MISCELLANEOUS REPORT 2008-8

Saskatchewan's Ultimate Potential for Conventional **Natural Gas**

November 2008 Report

Saskatchewan Ministry of Energy and Resources

National Energy Board

Office national de l'énergie

Canada

Saskatchewan Ministry of Energy and Resources

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TABLE OF CONTENTS

Appendices

FIGURES

TABLES

Acronyms

ARC	Alberta Research Council
BCMEMPR	B.C. Ministry of Energy, Mines and Petroleum Resources
CBM	coalbed methane
CERI	Canadian Energy Research Institute
CGPC	Canadian Gas Potential Committee
CSPG	Canadian Society of Petroleum Geologists
EMA	Energy Market Assessment
ER	Saskatchewan Ministry of Energy and Resources
ERCB	Energy Resources Conservation Board
GIP	gas in place
GSC	Geological Survey of Canada
NEB, the Board	National Energy Board
NGC	natural gas in coal
NGLs	natural gas liquids
the agencies	collectively, ER and the NEB
U.S.	United States of America
WCSB	Western Canada Sedimentary Basin

Units

Bcf	= billion cubic feet
cf/m^3	= cubic feet per cubic metre
kPa	= kilopascals
mD	= millidarcies
m	= metre
MMcf	= million cubic feet
psia	= pounds per square inch absolute
Tcf	= trillion cubic feet
10^6m^3	= million cubic metres
10^9m^3	= billion cubic metres
ºF	= degrees Fahrenheit

Acknowledgements

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The National Energy Board:

- Peter Budgell, Mike Johnson, Candice Servais and Jim Davidson

Saskatchewan Ministry of Energy and Resources:

- Rick McLean, Melinda Yurkowski, Arden Marsh, Erin Raaf, Fred Ochieng and Steve Rymes

FOREWORD

The Saskatchewan Ministry of Energy and Resources (ER) is the key provincial government agency responsible for economic growth and development of Saskatchewan's resource sector. ER's mandate is to achieve full and responsible development of Saskatchewan's energy, mineral and forestry resources; to work with businesses to expand the Saskatchewan economy by promoting, coordinating and implementing policies, strategies and programs that encourage sustainable economic growth; and to optimize resource revenues to fund government programs and services.

ER provides a wide variety of programs and services related to the oil and gas industry in Saskatchewan, including the administration of Crown mineral lands; the regulation of well licensing, drilling and completions; the licensing of pipelines; the regulation of well production and injection; the collection of production and disposition data; and the determination of Crown royalties and freehold production taxes. ER is also responsible for investigating, compiling and maintaining information on the geology, energy and mineral resources of the province.

The National Energy Board (NEB or the Board) is an independent federal agency whose purpose is to promote safety and security, environmental protection and efficient economic infrastructure and markets in the Canadian public interest[1] within a mandate set by Parliament. The NEB is an active, effective and knowledgeable partner in the responsible development of Canada's energy sector for the benefit of Canadians.

The Board's main responsibilities include regulating the construction and operation of interprovincial and international oil and gas pipelines, as well as pipeline tolls and tariffs. Another key role is to regulate international and designated interprovincial power lines. The Board also regulates the imports of natural gas and exports of natural gas, oil, natural gas liquids (NGLs) and electricity. Additionally, the Board regulates oil and gas exploration and development on frontier lands and offshore areas not covered by provincial or federal management agreements. In its advisory function, the Board provides energy information and advice by analyzing information about Canadian energy markets obtained through regulatory processes and monitoring.

This Energy Market Assessment (EMA), entitled *Saskatchewan's Ultimate Potential for Conventional Natural Gas*, is part of a series of EMA reports that provide information on the total conventional natural gas resources of sedimentary basins in Canada. This series includes the NEB's 2004 report, *Canada's Conventional Natural Gas Resources: A Status Report*; the 2005 report on Alberta, *Alberta's Ultimate Potential for Conventional Natural Gas*, completed with the Energy and Utilities Board, now the Energy Resources Conservation Board (ERCB); and the 2006 report on British Columbia, *Northeast British Columbia's Ultimate Potential for Conventional Natural Gas*, completed with the Ministry of Mines, Energy and Petroleum Resources and the Oil and Gas Commission.

1 The public interest is inclusive of all Canadians and refers to a balance of economic, environmental and social interests that changes as society's values and preferences evolve over time.

This EMA provides information on the undiscovered conventional natural gas resources remaining in the Saskatchewan portion of the Western Canada Sedimentary Basin (WCSB) which includes a portion of the Williston Basin and provides information on unconventional natural gas resources that could potentially be developed in the province.

Any comments on the report or suggestions for further analysis can be directed to:

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If a party wishes to rely on material from this report in any regulatory proceeding before the NEB, it may submit the material, just as it may submit any public document. Under these circumstances, the submitting party in effect adopts the material and that party could be required to answer questions pertaining to the material.

Information about ER, including its publications, can be found by accessing ER's website at www.er.gov.sk.ca. Information about the NEB, including its publications, can be found by accessing the Board's website at www.neb-one.gc.ca.

Executive Summary

The Saskatchewan Ministry of Energy and Resources (ER) and the National Energy Board (the NEB or the Board), (collectively; the agencies), estimate energy supply and demand on provincial and national scales, respectively. Ultimate potential of natural gas is recognized as a key component required to project future supply. The NEB's last study of the ultimate potential of Saskatchewan was completed in 1998 and was based on year-end 1997 data. From 1998 to 2007, an additional 14 885 natural gas wells were drilled in Saskatchewan, indicating growing industry interest in its natural gas resources. With the increased drilling activity, the discovery of at least one large gas pool in an existing play, and the fact that cumulative production was approaching the ultimate potential, ER and the NEB concluded that a new assessment of the Saskatchewan portion of the Western Canada Sedimentary Basin (WCSB) was needed. To achieve regulatory efficiency, the agencies decided to collaborate on a joint study. The current study is based on year-end 2004 data, the most complete gas reserves data that had been compiled by ER at the time; however, more recent well data were used to a certain extent, primarily to assist in determining play area boundaries. In addition to the joint study, ER undertook the development of a play map compilation which describes, in more detail, the petroleum geology of the plays considered in this report. This compilation will be available on ER's website late in 2008.

This report, *Saskatchewan's Ultimate Potential for Conventional Natural Gas*, presents the results of the joint study. The medium case estimate for Saskatchewan's ultimate potential of marketable conventional natural gas resources, and the estimate both agencies will rely on for technical and regulatory purposes until future revision, was calculated to be 297.4 10^9m^3 (10.6 Tcf).

The new estimate of ultimate potential is 42 percent higher than the NEB's previous estimate for conventional natural gas resources in Saskatchewan. It shows significant increases in some resource categories and plays, primarily the Milk River, while also showing decreases in others. The shallow biogenic gas in the Milk River Formation and Medicine Hat Sand is considered to be conventional gas because of its long production history in Saskatchewan. The geological plays that are responsible for much of Saskatchewan's oil production, especially in the southeast portion of the province, have not been assessed because the non-associated gas resources of those plays are very small. Furthermore, no resource estimates are made for solution, or dissolved gas because the initial gas in place data have not been compiled by ER, and thus were not readily available for use in this report. It is important to note that solution gas could contribute significantly to Saskatchewan's future supplies of marketable natural gas.

In conclusion, based on cumulative production to the end of 2004 of 146.8 10^9m^3 (5.2 Tcf), the remaining conventional natural gas in Saskatchewan available for future Canadian domestic and export demand is 150.6 10^9m^3 (5.3 Tcf). Current annual production of non-associated natural gas in Saskatchewan is approximately 6.9 10^9m^3 (245 Bcf). Importantly, additional natural gas volumes could become available from unconventional supplies in Saskatchewan and development of those additional resources could supplement long-term supply. However, estimates of unconventional resources were not attempted in this study because the play concepts are very immature in Saskatchewan. Finally, extraction of gas resources will contribute to a healthy and vibrant oil and gas industry in Saskatchewan for many decades to come.

INTRODUCTION

Canada plays an important role in the current North American natural gas market by providing about one-quarter of North American gas production. Canada's ability to remain a key supplier of natural gas will largely depend on the size and quality of its resource base. Within Canada, the province of Saskatchewan is a small, but important contributor to natural gas supply, accounting for about four percent of total Canadian production in 2004. Annual non-associated natural gas production from Saskatchewan is currently 6.9 $10^9 m^3$ (245 Bcf) which mostly comes from its western regions (Figure 1.1[2]).

Ultimate potential for natural gas is a key component required to make projections of future supply. It provides base information from which subsequent examinations of the pace of development, deliverability and economics can be conducted. As drilling and technology advance, they bring forth new information on the resources of a basin, which in turn, contributes to increased certainty. Increased drilling activity in Saskatchewan, the discovery of at least one large pool in an existing play not previously accounted for, and the fact that cumulative production was approaching the previous NEB ultimate potential estimate, warranted the need for a new assessment of Saskatchewan's ultimate potential for conventional natural gas.

1.1 Scope

This report focuses primarily on conventional natural gas. Saskatchewan's oil and gas bearing rocks lie within the WCSB, with most of the conventional natural gas resources found in the western third of the province. There are also conventional hydrocarbon resources in other parts of Saskatchewan, particularly in the southeast corner of the province in the Williston Basin. In addition, unconventional gas is of increasing interest. Currently, unconventional gas in Saskatchewan is at an early development stage, so available information is too limited to estimate its ultimate potential at this time. A more detailed description of unconventional gas is included in Appendix 1.

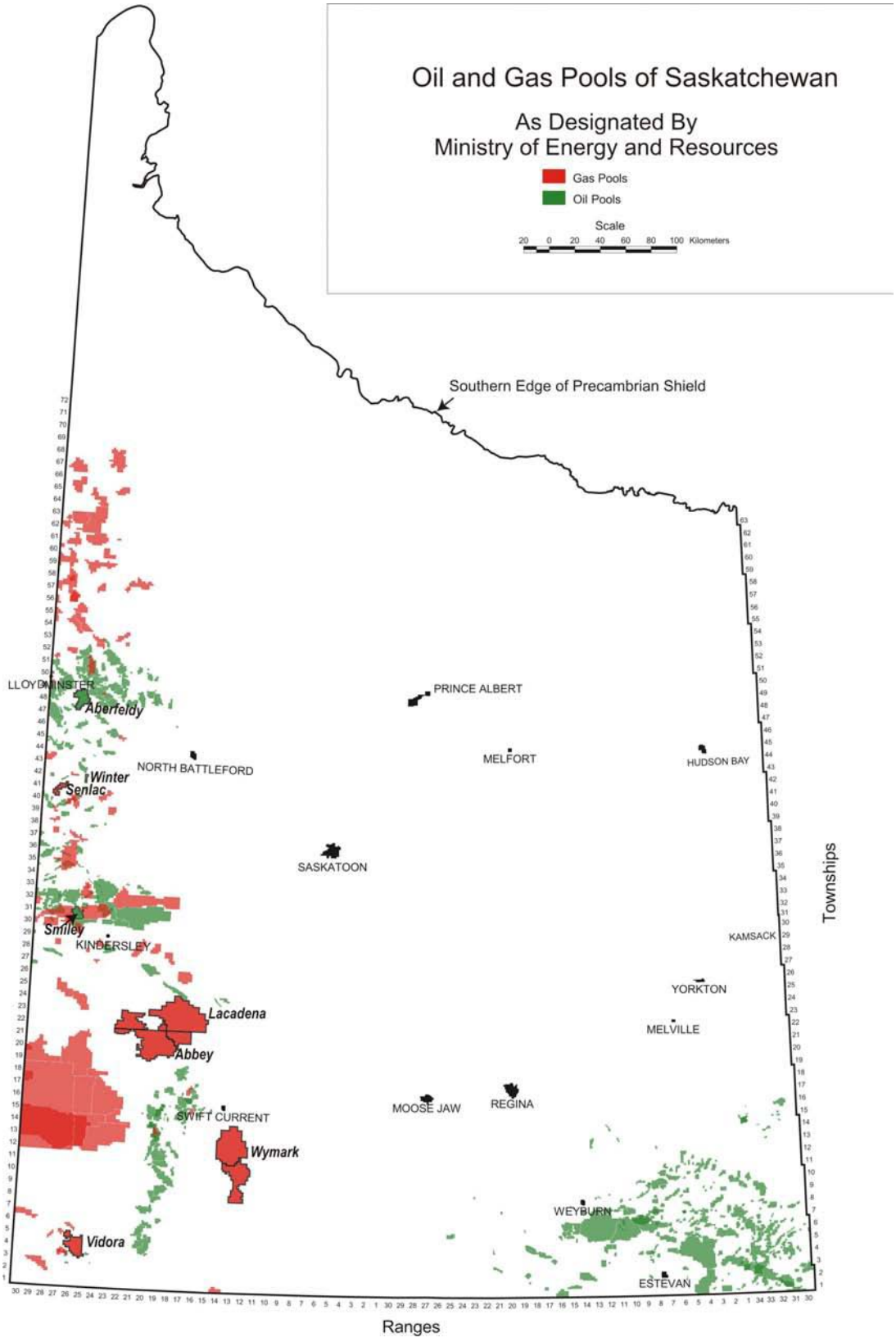
This report does not specifically address the economics of discovering, developing or producing Saskatchewan's natural gas resources, nor does it deal with the rate of discovery or productive capacity for natural gas. This report and the associated data are meant to form the basis for economic analysis and supply projections by ER, the NEB or others.

With the availability of more information as a result of increased drilling activity since 1997, this study provides more detailed information on a geological play basis than previous NEB studies of Saskatchewan. Additionally, this report applies further rigor in the analysis and provides enhanced results relative to previous studies. The joint assessment benefited from the local knowledge of ER geologists and engineers.

2 Pool names displayed are only those noted in this report.

FIGURE 1.1

Oil and Gas Pools of Saskatchewan



This report captures the resources of known geological plays, but does not include projections for conceptual plays, which are geological plays thought to exist but yet to be proven by oil or gas wells capable of production, as discussed in Section 3.2. An example of a conceptual play is the Cretaceous shallow gas play in eastern Saskatchewan where the presence of gas is known from past drilling, but the presence of economic hydrocarbons has yet to be confirmed. It also includes situations where the play is well developed in Alberta, but has only one or two wells producing in the same interval in Saskatchewan, such as the Devonian Torquay Formation. The geology is known to cross the provincial boundary, and the agencies expect discoveries to be made on the Saskatchewan side in the future. For this report, the project team only identified conceptual plays that it believes could exist in Saskatchewan. If any of those plays are proven to contain hydrocarbons in the future, the project team will assign a volume of undiscovered gas in subsequent reports.

Some portion of the identified gas resources may not be accessible from the surface due to physical features such as large lakes, difficult topography and environmentally sensitive areas, or because of alternative surface uses such as cities and parks. In Saskatchewan, resources in some of these areas may be accessible from adjacent areas via directional drilling. In some cases, access to natural gas resources could be prevented altogether as a result of surface access restrictions.

1.2 Terminology

For the purpose of this report, the term *ultimate potential* refers to an estimate of the volume of marketable gas resources that will be proven to exist in a geological basin or in a specific area after exploration has ceased, having regard for the geological prospects of that area and anticipated technology and economic conditions. Ultimate potential can be expressed as:

Ultimate potential = discovered resources + undiscovered resources

Discovered resources are the resources confirmed by wells already drilled, while *undiscovered resources* are the resources expected to be discovered by future drilling. Figure 1.2 presents the ultimate potential terminology used in this report. Discovered resources consist of both the volumes of gas already produced (cumulative production) and the known reserves that have yet to be produced.

Since estimates of ultimate potential refer to a volume of gas to be discovered in the future, the estimates always have a degree of uncertainty. The amount of uncertainty varies for each component

FIGURE 1.2

Terminology used for Study of Saskatchewan's Ultimate Potential for Conventional Natural Gas

<table>
<tr><th colspan="3">Terms</th><th>Level of Uncertainty</th></tr>
<tr><td rowspan="3">Ultimate Potential</td><td rowspan="2">Discovered</td><td>Cumulative Production</td><td>None</td></tr>
<tr><td>Reserves</td><td>Low</td></tr>
<tr><td>Undiscovered</td><td>Future</td><td>High</td></tr>
</table>

of the estimate. Undiscovered resources have the highest amount of uncertainty as there is less information known about the resources. For discovered resources, there is minimal uncertainty because pools can be measured using wells, seismic, flow and pressure data. Finally, there is no uncertainty for the volumes already produced.

Additional terminology used in describing discovered resources, or in calculating estimates of the undiscovered resources and ultimate potential are as follows: *gas in place (GIP)* is the initial volume of gas in the reservoir, *recoverable gas* is the initial volume of gas that can be produced and *marketable gas* is the volume that remains after processing and is available to the natural gas market. This report uses the GIP volumes from the discovered pools as provided in ER's annual reserves report[3] to make projections of the undiscovered GIP. The undiscovered GIP is reduced to marketable volumes by applying current recovery factors and surface losses using parameters from existing pools, also published in the annual reserves report. Gas that has been produced (cumulative production) and estimates of gas yet to be produced (reserves and future) are also identified. *Remaining gas* (ultimate potential minus cumulative production) represents the volume available for future market demands.

1.3 Units of Measure

The data in this report are presented in metric units, followed, where appropriate, by the imperial equivalents in brackets.

Both ER and the NEB state natural gas volumes in metric units at the standard conditions of 101.325 kilopascals (kPa) and 15 degrees Celsius. For historical data originally reported in imperial units, ER uses standard conditions of 14.65 pounds per square inch absolute (psia) and 60 degrees Fahrenheit (ºF). The NEB uses standard conditions of 14.73 psia and 60ºF for gas volumes reported in imperial units. For the purposes of this report, a conversion factor of 35.49373 cubic feet per cubic metre (cf/m^3) has been used, reflecting the standard conditions used by ER for historical data. Readers requiring an accurate conversion to the NEB standard conditions should use a conversion factor of 35.30096 cf/m^3. All gas volumes in this report are shown on an "as is" basis with no adjustment for heating value.

1.4 Effective Date of Data

The reserves data analyzed are effective as of 31 December 2004 and the final ultimate potential estimates are based on that date. To a certain extent, more recent well data and other information were used in the data analysis and preparations of the report, primarily to assist in determining play area boundaries. The latest available drilling and production information is also cited in several places in the report.

1.5 Updates to Study

Although this study accounts for reserves to year-end 2004, ongoing drilling activity requires continued monitoring of exploration in the province. The agencies intend to maintain the computer systems, databases and processes used in this report to update the data on an ongoing basis. Changes may be reported in the annual releases of ER's *Oil and Gas Reserves Summary Reports* or in various NEB publications.

3 Oil and Gas Reserves Summary Reports, 2004

1.6 Uses of Data in this Study

The agencies expect to make ongoing use of the data contained in this report and the systems used to produce this report for such tasks as the regional analysis of resources near pipelines, gas plants, and populated areas.

1.7 Play Map Compilation

ER has undertaken the development of a play map compilation which will more fully describe the geology of the individual geologic plays identified in this report. The compilation will also include maps for each formation that show the areal distribution of the play areas. The document, which will be published by ER by the end of 2008, is meant to be a companion piece to this report and will also be made available on the ER website.

1.8 Reader's Questions and Comments

The reader is encouraged to contact ER or the NEB with questions or comments respecting either this report or the associated data on the ER and NEB websites: www.er.gov.sk.ca and www.neb-one.gc.ca. Please contact:

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METHODOLOGY AND RESULTS

2.1 Methodology

The estimate of the ultimate potential of conventional natural gas in Saskatchewan was determined by:

- reviewing pertinent data, statistical analyses, maps and other information;
- using the @Risk methodology, described in the NEB report, *Canada's Conventional Natural Gas Resources: A Status Report (2004)*[4];
- using the graphical techniques outlined in the joint Alberta Energy and Utilities Board (now Energy Resources Conservation Board [ERCB]) and NEB report, *Alberta's Ultimate Potential For Conventional Natural Gas*[5] when sufficient data were available;
- for certain shallow gas plays, using the same techniques as the ERCB and NEB in the report *Alberta's Ultimate Potential For Conventional Natural Gas*[6] where the main play area is assumed to have a 100 percent success rate and surrounding areas have a lower success rate; and
- relying on the knowledge and expertise of the project team.

The @Risk methodology uses information from the discovered reserves and drilled lands to build statistical distributions within the software. Those distributions are then applied to lands where drilling has not occurred to determine a distribution of volumes of undiscovered resources at different probability values. The project team uses the P90, mean and P10 values for its low, medium and high cases, respectively. The software analyzes the discovered resources on a GIP basis and determines the undiscovered resources on a GIP basis.

The results from the graphical techniques were compared against the @Risk results. For those plays that did not have enough data to use the @Risk tool or the graphical techniques, the team used their geological expertise to estimate the ultimate potential (e.g., for plays that have either just been confirmed or where exploration is still limited) or identified that the play was conceptual and could have discoveries made in the future. Appendix 2 lists the methodology used to assess each play.

2.2 Available Information

Increases in natural gas prices have resulted in the exploration for and development of lower-productivity pools that were previously beyond economic reach. Advances in technology such as underbalanced mud systems, completion techniques and drill bits, and the use of refined seismic

4 Available at: www.neb-one.gc.ca/energy/energyreports

5 *ibid.*

6 *ibid.*

technologies including three-dimensional, have also resulted in the discovery and development of many new pools. In addition, new development strategies have allowed for the more efficient and economic development of resources that were previously considered to be uneconomic. These include the Milk River development which was extended by the discovery of the Abbey and Lacadena pools in 2002 and 2003.

The current study uses data from 23 981 natural gas wells drilled between 1956 and year-end 2004. Data on drilling counts prior to 1956 are not available. The NEB 1998 report was based on 9 096 natural gas wells drilled between 1956 and year-end 1997. The number of natural gas wells drilled in Saskatchewan on an annual basis increased rapidly in 1984, from about 200 wells per year to over 2 000 in 2003 (Figure 2.1). The current study is based on year-end 2004 data, as they were the most complete gas reserves data that had been compiled by ER at the time; however, to a certain extent, more recent well data were used, primarily to assist in determining play area boundaries. A stratigraphic correlation chart showing the stratigraphic nomenclature used in this report is available on the ER web site at www.er.gov.sk.ca/stratchart.

2.3 Miscellaneous Data

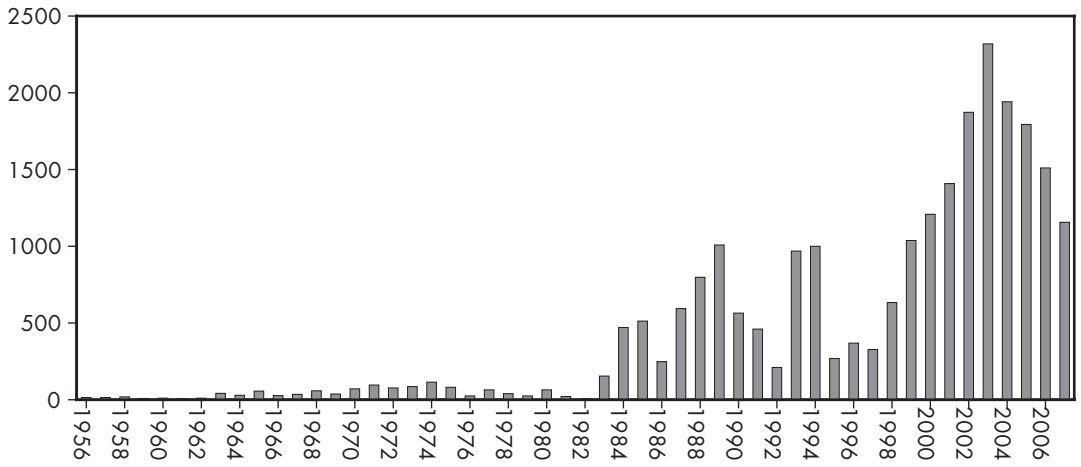
The established natural gas reserves figures published by ER in the *Oil and Gas Reserves Summary Reports* include initial GIP, initial recoverable reserves, cumulative production to date, remaining reserves and certain reservoir parameters, all grouped by designated pool. Gas reserves and production data for wells that are not located within existing pools designated by ER are reported under the "Miscellaneous" heading with the initial GIP, initial recoverable reserves, cumulative production to date and remaining reserves grouped by producing horizon.

The Miscellaneous gas reserves published for a particular horizon represents the total reserves assigned to all miscellaneous wells identified in that producing horizon. These miscellaneous reserves may comprise data from single well pools; multi-well, but undesignated pools; or possible extensions to existing pools.

While ER does not publish the detailed reserves and production data by well, for these miscellaneous wells, it does maintain a detailed database of reserves data. These detailed miscellaneous reserves data

FIGURE 2.1

Annual Saskatchewan Gas Well Counts



were used in the study and formed a significant portion of the discovered reserves data used in this study of ultimate gas potential in Saskatchewan.

2.4 Non-associated and Associated Gas

Non-associated gas is natural gas found in its natural state in a reservoir in which no crude oil is present at reservoir conditions. The gas is produced by its own expansion or by pressure from an underlying aquifer. The majority of natural gas found in Saskatchewan is of this type. Associated gas is natural gas found in a gaseous state in the reservoir that overlies and is in contact with crude oil in the same reservoir, at original reservoir pressure and temperature. It is also referred to as "gas-cap" gas. There are limited resources of associated gas in Saskatchewan.

For the purposes of this study, associated gas in all but one play area is treated as non-associated gas rather than calculated as a separate component. Only one play in Saskatchewan, Mannville Play Area 1 in the western part of the province, had enough associated gas pools to estimate a separate future associated gas resource using the agencies' methodology. For that play only, separate non-associated and associated undiscovered natural gas volumes were estimated.

2.5 Solution or Dissolved Gas

Solution gas, also called dissolved gas in Saskatchewan, is natural gas that is dissolved in crude oil in the reservoir at original reservoir temperature and pressure conditions and is normally produced with the crude oil. To be considered as a marketable gas resource, that gas must be captured at the surface, processed and compressed, if necessary, to pipeline specifications and have a connection to a natural gas pipeline system.

No resource estimates are presented for solution or dissolved gas because the initial GIP data have not been compiled by ER for oil pools in the province and thus were not readily available for use in this report. Also, a high percentage of the dissolved gas produced from oil pools is utilized as a fuel source within the oilfield operations or is produced at very low rates that cannot be economically collected and utilized.

It is important to note that a significant amount of the solution or dissolved gas produced in the province is surplus to oilfield requirements and is collected and available as marketable gas. Marketable solution gas production was 7.7 percent of the total marketable gas production in Saskatchewan in 2004 and, therefore, solution gas could contribute significantly to Saskatchewan's future supplies of marketable natural gas. Importantly, industry and government have been placing increasing emphasis on the collection and utilization of dissolved gas.

TABLE 2.1

Saskatchewan's Ultimate Potential for Conventional Natural Gas

Case	Gas In Place		Marketable Gas	
	10^9m^3	Tcf	10^9m^3	Tcf
Low	382.2	13.6	264.2	9.4
Medium	429.1	15.2	297.4	10.6
High	473.1	16.8	329.1	11.7

2.6 Results

Having regard for the inherent uncertainty in estimating geological prospects and predicting gas potential, the agencies estimated a range for the ultimate potential for marketable conventional natural gas in Saskatchewan. That range is 264.2 10^9m^3 (9.4 Tcf) to 329.1 10^9m^3 (11.7 Tcf), as shown in Table 2.1.

Table 2.2 shows a breakdown of ultimate potential (medium case) for natural gas into various categories as of 31 December 2004. Maps showing the distribution of discovered, undiscovered, ultimate potential and remaining ultimate potential for marketable conventional natural gas in Saskatchewan are in shown Appendix 3.

TABLE 2.2

Categorization of Ultimate Potential – Medium Case

Category	Gas In Place		Marketable Gas	
	10^9m^3	Tcf	10^9m^3	Tcf
Discovered[a,b]	319.7	11.3	221.5	7.9
Cumulative production (to 31 Dec 2004)	211.7[c]	7.5[c]	146.8	5.2
Remaining discovered	108.0	3.8	74.7	2.7
Undiscovered	109.4	3.9	75.9	2.7
Ultimate potential	429.1	15.2	297.4	10.6
Remaining ultimate potential	217.4	7.7	150.6	5.3

a Includes the discovered volumes of gas in the Frobisher and Alida Beds, whose resource potential is not estimated in this study

b Deviation from Oil and Gas Reserves Summary Reports, 2004 because of miscellaneous pool reserve estimates

c The value in the GIP column is an estimate of the volume of in-place gas represented by the produced marketable gas volume

The remaining ultimate potential represents the volume of gas that could be available in the future to meet Canadian domestic and export demands. The new estimate of remaining ultimate potential for marketable conventional natural gas in Saskatchewan is 150.6 10^9m^3 (5.3 Tcf). Additional volumes should also become available from unconventional natural gas resources in Saskatchewan, and development of those additional resources could supplement long-term supply from the province. Extraction of gas will contribute to a healthy and vibrant oil and gas industry in Saskatchewan for many decades to come.

2.6.1 *Gas In Place Results*

As explained earlier, in light of the inherent uncertainty in estimating the ultimate GIP, this study includes low, medium and high case estimates. The low case is 382.2 10^9m^3 (13.6 Tcf), reflecting a good deal of certainty that the ultimate potential meets or exceeds that estimate. The medium case is 429.1 10^9m^3 (15.2 Tcf) and represents the most realistic estimate. The high case of 473.1 10^9m^3 (16.8 Tcf) might possibly be discovered, but it should be considered as highly speculative.

Table 2.3 shows the low, medium and high case estimates for each play area.

2.6.2 *Marketable Gas Results*

Conversion of GIP estimates to marketable gas requires the application of a recovery factor to obtain producible reserves and a surface loss factor to yield marketable gas. The recovery factor recognizes that, for practical and economic reasons, only a portion of the GIP can be produced. Surface loss accounts for field-plant extraction of natural gas co-products and impurities from the raw gas, the flaring of test gas and solution gas (where solution gas is not conserved), and lease fuel. In Saskatchewan, the average recovery factor is 73 percent and the average surface loss is five percent.

The recovery and surface loss factors for future gas discoveries are generally assumed to be the same in each play as those for gas discovered to date. Table 2.1 shows the low, medium and high case results for marketable volume. Table 2.4 shows the medium case results for each play area of every analyzed play.

2.7 Comparison with Previous Studies

Estimates of ultimate potential for natural gas in Saskatchewan have been made periodically in the past. The last detailed NEB report to examine the undiscovered resources portion of the ultimate

TABLE 2.3

Low, Medium and High Case Ultimate GIP by Formation and Play Area

Formation	Play Area	Gas Type	10^9m^3			Tcf		
			Low Case	Medium Case	High Case	Low Case	Medium Case	High Case
Bearpaw	1	NA	0.618	0.675	0.731	0.022	0.024	0.026
Bearpaw	2	NA	0.035	0.091	0.147	0.001	0.003	0.005
Belly River	1	NA	1.161	1.735	2.914	0.041	0.062	0.103
Ribstone Creek	1	NA	2.174	2.624	3.315	0.077	0.093	0.118
Milk River	1	NA	171.149	171.149	171.149	6.075	6.075	6.075
Milk River	2	NA	0.786	1.488	2.190	0.028	0.053	0.078
Milk River	3	NA	2.148	4.675	8.886	0.076	0.166	0.315
Milk River	4	NA	6.096	8.910	14.539	0.216	0.316	0.516
Medicine Hat	1	NA	30.079	30.079	30.079	1.068	1.068	1.068
Medicine Hat	2	NA	1.732	3.236	5.001	0.061	0.115	0.178
Medicine Hat	3	NA	0.040	0.058	0.079	0.001	0.002	0.003
Second White Specks	1	NA	35.747	44.399	72.379	1.269	1.576	2.569
Second White Specks	2	NA	1.531	1.855	2.349	0.054	0.066	0.083
St. Walburg	1	NA	2.211	6.543	19.808	0.078	0.232	0.703
Viking Sand	1	NA/AS	27.825	31.501	41.950	0.988	1.118	1.489
Viking Sand	2	NA	0.102	0.138	0.248	0.004	0.005	0.009
Viking Sand	3	NA	4.813	6.673	8.190	0.171	0.237	0.291
Spinney Hill	1	NA	0.230	0.458	0.977	0.008	0.016	0.035
Mannville/Cantuar/Premier	1	NA	68.809	89.263	136.182	2.442	3.168	4.834
Mannville/Cantuar/Premier	1	AS	0.374	0.473	1.117	0.013	0.017	0.040
Mannville/Cantuar/Premier	2	NA/AS	2.648	2.857	3.402	0.094	0.101	0.121
Success	1	NA	1.764	2.446	3.927	0.063	0.087	0.139
Success	2	NA/AS	0.155	0.436	0.717	0.006	0.015	0.025
Roseray	1	NA	0.303	0.307	0.310	0.011	0.011	0.011
Shaunavon	1	NA	0.699	1.094	1.474	0.025	0.039	0.052
Bakken	1	NA/AS	6.896	14.799	34.993	0.245	0.525	1.242
NA=Non-Associated, AS=Associated								

TABLE 2.4

Ultimate Natural Gas Estimates by Formation and Play Area – Medium Case

Formation	Play Area	Gas Type	10^9m^3			Tcf		
			GIP	Producible	Marketable	GIP	Producible	Marketable
Bearpaw	1	NA	0.675	0.406	0.386	0.024	0.014	0.014
Bearpaw	2	NA	0.091	0.055	0.052	0.003	0.002	0.002
Belly River	1	NA	1.735	1.092	1.037	0.062	0.039	0.037
Ribstone Creek	1	NA	2.624	1.991	1.892	0.093	0.071	0.067
Milk River	1	NA	171.149	120.799	113.935	6.075	4.288	4.044
Milk River	2	NA	1.488	0.943	0.896	0.053	0.033	0.032
Milk River	3	NA	4.675	2.783	2.644	0.166	0.099	0.094
Milk River	4	NA	8.910	5.389	5.125	0.316	0.191	0.182
Medicine Hat	1	NA	30.079	23.744	22.264	1.068	0.843	0.790
Medicine Hat	2	NA	3.236	1.982	1.883	0.115	0.070	0.067
Medicine Hat	3	NA	0.058	0.047	0.044	0.002	0.002	0.002
Second White Specks	1	NA	44.399	28.095	26.710	1.576	0.997	0.948
Second White Specks	2	NA	1.855	1.424	1.353	0.066	0.051	0.048
St. Walburg	1	NA	6.543	4.862	4.619	0.232	0.173	0.164
Viking Sand	1	NA/AS	31.501	24.060	22.324	1.118	0.854	0.792
Viking Sand	2	NA	0.138	0.096	0.091	0.005	0.003	0.003
Viking Sand	3	NA	6.673	5.231	4.970	0.237	0.186	0.176
Spinney Hill	1	NA	0.458	0.372	0.354	0.016	0.013	0.013
Mannville/Cantuar/Premier	1	NA	89.263	72.389	69.126	3.168	2.569	2.454
Mannville/Cantuar/Premier	1	AS	0.473	0.347	0.330	0.017	0.012	0.012
Mannville/Cantuar/Premier	2	NA/AS	2.857	2.273	2.176	0.101	0.081	0.077
Success	1	NA	2.446	2.011	1.900	0.087	0.071	0.067
Success	2	NA/AS	0.436	0.320	0.304	0.015	0.011	0.011
Roseray	1	NA	0.307	0.240	0.228	0.011	0.009	0.008
Shaunavon	1	NA	1.094	0.875	0.833	0.039	0.031	0.030
Bakken	1	NA/AS	14.799	11.581	11.160	0.525	0.411	0.396
NA=Non-Associated, AS=Associated								

potential, *Non-Associated Natural Gas Resource Assessment Study - Saskatchewan*, was based on year-end 1997 data and published in 1998.

As described in previous NEB reports, estimates of ultimate potential generally tend to increase over time. This is usually the result of increased information, improved production practices and expansion into previously unexplored horizons as economics improve and development of a basin or area matures. Figure 2.2 shows just such an increase for ultimate potential estimates of marketable conventional natural gas in Saskatchewan. Future studies will continue to monitor trends in ultimate potential.

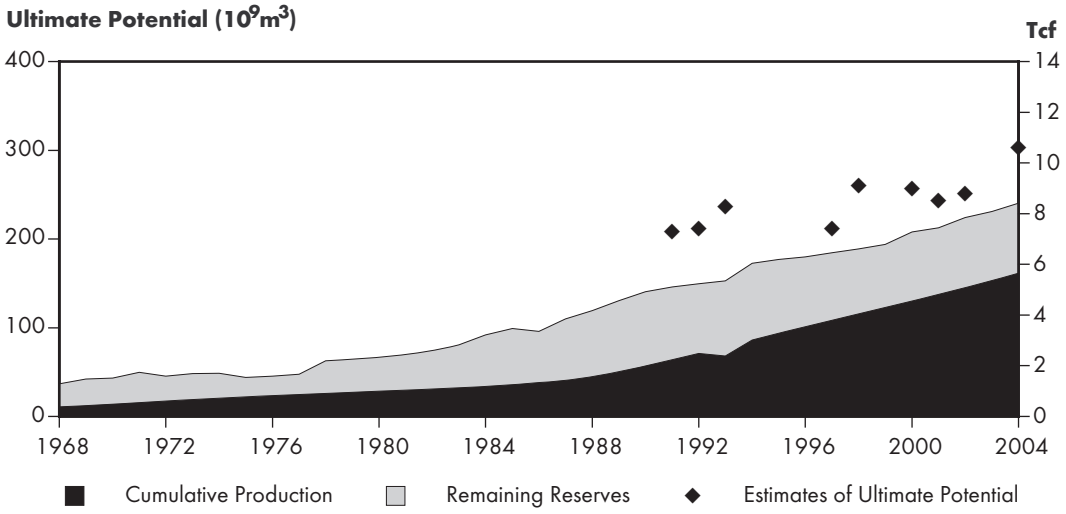
Studies of ultimate potential for conventional natural gas have been undertaken by others. Notably, the Canadian Gas Potential Committee (CGPC)[7] conducted studies for all of Canada and released reports in 1997, 2001 and 2005 entitled *Natural Gas Potential in Canada*. Table 2.5 shows a comparison of the estimates for conventional natural gas in Saskatchewan only.

2.8 Canadian Resources

The NEB, as part of its mandate, maintains estimates of ultimate potential for all regions of Canada. Its current estimates of Canadian resources were provided in its 2004 report, *Canada's Natural Gas Resources: A Status Report*. Tables 2.6A and 2.6B show the new estimate of Saskatchewan's ultimate potential for conventional natural gas in perspective with the rest of Canada in both metric and imperial units. The data presented in the tables are current to year-end 2004.

FIGURE 2.2

Changes in Estimates of Ultimate Potential for Conventional Marketable Natural Gas in Saskatchewan



Note: data reference dates are used as the year of the various studies

7 The CGPC uses the term Nominal Marketable Gas when it provides a marketable gas estimate. The nominal portion of the term is used to indicate that the estimate does not take into account restricted access issues, economics of developing all pools, not all pools will be found, undiscovered pools may not have the same characteristics as discovered pools and that production and transportation may not be available for the development of all pools. In this report, the CGPC estimates will be called marketable gas.

TABLE 2.5

Comparison of Ultimate Potential Estimates for Conventional Natural Gas in Saskatchewan

Source	Reference Date	Ultimate Potential (10^9m^3)	Ultimate Potential (Tcf)
ER/NEB 2008	2004	297.4	10.6
CGPC 2005	2002	249.0	8.8
Drummond 2002[a]	2001	241.0	8.5
Bowers 2000[b]	2000	255.0	9.0
CGPC 2001	1998	258.0	9.1
NEB 1998[c]	1997	210.0	7.4
CGPC 1997[d]	1993	235.0	8.3
NEB 1993	1992	212.0	7.4
GSC 1997[d]	1992	207.0	7.3

a Drummond, K.J., Canada's Natural Gas Ultimate Potential - Defining A Credible Upper Limit, CERI, 2002

b Bowers, B., Conventional Natural Gas Resources of the Western Canada Sedimentary Basin, in Journal of Canadian Petroleum Technology, 2000

c Non-associated volumes only

d Approximate volume only, for provincial breakdown

TABLE 2.6A

Current NEB Estimates of Ultimate Potential for Conventional Marketable Natural Gas in Canada (10^9m^3)

	Discovered Resources	Undiscovered Resources	Ultimate Potential[a]	Remaining Ultimate Potential[b]
Western Canada Sedimentary Basin				
Alberta	4 542	1 734	6 276	2 856
British Columbia	784	678	1 462	952
Saskatchewan	222	76	297	151
Southern Territories	27	169	196	181
Total	**5 575**	**2 657**	**8 231**	**4 140**
East Coast (Offshore)				
Labrador	130	660	790	790
East Newfoundland Basin	0	352	352	352
Grand Banks	110	375	485	485
Southern Grand Banks	0	86	86	86
Laurentian Sub-Basin	0	170	170	170
Nova Scotia	147	505	652	629
George's Bank	0	60	60	60
Total	**387**	**2 208**	**2 595**	**2 572**
West Coast				
Offshore	0	255	255	255
Intermontane	0	230	230	230
Total	**0**	**485**	**485**	**485**
Northern Canada				
Northwest Territories - Colville Hills	17	117	134	134
Mackenzie-Beaufort	254	1 460	1 714	1 714
Yukon - Eagle Plains	2	28	30	30
Yukon - Others	1	114	115	115
Arctic Islands	331	793	1 124	1 124
Eastern Arctic	0	140	140	140
Hudson Bay	0	28	28	28
Total	**605**	**2 680**	**3 285**	**3 285**
Ontario	**44**	**23**	**67**	**33**
Gulf of St. Lawrence (Maritimes Basin)	**2**	**38**	**40**	**40**
TOTAL CANADA[a]	**6 613**	**8 091**	**14 703**	**10 555**

a Numbers may not add due to rounding

b As of 31 December 2004, latest date for complete production information

TABLE 2.6B

Current NEB Estimates of Ultimate Potential for Conventional Marketable Natural Gas in Canada (Tcf)

	Discovered Resources	Undiscovered Resources	Ultimate Potential[a]	Remaining Ultimate Potential[b]
Western Canada Sedimentary Basin				
Alberta[c]	161	61	223	101
British Columbia[c]	28	24	52	34
Saskatchewan[c]	8	3	11	5
Southern Territories	1	6	7	6
Total	**198**	**94**	**293**	**146**
East Coast (Offshore)				
Labrador	5	23	28	28
East Newfoundland Basin	0	12	12	12
Grand Banks	4	13	17	17
Southern Grand Banks	0	3	3	3
Laurentian Sub-Basin	0	6	6	6
Nova Scotia	5	18	23	22
George's Bank	0	2	2	2
Total	**14**	**77**	**91**	**90**
West Coast				
Offshore	0	9	9	9
Intermontane	0	8	8	8
Total	**0**	**17**	**17**	**17**
Northern Canada				
Northwest Territories - Colville Hills	1	4	5	5
Mackenzie-Beaufort	9	52	61	61
Yukon - Eagle Plains	0	1	1	1
Yukon - Others	0	3	3	3
Arctic Islands	12	28	40	40
Eastern Arctic	0	5	5	5
Hudson Bay	0	1	1	1
Total	**22**	**94**	**116**	**116**
Ontario	**1**	**1**	**2**	**1**
Gulf of St. Lawrence (Maritimes Basin)	**0**	**1**	**1**	**1**
TOTAL CANADA[a]	**235**	**284**	**520**	**371**

a Numbers may not add due to rounding

b As of 31 December 2004, latest date for complete production information

c Converted to imperial using 35.49373 cf/m^3, refer to Section 1.3

OBSERVATIONS

3.1 General

The new estimate of ultimate potential for marketable conventional natural gas in Saskatchewan is 297.4 10^9m^3 (10.6 Tcf), an increase of 42 percent from the last NEB estimate.[8] The new estimate shows a different distribution of the ultimate potential in both a vertical sense (stratigraphic) and a horizontal sense (geographic). As exploration has shifted to new areas and into overlooked horizons since 1997, the understanding of the WCSB in Saskatchewan has continued to evolve. In a general sense, there has been an increased recognition of the undiscovered potential of the shallower Cretaceous intervals, due in part to better technology and production practices such as infill drilling that allows industry to step out into 'less permeable' frontiers and expand play areas.

In general, natural gas plays in Saskatchewan tend to be less developed than similar plays in Alberta. For example, when crossing from Alberta into Saskatchewan in the Cretaceous Milk River Formation and Medicine Hat Sand, the extent of the developed play area narrows by up to 19 km (12 miles). Whether this is a reflection of economic or geological conditions is not specifically known at this time. Regardless, from 1997 to 2004, natural gas reserves in these low productivity sandstones have increased significantly. The combined interval of the Milk River[9], Medicine Hat and Second White Specks zones contained an estimated 131 10^9m^3 (4.6 Tcf) of discovered marketable reserves at year-end 2004, 35 percent greater than the projection of ultimate potential made in 1998. The new projection of ultimate potential over these same stratigraphic intervals is 80 percent larger than the 1998 projection. This rapid growth in development and potential follows industry trends set in contiguous pools in neighbouring Alberta. Discovery of the Abbey and Lacadena pools since 2002 significantly expanded the primary play area to the east and north. These fields were discovered shortly before the release of the last CGPC assessment, and although the discovery was acknowledged in that report, it was too early to know its true size.

Most play areas have increased in size, indicating outward growth of exploration into areas that were once thought of as marginal or non-economic because of very low quality reservoirs. The more recent attractiveness of low quality sandstones is a factor of significantly improved natural gas prices and considerable advances in drilling and completion techniques. Since the last NEB estimate in 1998, industry has successfully developed several new geographically extensive pools, such as the Wymark Second White Specks, Abbey Milk River and Lacadena Milk River gas pools. From 1998 to 2004, the total number of gas wells put on production from the shallow biogenic gas accumulations (i.e., the top of the Bearpaw to base of Second White Specks), exceeds the total number of wells put on production for the same interval from the previous 45 years.

8 NEB, *Non-Associated Natural Gas Resource Assessment Study - Saskatchewan*, 1998

9 In recent geological literature, the Milk River in Saskatchewan is also referred to as Alderson Member of the Lea Park Formation; the Second White Specks is divided into an Upper Second White Speckled Shale Formation and the primary producing zone, the Belle Fourche Formation. For the purposes of this report, the producing intervals will be referred to as Milk River and Second White Specks.

It is expected that exploitation of these low quality sands will continue in shallow Cretaceous formations through existing wells that have generally bypassed these intervals, thus the new projections for the Bearpaw and St. Walburg Formations are fairly aggressive. Caution is advised because the Upper Cretaceous Belly River Formation has so far failed to live up to expectations set in 1998 and its ultimate potential has been revised downward despite a significant increase in the size of its play area.

As for the Lower Cretaceous, the Viking Formation's projection of ultimate potential has been revised significantly downward after very small gains in discovered reserves were added over the past several years. The combined interval of the Mannville Group and Success Formation, the latter included because its Upper Jurassic/Lower Cretaceous age is enigmatic, has been revised slightly upward after showing modest gains in discovered reserves. In total, because of significant additions from the St. Walburg Formation, there has been a slight increase of the Lower Cretaceous projected ultimate potential for gas. Furthermore, the Jurassic section has been significantly revised downward because of negative revisions of the discovered reserves in the Shaunavon and Roseray formations. It would appear that the high maturity of the above plays precludes more major discoveries and, other than the increased known and projected potential of the Mississippian-Devonian Bakken Formation, there is limited potential below the Cretaceous interval.

The discovered reserves of the tight sandstones and siltstones of the Bakken Formation in western Saskatchewan have surpassed 1998 ultimate potential projections for all Mississippian intervals by a small margin. The new ultimate marketable resources are now projected to be twice the 1998 value. The rapid development of the Bakken Formation since 2004 in southeastern Saskatchewan is not incorporated in this report, as it is primarily an oil zone with no known non-associated gas reserves. Estimates of solution or dissolved gas are not presented in this report; however, it is expected that there could be significant volumes of solution gas in the Bakken interval due to the possible large areal extent of the play.

TABLE 3.1

Saskatchewan Play Area Maturity

Formation	Play Area	Percent Drilled
Bearpaw	1	67
Bearpaw	2	17
Belly River	1	39
Ribstone	1	51
Milk River	1	70
Milk River	2	33
Milk River	3	32
Milk River	4	21
Medicine Hat	1	92
Medicine Hat	2	21
Medicine Hat	3	23
Second White Specks	1	28
Second White Specks	2	64
St. Walburg	1	15
Viking	1	46
Viking	2	6
Viking	3	16
Spinney Hill	1	29
Mannville/Cantuar/Premier	1	50
Mannville/Cantuar/Premier	2	75
Success	1	45
Success	2	74
Roseray	1	59
Shaunavon	1	25
Bakken	1	29

There are several active play areas on the Alberta side of the border that do not appear to have been pursued on the Saskatchewan side. Some of these plays, such as the Devonian Leduc zone, have several small oil or gas fields in Alberta, although none have been identified in Saskatchewan.

With respect to well density, the plays in the gas prone areas of Saskatchewan are relatively mature. Several play areas in Saskatchewan currently have more than 50 percent of their play area already drilled (Table 3.1). Several of these more mature play areas are in the shallower Cretaceous strata which the agencies interpret to mean the gas resources have been largely bypassed by early drilling, when the reservoir potential of these zones was not recognized. Such unrecognized potential may have been the result of historically low gas prices that were not able to support development of the lower productivity sands.

Two plays in the Jurassic strata (Success Formation Play Area 2 and Roseray Formation) also have a high percentage of their play areas already drilled but are not expected to have significant undiscovered resources because of very limited discoveries from 1997 to 2004, as previously discussed. Another Jurassic play, the Shaunavon Formation, is currently enjoying a resurgence of activity in the lower part of the formation for light oil. It is not inconceivable that a new gas play could also arise from that same oil exploration play or from a similar Lower Cretaceous, Jurassic or Mississippian oil play.

Despite Saskatchewan's reputation as an oil-rich province, associated natural gas is relatively uncommon. Only the Mannville has what can be considered significant amounts, although it is considerably smaller than its amount of non-associated gas resources. As a result, projections in all formations are dominated by non-associated gas reserves growth.

3.2 Conceptual Plays

Several geological plays were identified as being conceptual. Generally, in these cases, the reservoir potential has been identified by past drilling, but no hydrocarbons have been confirmed through drilling. The project team is of the belief that hydrocarbons will be found in the future. In some cases, there may be secondary evidence of hydrocarbon potential, such as a farm using gas from a zone that has not had commercial success, or a zone that is capable of commercial oil production but in which no gas reserves have been identified. In other cases, commercial quantities of gas have been noted in the "Miscellaneous reserves" category but there are no multi-well pools established yet. Finally, in some cases, the knowledge of a commercial zone on the Alberta side of the border may indicate hydrocarbon potential on the Saskatchewan side of the border. Table 3.2 lists the conceptual plays in Saskatchewan. At this time, no undiscovered resources have been assigned to these plays.

3.3 Access Restrictions

Surface access restrictions may preclude development of some natural gas resources – this can also be referred to as sterilization of the resource. Physical features such as large lakes, difficult topography and environmentally sensitive areas, as well as alternative surface uses such as cities and parks, result in these surface restrictions. In Saskatchewan, there is still a significant volume of gas located within areas that currently can not be accessed because of surface restrictions. The ultimate potential that is expected to be impacted by these restrictions is approximately 5 $10^9 m^3$ (178 Bcf).

TABLE 3.2

List of Conceptual Plays in Saskatchewan

Formation	Play Area	Gas Type	Comments
Quaternary	1	NA	Conceptual Only
Shallow Cretaceous - eastern Saskatchewan	1	NA	Conceptual Only
Victoria Sandstone/Lea Park	1	NA	Conceptual Only
Fish Scale/Colorado/Lwr Colorado	1	NA	Conceptual - miscellaneous gas discovered
Mannville/Cantuar/Premier	3	NA	Conceptual Only
Mannville/Cantuar/Premier	4	NA	Conceptual Only
Success	3	NA	Conceptual Only
Madison Group	1	NA	Conceptual - oil only discovered
Gravelbourg	1	NA	Conceptual - oil only discovered
Birdbear/Torquay	1	NA	Conceptual - oil only discovered
Duperow	1	NA	Conceptual - oil only discovered
Winnipeg Sandstone	1	NA	Conceptual - oil only discovered
Deadwood	1	NA	Conceptual Only
NA=Non-Associated			

Conclusions

- The revised estimate of ultimate potential for marketable conventional gas in the Saskatchewan portion of the WCSB is 297.4 10^9m^3 (10.6 Tcf), a 42 percent increase from the 1998 NEB estimate. Undiscovered potential has increased by 70 percent in Saskatchewan since 1997 to 75.9 10^9m^3 (2.7 Tcf).
- Discovered resources have increased by 30 percent since 1997. Large discoveries made since 1997, such as the Abbey and Lacadena pools, have resulted in the redistribution of undiscovered potential in the geological section towards shallower Cretaceous intervals, which were not recognized to such an extent in past assessments.
- Saskatchewan is a mature region, with several plays currently having more than 50 percent of their play area drilled to date.
- Limits on surface access have significant impact on the exploration for undiscovered resources. The agencies consider 5 10^9m^3 (178 Bcf) of the ultimate potential to be located under lands where access is not currently allowed and where the reservoirs cannot be accessed by directional drilling.
- Saskatchewan holds about four percent of the ultimate remaining conventional natural gas resources in the WCSB, the same percentage it contributes to the annual production from the basin.
- There is the potential for additional unconventional gas resources to be developed in Saskatchewan (Appendix 1).

GLOSSARY

@Risk	A computer program from Pallisade Corporation that adds risk analysis and modeling capabilities to Excel spreadsheets.
Associated gas	Natural gas that overlies and is in contact with crude oil in the reservoir, at original reservoir conditions.
Basin	A segment of the earth's crust which has been downwarped, usually for a considerable time, but with intermittent rising and falling. The sediments in such a basin increase in thickness toward the centre of the basin.
Coalbed methane, or natural gas in coal	An unconventional form of natural gas that is trapped within the matrix of coal seams.
Conceptual plays	Geological plays that are thought to exist or have been shown to exist, but have not been proven by the drilling of oil or gas wells to be capable of production.
Conventional gas	Natural gas that is found in the reservoir and produced through a wellbore with known technology and where the drive for production is provided by expansion of the gas or by pressure from an underlying aquifer.
Discovered volume	The quantity of gas and related substances that are estimated, at a particular time, to be initially contained in known accumulations that have been penetrated by a wellbore.
Gas in place	The total quantity of gas that is estimated to be contained in any given pool or reservoir and includes both the portion that can be recovered and the portion that will remain in the reservoir.
Geological play	A geological configuration, within a defined area, which combines source rock, reservoir rock, trap, migration and preservation in such a way that the critical factors that control the occurrence of oil and gas are essentially similar.
Marketable gas	The volume of gas that can be sold to the market after allowing for removal of impurities and after accounting for any volumes used to fuel surface facilities. As used in this report for undiscovered volumes, it is determined by applying the average surface loss from existing pools in that formation to the recoverable volumes of undiscovered pools of the same formation.

Natural gas in coal	See coalbed methane.
Non-associated gas	Natural gas found in a reservoir in which no crude oil is present at reservoir conditions.
Play area	The geographical area that contains a defined geological configuration within a stratigraphic interval. That geological configuration now contains or is expected to contain producible gas or oil, if the economic conditions are right.
Proppant	A material injected into a rock layer when it is being mechanically fractured. It usually consists of sand grains or ceramic beads and is designed to hold the fracture open after the fracturing pressure is released.
Recoverable gas	The volume of natural gas, including any impurities that can be recovered from the reservoir as a result of natural and/or induced recovery mechanisms. As used in this report for undiscovered volumes, it is determined by applying the average recovery factor from existing pools in a formation to the undiscovered pools of the same formation.
Recovery factor	A factor applied to the gas in place (or oil in place) in a reservoir in order to obtain the volume of gas (or oil) that can be physically recovered at the surface.
Remaining gas	Remaining gas (ultimate potential minus cumulative production) represents the volume available for future market demands.
Reserves	Reserves are estimated remaining marketable quantities of oil and natural gas and related substances anticipated to be recoverable from known accumulations, as of a given date, based on analysis of drilling, geological, geophysical, and engineering data; the use of established technology; specified economic conditions, which are generally accepted as being reasonable, and shall be disclosed.
Reservoir	A porous and permeable subsurface rock layer that contains a separate accumulation of petroleum that is confined by impermeable rock or water barriers and is characterized by a single pressure system.
Resources	As used in this report, resources refers to the total volume of oil or natural gas that is thought to be found in an area, or to that portion of the total resources that is not penetrated by a wellbore to date, or the volume that could be found as a result of appreciation.
Shale gas	A form of unconventional gas where the gas molecules are mainly trapped on the organic material in a host rock of fine-grained shale.

Solution gas (dissolved gas)	Natural gas that is dissolved in crude oil in the reservoir at original reservoir conditions and is normally produced with the crude oil.
Stratigraphic interval	A grouping of all the productive geological formations in the province into layers of sedimentary rocks of approximately the same geological age. For example, the Mannville Group and Cantuar Formation are geologically different, but they are approximately of the same geological age and are grouped in this study.
Surface loss factor	A factor applied to the gas recovered from a reservoir in order to determine the volume of gas actually available to be delivered to the market. It is generally used to account for impurities in the gas and the volume of gas used to fuel the equipment that allows for the production at a particular location.
Tight gas	A form of non-conventional natural gas that is held in the pore space of a rock that has a lower permeability or ability to flow than usual for that type of rock.
Ultimate potential	A term used to refer to an estimate of the marketable resources that will be developed in an area by the time that exploratory and development activity has ceased, having regard for the geological prospects of an area, known technology and economics. It includes cumulative production, remaining reserves, and future additions to reserves through extension and revision to existing pools and the discovery of new pools. For most of this report it is used as a short form of "ultimate potential of conventional natural gas".
Unconventional gas	Natural gas that is contained in a non-traditional reservoir rock that requires significant additional stimulus to allow gas flow. It may be that the gas is held by the matrix material such as coal, ice, or shale; or where the reservoir has an unusually low amount of porosity and permeability.
Undiscovered volume	The portion of the ultimate potential that has yet to be penetrated by a wellbore or that has yet to be proven by changes in a discovered pool's reserves through extension or revision.

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UNCONVENTIONAL GAS

Gas from low-permeability reservoirs, which could be considered as unconventional under some definitions and which is currently being developed, is included in the assessment of conventional ultimate potential in this report. Other unconventional resources such as natural gas in coal (NGC), tight gas, shale gas and gas hydrates are described below qualitatively with no estimates of marketable resources.

A1.1 Natural Gas in Coal

NGC, also known as coalbed methane (CBM), is gas found in coal seams, either in the open fracture pore space of the coal or adsorbed within the matrix of the coal. The majority of the gas is adsorbed in the coal matrix and, in order to get that gas to desorb, the pressure must be reduced. In the U.S., pressure reduction has been achieved by producing the water associated with coal seams, which then releases the gas that is co-produced with the water. Typically, over time, the amount of water produced declines and the amount of gas increases. In Canada, this gas has been commercially produced both from the shallow Cretaceous Horseshoe Canyon Formation and from the deeper Lower Cretaceous Mannville Group in Alberta. The Horseshoe Canyon Formation is a dry coal with little to no water production associated with the gas production. The Mannville coals in Alberta produce NGC with saline water and this water is then disposed into other formations.

In Saskatchewan, the Upper Cretaceous Belly River Formation and the Mannville Group are the two primary potential targets for NGC. Lignitic to sub-bituminous, the coal seams in both geological units are, for the most part, fairly thin (less than 2 m). Multiple seams are common and thicker seams do occur locally. Areas of thicker accumulations for the Mannville include, but are not limited to, the Aberfeldy, Senlac, Winter and Smiley fields. Belly River coals, when found in stacked intervals such as in the Vidora area, can attain aggregated thicknesses of up to 12 m. The reader is referred to Christopher (2003) and Frank (2005) for more information regarding these coal deposits.

Currently, there are no Mannville NGC-producing wells in the province; however, it is felt that some wells producing gas from conventional sandstone reservoirs are being continually charged by an adjacent coal seam. In a few wells in the Belly River, the coal seams have been completed along with gas-bearing sand zones and are contributing to the gas production.

A1.2 Tight Gas, Shale Gas and Hybrid Plays

Low permeability or ‘tight gas’ plays represent the majority of what could be defined as unconventional gas currently under development in Saskatchewan. Stricter Canadian definitions of tight gas are in the process of being developed by the Canadian Society for Unconventional Gas. Future reports by ER or the NEB may use those definitions.

In the U.S., tight gas is defined for tax purposes as production from sedimentary strata with less than 0.1 millidarcies of permeability. Generally, these rocks require the reservoir rock to be fractured using large volumes of fluid, such as nitrogen, under high pressure and the injection of materials (proppants – usually silica sand grains or ceramic beads) to hold the fractures open after the induced pressures are released. In addition, these beds may require the drilling of horizontal wells or multiple vertical wells to efficiently and economically produce these gas resources.

It has been estimated that as much as 30 percent of Canada's conventional gas fits within the tight gas category and studies are underway to more accurately determine that ratio. Saskatchewan plays that could be considered as tight gas formations include the Cretaceous Milk River and Medicine Hat plays; however, in this report, these producing plays have been included as conventional gas. The agencies believe that the conventional GIP attributed to these formations understates additional volumes that could be recognized as tight gas.

Shale gas resources are contained in strata that are comprised of shale – a very fine grained mixture of organic and inorganic material. Gas in these rocks is present within the microscopic pore spaces or adsorbed onto clay and organic material within the matrix. In the past, shales were considered to be a source rock, that is, the source of the petroleum products that migrated to conventional sand and carbonate reservoirs from which they were then produced. The quality of a source rock is dependent on the amount and type of organic material it contains and, for thermogenic gas, on the degree that it has been heated to (via depth and pressure) over time to convert the organic material to hydrocarbons. Biogenic gas, i.e., shallow gas, is generated by the action of anaerobic bacteria that convert the organic material in thermally immature source rocks to methane.

It has now been found that shales can be productive reservoirs with the right stimulation. Furthermore, shales are not simple and cover a wide range of rock types ranging from pure shale to shaley sands or silts, the latter considered by industry to be hybrid shale gas plays. In hybrid gas shales, very thin layers of silt and sand within shales can act as both the reservoir (albeit limited) and the conduit for the gas desorbed from the surrounding shale. All shale gas plays may need multiple wells per section, horizontal wellbores, or additional hydraulic fracturing to achieve economic flow rates. At present, there are several shale gas discoveries in Canada, although only one is currently producing significant amounts of natural gas (the Triassic Montney Formation of northeast British Columbia).

In Saskatchewan, the exploration focus has been primarily on two types of biogenic shale gas potential within the Upper Cretaceous. The first type is a hybrid shale gas play along the Saskatchewan–Alberta border, where thin laminae of sand and silt lie within the shales of the Upper Colorado Group. The reservoir quality of these intervals is not often readily evident on conventional geophysical logs, but can contain stratigraphically trapped, economic amounts of gas such as that found in the Fish Scales/ Joli Fou zone in the Senlac area. Since production started in 2002, 23 wells have produced at various times from this zone with a cumulative production of over 25.9 $10^6 m^3$ (919 MMcf). Other intervals within the Colorado Group that were once lumped and dismissed as 'non-productive shale' are also now being re-evaluated.

The second type of play currently being evaluated is the Colorado shale gas play in the eastern half of the province. These highly organic shales have been the focus of exploration in the past, prior to World War II, when gas seeps were reported near the towns of Kamsack and Hudson Bay. Several wells near Kamsack produced from the early 1930s to late 1940s with total gas production of 4.7 $10^6 m^3$ (168 MMcf). Reporting practices for the Kamsack Gas Pool were less than ideal, as reported production was attributed to only one well. Initial completions indicated that the producing zone was within the Colorado shales, but it is not clear if production was limited to just the shale or

if deeper, more permeable strata were also contributing to the production. From 2001 to September 2008, 59 new wells, licensed for gas, were drilled in the Hudson Bay and Kamsack areas, several of which are still standing cased.

Very little is known about the gas potential of the deeper organic-rich mudstone/shale packages in Saskatchewan. These include, but are not exclusive to, the Jurassic Rierdon, Mississippian Souris Valley and Mississippian-Devonian Bakken formations.

A1.3 Gas Hydrates

Gas hydrates consist of methane molecules trapped within a cage-like structure of ice. In Canada, hydrates have been found in marine areas as ice on or under the ocean bottom or in perma-frost conditions in the north. Saskatchewan is not considered to have any resources of gas hydrates.

Assessment Methodologies Used for Saskatchewan Play Areas

This appendix reviews the methodologies applied to each of the play areas, with reference to the accompanying play map compilation to be published by ER by the end of 2008 (Table A2.1)

TABLE A2.1

Methodology used for Assessing Geologic Plays in the Saskatchewan Conventional Gas Assessment

Geological Age	Play Area	Methodology Used	Reason(s)
Quaternary	Glacial Sand Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Upper Cretaceous	Shallow Cretaceous (Eastern Saskatchewan) Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Upper Cretaceous	Bearpaw Area 1	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Bearpaw Area 2	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Belly River Area 1	@Risk Model	Sufficient Data
Upper Cretaceous	Ribstone Creek Area 1	@Risk Model	Sufficient Data
Upper Cretaceous	Victoria Sandstone/Lea Park Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Upper Cretaceous	Milk River Area 1	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Milk River Area 2	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Milk River Area 3	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Milk River Area 4	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Medicine Hat Area 1	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Medicine Hat Area 2	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Medicine Hat Area 3	NEB/EUB Model	Zone is shallow gas and for continuity across Alberta – Saskatchewan border.
Upper Cretaceous	Second White Specks Area 1	@Risk Model	Sufficient Data
Upper Cretaceous	Second White Specks Area 2	@Risk Model	Sufficient Data
Upper Cretaceous	Fish Scale/Colorado/Lwr Colorado Area 1	Conceptual	Insufficient data for modelling.
Lower Cretaceous	St. Walburg Area 1	@Risk Model	Sufficient Data
Lower Cretaceous	Viking Sand Area 1	@Risk Model	Sufficient Data

TABLE A2.1 (CONTINUED)

Methodology used for Assessing Geologic Plays in the Saskatchewan Conventional Gas Assessment

Geological Age	Play Area	Methodology Used	Reason(s)
Lower Cretaceous	Viking Sand Area 2	@Risk Model	Sufficient Data
Lower Cretaceous	Viking Sand Area 3	@Risk Model	Sufficient Data
Lower Cretaceous	Spinney Hill Area 1	@Risk Model	Sufficient Data
Lower Cretaceous	Mannville/Cantuar/Premier Area 1	@Risk Model	Sufficient Data
Lower Cretaceous	Mannville/Cantuar/Premier Area 2	@Risk Model	Sufficient Data
Lower Cretaceous	Mannville/Cantuar/Premier Area 3	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Lower Cretaceous	Mannville/Cantuar/Premier Area 4	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Jurassic	Success Area 1	@Risk Model	Sufficient Data
Jurassic	Success Area 2	NEB/EUB Model	Insufficient data for @Risk modelling.
Jurassic	Success Area 3	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Jurassic	Roseray Area 1	@Risk Model	Sufficient Data
Jurassic	Shaunavon Area 1	@Risk Model	Sufficient Data
Jurassic	Gravelbourg Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Mississippian	Bakken Area 1	@Risk Model	Sufficient Data
Mississippian	Madison Group Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Devonian	Birdbear/Torquay Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Devonian	Duperow Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Ordovician	Winnipeg Sandstone Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.
Cambrian	Deadwood Area 1	Conceptual	Zone present, but not proven by the drilling of oil or gas wells.

Maps Showing the Resource Distribution in Saskatchewan

FIGURE A3.1

Discovered Conventional Natural Gas Resources

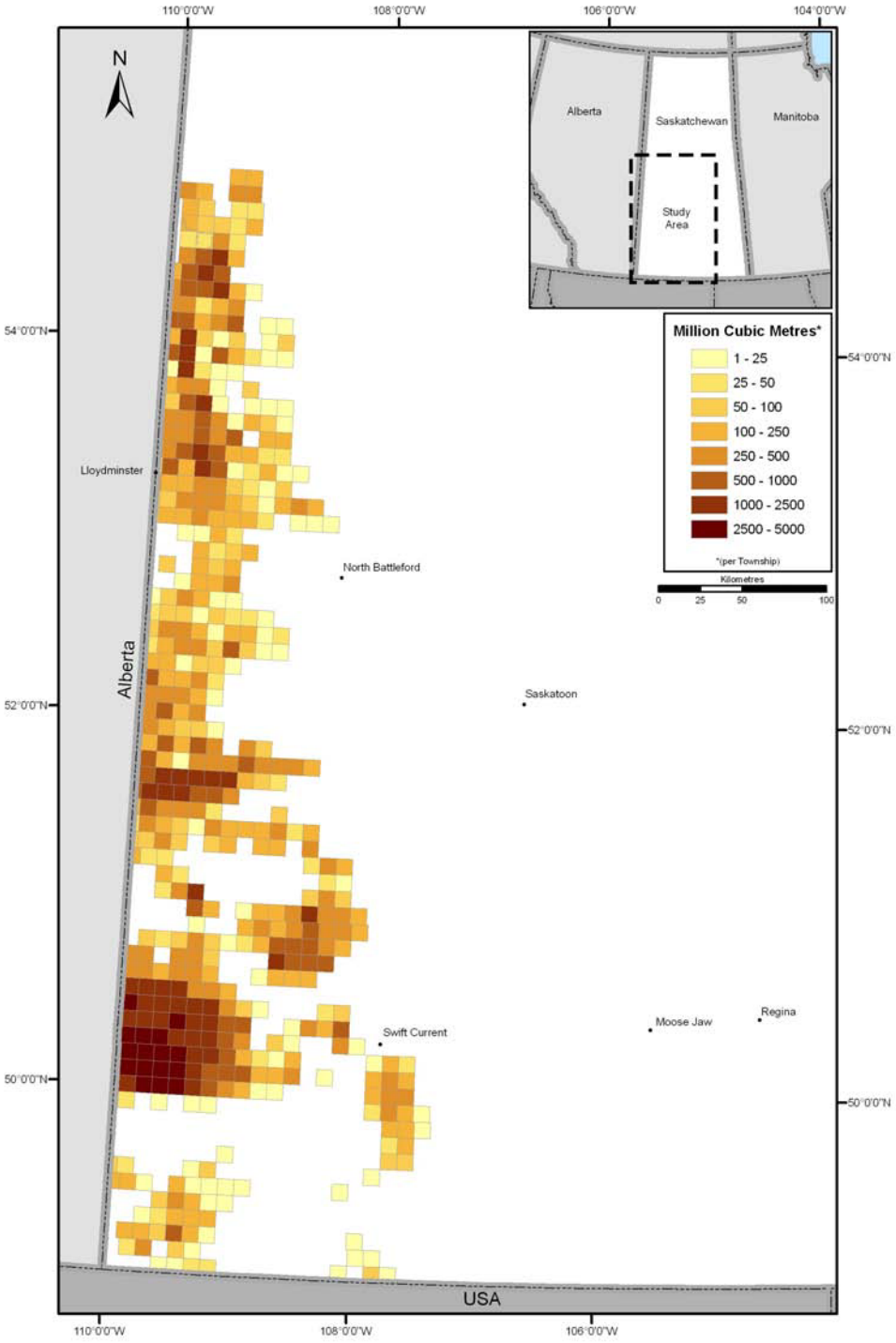

FIGURE A3.2

Undiscovered Conventional Natural Gas Resources

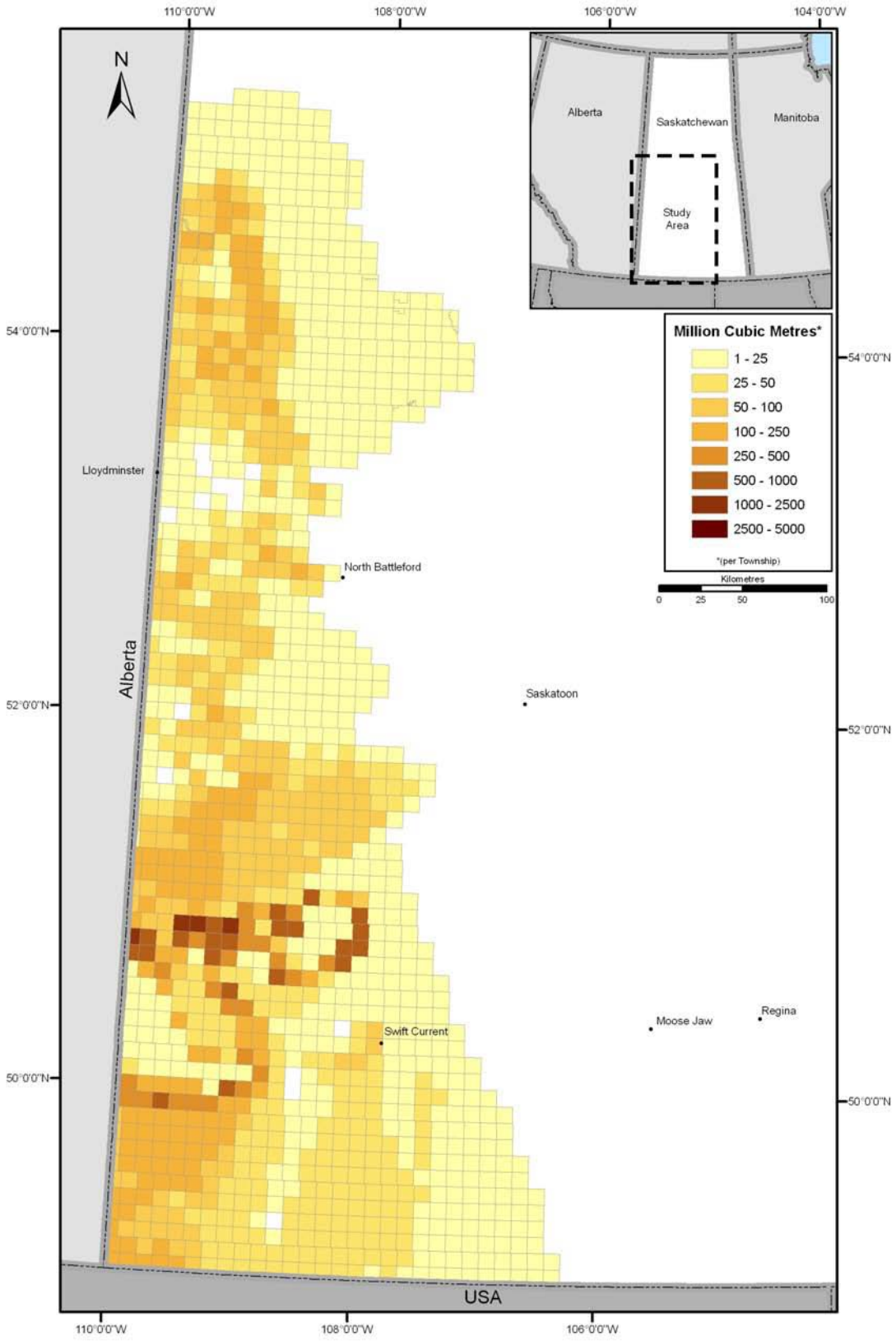

FIGURE A3.3

Ultimate Potential for Conventional Natural Gas

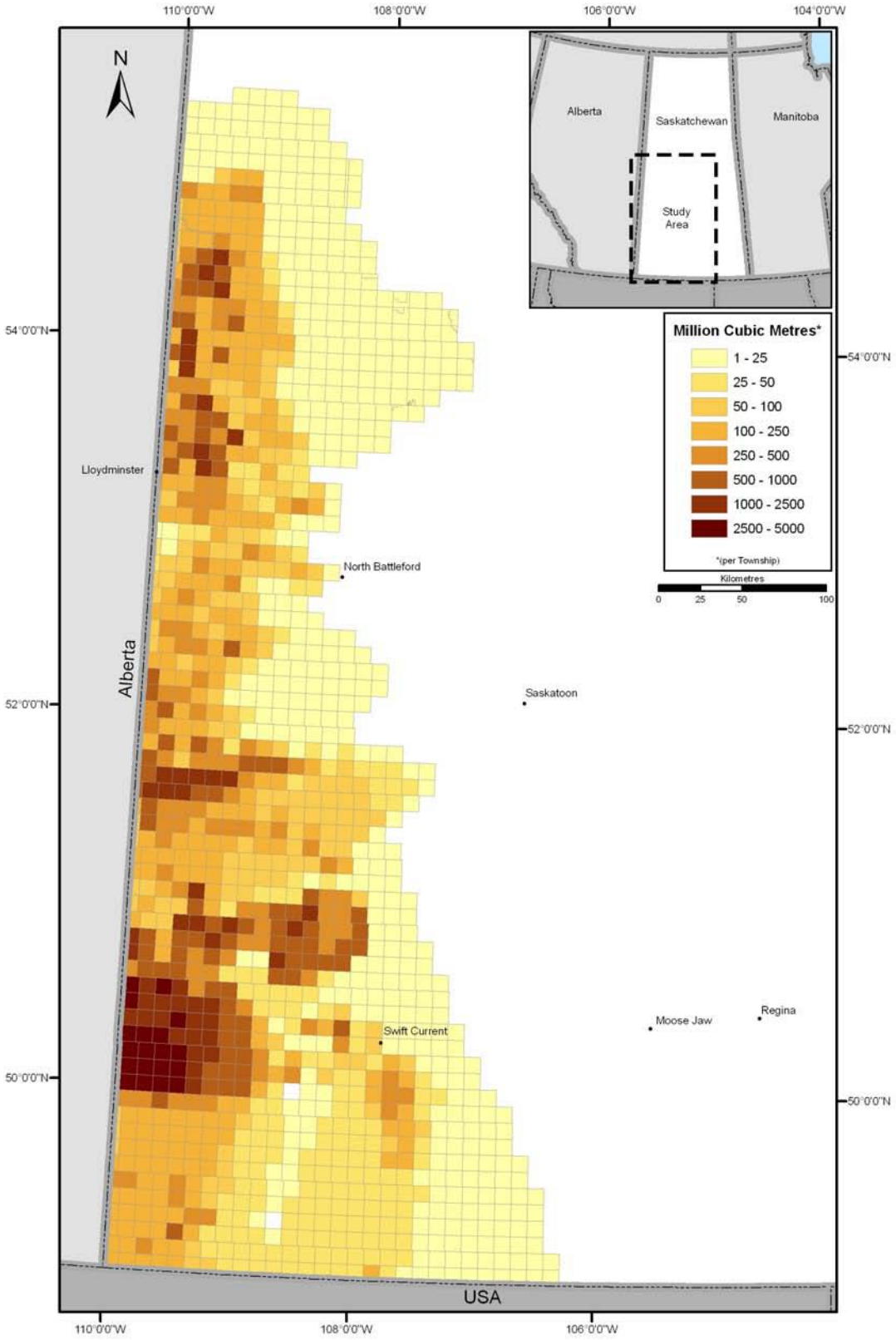

FIGURE A3.4

Remaining Ultimate Potential for Conventional Natural Gas