Peel Plateau and Plain
Petroleum Exploration and Development Model

1. Methodology

The 2005 Petroleum Resource Assessment of the Peel Plateau and Plain by Osadetz, MacLean, Morrow, Dixon and Hannigan has been the primary data source for this model. The basin resource, pool size distribution and geological framework from this report are incorporated in the model.

The methodology used in this model is:

1. model the pool size distribution and total resource as described by Osadetz et al;
2. simulate a basinal seismic exploration program and an exploratory drilling program using success ratios typical of basins in early exploration stages;
3. model development parameters (well count, number of pads, amount of infrastructure) for each successful discovery, and
4. model the regeneration of features over time and tabulate all values over a fifty year model lifetime.

There are several assumptions implicit to this modeling exercise:

1. A Mackenzie Valley Gas Pipeline is approved and constructed with initial operation by 2018.
2. A Dempster Highway lateral is constructed to connect potential Eagle Plains production to the Mackenzie Valley line by approximately 2025. This is expected to be the connection for eventual Peel production. While it may be possible to connect potential Peel discoveries directly to a Mackenzie valley line, the most economic route appears to be to tie into a Dempster Highway line.

2. Pool Size Distribution and Total Resource

Osadetz et al calculated 83.428 x 10^9 m^3 as initial gas in place, in approximately 88 pools and with a maximum size of 3.36 x 10^9 m^3. The majority of the potential resource described in the Petroleum Resource Assessment is expected to be in the Mesozoic Clastics Play – approximately 60% of the expected basin total. While it would be possible to model each of the plays and reservoir types separately the value of doing so is questionable given the limited data in the basin. Accordingly, the Mesozoic Clastics parameters were used as a generic reservoir model for all pools. This model attempts to replicate this as a series of lognormally distributed pools. The mean and standard deviation used in this run were 2450 and 500 x 10^6 m^3, respectively, with a minimum size of 300 x 10^6 m^3. The mean pool size was also forced to decline as: (total resource – cumulative discoveries) / total resource, effectively shrinking the discovery size over time, since the larger pools tend to be discovered first.

3. Basinal Seismic Program

According to EMR records, there is a total of 2032 km of existing seismic in the Peel basin. Without detailed current satellite or airphoto coverage and considerable

analysis, it is difficult to know how much of this seismic footprint has regenerated and to what extent. For the purposes of this modeling, it was assumed that 50% of the total has regenerated to approximately initial conditions and that complete regeneration of the remainder will be complete within the next forty years.
While this existing seismic was done using wide, straight lines, usually cut with a bulldozer, it is expected that all future seismic will be done using either small to medium vibroseis equipment, small track-mounted shothole drills or heliportable drilling equipment. The current practice of winter only operations is expected to continue for exploratory work, including seismic and drilling. It is now standard practice to survey lines using GPS, which eliminates the need for straight cutlines. It is also standard to do line clearing with either small to medium size mulchers or powered cutters, e.g. Hydro Axe, or by using chainsaws and hand cutting. In all cases, it is now mandatory to minimize or eliminate disturbance to the organic layer while clearing and during seismic operations. This can significantly affect line regeneration, although there remains much work to do to quantify these effects.
It was assumed that approximately 2000 km of 4m vibroseis would be required for large scale seismic coverage – approximately 5 km spacing – and that the heliportable and narrow track seismic would be used more in prospect and pool definition. Although some of the pre-existing seismic may be available for re-processing, its value is difficult to assess, given its age and data quality. The assumption used herein is that 4m vibroseis and heliportable will predominate in the early years with 1.5m narrow track dynamite drilling dominating in later years. While the use of narrow track shothole drilling equipment is not widespread in the industry at present, it is expected to increase as pressure to minimize seismic footprints grows.

4. Delineation Seismic

In addition to the 4m coverage, an additional 3000 km of 1.5 m seismic was assumed to be needed for prospect definition once the regional seismic was complete. Some of this will likely be for 2D source lines and some for detailed 3D surveys. For the 3D programs, it was assumed that receiver lines will be foot trails, i.e. the recording equipment – phones and cables – will be man-carried. These trails were not included in the model since their impact will be negligible at most.
Finally, approximately 1680 km of heliportable seismic was assumed to extend throughout the basin exploration lifetime. Heliportable would be useful in areas without easy trail access or in advance of more detailed surveys.
The amount of seismic line was allowed to vary normally with a standard deviation of 5%.

5. Exploration Drilling

The exploratory drilling program modeled herein is based on the following assumptions:

- An initial exploratory success rate of 10%, increasing to 16.7% after the first fifty wells. While this may seem optimistic given the lack of success in any of the 19 wells drilled to date, it must be remembered that in these early wells, the target was oil, not gas, and that the drilling techniques and testing and logging methods of the day would not have been particularly effective at detecting gas anyway.
- Drilling has been modeled to begin in 2020 with an effective halt in 2053. This is certainly an arbitrary choice but seems as realistic as any given the implicit assumptions of a Mackenzie pipeline and Eagle Plains development timing. A total of 192 exploratory wells was assumed for the Yukon portion of the basin. While it might seem desirable to model some flexibility into the exploratory drilling schedule since it serves as the driver for production and development scheduling, building in feedback to the exploratory drilling schedule usually introduces non-converging circular definitions.
- Exploratory drilling was assumed to be done from ice pads with access by ice roads, similar to the techniques used in 2005 by Devon at their K-58 well in Eagle Plains. While it may be possible to conduct year round operations in some areas, the techniques to do so with acceptable environmental impacts have yet to be developed and demonstrated. In the event of a dry hole, the ice road and pad would be allowed to regenerate naturally; in the event of a discovery, permanent development would be deferred until commerciality was assured and production infrastructure in place. For each exploratory well it was assumed that initially 12 km of ice road would be required, decreasing over the years to 6 km by 2028. These ice roads were assumed to have a 50% direct overlap with seismic.
- While earlier access was done from the Mackenzie valley via trails south from the Fort McPherson area and by the Wind River Trail from the south, it may also be feasible to access the area east of the Richardson Mountains solely from the Yukon just south of the Yukon/NWT border. There are several existing NW – SE seismic lines that have been used for access and could be again if required. Although it might be possible to access the area from the Peel River valley to the south, the distance from the Dempster Highway is considerably greater and the valley itself has some difficult terrain. Although the timing and amount of required road are uncertain, the assumption used was that 80 km of all-season road (15m width) would be required in 2024.

6. Field Development

The median reservoir parameters given by Osadetz et al for the Mesozoic Clastics plays are as follows:

• Area	km^2	5
• Net Pay	m	10
• Porosity		0.06
• Gas Saturation		0.77
• Reservoir Pressure	kPa	21 000

This yields a median initial gas in place of approximately 520 x 10^6 m^3 (18 BCF). A pool of this size should be easily developed with current technology from a single well pad with up to four directional wells (plus an assumed vertical discovery well). A typical drainage area for a single well is on the order of 2.5 km^2, i.e. one section, so this single pad assumption for a median pool size should be realistic in virtually all cases. Larger fields might require two or three well pads, depending on their configuration; for the purposes of this exercise the number of wells per pad was limited to four and the number of pads determined by dividing the number of wells by this number and rounding up to the nearest integer. Pad area was assumed to be 2.5 hectares.

The minimum reserves for commerciality was assumed to be 20,000 10^6 m^3, similar to the value determined by Fekete Associates for the Eagle Plains area. The anticipated resource for the Peel is approximately half that of Eagle Plains and the lack of infrastructure should increase the economic threshold for the basin. As well, the basin productivity should be reduced as compared to Eagle Plains. For this model a connecting pipeline of 16" diameter was assumed with an initial annual throughput of 1427 10^6 m^3 (138 MMCFD) rising to 2275 10^6 m^3 (220 MMCFD) after the first six years of production.

Once commerciality has been established, infrastructure for production can begin. It was assumed that 10 km of all-season road 15m wide would be required for each producing well pad. These roads were assumed to have a 90% overlap with previous trails and ice roads. In addition, flowlines and small to medium pipelines should be expected to follow the road rights-of-way. While not the most efficient from an engineering point of view, surface access constraints and environmental considerations make this the only practical approach. The main gas line to connect to the Dempster Highway lateral should also be assumed to follow the potential access road from the northwest. Other infrastructure – camps, compressor stations, field offices – would not require significant additional area, perhaps 20 to 40 ha. in a more or less central location.

7. Regeneration of Landscape Features

The most significant difference between past and future operational methods can be seen in seismic acquisition. The existing generation of seismic lines throughout the Yukon dates from the 1960's and 1970's at latest. These lines were completely straight and normally cut with a bulldozer with extensive disruption to the organic layer on top of the soils. Regeneration has taken place, although in many locations the lines have not recovered to their initial conditions and plant cover. In some cases, the changes in vegetative cover may be permanent. Some of the lines and access trails from the 1960's and 1970's have also been adopted as winter trails as well, which has also affected their regeneration.

The changes in operational practices have been:

- A switch to GPS survey methods from optical methods. This eliminates the need for completely straight lines with their attendant extensive sightlines. Long lines of sight can arguably affect predator-prey relationships where prey detection is an issue; straight lines are also visually highly obtrusive. The human eye / brain is extremely good at recognizing non-random linear features in a non-linear random landscape. The switch to GPS methods mean that lines can meander, split, etc. without any adverse effects on the seismic quality.
- It is also no longer considered acceptable to disturb the vegetative layer in seismic operations. The aforementioned use of mulchers, cutters, etc. should allow regeneration to begin much more quickly than with previous methods.

While there is certainly much more to learn about line regeneration with modern methods, it is a fact that with these methods, lines can be almost indistinguishable in very few years. This is partly due to the effect of narrow lines; where the line width decreases to less than the spacing of the disturbed vegetation, i.e. trees, and it becomes possible to simply drive around the trees, the amount of cutting required drops considerably.

With these arguments in mind, the following regeneration rates were used in the model:

a. Existing 8m lines: 5% per year with a maximum remaining lifetime of 40 years;
b. Heliportable (foot trails only): 100% per year;
c. Narrow lines – 1.5m: 67% per year, assuming meandering lines and no vegetative mat damage;
d. Medium width lines – 4m: 20% per year;
e. Trails – 8m: 12.5% per year;
f. Exploratory well pads: 5% per year
g. Production well pads and all-season roads: No regeneration.

8. Simulation Results

The following tables outline the linear features and their areas that the supposed exploration and development scenario will generate in the Peel Watershed area. The tables show the total active quantities by year and account for new additions and regeneration of old features.

Linear Features:

Active	early 8 (km)	(heli) (km)	seismic 1.5 (km)	seismic 4 (km)	Expl Pads	Expl trail 8 (km)	All Season road 15 (km)	Prod'n Pads
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2008	1,016	-	-	-	-	-	-	-
2009	965	-	-	-	-	-	-	-
2010	917	-	-	-	-	-	-	-
2011	871	-	-	-	-	-	-	-
2012	828	-	-	-	-	-	-	-
2013	786	-	-	-	-	-	-	-
2014	747	-	-	-	-	-	-	-
2015	710	-	-	-	-	-	-	-
2016	674	70	-	100	-	-	-	-
2017	640	70	-	180	-	-	-	-
2018	608	70	-	244	-	-	-	-
2019	578	70	-	295	-	-	-	-
2020	549	70	150	376	2	20	-	-
2021	522	70	200	441	4	38	-	-
2022	495	70	216	543	6	53	-	-
2023	470	70	221	627	7	60	-	-
2024	445	70	223	645	9	67	-	-
2025	419	70	224	659	11	72	-	-
2026	394	70	224	670	12	77	-	-
2027	368	70	224	679	13	82	-	-
2028	343	70	224	613	23	59	80	-
2029	318	70	224	561	32	112	80	-
2030	292	70	224	518	40	158	80	-
2031	267	70	224	385	48	198	80	-
2032	241	70	224	278	56	233	80	-
2033	216	70	224	192	63	264	80	-
2034	191	70	224	124	70	183	200	-
2035	165	70	224	69	76	220	200	-
2036	140	70	224	25	70	145	320	12
2037	114	70	224	8	75	175	320	12
2038	89	70	224	2	79	201	320	12
2039	64	70	224	1	83	224	320	12
2040	38	-	74	0	83	214	340	14
2041	13	-	24	0	85	223	340	14
2042	-	-	8	0	81	177	400	20
2043	-	-	3	0	80	170	410	21

2044	-	-	1	0	80	173	410	21
2045	-	-	0	0	79	166	420	22
2046	-	-	0	0	77	151	440	24
2047	-	-	0	0	73	120	480	28
2048	-	-	0	0	72	120	490	29
2049	-	-	0	0	72	120	500	30
2050	-	-	0	0	70	111	520	32
2051	-	-	0	0	70	112	530	33
2052	-	-	0	0	68	104	550	35
2053	-	-	0	0	66	88	580	38
2054	-	-	0	0	60	59	600	40
2055	-	-	0	0	57	52	600	40
2056	-	-	0	0	54	45	600	40
2057	-	-	0	0	52	40	600	40

Area of Features:

	early 8 (ha)	(heli) 0 (ha)	seismic 1.5 (ha)	4 (ha)	Expl (ha)	Expl trail 8 (ha)	All Season road 15 (ha)	Prod'n (ha)	Areal Features Total (ha)
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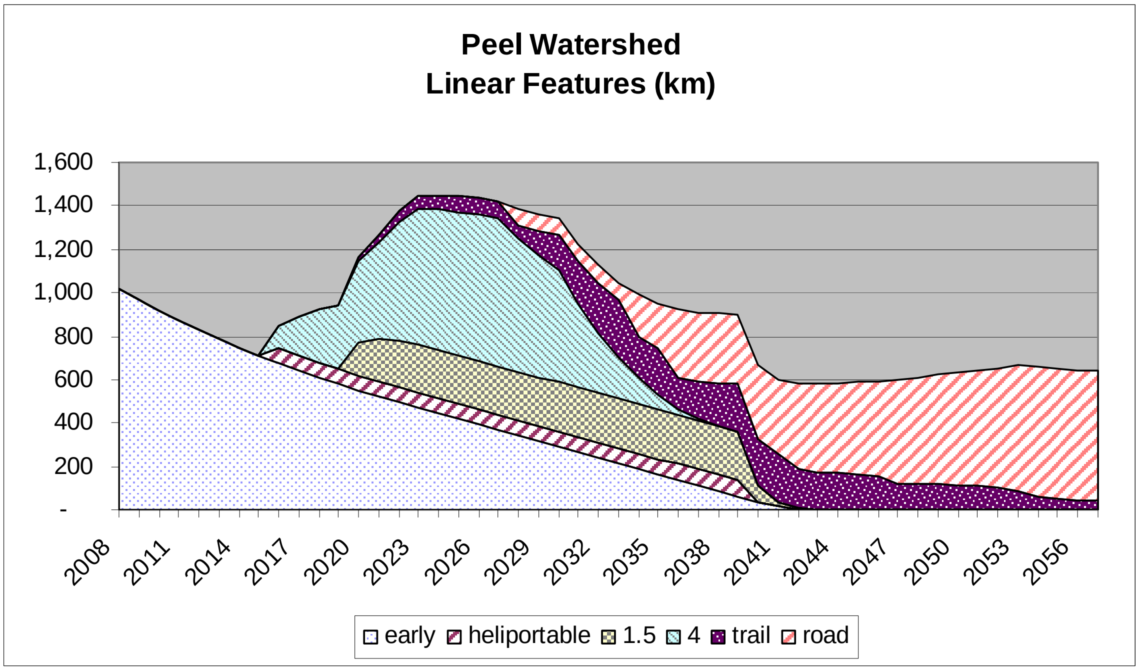
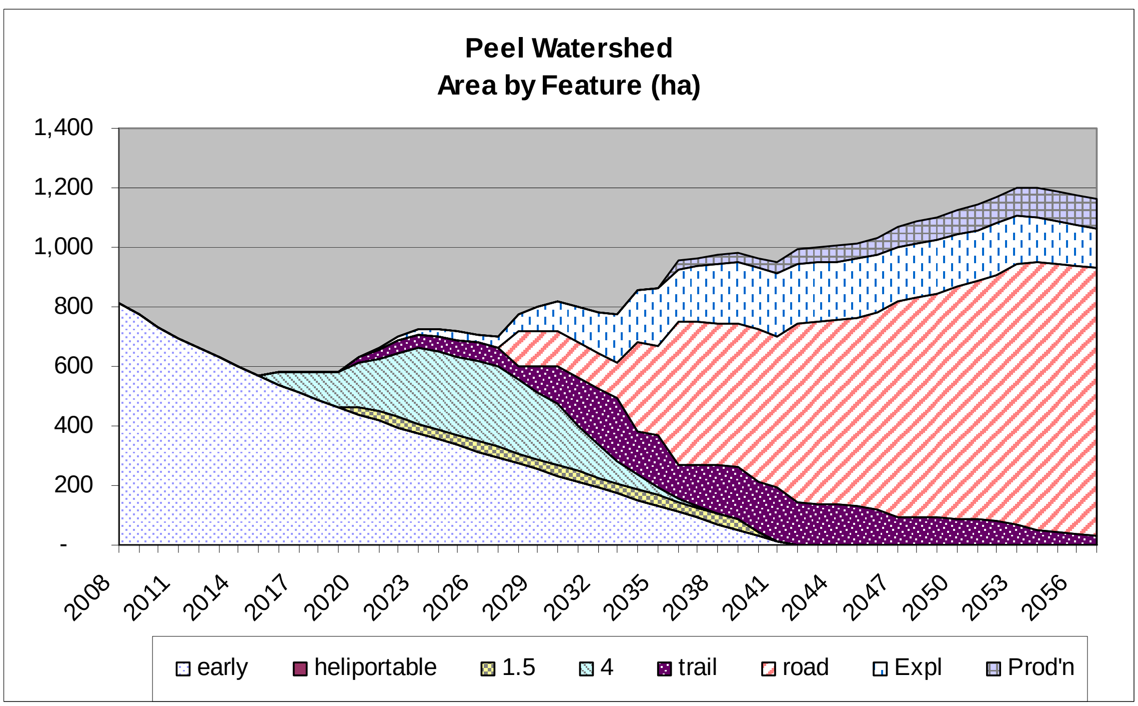
2008	813	-	-	-	-	-	-	-	813
2009	772	-	-	-	-	-	-	-	772
2010	734	-	-	-	-	-	-	-	734
2011	697	-	-	-	-	-	-	-	697
2012	662	-	-	-	-	-	-	-	662
2013	629	-	-	-	-	-	-	-	629
2014	597	-	-	-	-	-	-	-	597
2015	568	-	-	-	-	-	-	-	568
2016	539	-	-	40	-	-	-	-	579
2017	512	-	-	72	-	-	-	-	584
2018	487	-	-	98	-	-	-	-	584
2019	462	-	-	118	-	-	-	-	580
2020	439	-	23	150	5	16	-	-	633
2021	417	-	30	176	10	30	-	-	663
2022	396	-	32	217	14	42	-	-	702
2023	376	-	33	251	19	48	-	-	727
2024	356	-	33	258	23	53	-	-	723
2025	335	-	34	264	26	58	-	-	717
2026	315	-	34	268	30	62	-	-	709
2027	295	-	34	272	34	65	-	-	699
2028	274	-	34	245	57	48	120	-	778
2029	254	-	34	224	79	90	120	-	801
2030	234	-	34	207	100	126	120	-	821
2031	214	-	34	154	120	159	120	-	800
2032	193	-	34	111	139	187	120	-	784
2033	173	-	34	77	157	211	120	-	772
2034	153	-	34	50	174	147	300	-	857
2035	132	-	34	28	191	176	300	-	860

2036	112	-	34	10	176	116	480	30	958
2037	92	-	34	3	187	140	480	30	965
2038	71	-	34	1	198	161	480	30	974
2039	51	-	34	0	208	179	480	30	982
2040	31	-	11	0	208	171	510	35	965
2041	10	-	4	0	212	178	510	35	950
2042	-	-	1	0	202	142	600	50	995
2043	-	-	0	0	199	136	615	53	1,003
2044	-	-	0	0	199	138	615	53	1,005
2045	-	-	0	0	197	133	630	55	1,015
2046	-	-	0	0	192	121	660	60	1,033
2047	-	-	0	0	182	96	720	70	1,069
2048	-	-	0	0	181	96	735	73	1,084
2049	-	-	0	0	179	96	750	75	1,100
2050	-	-	0	0	175	89	780	80	1,124
2051	-	-	0	0	174	90	795	83	1,141
2052	-	-	0	0	170	83	825	88	1,166
2053	-	-	0	0	164	71	870	95	1,200
2054	-	-	0	0	151	47	900	100	1,198
2055	-	-	0	0	143	41	900	100	1,185
2056	-	-	0	0	136	36	900	100	1,173
2057	-	-	0	0	129	32	900	100	1,161

9. Graphical Summaries

The best way to visualize the magnitudes of the linear extent and total areas of features associated with oil and gas exploration and development is in graphical format:





There are several points that should be kept in mind regarding the graphs above:

- The ‘early’ seismic lines were Cat-cut and are straight; the seismic features supposed for the future will generally be meandering to mitigate line-of-sight issues and will generally not disturb the existing vegetative mat. Although the maximum of these new seismic features occurs around 2028 and is approximately equal to the amount of existing ‘early’ seismic, the two are of entirely different character and the supposed new features will be much less obvious.
- The significant long-term effect will be that due to permanent roads; this is presumed to total 600 km. by 2057. For the purposes of this study, no regeneration was postulated. It is not impossible for roads to regenerate, however; with time and appropriate mitigative and remedial measures, virtually anything will re-vegetate.