AREAS RECOMMENDED FOR

TIGHT FORMATIONS

IN

MERCER, McDOWELL, AND WYOMING COUNTIES

WEST VIRGINIA

TIGHT FORMATION COMMITTEE'S REPORT

NOVEMBER, 1981

(Tight Formation Committee, 1981)

CONTENTS

(Tight Formation Committee, 1981)

LIST OF APPENDICES

(Source: West Virginia Geological and Economic Survey)

(Tight Formation Committee, 1981)

LIST OF FIGURES

(Tight Formation Committee, 1981)

LIST OF EXHIBITS

(Tight Formation Committee, 1981)

LIST OF EXHIBITS (CONT'D)

INTRODUCTION

This report of the West Virginia Tight Formation Committee covers the three county area of Mercer, McDowell and Wyoming Counties. Sandstones recommended by the Committee as qualifying to be designated as tight formations are described in the first section of the report. In the second section, the various types of geological and engineering data used in making these recommendations are described. The Committee's recommendations are based on calculations of expected in-situ permeabilities, stabilized natural production rates, and oil production rates, as outlined in the Federal Energy Regulatory Commission's (FERC) guidelines for tight formations. The Committee also addressed the requirement of protecting fresh water aquifers before setting forth their final recommendations in a concluding section.

Composition of the Injun sandstone is ± 70% quartz, with the remaining 30% consisting of clays, feldspar and calcite. The Injun sandstone is poorly developed and ranges in thickness from a maximum of ± 10 feet in northwestern Wyoming County to thin stringers to the south and east. As shown on Figure 5, there are no producing Injun wells in the submittal area due to the lack of significant porosity and the shaliness of the sandstone.

3. Weir Sandstone: The Weir sandstone lies ± 20 feet below the Injun sandstone and ± 200 feet above the Berea Sandstone (see Fig. 2). The sandstone is gray to white, very fine grained, well sorted and argillaceous. The composition of the Weir sandstone is ± 70% quartz, with the remaining 30% being kaolinite (primary), feldspar, illite, mixed-layer clays and chlorite. The Weir ranges in thickness from thin stringers in the eastern and western part of the three county area to 60 feet thick in the central portion of the area (see Fig. 6).

4. Berea Sandstone: The Berea Sandstone lies ± 200 feet below the Weir sandstone and is the basal sandstone of the Mississippian System. The sandstone is gray, medium to fine grained, and poorly sorted. Composition of the Berea Sandstone is ± 70% quartz, with the remaining 30% being feldspars, clays and calcite. The Berea Sandstone reaches a maximum thickness of 45 feet in the central portion of McDowell and Wyoming Counties and thins to shaly sandstone stringers in the eastern portion of the evaluated area (see Fig. 7).

(Tight Formation Committee, 1981)

Permeability

Average in-situ permeability thoughout the pay sections of the Princeton - Ravencliff, Injun, Weir, and Berea Sandstone is expected to be less than 0.1 md. except in those field areas outlined in red and hatchered on the attached formation maps (Figs. 3, 5, 6, and 7). The method used to determine permeabilities is described below.

The method of determining permeability involves the relationship between measured core porosities and permeabilities from existing core data. All the above sandstones are consistent in that those with low porosity exhibit little or no premeability, whereas those with high porosity exhibit fair to good permeability.

Princeton - Ravencliff Sandstone Permeability - Central and Southwestern Areas

As described in the Fayette and Raleigh Counties report previously submitted by the Committee, two cores were analyzed, one from the Appalachian Exploration & Development #1 Bell (Permit Nic 445) well located in Nicholas County, West Virginia, and the other from the Appalachian Exploration & Development #1 Wriston (Permit Ral 460) well located in Raleigh County, West Virginia (Fig. 1). No additional cores were available in the three counties being submitted. However, the Ravencliff in the central and southeastern portion of the submittal area (see Fig. 3) is stratigraphically and environmentally equivalent to the sandstone to the north in Fayette and Raleigh Counties (delta facies). Plotting core-derived permeability versus porosity through the pay section for the above two wells (Exhibit Nos. I and II) shows that an average porostiy of 5.7% or less is expected to be associated with a permeability of less than 0.1 md. Plots of log porosity versus core porosity for the above two wells (Exhibit Nos. III and IV) show the close agreement

Please refer to the attached computer map (Fig. 6), in which an average well (based upon the average after frac volume for the field) was selected from each field to determine permeability. Fields with an average well porosity of less than 8.2% will qualify as tight formation fields. Porosities were calculated from representative wells in interfield areas and these wells showed less than 8.2% porosity and therefore qualify as tight formation areas. Water-bearing areas exhibit greater than 8.2% porosity and therefore do not qualify as tight formation areas.

Berea Sandstone Permeability

Cores were available from twelve wells in southern and central West Virginia, and eastern Kentucky. Data from ten of these wells (Exhibit Xl) were analyzed to evaluate permeability in the Berea Sandstone. Exhibit XI summarizes the ten wells and their porosities that are expected to be associated with a permeability of less than 0.1 md. Plots of core porosity versus permeability for these wells are Exhibits XII - XXI. Therefore, an average porosity of 7.7% or less is expected to be associated with a permeability of less than 0.1 md. A comparison of log porosity versus core porosity for four repersentative wells (Exhibit XXII) shows the close agreement between the results of these two methods. Therefore, where cores do not exist, log-derived porosities can be used to determine permeability.

Please refer to the attached computer map (Fig. 7), in which an average well (based upon the average after frac volume for the field) was selected from each field to determine permeability. Fields with an average well porosity of less than 7.7% will qualify as tight formation fields. Porosities were calculated from representative wells in interfield areas and these wells showed less than 7.7% porosity and therefore qualify as tight formation areas.

Please note on Figure 7 that the fringe areas of Huff Creek, Baileysville

(Tight Formation Committee, 1981)

and Mann-Oceana Fields qualify as tight formation areas. These areas are characterized by:

1. Huff Creek Fields A and B - Sufficient porosity logs were available to prove that the fringe area exhibits less than 7.7% porosity and, therefore qualifies as a tight formation area.
2. Baileysville B and Mann-Oceana Fields - Sufficient porosity logs were not available (old wells), therefore unstabilized natural flows were used to delineate tight formation ares.

Areas within the above mentioned Berea fields which exhibited greater than 7.7% log porosity or unstabilized natural flows greater than 91 Mcf were excluded.

Stabilized Production Rates

There are no examples of stabilized natural production against atmospheric pressure from the Princeton - Ravencliff, Injun, Weir or Berea Sandstones in Mercer, McDowell and Wyoming Counties, West Virginia. The absence of stabilized natural rates is due to the fact that tests conducted during drilling were either of short duration or were unrecorded. In order to obtain a stabilized flow to the atmosphere from the subject formations, it would be necessary to shut the drilling rig down for extended periods of time, a practice which is economically unfeasible. In addition, large volumes of gas would be vented to the atmosphere and wasted. The recorded natural flows (see Appendices) were generally from wells of exceptional magnitude, whereas natural flows from wells with small flows or no shows were not recorded. Therefore, natural flows as shown under Initial Gas Volumes (see Appendices) are always higher than stabilized natural flows to the atmosphere would be.

Natural flows after perforations, but before stimulation, are not recorded by operators in West Virginia because these flows are generally too small to measure.

(Tight Formation Committee, 1981)

Oil Production Rates

Oil production before stimulation in the Princeton - Ravencliff, Injun, Weir and Berea Sandstones meets the five barrels of oil per day (BOPD) maximum set by FERC. Based on the production history of all five sandstones in the recommended areas (see Appendices), no production of crude oil is expected.

Protection of Fresh Water

Existing State and Federal Regulations will assure that development of the Princeton - Ravencliff, Injun, Weir and Berea sandstones will not adversely affect any fresh water aquifers that are, or are expected to be, used as domestic or agricultural water supply. In West Virginia, the Oil and Gas Division of the State Department of Mines has the statutory responsibility for protecting surface and subsurface water from oil and gas production-associated activities. West Virignia Administrative Regulations (1979 Edition) Chapter 22-4 Section 15.01, 15.02, and 15.03 state as follows:

"15. Regulations Related to Code 22-4-5, 22-4-6, 22-4-7, 22-4-8, and 22-4-8a

15.01 Casing Not Exclusive. In addition to the casing and required by Code 22-4-5, 22-4-6, 22-4-7, 22-4-8, and 22-4-8a, there shall be used in each well such material and equipment and there shall be employed such additional procedures as are necessary for the purpose of separating high pressure zones from low pressure zones, the producing horizons, the water bearing strata, and mineable coal zones for the life of the well.

15.02. Multiple Casing Through Coal Seams. (a) The coal protection string of casing required by Code 22-4-5 through 22-4-8 to be installed through the workable coal seam or seams shall be in addition to the production string of casing.

(b) The coal protection string of casing required by Code 22-4-5 shall have cement circulated in the annular space outside said casing. The volume of cement needed shall be calculated by using approved engineering methods to assure the return of the cement to the surface. In the event cement does not return to the surface, every reasonable attempt will be made to fill the annular space by introducing cement from the surface.

15.03. Fresh Water Casing. The fresh water protective string of casing required by Code 22-4-8a shall extend 30 feet below the deepest fresh water horizon (being the deepest horizon which will replenish itself and from which fresh water or usable water for household, domestic, industrial, agricultural, or public use, may be economically or feasibly

(Tight Formation Committee, 1981)

recovered), and shall have cement circulated in the annular space outside said casing. The volume of cement needed shall be calculated using approved engineering methods to assure the return of the cement to the surface. In the event cement does not return to the surface, every reasonable attempt will be made to fill the annular space by introducing cement from the surface. If the coal protection string of casing is cemented to the surface in accordance with prescribed procedure, this may also be considered a fresh water string for water strata above the coal."

The Oil and Gas Division is required by statute to enforce proper casing and plugging practices which will protect subsurface fresh water aquifers. Legislation also allows the West Virginia Oil and Gas Conservation Commission to adopt and enforce rules and orders which relate to the prevention of pollution in regard to drilling, producing and operating deep gas wells, and oil wells in secondary recovery projects.

CONCLUSIONS

The Tight Formation Committee of West Virginia hereby recommends that those formations in areas in Mercer, McDowell and Wyoming Counties not outlined in red on Figures 3, 5, 6, and 7 meet those guidelines as set out in 18 C.F.R. 271, Subpart G (as set out in order 99, issued by FERC August 15,1981, Docket No. RM 79-76), as it relates to Section 107 (b) of the Natural Gas Policy Act of 1978.

The recommended formations, the Princeton - Ravencliff, Injun, Weir and Berea sandstones, all fall within the Mississippian System.

In recommending the above sandstones as tight formations, the Committee has concluded that all areas on the attached maps, except those outlined in red, meet each of the Federal Energy Regulatory Commission's guidelines for tight formation designation.

The Committee has prepared the necessary information for the recommendation (see attached Figures, Exhibits and Appendices).

The estimated average in-situ permeabilities throughout the pay section in areas not outlined in red in Figures 3, 5, 6, and 7 are expected to be less than 0.1 millidarcy.

The stabilized production rate, against atmospheric pressure of wells completed for production in the five (5) recommended sandstones in this three county area without stimulation, is not expected to exceed the production rate determined in accordance with the table in 18 C.F.R. 271.703 (c) (2) (i) (b).

No well drilled into these formations can be expected to produce, without stimulation, more than five barrels of oil per day.

Existing State and Federal Regulations assure that development of these five (5) formations will not adversely affect any fresh water aquifers that are used or expected to be used as a domestic or agricultural water supply.

Respectfully submitted,

TIGHT FORMATION COMMITTEE

Floyd B. Wilcox, Chairman, Peake Operating
Paul L. Gebhard - Cabot Oil and Gas

Members:
James Alkire - Allegheny Land and Mineral Co.
Katharine L. Avary - WV Geological & Economic Survey
Mary C. Behling - WV Geological & Economic Survey
Porter J. Brown - Columbia Gas Transmission Corp.
James Gehr - Allegheny Land and Mineral Co.
Michael E. Hohn - WV Geological & Economic Survey
Richard H. Martin - Tom Marsh Inc.
Chris McGill - Tom Marsh Inc.
David Meghreblian - Cabot Oil & Gas Corp.
Douglas Patchen - WV Geological & Economic Survey
Bruce Prather - Allegheny Land and Mineral Co.
Robert Pryce - Kem Gas Corp.
Edward Rothman - Columbia Gas Transmission Corp.
William Ryan - Spartan Gas Company
John P. Walsh - Pennzoil Company

EXHIBIT XI

BEREA CORE DATA

Well Location	Porosity Cut Off
Consolidated Gas #429 - McDowell County, WV	7.6%
Pennzoil #1092 - Boone County, WV	6.4%
Columbia Gas #2788 - Kanawha County, WV	5.6%
Pennzoil #1705 - Lincoln County, WV	7.0%
South Penn Natural Gas Co. #356 - Lincoln County, WV	7.8%
D. C. Malcolm #839 - Putnam County, WV	6.6%
Atlantic Inland Oil #729 - Putnam County, WV	9.2%
Preston Oil #14211 - Lawrence County, Ky.	11.0%
Columbia Gas #32260 - Lawrence County, Ky.	7.0%
Columbia Gas #32635 - Martin County, Ky.	8.7%
Average porosity for 10 cored wells	7.7%

(Tight Formation Committee, 1981)

EXHIBIT XXII

COMPARISON OF BEREA
CORE POROSITY VS LOG POROSITY

WELL	CORE POROSITY	LOG POROSITY
Boone County, WV #1092 Pennzoil	7.5%	7.0%
Kanawha County, WV #2788 Columbia Gas	10.1%	10.2%
Putnam County, WV #839 D. C. Malcolm	7.6%	8.1%
Martin County, KY #32635 Columbia Gas	6.8%	6.1%
Average Porosity for 4 Representative Wells	8.0%	7.9%

(Tight Formation Committee, 1981)

EXHIBIT XXIII

BEREA
UNSTABILIZED NATURAL OPEN FLOWS

MANN-OCEANA FIELDS

PERMIT #	O.F. (MCF)	PERMIT #	O.F. (MCF)
Wyo 155	5	Wyo 426	N/S
184	5	459	28
248	12	345	N/S
267	5	489	N/S
212	5	398	63
274	74	354	127
215	5	460	21
177	5	458	N/S
233	169	436	8
194	5	390	5
207	5	368	5
133	5	452	5
316	21	451	N/S
344	94	490	25
329	42	405	5
407	29	413	67
165	5	434	N/S
364	5	475	5
375	5	462	5
365	5	388	66
249	5	403	5
204	5	424	5
342	5	433	5
341	21	446	5
300	94	430	140
216	169	409	5
282	47	419	87
461	5	417	N/S
367	5	124	5
317	21	324	47
164	5	377	5
239	5	416	5
348	5	225	5
44	5	379	5
357	5	374	239
		386	5

(Tight Formation Committee, 1981)

EXHIBIT XXIV

BEREA
UNSTABILIZED NATURAL OPEN FLOWS

BAILEYSVILLE "A" FIELD

PERMIT #	O.F. (MCF)	PERMIT #	O.F. (MCF)
Wyo 339	1356	Wyo 374	239
287	37	127	127
321	1004	384	149
257	537	394	9366
288	730	400	852
49	49	181	1953
172	5	179	353
291	601	206	1565
236	15	167	1387
319	5	232	684
310	56	173	1332
42	184	136	4956
58	58	137	723
48	48	76	5116
265	1295	156	2773
70	103	116	1870
196	103	132	3603
180	3723	95	4640
231	1074	83	5097
72	1425	122	2467
324	47	139	600
99	5514	74	6981
343	808	71	771
135	5	93	3669
312	353	294	880
147	N/S	101	1581
370	198	87	1236
340	1604	104	2002
730	N/S	197	4642
241	1364	McD 27	211
393	393		
170	2631		
109	820		
182	30		

(Tight Formation Committee, 1981)

EXHIBIT XXV

BEREA
UNSTABILIZED NATURAL OPEN FLOWS

BAILYSVILLE "B" FIELD

PERMIT #	O.F. (MCF)	PERMIT #	O.F. (MCF)
Wyo 120	N/S	Wyo 573	11
264	N/S	371	321
84	N/S	568	163
330	84	421	5
66	N/S	643	N/S
592	179	613	119
620	75	514	4
576	N/S	335	18
588	80	356	5
619	70	372	N/S
597	N/S	484	N/S
571	84	378	N/S
570	234	382	N/S
549	N/S	469	32
601	169	428	9
607	5	408	24
569	5	504	8
625	60	518	38
584	133	425	33
564	N/S	395	46
624	148	401	53
512	210	651	50
479	15	545	172
480	N/S	566	N/S
594	N/S	581	N/S
633	16	745	119
		143	8

(Tight Formation Committee, 1981)

EXHIBIT XXVI

BEREA
UNSTABILIZED NATURAL OPEN FLOWS

HUFF CREEK "A" FIELD

PERMIT #	O.F. (MCF)	PERMIT #	O.F. (MCF)
Wyo 639	N/S	Wyo 652	80
634	N/S	655	5
538	62	691	N/S
604	179	701	60
635	5	664	60
618	N/S	671	160
598	15	716	5
617	33	McD 480	104
626	5	220	21
627	5	288	N/S
654	N/S	334	N/S
694	210	337	21
638	5		

BIG SANDY FIELD

McD 161	434	McD 193	38
165	19	195	197

(Tight Formation Committee, 1981)