EUB/AGS Information Series 135

The Occurrence, Production and Projected Consumption of Sand and Gravel in the Municipal District of Foothills

Alberta Energy and Utilities Board

Alberta Geological Survey

AGS

EUB/AGS Information Series 135

The Occurrence, Production and Projected Consumption of Sand and Gravel in the Municipal District of Foothills

W.A.D. Edwards[1] and H.D. Budney[2]

[1]Alberta Energy and Utilities Board/Alberta Geological Survey
[2]Simon Fraser University

January 2007

ISBN 0-7785-1503-6

Edwards, W.A.D. and Budney, H.D. (2006): The occurrence, production and projected consumption of sand and gravel in the Municipal District of Foothills; Alberta Energy and Utilities Board, EUB/AGS INF 135, 17 p.

Author Address
H.D. Budney
School of Resource and Environmental Management
Simon Fraser University
8888 University Drive
Burnaby, British Columbia
V5A 1S6
Canada
E-mail: hbudney@sfu.ca

Published January 2007 by:
Alberta Energy and Utilities Board
Alberta Geological Survey
4th Floor, Twin Atria Building
4999 – 98th Avenue
Edmonton, Alberta
T6B 2X3
Canada

Tel: (780) 422-3767 (Information Sales)
Fax: (780) 422-1918
E-mail: EUB.AGS-Infosales@gov.ab.ca
Website: www.ags.gov.ab.ca

Contents

Acknowledgments ..... **v**
Abstract ..... **vi**
1 Sand and Gravel Resources **1**
2 Aggregate Resource Production and Consumption **8**
3 Aggregate Resource Issues **15**
3.1 Trucking 15
3.2 Environment 15
3.3 Export 15
3.4 Community Aggregate Payment 15
3.5 Crushed Stone 16
4 Conclusions **16**
5 Recommendations **16**
6 References **17**

Tables

1 Sand and gravel volume estimates according to Alberta Geological Survey data 3
2 Sand and gravel volume estimates based on collaboration between the Municipal District of Foothills and Alberta Geological Survey 3
3 Gravel volume estimates based on collaboration between the Municipal District of Foothills and Alberta Geological Survey 5
4 Sand and gravel volume estimates according to Municipal District of Foothills and Alberta Geological Survey data with a 100 m no development buffer on rivers and lakes 5
5 Estimated sand and gravel volumes zoned INN with a 100 m no development buffer on rivers and lakes, based on Municipal District of Foothills and Alberta Geological Survey data 8
6 Populations and aggregate consumption rates used for aggregate resource modelling 10
7 Estimates of total potential sand and gravel resources relative to the Municipal District of Foothills aggregate consumption centre 12
8 Estimates of reasonably recoverable sand and gravel resources relative to the Municipal District of Foothills aggregate consumption centre 12
9 Estimates of total potential gravel resources relative to the Municipal District of Foothills aggregate consumption centre 13
10 Estimates of reasonably recoverable gravel resources relative to the Municipal District of Foothills aggregate consumption centre 13
11 Cost of hauling aggregate to the Municipal District of Foothill's consumption centre from 2005 to 2031 assuming haul rate remains constant 14
12 Cost of hauling aggregate to the Municipal District of Foothill's consumption centre from 2005 to 2031 assuming haul rate increases with time 14
13 Aggregate production cost in the MD of Foothills from 2005 to 2031 assuming production cost remains constant 14
14 Aggregate production cost in the MD of Foothills from 2005 to 2031 assuming production cost increases with time 14

Figures

Figure 1 Sand and gravel areas with aggregate resource potential as identified by the Alberta Geological Survey, Municipal District of Foothills, Alberta 2

Figure 2 Sand and gravel areas with aggregate resource potential as identified by the Alberta Geological Survey and Municipal District of Foothills 4
Figure 3 Sand and gravel areas with aggregate resource potential and a 100 m no development buffer around rivers and lakes 6
Figure 4 Areas zoned for industrial natural resource development (INN) with a 100 m no development buffer around rivers and lakes 7
Figure 5 Location of aggregate deposits relative to the primary aggregate consumption location 9
Figure 6 Sand and gravel consumption (2005-2031) and recoverable resources in the Municipal District of Foothills 10
Figure 7 Gravel consumption (2005-2031) and recoverable resources in the Municipal District of Foothills 11

Acknowledgments

This project was undertaken specifically to provide the Municipal District of Foothills with information on sand and gravel resources within the municipality for the effective and sustainable development of the municipality's aggregate resources in the future. The project was successful due to the dedicated efforts of Municipal District of Foothills staff Harry Riva Cambrin (municipal manager), Dan Ellice (public works superintendent) and Johanna Kortenschyl-Allan (GIS specialist). Inland Aggregates Ltd., Burnco Rock Products Ltd., McHugh Sand and Gravel, Wallator Sand and Gravel and other local sand and gravel operations are thanked for providing access to their pits for geological mapping. We thank those residents of the Municipal District of Foothills that provided information on sand and gravel or access to their land. Bill Symmonds, Alberta Municipal Affairs, and Don Peel, Alberta Sustainable Development deserve special mention for their efforts in supporting this initiative. Joanne Sweeney, Alberta Sustainable Development, and Kathleen Edwards, Alberta Geological Survey summer student, are thanked for their assistance with fieldwork. Cal Hill, Joe MacGillivray, Rick Marsh, Andy Warren, Rick Richardson and Reg Olson, all of the Alberta Energy and Utilities Board, are thanked for their support and encouragement. A report entitled "The Occurrence, Production and Projected Consumption of Sand and Gravel in the Municipal District of Foothills" was issued to the Municipal District of Foothills on June 23, 2004. This report contains the same information, analyses and conclusions as the earlier report.

Abstract

The Municipal District of Foothills is estimated to have 79 million m^3 of sand and gravel resources zoned for aggregate extraction. At modestly increasing consumption rates, these reserves will be exhausted in 15 years. As reserves are depleted, the cost to transport each tonne of resource will triple as haul distances increase from about 14 km to more than 40 km. This scenario is inevitable unless additional resources are identified and conserved, and producing pits developed.

In 2003, the Alberta Geological Survey, in collaboration with the municipality, identified 446 deposits containing at least 317,780,000 m^3 of sand and gravel during the update of a sand and gravel inventory of the Municipal District of Foothills. Depletion of nearby resources could be delayed and haul costs reduced by developing some of these deposits for aggregate.

The low-unit price of sand and gravel (~$5.79 per tonne) and common applications (roads, bridges, foundations) often conceal the fact that sand and gravel is a major mineral resource and aggregate an essential commodity. For example, the current, in-ground value of sand and gravel identified during the preliminary sand and gravel inventory could be in excess of $5 billion. This would equate to a community aggregate payment to the Municipal District of Foothills of $217 million (at $0.25 per tonne). If all deposits were developed the transportation costs to haul aggregate to market areas could be minimized to about $2 billion and the life of sand and gravel resources in the municipality extended beyond 2050.

The Municipal District of Foothills can control aggregate production and transportation costs, limit environmental and safety hazards associated with sand and gravel development, and determine aggregate resource revenue by maintaining the sand and gravel inventory that was updated in 2003 and devise a sand and gravel development strategy.

1 Sand and Gravel Resources

The Alberta Geological Survey (AGS) mapped and published information on sand and gravel deposits in and around the Municipal District of Foothills in 1979 (Edwards), 1981 (Shetsen, 1981a, 1981b, 1981c and 1981d), 1982 (Fox), 1987 (Shetsen) and 1996 (Edwards and Scafe). In 2003, the potential resources identified in these earlier studies were consolidated and a field review undertaken. Based on this review the amount of sand and gravel estimated to have aggregate potential in the Municipal District of Foothills ranges from 541,318,000 m^3 (total potential) to 286,382,000 m^3 (reasonably expected to produce aggregate) (Table 1 and Figure 1). The wide range in the estimates cited is due to the nature of the original surveys (reconnaissance, enhanced reconnaissance or site visited) and the reasonable expectation of recovery of aggregate resources from deposits.

AGS surveys used to identify sand and gravel deposits in the Municipal District of Foothills are defined as follows:

- Reconnaissance: sand and gravel areas were identified from remote sensing and/or other information without Alberta Geological Survey site investigation of the area. There is potential for the occurrence of sand and/or gravel.
- Enhanced reconnaissance: sand and gravel areas assumed to contain sand and/or gravel based on Alberta Geological Survey investigation of other sites in the area, remote sensing and/or other sources of information.
- Site visited: sand and/or gravel with resource potential were confirmed in these deposits by Alberta Geological Survey site investigation and limited sampling and/or testing.

Amounts are estimated as volumes. The volume of each deposit is calculated by multiplying the area of the deposit by its thickness. All area and thickness values are estimates that depend on the precision of the original mapping and the field review. The total volume estimate assumes there is no uncertainty in the area and thickness values and is not adjusted for the nature of the original survey. A second estimate that more closely reflects expected recovery applies a reduction factor to the volumes of certain deposits to illustrate the uncertainty of deposit area and thickness.

The reasonable expectation of recovery of aggregate resources from deposits described by the AGS is based on experience gained by tracking the development of deposits over a twenty-five period. This experience shows that the aggregate resources mined from areas estimated to have potential by the AGS are less than originally estimated depending on the level of the original survey. The reduction factor applied is generated from the mapping information as follows:

- Reconnaissance level: in general, aggregate is recovered from only one in ten deposits original identified as having potential based on reconnaissance study; in other words only ~10% of the originally estimated volume is recoverable.
- Enhanced reconnaissance level: in general, aggregate is recovered from four in ten deposits original identified as having potential based on enhanced reconnaissance study; in other words only ~25% of the originally estimated volume is recoverable.
- Site visited level: all deposits contain granular materials and in general, ~75% of the originally estimated volume is recoverable.

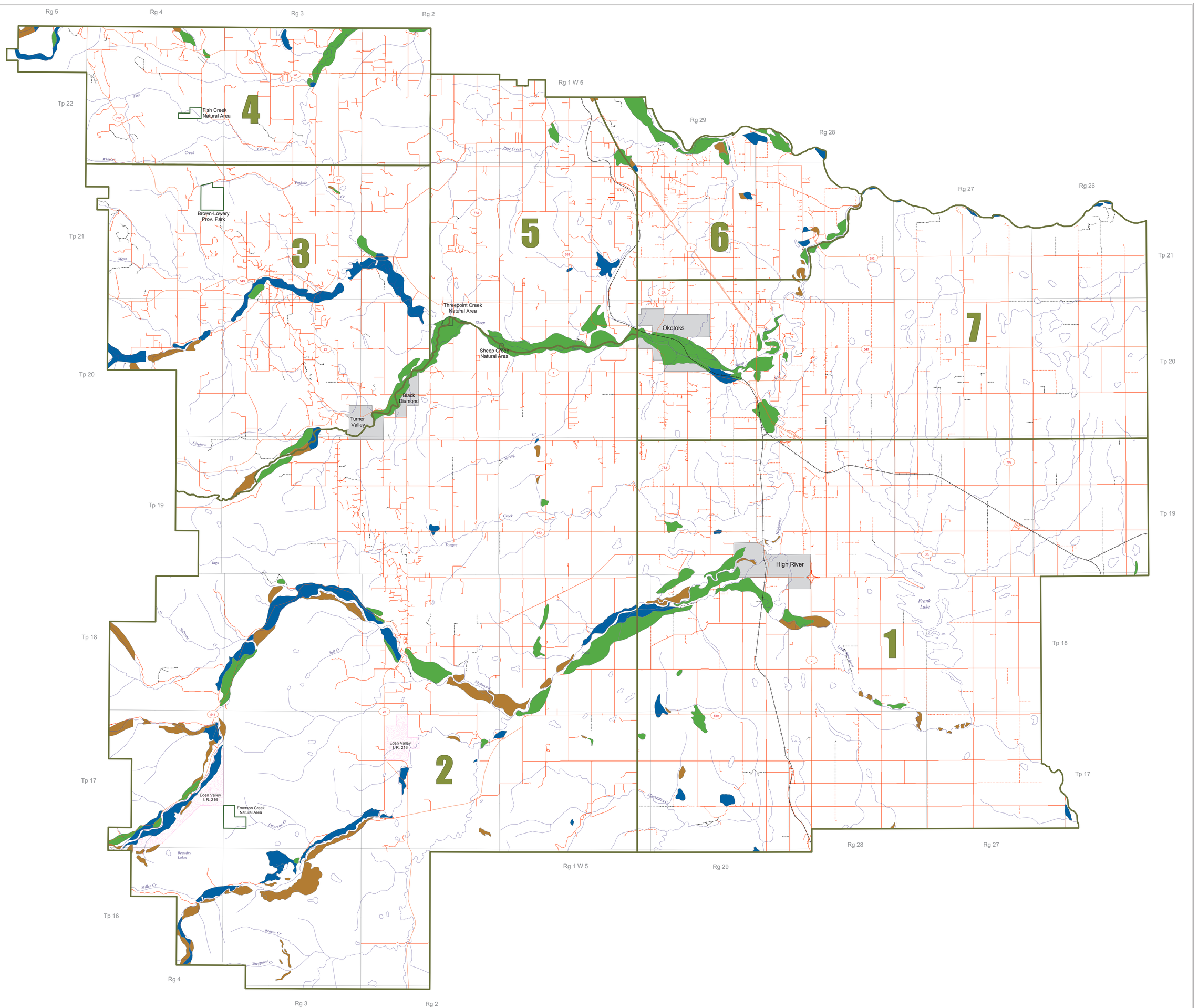

Figure 1: Sand and gravel areas with aggregate resource potential as identified by the Alberta Geological Survey, Municipal District of Foothills, Alberta

LEVELS OF INVESTIGATION BY THE ALBERTA GEOLOGICAL SURVEY

- Sand and/or gravel confirmed by Alberta Geological Survey site investigation and limited sampling and testing.
- Sand and/or gravel areas assumed by Alberta Geological Survey investigation of associated sites, remote sensing and other sources of information.
- Potential sand and/or gravel areas identified from remote sensing and other sources of information without Alberta Geological Survey site investigation.

Scale 1:100 000

0 2.5 5 10 15 20 Kilometres

0 1.25 2.5 5 7.5 10 Miles

Projection: 3 Degree Tranverse Mercator
Datum: North American Datum, 1983

Towns
Road - paved
Road - gravel
Road - unimproved
Trail
Railway
Rivers
Lakes
Township/range
Indian reserves
Councillor's divisional boundaries (1995) 5

Digital base map provided: Spatial Data Warehouse, Alberta Environment and Alberta Infrastructure

EUB Alberta Energy and Utilities Board | AGS Alberta Geological Survey

Table 1. Sand and gravel volume estimates according to Alberta Geological Survey data

Alberta Geological Survey Levels of Investigation			Total Volume (000's m^3)	
Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)		
91208	120643	329467	541318	total volume of material
9121	30161	247100	286382	expected recovery

The Municipal District of Foothills has also identified areas with sand and gravel potential. We consider this assurance of development and for the purposes of this study completely recoverable. Adding the Municipal District of Foothills information to our data set and applying it to jointly identified areas increased the overall expected recovery estimates by 31,398,000 m^3 (Table 2, Figure 2).

Table 2. Sand and gravel volume estimates based on collaboration between the Municipal District of Foothills and Alberta Geological Survey

Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)	Total Volume (000's m^3)	
Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)			
87125	102830	272013	79350	541318	total volume
8713	25708	204010	79350	317780	expected recovery

The Municipal District of Foothills is estimated to have between 182,432,000 m^3 and 303,135,000 m^3 of gravel with aggregate potential (Table 3). There is an important distinction to be made between gravel resources and sand and gravel resources. Gravel is the essential natural ingredient in the construction and maintenance of paved and gravel roads and is the primary application of aggregate. The estimation of gravel resources is more difficult than for combined sand and gravel and consequently estimates of gravel resources are much less certain. Even so, gravel estimates such as these are extremely valuable. To work without any estimates is to assume that gravel supplies are unlimited and this action can lead to very large, possibly avoidable, expenditures.

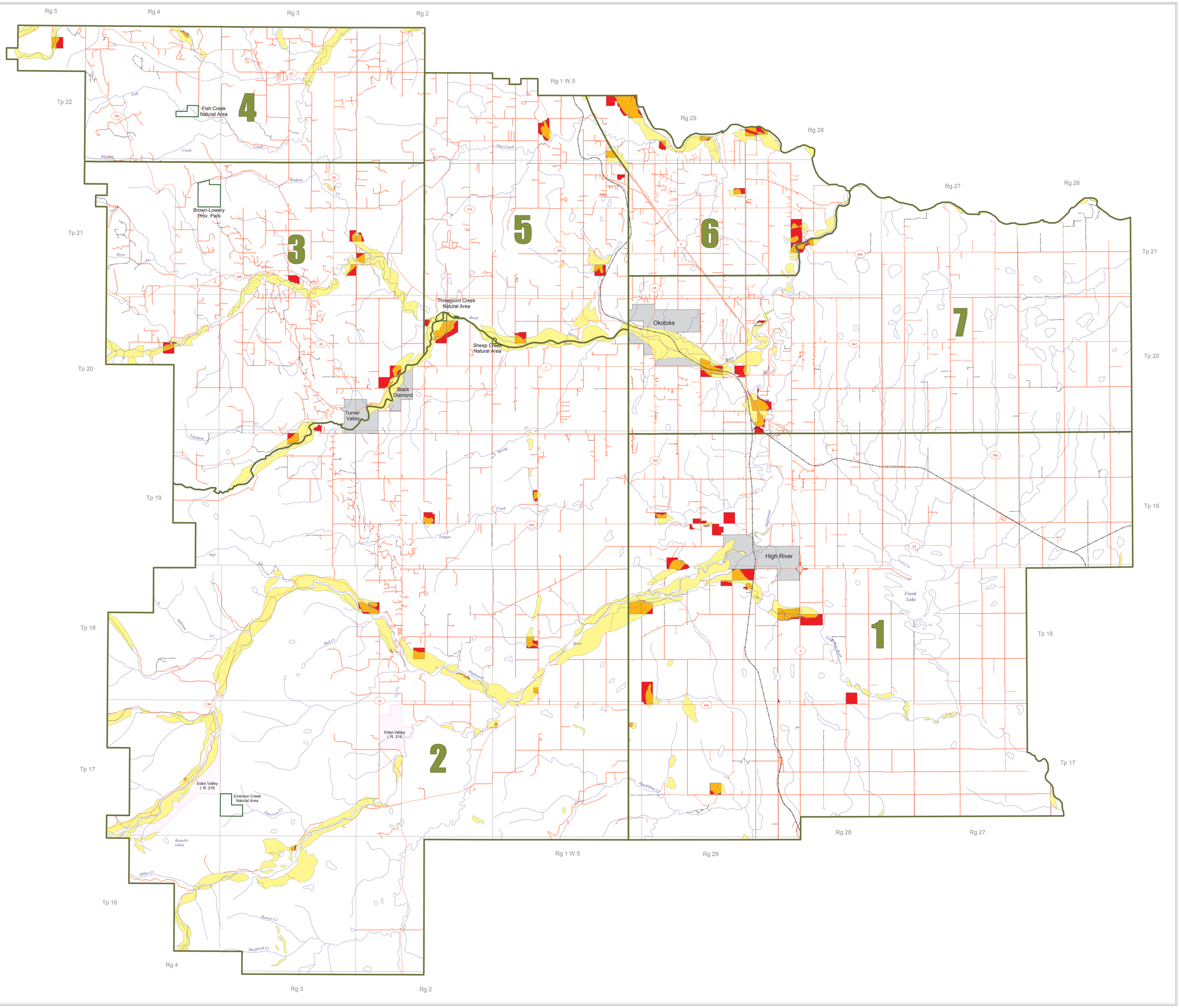

Figure 2: Sand and gravel areas with aggregate resource potential as identified by the Alberta Geological Survey and Municipal District of Foothills

SOURCES OF SAND AND GRAVEL INFORMATION

- Areas with aggregate resource potential identified by the Municipal District of Foothills
- Areas with aggregate resource potential identified by the Municipal District of Foothills and Alberta Geological Survey
- Areas with aggregate resource potential identified by the Alberta Geological Survey

Scale 1:100 000

0 2.5 5 10 15 20 Kilometres

0 1.25 2.5 5 7.5 10 Miles

Projection: 3 Degree Tranverse Mercator
Datum: North American Datum, 1983

- Towns
- Road - paved
- Road - gravel
- Road - unimproved
- Trail
- Railway
- Rivers
- Lakes
- Township/range
- Indian reserves
- Councillor's divisional boundaries (1995) — 5

Digital base map provided: Spatial Data Warehouse, Alberta Environment and Alberta Infrastructure

EUB Alberta Energy and Utilities Board | AGS Alberta Geological Survey

Table 3. Gravel[1] volume estimates based on collaboration between the Municipal District of Foothills and Alberta Geological Survey

Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)	Total Volume (000's m^3)	
Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)			
48407	50710	156415	47603	303135	total volume
4841	12678	117311	47603	182432	expected recovery

[1]The Alberta Geological Survey classifies and gravel deposits into four categories based on gravel content. The gravel calculations were made by applying the following factors to sand and gravel volumes in Table 2 based on gravel content:

- GRAVEL: deposits contain 75-100% gravel. A factor of 0.75 was applied to GRAVEL deposit volumes
- Sandy GRAVEL: deposits contain 50%-75% gravel. A factor of 0.5 was applied to sandy GRAVEL deposit volumes
- Gravelly SAND: deposits contain 25%-50% gravel. A factor of 0.25 was applied to gravelly SAND deposit volumes
- SAND deposits contain 0-25% gravel. A factor of 0 was applied to SAND deposit volumes

In addition to the natural and limited occurrence of sand and gravel deposits, there are societal rules and regulations that restrict aggregate resource development. The Federal Department of Fisheries and Oceans and Alberta Environment are charged with the protection of Alberta's groundwater resources and fish stocks and habitat. Sand and gravel deposits adjacent to and within rivers and lakes are usually precluded from development to protect groundwater and fish resources. Commonly a 100 m no-development buffer is applied around rivers and lakes. Figure 3 shows the occurrence of sand and gravel deposits after eliminating deposits within 100 m of rivers and lakes. The estimated volume of sand and gravel deposits with aggregate resource potential (Table 2) is reduced by 70,340,000 m^3 by the 100 m no-development buffer (Table 4).

Table 4. Sand and gravel volume estimates according to Municipal District of Foothills and Alberta Geological Survey data with a 100 m no development buffer on rivers and lakes

Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)	Total Volume (000's m^3)	
Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)			
72883	77093	201685	69615	421276	total volume
7288	19273	151264	69615	247440	expected recovery

Current municipal land use bylaws restrict the amount of developable sand and gravel resources to areas zoned for natural resource extraction (Figure 4). This further reduces the amount of developable sand and gravel to about 45 million m^3 (Table 5).

Figure 3: Sand and gravel areas with aggregate resource potential and a 100 m no development buffer around rivers and lakes

SOURCES OF SAND AND GRAVEL INFORMATION

- Areas with aggregate resource potential identified by the Municipal District of Foothills
- Areas with aggregate resource potential identified by the Municipal District of Foothills and Alberta Geological Survey
- Areas with aggregate resource potential identified by the Alberta Geological Survey

Scale 1:100 000

0 2.5 5 10 15 20 Kilometres

0 1.25 2.5 5 7.5 10 Miles

Projection: 3 Degree Tranverse Mercator
Datum: North American Datum, 1983

Towns
Road - paved
Road - gravel
Road - unimproved
Trail
Railway
Rivers
Lakes
Township/range
Indian reserves
Councillor's divisional boundaries (1995)

Digital base map provided: Spatial Data Warehouse, Alberta Environment and Alberta Infrastructure

EUB Alberta Energy and Utilities Board

AGS Alberta Geological Survey

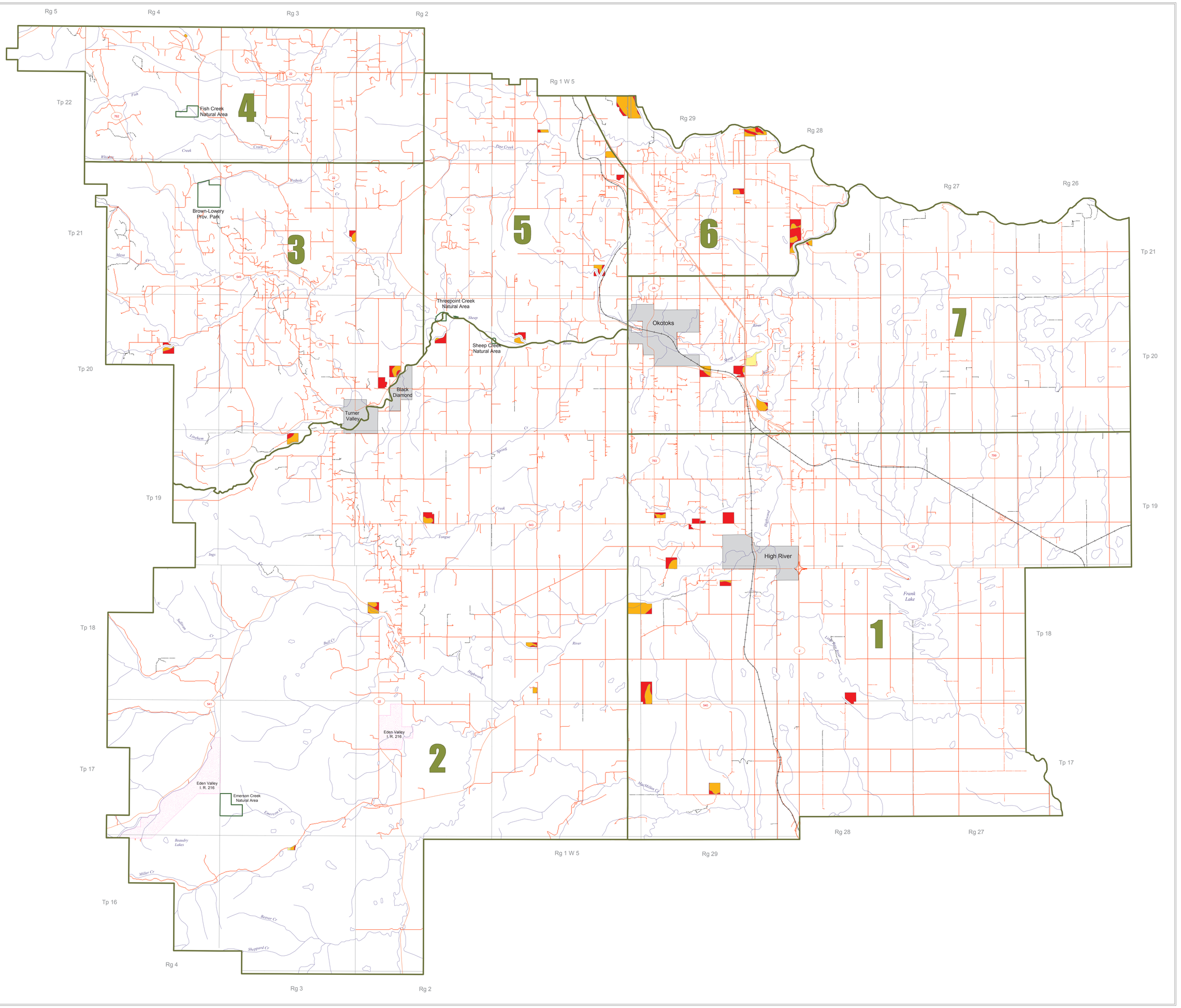

Figure 4: Areas zoned for industrial natural resource development (INN) with a 100 m no development buffer around rivers and lakes

SOURCES OF SAND AND GRAVEL INFORMATION

- Areas with aggregate resource potential identified by the Municipal District of Foothills
- Areas with aggregate resource potential identified by the Municipal District of Foothills and Alberta Geological Survey
- Areas with aggregate resource potential identified by the Alberta Geological Survey

Scale 1:100 000

0 2.5 5 10 15 20 Kilometres

0 1.25 2.5 5 7.5 10 Miles

Projection: 3 Degree Tranverse Mercator
Datum: North American Datum, 1983

- Towns
- Road - paved
- Road - gravel
- Road - unimproved
- Trail
- Railway
- Rivers
- Lakes
- Township/range
- Indian reserves
- Councillor's divisional boundaries (1995) — 5

Digital base map provided: Spatial Data Warehouse, Alberta Environment and Alberta Infrastructure

EUB Alberta Energy and Utilities Board | AGS Alberta Geological Survey

Table 5. Estimated sand and gravel volumes zoned INN[1] with a 100 m no development buffer on rivers and lakes, based on Municipal District of Foothills and Alberta Geological Survey data

Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)	Total Volume (000's m^3)	Area Used in Volume Calculations
Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)			
1	235	1430	43974	45640	total volume
0	59	1073	43974	45105	expected recovery
[1]INN: areas zoned for natural resource extractive industrial development according to the Municipal District of Foothills' Land Use Bylaw.					

2 Aggregate Resource Production and Consumption

Statistics on sand and gravel production are available from an annual survey of operators in Alberta by Natural Resources Canada and surveys conducted by the Alberta Geological Survey in 1981 and 1991 (Edwards, 1995). Historical air photos also provide an idea of the development and expansion of operating pits. Based on these sources of information and observations in the municipality we conclude:

- The largest consumption of aggregate in the municipality is currently near Okotoks, High River and along the Highway 2 corridor into Calgary.
- Large amounts of sand and gravel are exported from the municipality to Calgary.
- Aggregate resource demand will increase as population increases in both the Municipal District of Foothills and Calgary.
- Annual, per capita aggregate consumption values for the Municipal District of Foothills and Calgary were respectively 20 and 10 tonnes (Edwards, 1995).

A resource consumption model was developed using the statistical values shown in Table 6 and the assumptions stated above. Results of the modelling are presented as Figures 5, 6 and 7. Resource volumes are reasonably recoverable resources. According to the model, the municipality will produce 163 million tonnes of aggregate in the next 20 years to satisfy its own and Calgary's needs. The gross estimates of consumption presented in Figures 6 and 7 do not account for concentrated demand for aggregate near towns and major highways or the uneven distribution of sand and gravel deposits. Nor does this method enable the estimation of the huge haul costs associated with aggregate transport.

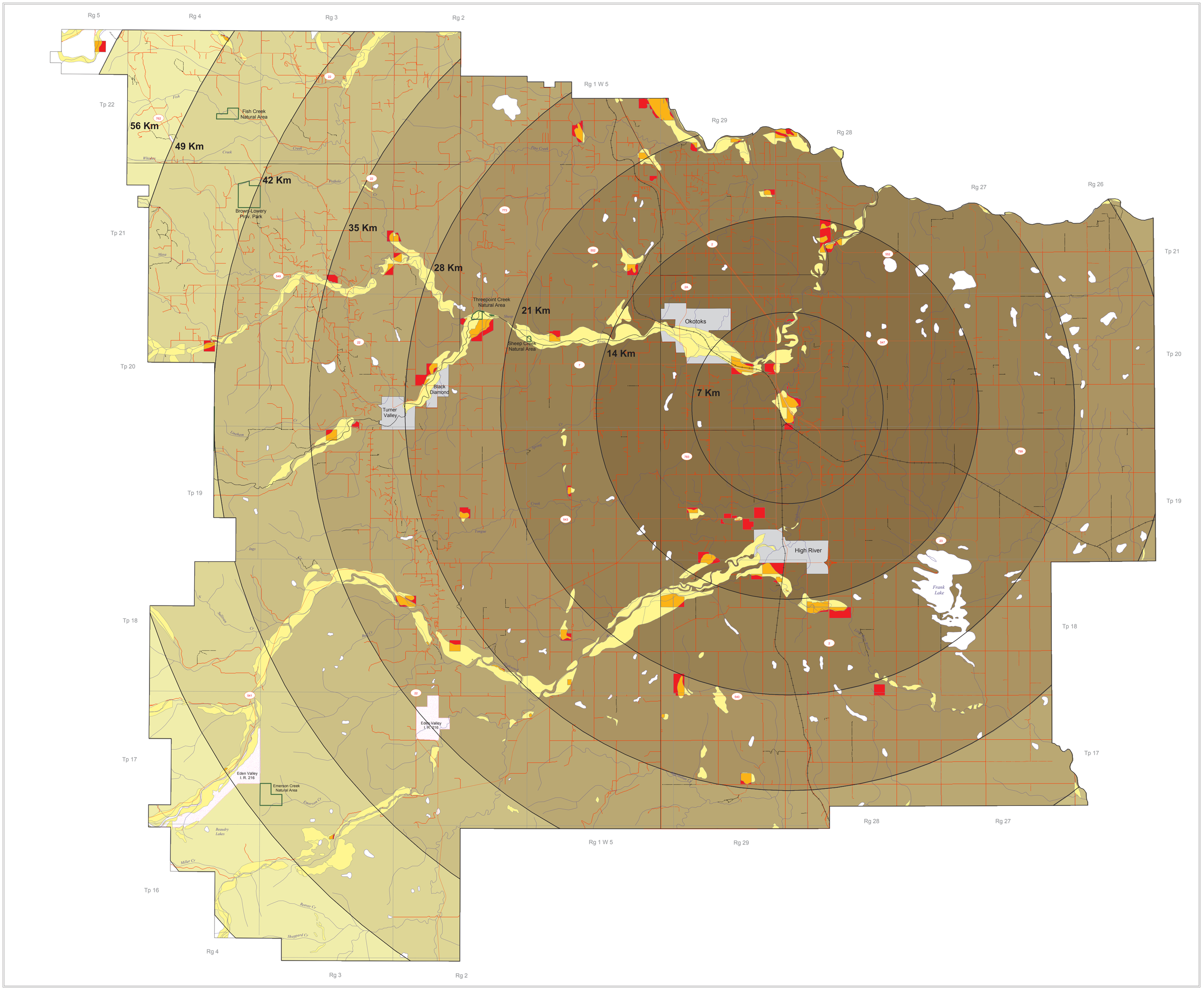

Figure 5: Location of aggregate deposits relative to the primary aggregate consumption location

SOURCES OF SAND AND GRAVEL INFORMATION

- Areas with aggregate resource potential identified by the Municipal District of Foothills
- Areas with aggregate resource potential identified by the Municipal District of Foothills and Alberta Geological Survey
- Areas with aggregate resource potential identified by the Alberta Geological Survey

EUB Alberta Energy and Utilities Board

AGS Alberta Geological Survey

Table 6. Populations and aggregate consumption rates used for aggregate resource modelling

Communities	Population[8]				Consumption Rate[9] (tonnes/year/capita)
	1996	2001	Increase From 1996 To 2001(%)	Increase For Every 5 Year Period (%)	
High River	7359	9345	27	~20	25
Okotoks	8528	11664	37	~30	25
Black Diamond, Turner Valley, Longview	3573	3774	7	~10	20
MD of Foothills	14331	16764	17	~10	20
Calgary[10]	253129	289251	14	~5	10

[8]Population information from http://www.municipalaffairs.gov.ab.ca/mahome/ms/official_pop_lists.cfm.

[9]Consumption rates are estimates from Edwards (1995). One cubic metre of sand and gravel is equal to 1.6 metric tonnes.

[10]Calgary's population in 2001 was 876,519 but a population of one-third is used as aggregate from the Municipal District of Foothills is assumed consumed by the southeast part of Calgary.

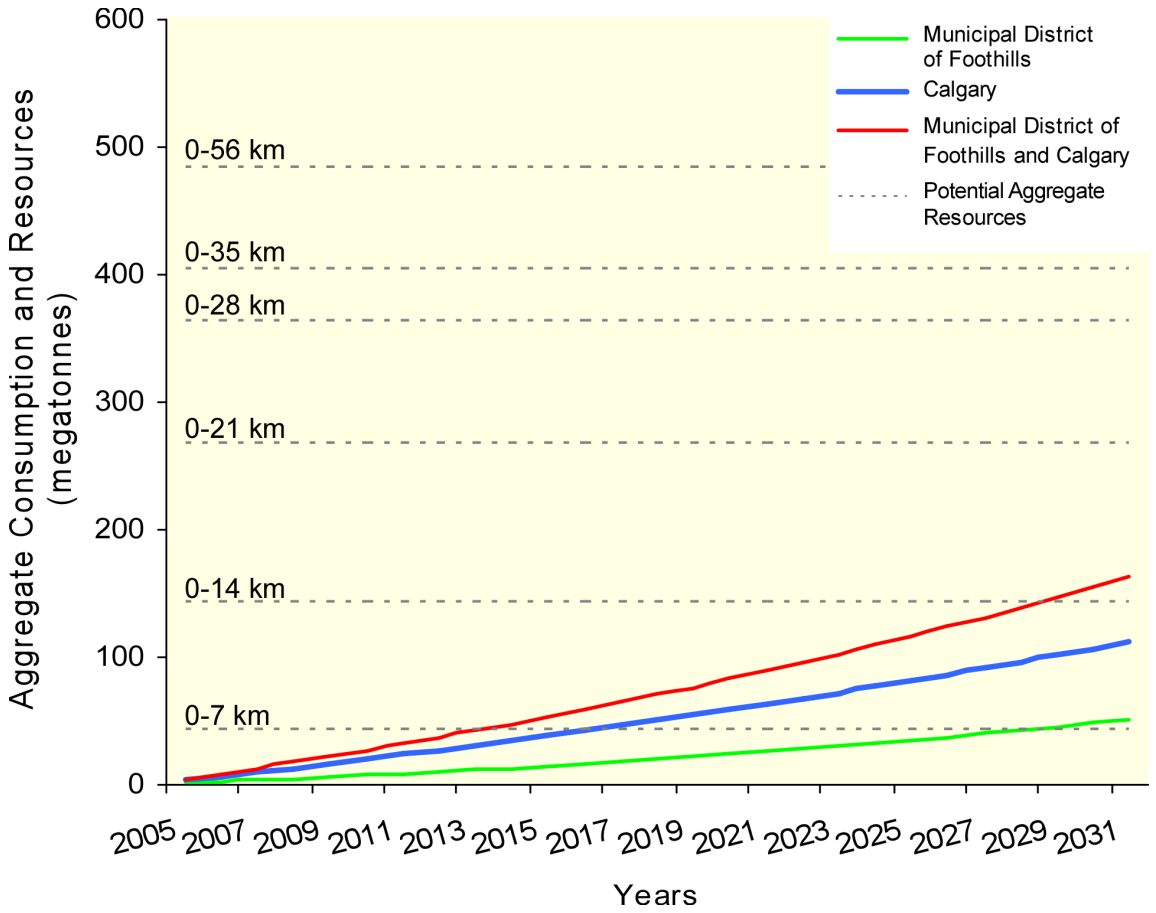

Figure 6. Sand and gravel consumption (2005-2031) and recoverable resources in the Municipal District of Foothills

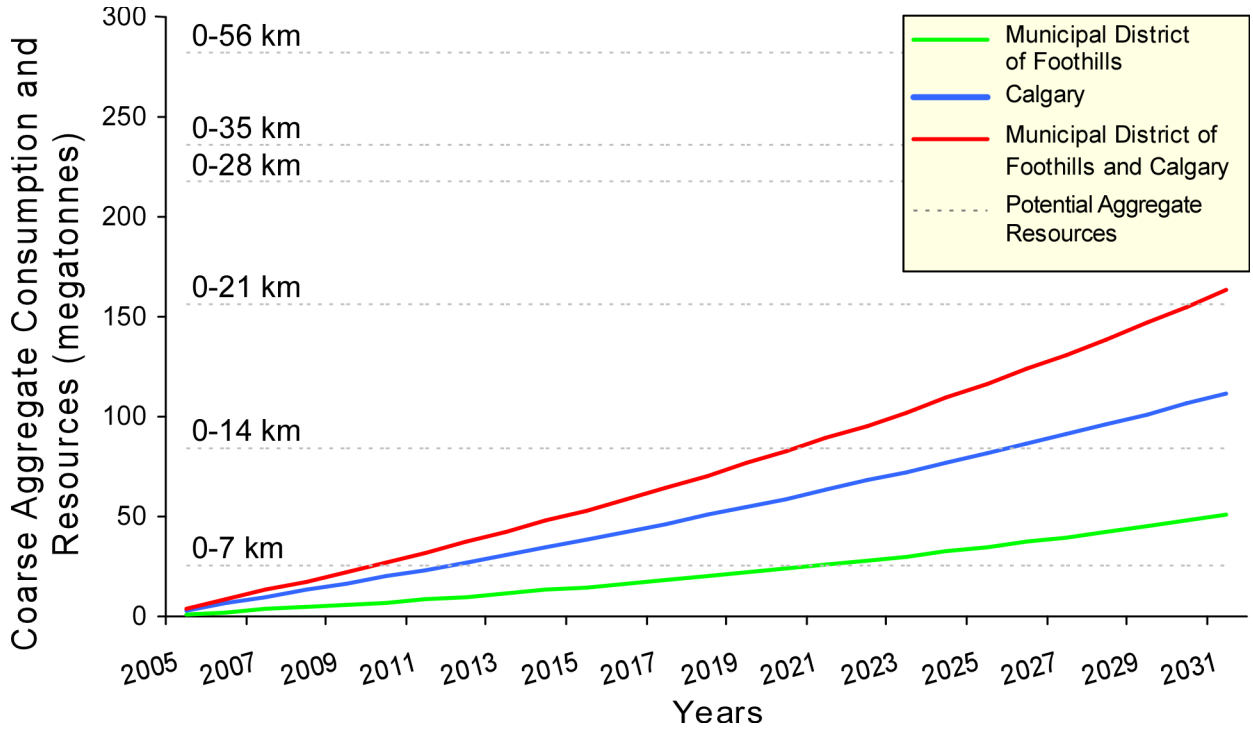

Figure 7. Gravel consumption (2005-2031) and recoverable resources in the Municipal District of Foothills

Another consumption model was developed to illustrate the uneven distribution of deposits and the impact of haul distance. A consumption centre was chosen at Aldersyde and concentric circles (every 7 km) generated outward from this location (Figure 5). Each ring in Figure 5 represents a minimum and maximum distance, as a straight line, from Aldersyde and defines an area for which volumes of sand and gravel (Tables 7 and 8) and gravel (Tables 9 and 10) were calculated in the GIS system. By comparing the resources available for each distance with the aggregate consumption curves in Figure 6, we estimate that by 2013 all the sand and gravel resources within 7 km of the municipality's consumption centre will be depleted and by 2028 the municipality will have depleted all the sand and gravel resources within 14 km of the consumption centre. If we run the model for gravel consumption alone, the situation becomes critical in a relatively short time. By 2009, all the gravel will be depleted within 7 km of the consumption centre and by 2030; gravel will be hauled from at least 21 km to the Aldersyde area. Some of the deposits used in the consumption model are nearly depleted and others will be precluded from development. Considering these variables and our experience with aggregate depletion in areas such as Edmonton, we conclude that aggregate haul distances will likely reach 40 km in the next 20 years.

Table 7. Estimates of total potential sand and gravel resources relative to the Municipal District of Foothills aggregate consumption centre

Distance From Consumption Centre (km)	Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)	Total Volumes (000's m^3)
	Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)		
0-7		1531	32493	14748	48772
7-14	5042	493	70714	8553	84802
14-21	8533	14159	73993	17723	114408
21-28	8746	6308	39937	28207	83198
28-35	10449	18185	15222	7243	51099
35-42	10156	17980	24706	0	52842
42-49	27846	25068	8621	1013	62548
49-56	14539	13721	6190	697	35147
				Total	**532816**

Table 8. Estimates of reasonably recoverable sand and gravel resources relative to the Municipal District of Foothills aggregate consumption centre

Distance From Consumption Centre (km)	Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m3)	Recoverable Resource Volumes (000's m3)
	Reconnaissance (000's m3)	Enhanced Reconnaissance (000's m3)	Site Visited (000's m3)		
0-7	0	383	24370	14748	39501
7-14	504	123	53036	8553	62216
14-21	853	3540	55495	17723	77611
21-28	875	1577	29953	28207	60611
28-35	1045	4546	11417	7243	24251
35-42	1016	4495	18530	0	24040
42-49	2785	6267	6466	1013	16530
49-56	1454	3430	4643	697	10224
				Total	**314983**

Table 9. Estimates of total potential gravel resources relative to the Municipal District of Foothills aggregate consumption centre

Distance From Consumption Centre (km)	Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)[5]	Total Volumes (000's m^3)
	Reconnaissance[1] (000's m^3)	Enhanced Reconnaissance[2] (000's m^3)	Site Visited[3] (000's m^3)		
0-7	0	766	17005	7327	25098
7-14	3431	196	40037	5678	49342
14-21	3425	6109	44879	10098	64511
21-28	5608	3637	23375	19232	51852
28-35	5944	9222	6502	3842	25510
35-42	3339	9433	13290	0	26062
42-49	17198	13576	5814	437	37025
49-56	9134	7524	4133	357	21148
				Total	**300548**

Table 10. Estimates of reasonably recoverable gravel resources relative to the Municipal District of Foothills aggregate consumption centre

Distance From Consumption Centre (km)	Alberta Geological Survey Levels of Investigation			MD of Foothills (000's m^3)	Recoverable Resource Volumes (000's m^3)
	Reconnaissance (000's m^3)	Enhanced Reconnaissance (000's m^3)	Site Visited (000's m^3)		
0-7	0	192	12754	7327	20272
7-14	343	49	30028	5678	36098
14-21	343	1527	33659	10098	45627
21-28	561	909	17531	19232	38233
28-35	594	2306	4877	3842	11618
35-42	334	2358	9968	0	12660
42-49	1720	3394	4361	437	9911
49-56	913	1881	3100	357	6251
				Total	**180671**

Transportation is one of the largest costs involved in the use of aggregate resources. Our consumption model estimates the total haul cost from 2005 to 2031 will be between $605 million (assuming no increase in fuel and labour costs) and $2.2 billion (assuming costs increase) (Tables 11 and 12). These values are underestimations because the modelling above is based on straight lines of travel and the model assumes optimal use of all resources.

Table 11. Cost of hauling aggregate to the Municipal District of Foothill's consumption centre from 2005 to 2031 assuming haul rate remains constant

Years	Aggregate Consumed (megatonnes)	Average Haul (km)	Haul Rate ($ /tonne/km)	Haul Cost ($)
2005-2013	42.36827005	14	0.14	83,041,809
2014-2028	96.5106385	28	0.14	378,321,703
2029-2031	24.43730827	42	0.14	143,691,373
			Total	**605,054,885**

Table 12. Cost of hauling aggregate to the Municipal District of Foothill's consumption centre from 2005 to 2031 assuming haul rate increases with time

Years	Aggregate Consumed (megatonnes)	Average Haul (km)	Haul Rate ($ / tonne km)	Haul Cost ($)
2005-2013	42.36827005	14	0.14	83,041,809
2014-2028	96.5106385	28	0.28	756,643,406
2029-2031	24.43730827	42	1.40	1,436,913,726
			Total	**2,276,598,941**

Aggregate is a low cost per unit commodity, but because huge quantities are required the ultimate cost of aggregate is very large. Based on our consumption model, between $946 million and $1.5 billion will be spent on producing enough aggregate to meet the needs of the municipality (Tables 13 and 14). Between 238,431,000 m^3 and 461,968,000 m^3 of aggregate resources will be left in the ground according to current land use bylaws. This equates to a loss of between $2.2 billion and $4.3 billion to the local economy.

Table 13. Aggregate production cost in the MD of Foothills from 2005 to 2031 assuming production cost remains constant

Years	Aggregate Consumed (megatonnes)	Cost per Tonne ($)	Production Cost ($)
2005-2013	42.36827005	5.79	245,312,284
2014-2028	96.5106385	5.79	558,796,597
2029-2031	24.43730827	5.79	141,492,015
		Total	**945,600,896**

Table 14. Aggregate production cost in the MD of Foothills from 2005 to 2031 assuming production cost increases with time

Years	Aggregate Consumed (megatonnes)	Cost per Tonne ($)	Production Cost ($)
2005-2013	42.36827005	6.9	292,341,063
2014-2028	96.5106385	9.31	898,514,044
2029-2031	24.43730827	11.56	282,495,284
		Total	**1,473,350,391**

3 Aggregate Resource Issues

Sand and gravel development is often met with opposition from people justifiably concerned with environmental and safety issues. Poor sand and gravel development planning and mining in the past has left a negative impression of the aggregate industry in the minds of some residents. These issues should be acknowledged and addressed in a sand and gravel development strategy.

3.1 Trucking

Poorly planned routes and long haul distances increases the amount of dust generated from trucks and releases more harmful greenhouse gases into the atmosphere. Minimizing haul distances can help the municipality maintain a high quality environment. Increased truck haul distances make injury to residents walking, cycling or driving on local roads more likely. Reducing haul distances not only consumes less non-renewable fuel resources, it can keep residents alive and well.

3.2 Environment

The Municipal District of Foothill's "Municipal Development Plan" identifies the impact of development on water supply and the minimization of air and water pollution as priority environmental concerns that must be addressed when making development decisions. A sand and gravel development strategy can help decision makers evaluate development proposals, especially for Environmentally Significant land.

It was noted earlier in the report that sand and gravel deposits adjacent to or within rivers and lakes are not developed to prevent damage to groundwater resources and fish habitats. Sand and gravel deposits can also contain freshwater resources (aquifers). Mining sand and gravel can reduce the flow of water to wells and poor mining practices may introduce pollutants, such as motor oil, into the aquifer. The first step to prevent aquifer damage is to identify sand and gravel deposits that are important freshwater resources, and secondly, to insist on sound sand and gravel mining practices to reduce the risk of aquifer damage.

3.3 Export

The Municipal District of Foothills is likely to remain an important supplier of sand and gravel to the City of Calgary. That said, the municipality must plan for the development and transport of sand and gravel in the municipality for its own use over the long term.

3.4 Community Aggregate Payment

At the same time that this study was underway, the Aggregate Resource Development Task Force proposed a community aggregate payment of up to $0.25/tonne to municipalities to compensate for the inconvenience imposed on communities by sand and gravel development. This has now been passed into law. This money would be designated as general revenue for the municipality. According to current land use bylaws, the municipality could receive $17,589,600 in revenue based on a $0.25/tonne community aggregate payment rate. However, if all sand and gravel deposits were developed, the municipality could receive as much as $216,527,200 in revenue.

3.5 Crushed Stone

The most common alternative to sand and gravel for aggregate is crushed stone. Local bedrock is too soft to use as aggregate, and the closest source of rock suitable for crushed stone is the Rocky Mountains and Foothills. Blasting and crushing stone to produce aggregate is more expensive than processing sand and gravel aggregate: $12.74 for stone in Alberta versus an average $5.79 for sand and gravel aggregate. The haul distance from the mountains is much longer than from local sand and gravel deposits. The municipality and Calgary will be forced to use crushed stone when sand and gravel resources are depleted. This eventuality can be moved farther into the future by a good sand and gravel development strategy that includes the provision for the change over to crushed stone as the primary source of aggregate.

4 Conclusions

Although this report identifies depletion of sand and gravel resources in the Municipal District of Foothills, it also suggests there are enough sand and gravel resources zoned INN to meet its and Calgary's aggregate resource needs for at least 20 years. The amount of sand and gravel that can and will be used in the Municipal District of Foothills may be far less than indicated in this report. Many variables used in the modelling have a high degree of uncertainty and true sand and gravel volumes may be far less than anticipated. Competing land uses will undoubtedly preclude the development of some sand and gravel deposits and restrictions on haul routes may make some deposits uneconomical. One certainty is that an aggregate resource development plan can reduce sterilization of resources, which will reduce haul distances, haul costs, greenhouse gas emissions and injuries or fatalities caused by gravel trucks. Although the data used in this study did not permit a high level of precision, the results demonstrated that a large amount of resource, as much as 462 million m^3 valued at $4.3 billion, might be left in the ground due to current land-use bylaws. Furthermore, even more resource can be expected to remain unused unless great care is used in the future.

5 Recommendations

1) An inventory of sand and gravel resources sufficiently detailed to identify with certainty potential aggregate resources including their quantity and quality should be completed in the Municipal District of Foothills.
2) A similar inventory of sand and gravel resources should be completed for surrounding municipalities and counties as the start of a regional inventory.
3) An aggregate resource analysis that includes projections of demand forward to depletion based on reliable estimates of municipal growth and development should be completed for the Municipal District of Foothills.
4) The Municipal District of Foothills should amend their bylaws to protect those supplies of aggregate identified as essential through the resource analysis.
5) The Municipal District of Foothills should continue to work with the Aggregate Resource Development Task Force and/or relevant mainline departments to promote aggregate conservation in neighbouring counties and municipalities.
6) The Municipal District of Foothills, provincial government departments and the Alberta Geological Survey should work together to educate residents and landowners about the uses and value of aggregate resources in the municipality.

6 References

Edwards, W.A.D. (1995): Mineral aggregate commodity analysis; Alberta Energy and Utilities Board, EUB/AGS Open File Report 1995-08, 54 p.

Edwards, W.A.D. (1979): Sand and gravel deposits in the Canmore corridor area; Alberta Research Council, Alberta Geological Survey, Earth Sciences Report 1979-02, 30 p.

Edwards, W.A.D. and Scafe, D. (1996): Mapping and resource evaluation of the Tertiary and preglacial sand and gravel formations of Alberta; Alberta Energy and Utilities Board, EUB/AGS Open File Report 1994-06, 241 p.

Fox, J.C. (1982): Aggregate resources of the Gleichen Lake map area, NTS 82I; Alberta Research Council, Alberta Geological Survey, Map A82I, scale 1:250 000.

Shetsen, I. (1981a): Aggregate resources of the Bragg Creek map area, NTS 82J/15; Alberta Research Council, Alberta Geological Survey, Map A82J15, scale 1:50 000.

Shetsen, I. (1981b): Sand and gravel resources of the Calgary area, Alberta; Alberta Research Council, Alberta Geological Survey, Open File Report 1981-08, 96 p.

Shetsen, I. (1981c): Aggregate resources of the Priddis map area, NTS 82J/16; Alberta Research Council, Alberta Geological Survey, Map A82J16, scale 1:50 000.

Shetsen, I. (1981d): Aggregate resources of the Turner Valley map area, NTS 82J/09; Alberta Research Council, Alberta Geological Survey, Map A82J09, scale 1:50 000.

Shetsen, I. (1987): Quaternary geology, southern Alberta; Alberta Research Council, Alberta Geological Survey, Map 207, scale 1:500 000.