Appendixes

Appendix A

Oil Resource for Enhanced Recovery Projections

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OTA Data Base

The oil recovery projections for enhanced oil recovery (EOR) processes were determined from the results of reservoir-by-reservoir simulations. The accuracy of this approach depends on the extent, representativeness, and accuracy of the reservoir data file. In earlier work, Lewin and Associates, Inc., collected detailed data on 245 reservoirs in three States, California, Louisiana and Texas. The Office of Technology Assessment (OTA) contracted with Lewln and Associates, Inc., to expand this data base to include all major oil-producing States and at least 50 percent of the remaining oil resources. The expanded data base, referred to as the OTA data base, covers a broad range of geographic locations and reservoir types as well as the largest 300 domestic reservoirs on which public data are available.

This appendix describes the development and content of the OTA data base. Sources of data are documented by geographic region.

Reservoir Selection

A list of the largest oilfields (measured by cumulative production plus remaining reserves) was constructed from available data.[1] The exponential distribution of the size of the Nation's oilfields—the largest 300 fields provide over two-thirds of the Nation's production-suggests that the preponderance of tertiary recovery opportunities lies in the major fields.

Data collection, therefore, began by focusing on the largest fields and the largest reservoirs within these fields. Smaller fields and reservoirs were added to the file to increase the proportion of each State's oil covered by the data base. Thus, the OTA data base contains reservoirs and fields of varying size, although the preponderance of the reservoirs is quite large (over 50 million barrels cumulative production plus remaining reservoirs). An analysis was conducted to ascertain whether the preponderance of large fields renders the data base unrepresentative. No systematic bias was introduced by the number of larger fields.

Selection of Data Items

The data items included in the file were established by the three key tasks involved in EOR analysis, namely to:

1. Screen fields and reservoirs at two levels: (a) favorable or unfavorable to tertiary recovery; and (b) for the favorable reservoirs, the most preferred tertiary technique.
2. Calculate the oil in place and amount to be recovered through primary, secondary, and tertiary methods-based on actual reservoir parameters and production histories.
3. Calculate investment and operating costs of the preferred tertiary technique--based on region, reservoir, and crude oil characteristics.

Detailed data were collected concerning formation and crude oil characteristics, production histories, and original (OOIP) and remaining oil in place (ROIP). Figure A-1 is a copy of the form used to display data for each field and its producing reservoir(s). Complete reservoir data (as shown on the form) were available for only a few reservoirs. Although there are many data missing, complete volumetric and production data were available for each reservoir in the OTA data base.

Data Collection

A three-step approach was used in collecting the reservoir data:

1, Identification of Data Sources

National level data were available for fields through the American Petroleum Institute (API) and the U.S. Geological Survey (USGS)-sponsored Oil Information Center. However, little was available for reservoirs within these fields. Detailed data on reservoirs were gathered from State agencies, State-level private organizations, and general publications. In this step, the available data sources were cataloged and evaluated as

Figure A-1. Big Fields Reservoir

REPORT RUN DATE *

IDENTIFICATION

FIELD:	RESERVOIR:		CURRENT SCREEN:
LOCATION:	REGION:	BASIN:	COUNTY(S):
FORMATION:	RESERVOIR ID:	FIELD ID:	

RESERVOIR CHARACTERISTICS

DEPTH:	VISCOSITY:	SCW:	STRUCTURE:
BOTTOMHOLE TEMP:	API GRAVITY:	SOI:	
PRESSURE-SATURATION BP:	SALINITY-CONNATE-WATER:	STB SOI:	GEO AGE:
PRESSURE-ORIG:	SALINITY-PRODUCED-FLUID:	SOC:	
PRESSURE-LATEST:	CALCIUM:	STB SOC:	LITHOLOGY:
DIP:	MAGNESIUM:	SOR P/S:	FRACTURES:
GROSS PAY THICKNESS:	GAS CAP-ORIG:	STB-P/S SOR:	FAULTING:
AVG NET PAY THICKNESS:	GAS CAP LATEST:	FVF-ORIG:	COMPLEXITY:
NUMBER PAY ZONES:	GOR-ORIG:	FVF-LATEST:	LENTICULARITY:
POROSITY:	GOR-LATEST:	OST: 1	HETEROGENITY:
AVG PERMEABILITY:			CLAY CONTENT:
			TURBIDITES:

DEVELOPMENT HISTORY

PRIMARY YEAR SECONDARY YEAR TERTIARY YEAR

LATEST EOR YEAR:
LATEST EOR STAGE:
LATEST EOR ACRES:

RESERVOIR ACRES-TOTAL:	FIELD ACRES-TOTAL:	CURRENT OPERATORS
RESERVOIR ACRES-LATEST:	FIELD ACRES-LATEST:	
RESERVOIR PRODUCING WELLS-TOTAL:	FIELD PRODUCING WELLS-TOTAL:	
RESERVOIR PRODUCING WELLS-LATEST:	FIELD PRODUCING WELLS-LATEST:	
RESERVOIR INJECTION WELLS-TOTAL:	FIELD INJECTION WELLS-TOTAL:	
RESERVOIR INJECTION WELLS-LATEST:	FIELD INJECTION WELLS-LATEST:	

PRODUCTION HISTORY

RESERVOIR ORIG OIL-IN-PLACE:	FIELD ORIG OIL-IN-PLACE:
RESERVOIR CUMULATIVE PRODUCTION TO 1-1-75:	FIELD CUMULATIVE PRODUCTION TO 1-1-75:
RESERVOIR ESTIMATED ULTIMATE P/S PRODUCTION:	FIELD ESTIMATED ULTIMATE P/S PRODUCTION:
RESERVOIR RESIDUAL OIL-AT-ABANDONMENT:	FIELD RESIDUAL OIL-AT-ABANDONMENT:
RESERVOIR ANNUAL PRODUCTION	FIELD ANNUAL PRODUCTION
1974	1974
RESERVOIR PRODUCTION DECLINE RATE:	FIELD PRODUCTION DECLINE RATE:

to their completeness and reliability. From this evaluation, priorities were assigned to the identified sources.

2. State Procedures

For each State, detailed procedures were developed which described the data to be collected from each source, the sequence of using the sources, and decision rules for any estimates or averaging necessary to complete the data collection forms.

3. Estimation and Calculation of Missing Data Items

After' rigorously examining and cataloging all available data sources, some of the data remained missing. When these data were critical to the analysis, they were estimated using engineering formulas and empirical correlations. All data were edited for volumetric consistency, a requirement of later steps in the analysis.

Application of this procedure required numerous followup contacts with Federal and State sources to elicit additional data, to verify interpretations, or to procure additional suggestions regarding data sources.

Data Coverage

Table 6 in Chapter Ill shows the scope and coverage of the OTA data base. The 19 States included account for 96 percent of the oil remaining in domestic reservoirs. The individual reservoirs in the data base account for over half of the Nation's remaining oil, The percentage coverage of each State is also relatively high. In only one case was the coverage less than 20 percent of the State's residual oil. For only two States did the coverage fail to reach 30 percent. Thirteen of the 19 States had coverage of 40 percent or greater. Based on the coverage and diversity of the reservoirs in the OTA data base, an extrapolation to the full United States appears justified.

The States for which the coverage is lowest, especially Kansas, Oklahoma, Pennsylvania, and West Virginia, are States which collect only limited information,

Fields and Reservoirs in the OTA Data Base

Field	*Reservoir*
Alabama	
Citronella	Rodessa
Gilbertown	Eutaw
Alaska	
Granite Point	Middle Kenai
McArthur River	Hemlock
Middle Ground Shoal	Hemlock E,F,G Pools
Prudhoe Bay	Kuparuk River
	Lisburne
	Prudhoe Oil Pool
Swanson River	Hemlock
Trading Bay	Middle Kenai
	Middle Kenai G–Hemlock, North
Arkansas	
Magnolia	Smackover
Smackover	Old
Schuler	Jones
California	
Coastal	
Cat Canyon	Old Area Pliocene
	Sisquoc Area Others
	Los Flores
Dos Cuadras	Federal Offshore
Elwood	Vaqueros
Orcutt	Monterey Point Sal
Rincon	Hobson-Tomson-Miley
	Padre Canyon Others
	Oak Grove Others
San Ardo	Lombardi
Santa Maria Valley	Main
South Mountain	Sespe Main
Ventura	C Block
	D-5, D-6 East
Ventura	D-5, D-6 North
	D-7, D-8
Los *Angeles*	
Beverly Hills	East Area Miocene
Brea Olinda	Olinda Area
	Brea Area
Coyote East	Anaheim
Coyote West	Main 99 Upper West
	Main 99 Upper East
Dominquez	First East (Abandoned)
	First East Central
	First West Central
	East Cooperative
	3 and 4 NW Central
	3-4-5 East
	West Unit

96-594 0- 78 - ~

Field	Reservoir
Huntington Beach	North Area Tar Bolsa
	South Area Upper Main
Inglewood	Vickers
Long Beach	Old Area Upper Pools
Montebello,	Baldwin
Richfield	East and West Area
Santa Fe Springs	Main Area Others
Seal Beach	South Block Wasam
	Alamitos
	North Block McGrath
Torrance	Main
Wilmington	Tar
	Upper Terminal
	Ranger
	Lower Terminal
	Ford
San Joaquin	
Belridge South	Tulare
Buena Vista ,	Upper Hills
	Front Area
Coalinga	Temblor
Coles Levee North	Richfield Main Western
Cuyama South	Main Area Homan
Cymric	Tulare
	Carneros
	Oceanic (all)
Edison ,	Schist Main Upper
	Vedder Freeman
Elk Hills	Upper Main
Fruitvale	Chanac-Kernco Main
Greeley	Rio Bravo-Vedder
Kern Front	Main
Kern River	Kern River Sands
Kettleman Dome North	Temblor
Lost Hills	Main
McKittrick	Upper Main
Midway-Sunset	Potter
Mt. Peso	Vedder
Rio Bravo	Vedder-Osborne-Rio Bravo

Colorado

Field	Reservoir
Adena	J-Sand
Akron, East ... ,	D-Sand
Azure	D-Sand
Badger Creek	D-Sand
Bijou	D-Sand
Bijou, West,	D-Sand
Black Hollow	Lyons
Bobcat	D-Sand
Boxer	D-Sand
Buckingham	D-Sand
Divide	D-Sand
Graylin, NE	D-Sand
Jackpot	D-Sand
Little Beaver	D-Sand
Little Beaver, East.	D-Sand
Phegley	D-Sand
Pierce	Lyons
Plum Brush Creek	J-Sand
Rangely	Weber
Saber	D-Sand

Florida

Field	Reservoir
Sunoco-Felda	Roberts
Jay .,	Smackover
Blackjack Creek	Smackover

Illinois

Field	Reservoir
Clay City Consolidated	Aux Vases
	McClosky
Dale Consolidated	Aux Vases
Lawrence	Cypress
Louden	Cypress
Main Consolidated	Pennsylvanian
New Harmony	Cypress
Salem Consolidated	Benoist
Robinson,	Robinson

Kansas

Field	Reservoir
Bemis-Shutts	Arbuckle
Blankenship	Bartlesville
Big Sandy	Bartlesville
Burket	Bartlesville
Bush City	Squirrel
Chase Silica	Arbuckle
Cunningham	Lansing-Kansas City
Edna	Bartlesville
El Dorado	Admire
Fairport	Arbuckle
Fox-Bush-Couch	Bartlesville
Gorham	Arbuckle
Hall-Gurney	Lansing-Kansas city
Hep[er	Bartlesville
Hollow-Nikkei	Hunton
Humboldt-Chanute	Bartlesville
Iola	Bartlesville
Kraft-Prusa	Arbuckle
Lament	Bartlesville
Madison	Bartlesville
McCune	Bartlesville
Moran, Southwest	Bartlesville
Rainbow Bend	Burgess
Ritz-Canton	Mississippian
Sallyards	Bartlesville
Thrall-Aagard	Bartlesville
Trapp	Arbuckle
Virgil	Bartlesville

Louisiana (North)

Field	Reservoir
Caddo Pine	Nacatoch
	Annona
	Paluxy

Field	*Reservoir*
Haynesvil[e.	Buck
	Pettit Lime
	Camp
	Smackover
Homer.	Homer (all)
Rodessa.	Rodessa (all)
Delhi	Delhi (all)

Louisiana (South)

Avery Island	Medium
	Deep
Bay St. Elaine	Deep
	Deep
Bayou Sale	Deep
Caillou Island.	Medium
	Medium
	Deep
Cote Blanche Bay West	Medium
	Medium
Cote Blanche Island.	Deep
	Deep
Garden Island Bay	Shallow
	Shallow
	Medium
	Medium
Grand Bay.	Medium
	Medium
Hackberry West.	Medium
Lake Barre.	Deep
	Deep
Romere Pass.	Medium
Timbalier Bay	Medium
Lake Pelto.	Deep
	Deep
Lake Washington.	Shallow
	Medium
	Deep
Paradis.	Deep
West Bay	Medium
Weeks Island	Deep
	Deep
Quarantine Bay	Medium
	Medium
Venice.	Medium
	Medium

Mississippi

Baxterville.	Lower Tuscaloosa Massive
Bay Springs.	Lower Cotton Valley
Cranfield.	Lower Tuscaloosa
Eucutta East	Eutaw
Heidelberg	East Eutaw, (2) West Eutaw
Little Creek.	Lower Tuscaloosa
Mallalieu, West	Lower Tuscaloosa
McComb.	Lower Tuscaloosa
soso.	Bailey
Tinsley.	Woodruff Sand
Yellow Creek, West	Eutaw

Field	*Reservoir*

Montana

Bell Creek.	Muddy
Cabin Creek.	Interlake-Red River
Cut Bank.	Kootenai
Deer Creek.	Interlake
Gas City	Red River
Glendive.	Red River
Little Beaver	Red River
Little Beaver, East. , ...	Red River
Monarch	Interlake-Red River
Outlook	Winnepegosis-Intedake
Pennel.	Interlake-Red River
pine. ., ...	Interlake
Poplar, East.	Madison
Richeu, Southwest.	Interlake-Red River
Sand Creek.	Interlake-Red River

New Mexico

Allison.	Pennsylvanian
Caprock	Queen
Caprock, East	Devonian
Cato	San Andres
Chaveroo	San Andres
Corbin.	Abo
Denton	Wolfcamp
	Devonian
Empire-Abe.	Abo
Eunice-Monument	Gray burg-San Andres
Hobbs	San Andres-Grayburg
Lea.	Devonian
Lusk.	Strawn
Maljamar. . . . ., ...	Gray burg-San Andres
Milnesand.	San Andres
Vacuum	Gray burg-San Andres
	Glorieta
	Abo Reef

North Dakota

Antelope.	Madison
Beaver Lodge	Madison
	Devonian
Blue Buttes	Madison
Capa	Madison
Charlson	Madison
Tioga.	Madison

Oklahoma

Star	Upper Misener-Hunton
Washington, East-Goldsby, West	Osborne
Sho-vel-tum	Pennsylvanian-Deese
Elmwood, West	Upper Morrow "A"
Elk City	Hoxbar
Salt Fork, Southeast.	Skinner
Dover Hennessey.	Meramec
	Manning
Red Bank.	Dutcher
Putnam	Oswego

Field	Reservoir
Stroud	Prue
Eola-Robberson	Pontotoc
Avant & West	Bartlesville
Bowlegs	Gilcrease
Burbank, North	Burbank
Carleton, Northeast	Atoka-Morrow
Cement	Medrano Sand, West
Cheyenne Valley	Red Fork
Cushing	Bartlesville
Dibble, North	Osborne
Delaware-Childers	Bartlesville
Earlsboro	Earlsboro
Edmond, West	Hunton
Flat Rock	Bartlesville
Healdton	Hoxbar
Lindsay, North	Bromide
Mustang	Hunton Bois D'Arc
North Northwest-Verden	Marchand
Oakdale Northwest	Red Fork
Oconee, East	Oil Creek
Oklahoma City	Wilcox
	Oil Creek-Lower Simpson
Red River, West	Gunsight
Seminole	Upper Wilcox
Stanley Stringer, North	Burbank

Pennsylvania

Field	Reservoir
Bradford	Third Bradford
Fork Run	Cooper
Foster-Reno-Oil City	Venago First
Kane	Kane
Sartwell	Third Bradford
	Sartwell

Texas

District 1

Field	Reservoir
Big Wells	San Miguel
Darst Creek	Buda-Edwards
Luling-Branyon	Edwards
Salt Flat	Edwards

District 2

Field	Reservoir
Greta (all)	4400
Lake Pasture	H-440
	569
Refugio	Refugio-Fox
Tom Oconnor	Catahoula-Frio-Miocene
West Ranch	41-A

District 3

Field	Reservoir
Thompson	Frio
Barbers Hills	Frio-Miocene
Columbia West	Miocene
Conroe	First Main Cockfield
Dickinson-Gillock	Frio 8300-8800
	Frio 9000-9300
Goose Creek	Miocene
Hastings East & West	Frio
High Island	Miocene
Hull Merchant	Yegua
Humble (all)	Miocene
Old Ocean	Armstrong
Oyster Bayou	Frio-Searbreeze
Pierce Junction	Frio
Sour Lake	Frio
Spindletop	Caprock-Miocene-Frio
Tomball	Cockfield
Webster	Frio
Magnet Withers	Frio
Anahuac	Frio

District 4

Field	Reservoir
Alazan North	Frio
Aqua Dulce-Stratton	Frio-Vicksburg
Borregos	Combined Zones
Government Wells North	North
Kelsey	Multiple Zones 5400-6400
Plymouth	Frio
Saxet	Het.-Mio
Seeligson	Combined Zones
T-C-B	Zone 21 -B
White Point East	Frio

District 5

Field	Reservoir
Mexia	Woodbine
Powell	Woodbine
Van	Woodbine

District 6

Field	Reservoir
Fairway	Lime
Neches	Woodbine
New Hope	Bacon Lime
	Pittsburg
Quit Man	Paluxy
Talco	Paluxy
East Texas	Woodbine
Hawkins	Woodbine

District 7-B

Field	Reservoir
Eastland Co	Strawn
Stephens Co.	Caddo

District 7-C

Field	Reservoir
Big Lake	Queen
Jameson	Strawn
	Pennsylvanian
McCamey	Grayburg
Pegasus	Pennsylvania
	Ellen burger

District 8

Field	Reservoir
Andector	Ellen burger
Block 31	Crayburg
	Devonian
	Ellen burger
Cowden North	Grayburg
	Deep
Cowden South	San Andres-Grayburg
	Canyon
	Ellen burger

Field	Reservoir
Crossett	Devonian
Dollarhide	Ellen burger
	Devonian
Dora Roberts	Ellenburger
Dune	Permian-San Andres
Emma	Gray burg-San Andres
	Ellen burger
Foster	Gray burg-San Andres
Fullerton	San Andres
	Clear Fork
	8500
Goldsmith	San Andres-Grayburg
	5600 Clear Fork
Harper	Permian
	Devonian
	Ellenburger
Headlee	Ellen burger
Hendrick	Yates-Seven Rivers
Howard-Glasscock	Yates-Seven Rivers-Queen
	San Andres-Grayburg
	Glorieta
Iatan East	San Andres
Johnson	Gray burg-San Andres
Jordan	Permian
	Ellenburger
Kermit	Permian-Yates
Keystone	Colby
	Ellenburger
McElroy	Crayburg
Means	Gray burg-San Andres
Midland Farms	Grayburg
	Ellenburger
Parks	Pennsylvanian
Penwell	San Andres
	Glorieta
Sand Hills	Tubbs
Shafter Lake	San Andres
	Devonian-Wolfcamp
	Ellenburger
Spraberry Trend	Spraberry
TXL	Tubb
	Pennsylvanian
University Waddell	Devonian
Waddell	Gray burg-San Andres
Ward Estes North	Yates-Seven Rivers
Ward South	Yates-Seven Rivers
Yates	Gray burg-San Andres
District **8-A**	
Anton Irish	Clearfork
Cogdell	Canyon Reef
Diamond M	Canyon Lime
Kelly Snyder	Cicso
	Canyon Reef (Watered)
	Canyon Reef
Levelland	San Andres
Prentice	Glorieta
	Clearfork 6700

Field	Reservoir
Russell	Glorieta
	Clearfork
	Devonian
Salt Creek	Canyon Reef
Seminole	San Andres
Slaughter	San Andres
Wasson	San Andres
	Clearfork
Welch	San Andres
District **9**	
Archer Co. Reg.	Strawn-Gunsight
Cooke Co. Reg.	Strawn
Hull Silk Sikes	Strawn 4300
KMA	Strawn
Walnut Bend	Huspeth
	Walnut Bend
	Winger
Wichita Co. Reg.	0-2100
Wilbarger Co. Reg.	Dyson-Milham
Young Co. Reg.	Gunsight
District 10	
Panhandle	Carson
	Gray
	Hutch inson

Utah

Altamount-Bluebell	Green River
Aneth	Desert Creek
McElmo Creek	Desert Creek
Ratherford	Desert Creek
White Mesa	Desert Creek
Bridger Lake	Dakota

West Virginia

Greenwood	Big Injun
Griffithsville	Berea

Wyoming

Big Muddy	Wall Creek
Big Sand Draw	Tensleep
Bonanpa	Tensleep
C-H Field	Minnelusa
Cottonwood Creek	Phosphoric
Dillinger Ranch	Upper Minnelusa B
Elk Basin	Embar-Tensleep
Frannie	Tensleep
Gailand	Combined
	Tensleep
Grass Creek	Curtis
	Embar-Tensleep
	Frontier
Hamilton Dome	Tensleep
Hilight	MuddY-MinnellJsa
Lance Creek	Leo
	Sundance

Field	*Reservoir*
Little Buffalo Basin	Tensleep
Lost Soldier	Combined
	Tensleep
Oregon Basin	North Tensleep
	South Tensleep
Salt Creek	Wall Creek
Smemlek, West	Minnelusa B
Steamboat Butte	Tensleep
Wertz	Tensleep
Winkleman Dome	Tensleep

Offshore Fields in Louisiana

Field	*Reservoir*
Bay Marchand 002	3600' D
	3650' (L) D
	3650' (U) D
	4900' D
	7100' F
	7600' MS
	7900' D
	81 75' B
	8200' F
	8200' BUQ
	8300' BU
	8300' EE
	8500' B
	8550' B
	8700' BU
	8750' BUW
	9100' c
	9200' B
	9600' B
	RA
	RA
	RD
Bay Marchand Block 2	BM 4350 D VU
	BM 4500 MLD VU
	BM 5000 D VU
	BM 4800 RD VU
	4800 AB VU
Eugene Island 126	2A-RF-B
	2A-RF-c
	2B (1) RF A
	2B (1) RF-BVU
	2B (U) RJ
	2B (U) RL-C
	C-1 RF
	C-1 RN
	D-1 RF A
	D-1 RF SU
	E-2 RF SU
	F-1 RF SU
	IM RF-B
	IM RL-A
	IM RL-SU

Field	*Reservoir*
Eugene Island 175	RA
	RA
	RA
	RB
	RD
	RB
	FB-D
	FB-D
	FB-A
	RB
	RC
	RA
Eugene Island 276	P RA SU 1 W
	P RA SU IW
	U RA SU 1 W
	U3 RA SU 1 W
	VH 10 DE* 1
	Crist Sub 3A RA
	Tex (P) 1 RF
Eugene Island Block 330	LF FBB 1
	7300 S1 ● 1
	FBB
	RA
	FBA
	FBA
	RA
	Seg. A
	Seg. 1
	Seg. 3
	GA-2
	HB-1
	Seb. ı
	B
	FBA
	FBB
	FBB
	FB
	FC
	FSI
	L RA
	L RB
	L RC
	L RE
	L RF
	LF FBA 1
Grand Isle Block 16	B-2 RC 1A
	B-2 RE 1 W
	B-4 RC
	B-4 RE
	B-4 RT
	BF-2 RE UC
	C-1 REF IW
	C-4 A RN
Grand Isle Block 43	G-1
	F-2
	c-l
	R-2
	C-1
	G-2

Field	Reservoir
	s-1
	R5
	D-1
	R-1
	s-1
	R1
	I-I
	F-1
	R-6
	F-1
	I-8
	E-6
Grand Isle Block 47	A-6
	A-6
	A-3
	A-2
	A-1
Main Pass Block 35.	G2 RA SU
	K2 RA SU
	LO RA SU
	L2 RA SU
	N RA SU
	O RA SU
	R2 RA SU
Main Pass Block 41	RD SU
	RA SU
	RA SU
	RB SU
	RA SU
	RB SU
Main Pass 41	A
	D
	D
	A
	A
	A
	A
	t
	A
	F
	A
Main Pass Block 69.	RB SU
	RA VU
	RC VU
	RH SU
	RB SU
Main Pass 144.	RI
	6250
	6250L
	6900
	7250
	7500
	7525
Main Pass 306	AB 28/29
	C45
	B 44/45
	AB4
	44/45
	A-213

Field	Reservoir
	A-4
	A-FB-1
	A-2
	A-3
	5AF81
	44/45
	FB-I
	FB-111
	2/3
	4
	29
	42
	44/45
Ship Shoal 204	D-1
	FB5
	FB4
	FB5
	RA
	BRA
	RA & BRA
	RB
Ship Shoal 207	AI
	RA
	RA
	RE
	RB
	RG
	RA
	RA
	RF
	RA
	RC
	RG
Ship Shoal 208	RC
	PA
	ARA
	RA
	FB-3
	FB-4
	FB-3
	FB-4
	FB-4
	FB-3
	FB-4
	FB-3
	FB-4
	FB-4
	RA
	RC
South Pass Block 24	4 RB SU
	8200 T SU
	8400 RA SU
	8600 RA SU
	8800 RD SU
	M2 RA SU
	NA RA SU
	02 RA SU
	P-Q RA SU
	Q RA SU

Field	*Reservoir*
	Q RB SU
	Q RC SU
	Q RE SU
	R2 RA SU
	SRA SU
	S RC SU
	T RA SU
	T RB SU
	T RC SU
	T RD SU
	T1 RB SU
South Pass Block 24	T1 A RB SU
	TIA RB SU
	U2 RA SU
South Pass Block 27	RA SU
	v u
	RB SU
	RA SU
	RA SU
	RA SU
	RB SU
	RC SU
	RD SU
	RB SU
	RC SU
	RD SU
	RE SU
	RC SU
	RA SU
	RB SU
	RA SU
	RA SU
	RB SU
	RA SU
	RA SU
	RB SU
	RC SU
	RD SU
South Pass 27	Pliocene
	10 D
	F 32 UP
	F 32 UP
	F 13 AUp
	F 13 AD
	RBSU
	10 UP
	RESU
	RASU
	6 UP
	RESU
	RESU
	F 13 AU
South Pass 61 ... , ...	RM
	RN
	RQ
	RR
	RN
	RM
	RA

Field	*Reservoir*
	RC
	RB
	RC
	RD
South Pass 62	RA
	RA
	RB
	RC
	RA
	RA
	RA
	RC
	RA
	RD
South Pass 65	RA
	RG
	RB
	RC
	RB
	RC
	RD
	RE
	RA
	RB
Ship Shoal 208	RA
South Marsh Island 73	B-35-K
	B-65-G
	C-5-6
Timbalier Bay Block 21.	DC
	Su
	I
	IIIB
	ZX3
	3X2
	DC
	Clc
	BID
	BSC
	DC
	DC
	DC
	DC
	EB
	TE
	BSU
	DC
	DC
W. Delta Block 30	A-1 Res. F
	A-2 Res. D
	A-3 Res. D
	C-45 and Res. Q
	D-6 Res. BB
	E RASU
	G RASU
	G-4 Res. C-1
	C-4. Res. E-1
	I RASU
	IF Res. C-2
	IM Res. C-10

Field	*Reservoir*
	P-1 Res. F
	P-2 Res. F
	P-45 Res. F
	P-6 Res. F
	6100 Res. E
	6300' Res. G-A-2 Res. F
	6400' Res. G-A-3 Res. F
	71 50' Res. E
	8500 Res, C
W. Delta 73.	RA
	FBI
	FB2
	RA

Field	*Reservoir*
	RA
	RA
	RA
W. Delta 79. ., ...	D2R6S
	SFFO
	NFF
	NFF
	I
	I
	II
	III
	Iv

Documentation of Data Sources

Data needed for individual reservoirs were obtained from many sources. Sources of data are summarized by State in the *Bibliography* beginning on page 129. The entries in this bibliography include 10 categories of data. Specific data items in each category are identified in the following section. These categories indicate the type of information sought. As indicated in the Selection of *Data Items* on page 111, there are many gaps in the specific data items under each category. Data which were available for essentially all reservoirs in the data base are indicated with an asterisk.

Geology
- * Structure name
- Geologic age
- Lithology
- Fractures
- Faulting
- Complexity
- Continuity
- Lenticularity
- Heterogeneity
- Clay content
- Turbidities

Reservoir condition
- * Depth
- * Bottom hole temperature
- Pressure
- Dip
- * permeability
- Gas cap

Reservoir volume
- * Net pay thickness
- * Number of zones
- * Porosity
- * Acres

Saturations
- * Connate water saturation
- * Initial oil saturation
- Current oil saturation
- Residual oil saturation after primary and secondary recovery

Water characteristics
- Salinity
- Calcium
- Magnesium

(il/ *characteristics*
- * Gravity
- * Viscosity (reservoir conditions)
- * Formation volume factors
- Gas/oil ratio

Oil volume - resources/reserves
- * Original oil in place
- * Estimated primary/secondary recovery
- * Remaining reserves

Oil volume - production history
- * Cumulative production
- * Annual production
- Production decline rate

Field development - conventional
- * Discovery year
- * primary drive type
- * Type of secondary recovery
- * Year of secondary initiation
- * Total wells drilled
- * Latest active wells
- Current operator(s)

Field development - EOR
- Type of EOR process
- Year of initiation
- Current stage of development
- Acres under development

Bibliography

Following the State-by-State charts is a bibliography providing the full citation for each source by State.

Documentation of Data Sources for Big Fields Reservoir File

State and Source	Type of Data						011 volume		Field Development	
	Geologv	Reservoir Condition	Reservolr volume	Satura-tions	Water c harac - teristics	Oil charac-teristics	Resources/ reserves	Produc-tion history	Conventlonal	EOR
Alabama										
1 American Association of Petroleum Geologists	•	•	•		......			•	•	
~ American Petroleum Institute					......		•			
1 Bureau of Mines					•					
4 International Oil Scouts Association		•	•		......			•	•	
5 Mississippi Geological Society	•	•	•	•	......	•	•		•	
6 Oil & Gas Journal				•	......		•	•		
7 Society of Petroleum Engineers of AIME					......	•				
Alaska										
1 Alaska Division of Oil & Gas	•	•	•	•	......	•	•	•	•	
2 Alaska Geological Survey	•	•	•		......	•			•	
i American Association of Petroleum Geologists	•	•	•		......	•		•	•	
4 American Petroleum Institute — a				•	......		•			
American Petroleum Institute — b					......		•			
5 Bureau of Mines		•		•	......					
b Federal Energy Administration	•	•	•	•	......	•	•		•	
7 International Oil Scouts Association		•	•		......			•	•	
8 Mortada International	•	•	•	•	......	•			•	
9 Oil & Gas Journal					......		•	•		
10 Petroleum Data System of North America		•	•	•	......	•			•	
11 Society of Petroleum Engineers of AIME					......	•				
Arkansas										
1 Arkansas Oil & Gas Commission		•	•	•	......		•	•	•	
2 Bureau of Mines — a	•		•	•	......	•	•			•
Bureau of Mines — b					•					
Bureau of Mines — c	•	•	•	•	......	•	•		•	
3 Gulf Universities Research Consortium	•	•	•		......	•				
4 International Oil Scouts Association		•	•		......	•			•	
5 Interstate Oil Compact Commission	•	•			......		•		•	
6 Oil & Gas Journal					......		•	•		
7 Society of Petroleum Engineers of AIME — a		•			......	•				
Society of Petroleum Engineers of AIME — b	•	•	•	•	•					•
California										
1 American Petroleum Institute — a					......		•	•		
American Petroleum Institute — b					......		•	•		
2 American Association of Petroleum Geologists	•	•	•		......	•	•		•	
3 California Division of Oil and Gas	•		•		•		.		•	•
4 Conservation Commission of California Oil Producers		•			......	•		•	•	
5 Energy Research and Development Administration — a	•	•	•		......	•	•	•	•	•
Energy Research and Development Administration — b			•		......					
6 Federal Energy Administration	•	•	•	•	......	•	•	•	•	
7 Gulf Universities Research Consortium	•	•	•		......	•				
8 National Petroleum Council — a	•	•	•		......	•	•	•	•	
National Petroleum Council — b	•				......	•				
9 Oil and Gas Journal — a		•			......	•				•
Oil and Gas Journal — b					......		•	•		

State and Source	Geology	Reservoir Condition	Reservoir volume	Satura- tions	Water charac- teristics	Oil charac - teristics	011 volume		Field Development	
							Resources/ reserves	Produc - tion history	Conventional	EOR
10 Petroleum Data System of North America	●	●	●	●	......	●			●	
11 Society ot Petoleum Engineers ot AIME — a	●	●	●	●	......	●	●	●	●	●
Society of Petroleum Engineers of AIME — b		●		●	......	●				
Society of Petroleum Engineers of AIME — C	●	●	●	●	●	●	●		●	
Society of Petroleum Engineers of AIME — d	●	●	●	●	●	●	●		●	●
12 12. Miscellaneous Petroleum Periodicals					......		●	●		
Colorado										
1 American Petroleum Institute . . .					......		●			
2 Bureau of Mines	●	●	●		......	●	●		●	
3 International Oil Scouts Association			●		......	●	[illegible]	●	●	
4 Petroleum Data System of North America		●	●	●	●				●	
5 Rocky Mountain Association of Petroleum Geologists — a	●	●	●	●	●	●	●	•,	●	
Rocky Mountain Association of Petroleum Geologists — b					●					
6 Society of Petroleum Engineers of AIME				●	......	●				
Florida										
1 American Association of Petroleum Geologists	●	●	●	●	......	●	●	●	●	
2 American Petroleum Institute . . .					......		●			
3 Federal Energy Admininstration . .	●	●	●	●	......	●	●	●	●	
4 International Oil Scouts Association			●		......	●				
5 Oil and Gas Journal					......		●	●		
6. Society of Petroleum Engineers of AIME — a					......	●				
Society of Petroleum Engineers of AIME — b	●	●	●	●	......	●	●	●	●	
Illinois										
1 Bureau of Mines	●		●	●	●	●				[illegible]
2 Gulf Universities Research Consortium	●	●	●		......	●				
3 Illinois and Indiana-Kentucky State Geological Societies	●	●	●		......	●	[illegible]	• ,		
4 Illinois State Geological Survey — a		●	●		......	●				
Illinois State Geological Survey — b	●	●	●	[illegible]	......	●		●	●	
5, International Oil Scouts Association			●		......	●		●	●	
6. Oil and Gas Journal — a					......	[illegible]				●
Oil and Gas Journal — b					......		●	●	[illegible]	●
7. Petroleum Data System of North America	●	●			......	●			[illegible]	
8 Society of Petroleum Engineers of AIME — a	●	●	●		......	●			●	●
Society of Petroleum Engineers of AIME — b					......				[illegible]	●
Kansas										
1 American Association of Petroleum Geologists — a	●		●		......				●	
American Association of Petroleum Geologists — b	●	●	●		●	●		•,		
American Association of Petroleum Geologists — c	●	●	●		......	●			●	
2 American Petroleum Institute					......		●			

State and Source	Geology	Reservoir condition	Reservoir volume	Satura-tions	Water charac-teristics	Oil charac-teristics	Oil volume: Resources/ reserves	Oil volume: Produc-tion history	Field Development: Conventional	Field Development: EOR
3 Bureau of Mines — a.	●	●	●	●	●	●			●	
Bureau of Mines — h				●	●		',			
4 Energy Research and Development Administration	●	●	●		......			●		
5 International Oil Scouts Association		●	●		......	●		●	●	
6 Kansas Geological Survey — a		●	●		......	●		●	●	
Kansas Geological Survey — b	●	●	●		......	●			●	
Kansas Geological Survey —c	●	●		●	......	●		●	●	
Kansas Geological Survey — d	●			[illegible]	......				●	
7 National Petroleum Council			●		......			●		
8 0il and Gas journal — a		●	●		......	●				●
011 and Gas Journal — b					......		●	●		
9 Petroleum Data System of North America	●	●	●		......				●	
10 Society ot Petroleum Engineers of AIME — a		●	●	●	......	●	[illegible]			
Society of Petroleum Engineers of AIME — b	●	●	●	\	......					●
Soclity of Petroleum Englneers of AIME — C	●	●		●	●		●	●		●
11 Miscellaneous Petroleum Periodicals	●	●	●	●	......	●			●	
Louisiana (Onshore)										
1 Amerlcan Petroleum Institute — a and b					......		●	●		
2 8ureau of Mines					●				\ \ \ \	
1 Louisiana Department ot Conservation — a		●	●	●	......	●	●		●	●
Louisiana Department of Conservation — b			●		......		|		●	
4 011 and Gas journal — a		●			......	●				●
011 and Gas journal — b					......		●	●		
5 Society of Petroleum Engineers of AIME — a	●	●	●	●	●	●	●	●	●	ž
Society of Petroleum Englneers of AIME — b	●	●	●		......		|		●	●
6 Society of Product Ion Well Analysts					●			|		
7 National Petroleum Council	●	●	●		......	●	●	●	●	
Louisiana (Offshore)										
1 U S Geologlcal Survey	●	●	●	●	......	●	●	●	●	
Mississippi										
1 American Association of Petroleum Geologists	●	●	●	●	......	●			●	
2 American Petroleum Institute					......		●			
3 Bureau of Mines — a	●				●					
Bureau of Mines — b		\		\	......		●			
4 Federal Energy Administration		●	●	●	......	●	●		●	
5 Gulf Universlties Research Consortium		●	●	●	......	●	\ [illegible]	●	●	
6. International Oil Scouts Association		●	●		......	●	\ \ \ \ \	●	●	
7 MIssissippi State 011 and Gas Board	●	●	●	●	......	●	●	●	●	●
8 011 and Gas journal — a					......	●				●
011 and Gas Journal — b					......		●	●		
9 Society of Petroleum Engineers of AIME					......	●				
Montana										
1 American Association of Petroleum Geologists		●	Q		.....				\ \ \ \	
2 Bureau of Mines	●	●	●	●	......	●			●	
3 Gulf Universities Research Consortium		●	●		......	●	[illegible]		●	

State and Source							011 volume		Field Development	
	Geology	Reservoir condition	Reservoir volume	Satura-tions	Water charac-teristics	Oil charac-teristics	Resources/ reserves	Produc-tion history	Conventional	EOR
4 International Oil Scouts Association	●	●	●		......			●	●	
5 Montana Oil and Gas Conservation Commission	●	●	●	●	......	●	●		●	
6 Oil and Gas Journal					......		●	●	●	
7 Society of Petroleum Engineers of AIME — a					......	●				
Society of Petroleum Engineers of AIME — b	●	●	●		......	●			●	
8 U.S. Office of Oil and Gas	●		●		......					
9. Landes, *Petroleum Geology of the U.S.*	●	●	●	●	......		●			
10 Ver Wiebe, *North American Petroleum*	●				......					
New Mexico										
1. American Association of Petroleum Geologists			●		......					
2 American Petroleum Institute					......		●			
3 Federal Energy Administration	●	●			......					
4 Gulf Universities Research Consortium	●	●	●		......	●			[illegible]	
5 Interstate Oil Compact Commission		●	●		......			●	●	
6 International Oil Scouts Association		●	●		......	●		●	●	
7 National Petroleum Council			●	[illegible]	......					
8 Oil and Gas Journal					......		●	●	[illegible]	
9 Petroleum Data System of North America	●	●	●	●	●	●			●	
10 Phifer Petroleum Publications	●	●	●	●	......	●				
11 Roswell Geological Society	●	●	●	●	●	●			●	
12 Society of Petroleum Engineers of AIME — a		●	●	●	......	●				
Society of Petroleum Engineers of AIME — b		●	●	●	......	●			●	●
13 Personal Communication			●	●	......					
North Dakota										
1 American Petroleum Institute					......		●			
2 Bureau of Mines	●	●	●	●	......	●			●	
3 International Oil Scouts Association		●	●	[illegible]	......	●		●	●	
4 North Dakota Geological Survey — a	●	●	●	●	●	●			●	
North Dakota Geological Survey — b		●	●	●	......	●		●	●	
5 Oil and Gas Journal — a					......		●	●		
Oil and Gas Journal — b		●			......					●
6 Society of Petroleum Engineers of AIME					......	●				
7 Personal Communication	●	●	●	●	......	●		●	●	
Oklahoma										
1 American Association of Petroleum Geologists	●	●	●	●	......	●	●		●	
2 American Petroleum Institute — a and b					......		●	●		
3 Bureau of Mines	●	●	●	●	●	●	●			
4 Energy Research and Development Administration	●	●	●	●	●	●	●	●	●	●
5 Gulf Universitites Research Consortium	●	●	●		......	●				
6 International Oil Scouts Association			, 0		......	●		●	●	
7 Interstate Oil Compact Commission					......				●	
8 National Petroleum Council			●		......				●	
9 Oil and Gas Journal — a		●			......	●				●
Oil and Gas Journal — b		[illegible]			......		●	●		

State and Source	Geology	Reservoir condition	Reservoir volume	Saturations	Water characteristics	Oil characteristics	Oil volume: Resources/reserves	Oil volume: Production history	Field Development: Conventional	Field Development: EOR
10	●	●	●	●	......	●	●		●	
11	●	●	●	●	......	●				●
12					......			●		
13		●		●	......	●				
	●	●	●	●	●	●	●	●	●	●
	●	●	●		......	●	●	●	●	●
1					......		●			
2	●	●	●	●	......	●	●		●	
3		●	●		......		●		●	●
4	●	●			......					
5			●		......				●	
6					......		●	●		
7		●			......	●				
		●			......					
8	●		●		......				●	
9	●	●	●	●	●			●	●	
10		●	●	●	●				●	
Texas										
1 American Association of Petroleum Geologists — a	●	●	●		......	●	●	●	●	
American Association of Petroleum Geologists — b	●	●	●		......	●	●	●	●	
2 American Petroleum Institute — a					......		●	●		
American Petroleum Institute — b					......		●	●		
3 Bureau of Mines					●					
4 Federal Energy Administration	●	●	●	●	......	●	●	●	●	
5 Gulf Universities Research Consortium — a	●	●	●		......	●	●	●		
Gulf Universities Research Consortium — b					......					●
6 International Oil Scouts Association			●		......	●		●	●	
7 National Petroleum Council — a					......			●	●	
National Petroleum Council — b	●	●	●		......	●	●	●	●	
8 Oil and Gas Journal — a		●	●		......	●				●
Oil and Gas Journal — b					......		●	●	●	
9 Petroleum Data System of North America	●	●	●	●	......	●			●	
10 Society of Petroleum Engineers of AIME — a		●	●	●	......					
Society of Petroleum Engineers of AIME — b	●	●	●	●	●	●	●	●	●	●
Society of Petroleum Engineers of AIME — c	●	●	●	●	●	●	●	●	●	●
Society of Petroleum Engineers of AIME — d	●	●	●	●	●	●	●	●	●	●
11 Texas Railroad Commission — a					......			●	●	
Taxas Railroad Commission — b		●	●		......					
Texas Railroad Commission — c	●	●	●	●	●	●	●	●	●	
Texas Railroad Commission — d		●	●		......	●	●	●	●	●
Utah										
1 American Association of Petroleum Geologists	●	●	●	●	......				●	
2 American Petroleum Institute					......		●			
3 Bureau of Mines	●	●	●	●	......	●			●	

State and Source	Geology	Reservoir condition	Reservoir volume	Saturations	Water characteristics	Oil characteristics	Oil volume: Resources/reserves	Oil volume: Production history	Field Development: Conventional	Field Development: EOR
4		●	, ,	, . .	. ,				●	
5.	●	●	●	●	●	●	●		●	
6		●	●			●		●	●	
7	[illegible]						, .	●		
8		●	●				●		●	
9				●		●				
	●	●	●	●		●	●	●	●	●
10	[illegible]	●		●		[illegible]			●	
1							●			
2.		●	●						[illegible]	●
3.			●						●	
4.		, . .	●						●	
5.	●	●	●	●	●			. , .	●	
6.	●	●	●	●		●		●	[illegible]	
Wyoming										
1. American Petroleum Institute			[illegible]				●	, .		
2. 8ureau of Mines	●	●	●		●	●			●	
3. Federal Energy Administration		●	●			[illegible]	●	●	●	
4 Gulf Universities Research Consortium	●	●	●			●			[illegible]	
5 International Oil Scouts Association		●	●		, . .	●		●	●	
6 National Petroleum Council.									●	
7 011 and Gas Journal —a.		.,		[illegible]			●	, .		
Oil and Gas journal — b.								. .		●
8. Society of Petroleum Engineers of AIME — a ,..		●	●	●		●	.			
Society of Petroleum Engineers of AIME — b . . .	●	●	●	●		●		,,	[illegible]	
Society of Petroleum Engineers of AIME — c	●	●	●	●	●	●	●		●	●
9. Wyoming Geological Association.	●	●	●	●		●	●		●	
10 Wyoming 011 and Gas Conservation Commission					●			●	●	
11 Miscellaneous Petroleum Periodicals.	●	●				●		. .		

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Analysis of Reservoirs in Data Base To Determine Amount and Distribution of Remaining Oil

Distribution of the Original Oil in Place

Reservoirs frequently taper out near the perimeter of the productive acreage. The OTA data base did not contain data which would approximate variation of thickness or oil saturation with a real position. For the purposes of this study it was assumed that 95 percent of the original oil in place was contained in 80 percent of the reservoir acreage.[2] All enhanced oil recovery (EOR) projects were developed in this "richer" portion of the reservoir. This assumption was implemented in individual reservoir calculations by increasing the net oil sand in the richer portion of the reservoir.

Volume of Oil Remaining

The oil resource for EOR processes is the oil which is not recovered by primary and secondary methods. The OTA data contained estimates of the original oil in place as well as the reserves attributed to current operations. Reserves were considered to be the maximum attainable from each reservoir without application of enhanced recovery methods. It was assumed that regions which could be waterflooded economically have been or are now under development. Thus, infill drilling would be considered to accelerate the production of known reserves rather than to add new reserves.

Distribution of the Remaining Oil Resource

Two models were used to approximate the distribution of the oil resource which remains for potential recovery processes.

[2] *Research and Development In Enhanced Oil Recovery,* **Final Report, The Methodology, U.S. Energy Research and Development Administration, Part 3 of 3, p. V-4,** *ERDA 77-2013,* December 1976.

Reservoirs With Limited Waterflood Response

Reservoirs which were candidates for thermal recovery processes were those where waterflooding has not been applied successfully over an appreciable portion of the reservoir. The oil resource at the beginning of thermal recovery operations was assumed to be distributed uniformly throughout each reservoir. The average oil saturation at this point was computed using equation 1A, which represents a material balance over the reservoir volume.

$$S_{o2} = (N - N_p)\left(\frac{B_o}{B_{oi}}\right)(S_{oi}) \qquad 1A$$

where

- S_{o2} = material balance, average oil saturation
- S_{oi} = oil saturation in the reservoir at discovery
- N = estimated initial oil in place, stock-tank barrels
- N_p = ultimate oil recovery by primary and secondary methods in **stock-tank barrels**
- B_{oi} = oil formation volume factor at initial pressure. Ratio of volume occupied by the oil at reservoir conditions to the volume of oil which would be recovered at the surface at stock-tank conditions
- B_o = oil formation volume factor at the reservoir pressure which exists when N_p stock-tank barrels are produced.

The OTA data base did not contain values of B_o for every reservoir but since reservoir temperatures were available the value of B_o was set at the value corresponding to thermal expansion at reservoir temperature. Equations 2A and 3A derived from the correlations of Katz[3] were used to estimate B_o:

[3] **1. W. Amyx,** D.M. Bass, **and** R.L. **Whiting,** *Petroleum Reservoir Engineering* **p. 429,** McGraw Hill Book **Company** (1960).

$$B_o = 1 + \alpha (T_R - 60) \qquad 2A$$

$$\alpha = 0.000288 + 8.04111 \times 10^{-6} \, API - 1.890 \times 10^{-7} (API)^2 \qquad 3A$$

where

API = stock-tank oil gravity in degrees API
T_R = reservoir temperature, "F.

There were insufficient data to estimate changes in B_o from dissolved gas.

Several large reservoirs in California do not have uniform oil saturation in all portions of the reservoir. Reservoirs which were known to have oil saturation distributions were identified by members of the Technology Task Force of the National Petroleum Council (NPC) study. These data were available for the OTA study. However, it was not feasible to subdivide the reservoirs in the economic model. Subdivision of the reservoirs would change the price versus ultimate recovery projections but would not alter the ultimate recovery.

Reservoirs Under Natural Water Drive or the Waterflooding Process

The carbon dioxide (CO_2 miscible process and the surfactant/polymer process will probably be applied in reservoirs where waterflooding—either through natural water influx or water injection-has been successful. The entire reservoir volume is not swept by a waterflood. Consequently, there is a distribution of oil saturation which varies from essentially initial oil saturation in regions not swept by water to a residual oil saturation in the volume swept by the water.

The oil recovery models for both CO_2 miscible and surfactant/polymer processes assume that the processes will be contacting residual oil in some portions of the volume swept by the waterflood. It is necessary to estimate the volume of this region as well as the residual oil saturation. Although these two parameters are not known for every reservoir, it is possible to develop a relationship between them for certain situations.

The data base contains estimates of the initial oil in place, oil recovered by primary and secondary processes, and the formation volume factors at initiation and end of primary and secondary recovery. If these data are considered correct, the volumetric sweep efficiency and the average residual saturation in the region swept by water are related by equation 4A.

$$E_{vm} = \frac{\frac{N_p}{N} + \frac{B_{oi}}{B_o} - 1}{\frac{B_{oi}}{B_o}\left(1 - \frac{S_{orw}}{S_{oi}}\right)} \qquad 4A$$

where

E_{vm} = volumetric sweep efficiency of the waterflood, fraction of the reservoir swept by the waterflood
S_{orw} = average oil saturation in the reservoir volume swept by the waterflood

Other terms were defined in equation 1A.

Equation 4A was derived from an overall material balance on the reservoir in which 1) all portions of the reservoir are considered hydraulically connected, 2) regions not swept by the waterflood are resaturated to the initial oil saturation at the current reservoir pressure, and 3) the rock pore volume is invariant with pressure.

Neither SO_{rw} nor E_{vm} were available in the data base. Estimates of S_{orw} on a geological and regional basis were made in the NPC study on enhanced oil recovery using the study group's general knowledge of the reservoirs in the Lewin data base and experience in similar reservoirs which were not included in the data base. Based on this knowledge, a residual oil saturation of 20, 25, or 30 percent was assigned to each reservoir in Texas, Louisiana, or California which was a candidate for surfactant/polymer or $C0_2$ miscible processes.

The Office of Technology Assessment investigated the validity of these estimates through discussion with members of the NPC study group and review of the technical literature. Additional data were obtained from a committee preparing a book on residual oil saturations for the Interstate Oil Compact Commission.[4] Personal inquiries

[4] Personal communication with Lincoln Elkins, November 1976.

were made to companies and/or personnel who did not participate in the selection of specific values for the NPC study but who had knowledge of the properties of reservoirs in the NPC/Lewin data base.

The following conclusions were reached:

- There are a relatively small number of reservoirs where estimated values of the residual oil saturation have been confirmed with independent methods of measurement.
- Values of the residual oil saturation assigned by the NPC study group are consistent with the information which was available in the public literature and obtained through personal inquiry. Specific reservoirs within a region are likely to vary from the assigned values, but this variation is believed to be within the uncertainty of the estimates.
- The uncertainty in the residual oil saturation estimates is significant. The uncertainty is primarily due to inadequate measurement techniques and limited application of existing methods. As a result, it is not uncommon to find technical personnel in different operating divisions of the same company whose estimates of the residual oil saturation in a particular reservoir differ by 5 saturation percentage points.
- Residual oil saturations in the region swept by water are judged to be known with more certainty than the volumetric sweep efficiency, The OTA study group accepted the NPC assignment of residual oil saturation for those reservoirs which were also in the NPC base case. Reservoirs not in this category were assigned saturations indicated in table A-1 .

Two constraints were imposed on the volumetric sweep efficiencies computed from equation 4A using the residual oil saturations in table A-1.

> The maximum sweep efficiency of *a waterflood was considered to be* 90 *percent of the reservoir volume.* If the computed E_{vm} was larger than 0.9, the value of E_{vm} was set to 0,9 and the value of S_{ORW} was computed from equation 4A for the reservoir.

Table A-1
Average Oil Saturation in the Region Swept by Waterflood

Region	S_{orw}
Texas District 3.	0.20
South Louisiana, Offshore Texas Districts 1,2,4,5, and 6.	0.25
California, North Louisiana, the balance of Texas, and all other States. . . . . . , ...	0.30

> *The minimum volumetric sweep efficiency of a waterflood was considered to be 40 percent in California and 50 percent in all other reservoirs.* If the computed E_{vm} was less than the minimum value, the appropriate minimum was assigned to E_{vm} and the value of S_{orw} computed from equation 4A was assigned to the reservoir.

Consistency of Oil Resource Estimates With Those Implied by Other Studies

The approach used in the NPC study involved assignment of both volumetric sweep efficiency and residual oil saturation for each reservoir. This led to overstatement of the resource when the ultimate production data were also known. However, ultimate production data were not available to the NPC Technology Task Force for every reservoir in the NPC data base.

The initial oil in place (N) for reservoirs used in the NPC study was computed by OTA by inserting NPC-assigned sweep efficiencies and residual oil saturations in equation 4A. Ultimate production for each reservoir was included in the data base so that the initial oil in place could be computed from equation 4A. The resulting values of the initial oil in place were significantly different from values in the data base. Differences were particularly large (>10 percent) in California. The difference could be attributed to either overstatement of the initial oil in place or understatement of the ultimate production. Information gained from contacts with oil industry personnel familiar with certain reservoirs was used to reevaluate the methods used by Lewin and Associates, Inc., to determine the initial oil saturations. Revisions of this analysis led to the reduction of oil-in-place estimates by 3.5 billion barrels in California.

Reservoirs assigned to one set of OTA runs for CO_2 miscible and surfactant/polymer processes were analyzed to determine if there were large differences between the initial oil-in-place estimates in the data base and those computed by using NPC sweep efficiencies and residual oil saturations in equation 4A. Results extrapolated to national totals are summarized in table A-2.

The comparison in table A-2 indicates a difference of about 10 percent between estimates for the surfactant/polymer reservoirs. This is within the range of uncertainty. The difference approaches 30 percent for reservoirs which were CO_2 candidates. However, as indicated in the section on Discussion 01 *Results* (page 46) in chapter III, the effect on calculated oil recovery by the CO_2 miscible process was minimal.

Table A-2
Comparison of initial Oil in Place Computed for Estimates of Sweep Efficiency and Residual Oil Saturations

Reservoirs *in Surfactant/Polymer Economic Evaluation*	
Original oil in place from OTA data base . . . . ~	**51.2 billion barrels**
Original oil in place determined from material balance calculations using NPC sweep efficiency and residual oil saturations	**46.4 billion barrels**
Difference—surfactant/polymer reservoirs	**4.8 billion barrels**
Reservoirs **in CO_2 Miscible Economic Evaluation**	
Original oil in place in OTA data base	**93. s billion barrels**
Original oil in place determined from material balance calculations using NPC sweep efficiency and residual oil saturations	**130.0** billion barrels
Difference-CO_2 miscible reservoirs . .	36.5 billion barrels