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Third Generation High-Performance Water-Based Fluid Successfully Replaces Oil-Based Fluid at Ricinus and Narraway Alberta

Doug Fletcher, Petro-Canada Inc., Carl Smith, Alex Stoian, Catalin Aldea, Arvind Patel, M-I *L.L.C.*

Abstract

A new water-based drilling fluid was developed to address shale inhibition problems through a specialized-product approach. One unique feature of this fluid is that the high level of inhibition does not rely on any salt. This aspect was fully utilized for an onshore project in Western Canada where the government regulatory agency imposes strict rules on cuttings and fluid disposal for oil-based and saltwater-based fluids.

The new fluid incorporates a polyamine shale intercalator and a shale encapsulator for hydration inhibition. The new fluid performed similar to invert emulsion muds used to drill offset wells in the area, where troublesome shale sections are encountered. The 7252 ft of 8.75-in. main hole section was drilled in 16 days – 3 days ahead of the plan.

The fluid met the regulatory standards for the Mix, Bury and Cover method of drilled cuttings disposal on location and for land spraying of whole fluids.

Introduction

Traditionally, invert emulsion drilling fluids have been the fluid of choice for drilling demanding wells. Such highly water-sensitive wells require a highly inhibitive fluid to minimize interactions between the drilling fluid and water-sensitive formations. The main driver in the development of alternatives to oil-based systems has been the concern about the environmental impact of using and disposing of these fluids. As a result, the development of an environmentally acceptable water-based drilling fluid, which is capable of insuring high rates of penetration, good lubricity, and low potential for stuck pipe has been an ongoing endeavor of the drilling fluids industry for some time.

Several water-based drilling fluid systems have been developed over the past ten years with the goal of approaching the drilling performance of an invert emulsion drilling fluid. These include potassium/PHPA systems, salt/glycol fluids, cationic systems, calcium chloride-polymer systems and silicate-based fluids. However, these fluids have not always been completely successful in inhibiting the hydration of highly water-sensitive formations.

Most of the inhibitive water-based systems developed in recent years rely on salts for shale inhibition and this presents a significant challenge for disposal of drilling fluid wastes for land-based projects. In Alberta, operators are limited to the overall amount of salt that can be disposed of at any one location. As a result, operators favor freshwater systems that pass the environmental criterion for on-site disposal.

Inhibitive Water-Based Fluids

Some of the first inhibitive water-based muds were based on cationic-exchange inhibition. The most popular of those systems are the potassium-based fluids. Although providing good shale inhibition due to the K+ ions perfectly fitting between the clay platelets, these fluids appeared to promote dispersion of certain shales. As a result potassium-based fluids have been enhanced with the incorporation of an encapsulating polymer (such as PHPA). The use of potassium-based fluids is further limited by the fact that disposing of large amounts of salt on land is unacceptable in many jurisdictions, including Alberta and British Columbia.

A significant improvement in the inhibitive water-based mud (WBM) area was made by a series of “second-generation” inhibitive fluids: silicate, glycol and amine-based fluids. Silicates (sodium or potassium) provide very good shale inhibition and wellbore stability by forming a true shale membrane. However, they are limited by temperature, tolerance to contaminants, and lubricity.

Glycol fluids provide inhibition by plugging the micro-pores or fractures inside the shale. They require the use of a salt and also may promote dispersion in certain formations.

Amine-based fluids generate hydration inhibition similar to K+ fluids, by intercalation between clay platelets. Early amine inhibitors provided limited shale inhibition. They were sensitive to solids build up and were restricted in their use by mud weight, temperature and, in some cases, toxicity.

Third-Generation Inhibitive Fluid
A highly inhibitive, salt-free, freshwater-based fluid system has been developed for land drilling applications in highly reactive and dispersive shale formations.[1-2] The system significantly reduces the clay dispersion and hydration without the use of salts. The system components are newly developed and designed to perform specific functions. The highly inhibitive aqueous fluid (HIAF) is environmentally friendly for land drilling applications. The system utilizes three components:

1) Shale Inhibitor - The newly developed shale inhibitor is a chloride-free amine-based multi-functional molecule, which is environmentally safe, non-ionic and completely water-soluble. The unique molecular structure of the shale inhibitor is theorized to function by making a perfect fit between clay platelets and binding the platelets together.
2) Dispersion Suppressant - This is a low-molecular-weight terpolymer, which exhibits good biodegradability and low toxicity. The polymeric additive is designed to have a molecular weight and charge density that allow superior inhibition by limiting water penetration into the clay platelets and binding the platelets together via cationic charges.
3) Fluid-Loss-Control Agent - This is an ultra-low viscosity, modified cellulose polymer, which allows the use of product for fluid loss control without contributing the excess viscosity. This polymer also exhibits low toxicity and good biodegradability for land drilling applications.

The design, selection, and concentrations of each component are selected to optimize the performance of the overall system to meet the environmental acceptance criteria required for land drilling application.

The laboratory results show that the system significantly reduces clay hydration, dispersion and accretion of drill cuttings. The freshwater, high-performance water-based system was evaluated against other industry standard freshwater HIAF systems. Table 1 shows the mud formulations of these systems. The laboratory evaluation of these systems is given in Figures 1 - 2 and Table 2.

Drilling Waste Disposal Options
Recent practice, for engineering reasons, in the Ricinus and Narraway areas has been to use either potassium sulfate or diesel-based invert emulsion fluids. In either case, the drilling fluid waste disposal options are limited and operators generally isolate the cuttings for landfill disposal and haul the salt-based fluids at an injection well for downhole disposal. This practice adds considerably to the overall costs of using these fluid systems. In addition, even if drilling wastes are handled properly and according to regulation,[3] the contingent environmental liability continues to rest with the generator of the wastes in perpetuity.

One of the goals when using the new HIAF system is to have a fluid that would be able to meet the inhibition requirements for these two areas while at the same time meet the environmental criterion for disposal on-site by Mix-Bury-Cover or landspreading.

In addition to oil and salt content regulations, an important criterion to be met, by any new fluid, is that all the components of the system and the whole fluid pass the Microtox screening test. Other tests that can be used in conjunction or in place of the Microtox tests include the earthworm survival test and the seed emergence and root elongation tests.[3]

Fluid formulation for Western Canada Drilling
To adapt to the specific environmental and drilling conditions of the Alberta foothills area, the new HIAF was formulated in fresh water, with a minimum number of products. A typical fluid formulation is given in the Table 3. This formulation passed all the required environmental testing: earthworm survival, seed emergence and root elongation tests. The shale inhibitor and the dispersion suppressant also passed the Microtox test at 10.5-lb/bbl and 2.5-lb/bbl concentrations respectively.

Field Applications
The new HIAF was utilized for two wells in the Foothills Front region of Alberta. These areas are both characterized by challenging geological conditions, with numerous faults and a high potential for wellbore instability. The shales drilled have a moderate reactivity, but they are highly dispersive and under mechanical stresses which can result in large washouts and even wellbore collapse. Some of the more troublesome formations drilled in Alberta are found at these two locations: the Wapiabi and Blackstone formations at Ricinus, and the Kaskapau, Dunvegan and Shaftesbury at Narraway.

Ricinus Well
The main criterion for fluid selection was to have a highly inhibitive fluid that will overcome the land disposal restrictions and allow the most economical cuttings and fluid disposal (Mix-Bury-Cover).

The new drilling fluid was used in the 8.75-in main section of this well. Previous wells used both water-based muds (WBM) and oil-based muds (OBM). The formations drilled consist of a sequence of sands and shales, with Blackstone being the most difficult shale formation.

Offset Wells - Water-based fluids varied from a simple “gel-chem” non-dispersed fluid to a more inhibitive potassium sulfate / PHPA fluid. The average hole washout was in the range of 35 – 75% (Fig. 3), indicating insufficient fluid inhibition. The “gel-chem” fluid generated the most drilling problems. Multiple stuck-pipe incidents and extensive reaming that took 20 days were reported in one application. The potassium sulfate/ PHPA fluid had better performance, although reaming of several sections was required. However, discharge of the fluid and cuttings for this type of drilling fluid is now more difficult because of new limits on soil conductivity for areas used for drilling-waste disposal.

Oil-based muds provided significantly better drilling performance in the area, although not completely trouble-free. The average washout was in the 9 – 19% range. One stuck pipe incident, as well as several cases of reaming / backreaming were reported. The OBM fluid and cuttings disposal are even more difficult, requiring transportation to an approved waste-management location.

HIAF Drilling Performance - A freshwater fluid was used on Ricinus well to drill the 8.75-in section from 1968 to 9144 ft. The fluid was prepared at the rig and displaced in the hole after drilling cement and shoe with water. Fluid mixing was done very quickly (2 hours for a 157-bbl pit) due to the reduced number of products used and the fact they do not require any special mixing.

The drilling began at high rate of penetration (ROP), up to 150 ft/hr. The cuttings had very good integrity and they were well encapsulated and dry inside. The rig was equipped with only one shale shaker, and some problems were noted initially handling the large volume of cuttings generated. The drilling progressed without further problems. The 7252-ft interval of 8.75-in was drilled in four bit runs and 16 days – 3 days ahead of the plan. As a general observation, the accretion on the bit and bottomhole assembly was eliminated. There was one instance where a minimal amount of shale adhered on one side of the first bit, attributed to the fact that the bit had the three nozzles on the same side plugged.

The entire well was drilled in 20 days to a depth of 9144 ft. This drilling performance was similar to recent OBM wells and significantly better than previous WBM wells. Offset well analysis indicates it required 21 – 26 days with OBM and 28 – 44 days with WBM to reach the same depth (Fig. 4). The average hole washout was 19%, closer to the OBM performance rather than the 35 – 75% for other WBM.

The shale inhibitor and the dispersion suppressant concentrations were measured during each fluid check. These concentrations and typical fluid properties are presented in Table 4. The average dilution rate expressed as “volume of fluid added while drilling / volume drilled” was 2.9 / 1.

Waste Management – The cuttings drilled with the HIAF were discharged in a separate sump, using the Mix-Bury-Cover method. The fluid was stored for further use.

Narraway Well

The new HIAF drilling fluid was used on the 12.25-in intermediate section of this well. The formations drilled consist of a sequence of sands and shales. The Shaftesbury formation is considered the most difficult shale formation here.

Offset Wells - Water-based fluids ranged from the “gel-chem” non-dispersed fluid to a more inhibitive amine / PHPA fluid. The average hole washout was 13 – 32% (Fig. 5). One of “gel-chem” fluids had an average rate of penetration of 14.4 ft/hr. However, twelve days of reaming and cleaning of sloughing shale from Dunvegan and Shaftesbury formations were needed prior to running the intermediate casing. The amine / PHPA fluid had better performance, with an average rate of penetration of only 15.1 ft/hr.

Oil-based muds provided significantly better drilling performance in the area, with an average washout in the 3 – 10% range. The OBM fluid and cuttings disposal are difficult, requiring transportation to an approved waste management location.

HIAF Drilling Performance - The HIAF fluid was used on well B to drill the 12.25-in section. This interval was programmed to 7841 ft, just after passing Shaftesbury formation. The drilling was extended to 8760 ft (Paddy formation) due to excellent hole conditions.

The top hole, 1991 to 3772 ft, containing mainly sandy formations (Brazeau and Chinook) was drilled without the addition of the shale inhibitor. The fluid was prepared at the rig and displaced in the hole after drilling cement and shoe with water. Fluid mixing was done very quickly due to the reduced number of products used and the fact they do not require any special mixing. A volume of 63 bbl was lost into formation at 3543 ft. The losses stopped after adding lost circulation materials. The average washout for this interval was 17.6%.

At 3772 ft the shale inhibitor was added to the fluid. Tight hole was experienced at 6732 ft. As a result the fluid density was increased to 9.7 lb/gal. While losing

314 bbl, the fluid density was dropped to 9.5 lb/gal. With the addition of loss-circulation materials, the losses were stopped. After tripping for bit and running in slick, the well was drilled to TD without problems. The average hole washout was 11.4%, closer to the OBM performance (2.7-9.9%) rather than the 13.5-31.8% for other WBM.

The entire 12.25-in interval was drilled in 27 days. This drilling performance was similar to recent OBM wells and significantly better than previous WBM wells (Fig. 6). The cuttings had consistently good integrity and hardness. No accretion was observed on the bit and bottomhole assembly.

An extensive logging program was run trouble-free, without any conditioning trip prior to, or between, logging runs. A volume of 949 bbl drilling fluid was lost while running casing.

The shale inhibitor and the dispersion suppressant concentrations were measured during each fluid check. The fluid properties and product concentrations are presented in Table 5.

Waste Management – The cuttings drilled with the HIAF were discharged in a separate sump, using the Mix-Bury-Cover method. The fluid was used to drill the next section without inhibitor and encapsulator additions.

Conclusions

A freshwater highly inhibitive drilling fluid was succesfully used to replace oil-based fluids in the Ricinus and Narraway areas of Alberta, Canada. The fluid contains a powerful shale hydration inhibitor and an encapsulating polymer that inhibits cuttings dispersion. The combination of these two products provided drilling performance comparable to oil-based muds from a water-based mud mixed without any salt. This performance was illustrated by the number of days required to drill the Ricinus and Narraway wells, and by the fluid inhibition characteristics (accretion, cuttings hardness). The fluid presented in this paper was mixed on-site and with few products, a logistical advantage versus previous fluid alternatives. The cuttings and fluids met the environmental requirements for Mix-Bury-Cover, which is the most economical disposal method.

Acknowledgments

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References

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Table 1 – Fluid Formulations for Inhibition Testing – 12 lb/gal

Product	HIAF Freshwater	HIAF 20% NaCl	PHPA Freshwater
Water (bbl)	0.79	0.75	0.84
NaCl (lb/bbl)		67.18	
PHPA (lb/bbl)			1.0
Fluid Loss Agent (lb/bbl)	2.0	2.0	3.0
Xanthan (lb/bbl)	0.75	0.75	0.75
Shale Inhibitor (lb/bbl)	10.5	10.5	
Dispersion Suppressant (lb/bbl)	2.0	2.0	
Barite (lb/bbl)	201.5	142.34	200.66

Table 2 – Rheology at 120°F, pH and Fluid Loss of Fluids Used in Inhibition Tests

	600/300	200/100	6/3	Gels (lb/100 ft²)	PV/YP (lb/100 ft²)	pH	API-FL (mL)
HIAF-Freshwater	68/43	32/20	6/4	5/6	25/18	8.8	4.6
HIAF-20% NaCl	73/44	31/21	6/5	6/8	29/15	8.8	3.0
PHPA-Freshwater	94/71	57/38	11/8	9/11	23/48	9.0	4.8

Table 3
Composition of HIAF Used in Western Canada

Water (bbl)	0.96
Shale Inhibitor (lb/bbl)	10.5
Dispersion Suppressant (lb/bbl)	2.5
Fluid Loss Agent (lb/bbl)	2
Rheology Modifier (lb/bbl)	1.25

Table 4
Typical Fluid Properties on Ricinus Well

Density (lb/gal)	8.4 – 9.0
Plastic Viscosity (cP)	11 – 25
Yield Point (lb/100 ft²)	17 – 30
6-rpm Dial Reading	6 – 9
API Fluid Loss (mL/30 min)	5.6 – 10.0
MBT (lb/bbl)	1 – 10
pH	8.7 – 9.5
Shale Inhibitor (lb/bbl)	2.5 – 3.4
Dispersion Suppressant (lb/bbl)	2.5 – 2.8

Table 5
Fluid Properties on Narraway Well

Density (lb/gal)	8.4 – 9.7	
Plastic Viscosity (cP)	28 – 40	
Yield Point (lb/100 ft²)	30 – 50	
6-rpm Dial Reading	11 – 20	
API Fluid Loss (mL/30 min)	5.6 – 7.4	
MBT (lb/bbl)	1 – 12	
Dispersion Suppressant (lb/bbl)	1.8 – 2.8	
Interval	1991 – 3772 ft	3772 – 8760 ft
Shale Inhibitor (%)	0	2.1 – 3.2
pH	7.5 – 8.5	9.9 – 10.5

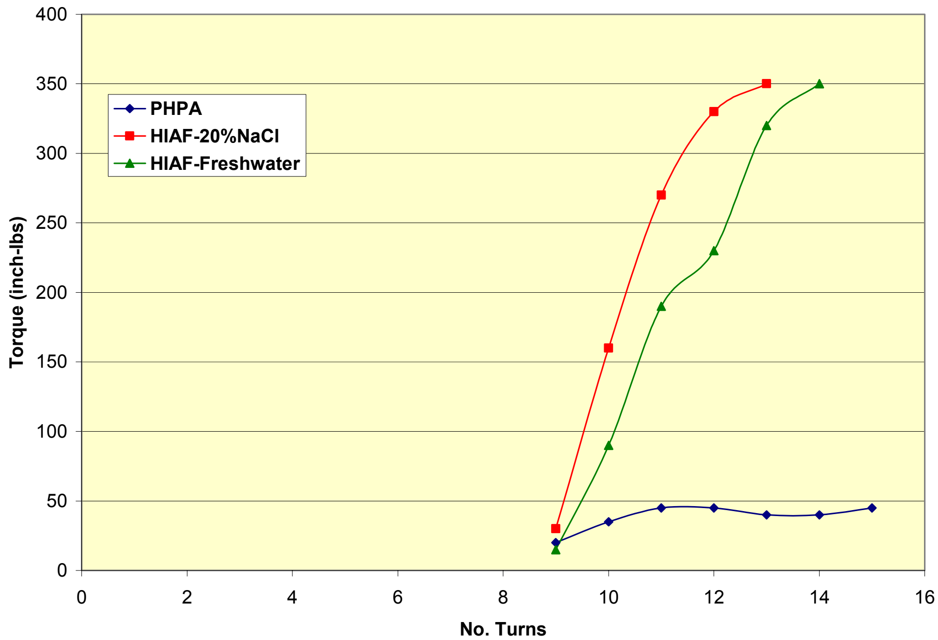

Fig. 1 - Bulk Hardness Tests for PHPA, HIAF with 20% NaCl and Freshwater HIAF.

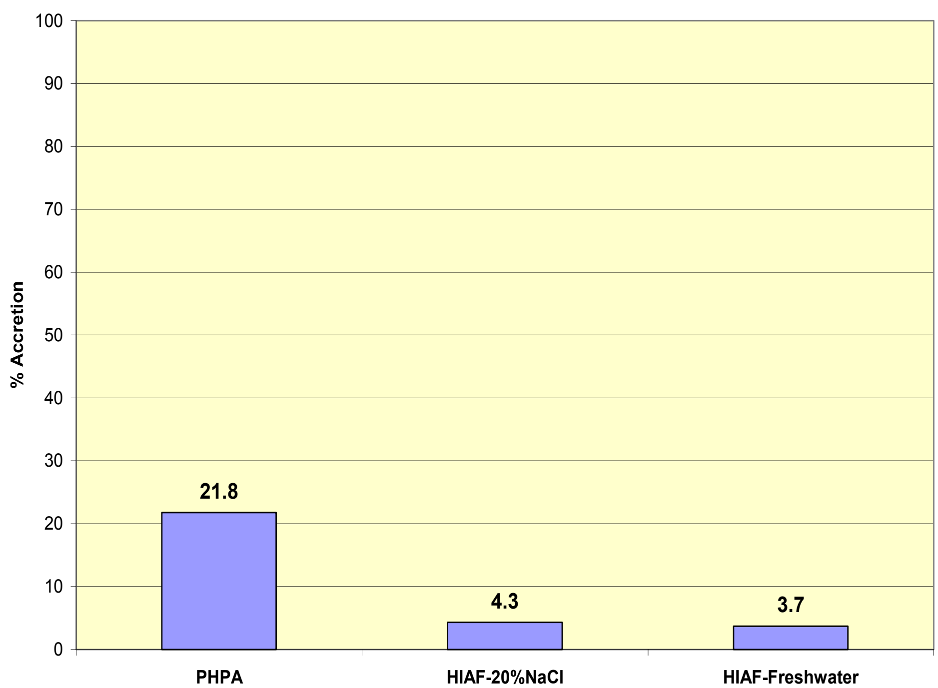

Fig. 2 - Accretion Tests for PHPA, HIAF with 20% NaCl and Freshwater HIAF.

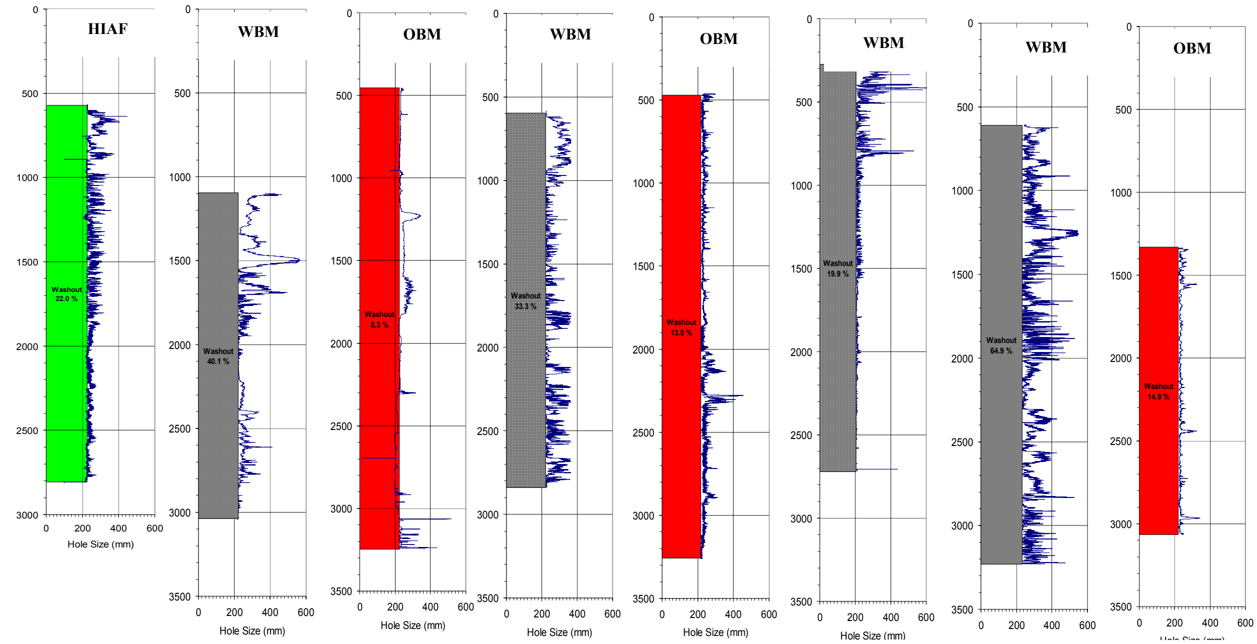

Fig. 3 - Caliper Log Comparison for Wells Drilled in the Ricinus Area with HIAF, OBM and WBM (Depth in Meters).

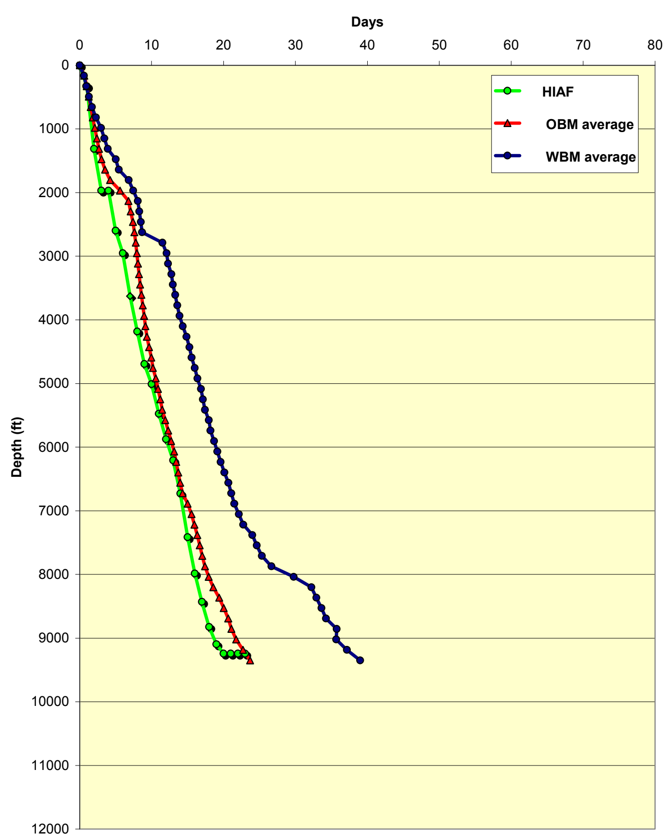

Fig. 4 - Days vs. Depth for the Ricinus area: HIAF, OBM and WBM.

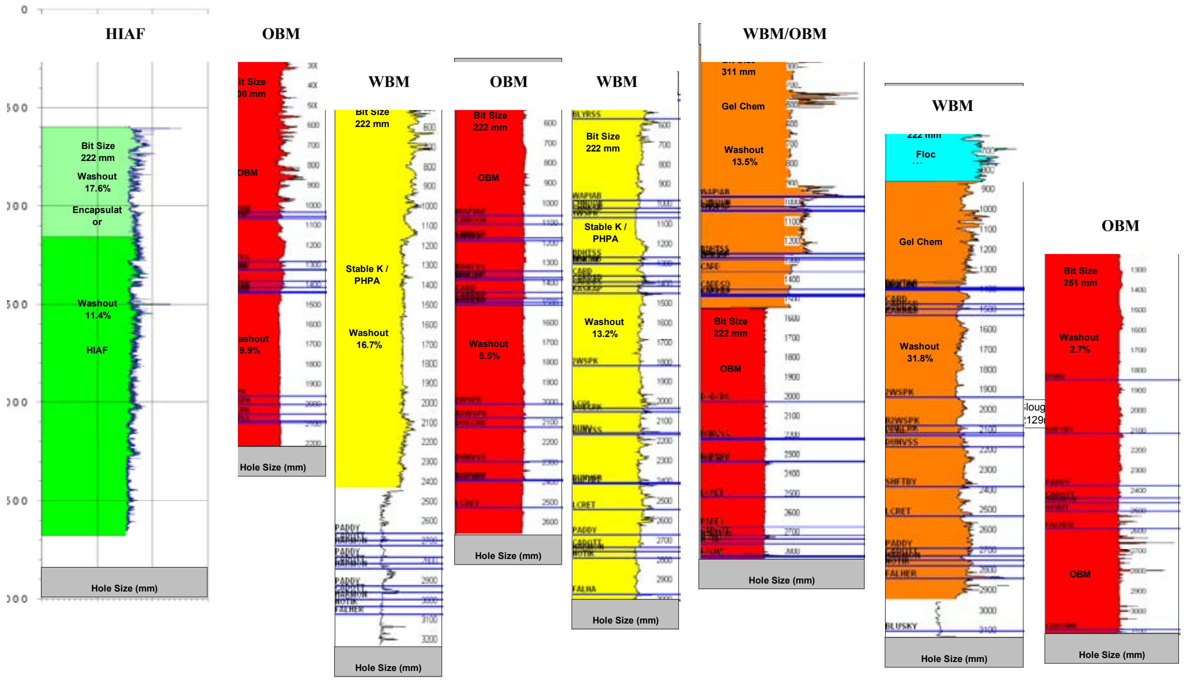

Fig. 5 - Caliper Log Comparison for Wells Drilled in the Narraway Area with HIAF, OBM and WBM (Depth in Meters)

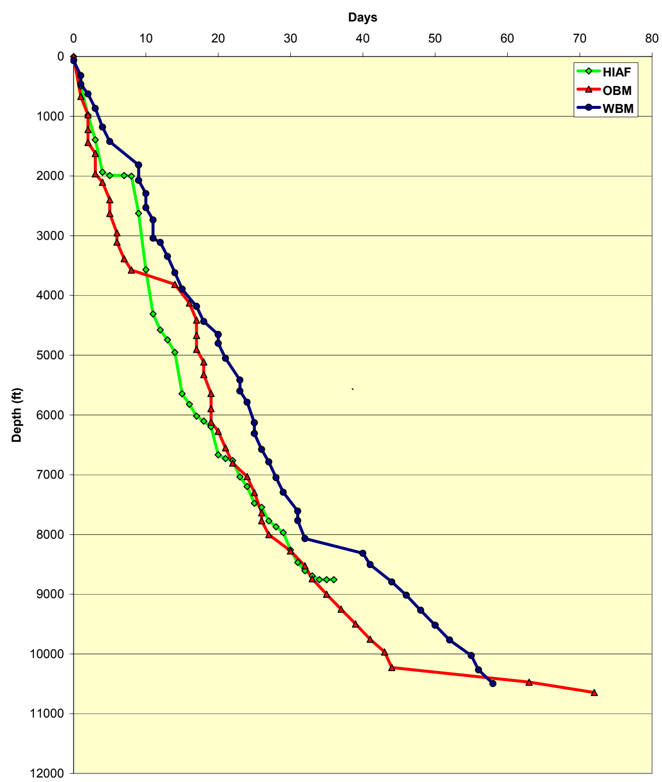

Fig. 6 - Days vs. Depth for the Narraway area: HIAF, OBM and WBM