The Historical Resource and Recovery Growth in Developed Fields, Arctic Slope of Alaska

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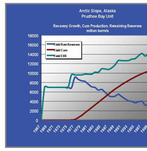
Arctic Slope Alaska, Development Highlights

Prudhoe Bay Field



Prudhoe Oil Pool

- Largest Oil Reservoir in North America
- 1968 - 2004 Produces 90% of the North Slope Oil Boom
- OOIP - 25 billion barrels
- Initial Recovery (circa 1977) - 9.6 billion barrels with Waterflood
  - Primary, Gravity Drainage, Gas cap Expansion - 7.6 Billion
  - Waterflood - 1.0 Billion
  - Gas Cycling - 1.0 Billion
- 1977 - Initial Development envisioned 500 wells:
  - **Gravity Drainage Concept** - light oil column
  - **Comprehensive Pressure, GOC, OPWC and Profile Surveillance programs have aided optimization of Recovery**
  - Very High Level of Technical Scrutiny by Working Interest Owners
- 2004 - 1500 penetrations with at least 200 more planned -
  - Entire oil column exploited
  - Well spacing reduced from 160 to 80 to 40 acres in some areas
  - Rotary and Coil Tubing Drilling (from existing well bores) targets bypassed oil

Recovery Growth

- 1982 Infill Drilling - 0.2 Billion Barrels
- Gas Handling Expansions increased recovery -
  - 1986 - Gas Lift Project, 3.4 x 3.5 MCFD/D - 0.4 Billion Barrels
  - 1990 - GRI - Gas Cycling Pilot, 2.5 TO 20 CFD - 0.4 Billion Barrels
- 1987 Gas Gathering & Compressional Recovery (includes NGLs & Miscible Injectant) - 1.5 billion barrels
- Waterflood Expansion - 0.5 Billion Barrels
- 1982-1992 Water Alternating Miscible Gas Injection – 0.6 Billion Barrels
- 1992 Gas Cap Water Injection (6% MIRWFO injection) - 0.2 Billion Barrels
  - Possible Increased Gas Cap Water Injection in the future
- Opportunistic Applications – MEST, Updip MWAG in Gravity Drainage area - 0.1 Billion Barrels

Prudhoe Satellite Development

- Ownership Realignment of Gas Rites and Oil Rim interests accomplished
- Unitization
- Facilities sharing agreements allow development of Satellite Reservoirs
- Satellites add low GOR and low water cut wells - "best player plays" in competition for space in facilities
- Facility access fees offset costs of recovery
- Five West Sak Satellites - 0.5 billion barrels EUR (Schrader Bluff Fm., Kuparuk Fm.)
  - Midnight Sun, Aurora, Borealis, Polaris and Orion
  - Schrader Bluff Viscous Oil -
  - Drilling Technology Improvements,
    - 2004 - Horizontal
    - 2005 - Tri-Lateral, 2006 - Quadri-Lateral, 2065 – Penta-Lateral
  - Hot Source Water Flooding
  - Lean Gas Injection
  - MWAG planned
- Liduarne Production Center - add 0.9 Billion Barrels - Pt. McIntyre, Niakuk, West Beach and North Prudhoe Pools
  - Waterfloods,
  - Gas Injection
  - MWAG Projects

Kuparuk RiverField

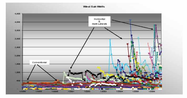
Kuparuk Pool

- Second largest reservoir in the US and Alaska - 5.1 billion barrels in place
- Deliberate initial development with early waterflood - 1983
  - Primary Recovery - 6.6 Billion Barrels
  - Waterflood Recovery - 1.0 Billion Barrels
- 1988 - Miscible Water Alternating Gas (MWAG) Gas Injection pilot - 8700 acres - OOIP 500 Billion Barrels
- 1992 - Large Scale Miscible Water Alternating Gas Injection (MWAG) - (10 pads) – 70 Million Barrels
- 1993 - Large Scale EOR – expanded MWAG at 18 HCAG drillsites -39000 acres - OOIP 2.9 Billion Barrels
  - Import 100 million barrels NGL (0.5 NGL recovered)
  - 250 million barrels ES (6.1 barrels 6.6 MCF Miscible Injectant)
- Infill drilling and delineation expanded reservoir area
- Extended reach drilling
- Coil tubing drilling and well work applications
- Immiscible Water Alternating Gas injection 1985 for EOR and gas storage
- **Extensive surveillance program for pressure, production profiles and well rate tests aided optimization of development**
- Efficient Ponds and expanded reservoir will recover nearly 2.500 million barrels

Kuparuk Satelites

West Sak Pool

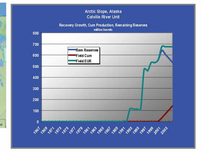
- Resource size — 16 billion barrels in place driven pilot viscous oil development in 1983 including waterflood.
- Pilot development — Conventional vertical wells – fractured to improve productivity – waterflood to improve recovery
- Pilot abandoned in 1986 as uneconomic
- Development restarted at 2 drillsites in 1997 including waterflood
  - 500 million barrel in place volume under development
- Started MWAG EOR project in 2003
- Expanded development south of pilot area – added 1500 million barrels in place.
- Horizontal drilling and multi-lateral drilling help drive development cost and improve well rates from 200-300 to 1000-2000 barrels per day.
- Unprecedented cooperation amongst North Slope viscous oil developers is pushing technology ahead
- ES is about 500 +/- million barrels of the current resource under development



Tarn, Tabasco, Meltwater Pools

- Opportunistic developments within or near large infrastructure
- Add 600 million barrels of in place resources
- EUR about 100 million barrels

Colville River Field



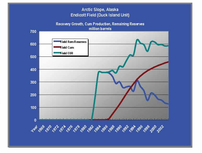
Alpine Pool

- First major stratigraphic reservoir development
- Initial Development utilized extended reach horizontal or slanted wells.
- Development plan was changed to all horizontal wells prior to startup
- Reservoir performed better than expected at startup
- Enhanced recovery Water Alternating Gas injection began at startup
- Reservoir has outperformed design specifications – 40 API, 0.46 cp viscosity,
- Excellent Mobility ratio – S_o after waterflood could be as low as 15-40%
- Facility capacity increased from 80,000 b/pd to 135,000 b/pd by debottlenecking and remodeling
- Alpine EUR has grown by 100 million to 445 million barrels

Satellite Reservoirs

- Satellite exploration will feed into the infrastructure – 5 additional reservoirs discovered and in development added 100 million barrels of in place resources
- Satellite EUR expected 55-70 million barrels
- Several other discoveries are being evaluated

Endicott Field (Duck Island Unit)



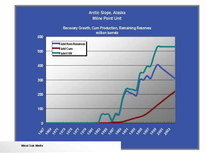
Endicott Oil Pool

- Currently the third largest Reservoir on the North Slope
- First Offshore development on North Slope – two islands connected by causeways to mainland
- Resource 1.1 billion barrels oil-in-place
- Initial EUR 350 million barrels
- Gravity Drainage Concept with Gas Injection begun at startup
- Comprehensive pressure, GOC and OWC reservoir surveillance programs aided recovery optimization
- 1998 - MWAG EOR project began - EUR increase of 22 million barrels
- 2003 - EUR 450 million barrels (77% over initial estimate)
- 2006 - Lofsul™ Waterflood enhancement will be tested to increase recovery by up to 30 million barrels

Endicott Satellites

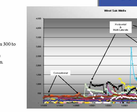
- Eider Delta North Jetbrak reservoir developed in 1989
- Eider Pool (Jetbrak) reservoir developed in 2000
- Added 11 million barrels EUR

Milne Point Field



Kuparuk Pool

- Began developing 1 billion barrels OOIP resource in 1986's
- Production and waterflood started 1985, immiscible gas injection started 1988
- Reservoir was shut-in 1987-early 1989 by low prices
- Reservoir is faulted – 77 hydraulic units
- Miscible gas injection started in 2001
- Discontinued in 2005 because of high cost Miscible Injectant.
  - Converted to Undersaturated Water Alternating Gas (UWAG)
  - Developing Lofsul EOR using 3000 ppm salinity source water
  - Lofsul Process may increase recovery 4-5% over water flood
- Forty-six fault blocks targeted
- Anticipated recovery increase 7.5-10%



Schrader Bluff Pool

- Began developing viscous resource (1.6 billion barrels OOIP) -1990
- 1999 Horizontal drilling improves rates
- Low prices slowed development - 1999
- Multi laterals - Duab (2000), Tri- (2003) – improve sustainable rate from 300 to 1000+ BPD
- Evaluating viscosity reduction water alternating gas injection (VRWAG)
  - Plan to use hot source water (165° F) for injection and viscosity reduction.

Ugnu Pool

- Pilot test well in 2000-2004 produced up to 150 BPD of 12-14 API
- Sand Plugging Problem
- 2-3 billion barrels OOIP in Milne Pt.
- Huge resource – Significant Technical Challenges

Arctic Slope, Alaska

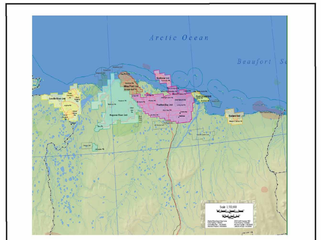
Summary of Current Province Size and Recent Growth

Field	Reservoir Stratigraphic Order	Discovery Year	Production Year	EUR Discovered & Developed Before 1989 million	Additions Discovered & Developed Before 1989 million	EUR Developed Between 1989-2004 million	EUR New Discoveries Between 1989-2004 million	12/31/2004 Cum Production million	12/31/2004 EUR & NGL million	12/31/2004 Cumulative Oil million
Prudhoe Bay Field		1967								
	Orion	1968	2002			209		209	2	2
	Polaris	1969	1999			48		48	4	4
	Aurora	1969	2000			63		63	11	11
	Borealis	1969	2001			154		154	31	31
	Midnight Sun	1997	1998				28	28	11	11
	Niakuk	1985	1994				117	117	81	80
	Pt McIntyre	1988	1993				583	583	384	378
	W Beach	1976	1993		9			9	3	3
	Prudhoe	1967	1969	9,600	4,267			13,867	11,144	10,889
	Ne Prudhoe	1970	1993				3	3	2	2
	Lisburne	1967	1981				192	192	154	139
Kuparuk River Field		1969								
	West Sak	1971	1983-1997			541		541	16	16
	Tabasco	1985	1998				23	23	10	10
	Meltwater	2000	2001				44	44	8	8
	Tarn	1991	1998				126	126	65	65
	Kuparuk	1969	1981			2,891		2,891	1,975	1,971
Colville River		1992								
	Nanuq	1996	2001			69		69	0	
	Fiord - Kuparuk	1992	2006			48		48	0	
	Nanuq - Kuparuk	2000	2006			28		28	0	
	Alpine	1994	2000			465		465	138	138
	Fiord - Nechelik	1992	2006			65		65	0	0
Endicott Field		1978								
	Sag Delta North	1978	1989		8			8	8	8
	Eider	1998	1998			5		5	3	3
	Endicott	1978	1986			572		572	448	427
Milne Point Field		1969								
	Schrader Bluff	1969	1989			117		117	38	38
	Kuparuk	1969	1985			405		405	180	180
	Sag River	1969	1994			8		8	2	2
North Star Field		1984								
	NorthStar	1984	2001				196	196	67	67
Badami Field		1990								
	Badami	1990	1998			4		4	4	4
				9,600	4,267	5,210	1,802	20,879	14,789	14,295

Alaska's total accumulated Oil Fields are modest in number but have had a large impact on energy supplies in North America. Arctic Slope exploration began in the 1940's did not yield significant results until discovery of the Prudhoe Oil Pool in 1967. The subsequent development of Prudhoe brought an influx of new technology for Arctic Regions and required a relatively aggressive exploration effort over the next decade. Beyond Prudhoe, Arctic Slope recovery growth more than doubled in the 25 years since production started. The Prudhoe, Kuparuk, Endicott and Milne Point discoveries provided a foundation for different exploration and development of smaller but promising reservoirs. The western push in the early 1990's led to the giant Alpine discovery. Exploration potential remains high in the NPR-A and ANWR regions of Alaska as well as known shallow viscous resources within the Central North Slope.

Arctic Slope, Alaska - Key Reservoir Characteristics

Field / Reservoir	Location: Formation by Stratigraphic Order	Size	Year of Discovery	Degrees Latitude	Depth	Onshore / Offshore	Water Depth	Volumetric: Net Area	Net Thickness	Porosity	Initial Sw	PVR/ FVF	Original Oil In Place	Average or Likely EUR	Rock Properties: Permeability	Continuity	Original Pressure	Drive Mechanism	Trap & Seal	Fluid Properties: API	Sulfur	Viscosity	Production: Initial Year	Peak Year	Peak Year Production	Cumulative Oil & Ngl	Development: Spacing	Spacing History	# Wells	Type Well	Post-Primary Recovery Methods	12/31/2004 Recovery	12/31/2004 Ult. Recovery	12/31/2004 Estimated Ultimate Recovery	12/31/2004 Current Recovery Factor 2004	Field / Reservoir
					feet		feet	acres	feet	%	%		million barrels	million barrels	md		psi			%	%	cp				million barrels	acres or feet				million barrels	million barrels	million barrels	%	
Prudhoe Bay Unit		Super Giant		70.296																																Prudhoe Bay Unit
	Orion	Cretaceous Colville Group, Schrader Bluff Formation	1968	70.34	4400	On		19010	66-160	25-32	35 - 105	1.14	1070-1785	1438	50-2000	Faulted	1950	Solution Gas	Structural	19-22.1	1.2	5-120	2004	2002	1.844	2	20			Horz & Vert	WF/MWAG	2		209	15%	Orion
	Polaris	Cretaceous Colville Group, Schrader Bluff Formation	1969	70.35	5000	On		11760	5-100	25-30	40-45	1.1-1.2	350-750	504	10-600	Faulted	2250	Solution Gas	Structural/Strat	16-24		1-500	1988	2004	0.985	1988	20	13	Horz & Vert	WF/MWAG	4		48	8%	Polaris
	Aurora	Neocomian Kuparuk River Formation and Sandstone	1969	70.36	6700	On		10400	60	16-25	14-60	1.35	110-150	139	2-158	Faulted	3433	Solution Gas	Structural/Strat	25-30		0-72	2000	2003	3.782	11	40-80 ac	22	Horz & Vert	WF/MWAG	11		63	49%	Aurora
	Borealis	Neocomian Kuparuk River Formation and Sandstone	potential Sub-Giant	1969	70.34	6600	On	7700	60	18-24	32-54	1.22	195-280	238	5-300	Faulted	3439	Solution Gas	Structural/Strat	23-30	1.7-2.8	2001	2003	2003	11.791	41	40 ac	41	Horz & Vert	WF/MWAG	30		154	53%	Borealis
	Midnight Sun	Neocomian Kuparuk River Formation and Sandstone		1997	70.34	8010	On	3110	0.70	23-30	13-26	1.33	40-80	58	3-1560	Cont	4045	Solution Gas, Gas Cap	Strat/Strat Faults Pinch-out	26		1-68	1998	2003	1.719	11	80 ac	5	Vert	WF	11		28	47%	Midnight Sun
	Niakuk	Neocomian Kuparuk River Formation and Sandstone		1985	70.35	8000	Off	6440	10-200	20	28	1.35	300	300	500	Segmented	4446	Solution Gas, Gas Cap	Strat/Strat Faults Pinch-out	24		1-5	1994	1996	11.045	81	1000 ft	27	Vert	WF	80	1	117	39%	Niakuk
	Pt McIntyre	Neocomian Kuparuk River Formation and Sandstone	Giant	1993	70.4	6900	On	10820	0-312	22	33	1.39	690	904	200	Faulted	4377	Solution Gas, Gas Cap	Strat/Strat Fault Pinch-out	27		0-6	1993	1997	58.464	40 ac	40 ac	76	Vert	WF/GI/MWAG	376	8	583	64%	Pt McIntyre
	West Beach	Neocomian Kuparuk River Formation and Sandstone		1976	70.36	8800	On	2510	71	19	35-41	1.36	12-65	38	100	Cont	4257	Solution Gas, Gas Cap	Structural/Strat	26		1-04	1993	1993	0.724	4	160 ac	3	Vert	WF	3	0	9	24%	West Beach
	Prudhoe	Permo Triassic Sadlerochit Group	Super Giant	1967	70.26	8800	On	205460	0-460	22	30	1.35	23000	23000	100-3000	Faulted	4335	Solution Gas/Gas Cap/Aquifer	Structural/Strat	27	1	0-8	1969	1987	549.655	1967	40-80 ac	150 ac	1315	Vert, Horz, ML	WF/GI/MWAG	10009	445	13867	60%	Prudhoe
	North Prudhoe	Permo Triassic Sadlerochit Group		1970	70.39	9245	On	2000	20	28		12	12	12	580	Cont	4600	Solution Gas/Water Influx	Structural	29	0.4	0-45	1993	1994	0.759	3	160	1	Vert	WF	2	0	3	20%	North Prudhoe
	Lisburne	Mississippian Lisburne Group		1967	70.32	8900	On	8000	0-250	10	20-40	1.39	5000	3000	0.1-2	Faulted	4400	Solution Gas/Gas Cap	Structural/Strat	27	0.9	0-6	1981	1987	16.199	114	160 ac	82	Vert	GI/NJ	140	14	192	6%	Lisburne
Kuparuk River Unit		Giant																																		Kuparuk River Unit
	West Sak	Schrader Bluff Fm., West Sak Sand	Giant	1971	70.29	3500	On	15450	26-120	30	30	1.07	2000-3000	2500	15-2000	Faulted	1600	Solution Gas	Structural	17-21	1.8	40	1987	2004	4.281	10	10-40	67	Vert & Horz	WF/MWAG	16		541	22%	West Sak
	Tabasco	Cretaceous Colville Group, Tabasco Sand		1985	70.05	3100	On	2970	110	20	30	1.06	48-131	90	1000-10000		1500	Solution Gas/Gas Cap	Structural	16.5		250	1998	1999	1.92	10	50	10	Vert	WF	10		23	20%	Tabasco
	Meltwater	Late Cretaceous Seabee Fm., Bermudal Sand		2000	70.05	3400	On	8280	45-110	20	40	1.34	125	65	10	Faulted	2570	Solution Gas/Gas Cap	Structural	36		0.75	2000	2000		1	50	1	Vert	WF	1		44	2%	Meltwater
	Tarn	Late Cretaceous Seabee Fm., Bermudal Sand		1991	70.19	5250	On	10520	40	20	40	1.39	136	298	9		2365	Solution Gas	Stratigraphic-pinchout	37		0.56	1998	2003	12.352	65	50	43	Vert	MWAG	65		126	45%	Tarn
	Kuparuk	Neocomian Kuparuk Formation	Giant	1969	70.35	7300	On	192270	100	20	15	1.26	5100	5100	150	Faulted	3600	Solution Gas	Structural	24	1.8	2	1981	1992	119.506	1977	160	160	940	Vert	WF/GI/MWAG	1971	3	2891	59%	Kuparuk
Colville River Unit		Giant																																		Colville River Unit
	Nanuq	Cretaceous Torok Formation, Nanuq Sandstone		1996	70.3	6100	On	8260	35	17		84-189	127	0	2.5		2740	Gas Cap, Solution Gas	Stratigraphic	39-42		0.5					1500	16	Horz				0		69	54%	Nanuq
	Fiord-Kuparuk	Neocomian Kuparuk River Formation and Sandstone		1992		6850	On		5	22	22	1.3	20-80	86	119 (est)		40	Solution Gas	Struct. Strat/Fault Pinch-out	29-32		79-95					4500?	5	Horz						48	80%	Fiord
	Nanuq-Kuparuk	Neocomian Kuparuk River Formation and Sandstone		2000		7000	On	6190	6	18			25-36	46	100		3240	Solution Gas	Stratigraphic	41		0.3					n/a	3	Horz						28	70%	Nanuq-Kuparuk
	Alpine	Jurassic Kingak Formation, Alpine Sandstone	Giant	1994	70.34	7000	On	28700	48	15-20	20	1.44	1100	1100	1-160		3175	Solution Gas	Structural/Strat	40		0-46	2000	2004	36.085	138	275 ac	135 ac	140	Horz	WF/GI/MWAG	138		465	37%	Alpine
	Fiord-Nechelik	Jurassic Kingak Formation Nechelik Sandstone		1992	70.42	6900	On	11710	7	16	34	1.3	60-130	90	8 (est)		3200	Solution Gas	Structural/Strat & non-res	29-31		79-90					2100?	12	Horz						65	69%	Fiord
Endicott Unit		Giant																																		Endicott Unit
	Sag Delta North	Permo Triassic Ivishak Sandstone		1978	70.3	10000	Off	14	1170				14	14			4825	Solution Gas	Structural	25			1989	1991	2.356	5	40	3	Vert	WF	8	0	8	57%	Sag Delta North
	Eider	Permo Triassic Ivishak Sandstone		1998	70.3	9700	Off	14	680	156-245	21	36	1.36	13	13	30-300		4635	Solution Gas/Gas Cap	Structural/Strat	23.8		1	1991		2.356	3	160	2	Horz-ML	WF	3	0	3	38%	Eider
	Endicott	Mississippian Kekiktuk Conglomerate	Giant	1978	70.3	10000	Off	14	16960	0-337	21		1100	1100	150-1200	Faulted	4870	Solution Gas/Gas Cap	Structural	22			1986	1992	42.67	448	40	155	Vert	WF/GI/MWAG	427	20	572	52%	Endicott
Milne Point Unit		Sub-Giant																																		Milne Point Unit
	Ugnu	Tertiary Sagavanirktok Formation, Ugnu Sand				3500	On			240	30																									Ugnu
	Schrader Bluff	Cretaceous Colville Group, Schrader Bluff Formation		1969	70.44	4900	On	29150	10-50	29	40	1.05	1250-2000	1600	100-3000	Faulted	1800	Solution Gas	Structural	16-22	1.9	30-120	1989	2004	7.693	38	10	111	Vert & Horz	WF	38		117	7%	Schrader Bluff
	Kuparuk	Neocomian Kuparuk River Formation and Sandstone		1969	70.46	7900	OnOff	30650	5-90	19-23	33	1.16	1000	1000	45-100	Faulted	3190	Solution Gas	Structural	25-26	1	3.3-5.5	1985	1998	18.314	189	160	160	Vert	WF/GI/MWAG	180		405	40%	Kuparuk
	Sag River	Triassic Sag River & Permo Triassic Ivishak Formations		1969	70.5	8700	On	6530	22-50	8-31	40	1.41-1.56	42	42	4	Faulted	4425	Solution Gas	Structural	34		0.29-0.72	1995	1997	0.363	1	40	3	Vert	GI/NJ	2		8	17%	Sag River
Northstar Unit																																				Northstar Unit
	Northstar	Permo Triassic Ivishak Sandstone	1984	70.49	11100	Off	36	9850	125	15	55	2.2	250	250	1-800	Faulted	5305	Solution Gas/Gas Cap	Structural-Fault	43	0.14	0.15	2001	2004	25.978	67	40	24	Vert	MI/GI/NJ	67		196	69%	Northstar
Badami Unit																																				Badami Unit
	Badami	Tertiary Canning Formation, Barbara Sandstone		1990	70.15	9900	OnOff	30	3680	15-20	2.13	1.1-1.35	300	300	0-400	Stratified	6300	Solution Gas	Structural	21-30			1998	1999	1.15	4	20 ac	13	Horz & Vert	GI/NJ	4		4	1%	Badami
Field / Reservoir	Location		Volumetric										Rock Properties							Fluid Properties			Production				Development									Field / Reservoir


Arctic Ocean
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Sale 186 (2002)
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