PROJECT SIMULATION MODEL

Topic: *Simulation model to determine optimal drilling parameters for proper hole inclination in Horizontal wells.*

NB: Software will have four packages

1. Home
2. Unit Conversion calculator
3. Mud Pump
4. Horizontal Drilling Optimization
5. Drilling Cost Analysis

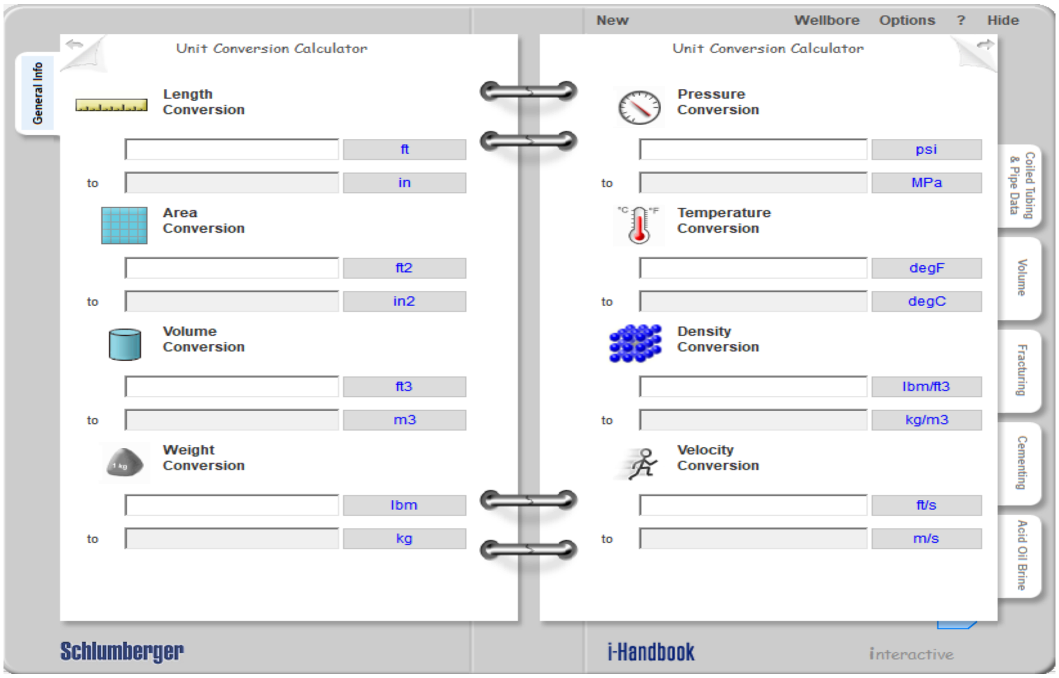
Name of Software: ***OPTIDRILL***

1. Unit Conversion Calculator

Variables:

1. Length
2. Area Conversion
3. Volume Conversion
4. Weight Conversion
5. Pressure Conversion
6. Temperature Conversion
7. Density Conversion
8. Velocity Conversion
9. Flowrate Conversion
10. Power Conversion

NB: Please refer to Schlumberger I-Handbook and Conversion table attached



2: Mud Pump Calculation

Input Variables
A: Duplex Pump
B: Triplex Pump

A. *Input Variable (Duplex Pump):*
   i. Liner Diameter (inch)
   ii. Rod Diameter (inch)
   iii. Stroke length (inch)
   iv. Efficiency (%)
   v. Pump rate (stk/min)

Equation (Duplex Pump)

Pump Output (bbl/stk) = [0.000162 x Stroke Length (inch) x (2 $x(\boldsymbol{Liner\ Diamter}(\boldsymbol{inch})^2 - \boldsymbol{Rod\ Diameter}\ (\boldsymbol{inch})^2$) x Efficiency (dec.)

Flowrate (gal per minute or gpm) = 42 x Pump output (bbl/stk) x Pump rate (stk/min)

Output Variables (Duplex Pumps)

i. Pump Output (bbl/stk)
ii. Flow rate (gpm)

B. *Input Variable (Triplex Pump):*

Liner Diameter (inch)
Stroke length (inch)
Efficiency (%)
Pump rate (stk/min)

Triplex Pump Output (bbl/stk) = [0.000243 x $Liner\ Diameter\ (inch)^2$ X (stroke length (inch) x Efficiency (dec.)

Flowrate (gal per minute or gpm) = 42 x Pump output (bbl/stk) x Pump rate (stk/min)

3: **Horizontal Drilling Optimization**

This is my main project concern. I am Optimizing the drilling parameters shown below from known drilling data. [this known drilling data will be called my reference data]. The drilling parameter include; ROP (ft/hr), RPM (rpm), WOB (lbm), Impact force (lbf), Flowrate (gpm), Hole Cleaning (this can be either good or bad) and finally ECD (ppg)

ROP (ft/hr)	RPM	WOB (lbm)	Impact Force (lbf)	Pump/Flow rate (gpm)	ECD (ppg)	Model Hole Cleaning	Hole Cleaning
70	50	5000	300	0	9.33	1	Good
70	90	80000	439	502	9.33	0	Poor
40	80	10000	330	137	9.23	0	Poor
34	90	32000	340	137	9.64	0	Poor
36	100	32000	578	562	9.83	0	Poor
40	85	32000	450	600	9.4	0	Poor
44	88	24000	450	560	9.65	0	Poor
48	92	24000	741	640	9.75	0	Poor
29	90	32000	749	640	9.84	0	Poor
70	50	25000	606	704	8.93	0	Poor
70	70	28000	650	492.8	9.5	0	Poor
55	60	28000	660	500	10.2	1	Good
50	100	27000	690	598.4	10.65	0	Poor
30	90	29000	672	598.4	10.37	1	Good
30	85	30000	669	598.4	10.31	1	Good
68	50	10000	575	704	8.45	1	Good
55	55	10000	600	643	9.5	1	Good
45	50	13000	743	647.6	9.75	1	Good
30	80	13000	748	605.4	11.32	1	Good
30	80	13000	752	605.4	11.37	1	Good
27	80	14000	744	580.7	12.25	1	Good
45	100	15000	563	499.8	12.33	1	Good
55	80	15000	665	542	12.52	1	Good
70	90	18000	500	450	8.9	0	Poor
57	80	20000	540	500	9.3	0	Poor
55	79	22000	554.9	549	10.28	1	Good
55	80	22000	552	549	10.35	1	Good
49	90	31500	563.3	556	10.43	1	Good
68	79	28000	755.6	644	10.77	1	Good
41.5	130	15000	1776	600	9.96	1	Good
24.3	130	15000	1611	670	8.95	1	Good
7.3	110	7500	1185	550	10.3	1	Good
9.5	110	10000	1324	590	10.8	1	Good
5.7	100	9000	1186	600	10.5	1	Good
25.9	90	15000	2196	730	10.4	1	Good

Table 1:

Main Input Variables:

a. RPM (rpm)
b. WOB (lbm)
c. Impact Force (lbf)
d. Flowrate (gpm) [This is not an input variable, but is computed as shown above, for Duplex or Triplex Pump]
    a. Liner Diameter (inch)
    b. Rod Diameter (inch)
    c. Stroke length (inch)
    d. Efficiency (%)
    e. Pump rate (stk/min)

e. Hole Cleaning (Good or Bad): [This is not an input variable, but is calculated as shown below]

Input Variables

1. Hole ID (inch)
2. Pipe OD (inch)
3. Mud Weight (ppg)
4. Plastic Viscosity (cP)
5. Yield Point (lb/100ft2)
6. Flowrate (gpm)

Output Variables

1: Carrying Capacity index (unitless)

2: Hole cleaning:

If CCI $\leq$ 0.5, Hole Cleaning = **Poor**

If CCI $\geq$ 1.0, Hole Cleaning = **Good**

NB: I tried to analyze the reference data using Multiple Regression in excel, it gave me a trend, and an equation. But I don't know how you can input the multiple regression analysis in your coding, so I think you should do it your own way..

Maybe do data analysis using Machine learning, just the way you're doing it for Azubuike….

After, the reference data has been analyzed, and a trend calculated, it will be used to derive future ROP (ft/hr) values, after inputting values for the "Main input variable"

The Hole Cleaning (Good or Poor) will be modelled as a "Dummy Variable" [1 or 0], or anyhow you seem fit.

Equations for Hole Cleaning:

1: **Annular Capacity (gal/ft)**

$$=\left[\frac{\text{sqrHole ID(in)} - \text{sqrP}ipe\ OD(in)}{24.51}\right]$$

2: **Annular Velocity (ft/min)**

$$= \frac{Flow\ rate\ (gpm)}{Annular\ Capacity\ (\frac{gal}{ft})}$$

3: **Flow behaviour index - n**

$$n = 3.322 \log \frac{(2 * Plastic\ Viscosity\ (cP) + Yield\ Point\ (\frac{lb}{100ft2})}{Plastic\ Viscosity\ (cP) + Yield\ Point\ (\frac{lb}{100ft2})}$$

4: **Power Law Constant - K (unitless)**

$K = (511)^{1-n} \times$ [Plastic Viscosity (cP) + Yield Point (lb/100ft2)]

5: **Carrying Capacity Index - CCI (unitless)**

$$CCI = \frac{K \times Annular\ Velocity\left(\frac{ft}{\min}\right) \times Mud\ Weight\ (ppg)}{400{,}000}$$

Example:

PV (cP)	YP (lbf/100ft2)	n = Flow Behaviour Index	K = Power Law Constant	MW (ppg)	Annular Velocity(ft/min)	CCI	Hole Cleaning	Model Hole Cleaning
1	4	0.263040099	495.4132317	9.21	70.6	0.8	Good	1
7	3	0.765551317	43.15048819	9.33	234.8	0.2	Poor	0
7	4	0.710508762	66.90472731	9.23	61.5	0.1	Poor	0
11	4	0.793566299	54.35013264	9.64	61.5	0.1	Poor	0
13	4	0.819445491	52.41631989	9.83	252.2	0.3	Poor	0
10	4	0.77762441	56.02923981	9.85	225.3	0.3	Poor	0
11	5	0.754903842	73.78083044	9.81	285.4	0.5	Poor	0
9	4	0.759008329	58.43192982	9.75	287.2	0.4	Poor	0
9	4	0.759008329	58.43192982	9.84	287.2	0.4	Poor	0
3	2	0.678086582	37.22605654	8.93	146	0.1	Poor	0
3	2	0.678086582	37.22605654	9.1	270.6	0.2	Poor	0
8	5	0.691892681	88.8030036	9.8	479.7	1	Good	1
9	4	0.759008329	58.43192982	10.65	549.9	0.9	Poor	0
11	9	0.632281901	198.1369071	10.37	549.9	2.8	Good	1
12	9	0.652090811	183.8670097	10.31	549.9	2.6	Good	1
1	4	0.263040099	495.4132317	8.45	146	1.5	Good	1
1	4	0.263040099	495.4132317	9.35	557.9	6.5	Good	1
14	10	0.662979363	196.3382785	9.75	595.1	2.8	Good	1
12	8	0.678086582	148.9042262	11.32	556.3	2.3	Good	1
18	10	0.716222537	164.3413476	11.37	556.3	2.6	Good	1
22	13	0.703622227	222.2203353	12.25	533.6	3.6	Good	1
32	12	0.788512962	164.5313229	12.33	459.3	2.3	Good	1
34	14	0.772606227	198.2071352	12.52	498.1	3.1	Good	1
3	2	0.678086582	37.22605654	8.9	460.4	0.4	Poor	0
3	2	0.678086582	37.22605654	10.25	470.6	0.4	Poor	0
11	7	0.688070887	125.9238038	10.28	479.7	1.6	Good	1
11	7	0.688070887	125.9238038	10.35	549.9	1.8	Good	1
11	7	0.688070887	125.9238038	10.43	549.9	1.8	Good	1
12	8	0.678086582	148.9042262	10.77	549.9	2.2	Good	1
1	4	0.263040099	495.4132317	9.96	146	1.8	Good	1
1	4	0.263040099	495.4132317	8.95	557.9	6.2	Good	1
11	9	0.632281901	198.1369071	10.3	595.1	3	Good	1
13	8	0.695160465	140.5571885	10.8	556.3	2.1	Good	1
12	7	0.706284085	118.6478643	10.5	556.3	1.7	Good	1
18	13	0.660527831	257.5106598	10.4	533.6	3.6	Good	1

Table 2.

Final Output Variable:

ROP (ft/hr)

NB: The Reference data will be as seen in Table 1.

4. Drilling Cost Analysis:

Input Variable:

1. Bit Cost ($)
2. ROP (ft/hr)
3. Footage drilled (ft)
4. Round trip (hr)
5. Footage Drilled
6. Rig Cost per hour ($/hr)

Output Variable

1. Drilled Cost per foot ($/ft)

Equation

Drilled Cost per foot ($/ft) =

$$\frac{\boldsymbol{Bit\ Cost}\ (\$) + \ \boldsymbol{Rig\ Cost\ per\ hour}\ (\frac{\$}{\boldsymbol{hr}})[\left(\frac{\boldsymbol{Footage\ Drilled}\ (\boldsymbol{ft})}{\boldsymbol{ROP}\left(\frac{\boldsymbol{ft}}{\boldsymbol{hr}}\right)}\right) + \boldsymbol{Round\ Trip}\ (\$)]}{\boldsymbol{Footage\ Drilled}\ (\boldsymbol{ft})}$$