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Downhole Oil/Water Separators - What's New?

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INTRODUCTION

The U.S. Department of Energy's (DOE's) National Petroleum Technology Office is interested in new technologies that can bring oil to the surface at a lower cost or with less environmental impact. DOE is particularly interested in technologies that can accomplish both of these goals, and downhole oil/water separators (DOWS) seem to achieve that. They have the potential to reduce operating costs while providing a greater degree of environmental protection. DOE learned of the innovative DOWS technology and funded a team from Argonne National Laboratory, CH2M Hill (a private-sector consulting firm), and the Nebraska Oil and Gas Conservation Commission (a state agency) to conduct an independent evaluation of the technical feasibility, economic viability, and regulatory applicability of the DOWS technology. The results of that investigation were published in January 1999 (Veil et al. 1999a) and represent the most complete publicly available reference material on DOWS technology (the full text of the report can be downloaded from Argonne's website at www.ead.anl.gov). Other abbreviated versions of this information have been published during the past year (Veil et al. 1999b, 1999c).

Last January, in the 1999 Produced Water Seminar, I provided an overview of the DOWS technology. For the 2000 Produced Water Seminar, I am providing updated information on DOWS and related technologies. To set the stage for the new information, the next few sections provided a review of previously reported information.

BACKGROUND

Review of DOWS Technology

DOWS technology reduces the quantity of produced water that is handled at the surface by separating it from the oil downhole and simultaneously injecting it underground. A DOWS system includes many components, but the two primary ones are an oil/water separation system and at least one pump to lift oil to the surface and inject the water. Two basic types of DOWS have been developed – one type using hydrocyclones to mechanically separate oil and water and one relying on gravity separation that takes place in the well bore.

Hydrocyclones use centrifugal force to separate fluids of different specific gravity without any moving parts. A mixture of oil and water enters the hydrocyclone at a high velocity from the side of a conical chamber. The subsequent swirling action causes the heavier water to move to the outside of the chamber and exit through one end, while the lighter oil remains in the interior of the chamber and exits through a second opening. The water fraction is then injected and the oil fraction is pumped to the surface. Hydrocyclone-type DOWS have been designed with electric submersible pumps, progressing cavity pumps, and rod pumps. Most of the development work on this type of DOWS was done through several joint industry projects by a Canadian organization, CFER-Technologies.

Gravity separator-type DOWS are designed to allow the oil droplets that enter a well bore through the perforations to rise and form a discrete oil layer in the well. A gravity separator tool has two intakes, one in the oil layer and the other in the water layer. The gravity separator-type DOWS use rod pumps. As the sucker rods move up and down the oil is lifted to the surface and the water is injected. The most common gravity separator-type DOWS is the dual-action pumping system (DAPS) developed by Texaco. Over the past year, an improved version that develops greater injection pressure, the triple-action pumping system (TAPS), has been tested (Wacker et al. 1999). The TAPS achieves greater injection pressure by adding a third, bottom plunger that has smaller surface area than the middle plunger. Performance data from the only TAPS yet installed is presented in a later section.

Why Should Operators Install DOWS?

Produced water lifting, treatment, and disposal costs are important components of operating costs. DOWS can save operators money by reducing produced water management costs. In all of the 29 DOWS installations examined by Veil et al. (1999a) that had both pre- and post-installation data, DOWS reduced the volume of water brought to the surface. The percent reduction ranged from 14% to 97%, with most of those installations exceeding 75% reduction in water brought to the surface.

In over half of the North American wells in which DOWS have been installed, the oil production rates increased following the installation. The percent increase in oil production rates ranged from 11% to over 1,100%, although a few wells lost oil production (Veil et al. 1999a). In some cases where surface processing or disposal capacity is a limiting factor for further production within a field, the use of DOWS to dispose of some of the produced water may allow additional production in that field.

DOWS provide a positive but unquantifiable environmental benefit through minimization of the opportunity for contamination of underground sources of drinking water through leaks in tubing and casing during the injection process. Likewise, DOWS minimize spillage of produced water onto the soil at the surface because less produced water is handled at the surface.

Economic Considerations

Nearly all of the DOWS installations to date have been made as retrofits to existing wells with standard pumps. Conversion of a well from a regular pump to a DOWS is a relatively expensive undertaking. Total costs include the cost of the DOWS tool itself and well workover expenses. Veil et al. (1999a) provide limited information on costs, but many of the operators polled by the authors did not provide any detailed cost information.

Costs for the hydrocyclone-type DOWS are high. For example, the cost of an electric submersible pump-type DOWS system is approximately double to triple the cost of replacing a conventional electrical submersible pump and is often in the range of $90,000 - $250,000, excluding the well workover costs, which can often exceed $100,000. Costs are somewhat lower for the gravity separator-type DOWS, ranging from $15,000 - $25,000. The cost of one complete gravity separator-type DOWS installation was $140,000 Canadian (Veil 1999a).

Summary Statistics on DOWS

To date, fewer than 50 DOWS have been installed in the world. Veil et al. (1999a) provide information on the geology and performance of 37 of these installations. Some of the key findings from those installations are summarized below:

- More than half of the installations have been hydrocyclone-type DOWS (21 compared with 16 gravity separator-type DOWS).

- Twenty-seven installations have been in Canada and 10 installations have been in the United States.

- Of the 37 DOWS trials described, 27 have been in four producing areas – southeast Saskatchewan, east-central Alberta, the central Alberta reef trends, and East Texas.

- Seventeen installations were in 5.5-inch casing, 14 were in 7-inch casing, 1 was in 8.625-inch casing, and 5 were unspecified.

- Twenty of the DOWS installations have been in wells located in carbonate formations and 16 in wells located in sandstone formations. One trial did not specify the lithology. DOWS appeared to work better in carbonate formations, showing an average increase in oil production of 47% (compared with an average of 17% for sandstone formations) and an average decrease in water brought to the surface of 88% (compared with 78% for sandstone formations).

- The rate of oil production increased in 19 of the trials, decreased in 12, stayed the same in 2, and was unspecified in 4. The top three performing hydrocyclone-type wells showed oil production increases ranging from 457% to 1,162%, while one well lost all oil production. The top performing well improved from 13 to 164 barrels per day (bbl/day). The top three gravity separator-type wells showed oil production increases ranging from 106% to 233%, while one well lost all oil production. The top performing well in this group improved from 3 to 10 bbl/day.

- All 29 trials for which both pre-installation and post-installation water production data were provided showed a decrease in water brought to the surface. The decrease ranged from 14% to 97%, with 22 of 29 trials exceeding 75% reduction.

What Problems Have Been Experienced

Although most of the DOWS installed to date have worked well, some of the installations have experienced problems. The problems can be broken down into several major categories, as noted below:

- Some installations were poorly chosen or designed. Some operators didn't want to risk damaging good performing wells with a new device and selected less than optimal candidate wells. Particularly in the earliest installations, many of the design flaws had not been worked out. Subsequent models avoided some of these flaws.

- Some installations did not allow a suitable difference in depth between the producing and the injection interval. If isolation between the intervals is not sufficient, the injectate can migrate into the producing zone and then short-circuit into the producing perforations. The result will be recycling of the produced water, with oil production rates dropping to nearly zero.

- Two installations suffered from low injectivity of the receiving zone; in both cases, incompatible fluids contacted sensitive reservoir sands, which plugged part of the permeability.

- Several installations suffered from corrosion or scaling. This problem may be a result of incompatible chemistry between the producing and injection formations.

- Several other installations had problems with excessive sand collection that either clogged or eroded the DOWS.

Regulatory Issues

Traditional produced water disposal wells are considered to be Class II injection wells under the U.S. Environmental Protection Agency's (EPA's) Underground Injection Control program. EPA's definition of Class II wells is "wells which inject fluids: (1) which are brought to the surface in connection with conventional oil or natural gas production....; (2) for enhanced recovery of oil or natural gas; ...." In the case of DOWS, the separated produced water is directly injected to a formation near the producing zone without ever coming to the surface. Operators are concerned that the Class II definition might not apply to wells with DOWS and that they might be subject to regulatory requirements for another class of injection wells. This issue has been presented to the EPA and is being studied by a workgroup of EPA regional experts. The workgroup has not yet published final guidance on this matter.

Because the technology is still new, no regulatory requirements for DOWS exist in many jurisdictions. Even though EPA has no specific requirements, five states (Colorado, Oklahoma, Louisiana, Texas, and Kansas) have developed either regulations or administrative guidelines for DOWS. Those states regulate DOWS with requirements comparable to or less stringent than those for regular Class II injection wells.

UPDATE FOR THE PAST YEAR

The past year has been dismal for the expansion of DOWS. To the author's knowledge, only two DOWS were installed in the United States in 1999. From late 1998 through the middle of 1999, oil prices reached near historic lows, and operators were not willing to spend scarce capital on new technologies. In early 1999, there were three primary U.S. vendors for DOWS. By the end of the year, one vendor has stopped marketing DOWS and a second vendor has reduced its marketing efforts substantially.

Texaco has been a leader in developing the gravity separator-type DOWS, including the DAPS and the TAPS. During the past year, however, Texaco management has changed its research focus, and several of its DOWS researchers have either retired or have been reassigned to non-DOWS activities.

In spite of the overall lack of success, several positive actions have taken place during the past year or are ongoing. These are described below.

DOE Funds Available for DOWS

In 1998, DOE transferred funds to Argonne National Laboratory to use to partially defray the costs of up to six DOWS installations. In exchange for the DOE funds, operators would provide performance details on the well for six months following installation. Argonne attempted to spread the word that these funds (typically \$15,000 to \$25,000 per installation) were available, but through December 1999, only one company, Texaco, has taken the DOE funds for a field trial. DOE and Argonne are eager to find other qualified candidates to take advantage of these funds. Interested parties should contact the author.

The Texaco TAPS Installation

Texaco installed a TAPS system on the Bilbrey 30 - Federal No. 5 well in the Lost Tank Delaware field near Hobbs, New Mexico in January 1999. The well's producing zone was at 4,780 feet and the injection zone was at 5,100 feet. Wacker et al. (1999) note that the well was a good candidate for several reasons:

- The well was fairly new, with casing strong enough to withstand high injection pressure.

- The well was already completed to deeper zones that later proved to be uneconomical to produce; nevertheless, rods and pumping units that were sturdier than needed were already in place.

- The well had dedicated tanks, a pumping controller, and no other partners.

Before the TAPS was installed, the well was producing 17 bbl/day of oil and 190 bbl/day of water to the surface. Because all water had to be hauled off the site by truck, operation of this well was no longer economical. Following TAPS installation, the volume of water brought to the surface decreased greatly; however, some produced water still came to the surface. Texaco devised a siphon tube to reintroduce that water back to the well, thereby returning 100% of the water to the formation. Table 1 provides daily measurements from the TAPS installation for a seven-month period of the volume of oil, water, and gas brought to the surface, the volume of water injected, the volume of water returned to the well by the siphon tube, and the injection pressure.

The long-term performance of the well for (1) all days beginning with TAPS installation (January 19) through August 30 and (2) for all days excluding those in which both oil and water production to the surface is zero[1] (indicated by brackets) is as follows:

- The average oil production was 7 bbl/day [7 bbl/day].

- The average water production to the surface was 77 bbl/day [84 bbl/day].

- The average injected water volume was 84 bbl/day [91 bbl/day].

- The average net water to the surface was 42 bbl/day [45 bbl/day].

Although oil production declined from 17 to 7 bbl/day (59% decrease), net water production to the surface declined from 190 to 42 bbl/day (88% decrease).

The oil production and net water production data are plotted in Figure 1. Throughout most of March and May, no produced water had to be trucked away from this well because all water was either injected by the TAPS or reintroduced to the well by the siphon tube. On some days, the well experienced a net loss of water at the surface as more water than was produced was reintroduced from the aboveground water storage tanks by the siphon tube.

[1] If neither oil nor water is brought to the surface on a particular day, one can assume that the TAPS was not operating that day.

The original TAPS stopped working on two occasions. Texaco determined that the problem was a damaged valve assembly. Following the second recurrence of the problem, Texaco substituted a heavier valve assembly (Wacker et al. 1999). The Texaco engineers involved with this project planned long-term experimentation with the TAPS installation. However, in early fall 1999, Texaco management decided to sell the well, and the TAPS was removed.

Instrumentation Experiment

Some state regulatory agencies have required that DOWS installations include downhole monitoring devices for flow and pressure. These devices can be quite expensive, adding tens of thousands of dollars to the cost of a DOWS installation. During the summer of 1999, Argonne received funding from DOE to install downhole and surface pressure and flow measuring devices on a DOWS. Before Argonne received the DOE funding, Texaco had offered its TAPS installation as a location on which to conduct the experiment. The purpose of the experiment was to develop a correlation between downhole and surface measurements, so that regulatory agencies would be more comfortable that surface measurements were providing accurate information about downhole conditions.

As noted above, Texaco no longer has its TAPS installation. Argonne was not able to conduct the planned experiment and is now seeking another company that is willing to host it. Any interested companies should contact the author.

Unocal DOWS Data

In late 1998, Unocal installed a DOWS system in a well near Van, Texas. At the 1999 Produced Water Seminar, Unocal's Ted Frankiewicz described this installation and showed some of the early performance data. He did not include the data in his written paper. Argonne and Unocal have recently signed a legal agreement so that Argonne will gain access to Unocal's DOWS performance data in exchange for analyzing the data. Argonne hopes to be able to share some of the data from this well in the future.

OTHER RELATED TECHNOLOGIES

Downhole Gas/Water Separators

Veil et al. (1999) evaluated downhole *oil*/water separators exclusively. Several companies have marketed similar devices for downhole *gas*/water separation. The Gas Research Institute (GRI) funded Radian International Corporation to prepare a "consumer guide" to downhole gas/water separation. The study is expected to be released in CD format by early 2000. Information on the study can be found on GRI's website at www.gri.org.

Downhole Water Sink

Oil production can decline in a well because water forms a cone around the production perforations, limiting the volume of oil that can be produced. A technology developed at Louisiana State University (LSU), the downhole water sink, combats this problem by using dual completions in the same well. The primary completion is made at a depth corresponding to strong oil production, and a secondary completion is made lower in the interval, at a depth with strong water production. The two completions are separated by a packer. The water collected below the packer is pumped into a lower injection zone. The technology is described by Wojtanowicz and Xu (1995) and on the Petroleum Technology Transfer Council's website at http://www.pttc.org/ts/ts_020.html. Andrew Wojtanowicz of LSU is coordinating a joint industry project to further develop this technology.

WHAT DOES THE FUTURE HOLD?

DOWS technology and the related technologies described above make a lot of sense in settings where they can be employed cost-effectively. Much of the oil and gas industry remains shell-shocked by last year's low oil prices and may be reluctant in the near-term to spend capital resources on relatively new technologies to prolong the life of small-to-medium sized wells. The major U.S. producers tend to be focusing their efforts on potential large plays in the offshore or overseas. The independent producers are capital-poor. If oil prices remain high through the first half of 2000, interest in cost-saving technologies like DOWS should increase.

Offshore DOWS

To date, all DOWS installations have been in onshore wells. A few years ago, several companies joined forces in a joint industry project (JIP) to develop an offshore DOWS. Little activity has occurred through the JIP during the past year. However, according to a representative of a DOWS vendor, his company plans to make two offshore installations in the next year, in China and Egypt (Shaw 1999).

In the United States, DOE awarded a large grant to Venoco, Inc., a southern California offshore producer, to conduct a pilot application using downhole water separation units attached to electric submersible pumps for improving field economics and minimizing water disposal in the South Ellwood Field, offshore Santa Barbara, California.

Centrifugal DOWS

Researchers at Oak Ridge National Laboratory have received funding from DOE to modify a centrifugal separator used in the nuclear industry for downhole oil/water separation. Oak Ridge has developed a bench-scale prototype but has not tested the device in any wells (Walker and Cummins 1999).

ACKNOWLEDGMENTS

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Table 1- TAPS Performance Data

Date	Oil to Surface (bbl)	Water to Surface (bbl)	Injected Water - Calculated (bbl)	Water Returned to Wellbore (bbl)	Net Water at Surface (bbl)	Gas to Surface (mcfg)	Injection Pressure (psig)
1/20/99	3	55	116		55	0	
1/21/99	3	61	98		61	0	
1/22/99	0	63	113		63	0	
1/23/99	0	58	97		58	0	
1/24/99	0	52	93		52	0	
1/25/99	0	58	98		58	0	
1/26/99	0	56	96		56	0	
1/27/99	0	56	95		56	0	
1/28/99	0	53	85		53	0	
1/29/99	0	55	95		55	0	
1/30/99	6	27	100		27	0	
1/31/99	8	30	95		30	0	
2/1/99	11	47	95		47	0	
2/2/99	33	47	95		47	0	
2/3/99	11	31	96		31	0	
2/4/99	11	41	90		41	0	
2/5/99	14	36	97		36	0	
2/6/99	8	33	96		33	0	
2/7/99	11	47			47	0	
2/8/99	11	41	94		41	0	
2/9/99	11	39	163		39	0	
2/10/99	14	52	143		52	0	
2/11/99	19	46	139		46	0	
2/12/99	14	63	131		63	0	
2/13/99	14	70			70	0	
2/14/99	14	50	120		50	0	
2/15/99	17	58	120		58	0	
2/16/99	17	52	120		52	0	
2/17/99	14	50	120		50	0	
2/18/99	17	61	120		61	0	
2/19/99	14	47	120		47	0	
2/20/99	14	58	120		58	0	
2/21/99	11	62	120		62	0	
2/22/99	6	31	167		31	0	
2/23/99	6	30	167		30	0	
2/24/99	8	64	167		64	0	
2/25/99	11	65	167		65	0	
2/26/99	11	65	167		65	0	
2/27/99	11	68	167		68	0	
2/28/99	8	63	167		63	0	
3/1/99	8	38	167		38	0	
3/2/99	11	62	147	70	-8	0	NA
3/3/99	11	71	142	70	1	0	NA
3/4/99	8	60	140	70	-10	0	NA
3/5/99	14	72	142	70	2	0	NA
3/6/99	11	65	142	70	-5	0	NA
3/7/99	11	65	132	70	-5	0	NA
3/8/99	8	66	133	70	-4	0	NA
3/9/99	8	56	133	70	-14	0	-474
3/10/99	11	67	135	70	-3	0	NA
3/11/99	14	72	135	72	0	0	NA
3/12/99	11	72	231	64	8	0	NA
3/13/99	6	58	225	52	6	0	NA
3/14/99	11	60	135	54	6	0	NA
3/15/99	14	68	155	65	3	0	NA
3/16/99	11	43	115	54	-11	0	-567
3/17/99	5	70	119	64	6	0	NA
3/18/99	6	75	135	67	8	0	NA
3/19/99	6	63	135	60	3	0	-778

Table 1- TAPS Performance Data

Date	Oil to Surface (bbl)	Water to Surface (bbl)	Injected Water - Calculated (bbl)	Water Returned to Wellbore (bbl)	Net Water at Surface (bbl)	Gas to Surface (mcfg)	Injection Pressure (psig)
3/20/99	5	76	135	73	3	0	NA
3/21/99	8	69	135	69	0	0	NA
3/22/99	11	68	135	71	-3	0	-618
3/23/99	3	68	131	71	-3	0	-295
3/24/99	6	68	135	63	5	0	NA
3/25/99	8	61	90	64	-3	0	NA
3/26/99	6	68	135	62	6	0	NA
3/27/99	6	72	135	72	0	0	NA
3/28/99	3	69	135	69	0	0	NA
3/29/99	5	76	135	73	3	0	NA
3/30/99	6	71	135	71	0	0	NA
3/31/99	6	78	135	78	0	0	NA
4/1/99	8	70	135	67	3	0	-384
4/2/99	0	63	120	0	63	1	NA
4/3/99	11	66	123	0	66	1	NA
4/4/99	14	50	123	0	50	1	-796
4/5/99	11	53	123	0	53	1	-651
4/6/99	11	55	120	0	55	1	NA
4/7/99	6	63	118	0	63	1	NA
4/8/99	8	60	115	0	60	0	NA
4/9/99	8	72	115	0	72	0	NA
4/10/99	8	58	113	0	58	0	NA
4/11/99	6	66	113	0	66	0	NA
4/12/99	8	66	111	0	66	0	-609
4/13/99	6	66	111	0	66	0	NA
4/14/99	6	77	108	0	77	0	NA
4/15/99	6	66	108	0	66	0	NA
4/16/99	6	74	106	0	74	0	NA
4/17/99	3	72	106	0	72	0	NA
4/18/99	3	72	106	0	72	0	NA
4/19/99	6	72	106	0	72	0	-775
4/20/99	3	69	101	0	69	0	NA
4/21/99	22	63	0	74	-11	1	NA
4/22/99	3	91	0	80	11	0	NA
4/23/99	8	85	0	82	3	0	NA
4/24/99	0	95	0	78	17	0	NA
4/25/99	0	89	0	75	14	0	NA
4/26/99	0	91	0	77	14	0	NA
4/27/99	0	44	0	83	-39	0	NA
4/28/99	0	0	0	0	0	0	NA
4/29/99	0	0	0	0	0	0	NA
4/30/99	0	0	0	0	0	0	NA
5/1/99	0	0	0	0	0	0	NA
5/2/99	0	0	0	0	0	0	NA
5/3/99	0	0	0	0	0	0	NA
5/4/99	0	0	0	0	0	0	NA
5/5/99	0	0	0	0	0	0	NA
5/6/99	0	0	0	0	0	0	NA
5/7/99	0	0	0	0	0	0	NA
5/8/99	0	0	0	0	0	0	NA
5/9/99	0	0	0	0	0	0	NA
5/10/99	0	0	0	0	0	0	NA
5/11/99	0	8	0	85	-77	0	NA
5/12/99	0	7	0	86	-79	0	NA
5/13/99	0	0	0	0	0	0	NA
5/14/99	0	52	154	0	52	0	NA
5/15/99	0	55	132	0	55	0	NA
5/16/99	0	6	57	0	6	0	NA
5/17/99	0	14	24	14	0	0	NA

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Date	Oil to Surface (bbl)	Water to Surface (bbl)	Injected Water - Calculated (bbl)	Water Returned to Wellbore (bbl)	Net Water at Surface (bbl)	Gas to Surface (mcfg)	Injection Pressure (psig)
5/18/99	0	59	79	87	-28	0	NA
5/19/99	0	85	154	79	6	0	NA
5/20/99	0	83	161	83	0	0	NA
5/21/99	11	95	184	92	3	0	NA
5/22/99	5	78	184	78	0	0	NA
5/23/99	8	83	184	83	0	0	NA
5/24/99	6	82	183	82	0	0	-563
5/25/99	8	87	183	84	3	0	NA
5/26/99	5	75	174	53	22	0	NA
5/27/99	6	93	164	60	33	0	NA
5/28/99	11	74	177	60	14	1	NA
5/29/99	8	41	171	71	-30	1	NA
5/30/99	5	83	95	69	14	0	NA
5/31/99	11	77	184	74	3	1	NA
6/1/99	8	80	184	80	0	1	NA
6/2/99	8	76	184	0	76	0	NA
6/3/99	12	73	183	67	6	1	NA
6/4/99	11	76	184	65	11	1	NA
6/5/99	8	78	184	64	14	0	NA
6/6/99	8	71	184	55	16	1	NA
6/7/99	11	76	184	65	11	1	-420
6/8/99	11	76	184	62	14	1	NA
6/9/99	11	65	184	7	58	0	NA
6/10/99	11	67	180	75	-8	1	NA
6/11/99	8	79	184	71	8	0	-1062
6/12/99	11	75	184	64	11	0	NA
6/13/99	8	78	184	75	3	0	NA
6/14/99	8	71	184	63	8	0	NA
6/15/99	6	71	184	79	-8	0	NA
6/16/99	6	71	184	71	0	0	NA
6/17/99	6	71	184	71	0	1	NA
6/18/99	14	92	184	95	-3	0	-892
6/19/99	11	73	184	73	0	0	NA
6/20/99	11	67	184	64	3	0	NA
6/21/99	0	56	184	48	8	0	NA
6/22/99	0	0	0	0	0	0	NA
6/23/99	0	0	0	0	0	0	NA
6/24/99	0	0	0	0	0	0	NA
6/25/99	11	256	0	0	256	0	NA
6/26/99	8	284	0	0	284	1	NA
6/27/99	14	286	0	0	286	2	NA
6/28/99	17	273	0	0	273	2	NA
6/29/99	19	299	0	0	299	2	NA
6/30/99	11	206	0	0	206	2	NA
7/1/99	11	228	0	0	228	1	NA
7/2/99	8	248	0	0	248	1	NA
7/3/99	11	182	0	0	182	1	NA
7/4/99	8	221	0	0	221	1	NA
7/5/99	8	204	0	0	204	1	NA
7/6/99	8	195	0	0	195	1	NA
7/7/99	8	193	0	0	193	1	NA
7/8/99	11	209	0	0	209	1	NA
7/9/99	8	173	0	0	173	1	NA
7/10/99	8	188	0	0	188	1	NA
7/11/99	8	187	0	0	187	0	NA
7/12/99	8	193	0	0	193	1	NA
7/13/99	8	179	0	0	179	1	NA
7/14/99	8	190	0	0	190	1	NA
7/15/99	8	202	0	0	202	1	NA

Table 1- TAPS Performance Data

Date	Oil to Surface (bbl)	Water to Surface (bbl)	Injected Water - Calculated (bbl)	Water Returned to Wellbore (bbl)	Net Water at Surface (bbl)	Gas to Surface (mcfg)	Injection Pressure (psig)
7/16/99	8	185	0	0	185	0	NA
7/17/99	8	187	0	0	187	1	NA
7/18/99	8	179	0	0	179	1	NA
7/19/99	8	208	0	0	208	1	NA
7/20/99	8	187	0	0	187	1	NA
7/21/99	3	66	0	0	66	0	NA
7/22/99	0	0	0	0	0	0	NA
7/23/99	3	64	65	86	-22	0	NA
7/24/99	6	70	167	89	-19	0	-961
7/25/99	8	70	172	78	-8	1	NA
7/26/99	6	71	172	74	-3	0	NA
7/27/99	8	66	172	72	-6	0	-825
7/28/99	0	27	153	63	-36	0	NA
7/29/99	3	69	107	36	33	0	NA
7/30/99	5	66	171	74	-8	1	NA
7/31/99	6	73	171	79	-6	1	NA
8/1/99	3	64	171	69	-5	1	NA
8/2/99	5	70	165	70	0	1	NA
8/3/99	6	76	147	54	22	0	NA
8/4/99	5	85	171	58	27	1	NA
8/5/99	6	92	172	59	33	1	NA
8/6/99	5	88	172	77	11	0	NA
8/7/99	8	89	172	67	22	1	NA
8/8/99	8	81	165	59	22	1	-947
8/9/99	3	72	159	64	8	2	NA
8/10/99	6	78	158	64	14	2	-1019
8/11/99	5	85	158	68	17	1	NA
8/12/99	3	63	158	57	6	1	NA
8/13/99	8	74	163	74	0	0	NA
8/14/99	6	80	161	75	5	1	NA
8/15/99	5	66	163	69	-3	0	NA
8/16/99	3	72	158	66	6	1	NA
8/17/99	3	72	158	67	5	1	NA
8/18/99	3	69	154	66	3	1	NA
8/19/99	3	89	168	103	-14	0	NA
8/20/99	2	81	165	78	3	0	NA
8/21/99	6	69	152	66	3	1	-972
8/22/99	3	64	151	64	0	1	NA
8/23/99	3	67	151	64	3	0	NA
8/24/99	11	68	163	62	6	1	NA
8/25/99	3	62	155	59	3	0	NA
8/26/99	2	72	155	66	6	1	NA
8/27/99	3	63	155	60	3	1	NA
8/28/99	3	76	154	71	5	0	NA
8/29/99	0	76	153	70	6	1	NA
8/30/99	0	76	153	70	6	0	NA

Figure 1- TAPS Oil and Net Water Production Data