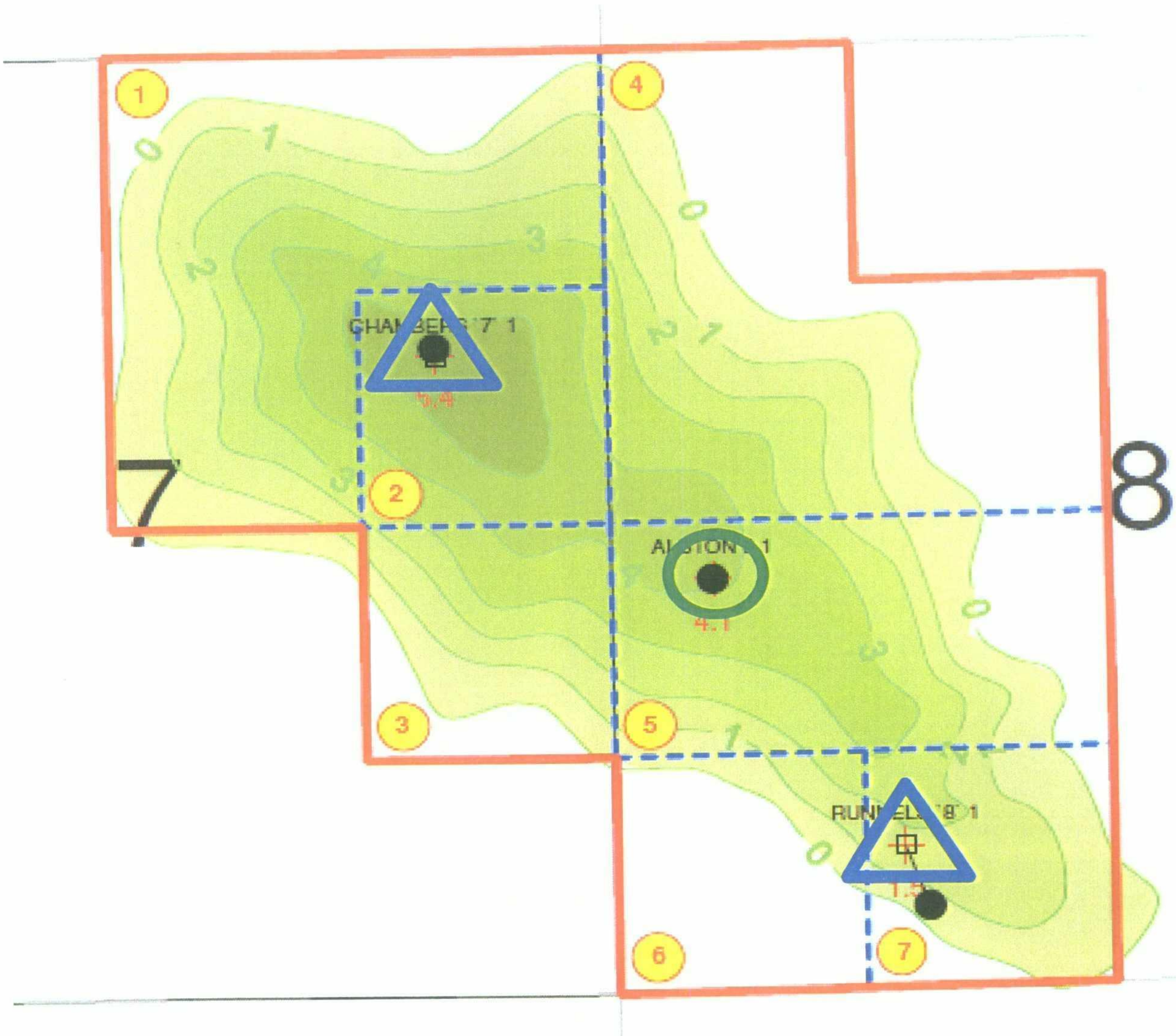
Chesapeake ENERGY

# Feasibility Study

# Chambers Strawn Unit

**Lea County, New Mexico**
**T16S-R36E**




**April 15, 2010**

# Proposed Chambers Strawn Unit

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# Proposed Chambers Strawn Unit
## Executive Summary

In Pennsylvanian times a series of phylloid algal bioherms (Strawn mounds) developed along the northwest flank of the Central Basin Platform. These mounds underlie an area of present day northwest Lea County, NM, near the town of Lovington. The average depth is 11,400 ft and the features are generally small, elongated porosity mounds of from a few acres up to several hundred acres and from 20 to 180 ft in thickness. The mounds are generally separated and sealed by tight lime mudstones.

Chesapeake plans to unitize a mound and conduct waterflood operations in order to prevent the waste of secondary reserves. The location is in Sections 7 and 8 of T16S-R36E, which is in the southeast of what is now designated the Shoe Bar NE Field. The proposed unit will contain 480 acres of which 346 acres are productive. Average thickness is 54 feet, average porosity is 8.7 percent, and water saturation is 34 percent. The drive mechanism is solution gas, and there is little evidence of the formation of a secondary gas cap nor of a significant water drive. This is an appropriate candidate for waterflood operations. The OOIP was 5.749 MMBO. The estimated ultimate primary recover is 777 MBO from three completions. The primary recovery efficiency will be 14 percent. The primary is now 91 percent depleted.

We plan to convert the Chambers 8-1 and Runnels 7-1 to injection service. Since there are no analogy floods and no relative permeability data, the estimate of secondary recovery is based on a Secondary-to-Primary ratio of 0.75, yielding anticipated secondary reserves of 582 MBO. The secondary efficiency is 10 percent and total efficiency is 24 percent. Capital costs are estimated at $1.25 million, resulting in a net finding cost of $2.66/BO to the working interest owners.

### Findings:

1. The OOIP is 5.749 million barrels.
2. Primary recovery will be 776,540 BO from three completions.
3. Primary recovery efficiency calculates to be 14 percent.
4. The unit will have a positive mobility ratio for 0.686
5. The secondary recovery will be 582,400 BO of oil, gross.
6. The secondary to primary ratio is 0.75
7. The secondary recovery efficiency is 10 percent.
8. The total recovery efficiency is 24 percent.
9. The capital investment is $1.25 million.
10. The finding cost for the working interest owners is $2.66/BO.

### Conclusions:

1. The field is a waterflood candidate.
2. The absence of a flood will result in the loss of 582,400 BO & 580,000 Mcf.
3. There is strong economic incentive to flood this mound.

### Recommendations:

1. Unitize the Chambers Strawn Unit.
2. Implement the flood plan.

# Proposed Chambers Strawn Unit

## Summary:
## Geologic, Fluid, Production and Engineering Data

| | | |
|---|---|---|
| Formation | Strawn | |
| Lithology | Limestone | |
| Trap | Algal bioherm | |
| Drive Energy | Solution Gas | |
| Unit Area | 480 | Acres |
| Net Productive Area | 346 | Acres |
| Depth | 11,392' | ft., top perf |
| Temperature | 162 | °F |
| Net Thickness, Avg. | 53.94 | ft. |
| Porosity, Avg | 8.727 | % |
| Permeability | 8.73 | md |
| Water Saturation, Avg. | 34.080 | % |
| Initial Reservoir Pressure | 4,224 | psi |
| Oil Gravity | 43.95 | °API |
| Gas Gravity | 0.61 | Ratio |
| Initial Gas/Oil Ratio | 1.33 | Cu. ft./BO |
| Bubble Point Pressure | 2,950 | Psi |
| Oil form. Vol. factor, Init. | 1.45495 | BO/STB |
| Original Oil in Place | 5,749,177 | STB |
| Primary Cumulative (4/1/10) | 708,515 | STB |
| Primary Reserve (4/1/10) | 68,025 | STB |
| Primary Est. Ult. Rec. | 776,540 | STB |
| Stage of Pri. Depletion | 91.2 | % |
| Primary Rec. Efficiency | 13.5 | % |
| Abandonment Pressure | 500 | psi |
| Oil Form. Vol. factor, Aband. | 1.123 | BO/STB |
| Secondary Reserves | 582,404 | BO, gross |
| Sec. Rec. Efficiency | 10.1 | % |
| Total Est. Ult. Rec. | 1,358,944 | BO |
| Total Rec. Efficiency | 23.6 | % |
| Sec. to Prim. Ratio | 0.75 | Ratio |
| Capital Investment | 1,250,000 | $ |

## General Geology

The Lovington Strawn area is situated locally in eastern central Lea County, New Mexico and regionally on the Northwest Shelf of the Delaware basin. The Strawn is Pennsylvanian (Desmoinesian) age, which unconformably overlies Atoka-age shale and shallow marine sand and is overlain by clastics of Missourian age. Strawn at Lovington produces oil and gas from phylloid algal bioherms within the lower Strawn limestone. These Strawn carbonates were deposited along the northwest flank of the Central Basin Platform axis in a low energy, middle to outer ramp setting. Growth of algal bioherms developed into elongated, steep-sided, loaf-shaped buildups in a dip direction separated by tight lime mudstones. The average depth of Strawn mounds is 11,400 feet, and thickness ranges from 40 to 180 ft, while average areal extent is 1.5 miles long by 0.5 to 1 mile wide. Within the mound facies, porosity ranges from 4 to 14 percent. Intermound facies of nonporous lime mudstones form the vertical and lateral seals for the porous bioherms. Basinal black shale overlies the Strawn limestone across the play fairway and possibly provides a source for Strawn oil.

## Field Discovery and History

The field known as Shoe Bar Northeast has ten well completions in portions of six sections and contains roughly 800 gross acres. The field lies two miles west-southwest of the town of Lovington in Lea County, New Mexico. An orientation map is attachment 1. The first well to produce in the Lovington Northeast Strawn Field was the Chambers 7 No. 1 in Section 7H-T16S-R36E. This well was completed by Chesapeake Operating Inc in November 1996 and averaged 380 BOD of 43.2 $^{o}$API oil from perforations at 11,392' – 11,480' in the Strawn member of the Pennsylvanian. The well is still active and has cumulative production of 496,345 BO, 1,794,165 Mcf, and 353,363 BW. The well is 94 percent depleted.

The Strawn Mounds are not a single reservoir but a grouping of separate, discrete, sealed porous units. The long development life, 56 years, numerous dry holes, and the many development wells found to be at virgin pressure all attest to the discontinuous nature of many of the mounds in this area. Thus, we are proposing to unitize and waterflood a single mound.

## Reservoir of Interest

The single mound that Chesapeake proposes to unitize is in the far southwest area of the Shoe Bar Northeast field. This area has had three wells drilled in a 17 month period from November 1996 to March 1998. These wells are located on the base map on attachment 2. A structural cross-section, showing each well with perforations, is attachment 3. The cross-section is located in the plastic sleeve at the end of this report. A structure map, attachment 4, on top of the Strawn formation shows 1.5 degree dip to the east-northeast. There is a drop of 91 ft from the structurally highest well, the Chambers 7-1, to the lowest well, the Runnels 7-1. This is a significant change for this pay, which is about 100 ft thick. The structure of the Strawn does not play a role in trapping; rather it is the development of algal bioherms that provides the porous reservoir and encasement in lime mud provide the trap. A table of well data is attachment 5 and has date of first production, production totals, perforations, discovery pressure, oil gravity, log derived porosity and water saturation, and oil formation volume factor.

**Mound History and Production Data:** The mound was drilled and completed in a 17 month period from November 1996 to March 1998. The initial well, Chambers 7-1 had initial pressure of 4,224 psi and produced at initial rates of 400 BOD. The three wells have a combined estimated ultimate recovery (EUR) of 782,895 BO, 827,247 Mcf. The average EUR per well is 260,965 BO per well. A performance curve of each well the combined mound is attachment 6-1 through 6-4. Over the initial 12 years of production the field has depleted 92 percent. The remaining 8 percent or 68 MBO are forecast to last another 26 years.

**Reservoir Rock and Fluid Characteristics:** The reservoir is a phylloid algal bioherm that has experienced weathering. Weathering led to grain dissolution and significant vug development and contributed to brecciation and initial fracture development. Core data and Formation Micro-Imager log on the Alston 1-8 and numerous routine core studies of mounds in the area indicate that fracture and other secondary pores are important reservoir characteristics. General standard porosity logs are pessimistic and may miss vuggy porosity that is not developed entirely around the borehole. This mound's Neutron-Density crossplot porosity averages 8.7 percent, when a cut-off of 6 percent was applied. No attempt has been made to adjust for the fractured, vuggy nature of the rock. The water saturation calculates to be 27.7 percent. The porosity and water saturations may both be pessimistic.

The initial pressure in this mound was 4,224 psi, which is equivalent to discovery pressures in this area. We do not have a PVT study on this mound, but Lasater's correlation (Frick Petroleum Handbook, pg 19-9) indicates the bubble point pressure is approximately 2,950 psi. The reservoir temperature is 162 $^{o}$F, initial GOR was 0.7 Mcf/Bbl, and the oil gravity is 43.95 $^{o}$API. By correlation, the oil formation volume factor is 1.455 STB/Res Bbl and matches measurements from Drill Stem Tests.

We have routine core analysis of the Strawn formation taken from the Alston 1-8. The porosity to permeability relationship is fairly strong and shows that for porosity of 8%, the permeability is about 10 md. The relationship of horizontal to vertical permeability is also shown, and vertical permeability is about 56% of horizontal permeability, which suggests we may expect fairly good vertical fluid movement. These relationships are shown on attachment 7. The Dykstra-Parsons coefficient of permeability variation is 0.83, shown at attachment 8. Most reservoirs fall between 0.6 and 0.9 and this reservoir fits comfortably within this range.

**Reservoir Size and Original Oil in Place:** Studies of multiple cores in closely spaced wells conducted in the Lovington Strawn area indicate mounds rarely correlate over long distances. We believe three-dimensional (3D) seismic data analysis is critical in determining the location and shape of individual mounds. Log data, presented in attachment 5, and 3-D seismic analysis were used to develop the $\phi$h isopach map at attachment 9. The mound is 1.4 mile long, and ¼ to ½ miles wide, runs northwest to southeast, and has a productive area of 346 acres. The maximum reservoir thickness is 120+ feet, and the average thickness is 54 feet. Porosity averages 7.7 percent and pay was considered to be porosity of six percent and greater. Core studies, discussed above, indicate the log derived values may be pessimistic, nevertheless, these are the values used in the OOIP determination. Water saturation averages 34 percent from Neutron-Density crossplot calculations. The water saturations are not equally distributed over this mound but rather are higher in the southeast due to the structural dip in that direction. Due to this variability of water saturation a hydrocarbon pore volume (HCPV) map was developed for this mound and is attachment 11. The HCPV was used to determine the hydrocarbon volume for each tract of the unit. The oil formation volume factor is 1.455 STB/Bbl. The original oil in place (OOIP) is 5,749,177 STB. The OOIP calculation is presented in the Waterflood Calculation sheet, attachment 12-1.

## Waterflood Recovery

**Primary Drive Mechanism:** The production behavior is indicative of solution gas drive. The reservoir initially produced about 1 to1.5 Mcf/Bbl. The GOR of the various wells reached a maximum range of 10 to16 Mcf/Bbl. The formation has produced steady volumes of water that have not increased over time; there is mobile water saturation in the reservoir but little or no active water drive.

**Primary Recovery Efficiency:** The waterflood calculations for this project are shown on Attachment 11-1 through 11-4. The OOIP is 5.749 million STB, and the primary recovery will be 0.783 million barrels, for a primary recovery efficiency of 14 percent. A review of primary efficiencies of mounds in this area indicates that between 15 and 22 percent is the norm.

**Mobility Ratio:** The mobility ratio is 0.686, and the calculation is at attachment 11-2. This ratio is one of the most important single characteristics of a flood and a ratio of less than one implies that the water bank is less mobile than the oil bank and, hence, high volumetric sweep efficiencies are possible.

The calculation of the mobility ratio requires information about the relative permeability of the formation. Because we did not have special core analysis from any Strawn well in the mound area, we used special core analysis from carbonate core taken in the Abo formation, which we waterflooded in the Trinity-Burrus Unit in Lea County, New Mexico. For completeness, that relative permeability curve is shown on attachment 12.

**Waterflood Recovery:** Waterflood recovery calculations use terminal oil saturations at flood out, and these are generally between 25 to 30 percent. The Abo core reference above had a terminal saturation of 30 percent, and similar values are available in numerous texts. The fractional flow curve from the Trinity-Burrus Unit is on attachment 13. Volumetric sweep efficiency calculates to 86 percent for this flood, which represents a recovery of 1,329 MBO. However, the configuration of this mound and the placement of existing wells are such that portions of the northeast extremities may not be well swept. Much of this area will fill-up and be swept back toward the producer. About six percent of the mound lying northeast of Chambers 7-1 will likely remain upswept. This reduces the expected secondary reserves to 1,143 MBO. The secondary efficiency of 21 percent, the total recovery of 35 percent, and 1.46 is the Secondary-to-Primary (S:P) ratio. We have concerns about the reliability of these estimates: There are no existing Strawn Mounds under flood, no analogy floods available and no special core analysis on this specific reservoir. As an alternative estimate, a Secondary-to-Primary ratio of 0.75 indicates a secondary target of 587 MBO and 600 Mcf. This implies a secondary recovery efficiency of 14.2 percent and a total recovery efficiency of 25 percent. This may be a conservative estimate but it is the volume Chesapeake is using in its current reserve and economic planning.

**Interference, Fill-up and Response:** Time to interference and fill-up are also estimated in calculations of attachment 11-3. The fillup volume is 2.0 to 2.4 million barrels, and at 1600 BWID, discussed below; fillup will be reached in 3 to 3.6 years. Initial response will occur at 50 to 60 percent of full fillup, or at about 1.8 years. With start of injection at September 2010, the first response will be around April 2012 and the peak at January 2014. The peak rates of the early wells in the field were 400 BOD. For this unit, the anticipated peak is 250 BOD, about 63% of initial primary rate. Total flood life is 15 to 18 years. Timing events and peak rate calculations are at attachment 14. The anticipated waterflood performance curve is shown on attachment 15. Please note, the above is based on the larger secondary reserve estimate of 1.1 million barrels and the timing may be quicker than indicated in these calculations.

## Water Source

Water supply needs are based on injecting 800 BWID into two injection wells, for a total water requirement of 1,600 BWID. This is believed to be a reasonable rate for several reasons; Strawn wells in this area report high initial rates, often in the 600 to 700 BTFD rate; The Chesapeake operated Easley No. 1 produces in an area where there are higher water saturations; having been on for 12 years, this well still yields 940 BTFD. Also, extensive treating experience leads to a subjective belief that 800 BWID is a reasonable sustained injection rate.

There are several options for make-up water in this area. Water is available from a few Devonian producers in the area, from Strawn producers to the north, from Wolfcamp production to the northeast and possibly effluent water from the Lovington Waste Water Treatment Plant. Unfortunately, all of these sources require a supply line of 4 to 5 miles. Of the three options, the preferred is the Wolfcamp and Strawn water. These produced waters are now being disposed of in the Big Bertha Water Disposal Well Section 11-T16S-R36E. The available water is 2,000 to 3000 BWD. This water option has the advantages of long economic life, 37 years; wells are operated by Chesapeake; and there is no charge to the Unit for the water. The Big Bertha SWD well is also in the vicinity of Lovington's effluent line, should additional water be needed, the effluent water is another possibility. A map showing the anticipated water supply route is attachment 16.

## Capital Cost Estimate

We plan to use two wells for injection and one for production. The map on attachment 17 shows the proposed pattern and the costs associated with the development of this flood. Total gross costs are estimated to be $1,250,000. This cost is extremely modest and even using our most conservative recovery estimate of 587,175 barrels gross the anticipated net finding cost is $2.67/Barrel.

## Unitization

We propose to unitize this mound for secondary recovery operations. The unitization will be based upon three general components: Primary Reserves, Secondary Reserves and Wellbores to recover reserves.

In this mound primary reserves, as of April 1, 2010, are estimated to be between five and 11 percent of total reserves. The tract participation factor for primary reserve is set at 15 percent. This higher percentage is to recognize the lower level of uncertainty associated with these reserves and to recognize the production delay that the current wells will experience after conversion but before response.

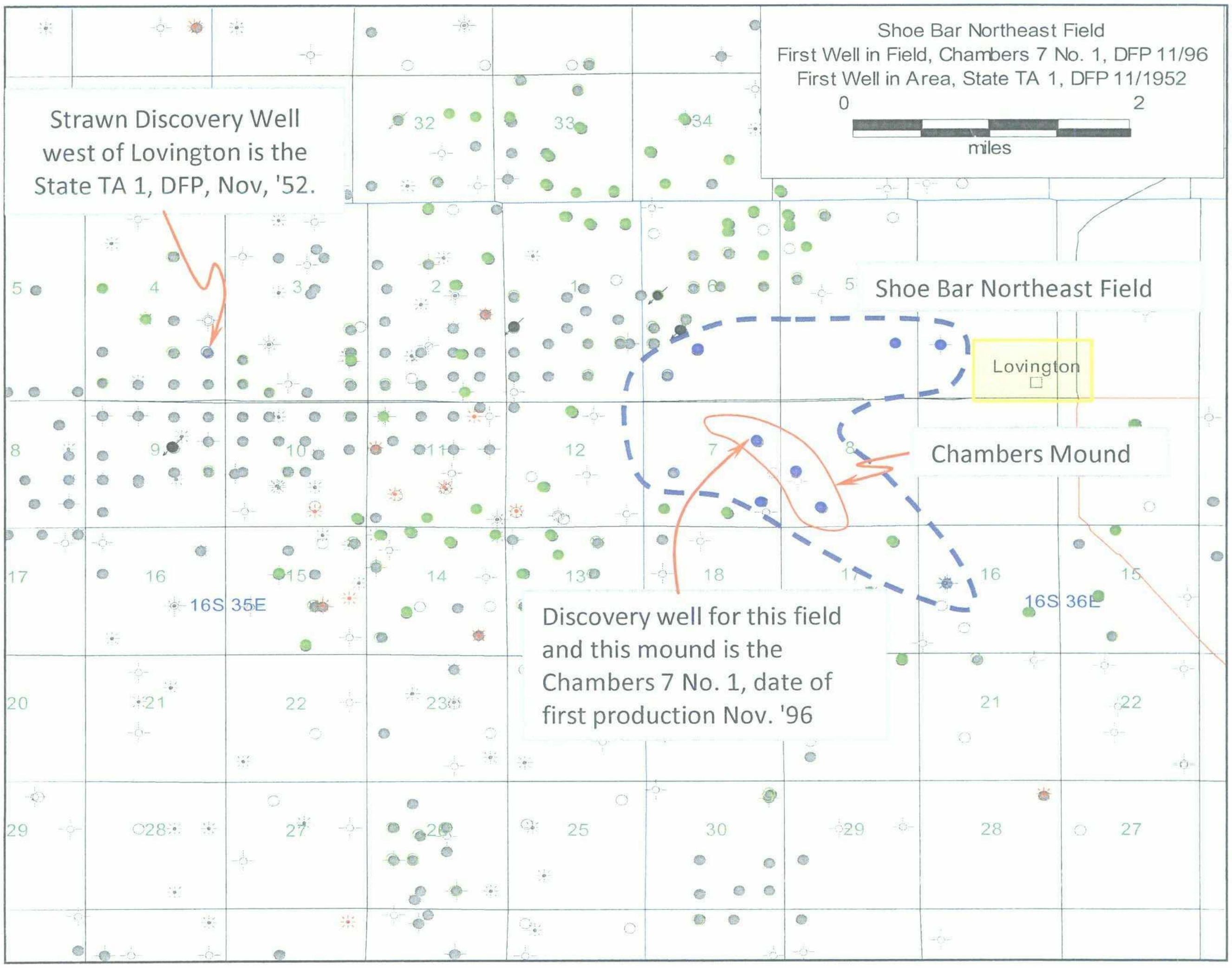
At this depth, 11,000 ft, drilling costs have a tremendous impact upon project economics and can determine whether or not an attempt will be made to flood the reservoir. For this unitization, a 10 percent factor is assigned to the existence of a wellbore that we believe can be and will be re-entered and used in the flood.

Because secondary oil is an absolute requirement for a successful flood, we put this component at 75 percent of the tract factor. The secondary reserve each tract contributes is reflected by both the original oil in place and the primary recovery of each tract. As primary is reflective of numerous factors that may not be in play during secondary recovery—such as date drilled, number of wells drilled, completion efficiencies, competitive drainage—we have placed primary recovery of 40 percent and OOIP at 50 percent of the tract factor.

The Unit Participation Factors, by tract, are presented in a table at attachment 18. The equation below is the proposed tract participation equation for each tract in this unit:

$$\text{Tract Factor} = 0.15\left\{0.4\left(\frac{\text{Tract Rate}}{\text{Unit Rate}}\right) + 0.6\left(\frac{\text{Tract Reserve}}{\text{Unit Reserve}}\right)\right\} + 0.75\left\{0.4\left(\frac{\text{Tract EUR}}{\text{Unit EUR}}\right) + 0.6\left(\frac{\text{Tract OOIP}}{\text{Unit OOIP}}\right)\right\} + 0.1\left(\frac{\text{Tract Well Count}}{\text{Unit Well Count}}\right)$$

# Proposed Chambers Strawn Unit
# Orientation Map



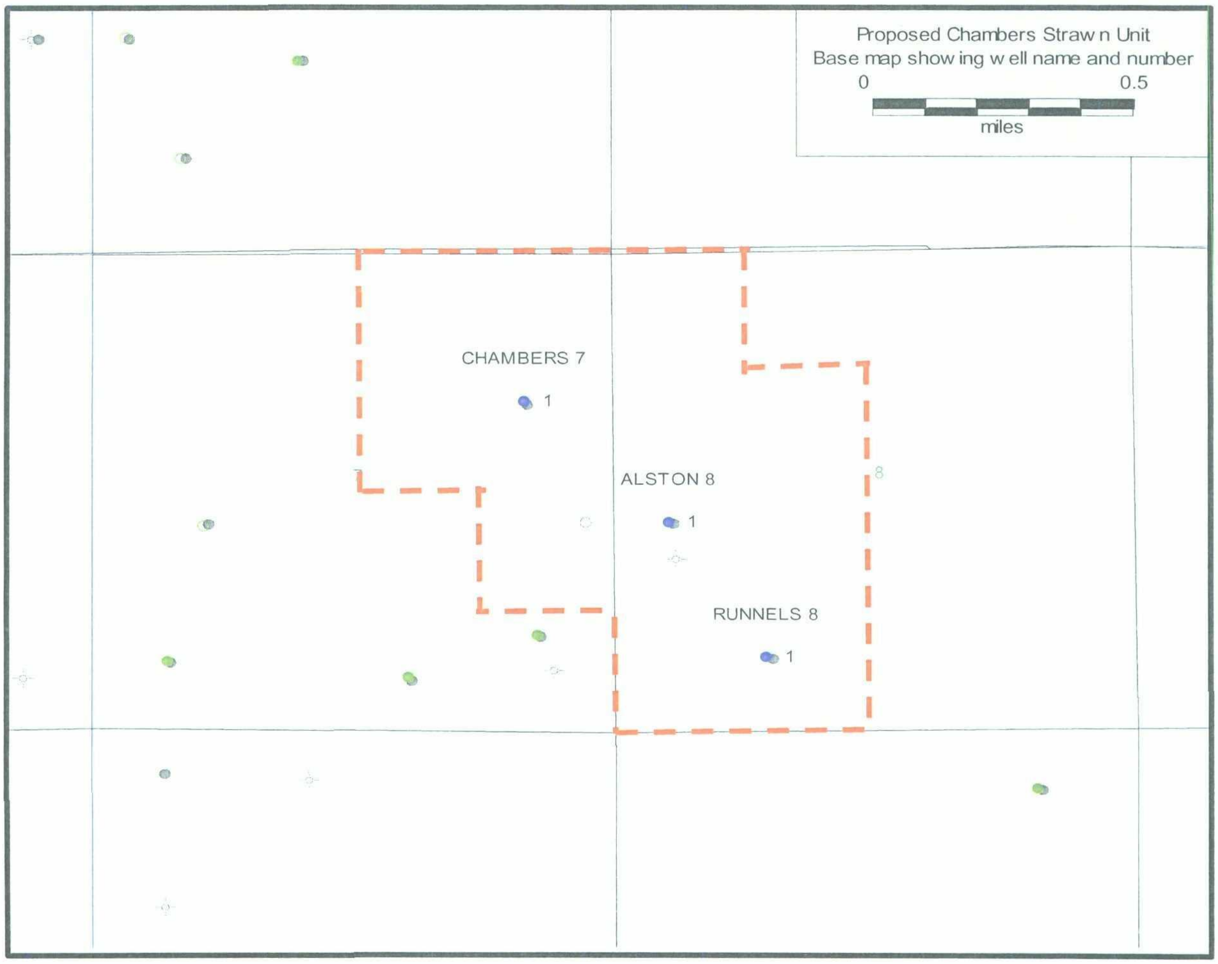

The group of Strawn wells known as the Shoe Bar Northeast Field is shown above. The field contains 10 Strawn completions in portions of six sections. The field lies generally to the southwest of Lovington, New Mexico.

The first Strawn completion in this field was the Chambers 7 No. 1 in section 7H-T16S-R36E, completed by the Chesapeake Operating Company in November 1996.

The proposed Chambers Strawn Unit is located at the southwest of the Shoe Bar Northeast Field. This proposed unit is 1.5 miles southwest of Lovington, New Mexico.

# Proposed Chambers Strawn Unit

## Base Map showing wells
## and
## Unit Boundary



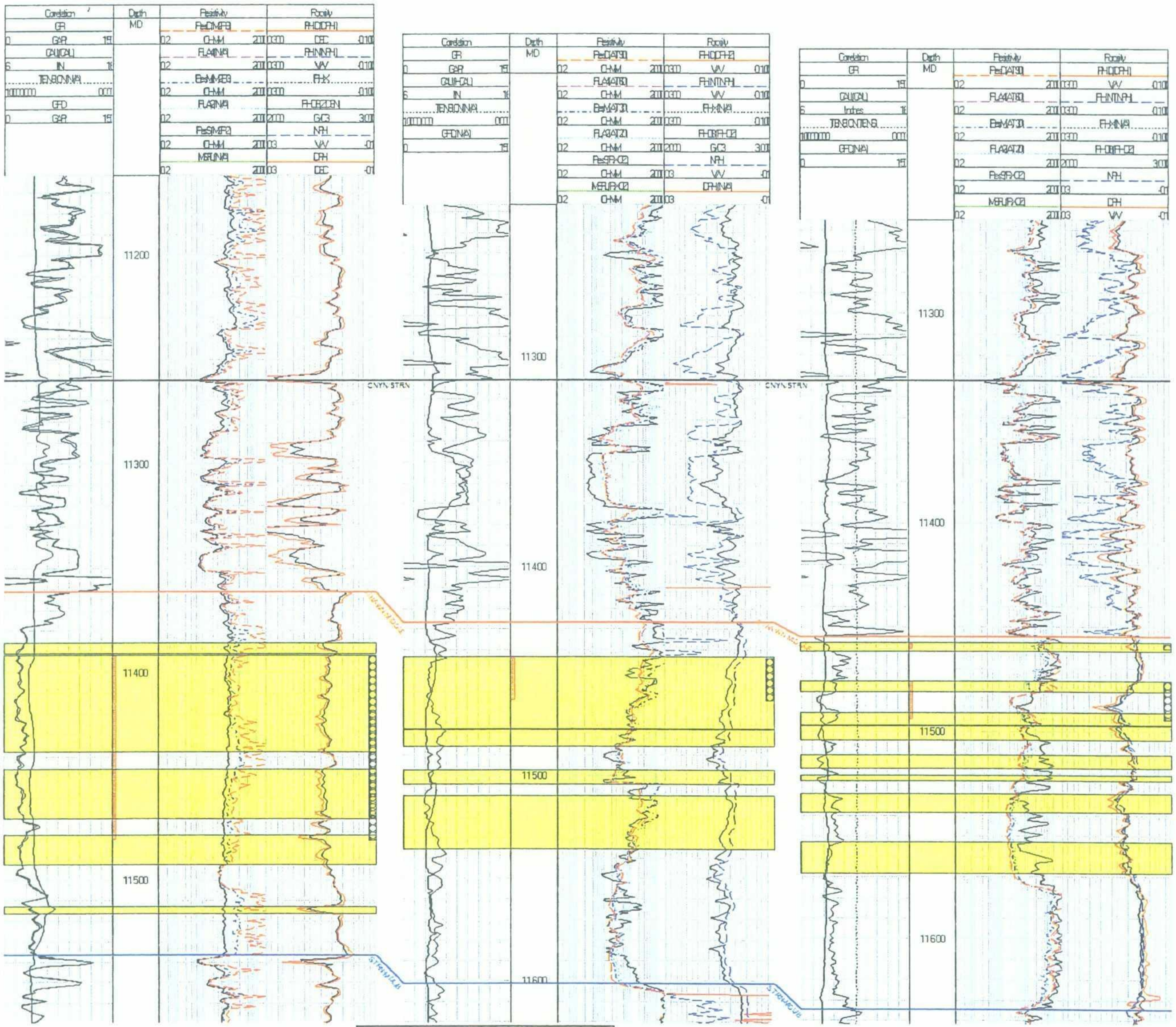
# PROPOSED CHAMBERS STRAWN UNIT

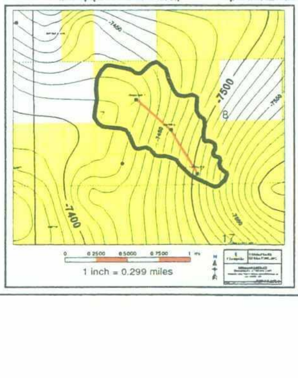
## STRATIGRAPHIC CROSS SECTION - DATUM: TOP OF STRAWN

COI
CHAMBERS 1-7
1700 FNL 900 FEL
TWP: 16 S - Range: 36 E - Sec. 7

COI
ALSTON 8 1
2281 FSL/531 FWL
TWP: 16 S - Range: 36 E - Sec. 8

COI
RUNNELS '8' 1
780 FSL 1510 FWL
TWP: 16 S - Range: 36 E - Sec. 8




CHESAPEAKE OPERATING, INC.

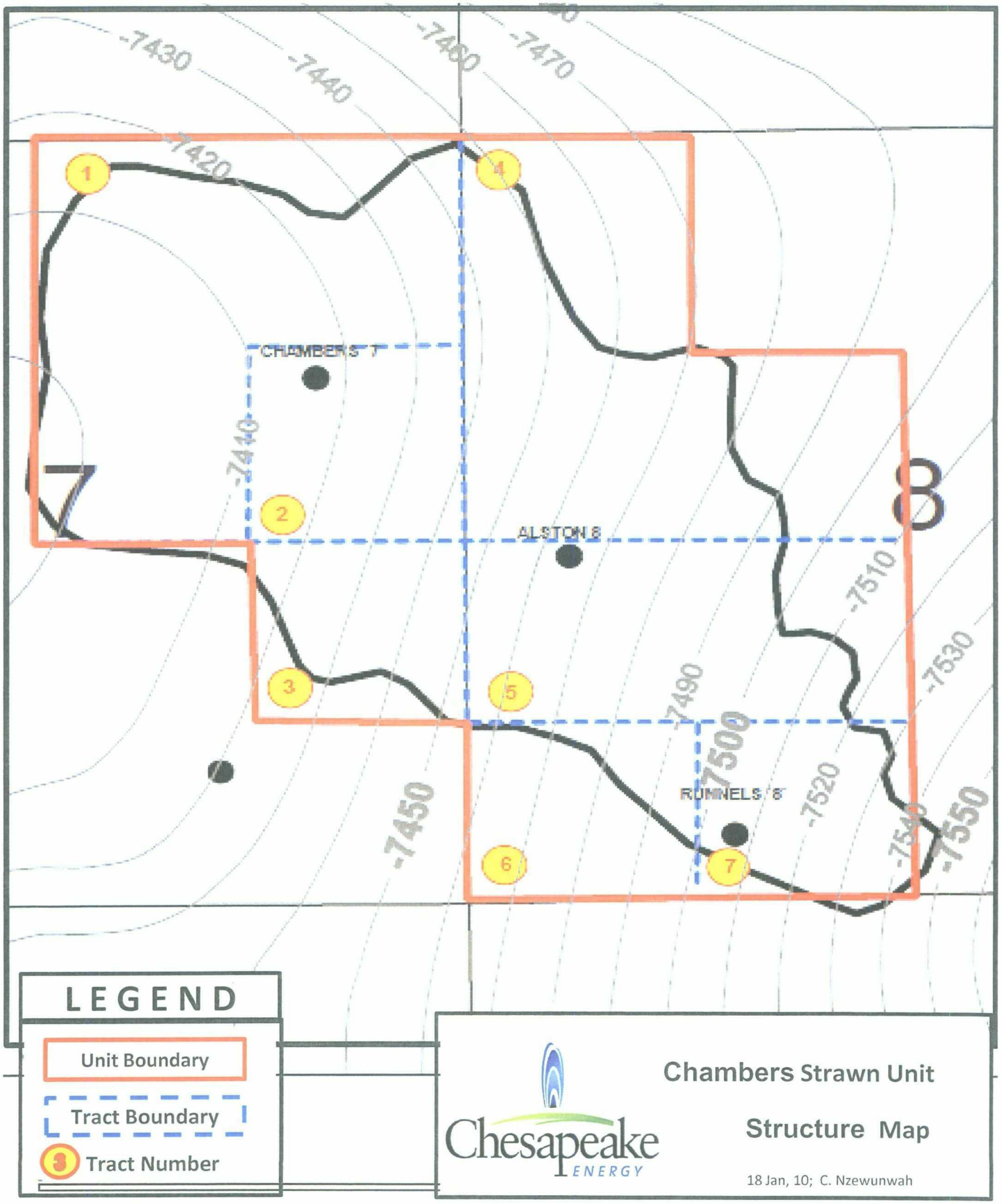
CHAMBERS STRAWN UNIT
X-SECTION

12 April, 2010; C Nzewunwah

Attachment 3

# Proposed Chambers Strawn Unit

## Structure Map




Attachment 4

# Proposed Chambers Strawn Unit

## Well, Reservoir Data

| | Chambers 7 No. 1 | Alston 8 No. 1 | Runnels 8 No. 1 | Averages |
|---|---|---|---|---|
| **1st Prod** | Nov-96 | May-97 | Mar-98 | |
| **API** | 3002533623 | 3002533876 | 3002534264 | |
| **EUR Oil** | 529,950 BO | 157,324 BO | 89,265 BO | 258,846 BO |
| **EUR Gas** | 1,853,355 Mcf | 541,504 Mcf | 531,910 Mcf | 975,590 Mcf |
| **Initial GOR** | 1.1 Mcf/Bbl | 1.7 Mcf/Bbl | 1.2 Mcf/Bbl | 1.33 Mcf/Bo |
| **Perfs** | 11,392' - 11,480' | 11,444' - 11464' | 11,458'-60'<br>11,476'-94' | 11,392' top<br>11,494' bottom |
| **DST Interval** | 11,392'-404' | 11,438' - 11,483' | No DST | DST data 3 wells |
| **Oil Gravity** | 43.20 °API | 44.70 °API | | 43.95 °API |
| **BHP** | 4,224 Psi @ 11,376' | 3,474 Psi @ 11,416' | | |
| **Perm.** | 7.97 md* | 6.39 md | | 7.18 md |
| **$h$ ($\phi \geq 6\%$) (ft)** | 100 | 110 | 42 | |
| **$h$ above O/W Contact** | 85 | 68 | 22 | |
| **$\phi$ (frac.) above O/W** | 0.0865 | 0.0765 | 0.0988 | 0.087 **Avg. $\phi$** |
| **$S_w$ (frac.) in net pay** | 0.265 | 0.215 | 0.331 | 0.270 Avg. $S_w$** |
| **$S_o$ (frac.) in net pay** | 0.735 | 0.785 | 0.669 | 0.730 Avg. $S_o$** |
| **$\beta_{oi}$ (bbl/bbl)** | 1.4512 | 1.4587 | | 1.455 Avg. $\beta$oi |

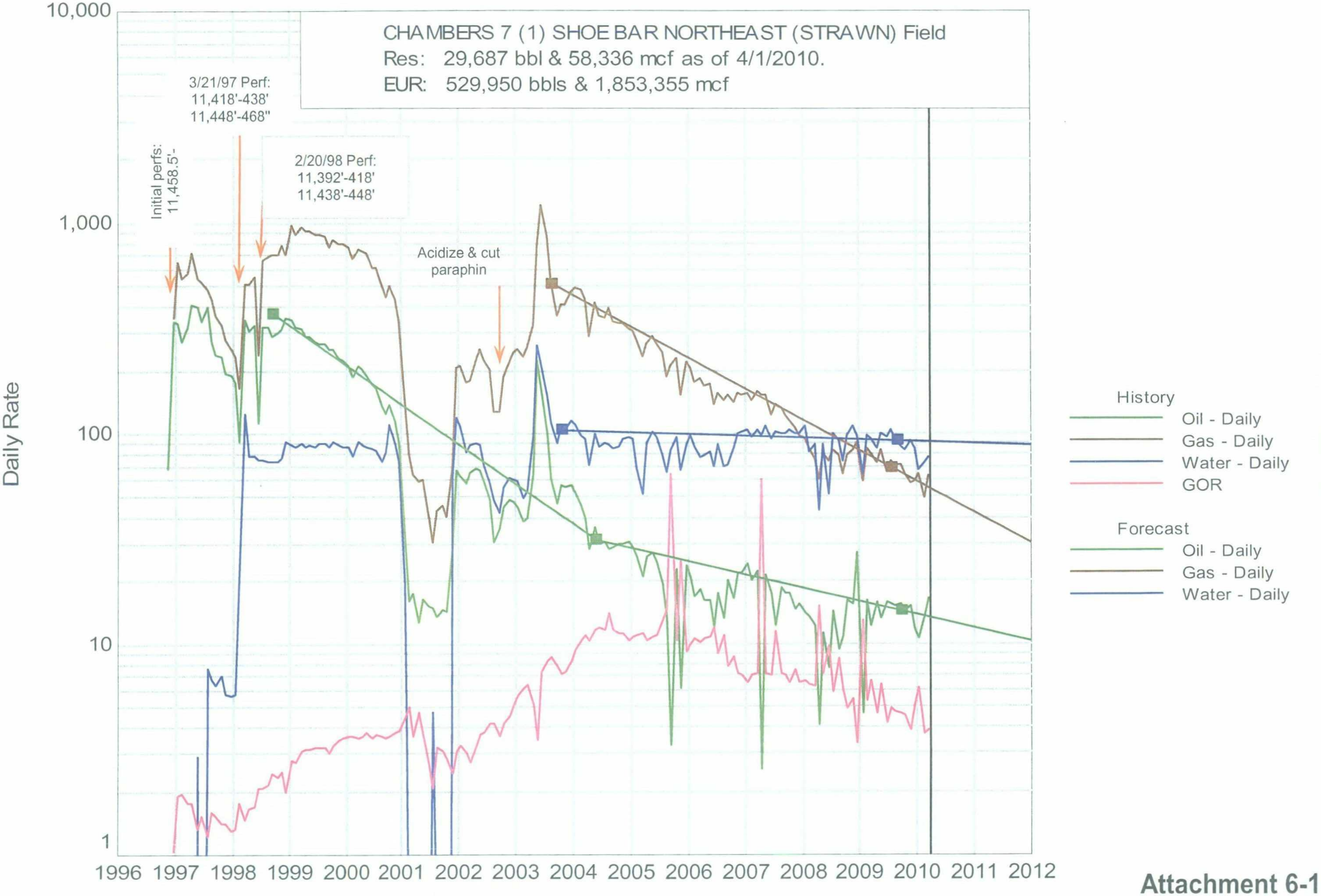
*Chambers 7 No. 1 had pressure transient test in August 23, 2001 with all pay perforated which showed permeability of 7.97 md.

**Saturations in this table are the geometric mean from net pay log values.
Average saturations in the reservoir, determined from the hydrocarbon pore volume map, are 34% water and 66% oil.



Attachment 5

# Proposed Chambers Strawn Unit

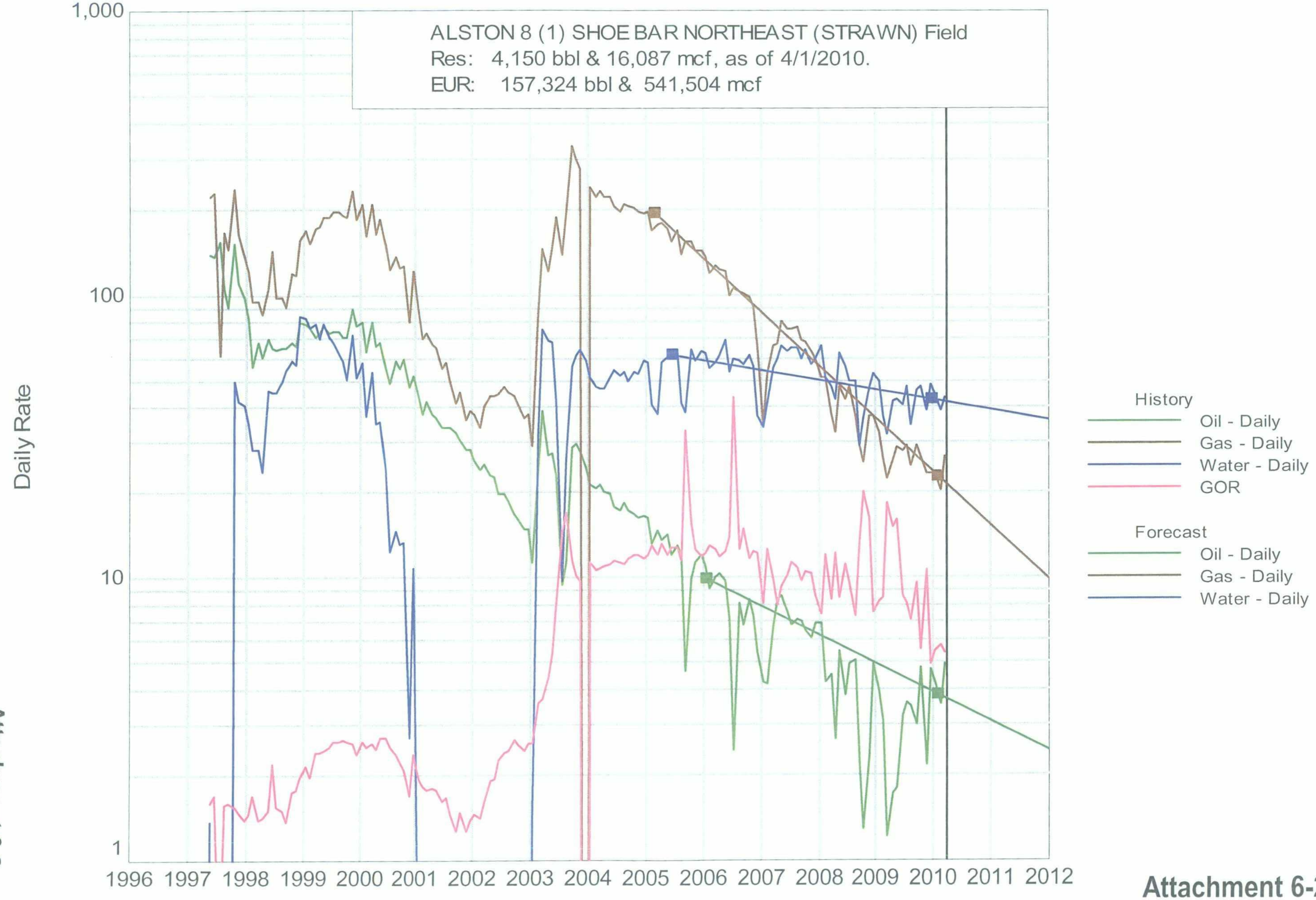



Attachment 6-1

Attachment 6-1

# Proposed Chambers Strawn Unit

## Well Performance Curve - Alston 8-1

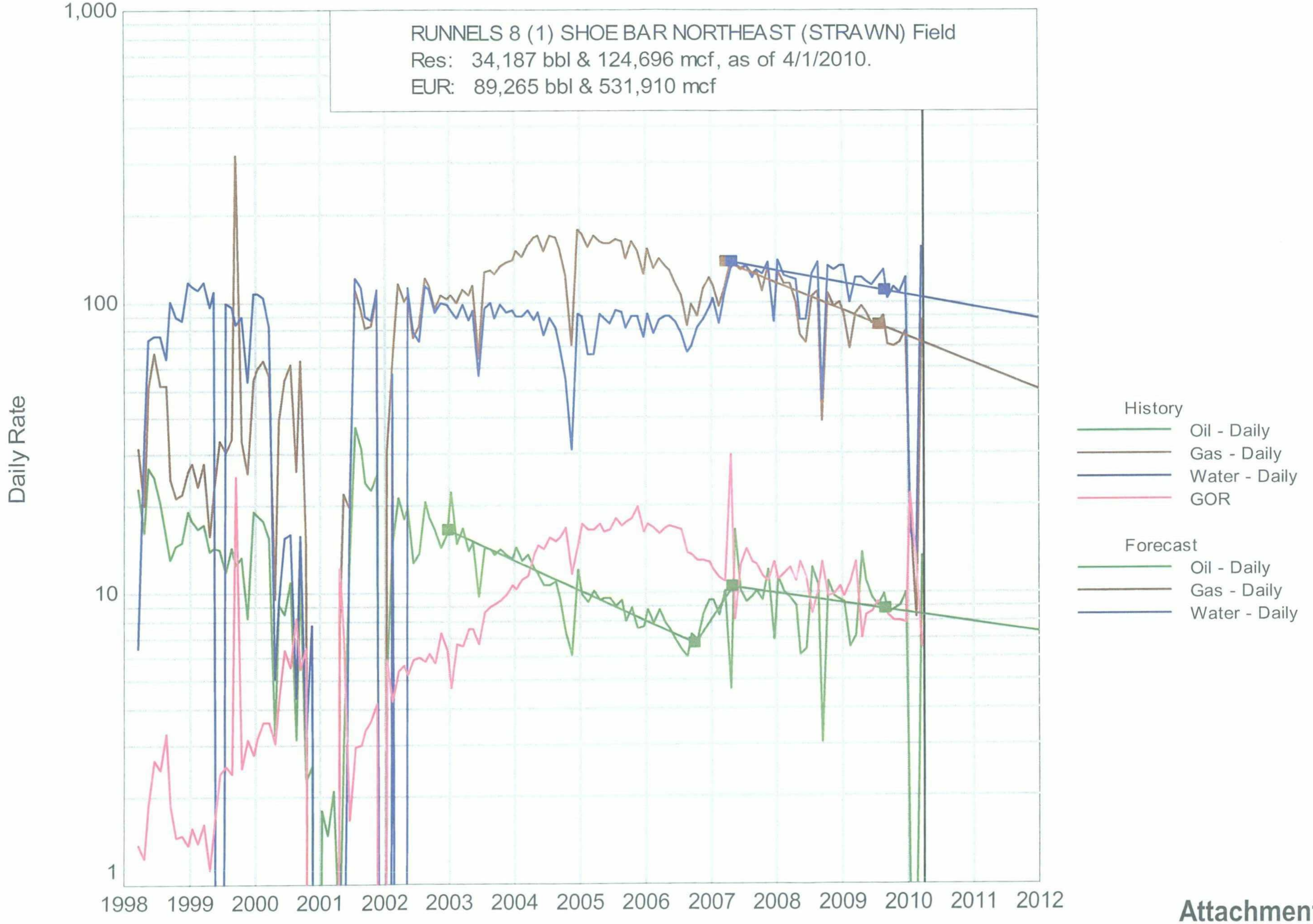



Attachment 6-2

Attachment 6-2

# Proposed Chambers Strawn Unit

## Well Performance Curve - Runnels 8-1




Attachment 6-3

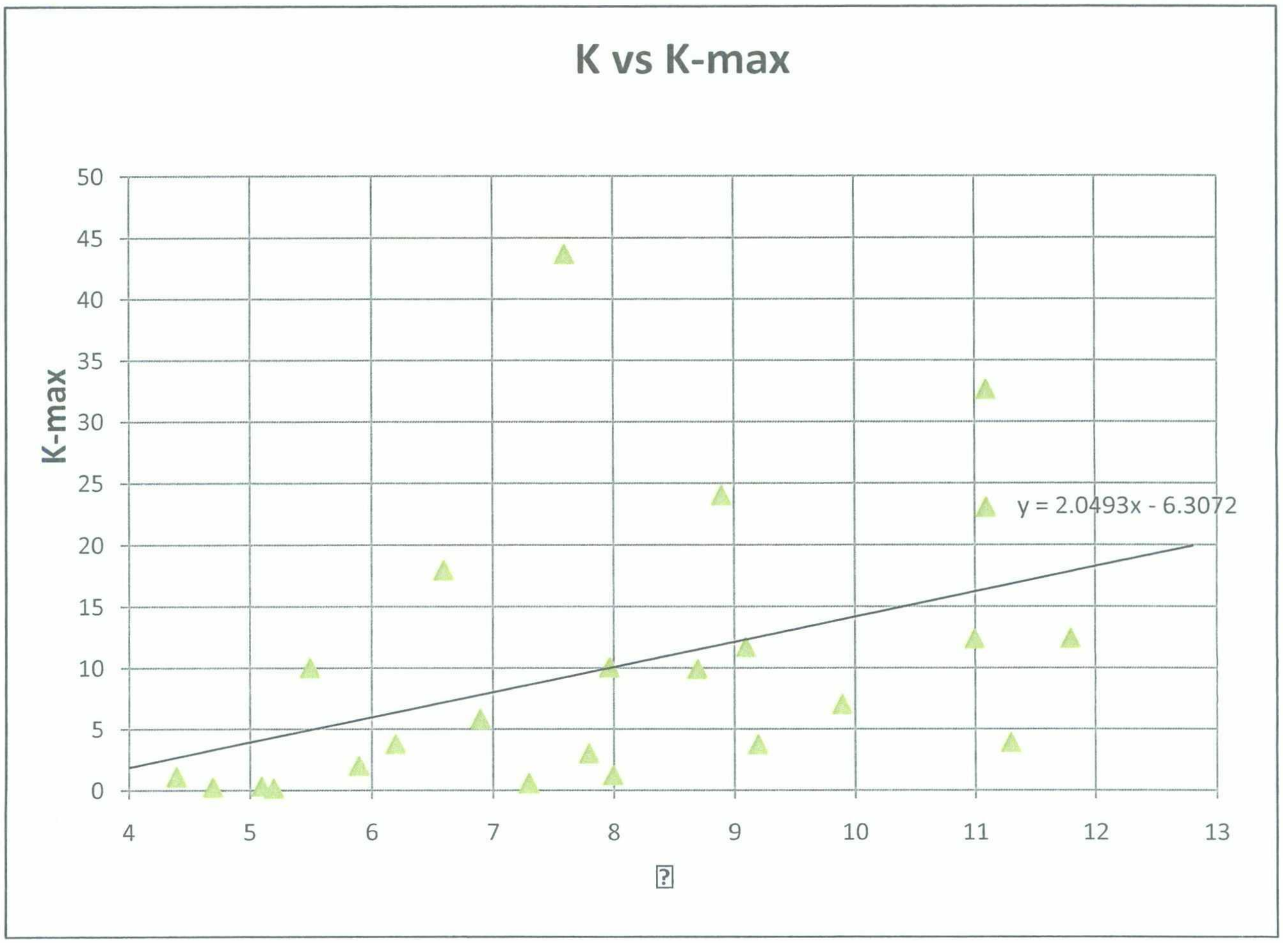
Attachment 6-3

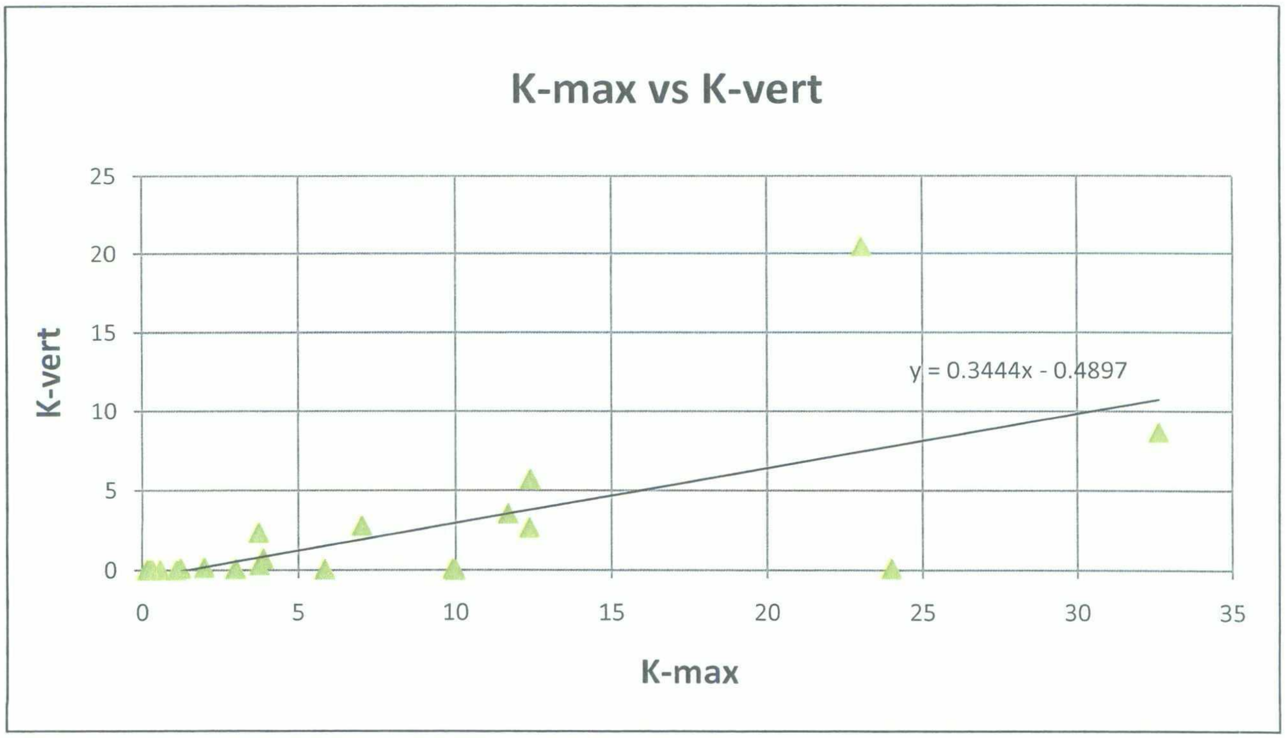
# Proposed Chambers Strawn Unit


Attachment 6-4

Attachment 6-4

Proposed Chambers Strawn Unit
Routine Core Analysis - Strawn Formation - Alston 1-8

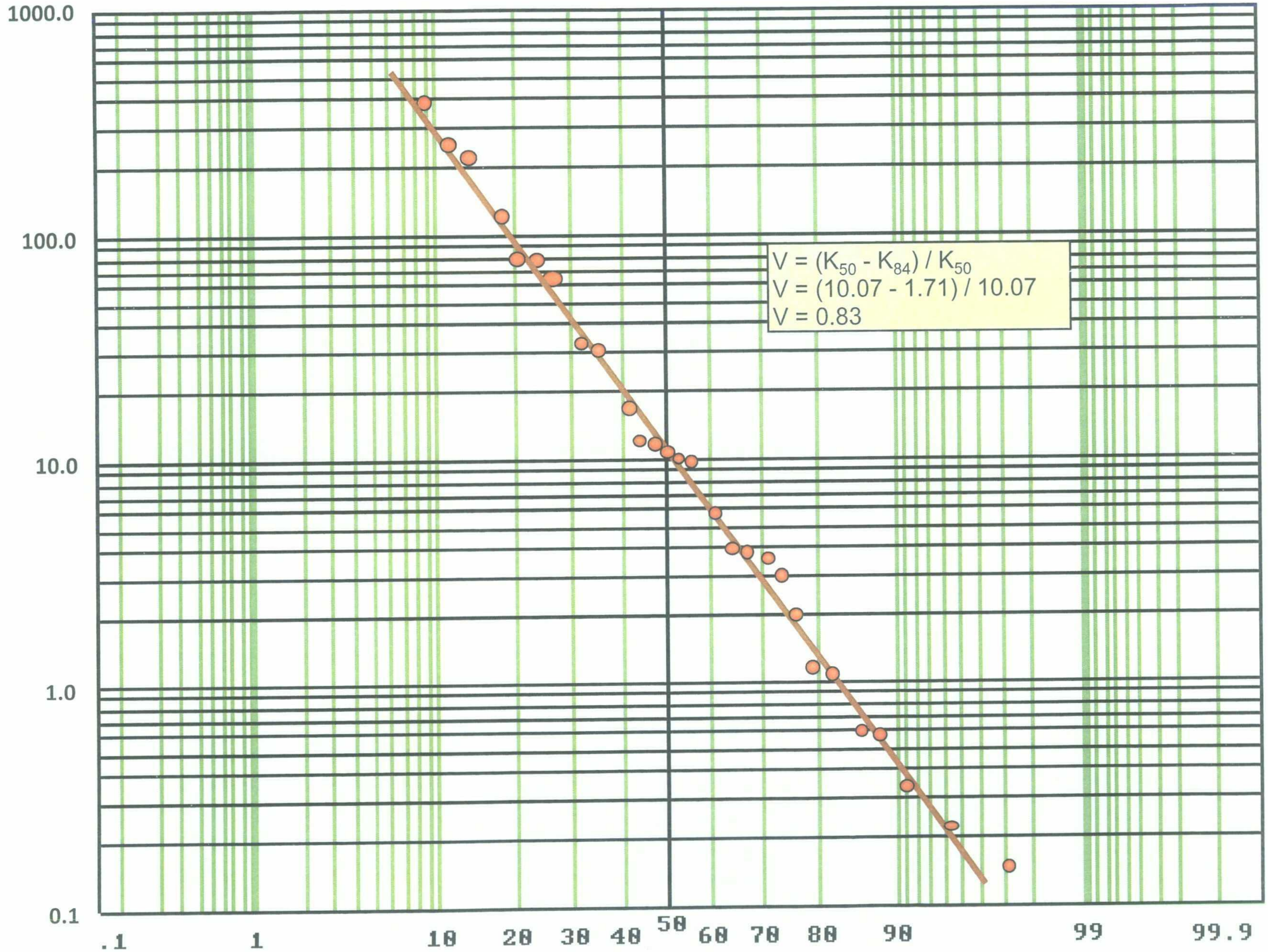



Attachment 7

# Proposed Chambers Strawn Unit

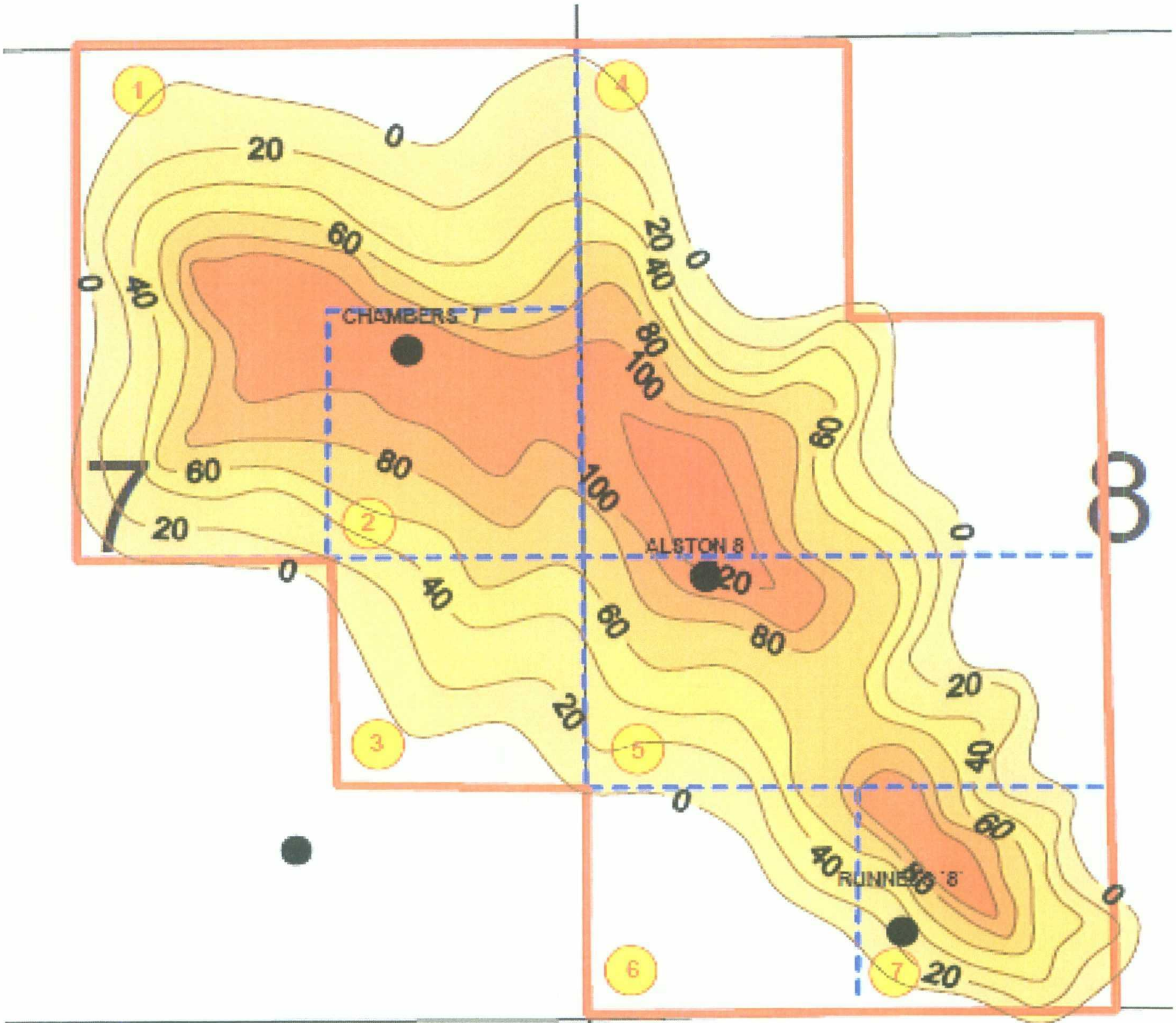
## Permeability Distribution - Alston 1-8 Core Data






Attachment 8

# Proposed Chambers Strawn Unit




**LEGEND**

- Unit Boundary
- Tract Boundary
- Tract Number

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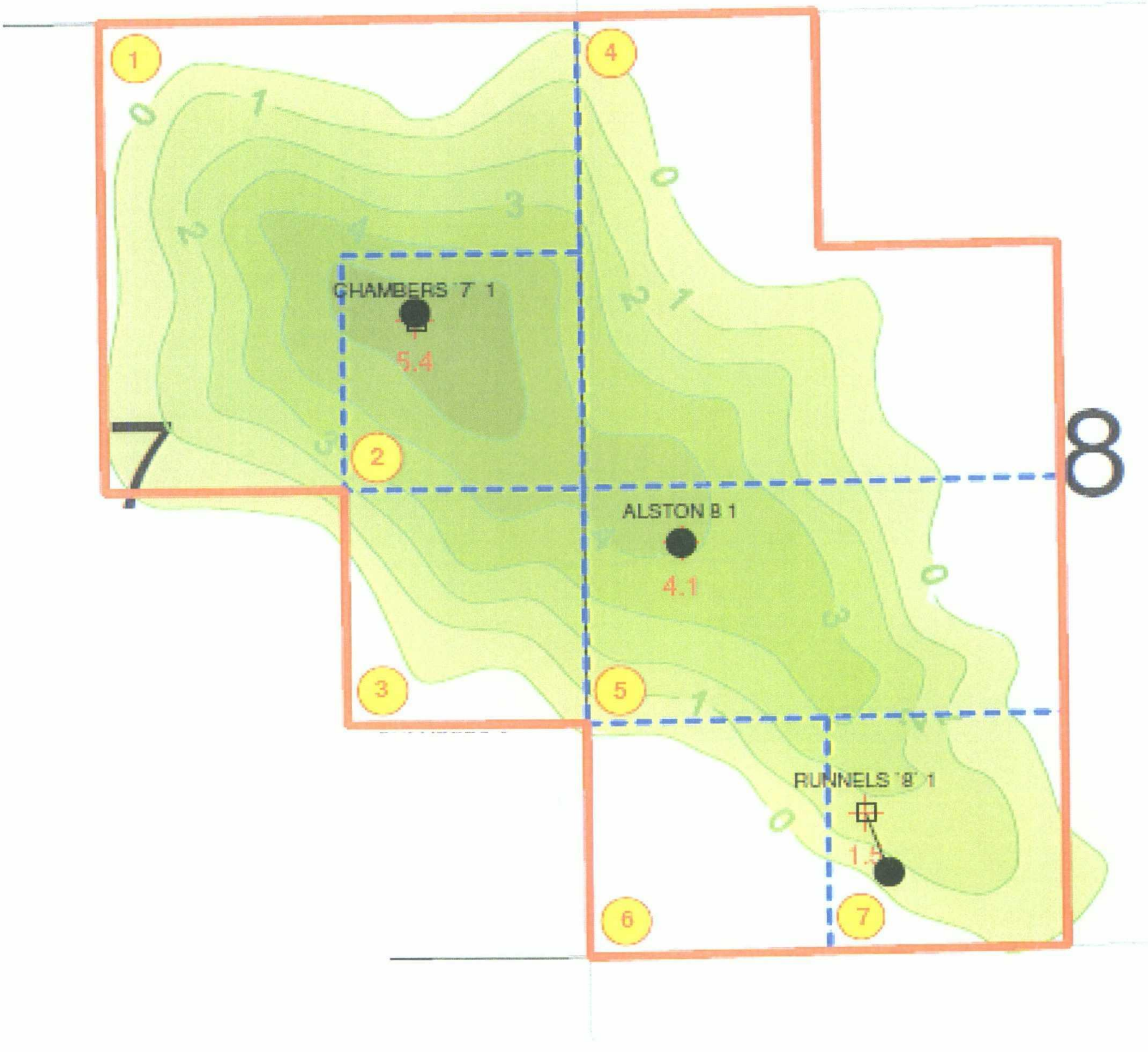
**Chambers Strawn Unit**

**$\phi h$ Isopach Map**

18 Jan, 10; C. Nzewunwah

**Attachment 9**

# Proposed Chambers Strawn Unit
## Hydrocarbon Pore Volume Isopach

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Chambers Strawn Unit
HCPV Isopach Map

02 Feb, 10; C. Nzewunwah

Attachment 10

# Proposed Carter-Shipp Strawn Unit
# Waterflood Calculations

| **Basic Data** | | |
|---|---|---|
| Area ............................................ | 346 | Acres |
| Average | | |
| Thickness ...................................... | 53.94 | ft |
| Porosity ........................................ | 0.0873 | This is the average of 4 wells |
| Initial Water Saturation ........................ | 0.3385 | |
| Oil Formation Volume Factor, initial ........... | 1.455 | STB/RB, |
| Oil Formation Volume Factor, at depletion | 1.12 | STB/RB, |
| Initial Reservoir Pressure ......................... | 4,224 | Psi by DST measurement |
| Abandonment Pressure, end of Primary | 500 | Psi, or about 700' above pump. |
| Est. Ultimate Primary, ............... | 782,900 | STB |

**1 . Original Oil in Place**

OOIP = $\{7758\ A\ (\phi\ h)\ (1\text{-}Sw)\}\ /\ \beta_{oi}$

$= \quad 7758\left[346.3\right]\left[0.09\right]\left[\ 53.94\right]\ \left[1 -\ 0.339\right] \Big/ 1.45$

$= \quad 5{,}749{,}177 \quad$ STB

Present Development, based on decline curve analysis, 782,900 Bbls
Present primary recovery factor = 782,900 Bbls/5,749,177 Bbls
Present primary recovery factor = 0.13618 Bbls

**3 . Oil Saturation at Depletion of Primary Pressure**

$S_{or\text{-}pri} = \{(1 - (\Delta N_p/N)\}\ (b_{or}/b_{oi})\ (1\text{-}S_w)$

$S_{or\text{-}pri} = \left\{1\text{-}\left(\ 782{,}900\ \big/\ 5{,}749{,}177\right)\right\}\left\{1.12\big/\ 1.45\right\}\left(\ 1 -\ 0.339\right)$

$S_{or\text{-}pri} = \quad 0.44105$

Gas Saturation = Oil Saturation initial - Oil saturation at Abandonment.

$= \quad (1 -\ \ 0.339\ ) -\ 0.441$

$= \quad 0.220$ Average in reservoir

**4 . Relative Permeability and Fractional Flow**

We have no relative permeability data on this project.
We looked at relative permeability data from similar rock such as Abo and Wolfcamp.
We know the oil saturation is initially 30% and the fraction flow of water at 98% is at 70 to 75 % water saturation, 25 to 30% oil saturation

**Mobility = $\lambda = k_r/\mu$**

**Mobility of the water in the water bank**

The fractional flow curve from similar rock shows the average water saturation in the water bank is about 67 percent. At this water saturation the adjusted relative permeability curve shows the $k_{rw}$ to be and similar crude (Abo at Trinity-Burrus Unit) at 25%..

$\lambda_w = 0.25\big/\ 0.51 = \quad 0.4902$

**Attachment 11-1**

# Proposed Carter-Shipp Strawn Unit
# Waterflood Calculations

## Mobility of the oil in the oil bank

In the oil bank the relative mobility to oil is 100 percent.
Crude is 42.5 °API Gravity.
Oil Viscosity is 2.7 cp at 100°F per Beals Correlation, Fig 19-39, Frick Handbooks, Vol. II, pg 19-38.
Reservoir temperature is 165 °F
Oil Viscosity is 1.4 cp at 165°F per Beals etal, Fig 19-40, Frick Handbooks, Vol. II, page 19-39

$\lambda_o = k_{r0}/\mu_o = 1.0/1.4 = 0.71$

Mobility Ratio = $M = \lambda_\omega/\lambda_o$
Mobility Ratio = $M = 0.49 / 0.714$

**Mobility Ratio = $M$ = 0.6863**

$M$ is less than 1 and is favorable for waterflooding.

## 5 . Permeability Variation

$V = (k_{50} - k_{84})/k_{50} = 0.83$

Core data, Alston 1-8, Strawn Reservoir, this reservoir.

## 6 . Volumetric Sweep Effieciency

The favorable mobility ratio will provide good areal sweep.
Empirical correlation with 100 layer Higgins-Leighton streamtube model show
If WOR = 25, V = .76 and at WOR = 50, then $E_v = 0.79$

Refer to fig 6.22 and 6.23, Page 206, Whillhite's SPE Text Vol. 3.

## 7 . Waterflood Recovery

Secondary Reserves = $7758\ A\ h\ \phi\ (S_{or\text{-}pri} - S_{or})\ E_v / \beta_{oa\text{-}pri}$
Secondary Reserves = $7758\ (346)\ (53.9)\ (0.087)\ (0.44 - 0.30)\ 0.79 / 1.12$
Secondary Reserves = 1,254,768 BO

*This recovery calculation should be adjusted downward for reservoir shape and well placements. There are areas outside of the injection patterns that will not be swepted during the life of this flood. These are estimated to be about 54 to 56 acres and contain about 6% of the OOIP. The calculation below*

## Waterflood Recovery - adjusted for sweep:

Secondary Reserves = $7758\ A\ h\ \phi\ (S_{or\text{-}pri} - S_{or})\ E_v / \beta_{oa\text{-}pri}$
Secondary Reserves = $\{7758\ (292)\ (84.6)\ (0.087)\ (0.44 - 0.30)\ 0.79 / 1.12\}$
Secondary Reserves = 1,176,115 BO

Secondary Recovery Factor = 1,176,115 / 5,749,177 = 0.2046
Total Recovery Efficiency = 0.1362 + 0.2046 = 0.3407
Secondary : Primary Ratio = 1,176,115 / 782,900 = 1.502

**Attachment 11-2**

# Proposed Carter-Shipp Strawn Unit
# Waterflood Calculations

The S:P ratio of 1.46 is quite high. Successful West Texas waterfloods commonly have a S:P of 1.0 in applications of repeating five-spot patterns. In this mound I would expect less effective sweap and a S:P of 0.75 to one. For this flood we have no relative permeability data and no analogy floods, I feel *more comfortable forecasting a Secondary-to-Primary ratio of 0.75-to-1.0 and a secondary reserve of* 587,175 BO and 600,000 Mcf. This is the value that Chesapeake will use in their initial reserve and planning work.

## Summary, Reserve Estimate

1 . OOIP is 5,749,177 Stock Tank Barrels.
2 . Primary EUR is 782,900 Stock Tank Barrels.
3 . Primary recovery efficency is 13.6 percent.
4 . Secondary Target is 587,175 Bbls oil and 600,000 Mcf gas.
   The secondary recovery efficiency is 10.21 percent.
   The calculated recovery is 1,143,145 Bbls, the value of 587,175 Bbls is S:P of 0.75.
5 . Total Recovery Efficiency = Primary + Secondary = 0.136 + 0.1021 = 0.2383
6 . Secondary : Primary = 0.1021 / 0.1362 = 0.7500

**8 . Water Injection Volume at Interference**

The distance between injectors and producers:

From Chambers 7-1 to Alston 8-1 = 823 ft
From Runnels 8-1to Alston 8-1 = 1,721 ft
= 1,272 ft avg.

In repeating patterns we frequently see the fill-up calculation based on the average size pattern. However, in this mound patterns do not repeat, spacing is irregular and the reservoir border is a no-flow boundary. All flow is contain and flow streams will trend toward the producers at the initial expense of the reservoir contained at the extremities. Hence, the timing below may be a little less reliable in this flood than is generally the rule.

$W_{ii} = \pi h \phi S_{gc} r_{ei}^2 / 5.61$ , where $r_e =$ 1,272 ft

$(3.1416)(53.94)(0.087)(0.220)(1272^2)/5.61$

940,122 Bbls Assuming 800 BWID/Injection Well.

Estimated time to interference is 1.6 years, 19 months .
Adjusting for poor sweep the volume would be 809 MBO occurs in 1.4 years.

**9 . Water Injection at Fillup**

$W_{if} = 7758.4\ A\ \phi h\ S_{gc}$

$= 7758\ (346)(0.087)(53.935)(0.220)$ Full Reservoir Basis

= 2,787,780 Bbls Estimate time to fillup at 4.24 years

Adjusting for poor sweep the volume would be 2.4 MMBW & takes 3.6 years.

I would normally expect first response to occur at about 60% of fill-up, however in this situation, given odd patterns and variable spacing I believe we will see first response at about the 50% point, or about 1.8 years.

# Proposed Carter-Shipp Strawn Unit
# Waterflood Calculations

**10 . Water Injection at Breakthrough:**

$W_{ibt}$ = 7758.4 A $\phi h$ $E_a$ ($S_{wbt}$ - $S_{wc}$) =

= 7758 (346)(0.087)(53.94)(0.790) (0.700 - 0.339)

= 4,225,629 Bbls [Unit Basis]

$W_{ibt}$ = 2,112,814 Bbls [Injection Well Basis]

3,634,041 Bbls, adjusted for sweep reduction .

Estimated time to water breakthrough is 6.4 years. Assuming 800 BWID/Well and uniform spacing.

Timing, adjusted for sweep is 5.5 years.

**11. Waterflood Life:**

Estimateed to be the time to inject 1.25 pore volumes

The pore volume is = 7758 * Area * thickness * porosity

= 7758 * 346 * 53.94 * 0.087 = 12,645,147 Bbls

Adjusted for non-active area = 10,874,826 Bbls

Time to inject 1.25 pore volues at 1600 bbls/day

= (1.25)(12,645,147) (1600) (365) = 27.0 years

adusting for non-active area yields = 23.26 years

**Other "Rules-of-Thumb" some times seen for quick estimates are:**

***Time to interference***

Estimated to be 0.104 times project life

2.7 years, about 32 months, which is approximately as calculated above.

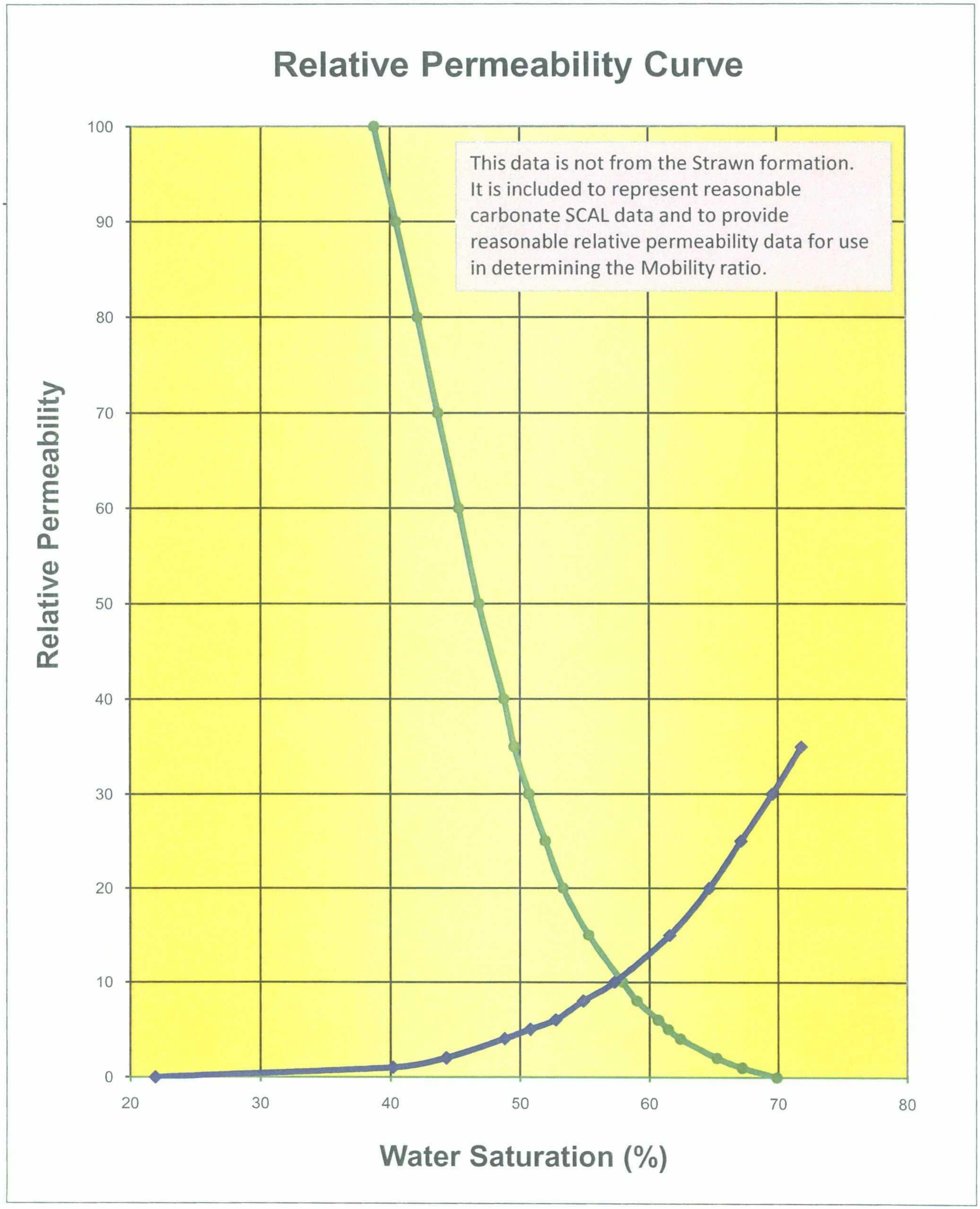
**Time to peak response:**

Estimated to be 0.23 * waterflood life or 6.2 years

# Proposed Chambers Strawn Unit

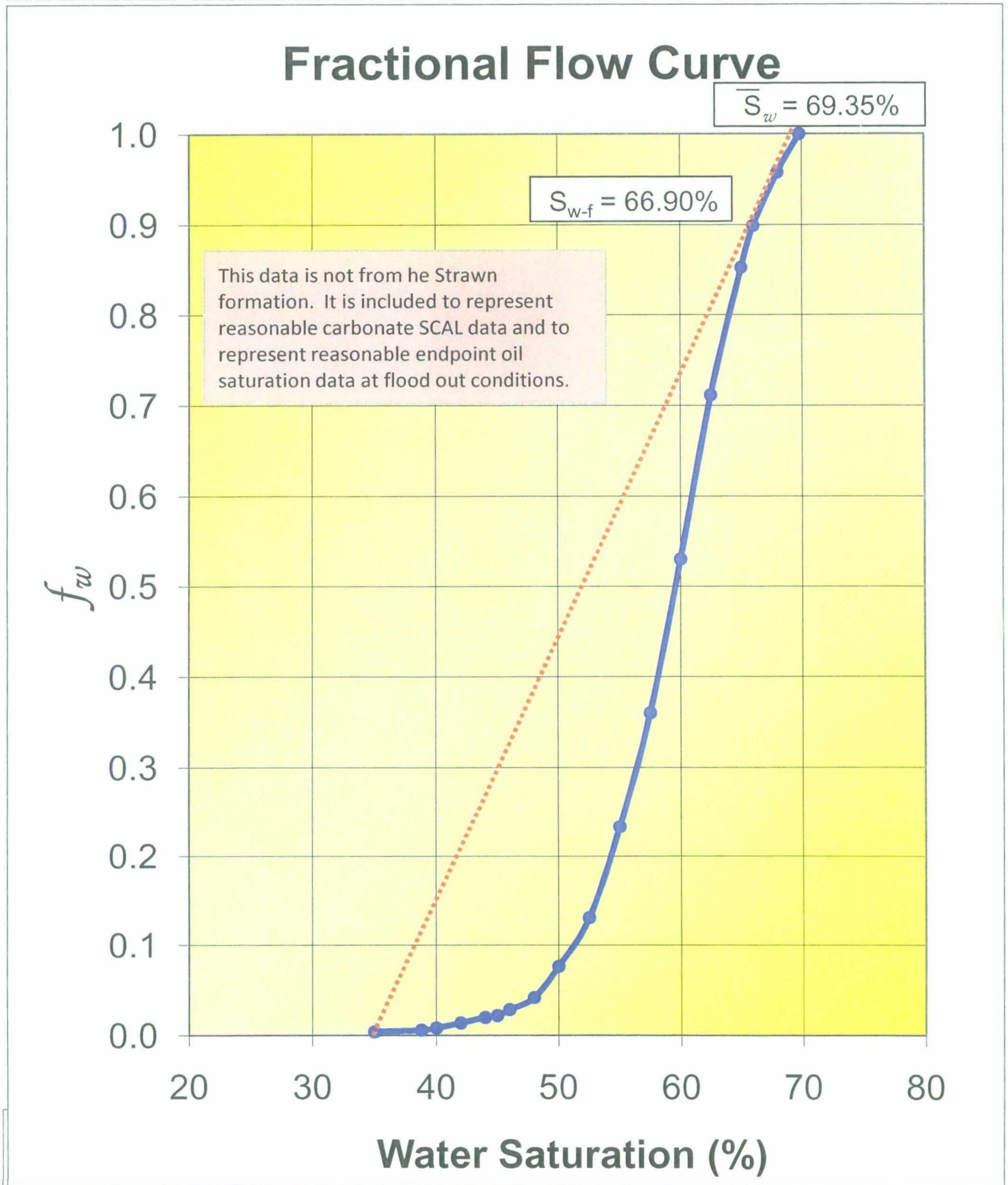
## Burrus 5 SCAL Data - Trinity-Burrus Abo Unit

## Averaged and Normalized Data




Attachment 12

# Proposed Chambers Strawn Unit




Attachment 13

# Proposed Chambers Strawn Unit

## First Response and Peak - Timing

**Start of Injection**
Starting injection about September 1, 2010.

**Fill-up**
Fill-up calculates to be about 3.6 years and requires 2.4 to 2.8 MMBW.

**First Response**
I expect 1st response to be at about 50 to 60 % of fill-up.
That puts first response in 21.8 to 2.2 years, or September 2012.

**Peak Rate - Time**
Peak will occur at about 4.5 to 5.0 years from start of injection or about December 2015.

## Peak Rate - Amount

**Initial Stable Primary Rates**

| | |
|---|---|
| Chambers | 400 BOD |
| Alston | 140 BOD |
| Runnels | 20 BOD |
| BOD per well | 187 BOD |

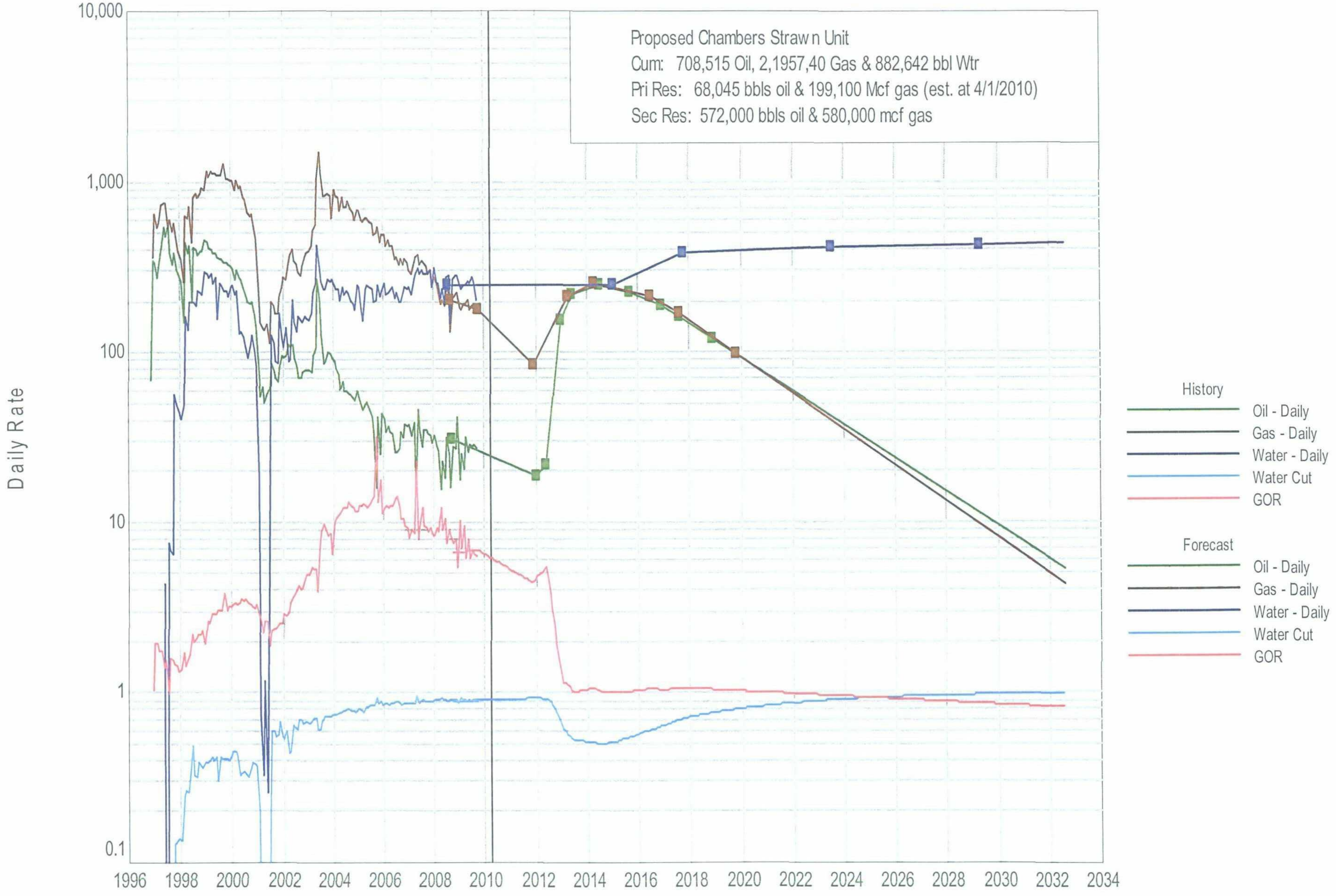
The Chambers and Alston have very similar log character, $\phi h$ and HCPV. The Chambers was the initial well, its reservoir pressure was 4,224 psi and the initial stable rate was 400 BOD. When the second well was drilled, the Alston, its reservoir pressure was 3,474 psi and the rate was 140 BOD, indicating that some depletion had occurred from the Chambers. Had both been drilled at the same time, I expect the rates would have been similar, about 400 BOD.

The two producers will not feel the pressure effects of the two injectors at the same time. Hence, the peak will be at a lower rate than the primary but will be sustained for several years. I scheduled the peak at about 250 BOD, which is 62.5 percent of the average primary peak.

**Peak Secondary is 250 BOD.**

**Attachment 14**

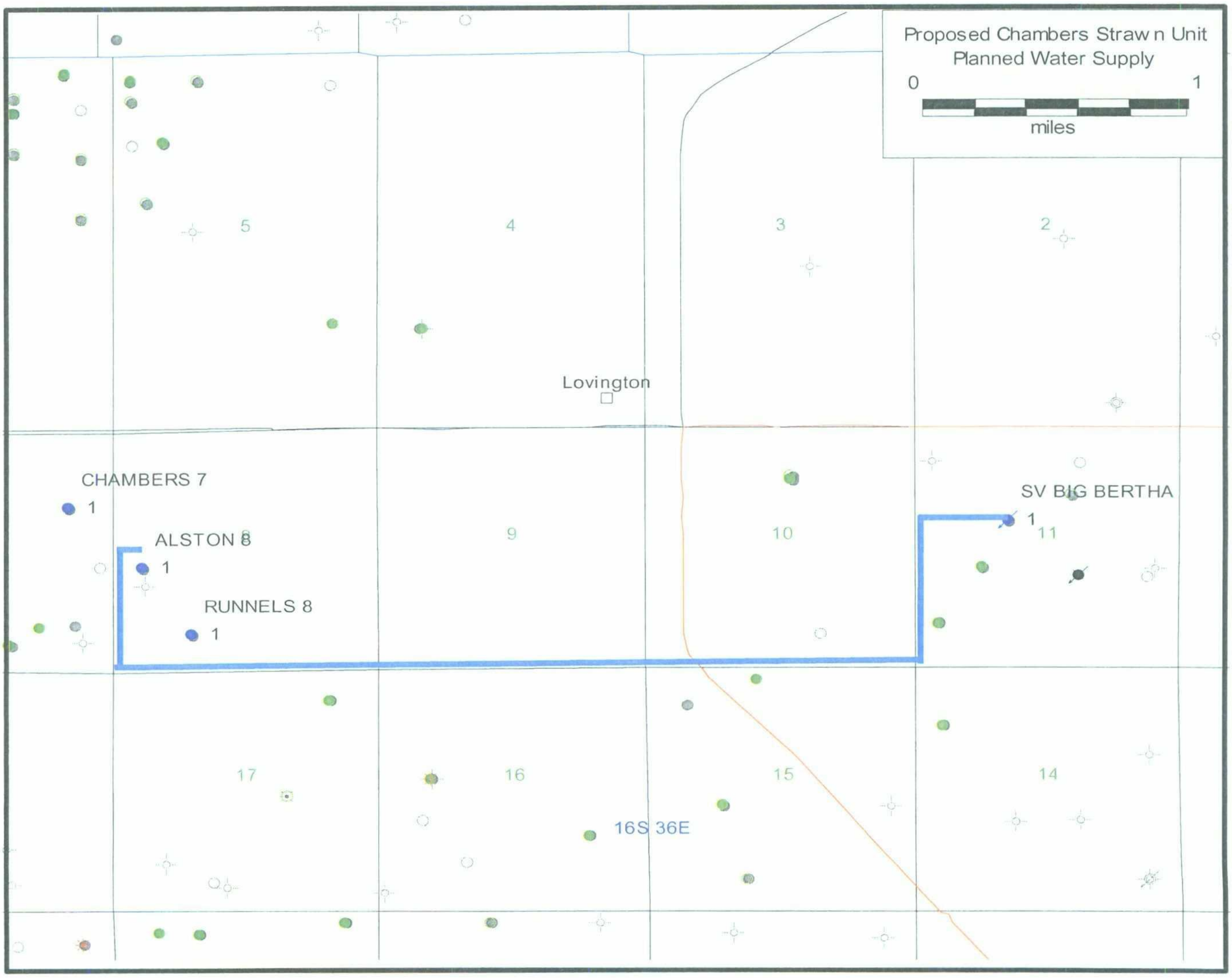
# Proposed Chambers Strawn Unit
## Waterflood Performance Prediction




Attachment 15

# Proposed Chambers Strawn Unit

# Water Supply Plan

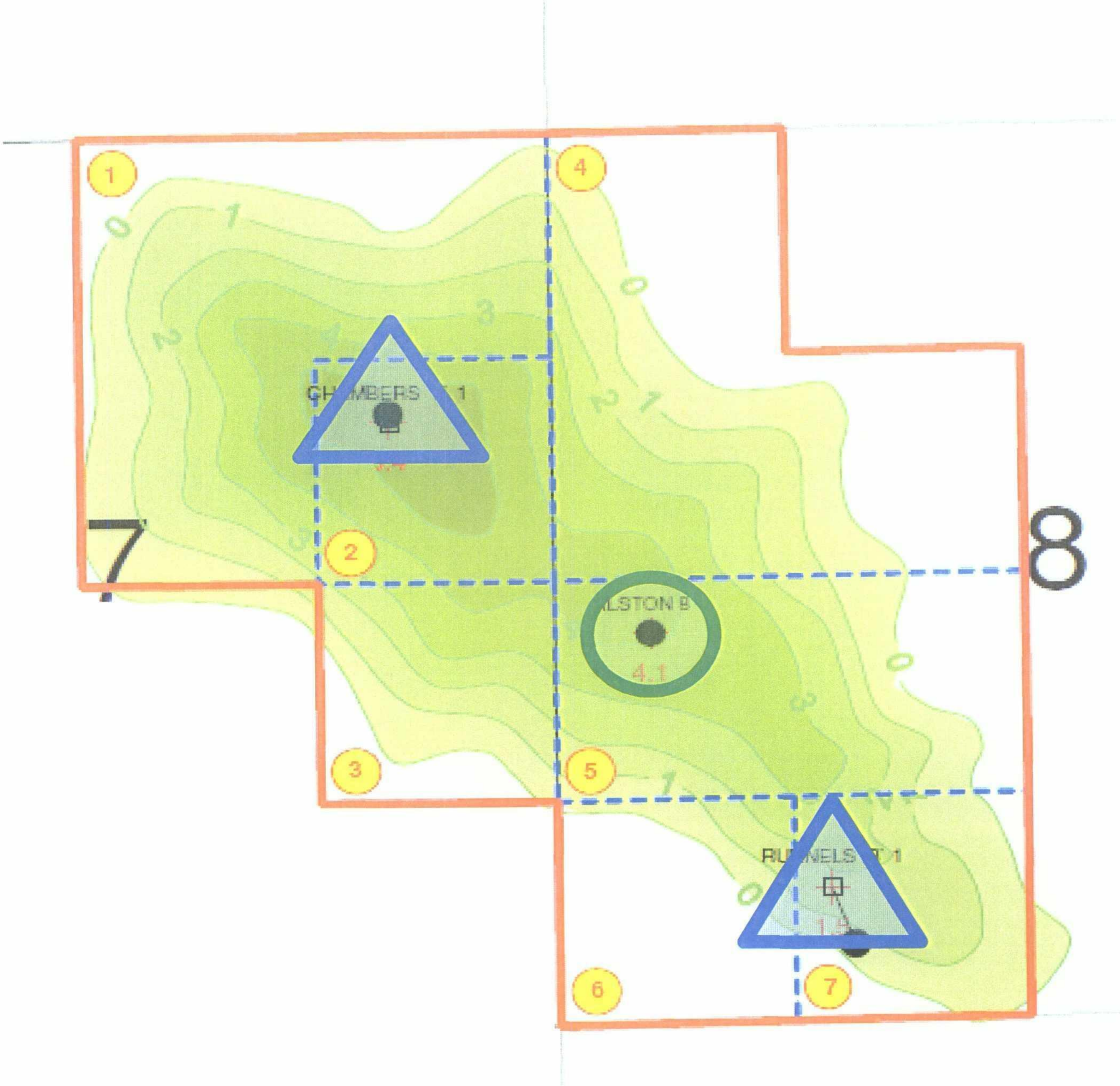



Water supply will be provided by the Big Bertha water disposal system. The water is from the Strawn formation and the Wolfcamp formation. The injection water is compatible with the formation. The route above is one of several being considered. We believe the final route will be 6 miles or less and will require boring under State Highway 18 and State Higway 483.

**Attachment 16**

# Proposed Chambers Strawn Unit
## Capital Cost Estimate

| Costs | | |
|---|---|---|
| 1) Convert Chambers 8-1 to water injection service. | $ | 175,000 |
| 2) Convert Runnels 7-1 to water injection service. | | 175,000 |
| 3) Alston 7-1, check for fill and acidize well. | | 75,000 |
| 4) Injection facility | | 325,000 |
| 5) Water Supply System | | 500,000 |
| Total Project Cost | $ | 1,250,000 |



# Proposed Chambers Strawn Unit

## T16S-R36E Sec 7-8

## Unitization Parameters

Tract participation will be based on remaining primary, future secondary recovery and the wellbores to recover it.

Parameters for TPF:

| | | | | | | |
|---|---|---|---|---|---|---|
| Remaining Primary | 0.15 | Reflected as | 0.40 | Present Rate and | 0.60 | Reserve |
| Future Secondary | 0.75 | Reflected as | 0.40 | Est. Ult. Rec. and | 0.60 | OOIP |
| Well bores | 0.10 | | | | | |
| Total | 1.00 | | | | | |

| Well Name | Tract | Avg. Rate (Jan-Feb-Mar) | | | | Primary Reserve at 4-1-2010 | | | | Primary EUR | | | | OOIP | | Wellbores | | TPF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil BOD | Gas Mcf | OilE BOE | Tract (Frac) | Oil MBO | Gas MMcf | OilE MBOE | Tract | Oil MBO | Gas MMcf | BOE MBOE | Tract (Frac) | Tract (MBO) | Tract (Frac.) | Tract (Count) | Tract (Frac.) | |
| No well | 1 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 1,470,917 | 0.257 | 0 | 0.000 | 0.115478567438 |
| Chambers 7-1 | 2 | 13.6 | 59.7 | 23.6 | 0.452 | 29.7 | 58.3 | 39.4 | 0.389 | 530.0 | 1,853.4 | 838.8 | 0.663 | 1,416,611 | 0.247 | 1 | 0.333 | 0.405727653921 |
| No well | 3 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 467,807 | 0.082 | 0 | 0.000 | 0.036726569707 |
| No well | 4 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 840,191 | 0.147 | 0 | 0.000 | 0.065961650071 |
| Alston 8-1 | 5 | 4.3 | 23.9 | 8.3 | 0.159 | 4.2 | 16.1 | 6.8 | 0.067 | 157.3 | 541.5 | 247.6 | 0.196 | 1,215,679 | 0.212 | 1 | 0.333 | 0.203122703991 |
| No well | 6 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.000 | 67,793 | 0.012 | 0 | 0.000 | 0.005322246380 |
| Runnels 1-8 | 7 | 8.4 | 71.5 | 20.3 | 0.390 | 34.2 | 124.7 | 55.0 | 0.543 | 89.3 | 531.9 | 177.9 | 0.141 | 252,911 | 0.044 | 1 | 0.333 | 0.167660608492 |
| | | 26.3 | 155.1 | 52.2 | 1.000 | 68.0 | 199.1 | 101.2 | 1.000 | 776.5 | 2,394.9 | 1,264.3 | 0.859 | 5,731,908 | 1.000 | 3 | 1.0000 | 1.000000000000 |

The Tract Participation Formula:

Tract Factor = 15 % Remaining Primary + 75 % Secondary + 10 % Well Bores

Tract Factor = 15% x [(40% Rate) + 60 % Reserve)] + 75 % x [(40% x EUR + 60 % x OOIP)] + 10% Wellbores

$$\text{Tract Factor} = 0.15\left\{0.4\left(\frac{\text{Tract Rate}}{\text{Unit Rate}}\right) + 0.6\left(\frac{\text{Tract Reserve}}{\text{Unit Reserve}}\right)\right\} + 0.75\left\{0.4\left(\frac{\text{Tract EUR}}{\text{Unit EUR}}\right) + 0.6\left(\frac{\text{Tract OOIP}}{\text{Unit OOIP}}\right)\right\} + 0.1\left(\frac{\text{Tract Well Count}}{\text{Unit Well Count}}\right)$$

Attachment 18