Safety Performance Review - Shallow Water Flows Can Pose Significant Hazards to Deepwater Drilling

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This technical discussion is intended to share information on an important safety issue. Data included in this article are current as of March 25, 2015.

Since 1984, companies operating in the Gulf of Mexico (GOM) have reported shallow water flow (SWF) events to the BOEM, a phenomenon occurring in water depths generally exceeding 600 feet. SWF events are encountered at depths between a few hundred feet to more than 4,000 feet below the mudline (BML). To date, SWF events have been reported in 163 wells (Appendix A). The average water depth and the average depth BML in which SWF events have been encountered is displayed in Figure 1.

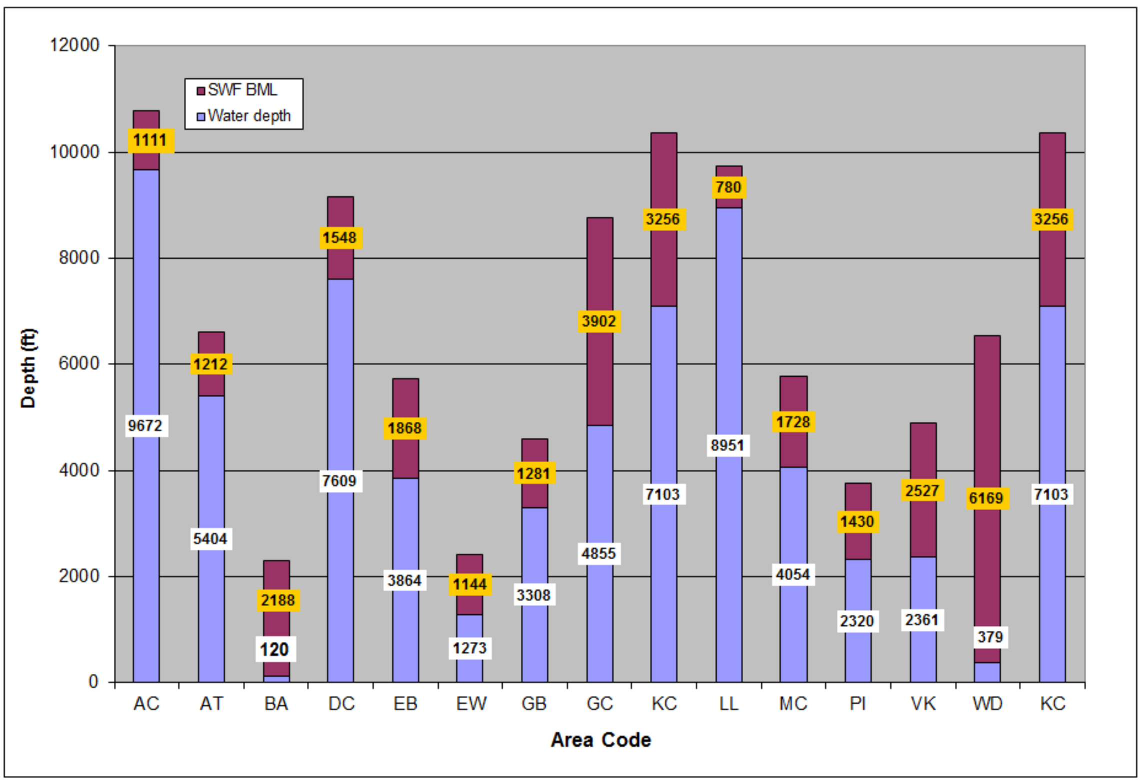

Figure1. Average water depth and average depth BML of SWF Events

Shallow water flow events occur in abnormally pressured shallow sands as a result of rapid sediment deposition, rapid slumping, rotating fault blocks, or reworked cut-and-fill channels sealed by impermeable mud or clay. Regional interpretations of depositional settings, facies, and sediment accumulation rates, allow shallow hazard reviewers to identify areas that are susceptible to SWF events (Figures 2 & 3).

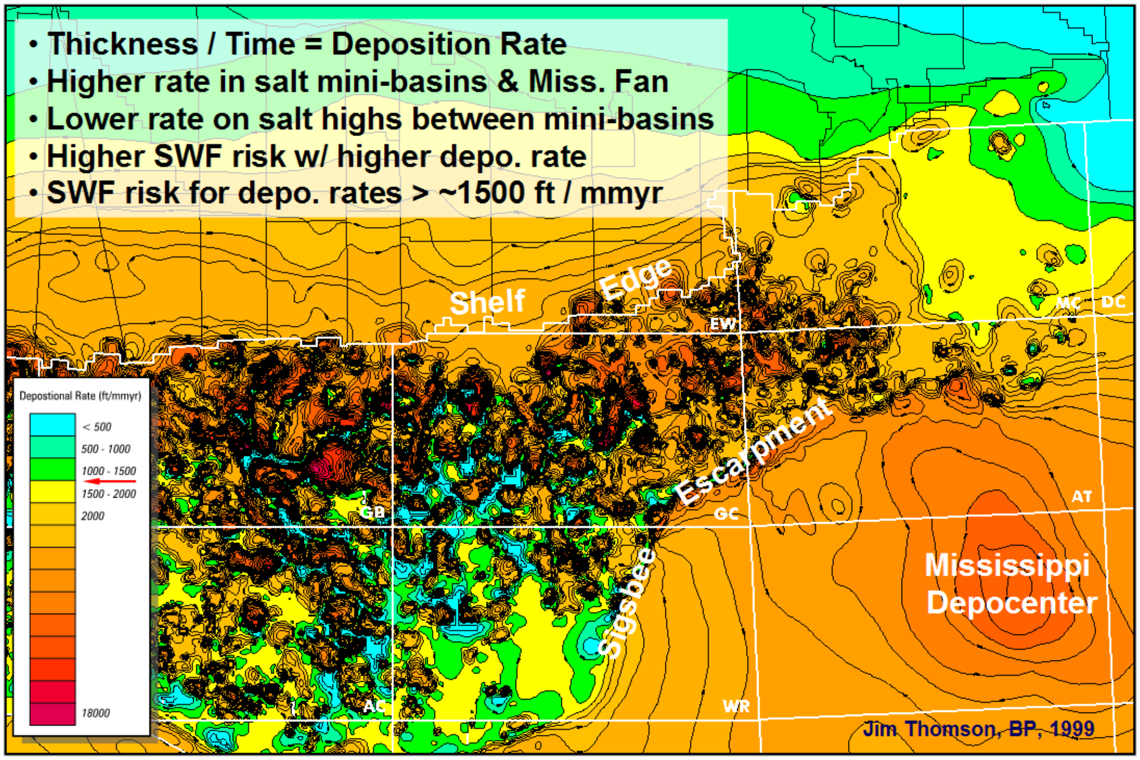

Figure 2. Average deposition rate map: Seafloor to Ps60 Reflector (0 to 1.3 Ma).

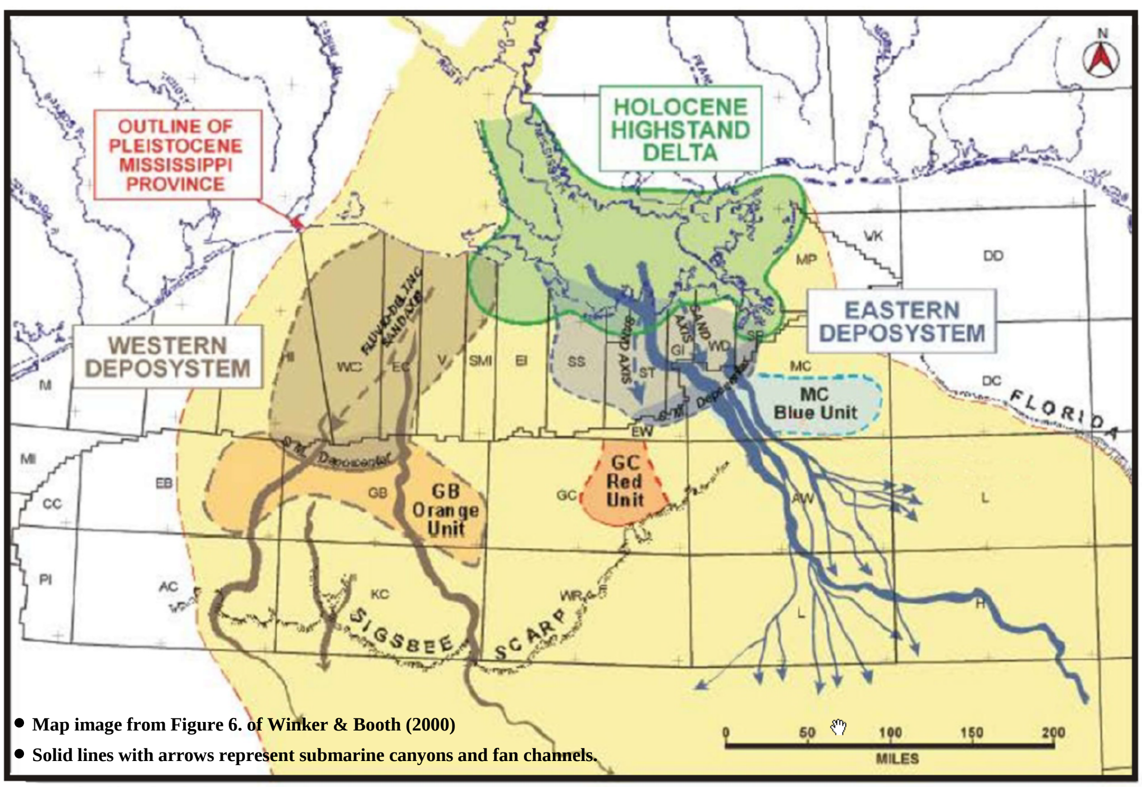

Figure 3. Map of late Pleistocene Mississippi River deposystems and SWF prone lowstand sands.

In rare cases, the disassociation of hydrates during oil production could be a source of SWF. Incidents of SWF are by far the greatest in the GC and MC protractions (Figure 4).

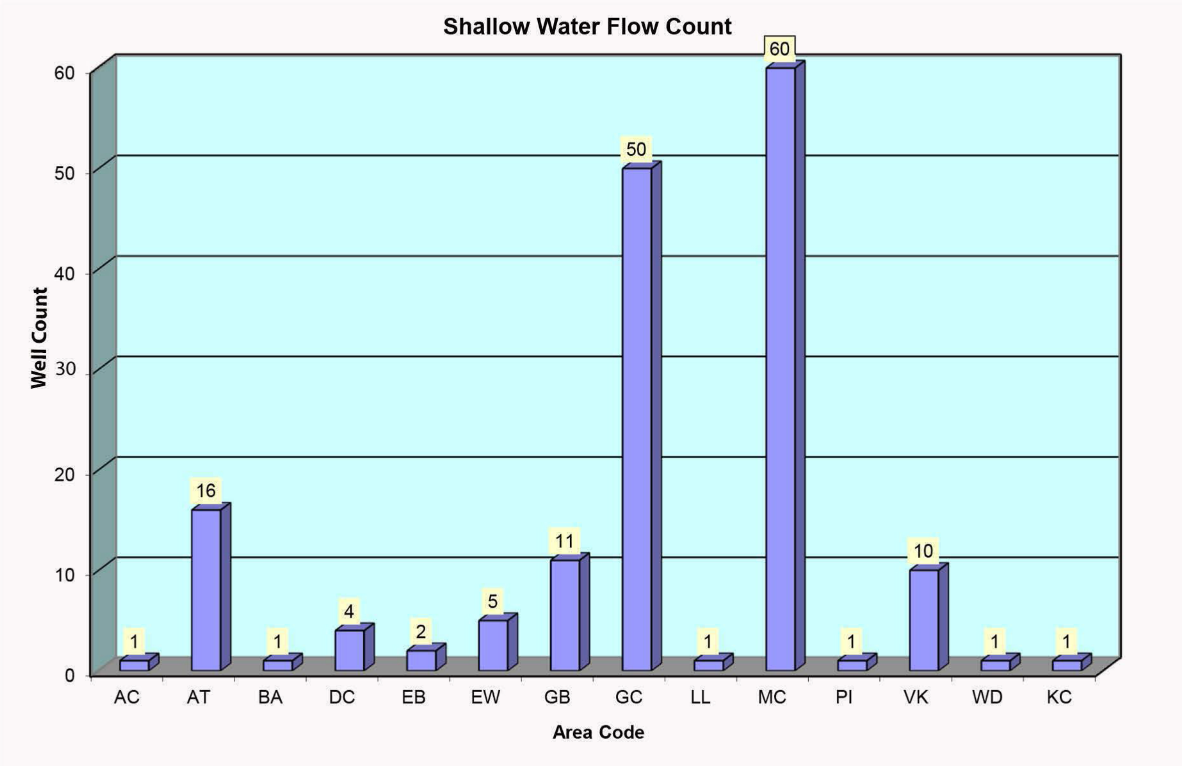

Figure 4. Shallow water flow count by area.

Shallow water flow events can threaten human safety and the environment while causing significant economic loss. Federal regulation 30 CFR 250.415 (Appendix B) requires operators to provide a statement of how they evaluated the best practices contained in API RP 65 (Appendix C) for cementing SWF zones in deep water where SWF potential is unknown or known. An example of Shell's site specific procedure for controlling SWFs is provided in Appendix D. SWF events can cost the operator additional time and money while the driller attempts to maintain control of the well and resume drilling. In some cases, the operator may have to permanently plug and abandon the well. Water flowing around the well annulus will deposit sand or silt on the seafloor within a few hundred feet of the wellhead. Although a typical, when gas is associated with a SWF, gas hydrates will form on the flat surfaces of seafloor drilling equipment. Losing time and millions of dollars encouraged the major operators to study this phenomenon. Video tapes from remotely operated vehicles (ROV) document the flow at the seafloor (Video 1). Electric logs, temperature logs, pressure logs, and geotechnical data from test wells, combined with high-resolution 3D seismic surveys, 2D high-resolution seismic surveys, or reprocessed conventional 3D surveys, are essential to properly identifying the source of the problem and refining a geologic model to determine the mechanism of SWF.

The Deep Star Consortium and Energy Research Clearing House (ERCH) previously compiled detailed information about SWFs and made some of the data available on CD. Since 2004, operators have utilized the Bureau of Safety and Environmental Enforcement's (BSEE) e-Well Permitting and Reporting System to report any significant well problems including SWF. Additionally, BOEM has contacted major oil companies in an effort to update the SWF database. The SWF map of the Gulf of Mexico (Appendix E) displays SWF blocks and wells with severity annotated by color code and depth below the mud line in feet. This classification was suggested by British Petroleum's geohazards group and adopted by the BOEM geohazard group (Figure 6).

Video 1: ROV Video, courtesy of LLOG, documenting SWF at the seafloor.

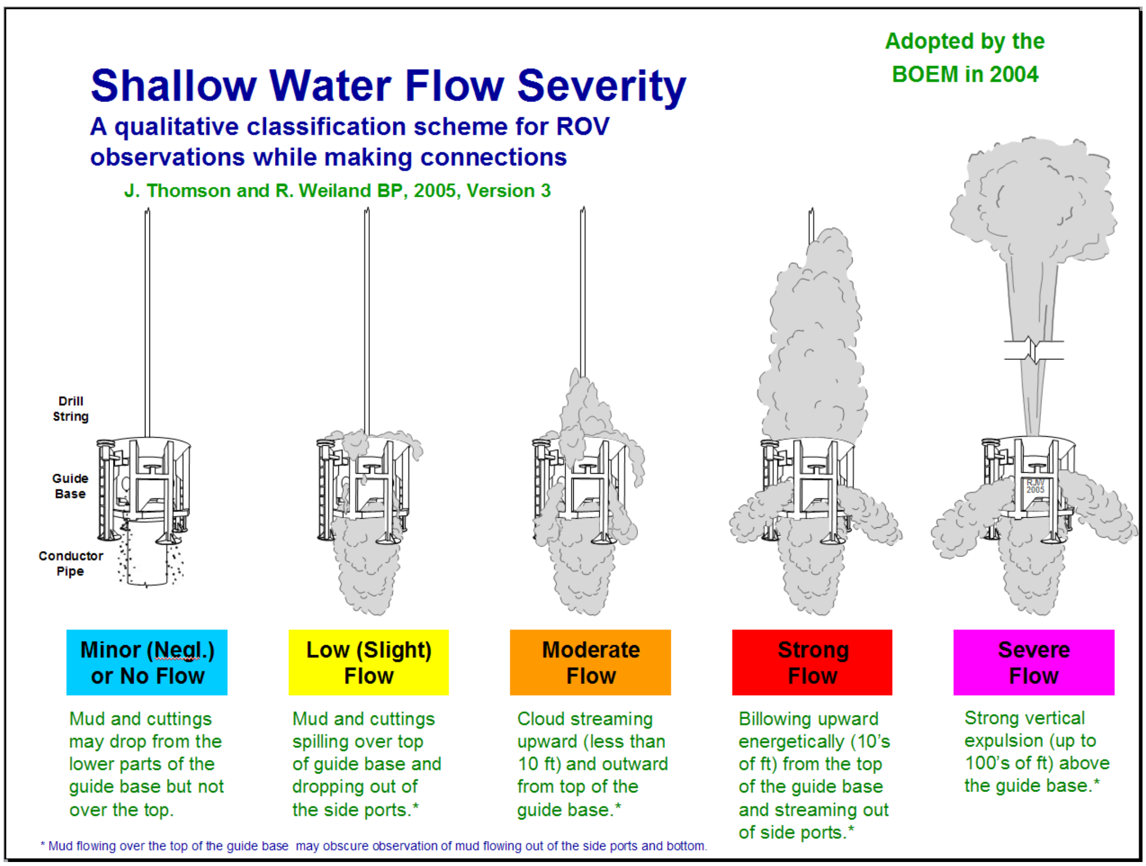

Figure 6. SWF Severity classification.

The classification is based on the height of the uncontrolled SWF flow above the wellhead monitored by ROV. Severity varies from minor to severe. The relationship between SWF count, average severity, and number of wells lost to SWF for each GOM area is displayed in Figure 7.

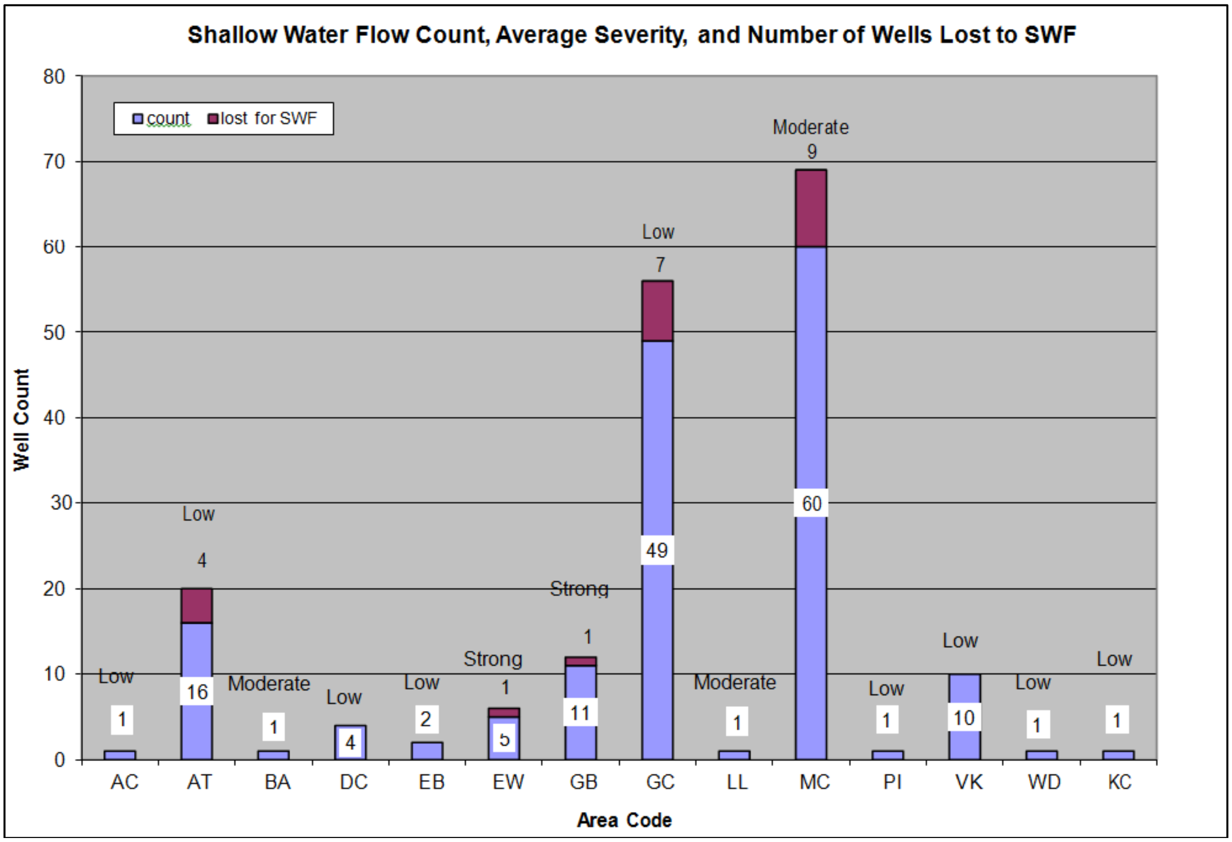

Figure 7. SWF count, average severity, and number of wells lost to SWF.

When the severity of the SWF was not reported, it was classified as Low. These maps and files will be updated annually to assist operators in identifying potentially hazardous areas, so that they may take the appropriate drilling precautions.

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Acknowledgment

Pierre Abadie, Geologist, for the technical support in creation of the map and associated files.

References

Winker, C.D., and Booth, J.R., 2000. Sedimentary dynamics of the salt-dominated continental slope, Gulf of Mexico: integration of observations from the seafloor, near-surface, and deep subsurface. *Deep-Water Reservoirs of the World: Proc. GCSSEPM 20th Annual. Res. Conf.,* 1059–1086.

Appendix A

API	WELL	S. AREA	S.BLOCK	S.LEASE	SEVERITY	SWFT_SS	WD	SWFT_BML	OPERATOR	WELL_INTEGRITY	SPUD_DATE
427044011600	004	BA	A7	G04558	Moderate	2308	120	2188	PIONEER NATURAL RESOURCES USA INC	yes	5/8/83
608024000200	001	PI	654	G13395	Low	3750	2320	1430	SHELL DEEPWATER DEVELOPMENT INC	yes	12/15/96
608044020000	SS001	EB	421	G17255	Unkown	4090	2740	1350	NOBLE ENERGY INC	yes	1/8/01
608044023600	001	EB	645	G22293	Unkown	4548	3789	759	MAXUS US EXPLORATION COMPANY	yes	10/22/02
608054002100	001	AC	947	G20882	Low	10783	9672	1111	UNION OIL COMPANY OF CALIFORNIA	yes	9/17/02
608074003700	001	GB	426	G08241	Moderate	5563	2837	2726	SHELL OFFSHORE INC	yes	7/21/88
608074004500	001	GB	471	G07498	Low	4250	2873	1377	SHELL OFFSHORE INC	yes	2/23/87
608074006500	001	GB	594	G11548	Moderate	3535	2560	975	SHELL OFFSHORE INC	yes	2/8/90
608074008600	001	GB	425	G07492	Unkown	2967	2217	750	EXXON MOBIL CORPORATION	yes	8/27/91
608074014200	001	GB	602	G11553	SEVERE	4768	3708	1060	SHELL OFFSHORE INC	no	9/13/95
608074014400	A002	GB	602	G11553	Low	4674	3693	981	SHELL OFFSHORE INC	yes	9/25/95
608074018000	001	GB	785	G09240	Low	5500	4640	860	CONOCO INC	yes	12/17/97
608074020900	SE001	GB	516	G08252	Low	4348	3380	968	SHELL OFFSHORE INC	yes	7/13/99
608074022900	A003	GB	783	G11573	Low	5424	4674	750	CONOCOPHILLIPS COMPANY	yes	3/22/01
608074023300	002	GB	515	G20792	Minor	4390	3290	1100	MARATHON OIL COMPANY	no	8/7/01
608074030400	LL003	GB	385	G17358	Low	5056	2514	2542	SHELL GULF OF MEXICO INC	yes	9/7/09
608084002000	001	KC	875	G21444	Low	10359	7103	3256	ANADARKO PETROLEUM CORPORATION	yes	10/15/09
608104005300	002	EW	947	G05803	Unkown	1456	496	960	MCMORAN OIL & GAS LLC	yes	8/18/86
608104006300	001	EW	1006	G05820	Unkown	3768	1783	1985	MOBIL OIL EXPLORATION & PRODUC	yes	11/28/87
608104009900	001	EW	986	G13087	Strong	1028	528	500	UNION OIL COMPANY OF CALIFORNIA	no	8/11/96
608105003800	001	EW	1005	G10967	Unkown	3456	1681	1775	MARATHON OIL COMPANY	yes	3/3/92
608105004000	001	EW	1006	G10968	Strong	2379	1879	500	MARATHON OIL COMPANY	no	9/18/93
608114002900	002	GC	31	G06994	Unkown	3329	2090	1239	EP OPERATING LIMITED PARTNER	no	8/24/84
608114003803	001	GC	254	G07049	Unkown	4792	3135	1657	ENI US OPERATING CO INC	yes	4/26/85
608114005400	001	GC	72	G05896	Unkown	3762	1980	1782	SHELL OFFSHORE INC	no	11/12/85
608114007800	001	GC	32	G06995	Low	3401	2269	1132	BP AMERICA PRODUCTION COMPANY	no	8/14/87
608114018300	001	GC	286	G07053	Unkown	4266	3124	1142	EXXON MOBIL CORPORATION	yes	4/9/91
608114019700	001	GC	200	G12209	Low	4027	2761	1266	SHELL OFFSHORE INC	yes	2/14/94
608114020200	001	GC	506	G08880	Low	4863	4243	620	TEXACO EXPLORATION AND PROD	yes	11/13/94
608114020300	002	GC	180	G12205	Low	3554	2200	1354	BP AMERICA PRODUCTION COMPANY	yes	3/16/95
608114020501	TA005	GC	200	G12209	Low	3936	2670	1266	SHELL OFFSHORE INC	yes	3/28/98
608114023000	001	GC	461	G11064	Low	4893	4229	664	BP EXPLORATION & OIL INC	yes	6/7/98

Appendix A

API	WELL	S. AREA	S.BLOCK	S.LEASE	SEVERITY	SWFT_SS	WD	SWFT_BML	OPERATOR	WELL_INTEGRITY	SPUD_DATE
608114023200	001	GC	212	G18344	Moderate	3630	2585	1045	TOTAL E&P USA INC	yes	7/19/98
608114023300	001	GC	463	G11066	Low	4488	4032	456	BP EXPLORATION & OIL INC	yes	8/29/98
608114023500	001	GC	644	G11080	Minor	4930	4292	638	BP EXPLORATION & PRODUCTION INC	yes	12/20/98
608114024600	SS001	GC	562	G11075	Unkown	5689	3979	1710	ANADARKO PETROLEUM CORPORATION	yes	5/17/99
608114024700	003	GC	237	G15563	Low	2705	1985	720	BHP BILLITON PETROLEUM (GOM) INC	yes	4/17/99
608114027300	002	GC	473	G05922	Unkown	5888	3833	2055	ENI US OPERATING CO INC	yes	2/27/00
608114027606	SS001	GC	243	G20051	Unkown	4080	3065	1015	NEXEN PETROLEUM USA INC	yes	5/27/02
608114027800	001	GC	165	G15555	Low	4564	2705	1859	BP EXPLORATION & PRODUCTION INC	yes	5/17/00
608114028500	001	GC	783	G15611	Low	5591	4317	1274	BP EXPLORATION & PRODUCTION INC	yes	9/6/00
608114028700	002	GC	165	G15555	Low	3979	2780	1199	BP EXPLORATION & PRODUCTION INC	yes	8/30/00
608114029800	002	GC	743	G15607	Low	7190	6587	603	BP EXPLORATION & PRODUCTION INC	yes	5/8/01
608114030800	001	GC	282	G16727	Moderate	4507	2386	2121	BHP BILLITON PETROLEUM (GOM) INC	yes	8/17/01
608114034000	SS002	GC	243	G20051	Unkown	4171	3048	1123	NEXEN PETROLEUM USA INC	yes	6/19/02
608114034800	004	GC	743	G15607	Low	8350	6896	1454	BP EXPLORATION & PRODUCTION INC	yes	8/12/02
608114034900	005	GC	743	G15607	Low	8525	5405	3120	BP EXPLORATION & PRODUCTION INC	yes	11/7/02
608114037500	001	GC	435	G18387	Moderate	5215	3815	1400	CONOCOPHILLIPS COMPANY	no	7/13/03
608114038400	001	GC	823	G16808	Low	5844	4129	1715	BP EXPLORATION & PRODUCTION INC	yes	8/11/03
608114038900	002	GC	826	G09982	Low	6855	5062	1793	BP EXPLORATION & PRODUCTION INC	yes	1/30/04
608114040400	DC122	GC	743	G15607	Moderate	7343	6822	521	BP EXPLORATION & PRODUCTION INC	yes	4/30/04
608114040600	DC131	GC	743	G15607	Moderate	7607	6824	783	BP EXPLORATION & PRODUCTION INC	yes	4/19/04
608114040700	DC132	GC	743	G15607	Low	7619	6820	799	BP EXPLORATION & PRODUCTION INC	yes	5/10/04
608114041100	DC142	GC	743	G15607	Moderate	7607	6825	782	BP EXPLORATION & PRODUCTION INC	yes	4/14/04
608114042200	SS001	GC	141	G21785	Moderate	2308	1041	1267	LLOG EXPLORATION OFFSHORE LLC	yes	2/13/05
608114047500	002	GC	82	G26292	Strong	3200	2435	765	W & T OFFSHORE INC	no	4/4/06
608114048500	001	GC	246	G16716	Unkown	7000	3271	3729	WOODSIDE ENERGY USA INC	yes	10/2/06
608114050400	001	GC	448	G28077	Low	4496	3266	1230	DEEP GULF ENERGY LP	yes	12/19/07
608114052000	003	GC	610	G16765	Low	6340	4389	1951	BHP BILLITON PETROLEUM (GOM) INC	yes	8/2/08
608114057000	BA003	GC	825	G09981	Low	10748	5221	5527	BP EXPLORATION & PRODUCTION INC	no	4/25/10
608114060000	001	GC	36	G26287	Strong	6030	1910	4120	STATOIL USA E&P INC.	no	9/1/12
608114064300	004	GC	859	G24194	Low	6968	5346	1622	ANADARK PETROLEUM CORPORATION	yes	
608115006400	001	GC	158	G07995	Low	5006	2950	2056	SHELL OFFSHORE INC	yes	3/15/89
608115006600	001	GC	472	G05097	Low	4317	3778	539	ENI US OPERATING CO INC	yes	12/8/88

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API	WELL	S. AREA	S.BLOCK	S.LEASE	SEVERITY	SWFT_SS	WD	SWFT_BML	OPERATOR	WELL_INTEGRITY	SPUD_DATE
608115007600	001	GC	161	G05909	Moderate	3717	2575	1142	CHEVRON USA INC	yes	8/28/90
608115007800	002	GC	205	G05911	Moderate	3683	2700	983	CHEVRON USA INC	yes	7/9/91
608115008200	001	GC	429	G07069	Unkown	4612	3690	922	EXXON MOBIL CORPORATION	yes	1/4/94
608115008400	001	GC	296	G07057	Moderate	3928	3290	638	SHELL OFFSHORE INC	yes	3/7/94
608115008800	003	GC	205	G05911	Low	3448	2600	848	CHEVRON USA INC	yes	12/4/94
608115012100	001	GC	113	G15546	Low	2220	2045	175	MARUBENI OIL & GAS USA INC	yes	8/8/97
608115012600	001	GC	338	G11054	Low	4162	3244	918	SHELL DEEPWATER DEVELOPMENT INC	yes	2/21/98
608115012900	001	GC	341	G13171	Unkown	4457	3394	1063	NEWFIELD EXPLORATION GULF COAST LLC	yes	3/12/98
608164008800	001	VK	783	G06886	Low	5954	1450	4504	W & T ENERGY VI LLC	yes	11/2/84
608164009000	001	VK	912	G06893	Low	5020	2441	2579	SHELL OFFSHORE INC	yes	3/1/85
608164009400	002	VK	783	G06886	Low	2258	1151	1107	W & T ENERGY VI LLC	yes	8/3/85
608164009800	001	VK	956	G06896	Minor	5068	3112	1956	SHELL OFFSHORE INC	yes	11/16/85
608164010200	003	VK	912	G06893	Low	5897	2952	2945	SHELL OFFSHORE INC	yes	6/23/86
608164012400	001	VK	873	G08471	Low	5014	3810	1204	SHELL OFFSHORE INC	yes	2/21/88
608164013000	001	VK	869	G05784	Unkown	4164	1918	2246	EXXON MOBIL CORPORATION	yes	5/26/88
608164013400	004	VK	783	G06886	Low	7060	1494	5566	W & T ENERGY VI LLC	yes	11/22/88
608164013800	002	VK	869	G05784	Unkown	4450	2050	2400	EXXON MOBIL CORPORATION	yes	4/6/89
608164018100	A001	VK	915	G06894	Moderate	4004	3236	768	BP AMERICA PRODUCTION COMPANY	yes	4/13/93
608174028900	001	MC	731	G07955	Low	7022	5400	1622	SHELL OFFSHORE INC	yes	11/20/86
608174033000	001	MC	730	G07954	Moderate	7170	5328	1842	SHELL OFFSHORE INC	yes	6/11/88
608174033600	001	MC	764	G08852	Unkown	4775	3252	1523	SHELL OFFSHORE INC	no	7/23/88
608174033700	002	MC	764	G08852	Unkown	4030	3252	778	SHELL OFFSHORE INC	yes	8/6/88
608174035100	001	MC	763	G07958	Moderate	5764	3170	2594	SHELL OFFSHORE INC	yes	4/5/89
608174036200	001	MC	807	G07963	Low	5062	3013	2049	SHELL OFFSHORE INC	yes	11/1/89
608174037700	002	MC	807	G07963	Low	3282	2927	355	SHELL OFFSHORE INC	yes	3/16/90
608174038000	003	MC	807	G07963	Moderate	6222	2930	3292	SHELL OFFSHORE INC	yes	7/5/90
608174038300	001	MC	854	G09883	Low	5989	4020	1969	SHELL OFFSHORE INC	no	7/10/90
608174038500	002	MC	854	G09883	Low	4723	4020	703	SHELL OFFSHORE INC	yes	8/17/90
608174038800	004	MC	807	G07963	Moderate	4043	2956	1087	SHELL OFFSHORE INC	yes	3/11/91
608174039200	001	MC	899	G09896	Moderate	7052	4340	2712	SHELL OFFSHORE INC	no	1/25/91
608174039400	002	MC	899	G09896	Low	4568	4340	228	SHELL OFFSHORE INC	no	3/6/91
608174039500	003	MC	899	G09896	Low	5056	4340	716	SHELL OFFSHORE INC	no	3/9/91

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608174039600	004	MC	899	G09896	Low	8730	4340	4390	SHELL OFFSHORE INC	yes	3/11/91
608174040200	005	MC	807	G07963	Low	4330	2937	1393	SHELL OFFSHORE INC	yes	7/24/91
608174045500	001	MC	809	G05868	Moderate	4632	3762	870	SHELL OFFSHORE INC	yes	12/11/93
608174046000	A001	MC	807	G07963	Low	4121	2945	1176	SHELL OFFSHORE INC	yes	10/17/93
608174047000	001	MC	935	G07976	Low	5626	3918	1708	SHELL OFFSHORE INC	yes	4/14/94
608174050300	002	MC	935	G07976	Low	5270	3859	1411	SHELL OFFSHORE INC	yes	12/22/94
608174050900	SS005	MC	292	G08806	Low	5189	3405	1784	NOBLE ENERGY INC	yes	5/7/95
608174051000	001	MC	718	G07952	Unkown	4039	2828	1211	MARINER ENERGY INC	yes	6/3/95
608174051300	A001	MC	429	G07944	Low	7978	6240	1738	BP EXPLORATION & PRODUCTION INC	yes	11/10/95
608174053700	004	MC	810	G09873	Moderate	5348	3907	1441	SHELL OFFSHORE INC	no	7/4/96
608174054600	H001	MC	520	G09821	Low	9109	6738	2371	BP EXPLORATION & PRODUCTION INC	yes	10/30/96
608174057800	001	MC	607	G09837	Low	7836	6590	1246	BP EXPLORATION & PRODUCTION INC	yes	9/20/97
608174058000	005	MC	899	G09896	Low	6216	4394	1822	SHELL OFFSHORE INC	yes	10/6/97
608174058400	003	MC	764	G08852	Moderate	4916	3263	1653	SHELL OFFSHORE INC	no	11/19/97
608174058500	001	MC	476	G09813	Low	7075	6627	448	BP AMERICA PRODUCTION COMPANY	yes	11/27/97
608174060000	001	MC	667	G14013	Unkown	3930	2902	1028	ANADARKO E&P COMPANY LP	yes	3/3/98
608174081000	002	MC	546	G25098	Unkown	4220	2508	1712	ENI US OPERATING CO INC	yes	5/2/98
608174082000	001	MC	941	G16661	Low	4918	3927	991	ATP OIL & GAS CORPORATION	yes	7/27/98
608174084000	003	MC	711	G14016	Unkown	3400	2950	450	ATP OIL & GAS CORPORATION	no	1/24/99
608174084200	001	MC	243	G19931	Low	4184	2805	1379	W & T ENERGY VI LLC	yes	2/20/99
608174085700	001	MC	1002	G16670	Minor	8436	7416	1020	CHEVRON USA INC	yes	10/5/99
608174086400	A002	MC	773	G19996	Moderate	6534	5610	924	ENI US OPERATING CO INC	yes	11/17/99
608174089400	001	MC	727	G13145	SEVERE	6547	4891	1656	CHEVRON USA INC	yes	8/21/00
608174091100	001	MC	696	G16641	Low	8912	6941	1971	CHEVRON USA INC	yes	1/17/01
608174091300	001	MC	864	G15519	Moderate	7858	6265	1593	CHEVRON USA INC	yes	1/23/01
608174094500	002	MC	496	G14005	Unkown	4308	1637	2671	MARUBENI OIL & GAS USA INC	yes	8/30/01
608174094900	001	MC	587	G16625	Low	4430	2338	2092	BP EXPLORATION & PRODUCTION INC	yes	9/24/01
608174097900	001	MC	849	G21188	SEVERE	4819	3599	1220	NOBLE ENERGY INC	yes	2/14/02
608174100900	001	MC	725	G22898	Low	5436	4334	1102	HESS CORPORATION	yes	3/25/03
608174102500	003	MC	718	G07952	Low	3410	2920	490	BP EXPLORATION & PRODUCTION INC	yes	11/9/03
608174102800	002	MC	762	G07957	Moderate	3412	3147	265	SHELL OFFSHORE INC	no	12/6/03
608174103100	013	MC	778	G09868	Low	8408	6034	2374	BP EXPLORATION & PRODUCTION INC	yes	3/16/04

API	WELL	S. AREA	S.BLOCK	S.LEASE	SEVERITY	SWFT_SS	WD	SWFT_BML	OPERATOR	WELL_INTEGRITY	SPUD_DATE
608174105400	001	MC	937	G16659	Strong	6605	4181	2424	BHP BILLITON PETROLEUM (GOM) INC	no	10/18/04
608174112100	001	MC	775	G19997	Moderate	7560	5673	1887	BP EXPLORATION & PRODUCTION INC	no	4/19/07
608174112501	SS001	MC	460	G18245	Moderate	3983	2823	1160	ENI US OPERATING CO INC	yes	6/23/07
608174112800	003	MC	860	G18301	Low	6548	5667	881	CHEVRON USA INC	yes	7/21/07
608174113100	SS001	MC	503	G27277	Moderate	3929	3099	830	LLOG EXPLORATION OFFSHORE LLC	yes	11/2/07
608174114000	001	MC	761	G28025	Low	4950	3031	1919	LLOG EXPLORATION OFFSHORE LLC	no	1/28/08
608174114100	002	MC	754	G24104	Strong	4700	2696	2004	ATP OIL & GAS CORPORATION	no	2/4/08
608174114200	001	MC	540	G26265	Strong	3530	2036	1494	STATOIL USA E&P INC.	yes	11/15/09
608174114800	001	MC	948	G28030	Moderate	7025	6090	935	NOBLE ENERGY INC	no	5/19/08
608174118200	SS001	MC	199	G32301	Low	4727	2465	2262	LLOG EXPLORATION OFFSHORE LLC	yes	1/7/10
608174121600	003	MC	726	G24101	Low	7548	4608	2940	Hess CORPORATION	yes	6/10/12
608174127500	005	MC	29	G13997	Strong	5093	2121	2972	Stone Energy Corporation	yes	1/18/14
608174127600	001	MC	525	G31507	Moderate	11259	7465	3794	Shell Offshore INC	no	2/1/14
608174127800	001	MC	812	G34461	Moderate	5171	4471	700	Shell Offshore INC	yes	5/6/14
608184000300	001	AT	222	G12270	Low	4374	3170	1204	BP EXPLORATION & OIL INC	yes	3/13/92
608184000500	001	AT	575	G08036	Unkown	7470	6220	1250	BHP BILLITON PETROLEUM (GOM) INC	yes	3/26/95
608184000700	001	AT	378	G08918	Low	7758	5843	1915	CHEVRON USA INC	yes	7/11/97
608184000800	001	AT	574	G08035	Unkown	8496	6133	2363	BHP BILLITON PETROLEUM (GOM) INC	yes	7/21/97
608184001000	001	AT	119	G10006	Minor	9171	7716	1455	CHEVRON USA INC	yes	8/12/98
608184001100	001	AT	26	G13197	Low	7048	6505	543	BP EXPLORATION & OIL INC	yes	7/8/99
608184002300	001	AT	194	G16874	Moderate	6704	4572	2132	CHEVRON USA INC	no	8/23/01
608184002700	002	AT	63	G13198	Low	6469	4457	2012	ATP OIL & GAS CORPORATION	no	2/21/02
608184004200	001	AT	182	G23021	Unkown	5432	3710	1722	CHEVRON USA INC	yes	4/7/03
608184004400	002	AT	574	G08035	Minor	8236	6215	2021	BHP BILLITON PETROLEUM (GOM) INC	yes	7/2/03
608184004600	001	AT	618	G08038	Low	7202	6257	945	BHP BILLITON PETROLEUM (GOM) INC	no	2/19/04
608184005000	001	AT	267	G18537	Minor	4275	3341	934	SHELL OFFSHORE INC	yes	1/6/05
608184005700	001	AT	398	G16910	Minor	4473	3619	854	BP EXPLORATION & PRODUCTION INC	yes	6/18/05
608184006000	SA001	AT	617	G08037	Moderate	7211	6171	1040	BHP BILLITON PETROLEUM (GOM) INC	yes	6/16/06
608184007200	002	AT	428	G28129	Low	8679	7142	1537	ENI US OPERATING CO INC	yes	1/6/10
608184007400	002	AT	362	G34584	Moderate	6551	5588	963	Bp Exploration & production Inc.	no	5/24/14
608234000300	001	DC	177	G10445	Low	8655	6740	1915	ATP OIL & GAS CORPORATION	yes	2/22/97
608234001000	SS001	DC	618	G23526	Low	8900	7823	1077	ENI US OPERATING CO INC	yes	4/3/04

API	WELL	S. AREA	S.BLOCK	S.LEASE	SEVERITY	SWFT_SS	WD	SWFT_BML	OPERATOR	WELL_INTEGRITY	SPUD_DATE
608234001200	SS002	DC	618	G23526	Moderate	9427	7787	1640	ENI US OPERATING CO INC	yes	9/19/04
608234001300	SS002	DC	621	G23529	Low	9647	8087	1560	ANADARKO PETROLEUM CORPORATION	yes	5/11/05
608244000300	001	LL	399	G23480	Moderate	9731	8951	780	ANADARKO PETROLEUM CORPORATION	yes	5/22/04

Appendix B.

(i) Projected plans for well testing (refer to § 250.460 for safety requirements).

[68 FR 8423, Feb. 20, 2003]

§ 250.415 What must my casing and cementing programs include?

Your casing and cementing programs must include:

(a) Hole sizes and casing sizes, including: weights; grades; collapse, and burst values; types of connection; and setting depths (measured and true vertical depth (TVD));

(b) Casing design safety factors for tension, collapse, and burst with the assumptions made to arrive at these values;

(c) Type and amount of cement (in cubic feet) planned for each casing string; and

(d) In areas containing permafrost, setting depths for conductor and surface casing based on the anticipated depth of the permafrost. Your program must provide protection from thaw subsidence and freezeback effect, proper anchorage, and well control.

(e) A statement of how you evaluated the best practices included in API RP 65, Recommended Practice for Cementing Shallow Water Flow Zones in Deep Water Wells (incorporated by reference as specified in § 250.198), if you drill a well in water depths greater than 500 feet and are in either of the following two areas:

(1) An ''area with an unknown shallow water flow potential'' is a zone or geologic formation where neither the presence nor absence of potential for a shallow water flow has been confirmed.

(2) An ''area known to contain a shallow water flow hazard'' is a zone or geologic formation for which drilling has confirmed the presence of shallow water flow.

[68 FR 8423, Feb. 20, 2003, as amended at 72 FR 8903, Feb. 28, 2007]

§ 250.416 What must I include in the diverter and BOP descriptions?

You must include in the diverter and BOP descriptions:

(a) A description of the diverter system and its operating procedures;

(b) A schematic drawing of the diverter system (plan and elevation views) that shows:

(1) The size of the annular BOP installed in the diverter housing;

(2) Spool outlet internal diameter(s);

(3) Diverter-line lengths and diameters; burst strengths and radius of curvature at each turn; and

(4) Valve type, size, working pressure rating, and location;

(c) A description of the BOP system and system components, including pressure ratings of BOP equipment and proposed BOP test pressures;

(d) A schematic drawing of the BOP system that shows the inside diameter of the BOP stack, number and type of preventers, location of choke and kill lines, and associated valves; and

(e) Information that shows the blind-shear rams installed in the BOP stack (both surface and subsea stacks) are capable of shearing the drill pipe in the hole under maximum anticipated surface pressures.

[68 FR 8423, Feb. 20, 2003]

§ 250.417 What must I provide if I plan to use a mobile offshore drilling unit (MODU)?

If you plan to use a MODU, you must provide:

(a) *Fitness requirements.* You must provide information and data to demonstrate the drilling unit's capability to perform at the proposed drilling location. This information must include the maximum environmental and operational conditions that the unit is designed to withstand, including the minimum air gap necessary for both hurricane and non-hurricane seasons. If sufficient environmental information and data are not available at the time you submit your APD, the District Manager may approve your APD but require you to collect and report this information during operations. Under this circumstance, the District Manager has the right to revoke the approval of the APD if information collected during operations show that the drilling unit is not capable of performing at the proposed location.

(b) *Foundation requirements.* You must provide information to show that site-specific soil and oceanographic conditions are capable of supporting the proposed drilling unit. If you provided sufficient site-specific information in

Appendix C.

API RP 65: Cementing Shallow Water Flow Zones in Deep Water Wells

Publication Date: Sep 1, 2002
SDO: API: American Petroleum Institute
DOD Adopted ANSI Approved

FLOWS

This document is the compilation of technology and practices used by many operators drilling wells in deep water. In a number of cases, there is not a single way of performing a specific operation. In some cases, several options may be listed, but in others there may be practices which are successful, but which are not listed in this document. This document is not meant to limit innovation.

In wells drilled in deep ocean waters, water flows from shallow formations can compromise the hydraulic integrity of the tophole section. Modes of failure include: (1) poor isolation by cement resulting in casing buckling/shear; (2) pressure communication to other shallow formations, causing them to be overpressured; and (3) disturbance of the seafloor due to breakthrough of the shallow flow to the mudline. Such damage can and has resulted in the complete loss of drilling templates containing previously cased wells. Additionally, such shallow flow can result in changes in the state of stress in the tophole section, possibly resulting to damage to existing casings in the present or adjacent wells later in the life of the well.

Flows from these shallow formations are frequently a result of abnormally high pore pressure resulting from under-compacted and over-pressured sands caused by rapid deposition. Not all flows are the result of these naturally developed formation geo-pressures. Hydraulic communication with deeper, higher pressure formations is another cause for abnormal shallow pressures. Some of the observed shallow flow problems have been due to destabilization of gas hydrates or induced storage during drilling and casing and cementing operations. Although minor compared to geo-pressured sands, flows due to induced storage may still cause damage from sediment erosion or mining, breakthrough to adjacent wells and damage to the cement before it sets. These problems can worsen with each additional well when batch setting shallow casings. Although most of the discussion in this text is focused on shallow water flow (SWF), shallow flows can be mixtures of water, gas and formation fines. In most cases the concepts are similar and can be employed with minor modifications, depending on the type of flow.

Flows allow production of sand and sediments resulting in hole enlargement which can increase the flow potential and make it more difficult to control. The enlargement may also cause caving of formations above the flow interval. The flow of water and formation material from these zones can result in damage to the wells including foundation failure, formation compaction, damaged casing (wear and buckling), reentry and control problems and sea floor craters, mounds and crevasses (OTC 11972, IADC/SPE 52780).

HAZARDS

The Gulf of Mexico has been divided into areas by the severity of the hazard based on data from geotechnical wells (SPE/IADC 67772). The Minerals Management Service (MMS) also maintains a map showing the location of flow incidents on a web site at http://www.gomr.mms.gov/homepg/offshore/safety/wtrflow.html.

Appendix C.

The following factors make drilling in deep water with SWF potential unique:

a. Temperatures at the mud line and through the shallow sediments are quite low and may approach 40°F.

b. Pore and fracturing pressures are very close, making the drilling window very narrow.

c. The hole is drilled riserless, with returns taken to the sea floor.

d. Seawater is used for drilling.

e. There is no means to control flow at the wellhead.

f. Returns and flows are observed only remotely through video from a remotely operated vehicle (ROV).

g. In development projects, conductor and surface casing are batch set.

The shallow water flow conditions described in this document exist in wells drilled in water depths greater than about 500 ft and more commonly at water depths greater than 1000 ft. These wells are commonly drilled from floating drilling rigs such as drill ships, semi-submersibles, spars and tension leg platforms.

Shallow water flow sands are typically encountered at depths of 600 ft - 2500 ft below mud line (BML). The conditions favoring the formation of shallow water flow sands include:

a. High rate of deposition (> 1500 ft/million years) sedimentary basins of current or ancestral river complexes, such as the Mississippi River depocenter.

b. Areas with substantial regional uplift, in which once deeply buried sediments are encountered at shallow depths - North Sea, Norwegian Sea.

c. Continental slope regions subject to large scale subsea slides - Storegga Slide area, Norwegian North Sea.

Abnormal pressures may be present in the tophole section of a deepwater well. Abnormal pressure can be trapped below the impermeable layers found above the SWF sands, or may begin at or near the mud line and increase more-or-less linearly with depth. In general, the degree of over-pressurization is consistent with the rate of deposition. Pore pressures equating to 8.6 lbm/gal to 9.5 lbm/gal equivalent mud weight (EMW) may be encountered in the SWF zones. When abnormal pressures are trapped below impermeable barriers, the pore pressure can be very close to the fracture gradient of the sediment. This results in a very narrow pressure margin within which drilling operations must be conducted to maintain well control and prevent induced fracturing of formations. (See SPE/IADC 67772.) The margin between pore pressure and fracture gradient becomes more narrow as water depth increases.

Temperatures at the mud line of a deepwater wellbore are quite low, in the range of 35°F - 55°F depending on water depth, latitude, and presence of warm/cold ocean currents. The low temperatures result in slow hydration of the cement making special slurries and/or additives necessary. The geothermal gradients found in deepwater areas may be sequestered as a result of the water depth effect and may suppress wellbore temperatures throughout the entire stratigraphic column. In other areas the geothermal gradient may rise quickly to normal values as depth increases.

Appendix C.

BEST PRACTICES

Because of such problems and to form an effective seal while preventing flow, careful attention must be paid to the cementation of wells having the potential for shallow flow. This document addresses the drilling and cementing process and makes recommendations for such wells. Appendix D gives a matrix for this process with values for each step. The resultant score provides the user with a factor of the relative chance of success of the cementation process. This process and matrix are based on known industry practices and are meant to be used to apply the process within the constraints of the well conditions with the greatest degree of risk minimization.

The process includes:

a. Site selection.

b. Drilling.

c. Fluid properties.

d. Wellbore preparation and conditioning.

e. Operational procedures and good cementing practices.

f. Mud removal and placement technique.

g. Cement slurry design.

h. Pre-job preparation.

i. Cement job execution.

j. Additional considerations.

k. Post cementing operations.

l. Remediation of flows.

A number of "best practices" have been developed for drilling and cementing in the deepwater, shallow water flow environment. Generally, these have been developed from lessons learned while drilling deepwater wells. These practices are applied to minimize the risk of shallow water flow and to aid in successfully drilling and cementing the casing through the SWF zones. These practices include the following, which are discussed in more detail throughout the document.

a. Site selection to minimize the risk for and severity of shallow water flow.

b. Use of pressure while drilling and resistivity tools to identify permeable sands and flow events.

c. Use of ROV to check for flow with each connection.

d. Rapid action to contain flows.

Appendix C.

e. Switching to mud to control flow as soon as it is encountered.

f. Selection of casing seats/casing program to facilitate control and to reach the well objectives.

g. Low fluid loss and gel strengths of pad mud spotted in the hole just prior to running casing.

h. Use of foamed cement and/or special slurries to maintain control across the SWF zones.

i. Batch setting conductor and surface casings.

A list of "lessons learned" in successfully isolating the top hole section in the presence of SWF include the following:

a. The pore pressure of SWF sand(s) must be hydrostatically contained at the first indication of flow.

b. SWF zones that are drilled underbalanced while flowing will not likely be isolated with cement.

c. Flows that are not contained soon after beginning can jeopardize the success of the project.

d. Wells in which the SWF sands have been hydrostatically controlled must still be cemented with flow mitigating cement systems.

e. Mechanical isolation devices, when used without flow mitigating cement systems, may not provide zonal isolation over the life of the well.

Note that this document is not meant to be a training manual. Although fairly comprehensive, there are still many details which are not discussed and which must be addressed when drilling and cementing wells in deep water. It is meant to highlight key parameters for increasing the chance of successfully drilling and cementing casings where there is a risk of shallow water flow and to discuss options that are available. Many more details can be gleaned from the references listed in the Bibliography. Most of the information in this document is from U.S. Gulf of Mexico experience. The concepts can be applied in other deep water environments with appropriate modifications. The user should consult experts within the industry for specific details of the cementing process relating to the technology being employed by a specific company for a specific scenario. The construction of the casings through the SWF zones must be a team effort to be successful. All parties involved must participate in the planning and execution of all phases of the process to ensure successful construction of the conductor and surface casings.

Appendix D.

The following procedures relate to a specific operation to address shallow water flow based on a particular set of circumstances. The following procedures are provided as an example only, and are not intended to represent appropriate procedures for all circumstances and situations. Each operator should develop, in accordance with BOEM & BSEE rules and regulations, procedures appropriate for its operations to control shallow water flow in deepwater operations.

Site Specific procedure to control SWF in deep water

Cementing Summary

Include data per 30 CFR 250.415 (e). Discuss how API RP 65 was used in planning the cementing program to prevent Shallow Water Flow.

Major items that go into the planning of the cementing of the open water strings of casing (32", 28", and 22") are:

- Use a specialized Shallow Water Flow Team – if available - whose primary focus is identifying drilling locations that minimize as many sub-surface shallow hazards as possible. This includes identifying potential water flow sands, hydrate bearing strata, shallow faults, shallow gas sands and seabed slopes.
- The manifold location for the development should consider all of the above. In addition, the manifold location should be selected in close proximity to wells which successfully drilled and secured the shallow water flow section of the well.

In addition to picking a location which avoids / minimizes risks in the shallow portion of the well, the following practices will be implemented:

- Lead cement will be designed as foam cement.
- Bottom portion (shoe joints) of the casing will be centralized.
- Minimum cement volumes will be based on a minimum of 100% open and cased hole volume.
- A shallow water flow annular shut off device will be deployed with the HP wellhead.
- Valves will be run on the 28" casing X 32" casing annulus which will be shut after cementing to isolate this annulus.
- Cement weights will be designed to provide higher hydrostatic pressure than the pad mud left in the well prior to cementing.
- The well will not be flowing prior to the trip out of the well to run casing and when cementing operations commence.
- The job will be pumped thru an inner string.
- Minimum of 2 times the hole volume of kill mud will be on location at all times while drilling the 32", 28" and 22" casing hole section.
- The hole interval for the 28" casing and 22" casing will be drilled with mud.
- Any flows identified on connections or with the PWD will be killed immediately.

Appendix D.

- Displacement rates will be designed to minimize the chances for loss circulation due to equivalent circulating densities.
- The cement will be tested according to API Specs and the tests appropriately reviewed.
- The well will be conditioned and fresh kill / pad mud with the lowest practical gel strengths / yield point will be spotted prior to tripping out of the well to run casing.
- The well will be monitored on final trip out to ensure there is no flow.
- The 32”, 28”, and 22” casing strings will be run and hung off on a casing cart prior to drilling the interval to minimize the time the hole is static without pipe (drill pipe or casing) being on bottom.

Discuss drilling precautions taken to prevent possible Shallow Water Flow Zones.

- 5,000 bbls of 16.0 ppg mud will be available at the rig for drilling to the 32" casing point at 4,300’ (~880’ of hole below the 38” jet pipe). The bottom 200’ to 500’ of hole will be drilled with 11.0 ppg mud.
- 15,000 bbls of 16.0 ppg mud will be available for drilling to the 28” casing point. The entire interval will be drilled with 12.0 ppg mud. A conditioning trip will be made and 12.3 ppg pad mud will be spotted prior to tripping out of the hole to run 28” casing.
- 45,000 bbls of 16.0 ppg mud will be available for drilling to the 22” casing point. The entire interval will be drilled with 13.2 ppg mud. A conditioning trip will be made and 13.5 ppg pad mud will be spotted prior to tripping out of the hole to run 22” casing.
- 28" casing will be set prior to drilling into the interval with the highest likelihood of encountering shallow water flow sands. This will provide the highest fracture gradient possible for handling an unlikely flow from this interval.
- The rig will have a backup ROV. Drilling operations will stop if an ROV is unable to be on bottom monitoring the wellhead 100% of the time.
- The PWD will be monitored continuously on the rig as well as office based Real Time Monitoring for changes. Anytime the slope of the PWD curve changes radically, drilling will stop, the pumps will be turned off, and the well will be checked for flow with the ROV. If the well is flowing, the mud weight will be increased until the flow stops.
- All connections will be monitored for flow with the ROV. If the well is flowing on connections the mud weight will be increased until the flow stops.
- ROV feed will be made available for monitoring by the office based Real Time Monitoring Team (24/7) and the SWF Team if they are available, as well as the sub surface geologists, onshore drilling engineers, and superintendents.

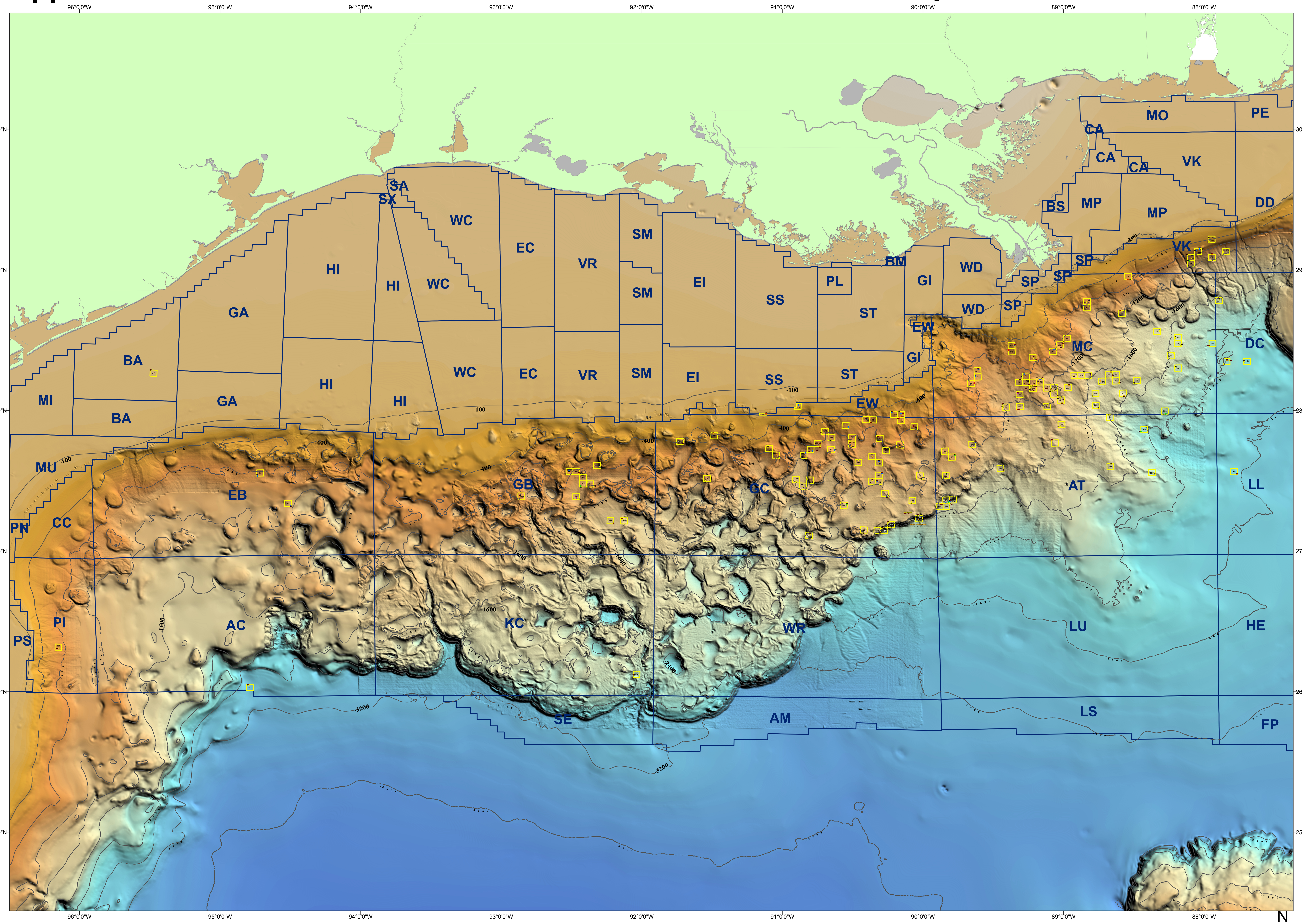
Appendix D.

- Mud weights for drilling the riserless section are based on both what was successful at near-by Wells, and a shallow pore pressure / fracture gradient prediction (plot) for the interval
- 22” casing point was based on stopping above potential sands below 5,850’.

Appendix E

Shallow Water Flow Map

Updated: March 25, 2015



LEGEND

SEVERITY

- Low
- Minor
- Moderate
- Severe
- Strong
- Unkown

Blocks

Bathymetry Contours

ci = 400 meters

BML Feet below the Mud Line

Bathymetric map courtesy of Texas A&M University & Geosciences Earth & Marine Services

0 25 50 100 150 200 Miles

Reference Scale: 1:650,000

N

BOEM Bureau of Ocean Energy Management