1975. At this rate it is estimated that \$17 billion worth of resources will have been saved by the year 2000 (Tepordei, 1990).

Although there are numerous examples of this sort of legislation throughout the United States, there is one common theme. In all cases where the state or provincial government has stepped in to preserve aggregate resources it has always been out of necessity rather than out of forethought.

In British Columbia, the Ministry of Crown Lands "...does not have any plans to further regulate the aggregate industry or to ensure that gravel resources are recovered before other land uses are developed (Coopers and Lybrand, 1993, page

12)". This would seem to indicate that Crown Lands feels that sequential land use planning is not required to protect aggregate resources. However, when defending its policy of not releasing land in fee simple for gravel extraction (and in doing so forfeit their royalty), the Coopers and Lybrand Report (1993) identifies the Crown Lands position as follows (Executive Summary): "Gravel is a temporary use of land which, subject to proper reclamation, does not significantly change the value of land in the long term." This statement outlines a fundamental principal of sequential land use, and shows that in some instances the Ministry of Crown Lands is willing to be flexible.

Both Ontario and California have legislated to protect aggregate resources and ensure the orderly development of these resources. Government agencies are assigned to develop and maintain aggregate material inventories and to disseminate this information to local planners.

In British Columbia, although some information as to Crown policy does exist in an official "Quarry Materials Policy Statement", it is not widely available. It was noted in the Thurber Report (1990) that at the time, neither the sand and gravel industry, nor the BCMoTH, knew of its existence. In 1995, in researching this thesis, a Crown Lands representative informed the author that, to his knowledge, the policy statement did not exist. A 1994 version of the policy was finally obtained from an industry representative.

7.4.2 Multiple Land Use

Multiple land use can exist if there exists a compatibility between activities such that overall benefits increase by the coexistence of the activities. Ideally these activities should be chosen to maximize social benefits and not focus entirely on economics. Uses that have limited or undefinable market values such as environmental resources must still be evaluated for land use purposes.

To evaluate the viability of multiple land use a number of aspects must be examined. The distribution of benefits must be considered. Parties that will benefit from the introduction of a new use as well as those that will benefit from its non-introduction should be identified along with their motivations. Existing land uses and property rights especially for publicly owned resources have been conceded over time to various groups or individuals. New uses may violate "trusts" and could result in legal actions along with possible compensation to the injured parties.

Finally, political acceptability cannot be ignored. An unpopular land use decision, no matter how practical or logical, if politically unpopular, will not succeed.

An example of the problems which might arise from poor or non-existent multiple land use planning is exemplified in one of the conflicts which arises between forest and aggregate extraction land-use. Prior to the release of land for sand and gravel

extraction, tree removal may be permitted to another company or individual. The land is first cleared of trees and subsequently mined for aggregate resources. At the conclusion of operations however, the Mines Act requires aggregate resource users to be entirely responsible for reforestation. Aggregate producers feel this is an unfair environmental burden as during aggregate extraction, it is rarely necessary to remove all of the trees from the area of the lease. Furthermore the removal of trees can negatively effect slope stability and result in increased stabilization expenses during operations.

7.5 SYSTEMS OF TENURE

Property rights are allocated to aggregate resource users in different ways depending on whether the resource exists on crown, private or aboriginal land.

7.5.1 Crown Land

While anyone is entitled to search for sand and gravel deposits, if on crown land, once discovered, the deposit becomes the property of the Ministry of Crown Lands. The method of disbursement preferred by the Crown is by "...open competition , except where new quarry deposits have been identified through public initiative or where a replacement tenure is required." In the noted exceptions "... (a) direct offer from a single applicant will be considered ...". The term "considered" is quite important in this quote as it leaves the Crown the option

of either publicly tendering, or claiming for itself (for government use), any independently identified deposits.

For development of sand and gravel resources on Crown Land the procedure is as follows.

1. An inquiry is made by the applicant to the Ministry of Crown Lands.
2. Tenure application is submitted to Crown Lands on a Form 1 Staking Notice and Form 184 along with a pit concept plan.
3. Crown Lands conducts a land status check and refers the application to other government agencies including: MoEMPR, MoE, Ministry of Transport and Highways (MoTH), ALC and local governments.
4. The government comments are reviewed by Lands, and a field inspection is carried out. If the application is approved, the Crown advises the applicant of rent and royalty rates. A Notice of Work or mining plan must be submitted to MoEMPR.
5. The Notice of Work is referred to DFO, MoE, MoF, and Crown Lands for comment.
6. The Applicant advertises notice of filing in the BC Gazette and local newspapers inviting comments from those individuals affected by the planned operation.
7. MoEMPR and Crown Lands establish conditions and environmental bond required.

8. Subsequent to the posting of the bond, tenure is given by Crown Lands and the pit development may begin.

Tenure available on Crown Land is granted in several forms and are described in section 2.6, "Form and Term of Tenure Reserve" of the BC Lands Quarry Materials Policy (1994).

7.5.1.1 License of occupation

A License of Occupation is granted for terms normally ranging up to 5 years in length although terms can be extended to a maximum of 10 years. New operators may only receive a 5 year term with an available 10 year replacement license available following satisfactory performance of the initial license term. This type of tenure is typically extended for the preliminary, promotional period and for pre-production development. Rent is charged at a rate of the greater of \$500 annually or 1% of the appraised land value. Rental fees must be pre-paid annually. Appraised market value is determined by the Government and reviewed at 10 year intervals. Lands required for secondary use (an industrial or commercial use associated with, but not defined as a quarry operation, such as a permanent asphalt or ready-mix plant) are subject to a fee rental of 7.5% of appraised market value. Appraised value of secondary uses remains fixed for the sooner of 10 years or the duration of the license. Royalties must also be paid based on the quantity of material removed.

7.5.1.2 Lease

A lease is granted for periods up to 10 years with extension available to a maximum of 20 years at the Regional Director's discretion. New operators may hold a maximum 5 year term, however an additional 10-20 year replacement lease may be granted subject to the operators satisfactory performance during the initial term. This form of tenure is available in cases where a term under a License of Occupation is insufficient. Rent and Royalties are identical to those paid under a License of Occupation with the exception of the secondary use fee which is 8% of appraised value within a lease. Rental fees must be prepaid annually. Appraised values of primary and secondary uses are described under License of Occupation (above).

7.5.1.3 General (section 10) Quarry License

A General Quarry License is granted for terms of up to 6 months. These licenses are typically used in cases where a quarry will only be opened for a short term, small quantity project, or if the property is only in the exploration stage. A rental fee of \$250 must be prepaid prior to issuance of a license.

7.5.1.4 Map reserve

Reserves are granted for terms of 5 years with extensions available to a maximum of 10 years subject to a review of the necessity of the reserve. Reserves are used to withdraw sand and gravel resources on Crown Land from private use. They are issued at the request of Government agencies able to demonstrate a need for the

resource. A reserve does not constitute tenure. A Land Act tenure is required prior to extraction with the excepting Government ministries. Once reserved, gravel can be removed by Government agencies and can only be used for public purposes. The Government ministry for whom the reserve was issued can issue a Transfer of Administration to allow a third party (private or public) access to the reserve.

7.5.1.5 Crown Grants

Crown Grants are not normally issued for aggregate production and require an order in council to do so.

7.5.2 Private Tenure

Sand and gravel and crushed stone may be extracted from privately owned land.

The operator may own the land outright or lease the land from a private owner.

To develop a pit on private land the permitting procedure is as follows:

1. An inquiry is made to the local Agricultural Land Commission (ALC) or Ministry of Energy Mines and Petroleum Resources (MoEMPR).
2. Application is made to the local government office.
3. If accepted, the ALC establishes conditions for pit development
4. The ALC refers the application with conditions to MoEMPR.
5. The applicant submits a mine plan (a Notice of Work) to the MoEMPR.
6. The Notice of Work is referred to the Ministry of the Environment (MoE), Ministry of Forests (MoF), the Department of Fisheries (DoF), and the local government. These departments may all then comment on the Notice of Work.

7. Notices are filed in the BC Gazette and local newspapers to solicit written responses from persons affected.
8. MoEMPR establishes permit conditions and an appropriate reclamation bond.
9. Subject to the posting of the environmental bond, a permit is issued and pit development commences

The permitting process is clearly much less complicated and involves fewer government bodies than does the process for crown land. The regulatory agencies are identical but the absence of the Ministry of Crown Lands.

7.5.3 Aboriginal Lands

Regulations and procedures for aggregate development on aboriginal lands is not clearly defined. Clearly, the permission of the Band Council is required but beyond this, few government agencies have either the jurisdictional authority or political will to regulate activities on Band Land. Although the MEMPR traditionally inspects aggregate operations on aboriginal lands they have only recently been granted the legal authority to do so. Historically, despite a lack of official regulation and government control, aggregate operations on aboriginal lands tend to operate within conventional standards. Band Councils have a direct interest in maintaining high environmental and operational standards as do aggregate producers who seek to maintain a congenial relationship with the land holders. Aboriginal lands are less affected by urban encroachment allowing aggregate operations more secure, long term tenure. Municipal zoning by-laws, seen as

hostile to aggregate operations, have less jurisdiction on aboriginal land.

Chilliwack has imposed a soil removal fee for production on aboriginal lands, which was found to be legally enforceable by the courts. It is not yet known how this judgment will stand up should it be appealed nor how land claims settlements will influence the decision.

7.6 TAXATION

Central to any property rights scheme is the method by which the owner obtains his or her entitled benefits. Taxation represents the method by which governments obtain a share of any stream of benefits generated by the exploitation or use of a state owned resource. In the case of the aggregate industry a number of taxes are used (Table 5.1) including a mining tax (a tax to reclaim resource rent), and several separate royalties paid to the Ministry of Crown Lands as well as the Municipality controlling the resource.

7.6.1 RESOURCE RENT

Aggregate production generates revenues by the extraction and processing of sand and gravel or by the mining, crushing, and screening of solid rock. While the aggregate producer adds value to the resource through extraction and processing, a large proportion of the profits earned by the producer are generated by characteristics of the rock or deposit itself. These characteristics produce a non-

man made value which can be considered a “gift of nature” (Kumar, 1991) and are the basis for economic or resource rents.

The theory of resource rent asserts the idea that the extractor of the resources is not entitled to benefit from the “natural” value of the resource. The inherent values of natural resources such as quarryable rock and sand and gravel deposits (other examples include minable ore deposits and timber) are considered to belong to the public. The public entrusts their elected officials, the government, to manage their resources and ensure that an appropriate portion of the proceeds generated by the sale of these resources is given back to the people. As the government is often unable to exploit these resources itself, private organizations and individuals are permitted to explore and extract whatever revenues they can from the sale of the public’s resource. In return for their efforts the government allows these private organizations to keep a portion of these revenues to compensate for costs incurred in extraction and processing. In addition an appropriate return on investment must be allotted to allow the producer to profit from his or her endeavor and to encourage further development of the resource (the supply price of investment). After these allowances are made the government “extracts” the public’s share of the proceeds in the form of resource rent.

Determining an appropriate rent that allows the public to collect maximum revenue but does not discourage resource development is a daunting task. Each sand and

gravel or quarryable rock deposit possesses certain characteristics which will effect the profitability of the extraction operation. Factors such as depth of overburden, material desirability, local competition, reclamation bonds, and distance to market are each able to make a deposit of ideal quality marginal or uneconomic.

A taxation regime should be sensitive to such situations. Resource rents should not play a factor in production decisions. The objective of resource rent is to tax surpluses. Calculating rents can be compared to determining annual allowable harvests in the renewable resource industries; one can only claim up to a certain quantity of the resource before its long term viability is threatened. In the case of aggregates, marginal properties containing lower quality material or with higher extraction costs have correspondingly lower inherent values. The companies or individuals mining these properties may have to invest more into their operations and assume a greater risk of loss than do those whose mines exist under more ideal conditions. Consequently, as there is less natural value contained in some deposits, the rent which reflects this value should be lowered accordingly. Taxes which go beyond reclaiming surplus rent influences production by encouraging the rent payer to generate higher profits to pay for the excess claimed by the government. This is typically achieved by:

- Extracting only higher value, lower cost material-a practice known as high grading;

- Avoiding deposits with lower potential. In these cases, sand and gravel or quarry deposits of marginal quality or with potentially high operating costs will not be developed;
- Charging higher prices for their product thereby passing the non-rental portion of their tax onto customers.

In these situations the public loses on three counts:

1. Rent is forgone due to lower tonnages produced
2. No benefit is realized from a potential reserve of aggregate material.
3. Higher aggregate prices resulting in higher construction costs which are ultimately paid by members of the public.

Conversely, in situations where the rate of taxation fails to recover all of the resource rent, the government, and consequently the public, foregoes proceeds which rightfully belong to them.

Theoretically, taxation of sand and gravel or quarry deposits can therefore be justified by the following:

- the natural value of the deposit is owned by the public
- without taxation the public loses a valuable asset without compensation
- taxation should reclaim only surplus revenues, therefore not effecting production (in theory)

Taxation in excess of resource rent however, is borne by the public in the form of higher aggregate prices and a diminished resource base.

The following taxes are paid by aggregate producers in BC (Smith, 1990):

<u>Jurisdiction</u>	<u>Tax</u>
Municipal	Property Tax
	Royalty/Permit Fee*
Provincial	Corporate Income Tax
	Mining Tax
	Sales Tax
	Fuel Tax
	Royalty (Crown Lands)*
	Land Rent (Crown Lands)*
	Property Tax
Federal	Corporate Capital Tax
	Corporate Income Tax
	Fuel Tax
	Sales Tax
	Payroll Tax (CPP, UIC)

* Taxes unique to the aggregate industry

Table 7-1: TAXATION OF THE AGGREGATE INDUSTRY ON THE LOWER MAINLAND OF BRITISH COLUMBIA

A brief outline of the taxes unique to the sand and gravel industry follows as does a comparison with the mining industry. In 1991, the law firm of Thorsteinssons

completed a study comparing the taxes paid by the sand and gravel industry with those paid by the mining industry. The study failed to account for a number of provincial and municipal royalties and did not examine the difference in taxation between a privately owned pit and a Crown Land operation. In this sense the report cannot be considered complete. Nevertheless the applicable federal and provincial tax systems described in it are comprehensively examined and are summarized in the following paragraphs.

The mining industry in both Canada and BC is taxed specifically under the Income Tax Act which describes a mineral resource as follows:

- “(a) a base or precious metal deposit,
- (b) a coal deposit,
- (c) a bituminous sand deposit, oil sands deposit or oil shale deposit, or
- (d) a mineral deposit in respect of which
 - (i) the Minister of Energy and Resources has certified that the principal mineral extracted is an industrial mineral contained in a non-bedded deposit,
 - (ii) that the principal mineral extracted is sylvite, halite, gypsum or kaolin, or,
 - (iii) the principal mineral extracted is silica that is extracted from sandstone or quartzite...”

In this respect sand and gravel is implicitly excluded from the definition of a resource property under the Income Tax Act. Nevertheless the rate of federal income tax payable by a sand and gravel producer is identical to a specified resource user at the rate of :

Base rate	38%
less Provincial Abatement	(10%)
Federal Surtax	3%
Net Federal Tax	31%

The Provincial Abatement is an allowance made for provincial governments to impose their own corporate tax (which in BC stands at 14%). A further 5% deductible as manufacturing and processing profits deduction. Sand and gravel producers may use this deduction for profits earned in washing, drying, crushing, sorting and bagging of their products. It should be noted that conventional base metal, precious metal and industrial mineral mining operations are excluded from this deduction for initial processing. Mineral resource property developers are however allowed to claim both Canadian exploration expenses (CEE) and Canadian development expenses (CDE) for costs incurred in exploration and development of a mine. Both CEEs and CDEs can be carried forward and claimed against future revenues allowing mining companies to recover what are usually substantial costs. Neither CEEs or CDEs are available to commercial sand and gravel producers. Exploration and development of sand and gravel deposits are deductible either as current expenses in the year they are incurred or are added to the capital cost of the property depending upon the stage of development. While CEEs and CDEs may be carried forward indefinitely, the non-capital losses created by exploration and development of a sand and gravel operation must be used within 7 years. The cost of a sand and gravel property is depreciable and can be deducted on a per units of production basis as a capital cost allowance

(Thorsteinssons Report, 1991). Buildings and machinery used in sand and gravel can also be written off as a capital cost allowance on a 25% declining balance basis. A 100% capital cost allowance available to the mining industry for new equipment and expansions (post 1988) is not available to the sand and gravel industry. Similarly the resource allowance, which encourages exploration and development in the mining industry, is not available to sand and gravel operations.

The right of taxation was given for natural resources to the provinces in section 92A(4) of the Constitution Act in 1867 which reads:

“(4) In each province, the legislature may make laws in relation to the raising of money by any mode of taxation in respect of
(a) non-renewable natural resources and forestry resources in the province and the primary production therefrom,...”

In BC the provincial government charges a tax of 14% of income based on the calculated income for federal tax purposes. Additional provincial mining taxes also apply. The Mining Tax Act applies exclusively to sand and gravel, soil, and peat while the Mineral Tax Act applies to other mining operations. Sand and Gravel operations are charged at a rate of 12.5% on income over \$50,000 (this is inclusive of all operations within a company). Income eligible is considered to be earned from: extraction; processing; manufacture of products from sand and gravel; and, the sale of sand and gravel. Processing and manufacturing allowances can reduce this tax by an amount based on a formula (in some cases as much as 50-70%) (Thorsteinssons, 1991). Further royalties and land rents are charged on

Crown Lands operations by the Ministry of Crown Lands. These rates are highly variable and are subject to frequent reviews.

Municipal soil removal fees are production based, and similar to Crown Land royalties in that their rates are somewhat arbitrarily set without regard to the profitability of the taxpayer.

7.6.2 ROYALTIES

Compared to other methods of taxation, royalties have a negative impact on efficiency, are not progressive, and are inequitable. Other charges such as license fees, land rent, and soil removal fees have similar impacts. Efficiency in terms of mining can be described as optimizing the recovered minerals and byproducts in accordance with good mining practices. As royalties are charged to aggregate producers on the basis of tonnages produced, they create inefficiencies by encouraging low tonnage, high value production. Kumar (1991) states:

“...a royalty is not related to [market] cycles and profits and therefore distorts operating decisions by reducing the size of economically recoverable reserves...”

“[Royalties] have a greater effect when prices are lower or when the deposit is marginal.” “[A] high rate can lead to an increase in the cut off grade of ore reducing the size of economically recoverable reserves - the well discussed phenomenon of tax induced high grading.” “[A royalty] should not be the main source of revenue generation as it is not profit related. It should not be used to collect any portion of the economic rent, but rather as a device to check wasteful extraction.”

As a tonnage based fee, royalties fail to capture economic rents in the event of windfall profits in the industry. A royalty's sensitivity to market cycles can theoretically be increased by frequently reviewing and adjusting royalty rates. Reviews can be conducted on smaller scales; from an industry wide review to reviewing on an operation by operation basis. As the frequency of the review period increases, and the scale of review decreases (to obtain optimum rate levels), the royalty regime becomes more complex. This defeats the prime appeal of a royalty system; that of simplicity of administration.

Royalties can be inequitable and result in lost resource rent. Flat, tonnage based fees fail to account for unique depositional characteristics which can differentiate between the economic viability of various operations. Even adjacent properties can have considerable differences in material quality and accessibility. This difference is not accounted for in a royalty system. An operation with high quality, accessible material pays a similar royalty to a nearby operator on a similar quality, more deeply buried deposit. If the royalty is determined by the rate bid for the more profitable deposit, the less profitable operation will likely experience difficulty. In the first case the Crown may not be recovering sufficient rents on highly profitable material. In the second instance the royalty may render what is otherwise good material un-economic which also results in lost revenues.

7.6.2.1 *Royalty determination on Crown Land*

The BC Ministry of Crown Lands allocates extractive rights on public land by competitively auctioning tenures on the basis of royalties to be paid. Crown Lands uses this rate to conduct tenure reviews on nearby properties. Every two years a tenure review is conducted and the payable royalty is adjusted using the most recent, regional bid offered. The firm of Coopers and Lybrand was retained by the BC Ministry of Crown Lands to conduct an aggregate pricing study in 1993. The study noted the following royalty related concerns (among others):

- the review and adjustment procedure places an administrative burden on both the Crown and the operator;
- the Crown has concerns that its rates may be too low in some areas (operators disagree);
- the Crown expends considerable time and resources reviewing tenures;
- a maximum of 2 years of rate certainty is provided to operators making long term project financing difficult;
- the Crown may set royalty rates using bids from other geographical areas;

7.6.3 Soil Removal By-Laws

Roadways used for aggregate transport tend to suffer greater than usual damage and require more frequent maintenance. In some instances roads must be widened to accommodate the heavy truck traffic. To pay for these repairs and upgrades, many Lower Mainland municipalities enacted soil removal bylaws which imposed a fee for the removal of sand and gravel. The intent of these bylaws was to have

those responsible for the increased truck traffic and associated road damage pay for the additional repairs and maintenance.

What began as a flat, annual fee used to defray the cost of road repairs evolved into a production based royalty in which aggregate producers pay a fee on a per cubic meter basis. Soil removal bylaws are now used as planning tools to influence or prohibit production and as sources of general revenue for the municipalities. In this sense municipalities have used what was originally a limited power to charge a permit fee, to squeeze themselves in to what is already a crowded body of government officials regulating and taxing the aggregate industry. In examining a history of court challenges it is interesting to observe this evolution.

7.6.3.1 Legal challenges

Aggregate producers in the Lower Mainland have found soil removal bylaws to be a major irritant to their operations and contend that the bylaws are discriminatory, an indirect tax, and beyond the authority of the municipality to impose.

Furthermore there is suspicion among the aggregate producers that soil removal bylaws are also

(1) a method of revenue generation, and (2) a tool which may be used to force them to close their operations prematurely. As a result there have been numerous court challenges to the legality and validity of the bylaws.

The Municipal Act gives local governments the authority to regulate and prohibit removal and deposition of soil within municipal boundaries.

Section 930(d) of the Municipal Act states:

930. The Council may by-law regulate or prohibit...

(d) the removal of soil, sand, gravel rock or other substance of which land is composed from any land in the municipality , or in any area of the municipality, and require the holding of a permit for the purpose and fix a fee for the permit, and different regulations and prohibitions may be made for different areas;

The years 1969-1980

The first attempt at imposing soil removal by-laws occurred in 1969 when the District of Maple Ridge charged a fee for the removal of sand and gravel from within their jurisdiction. This was challenged by a number of aggregate producers in the 1970s on the grounds that the fees paid by the producers discriminated unfairly against them and not other users of the roadways such as logging and freight trucking companies. In addition, the fees were challenged on the grounds that they constituted an indirect tax and hence beyond the power of the Province to authorize through the Municipal Act.

The most noted case of this era was *Coquitlam v. LaFarge Concrete Limited* ([1973] 1 W.W.R. 681, 32 D.L.R. (3d) 459 (B.C.C.A.)).

In his decision, Bull J.A. concluded that 92(2) of the 1867 B.N.A. could allow indirect taxation with allowances laid out in legislation such as that which was found in 92(9). The key, it was felt, was in the purpose of the legislation:

“-is the levy or tax (whether direct or indirect by nature) merely ancillary, or adhesive to the licensing scheme of regulating or prohibiting a trade, or is it essentially a fiscal imposition, or taxation under a form of disguise or a colourable concept?”

Taggart J.A. expanded on this idea by interpreting soil removal bylaws “real purpose” as not to

“...become a cloak for the raising of funds by indirect taxation, but rather to cause the holders of permits issued under the by-law to pay permit fees which will be adequate to cover the cost incurred and to be incurred by the appellant municipality in constructing and maintaining roads giving access to gravel pits and the cost of supervising, inspecting and enforcing the by-law.”

Although the court decided in Coquitlam’s favour, it is important to note that in these early stages of legal challenges, the validity of the by-law hinged on the concept that for the by-law to be valid, the revenues raised by the fees should be used to repair the roads damaged by the aggregate producers.

Kirkpatrick v. The District of Maple Ridge

In 1980 Maple Ridge enacted a by-law which charged a permit fee of \$0.20 per cubic meter of sand and gravel removed. This by-law was challenged in 1980 (119

D.L.R. (3d) 598, 14 M.P.L.R. 19) resulting in the BC Supreme Court quashing the by-law followed by a 1983 decision (49 B.C.L.R. 134) by the British Columbia Court of Appeal overturning that decision. The courts examined whether the by-law was a form of indirect taxation which is beyond the power of the province and the municipality as stated in the Constitution Act of 1867 (s. 92(2)). The District of Maple Ridge held that the fee was a genuine license allowed under s.92(2) and a regulatory charge as described in s.92(9), (13), and (16) of the same act. The 1980 decision by Murray J. (119 D.L.R. (3d) 598, 14 M.P.L.R. 19) described the Maple Ridge bylaw as a "...colourable attempt to impose an indirect tax on the gravel operator..." and containing "...an unlawful delegation of the districts' powers." The 1983 appeal (49 B.C.L.R. 134) found the bylaw to be ancillary to a valid scheme regulating soil removal and hence overturned the previous decision.

To a lesser extent the courts examined whether the province could delegate the power to charge the fee.

The case then moved in 1986 to the Supreme Court of Canada on appeal from the Appeal Court for British Columbia in 1986. The court examined (1) whether the by-law was authorized by section 930d of the Municipal Act, and (2) whether the province had the power to allow a tax such as the soil removal fee.

The findings were as follows. Although the Municipal Act grants taxing powers to the municipalities they tend to be strictly limited and well defined in the act.

Speaking for the court Judge La Forest quoted from the Supreme Court of Canada decision in the City of Montreal v. Civic Parking Center Ltd. in which the City of Montreal had attempted to impose taxes on the operation of private parking lots and collect them via permit fees based on the square footage of the property rather than as a flat fee. The Court found in this case that although the City had the power to impose a flat fee on parking lots, the Act which empowered the City of Montreal to do this was very specific in other provisions when it was apparent that the legislature wished to add unique features to a tax or to make it variable.

Therefore had the legislature wanted such a tax, it would be specifically noted in the Act. Judge La Forest noted that s.930(d) of the Municipal Act gives the power to "fix a fee for the permit" which suggested a flat fee as opposed to an increasing amount based on a measure of activities. Furthermore it was noted that when s.930(d) was originally applied it was done so on a flat fee basis indicating that the municipality itself originally interpreted the Act in same way. In further examining other areas of the Municipal Act Judge La Forest noted numerous instances where the municipalities were specifically empowered to vary license fees: "Municipal councils are even empowered to vary the amount of fees for dog licenses according to sex, age, size or breed (s.524)."

"Even in s.930(d) itself, the legislature averted to the need for differential treatment in certain circumstances. it provided for different regulations and prohibitions for different areas. In light of this it is significant that it did not provide for differential fees on the basis of use."

The Supreme Court therefore decided that because the structure of the soil removal fees was not strictly outlined in the Municipal Act, the municipalities were not within their powers to charge the fees. It is important to note the very narrow interpretation by the court of a municipalities right to impose taxes.

Allard Contractors Ltd. v. District of Coquitlam; Rempel Bros. Concrete Ltd. v. District of Mission; Kirkpatrick v. District of Maple Ridge (June 1988):

Rather than continue the fight in the courts the BC Government passed Bill 44 which amended section 930(d) and (e) to allow local governments to apply a fee for the removal or deposition of soil. Subsection (d) of the act became s.930(1)(d).

The subsection amending the act read as follows:

(2) The council may, by bylaw, impose a fee for the removal referred to in subsection (1)(d) or for the deposit referred to in subsection (1)(e) and the fee may impose a charge for each volumetric unit, as provided in the bylaw, of soil, sand, gravel, rock, or other substance removed or deposited and the volumetric fee may be different for different areas in the municipality.

Coquitlam, Maple Ridge and Mission all promptly re-enacted their bylaws to allow permit fees to be charged based on volume. (respectively, \$0.26, \$0.20, \$0.35/m³ of soil removed).

Allard Contractors, Rempel Brothers Concrete, and Kirkpatrick all challenged the new bylaws in (respectively) Coquitlam, Mission, and Maple Ridge in the BC Supreme Court. The basis of their challenge was listed as follows:

(1) The Municipal Act, as amended does not authorize the enactment of a variable permit fee.

(2) The bylaws are discriminatory, since the fees are levied only against gravel operators although largely to be used in the repair and construction of municipal roads used by transportation industries other than gravel operators.

(3) The fees are not ancillary to a scheme regulating soil removal. They are an indirect tax therefore ultra vires.

(4) Even if the fees are ancillary or adhesive to a scheme regulating soil removal they are an indirect tax and therefore ultra vires.

In (1) Allard (et al) argued that although the Act clearly allowed a flat fee for a soil removal permit, 930(2) did not authorize a variable permit fee, but rather a separate and distinct charge based on the volume of soil removed. As it stood, the municipalities wished to charge two permit fees while they were only allowed to charge one - that one of course being the narrowly interpreted flat fee. The municipalities argued that the amendment should be interpreted broadly with regard to the intent of the legislation: that the legislature had intended to authorize a variable permit fee whether the Act said so specifically or not.

In the courts decision, Judge Trainor referred to the case as "...the next episode in the continuing efforts of the municipalities to extract fees from the companies in gravel removal...". Although Judge Trainor expressed no doubt that the legislature had likely intended to authorize a variable permit fee, he held with the ruling in *Kirkpatrick v. Maple Ridge* that the legislation to impose a variable permit fee can not be implied by the circumstances surrounding the case. As the legislation did not expressly give the authority to the municipalities to impose variable permit fees, the bylaws were quashed on this basis.

Although this ruling alone was enough to decide the case, Judge Trainor quite wisely predicted "...having in mind the relationship between the municipalities and the gravel operators, it is not likely that this matter will rest at this level. Consequently and in the event that I should be in error in construing the legislation I will go on to deal with the other heads of argument."

For (2), (discrimination) the court ruled that to be seen as unfairly discriminating a bylaw must:

(1) discriminate in fact. By-laws discriminate if they "give permission to one and refuse it to another".

(2) The factual discrimination must be carried out with the improper motive of favouring or hurting one individual and without regard to the public interest.

Judge Trainor found neither discrimination in fact nor was there found to be any improper motive on the part of the municipalities with regard to the public interest.

It was felt that the legislature had authorized a fee for the purposes of regulation rather than discrimination and as a form of recouping expenditures for road building and maintenance. Furthermore Trainor's view was that only the parties involved in soil removal could be considered in (1). Discrimination was only viewed therefore, in the context of aggregate producers who, of course, were treated equally under the by-law. Consequently the discrimination argument was rejected.

In argument (3) (fees are indirect tax hence ultra vires) the court employed the John Stuart Mill's test for indirect tax which states:

"Taxes are either direct or indirect. A direct tax is one which is demanded from the very person who it is intended or desired should pay it. Indirect taxes are those which are demanded from one person in the expectation and intention that he shall indemnify himself at the expense of another, such are the excise or customs."

"The producer or importer of a commodity is called upon to pay a tax on it, not with the intention to levy a peculiar contribution upon him, but to tax through him the consumers of the commodity, from whom it is supposed that he will recover the amount by means of an advance in price."

Trainor found that if the fees were imposed on the gravel operators with the expectation that they were to be passed on to the consumers the fees would indeed be an indirect tax. However it was ruled that the fees were ancillary to the regulatory scheme; they were simply a method for the municipality to collect money to pay for road building and maintenance. Trainor felt that moneys raised for this purpose cannot be considered taxes and therefore the issue of whether the fees are passed on to consumers could not be considered. In justifying this decision Trainor quoted J. La Forest (the Supreme Court of Canada Judge mentioned in *Kirkpatrick v. Maple Ridge*), in his book *The Allocation and Taxing Power Under the Canadian Constitution* (2nd ed. 1981, p 160), as stating:

“The limitation imposed by the Supreme Court of Canada [that fees must be limited to the costs of administering a licensing scheme] appears sound; to permit the provinces to raise indirect taxes by simply framing their legislation in the form of a license threatens to open the whole field of indirect taxation to the provinces unless one frames a test for genuine and non-genuine licenses.”

“The test of limiting fees to the costs of administering a scheme appears reasonable but it will require further refining. As this is done one can expect the courts to give a sympathetic ear to municipal licensing schemes. This is understandable in the light of the restrictive taxing powers of municipalities and the fact that their by-laws will only be felt locally.”

Judge Trainor in this instance did indeed give a sympathetic ear to the municipality for he ruled that despite evidence that indicated considerably more money would be raised by the new by-law than was required to pay for roads and administration, it was not for him to "...measure those amounts with exactitude." The fact that there was further evidence to show that moneys raised by this scheme were to be used as a source of general revenue was also considered irrelevant.

Argument (4) was not dealt with as it was felt by the court that it was ruled on in the judgment on argument (3).

The bylaws were quashed and the complainants were awarded costs.

The municipalities quickly changed their bylaws to include a flat permit fee along with a new volumetric removal fee.

This case marked an important point in the evolution of soil removal by-laws.

Firstly it became apparent that by the speed with which the provincial government amended the Municipal Act that the support for volumetric soil removal fees went beyond the municipal level. Secondly it was noted that discrimination on the part of the municipality is permitted provided it is provincially authorized. Thirdly, although many of Justice Trainor's (and previous) decisions justifying soil removal fees were based on the concept of these fees being for road remediation only,

evidence was presented to demonstrate that the municipality was receiving more than enough money for this purpose. In addition the municipality considered the funds raised to be general revenue and gave no evidence to show that any of the funds were used for their originally intended purpose. Although this case ended in the aggregate producers favour, Judge Trainor's other decisions would cause considerable harm to the aggregate producers future challenges.

Allard Contractors v. The District of Coquitlam (Feb. 1989):

Allard returned to the courts in 1989 to challenge the new municipal bylaws of Coquitlam on essentially the same grounds that were raised in the previous challenge. Unfortunately for the gravel operators the new bylaw had been changed to allow the new volumetric fee and the groundwork for their other challenges had been done by Judge Trainor in the previous challenge. Judge Paris in this case found no discrimination on the part of the municipalities with respect to the bylaw. With regard to the taxation issue (that the fees constitute an indirect tax and hence are ultra vires) Paris found that a licensing or permit fee can be an indirect tax and still be valid providing it is ancillary to a regulatory scheme.

Once again, evidence was produced by Allard showing that the municipality would raise more money than was needed for the stated purpose of the fee; to build and repair roads used by gravel trucks. This fact was not disputed by the municipality (however they did challenge the amount of the surplus).

Allard's challenge was rejected on all points.

Bill 20 (June 1989):

The constant legal challenges and lobbying on the part of the sand and gravel operators had caused the Provincial Government to take an interest in the controversy. The MoEMPR was becoming concerned at the rate at which aggregate resources were being overrun and sterilized by municipal boundaries and bylaws. The Municipal Act was Amended in June 1989 by Bill 20 which although upholding the right of municipalities to regulate sand and gravel operators and to charge soil removal fees, included the provision that:

- bylaws prohibiting removal must be approved by the Ministers of Municipal Affairs, and Energy, Mines and Petroleum Resources.
- bylaws imposing fees must be approved by the Minister of Municipal Affairs

Rempel Bros. Concrete v. District of Mission (Oct. 1989) Thornhill**Aggregates v. District of Maple Ridge (June 1990):**

The following challenges to the soil removal bylaws were based on a suggested discrimination between land owners and lessees of crown land. In addition different charges were levied depending on the quantity removed as well as for the purposes for which the soil/sand/gravel would be used for.

Missions bylaw at the time charged a fee of \$0.35/m³ for soil removal for a land owner however if the owner was a lessee of crown land the charge was a mere \$1.00 per year. A permit fee of \$100 per year is also charged if more than 200m³

of material is removed while no permit fee is payable if less than 200m³ is removed or if the material is not to be removed for commercial purposes.

Judge McKenzie ruled that contrary to Judge Trainor's decision that discrimination had to be present in fact and in improper motive in order to invalidate the bylaw. The Judge felt that while the Municipal Act provided for discrimination between areas of the municipality it did not authorize discrimination between types of land owners.

The bylaw charging different fees to land owners was quashed.

Judge McKenzie did not invalidate the non-commercial and under 200m³ permit fee on the grounds that he did not wish to compel persons to pay commercial scale fees if their intentions were non-commercial.

In his conclusion Judge McKenzie echoed Judge Trainors comment that "...it is not likely that this matter will rest at this level."

In the Thornhill challenge an aspect of Maple Ridge's bylaw was contested on the grounds that it exempted from removal charges or permit fees anyone removing less than 75 cubic meters of material or those removing material for the purposes

of development or improvement of land or if the removal was related to building construction. Thornhill produced evidence showing in one instance 26000 cubic meters of soil being removed without removal charges or permit fees being levied.

Justice Callaghan however held with Paris's judgment (Allard . Coquitlam 1989) in that the bylaw did not discriminate between those it was seeking to regulate.

The bylaw was upheld.

7.6.3.2 Appeals

Allard Contractors v. The District of Coquitlam

Thornhill Aggregates v. District of Maple Ridge

Kirkpatrick v. District of Maple Ridge

Allard Contractors v. The District of Coquitlam

Kirkpatrick v. District of Maple Ridge

(Nov. 1991)

This case heard 3 appeals by the municipalities of Trainor's decision overturning their soil removal bylaws as well as 2 appeals by the gravel operators on the upholding the bylaws made by Judges Paris and Callaghan.

The court refused to overturn the Paris and Callaghan decisions finding that the fees were indeed constitutionally authorized and did not unfairly discriminate against commercial gravel extraction.

The court overturned the Trainor decisions. Judge Southin stated that in the courts opinion the decision to not authorize a volumetric fee - what the legislation was intended to do- on the grounds that it could not be imposed as a permit fee but only as a separate charge was to "...make a distinction without a difference."

The years 1992-1995

The results of the appeal have apparently not diminished the appetites of the aggregate producers for court challenges. The municipalities on the other hand have continued to charge soil removal fees as well as add more restrictive zoning regulations. Some of the more contentious examples are:

- The municipality of Chilliwack imposes a soil removal fee for sand and gravel extracted from an aboriginal reserve. In *Rempel vs. Chilliwack* (1994) the BC court of appeals held that municipal soil removal bylaws apply to Reserve Lands. In addition the court ruled that in order to remove sand and gravel from an Indian Reserve, permits must be obtained from the MEMPR, the local Band Council and the Federal Minister of Indian Affairs. Aboriginal land claims in the province are based on the fact that no land was ever ceded under treaty to the Federal Government. Consequently it is difficult to reconcile the logic of the courts decision, that a municipal by-law and provincial regulations can apply on Aboriginal Lands.
- The Dewdney /Allouette Regional District has enacted a bylaw making crusher operation illegal which will effectively prevent any aggregate production. Existing operations have been "grandfathered" and no new operations will be allowed. Although Regional Districts may not charge soil removal fees they are entitled to regulate operations such as crushing within their district. As the bylaw does nothing to restrict extraction, no action was taken by the Province

under the terms of Bill 20. The Supreme Court of BC upheld the by-law although the case is under appeal.

- In Cannon vs. Mission, the Court of Appeal upheld a previous decision allowing the municipality of Mission to require a permit be issued before gravel can be mined in the Municipality. Mission (and consequently any other municipality) is able to circumvent 930.1(3) of the Municipal Act, which requires that bylaws prohibiting extraction be subject to review (see Bill 20 above), by restricting or not issuing permits rather than “prohibiting” extraction.
- In the District of Coquitlam vs. Construction Aggregates, the municipality sued the producer for withheld soil removal fees. Construction Aggregates argued that transportation of aggregates on municipal roads was prohibited and furthermore impossible due to a load limit on a bridge. Consequently, the operator argued that as no road was used by the operation, a soil removal fee to repair municipal roadways should not apply. Construction Aggregates felt that any such fee would be illegal and unconstitutional as the fees were to be used for purposes other than in regulation of the property. The Supreme Court of BC dismissed Coquitlams case and held that Construction Aggregates had an arguable question to be tried as to whether or not the Coquitlam bylaw was illegal or unconstitutional. Although no appeal has been issued and no trial date has been set, should an appeal occur the issue to be decided will be whether a

municipality can raise funds through soil removal by-laws in excess of what is required to repair roads. Although this issue has been raised in previous cases it has not yet been considered by the courts.

7.6.3.3 Summary

Perhaps the most noticeable lesson which can be learned from the court battles fought over soil removal fees is summarized in the old adage "you can't fight city hall" (you actually can fight, you just can't win). The Aggregate Producers only victories were temporary; minor points in the Municipal Act or in the by-laws themselves. These were quickly amended and the bylaws re-enacted. The fundamental decision that the Producers required - that soil removal by-laws were discriminatory and beyond the powers of a municipality to impose - was not forthcoming. In each of the cases described here the challengers listed essentially the same complaints, that soil removal fees are discriminatory, that soil removal fees are a form of indirect taxation, and that the bylaws are not within the power of the municipalities to enact. In every decision these complaints were dismissed. One cannot doubt therefore that the several BC Supreme Court Judges who dismissed the complaints did so on solid legal grounds. One can however question whether the outcome of these decisions was the "right" one.

Although Judges Trainor and Paris ruled that soil removal fees are ancillary to a regulatory scheme and are not a form of indirect tax, the effect on the public is nevertheless identical. The public, as the consumer, pays the fee. Although in many cases due to the competitive nature of the gravel business, soil removal fees are not passed on to the consumer over the short term by the producer, they eventually

result in higher gravel costs, lower reserve inventories (as marginal pits are sterilized due to the added cost of production), and greater transportation costs (producers must exploit more distant deposits to avoid punitive charges). In addition, as gravel is often transported across municipal boundaries the overall effect is that the consumers and taxpayers throughout Lower Mainland pay fees to a few municipalities. Although the municipalities would argue that they must charge the fees to repair their roadways, gravel trucks do not stop damaging roadways at municipal boundaries.

The description of soil removal bylaws as a regulatory scheme can in some cases be questioned as the municipal regulations often needlessly duplicate provincial regulations. For instance, some bylaws are understood to establish security bonds for gravel pit operations. As municipal staff do not have the expertise to regulate mining and reclamation procedures, inspections must be carried out by provincial inspectors (Thurber 1990). Similarly, stipulations in by-laws that "pit wall slopes must be stable" are laudable but are duplicated by the MoEMPR which enforces and regulates pits and quarries. It is doubtful that the municipalities have the same expertise.

As aggregate materials represent only a small fraction of overall building costs but are absolutely essential to the building process, costs added by municipal regulatory schemes are unlikely to effect demand. In forecasting aggregate demand, studies have shown that price is not a relevant factor (Poulin, 1995).

People simply pay the additional cost as they cannot substitute or reduce their consumption. The fact that the price paid is relatively small - approximately \$3.50 per capita per year based on an average fee of \$0.50/m³ and an average consumption of 14 tons per capita - does not change the fact that certain Lower Mainland municipalities earn revenue by charging a fee for the removal of an essential resource which effects residents and non-residents alike.

This is not to imply that the Judges were incorrect when they ruled against the notion that soil removal fees are discriminatory or an indirect tax. Clearly, the number of challenges and appeals conducted over the past 15 years show that the by-laws are indeed legally enforceable. It has become apparent by these decisions that both of the primary complaints - discrimination, and indirect taxation - are justified in the Municipal Act.

With the tacit approval of the provincial government, the municipalities of the Lower Mainland have taken that was originally authorized only to recover fees required for the roads damaged by gravel trucks and amended it to become a tool for planning and revenue generation. In several court challenges these by-laws have been found to constitute an indirect tax on the public as well as to discriminate against the aggregate producers. As both the discrimination and taxation are allowed under the legislation however, the by-laws have been found to be enforceable.

This combination of circumstances has served to increase the price of aggregate to the point at which alternatives or substitutes are considered. Recycled aggregate can in some circumstances result in substantial savings for the consumer.

8. CONCLUSION

Many areas in the Lower Mainland and Fraser Valley contain sand and gravel deposits. Economic, accessible aggregate resources of acceptable quality are, however, not as common. Aggregate end use applications can be demanding with respect to resource characteristics. Mechanical, chemical and physical properties all play an important role in determining an aggregate's acceptability.

The right of ownership of aggregate resources, legally, belongs to the Province which is entrusted by its citizens to manage the resource. In other Canadian jurisdictions aggregate resources are the responsibility of either a mining or a natural resource ministry. In British Columbia, although other natural resources are managed exclusively within a specific ministry (examples include: forestry, mining, tourism, agriculture and fisheries), the Province has chosen to allow aggregate resources to be regulated and managed by numerous other government agencies. This decentralization of powers has resulted in a bureaucratic form of government controlled, open access ownership of aggregate resource. Claimants seek to maximize jurisdictional turf and revenues without concern for the long term consequences of their actions. Although a number of the agencies seek only to regulate, others claim the benefits of ownership through royalties and regulatory fees. The MoEMPR and the Ministry of Crown Lands each have partial responsibility for the resource with respect to regulation and taxation. Municipalities claim ownership benefits through soil removal by-laws. Fees and royalties are passed on to the public in the form of higher costs for construction and public works. This can be seen as a form of indirect taxation.

Although numerous levels of government benefit from aggregate resources, as a provincial resource, the right to benefit from aggregate production belongs to the public. It should therefore be the responsibility of the Province to ensure (1) that the public benefits from resource extraction, (2) that the resource is developed in an efficient manner, (3) that the long term viability of the resource industry is protected (to ensure the stream of benefits continues into the future). The current bureaucratic, open access regime is not accomplishing these tasks.

1. Although the public benefits from resource rents generated by aggregate extraction, each bureaucratic claimant sets their fee without regard to other claimants. Fees in excess of rent result in higher product prices, inefficient extraction (high grading), or the abandonment of marginal resources. Each of these outcomes result in public losses either directly, through higher taxes and consumer costs, or indirectly through forgone resource rents.
2. The current system of royalties and fees encourage inefficiencies. Aggregate producers are subject to frequent royalty reviews. Royalty rate increases are not limited and cannot be predicted. This makes long term planning and project financing a virtual impossibility. Furthermore, the primary benefit of a royalty system, that of ease of administration, has not been realized by the Ministry of Crown Lands.
3. No government body represents the aggregate resource with respect to long-term planning. The Ministry of Crown Lands has expressed no interest in land use planning for aggregate resources. Planning is primarily left in the hands of local governments. Although legislation was introduced to prevent the banning

of production by parochial interests, no Provincial Ministry has objected to the by-law enacted by the Dewdney/Allouette Regional District effectively banning aggregate production. Similarly, the Municipal Act has been frequently amended to allow municipalities to generate revenues through soil removal by-laws.

The lack of a single responsible government body has resulted in an absence of expertise on either the industry or the available resource in the province. No knowledge exists as to the predicted demands for aggregate nor if these demands can be met with current resources. Although the MoTH maintains aggregate inventories and plans for future sources of aggregate, their interest is that of a consumer. It is their objective to ensure an economic supply is available for themselves.

In contrast to the conventional aggregate industry, the recycled aggregate industry of the Lower Mainland exists in an absence of government regulation. While the GVRD monitors waste disposal and recycling in Greater Vancouver, their information regarding the recycling and disposal of aggregate waste is inaccurate. Although the GVRD studies have indicated 85% of all clean, waste aggregate is being recycled, recyclers on the Lower Mainland have introduced dumping fees to limit supply.

Recycled aggregate producers pay no soil removal fees. This is despite the fact that they use identical trucks to conventional producers, under identical conditions. Recycled aggregate provides an alternative to conventional aggregate use. A number of benefits can be realized from optimizing the recycling of aggregate waste. Recycled product can be a suitable substitute for conventional aggregate in a number of applications. Unfortunately, the quality of source materials is difficult to control and, without standards, limits the feasibility of large scale substitution of recycled products in demanding applications. In road base and sub-base applications however, recycled aggregate has, in some studies, shown itself to be superior to conventional materials. Examination of other regions with an established recycling industry indicates that it is unlikely that consumed tonnages of recycled aggregate will ever exceed 3% of the overall total.

The following recommendations are suggested.

- Aggregate materials should be included in the Mineral Tenure Act and thus placed under the control of the MoEMPR. This would remove an entire layer of bureaucracy and simplify the taxation and tenure allocation system. It would also do away with the current system of bidding for tenure.
- The current system of production based royalties should be replaced with a more progressive profit tax.
- Government policies influencing the recycled aggregate industry should focus on stimulating demand for recycled products.
- The Municipal Act should be amended to limit the use of soil removal by laws as tools for revenue generation and prohibition of aggregate development.

Other municipal by laws effectively banning aggregate production should be subject to review at the provincial level.

- Experiences in Ontario and California suggest that the Province of British Columbia will eventually be forced to adopt a centralized, form of land-use planning for aggregate resources. Each of these areas adopted similar types of legislation which would (1) assist in the resolution of land-use conflicts, (2) protect aggregate resources, and (3) minimize environmental damage. The Surface Mining and Reclamation Act of California (SMARA), acts to objectively identify significant deposits and to provide this information to local governments who can then incorporate them into a development strategy. By using sequential land use planning, the aggregate resource can be extracted with an eventual land use target in mind. City planners can design areas of production to avoid or minimize residential disturbance and traffic problems.

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