

## Produced Water in Louisiana: Analyzing the Magnitude of the Problem

by

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### ABSTRACT

Produced water is a fact of life in Louisiana. The largest volume of waste associated with oil and gas production operations in Louisiana, as well as nationally, is produced water.

The amounts of produced water are overwhelming compared to the amounts of hydrocarbons produced. In 1993, while over 1.2 billion barrels of produced water was being generated, less than 200 million barrels of oil and condensate and a little over 200 million BOE of gas was produced. From 1990 to 1993, the statewide WHR averaged approximately 3.2. Based upon numbers available for 1994 (through October) there has been a dramatic increase in the statewide WHR to over 4.

The data was further broken down into north and south Louisiana, deep (greater than 10,000-ft) and shallow formations. South Louisiana not only produces much more oil and gas, it also produces much more water. In 1993, south Louisiana wells generated over 900 million barrels of produced water while north Louisiana only generated a little over 300 million barrels of produced water.

The majority of the produced water, in both north and south Louisiana, originates from shallow production. In 1993, shallow production in south Louisiana generated almost 700 million barrels of water and shallow production in north Louisiana generated a little over 300 million barrels of water. In contrast, deep south Louisiana generated under 250 million barrels of water and deep north Louisiana generated under 10 million barrels of water.

In 1993, downhole injection of produced water in Louisiana was 903,106,978 barrels. Of this sum, 381,583,319 barrels were injected into facilities in north Louisiana and 521,523,659 barrels were injected into facilities within south Louisiana. In 1993, approximately 1,507,552 barrels a day were being discharged into inland waters and territorial waters. This would be an estimated cumulative discharge for 1993 of 550,256,480 barrels of produced water and would represent approximately 38% of the total produced water being generated within the entire state and 51% of the produced water being generated within south Louisiana.

Hydrocarbon production in south Louisiana, primarily shallow production, is expected to be affected severely by the zero discharge regulations of the present and future years. Just in injection costs alone, south Louisiana operators will have to spend an estimated additional \$12 million annually to make up for the water now being discharged. This is double the amount spent at present. Note that this does not include the major costs of drilling, completing and constructing the new disposal wells and related facilities that will be necessary. The estimated average cost within south Louisiana for drilling and completing new disposal wells is \$246,000. This equates to an average cost of \$ 69.58 per foot with an average depth of 3,666 feet. Conversion costs vary over a wide range.

## ***INTRODUCTION***

Produced water is a fact of life in Louisiana. Practically all of the reservoirs found in Louisiana produce water along with the hydrocarbons during the majority of their life. The largest volume of waste associated with oil and gas production operations in Louisiana, as well as nationally, is produced water. It flows from separators into storage tanks, filtered and/or chemically treated and either injected into separate disposal wells, enhanced recovery wells, annular completions or discharged into surface waters.

## ***PRODUCED WATER GENERATION***

### **Data**

Comparison numbers were accumulated from well test data obtained from the Louisiana Department of Natural Resources - Production Audit Recording System (PARS) database with the help of Mike Surman of the Louisiana State University's Center for Energy Studies.

Operators are required to submit to the state well tests reports for all wells that they operate. Oil wells have test information submitted bi-monthly, while gas wells have their test data submitted quarterly. This data is the only source for the amounts of water actually produced from oil and gas wells in the state.

Annual totals were generated from this test data for oil, condensate, gas and water. The generated figures, qualitatively, were good estimates of actual amounts. Actual amounts were available for annual production of oil, condensate and gas from the Department of Natural Resources. Actual amounts for the annual disposal of produced water through injection wells were provided by Mr. Bill Walters of the Department of Natural Resources. Actual amounts for annual disposal by surface water discharge were estimated from averaged numbers for daily rates of discharge provided by Mr. Don Weinnel and Mr. Doug Hale of the Louisiana Department of Environmental Quality. For the period for which comparisons were done, 1990 through 1994, water discharge estimates were made only for 1993 due to lack of source information. It should be noted that the information obtained from Mr. Walters, Mr. Hale and Mr. Weinnel were from projects of their own personal initiative because of their realization of the importance of tracking these volumes.

In an attempt to keep the data as consistent as possible and after some quality comparison, the values generated from the test data were used for most of this analysis. Gas was converted into barrels of oil equivalent (BOE) using a value based ratio of 0.1 BOE/MCF.

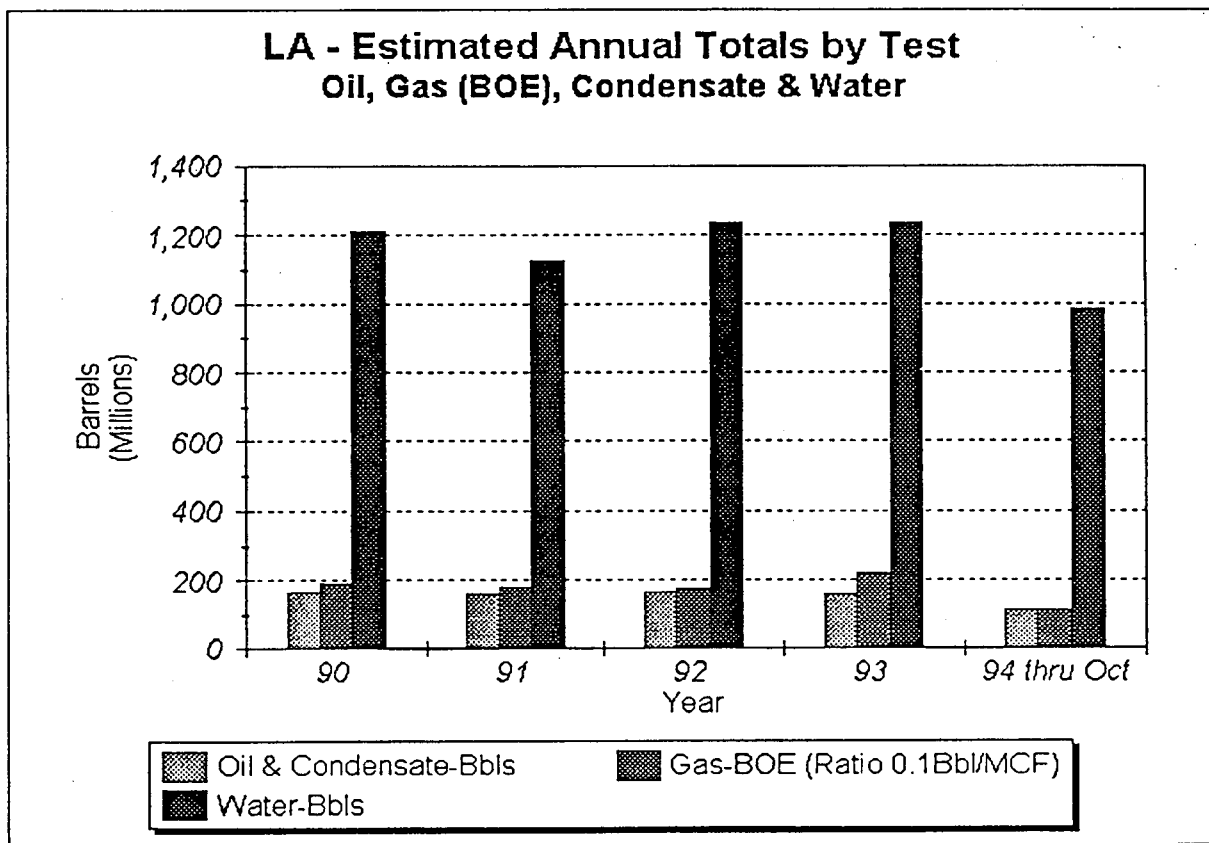
### **Analysis**

The amounts of produced water are overwhelming compared to the amounts of hydrocarbons produced; Table 1 and Figure 1. In 1993, for example, while over 1.2 billion barrels of produced water was being generated, less than 200 million barrels of oil and condensate and a little over 200 million BOE of gas was produced.

**Table 1**  
**Annual Totals by Test Data**

Year	Oil & Condensate	Gas (BOE)	Water
90	163,156,040	191,997,769	1,210,984,669
91	157,702,067	180,065,107	1,124,844,506
92	165,602,206	174,668,629	1,234,513,144
93	157,792,446	222,230,870	1,236,309,267
94 through Oct.	113,489,067	116,560,504	979,599,598

**FIGURE 1**



Viewing this another way by combining oil, gas(BOE) and condensate versus produced water gives another contrast as shown in Figure 2 and Figure 3. Figure 2 shows the contrast between the amounts of water produced and the amounts of hydrocarbons produced for the entire state. Figure 3 is a ratio of these two numbers giving a water/hydrocarbon ratio (WHR). From 1990 to 1993, the statewide WHR averaged approximately 3.2. However, based upon numbers available for 1994 (through October) there has been a dramatic increase in the statewide WHR to over 4.

FIGURE 2

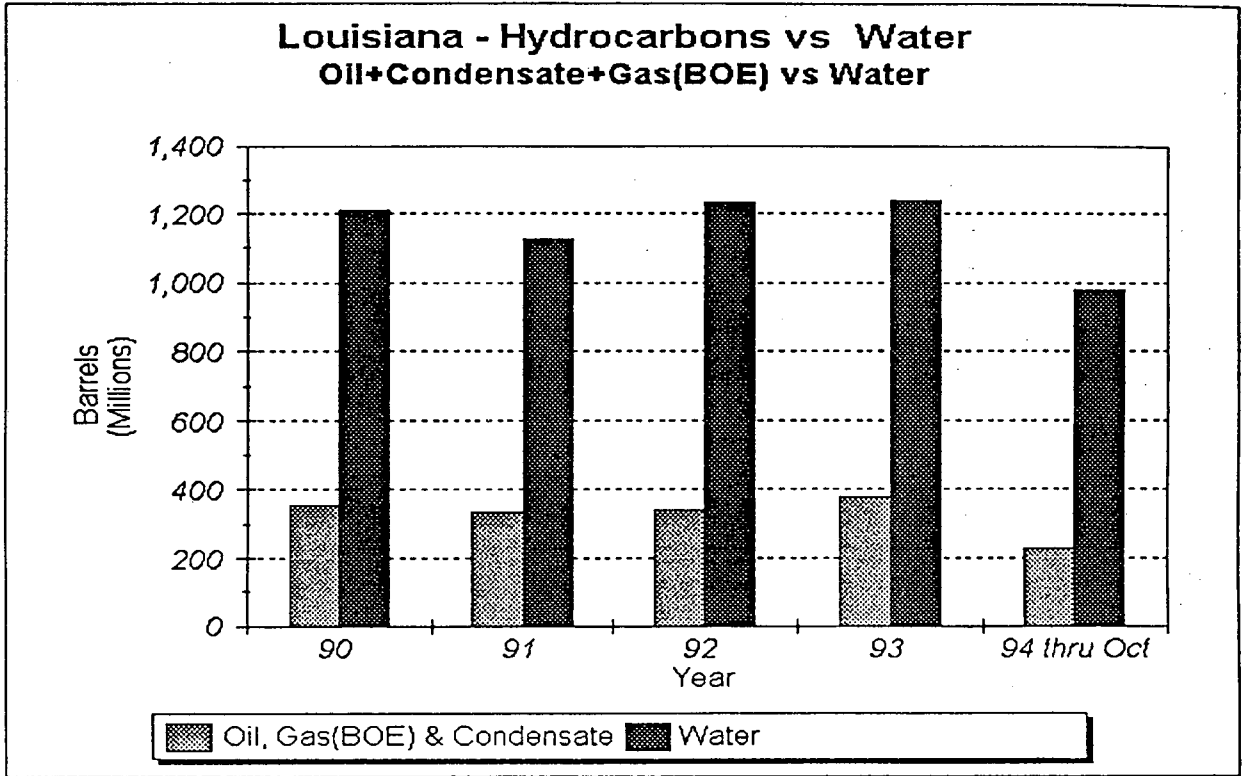
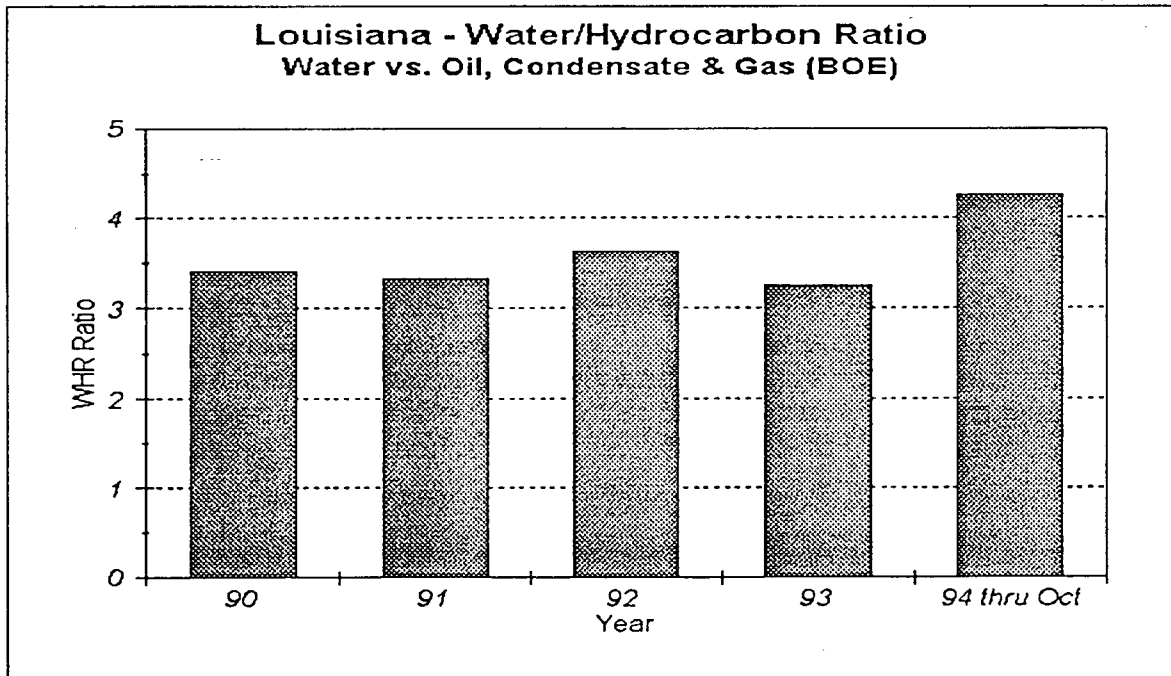


FIGURE 3



The data was further broken down into north and south Louisiana, deep (greater than 10,000-ft) and shallow formations. Figure 4 and Table 2 illustrate the breakdown between south and north Louisiana. South Louisiana not only produces much more oil and gas, it also produces much more water. In 1993, south Louisiana wells generated over 900 million barrels of produced water while north Louisiana only generated a little over 300 million barrels of produced water. If 1994 was extrapolated based on the numbers through October, everything would have declined; oil production by 15%, gas production by 42%, and water production by 8%. However, values in north Louisiana indicate that oil production decreased by 4%, gas production decreased 15% and water production increased 4%. This has been illustrated in Figure 4A.

Breaking down to compare shallow and deep production creates Figures 5, 5A, 6, 6A and 7 and Table 3. Figure 5 compares the shallow production of hydrocarbons to water production and Figure 6 compares the deep production of hydrocarbons to water production. Figures 5A and 6A illustrate the changes for 1994 if extrapolated from October for shallow and deep production, respectively. For shallow production, in south Louisiana oil production declines 15%, gas production declines 11% and water declines 5%. For shallow production in north Louisiana, oil production declines 4%, gas production declines 17% and water production increases 4%. For deep production, in south Louisiana oil production declines 17%, gas production declines 47% and water declines 15%. For deep production in north Louisiana, oil production declines 6%, gas production declines 1% and water production increases 6%.

Table 2

<i>South Louisiana</i>			
Totals	Oil & Condensate	Gas (BOE)	Water
90	135,299,213	138,782,004	924,021,315
91	129,202,645	132,628,895	823,688,547
92	138,215,910	131,090,616	910,730,162
93	132,581,088	179,395,179	926,797,747
94 through Oct.	93,411,296	86,042,385	711,411,832
<i>North Louisiana</i>			
Totals	Oil & Condensate	BOE	Water
90	27,856,827	53,215,765	286,963,354
91	28,499,422	47,436,212	301,155,958
92	27,386,296	43,578,014	323,782,982
93	25,211,358	42,835,692	309,511,520
94 through Oct.	20,077,771	30,518,119	268,187,766

FIGURE 4

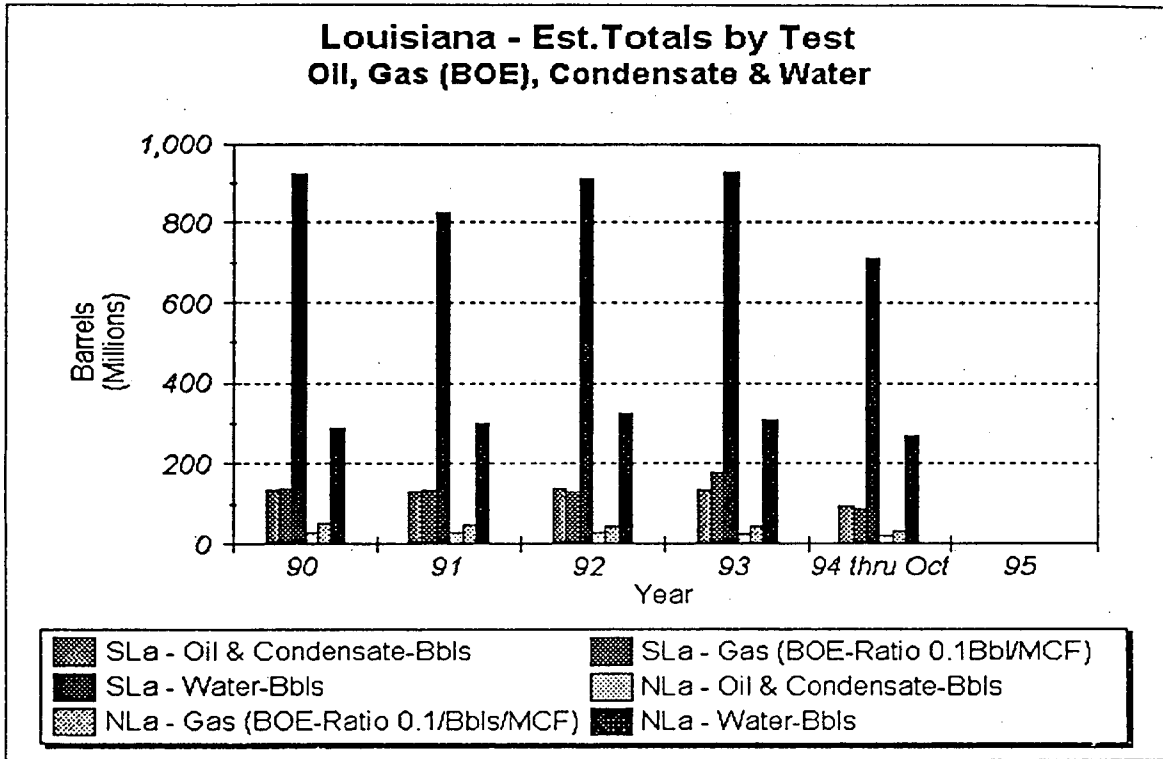


FIGURE 4A

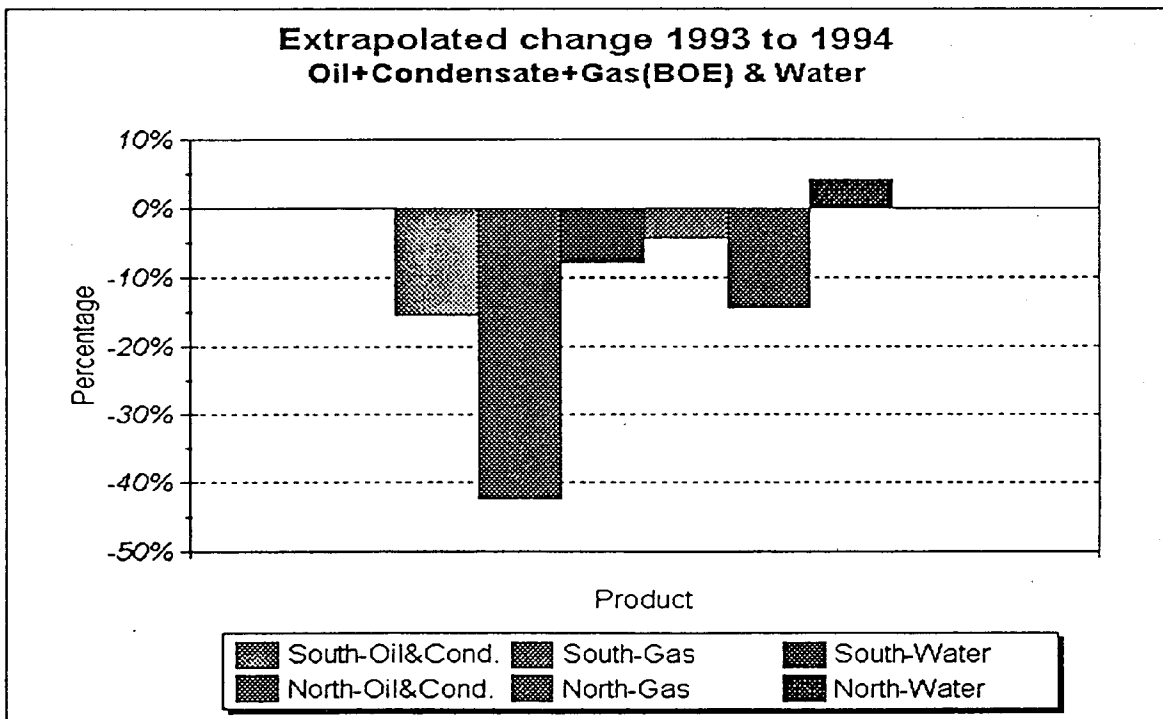


FIGURE 5

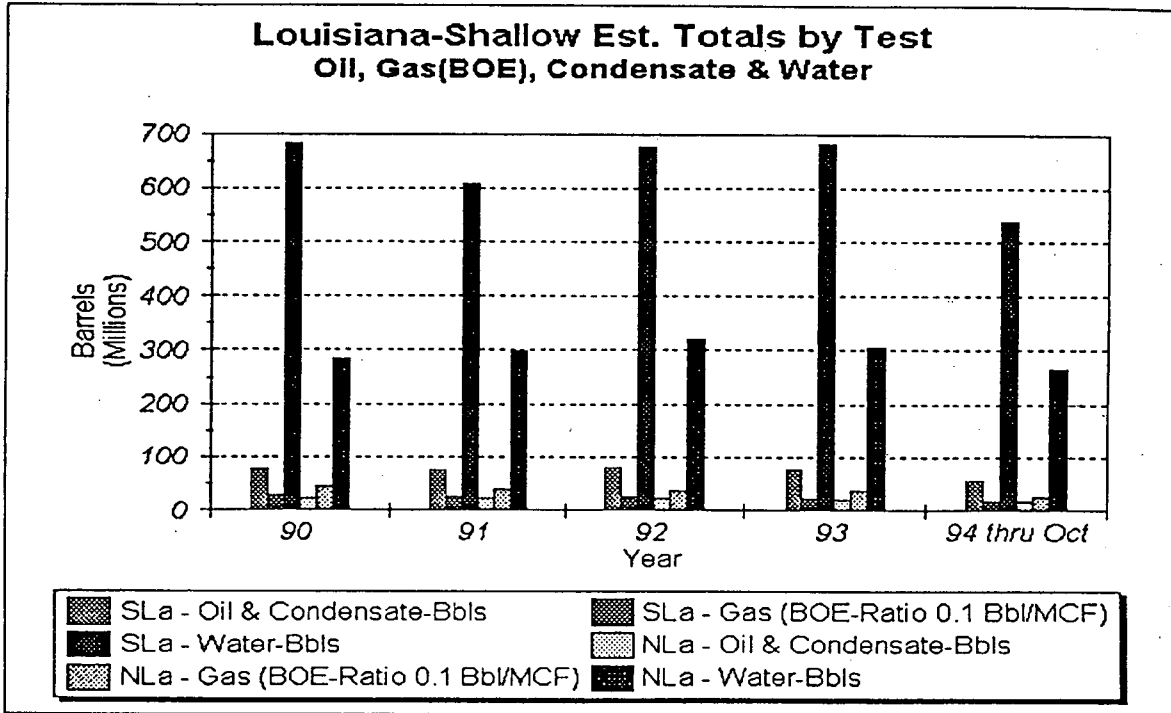


FIGURE 5A

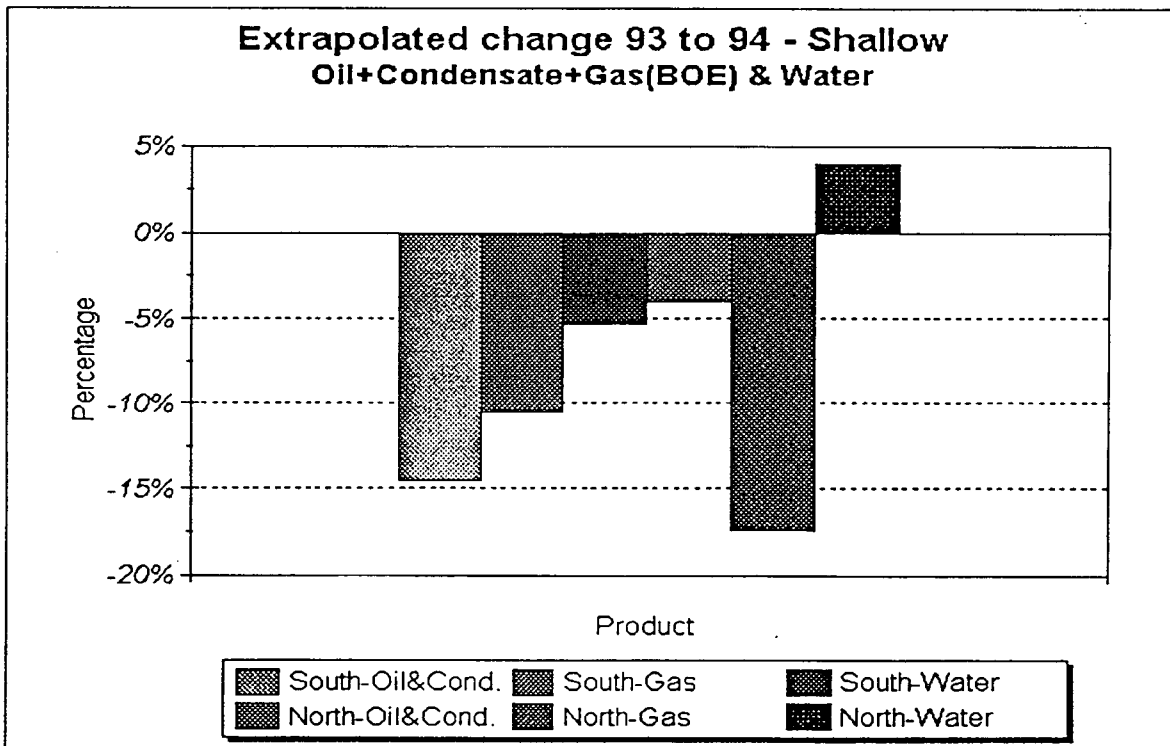


FIGURE 6

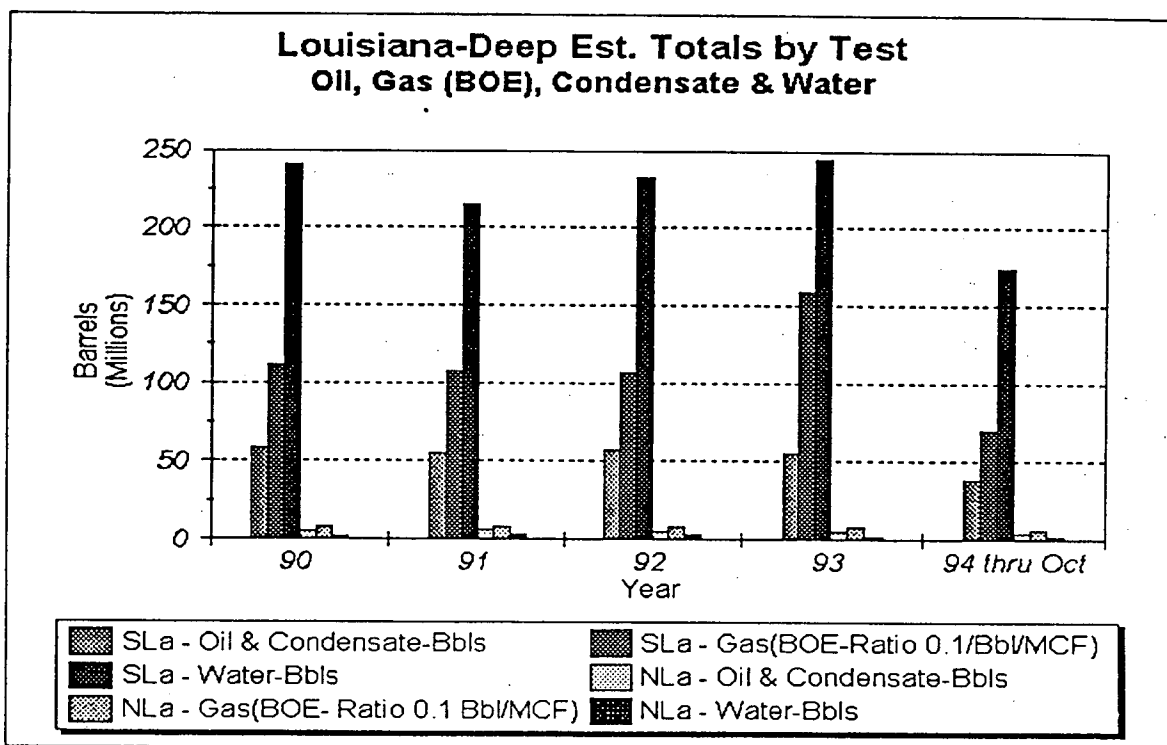


FIGURE 6A

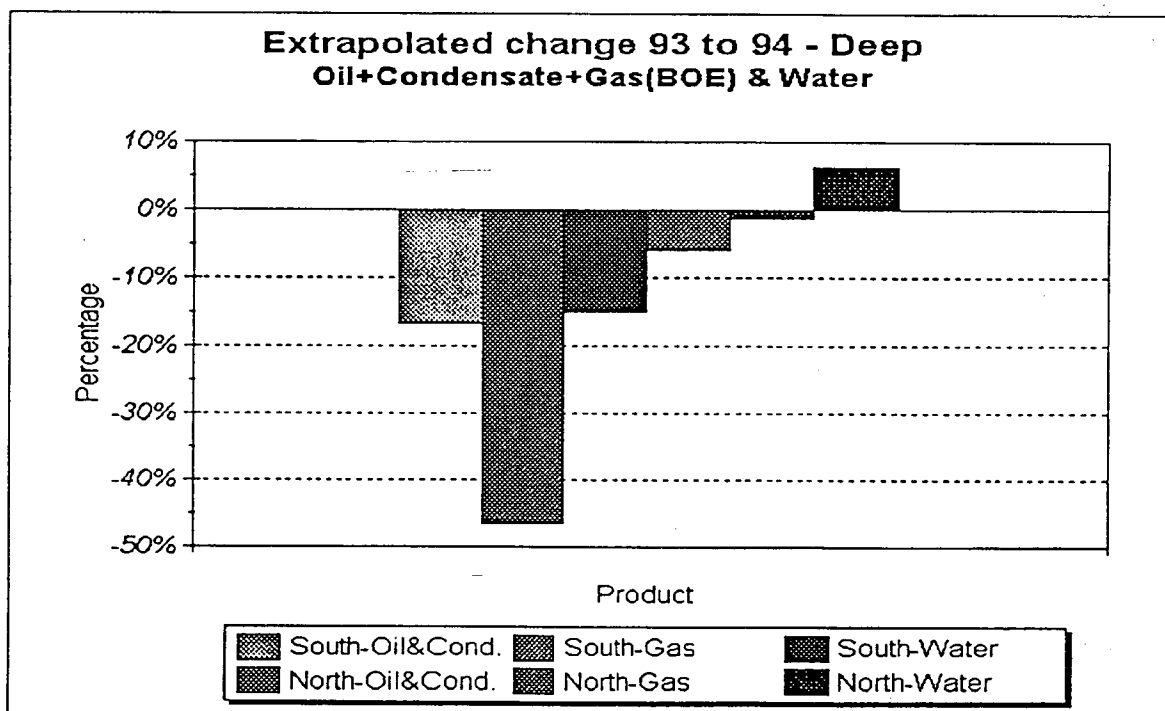




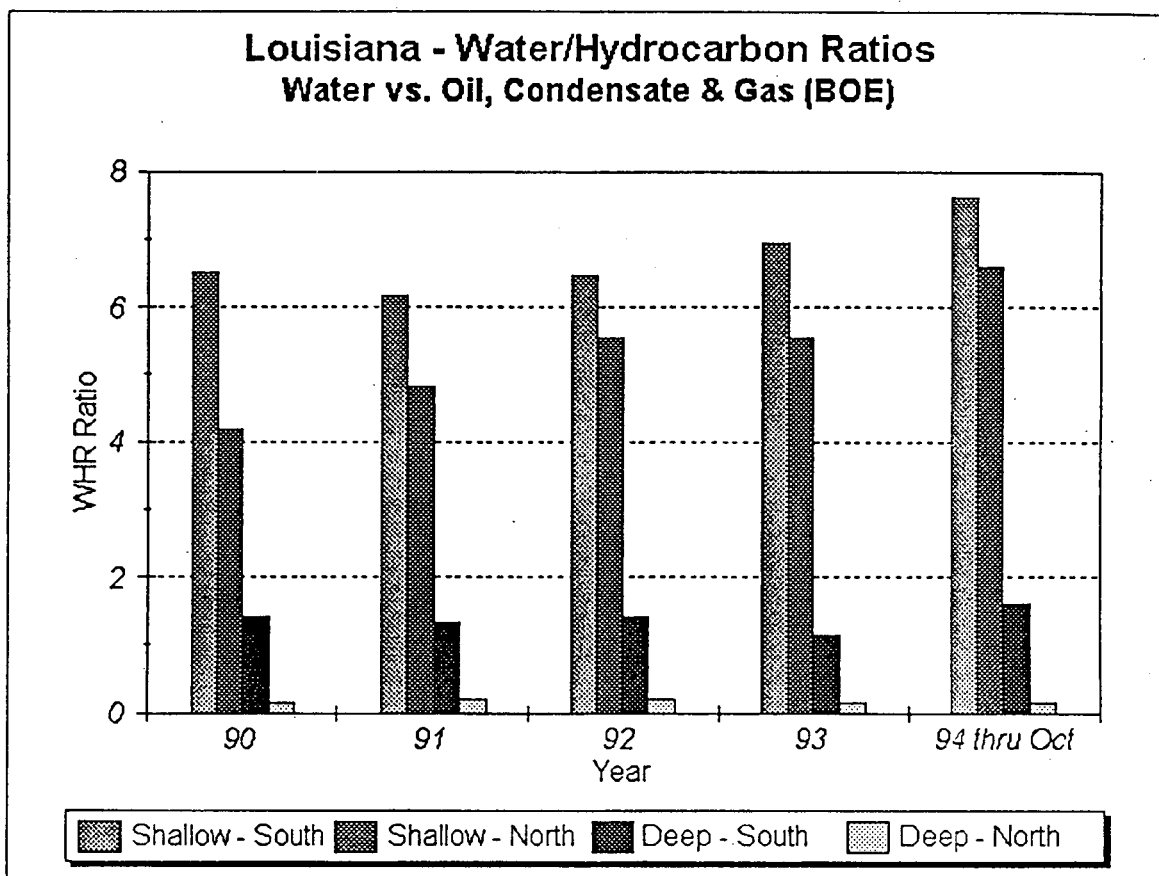
Table 3

<i>Shallow, South</i>					
	Oil & Condensate	Gas (BOE)	Water	WHR	
90	77,223,205	27,831,659	683,310,498	6.50	
91	73,620,410	25,097,118	608,362,398	6.16	
92	80,719,813	24,338,918	677,964,414	6.45	
93	77,379,096	21,036,958	682,237,925	6.93	
94 through Oct.	55,123,530	15,685,944	538,155,483	7.60	
<i>Shallow, North</i>					
	Oil&Condensate	Gas (BOE)	Water	WHR	
90	22,904,819	45,205,715	284,855,478	4.18	
91	22,656,390	39,079,583	298,408,467	4.83	
92	22,340,869	35,419,800	321,192,021	5.56	
93	20,295,131	35,167,741	307,640,795	5.55	
94 through Oct.	16,227,854	24,213,719	266,531,878	6.59	
<i>Deep, South</i>					
	Oil&Condensate	Gas (BOE)	Water	WHR	
90	58,076,008	110,950,345	240,710,818	1.42	
91	55,582,235	107,531,777	215,326,149	1.32	
92	57,496,098	106,751,698	232,765,747	1.42	
93	55,201,992	158,358,221	244,559,822	1.15	
94 through Oct.	38,287,766	70,356,441	173,256,349	1.59	
<i>Deep, North</i>					
	Oil&Condensate	Gas (BOE)	Water	WHR	
90	4,952,008	8,010,050	2,107,875	0.16	
91	5,843,032	8,356,629	2,747,491	0.19	
92	5,045,427	8,158,214	2,590,962	0.20	
93	4,916,227	7,667,950	1,870,725	0.15	
94 through Oct.	3,849,917	6,304,401	1,655,888	0.16	

Evidently the majority of the produced water, in both north and south Louisiana, originates from shallow production. In 1993, shallow production in south Louisiana generated almost 700 million barrels of water and shallow production in north Louisiana generated a little over 300 million barrels of water. In contrast, deep south Louisiana generated under 250 million barrels of water and deep north Louisiana generated under 10 million barrels of water.

Figure 7 illustrates this contrast further by plotting the WHR for shallow-south, shallow-north, deep-south, and deep-north. In 1993, shallow-south had an average WHR of almost 7 and shallow-north had an average WHR of almost 6. Deep-south had an average WHR of a little over 1 and deep-north had an average WHR below 0.2.

FIGURE 7



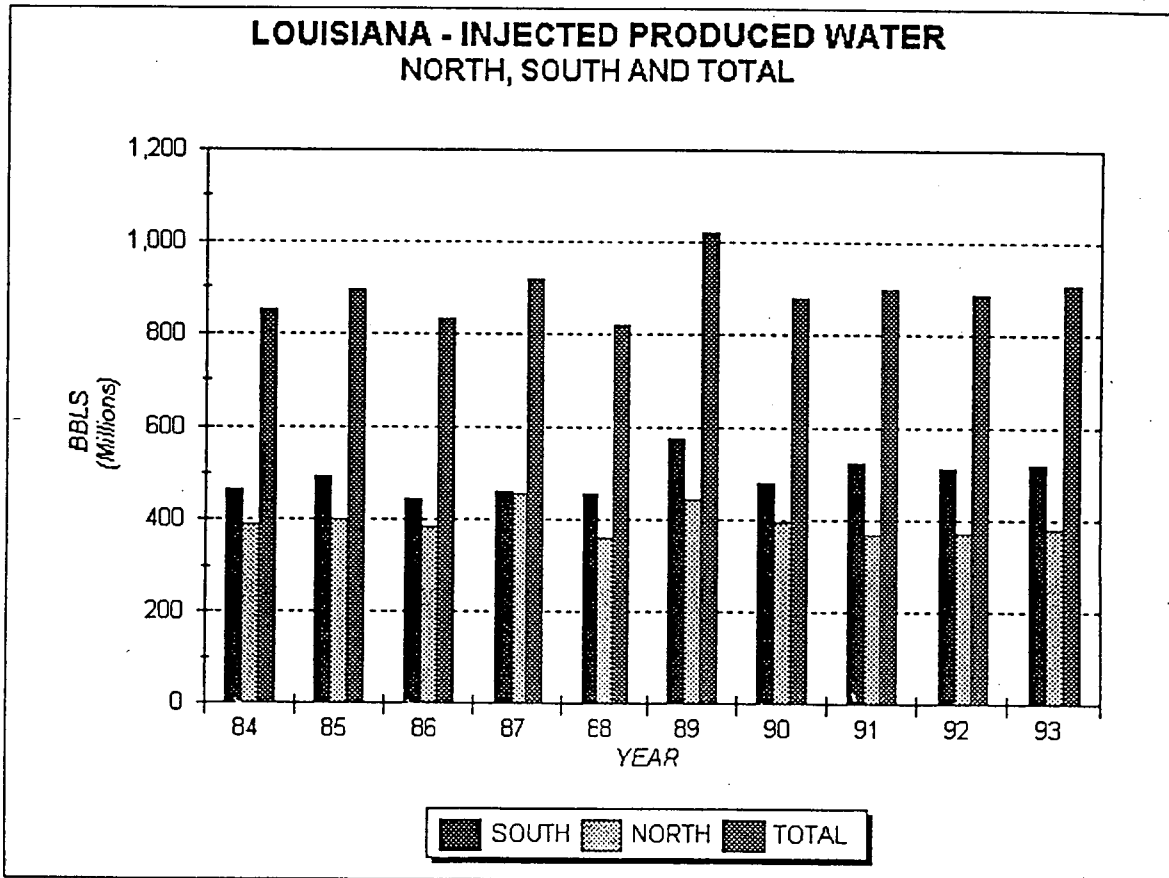
## PRODUCED WATER DISPOSAL

### Downhole Injection

Nationally, approximately 80 percent of all produced water is disposed of in injection wells permitted under EPA's Underground Injection Control (UIC) program under the authority of the Safe Drinking Water Act. The injection may be done at injection wells onsite, offsite or at centralized facilities. By regulation, injection for the purpose of disposal must be below the base of the United States Drinking Water (USDW). Disposal wells can be new wells drilled for the sole purpose of disposal, conversion of past productive wells or plugged and abandoned wells or disposing through the annulus of producing wells.

In 1993, downhole injection of produced water in Louisiana was 903,106,978 barrels. Of this sum, 381,583,319 barrels were injected into facilities in north Louisiana and 521,523,659 barrels were injected into facilities within south Louisiana, Figure 8. Accounting only for injection into disposal wells and discharges into surface waters, this represents approximately 62% of all produced water generated within the state.

FIGURE 8



### Surface Water Discharge

Surface water discharge is another method of handling produced water generated from oil and gas operations within south Louisiana. However, by January 1997, zero discharge compliance will be in place and this will not be a viable disposal technique. In 1993, approximately 1,507,552 barrels a day were being discharged into inland waters and territorial waters. This would be an estimated cumulative discharge for 1993 of 550,256,480 barrels of produced water. This estimate was obtained from the Louisiana Department of Environmental Quality. Because of the inexact nature of the data sources, a slight discrepancy exists between the totals of produced water, injected water and discharged water. It was assumed for these comparisons, that the values for surface discharge and injection were accurately estimated, and thus their sum would equal the total amount generated. Therefore, based on this assumption, approximately 38% of the total produced water being generated within the entire state was discharged to surface waters and 51% of the produced water being generated within south Louisiana was discharged to surface waters, Figure 9 and Figure 10.

FIGURE 9

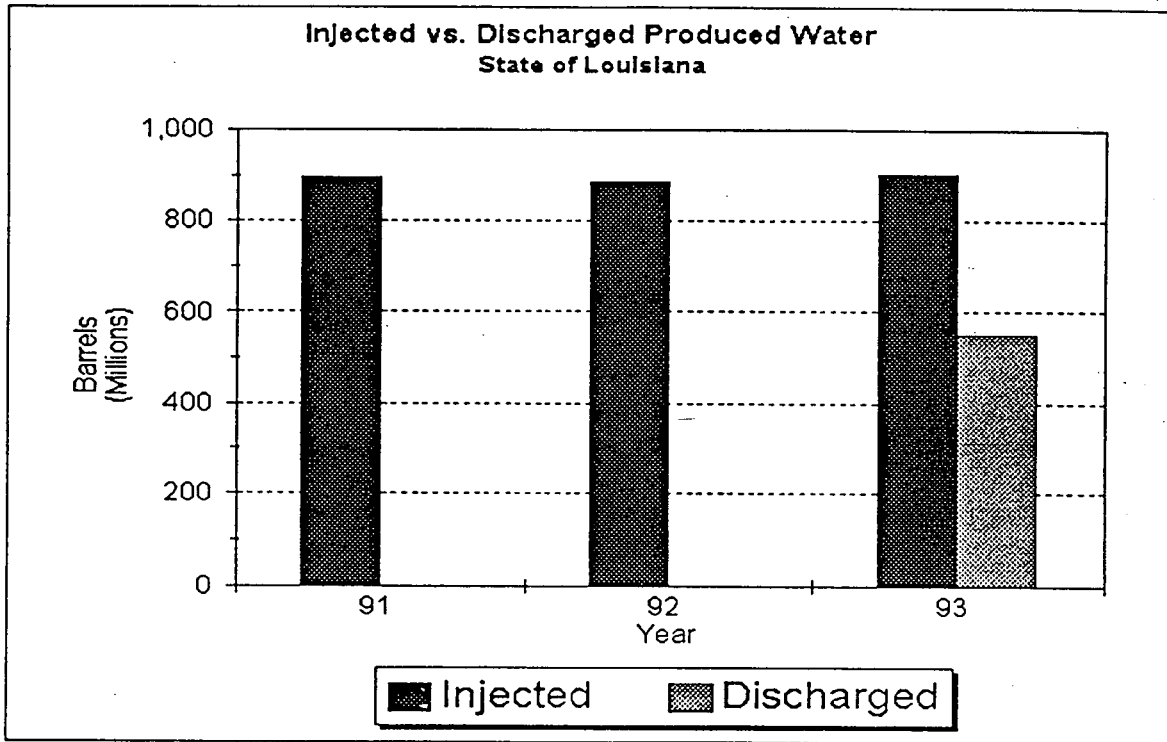
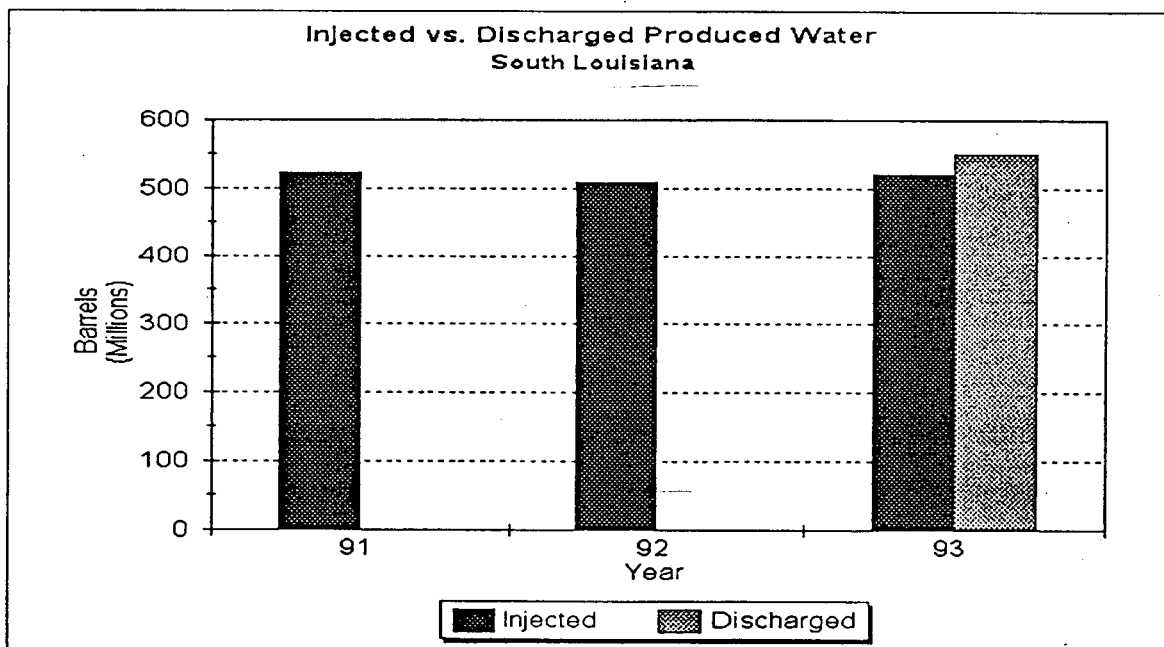


FIGURE 10



## ECONOMIC ANALYSIS

The average cost of the actual downhole injection of produced water among all types is \$0.025. Just in injection costs alone, south Louisiana operators will have to spend an estimated additional \$13.8 million annually to make up for the water now being discharged. This is double the amount spent at present.

This does not include the major costs of drilling, completing and constructing the new disposal wells and related facilities that will be necessary. Based upon public records obtained from the Louisiana Department of Natural Resources, Injection and Mining Division, the estimated average cost within south Louisiana for drilling and completing new disposal wells is \$246,000. This equates to an average cost of \$ 69.58 per foot with an average depth of 3,666 feet, as shown in Table 4 and Figure 11. For wells on water, the expense can double.

Converting shut-in wells or plugged and abandoned wells to salt water conversion is one approach which can save tremendous amounts of expense, if they are available. The cost to convert an existing well to salt water disposal varies widely, depending on what needs to be done to accomplish the task. However, the decrease in cost can be ten times less expensive than drilling and completing a new disposal well. Another cost efficient alternative is annular disposal. The most efficient of all, of course, is surface water discharge.

FIGURE 11

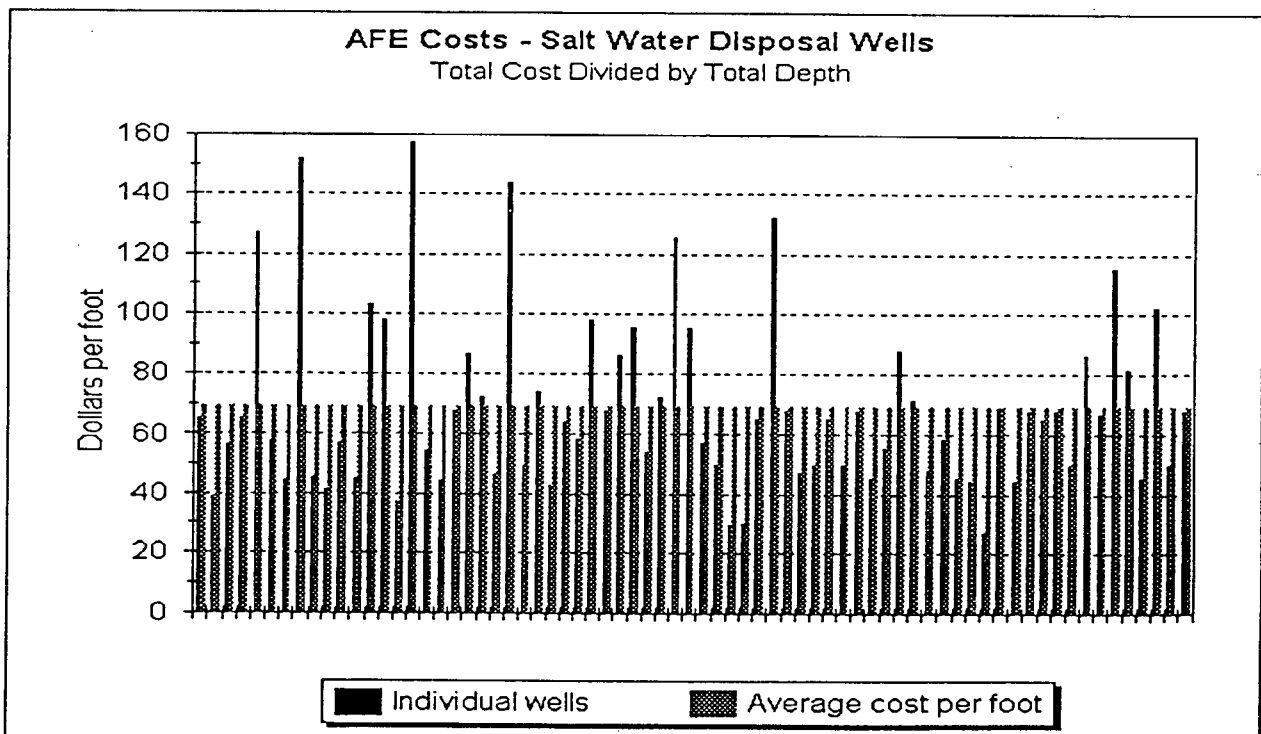


Table 4

Estimated Costs to Drill and Complete Salt Water Disposal Wells in Louisiana  
Based on Public Documents at the Louisiana Department of Natural Resources\*

WELL SERIAL	WELL NAME	DATE OF AFE	PARISH	FIELD	DEPTH	AFE AMOUNT	\$/ft
52823	CAM RB SUA	3/94	Acadia	Ellis	3000	\$195,700	\$65.23
71586	SL 3035	2/95	Plaquemines	Saturday Island	4500	\$174,000	\$38.67
82025	NS SUF	9/94	Acadia	Ellis	3000	\$170,000	\$56.67
86138	E M ANDERSON	9/94	Lafayette	Duson	3000	\$195,700	\$65.23
117939	PREN 2 RB SUA	2/95	Terrebonne	Houma	1200	\$152,000	\$126.67
125809	FORESTIER SUB	5/95	Lafayette	Vatican	2500	\$143,920	\$57.57
133600	WLPE 41 7600 SU	1/91	Terrebonne	W Lk Pontchartrain	9250	\$412,500	\$44.59
144551	VUA; ARLITT SL 3382	12/93	Plaquemines	SP24	4000	\$607,662	\$151.92
150168	HOSS C RA SUC	4/95	Ouachita	Cheniere Creek	4000	\$183,000	\$45.75
151237	L HACK RB SUB	4/95	Calcasieu	Sulphur Mines	2200	\$91,400	\$41.55
157782	5300 RA VUA	7/95	Cameron	Little Chenier	5000	\$285,100	\$57.02
158143	VUC; IRIS MAGEE	11/94	Cameron	Big Lake	2000	\$89,900	\$44.95
159374	ST MARY PAR LAND	7/95	St. Mary	Bayou Sale	3100	\$319,500	\$103.06
159964	SL 2918	3/94	St. Charles	W Lk Pontchartrain	5300	\$518,550	\$97.84
164583	U WX RA SUB	9/93	Allen	Lyles	3500	\$130,150	\$37.19
171326	VUA;LL&E	10/93	Plaquemines	Drakes Bayou	2000	\$315,000	\$157.50
183055	VUA; PERSLEY	10/92	Desoto	Persley	1400	\$76,925	\$54.95
184365	CAM 1 RD SUA	8/95	Calcasieu	Lake Charles South	2500	\$111,500	\$44.60
184611	LL&E FEE	12/94	Terrebonne	Salt Bay	5700	\$386,000	\$67.72
186454	CIB J 2 RA SUA	4/94	Jefferson Davis	Lake Arthur	1440	\$125,000	\$86.81
187477	9000 RA SUA	8/95	Vermilion	Tigre Lagoon	2350	\$170,500	\$72.55
189755	DISC 15 RE SUA	6/95	Iberia	E Bayou Pigeon	4700	\$218,708	\$46.53
193744	10 RA SUA	12/94	Terrebonne	Bayou Junop	4000	\$574,805	\$143.70
195949	VUA;L A COWLEY	6/88	Bossier	Elm Groove	3000	\$148,200	\$49.40
197776	LL&E	8/93	Terrebonne	Bayou Jean La Croix	3000	\$222,150	\$74.05
198612	C R JAMES	10/90	Beauregard	S Bear Head Creek	3700	\$159,600	\$43.14
201146	DISC 12 RE SUA	12/93	Plaquemines	Bastian Bay	4200	\$270,500	\$64.40
201155	FJ RB SUA	8/90	Lafayette	Maurice	4200	\$247,000	\$58.81
202536	VUA;SL 11982	8/94	Jefferson	W Lk Pontchartrain	5300	\$518,550	\$97.84
202864	VUA;LL&E T	7/94	Lafourche	Bayou Raphael	5700	\$386,000	\$67.72
204577	9600RASUA;SL 2383	11/94	Jefferson	Little Lake	3800	\$326,800	\$86.00
204983	11050 RA SUA	3/95	Terrebonne	Bayou Rambio	3000	\$285,500	\$95.17
205738	AVERY ISL. INC	8/94	Iberia	Avery Island	4800	\$259,820	\$54.13
205793	Y 1 RA SUA	1/94	Calcasieu	SE Lunita	5000	\$362,500	\$72.50
207304	9900 RA VUA	6/95	St. Charles	Lke Pontchartrain	2500	\$313,600	\$125.44
207371	VUB;KYLE	1/95	Iberia	Bayou Pigeon	3000	\$285,500	\$95.17
207955	SONAT MINERALS	2/95	Calcasieu	Lunita	4000	\$229,425	\$57.36
208660	MARG H RA SUB	2/95	Cameron	SW Lake Arthur	3000	\$150,000	\$50.00
208748	U SMK RA SUA	5/95	Union	Tick Creek	2500	\$74,250	\$29.70
209975	VUA;DUPUY LAND	6/95	Avoyelles	Five Mile Bayou	4000	\$120,490	\$30.12
210133	NB 2 RB SUA	1/95	Acadia	Branch	3250	\$212,000	\$65.23
211435	HET 3 RB SUB	6/94	Acension	Darrow	2750	\$362,600	\$131.85
211632	28 A RA VUA	12/94	Plaquemines	Bay Baptiste	5700	\$386,000	\$67.72
211653	M HOFFPAUIR	8/95	Acadia	Crowley	2500	\$119,200	\$47.68
211827	U WX RA SUB	2/95	East Baton Rouge	Port Hudson	3200	\$160,773	\$50.24
211940	A WILBERT SONS	9/95	Iberville	Bayou Sorrel	3000	\$195,700	\$65.23
212791	U WX RA SUC	12/93	East Barton Roug	Port Hudson	3200	\$160,863	\$50.27
213513	BIG B 1 RA SUA	5/94	Plaquemines	Lake Washington	5700	\$386,000	\$67.72
213781	REALITY RA SUA	1/95	Terrebonne	Crescent Farms	4000	\$183,000	\$45.75
213902	KBR RA VUA	12/93	Terrebonne	Houma	3900	\$218,000	\$55.90
213931	A BROUSSARD	2/94	Vermilion	Bayou Hebert	4000	\$350,000	\$87.50
214037	NS 1 RB SUA	9/94	Acadia	Church Point	2500	\$179,000	\$71.60
214190	ROBU 6 RA SUA	11/94	St. James	Lower Vacherie	4500	\$216,850	\$48.19
214256	VUA; CL&F	6/93	Terrebonne	W Deer Island	2500	\$147,000	\$58.80
214369	14700 RC SUA	6/95	Acadia	S Mermentau	3500	\$159,715	\$45.63
214384	AUS RA SUB	9/95	Avoyelles	N Bayou Jack	5000	\$222,860	\$44.57
214428	VUA;V M VINCENT	5/95	Vermilion	Riceville	3500	\$95,500	\$27.29
214668	L TUSC RB SUA	7/94	Livingston	Beaver Dam Creek	3800	\$261,000	\$68.68
214712	MARG 1 RB SUA	9/95	St. Martin	Section 28	2500	\$111,500	\$44.60
215368	10400 RC SUA	12/94	Terrebonne	Bay Baptiste	5700	\$386,000	\$67.72
215432	TEX W 1 RB SUA	8/95	Terrebonne	Lake Boudreaux	2600	\$170,500	\$65.58
215941	CAM 2 RB SUA	3/95	Calcasieu	Bell City	2500	\$170,000	\$68.00
216467	VUA; WALKER	9/95	Calcasieu	Holmwood	3000	\$151,020	\$50.34
216632	RUTHERFORD	11/94	Cameron	Hog Bayou	3800	\$326,800	\$86.00
216785	SP A RB SUA	6/94	Pointe Coupee	Bayou Gross Tete	3500	\$235,000	\$67.14
216818	SL 508	9/95	Plaquemines	Potash	4000	\$460,550	\$115.14
216843	6400 RA SUA	7/95	Cameron	Little Cheniere	3000	\$245,000	\$81.67
216918	TEX W5 RC SUA	8/95	Terrebonne	Lake Page	4000	\$183,000	\$45.75
217250	OPERC RA SUA	7/95	St. James	Hester	2500	\$254,653	\$101.86
217922	CV RA SU66	10/95	Caddo	Elm Grove	3000	\$150,000	\$50.00
218210	LL&E FEE A	12/94	Plaquemines	Bastian Bay	5700	\$386,000	\$67.72

Average Depth = 3,666 Average Cost per foot \$69.58

\* From permit applications for annular disposal of produced water; AFE's are contained in applications for comparative purposes

## CONCLUSIONS

Using averages, of the estimated 1.2 billion barrels of water generated annually by oil and gas operations within the state of Louisiana between the year of 1990 through 1993, approximately 60% was injected downhole and 40% was discharged into surface waters. Using an average cost of downhole injection of \$0.025/bbl, approximately \$18 million was spent, on average, annually between 1990 and 1993 injecting water in Louisiana. The remaining water was discharged to surface waters.

North Louisiana injected 100% of their produced water while generating 25% of the total water and 21% of the total hydrocarbons and south Louisiana injected 49% and discharged 51% of their produced water while generating 75% of the total water and 79% of the total hydrocarbons, Figure 12.

North Louisiana will be affected little, if none, by these regulations, since they already have an injection system able to handle affectively 100% of their produced water needs.

For the coming years, most notably 1995 through 1998, the above numbers should be tracked closely. North Louisiana should continue on trend with no notable changes. South Louisiana, on the other hand, should show drastic trend changes, especially from its shallow production. Hydrocarbon production in south Louisiana is expected to be affected severely by the zero discharge regulations of the present and future years.

This is also a challenge for the bright innovators among us to design a method for cleaning produced water sufficiently for surface discharge, confirming it causes no adverse affects to the environment and convincing the regulators that this very economical manner of disposing of produced water is just as valid a method as subsurface disposal.

FIGURE 12

