



Using a System Cost Analysis to Quantify Drilling Fluids and Solids Control Costs

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Abstract

A System Cost Analysis is a methodology used to quantify drilling fluid costs to a common value, the monies spent/saved which are impacted by the mud system. Traditionally, most drilling fluid vendors and operators are concerned only with the actual costs of the mud materials, trucking, etc.. These "costs" only provide a minor piece of the total impact which mud has on the total well drilling costs. The System Cost Analysis provides a more complete picture of drilling fluid costs by considering both the material costs and actual time lost and/or gained due to the fluid. In addition, production data is readily included in a System Cost Analysis to ascertain the amount of impairment seen in the drilling process.

Items considered in an analysis include lost time due to mud related problems such as lost circulation, borehole instability, inability to log properly, ineffective solids control, etc.. In addition, drilling fluids can have a positive/negative impact on time by increasing/decreasing ROP's; the System Cost Analysis fixes a dollar value to this important variable.

The measurement method provides a framework for measuring both past, present and future performance of drilling fluid performance in a given study area. This paper describes how a System Cost Analysis is done and gives examples of analyses completed on projects in Western Canada and South America.

Introduction

Over the last number of years, the quantification of drilling costs has been rising dramatically, especially in offshore and remote locations. As a result, a number of studies have been published on quantifying those costs in order to both understand where the dollars are being spent and where savings potential exists.¹⁻⁴

While drilling fluids normally account for a relatively small percentage (< 10% normally) of a well cost, they are directly involved in a large number of the costs

incurred on a well. This is especially true for borehole instability where the correct drilling fluid choice can eliminate problems, or conversely lead to large cost overruns. Similarly, improper handling of solids control equipment can lead to massive wellbore problems and needlessly expensive drilling costs.

This paper will describe the use of a "System Costs Analysis" methodology to quantify the actual costs of a drilling fluid on the actual costs of drilling a well. The analysis looks at more than just the material costs of mud products. It also focuses on the problems associated with poor drilling fluid performance and on the benefits of that drilling fluids can provide in drilling wells faster.

System Cost Analysis Methodology

A System Cost Analysis (SCA), in basic terms, equates all incidences on a well impacted by drilling fluids, either positive or negative, back to a fundamental value – dollars and cents. The analysis attempts to remove the "fuzzy" qualitative feelings often associated with drilling, items such as "trying hard, unforeseen circumstances, bad luck, etc.". While there will always be some qualitative measurement needed to reflect trust and honesty on the multidisciplinary task of drilling a well, the System Cost Analysis provides a quantitative measurement tool. This tool is a direct measuring stick on how well an operator and service company perform.

The simplest version of a System Cost Analysis for drilling fluids is determined in one simple equation:

$$\text{System Cost} = \text{Material Costs} + \text{Unproductive Time}$$

This System Cost has been further refined, as will be discussed in the following section.

The material costs are quite simple, the costs of the drilling fluids added to the well, plus any associated costs as required for trucking, engineering services, etc.. It is generally common for drilling fluid companies and the contribution of fluids to be evaluated on this "material

cost" alone.

The unproductive or problem time for drilling fluids involves any drilling function that has to do with drilling fluids. A list of items is given in Table 1. Reaming and cleaning, lost circulation, stuck pipe and mud rings are just some of the items included in the trouble time cost.

The actual dollar value of the trouble time cost is governed by the rig cost, usually determined on an hourly basis.

In practice, the rig cost is agreed upon by the operator and drilling fluid provider prior to the commencement of the analysis. Any additional items to be covered in the trouble time costs are also agreed upon by the parties involved.

System Cost Analysis Methodology - Enhanced

Quantitative measurement of drilling fluid performance is only one step in the process of how mud impacts on the well performance and costs. Three additional items may be included in a System Cost Analysis. First, drilling fluids will certainly impact the time to drill as seen in rate-of-penetration (ROP). ROP's will vary greatly depending upon densities, viscosities and filtration control properties. Solids control and disposal costs are directly related to mud types, especially in offshore and environmentally sensitive regions. Thirdly, the production of hydrocarbons from wells and fields may be included if formation impairment is a real possibility.

Therefore the expanded System Cost equation is:

$$\text{System Cost} = \text{Material Costs} + (\text{Trouble Time} * \text{hourly rig cost}) + \text{ROP impact} + \text{solids control/disposal} + \text{production}$$

For example, comparison of water-based and oil-based fluids by only the material costs only will invariably show that water-based fluids cost less. The SCA may provide a different answer once unproductive time, ROP, solids/disposal costs and production data is included.

Benefits of a System Cost Analysis

System Cost Analyses can be done for any drilling project, but are best utilized in areas where drilling is troublesome and where a number of wells have previously been drilled. In order to provide a relevant analysis, ideally the wells included in the study should be less than two years old. Wells older than this tend drill somewhat slower (and are more costly) because of the changes in technology (bits, MWD, etc.). In addition, the wells used in the study should be of similar deviational design and pass through similar lithologies since

wellbore trajectory plays a major part in well costs.

Drilling fluids system costs analysis are primarily used for the following applications:

- *Benchmarking:* Drilling in troublesome areas often involves problems with borehole instability. A number of drilling fluids are often used to alleviate that instability with varying degrees of success. The System Cost Analysis provides a means of determining which drilling fluid, casing design, etc. is the most efficient fluid to use. In addition, benchmarking provides a dollar value on the problems which are most acute in the drilling region. A risk cost analysis at this stage provides an excellent tool for determining which drilling fluid and casing design is optimum for drilling difficult, expensive wells.
- *Measuring change:* Benchmarking in itself is a good tool to determine the optimal method of how a well/area is drilled now. Most times in difficult drilling areas, the benchmarking exercise provides a tool for indicating where improvements need to be made and then provides a method of measuring those changes. The real beauty of a dedicated system cost analysis is in the cooperation of the drilling fluid supplier to lower the overall well costs to the operator by the cost effective means of mud technologies and practices. Measuring change provides a method of accomplishing this objective in a quantifiable organized manner.
- *Production measurement:* Drilling fluids are the first fluid to contact the native reservoir and often have a large impact on the formation impairment of a well/field. The System Cost Analysis is easily modified to include the fluid costs as well as the production numbers in a field. This type of analysis is ideal for fields where different mud types are being used and/or horizontal and vertical wells have or will be drilled.

System Cost Analysis - Examples

1. Chicken/Route Area – Western Canada

The Chicken/Route area of the Alberta Foothills (Figure 1) is characterized by instability problems leading to some reaming and cleaning, but primarily an inability to get logs to bottom. A system cost analysis of 38 wells in the field was undertaken to determine the root cause of the problem, whether different drilling fluid types have helped this problem, whether the problem was localized to a certain portion of the field, and to determine if any improvements could be made to the drilling fluid and drilling practises. Typical well design in this field is to drill with flocculated water as deep as possible

(usually about 3600-3900 feet) and then mud-up to either a gel-polymer or K_2SO_4 -gel mud system to TD around 5300 feet.

Figure 2 shows the wells in which logs either bridged on first (or more) attempts and wells in which no logs were obtained. Also on this area map is an indication of where major lost circulation occurred. As can be seen, logging problems were evident on 23 of the 38 wells in the study. These problems are evident in the system costs per foot seen in the wells as shown in Table 2 and Figure 3. Wells with the bridging problems always had greater system costs than those without the problems. Note that the data is given per foot to normalize the data and is only for the main hole section where mud was in the hole.

Following completion of the data gathering and analysis phases of the SCA, a number of conclusions and recommendations were made, including:

- Wells in the 62-8 sector were generally trouble free as seen by the system cost being twice the material cost. This "twice value" or less of system cost over material cost is generally seen for land-based wells experiencing only minor problems.
- majority of lost time which increased system costs were due to logging difficulties as caused by poor hole conditions. Logs normally bridged somewhere in the water drilled section of the well between 2625 and 3275 feet.
- A direct correlation existed between logging problems and mud-up depth in which wells which mudded-up deeper than 3925 feet were most likely to experience logging problems. For future wells, recommendations to drill no deeper than 3900 feet with water were made.
- For all wells in area study, recommendation was made to use silicate sweeps while floc water drilling to stabilize the wellbore.
- Recommend drilling wells in 62-8 sector with simple gel polymer mud systems previously used. In all other areas, an inhibited fluid with K^+ as provided from K_2SO_4 was recommended.

The recommendations were implemented in the field over a series of wells. The results from some of the wells are shown in Table 3. All of the newly drilled wells successfully ran logs to bottom on the first attempt and hole problems due to wellbore instability were minor. While the material costs were higher for the post System Cost Analysis wells, the fewer problems hours resulted in lower system costs.

2. *Tipischa Jungle Basin – Ecuador*

A System Cost Analysis in the Tipischa basin

compared the performance of an initial 14 well program to a later 12 well program. The initial 14 wells were drilled with gel PHPA muds while a KNO_3 ss-PHPA fluid was used on the later wells. A typical well schematic with intermediate casing is shown in Figure 4.

Table 4 and Figure 5 summarize the material and system costs for the total well data for wells. Also included is the solids control costs for the wells. The following conclusions were made from the information contained within the data:

- material costs/ft for the later drilled set of wells was 13% greater than the previous wells. In contrast the system costs were 5% less for the later well grouping. The average amount of unproductive time on the earlier wells was 79 hours while the later wells had 60 hours of unproductive time.
- Solids control costs improved on the later wells by 25% of \$4.40/ft drilled. The savings were a direct result of the KNO_3 ss-PHPA system being easier to strip solids from and thereby minimize dumping and dilution of drilling fluid.

The Tipischa SCA study also analyzed drilling time in terms of ROP, time to TD and time to rig release. The data is summarized in Table 5 and Figure 6. While the drilling fluid is certainly not the only parameter which influences ROP, it is an important variable. Other parameters such as bit type, weight on bit, rpm, etc. are also of major importance. The conclusions drawn from the data include:

- ROP, as reflected in the drilling ft/day was ~ 175 ft/day faster in the later well set.
- The later well set was about 10% faster or 1.8 days to TD. This is due to a combination of higher ROP's and fewer unproductive hours.
- The days to rig release was also faster, 2.4 days faster, on the later well set. The additional 0.6 days of savings resulted from increased efficiencies in running logs and in conducting liner/cementing operations.

Conclusions

- A System Cost Analysis provides a quantitative tool for measuring the actual costs of drilling fluids on overall well drilling costs.
- Simple System Cost is composed of drilling fluid material costs, unproductive time due to drilling fluid performance - converted to cost.
- An ideal total analysis of drilling fluid performance will include the System Cost as noted above, an ROP analysis, solids control/disposal impact

analysis and formation impairment – production review.

- The prime benefits of a SCA are (1) benchmarking current drilling fluid performance and (2) measuring the impact of changes on the drilling fluid performance.
- System cost Analysis provides operators and service companies with methodology of determining where costs are most prevalent.
- In general terms for a land-based operation, a well with minimal problems related to mud will have System Costs no greater than twice the material cost.
- SCA lends itself well to using a risk analysis method for determining relative well costs using varying well casing and drilling fluid combinations. The SCA will provide a large number of accurate input data sets in order to generate accurate output well cost information.

World-Class Exploration Drilling-Integration of Design, Planning, and Execution”, SPE Paper No. 61798, presented at the 2000 IADC/SPE Drilling Conference, New Orleans, February 23-25.

4. Aldred, W.D., “Improving Drilling Efficiency Through the Application of PERFORM”, Performance by Risk Management”, SPE Paper No. 57574, presented at the 1999 SPE/IADC Middle East Drilling Technology Conference, Abu Dhabi, UAE, November 8-10.

Acknowledgements

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Nomenclature

ft = feet

K+ = potassium sulphate containing fluids

KNO₃ = potassium nitrate

K₂SO₄ = potassium sulfate

MWD = measurement while drilling

N/A = not available

PHPA = partially hydrolyzed polyacrylamide

ROP = drilling rate of penetration

rpm = revolutions per minute

ss-PHPA = sterically stabilized partially hydrolyzed polyacrylamide

SCA = System Cost Analysis

TD = total depth

References

1. Carter, T.: “A Model for Evaluating Mud Engineer Performance” presented at the 1996 AADE Drilling Fluids Technology Conference, Houston, Texas, April 3-4.
2. Trantham J.A. and Deagen J.M.: “Barrier-Free Learning for Well Construction” SPE Paper No. 62833, presented at the 2000 SPE/AAPG Western Regional Meeting, Long Beach, California, June 19-23
3. Thorogood, L., Jackson, M.D., Thorsen, O.H., “Delivering

SYSTEM COST ITEM	DESCRIPTION OF TROUBLE TIME INCLUDED
Lost Circulation	▪ Material costs and time (rig and other items such as water hauler).
Reaming and Cleaning	▪ Reaming and/or cleaning while rih or pooh due to poor hole conditions. Does not normally include reaming undergauge hole after motor drilling.
Logs Bridging	▪ Due to poor hole conditions. Includes time spent reaming logging tool to bottom, time lost due to no logs run, hole conditioning and running tool back into hole.
Casing/Liner	▪ As above noted in "Logs Bridging" section.
Sidetrack/Redrill	▪ Includes time and material costs incurred from running cement plugs to reaching original depth before plugging back. Does not include sidetracks for geological reasons.
Stuck Pipe	▪ Includes material/time due mechanically stuck pipe. May or may not include problems because of differentially stuck pipe.
Gravel/Boulders	▪ Material costs and time.
Mud Rings	▪ Material costs and time.
Kicks	▪ Material costs and time.
Additional Costs	▪ Includes items such as cementing, disposal (fluids and cuttings), trucking, engineering, etc. as appropriate.
Rate-of-Penetration	▪ Hours on bitover footage intervals. May include time spent on trips.
Production Comparisons	▪ Captures formation damage issues. Works best for large sample sets and fairly homogeneous reservoirs.

Table 1 – Items Included in a System Cost Analysis

Well LSD	Mud Type	ft drilled	\$ material	\$ material/ft	\$ system cost	\$ sc/ft
02-20-61-7 W6	K+/K+	1365	33445	24.50	42445	31.10
12-26-61-7W6	PHPA	3491	25248	7.23	70623	20.23
05-33-61-7 W6	gel chem	1654	18586	11.24	76336	46.17
09-11-62-7 W6	PHPA	738	2735	3.71	9860	13.36
07-03-62-7 W6	PHPA	3940	33261	8.44	151761	38.52
16-21-62-7W6	PHPA	1165	16614	14.26	46052	39.54
06-22-62-7 W6	PHPA	3694	13640	3.69	25265	6.84
16-20-62-7W6	gel chem	3002	11939	3.98	43252	14.41
09-31-62-7 W6	PHPA	1388	10423	7.51	37611	27.10
14-07-62-7 W6	PHPA	965	28023	29.05	38336	39.74
16-15-62-7 W6	K+/K+	978	22792	23.31	97417	99.64
16-14-62-7 W6	/K+	2510	38744	15.44	56744	22.61
05-12-62-7 W6	/K+	2707	25330	9.36	30393	11.23
11-23-62-7 W6	K+/K+	2461	34095	13.86	53408	21.70
03-28-62-7 W6	K+/K+	2411	34830	14.44	48143	19.96
04-18-62-7 W6	K+/K+	2871	45434	15.83	62872	21.90
10-23-62-8W6	PHPA	548	4467	8.15	13280	24.24
14-11-62-8W6	PHPA	2126	12649	5.95	25024	11.77
11-14-62-8W6	PHPA	1234	13168	10.67	32293	26.18
05-26-62-8 W6	/K+	2280	23632	10.36	33945	14.89
01-33-62-8 W6	PHPA	1772	8972	5.06	18160	10.25
02-04-63-8 W6	PHPA	1611	9102	5.65	29352	18.22
04-09-63-8 W6	PHPA	1453	5655	3.89	16530	11.37
08-12-63-8 W6	gel chem	600	9755	16.25	75943	126.49
13-12-63-8W6	gel chem	876	10353	11.82	45228	51.63
03-13-63-8W6	gel chem	1732	20868	12.05	30993	17.89
06-14-63-8 W6	gel chem	912	9742	10.68	63180	69.27
13-28-63-8W6	PHPA	1188	5480	4.61	15043	12.67
02-31-63-8W6	PHPA	1401	5297	3.78	16360	11.68
12-32-63-8W6	PHPA	1332	5190	3.90	13440	10.09
12-33-63-8W6	PHPA	1690	6667	3.95	28042	16.60
16-20-63-8W6	PHPA	755	5603	7.43	60353	79.98
13-14-63-8W6	PHPA	2051	11880	5.79	19005	9.27
04-15-63-8W6	PHPA	1325	6903	5.21	47966	36.19
10-18-63-8W6	PHPA	509	6102	12.00	32915	64.72
13-19-63-8W6	PHPA	525	5463	10.41	9963	18.98
07-21-63-8W6	PHPA	2461	5204	2.11	7829	3.18
05-22-63-8W6	PHPA	2927	6824	2.33	46387	15.85
10-22-63-8W6	gel chem	663	10699	16.14	66762	100.74
61-7 MEAN						
		2170	25760	14.33	63135	32.50
62-7 MEAN						
		2218	24451	12.53	53932	28.97
62-8 MEAN						
		1592	12578	8.04	24540	17.46
63-8 MEAN						
		1334	8155	7.67	34738	37.49

Table 2 - Chicken Area (Alberta) Material and System Cost Values in Main hole mud drilled section. Lowest mean material cost/ft as well as the highest system cost/ft was in the 63-8 section. The 62-8 section had the lowest system cost mean and therefore the fewest amount of problems.

Well LSD	Mud Type	ft drilled	\$ material	\$ material/ft	\$ system cost	\$ sc/ft
61-7 MEAN		2170	25760	14.33	63135	32.50
06-36-61-07	K ₂ SO ₄	2648	78335	29.58	90335	34.11
62-7 MEAN		2218	24451	12.53	53932	28.97
16-30-62-07	K ₂ SO ₄	2415	29286	12.13	56474	23.38
12-18-62-07	K ₂ SO ₄	2740	45821	16.73	64196	23.43
63-8 MEAN		1334	8155	7.67	34738	37.49
12-27-63-08	K ₂ SO ₄	722	6720	9.31	24720	34.23
16-07-63-08	K ₂ SO ₄	6115	46163	7.55	54788	8.96

Table 3 - Chicken Area System Cost Analysis Comparison for wells drilled pre- and post-analysis. The individual well locations are for the post-drilled SCA wells. Note that all of the post-analysis wells achieved successful logs on first attempt. The well @ 06-36-61-07 had a high material cost due to massive lost circulation.

WELL NAME	Ft DRILLED	\$ MATERIAL	\$ MATERIAL/ft	\$ SYSTEM COST	\$ SYSTEM COST/ft	\$ SOLIDS CONTROL	\$ SOLIDS CONTROL/ft
INITIAL 14 WELL SET							
M 8	8870	297531	33.54	421281	47.50	172,000	19.39
D 1	9599	351809	35.77	735559	74.79	186,000	19.38
F 18b 13	8656	135135	15.74	300135	34.96	132,000	15.25
F 18b 14	8557	122928	14.37	244178	28.54	122,000	14.26
F18b 15	8762	96549	11.02	96549	11.02	136,000	15.52
D 2	9600	216650	22.60	352900	36.81	134,000	13.96
F 18b 16	8150	149112	18.28	229112	28.08	116,000	14.23
D 3	9356	305746	32.68	610746	65.28	232,000	24.80
D 7	10805	218232	20.20	385732	35.70	148,000	13.70
F 18b 20	8880	N/A	N/A	N/A	N/A	145,000	16.33
D 8	9093	148487	16.33	343487	37.77	100,000	11.00
F 18b 21	8880	N/A	N/A	N/A	N/A	188,000	21.17
M 4A	9145	144592	15.81	144592	15.81	125,000	13.67
F 18b 26	9388	240252	25.65	547752	58.47	166,000	17.68
LATER 12 WELL SET							
T 1	10255	193515	18.87	434765	42.40	159,000	15.50
F18b 27	9061	281302	31.04	753802	83.18	130,000	14.35
P 1	9017	243320	26.98	329570	36.55	141,000	15.64
F 18b 25	9036	191113	21.15	256113	28.34	57,000	6.31
F 18b 37	9413	427153	43.93	528403	54.35	121,000	12.85
D 6	9220	243940	26.46	360190	39.07	131,000	14.21
M 4A2	8771	234838	26.77	347338	39.60	84,000	9.58
M 4A3	9362	163872	17.50	321997	34.39	93,000	9.93
T 1	9249	219644	23.75	318394	34.42	98,000	10.60
F 18b 46	8890	264718	29.78	395968	44.54	93,000	10.46
M 4A4	9207	N/A	N/A	N/A	N/A	89,000	9.67
T 2	9088	239000	26.30	312750	34.41	138,000	15.18
Initial 14 MEAN	9135	218588	23.51	417088	44.79	150,100	16.43
Later 12 MEAN	9240	245674	26.59	396299	42.84	111,200	12.03

Table 4 - System Cost Analysis raw data and solids handling costs for Ecuador Tipischa Basin area. Data is included for total well analysis, surface hole to TD.

WELL NAME	Ft DRILLED	DRILLING DAYS	ft/ DRILLING DAY	DAYS to TD	ft/ DAYS to TD	DAYS to RIG RELEASE	ft/ DAYS to RIG RELEASE	TROUBLE TIME (hrs)
INITIAL 14 WELL SET								
M 8	8870	6.7	1318	24.0	370	26.6	334	49.5
D 1	9599	12.4	795	31.0	317	35.0	281	153.5
F 18b 13	8656	7.4	1168	14.0	615	15.7	546	66.0
F 18b 14	8557	7.3	1170	13.7	623	19.1	448	48.5
F18b 15	8762	N/A	N/A	N/A	N/A	17.0	515	N/A
D 2	9600	8.8	1085	19.0	505	21.0	457	54.5
F 18b 16	8150	7.5	1094	13.6	600	17.4	470	22.0
D 3	9356	10.5	888	31.0	302	41.0	228	122.0
D 7	10805	14.7	735	24.6	440	27.5	393	67.0
F 18b 20	8880	8.9	1003	21.0	423	25.0	355	20.5
D 8	9093	7.8	1173	16.8	541	21.0	433	78.0
F 18b 21	8880	N/A	N/A	N/A	N/A	34.0	261	N/A
M 4A	9145	N/A	N/A	N/A	N/A	24.0	381	N/A
F 18b 26	9388	13.9	675	26.5	353	29.9	313	123.0
LATER 12 WELL SET								
T 1	10255	13.0	789	28.7	357	31.7	323	96.5
F18b 27	9061	11.3	801	18.7	485	29.4	308	179.0
P 1	9017	9.2	977	23.5	384	26.3	343	34.5
F 18b 25	9036	5.4	1662	11.3	799	14.6	620	26.0
F 18b 37	9413	7.4	1317	26.5	367	32.1	303	40.5
D 6	9220	5.9	1553	17.1	540	19.5	474	46.5
M 4A2	8771	8.3	1053	17.0	516	19.6	448	45.0
M 4A3	9362	9.8	955	18.6	502	19.5	479	63.25
T 1	9249	5.8	1591	16.4	565	17.5	528	39.5
F 18b 46	8890	9.3	956	18.9	471	22.5	396	52.5
M 4A4	9207	N/A	N/A	N/A	N/A	21.0	438	N/A
T 2	9088	6.5	1398	19.2	474	20.8	438	29.5
Initial 14 MEAN	9135	9.6	1009	21.4	463	25.4	387	79
Later 12 MEAN	9240	8.4	1186	19.6	496	23.0	424	60

Table 5 - Time Analysis information for wells drilled in Ecuador Tipischa Basin area. Initial 14 wells used a gel-PHPA system while the later 12 wells used a KNO3 ss-PHPA fluid. Drilling Days is a measure of rotating time to reach total depth.

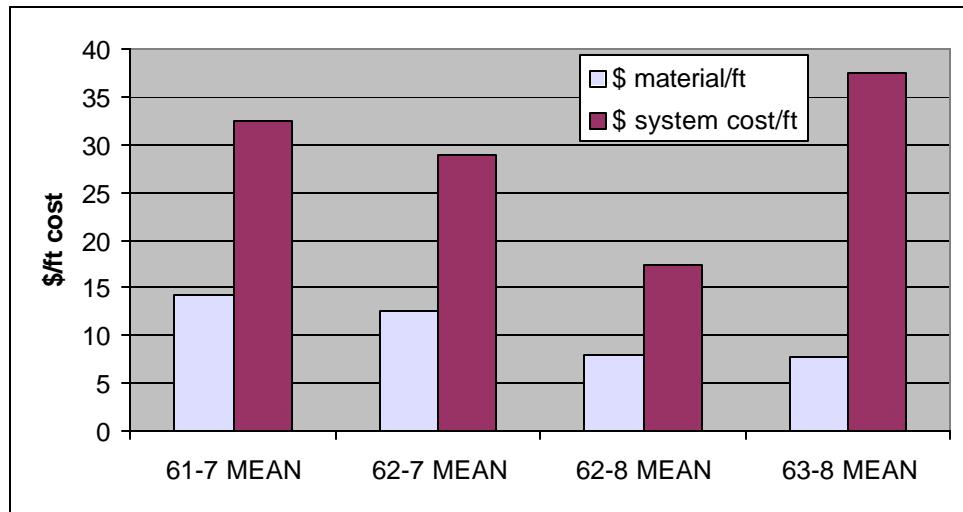


Figure 3 – Comparative material and system costs for Main Hole section of wells in the various sectors of the Chicken/Route area. Data taken from Table 2.

<u>HOLE SIZE</u>	<u>DEPTH</u>	<u>CASING SIZE</u>
17.5"	1400-1700'	13.375"
12.25"	7000-9000'	9.625"
8.5"	8500-10000'	7"

Figure 4 – Typical well design for Ecuadorian Tipischa Jungle basin wells.

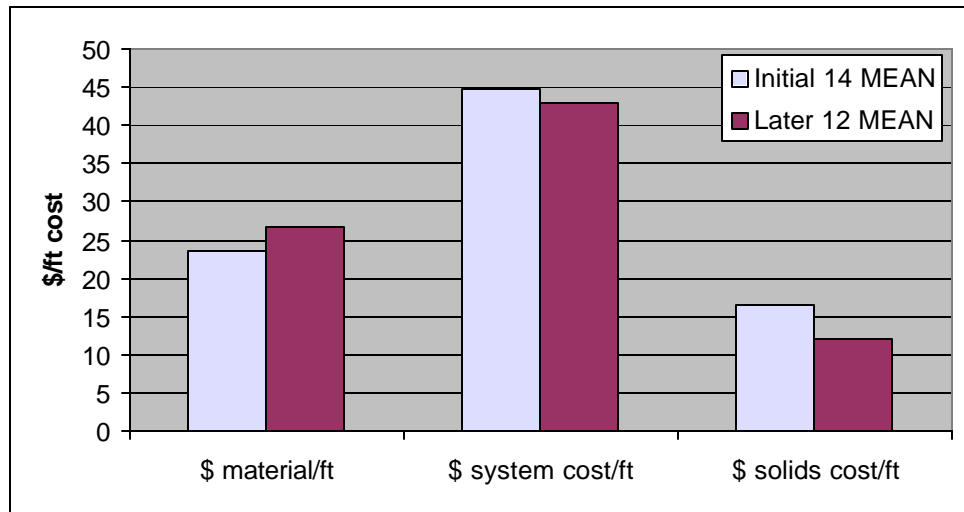


Figure 5 – Comparison of material costs, system costs and solids costs for initial 14 and later 12 wells in Tipischa study area. Costs are given per foot to normalize the data and are shown for the entire well. Data taken from Table 4.

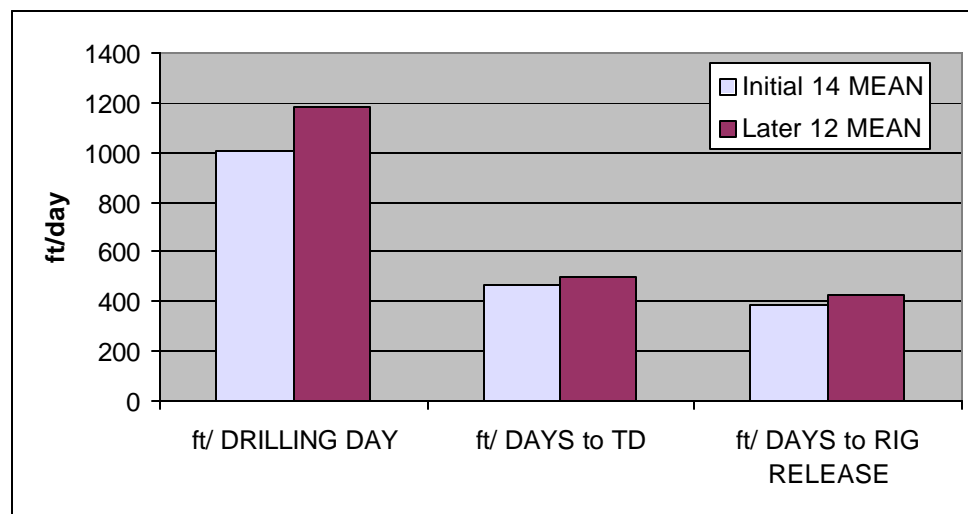


Figure 6 – Comparison of drilling rate (ROP), time to total depth and time to rig release for initial 14 and later 12 wells in Tipischa study area. Information is presented in value ft per days to normalize data. Data taken from Table 5.