MAXIMIZING PROFITS BY UNDERSTANDING HYDRAULIC DREDGE EFFICIENCY

HOW, MAINTENANCE, DREDGE DESIGN, & MINING PLAN AFFECT DREDGING EFFICIENCY

By: Charles H. Johnson

MAXIMIZING PROFITS BY UNDERSTANDING HYDRAULIC DREDGE EFFICIENCY

Charles H. Johnson[1]

Abstract

Many references to “dredging efficiency” exist in publications pertaining to the dredging industry but there exists, in my opinion, an absence of reference to the individual components of dredging efficiency, how each component is measured, and how each measurement is then calculated and expressed in useful terms. Most references regarding dredging efficiency to date refer only to the physical result of dredging efficiency as it pertains to the dredge’s output. However, the dredge’s style, method of operation and other important variables imposed on the dredge operator including various project parameters and requirements are not explored. This paper will attempt to address these variables in a systematic approach allowing the dredging manager to analyze various factors affecting his overall dredging efficiency on an individual project basis.

Keywords: Dredging, efficiency.

Defining Efficiency

The American Heritage Dictionary describes “efficiency” as:

ef·fi·cien·cy (ĭ-fĭsh'ən-sē)

1. The ratio of the effective or useful output to the total input in any system.
2. The ratio of the energy delivered by a machine to the energy supplied for its operation.

In the case of a “dredge”, efficiency can be described as the ratio of energy delivered by a dredge to the energy supplied for its operation. With respect to “dredging”, since supplied energy can have various forms, energy can be examined and analyzed in two main parts; the energy delivered by men measured in time, and the energy delivered by machine measured in productivity.

Since overall dredging efficiency encompasses these two distinct areas, we will use this as the framework for our analytical endeavor.

Time Efficiency (E_t)

Time Efficiency (E_t) is used to measure and analyze the amount of time applied to the operation of dredging by men and machines as a ratio to the time planned or scheduled in a shift. Since time efficiency applies to “men” and “machines”, two sub-categories of time must be analyzed separately. These two sub-categories are defined as “Downtime” (T_d) or (%T_d), and “Utilization” (U) or (%U).

Downtime

Downtime (T_d) - This is the percent of total time a machine or system failed and was not available for operation in comparison to the total time it was operated.

Downtime is an important tool to evaluate the condition and reliability of a machine or machines (i.e.; dredge, booster, etc.) and the effectiveness of the Preventive Maintenance Program put in place by management. It is important to segregate and track downtime for the various machines or areas of the system separately in order to pinpoint and measure the sources of downtime and direct maintenance resources accordingly.

Utilization

Utilization (U) or (%U) – This is the percent of total time spent operating the dredge, known as “Run Time” (T_r), compared to the total time the dredge was available to operate.

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

This is a widely misused expression in our industry and many operations fail to sufficiently segregate this time from other time measurements, hampering management's ability to properly analyzing the data. The key word to remember when determining Utilization is "Time Available (T_a)". If a dredge could not operate due to a failure of the dredge, booster, pipeline, etc. (see "Downtime" above), the dredge was then NOT available for operation and therefore this time can not be used in calculating the utilization of the resource.

Tracking Time

The tool used to track time in a dredging operation is the dredge log. Dredge logs can be maintained in paper log book form or electronically. Below is an example of log file from a shift.

Shift Start	Shift End	Length of Shift (hh:mm)
8:00	18:00	10:00

	Run Time		Dredge Downtime		Booster Downtime		Other Downtime	
Comment	Start	Stop	Start	Stop	Start	Stop	Start	Stop
Dredging	8:15	11:05						
Clutch slip on Booster					11:05	12:37		
Dredging	12:37	14:00						
Swing cable broke							14:00	14:25
Adjust Packing								
Dredging	14:40	15:50						
Unclog Gauge Line			15:50	16:05				
Bathroom Break								
Pumping	16:20	17:50						
Totals	**6:53**		**0:15**		**1:32**		**0:25**	

Figure 1 - Dredge Log File

Notice that the operator was instructed not to record the time spent adjusting the dredge pump packing or when he or she visited the restroom facilities. These events are considered normal operating events and do not apply to either "run time" or "downtime", but is a factor in analyzing "utilization".

Calculating Utilization

To calculate Percent Utilization (%U), first deduct the total downtime (T_d^T) from the shift time (T_s) to determine the total amount of time the dredge was available to operate (T_a). Utilization is the Run Time (T_r) divided by Time Available (T_a).

$$\%U = \frac{T_r}{T_s - T_d^{T}}$$

Equation 1 - Utilization Calculation

Or, as our log file example above indicates:

$$88.2\% = \frac{6{:}53}{10{:}00 - ({:}15 + 1{:}32 + {:}25)}$$

Equation 2 - Example Utilization Calculation

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

Calculating Downtime

When calculating downtime percentages of multiple pieces of equipment or areas of operation, it is important that the percentages applied to each area of downtime equal the total percentage of downtime experienced within the shift. This allows the manager to examine what portion of the total downtime percentage was caused by which area of operation or machine. To accomplish this, individual downtime calculations should be performed for each area or machine tracked by the dredge log. Since our example included downtime tracking for the dredge (T_d^D), booster (T_d^B), and other (T_d^O), we will use these areas in our example. The downtime percentage for each individual area of operation or machine is the individual downtime divided by the sum of the Run Time (T_r) + Total Down Time (T_d^T). The formula for calculating the booster downtime percentage would be performed in this manner:

$$\% \, T_d^B = \frac{T_d^B}{(T_r + T_d^T)}$$

Equation 3 – Booster Downtime Calculation

Or in our example:

$$16.88\% = \frac{1{:}32}{6{:}53 + (:15 + 1{:}32 + :25)}$$

Equation 4 - Example of Booster Downtime Calculation

Below is a summary of the downtime percentages as tracked by the dredge log in Figure 1.

Down Time Summary				
Machine or Area or Operation	**Time Operated**	**Down Time**	**% Down Time**	**% Uptime**
Dredge	6:53	0:15	2.75%	97.25%
Booster	6:53	1:32	16.88%	83.12%
Other	6:53	0:25	4.59%	95.41%
Combined	6:53	2:12	24.22%	75.78%

Table 1 - Example Downtime Summary

From the example above, it would clear to see that the area of concern for management would be the booster pump.

An important value to note is the Total Downtime (T_d^T) as this percentage is averaged through historical data and used in developing future daily, weekly, and monthly project production estimates. The percent of uptime should also be noted as this value will be used in dredging efficiency calculations later in the section.

Production Efficiency (E_p)
Step One

Determining production efficiency is the second main part in determining overall dredging efficiency. Expressed as a percentage, it is the ratio of the output of the dredge measured in productivity divided by the Peak Production (P_p). The process of determining production efficiency is to compare the peak production to the amount of material the

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

dredge can physically reach per hour due to dredging requirements and dredge design, known as the Expected Production (P_e). The first step in this process is to determine the dredge's Peak Production.

Peak Production

Since a dredge is made up of two separate systems working in harmony, the excavation system and the transportation system, we must examine both systems separately to calculate the peak production of the dredge.

Dredges are always limited at any given time by either of these two systems. When a dredge has the ability to excavate material at a higher rate than the transportation system can transport it, the dredge is said to be in a "suction limited" condition. When the opposite is true, the dredge is in a "cutter limited" condition.

Excavation System

To determine the excavator's production rate, the following formula is used:

$$\text{Tons/Hr.} = \frac{\pi \;\; OD^3 \;\; RPM \;\; BL \;\; TPY}{98743}$$

Equation 5 - Excavation Rate Calculation

Or in our example using a 12" discharge conventional dredge:

$$525 \text{ Tons/Hr.} = \frac{3.1416 \;\; 40^3 \;\; 38.2 \;\; 5 \;\; 1.35}{98743}$$

Equation 6 - Example Excavation Rate Calculation

Transportation System

Calculating the peak production of the dredge's transportation system takes into account various project parameters such as; type of material, shape of material, pumping distance, discharge elevation, pipeline type, pipeline inner diameter, pump curve etc.

This is usually best accomplished by contacting a dredge manufacturer or a person experienced in calculating the hydraulic properties of a slurry transport system and analyzing dredge pump curves.

Below is one such calculation performed using computer software designed by William Wetta, P.E. of Dredging Supply Company, Inc.

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

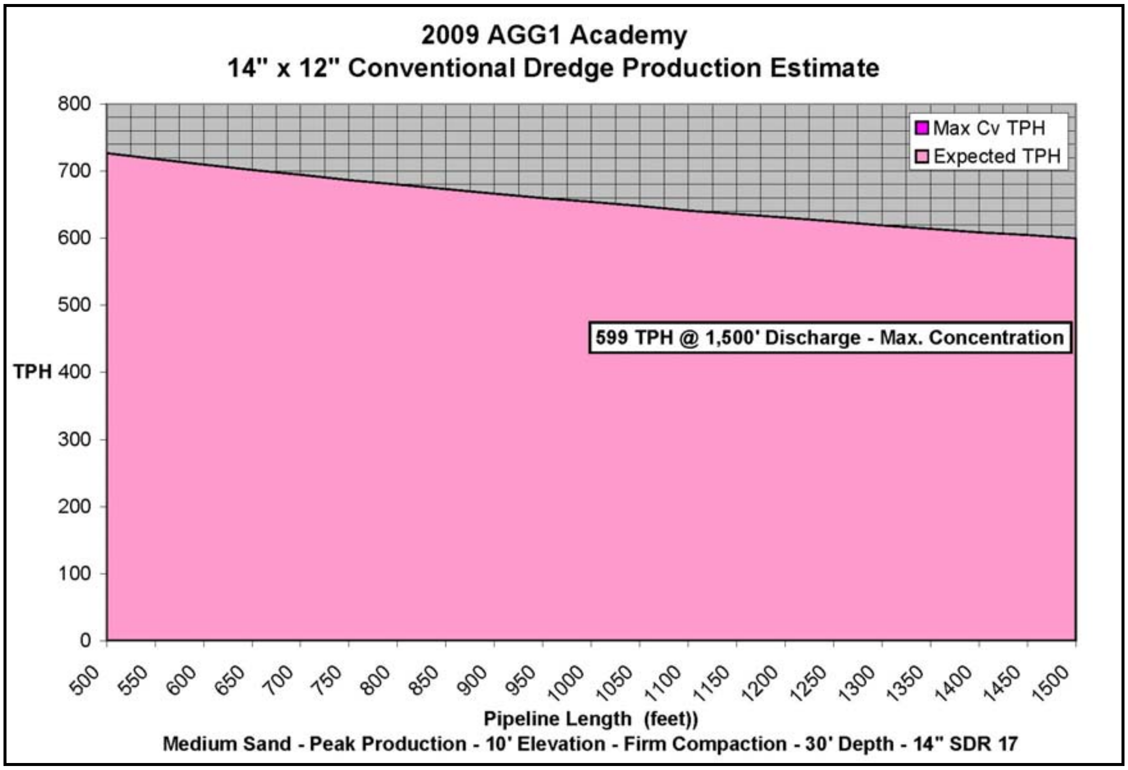

Figure 2 - Transportation System Production Calculation

As you can see from the above calculation, the peak production of the transportation system, based on the dredging requirements, is 599 Tons/hr. This calculation indicates that the dredge is operating in a "cutter limited" condition.

To recap the findings:

Excavator System Production = 535 Tons/Hr.
Transportation System Production = 599 Tons/Hr.
Therefore, **Peak Production = 525 Tons/Hr.**

Production Efficiency (E_p)
Step Two

The second step in determining the Production Efficiency is to measure the amount of material the dredge can reach each hour, or the expected production. To accomplish this we'll need to examine the many factors affecting the ability to reach material, with respect to project and dredge design. I will list these factors followed by an example of a spreadsheet I developed that take these factors into account and calculates the Expected Production.

Overall Dredge Length

A conventional dredge pivots on a spud located on the stern of the dredge and swings from side to side. The distance between the spud and the cutter is therefore the length of the arc and determines the amount of distance covered during the swing cycle. (For the purposes of this paper, a swing cycle is the cycle of swinging to starboard and back to port, or visa versa)

Dredging Depth

Dredging Depth also plays a role in determining the distance covered during the swing cycle in that the distance from the spud to the cutter decreases as the dredge depth increases. The figure below illustrates the reduction in swing width in comparison to dredging depth.

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

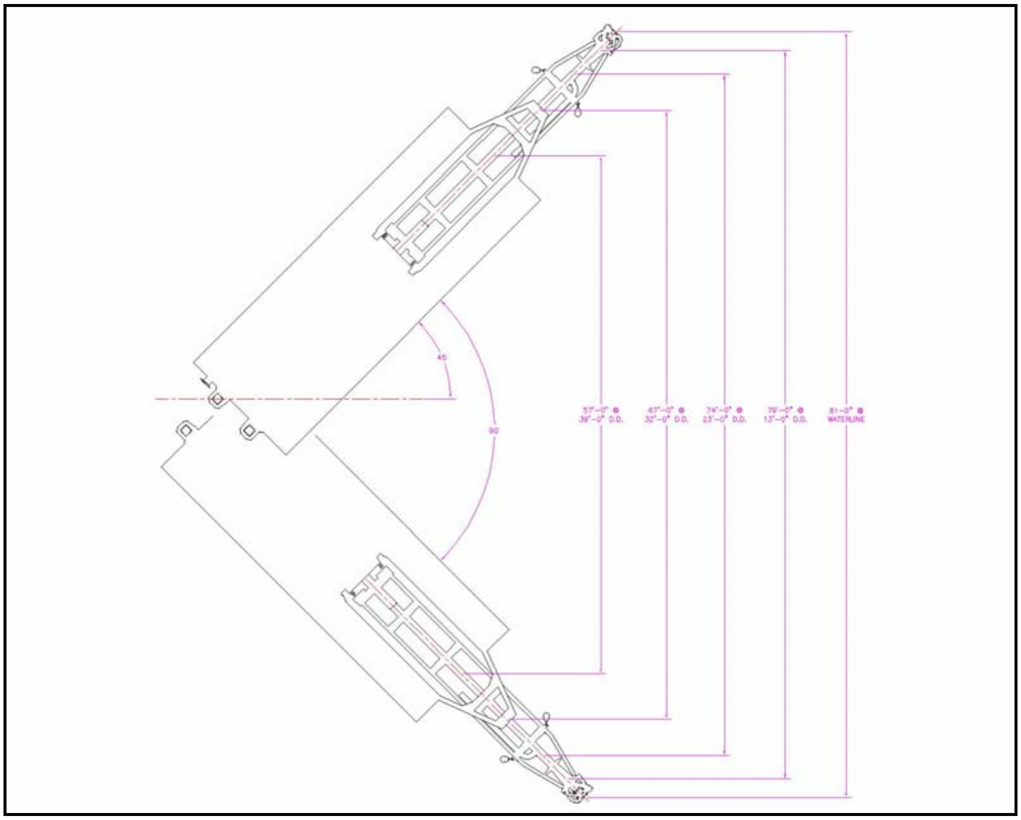

Figure 3 - Cut Width Diagram

Swing Angle

Swing angle is the angle of swing to port and starboard off the centerline of cut. This angle is typically 45°, however, a smaller angle may be required due to a project restriction, or a greater angle, of say 50°, may be achievable. The greater the angle, the greater the distance covered during the swing cycle.

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

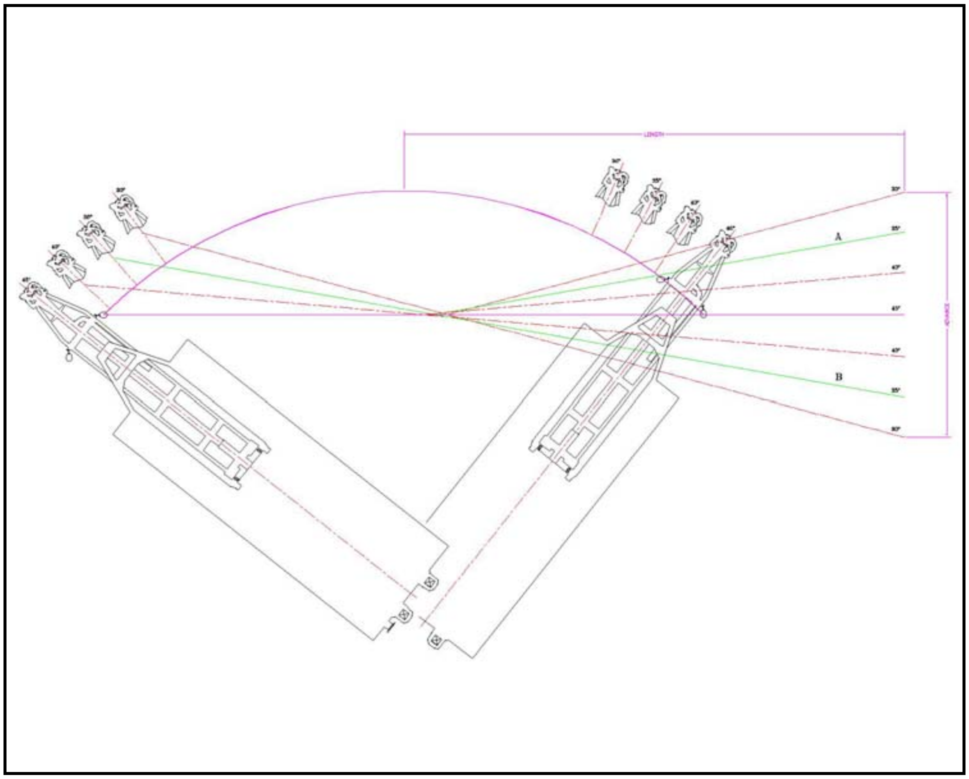

Figure 4 - Variations in Swing Angle

Bank Height

Of all of the variables, bank height effects dredging efficiency the most since a higher bank height will allow the dredge to remove a greater number of cubic yards or tons from a cut before an advance must be made. This consideration in determining dredging efficiency explains why a mining dredge, which typically dredges a bank of 20' or more in height, has a much greater dredging efficiency than that of a navigational dredge typically having a much lower bank height. This usually results in a dredging efficiency for navigational dredges of approx. 50% to 60% and for mining dredges of approx. 70% to 90%.

Depth of Cut

Depth of cut is important because it is used to calculate how many swings must be made across the bank or face of material before the bank height is consumed and an advance must be made. Since the dredge's efficiency is 0% while advancing, the shorter the advance time, the better the dredging efficiency. The depth of cut varies depending on the material type, material compaction, and cutter power. Typically, the cut depth is 66% to 75% of the cutter outer diameter during the productive portion of the swing cycle, and very little or no additional cut depth is taken during the back swing.

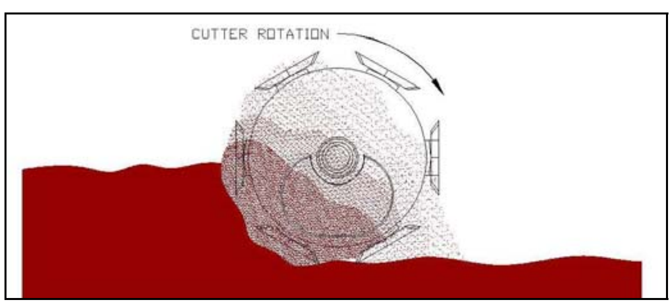

Figure 5 - Depth of Cut

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

Swing Cycle & Advance Time

A complete swing cycle, as mentioned earlier, encompasses both the productive portion of the swing and the back swing or "clean up" swing. The swing speed during the productive portion of the swing cycle can be calculated by using the following formula:

$$\text{Swing Speed} = \frac{OD \quad \#BL \quad RPM}{120}$$

Equation 7 - Swing Speed Calculation

Or in our example:

$$61.67 \text{ ft/min.} = \frac{40 \quad 5 \quad 37}{120}$$

For the back swing or "clean up" swing, the swing speed varies from operator to operator. Some operators consume only 50% of the time consumed during the productive portion of the swing cycle during the back swing, while others consume up to 75%. This author feels that 75% would be a conservative number to use in calculating the time consumed during the back swing.

Since we now know the width of the cut and the time spent during the swing cycle, we can now calculate how many swings and advances will be made each hour, and based on the size of the cutter, and the volumetric displacement it represents, we can determine the cubic yards or tons of material the dredge will reach per hour. Below is a spreadsheet I developed to calculate the Expected Production & Production Efficiency of a dredge based on project parameters and dredge design as well as a few other factors not discussed in this paper.

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	18.0	22.1	403.26	139,795	76.81%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 6 - Dredge Efficiency Analyzer

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

From the spreadsheet above, our example dredge, due to project parameters and dredge design, has an Expected Production of 403.26 tons/hr. This in comparison to the Peak Production (P_p) of 525 tons/hr, results in a Production Efficiency (E_p) of 76.81%.

Conclusion

We have now completed the necessary steps in determining dredging efficiency. So let's summarize our findings;

Downtime (T_d) = 24.22%
Utilization (U) = 88.2%
Production Efficiency (E_p) = 76.81%

We have scheduled 10 hours to work each day, but based on historical downtime records, we know that unless we make operational changes, we will be in downtime status 24.22% of this time.

Shift Time (T_s)	10:00
Total Downtime (T_d^T) (24.22%)	-2:12
Time Available (T_a)	7:48

Of the 7 hours and 48 minutes we have available, again based on historical data, we will Utilize 88.2% of this time dredging, resulting in a Run Time (T_r) of 6 hours and 53 minutes.

Time Available 7:48 x 88.2% = 6:53 Run Time (T_r)

Now examining the production side of efficiency, we know,

Peak Achievable Production (P_p)	525 ton/hr.
Production Efficiency (E_p)	76.81%

525 tons/hr x 76.81% = 403.26 tons/hr Expected Production (P_e)

Now multiplying the Expected Production rate by the run time will result in our Total Shift Production (P_s^T).

6:53 (6.88) x 403.26 tons/hr = 2,775.8 tons of Total Shift Production (P_s^T)

Now,

2,775.8 Tons Total Shift Production (P_s) ÷ 10:00 Shift Time (T_s) = 277.58 tons/hr Shift Production (P_s)

Therefore, the Overall Dredging Efficiency (E_d) is determined by,

277.58 tons/hr. Shift Production ÷ 525 tons/hr Peak Production (P_p) = 52.87% Dredging Efficiency (E_d)

The equation for determining dredging efficiency is,

$$\textbf{Shift Efficiency} = \frac{\textbf{Shift Production } (P_s)}{\textbf{Peak Production } (P_p)}$$

We have now completed all the steps in determining the various efficiencies:

- Downtime (Td) = 24.22%
- Uptime (Tu) = 75.78%
- Utilization (U) = 88.2%
- Production Efficiency (Ep) = 76.81%
- Shift Efficiency (Es) = 52.87%

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

How Dredge Design Impacts Dredging Efficiency

55° vs. 45° Maximum Ladder Down Angle

When considering the various dredge models during a dredge purchase, remember that dredge manufacturers are reluctant to build dredges with longer ladders or hulls to increase dredging efficiency due to competition on similar models. Taking the time to analyze how these features improve dredging efficiency over the life of the dredge will save your company time and money, will make your dredging operations more productive.

Typically, dredge design incorporates a maximum ladder down angle of 60°, meaning, the ladder angle when at the maximum design dredging depth.

Reducing the maximum ladder down angle requires a longer ladder to reach the design dredging depth. Increasing the ladder length also results in a greater distance from the spud to the cutter and therefore results in an increased width of cut due to the longer radius.

In the next example we will analyze the variances in the Production Efficiency (E_p) caused by a 55° vs. 45° maximum ladder down angle. Keep in mind that these calculations are based on removing only 3 feet of material per cut. As discussed earlier, and as we will learn later in this paper, height of cut has the greatest effect on Production Efficiency (E_p).

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	18.0	22.1	403.26	139,795	76.81%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 7 - 55° Ladder Down Angle Design Calculation

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	83	44	0	45	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	70.1	102.5	144.9	16.1	19.8	415.17	143,927	79.08%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 8 - 45° Ladder Down Angle Design Calculation

Based on the calculation in figures 7 & 8, the ladder was extended from 38' to 44', which increased the overall length of the dredge from 77' to 83'. This increased the cut width from 89.3' to 102.5' and increased the tons the dredge could reach in an hour from 403.26 tons to 415.17 tons. Therefore, the resulting increase in the dredge's Production Efficiency was 76.81% to 79.08%.

Total Shift Production (PsT) is:
6:53 (Tr) (6.88 hrs.) x 415.17 Tons/hr =
2,856.4 Tons of Total Shift Production (PsT)

2,856.4 Tons of Total Shift Production (PsT)
÷ 10:00 Shift Time (Ts)
= 285.64 Tons/hr Shift Production (Ps)

285.64 Tons/hr of Shift Production (Ps)
÷ 525 Tons/hr Peak Production (Pp)
= 54.41% Shift Efficiency (Es)

	Before	After
Shift Efficiency	52.87%	54.41%
Tons/Hour	403.26	415.64
Tons/Shift	2,775.8	2,856.4
Tons/Month	139,795	143,927
Tons/Annual	1,677,654	1,727,124

49,470 Additional Tons/Year

49,470 Additional Tons/Year
x $8/Ton

$395,760 in Additional Gross Revenue/Year
$32,980 in Additional Gross Revenue/Month

Cost to Extend Ladder & Hull?
Approximately $21,000

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

As you can see from this example, again, based on a cut height of only 3', this dredge design would pay for itself in less than a month.

90° vs. 96° Swing Arc

We have based our calculations on a swing arc of 90° (45° each side of center), but what if we could swing an additional 3 degrees each side with a swing arc of 96°?
The following example analyzes this possibility.

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	18.0	22.1	403.26	139,795	76.81%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 9 - 90° Swing Arc

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	48	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	93.7	132.4	17.3	21.3	407.51	141,270	77.62%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 10 - 96° Swing Arc

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

As you can see from the charts in figures 9 & 10, the swing width was increased slightly and resulted in a slight increase in the tons reachable by the dredge per hour, from 403.26 tons/hr. to 407.51 tons/hr.
You might be surprised that while this resulted in only a slight increase in production per hour, the increase in annual gross revenue is significant.

Total Shift Production (PsT) is:
6:53 (Tr) (6.88 hrs.) x 407.51 Tons/hr =
2,803.7 Tons of Total Shift Production (PsT)

2,803.7 Tons of Total Shift Production (PsT)
÷ 10:00 Shift Time (Ts)
= 280.37 Tons/hr Shift Production (Ps)

280.37 Tons/hr of Shift Production (Ps)
÷ 525 Tons/hr Peak Production (Pp)
= 53.40% Shift Efficiency (Es)

	Before	**After**
Shift Efficiency	52.87%	53.40%
Tons/Hour	403.26	407.51
Tons/Shift	2,775.8	2,803.7
Tons/Month	139,795	141,270
Tons/Annual	1,677,654	1,695,240

17,586 Additional Tons/Year

17,586 Additional Tons/Year
x $8/Ton

$140,688 in Additional Gross Revenue/Year
$11,724 in Additional Gross Revenue/Month

Cost to Swing Dredge Additional 3°?
$0

While this change in swing width was merely slight change, the annual increase in gross revenue could possibly fund the purchase of additional needed equipment.

3’ vs. 8’ Height in Cut

As stated earlier, the height of cut has one of the greatest influences on Production Efficiency. The next example examines the effects of an increase in cut height of 5’.

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	18.0	22.1	403.26	139,795	76.81%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 11 – 3' Cut Height

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	8.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	7.9	25.7	468.88	162,544	89.31%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 12 – 8' Cut Height

Increasing the height of cut means the dredge can remain in the cut longer before an advance must be made. As you can see, this reduces the number of advances per hour from 18.0 to 7.9 and increases the number of tons the dredge can reach per hour from 403.26 to 468.88, thus increasing the Production Efficiency to 89.31%.

Total Shift Production (PsT) is:
6:53 (Tr) (6.88 hrs.) x 468.88 Tons/hr =
3,225.9 Tons of Total Shift Production (PsT)

3,225.9 Tons of Total Shift Production (PsT)
÷ 10:00 Shift Time (Ts)

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

= 322.59 Tons/hr Shift Production (Ps)

322.59 Tons/hr of Shift Production (Ps)
÷ 525 Tons/hr Peak Production (Pp)
= 61.45% Shift Efficiency (Es)

	Before	**After**
Shift Efficiency	52.87%	61.45%
Tons/Hour	403.26	468.88
Tons/Shift	2,775.8	3,225.9
Tons/Month	139,795	162,544
Tons/Annual	1,677,654	1,950,528

272,874 Additional Tons/Year

272,874 Additional Tons/Year
x $8/Ton

$2,182,992 in Additional Gross Revenue/Year
$181,916 in Additional Gross Revenue/Month

Cost to make a Deeper Cut?
$0

The effects of Automation – 45 Second vs. 30 Second Advance Time

What if we could reduce the amount of time required to advance the dredge? What if we could constantly monitor the swing speed and optimize the swing speed to get the most production during each minute of the swing cycle?

Swing Automation and Automated Advancing systems already exist and can be offered at a surprisingly low additional cost to the dredge's selling price.

Below is an analysis of the effects of reducing the advance time from 45 seconds to 30 seconds. This seems like a slight adjustment to the dredge operation, but can have an extreme impact on annual production.

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	45	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	18.0	22.1	403.26	139,795	76.81%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 13 – 45 Second Advance Time

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

DREDGE EFFICIENCY ANALYZER
Version 4

Number of Shifts per Day	Hours per Shift	Number of Days per week	Overall Length of Dredge (feet)	Length of Ladder (feet)	Trunnion Height above Water (feet)	Max. Ladder Down Angle (degrees)	Maximum Swing Angle off Center Line (degrees)	Advance Cycle Duration (seconds)	
2	8	5	77	38	0	55	45	30	
Cutter Outside Diameter (inches)	% of Cutter Diameter Cut During Swing Cycle	Percent of Time Required for Back Swing	Cutter RPM	# of Cutter Blades	Height of Cut (feet)	Operator Proficiency (percent)	Percent Spillage	Peak Production Rate from Calculation (tons/hr)	Tons per Yard
40.0	75%	50%	38.2	5	3.00	98%	2%	525	1.35
Length of Cutter (inches)	Dredging Depth (feet)	Distance from Spud to Cutter (feet)	Channel Width (feet)	Swing Cycle Duration (seconds)	Advances per Hour	Swings per Hour	Tons per Hour	Tons per Month	Overall Efficiency (use in production calculation)
20.0	31.1	60.8	89.3	126.3	19.4	23.9	435.72	151,051	82.99%

SWING CYCLE = Period in Seconds from Port to Starboard & Starboard to Port
ADVANCE CYCLE = Period in Seconds from End of Swing Cycle to start of next Swing Cycle

Figure 14 – 30 Second Advance Time

Merely reducing the advance time from 45 seconds to 30 seconds increases the number of advances that can be made in an hour and affords more time for productive dredging. This change alone increases the production from 403.26 tons/hour to 435.72 tons/hour.

Total Shift Production (PsT) is:
6:53 (Tr) (6.88 hrs.) x 435.72 Tons/hr =
2,997.8 Tons of Total Shift Production (PsT)

2,997.8 Tons of Total Shift Production (PsT)
÷ 10:00 Shift Time (Ts)
= 299.75 Tons/hr Shift Production (Ps)

299.75 Tons/hr of Shift Production (Ps)
÷ 525 Tons/hr Peak Production (Pp)
= 57.09% Shift Efficiency (Es)

	Before	**After**
Shift Efficiency	52.87%	57.09%
Tons/Hour	403.26	435.72
Tons/Shift	2,775.8	2,997.8
Tons/Month	139,795	151,051
Tons/Annual	1,677,654	1,812,612

134,958 Additional Tons/Year

134,958 Additional Tons/Year
x $8/Ton

$1,079,664 in Additional Gross Revenue/Year
$89,972 in Additional Gross Revenue/Month

Cost to Automate the Swing & Advance Cycles?
$25,000

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.

Summary
Using an analytical approach to examine your day to day dredging plan and fine tuning your process, can reap enormous increases in annual revenues, increase your profitability, and increase your competiveness in the market place.

LEGEND
T_s – Shift Time (expressed in hh:mm)
T_d – Down Time (expressed in hh:mm, used when only one down time value is used)
% T_d – Percent Down Time (expressed as a %, used when only one down time value is used)
T_u – Up Time
% T_u – Percent Up Time
T_d^D – Dredge Down Time
% T_d^D – Percent Dredge Down Time
T_d^B – Booster Down Time
% T_d^B – Percent Booster Down Time
T_d^O – Other Down Time
% T_d^O – Percent Other Down Time
T_d^T – Total Down Time (used when multiple individual down time values are used)
% T_d^T – Percent Total Down Time (used when multiple individual down time values are used)
T_a –Time Available
T_r – Run Time
U – Utilization (expressed in time)
% U – Percent Utilization
P_p – Peak Production
P_e – Expected Production
P_s – Shift Production
P_s^T – Total Shift Production
E_t – Time Efficiency
E_p- Production Efficiency
E_d – Dredging Efficiency

REFERENCES

Simon, F. Lester (1920). *Dredging Engineering***.** New York: McGraw-Hill, Inc.
Huston, John (1970). *Hydraulic Dredging***.** Centerville, Maryland: Cornell Maritime Press, Inc.
Herbich, John B., Ph.D, P.E. (1975). *Coastal & Deep Ocean Dredging***.** Houston, Texas: Gulf Publishing Company
Turner, Thomas M. (1984). *Fundamentals of Hydraulic Dredging***.** Centerville, Maryland: Cornell Maritime Press
Huston, John (1986). *Hydraulic Dredging***.** Corpus Christi, Texas: John Huston, Inc.
Herbich, John B., Ph.D, P.E. (1992). *Handbook of Dredging Engineering***.** New York: McGraw-Hill, Inc.
Turner, Thomas M. (1996). *Fundamentals of Hydraulic Dredging***.** New York: ASCE Press
Herbich, John B., Ph.D, P.E. (2000). *Handbook of Dredging Engineering***.** New York: McGraw-Hill, Inc.

[1]Director of Sales, Dredging Supply Company, Inc., 156 Airport Road, Reserve, Louisiana, 70084, USA,
T: 985-479-1355, Fax: 985-479-1367, chjohnson@dscdredge.com.