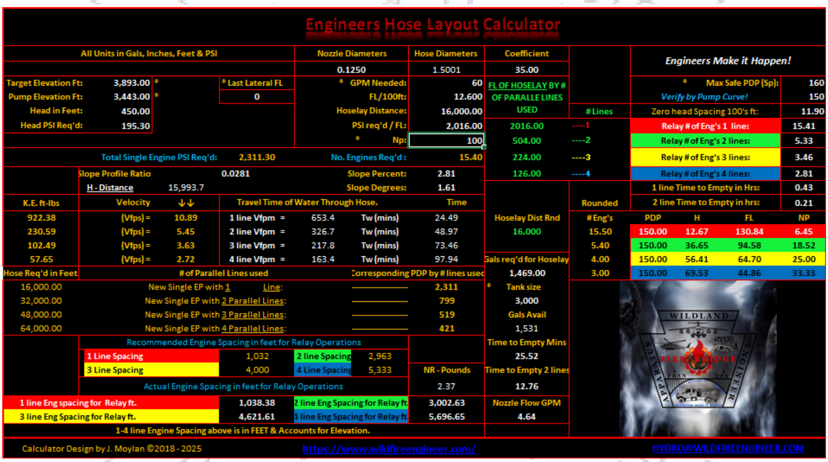
Wildland Engineers

Engine Pumping Calculator with MULTI - Hose Layout, Helicopter & Water Tender Equalization Optimizer.



Ver 4E23 as of 3-2025

Introduction

If you are reading this manual then you are either an Engine Operator in the Wildland Fire Service (ENOP), an Apparatus Engineer, Aspiring Engineer, a Contract Fire Fighter or a person who simply has a fascination with the science of fire-ground hydraulics and wants to always know how to get the most out of your apparatus and/or pump.

For myself, I would routinely see suppression operations with aircraft being shut down because not enough ground resources were ordered to handle the operation to facilitate continuous uninterrupted operations, nor did they know how to calculate such.

The folks were doing their best, yet did not grasp the exactness of the complexity within their situations simplicity.

That sounds like a lot to chew on but it's rather quite simple if you remove yourself from the situation and look at it from beyond. You are in a life-sized pump and if you think of it in those terms, it becomes much simpler to know what must happen.

The spreadsheet got its origin from the desire to reduce the amount of time it took to use pencil and paper in the field. It was originally designed for engineers, yet it soon became apparent that non-engineers alike could use this tool as well as to aid the non-hydraulically minded IC to get a much greater handle on what it's going to take to make things work between Engines, Helicopters and Water Tenders for uninterrupted(continuous) operations.

If you've had 4 to 6 engines, a helicopter or two and some portable tanks on every fire with 1 water tender to support all of it and always find yourself waiting for water to arrive, just to be rationed out, then it's possible you probably need to gain a better understanding of fire-ground hydraulics.

Definitions & Descriptions:

Hydro-PDP. EFF/EGPM: Helicopters, Water Tenders and Engines all have what are called <u>Effective Fire Flows</u> or corrected *Equivalent Gallons Per Minute* ratings. Effective Fire Flow as I use here is not actually an industry standard term, although the term Fire Flow is. The flow of water, either through a hose or some other delivery system, that is the final amount available for suppression operations after the accounting of friction loss and other losses, including the time in getting the water to the nozzle or its final destination point must still be in sufficient quantity to be "effective" in suppression of the fire. I have simply joined the word "effective" to Fire Flow to make it more intuitive, i.e. Effective Fire Flow = The final amount available to be effective in suppressing a fire.

Pump Elevation: Pump Elevation is the actual altitude above sea level that your pump is located. Whether this is an auxiliary pump or an apparatus, in order to properly calculate the required head pressure in plus or minus numbers, this elevation should be determined first.

Target Elevation: This is referring to the height above the pump that your most distance nozzle is or will be located in order to determine the Head Pressure to be overcome by the pump. This can be either the open end of a hose or the elevation above the pump to which the next apparatus or port-a-tank is located. If this location is above the pump, it is positive. If the location is below the pump elevation, it is a negative number. If your apparatus is parked at an elevation of 4,900 feet and you need to supply a hose lay to an elevation of 3,600 feet, the elevation drop is -1,300 feet. This is a negative head pressure of -564.2psi. The spreadsheet does the arithmetic for you and this number is then used with the other parameters for the Engine Pressure Calculations.

Nozzle Diameters: A drop-down list box of nozzle diameters in decimal form ranging from 1/8" to 2-1/2" diameter. Figured for smooth bore sizes, you can use the information under this section for 1" and 1 ½" combination nozzles Also. Select .2582 for 1" and .4472 for 1 ½" (These are the equivalent internal diameters).

Hose Diameters: This is a drop-down box of the most common hose diameters in the fire service today including 6 inch hi-vol supply hose. There are two (2) types of 1½" diameter hoses used. A 1.5000 and 1.5001. The difference is for allowance of the hose coefficients of 24 and 35. Wildland uses 35. In order for your friction loss and gallons required calculations to be accurate, you must make sure to supply the correct size hose for your particular layout. Hose diameters range from 5/8" to 6".

Coefficients: This is not selectable and will display the correct math coefficient once you have selected the hose diameter that you wish to use, reducing the chance of error.

Max Safe PDP: Is a number that the operator selects based upon his or her experience & knowledge with a particular apparatus they are operating and is for safe continuous pumping pressures that will not cause any harm or damage to the pump impeller etc. It is not intended to be a set and forget number, you have to understand the particular task you are about to engage in and adjust accordingly. On NFPA rated fire pumps, always remember that once you reach 200 psi you're now at 70% of your capacity and at 250 psi you dropped to 50% capacity.

Net Pump Pressure: This is NOT the same thing as used for Engine Pump Certification testing. This is a pressure used in relay operations as it automatically subtracts 10 psi off the Max Safe PDP for those operations to ensure that at min 10 psi of pressure will be supplied to any relay pumping apparatus in the line.

Last Lateral FL: This box you enter in the needed friction loss for the last lateral based upon the flow (GPM).

GPM Needed: Enter the total GPM's needed to be pumped for the destination you use for your calculations.

FL per 100 ft: The calculated friction loss for each 100-foot section of hose.

Length of Hose lay: The total length of hose is stretched out from the pump to the most distant nozzle or point for water to be delivered.

PSI req'd for FL: This figure represents the total psi that the pump must produce based upon the variables; GPM, Hose length & Diameter.

Nozzle PSI: This is a pressure you determine you want your nozzle to operate at. It can be any pressure you decide and does NOT have to be the industry standard pressures of 50 psi or 100 psi.

Total Single Engine PSI: This box is the total pump pressure a single apparatus will have to develop in order to supply the amount of water for the operational parameters you selected. This assumes single hose pumping operations.

No. Engines Req'd: This number represents the total number of engines that will be required to complete the operation for single-hose line operations. Look at this figure as either requiring whole apparatus or not. A figure of 1.7 is exceeding the Engine Capacity by 70%.

Slope Ratio: This number tells you the rate of change in rise or fall your particular hose lay drops or rises for each foot of horizontal distance traveled. A negative number indicates a drop.

Slope Percent: This tells you how steep the slope is in terms of a percentage. 45 degrees is a 100% slope. While 200% slope is 63 degrees and a 50% slope is 26.5 degrees. **Slope Degrees:** This number in this cell simply gives the degrees readout of the slope.

Zero head spacing 100's Ft: This number will tell you that for the parameters entered, and no change in elevation, your pump should be capable of pumping to the distance specified by the number indicated x 100. Ex., if it is 11, 11x100 = 1,100 feet. If it's 127, then 127x100 is 12,700 feet, etc.

Relay # of Engines "x" line(s): The Red, Green, Yellow and Blue boxes here all pertain to the number of engines required for a closed relay operation based upon how many parallel lines are used in the relay configuration.

Travel Time of Water in Minutes: This gives the flow velocity in feet per minute and then shows the amount of time in minutes it will take for the water to reach its destination.

Hose Req'd, New Single Engine PSI with 2, 3, 4 parallel lines: This section gives the total number of hose required (left side) for each type of hose layout configuration, and the new single engine pump discharge pressure required. When using parallel hose lines in single engine operations, this will be the PDP you will pump too.

1, 2, 3, 4-line Eng Spacing for Relay These Red, Green, Yellow, and Blue colored boxes are based upon the previous matching-colored boxes on the upper right corner of the sheet and pertain to relay pumping engine spacing.

The distances are in feet and are the distances that you would space each engine from one another to complete the relay operation. This section has been calculated for the elevation and is adjusted accordingly, and Relay refers to the "Length of Hose lay" cell.

Gals req'd for Hose lay, Tank size and Gals Avail: This section calculates the gallons required to charge the hose lay based upon hose diameter and length. **Tank size:** This is a "user item" and you enter the gallon size your tank is. The gallons available are thus finally computed from the tank size and the hose lay size and length. The "Gals Available" is what you actually have remaining for firefighting. This does NOT consider 10% for reserve.

1 line time to empty, 2-line time to empty hrs: Just below the **RELAY # of Engines** boxes are the cells that display the time to empty in hours for both 1- and 2-line operations. This assumes each line is of same size diameter and flow.

Nozzle Flow GPM: This displays the flow to be discharged when the nozzle diameter and pressure are set.

Hydro-PDP: Will likely be the most utilized sheet if being used by an Engine crew on assignment so he or she can gauge how and where to place engines during the planning phase of the operation. Not every cell is editable. The cells to which data can be entered are listed below:

1. Target Elevation
2. Pump Elevation
3. Last Lateral FL
4. Nozzle Diameter (selectable)
5. GPM Needed
6. Length of Hose lay (Ft)
7. Nozzle PSI
8. Hose Diameter (selectable)
9. Max Safe PDP
10. Tank size

The **Multi-Leg Tab**, is for determining the same information as the Hydro tab with the exception that you now have the ability to calculate pressures for up to 9 different legs of a single hose lay that would comprise varying lengths, elevations, diameters etc. to more accurately determine needs.

Heli-Wt: The primary purpose of this tab is to be able to determine the effectiveness of both the helicopter's and water tender's relationships with each other. If you are using this tab for setting up helicopter operations to attack a fire, a STRONG CAUTION IS ADVISED.

Avoid the most common and drastic mistake nearly everyone on the fire-ground always makes, which is to place the intended dip site right next to the fires edge as close as possible. This will often lead to failure of the operation as the helicopters will ALWAYS run away from your water supply. The proper way to think of the helicopters in this manner is that they have become your IMPELLER, and the Water Tenders are the plumbing into that impeller.

If the impeller spins too fast for the incoming flow it cavitates. Likewise, if the tenders can't move enough water in round trip time, the operation comes to a grinding halt because your helicopters are essentially cavitating only on a much larger scale.

A secondary reason this tab was created is to give a visual representation as to what must happen and where, in order for 100% sustainable operations to take place. If you ignore the warnings given, you do so at your own risk. Learn fire-ground hydraulics.

A Third use for the tab is that you can use the Water Tender side of the sheet by itself to determine the Effective Fire Flow for shuttle operations.

The User Editable and Data Entry items on Heli-Wt tab are:

Helicopters:

1. Bucket Size(Gal)
2. Flight Speed (Kts)
3. Round Trip Distance Flown
4. Dip Time(Min)
5. Additional Like helicopters

Water Tenders:

1. Tank Capacity (Gals)
2. Vehicle Speed (MPH)
3. Round Trip Dist(miles)
4. cnct-discnt time(min)
5. Additional Like Tenders

The Water Tender side of the sheet has the benefit of being used in conjunction with Hydro-PDP and Heli-Wt. On Hydro-PDP, you are given the "time to empty" time frame in hours. You can then use Heli-WT Tender side to determine how many tenders you'll need to sustain your operation by both adding tenders as well as spacing out the "leapfrog" time between Tenders.

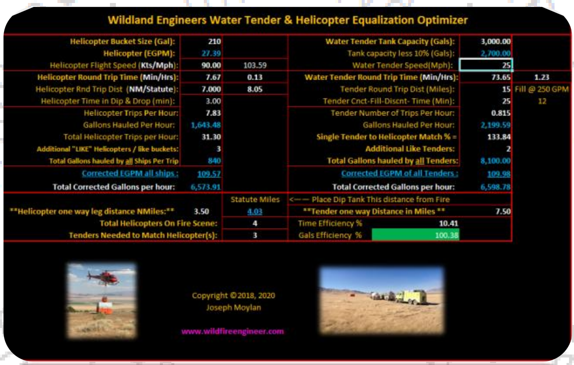
Heli-Wt tab is further able to be used with Thermo tab from the standpoint that if you are engaged in structure protection you can estimate the building size and % involvement and this gives you a Needed Fire Flow estimate.

Doing the math for the GPM to GPH (x by 60 for gallons per hour) you can then calculate how many tenders you would need for water shuttle operations or relay operations. (Caveat: make sure your tenders have bulk dumps and pumps are capable of 500 GPM at a minimum for the best overall capability).

Ex: a building 120 x 60 feet with 25% involvement would require 600 GPM, this equates to 36,000 gallons per hour. Using Heli-Wt tab, you can enter in the distance from a hydrant or pond (say 5 miles), and the vehicle tank size

(3000), and vehicle speed(45mph) and additional like tenders (7) till you get the corrected gallons per hour of 38,495.

The term “additional like tenders”, is not the TOTAL tenders, you have to add them to the original tender, the keyword is “Additional”. In this case 8 total tenders are needed at the same tank size. If for example, you have 3 tenders; one with a 3,000-gal tank, 1 with a 2,500 gal and 1 with a 1,850 gal tank, average the tank sizes and place into the “tank capacity cell” (2,670) and re compute.



Description of Heli-Wt: As the majority of the information displayed on this tab is self-explanatory, there are a few items that need to be clarified.

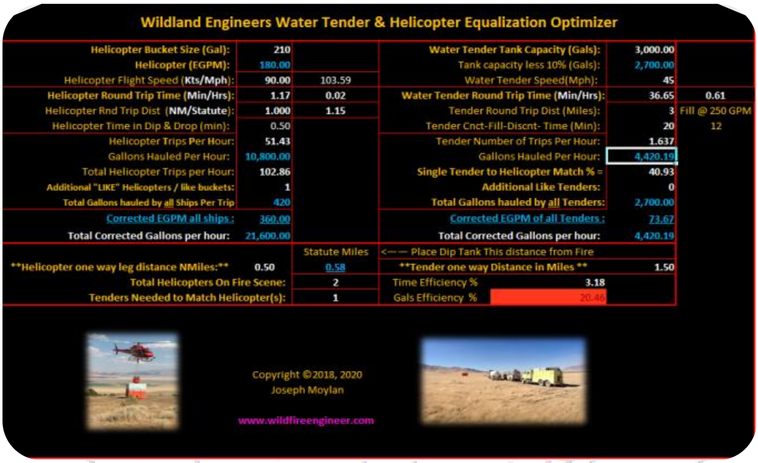
Corrected EGPM for all ships: This cell displays the result considering the following aspects: Bucket size, Round Trip Distance, Time in the Dip/Drop, Flight speed, any additional like helicopters, produce this number. This serves several points of interest to an engineer. If the demand by the helicopters is known as shown in this cell, the tender operations can be adjusted to match by either scaling up or down the size of the operation as needed, also, if there is a Crew on a hilltop with a pumpkin and they are flowing x gallons per hour via gravity or Mark 3 pumps, then you could essentially use the helicopter side of this sheet to fly water to their dip tank. This will then tell you if the helicopter operations are able to keep up with their flowing abilities.

Total Corrected Gallons Per hour: This cell gives the same information as that noted for EGPM as described above, however, it has been computed on an hourly basis.

Calculated Dip Tank Distance from Fire: This figure represents Statute miles and is the location you need to set up your helicopter dip tank for the fire. This figure increases or decreases based upon variables related to and inputted to the tab. Not paying attention to this number may cause you problems in keeping up with the demand the helicopters are placing on you. Nearly all dip site locations are NOT easily mobile once setup. If you are limited in the number of tenders for your operation, it is advised to pay close attention to this number.

Gals Efficiency %: This number as can be seen has a colored box. The color will change from Red to Green when the match efficiency changes. Ideal numbers are 100% or higher. Anything lower you may start to see and experience control problems such as helicopters having to shut down until water reserves are re-supplied. You use this in conjunction with the Tenders needed to match figure.

If it is giving a number and the "Gals Efficiency" number is well below 100% and changing to **Yellow** or **Red**, add more tenders, slow your helicopters down or move the dip site farther away from the fire.



Wildland Engineers Water Tender & Helicopter Equalization Optimizer

Helicopter Bucket Size (Gal):	210		Water Tender Tank Capacity (Gals):	3,000.00	
Helicopter (EGPM):	180.00		Tank capacity less 10% (Gals):	2,700.00	
Helicopter Flight Speed (Kts/Mph):	90.00	103.59	Water Tender Speed(Mph):	45	
Helicopter Round Trip Time (Min/Hrs):	1.17	0.02	Water Tender Round Trip Time (Min/Hrs):	36.65	0.61
Helicopter Rnd Trip Dist (NM/Statute):	1.000	1.15	Tender Round Trip Dist (Miles):	3	Fill @ 250 GPM
Helicopter Time in Dip & Drop (min):	0.50		Tender Cnct-Fill-Discnt- Time (Min):	20	12
Helicopter Trips Per Hour:	51.43		Tender Number of Trips Per Hour:	1.637	
Gallons Hauled Per Hour:	10,800.00		Gallons Hauled Per Hour:	4,420.19	
Total Helicopter Trips per Hour:	102.86		Single Tender to Helicopter Match % =	40.93	
Additional "LIKE" Helicopters / like buckets:	1		Additional Like Tenders:	0	
Total Gallons hauled by all Ships Per Trip	420		Total Gallons hauled by all Tenders:	2,700.00	
Corrected EGPM all ships :	360.00		Corrected EGPM of all Tenders :	73.67	
Total Corrected Gallons per hour:	21,600.00		Total Corrected Gallons per hour:	4,420.19	
		Statute Miles	<—— Place Dip Tank This distance from Fire		
Helicopter one way leg distance NMiles:	0.50	0.58	**Tender one way Distance in Miles **	1.50	
Total Helicopters On Fire Scene:		2	Time Efficiency %	3.18	
Tenders Needed to Match Helicopter(s):		1	Gals Efficiency %	20.46	

Copyright ©2018, 2020
Joseph Moylan
www.wildfireengineer.com

As an example, there are 2 helicopters on a fire, but someone has placed the dip tank only half a mile from the fire edge. Both helicopters have 210 gal buckets and are moving 21,600 GPH. It only takes 30 seconds in the Dip. There is only 1 water tender, and it travels only a mile and a half one way to get water and does so at 45MPH. Even at this close distance it's only able to provide 20% efficiency with 4,420 GPH. This operation will fail and is providing a red warning in the Gals Efficiency cell.

Total Helicopters on Scene: This is based upon the "additional like helicopters" number you entered into the box. Like helicopters, it is more for assuming like sized bucket capacity as speeds can be adjusted in flight.

Tenders Needed to Match Helicopters: is a number that is based upon multiple factors. Those factors are the variables you see on the tab. Use this as a guide and make your operations decisions on the "**Gals Efficiency %**"

Time Efficiency: This number will most likely never increase to a sizeable figure as it is a time comparison between a helicopter and a water tender.

Description of Therm & Time-Dist-Noz

Therm: is the place to calculate the heat absorption capacity of water. On this tab there are only 3 user editable data points. The Desired Flow, Tank Temperature and the Altitude at location. The best way to use this tool is to is with the use of Fire Behavior Nomograms. If a fire is moving in 2.5ft tall grass (FM3) and traveling at 655(Ch/hr. or 12 ft/sec), this fire will be generating approximately 10,800 Btu/sec/ft. for a 1ft x 12ft area. You need to supply enough water to knock the heat out of this. You want an Effective Fire Flow that is able to absorb as much energy as the fire is generating. This will allow you to determine that. This tab allows you to determine the amount of heat absorption a particular volume of water can handle.

Time-Dist-Noz: Is a tab that allows you to perform time speed and distance calculations. Determine the amount of vacuum in in/Hg to raise water to a desired length. And it will also allow you to determine both required nozzle diameters and nozzle pressure when certain other criteria are known.

On this tab, you can select a nozzle diameter to determine the pressure setting you need, or you can enter a desired pressure and flow to determine diameter. For example, if you have a 1" combination nozzle and you normally would flow 20 gallons per minute but this time desire 8, simply enter in the information and it will tell you the corresponding pressure you should use. 16psi

The Data Tab is non-editable, password protected and is the location for your Nozzle, Hose Diameters and Hose Coefficients and ERC and BTU information for Sheet 1 and 5 respectively.

The purpose of this Engine Calculator is to aid the Engineer in his/her job by allowing their experience and training to utilize this tool to make faster decisions on the fire-ground. It is NOT intended to be a replacement of "your" experience, training and knowledge!

One should revisit the purpose of the Fire Nomograms as discussed in the S-390 and S-490 materials.

Comments to:

Joseph Moylan

hydro@wildfireengineer.com

http://www.youtube.com/user/ENOPFFT/

http://www.wildfireengineer.com

FireBridge.substack.com

DECIMAL TO FRACTION OF INCH CHART FOR NOZZLE SELECTION.

COMMON FRACTIONS OF AN INCH WITH DECIMAL & METRIC EQUIVALENTS

FRACTION	DECIMAL	MM	MM	DECIMAL	FRACTION
1/64	.015625	0.396	13.096	.515625	33/64
1/32	.03125	0.793	13.493	.53125	17/32
3/64	.046875	1.190	13.890	.546875	35/64
1/16	**.0625**	1.587	14.287	**.5625**	**9/16**
5/64	.078125	1.984	14.684	.578125	37/64
3/32	.09375	2.381	15.081	.59375	19/32
7/64	.109375	2.778	15.478	.609375	39/64
1/8	**.125**	3.175	15.875	**.625**	**5/8**
9/64	.140625	3.571	16.271	.640625	41/64
5/32	.15625	3.968	16.668	.65625	21/32
11/64	.171875	4.365	17.065	.671875	43/64
3/16	**.1875**	4.762	17.462	**.6875**	**11/16**
13/64	.203125	5.159	17.859	.703125	45/64
7/32	.21875	5.556	18.256	.71875	23/32
15/64	.234375	5.953	18.653	.734375	47/64
1/4	**.250**	6.350	19.050	**.750**	**3/4**
17/64	.265625	6.746	19.446	.765625	49/64
9/32	.28125	7.143	19.843	.78125	25/32
19/64	.296875	7.540	20.240	.796875	51/64
5/16	**.3125**	7.937	20.637	**.8125**	**13/16**
21/64	.328125	8.334	21.034	.828125	53/64
11/32	.34375	8.731	21.431	.84375	27/32
23/64	.359375	9.128	21.828	.859375	55/64
3/8	**.375**	9.525	22.225	**.875**	**7/8**
25/64	.390625	9.921	22.621	.890625	57/64
13/32	.40625	10.318	23.018	.90625	29/32
27/64	.421875	10.715	23.415	.921875	59/64
7/16	**.4375**	11.112	23.812	**.9375**	**15/16**
29/64	.453125	11.509	24.209	.953125	61/64
15/32	.46875	11.906	24.606	.96875	31/32
31/64	.484375	12.303	25.003	.984375	63/64
1/2	**.500**	12.700	25.400	**1.0000**	**1**