2.3.5 Section 30 VIP Simulation

The objectives of the reservoir simulation were: (1) evaluate the characterization and distribution of various reservoir parameters, (2) obtain a history match of the past production performance, (3) determine the remaining oil in place, (4) assess the viability of infill drilling, and (5) identify optimal sites for infill wells.

Simulation of the Schaben Field performance in Section 30 was done by personnel in the Tertiary Oil Recovery Project by matching production history from discovery of the field to 1995. Following development of the history match, production histories for potential locations of infill wells were simulated. Results of these simulations provide the basis for selection of sites for development in Budget Period 2.

In this section, the methodology for developing the reservoir simulation is summarized. A brief overview is presented describing the input data for the simulation. The procedure for obtaining the history match is outlined and results are presented for field and the individual wells. Finally, the rationale for selection of potential infill well sites is presented with results from simulation of thirteen possible infill locations.

Reservoir Simulator

The reservoir simulation was completed using Western Atlas VIP Executive simulation software installed on a Silicon Graphics workstation. The VIP simulator is a conventional black oil simulator, equipped with a graphics interface. VIP consists of a series of software products developed to perform simulation, pre-processing, and post-processing functions. The graphics package allows visualization of the reservoir depletion using three dimensional displays including recording on video tape for subsequent presentations.

The model developed in this study consisted of a two layered reservoir, with both layers having identical properties and an infinite acting water aquifer at the bottom of the reservoir. The area modeled was Sec.30-T19S-R21W. This area was selected based upon: (1) being the most prolific producing area within the field, (2) Ritchie Exploration’s interest and ownership rights, and (3) time constraints associated with the development of an accurate geological model which was needed as data input for the simulation model.

Reservoir Description

Most of the data required for simulation was provided based upon the geological model developed at the Kansas Geological Survey. The data received were in the format of contour files, which were transferred electronically from KGS to the Silicon Graphics workstation at TORP. The data files consisted of top and bottom of the reservoir, net pay interval, porosity, horizontal permeability, and water saturation. Additional files necessary for simulation were developed at TORP for directional permeability, oil saturation, well locations, and PVT data. Adjustments were made in the initial data based on simulated production history. These adjustments are described in the section on the history match.

Production Data

The primary source of production data was from commercial oil sales records. This provided information on oil sales by lease, with no water production or individual well production data. A search was conducted to obtain individual well oil and water production from operators in the field. The only operator that supplied individual well oil and water production was Pickrell Drilling Company.

Annual productivity tests for Schaben Field wells were obtained from the file at the Kansas Corporation Commission. These tests were required as the production from the field was prorated by the KCC from 1964 to present. Annual productivity tests were used to allocate annual oil production from sales records to individual wells. Although overall oil production for the field should be accurate, there is uncertainty associated with the water production and individual well production.

An important parameter in the reservoir simulation is the bottom hole pressure in the production wells during production. The bottom hole pressure must be known to accurately match field performance using the reservoir simulator. When the history match is completed properly, the reservoir simulator will match production performance when the bottom hole pressure is specified in each production well.

Fluid levels and operating practices were obtained from individual well files and discussions with Ritchie field production personnel. Table 1 (Appendix J) summarizes initial production data and information on the fluid level in each well. It is difficult to tell whether the wells were pumped off following the initial completion. It appears that most of the wells were initially capable of producing in excess of their daily oil allowable.

Oil production declined fairly rapidly following initial completion and some water production began to appear. Well tests indicated reduced productivity following initial completion of less than 100 bbls of total fluid per day. During this time all the wells were pumped off. Periodic acid jobs provided minor stimulation of production, but the wells remained pumped off. The majority of the water production occurred following recompletion with the perforation of additional Mississippian or Ft. Scott pay. A few wells have consistently high fluid levels.

Rock/Fluid and Fluid Property Data

Limited data were available for reservoir rock and fluids in this field. Oil gravity is 40.2 ^{o}API. Viscosity of dead oil at reservoir temperature (Rein "A" Lease June 24, 1965) was 2.5 cp. There was no evidence of significant solution gas in this field so the bubble point pressure is low. Reservoir temperature is about 125 ^{o}F. Viscosity of the reservoir brine at reservoir temperature (0.64 cp) was estimated from the a correlation based on the TDS analysis from a water sample from Rein A-1(26,134 ppm). Residual oil saturation varied from 20-25% from core analysis so a value of 23% was selected for simulation.

Relative permeability data are required for the reservoir simulation. A limited amount of data were available from core samples on Moore "D" No. 1, Moore "B" No. 1, and Humberg "A" No. 1. Data included end point permeabilities, water/oil permeability ratios at several water saturations, initial water saturations and residual oil saturations. Initial water saturations from the core data varied from 31 to 56%. The relative permeability to water at residual oil saturation averages 0.25 which was selected for the simulation. The correlation developed from this data for the Schaben simulation is given below:

Relative Permeability Curves

$$k_{ro} = \underline{\ }_1(1 - S_{wD})^m$$
$$k_{rw} = \underline{\ }_2(S_{wD})^n$$

where,

$$S_{wD} = (S_w - S_{iw})/(1 - S_{iw} - S_{or})$$

In these correlations, S_{iw} = initial water saturation, S_{or} = residual oil saturation, while $\underline{\ }_1$,m,and n are determined by fitting the data. The parameter $\underline{\ }_2$ is the relative permeability to water at residual oil saturation was determine from core data to be 0.25.

History Match

The reservoir was divided by 20 x 20 x 2 grids in x, y, and z direction respectively. The simulator allowed non-uniform gridding with the well forced to be located at the center of the grid block. The grid layout is shown in Figure 2.51 which depicts the pore volume of each grid block. All the wells were perforated in the top layer. An infinite aquifer with strength set to 100 was used to support the field from the bottom. The total pressure drop in the reservoir was less than 100 psi for the entire production period of the field which is consistent with the pressure observation of the field.

The process of matching the history of the reservoir from 1963 to 1995 involved running numerous simulations to determine if the reservoir properties were consistent with the observed production response. It is not unusual to find that the initial reservoir description cannot be used to match oil and water production history. Rock properties such as permeability are often adjusted in an attempt to secure a satisfactory history match.

In simulating the Schaben field, the initial runs indicated that production response could not be matched for any reasonable changes in permeability. Large volumes of water were produced from wells that were known to produce *"water free"* oil in the initial 1-2 years. Initial water saturations provide by KGS ranged from 50 to 80 percent. The average water saturation in Section 30 was 62 percent. It became clear that the initial water saturations provided by KGS were not correct.

A revision in the reservoir description was made by KGS personnel based on the assumption the reservoir has a two phase pore geometry consisting of macro and micro pores. It was further assumed that oil was contained only in macro pores and that micro pores contained 100 percent water, which was assumed to be immobile. The effective porosity was reduced as well as the water saturation in permeable rock. The revised initial water saturations varied from 19 to 45 percent, with the resulting average water saturation in Section 30 being 30 percent. The oil saturations were changed to correspond with the new water saturation data. Figures 2.52 and 2.53 show the map of the revised initial oil saturation and the porosity distribution in Section 30.

Following adjustment of the porosity and water saturations, a series of simulations were run to determine if a satisfactory history match could be obtained. Criteria for a successful match include matching cumulative oil and water production within 10%. Water production was more difficult to match but was within 10% for most wells. However, the water production data have the highest uncertainty.

Adjustments in permeability modifications were made both laterally and locally to obtain the history match for oil and water production. When it became apparent that a history match could be obtained, bottom hole pressures in production wells were set at values estimated from the data presented in Table 1 and the history match was refined. The changes in the original reservoir description are summarized in Appendix K.

The history match was made in three stages:

Stage 1: Oil production was set to the actual production and water production was matched for each well from 1963 to 1995 by adjusting relative permeability curves. Pressure limitation was set to 15 psi.

Stage 2: Oil and water production was predicted from 1978 to 1995 by adjusting fluid level in each well based on the available data. Local adjustments for each well were made for k_x, k_y, and k_z to get the best match for each well. Figures 2.54-2.56 show the distribtution of permeability thickness, X-direction and Z- direction permeability used in the final simulation.

Stage 3: Fluid level in each well was set based on the available data in Table 1. Oil and water production was simulated for each well for the entire period of 1963 to 1995 using the reservoir parameters determined in Stages 1 and 2..

Results from the Stage 3 simulation are summarized in Table 2. Cumulative oil production through 1995 was 1.84 MMSTB and cumulative water production was estimated to be 10.46 MMSTB. Cumulative oil production from the simulation was 1.82 MMSTB and cumulative water production was 11.79 MMSTB. Graphs of the cumulative oil and water production for the field and individual wells are presented in Figures 2.57-2.59. Oil production rate is plotted against time in Figure 2.58. Figure

2.59 shows the water production rate during the same period. Graphs of cumulative oil and water production for individual wells during the life of the project are included in Appendix B. Figures 2.60 and 2.61 show the ratios of actual/simulated oil and water production from each well.

The overall agreement is excellent considering the amount and quality of the data used to develop the reservoir description and history match. The agreement between simulated and actual history could be improved by fine tuning of the reservoir description, particularly adjustment of initial water saturations in regions where wells produced "clean" oil for 1-3 years after completion.

Potential Infill Locations

Potential locations for infill wells were identified from examination of the oil saturation map at the end of 1997 shown in Figure 2.62. A map of mobile oil was generated from saturation, net thickness and porosity maps. This map is presented in Figure 2.63 in terms of barrels per acre. Figure 2.63 should be used with caution because significant mobile oil is indicated in the region between Wells B-1 and B-6 even though Wells B-3 and B-7 were completed in this region and abandoned.

Figure 2.64 shows the locations of nine potential infill wells selected from Figures 2.60 and 2.61. These are identified as New Wells 5-13 on the map. Wells 6-9 and Well 13 were vertical wells. Wells 10-12 were horizontal wells which were drilled at the same locations as corresponding vertical wells. These wells had horizontal sections 1284 to 1402 ft in length. Grid locations(row and column indices) of these wells are included in Table 3 along with cumulative oil and water production for the period from 1998 to 2005. Simulated production from individual wells is summarized in Tables 4-12. Production from the vertical wells ranged from 32.55 to 116.03 MSTB. Simulated oil production from five of the six wells was in excess of 60 MSTB. Thus, there is potential for significant additional oil production from Section 30 by drilling vertical infill wells and these well would be economic at current oil prices.

Estimated cumulative production from horizontal wells ranged from 133 MSTB to 352 MSTB. Production from these wells(Wells 11-13) is summarized in Tables 10-12. Production is characterized by high initial rates in first year or two followed by a rapid decline. Estimated production rates are on the order of several thousand barrels of fluid per day which will require installation of high volume pumps and will increase operating costs but appear to be economic if high initial oil production rates are found.

Four additional vertical infill wells were simulated at locations identified by Ritchie Exploration Co as potential sites with offsetting lease considerations. These wells are identified as Wells 1-4 and are shown in Figure 2.64. Cumulative oil and water production for the period 1998-2005 is summarized in Table 13. Simulated production from individual wells is presented in Tables 14-17. Cumulative oil production from these wells varies from 21 MSTB to 28 MSTB. These sites are considered marginal and would not be supported as potential sites in Budget Period II.

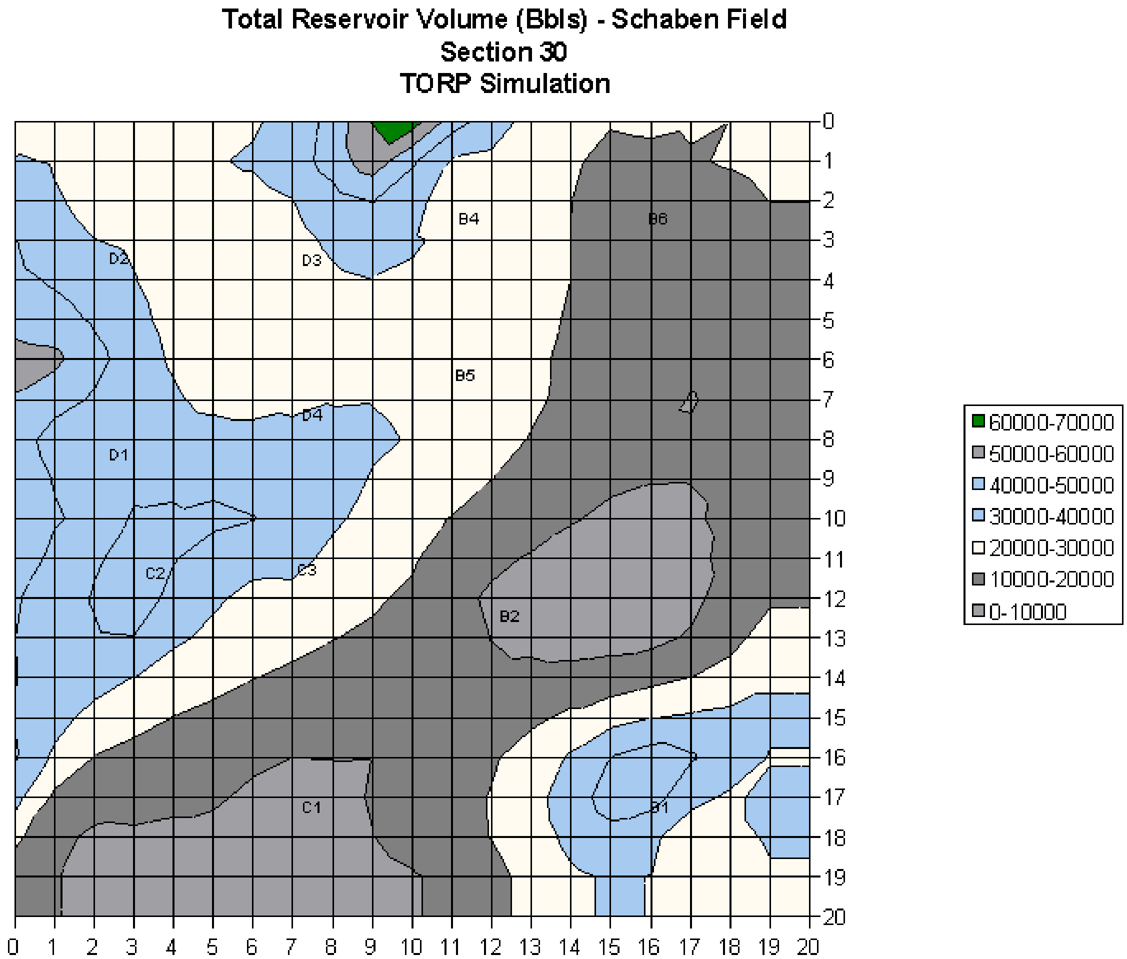

Figure 2.51. Grid layout with reservoir volume for Section 30 simulation

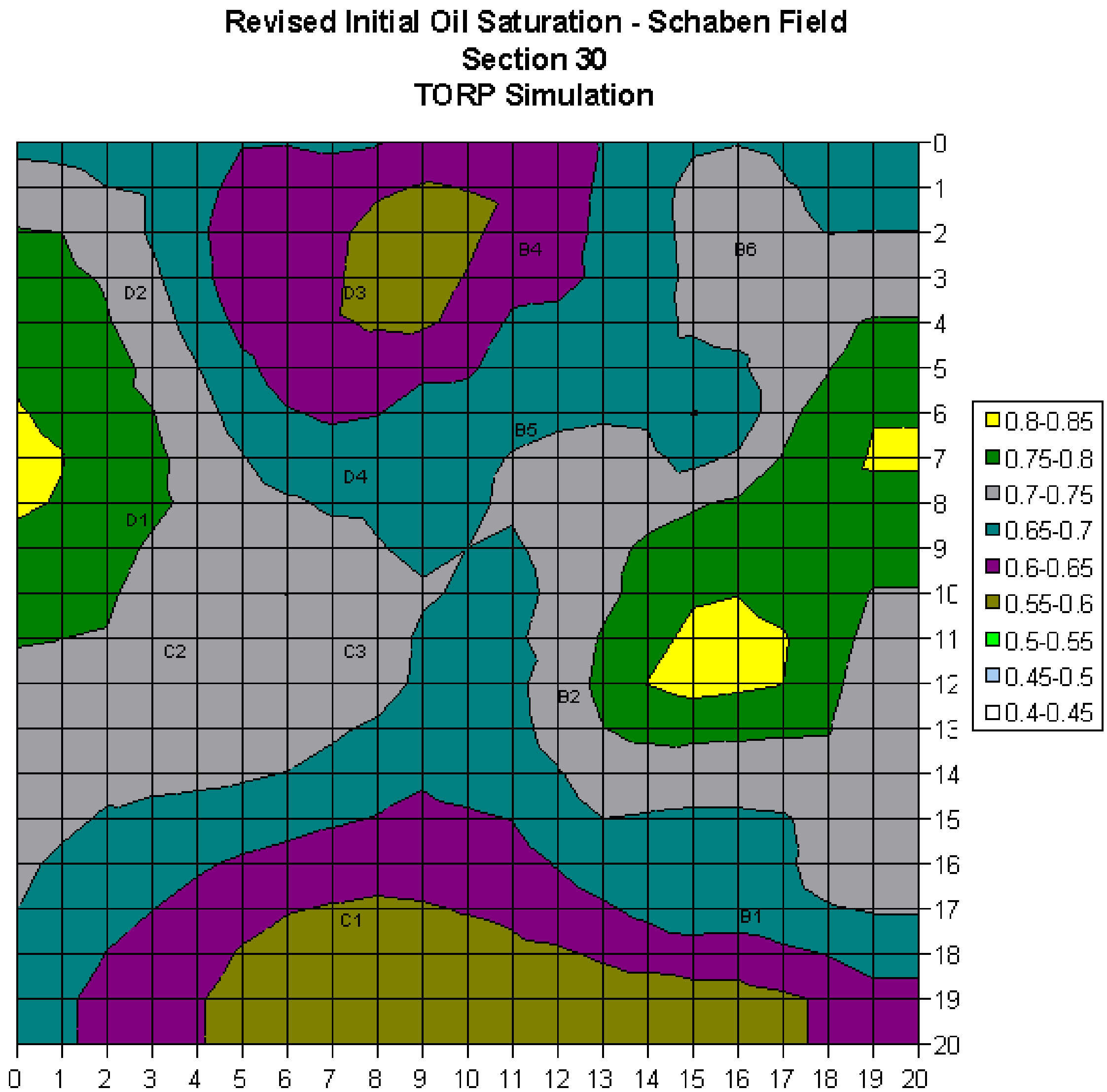

Figure 2.52 Revised initial oil saturation Section 30

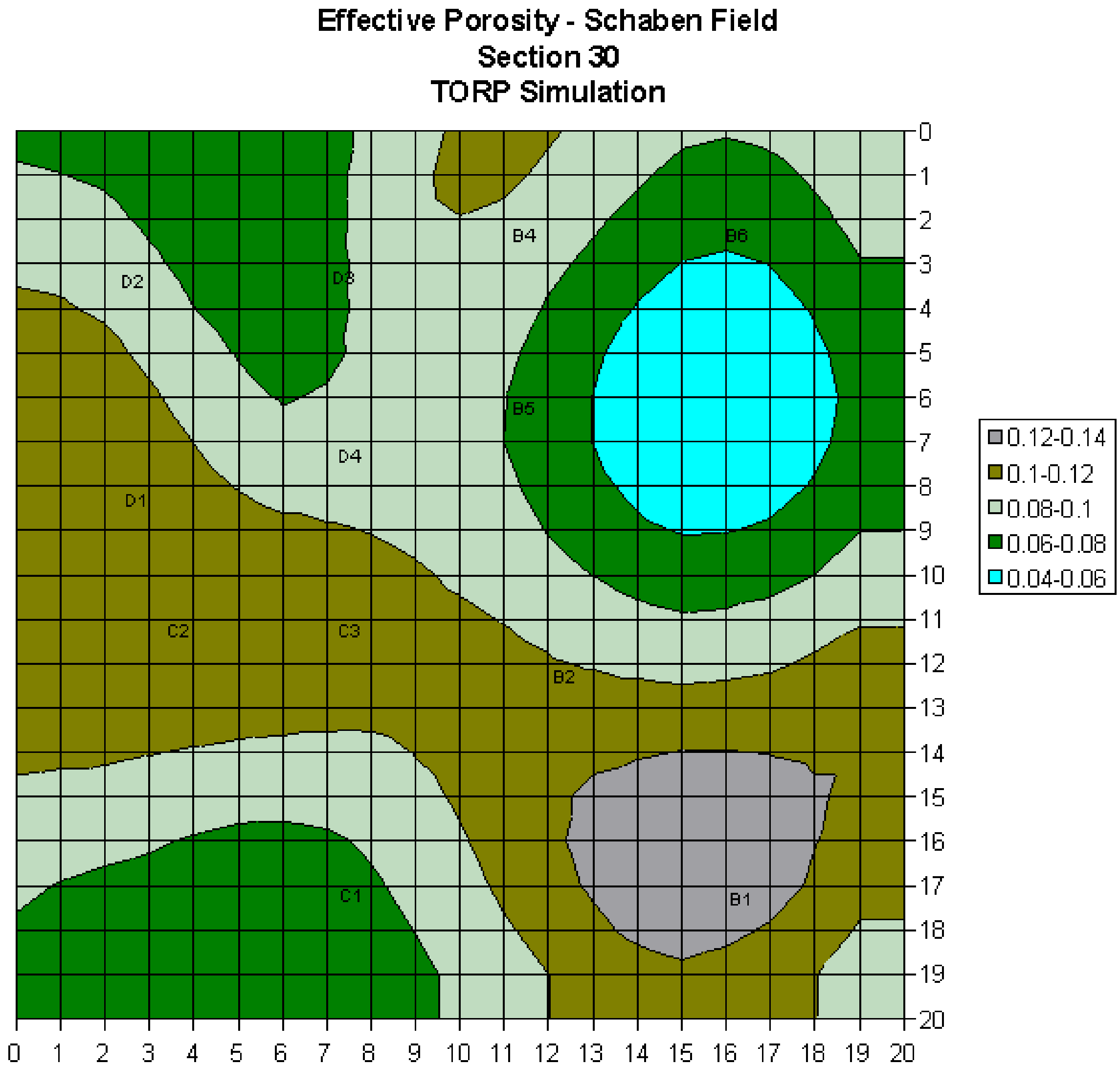

Figure 2.53 Effective porosity Section 30

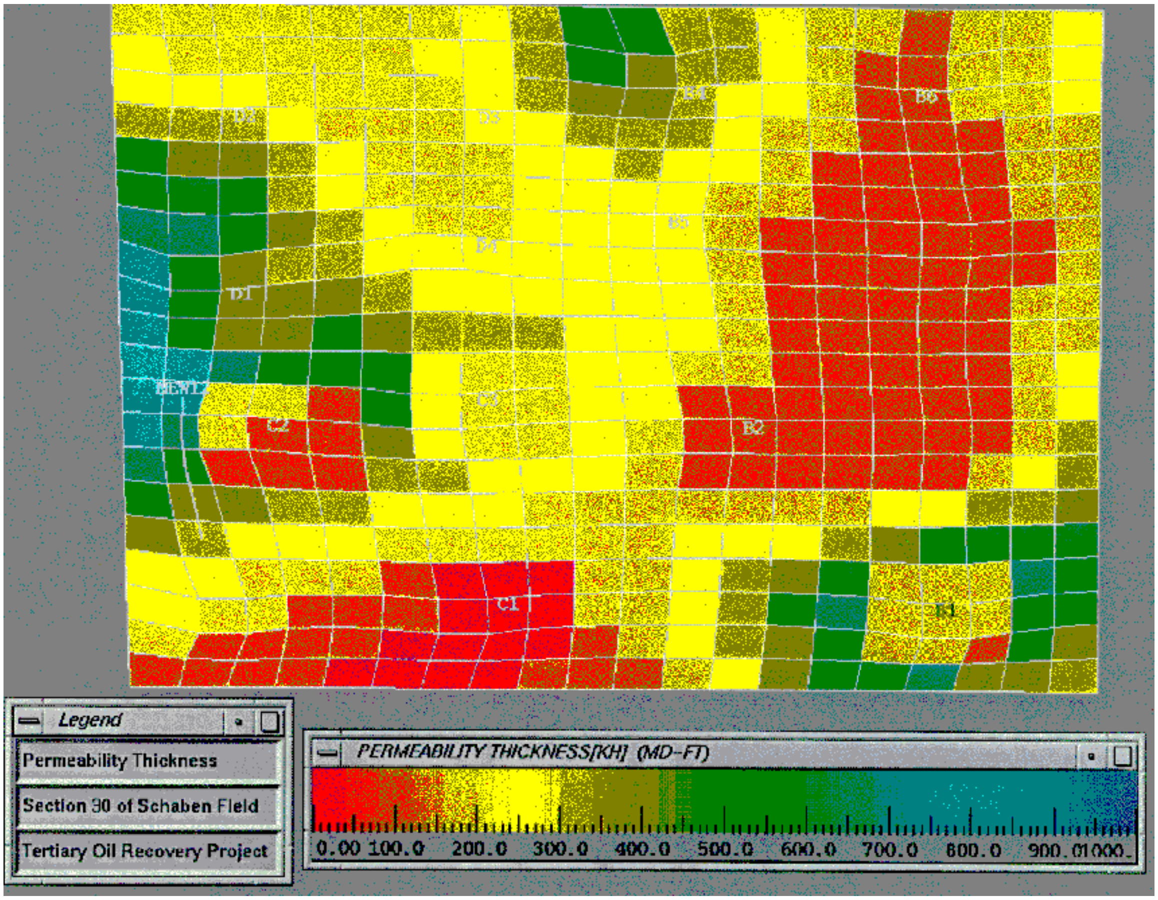

Figure 2.54. Permeabilility thickness distribution Section 30

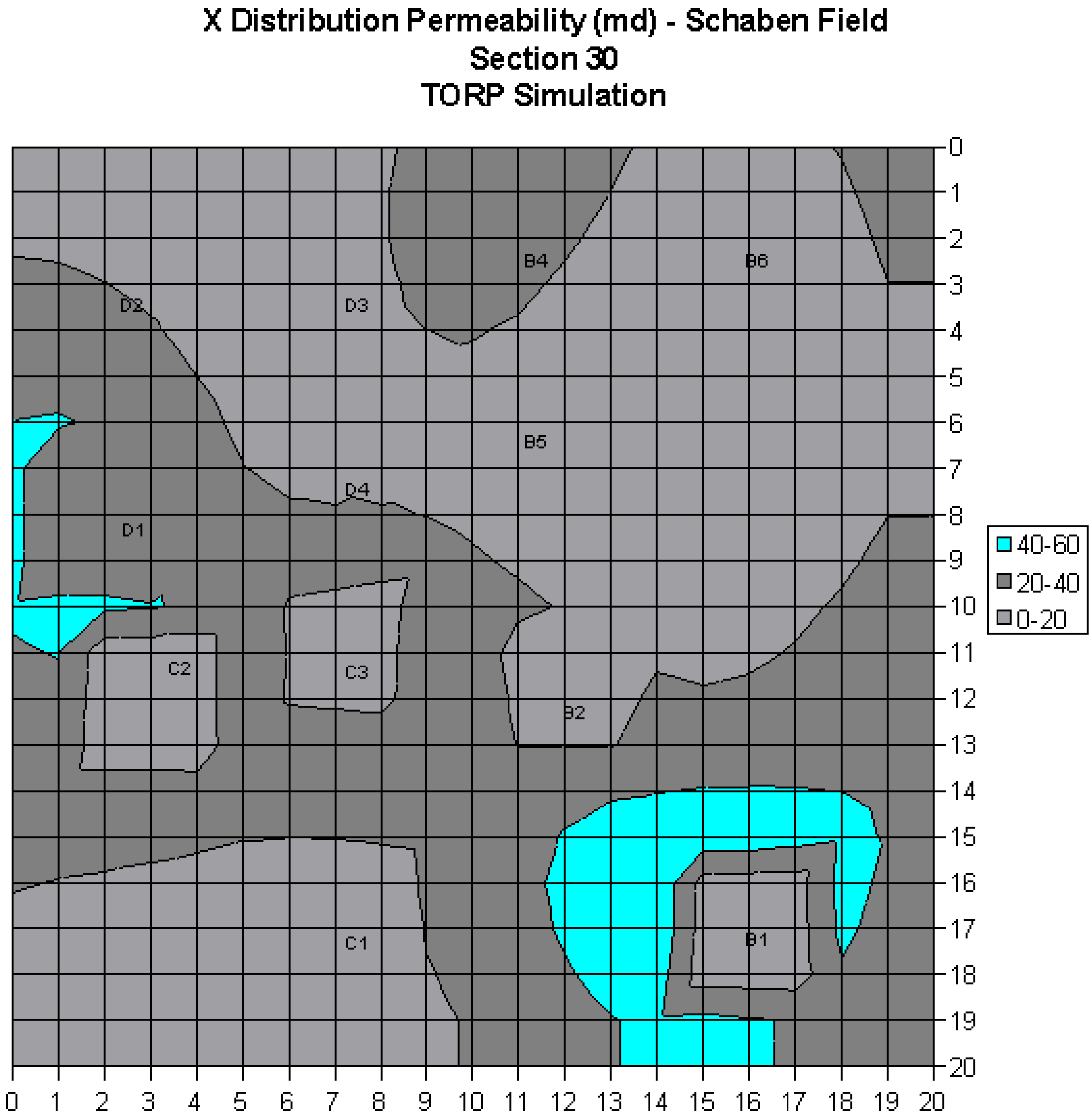

Figure 2.55 X Distribution perneability in Section 30

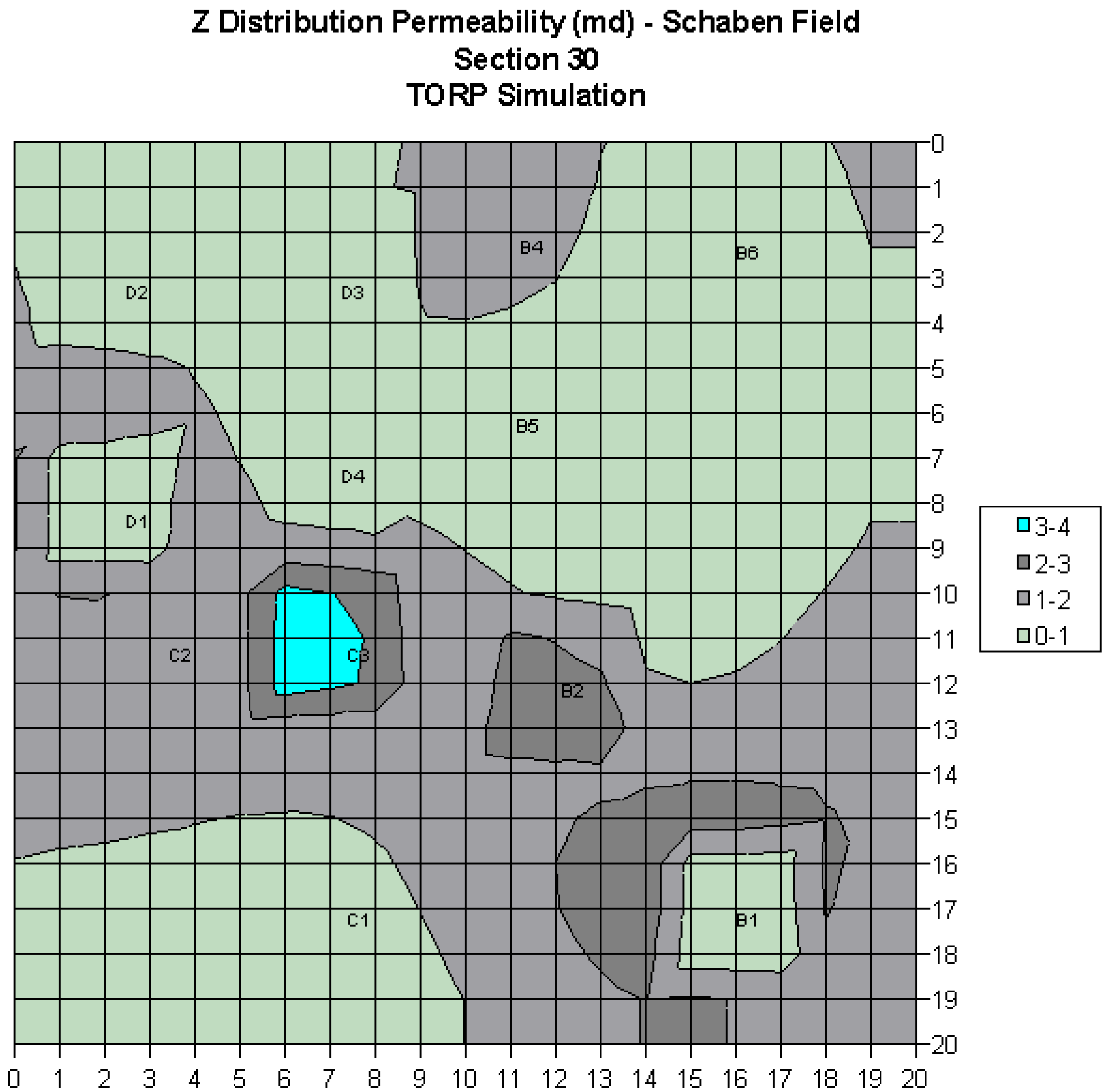

Figure 2.56 Z Distribution permeability in Section 30

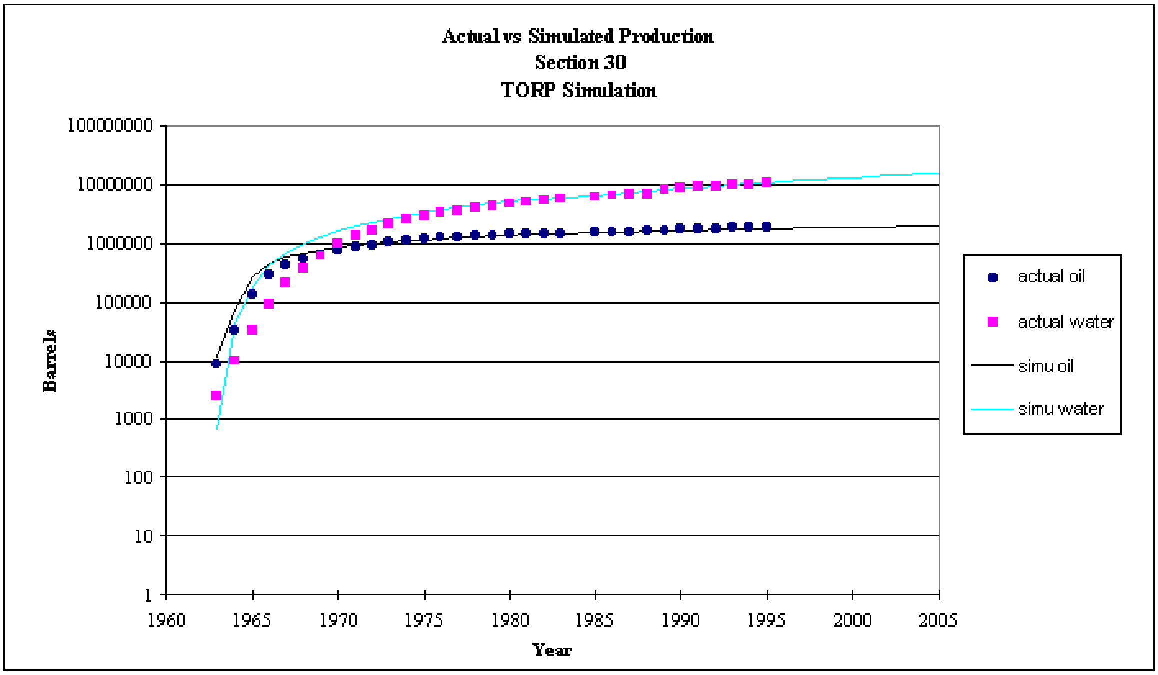

Figure 2.57 Actual vs. Simulated oil production rates in Section 30

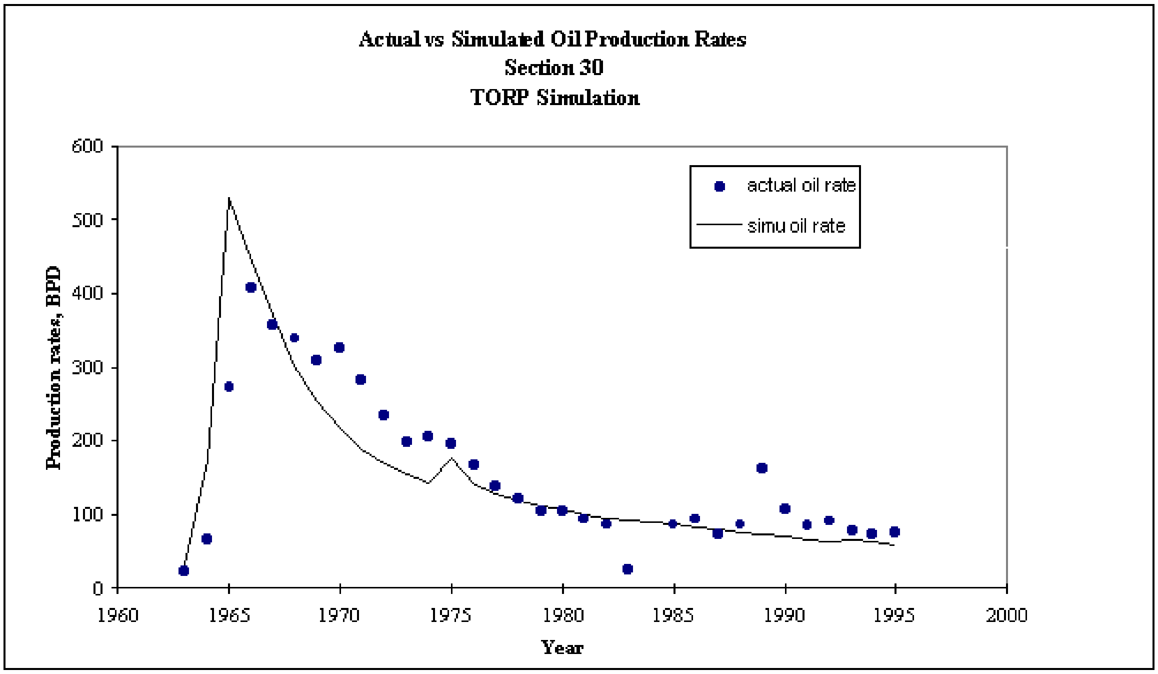

Figure 2.58 Actual vs. Simulated oil production rates in Section 30

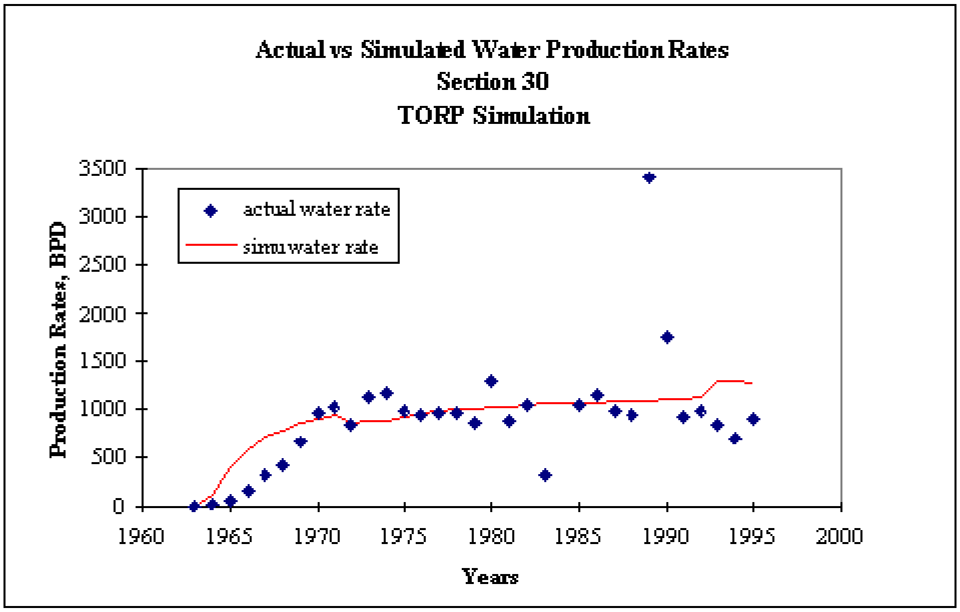

Figure 2.59 Actual vs. Simulated water production rates in Section 30

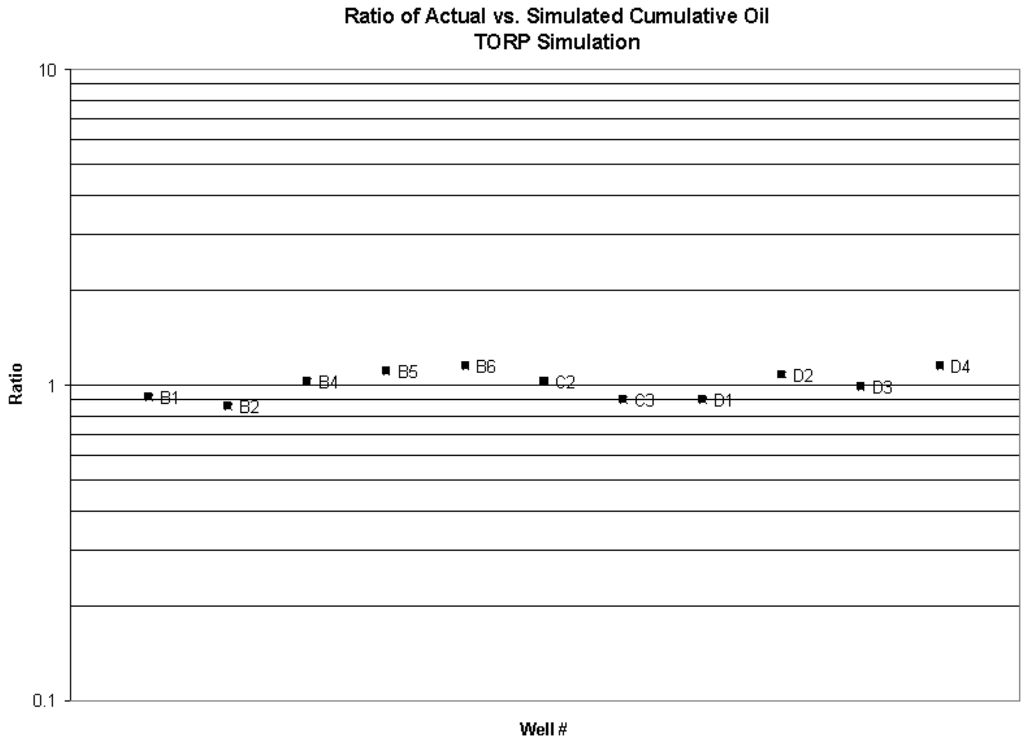

Figure 2.60 Ratio of actual vs. Simulated cumulative oil

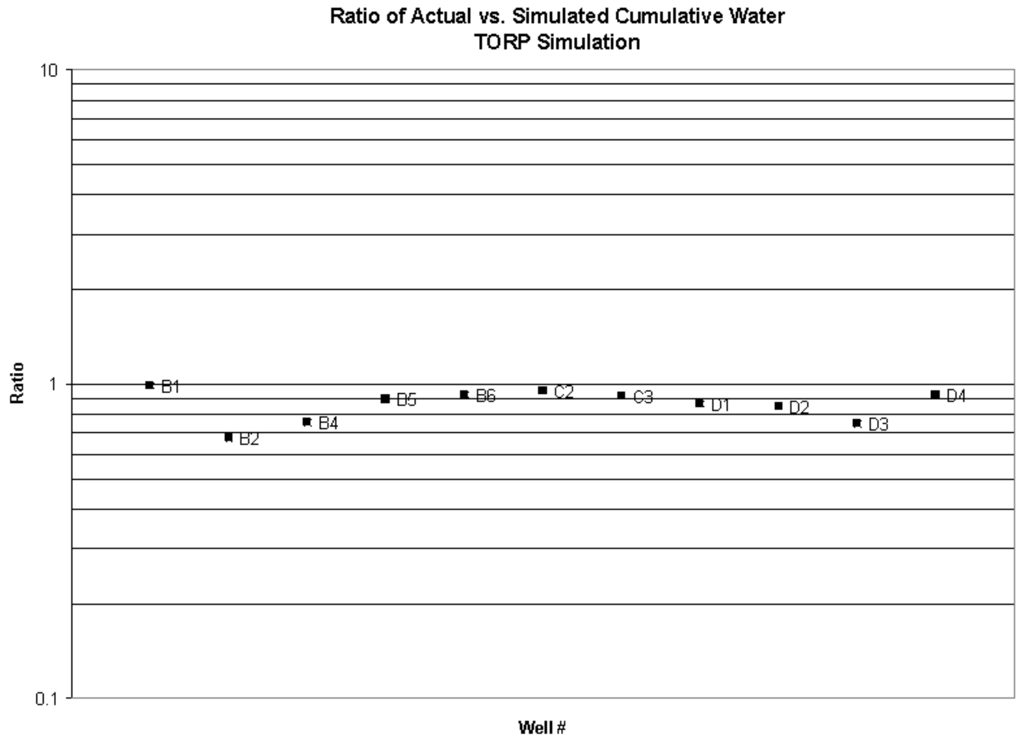

Figure 2.61 Ratio of actual vs. Simulated cumulative water

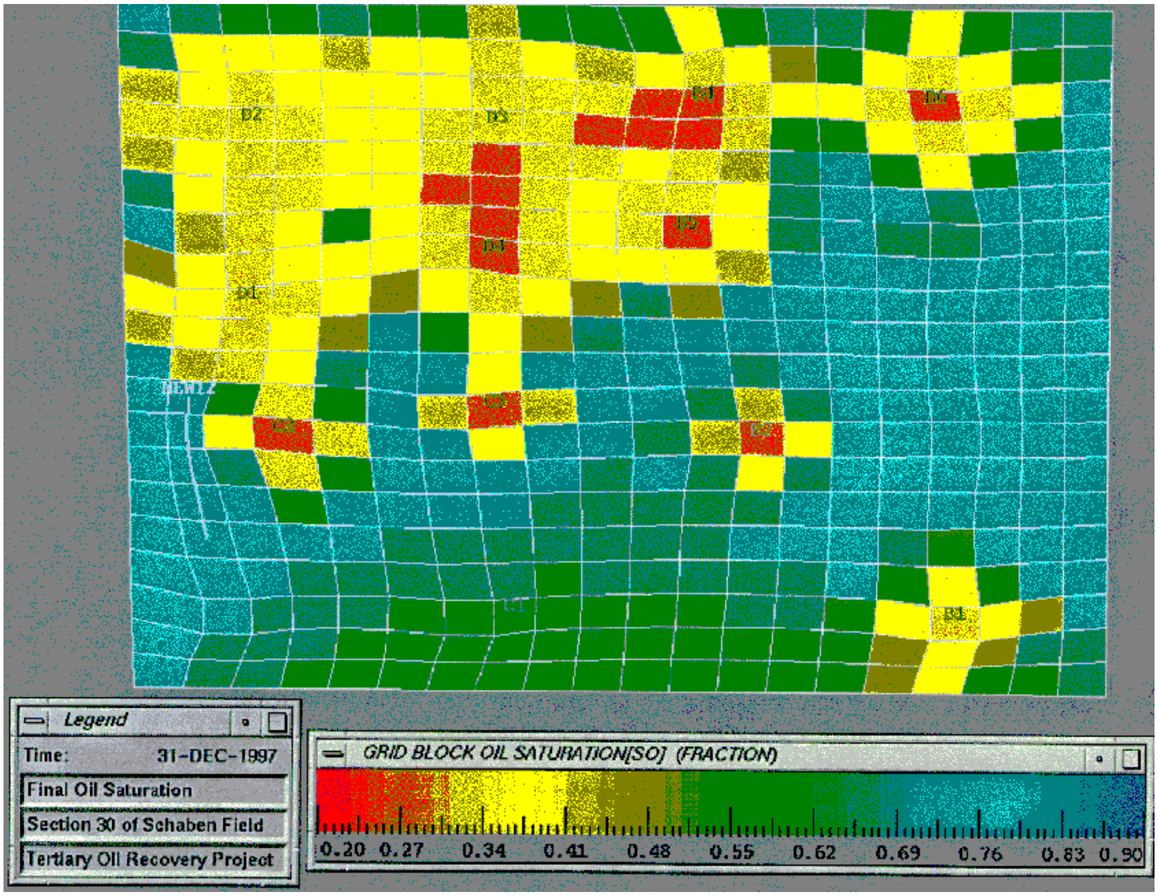

Figure 2.62 Oil saturation in Section 30, end 1997.

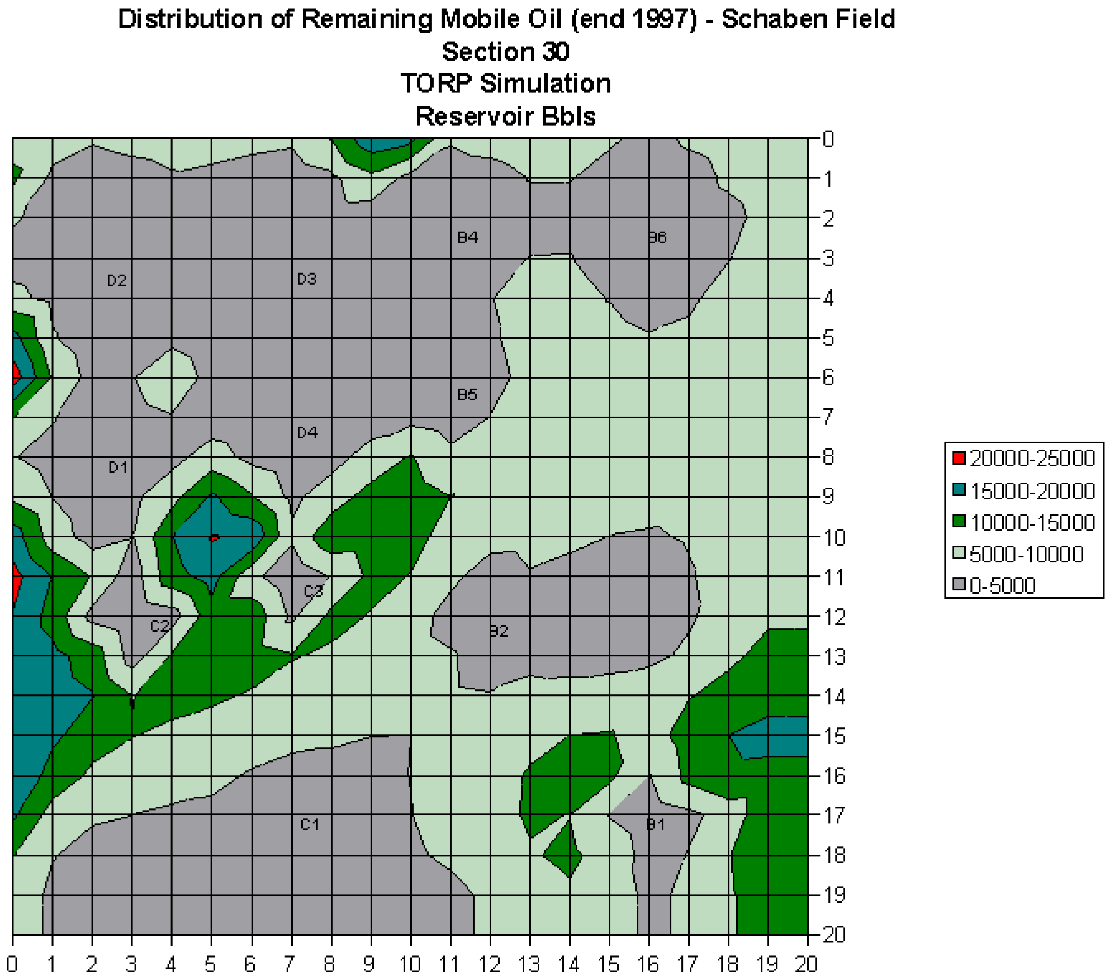

Figure 2.63 Distribution of mobile oil in Section 30, end 1997

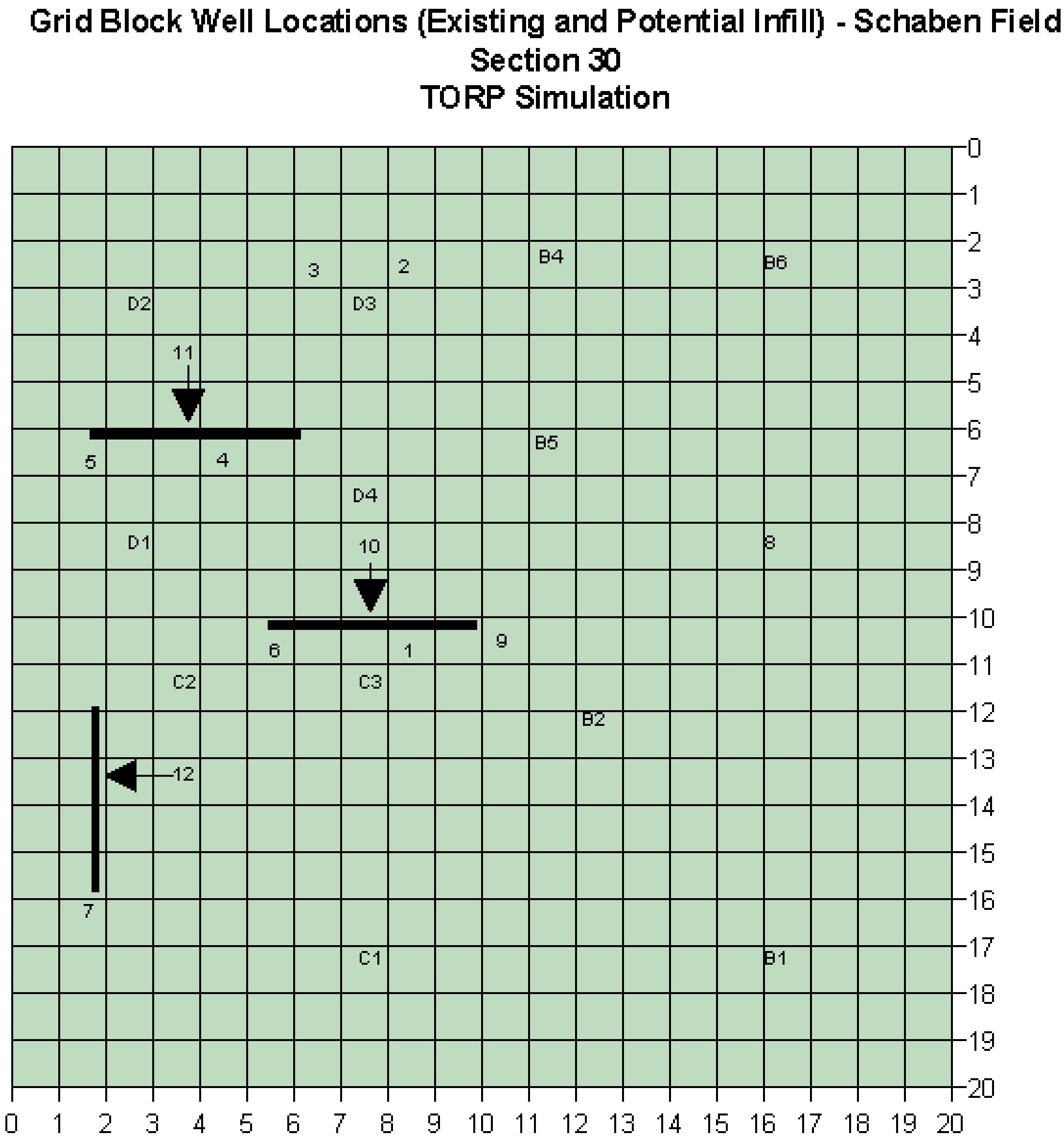

Figure 2.64 Location of existing and potential infill wells.

2.4 TECHNOLOGY TRANSFER ACTIVITIES

2.4.1 Traditional Activities

The data, results and technology have been presented at numerous technical meetings and published in technical papers in local, regional and national publications. PfEFFER a software package using a widely available spreadsheet was developed tested and demonstrated as part of the Class 2 project. In addition, BOAST 3 a public-domain program for reservoir simulation has been modified and demonstrated for full-field simulation. All technologies, developed and demonstrated as part of the Kansas Class 2 project, were tailored specifically to the scale appropriate to the operations of Kansas producers. The majority of Kansas production is operated by small independent producers that do not have resources to develop and test advanced technologies (90% of the 3,000 Kansas producers have less than 20 employees). For Kansas producer's, access to cost-effective new technology is important for sustaining production and increasing viability

2.4.2 Non-Traditional Activities (Internet)

All data and results of the Schaben project are being added to a world-wide-web server. The Internet protocol provides independent operators with on-line access to digital information, digital data bases, results of the field study, related regional geologic and production data, and purposeful transfer of technology. Access is through the Ness County page of the Digital Petroleum Atlas prototype (Figure 1.6; the uniform resource locator [URL] is http://crude2.kgs.ukans.edu:80/DPA/County/ness.html). It should be emphasized that the Schaben Project is an additional play/field to the Digital Petroleum Atlas and is not a substitute. The Internet provides just-in-time accessibility to fundamental well, reservoir, and geographic data (such as e-logs, production volumes, and digital map data), to petroleum related data compilations (such as the Schaben field study, regional maps [see Ness County page] and bibliographies), and to the latest research ideas. The virtual resource center provides a flexible and efficient method to disseminate data and technology to a geographically dispersed high technology industry.

We provide to independent operators, through on-line access, an evaluation of the technologies best suited for additional hydrocarbon recovery at Schaben and other Mississippian sub-unconformity fields. Information is available when and where operators need it (figuratively on the operator's desk). The digital structure permits the operator to access comprehensive reservoir data and customize the interpretative products (for example, maps and cross-sections) to their needs. Schaben Field and regional data sets along with technical studies are free-standing, but linked, entities that will be made available on-line through the Internet to users as they are completed.

Data sets have relational links that provide opportunity for history-matching, feasibility, and risk analysis tests on the Schaben demonstration site. The flexible "web-like" design provides ready access to data, and technology at a variety of scales from regional, to field, to lease, and finally to the individual bore. The digital structure permits the operator to access comprehensive reservoir data and customize the interpretative products (for example, maps and cross-sections) to their needs. The results of the Schaben study are accessible in digital form on-line using a World-Wide-Web browser as the graphical user interface.

2.5 PROBLEMS ENCOUNTERED

Permitting problems in the Schaben Field demonstration area delayed wells, but have not had a significant impact on project results. A recent ruling by the Kansas Corporation Commission provides some flexibility and should assist continued operations. The project is well within budget and cost sharing is in excess of 50%.

2.6 RECOMMENDATIONS FOR BUDGET PERIOD 2

Tasks for Budget Period 2 as outlined in the original Statement of Work remain as originally proposed. Modifications in subtasks reflect the results and knowledge gained in Budget Period 1. The tasks, subtasks and recommendations for Budget Period 2 are listed below.

Task 2.1 DEMONSTRATION OF RESERVOIR MANAGEMENT STRATEGY

Subtask 2.1.1 Infill Drilling-Schaben Demonstration Site

On the basis of the results of the advanced reservoir characterization and the simulation results for Schaben field, four well locations will be selected for infill drilling and possible horizontal reentry/drilling. An optimal drilling, completion, and production strategy will be demonstrated for each well. It is anticipated that the strategy will include the following components. Each well will be drilled, cored and logged. All cores will be petrophysically analyzed, photographed, slabbed, and boxed. Petrophysical analysis will include porosity, multi-directional permeability, oil and water saturation, capillary pressure and NMR. Cores will also be analyzed to determine fracture density and orientation. Drilling information, drillstem test data, and log evaluation will provide the basis for the casing point decision. If warranted, the wells will be completed and equipped for production. All pertinent well data will be entered into the digital computer database for use in modifying the reservoir simulation and evaluation of additional vertical wells and potential horizontal well.

Subtask 2.1.2 Production Performance Evaluation-Schaben Demonstration Site

Following drilling, deepening, and completion of the demonstration wells, production will be monitored and reservoir performance will be evaluated. The incremental contribution to recoverable reserves of all wells completed or recompleted as producing wells will be evaluated. Wells drilled during Budget Period 1 and completed as producers will continue to be evaluated for their contribution to incremental reserves, and the implications for infill drilling potential. The results of drilling, completion, and production of the demonstration wells will be compared to the predictions of the advanced reservoir characterization and reservoir simulation. The incremental contribution to recoverable reserves and the implications for additional infill and horizontal drilling will be evaluated using commercial and public domain simulators. These simulators will include BOAST 3 and BOAST-VHS.

Subtask 2.1.3 Regional Comparison

The detailed reservoir models developed and demonstrated at the Schaben Field demonstration site will provide the basis for evaluating the critical reservoir parameters characterizing the sub-unconformity Mississippian reservoirs of the central Kansas and the Mid-continent. In conjunction with a regional database consolidated from Kansas Geological Survey, Kansas Corporation Commission and operator data sources, reservoir models from the field site will provide a basis for comparison to other sub-unconformity reservoirs, and will facilitate transfer of technology developed and demonstrated to other nearby reservoirs in the producing trend. All data and interpreted products will be available on-line through the Internet. Regional potential for recovery of additional reserves will be evaluated.

Task 2.2 TECHNOLOGY TRANSFER

Subtask 2.2.1 Preparation of Technology Transfer Materials

Continued development and publication of manuscripts and software.

Develop an improved interface between BOAST 3 and PfEFFER along with improve preprocessing (e.g., spreadsheets), data management and post-processing (graphics) tools.

Develop a teaching manual and improved user's manual for BOAST 3.

Preparation of presentation figures, maps and core displays.

Development of improved on-line access to digital databases, information and technologies developed as part of the project.

Subtask 2.2.2 Technology Transfer Activities.

Continued on-line, open-file publication of technical results.

Presentation of results in at least two seminars/workshops targeted to Kansas and other operators of Class II reservoirs. These will include integrated short courses involving the Schaben Demonstration project and cost-effective technologies developed and demonstrated in Budget Period 1. These technologies include PfEFFER, BOAST 3 and the Internet. A first round of classes has been scheduled for June 23-27 in Lawrence, Kansas.

Continued presentation of results via oral or poster presentations at local, regional, and national meetings. Upcoming scheduled presentation include the National AAPG Meeting (Dallas) and the National SPE Meeting (San Antonio)

Continue publication of technical papers in local, regional, and national professional/technical publications.

Task 2.3 FULFILLMENT OF REPORTING REQUIREMENTS

All reporting requirements of the Department of Energy, other federal agencies and state and local governments will be fulfilled in a timely fashion.

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4.0 APPENDICES

4.1 Appendix A

PfEFFER "Super Pickett" PLOTS

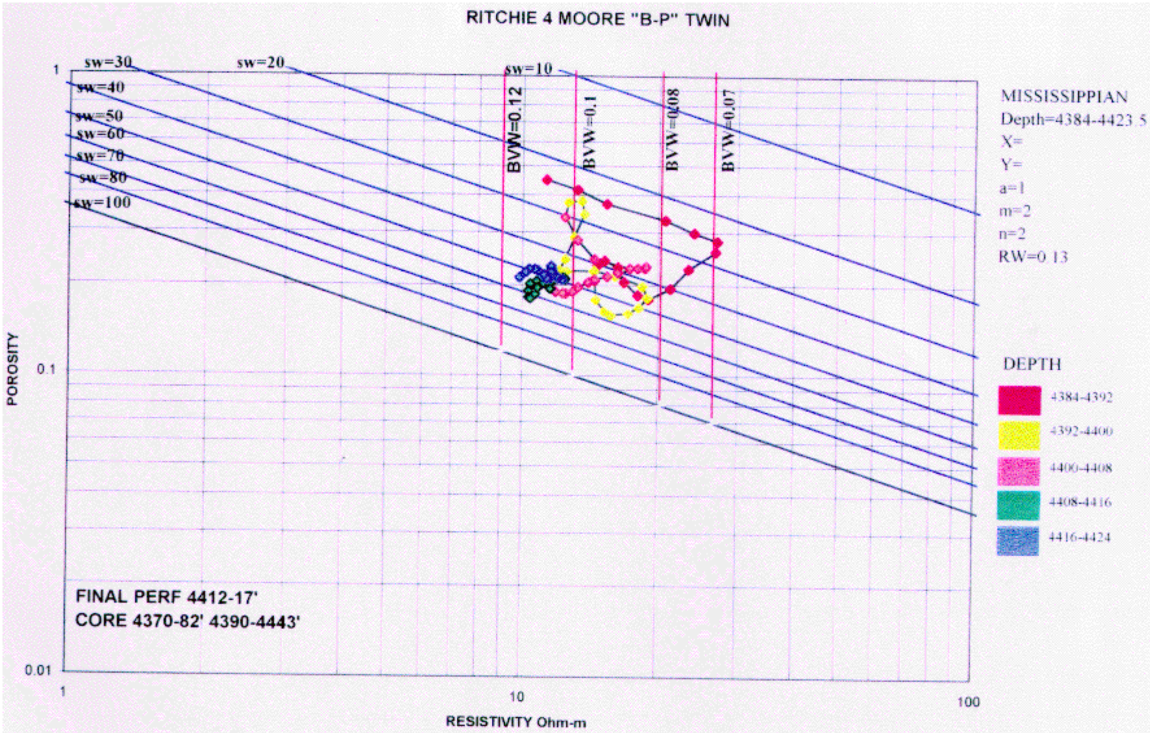
from

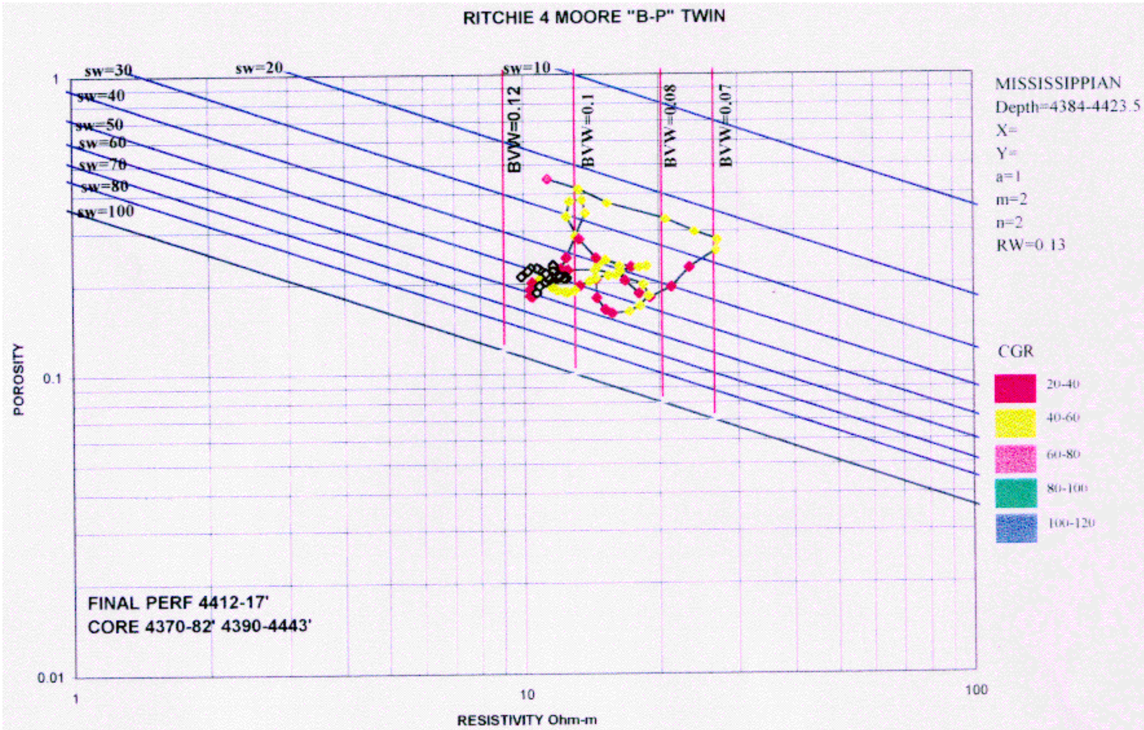
Ritchie 4 Moore "B-P" Twin

NW NE Sec. 30-T19S-R21W

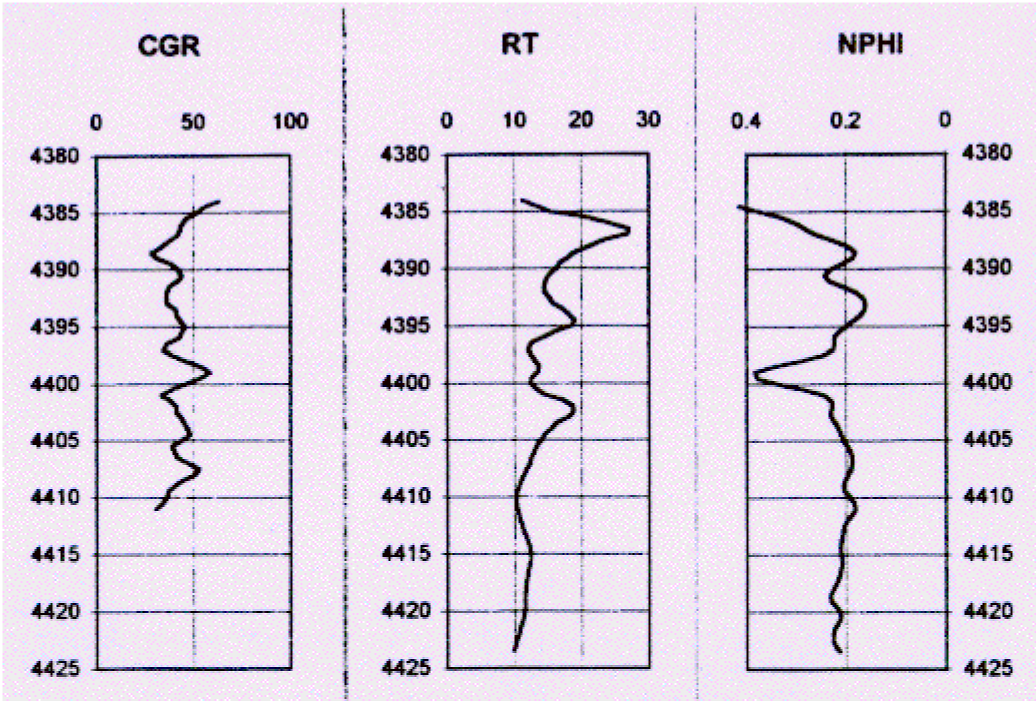
Ness County, Kansas

Resistivity-porosity plots on depth with an attribute of computed Gamma Ray indicate a reservoir with a high bulk volume water (.08-.11), a relatively constant porosity (20%), and a medium high water saturation (up to 60%). This would agree with Franseen's core description of the reservoir as a very fine-to-fine crystalline dolomite. The reservoir presently open by perforations has a BVW of 0.11 and a SW of 50-60%. The upper section is more heterogeneous. The multi-coarsening upward cycles are indicated by the plots cyclically changing direction.


RITCHIE 4 MOORE "B-P" TWIN
sw=30
sw=20
sw=10
sw=40
sw=50
sw=60
sw=70
sw=80
sw=100
BVW=0.12
BVW=0.1
BVW=0.08
BVW=0.07
MISSISSIPPIAN
Depth=4384-4423.5
X=
Y=
a=1
m=2
n=2
RW=0.13
DEPTH
4384-4392
4392-4400
4400-4408
4408-4416
4416-4424
POROSITY
1
0.1
0.01
RESISTIVITY Ohm-m
1
10
100
FINAL PERF 4412-17'
CORE 4370-82' 4390-4443'



RITCHIE 4 MOORE "B-P" TWIN
sw=30
sw=20
sw=10
sw=40
sw=50
sw=60
sw=70
sw=80
sw=100
BVW=0.12
BVW=0.1
BVW=0.08
BVW=0.07
MISSISSIPPIAN
Depth=4384-4423.5
X=
Y=
a=1
m=2
n=2
RW=0.13
CGR
20-40
40-60
60-80
80-100
100-120
POROSITY
1
0.1
0.01
FINAL PERF 4412-17'
CORE 4370-82' 4390-4443'
1
10
100
RESISTIVITY Ohm-m


CGR
0
50
100
RT
0
10
20
30
NPHI
0.4
0.2
0
4380
4385
4390
4395
4400
4405
4410
4415
4420
4425

4.2 Appendix B

PfEFFER "Super Pickett" PLOTS

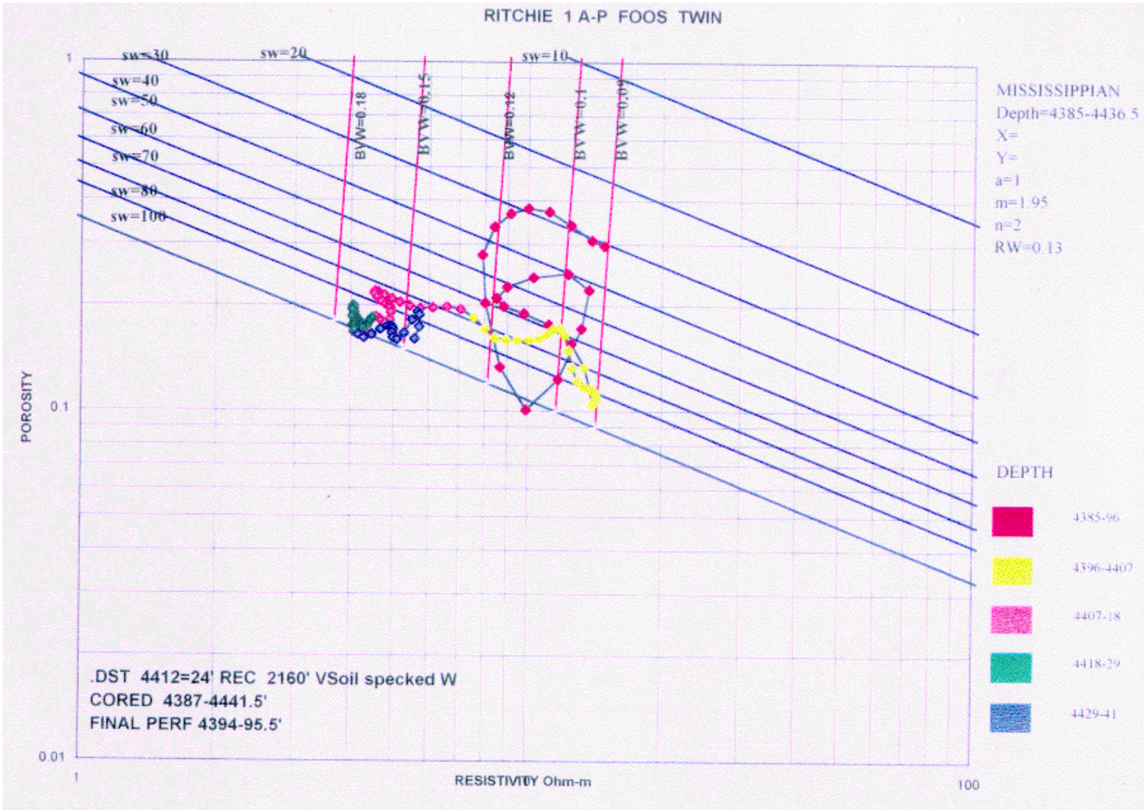
from

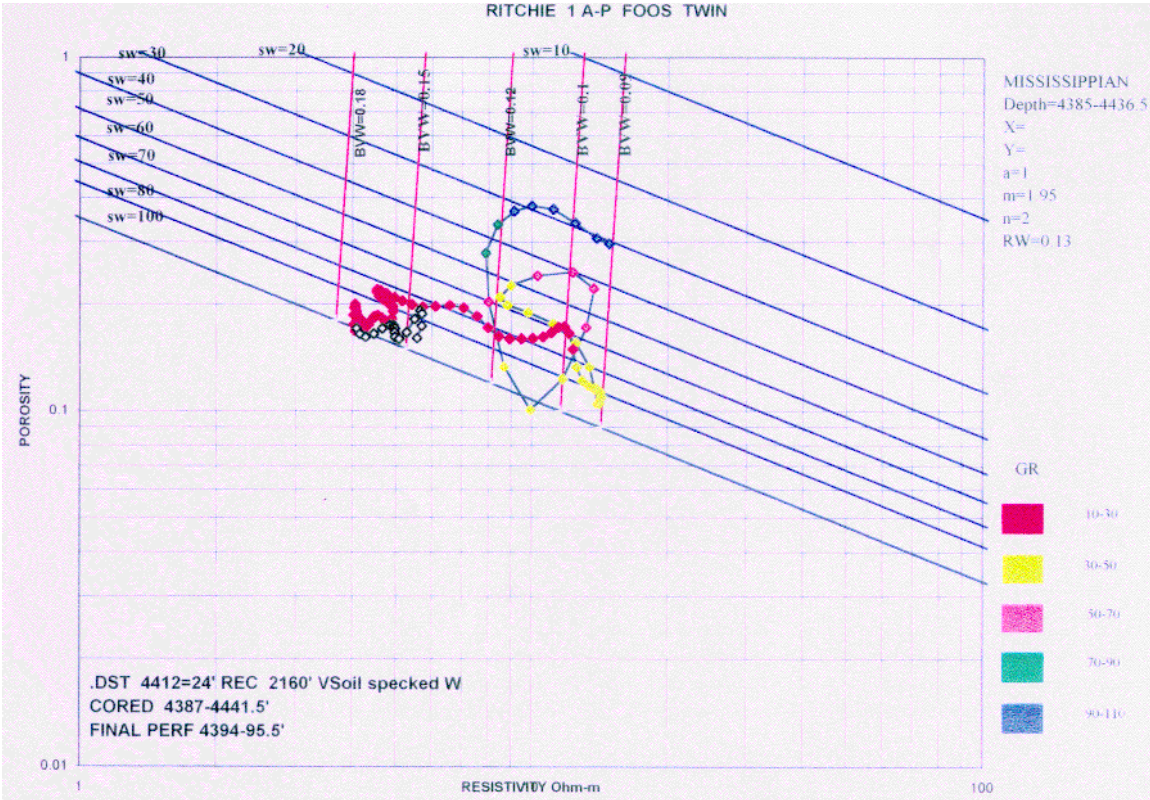
Ritchie 1 Foos "A-P" Twin

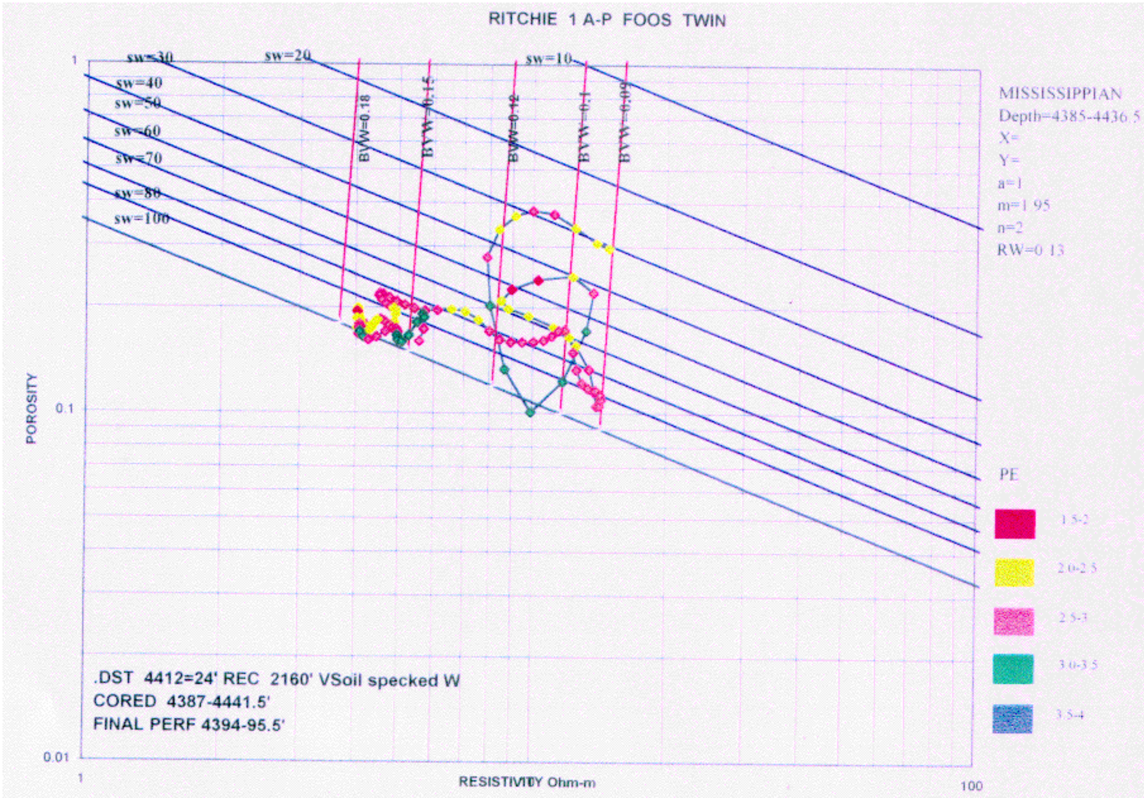
NE SW SW Sec. 31-T19S-R21W

Ness County, Kansas

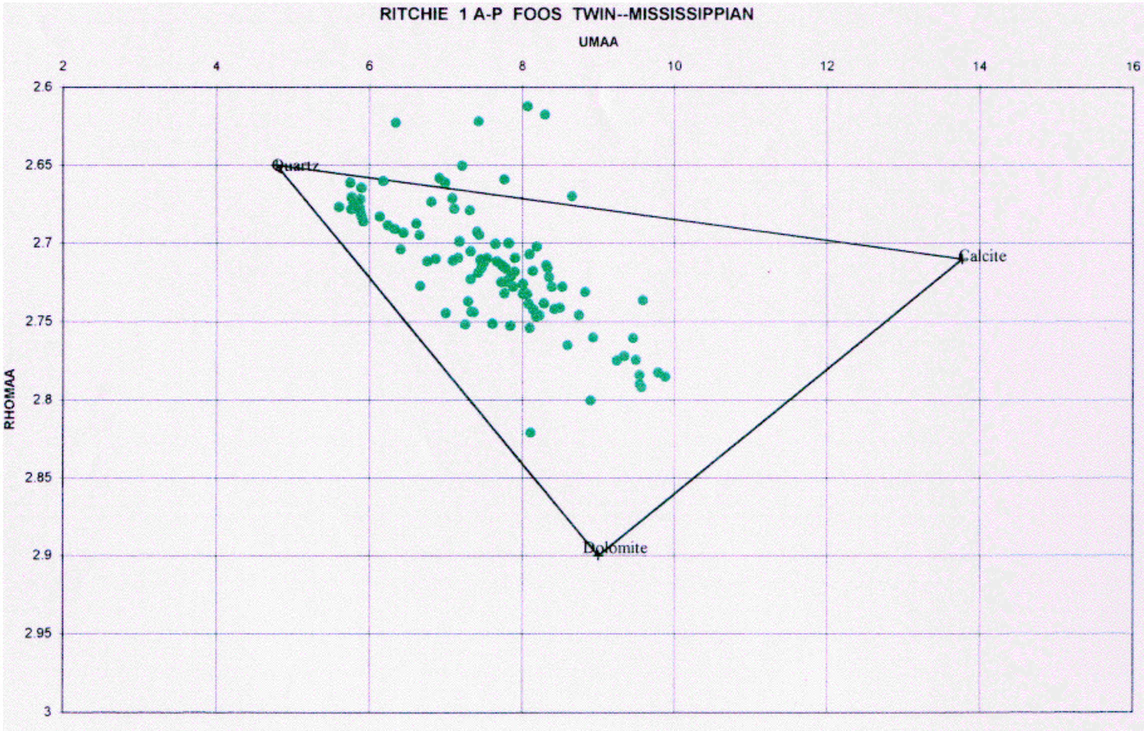
Resistivity-porosity cross plots on depth attributes of computed Gamma Ray and Photo-Electric effect indicate a reservoir that is very heterogeneous of the top with a high bulk volume water (.09-.12), varying porosity (10-30%), and a varying water saturation (30-100%). The lower section indicates a more constant porosity (17-20%), an increasingly high BVW with depth (0.1 to 0.17), a increasing water saturation with depth (60%-100%). This indicates that the reservoir is in a long transition zone from oil to water. The Photo-Electric effect readings of 2.5-3 indicates a dolomite and chert reservoir. The Rhomaa-Umaa plot indicates that the reservoir is a mixture of chert and dolomite. The multi-coarsening upward cycles are indicated by the plots cyclically changing direction.

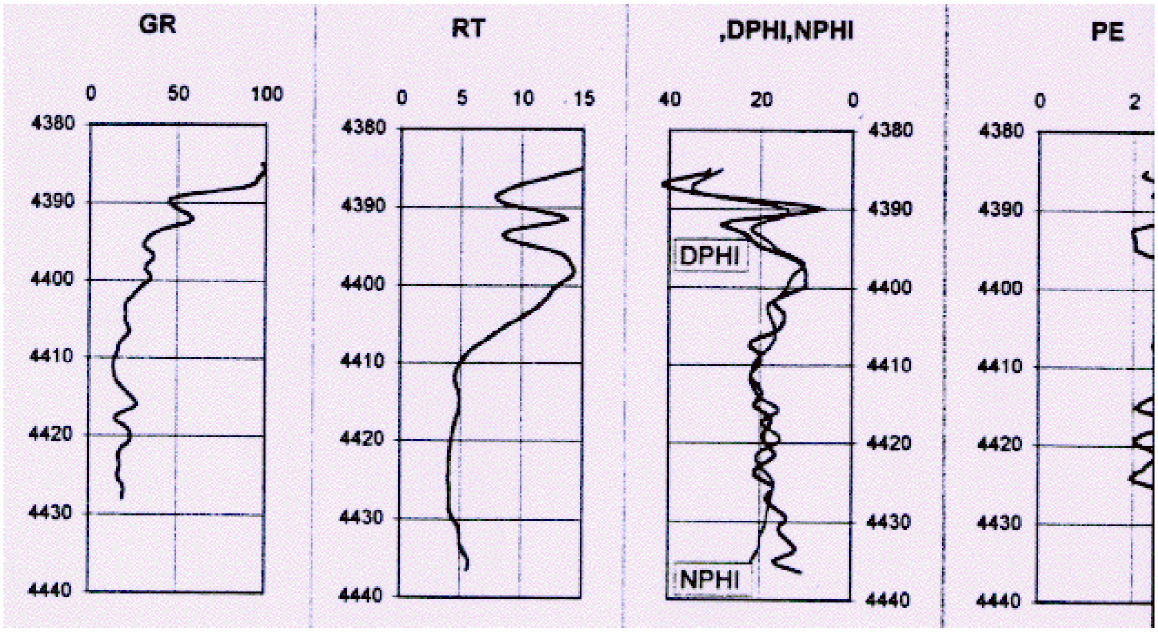

RITCHIE 1 A-P FOOS TWIN
sw=30
sw=20
sw=10
sw=40
sw=50
sw=60
sw=70
sw=80
sw=100
BVW=0.18
BVW=0.15
BVW=0.12
BVW=0.1
BVW=0.09
MISSISSIPPIAN
Depth=4385-4436.5
X=
Y=
a=1
m=1.95
n=2
RW=0.13
DEPTH
4385-96
4396-4407
4407-18
4418-29
4429-41
POROSITY
1
0.1
0.01
.DST 4412=24' REC 2160' VSoil specked W
CORED 4387-4441.5'
FINAL PERF 4394-95.5'
RESISTIVITY Ohm-m
1
10
100


RITCHIE 1 A-P FOOS TWIN
sw=30
sw=20
sw=10
sw=40
sw=50
sw=60
sw=70
sw=80
sw=100
BVW=0.18
BVW=0.15
BVW=0.12
BVW=0.1
MISSISSIPPIAN
Depth=4385-4436.5
X=
Y=
a=1
m=1.95
n=2
RW=0.13
GR
10-30
30-50
50-70
70-90
90-110
POROSITY
1
0.1
0.01
.DST 4412=24' REC 2160' VSoil specked W
CORED 4387-4441.5'
FINAL PERF 4394-95.5'
RESISTIVITY Ohm-m
1
100



RITCHIE 1 A-P FOOS TWIN
sw=30
sw=20
sw=10
sw=40
sw=50
sw=60
sw=70
sw=80
sw=100
BVW=0.18
BVW=0.15
BVW=0.12
BVW=0.1
BVW=0.09
MISSISSIPPIAN
Depth=4385-4436.5
X=
Y=
a=1
m=1.95
n=2
RW=0.13
PE
1.5-2
2.0-2.5
2.5-3
3.0-3.5
3.5-4
POROSITY
1
0.1
0.01
.DST 4412=24' REC 2160' VSoil specked W
CORED 4387-4441.5'
FINAL PERF 4394-95.5'
1
RESISTIVITY Ohm-m
100


RITCHIE 1 A-P FOOS TWIN--MISSISSIPPIAN
UMAA
RHOMAA
Quartz
Calcite
Dolomite
2
4
6
8
10
12
14
16
2.6
2.65
2.7
2.75
2.8
2.85
2.9
2.95
3


GR
0
50
100
4380
4390
4400
4410
4420
4430
4440
RT
0
5
10
15
,DPHI,NPHI
40
20
0
DPHI
NPHI
PE
0
2

4.3 Appendix C

PfEFFER "Super Pickett" PLOTS

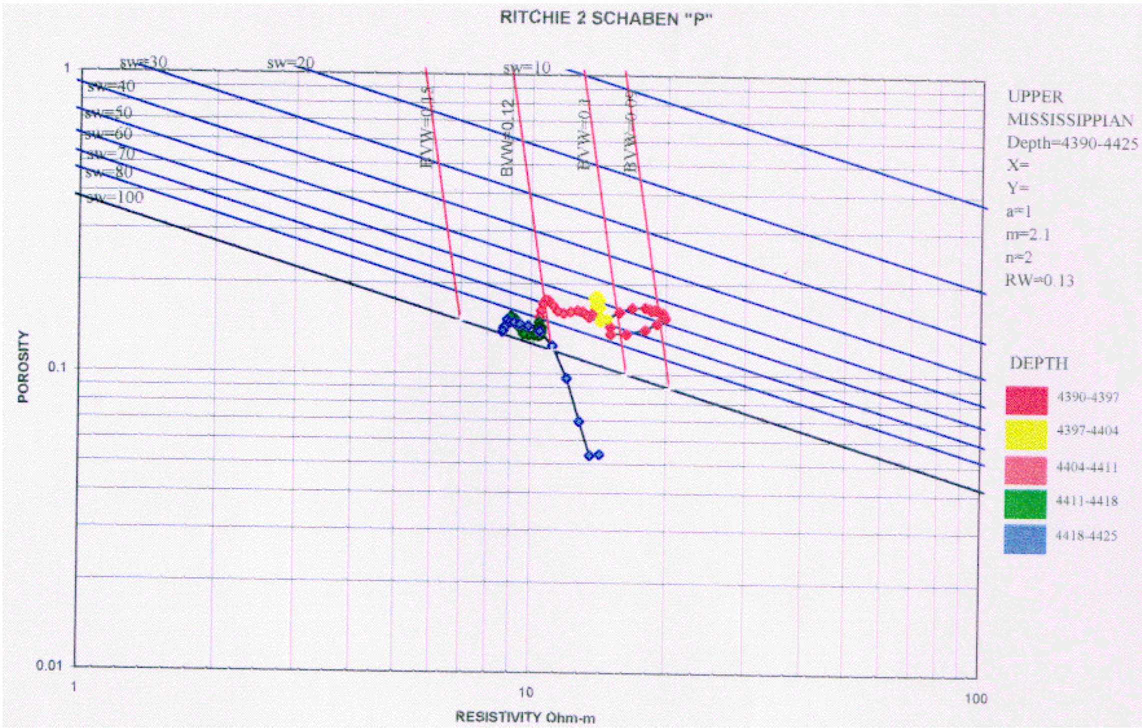
from

Ritchie 2 Lyle Schaben "P"

400' FNL and 400" FEL, NE/4 Sec. 31-T19S-R21W

Ness County, Kansas

Resistivity-porosity cross plot on depth showing transition zone from oil to water ("irreducible" to aquifer).



RITCHIE 2 SCHABEN "P"
sw=30
sw=20
sw=10
sw=40
sw=50
sw=60
sw=70
sw=80
sw=100
BVW=0.15
BVW=0.12
UPPER
MISSISSIPPIAN
Depth=4390-4425
X=
Y=
a=1
m=2.1
n=2
RW=0.13
DEPTH
4390-4397
4397-4404
4404-4411
4411-4418
4418-4425
POROSITY
RESISTIVITY Ohm-m
1
0.1
0.01
1
10
100

Appendix D
Individual Well Fluid Matches
TORP Simulation for Section 30 of Schaben Field

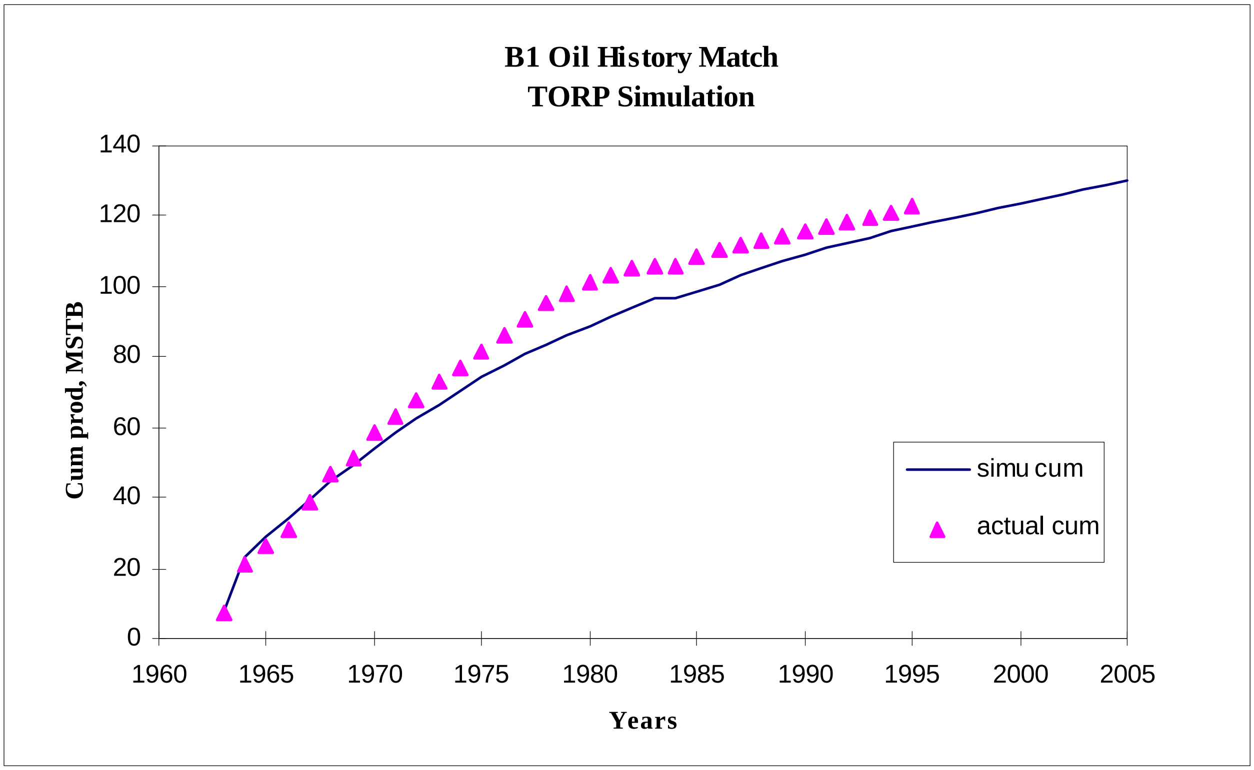


Figure D.1

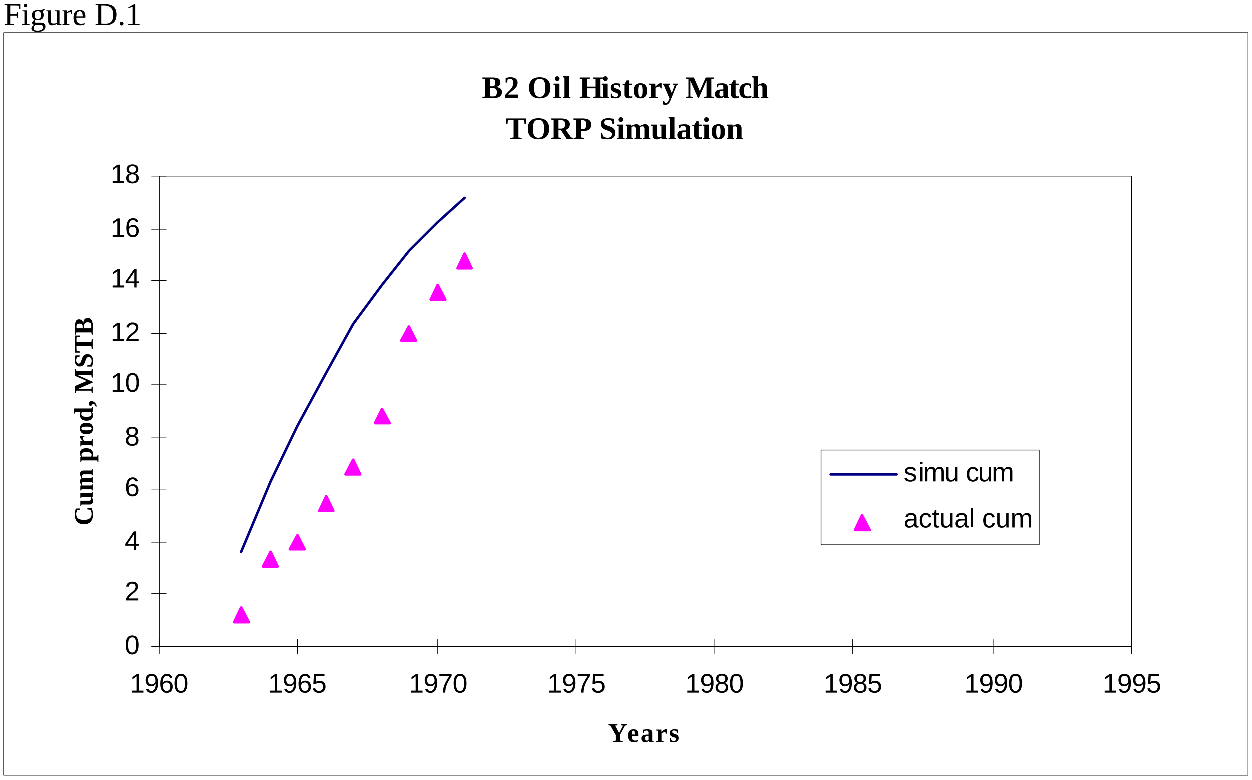


Figure D.2

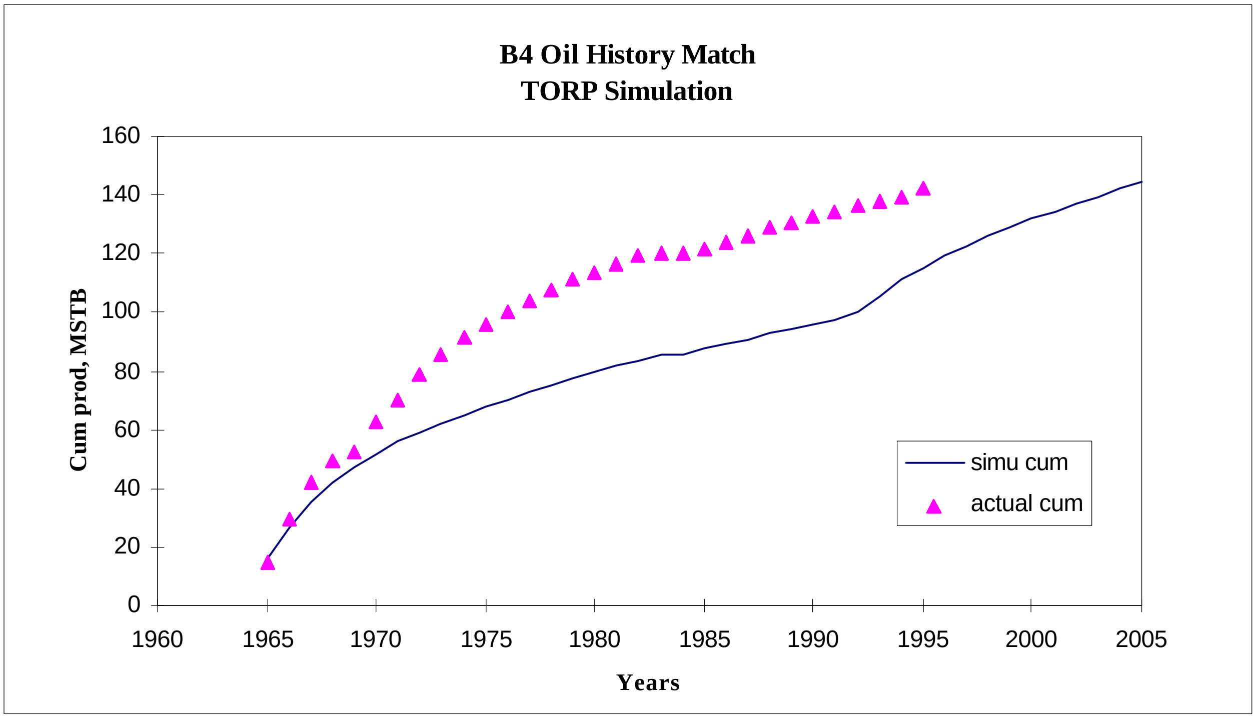


Figure D.3

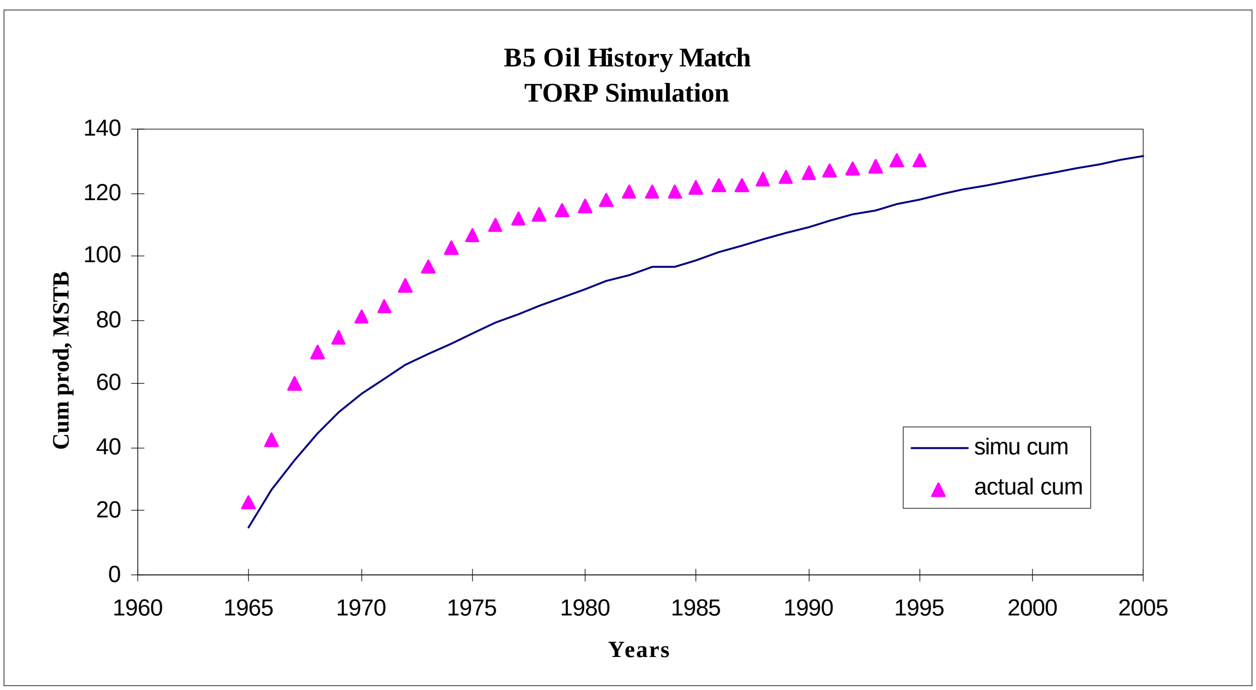


Figure D.4

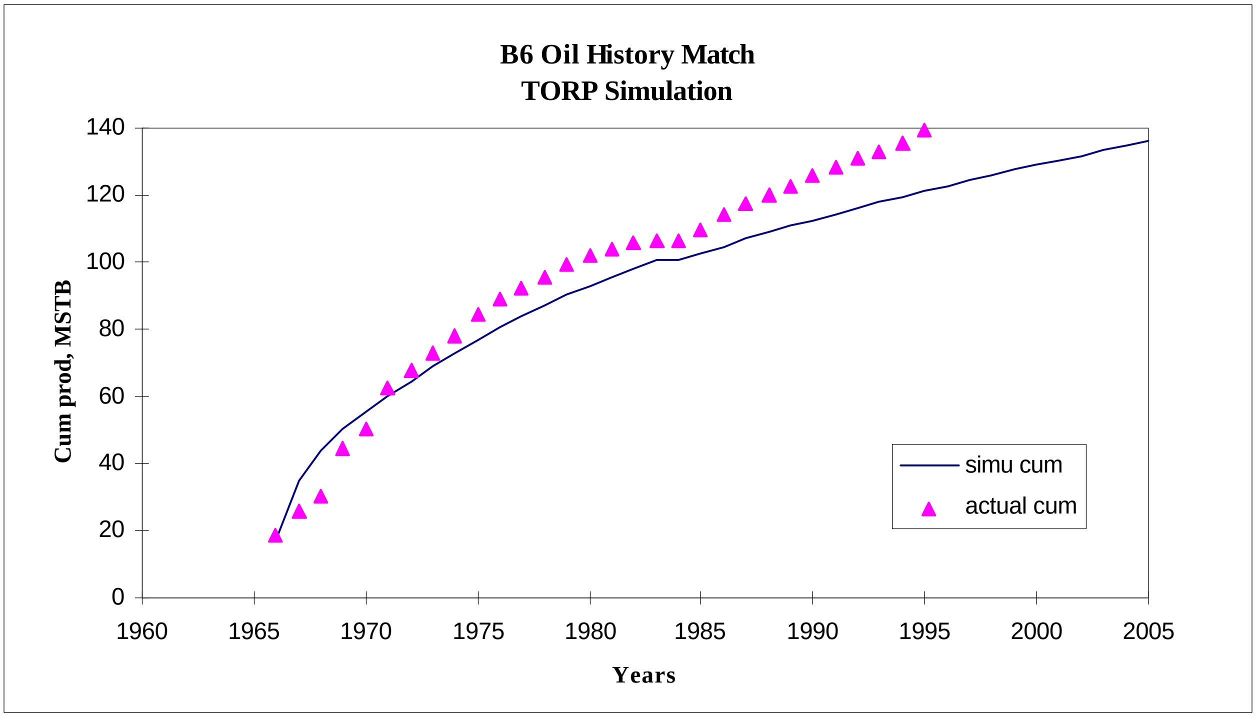


Figure D.5

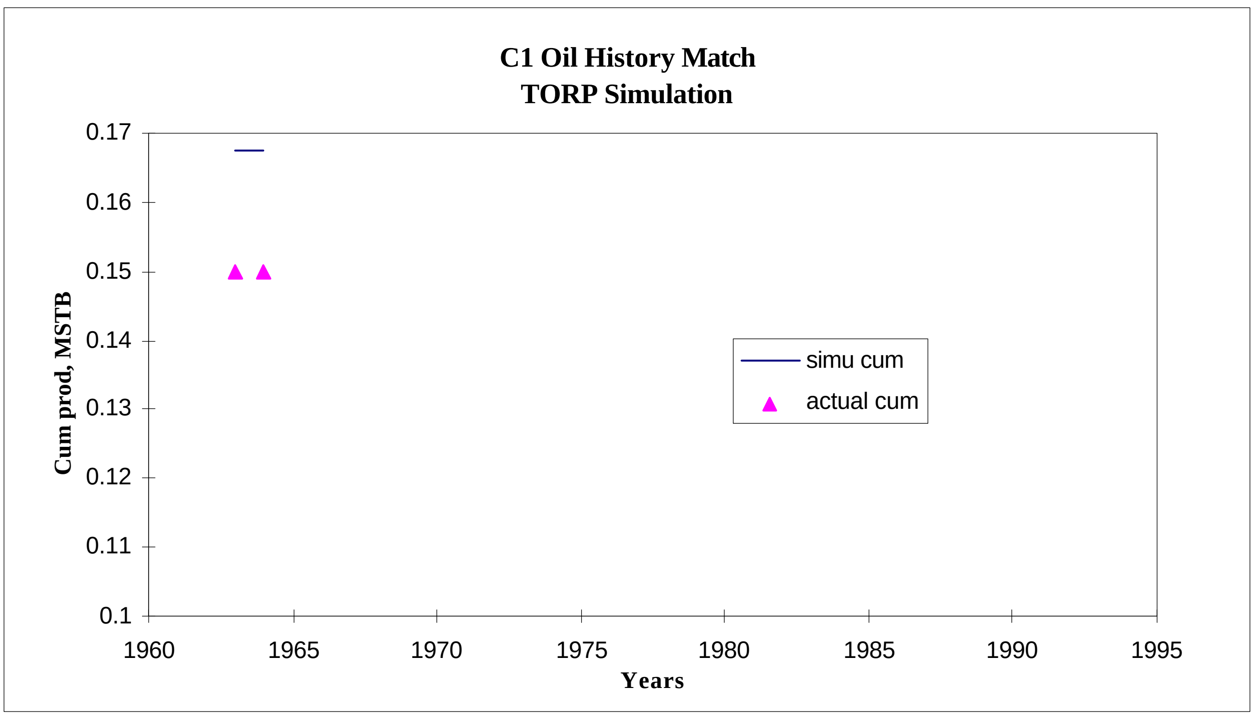


Figure D.6

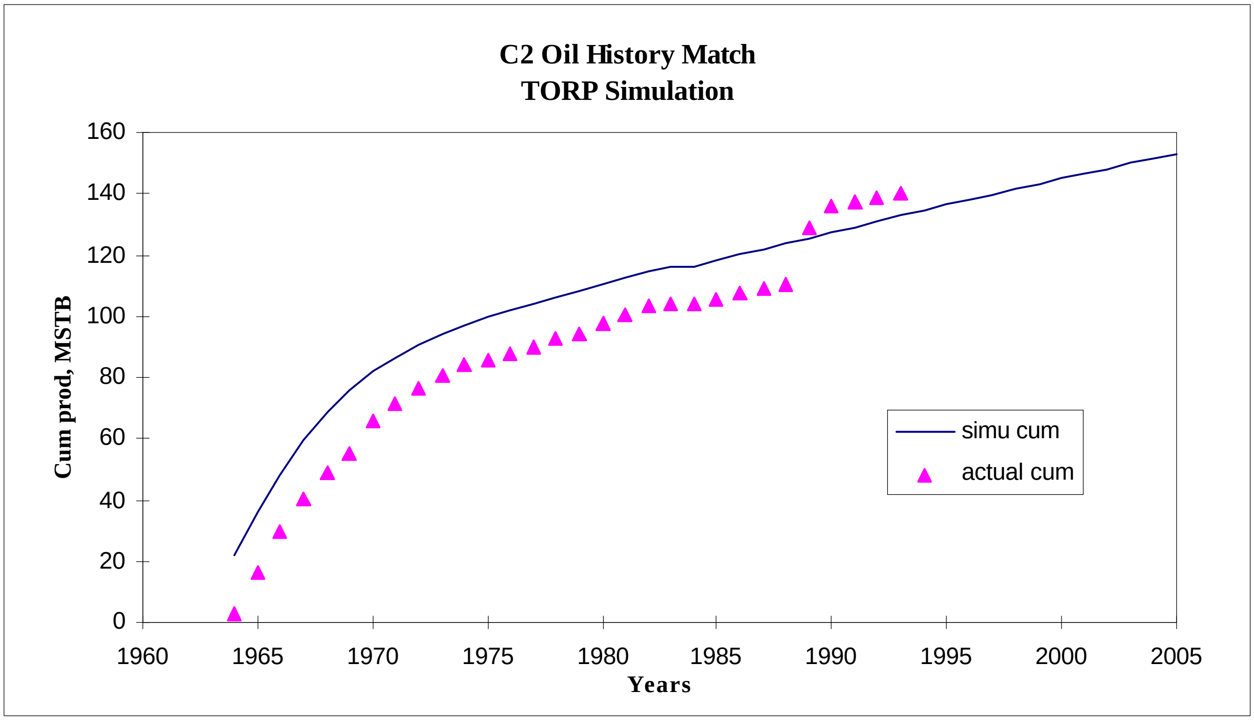


Figure D.7

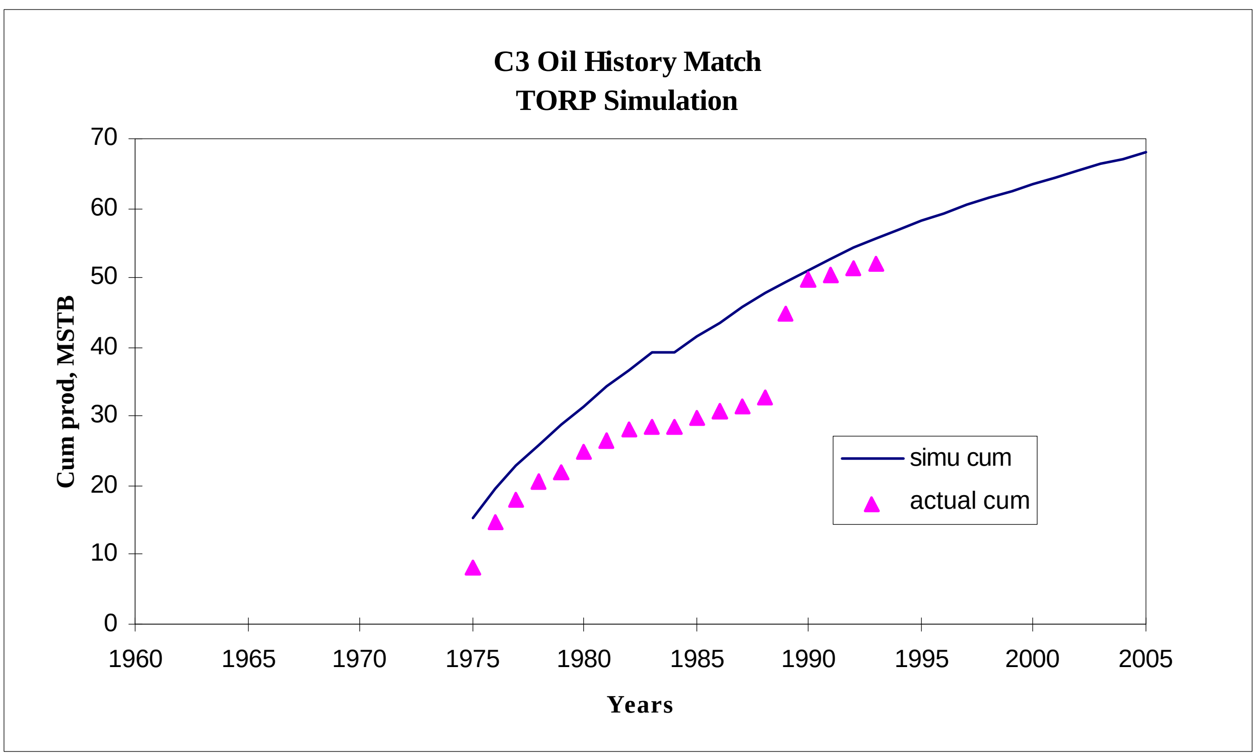


Figure D.8

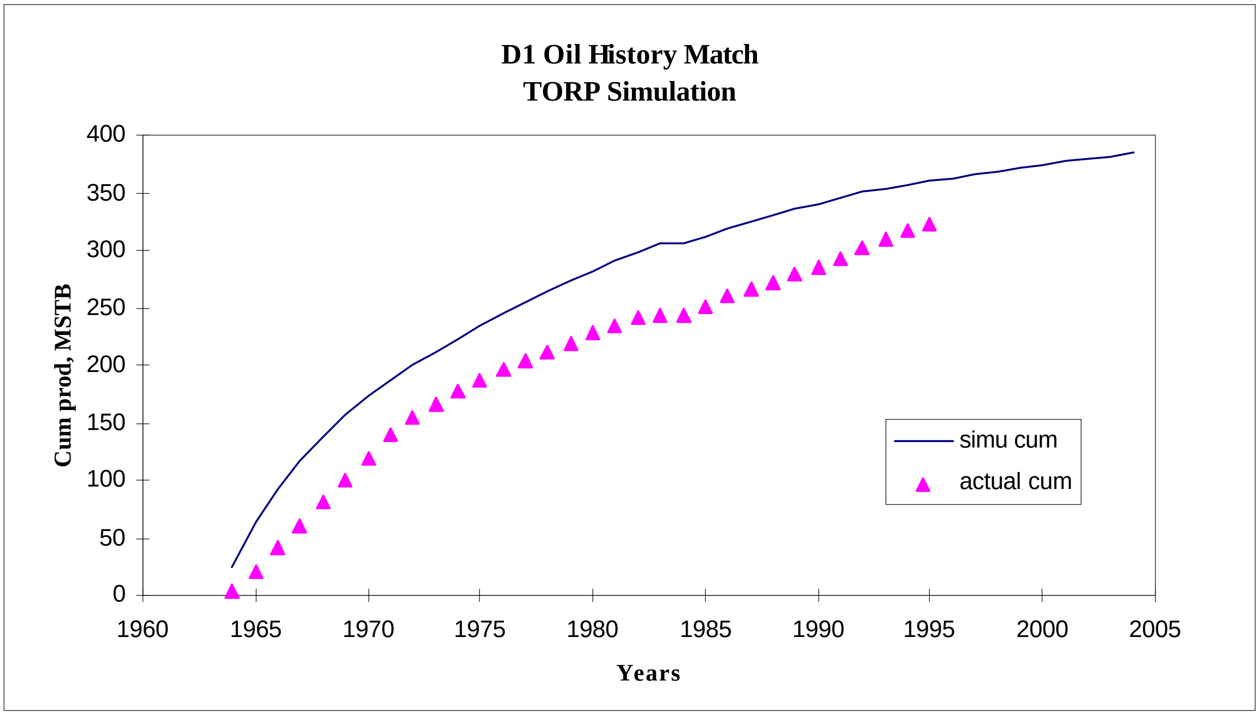


Figure D.9

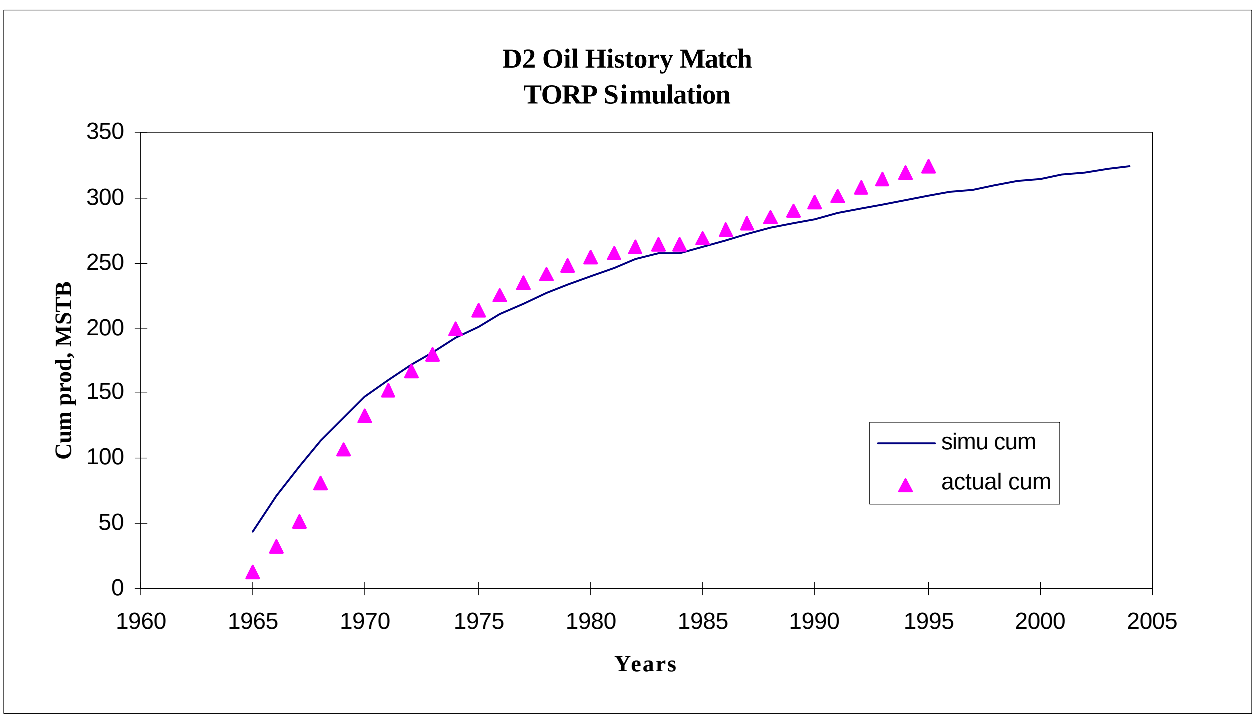


Figure D.10

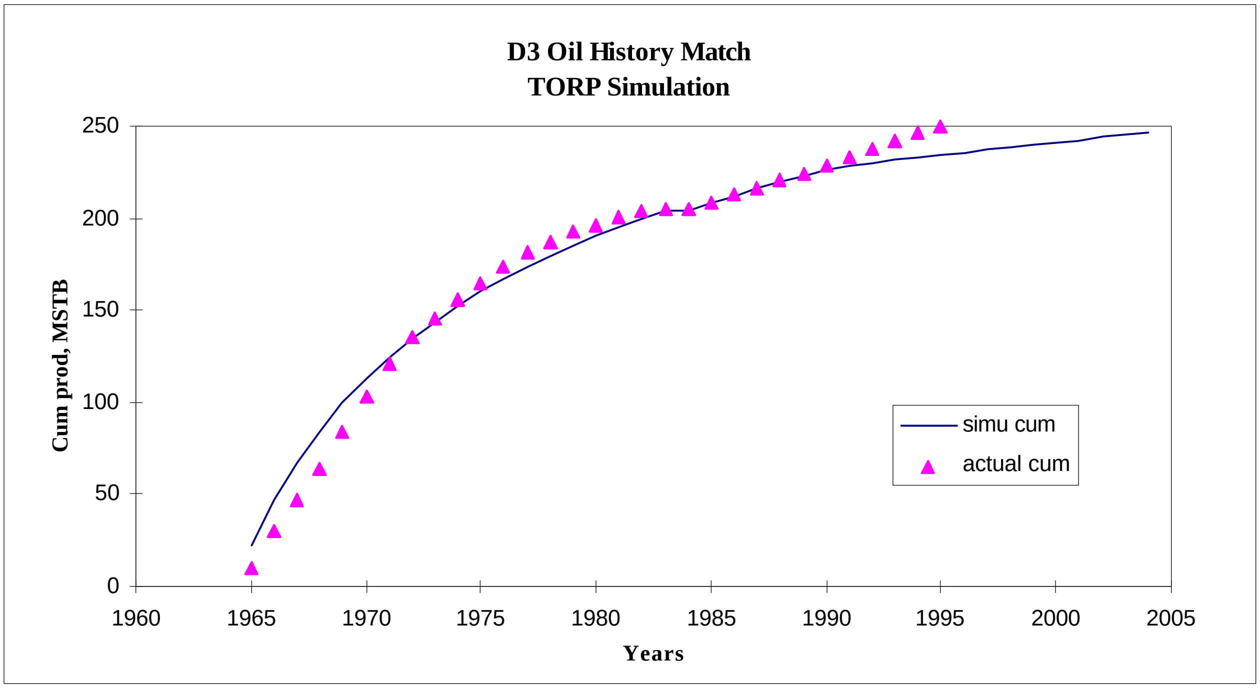


Figure D.11

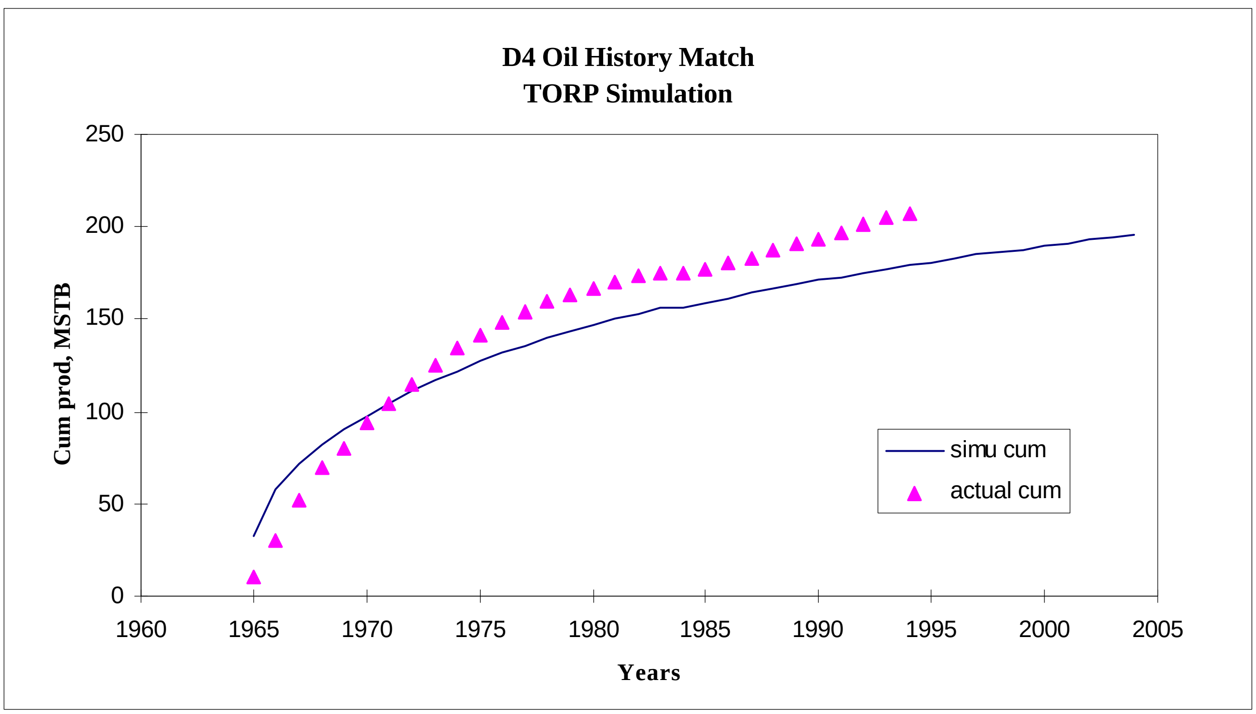


Figure D.12

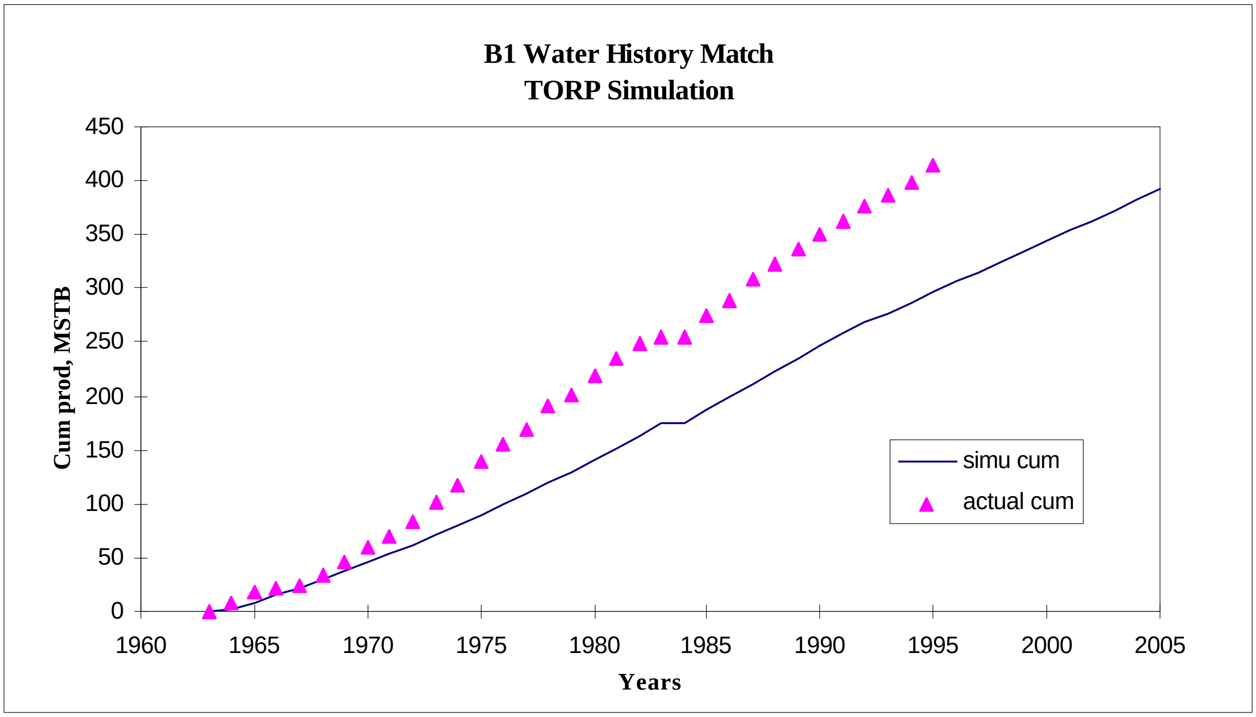


Figure D.13

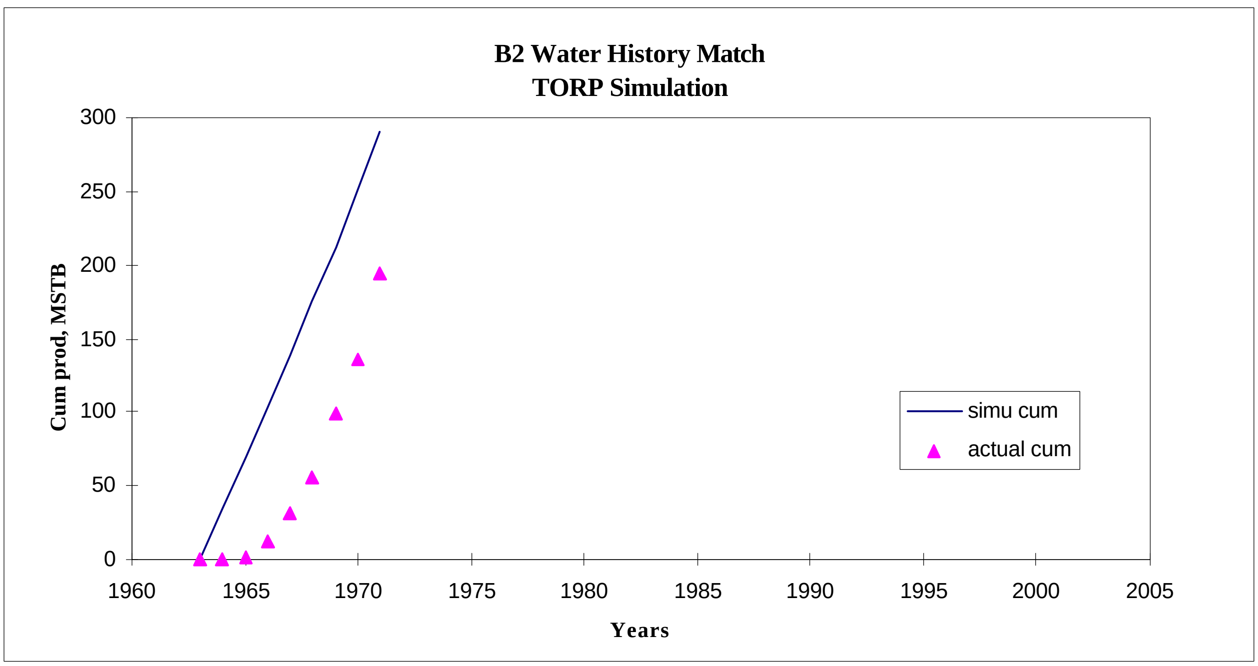


Figure D.14

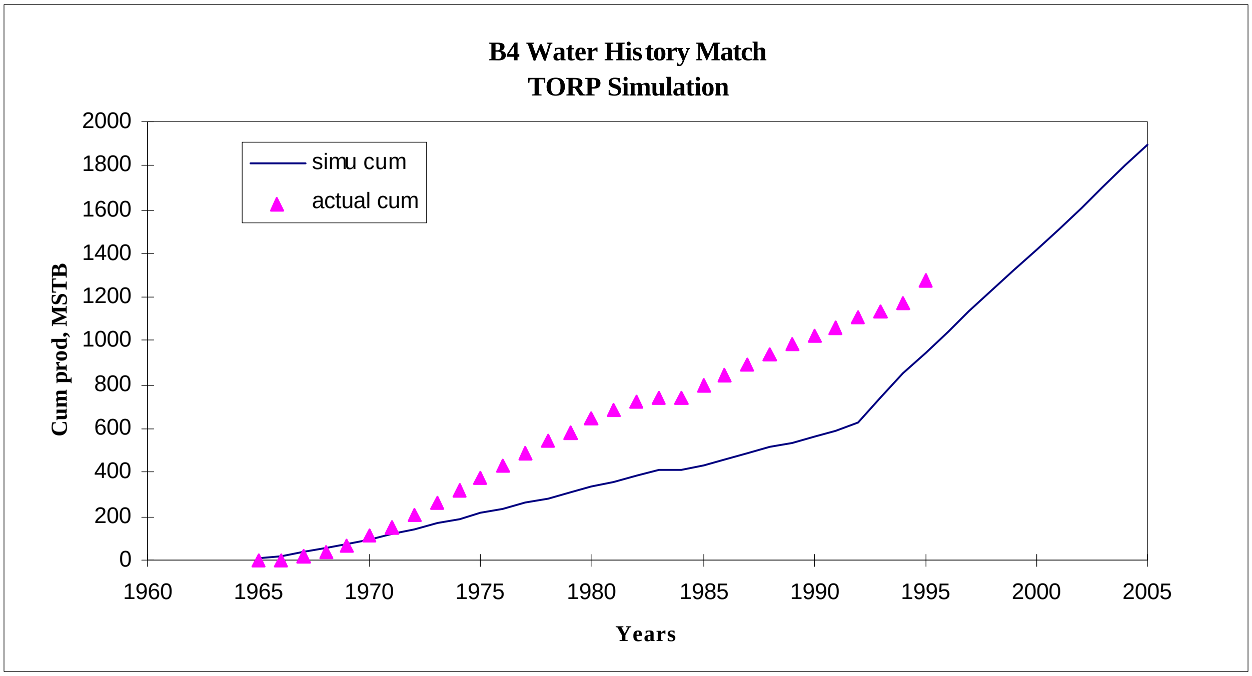


Figure D.15

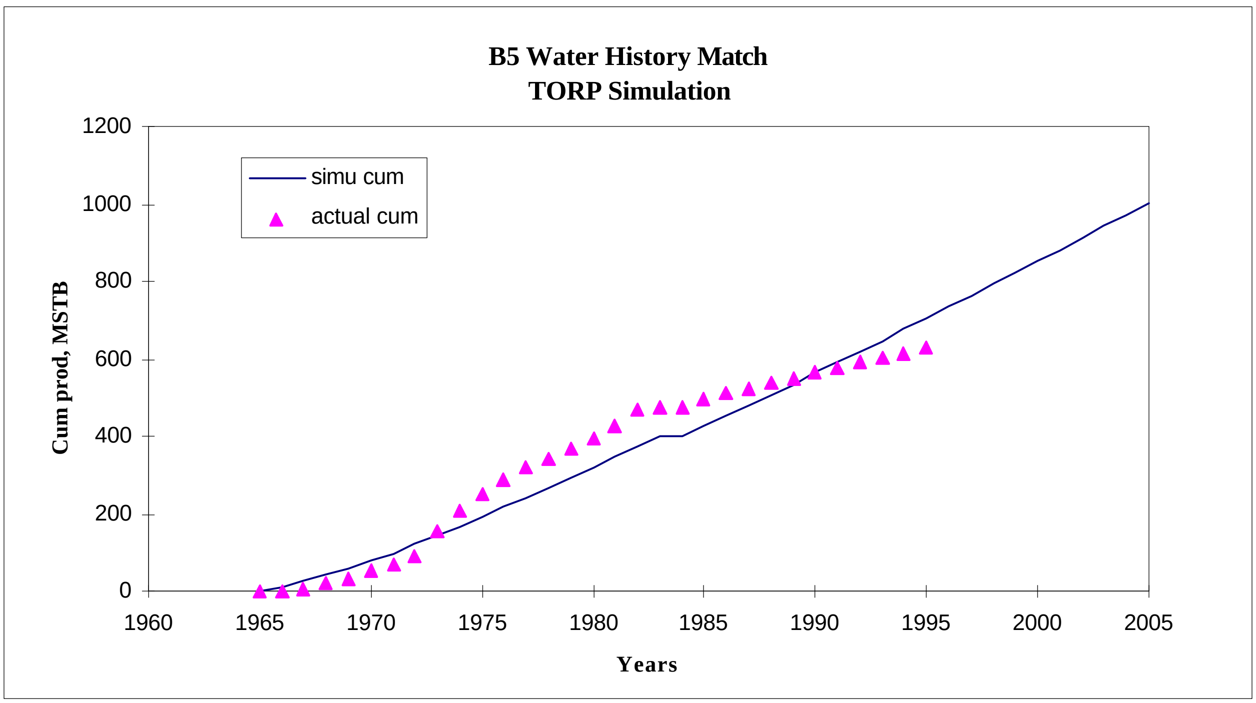


Figure D.16

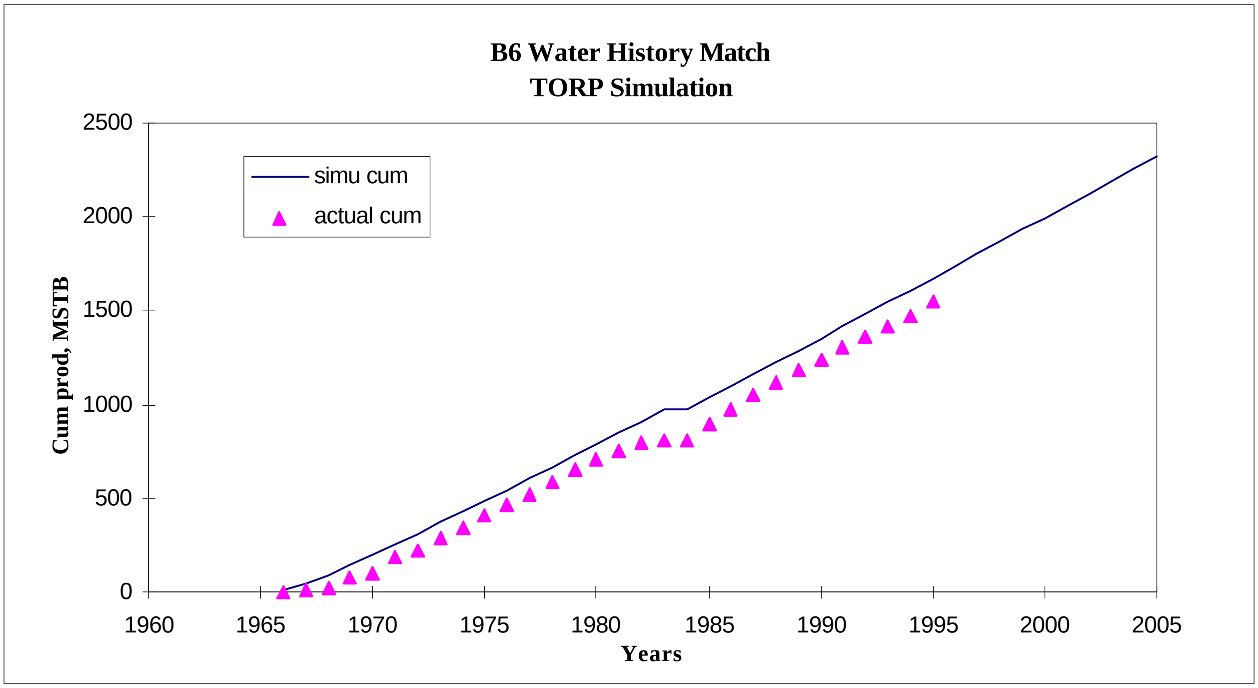


Figure D.17

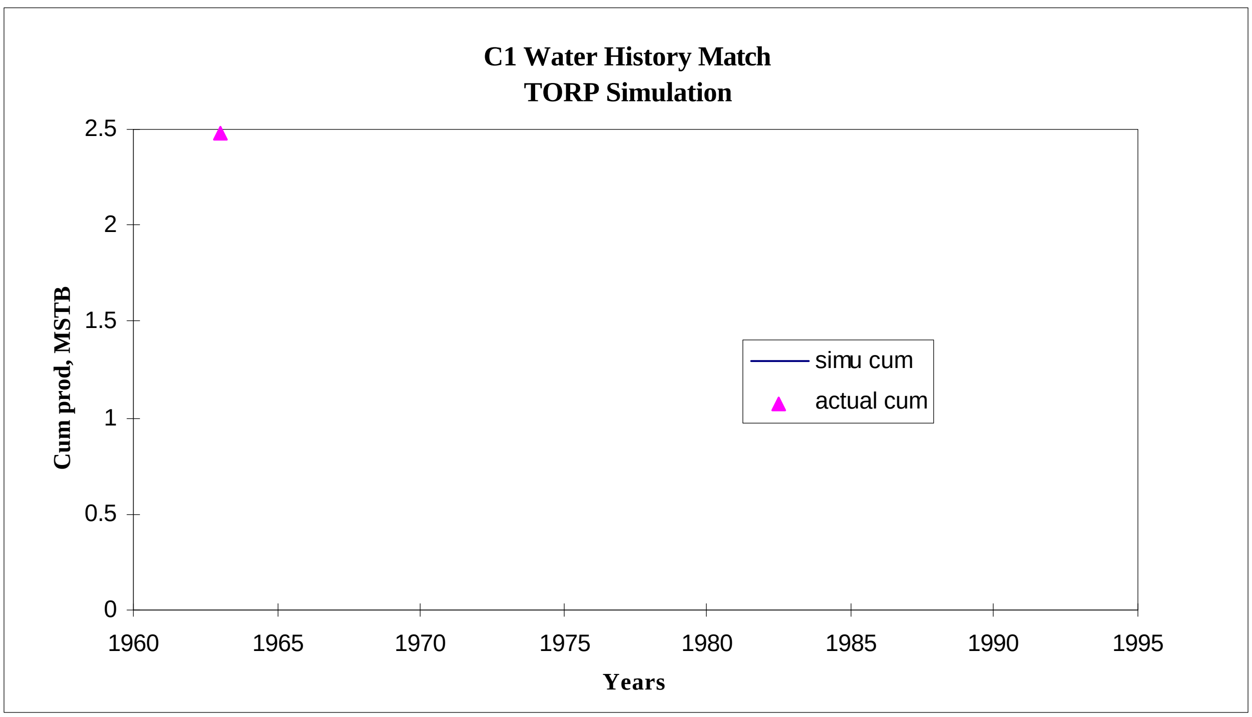


Figure D.18

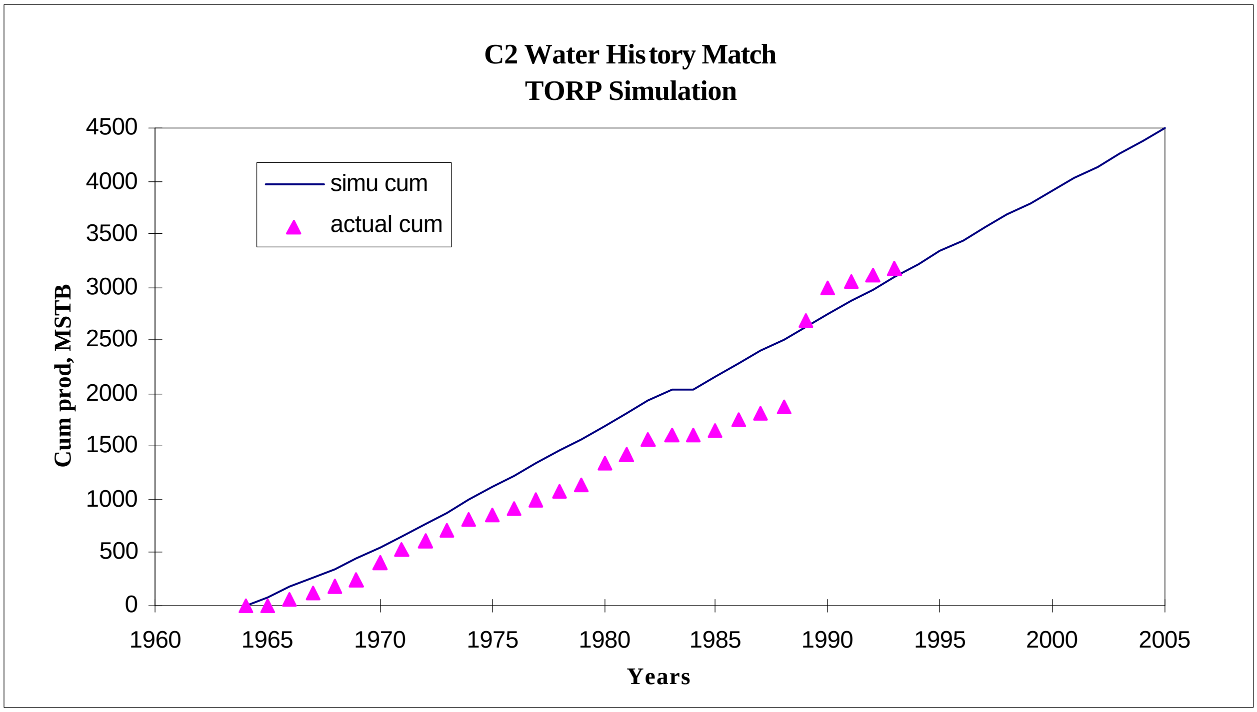


Figure D.19

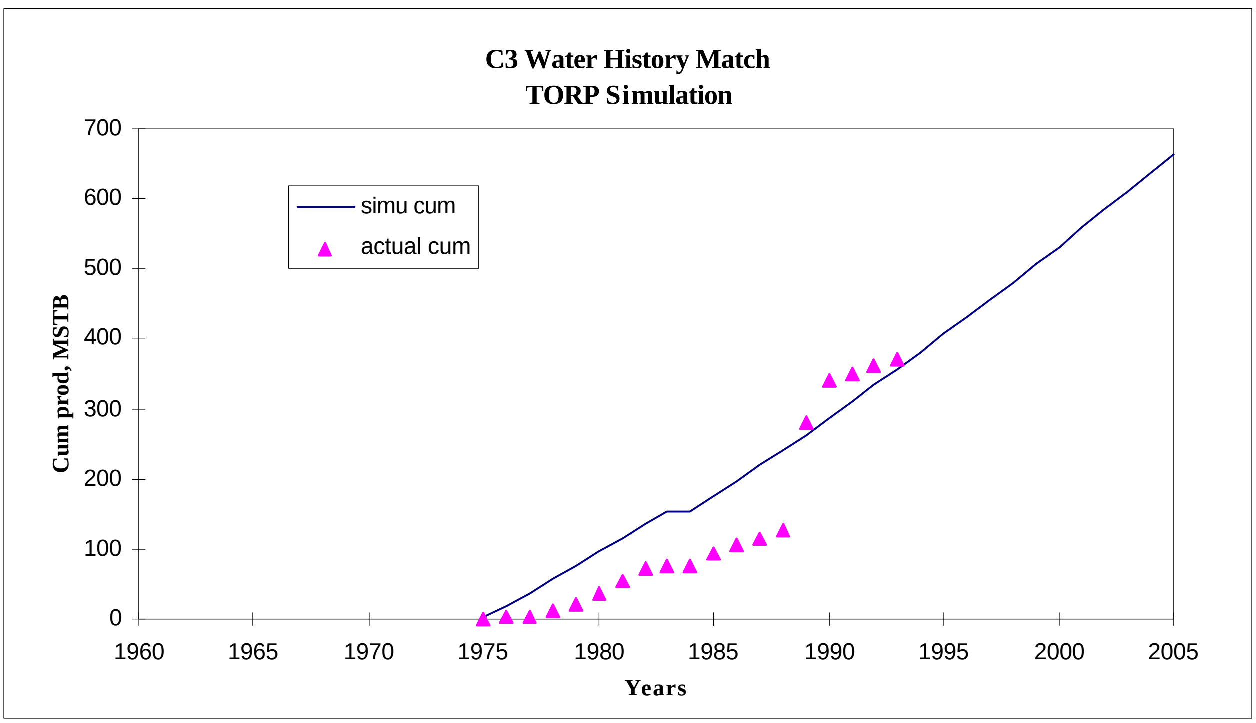


Figure D.20

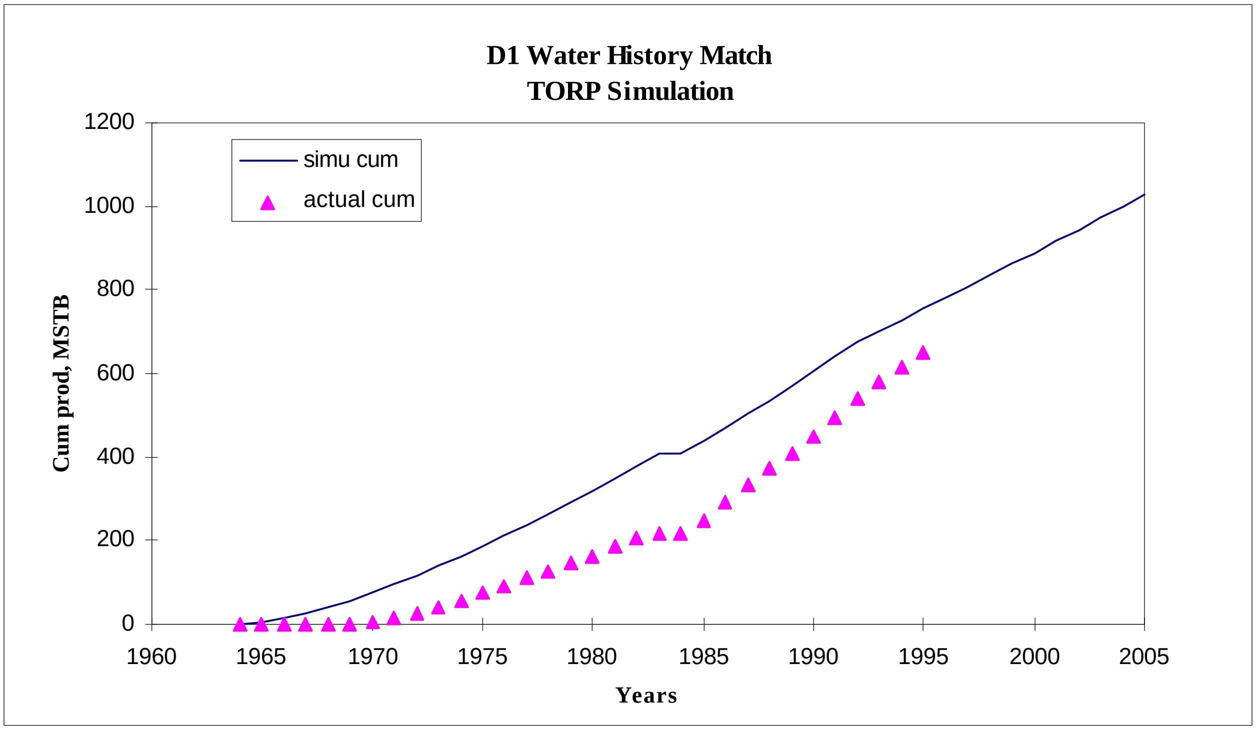


Figure D.21

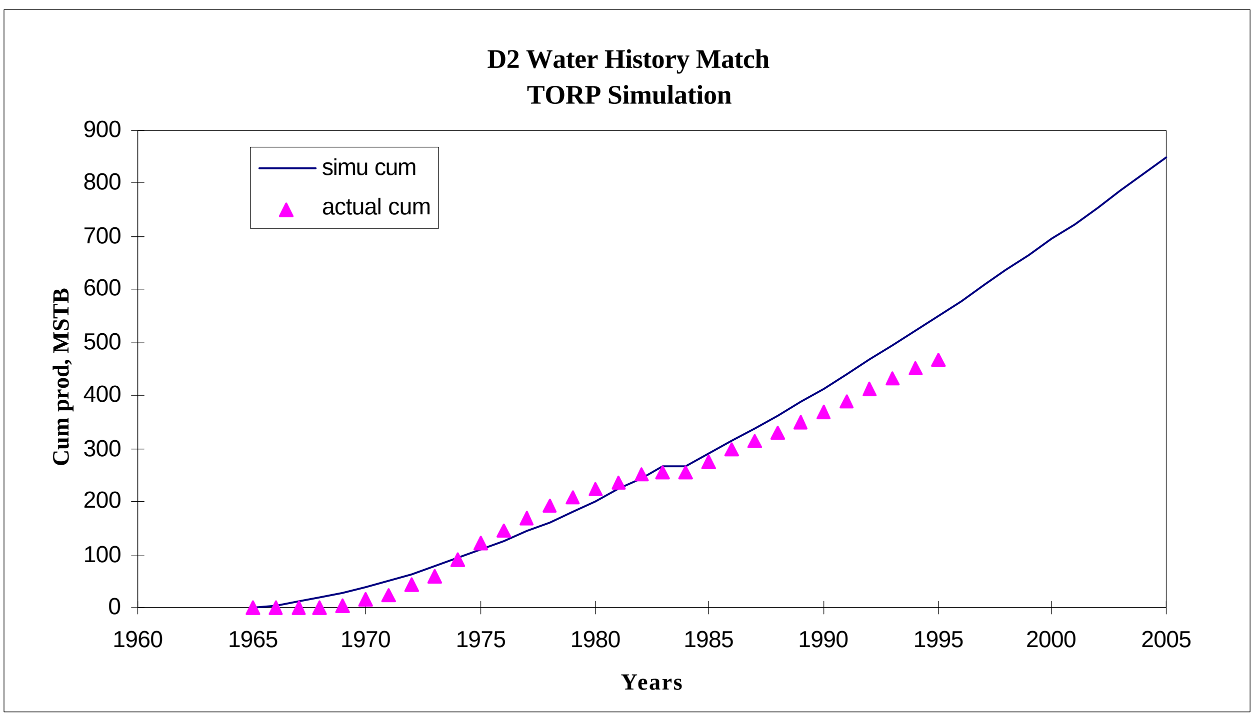


Figure D.22

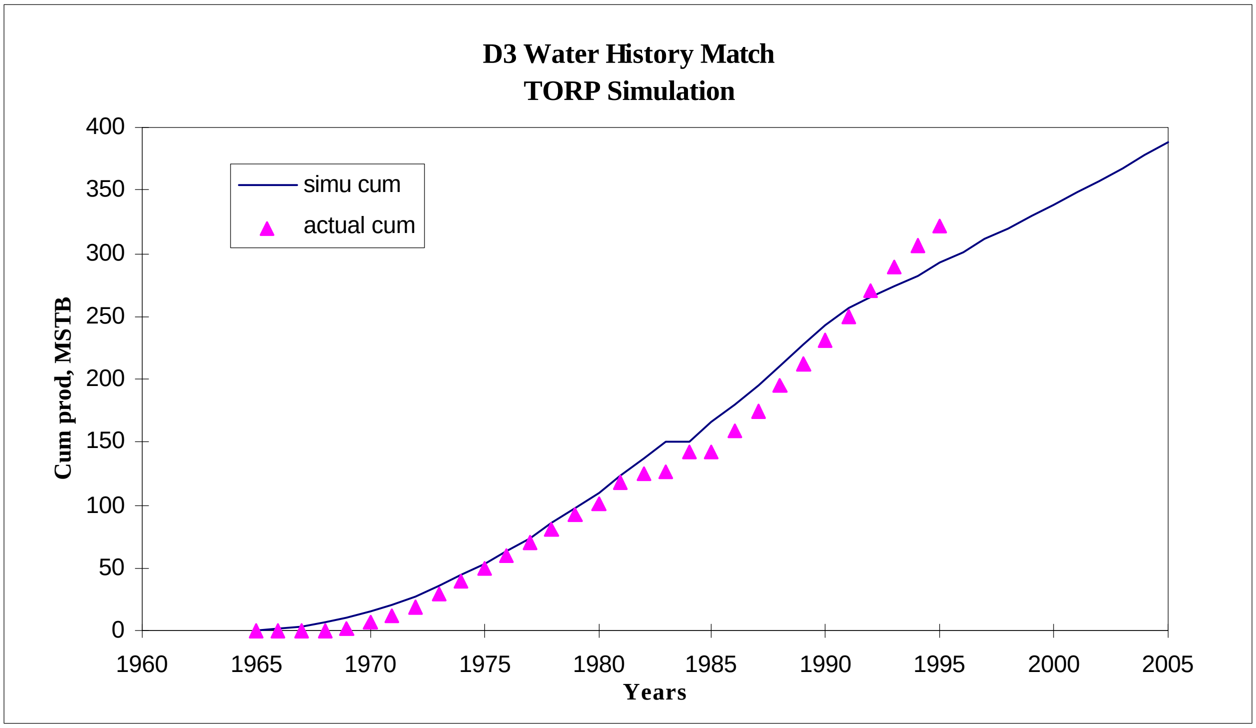


Figure D.23

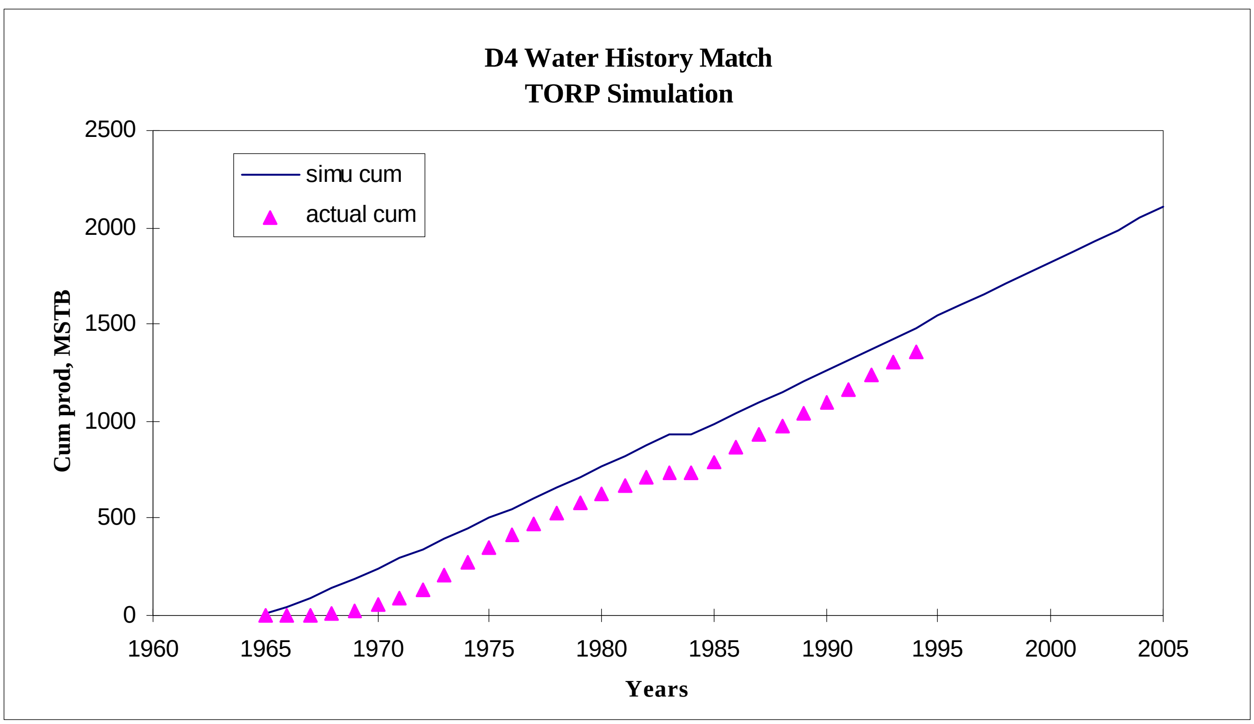


Figure D.24

Appendix E
Summary of Tables for TORP Simulation of Section 30

Table E.1
Wellbore Flowing Pressures

Well	Date	Perfs/Formation	Test Rate	Status/Fluid Level	BHP (psi)
Moore B-1	**8/24/63** **10/1/82** **12/3/91** **Current**	**4401-16 (Miss)** **4316-18 (Ft Scott)** **4416-32 (Miss)**	**122 BOPD, 0 BWPD** **10 BOPD, 52 BWPD** **10 BOPD, 206 BWPD**	 **Pumped off** **3682'** **Pumped off**	 **15** **323**
Moore B-2	**1963 - 1971**	**NA (Miss)**	**NA**	**Pumped off**	**15**
Moore B-4 & B-4 Twin	**5/11/65** **3/13/74** **12/9/91** **10/7/92** **Current**	**4408-14 (Miss)** **4394-96 (Miss)** **4398-4400 (Miss)** **4408-14 (Miss)** **4394-4408 (Miss)** **4418-19 (Miss)** **B-4 Twin**	**121 BOPD, 0 BWPD** **27 BOPD, 247 BWPD** **4 BOPD, 284 BWPD** **0 BOPD, 184 BWPD** **NA**	 **2100'** **3844'** **A lot of fluid**	 **997** **247**
Moore B-5	**7/17/65** **9/20/75** **10/83** **12/83** **Current**	**4388-92 (Miss)** **4398-4404 (Miss)**	**123 BOPD, 0 BWPD** **16 BOPD, 175 BWPD** **9 BOPD, 196 BWPD** **10 BOPD, 187 BWPD**	**Pumped off** **Pumped off**	**15** **15**
Moore B-6	**7/20/66** **3/20/85** **Current**	**4436-45 (Miss)** **4410-16 (Miss)** **4420-22 (Miss)** **4428-32 (Miss)**	**149 BOPD, 1 BWPD** **7 BOPD, 195 BWPD**	 **Pumped off**	 **15**
Moore C-1	**1963**	**NA**	**Uneconomical**	**Pumped off**	**15**
Moore C-2	**10/16/64** **4/27/91** **6/19/91** **Current**	**4402-06 (Miss)** **4311-20 (Ft Scott)** **4304-09 (Ft Scott)**	**184 BOPD, 8 BWPD** **7 BOPD, 339 BWPD** **7 BOPD, 259 BWPD**	 **Pumped off**	 **15**
Moore C-3	**6/10/75** **10/12/81** **Current**	**4416-20 (Miss)** **4438-42 (Miss)**	**60 BOPD, 4 BWPD** **6 BOPD, 63 BWPD**	**Pumped off** **Pumped off** **Pumped off**	**15** **15** **15**
Moore D-1	**9/17/64** **10/10/73** **1991** **Current**	**4388-94 (Miss)** **4372-78 (Miss)** **4365-72 (Miss)** **4378-88 (Miss)** **4394-97 (Miss)**	**195 BOPD, 0 BWPD** **55 BOPD, 57 BWPD** **10 BOPD, 196 BWPD**	 **Pumped off** **800-900'**	 **15** **366**
Moore D-2	**3/18/65** **5/30/91** **Current**	**4384-90 (Miss)** **4356-96 (Miss)**	**153 BOPD, trace wtr** **24 BOPD, 128 BWPD**	 **Pumped off**	 **15**
Moore D-3	**4/5/75** **1/11/74** **7/19/91** **Current**	**4399-4403 (Miss)** **4386-90 (Miss)** **4378-86 (Miss)** **4390-99 (Miss)** **4401-05 (Miss)**	**121 BOPD, 0 BWPD** **58 BOPD, 45 BWPD** **12 BOPD, 277 BWPD**	 **Pumped off** **3045'** **Some fluid ?**	 **15** **585**
Moore D-4	**6/29/65** **7/17/91** **Current**	**4421-23 (Miss)** **4404-24 (Miss)**	**121 BOPD, trace wtr** **18 BOPD, 342 BWPD**	 **A lot of fluid**	 **904**

Table E.2

Summary of TORP Simulation Results for Section 30

Year of Production	Total Cumulative Oil Production	Total Cumulative Water Production	Simulated Cumulative Oil Production	Simulated Cumulative Water Production
1963	8322	2482	11844.96	656.41
1964	31877	9916	74935.81	41066.47
1965	131275	31147	268774.43	187691.31
1966	279184	91893	430394.14	402963
1967	409449	211536	565798.64	664747.18
1968	533119	362779	675840.44	954734.5
1969	645340	602103	767451.74	1266945.4
1970	763768	956614	846283.74	1595070.8
1971	867194	1329382	915324.54	1936682.9
1972	952000	1636829	976723.34	2249779.7
1973	1024248	2048778	1032956.14	2570433.8
1974	1099302	2476614	1085204.04	2896895.1
1975	1170506	2832896	1149742.24	3232198.5
1976	1230734	3176181	1200672.04	3586307.6
1977	1280718	3527560	1247148.24	3964150.8
1978	1324996	3878557	1290489.34	4310509.7
1979	1363588	4193089	1331768.84	4680869.6
1980	1402226	4662112	1370925.14	5055538.1
1981	1436301	4988763	1407655.64	5432589.6
1982	1467439	5371433	1442257.04	5813236.6
1983	1476659	5487464	1475426.44	6198822.6
1985	1507880	5872734	1506717.84	6587296.6
1986	1541628	6290346	1536450.24	6978586.6
1987	1568437	6649033	1565147.94	7373647.6
1988	1599844	6990680	1592702.94	7771573.6
1989	1658659	8231489	1618988.14	8170403.6
1990	1697855	8870356	1644233.74	8571961.6
1991	1728567	9210034	1668054.04	8972733.6
1992	1761508	9566827	1690968.14	9387527.6
1993	1789601	9871674	1714930.14	9855413.6
1994	1816158	10127983	1737895.34	10327382
1995	1843783	10455807	1759499.14	10788136
1996			1780065.64	11244552
1997			1799820.34	11701391
1998			1818884.94	12159995
1999			1837300.44	12620065
2000			1855143.64	13082555
2001			1872347.64	13544786
2002			1889408.24	14013097
2003			1906227.04	14482482
2004			1922692.94	14953668
2005			1938696.34	15424211

Table E.3

Locations of Potential Infill Wells and Cumulative Production for 1998-2005

Cumulative Production from 1998 to 2005
(MSTB)

Well Name	Orientation	Location i	Location j	Oil Production	Water Production
Well 5	Vertical	2	7	60.56	770.58
Well 6	Vertical	6	11	96.38	528.72
Well 7	Vertical	2	17	72.91	183.15
Well 8	Vertical	17	9	32.55	41.65
Well 9	Vertical	11	11	64.28	215.71
Well 10	Horizontal	6-10	11	266.0	12,222.00
Well 11	Horizontal	2-6	7	132.75	8,650.00
Well 12	Horizontal	2	12-16	352.08	17,073.00
Well 13	Vertical	2	12	116.03	736.40

Table E.4

Well New 5 (Richie5)
(i = 2, j = 7)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	43.81	193.40
1999	25.27	236.77
2000	16.89	263.37
2001	12.80	278.37
2002	10.61	293.90
2003	8.76	302.65
2004	7.30	309.41
2005	6.25	315.07
Cumulative (MSTB)	**60.56**	**770.58**

Table E.5

Well New 6 (Sim6)
(i = 6, j = 11)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	60.71	110.91
1999	37.82	147.03
2000	23.77	178.74
2001	16.59	199.26
2002	13.11	214.45
2003	10.75	223.05
2004	9.19	230.50
2005	8.03	235.87
Cumulative (MSTB)	**96.38**	**528.72**

Table E.6

Well New 7 (Sim7)
(i = 2, j = 17)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	33.70	44.8
1999	28.23	51.76
2000	23.58	58.23
2001	19.10	65.40
2002	16.26	72.50
2003	13.56	78.05
2004	11.70	82.70
2005	10.38	85.90
Cumulative (MSTB)	**73.00**	**184.00**

Table E.7

Well New 8 (Sim 8)
(i = 17, j = 9)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	13.35	10.19
1999	11.46	12.01
2000	10.53	13.06
2001	9.18	14.58
2002	8.07	16.39
2003	6.81	18.23
2004	5.80	19.84
2005	5.07	21.24
Cumulative (MSTB)	**32.64**	**42.04**

Table E.8

Well New 9 (Sim9)
(i = 11, j = 11)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	33.34	49.51
1999	26.59	58.55
2000	20.05	68.97
2001	15.17	78.82
2002	12.49	86.88
2003	10.42	92.15
2004	9.12	95.70
2005	8.25	98.43
Cummulative (MSTB)	**64.28**	**215.71**

Table E.9

Well New 10 (Sim10)
(Horizontal Well: i = 6,7,8,9,10, j = 11)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	195.59	3945
1999	76.31	4355
2000	51.36	4448
2001	38.52	4491
2002	31.99	4544
2003	26.02	4553
2004	21.58	4551
2005	18.37	4540
Cumulative (MSTB)	**266.0**	**12,222.**

Table E.10

Well New 11 (Sim11)
(Horizontal Well: i = 2,3,4,5,6, j = 7)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	80.77	2777
1999	40.68	2953
2000	26.35	3021
2001	19.10	3052
2002	15.37	3096
2003	12.82	3100
2004	11.02	3097
2005	9.64	3091
Cummulative (MSTB)	**132.75**	**8650**

Table E.11

Well New 12 (Sim12)
(Horizontal Well: i = 2, j = 12,13,14,15,16)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	550.00	4144.
1999	106.19	6554.
2000	51.42	6788.
2001	32.44	6840.
2002	25.07	6815.
2003	20.54	6801.
2004	17.44	6776.
2005	15.16	6744.
Cumulative (MSTB)	**353.**	**17491.**

Table E.12

Well New 13 (Sim13)
(i = 2, j = 12)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	78.06	162.11
1999	42.23	223.36
2000	30.19	252.78
2001	23.62	271.35
2002	19.55	289.23
2003	15.96	300.64
2004	13.41	311.79
2005	11.54	320.26
Cumulative (MSTB)	**116.03**	**736.40**

Table E.13

Location of Potential Infill Wells and Cumulative Production for 1998-2005

Cumulative Production from 1998 to 2005
(MSTB)

Well Name	Orientation	Location i	Location j	Oil Production	Water Production
Well 1	Vertical	9	11	27.93	195.80
Well 2	Vertical	9	3	24.66	310.71
Well 3	Vertical	7	3	20.67	164.88
Well 4	Vertical	5	7	25.18	429.49

Table E.14

Well New 1 (Ritchie 1)
(i = 9, j = 11)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	10.07	58.29
1999	6.77	67.22
2000	6.00	69.71
2001	5.50	71.21
2002	5.29	73.20
2003	4.82	74.68
2004	4.33	76.19
2005	3.91	77.50
Cumulative (MSTB)	**27.93**	**195.80**

Table E.15

Well New 2 (Ritchie 2)

(i = 9, j = 3)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	12.40	93.83
1999	10.31	99.07
2000	8.83	103.62
2001	7.63	107.29
2002	6.79	111.82
2003	6.03	114.22
2004	5.45	116.79
2005	4.92	119.14
Cumulative (MSTB)	**24.66**	**310.71**

Table E.16

Well New 3 (Ritchie 3)

(i = 7, j = 3)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	9.71	49.56
1999	8.36	52.56
2000	7.37	54.91
2001	6.57	56.82
2002	6.02	59.26
2003	5.50	60.84
2004	5.03	62.25
2005	4.62	63.49
Cumulative (MSTB)	**20.67**	**164.88**

Table E.17

Well New 4 (Ritchie 4)
(i = 5, j = 7)

Year	Oil Production Rate STB/D	Water Production Rate STB/D
1998	14.59	118.86
1999	8.82	137.01
2000	6.17	147.74
2001	4.61	155.30
2002	3.72	162.26
2003	3.12	165.97
2004	2.68	169.08
2005	2.34	171.40
Cumulative (MSTB)	**25.18**	**429.49**

Appendix F

TORP Simulation Summary for Section 30 of Schaben Field

Final Simulation Input Data

Fluid Properties:

Oil Gravity: 40^{o}API

Reservoir Temperature: 125^{o}F

Water Viscosity at Reservoir Temperature: 0.647 cp

PVT data:

PSAT	R_s	B_o	Z_g	GR	μ_o	μ_g
194.7	50	1.038	0.9054	0.123	1.9	0.01
15	0.0	1.0	0.993	0.123	2.5	0.00972

Reservoir Properties:

Two layers of identical properties with top layer perforated

Permeability:

K_x and K_y set equal and both multiplied by 3.1 for all grids

Local modification of K_x and K_y:

i = 16-18, j = 17-19, k = 1-2	K_x and K_y multiplied by 0.2
i = 3-5, j = 12-14, k = 1-2	K_x and K_y multiplied by 0.21
i = 7-9, j = 11-13, k = 1-2	K_x and K_y multiplied by 0.5
i = 7-9, j = 17-19, k = 1-2	K_x and K_y multiplied by 0.1
i = 12-14, j = 12-14, k = 1-2	K_x and K_y multiplied by 0.6
i = 2-4, j = 8-10, k = 1-2	K_x and K_y multiplied by 0.7

Local modification of K_z:

i = 16-18, j = 17-19, k = 1-2	K_z multiplied by 0.21
i = 3-5, j = 12-14, k = 1-2	K_z multiplied by 0.8
i = 2-5, j = 3-5, k = 1-2	K_z multiplied by 0.27
i = 6-9, j = 3-5, k = 1-2	K_z multiplied by 0.11
i = 12-14, j = 12-14, k = 1-2	K_z multiplied by 1.8
i = 7-9, j = 11-13, k = 1-2	K_z multiplied by 0.2
i = 7-9, j = 7-9, k = 1-2	K_z multiplied by 0.65
i = 2-4, j = 8-10, k = 1-2	K_z multiplied by 0.3
i = 11-13, j = 2-4, k = 1-2	K_z multiplied by 1.2
i = 16-18, j = 2-4, k = 1-2	K_z multiplied by 1.1
i = 11-13, j = 6-8, k = 1-2	K_z multiplied by 1.1

Relative Permeability Curves:

$$k_{ro} = \alpha_1(1 - S_{wD})^m$$
$$k_{rw} = \alpha_2(S_{wD})^n$$

where,

$$S_{wD} = (S_w - S_{iw})/(1 - S_{iw} - S_{or})$$
$$S_{iw} = 0.305139$$
$$S_{or} = 0.23$$
$$\alpha_1 = 1.0922$$

$m = 1.6$
$\alpha_2 = 0.25$
$n = 2.9$

k_{ro} at S_{iw} was set at 1.0

Capillary Pressure Data:

$$P_{cow} = a + b \exp(-S_{wD}/c)$$

where,

$a = -7.4799213$
$b = 12.751247$
$c = 1.896574$

Well Data:

Well No.	Skin	BHP, psi
D2	+2	15
D3	-4.5, +1.5	15 (up to 1991), 584.8 (in 1991 and after)
B4	-4.5, -3.0	997.2 (up to 1992), 247.25 (in 1992), 438 (in 1995 and after)
B6	-3.7	15
C2	-4	15
D1	+3	15 (up to 1992), 366 (in 1992 and after)
B2	0.0	15
C3	+2	15
B5	+1	15
B1	-3, +4	15(up to 1991), 322.5 (in 1991 and after)
C1	-1	15
D4	-4.5	904

Appendix G
List of Publications and Presentations
Resulting from Class 2 Project

Bhattachatya, S, and P. M. Gerlach, 1997, Carbonate Reservoir characterization and field simulation using boast 3: The Schaben Field (Mississippian), Ness County , Kansas; Presentation at University of Kansas / TORP Conference, March 19-20, 1997

Carr, T. R., 1996, Technology transfer for the independent; Society of Independent Professional Earth Scientists National Convention Abstracts, p. 10. Invited Talk/Panel Discussion at Society of Independent Petroleum Earth Scientists (SIPES) National Convention, March 20 -- 23, Dallas, TX.

Carr, T. R., J. Hopkins, H. Feldman, A. Feltz, J. Doveton, and D. Collins, 1994, Color Image Transforms of Wireline Logs: A Seismic Approach to Petrophysical Sequence Stratigraphy, Landmark Worldwide Technology Symposium, p. 36. Invited Talk at Landmark Worldwide Technology Forum, November, 29 - December 1, 1994, Houston, Texas.

Carr, T. R., Hopkins, J. H., Feldman, H. R., Feltz, A., Doveton J. H., and D. Collins, D. R., 1995, Color 2-D and 3-D Pseudo-Seismic Transforms of Wireline Logs: A Seismic Approach To Petrophysical Sequence Stratigraphy; Landmark Computer Graphics UserNet, 6p.

Carr, T. R., W. R. Guy, E. K. Franseen, and S. Bhattacharya, 1996, Enhanced Carbonate reservoir model for an old reservoir utilizing new techniques: The Schaben Field (Mississippian), Ness County, Kansas; American Association of Petroleum Geologists, Annual Meeting Abstracts, p. A23-A24.

Carr, T. R., H. R. Feldman, W. J. Guy, 1996, A new look at the reservoir geology of the Mississippian Schaben Field, Ness County, Kansas; Oklahoma Geological Survey Workshop on “Platform Carbonates in the Southern Midcontinent” Abstracts, p. 8.

Carr, T. R. , 1996, New Techniques for Sequence Stratigraphic Analysis Using Wireline Logs. Invited Talk, at San Joaquin Geological Society, December 3, 1996.

Doveton, J. H., Guy, W., Watney, W. L., Bohling, G. C., Ullah, S., and Atkins-Heljeson, D., 1995, PfEFFER 1.0 Manual, Kansas Geological Survey Open File Report 95-86.

Doveton, J.H., Guy, W.J., Watney, W. L., Bohling, G.C., Ullah, S., and Adkins-Heljeson, D., 1996, Log analysis of petrofacies and flow-units with microcomputer spreadsheet software: 1995 AAPG Mid-Continent Meeting.Transactions, p.224-233.

Guy, W. J., T. R. Carr, E. K. Franseen, S. Bhattacharya, and S. Beaty, 1997, Combination of magnetic resonance and classic petrophysical techniques to determine pore geometry and characterization of a complex heterogeneous carbonate reservoir: American Association of Petroleum Geologists Annual Meeting Abstracts, Dallas.

Hopkins, J. F., T. R. Carr, H. R. Feldman, 1996, Pseudoseismic Transforms of Wireline Logs: A Seismic Approach to Petrophysical Sequence Stratigraphy, in J. A. Pacht, R. E. Sheriff and B. F. Perkins, eds., Stratigraphic Analysis Utilizing Advanced Geophysical, Wireline and Borehole Technology for Petroleum Exploration and Production: Gulf Coast SEPM Seventeenth Annual Research Conference, p. 133-144.

Watney, W.L., W.J. Guy, J.H. Doveton, S. Bhattacharya, P. M. Gerlach, G. C. Bohling, T. R. Carr, 1997, Petrofacies Analysis - A petrophysical tool for geologic/engineering reservoir characterization, Manuscript for USDOE Reservoir Characterization Workshop, Houston, Texas, March 3- 5.