

Oil and Gas Potential in the Secretaries Potash Enclave*

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Abstract

Potash, oil and gas leases in the Secretary's Area are managed by the Bureau of Land Management (BLM) and oil and gas drilling is allowed by special permit. Since oil and gas wells must pass through potash, wells must be more than 1/4 mile from existing potash mines and, conversely, mining companies must allow 1/4 mile around existing oil wells. These limits are extended to 1/2 mile in formations below the Bone Spring where production has been from high pressure gas wells. Persistent conflict between the two industries has created management problems for the BLM and an understanding of the economic impact of potential resources within the area is important to making development decisions.

This study combines to-date geologic understanding of the area with historic production data to make per-acre estimates of underdeveloped oil and gas reserves within the geologic boundaries of the main body of the Oil Potash leasing Area, as defined by the New Mexico Oil Conservation Division Rule R-111-p. Production and development within that area was compared to production and development in a 1-township wide buffer zone immediately surrounding the R-111-p area (Figures 1-3, Tables 1-2).

The purposes were twofold: First to provide a database and Geographic Information System which illustrates development potential utilizing existing oil and gas plays; and second to provide economic estimates of the total values of those resources and as royalty and tax revenues to federal, state, and local governments. This study does not address the economic impact of the jobs that would be created to produce this oil and gas, or the economic impacts of mining operations.

Untapped oil and gas resources using only existing plays was estimated at 1.4 billion BOE (Barrels Oil Equivalent), or 468 million barrels of oil and 5.5 TCF of gas. Secondary recovery could add an additional 318 million barrels of oil. Economic

valuations using oil prices of \$50, \$75, and \$100 per barrel and gas values of prices of \$3, \$5 and \$7 per MCF yielded a resource value between \$40-\$86 billion for primary recovery and an additional \$16-\$32 billion for secondary oil recovery. The majority of the R-111-p area (-71%) is administered by the BLM and of the remainder -19.4% are New Mexico State lands. Royalties and taxes for a fully developed R-111-p area represent \$11.4-\$24 billion in potential revenues for Federal, State and County governments (-20% of the total resource value) of which \$7.5-\$15.8 billion would go to the State of New Mexico in MMS royalty shares, state royalties, and various taxes. Ad valorem taxes would provide Lea and Eddy Counties a combined \$1.4-\$3.0 billion in revenue. The Federal MMS royalty share would provide \$2.5-\$5.2 billion at full estimated ultimate recovery.

Major existing plays that are under-developed in the Potash Enclave include the Brushy Canyon formation in the Delaware Mountain group, the Morrow, and the Bone Spring. Further, mature plays such as the Artesia group would likely have renewed interest within the currently restricted areas of the reserve both for primary production and for Residual Oil Zone (ROZ) Development. In recent years, the use of Drilling islands has already led to increased Brushy Canyon production within the enclave.

This study used only existing production data and represents a conservative estimate of available resources. It does not, at present, fully consider recent changes to technology and future plays that do not have extensive existing production data, such as the Siluro-Devonian carbonates, Woodford Shale, Bone Springs shale, and the Wolfcamp, which could significantly impact regional production as the lower Brushy Canyon play did in the late 1980s and early 1990s. Preliminary work on the Woodford Shale, Bone Spring/Avalon Shale, and ROZ potential in the Sand Andres and Grayburg strongly indicate significant additional potential reserves within the Potash Area.

Acknowledgement

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Selected References

Bammidi, V.S., R.S. Balch, and T.W. Engler, 2011, Ranking the Resource Potential of the Woodfordshale in New Mexico: SPE Western North American Region Meeting, Anchorage, Alaska, USA, Paper 144576-MS, 10 p.

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Hills, J.M., 1984, Sedimentation, Tectonism, and Hydrocarbon Generation in Delaware Basin, West Texas and Southeastern New Mexico: AAPG Bulletin 68/3, p. 250-267.

Walsh, W., and B. Kerr, 2005, Mitigating terrain-based access concerns on the Fort Nelson lowland, British Columbia; a geographic information system (GIS) application: AAPG Annual Abstracts, v. 14, p. A72.

Website

Reservoir Evaluation and Advanced Computational Technologies: New Mexico Petroleum Recovery Research Center, New Mexico Tech, Socorro, New Mexico, Web accessed 2 August 2011, <http://ford.nmt.edu>

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AAPG SW Section Meeting, Ruidoso, NM - June 7, 2011

Overview

- Acknowledgements
- Introduction
 - Background, setting, significance
- Existing Production Analysis
 - Historic plays and production data
 - Under-drilling within the enclave
- Projected Resource Value
 - Value of Oil and Gas resources in the Potash Area
- That's not all... There's more
 - New Technologies/New Plays
 - Horizontals
 - Multi-stage fracking
 - Secondary/tertiary recovery/ROZ's?
 - Shale oil/gas

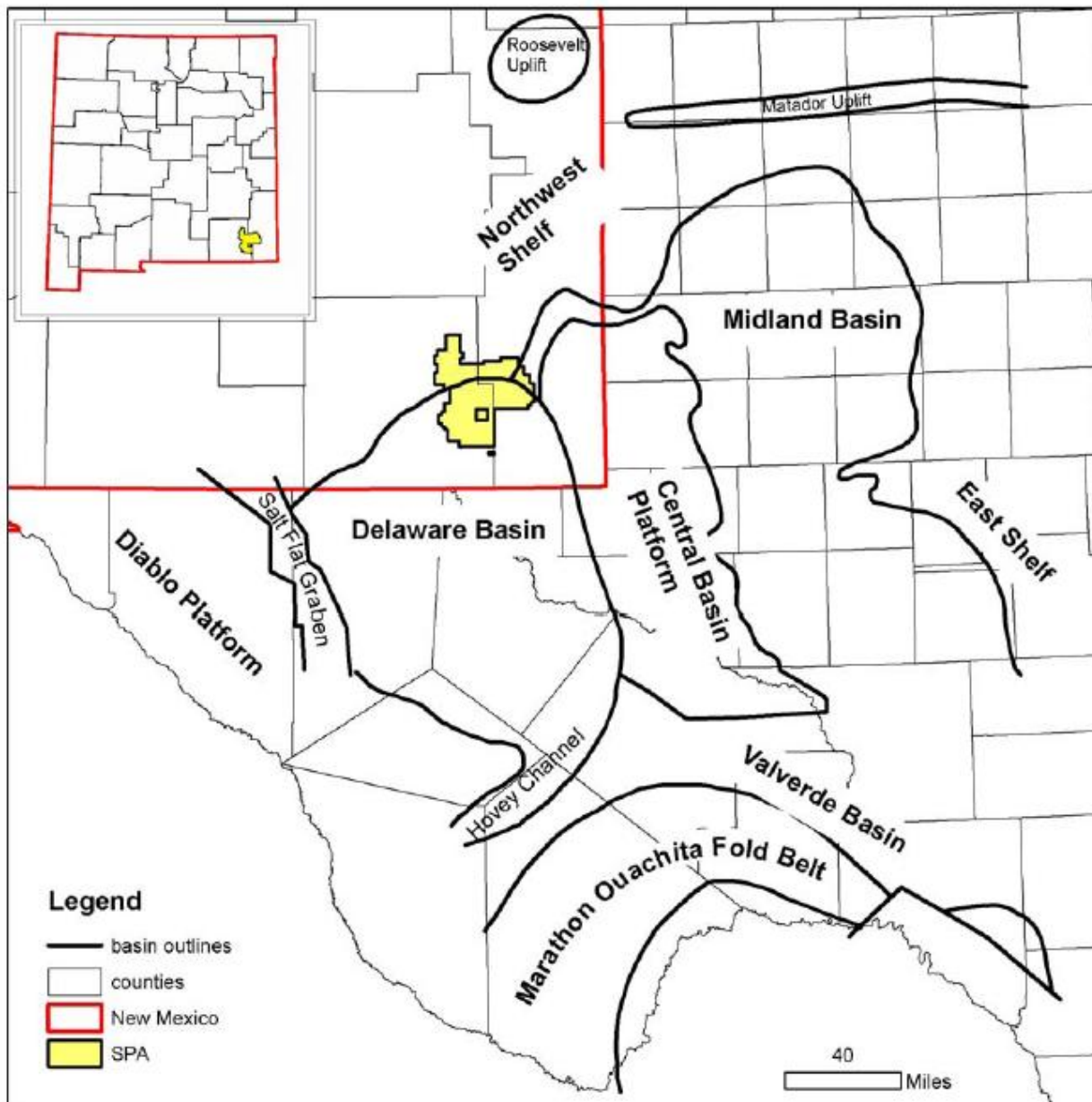
Acknowledgements

- Initial work requested by industry in late 2009
 - Existing data study ~2 months
- Refinements and continuing analyses funded as part of the BLM Pecos District RFD
 - PI- Tom Engler. Co-PI's Martha Cather and Robert Balch
- Numerous students have worked on portions of this data
- Previous area studies by Ron Broadhead and Patrick Walsh provide a robust framework

Introduction

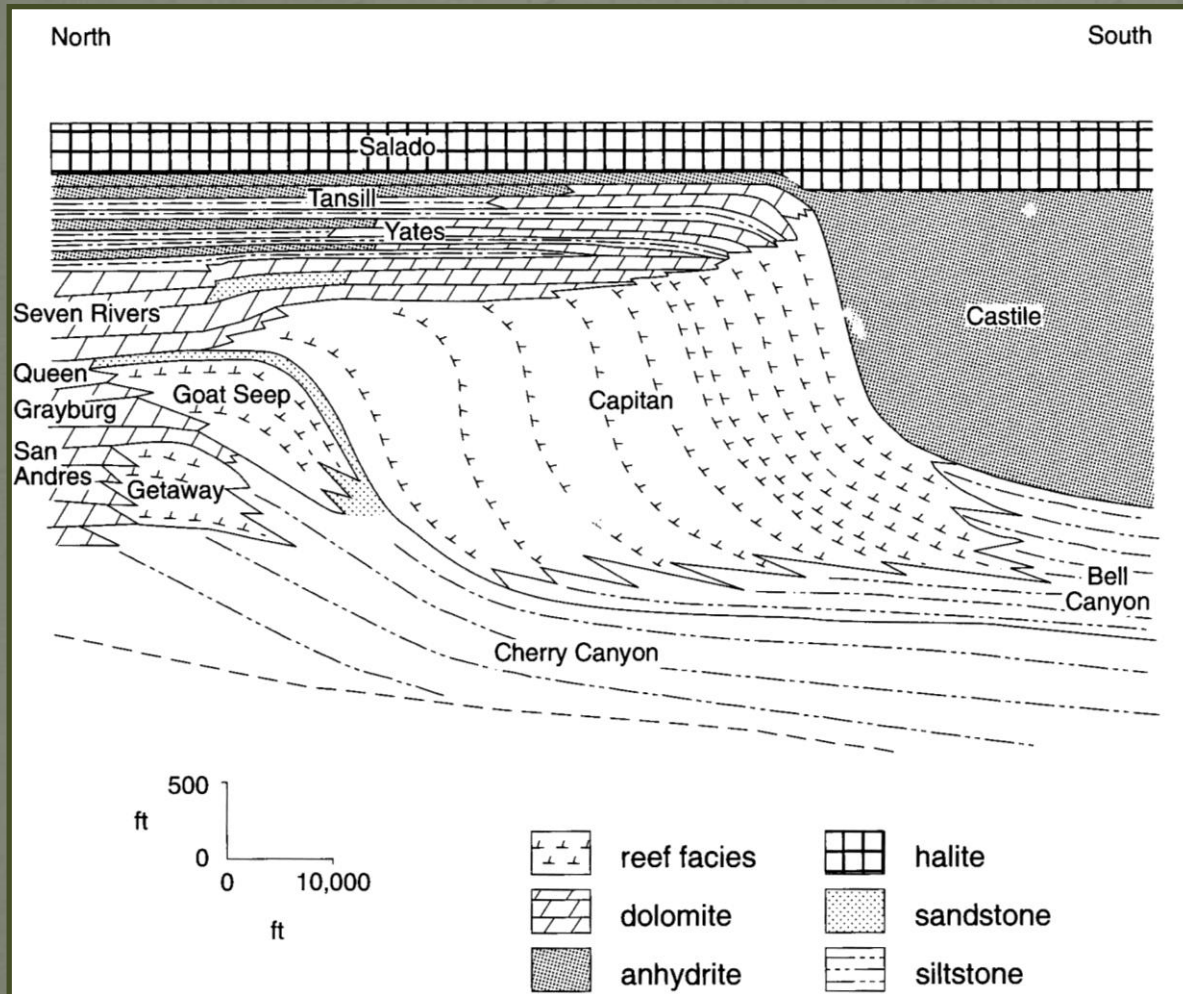
- ~777 sq miles of SE NM reserved for potash mining for over 70 years
 - Potash was a strategic mineral in World War II
- Underdevelopment of petroleum resources within the area
 - Significant reserves and development potential in the center of a mature basin
- History of conflicts between Oil/Gas and Mining stakeholders
 - Recently cooperation is becoming more common
 - Drilling Islands
 - Long horizontals
 - Solution Mining

Regional Geologic Setting



After Hills 1984

N-S Generalized Cross-Section



After Garber et al. [1989]

TIME
UNITSROCK
UNITS

Quat.	alluvium
Tertiary	Ogallala Fm
Cretaceous	
Jurassic	
Triassic	Late
	Middle
	Chinle Group
Permian	Early
	Ochoan
	Dewey Lake Fm
	Rustler Fm
	Salado Fm
	Castile Anhydrite
	Guad.
	Delaware Mountain Group
	Leo.
	Bone Spring Formation
Pennsylvanian	Wolf.
	Wolfcamp Group
	Virg.
	Cisco Group
	Mis.
	Canyon Group
	Des.
Atoka	Strawn Group
	Atoka Group
	Morr.
Morrow	Morrow Group

(match line)

(match line)

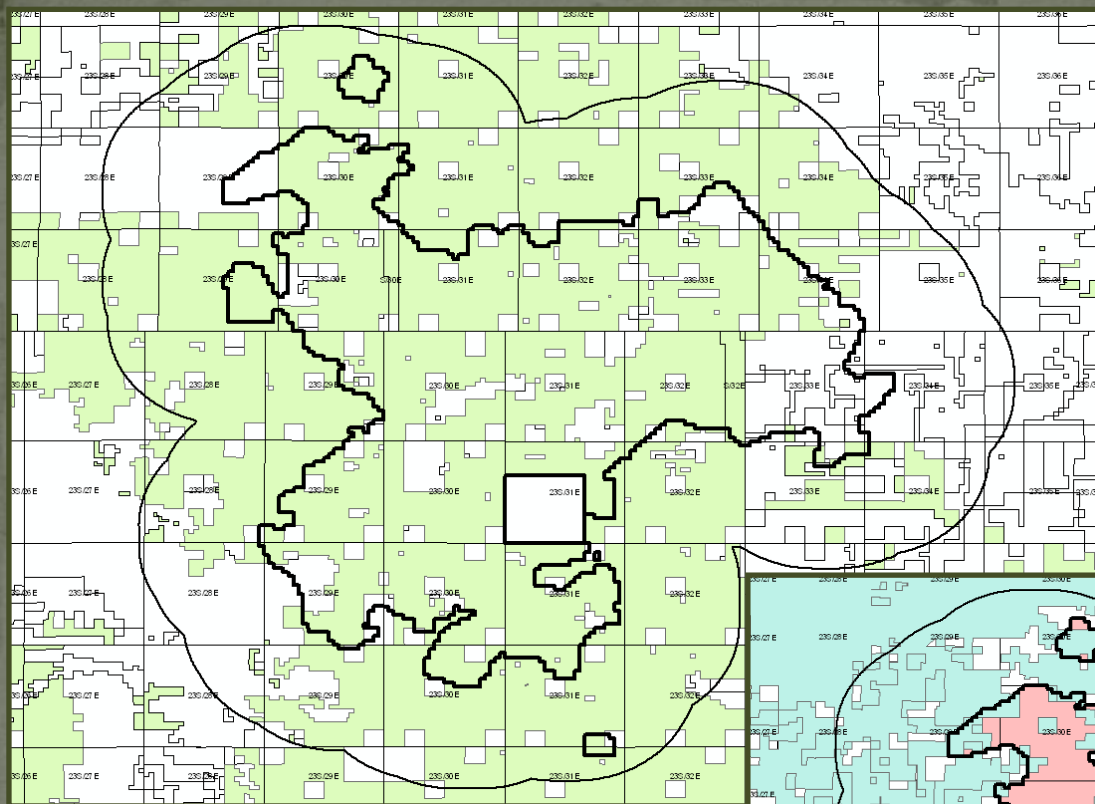
Mississippian	Late	Mississippian limestone
	Early	
Devonian	Late	Woodford Shale
	Middle	
	Early	Lower Devonian rocks
Silurian	Late	Upper Silurian rocks
	Early	Fusselman Dolomite
Ordovician	Late	Montoya Dolomite
	Middle	Simpson Group
	Early	Ellenburger Dolomite
	Early	
Cambrian	Late	Bliss Sandstone
	Middle	
	Early	
Precambrian		Precambrian rocks

Stratigraphy

Modified from Broadhead et al. [1998]

Methods

1. Developed GIS database for production data, play boundaries (Walsh, 2005), cultural features
2. Established study area as the R-111p (567 mi²) designation by the State of New Mexico
3. Defined a 1 township wide boundary around the study area for analysis of comparative development (926 mi²)
4. Used Broadhead (1998) WIPP area study as a representative Township for production potential
5. Computed production totals within the area and in the buffer and made projections of potential future reserves

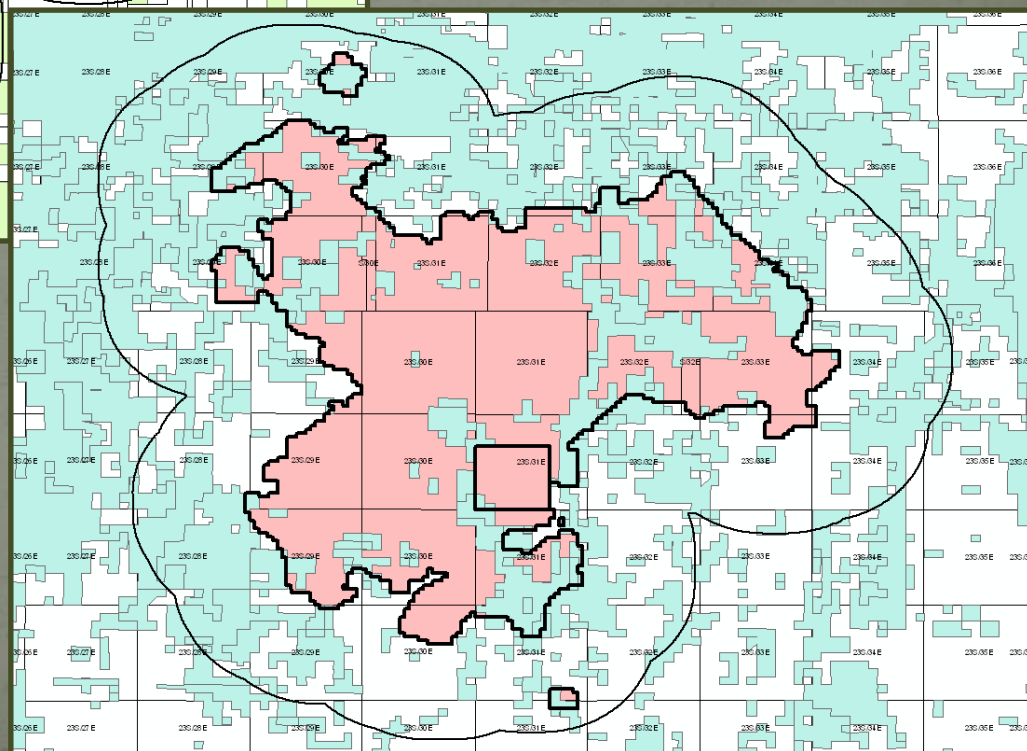


BLM Lands

~71%

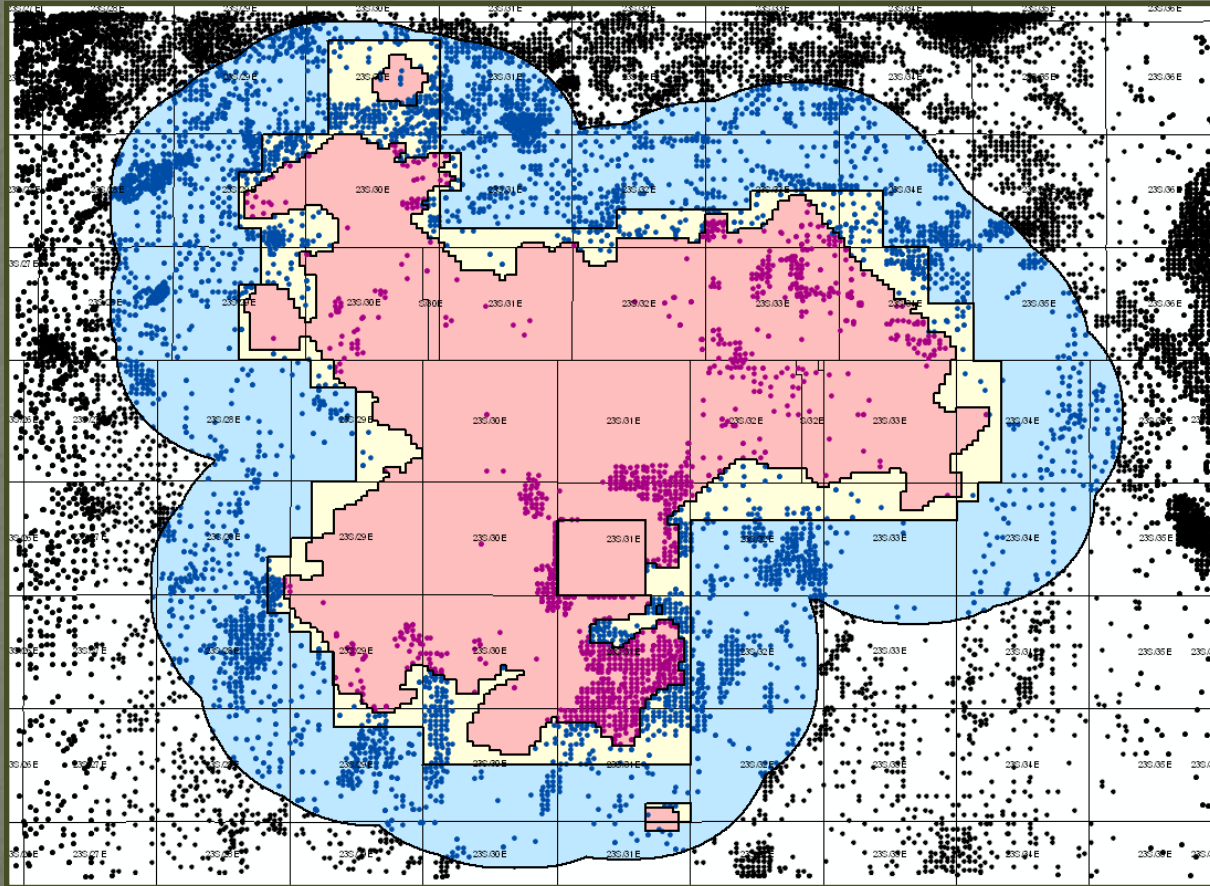
State Lands

~19.4%



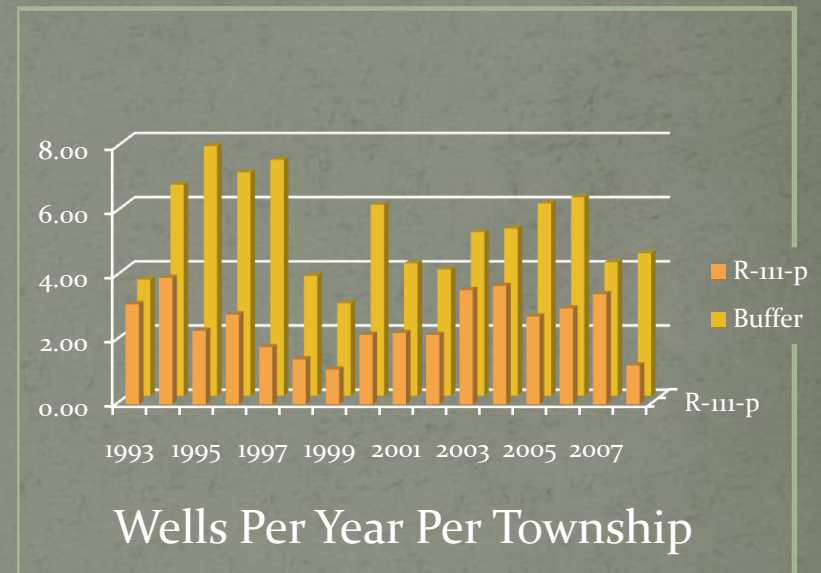
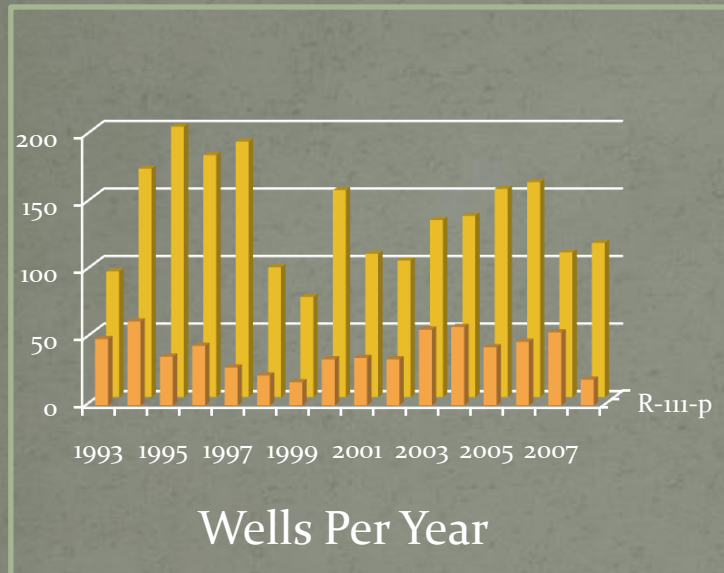
Defined Pools

Potash Area Wells through 2009



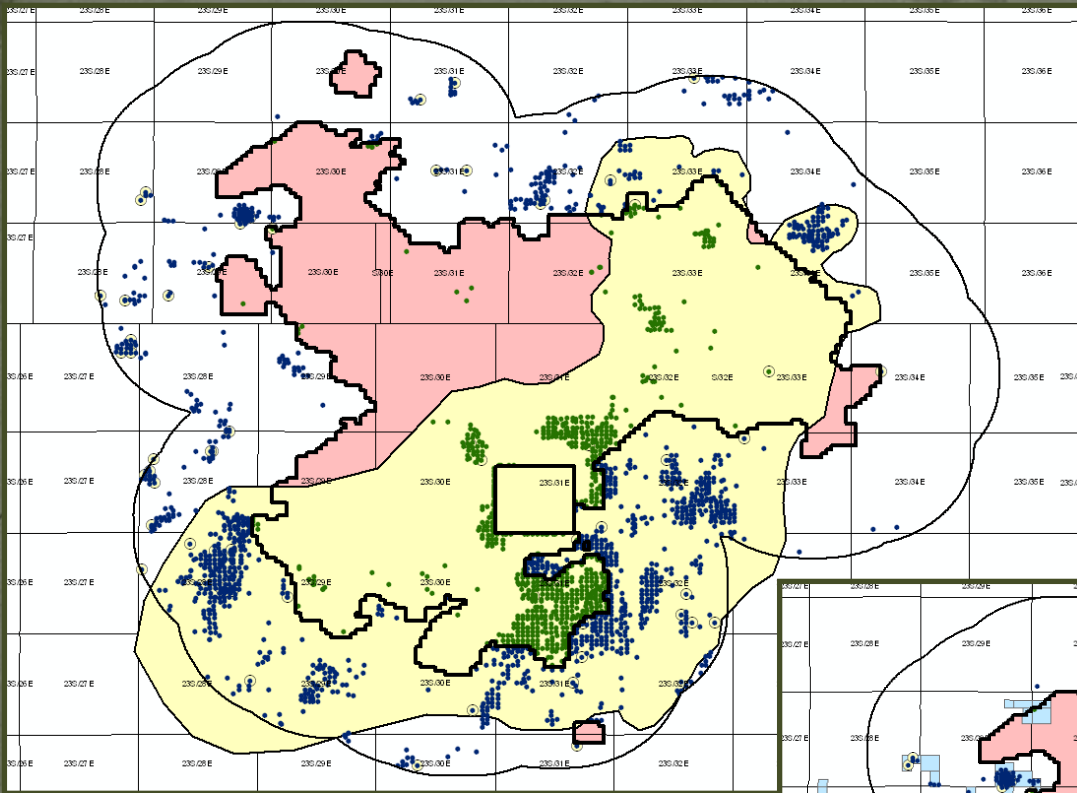
- First wells in 1920's
 - NW Shelf
 - Some 1930's wells still producing
- Mostly shallow development until 1970's
 - Morrow, Atoka
- Uptick in drilling in 1980's-90's
 - Brushy Canyon Play
 - Opening of parts of the reserve
- In the Study area (r-111p + Buffer) 6257 wells drilled through 2009
 - 1291 in the Reserve
 - 4966 in Buffer

Completed Wells in or Near Potash Area

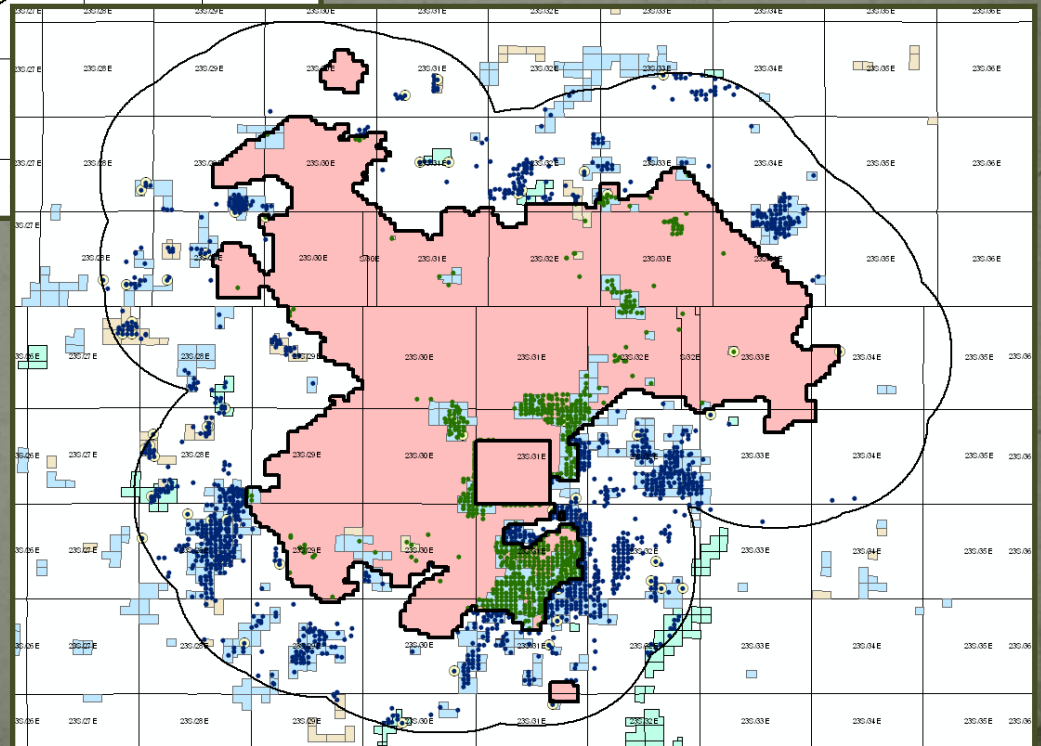


2003-2008 Completions			
Formation	In R-111-p	In Buffer	Combined
Delaware Mountain	182	231	413
Bone Spring	33	231	264
Morrow	31	198	229
Artesia Group	5	61	66
Atoka	6	35	41
Strawn	2	18	20
Wolfcamp	8	12	20
Pennsylvanian	8	9	17
Other	3	3	6
Total	278	798	1076

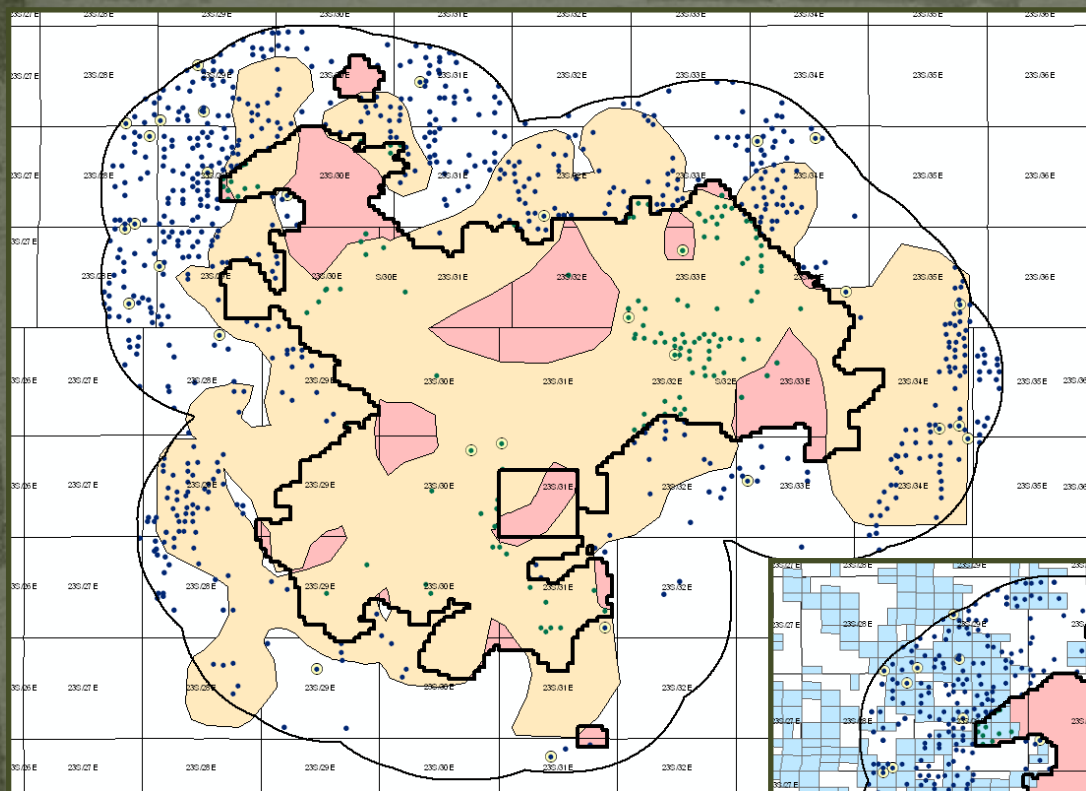
Brushy Canyon Potential (Walsh 2005)



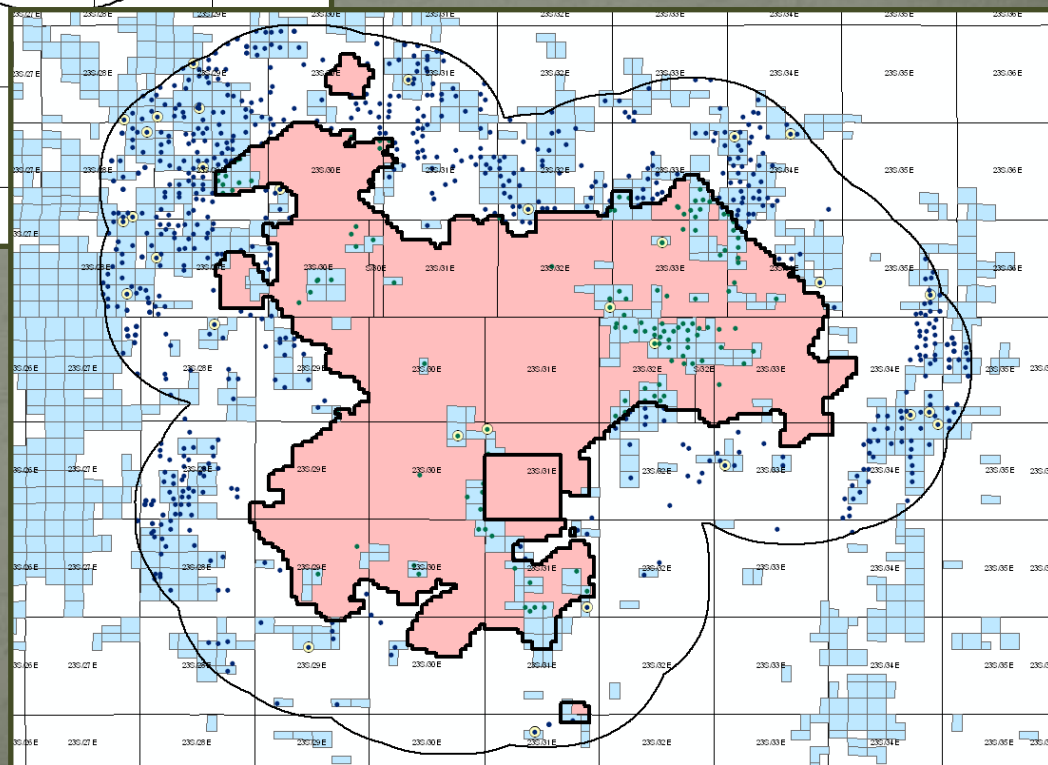
Brushy Canyon Pools



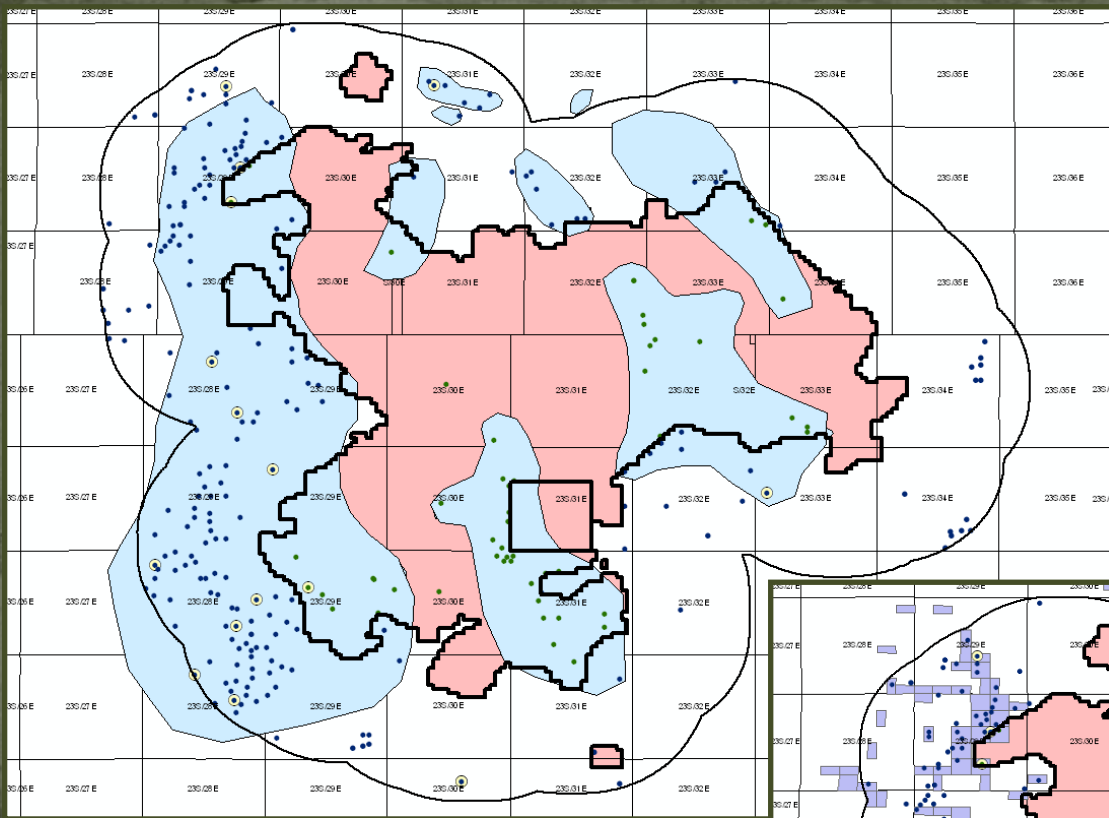
Morrow Potential Area (Walsh 2005)



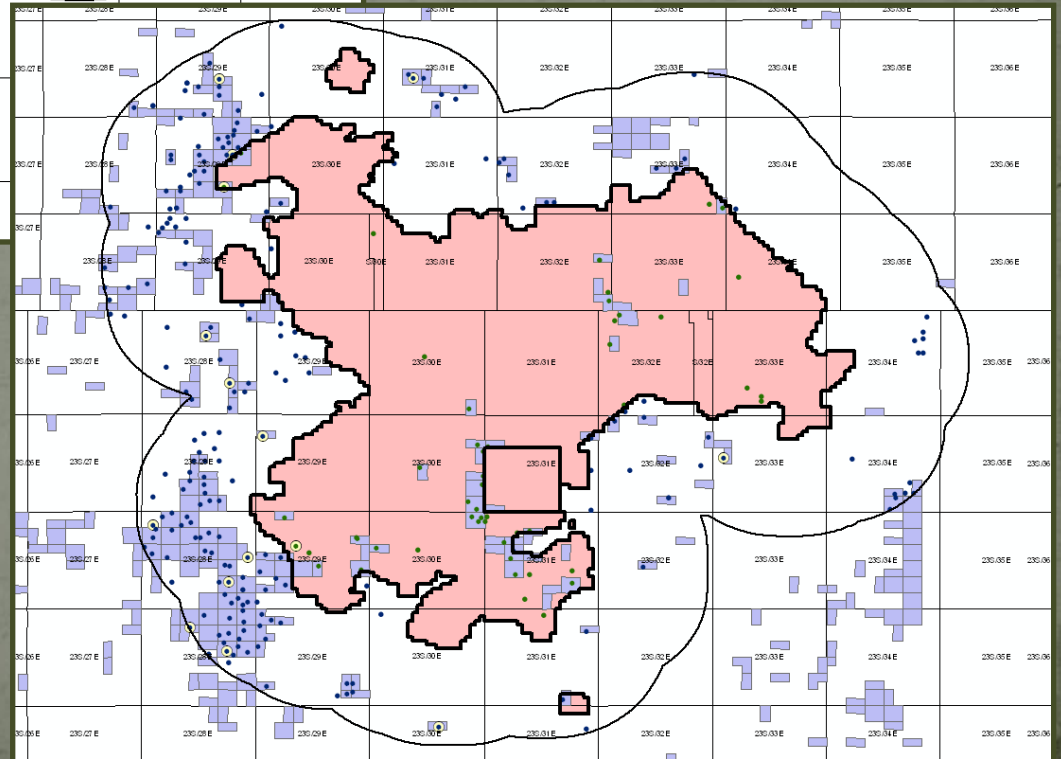
Morrow Pools

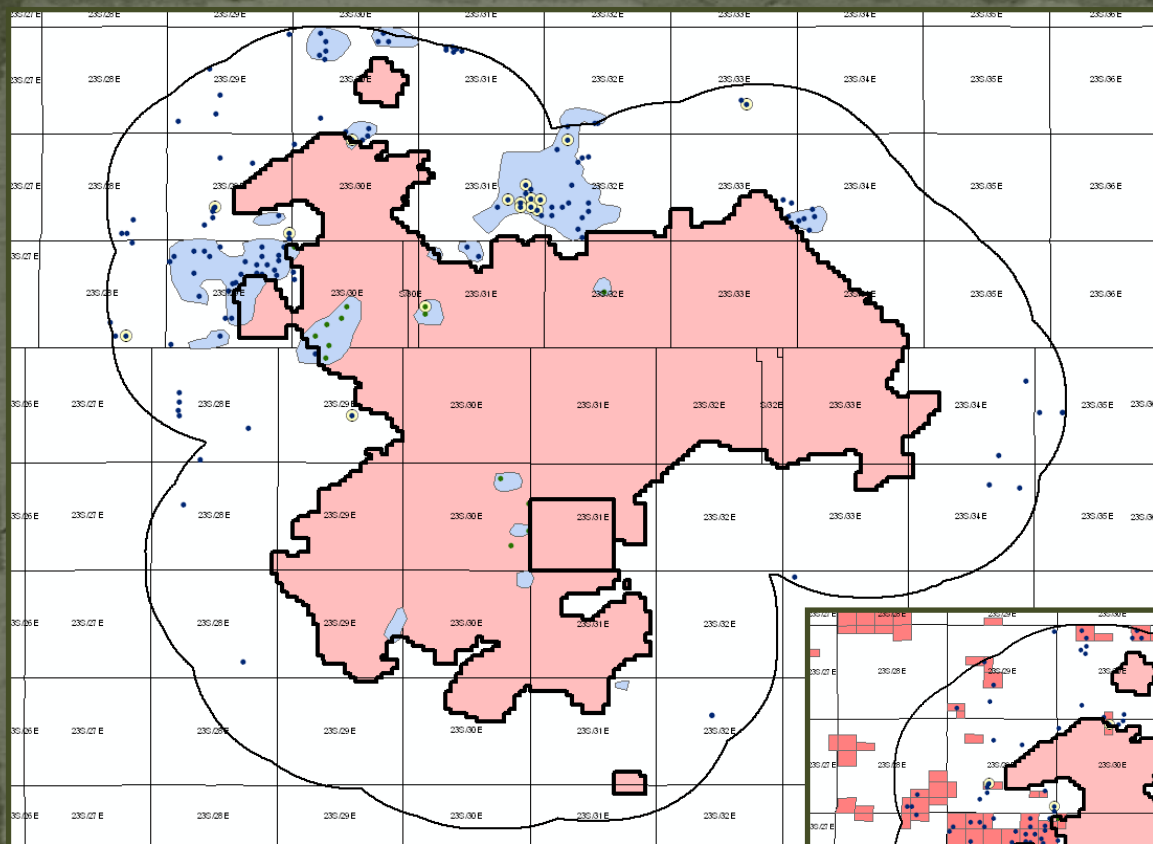


Atoka Potential Area (Walsh 2005)



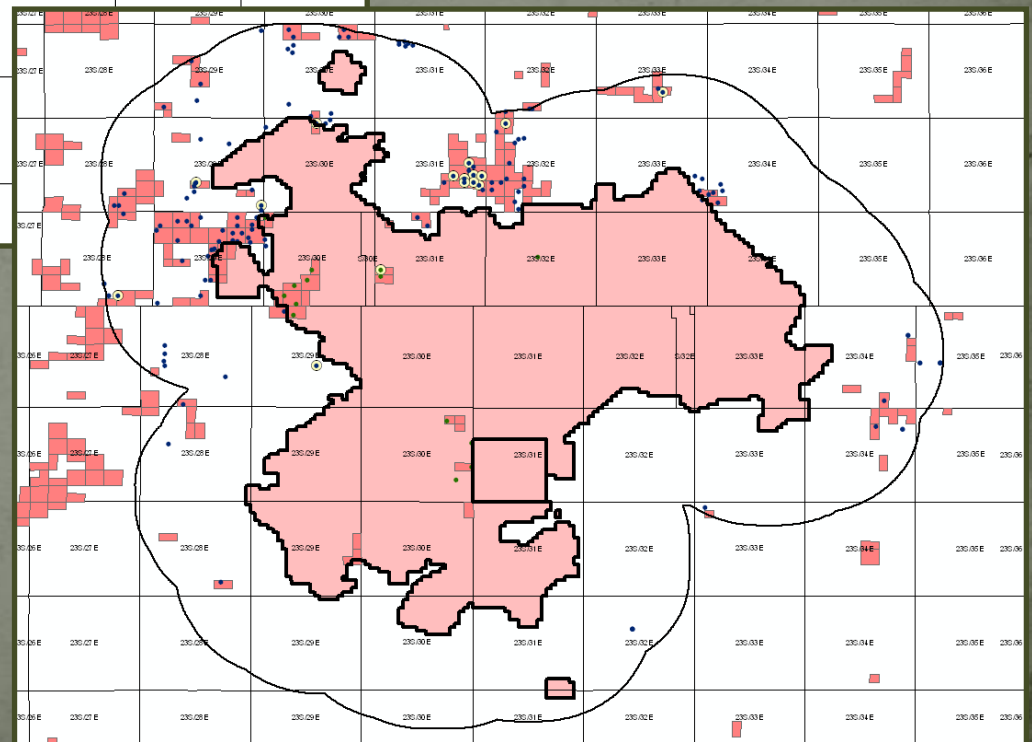
Atoka Pools



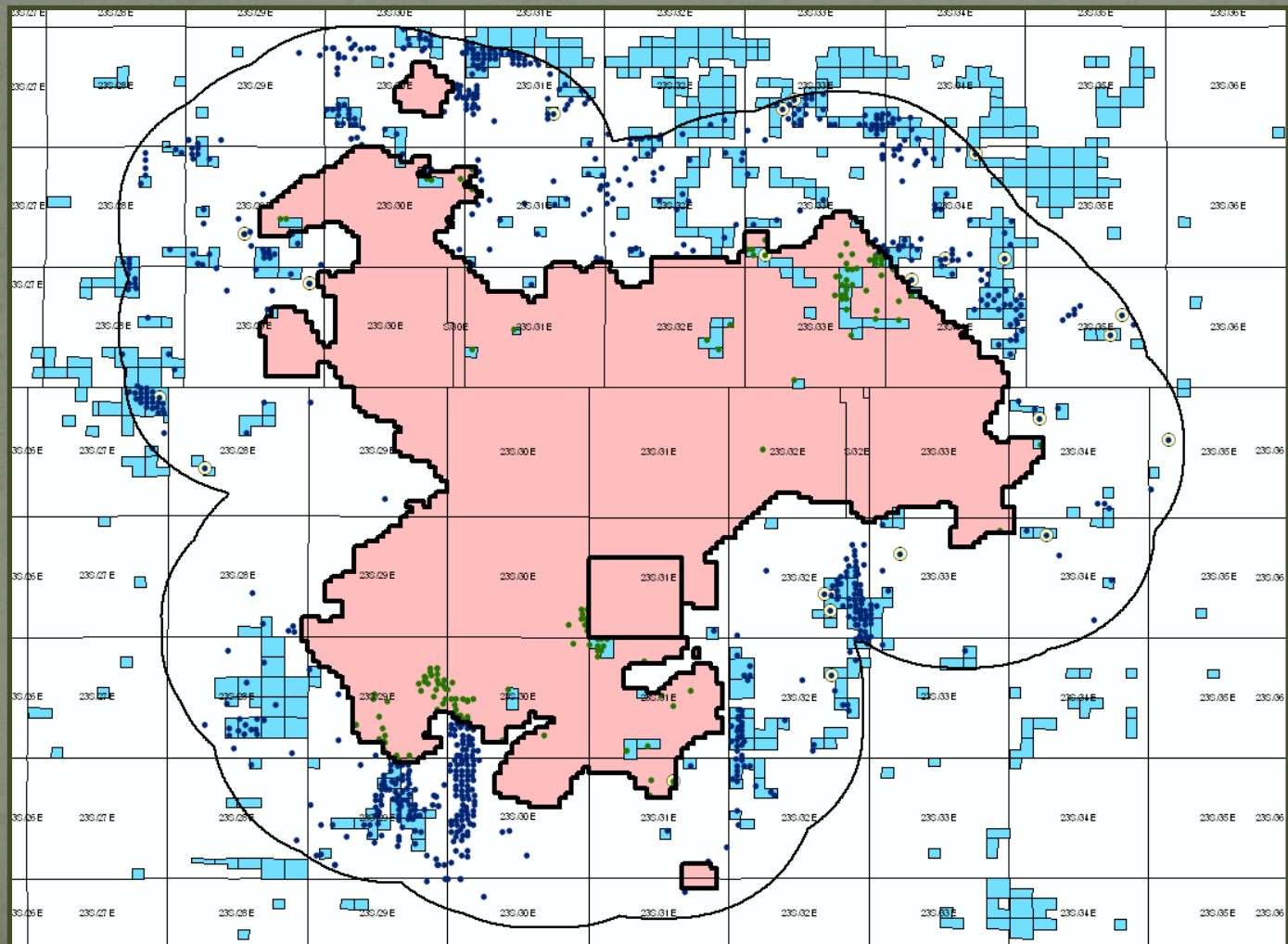


Strawn Potential Area (Walsh 2005)

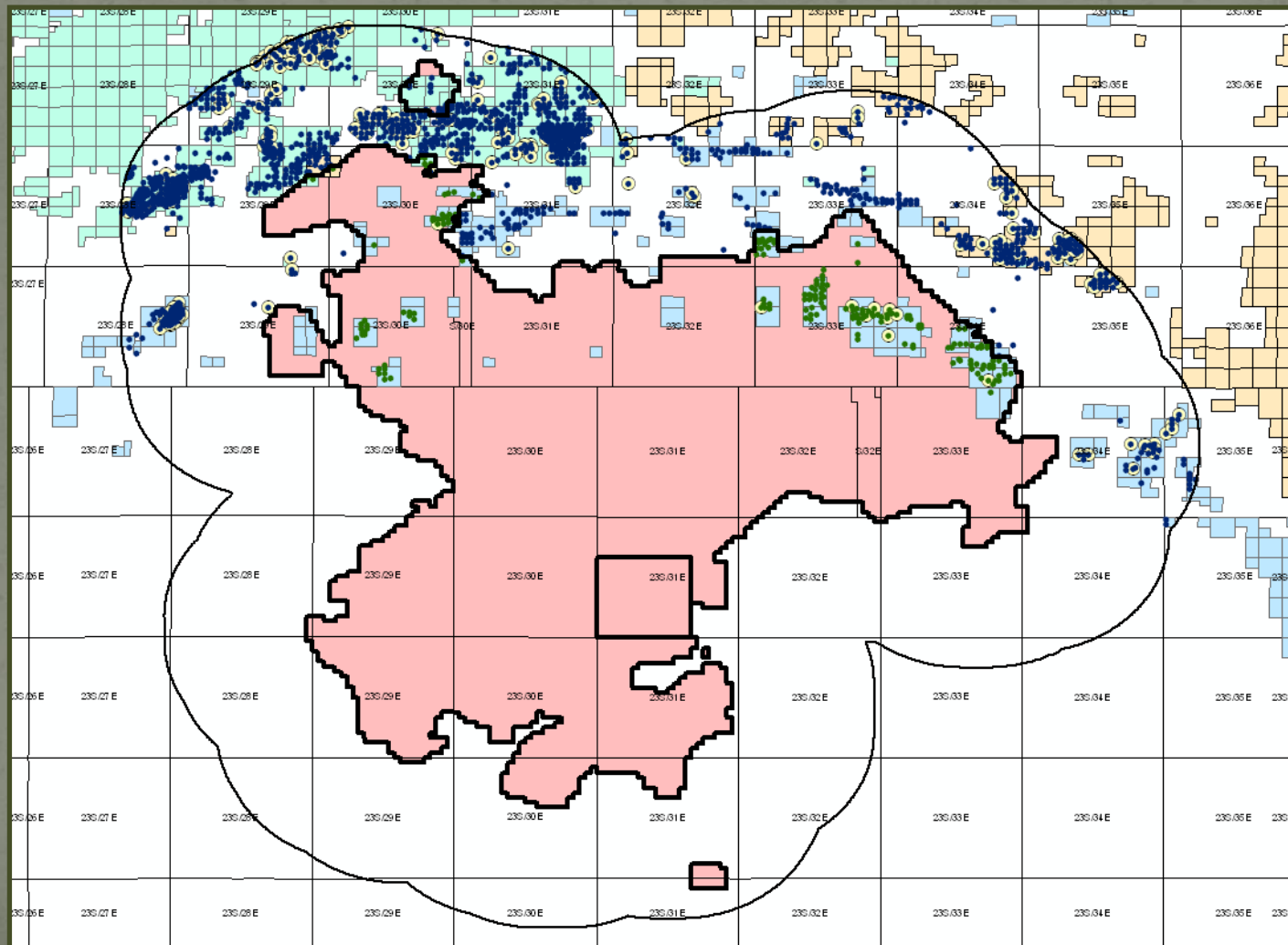
Strawn Pools



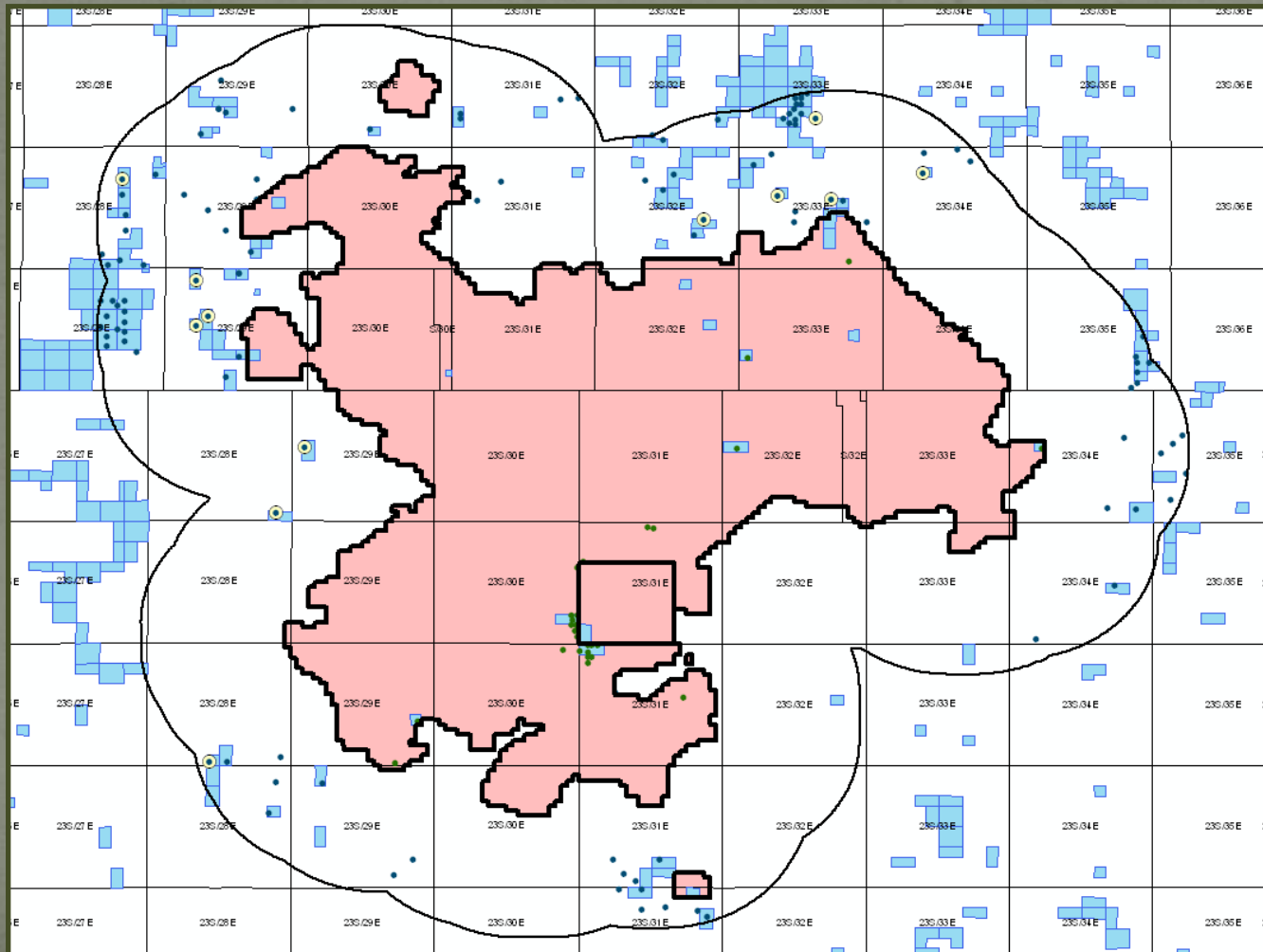
Bone Spring Pools



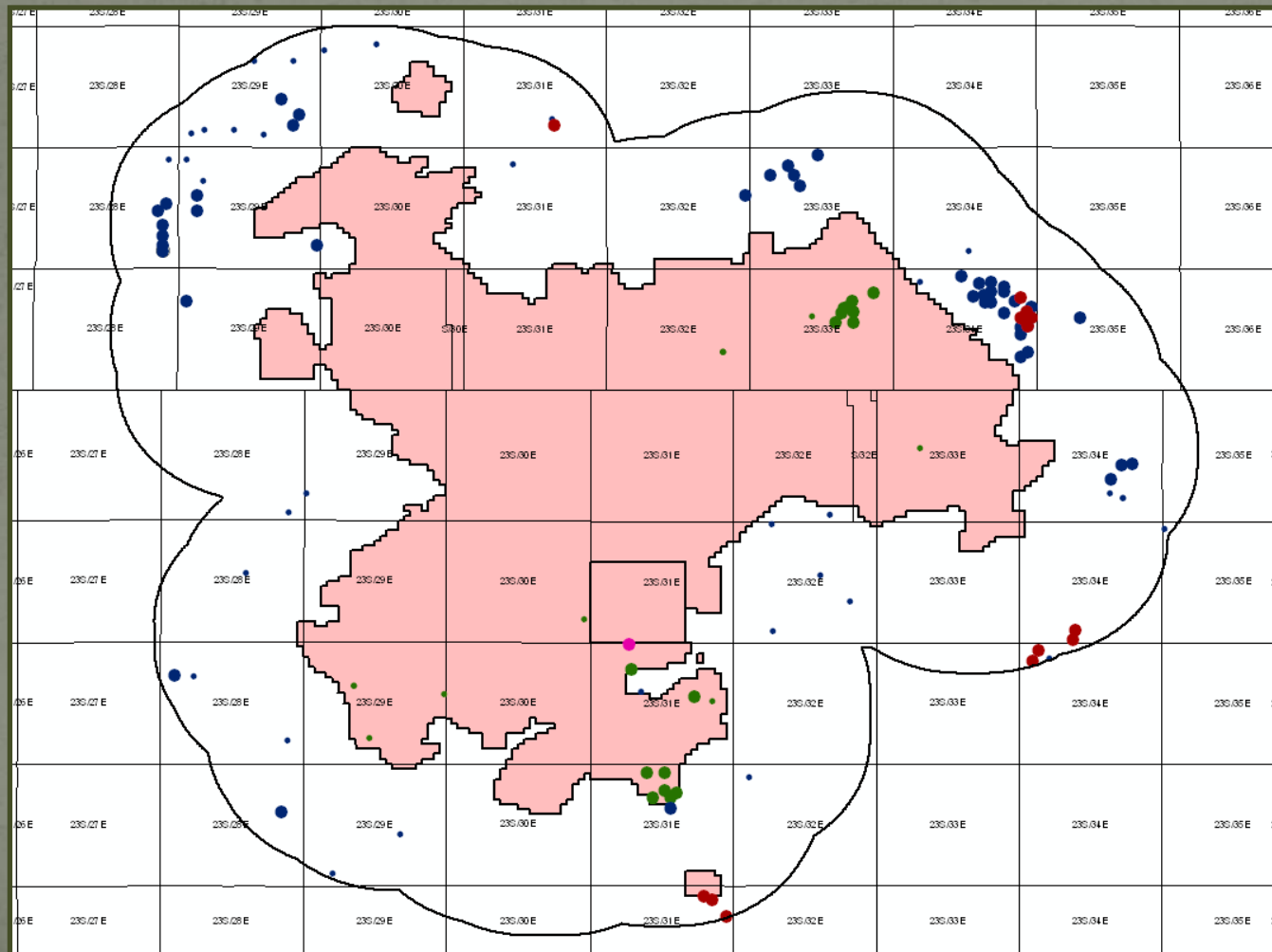
Artesia Group Pools



Wolfcamp Pools



Pennsylvanian, Devonian, and Other



Summary of Statistics for Major Existing Plays in the Potash Area

Formation	Oil	Gas	BOE	Area	Wells	Wells/mi2	BOE/Well
Delaware (Buffer)	86,337,549	201,258,127	119,880,570	306	1,446	4.7	82,905
Delaware (R-111-p)	53,315,796	129,750,008	74,940,797	351	703	2.0	106,601
Morrow (Buffer)	10,563,075	978,450,154	173,638,101	425	711	1.7	244,217
Morrow (R-111-p)	3,516,503	275,300,118	49,399,856	440	136	0.3	363,234
Atoka (Buffer)	1,380,074	271,412,977	46,615,570	331	229	0.7	203,561
Atoka (R-111-p)	465,665	99,406,351	17,033,390	159	52	0.3	327,565
Strawn (Buffer)	12,247,828	104,250,890	29,622,976	49	138	2.8	214,659
Strawn(R-111-p)	1,682,584	39,424,918	8,253,404	15	14	0.9	589,529
Artesia (Buffer)	65,139,168	44,455,127	72,548,356	N/A	1,481	N/A	48,986
Artesia (R-111-p)	19,160,356	4,895,241	19,976,230	N/A	209	N/A	95,580
Penn (Buffer)	1,121,309	45,609,348	8,722,867	N/A	44	N/A	198,247
Penn (R-111-p)	180,777	19,719,284	3,467,324	N/A	16	N/A	216,708
Bone Springs (Buffer)	34,612,267	141,882,018	58,259,270	N/A	820	N/A	71,048
Bone Springs (R-111-p)	7,427,454	31,282,322	12,641,174	N/A	142	N/A	89,022
Wolfcamp (Buffer)	8,072,109	78,333,623	21,127,713	N/A	121	N/A	174,609
Wolfcamp (R-111-p)	758,101	5,377,762	1,654,395	N/A	27	N/A	61,274

Method of Reserve Estimates

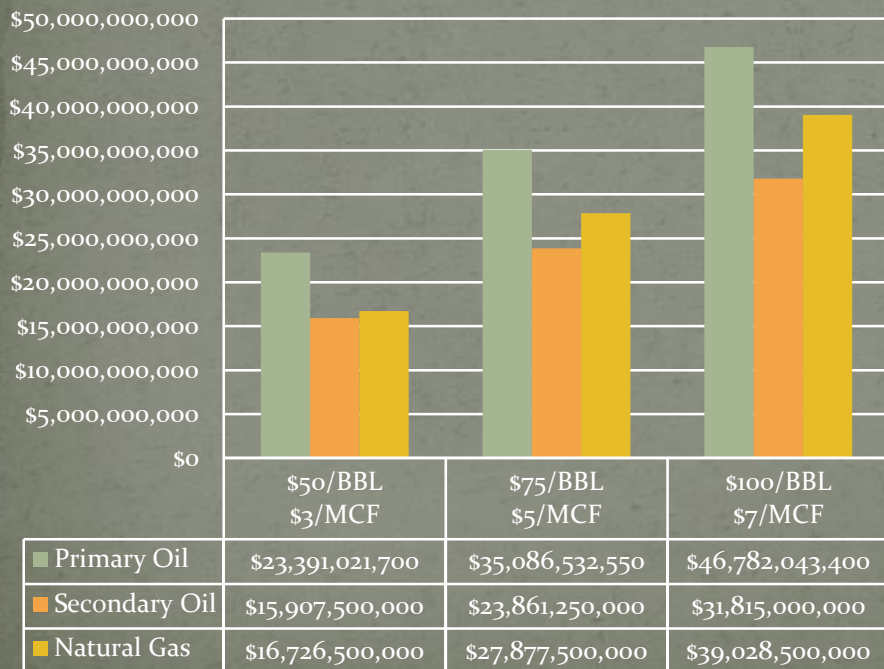
- Used EUR estimates from Broadhead (1998) for the WIPP area ~1 Township
 - Near geographic center of Potash Area
 - Detailed decline curve analysis by formation
 - Representative single Township area
- We consider these numbers to be conservative
 - New Plays not included
 - New technologies not addressed

Production Type	per Township	per acre
Oil and Condensate	35,200,000.00 BBL	1,527.78 BBL
Oil Secondary	20,200,000.00 BBL	876.74 BBL
Natural Gas	354,000,000.00 MCF	2,560.76 BOE

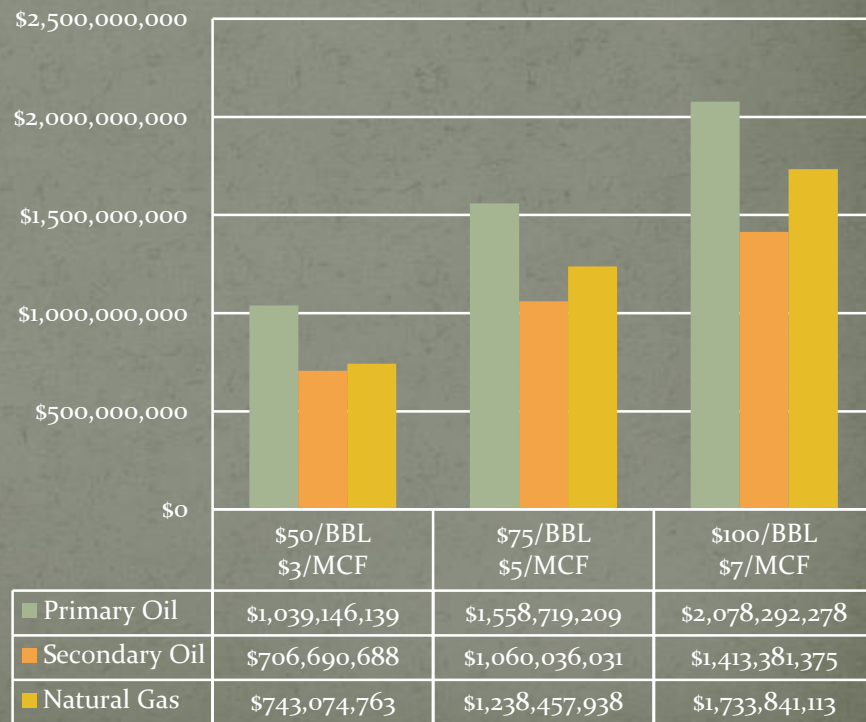
Reserves -Resource Value -Royalties

R-111-p Production through August 2009		Primary Reserves		Secondary Reserves
Cum. Oil BBL	86,579,566	Oil BBL	467,820,434	318,150,000
Cum. Gas MCF	605,492,694		5,575,500,000	--
CUM. BOE	187,495,015	BOE	1,397,070,434	318,150,000

R-111-p Oil and Gas Resource Value



R-111-p Federal Royalty Values



Valuation of Existing Reserves

- Over next 20-30 years if fully developed
 - 800 Million barrels oil
 - 5.5 TCF gas
- Resource Value at \$100 per bbl and \$4 per MCF
 - ~\$101 Billion
- Royalty and Tax Value
 - ~20% of Resource Value
 - ~\$20.5 Billion
 - State ~\$13.5 Billion
 - Federal ~\$4.5 Billion
 - Local ~\$2.5 Billion

Reserves

- Largest Existing Reserves
 - Morrow
 - Brushy Canyon
 - Bone Spring Conventional
- Potential additional reserves
 - Avalon Shale
 - Woodford Shale
 - Wolfcamp
 - Wolfcamp Shale
 - Pennsylvanian
 - Siluro-Devonian

Brushy Canyon Waterfloods

Poolname	Yr of first production	Yr of first injection	S:P ratio	formation	comments
Avalon	1977	1996	0.44	Upper Cherry Canyon and Upper Brushy Canyon	good waterflood response
Brushy Draw	1959	1990	none observed		insufficient injection
El Mar	1959	1978*	none observed	Bell Canyon - Ramsey and Olds sands	Approved WF in 10/68, no waterflood response
Indian Draw	1973	1981	1.17		excellent waterflood response
Los Medanos	1990	2004	N/A		limited injection, response due to add dev
Lost Tank	1991	2004	N/A		limited injection, response due to add dev
Lusk, West	1987	1997	0.28		fair waterflood response
Paduca	1961	1978*	0.73	Bell Canyon - Ramsey and Olds sands	Approved WF in 9/67, excellent waterflood response
Parkway	1987	1993	1.50		excellent waterflood response
Shugart, East	1985	2001	0.42		good waterflood response

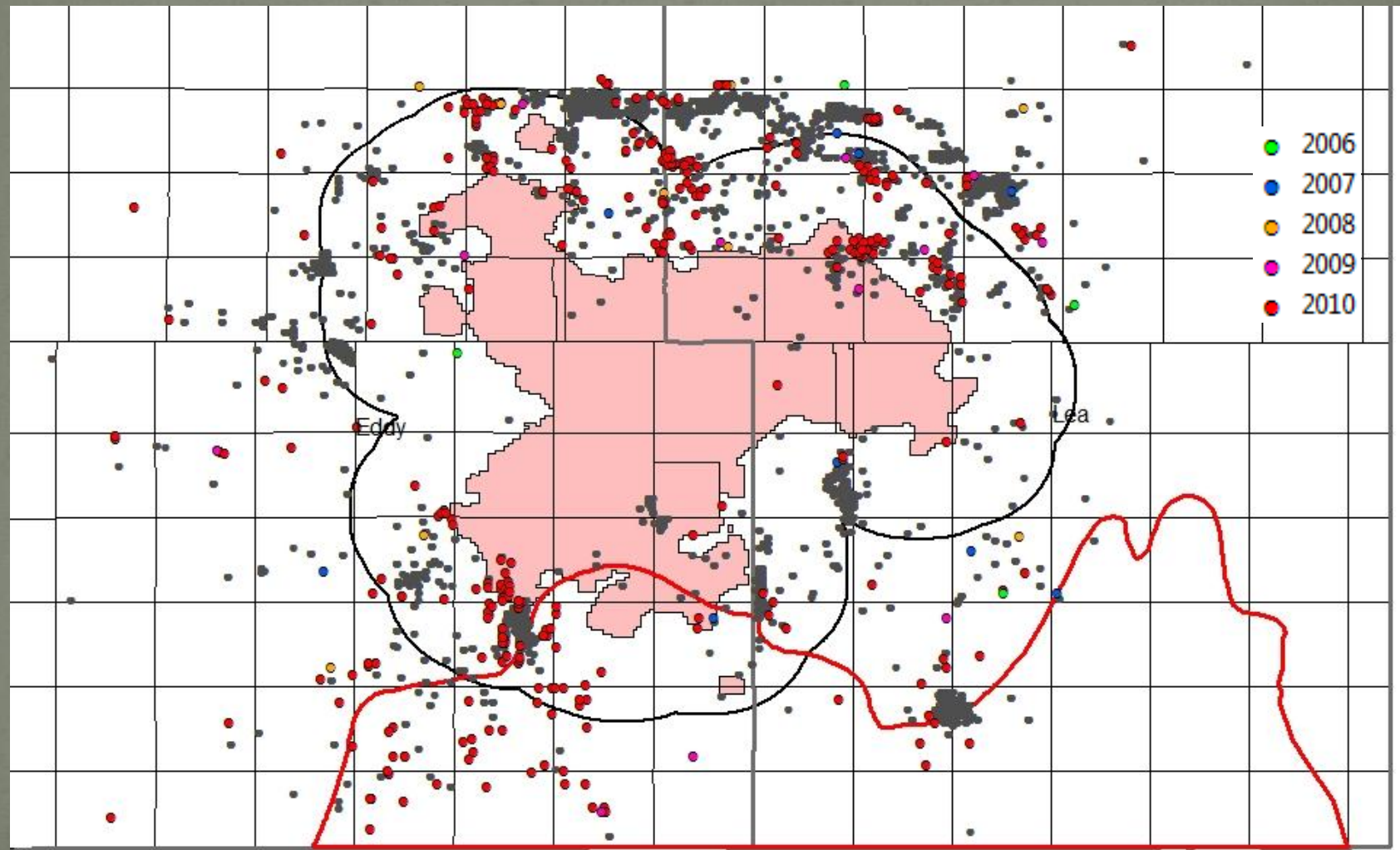
* Earliest year Dwights reports injection data

	Top ten oil producing pool for 2010
	Top ten cumulative oil producing pool

Conservative evaluation assumed a 0.6 S –P ratio, while 0.8 to 1.0 may be more likely. This would increase secondary Brushy Canyon potential:

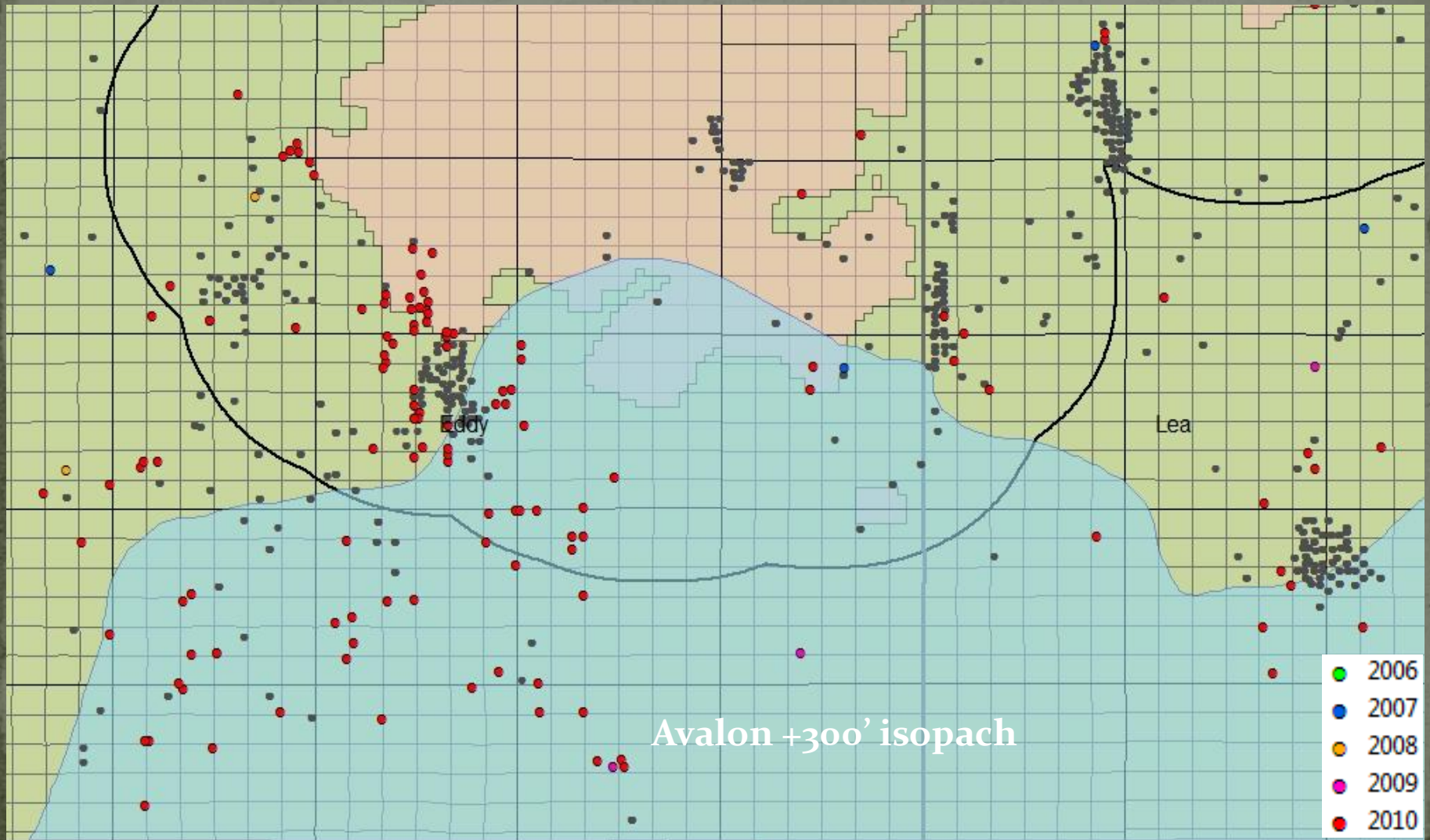
An additional 60-120 Million Barrels within the enclave?

Bone Spring / Avalon Shale



Avalon Shale +300' isopach, Worrell (2011) Pers. Comm.

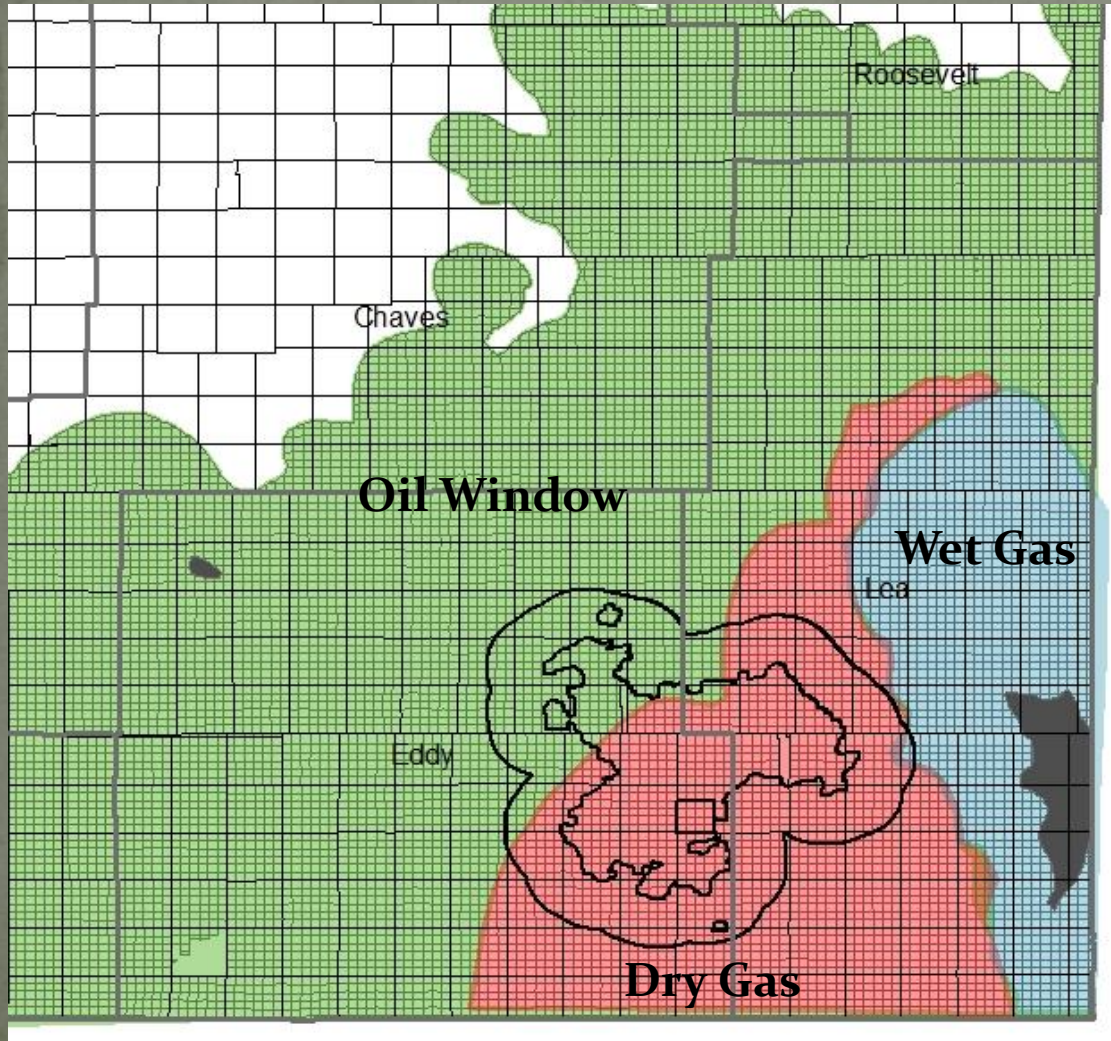
Bone Spring/Avalon Potential



Some Avalon Potential

- 26 sections with > 300ft thickness if produced with 4000' horizontals 4 to a section would yield 104 Avalon wells
 - At ~300,000 BOE recoverable in an average well reserves in the potash area could be 31 Million BOE
- The 300 ft thickness may be conservative and additional Avalon shale potential could exist in the enclave

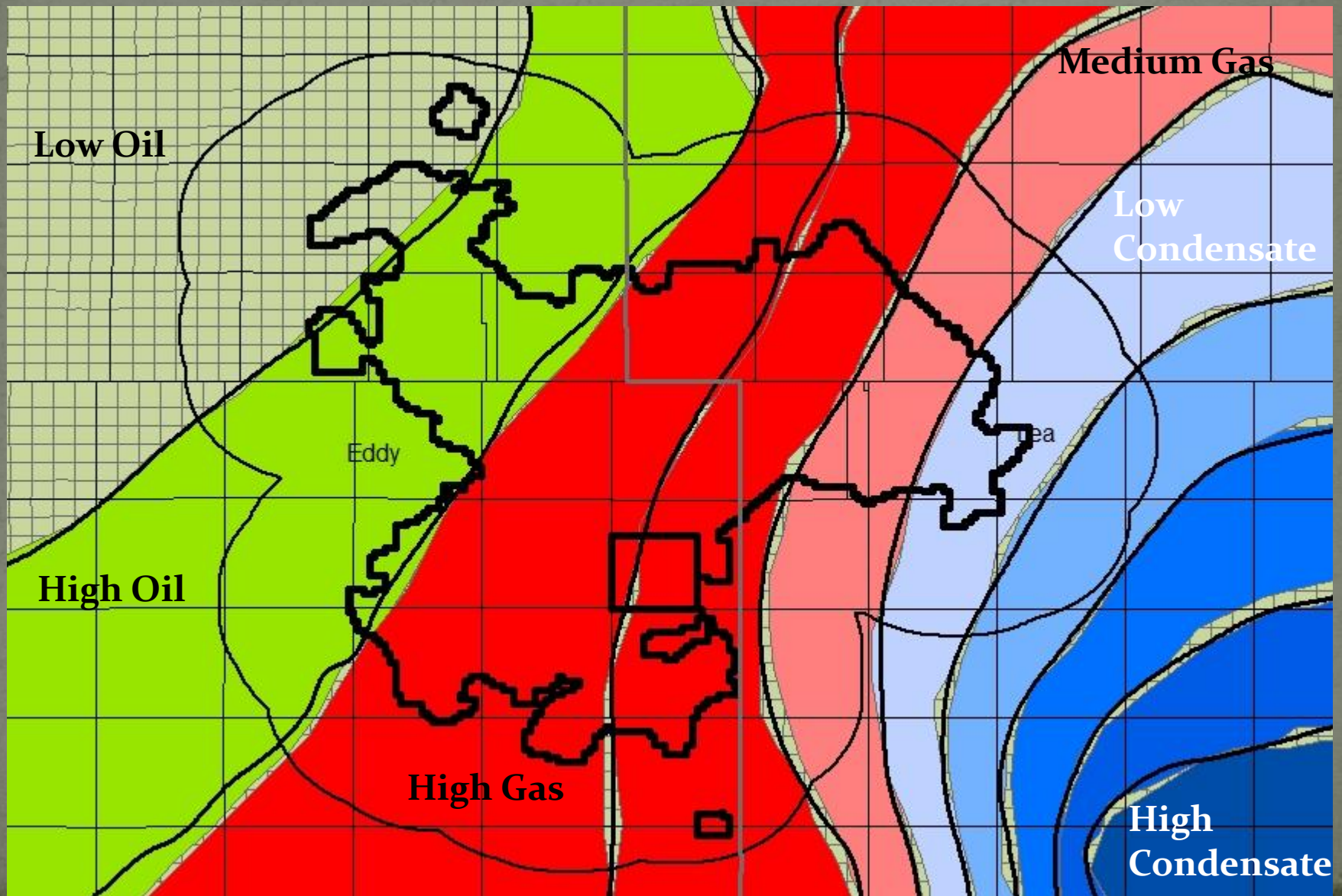
Woodford Shale?



Woodford Shale
Regions Categorized
based on Thermal
Maturity ($R_o\%$),
Fracture Intensity
(per 10ft) & TOC
(wt%).

Bammidi (2011) after
Comer (2005) &
Broadhead (2010)

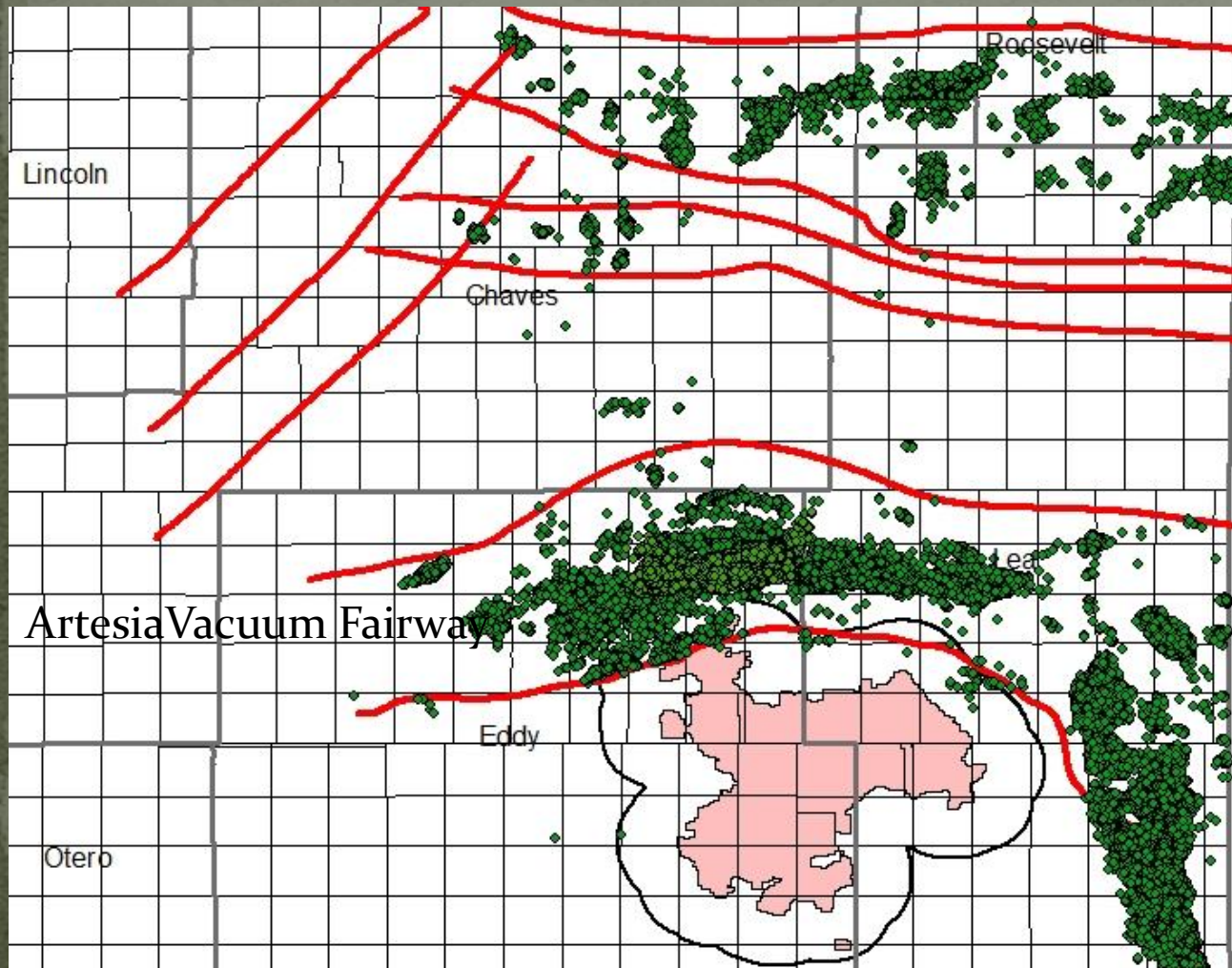
Woodford Potential Regions (Bammidi 2011)



Woodford Potential?

- Bammidi (2011) determined that:
 - High Oil ~4 million barrels oil remains per section
 - High Gas ~4.65 BCF gas remains per section
 - High Condensate ~ 0.94 million BOE remains per section
- The majority of the Potash reserve lies within the high oil and high gas potential regions
- If 4 initial horizontal wells per section were drilled and a recovery factor of 8% is assumed this yields
 - ~80,000 barrels per oil well or
 - Total additional potential reserves for potash area ~34 Million BBL
 - ~106 sections
 - ~372,000 MCF per gas well or
 - Total additional potential reserves for potash area ~536 BCF
 - ~360 sections

ROZ Potential?



- Limited ROZ potential in the San Andres Greyburg

Trends from
Trentham (2011)

Technology Changes Everything

- Long horizontals and drilling islands could put the majority of the SPA into play
- Changes in completions, in particular multi-stage fracking now being done in more than just shale has re-introduced life into old plays and in the underdeveloped Potash area could dramatically increase reserves from those projected by this study

Conclusions

- Significant under-development of oil and gas resources has occurred in the Potash Reserve compared to immediately adjacent locations
- Using conservative estimates producible reserves are on the order of:
 - 800 Million BBLS oil
 - 5.5 TCF gas
- Technology and new plays will both allow development, and add to these resources.

Future Work

- As part of the BLM Pecos RFD we are generating pool scale analyses for all of SE New Mexico and this will allow direct calculation of resources in the enclave
 - Refined EUR estimates
 - Better estimates of the impacts of horizontal drilling fracing and other technologies
 - Better estimates for emerging and potential plays
- GIS and full report available at
 - [HTTP://ford.nmt.edu](http://ford.nmt.edu)