Contents

Chapter	Pa	age
1.	EXECUTIVE SUMMARY	3
	Introduction and Summary of Findings	3
	Method of Analysis Data Base. Technical Screen Economic Screen Rate of Initiationof EOR Projects Cases Examined	5 5 5 5
	Oil Recovery Potential Ultimate Oil Recovery. Rate of Oil Production. Major Uncertainties. Resource Availability and Process Performance Availability and Cost of Injection Materials. Rate of Investment in EOR Projects Marketability of Heavy Crudes Combinations of Uncertainties	6 7 7 8 8 9 9
	Impact of Price and Tax Policies Price Special Tax Treatment for EOR Projects Price Guarantees and Subsidies for EOR Production.	9 10 11
	Legal Issues	12
	Environmental Effects	13
II.	AN ASSESSMENT OF THE POTENTIAL OF ENHANCED OIL RECOVERY	17
Ш.	OIL RECOVERY POTENTIAL	23
	The Resource Base	23
	Oil Recovery Primary Recovery Secondary Recovery Enhanced Recovery Thermal Processes Miscible rocesses Chemical Processes Other EOR Processes.	24 24 26 27 29 31

Chapter P	age
Oil Resource for Enhanced Oil Recovery processes	33
Methodology for Calculating Oil Recovery	35 35
Ultimate Recovery for the Nation	37
Estimated Oil Recovery. Definition of Cases	38 38 39 39 39
Discussion of Results. Projected Results for the United States Ultimate Recovery. Production Rate. Uncertainties in Projections. Uncertainties in Ultimate Recovery Uncertainties in Projected Production Rates Effect of Uncertainty in the Residual Oil Saturation and Volumetric Sweep on Projected Results Residual Oil Saturation Volumetric Sweep Maximum Oil Recovery by EOR Processes	46 46 47 47 49 50 50
Comparison With Other Studies	52 54
Technological Constraintson EOR Resource Availability	59 59 59 60 60
Carbonate Reservoirs	61

Contents: Chapter /// - Continued

Chapter			Page
		Reservoir Characteristics. Raw Material Availability Human Resources Environmental Effects The Rate of Technology Evolution.	62 62 63 63
		The ERDA Programs	64
	Iv.	IMPACTS OF PRICE AND TAX POLICIES ON OIL RECOVERY	69
		Policy Considerations	69
		Policy Options ,	69
		Analytical Approach	70
		Analysis of Government Policy Options Reservoir Sample. Analysis Assuming Information Certainty Price Analysis. Analysis of Other Policy Options. Analysis Assuming Information Uncertainty. Option Designed To Alleviate Uncertainty Analysis Assuming a Rising Real Price	71 71 71 71 74 76 76 78
		Impact of Alternative OCS Leasing Systems	79
		Administrative Issues	80
	٧.	LEGAL ASPECTS OF ENHANCED OI L RECOVERY	85
		Method o fApproach	85
		Legal Issues in EOR Development	85
		Policy Options	88
	VI.	ENVIRONMENTAL ISSUES	91
		Physiographic Regions. Continental Shelf. Coastal Plains Interior Basins Mountain Ranges.	91 91 91 91 92
		Causes of Environmental Effects	92
		Potential Impacts on the Environment	94 94 95
		Methods	97

	Air Pollution Impacts of Chemical Recovery Methods. 97 Surface Water 98 Ground Water 100 Land Use 100 Geologic Hazards 100 Noise 101 Biota 101 Process Independent Impacts 101 Process Dependent Impacts 102
APPENDIXES	
A. Oil Re	esource for Enhanced Recovery Projections
	orting Materials for Oil Recovery Projections From Application of Enhanced Oil Recovery Processes
LIST OF T	ABLES
Table Number	Page

Table	
Numbei	

Page

13.	Estimated Recoveries for Advancing Technology- Low- and High- Process
	Performance Cases - Carbon Dioxide Miscible
14.	Estimated Recoveries for Advancing Technology- Low- and High-Process
	Performance Cases — Polymer-Augmented Waterflooding
15.	Ultimate Recovery by State- High-Process Performance
16.	Extrapolation of Ultimate Oil Recovery From Data Base Calculations to
	the Nation-World Oil Price (\$13.75/bbl)
17.	Summary of Oil Recovery Evaluations— Data Base Reservoirs
18.	Projected Distribution of Known Oil in the United States
19.	Uncertainty in Projections of Ultimate Recovery for Advancing
	Technology Cases
20.	Comparison of Technological Assumptions for the Surfactant/Polymer
	Process
21.	Comparison of Ultimate Recovery Under Two Technological Scenarios,
	Both Assuming High-Process Performance— Surfactant/Polymer Process
22.	High-Process Performance at World Oil Price (\$13.75/bbl)
23.	Impact of Technological Advances in Emission Control in California
	Thermal Recovery Projects on Projected Rates for the United States
	United States at World Oil Price (\$13.75/bbl)
24.	Projections of Ultimate Recovery and Production Rate From the Application
	of Enhanced Oil Recovery Processes
25.	Field Activity in Enhanced Oil Recovery
26.	Number and Percent of Reservoirs Sampled by EOR Process
27.	EOR Reservoir Development Production by Process and Price Level72
28.	Price Elasticity of Supply Comparison
29.	EOR Development by Process and Policy Option
30.	Input Variables and Subjective Probability Distributions Used for Monte
	Carlo Simulations
31.	Monte Carlo Simulation of Policy Option Impacts in Reducing Uncertainty77
32.	Monte Carlo Simulation of EOR Oil Price Deregulation
33.	Monte Carlo Simulation of OCS Leasing Systems and EOR Potential81
34.	Comparative Chart of Aspects of Unitization Statutes
35.	Matrix Evaluation of Relative Potential for Environmental Impacts for
	Enhanced Oil Recovery
36.	Potential Distribution of Environmental Impacts for Enhanced Oil Recovery94
37.	Cross Plot of Environmental Impacts for Enhanced Oil Recovery
38.	Emission Factors for Fuel Oil Combustion
39.	Steam Generator Emissions
40.	Projected Emissions from Steam Flooding of a Major Oil Field Compared to
	Los Angeles County Emissions
41.	Potential Biological Impacts Resulting From EOR

LIST OF FIGURES

-igur Num	Daga
1.	Projected Oil Production by Conventional Methods From Known U.S.
	Reservoirs, 1976-95
2.	Closeup of Oil Between Grains of Rock
3.	Oil Accumulation in the Top of a Dome
4.	Oil Accumulation in a Dome at the Top of a Salt Dome and Also in a Region
	on the Side of the Dome
5.	Oil Accumulation Caused by a Fault
6.	Oil Trapped by Overlying Impervious Cap Rock ,
7.	Oil Trapped Within Larger Body of Impervious Shale
8.	Cyclic Steam Stimulation Process
9.	Steam Drive Process (Steam Flood)
10.	In Situ Combustion Process—Wet Combustion
11.	Carbon Dioxide Miscible Flooding Process
12.	Surfactant Flooding Process
13.	Projected Production From Known U.S. Reservoirs, 1976-95, by Conventional .
	Methods and by Enhanced Oil Recovery at World Oil Price
14.	Water Use and Supplies