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VIA COURIER

25 October 1996

Mr. James E. Lewis
Ministry of Energy, Mines and Petroleum Resources
Fourth Floor, 1810 Blanshard Street
Victoria, B.C.
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Dear Mr. Lewis:

RE: Lower Mainland Aggregate Study

Please find attached our first draft of the Lower Mainland Aggregate Study. Please be aware that there are still a few refinements to be made. We thought it would be appropriate to deliver this draft at this time so that you can review it and provide some feedback.
We have sent a copy of this draft to you and Mr. Phil Seabrook concurrently so that you both can have an opportunity to review and discuss the preliminary findings.

We have enjoyed working on this report and we look forward to receiving your comments.

Yours truly,

CORIOLIS CONSULTING CORP.

Mark Savoy

DEVELOPMENT OF A MODEL FOR FORECASTING THE CONSUMPTION OF AGGREGATES IN THE LOWER MAINLAND

PREPARED FOR:

THE MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

OCTOBER 1996

CORIOLIS CONSULTING CORP.

DRAFT

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1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The Ministry of Energy, Mines and Petroleum Resources commissioned a study of mineral aggregates in the Lower Mainland region of B.C. for the period from 1996 to 2021. The purpose of the study is to provide an overview of the current state of the mineral aggregate industry in the Lower Mainland and provide forecasts of future supply and demand of aggregates. This information will be used by the Provincial Government to develop a strategy for the management of the resource.

The Ministry's overall objectives for this study are:

1. Forecast aggregate consumption (sand and gravel and crushed rock for construction purposes) as accurately as possible,

2. Contribute to a more definitive understanding of current and future resource constraints,

3. Contribute ideas for improving the provincial management process and assist in the smooth functioning of the aggregate sector and,

4. Assist in provincial, regional and municipal strategic planning regarding aggregate supply and demand and urban development.

The Ministry commissioned Levelton Associates and Coriolis Consulting Corp. to complete this study. Coriolis Consulting Corp. was retained to complete the section of the study that addresses the demand for aggregates, and was responsible for developing forecasting models for projecting future consumption of aggregates in the Lower Mainland. This report documents the development of the forecasting models and the resulting forecasts of aggregate consumption in the study area.

The Ministry also specified that the modelling should be easily adjustable to respond to changes in demand patterns and that the underlying assumptions in the demand forecasts could be easily changed to update or modify the forecasts. Three scenarios were analyzed in the demand forecast:

1. A demand forecast assuming current urban growth trends continue which results in a significant amount of growth in the Fraser Valley.

2. A demand forecast assuming that there is no future growth in the study area. This scenario implies that the only source of demand for aggregates would come from the need to rehabilitate existing roads and services and replace obsolete buildings and infrastructure.

3. A demand forecast assuming that population growth will follow the Greater Vancouver Regional District's (GVRD's) compact metropolitan regional growth strategy which recommends that the majority of population growth should be concentrated closer to the Vancouver urban core.

2.0 DEFINITION OF KEY STUDY PARAMETERS

2.1 DEFINITION OF AGGREGATES

There are four species of aggregates for which Levelton Associates provided the following descriptions:

Shotrock: This includes limestone quarry rock used in the manufacture of cement along with the premium rock products such as railway ballast, clean crushed rock of various dimensions, rip rap, and crushed rock blended with sand for road base. These materials are subject to high levels of processing including crushing, washing, screening, and blending.

Premium Products: These products consist of gravels, washed, screened and blended materials such as fine and course concrete aggregate, masonry sand, drain rock, and roofing (pea) gravel.

Road Aggregates: This species includes screened pit run sand and gravel, blended base gravels and asphalt aggregate. These products may be crushed and are generally characterized as being well graded (poorly sorted) with less than 10 percent fines (passing the 0.080 mm sieve).

Granular Fill: These materials consist of unprocessed bank run sands and gravels and dredged sand generally used as bulk fills. Typically, they are the lower cost materials because no processing is involved.

2.2 DEFINITION OF STUDY AREA

The Ministry requires forecasts of demand for aggregates for the Lower Mainland region of B.C. This region is made up of four Regional Districts: Greater Vancouver, Fraser-Cheam, Fraser Valley, and Squamish-Lillooet. Map 1 on the following page shows the study area.

The demand for aggregates to be forecasted is the amount consumed within the Lower Mainland, regardless of its source (i.e. some aggregate is imported from other areas such as Texada Island).

Definition of Market sub-areas

Levelton Associates defined four market sub-areas within the study area which are shown on May 1 (on the following page):

- sub-area A (blue) includes Whistler/Squamish, Lions Bay, West Vancouver, North Vancouver, Vancouver, Richmond, and Delta. We refer to this sub-area as the West Region in this report.
- sub-area B (red) includes Burnaby, Port Moody, Coquitlam, Port Coquitlam, and New Westminster. We refer to this sub-area as the Midwest Region.
- sub-area C (yellow) includes Pitt Meadows, Maple Ridge, Langley, Mission, and Abbotsford. We refer to this sub-area as the Central Region.
- sub-area D (green) includes Chilliwack, Harrison Hot Springs, Kent, and Hope. We refer to this sub-area as the East Region.

Levelton defined these market sub-areas principally on the basis of supply, but it was agreed to also use them for the demand side of the study, because one of the major costs involved with the consumption of aggregates is transportation cost. Therefore, aggregate users are likely to obtain aggregates from nearby producers with low transportation costs.

Figure 4 Lower Mainland Market Areas (Map)

3.0 APPROACH AND KEY ASSUMPTIONS

3.1 APPROACH

We used two broad approaches to developing models for forecasting the demand for aggregates in the study area. The following is a brief summary of each approach:

- the direct usage forecast is based on the total estimated amount of aggregates consumed by all users of aggregate. The overall demand for aggregates is made up of a wide range of individual consumers of aggregates in residential development, commercial development, and construction of new roads and utilities and other major projects. This method of estimating the overall demand involves forecasting all of the individual sources of demand for aggregates and then applying estimates of the amount of aggregates required by each individual source. Levelton Associates provided us with usage factors to apply to the various demand sources of aggregates, along with estimates of the amount of aggregates that will be demanded by future major projects.

- the regression analysis forecast involves determining a regression equation that relates aggregate usage to various demographic or macroeconomic variables, then applying the equation to forecasts of the variables with the highest correlation. Aggregate is used in the construction of new urban development and infrastructure, int he rehabilitation of existing infrastructure, and in replacement of obsolete buildings. These sources of demand are in turn driven by macro-economic and demographic factors like population growth and economic growth (as measured by Provincial GDP). Regression analysis provides a method of determining whether or not there is a statistical relationship between a dependent variable (in this case the consumption of aggregates) and one or more independent variables (e.g., population, provincial gross domestic product). Regression analysis compares historic changes in the dependent and independent variables and determines whether or not they are related. If the results of the regression analysis conclude that there is a strong relationship, then forecasts of the independent variable(s) can be used to predict the dependent variable.

3.2 KEY ASSUMPTIONS

In both of these approaches, it is necessary to examine the relationships between historic consumption of aggregates and trends in indicators of demand for aggregates such as population growth, economic growth, urban development growth rends (e.g., amount and type of new development and related infrastructure). For this study, it was agreed that this historical analysis should be over the ten year period from 1985 to 1995 which should allow a reasonable length of time to establish these relationships. However, in the direct usage approach, a complete set of reliable data was only available for the past five years.

While there is no historic data of actual aggregate consumption in the Lower Mainland, there is historic date for annual production of aggregates. The data include production of aggregates that occurs outside of the study area (e.g., Texada Island) but which is consumed within the study area. A key assumption made for the purpose of this study is that historical production equals historical consumption in the study area. This is a reasonable assumption because a) the amount of exported and imported aggregate in the study area is minimal and so has been assumed to have a net zero effect on consumption in the study area; and b) no major aggregate stockpiling takes place.

The aggregate production data is available for the study area on a total study area basis only, and is not broken down by the defined market sub-areas within the study area. Furthermore, 1995 is the only year for which a breakdown of total study area production by type of aggregate (i.e., dredging, shotrock, bulk fill) is available.

4.0 DEVELOPMENT OF FORECASTNG MODELS

4.1 DIRECT USAGE APPROACH TO FORECASTING THE DEMAND FOR AGGREGATES

This approach to forecasting the demand for aggregate involved summing all aggregate users and then estimating the amount of aggregate required by each user. This section provides a summary of the methodology of this approach and its results.

4.1.1 *Review of Previous Aggregate Demand Studies Using a Direct Usage Approach*

As a first step in this approach, we reviewed previous aggregate studies that have used this approach for forecasting the demand for aggregates. These previous studies are discussed below.

Ontario Model by Gartner Lee Associates Limited and Proctor and Redfern (1977)

This study presumed that demand for aggregates is driven by construction and the following model was developed:

$C = f(GPP, Y/P, \text{change in POP})$

$D = \sum_{i=1} w_i \varnothing_I(C_i)$

where:

f and ∅, stand for 'function of'

C = dollar value of construction activity

GPP = gross provincial product

Y/P = real per capital income

change in POP = year to year population growth

D = demand for mineral aggregates in short tons

w_i = weights or input coefficients measuring tons of aggregate per $1000 value of construction (residential, non-residential, engineering)

C_i = value of construction in residential (C_1), non-residential (C_2), and engineering (C_3) categories.

In a later study completed by Planning Initiatives Ltd. and Associates titled, “Aggregate Resources of Southern Ontario: A State of the Resource Study”, some shortcoming of this approach were pointed out:

- aggregates used for non-construction purposes were not accounted for,

- an assumption was made that the proportion of total construction accounted for by each individual type of construction would remain steady over the forecasting period. Each type of construction was not forecasted separately, which would have been a more accurate approach.

- the study acknowledged that road construction is the single largest consumer of aggregates and actually provided separate usage factors for road versus other kinds of engineering construction but then in the forecasting part of the study used an overall input usage factor for all engineering.

<u>An Economic Analysis of Construction Aggregate Markets and the Results of a Long-term forecasting model for Oregon (1995)</u>, by Robert M. Whelan (Oregon Department of Geology and Mineral Industries): For this study, Oregon’s Department of Geology and Mineral Industries built a forecasting model for every county in the state based on a direct usage. The models were developed on an individual county basis by producing forecasts of each county’s expected housing, road, and other construction. Aggregate usage rates were derived (the amount of aggregate consumed for a given unit of construction) and applied to the forecasted construction to yield projections of total aggregate consumption. Factors were built into the models to help capture large users of aggregates, such as commercial airports, in a given county. The models included several other categories of aggregate consumption such as use of railroad ballast.

This study emphasized that the usage factors were a crucial part of the model and cautioned that they are highly variable because two structures built for the same purpose and of the same size can use vastly different amounts of aggregate. Therefore, the usage factors used in this model were broad averages.

<u>Aggregate Resources of Southern Ontario: A State of the Resource Study (1992)</u>, by Planning Initiatives Ltd. and Associates: This study used an approach called the “Construction Expenditures/Input Factors Approach”. Forecasts of construction spending by type (e.g., new residential, new non-residential, new and repair road) were produced to which aggregate usage factors using construction dollar value measures were applied in order to yield forecasts of aggregate consumption.

Based on the Aggregate Demand Studies discussed above, various forms of construction demand/aggregate usage factor approach have been used in other regions to forecast the consumption of aggregates. In these studies, it was apparent that the reliability/success of the forecast depended heavily on the accuracy of the usage factors. Furthermore, accurate usage factors were hard to comeby, due to the many variables inherent aggregate usage in construction (e.g., the amount of aggregate used in a foundation of a structure varies depending on the type of structure, soil conditions, etc.). It appears that previous studies using this approach required many assumptions and could only provide approximate results.

4.1.2 *DEVELOPMENT AND TESTING OF A FORECASTING MODEL BASED ON THE DIRECT USAGE APPROACH*

The Direct Usage Approach to forecasting the demand for aggregates involves the following steps:

Step 1: identify every source of demand for aggregates (this includes new construction and rehabilitation/maintenance).

Step 2: estimate aggregate usage factors that apply to a given unit measure of each user (e.g., a single family house, 1000 sq.ft. of office floorspace, etc.).

Step 3: test the approach through historical analysis. This involves applying the usage factors to historical date for the identified users of aggregate (e.g., number of single family housing starts) to obtain estimates of aggregate consumption by user type, and then summing all of these to get an estimate of total consumption. The approach is tested by comparing these estimates of consumption to the aggregate production date provided to us by the Ministry. The modelling/forecasting would proceed beyond this step only if the results of the testing show that the method is reliable.

Step 4: produce forecasts of all aggregate users (e.g., forecasts of residential housing starts, forecasts of new commercial floorspace, etc.).

Step 5: multiply the appropriate aggregate usage factor to the forecasts of aggregate users to yield forecasts of the demand for aggregates for each type of aggregate user.

Step 6: estimate the amounts of aggregate that will likely be required for planned, large projects such as airport terminals, bridges, major highway expansions.

Step 7: sum all of the demand forecasts for each aggregate user to produce a forecasts of overall aggregate demand.

Step 1: Identification of Users of Aggregate

We gathered historic data on all potential users of aggregate in the Study Area. The historic data and the sources from which we obtained the data are listed below:

1. Annual single family starts data (source: CMHC housing start data, BC Stats building permit data).

2. Annual townhouse (row-housing) starts data (source: CMHC housing start data).

3. Annual high-rise residential apartment starts data (source: 1994 CMHC housing start data. For the years 1991 to 1993, we applied the 1994 high-rise to low-rise ratio to apartment starts data. The apartment starts data was not broken down into low-rise and high-rise prior to 1994).

4. Annual low-rise residential apartment starts data (source: 1994 CMHC housing start data. For the years 1991 to 1993, we applied the 1994 high-rise to low-rise ratio to apartment starts data. The apartment starts data was not broken down into low-rise and high-rise prior to 1994).

5. Annual amount of new high-rise office space in square feet (source: GVRD office floorspace inventories, Colliers floorspace inventories and additional new construction amounts, Metrotrends (REBGV) floorspace inventories. The high-rise/low-rise apartment ratio was sourced from Metrotrends.

6. Annual amount of new low-rise office space in square feet (source: GVRD office floorspace inventories, Colliers floorspace inventories and additional

new construction amounts, Metrotrends (REBGV) floorspace inventories. The high-rise/low-rise apartment ratio was sourced from Metrotrends and the Real Estate Board of Greater Vancouver).

7. Annual amount of new retail space in square feet (source: GVRD floorspace inventories, Colliers floorspace inventories and additional construction amounts).

8. Annual amount of new industrial space in square feet (source: GVRD floorspace inventories, Colliers floorspace inventories and additional construction amounts).

9. Annual amount of new institutional space (schools) in square feet (source: Levelton Associates).

10. Annual amount of new roads constructed in kilometres (source: Ministry of Municipal Affairs, Municipal Statistics).

11. Annual amount of new underground utilities (e.g. sewers, water mains) in kilometres (source: Ministry of Municipal Affairs, Municipal Statistics).

12. Major projects like the Vancouver International Airport, the Deltaport Container Project, CN Intermodal Yard - Surrey Docks, Highway 1 High Occupancy Vehicle (HOV) Lanes (source: Levelton Associates).

Step 2: Estimates of Aggregate Usage Factors

Levelton Associates provided us with aggregate usage factors that were estimated based on their discussions with builders, developers, and concrete suppliers. "Usage factors" refer to the amount of aggregate typically required for a unit of construction (e.g., a single family dwelling, a townhouse dwelling, 1,000 sq.ft. of office space, a kilometre of road and so on).

Levelton estimated aggregate usage factors corresponding to the users of aggregates listed above. These usage factors and the key assumptions about them are described below:

1. Single family housing: Single family houses in the immediate Vancouver area tend to have deeper basements and so require more concrete compared to houses in the Fraser Valley. Therefore, Levelton calculated two usage factors for single family housing in the Study area. Both usage factors assume an average house with a floor area of 2,000 sq.ft., a driveway of 500 sq.ft., and a 2 car garage. The single family aggregate usage factors are:
   - 460 tonnes per single family dwelling in the municipalities of Vancouver, Burnaby, New Westminster, West Vancouver, and North Vancouver.
   - 340 tonnes per single family dwelling in the rest of the Study Area (i.e. excluding the municipalities of Vancouver, Burnaby, New Westminster, West Vancouver, and North Vancouver).

2. Townhouse development 200 tonnes per townhouse unit assuming two or three storey wood-frame construction supported with an underground concrete parking structure.

3. Low-rise multifamily condominium development: 38.5 tonnes per low-rise apartment unit assuming three or four storey wood frame construction supported with an underground concrete parking structure.

4. High-rise development (both residential and commercial): 59 tonnes per 1,000 sq.ft. assuming concrete construction (not steel) and underground parking.

5. Low-rise commercial and industrial development: 38.78 tonnes per 1,000 sq.ft. of space assuming tilt-up panel wall construction with concrete slab-on-grade commercial space (i.e., low-rise office, retail, and industrial space).

6. Underground utilities: 7,000 tonnes per km of new utilities constructed, assuming that:
   - sanitary and storm sewers are included in a single trench (2m wide x 4m deep)
   - water mains are completed in a separate trench from sewers (1m wide x 0.5m deep)
   - B.C. Hydro and B.C. Tel trenches are backfilled with native material
   - Street lighting trenches are backfilled with native material.

7. New Roads: 10,303 tonnes per km of new road, including the aggregate required for the actual road structure, sub-base, sidewalks, and curb and gutter.

8. Rehabilitation of existing roads: Levelton gathered historic annual data about the volume of aggregate used to rehabilitate existing municipal reads where available (data was available for Port Coquitlam, Pitt Meadows, Vancouver, Burnaby, North Vancouver, Township of Langley, Abbotsford). The individual municipal usage rates for road rehabilitation ranged from 40.5 to 324 tonnes per km of existing road. For other municipalities within the Study Area (for which no data was available), we applied the usage rates of nearby municipalities.

9. Major Projects: Estimates of individual aggregate consumption amounts for major projects (e.g. Ministry of Highways uses about 600,000 tonnes of aggregate annually).

Step 3: Testing the Construction Demand/Aggregate Usage Factor Approach

The third step in this approach is to test its accuracy using historical construction data (e.g., residential, office, retail, industrial, roads and services, etc.), and applying aggregate usage factors and the historical aggregate production data provided to us by Levelton. We tested this approach for the years from 1991 to 1994.

Table A on the following page provides a summary of the historical analysis we conducted using the Direct Usage approach. We used this approach on an individual municipal basis and then summed these estimates to get a total estimate of consumption for the study area. The table shows that the estimates of aggregate consumption derived using this approach are significantly lower than the aggregate production figures for 1991, 1992, and 1993. In these years the estimated consumption only accounts for between 48% to 62% of overall aggregate production. 1994 was the only year for which the estimate of consumption was relatively close to the production figure (85%). In 1994 the utilities construction/maintenance and major projects categories accounted for a substantially larger portion of consumption that other years, which might partially explain the better match.

Because of the poor results of the tests in this step, we could not proceed to Step 4. Due to the wide discrepancy between the estimates of consumption made through the Construction Demand/Aggregate Usage Factor approach and the actual historic production data, this method cannot be used in this study to produce reliable forecasts of aggregate consumption. The results of the testing are inconclusive and because there are several data variables involved in this approach, it is not possible within the scope of this project to determine in detail which data variable(s), or assumptions, are causing the discrepancy. There could be a problem with one or more of the data inputs including the aggregate usage factors, historical development data, and the historic aggregate production data.

The methodology of this approach should work if all data inputs and factors are accurate. In our opinion, more research is required on the usage factors. A separate study of how much aggregate is required for the various types of urban

TABLE A: Construction Demand/Aggregate Usage Factors Approach to Aggregate Consumption for the Study Area

	1991			1992			1993			1994		
	Units	Factor (tonnes/unit)	Total Usage (tonnes)	Usage Units	Factor (tonnes/unit)	Total (tonnes)	Usage Units	Factor (tonnes/unit)	Total (tonnes)	Units	Factor (tonnes/unit)	Total Usage (tonnes)
Residential Development												
Single Family Dwellings:	8,708	360.5	3,139,400	9,454	370.6	3,504,040	8,064	374.9	3,022,800	8,013	370.7	2,970,180
Two Family Dwellings:	742	200.0	148,400	948	200.0	189,600	1,409	200.0	281,800	1,112	200.0	222,400
Row/Townhouse:	1,701	200.0	340,200	2,836	200.0	567,200	3,098	200.0	619,600	3,284	200.0	656,800
Low-rise Apartment Units:	5,094	38.5	196,127	6,378	38.5	245,551	10,098	38.5	388,763	8,350	38.5	321,475
High-rise Apartment Units:	2,029	59.0	119,698	2,543	59.0	150,041	3,453	59.0	203,742	3,398	59.0	200,482
Total Residential Usage:	18,274	215.8	3,943,826	22,159	210.1	4,656,431	26,122	172.9	4,516,705	24,157	181.0	4,371,337
Utilities Construction / Maintenance												
New Roads (km):	200	10,303.0	2,060,600	145	10,303.0	1,493,935	81	10,303.0	834,543	308	10,303.0	3,173,324
New Services (km):	514	7,000.0	3,598,000	591	7,000.0	4,137,000	236	7,000.0	1,652,000	713	7,000.0	4,991,000
Utilities Maintenance:			2,346,795			2,391,703			2,409,809			2,472,366
Total Utilities Usage:			8,005,395			8,022,638			4,896,352			10,636,690
Other Urban Development												
Office High Rise (s.f.):	1,504,220	0.059	88,749	1,302,000	0.059	76,818	1,148,100	0.059	67,738	158,000	0.059	9,322
Office Low Rise (s.f.):	615,925	0.039	23,886	539,439	0.039	20,919	0	0.039	0	585,000	0.039	22,686
Retail (s.f.):	714,187	0.039	27,696	303,599	0.039	11,774	439,131	0.039	17,030	484,004	0.039	18,770
Industrial (s.f.):	3,543,946	0.039	137,434	3,219,355	0.039	124,847	1,348,814	0.039	52,307	2,005,741	0.039	77,783
Institutional (Schools):			22,388			22,220			58,469			26,187
Total Other Development			300,153			256,578			195,543			154,747
Total Major Projects:			600,000			1,400,000			1,400,000			2,650,000

	1991	1992	1993	1994
Total Study Area Calculated Consumption	12,849,373	14,335,647	11,008,600	17,812,744
Total Study Area Production:	23,608,000	23,135,000	23,178,000	21,074,000
Consumption as a % of Production	54%	62%	47%	85%

Note 1: This single family aggregate usage factor is a weighted average of the two single family usage factors listed below (i.e. 340 and 460 tonnes/unit)

Aggregate Usage Factors:

SFD	340 tonnes per unit (except 460 per unit in Vancouver, North & West Vancouver, Burnaby, New Westminster)
2FD	200 tonnes per unit
Row	200 tonnes per unit
LR Apt..	38.5 tonnes per unit
HR Apt.	59 tonnes per unit (assuming 100 sf/unit)
New Roads	10.303 tonnes per km
New Services	7.000 tonnes per km
HR Office	0.059 tonnes per sf
LR Office	0.03878 tonnes per sf
Retail	0.03878 tonnes per sf
Industrial	0.03878 tonnes per sf

development (e.g., residential: single family, townhouse, low-rise, highrise; office; industrial) would be particularly useful. This could involve site visits to several types of development projects during construction to obtain accurate estimates of the amounts of concrete and fill required. This approach could also be enhanced so it forecasts aggregate consumption by type of material.

4.2 REGRESSION ANALYSIS

Regression analysis is the second broad approach we used to develop a forecasting model for the consumption of aggregates in the study area. This approach also requires an analysis of household growth in terms of distribution and type of households (based on the different scenarios). The household growth analysis is required as part of this approach because the different growth scenarios will result in different urban forms of residential development which would affect overall aggregate consumption (e.g., higher density residential development in a compact region should require less aggregate usage per capita).

Regression analysis produces an algebraic formula, calculated on a time series of data points for one or more independent variables and a dependent variable, that describes the functional relationship between the variables. The regression also produces a coefficient of determination (r^2)[1] which is a measure of the strength of the regression function. An r^2 value is expressed as a ratio, so the closer it is to a value of 1.0 (or -1.0) the stronger the regression relationship. For example, an r^2 of 1.0 implies a perfect regression relationship (100% of the variance in the dependent variable is explained by the variance in the independent variable(s)).

In this study, aggregate consumption is the dependent variable and the demographic/macroeconomic factors (such as population growth, GDP, housing starts) are the independent variables. Presumably aggregate consumption will vary with changes in growth rates and/or economic indicators. This analysis will test this presumption.

1

4.2.1 *REVIEW OF PREVIOUS REGRESSION ANALYSIS CONDUCTED FOR THE CONSUMPTION OF AGGREGATES*

As a first step in this approach, we reviewed the results of regression analyses on aggregate consumption attempted in previous studies:

[1] As defined in Basic Statistics in Business and Economics (1973), by George Summers and William Peters: "The coefficient of determination (r^2) is the portion of the variance in observations of the dependent variable that is explained by least squares linear regression with an independent variable. Alternatively, the coefficient of determination is the remainder when the portion of variance unexplained by linear regression is subtracted from the whole.", page 81.

Sivertson and Carson (1974): In their 1974 study titled, "Sand and Gravel in British Columbia: A Commodity Study", Lorne Sivertson and Robert Carson used regression analysis to test whether or not aggregate consumption was related to real income, a surrogate variable for economic activity in British Columbia. Using historical data from 1962 to 1973 they calculated the following equation:

C/P = -77.74 + 11.62 log Y/P
r^2 = .72 F = 25.26
where:
C/p = consumption per capita in short tons/person
log Y/P = log normalized form of real per capita personal income in constant 1961 dollars
r^2 = coefficient of determination
F = 'F' statistic for testing overall significance of regression.

The equation suggests that, per capita, consumption of sand and gravel in British Columbia tends to rise sharply initially with increases in income and then rises less steeply.

From this particular regression analysis, the regression was retested in the 1980 "Sand and Gravel Study for British Columbia Lower Mainland" by the Ministry of Energy, Mines and Petroleum Resources". The time-frame for the analysis was extended five years so that the period covered was from 1962 to 1978. The resulting equation was:

C/P = -37.51 + 12.95 log Y/P, with an r^2 of 0.59.

This model was rejected because of the poor correlation.

British Columbia Model (1980): This study employed multiple non-linear (as well as linear) regression techniques, and selected the following model:

C = f(1n Y/P)
C = -99 910.7 + 13 355.33 1n Y/P
where:
C = lower mainland consumption of sand and gravel in thousands of tonnes.
1n Y/P = natural log of BC real per capital income in dollars (base year = 1971).

This model resulted in an r^2 of 0.81. This model was used in this study to produce forecasts of aggregate consumption over an eight year period (1979 to 1986).

Ontario Model (1992) by Planning Initiatives Ltd. and Associates: In this study, the relationships between aggregate consumption (for the entire province) and selected macroeconomic and demographic statistics were tested through regression analysis: The variables tested (based on sample data for the 1971 to 1990 period) and the resulting coefficient determination in this study were:

Variable	Coefficient of Determination (r^2):
Real gross domestic product	0.79
Real personal income	0.71
Employment	0.70
Population	0.69
Total housing starts	0.55
Rate of inflation	-0.47
Unemployment rate	-0.44
Real prime rate	0.35
Real average weekly earnings	0.07
Prime rate	-0.06
Real provincial deficit	-0.12
Total construction spending	0.94
Residential construction spending	0.93
Non-residential construction spending	0.91
Total engineering construction spending	0.72
Non-road engineering spending	0.69
Roads and highways spending	0.28

This study appeared to be the most thorough in terms of the number of variables tested through regression. The bi-variable regressions which resulted in high coefficients of determination (r^2) were those which used total construction spending, residential construction spending, and non-residential construction spending as the independent variables. The regression results using macroeconomic indicators like population and GDP as the independent variables has relatively low r^2's (0.79 for real GDP and 0.69 for population).

The forecasting model that was eventually used to forecast the demand for aggregates in this study was:

AGG = 21010 + .548xRGD + .450xSTRTT - 4388xUR and the r^2 = .952
where:
AGG = total demand for aggregate (thousands of tonnes)
RGDP = real gross domestic product (millions of 1990 dollars)
STRTT = total housing starts (units)
UR = unemployment rate (%)

4.2.2 *DEVELOPMENT OF A FORECASTING MODEL THROUGH REGRESSION ANALYSIS*

We tested several bi-variable and multiple regressions in which the dependent variable was historic aggregate production, and the independent variable(s) were macro-economic indicators such as study area population, provincial gross domestic product (GDP), and study area housing starts data.

The Ministry provided us with historic aggregate production data for the study area for the period 1980-1995. This data[2] is shown in the table below:

Sources of Aggregate Production ('000 tonnes):

Year	Land Based Aggregate Mineral Production	Borrow Dredging	Total Aggregate Mineral Production
1980	13,329	4,562	17,891
1981	16,250	4,217	20,467
1982	9,853	1,622	11,475
1983	12,588	6,043	18,631
1984	18,524	7,154	25,678
1985	23,205	5,577	28,782
1986	14,219	2,973	17,192
1987	12,426	4,417	16,843
1988	15,291	4,950	20,241
1989	15,694	7,785	23,479
1990	16,052	5,481	21,533
1991	19,249	4,359	23,608
1992	19,962	3,173	23,135
1993	20,121	3,057	23,178
1994	19,051	2,023	21,074
1995	18,520	4,400	22,920

2

After some preliminary regression analyses, we found that the two unusually high production figures in years 1984 and 1985 were significantly distorting the regression results. Levelton Associates was unable to find an explanation for the

[2] Sources: 1978 to 1988: "Sand and Gravel Industry of British Columbia - Private Pitts", Thurber Engineering Ltd. Report to B.C. Ministry of Energy Mines and Petroleum Resources, D. Smith, P. Eng., September 28, 1990, File 15-8-10.

1989 to 1994: Energy and Mines data base.

1995: Survey of Aggregate Producers by Levelton Associates Ltd.

peak in these two years, so we smoothed them (years 1984 and 1985) by replacing the actual figures in those years with an average of the 1983 and 1986 figures.

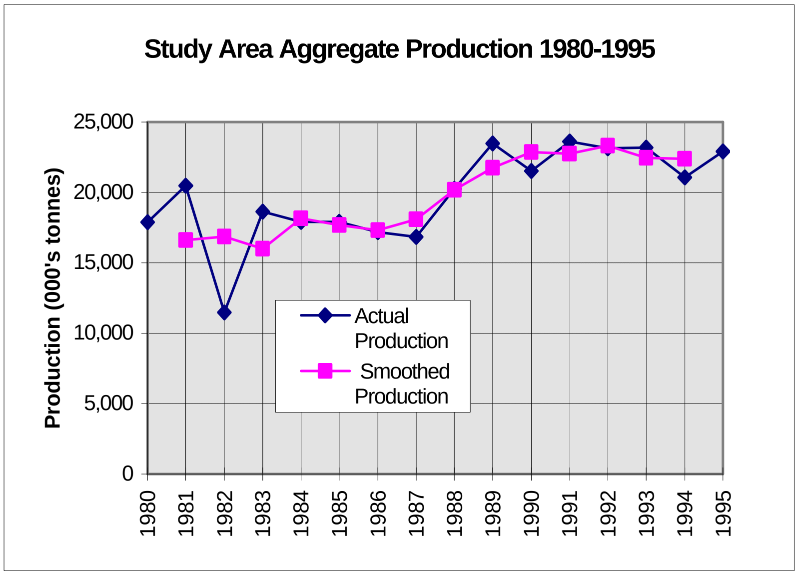
To further smooth the production data we used three year rolling average annual aggregate production figures instead of the actual figures in the regressions. This is done by taking three consecutive years and calculating an average of the three which becomes the figure input for the middle year. Using production figures that are three year rolling averages helps smooth out the lag that occurs from year to year between the variables. For example, building starts issued in December of a given year will be reported in that year's building starts data, but the consumption of aggregates associated with those building starts will likely not occur until the following year.

The actual production figures and the smoothed annual figures for aggregate production [3] from 1981 to 1994 are shown in the following table and graph.

3

[3] The smoothed aggregate production figures were calculated by first replacing the two peak year (1984 and 1985) figures with average figures using the 1983 and 1986 figures and second, by calculating three year rolling averages.

Year	Actual Production	Smoothed Production
1980	17,891	
1981	20,467	16,611
1982	11,475	16,858
1983	18,631	16,006
1984	17,912	18,151
1985	17,912	17,672
1986	17,192	17,316
1987	16,843	18,092
1988	20,241	20,188
1989	23,479	21,751
1990	21,533	22,873
1991	23,608	22,759
1992	23,135	23,307
1993	23,178	22,462
1994	21,074	22,390
1995	22,919	



All of the separate regression analyses we conducted are contained in Appendix A. The following table provides a summary of the independent variables we tested through regression analysis and the resulting coefficients of determination (r^2).

Bi-Variable Regressions using "Smoothed" Annual Aggregate Production Data:

Independent Variable	Coefficient of Determination (r^2)
Study Area Population	0.90
Study Area Employed Labour Force	0.12
GVRD Unemployment Rate	0.17
British Columbia GDP	0.89
GVRD total office, industrial and retail space (s.f.)	0.76
Study Area # of Resid. Building Permits	0.59
Study Area Residential Building Permit Values (real dollars)	0.77
Study Area Commercial Building Permit Values (real dollars)	0.50
Study Area Industrial Building Permit Values (real dollars)	0.04
Study Area Institutional Building Permit Values (real dollars)	0.33
Study Area Total Building Permit Values (real dollars)	0.74
Study Area Utilities (km)	0.34
Study Area Roads (km)	0.86

It is interesting to note that the bi-variable regressions using population and GDP as the independent variables in this analysis produced coefficients of determination (r^2) substantially higher than those from the regressions which were completed in the 1992 Ontario Study (population: this study, $r^2 = 0.90$; Ontario study, $r^2 = 0.69$; GDP: this study, $r^2 = 0.79$).

The results of our bi-variable regressions show that population and GDP are likely good indicators for predicting consumption of aggregates for the entire study area.

We also conducted several multiple regressions in which we tested the relationship of aggregate production to more than one independent variable, such as population and residential housing starts. The independent variables of the multiple regressions and the resulting coefficients of determination (r^2) are as follows:

Independent Variable	**Coefficient of Determination (r^2)**
BC GDP, Study Area total Residential Starts, GVRD Unemployment Rate	0.61
BC GDP, Study Area Total Residential Starts	0.93
GVRD Total Office/Retail/Industrial Space, Study Area Population	0.89
GVRD Total Office/Retail/Industrial Space, BC GDP	0.89
BC GDP, Study Area Population	0.91
Study Area Population split into two variables: existing residents and new residents (from immigration)	0.94

As shown in these two tables, relatively high coefficients of determination (i.e., r^2 greater than 0.90) were obtained in three of the multiple regressions. An r^2 of 0.91 was achieved in the regression that used population and GDP together (this is a greater r^2 than was achieved for either of the independent, bi=variable regressions using population or GDP alone). An r^2 of 0.93 was obtained through the regression that used BC GDP and study area total residential building starts as the independent variables.

The highest r^2 (0.94) was obtained through the multiple regression that split population into existing residents (i.e., existing population plus new growth through natural increase) and new residents (i.e., net in-migration to the study area).

We tested this regression (i.e., population split into two independent variables) based on the assumption that a newly immigrated resident (or family) will directly or indirectly create demand for an additional household in the year of arrival. The formation of this new household will result in higher demand for aggregates (also due to the required associated new roads, services, commercial and institutional development). On the other hand, the demand for aggregates created by an existing resident mainly comes from the maintenance and rehabilitation of existing roads and other infrastructure and from the replacement of physically of economically obsolete buildings. Natural increase (births minus deaths), will also have an effect on overall aggregate consumption, but there will be at least a 20-25 year lag in demand for new households and related infrastructure.

This regression analysis produced the following equation (assuming the y-intercept = 0):

Aggregate Consumption (000's tonnes) = 0.0095 x A + 0.123 x B

where:
A = existing number of residents plus natural increase.
B = new residents due to in-migration.

Because this regression produced the highest coefficient of determination (r^2 = 0.94), we selected this equation as the model for forecasting aggregate consumption. The regression equation's application is in Appendix B.

In order to use this equation to forecast demand for aggregates, forecasts of population that separate growth into natural increase and net-migration are required. BC Statistics provides annual population data for the study area, and separates new population growth into natural increase and net-migration. Using this population data as inputs for regression equation, we were able produce forecasts of aggregate consumption (see Appendix B for population data).

5.0 FORECASTS BASED ON THE REGRESSION MODEL

Scenarios for Demand Forecasts

The Ministry requires aggregate demand forecasts for three alternative scenarios:

1. **Current Growth Trends Continued Scenario:** In this scenario we assume that current trends in the distribution of population growth throughout the study area continues. This scenario implies that development will continue throughout the region and the Fraser Valley (the central and east sub-areas) will continue to capture a significant share of new population growth.
2. **Maintenance/Steady State Scenario:** In this scenario, we assume that there is no future growth in the study area. Therefore, the main source of demand for aggregates would come from the need to rehabilitate or replace existing infrastructure. While the Ministry recognizes that this is not a very realistic scenario, the intent is to obtain a sense of what the minimum demand for aggregates would be within the study area. We split this scenario further into two scenarios: one based on the assumption that no growth occurs whatsoever (i.e., no natural increase, no in-migration); the second (perhaps more realistic) based on the assumption that only natural increase occurs (i.e., no in-migration).
3. **Compact Metropolitan Growth Scenario:** This scenario is based on the growth strategy adopted by the Greater Vancouver Regional District (GVRD) in its Greater Vancouver Livable Strategic Plan. The Regional District has adopted a plan that encourages a more compact distribution of population growth with new growth being concentrated in the municipalities immediately surrounding the Vancouver urban core (i.e. the west and mid-west sub-areas defined in this study). This Livable Region Strategy is intended to discourage major urban development in the outer lying municipalities in the Fraser Valley. An additional piece of analysis of household growth is required for this scenario because the different form of urban development (higher density housing, more development in already established town centre areas) should affect overall aggregate demand.

5.1 CURRENT GROWTH TRENDS CONTINUED SCENARIO

BC Stats provides two sets of population forecasts for the study area: one which assumes that current growth trends continue in terms of the distribution of population and type of housing, and the other which assumes the more compact distribution of population growth as set out in the GVRD's Livable Region Strategic Plan (these forecasts are in Appendix B). Both sets of population forecasts produce the same total study area population; the only difference is the distribution of population within the study area (i.e., the compact scenario focuses more population in urban town centres in the west and mid-west sub-areas).

As the regression model is based on historic population growth patters and historic aggregate production data, the derived regression equation can be applied directly to population forecasts for the Current Trends scenario. Regression analysis implicitly relies onhistorical trends, so applying the regression equation to population forecasts for this scenario (which assumes historic growth trends continue and the broad mix of housing types remains the same) should provide a good indication of aggregae demand and distribution within the study area. The overall aggregate demand forecast for this growth scenario based on the regression equation, is presented below[4]. These forecasts are shown in detail in Appendix B.

4

Aggregate Consumption (000's tonnes) = 0.0095 x A + 0.123 x B

where:

A = the number of existing residents plus natural increase.

B = the number of new residents due to in-migration.

[4] The annual forecast for this scenario broken down into the four market sub-areas is contained in Appendix B. While the regression model was derived using the total study area population and total study area aggregate production data, the defined market sub-areas are large enough to apply the model directly to population forecasts of each market sub-area.

Aggregate Consumption Forecasts (000's): Current Trends Continued Growth Scenario

	1996-2000	2001-2005	2006-2010	2011-2015	2016-2021	1996-2021
West Consumption	53,195	56,011	58,489	60,950	75,888	304,532
Mid-west Consumption	43,859	47,768	51,355	54,994	70,372	268,349
Central Consumption	21,680	25,217	28,925	32,402	43,514	454,738
East Consumption	6,246	8,085	9,560	11,208	15,775	50,874
Total Consumption	124,980	137,081	148,329	159,553	205,550	775,492
Avg. Ann. Consump.:	24,996	27,416	29,665	31,910	34,258	29,826

As the table shows, assuming current growth trends continue within the study area there would be a demand for 775,492,000 tonnes of aggregate over the 26 year period from 1996 to 2021.

5.2 MAINTENANCE/STEADY STATE SCENARIO

We used this scenario to arrive at a base level of demand for aggregates. We applied the regression equation to two population forecasts in this scenario: a) population with only natural increase (no in-migration); and b) population with no growth whatsoever (no natural increase, no in-migration). Based on these assumptions, the minimal level of demand for aggregates can be determined as demand would only come from maintenance/rehabilitation of existing infrastructure and the replacement of obsolete infrastructure and no new residential areas would need to be developed or redeveloped to higher density.

The overall aggregate demand forecast for this scenario, based on the regression equation, are presented below[5]. These forecasts are shown in detail in Appendix B.

Aggregate Consumption (000's tonnes) = 0.0095 x A + 0.123 x B

where:

A = the number of existing residents plus natural increase.

B = the number of new residents due to in-migration (0 in this scenario).

5

Aggregate Consumption Forecasts (000's): Maintenance Scenario (with natural increase, no in-migration)

	1996-2000	2001-2005	2006-2010	2011-2015	2016-2021	1996-2021
West Consumption	46,890	47,981	48,906	49,651	60,306	253,734
Mid-west Consumption	34,261	35,416	36,500	37,541	46,351	190,071
Central Consumption	15,419	15,929	16,461	17,053	21,305	86,167
East Consumption	4,038	4,124	4,220	4,341	5,404	22,128
Total Consumption	100,609	103,449	106,087	108,587	133,368	552,099
Avg. Ann. Consump.:	20,122	20,690	21,217	21,717	22,228	21,235

[5] The annual forecast under each growth scenario (compact metropolitan, current trends continued, and no growth) broken down into the four market sub-areas are contained in Appendix C. While the regression model was derived using the total study area population and total study area aggregate production data, the defined market sub-areas are large enough to apply themodel directly to population forecasts of the market sub-areas.

These forecasts show that over the entire study period (1996-2021) the demand for aggregates would total 552,099,000 tonnes with no in-migration to the study area. This is only about 30% lower than the forecasted demand for aggregates assuming current growth trends continue.

If we remove the natural increase component out of the population forecast (i.e. constant study area population of about 2,100,000), aggregate consumption is constant at about 19,761,000 tonnes per year, or a total of 514,450,000 tonnes between 1996 and 2021 - still only about 35% less than the current trends scenario.

The results of the analysis of this scenario are somewhat surprising. The base level of aggregate demand in only 30% - 35% lower than total demand under current trends, which suggests that only one third of aggregate demand comes from 'growth'. Because of this somewhat surprising result, we used data on actual construction by type of use as a way to test this result[6]. We used the 1994 data from the direct usage approach (Table A in Section 4.1), because of that year's relatively good match between overall aggregate consumption and overall aggregate production. We based this check on the following assumptions for a 'maintenance/steady state' scenario:
6

- Average useful life of a residence is 40 years, so 2.5% of the residential stock is replaces annually. The study area contains about 775,000 households. At an average of about 180 tonnes per replaces residential unit, this translates into residential aggregate demand of about **3.5** Million tonnes per year.
- Include 100% of the utilities maintenance amount: about **2.5** Million tonnes per year.
- Include 30% of the new utilities amount, based on the assumption that 30% of new utilities are actually required replacements of old utilities: about **1.5** Million tonnes per year.

[6] That 'direct usage' approach was not used to forecast overall aggregate consumption because of the poor match between total aggregate consumption and production in past years. The data in 1994 matched more successfully, so we used it only as a way of checking the result of this forecast.

- Include 5% of the new roads amount since low population growth results in low demand for new roads, but still a continuing need to widen or replace some existing roads: about **0.2** Million tonnes per year.
- The average useful life of a commercial development is about 40 years, so 2.5% of the commercial stock is replaced annually. The approximate combined total study area office, retail and industrial floorspace inventory is 230 Million s.f., and about 40 tonnes are required per 1000 s.f.: about **0.2** Million tonnes per year.
- 50% of the major projects amount since low population growth results in lower demand for major infrastructure projects, but still a continuing need to replace/upgrade obsolete infrastructure: about **1.3** Million tonnes per year.

This check results in a base level of aggregate demand of about **9.2** Million tonnes per year, which is about 45% of that year's total aggregate production. This seems to confirm that a substantial portion of aggregate demand comes from the maintenance, rehabilitation or replacement of existing infrastructure.

Overall, it appears that 45% to 65% of overall aggregate demand can be attributed to the existing population for the rehabilitation and maintenance of existing infrastructure; and therefore, about 35% to 55% of overall aggregate demand can be attributed to growth.

5.3 COMPACT METROPOLITAN GROWTH SCENARIO

Forecasting aggregate demand for this scenario requires more complex analysis. Because this scenario assumes a departure from past trends in terms of residential development and population growth[7], and because our regression model does not account for different housing types, we overlaid a manual adjustment to the demand forecast to account for a different mix of housing types. Population growth distribution and the type of residential development will be different from the Current Trends scenario. Population growth will be focused in already established urban areas, so residential development will be higher density (more apartments) and there will be less need for new infrastructure (major projects, roads, utilities, in new areas). Conceivably, aggregate demand should be lower in this scenario.

7

As a preliminary analysis of the amount and distribution of aggregate demand in the study area, we can apply our regression equation to the population forecast based on the compact metropolitan growth strategy (the population forecasts are in Appendix B). It is important to note that the population forecasts for the compact region and current trends show same total study area population - the only difference is the distribution of population within the study area (i.e., the compact scenario focuses more population in urban town centres in the west and mid-west sub-areas).

Based on the following regression equation and using BC Stat's Compact Region Population forecast, the following table shows the geographic distribution of overall aggregate demand (ignoring, for the time being, the difference in aggregate demand due to different residential development patters). These forecasts are shown in detail in Appendix B.

[7] Development patterns presumed in compact metropolitan scenario differ significantly from the past in that growth is to occur in a select few urban town centres, resulting in higher density residential development, and therefore less demand for infrastructure in new areas.

Aggregate Consumption (000's tonnes) = 0.0095 X A + 0.123 x B

where:

A = the number of existing residents plus natural increase.

B = the number of new residents due to in-migration.

Preliminary Aggregate Consumption Forecast (000's): Compact Metropolitan Scenario

	1996-2000	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2021**	**1996-2021**
West Consumption	52,127	54,957	57,627	60,137	75,027	299,876
Mid-west Consumption	48,556	55,854	62,054	67,954	89,186	323,605
Central Consumption	19,672	21,458	23,500	25,955	34,266	124,850
East Consumption	4,642	4,824	5,156	5,512	7,078	27,212
Total Consumption	124,996	137,093	148,337	159,559	205,557	775,542
Avg. Ann. Consump.:	24,999	27,419	29,667	31,912	34,259	29,828

Note that the overall demand for aggregates in this scenario's preliminary forecast is the same as overall demand for the Current Trends Scenario, only the distribution between sub-areas is different.

5.3.1 *COMPARATIVE ANALYSIS OF HOUSEHOLD DISTRIBUTION AND DEVELOPMENT*

Further analysis is required with respect to the Compact Metropolitan scenario because in addition to the differing geographic distribution of population and households within the study area, there will be differences in the predominant types of residential construction (i.e. housing in the compact scenario will be, by definition, higher density). Because different types of housing development (single family, townhouse, apartment) have different aggregate requirements, this will have implications for overall aggregate consumption (on both a sub-market basis and a total study area basis)[8].

8

To estimate the difference in aggregate consumption associated with residential development for the compact metropolitan growth scenario, three tasks were required:

1. Obtain household forecasts for both growth scenarios (current trends continued and compact metropolitan).[9]
2. Apply an appropriate housing type split to the household forecasts for both growth scenarios.[10]
3. Apply aggregate usage factors that are associated with the different types of residential development to the household forecasts.[11]

9

10

11

Full documentation of the comparative household analysis iscontained in Appendix C. The following is a summary of aggregate usage (in tonnes) for residential development by sub-area, which shows the difference in aggregate demand due to the expected difference in type residential development between the two scenarios:

[8] We expect the amount, type and distribution of other kinds of urban development (e.g., office, retail, institutional, and industrial), will be constant across both scenarios since this type of development generally occurs in already established urban areas.

[9] BC Stats produces household forecasts for each growth scenario that are based on their population forecasts.

[10] CMHC reports housing start data by municipality. BC Stats household projections are on a local health area basis. Boundaries of local health areas generally correspond closely with boundaries of municipalities. We applied CMHC's municipal housing splits to the appropriate local health area(s), and then summed the local health areas within each of the four market sub-areas to obtain ratios of housing type on a market sub-area basis.

[11] Levelton Associates provided us with aggregate usage factors for each type of housing (single family, townhouse, lowrise and high-rise apartment) and their associated roads and services. By applying these to the forecasts of households by type in each growth scenario (current trends continued and compact metropolitan), we can forecast the aggregate demand for residential development within each growth scenario.

West Sub-area	Current Trends Continued	Compact Metropolitan
1996-2000	5,511,830	4,745,350
2001-2005	7,310,618	6,223,343
2006-2021	18,817,598	13,192,375
Total (1996-2021)	31,640,046	24,161,068

Mid-west Sub-area	Current Trends Continued	Compact Metropolitan
1996-2000	12,133,541	14,117,022
2001-2005	13,780,847	16,558,167
2006-2021	33,784,877	35,380,361
Total (1996-2021)	59,699,265	66,055,550

Central Fraser Valley	Current Trends Continued	Compact Metropolitan
1996-2000	5,940,647	4,226,067
2001-2005	7,704,908	4,495,107
2006-2021	21,753,133	10,199,616
Total (1996-2021)	35,398,688	18,920,790

East Fraser Valley	Current Trends Continued	Compact Metropolitan
1996-2000	2,207,062	824,371
2001-2005	3,845,757	979,445
2006-2021	12,232,196	2,117,915
Total (1996-2021)	18,285,015	3,921,731

Total Study Area	Current Trends Continued	Compact Metropolitan
1996-2000	25,793,080	23,912,811
2001-2005	32,642,131	28,256,062
2006-2021	86,587,806	60,890,268
Total (1996-2021)	145,023,017	113,059,141

Up until 2006, the compact metropolitan growth scenario will result in more aggregate demand in the Mid-west sub-area than the current trends continued growth scenario. This is because Mid-west market sub-area will capture a larger proportion of household growth in the compact growth scenario than it will in the current trends growth scenario.

This analysis suggests that due to higher density residential development focused in established town centres, the compact metropolitan growth scenario will require less aggregate for new residential construction over time. Over the entire study period (1995-2021), the total difference between the two growth scenarios is about 32,000,000 tonnes. The difference of about 32,000,000 is about 4% of the study area's total forecasted demand for aggregates of 775,492,000 tonnes in the current trends scenario over the study period (1996-2021), which implies that the compact metropolitan growth strategy will not drastically impact overall aggregate consumption in the study area.

Now we can take the differences in aggregate demand due to residential development for each sub-area and overlay these amounts on the demand forecast based on the regression equation for the compact metropolitan scenario. For example, from 1996 - 2000, aggregate demand for residential development in the west sub-area in the compact scenario is expected to be about 766,480 tonnes less than in the current trends scenario (see summary tables on previous page); we then take this difference and subtract it from the west sub-area in the compact scenario for that same time period. After repeating this process for each sub-area in each time period, we can forecast the total demand for aggregates in the compact scenario and thus account for differences in geographic distribution (determined by the regression equation) as well as differences in the type of residential development (determined by the comparative household analysis).

The following table shows the forecast for total aggregate demand based on the compact metropolitan scenario:

Final Aggregate Consumption Forecast (000's): Compact Metropolitan Scenario

	1996-2000	2001-2005	2006-2010	2011-2015	2016-2021	1996-2021
West Consumption	51,360	53,870	55,869	58,379	72,918	292,397
Mid-west Consumption	50,539	58,631	62,553	68,453	89,784	329,961
Central Consumption	17,957	18,248	19,890	22,345	29,933	108,373
East Consumption	3,259	1,958	1,995	2,351	3,285	12,848
Total Consumption	123,115	132,707	140,307	151,528	195,920	743,579
Avg. Ann. Consump.:	24,623	26,541	28,061	30,305	32,653	28,599

In the compact metropolitan scenario, demand should total about 743,579,000 tonnes between 1996 and 2021.

5.4 SUMMARY OF THE AGGREGATE DEMAND FOREGAST BASED ON REGRESSION ANALYSIS

Based on the analysis of household type and distribution, overall aggregate consumption for residential development will be somewhat less under the compact metropolitan scenario compared to the current trends. The difference in aggregate consumption due to different residential development patterns accounts for about 4% of overall aggregate consumption for the study area. Therefore, the compact metropolitan regional growth strategy should only have a small effect on overall aggregate consumption.

In the maintenance scenario with absolutely no growth, aggregate demand will still total about 19,761,000 tonnes per year (about 514,451,000 tonnes between 1996 and 2021) - roughly 65% of the demand estimate using the current trends scenario. It is interesting to note that a substantial portion of overall demand for aggregates comes from the existing population.

The following table summarizes the results of the demand forecasts for the various scenarios:

Summary of Aggregate Demand Forecast (000's): All Scenarios

	1996-2000	2001-2005	2006-2010	2011-2015	2016-2021	1996-2021
Current Trends Scenario:	124,980	137,081	148,329	159,553	205,550	775,492
Avg. Ann. Demand:	24,996	27,416	29,665	31,910	34,258	29,826
Maintenance State (only natural inc., no in-mig.):	100,609	103,449	106,087	108,587	133,386	552,099
Avg. Ann. Demand:	20,122	20,690	21,217	21,717	22,228	21,235
Maintenance State (no nat.inc, no in-mig.):	98,805	98,805	98,805	98,805	98,805	514,450
Avg. Ann. Demand:	19,761	19,761	19,761	19,761	19,761	19,761
Compact Metropolitan Scenario:	123,115	132,707	140,307	151,528	195,920	743,579
Avg. Ann. Demand:	24,623	26,541	28,061	30,305	32,653	28,599

6.0 MUNICIPAL RESIDENTIAL CAPACITIES

All forecasts in this analysis have been based on the assumption that the supply of developable land will not constrain future residential development. The GVRD, in cooperation with municipalities, identified residential dwelling unit capacities for municipalities in the Lower Mainland in its Livable Region Strategic Plan (the household forecasts in Appendix D show municipal capacities). On average, ground oriented household capacities are reached sooner under the Current Trends Continued scenario, as more single family (low density) residential development takes place, taking up more developable land. The following table shows residential capacities for areas in the study area. The year that capacity is reached was found by projecting the number of households by the historic average annual rate of household growth for each scenario.

		Current Trends	Compact Scenario		Current Trends	Compact Scenario
Area	Ground Oriented Capacity	Year Capacity Reached	Year Capacity Reached	Apartment Capacity	Year Capacity Reached	Year Capacity Reached
Lillooet	n/a	n/a	n/a	n/a	n/a	n/a
Howe Sound	n/a	n/a	n/a	n/a	n/a	n/a
West Van.	15,800	2003	2006	8,000	2022	2015
North Van.	44,100	2027	2033	20,000	2007	2006
Vancouver	122,100	2027	2027	181,300	2043	2030
Richmond	46,500	2002	2008	34,000	2027	2028
Delta	31,000	1998	2000	8,100	2009	2009
Burnaby	57,400	2059	2013	52,900	2091	2014
New West.	7,600	1990	1991	33,300	2034	2025
Coquitlam	82,400	2030	2022	35,000	2018	2009
Maple Ridge	40,600	2019	2033	8,000	2009	2008
Surrey	136,200	2014	2017	64,900	2019	2014
Langley	57,300	2014	2039	13,500	2009	2013
Mission	21,400	2024	2024	3,700	1996	1995
Abbotsford	33,600	2003	2009	31,900	2030	2031
Chilliwack	n/a	n/a	n/a	n/a	n/a	n/a
Agassiz/Har.	n/a	n/a	n/a	n/a	n/a	n/a
Hope	n/a	n/a	n/a	n/a	n/a	n/a

Source: Greater Vancouver Regional District

In most areas where supply appears to be reached earlier in the study period (i.e., 1998-2003), such as West Vancouver, Delta, New Westminster, the forecast of ground oriented dwellings does not dramatically surpass capacities. It is conceivable that adjustments could be made to accommodate the extra growth in these areas.

Richmond appears to be the only area where the supply of developable land appears to be well below expected household growth (69,005 ground oriented dwellings expected by 2021, capacity exists for 46,500 ground oriented dwellings). It appears that substantial adjustments will have to be made to accommodate this growth (i.e. allowing significantly more higher density ground oriented housing, such as townhomes).

According to GVRD Strategic Planning Department, the capacities in the above table based on population projections done in 1991 and 1992 (by BC Stats), which were significantly lower than the 1995 and 1996 forecasts. According to the GVRD, these household capacities will be revisited (especially those that appear to have been reached already or are nearing capacity), and will be adjusted to reflect the most recent population projections.

7.0 SUMMARY OF CONCLUSIONS

We developed two models for forecasting the overall demand for aggregates in the study area: Direct Usage Approach and the Regression Analysis Approach.

1. The direct usage approach involved applying typical aggregate usage amounts (i.e. 'usage factors') to forecasts of all potential users of aggregates.
    - we were not able to use this approach because the results of testing the model proved unreliable. The failure ofthe model could have been due to inaccurate historic data and/or inaccurate usage factors.

2. The regression analysis approach involved forecasting aggregate consumption by applying coefficients of a regression equation to the two components of population growth (natural increase and in-migration) for three scenarios: Current Trends Continued, Maintenance/No Growth, and Compact Region Scenario. Further analysis was required in the compact scenario to determine whether expected different forms of residential development between growth scenarios will have a significant impact on overall demand for aggregates.
    - We found that there was a high degree of correlation between historic aggregate consumption and historic population growth (separating natural increase and in-migration), resulting in the following regression equation:

      Aggregate Consumption (000's tonnes) = 0.0095 x A + 0.123 x B

      where:
      A = the number of existing residents plus natural increase.
      B = the number of new residents due to in-migration.

- Because this regression produced the highest coefficient of determination (r^2 = 0.94), we selected this equation as the model for forecasting overall aggregate consumption. The regression equation's application is Appendix B.

- Using this regression equation was ideal for the current trends scenario, as the approach implicitly relies on historical statistical relationships. The current trends scenario is also based on recent historical growth patters of urban development. Applying the regression equation to the current trends population forecast resulted in a total aggregate demand forecast of about 775,500,000 tonnes for the 26 year period between 1996 and 2021.

- The results of the regression analysis also showed that aggregate demand in the Maintenance/No Growth Scenario turned out to be only 30% - 35% less than the other scenarios, suggesting that the majority of aggregate usage comes from the existing population base and the 'maintenance' of existing infrastructure.

- Further analysis was required to account for different residential development patterns (i.e. higher density housing in the compact metropolitan scenario compared to current trends scenario) as they would have an effect on overall demand for aggregates in the study area. Based on our analysis, we determined that the difference in demand for aggregates for use in residential development between the compact metropolitan and the current trends scenario was only about 4% of the overall aggregate demand over the study period. We then applied the appropriate difference in aggregate consumption due to different residential development to each sub-area's total demand forecast based on the regression equation for the compact scenario. Overall demand in the compact scenario totalled about 744,000,000 tonnes between 1996 and 2021.

- The following table summarizes the demand forecasts for each scenario.

	1996-2000	2001-2005	2006-2010	2011-2015	2016-2021	1996-2021
Current Trends Scenario:	124,980	137,081	148,329	159,553	205,550	775,492
Avg. Ann. Demand:	24,996	27,416	29,665	31,910	34,258	29,826
Maintenance State (only natural inc., no in-mig.):	100,609	103,449	106,087	108,587	133,386	552,099
Avg. Ann. Demand:	20,122	20,690	21,217	21,717	22,228	21,235
Maintenance State (no nat.inc, no in-mig.):	98,805	98,805	98,805	98,805	98,805	514,450
Avg. Ann. Demand:	19,761	19,761	19,761	19,761	19,761	19,761
Compact Metropolitan Scenario:	123,115	132,707	140,307	151,528	195,920	743,579
Avg. Ann. Demand:	24,623	26,541	28,061	30,305	32,653	28,599

- It should be noted that the household growth section of the forecasting model cannot be used for other regions in B.C. as it is based on a comparison of two separate regional growth scenarios. Most areas in B.C. are not subject to growth management or growth policy issues, so a comparative household analysis would not be required.