

Comprehensive Regional Transportation Infrastructure Planning for the Alberta Oil Sands

By:

Gordon Molnar, M.A.Sc., P.Eng. – Manager, Planning and Operations  
Principal Author  
AECOM Canada Ltd.  
17007 – 107 Avenue  
Edmonton, AB, T5S 1G3  
[gordon.molnar@aecom.com](mailto:gordon.molnar@aecom.com)

And

Francis Wambugu, P. Eng. – Transportation Planning Engineer  
AECOM Canada Ltd.  
17007 – 107 Avenue  
Edmonton, AB, T5S 1G3  
[francis.wambugu@aecom.com](mailto:francis.wambugu@aecom.com)

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## **ABSTRACT**

Fort McMurray and the Athabasca oil sands regional area have experienced significant growth pressures since the mid 1990's due to the increasing viability of oil sands development. Current industry and economic forecasts indicate the potential for increased bitumen production from less than 2 million barrels per day to 6 million barrels per day by the year 2045. This industry activity will be accompanied by community population growth and significant infrastructure to support this growth. In planning for this rapid growth, transportation infrastructure was an immediate and vital component to provide for worker transport to the oil sands. Several transportation options were developed and assessed on an iterative basis including a multi-modal analysis considering roadways (passenger vehicles and buses), commuter air, heavy commuter rail, and high-speed rail. A holistic approach was used considering the full cost to society (i.e. capital, operations & maintenance, user, and environmental). A dominating factor in each scenario was the user cost (i.e. travel time and vehicle operation). The strategy centered on the appropriate investment in transportation infrastructure to move workers to and from site as efficiently and effectively as possible; as well as an investment in new community infrastructure, so as to minimize travel time by reducing the travel distance. This plan provided an intermodal solution to meet future industry and community travel demands. In considering the true cost to society, this study demonstrated the link between the economy and transportation infrastructure; and determined that a timely investment in infrastructure was needed to maximize the net economic benefit to society.

## 1. Introduction

The Athabasca Oil Sands Area is located in Northern Alberta. In 2010, the population was 118,200 people. In the center of the oil sands activity is the Regional Municipality of Wood Buffalo, which includes Fort McMurray as the major population centre with a 2010 population of 71,700 people. **Figure 1** illustrates the geographic area of the Athabasca oil sands illustrating Fort McMurray and other population centres.

The Alberta oil sands are a unique oil producing formation. Oil is contained within near surface and deep sand deposits requiring unconventional and relatively expensive processes to extract and separate bitumen from the sand before transporting the crude via pipelines for refining. However, with increasing world demand and increasing world prices, production becomes economically viable. Alberta's Energy Resources Conservation Board (ERCB) estimates of recoverable oil reserves in the Northern Alberta (Peace River Area, Athabasca Area, and Cold Lake Area) are:

- Oil Sands near the Surface – 69 billion barrels
- In-Situ Oil Sands – 188 billion barrels
- Carbonate reserves – 57 billion barrels

However, in the Athabasca Area, 34.2 billion barrels are recoverable through mining and 135 billion barrels is recoverable through in-situ methods for a total of 169.2 billion barrels of recoverable oil in the study area. The current production rates are 2 million barrels per day. However, economic forecasts are projecting a production increase to 6 million barrels per day over the next 35 years with new oil sands developments emerging throughout the region; mostly concentrated immediately north of Fort McMurray. Therefore, at an assumed long range production average of 6 million barrels per day, the Athabasca oil sands have the potential for a service life of 80 years plus, which may provide the catalyst for other industry growth to follow. With industry growth emerges increased community population and increased demand for transportation infrastructure. In preparing for the future, the challenge is to develop an effective comprehensive regional infrastructure sustainability plan to service the community and industry demands. A holistic approach provides opportunities to include a societal costing approach in evaluating the social and economic effectiveness of multi-modal transportation systems scenarios.

## 2. Economic and Growth Forecasts

The Province of Alberta is currently experiencing economic fluctuations due to a relative imbalance in economic diversification. A whitepaper by the Edmonton Chamber of Commerce on Economic Diversification illustrates 12 economic sectors in which 30.8% of the GDP lies in the Energy sector. The second highest economic sector was at a distant 8.5% of the GDP. With annual oil sands production rates expected to triple current day values within the thirty-five year horizon, comes significant economic and population growth pressures on the Athabasca Oil Sands Area. This growth was in part determined through geologic determination of oil sands reserves. **Figure 2** illustrates the concentration/depth of oil sands reserves and the projection of lease area site development based on the 6 million barrels per day production by the year 2045. This industry activity will generate travel demands, which will require an investment in transportation infrastructure. The challenge will be to develop the optimal transportation infrastructure scenario that will meet the industry needs in a timely fashion and provide the best social and economic net value.

Another economic factor related to economic diversification and travel needs is workforce availability. In efforts to provide a transportation system with the best social and economic net value is consideration of a forecast Northern Alberta labor shortage addressed by the Edmonton Chamber of Commerce in economic diversification roundtable discussions. Therefore, not addressing travel impedances will create social costs, which will discourage the attraction of labor resources to the Athabasca Oil Sands Area.

### **3. Traffic Generation**

Traffic projections were generated from two sources. The first is the direct connection between labor and production rates, based on oil sands extraction methods. Surface mining typically employs 45 staff per ten thousand barrels per day production. In-situ production typically employs 6 staff per ten thousand barrels per day production. The second component is background traffic. This includes natural growth along the corridor separate from the industry employment specific traffic generation. The average annual background traffic growth for the Athabasca Oil Sands Area is 2.5%. **Figure 3** illustrates the forecast employment traffic generation for the 6 million barrels per day (year 2045) design horizon. The traffic analysis assumes a passenger vehicle occupancy rate of 1.24 passengers per vehicle and a bus occupancy rate of 50% (i.e. 20 passengers per vehicle). This was used to generate the employment related traffic moving in and out of the mining sites. This is added to the forecast background traffic growth on the highway system, which determines the total average annual daily traffic (AADT) and peak hour traffic. The plant-site shift changes can influence the traffic peaking. This is not known since the future plant operations are not known. However, the assumption uses a relatively modest peaking factor of 0.10 to estimate the peak hour volume traffic; which would assume staggering of the shift change times among the various plant operations. The forecast peak hour traffic was placed in a traffic model to determine the infrastructure roadway needs to sustain a level of service (LOS) C or D. Scenarios with a multimodal alternative (i.e. commuter rail) diverting people movement from the highway system, would be reflected through traffic analysis resulting in a reduction in the highway lane requirements. Figure 3 shows the existing infrastructure system and employee generation from future sites currently not accessible by any mode of transportation. This figure clearly demonstrates the generation of traffic in locations not currently supported by transportation infrastructure, therefore, geographically illustrating the infrastructure gap.

In balancing the employment traffic origin from communities, a 0.3 plant site employee to community population factor was used to estimate the limit of available people that can originate from any particular community. The origin-destination (O-D) analysis applies a matrix of travel between each origin and destination node through the network. Each node is either a roadway junction, end of highway control section, community or local concentration of plant sites (i.e. employment node). This matrix balances the total flow of people commuting between the communities and the plant sites. This is how the link-node system was set up for travel forecasting. Therefore, the expectation for community growth had a direct impact on the travel patterns and ultimately the infrastructure needs. Community growth closest to the employment centres had a positive impact to minimizing travel length and associated infrastructure needs.

### **4. Infrastructure Scenarios**

Transportation infrastructure scenarios were based on creating the transportation links between the communities and the projected oil sands production areas in conjunction with the horizon production rate. With the transportation link-node system set up, traffic volumes were applied to the system to

determine the infrastructure needs. In developing the alternative infrastructure scenarios, numerous options were available including:

- The Transportation Mode:
  - Road (passenger vehicle or bus)
  - Commuter rail (high speed rail or passenger heavy rail)
  - Air (mid-size craft)
- Community Growth:
  - Variability on growth potential of existing communities
  - New temporary work camps
  - New permanent community (city)

The first infrastructure scenario began with a basic functioning transportation system primarily comprising a road system to meet the community-industry connectivity needs. This included upgrades to 763 km of roadway and 718 km of new roadway development. Based on the assessment of this status quo development scenario, alternative scenarios were developed on an iterative approach of adjusting the transportation mode and community growth parameters. The optimization process endured numerous iterations for each scenario development. **Table 1** illustrates the initial status quo development type scenario along with the latest four scenarios considered in the decision process.

Each scenario adds an element designed to improve the net effectiveness of the overall transportation system. As most of the industry growth and oil production activity is expected immediately north of Fort McMurray, most of the transportation infrastructure occurs there, even though the Athabasca Oil Sands Area is much more extensive. The Hwy 63 corridor through Fort McMurray going north is high traffic volume. Infrastructure assessments are projecting the need for up to 10-lane highway sections in the absence of a multi-modal transportation alternative. Therefore, north of Fort McMurray, infrastructure scenario options will include the following:

1. A status quo typical highway development – Base Case
2. A new community (assumed population 40,000) located 116 km north of Fort McMurray to minimize commuter travel distances
3. Enhanced commuter bus and commuter air services
4. A heavy track (80 km/hr) commuter rail link along the heaviest travel corridor (Fort McMurray and new community 116 km north )
5. Optional upgrading of the commuter rail link to High Speed Rail with a travel speed of 180 km/hr

Through the rest of the region, the needs are typically roadway infrastructure without too much transportation multi-modal variation beyond a typical rural highway network.

Each scenario progression builds on the addition of a new attribute. The evolution from the Base Case scenario adds a new community north of Fort McMurray to provide of shorter commuter travel distances. The third scenario adds an enhanced industry bus transit system increasing the commuter proportion of bus travel from 10% to 45% and regional air travel from 1% to 4%. The fourth scenario adds two passenger trains on single track between Fort McMurray and the new community; where the train would stop at transit stations along the way for passenger transfer to bus shuttle services to their respective employment sites. The final scenario upgrades the slower heavy track commuter rail service to high speed rail. Figure 4 geographically illustrates the five scenarios.

## 5. Societal Costing Principles

A societal costing approach was used to evaluate the merit of each scenario. Each scenario included an annualized costing model for **capital** costs, operations and maintenance (**O&M**) costs, **user** costs (i.e. people time and vehicle operating), and **environmental** cost (carbon emission). This holistic approach is important in the evaluation process as there are significant societal impacts as a result of the level of infrastructure investment. Currently, travel time between the communities and the employment sites are a significant issue for the employees. Knowing this impact will help determine the appropriate level of infrastructure investment. The Organization of Economic and Cooperative Development (OECD) determined that traffic congestion alone in developed countries has a negative impact of three percent on the gross domestic product (GDP). In relation to the Athabasca oil sands, there is a significant amount of delay and commuting time, thus having a negative impact on the economy. Knowing the infrastructure cost to mitigate this will provide direction on investment that will have the greatest net socio-economic effect; and potentially help determine cost recovery models for the infrastructure investment. **Table 2** illustrates the unit pricing associated with each of the four cost components.

## 6. Infrastructure Scenario Evaluation

Each scenario was evaluated by assessing the annualized societal costing components (capital, O&M, user, environmental). The objective was to minimize the overall net cost to society. As such, this illustrates the tradeoffs between the impact to society (i.e. user and environmental) and the agency cost of infrastructure (i.e. capital and O&M) to address these impacts. **Table 3** illustrates some of the key social impacts (i.e. travel time and carbon emissions) for each scenario. **Table 4** illustrates the annualized costing analysis for the scenario evaluation. The integration of agency and social costs provides a quantified approach in direct comparison monetary terms. The highlights of each scenario are summarized as follows.

1. Status Quo Development (Base Case) – This scenario develops a conventional highway network to address passenger vehicle travel demand needs. It has the highest user travel time and carbon emissions, but lowest up-front infrastructure costs.
2. New Community - By strategically developing a new community (small city), both travel time and environmental carbon emissions are each reduced by 14%. This has no direct cost to the transportation system and community growth costs are offsetting between either expansion to Fort McMurray or by development of the new community. As such, the overall annualized costs are reduced by 28% (\$344 Million/yr).
3. Enhanced Commuter Transit and Air Services – With the enhancement of these services, there is a 17% reduction in carbon emissions and 19% reduction in vehicle operating costs, but offset by increased capital for airport improvements. As such, on this scenario, there is no net gain in total annualized costs.
4. Added Heavy Track Commuter Passenger Link – The added track and train operations increases capital and O&M costs by 13%, but with the benefit of reduced vehicle operating costs for a total annualized cost reduction of 3% (\$28 Million/yr).
5. Optional High Speed Rail Commuter Passenger Link – This option has the highest capital cost and O&M cost with a 31% increase over the heavy track commuter rail option. However, it provides a significant reduction in user time. As such, it provides a further total annualized cost reduction of 2% on top of the previous 3% reduction from the rail system for an overall 5% annualized cost reduction benefit (\$48 Million/yr).

## 7. Conclusions

The oil sands development is expected to drive the timing of future infrastructure development throughout the regional area and particularly north of Fort McMurray. The study identified key infrastructure gaps that need to be addressed in order to support the industry initiatives anticipated by the oil sands mining companies. This includes a transportation system designed to minimize travel impedances, so to attract employees to the Athabasca Oils Sands Area; especially in forecast labor shortages. Infrastructure gaps include road connectivity to key tie-ins external to the study area, including Peace River, Saskatchewan, and the Northwest Territories. Infrastructure gaps also include internal connectivity by developing the primary transportation arteries between communities and the oil sands development sites. Still to be included are the private industry transportation needs for access from the respective plant sites to the Provincial arterial transportation system.

The vast amount of the regional transportation infrastructure development includes approximately 763 km of roadway upgrades and 718 km of new roadway development. However, between the five scenarios discussed in this study, the major differences between each scenario occur in the Hwy 63 high volume corridor between Fort McMurray and the planned community located 116 km north. The total regional capital cost estimates vary from \$1.213 Billion (lowest) to \$2.547 Billion (highest) with O&M cost estimates of \$12.271 Million/yr (lowest) to \$73.902 Million/yr (highest). Most of these incremental infrastructure requirements occur in 8% of the study area where the multi-modal transportation alternatives prevail.

This study illustrates how the aggregate of the full societal costing component (capital, O&M, user, and environmental), can influence the decision process when applied to multi-modal transportation alternatives. The scenario analysis began with a base case primarily involving an expanded highway network sized for passenger vehicle dominant travel. Each scenario alternative evolved with added components including a new community to reduce travel distances, enhanced commuter bus and air service, and an additional commuter rail along the primary high volume corridor through the high-producing oil sands fields. The following bullets highlight some of the key findings of the scenario evaluation:

- The worst case scenario (Scenario 1) was the 'Base Case', which was the status quo development for an expanded highway network. The dominant mode of travel was passenger vehicles. The total annualized cost was \$1,036 Million/yr. The largest societal costing component of this was the user cost at 95% of this total annualized cost.
- The best case scenario (Scenario 5) included numerous transportation enhancing components. The total annualized societal costs were reduced to \$845 Million/yr, with the user cost component reduced to 82% of the total annualized cost. The following summarizes the key scenario elements:
  - Developing a new community (assumed 40,000 population) north of Fort McMurray on the northerly extreme of oil sands development to minimize commuter travel times
  - Enhancing the commuter bus travel from 10% people movement to 31%
  - Enhancing the commuter air travel from 1% to 3% of people movement to provide both remote and faster service access, thus requiring airfield capital cost upgrading.
  - Adding a high-speed rail commuter link between the communities of Fort McMurray and the planned community 116 km north; whereby stops would be at select transit stations providing the intermodal connectivity to mine-site shuttle bus transport. These

trains have an assumed operating speed of 180 km/hr. This model becomes cost effective when two trains travel the same track and pass at a rail siding located approximately mid-way.

- The annualized capital and O&M cost components of the best case scenario are incrementally \$99 Million/yr higher in comparison to the worst case. This is over three times the status quo agency development and operation needs. However, considering the overall societal impact, this has a net benefit of \$191 Million/yr; resulting in a 93% rate of return on the infrastructure capital and O&M investment.
- The Greenhouse gas emissions are reduced from 188,000 t/yr to 125,000 t/yr through the combined efforts of fostering communities closer to the employment, providing enhanced commuter bus service, and the addition of high speed rail along the main high volume corridor. This translates into an economic benefit of nearly \$1.0 Million/yr. This is only approximately 0.2% of the full societal cost. However, the multi-modal initiatives did provide this environmental benefit at no net economic loss; which is often contrary on environmental enhancing initiatives.

Conventional planning and program management typically minimizes agency costs while maintaining an acceptable level of service. On this approach Scenario 1 (Base Case) would be the preferred option with an incrementally lower total capital cost and annualized O&M cost difference of \$ 1.334 Billion and \$61.631 Million/yr respectively in comparison to Scenario 5. However, considering these agency costs (capital and O&M) together with the social components (user and environmental) the net socio-economic benefit swings in favor of the Scenario 5 with a net annualized savings of \$191 Million/yr. This is an important consideration due to the high proportion of social costs, which impedes the economy reflected through the GDP. These findings would be consistent with the OECD report, which discusses the general connection between the user costs and the economy; in particular the loss in GDP through travel delay. In both cases, the solution to mitigating the net economic losses to society is an investment in infrastructure. Given there is a 93% return on investment, through the direct benefit to the user, this opens the door to capital and operating cost recovery to the agency. Therefore, in cases such as this, where there is a significant savings to the user as a result of the infrastructure investment, there is opportunity to recover part of these savings. This can be accomplished through user fees or otherwise to balance the offsetting agency costs. This approach results in a WIN-WIN-WIN situation where the agency costs are recovered, the user sustains a net saving through reduced travel time and vehicle operating, and there is a benefit to the environment through green house gas emission reduction.

Given the high level nature of this network level strategic infrastructure assessment, the best case scenario only provides an indication of the optimal solution. Further detail investigation is required on the various options as well as more location specific implementation planning. However, this study does provide a strong indication that a multi-modal transportation planning solution is economically viable, offering the potential for state of the art transportation solutions, such as high speed rail, in even remote locations such as the Alberta oil sands.

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## Tables and Figures

**Table 1 – Transportation Infrastructure Scenarios**

Parameter	Scenario 1	Scenario 2	Scenario 2	Scenario 4	Scenario 5
Description	Status Quo Development – Primarily passenger vehicles	New community north of Fort McMurray	Enhanced public transit and air service	Additional heavy rail passenger service between Fort McMurray and new community with two trains on single track	Optional high speed rail in lieu of heavy passenger rail between Fort McMurray and new community with two trains on single track
Infrastructure:					
• New Roadways (lane-km)	1823	2168	1797	1797	1797
• Upgrade Roadways (lane-km)	2267	2334	2589	2546	2546
• New Commuter Rail (km)	0	0	0	116	116
Modal Split:					
• Passenger Vehicles (%)	89	89	51	51	51
• Buses (%)	10	10	45	37	35
• Commuter Rail (%)	0	0	0	8	10
• Airplane (%)	1	1	4	4	4

**Table 2 – Societal Unit Costing Parameters (2010 Rates)**

<b>Cost Component</b>	<b>Parameter</b>	<b>Description</b>	<b>Unit Value</b>
Capital	Right of Way	50m wide right of way	\$20,000/km
	Subgrade Construction	Cost of	\$250,000/km
	Pavement Structure	Asphalt and Gravel Base course	\$400,000/Km
	Bridge Structure	Total labor and material cost of constructing a square metre of bridge	\$3,800/m <sup>2</sup>
	Nominal Upgrades	Minor upgrades such as repainting of pavement markings	\$20,000/km
O&M	Gravel Pavement	Yearly maintenance of the gravel pavement surface including gravelling, dust abatement	\$10,500/km/yr
	High Speed Rail	Maintenance of track, signals and communication Equipment	\$30/train km
User	Passenger Vehicle	Cost of mileage per km	\$0.52/km
	Commercial truck	Cost of mileage per km	\$1.2/km
	Passenger Time Value	Average time value in Northern Alberta per hour	\$25.0/hr
Environmental	Passenger Vehicle Emission	Grammes of carbon dioxide emitted per km	250g/km
	Bus Emission	Grammes of carbon dioxide emitted per km	272g/km
	High Speed Rail	Amount of emission per passenger per Km of travel	45g/passenger/km
	Aircraft Emission	Aircraft carbon dioxide emission per Km	158g/km

**Table 3 – Societal Impacts Summary**

Scenario	Travel Mode	Travel Time (hours/yr)	Carbon Emissions (tonnes/yr)
1	Passenger Vehicles	19,429,831	186,421
	Bus Vehicle	2,255,132	1,923
	Commuter Rail	-	-
	Plane	153,722	170
2	Passenger Vehicles	16,577,547	159,704
	Bus Vehicle	1,921,882	1,647
	Commuter Rail	-	-
	Plane	131,672	146
3	Passenger Vehicles	11,135,002	127,498
	Bus Vehicle	8,099,686	5,932
	Plane	135,371	150
4	Passenger Vehicles	9,595,986	109,887
	Bus Vehicle	6,444,297	4,743
	Commuter Rail	2,692,268	9,692
	Plane	95,436	106
5	Passenger Vehicles	9,595,986	109,887
	Bus Vehicle	5,915,774	2,887
	Commuter Rail	1,466,409	11,878
	Plane	95,436	106

**Table 4 – Annualized Societal Cost Summary**

Scenario	Travel Mode	Total Capital (\$)	Annualized Capital (\$/yr)	Annualized O&M (\$/yr)	Annualized User Vehicle Operating (\$/yr)	Annualized User Time (\$/yr)	Annualized Environmental Carbon (\$/yr)	Annualized Total Cost (\$/yr)
1	Passenger Vehicles	1,211,911,473	34,626,042	12,271,440	420,979,668	485,745,771	2,796,308	956,419,229
	Bus Vehicle	-	-	-	18,041,055	56,378,298	28,841	74,448,194
	Commuter Rail	-	-	-	-	-	-	-
	Plane	-	-	-	2,157,507	3,843,059	2,557	<u>6,003,122</u>
	<b>TOTAL</b>							<b>1,036,870,545</b>
2	Passenger Vehicles	1,216,147,436	34,747,070	13,565,220	359,180,181	414,438,670	2,395,563	824,326,704
	Bus Vehicle	-	-	-	15,375,055	48,047,048	24,708	63,446,811
	Commuter Rail	-	-	-	-	-	-	-
	Plane	-	-	-	1,848,031	3,291,805	2,190	<u>5,142,026</u>
	<b>TOTAL</b>							<b>892,915,541</b>
3	Passenger Vehicles	973,039,448	27,801,127	13,669,140	241,258,380	278,375,054	1,912,466	563,016,168
	Bus Vehicle	-	-	-	64,797,491	202,492,160	88,973	267,378,624
	Commuter Rail	-	-	-	-	-	-	-
	Plane	372,826,753	10,652,193	46,823,400	1,899,943	3,384,274	2,251	<u>62,762,061</u>
	<b>TOTAL</b>							<b>\$893,156,853</b>
4	Passenger Vehicles	861,803,288	24,622,951	13,134,540	207,913,026	239,899,645	1,648,307	487,218,469
	Bus Vehicle	-	-	-	51,554,377	161,107,727	71,141	212,732,945
	Commuter Rail	488,800,000	13,965,714	3,021,200	17,948,451	67,306,693	145,382	102,387,441
	Plane	372,826,753	10,652,193	46,823,400	1,339,449	2,385,894	1,587	<u>61,202,523</u>
	<b>TOTAL</b>							<b>863,541,378</b>
5	Passenger Vehicles	861,803,288	24,622,951	13,134,540	207,913,026	239,899,645	1,648,307	487,218,469
	Bus Vehicle	-	-	-	31,550,794	147,894,347	43,299	179,488,440
	Commuter Rail	1,312,700,000	37,505,714	13,944,000	29,328,170	36,660,213	178,169	117,616,266
	Plane	372,826,753	10,652,193	46,823,400	1,339,449	2,385,894	1,587	<u>61,202,523</u>
	<b>TOTAL</b>							<b>845,525,698</b>

Figure 1 – Athabasca Oil Sands Region

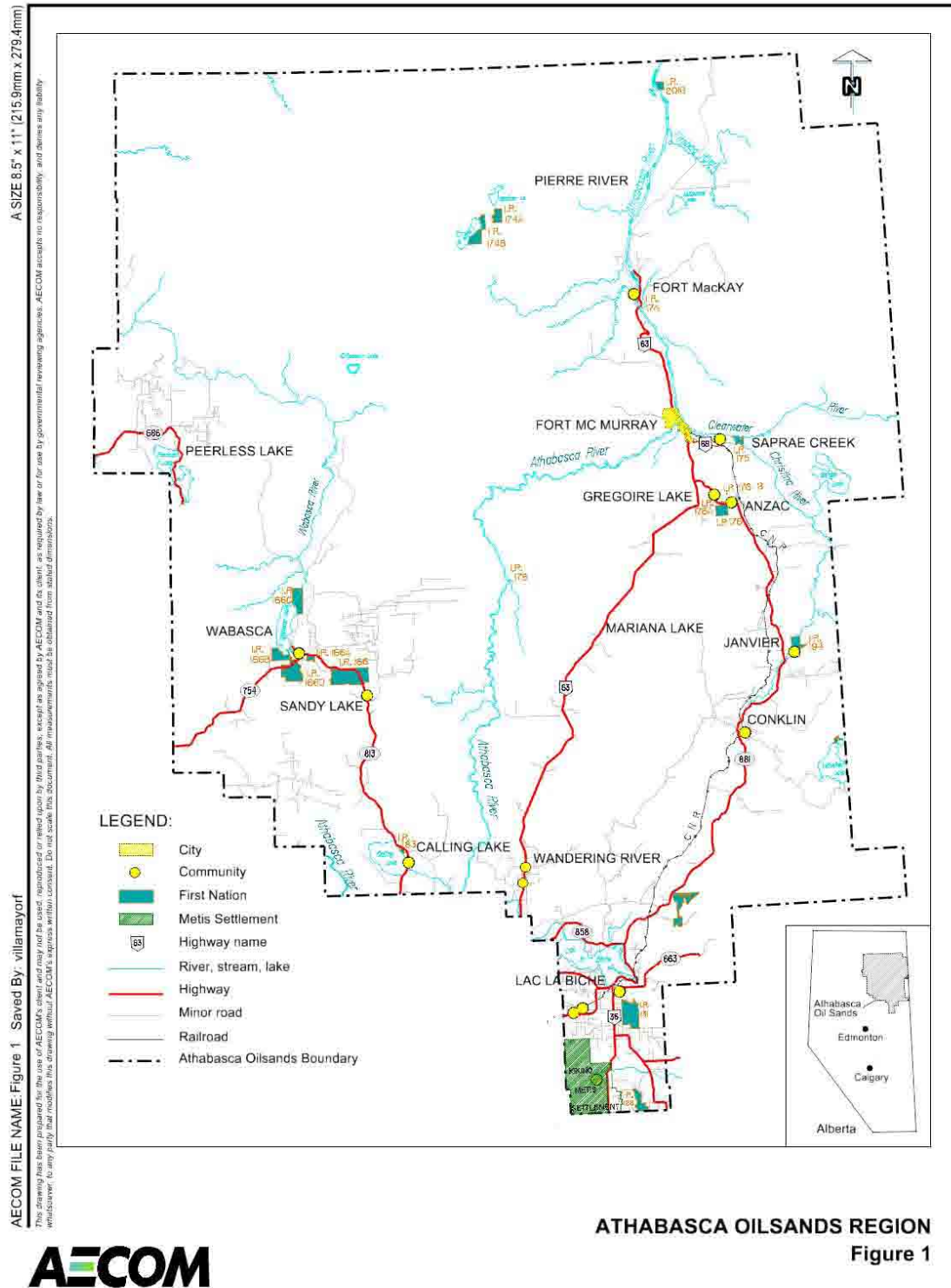


Figure 2 – Oil Sands Reserves and Projected Oil Sands Lease Area Development Activity – to 2045

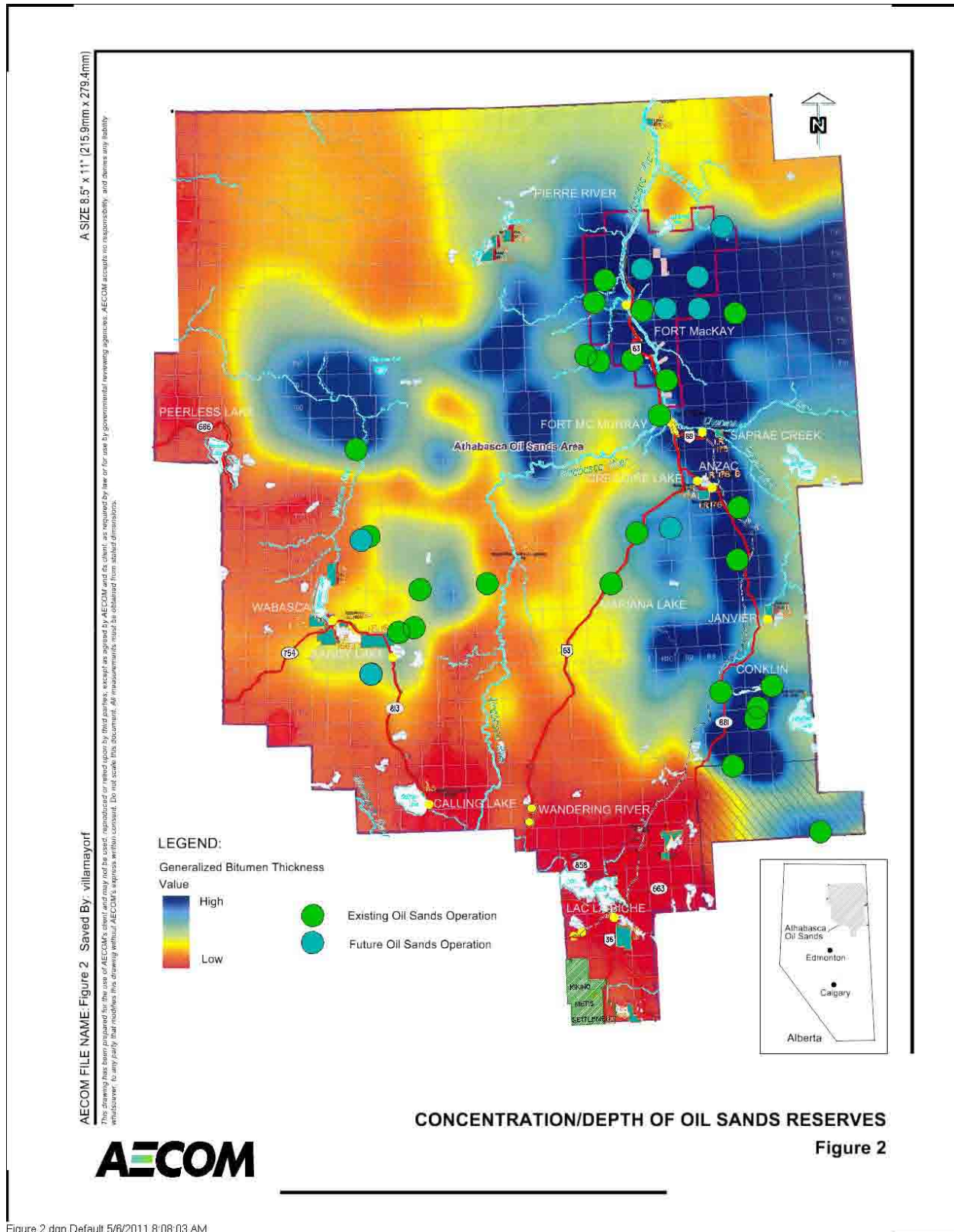


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Figure 3 – Future Traffic Generation on Existing Transportation Infrastructure System

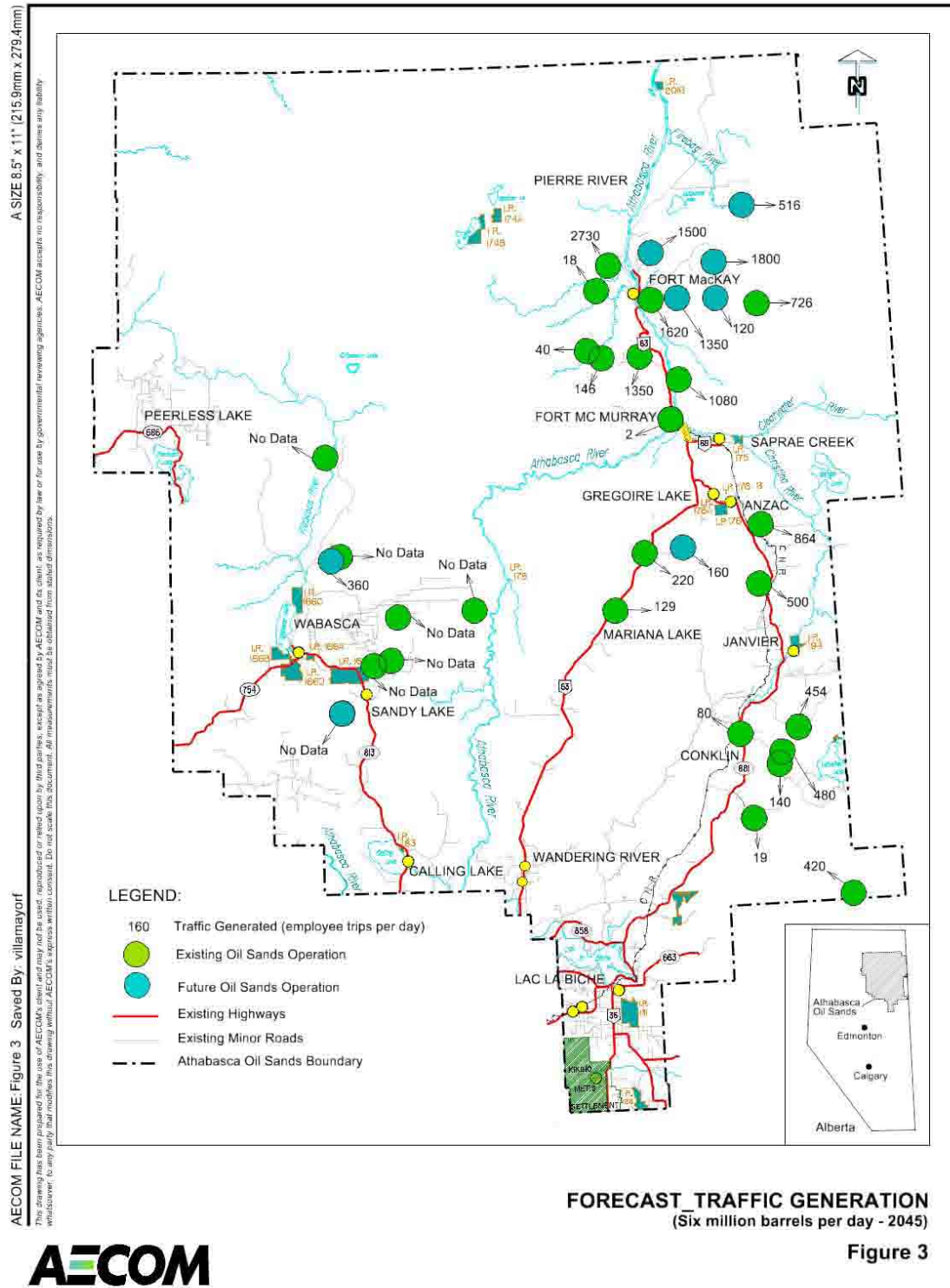




Figure 4 – Transportation Infrastructure Scenarios

