GAS RESERVES GROWTH
IN THE
WESTERN CANADA SEDIMENTARY BASIN

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Prepared For Presentation:
May 30, 1995
1995 CSPG - CWLS Symposium, Calgary, Alberta
Session, Reserve & Reservoir Modelling

ABSTRACT

Gas Reserves Growth in the Western Canada Sedimentary Basin

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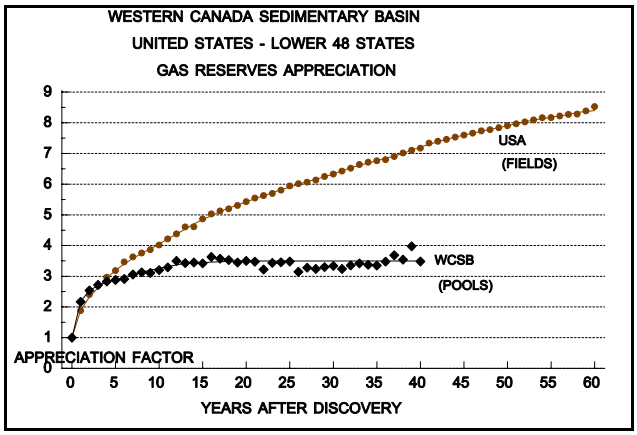
Reserves growth, or reserves appreciation, is the reserves that will be added in the future from existing discoveries, and is an important aspect in assessing the total resources for a region or country. Recent reports highlight the importance of reserves growth in assessing future natural gas resources for the United States. This paper reviews the historical record for reserves growth in the Western Canada Sedimentary Basin, the impact on future gas resources and makes comparisons with the lower 48 United States.

There are important differences concerning reserves growth in the United States and Canada. In the US there is a more restricted definition of reserves, with proved reserves credited to the year of discovery on a field basis. In Canada reserves data are reported on a pool basis, and includes established reserves estimates for in-place, recoverable, and marketable gas. Established reserves, are generally considered closer to the true ultimate, including proved plus a portion of probable reserves. There are more factors which can impact reserve growth of US fields versus pools in the Western Canada Sedimentary Basin. Canadian pools can grow only through pool extensions, infill drilling, and improved recovery.

Reserve growth curves for natural gas, using year of discovery data, have been constructed for Western Canada and the USA. Cumulative growth factors are 8.5 for the US, and 3.5 for the Western Canada Sedimentary Basin. The US growth occurs over a period of at least 60 years, with 80% of the growth achieved in about 35 years. For the Western Canada Sedimentary Basin maximum growth is achieved in about 15 years and 80% of the growth is achieved in the first 4 to 5 years. Although important, the impact of reserves growth on the ultimate gas resource for the Western Canada Sedimentary Basin is minimal.



Gas Reserves Growth in the Western Canada Sedimentary Basin

K.J. Drummond, National Energy Board

Recent studies have placed considerable emphasis on the subject of reserves appreciation and its possible impact on future supply of natural gas. This paper reviews the historical record for gas reserves growth in the Western Canada Sedimentary Basin; it's impact on future resources, and makes comparisons with the Lower 48 United States.

The Western Canada Sedimentary Basin (Figure 1) covers an area of approximately 450,000 square miles, thickening from a zero edge along the Canadian Shield to over 6 kilometres in the Rocky Mountain Foothills. Sedimentary fill is approximately 500,000 cubic miles.

The distribution of gas resources by provincial area is shown in Figure 2, and tabulated in Figure 3. The current NEB estimate for ultimate marketable gas resources is 255.0 trillion cubic feet. Cumulative production to the end of 1993 is 81.5 TCF, with remaining reserves of 66.5 TCF. Undiscovered gas resource is estimated at 101.0 TCF, and an additional 6.0 TCF is expected to be added by reserves appreciation of existing discoveries. Estimates of remaining reserves of natural gas were compiled from assessments and studies of individual pools by Board staff, industry studies and estimates from provincial agencies.

Figure 4 illustrates marketable gas resource potential estimates, through time, for the Western Canada Sedimentary Basin (WCSB). Estimates have more than doubled over a twenty year period and the total of cumulative production plus remaining established reserves exceed estimates of potential dating from the mid-1970's. Estimates for undiscovered conventional gas resources often display a wide range. These estimates are expected to change over time with the development of new technologies, increase in geological or geophysical knowledge, or the range of supply costs. The estimates represent the marketable gas portion of the undiscovered resource.

The pool size distribution of initial established marketable reserves in the Western Canada Sedimentary Basin is shown in slides 5 and 6. For the total population the mode, or most likely pool size is 0.5 BCF. Before 1960 there were only 2,076 (8%) pools discovered, containing 57.2 TCF (40%), of the Western Canada Sedimentary Basin discovered marketable gas. Approximately one half (51%) of the pools were discovered before 1980, and contain 82% of the marketable gas.

Figure 7 and 8 show another view of the discovered gas over time. The number of pools discovered each year is increasing with fewer reserves added per year. Shown along the bottom of Figure 8 is the average pool size, deceasing from 63.5 BCF for pools discovered before 1950 to 2.0 BCF for pools discovered in 1990 - 1993. It is expected the average pool size in the future will be about 1.5 BCF. A total of 26,120 pools, containing 148 TCF of marketable gas have been discovered, for an overall average pool size of 5.7 BCF. Approximately 28% (40.9 TCF), of the Western Canada Sedimentary Basin gas was discovered in the period 1950 - 1959.

The undiscovered potential will be found in many more pools than in the past. The number of future pools will likely number in the ten's of thousands.

Figure 9 gives a definition of reserves appreciation for the U.S., taken from the NPC 1992 Natural Gas Study. It is the reserves that will be added in the future from existing discoveries. Appreciation may occur by extension of the existing discoveries and by improved recovery.

It is important to understand the differences between Canada and the U.S. concerning reported reserves. Reporting of United States reserves estimates includes only proven reserves. The Energy Information Administration (EIA) defines proved reserves as "those volumes of oil and gas that geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions." In the U.S., reporting of reserves is based on field designations, rather than a pool-by-pool basis as in Canada. As such, reserves appreciation for a field includes new pool discoveries, deeper pool discoveries and pool extensions. Although the range of estimates assigned to reserves appreciation in the U.S. vary greatly, the overall effect is significant.

Reserves appreciation in Canada is considered to be considerably less significant than that being suggested for field growth in the United States. In the Western Canada Sedimentary Basin reserves are reported as initial established on a pool basis. Initial established reserves, generally include proved reserves plus a portion of the probable, generally one-half. The initial established reserves is meant to be as accurate an estimate of the true reserves as possible, and some of the appreciation potential is accounted for in the original estimate. The inclusion of some probable reserves also adds a degree of uncertainty to the reserve estimate.

There is a greater opportunity for reserves growth in the USA, than there is in Canada. Western Canada gas reserves can grow only through pool extensions and revisions due to infill drilling, improved technology and enhanced recovery.

Figure 10 is a graphic illustration that significant reserves growth has occurred in the Western Canada Sedimentary Basin. Shown is the cumulative production and remaining reserves for the Western Canada Sedimentary Basin gas pools by year of discovery. The upper curve represents the initial established marketable gas for pools by year of discovery, as estimated year-end 1993. There are two periods of increased rate of reserves additions, 1951 to 1961, and 1975 to 1980. Also note that post-1980 discoveries have added little to cumulative production, but there is still a significant growth in reserves over the period.

Overlain on the year of discovery data is the actual year-end estimates that were made at the time. The difference between this line and total established reserves is an indication of the reserves appreciation that has occurred. For instance the total reserves for pools discovered in 1960 and earlier in 1992 was estimated to be 60 TCF, whereas the estimate made at the end of 1960 was only 35 TCF, indicating a reserves growth of 25 TCF for pools discovered to the end of 1960. At the end of 1980, the difference is only 12 TCF, indicating that reserves added by reserves appreciation were approximately 23 TCF in 20 years, or 1.2 TCF per year on average. At the end of 1990, the difference is only 5 TCF, suggesting that reserves appreciation for 1990 and earlier pools is 55 TCF for 30 years, or 1.8 TCF per year. Although this chart clearly shows that reserves growth has occurred it is difficult to quantify any numbers from this chart.

Figure 11 shows the actual reserve estimate by year of discovery for individual years. There is quite a divergent spread and it is difficult to get an average growth curve from this chart. It is necessary to aggregate the data to establish appreciation factors.

There are several methodologies developed to calculate a growth factor from historical data. The one used has been adapted from CERI and Walter Haessel (CEC), shown graphically in Figure 12. It involves tabulating year of discovery data in such a manner that all years after discovery are lined up in columns. All one year after discovery numbers are in one column, as are the two year, three year, etc. An appreciation factor for a certain year is obtained by summing a certain number of years data, i.e., 1979 to 1992 and dividing by the same years in the previous column. The factors are then accumulated to get the cumulative appreciation factor. This methodology has been applied to the Western Canada data and the DOE year of discovery data for the USA, published by Attanasi and Root in the June 1993 AAPG Bulletin.

Gas appreciation curves for the US Lower 48 States and the Western Canada Sedimentary Basin are plotted in Figure 13. Examining these curves suggests that the appreciation factor in the United States for proven reserves in fields is at least 8.5 compared to 3.5 for established reserves in pools in western Canada. The growth curve for the Lower 48 basins occurs over a considerable period of time. The factor could exceed a multiplier of 8.5 over time. Whereas for Canada, the growth curve is lower, with a maximum multiplier of only 3.5, with 80 percent of the growth attained within 4 years following discovery. In fact, some of the resource assigned as appreciation in Canada is often recorded at the same time as the original discovery due to the additional drilling that occurs in the one to two year period after discovery, prior to the recording of the reserves.

Since reserve growth is more likely to be applicable to larger fields and/or pools and smaller pools are expected in the future, we could expect reserves growth for gas pools to be less than in the past.

Individual pool estimates are generally only available since about 1962. I have examined about 100 of the largest Western Canada Sedimentary Basin gas pools, which in general are greater than 10 BCF. Figures 14 and 15 are just two of these pools to show the great variability in the reserve estimates, for gas-in-place, recoverable raw gas, and marketable gas, as well as cumulative marketed production. Since there are a significant number of sour gas pools in the Western Canada Sedimentary Basin, there is often a great variability in estimating the shrinkage factor.
Figure 14 shows a uniform growth history for the Blackstone Beaverhill Lake A pool. This is one of the few larger gas pools for which there is a complete historical record, from the year of discovery. Laprise Creek Baldonnel A, (Figure 15) is a typical picture for one of the larger, older gas pools, many of which have been overestimated, and later require negative revisions.

From the group of 100 pools, there were 63 pools, with an adequate record from the early 1960's to the end of 1993. The aggregate curve for these 63 pools is shown in Figure 16. This gives a rather uniform growth curve, and one could possibly use this curve to apply to any larger new pools, that are discovered. The maximum appreciation factor for the 25-year history of these pools is 2.3. As the Western Canada Sedimentary Basin maximum factor is 3.5, we conclude that the appreciation for the other pools, which have not been evaluated, would be slightly larger than 3.5, the basin average.

In the Western Canada Sedimentary Basin, mainly Alberta, there are several multi-field pools. These are gas pools in a single reservoir, which extend over two or more field areas. These may have been single pool discoveries, which over time, development has found to be one large pool. In the database, these are generally considered as separate pools.

The historical record on some of the larger multi-field pools has been tabulated, to track the growth of reserve estimates, and aggregated. Many of these pools were discovered in the early 1900's, and undoubtedly there was significant growth of these pools in the earlier years. As shown in Figure 17, on an aggregate basis there has been essentially no change in reserves estimates for the past 13 years. Most of these are shallow, low-pressure reservoir pools, which require close spacing and many wells. Infill development can increase producibility, and could possibly add reserves for these pools.

Appreciation factors (Figure 18) developed from the growth curves have been applied to the Western Canada Sedimentary Basin, and this gives a reserves growth potential of 6.0 TCF possibly available from the discovered pools.

Figure 19 shows the discovered reserves by year of discovery, and also the appreciated reserves, which could be added using the data from Figure 18. Even with appreciation the reserves discovered in the 1980's is significantly less than that discovered in the 1970's.

Figure 20 illustrates the growth of marketable gas by year of discovery versus cumulative number of gas pools for unappreciated and appreciated marketable gas values. The growth curve shows a typical double exponential discovery pattern, as observed by Root and others of the USGS. The largest part of the marketable gas (40%) was discovered with the first 5,000 pools before 1970, and the largest numbers of pools discovered are post 1970. As shown the difference between the unappreciated and the appreciated values are rather small. However the change in the trend of the values becomes very important in making any forward projection.

Major conclusions are:

(1) In the Western Canada Sedimentary Basin discovered pools can grow only through pool extension and improved recovery.

(2) The inclusion of probable reserves in the initial estimate leaves less opportunity for future growth.

(3) Reserves growth of larger, older pools and multi-field pools is expected to be minimal, generally offset by negative revisions.

(4) Appreciation factors should be developed to estimate the amount recent discoveries could grow in the future.

(5) Appreciation of existing discoveries is estimated to be 6.0 TCF as of December 31, 1993.

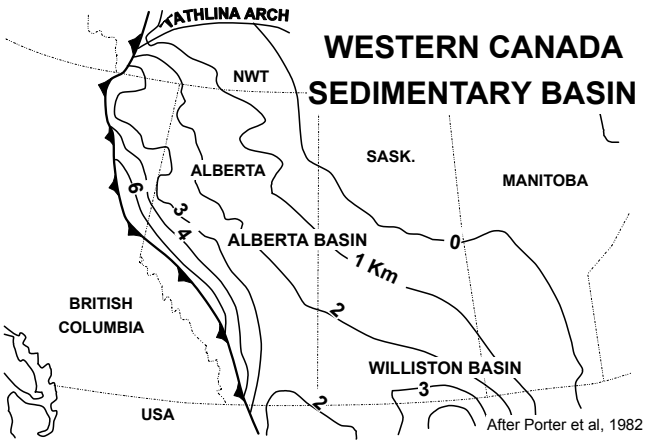


FIGURE 1.

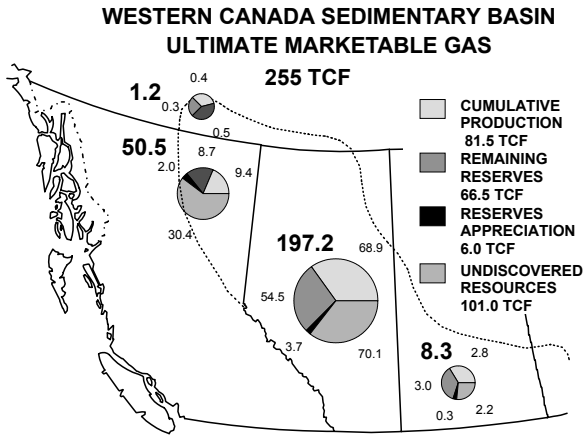


Figure 2.

WESTERN CANADA SEDIMENTARY BASIN
MARKETABLE GAS RESOURCES (TCF)
(DECEMBER 31, 1993)

CUMULATIVE PRODUCTION	81.5
REMAINING RESERVES	66.5
RESERVES APPRECIATION	6.0
UNDISCOVERED RESOURCES	101.0
ULTIMATE RESOURCES	255.0

Figure 3.

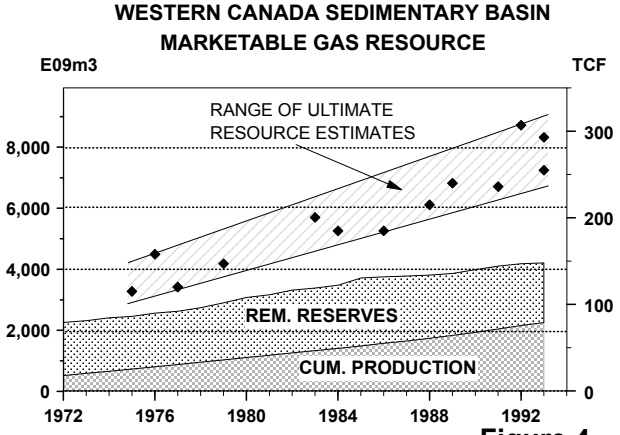


Figure 4.

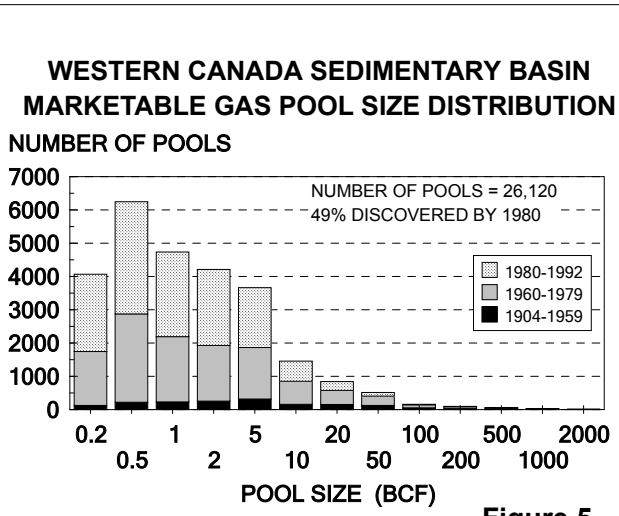


Figure 5.

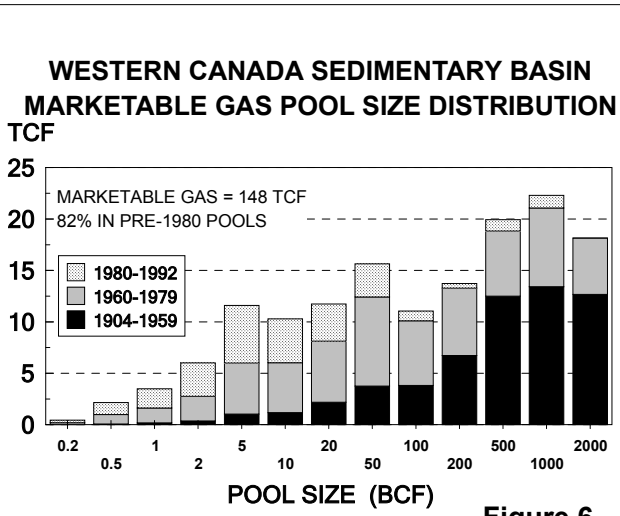


Figure 6.

WESTERN CANADA SEDIMENTARY BASIN
NUMBER OF GAS POOLS BY DECADE

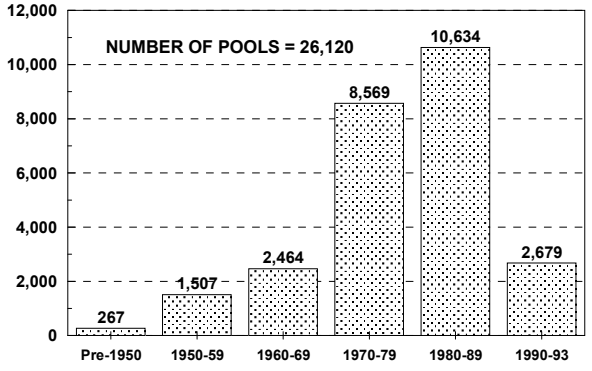


Figure 7.

WESTERN CANADA SEDIMENTARY BASIN
MARKETABLE GAS BY DECADE

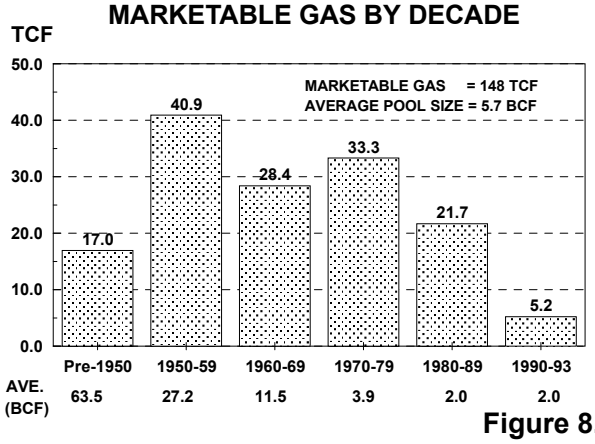


Figure 8.

RESERVES APPRECIATION

- **That portion of the resource base resulting from the recognition that the currently booked proved reserves are conservative by definition and will continue to grow over time.**
- **It is an estimate of the growth expectation from today forward for currently discovered conventional gas fields.**
- **The appreciation occurs as a result of reserve additions from field extensions, new reservoirs and revisions due to infill drilling, improved technology, enhanced recovery, well workovers and recompletions.**

NPC, 1992

Figure 9.

WESTERN CANADA SEDIMENTARY BASIN
MARKETABLE GAS PRODUCTION AND RESERVES
CUMULATIVE BY YEAR OF DISCOVERY

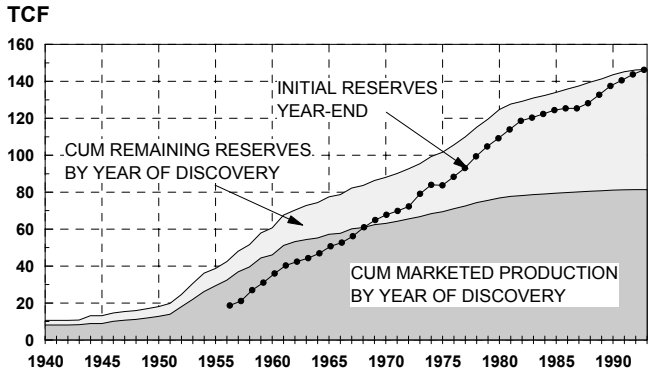


Figure 10.

WESTERN CANADA SEDIMENTARY BASIN
MARKETABLE GAS RESERVES BY YEAR

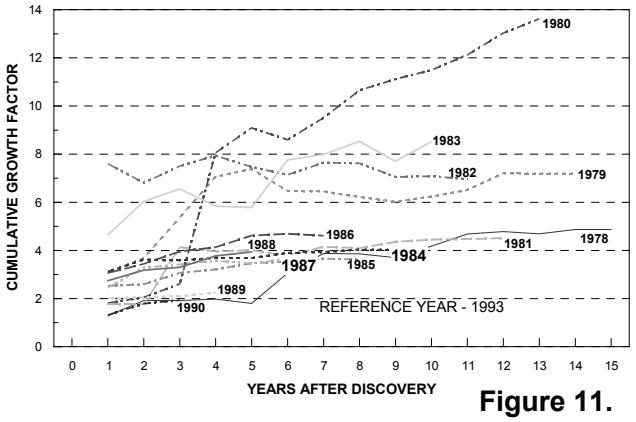


Figure 11.

CALCULATION OF APPRECIATION FACTOR

	A	B	C	D	E	F
1	YEAR OF DISC.	YEARS AFTER DISCOVERY 0	1	2	3	4
2	1983					1.2
3	1984				1.2	1.3
4	1985			1.0	1.3	1.4
5	1986		1.2	1.4	1.5	1.6
6	1987	0.4	1.0	1.4	1.4	1.5
7	1988	0.6	1.6	1.8	1.9	2.2
8	1989	0.8	1.5	1.5	1.6	
9	1990	1.1	1.5	2.1		
10	1991	0.6	1.4			
11	1992	0.4				
12	SUM (C6..C10) →		9.3	10.4	10.3	11.0
13	SUM (B6..B10) →		4.3	8.9	9.6	10.3
	YEAR APPR. FACTOR		2.1	1.2	1.1	1.1 ← F12/F13
	CUM. APPR. FACTOR		2.1	2.5	2.7	2.8

1993 YEAR OF DISCOVERY DATA

Figure 12.

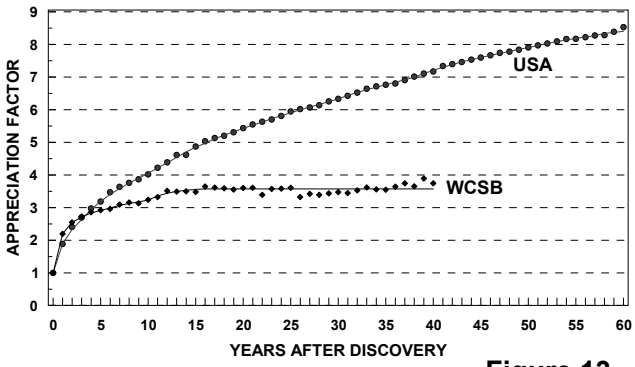


Figure 13.

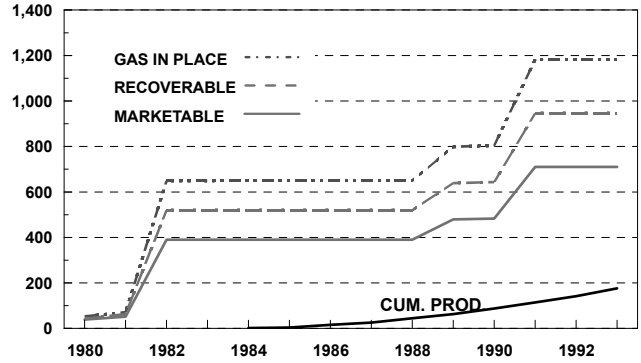


Figure 14.

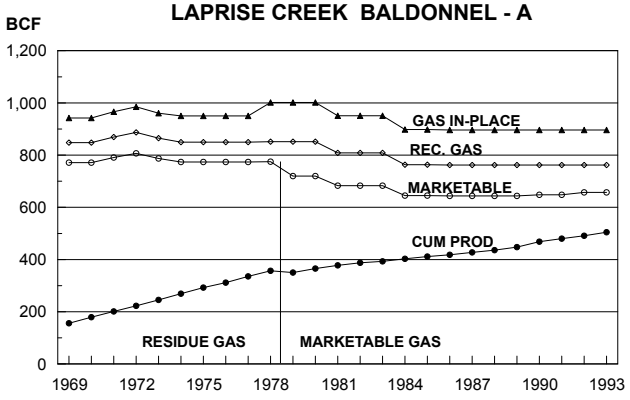


Figure 15.

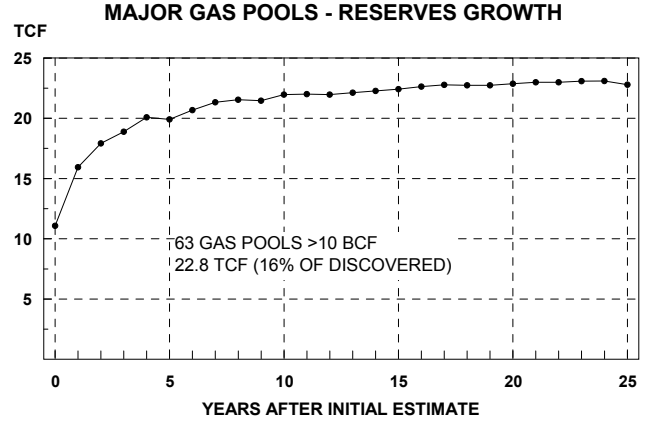


Figure 16.

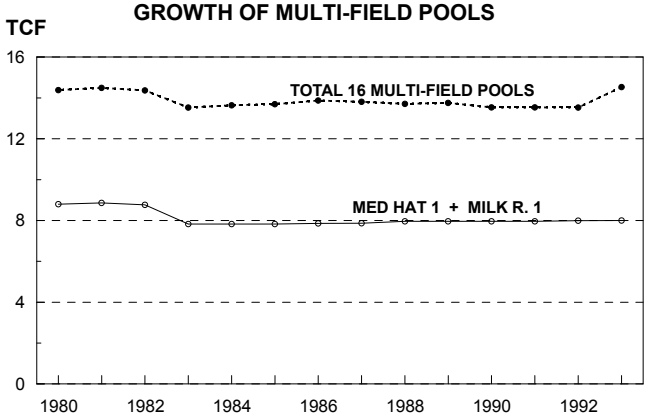


Figure 17.

WESTERN CANADA SEDIMENTARY BASIN
RESERVES APPRECIATION (BCF)

YEAR OF DISCOVERY	RESERVES YR OF DISC	APPREC. FACTOR	APPREC. RESERVES	RESERVES BY APPREC
1978-79	8,890	1.007	8,953	62
1980	4,271	1.020	4,356	85
1981	2,817	1.037	2,922	104
1982	1,485	1.063	1,579	94
1983	1,660	1.105	1,834	174
1984	1,361	1.125	1,531	170
1985	1,562	1.142	1,784	222
1986	1,784	1.164	2,076	293
1987	1,560	1.195	1,864	304
1988	2,547	1.227	3,014	558
1989	1,707	1.260	2,151	444
1990	2,335	1.317	3,075	740
1991	1,581	1.402	2,217	636
1992	936	1.626	1,522	586
1993	591	3.570	2,110	1,519
TOTAL	34,998		40,988	5,991

Figure 18.

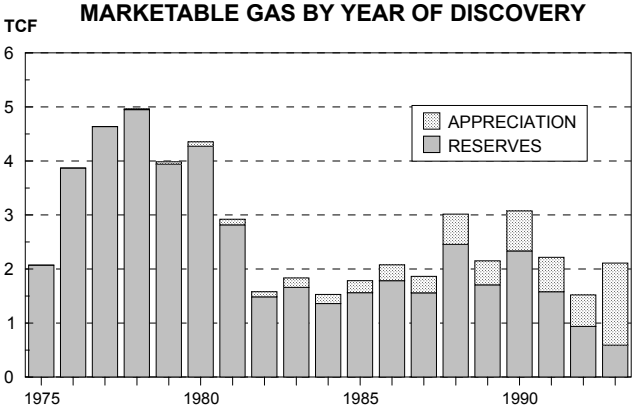


Figure 19.

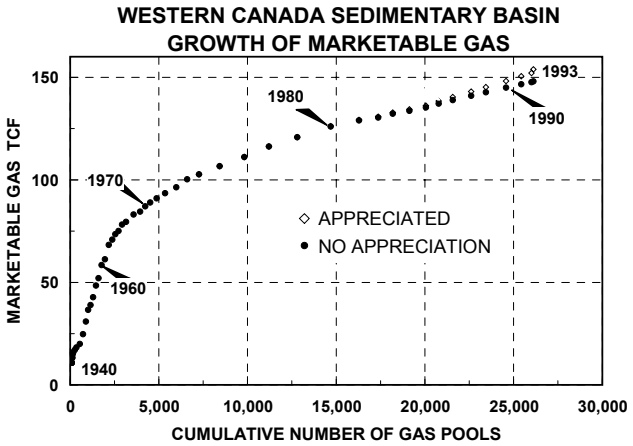


Figure 20.

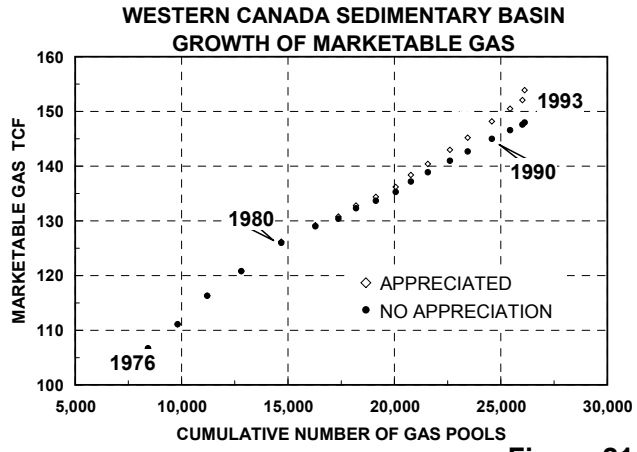


Figure 21.

CONCLUSIONS

- **Discovered pools can grow only through pool extension and improved recovery**
- **Inclusion of probable in initial estimate lessens the opportunity for reserves growth**
- **Reserves growth of larger, older pools expected to be minimal and offset by negative revisions**
- **Appreciation factors should be applied to year of discovery data to determine appreciated reserves**
- **Appreciation of existing discoveries estimated to be 6.0 TCF (Dec. 31, 1993).**

Figure 22.