HydroHelp 1

AN EXCEL PROGRAM DEVELOPED FOR TURBINE-GENERATOR SELECTION FOR HYDROELECTRIC SITES

Selecting the correct turbine for a hydro site is difficult, particularly for small low-head sites. Manufacturers are currently inundated with requests for assistance; hence many such requests are not answered. The HydroHelp 1 program was devised to assist in the selection process. The program uses Microsoft Office Excel 2003 on Windows XP.

The program uses data provided by manufacturers on the operating envelope and commercial availability for 28 different types of turbines, and has been updated to reflect the recent expansion of the envelope where applicable. The program has been extensively tested, and can be used on turbine sizes from about 1,000kw up to large turbines.

The program size is 2.0Mbytes, and can be downloaded free from a website maintained by OEL-Hydrosys, a hydro consulting company based in Montreal, Canada. Just go to www.hydrohelp.ca The program includes the following types of turbines:-

Propeller turbines.

Horizontal axis "S" type turbine.
Horizontal axis pit type turbine.
Vertical axis turbine with a concrete casing.
Vertical axis turbine with a steel casing.

Kaplan turbines.

Inclined axis very low hear geared turbine.
Horizontal axis mini or pit bulb turbine.
Horizontal axis "S" type turbine.
Horizontal axis turbine, elbow draft tube.
Vertical or inclined axis "Saxo" axial flow turbine.
Vertical axis turbine with a concrete casing.
Vertical axis turbine with a steel casing.

Francis turbines.

Horizontal axis turbine.
Horizontal axis double runner turbine.
Vertical axis turbine with a concrete casing.
Vertical axis turbine with a steel casing.

Horizontal axis, low head impulse turbines.

Horizontal axis BANKI (Ossberger) turbine.
Horizontal axis, 1 jet Turgo turbine.
Horizontal axis, 2 jet Turgo turbine.

Horizontal axis impulse turbines.

Horizontal axis 1-jet, 1-runner turbine.
Horizontal axis 2-jet, 1-runner turbine.
Horizontal axis 1-jet per runner, 2-runner turbine.
Horizontal axis 4-jet, 2-runner turbine.

Vertical axis impulse turbines.

Vertical axis, 1-jet,1-runner turbine.
Vertical axis, 2-jet,1-runner turbine.
Vertical axis, 3-jet,1-runner turbine.
Vertical axis, 4-jet,1-runner turbine.
Vertical axis, 5-jet,1-runner turbine.
Vertical axis, 6-jet,1-runner turbine.

The program requires the input of 12 items describing the site characteristics. These are shown in the following illustration. If the user needs help entering data, there is an adjacent yellow comment cell which will open to provide assistance. Another input is needed, the shaft slope, if the program recommends a “Saxo” unit, since bend losses are included in the efficiency, and this varies considerably with slope. All illustrations have been copied from the program.

HydroHelp 1- Turbine selection - BAKER issue, January 2009.		
BAKER - 10MW	**Enter data in blue cells only. Comment.**	
Project input data.	**Date of estimate --- >**	**5-Jan-09**
Headpond full supply level, m.	**295.00**	
Headpond low supply level, m.	**293.00**	
Head loss to turbine, % of gross head, at full load.	**2.00**	**Comment**
Normal tailwater level, m.	**274.60**	**Comment**
Flood tailwater level, m.	**275.60**	**Comment**
Design powerplant flow, cubic meters per second.	**61.00**	
Desired number of units.	**1**	
Summer water temperature, degrees Celsius.	**10**	
System frequency, Hz.	**60**	
Generator power factor.	**0.90**	
Maximum allowable gearbox power, MW.	**2**	**Comment**
Design standard & generator quality, industrial = 0, utility = 1.	**0**	**Comment**
Inflation ratio since 2008	**1.01**	

The third item, optimum head loss within the conduit, can be determined from a sub-routine within the program, and is based on experience obtained from developed hydro sites. This requires two inputs as shown in the following illustration:-

Optional optimum head loss calculation module	
Gross head on turbine, m.	20.40
Total conduit length intake to powerhouse, m.	**600**
Plant capacity factor (0.4 to 0.8)	**0.78**
Calculated probable optimum conduit head loss intake to powerhouse, %. -- >	**4.5**

The program calculates a recommended % head loss for use in the previous input data-set. The user can select whatever other head loss they deem suitable. The program then looks at the operating envelope for all turbines and rejects all unsuitable types. The program calculates the approximate cost of the water-to-wire generating unit, and recommends the least-cost suitable unit. For the illustrated Baker example, there are 3 suitable types of units:-

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If the recommended turbine is not satisfactory, a second recommendation (based on cost) can be obtained by eliminating the recommended turbine from consideration with a zero (0) placed opposite the recommended turbine in Column E. Suitable turbines are shown in column D.

REACTION TURBINES

	Column D	Column E
Propeller turbines		
Horizontal axis "S" type propeller turbine.	--------------	**1**
Horizontal axis pit type propeller turbine.	--------------	**1**
Vertical axis propeller turbine, concrete casing.	--------------	**1**
Vertical axis propeller turbine, steel casing.	--------------	**1**
Kaplan turbines		
Inclined axis very low head Kaplan gear turbine.	--------------	**1**
Horizontal axis pit or mini bulb Kaplan turbine unit.	--------------	**1**
Horizontal axis "S" type Kaplan turbine.	--------------	**1**
Vertical axis small Kaplan turbine, elbow draft tube.	--------------	**1**
Vertical or inclined axis "Saxo" axial flow Kaplan turbine.	---- YES ---	**1**
Vertical axis Kaplan turbine, concrete casing.	---- YES ---	**1**
Vertical axis Kaplan turbine, steel casing.	---- YES ---	**1**
Francis turbines.		
Horizontal axis Francis turbine.	--------------	**1**
Horizontal axis double runner Francis turbine.	--------------	**1**
Vertical axis Francis turbine, concrete casing.	--------------	**1**
Vertical axis Francis turbine, steel casing.	--------------	**1**

If the user does not wish to use the recommended unit, it can be removed by inserting a zero in the cell adjacent to the unit. The recommended unit appears as follows:-

Recommended type of reaction turbine.

Vertical axis Kaplan turbine, concrete casing.

Recommended type of impulse turbine.

No suitable impulse turbine, select reaction turbine.

If no suitable turbines, change number of units.

In addition, the program calculates the basic characteristics and cost of the recommended unit as shown in the following illustration:-

Generating equipment details.	Reaction unit.	Impulse unit.
Turbine runner speed, rpm.	225.0	0.0
Reaction turb. runner throat, impulse turb. outside diameter, m.	3.099	0.000
Required powerhouse crane capacity, tonnes. **Comment.**	38.3	0.0
Reaction unit vertical axis, casing centerline elevation.	274.03	--------------
Impulse turbine runner centerline elevation.	--------------	0.00
Generating unit capacity, MW.	10.17	0.00
Powerplant capacity, MW.	**10.17**	**0.00**
	Comment.	
Water to wire cost of generating units. $US, millions.	**13.90**	**0.00**

The program will not recommend the use of lower-cost propeller units if there are less than three units selected, due to the loss of efficiency at part loads. With three or more propeller units, the program assumes that the load can be shared efficiently between units by closing down units at low flows.

The program also calculates an alternative reaction unit based on including the powerhouse cost. For example, if there is a very large increase in tailwater level at flood, it may be more economic to use a vertical axis unit instead of a horizontal axis unit, since the large footprint of a horizontal unit may require additional concrete and therefore cost to counter floatation. The program calculates the added cost of concrete to counter floatation if required by the site conditions. Of course, this alternative is not necessary with an impulse unit, since the program assumes that all impulse units will be installed well above flood tailwater, without resorting to the use of compressed air to lower flood tailwater. To calculate the reaction unit alternative including powerhouse costs, the input data is needed for the powerhouse is shown in the following illustration. In the comment cell opposite the powerhouse rock level, the user is warned to enter the correct rock level, since a low level will result in negative excavations, and an incorrect answer. The comment opens when the user holds the cursor over the cell.

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Reaction turbine selection to include powerhouse costs, ancilliary equipment and effect of tailwater level.

Additional input data.		**Comment**
Unit cost of overburden excavation, $/m3.	**50**	
Unit cost of rock excavation, $/m3.	**125**	
Unit cost of concrete, including forms and reinforcing, $/m3.	**1500**	
Unit cost of walls and roof, $/m2.	**200**	
Unit cost of steel in superstructure, $/ton.	**9,000**	
Average rock level at powerhouse, elevation, m.	**280.0**	**Comment**
Average depth of overburden at powerhouse, m.	**1.0**	

With this data the program calculates basic characteristics of the powerhouse, providing the following data:-

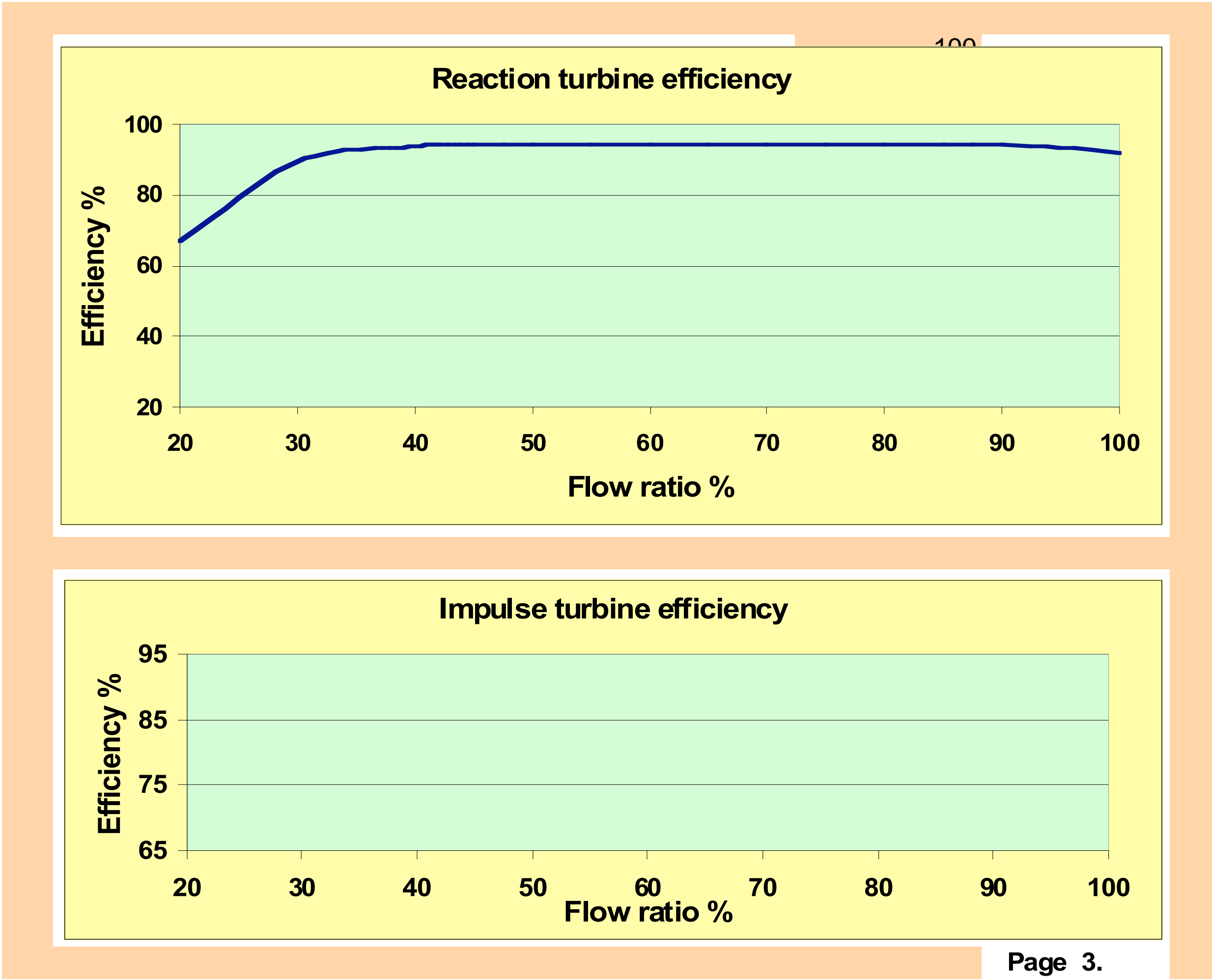
Powerhouse statistics.	Reaction unit.	Impulse unit.
Overburden excavation volume, m3.	705	0
Rock excavation volume, m3.	4,180	0
Concrete volume, m3.	3,171	0
Additional concrete required to counter floatation, m3.	0	Not applicable
Steel superstructure weight, metric tonnes.	57	0
Powerhouse length, m.	25.5	0.0
Powerhouse footprint area, m2.	435	0
Distance between unit centerlines, m.	12.76	0.00
Approximate turbine floor level, Elevation, m.	277.13	0.00
Draft tube sill level, elevation, m.	265.9	0.00

As noted from the above illustration, the program also calculates the powerhouse characteristics for impulse units. Costs of powerhouse ancillary equipment are developed as shown in the following illustration. If a utility design standard option was selected in the first illustration (Page 2), all electro-mechanical equipment costs will increase due to the higher inspection, documentation and installation standards required by utilities.

Powerhouse and ancilliary equipment cost, $millions.	Reaction unit.	Impulse unit.
Powerhouse excavation, concrete and superstructure.	6.06	0.00
Total cost of draft tube gate guide and hoist equipment.	0.89	0.00
Total cost of powerhouse crane, HVAC and water systems.	0.56	0.00
Cost of powerhouse and miscellaneous equip. - no units	**7.49**	**0.00**

Finally, the program calculates the expected unit efficiency curve, based on the ASME definition of efficiency, with no allowance for energy remaining at the draft tube outlet, since this cannot be converted to useful electrical energy. The efficiency is provided both in a chart and in graphical form, as shown in the following illustrations:-

BAKER - 10MW		If SAXO, shaft slope, degrees	**Comment** / **0**
Efficiencies of selected units. (reaction with powerhouse)		**Reaction unit.**	**Impulse unit.**
Percent of rated flow.		Efficiency, %.	Efficiency, %.
Calc. flow and efficiency at 100 % rated flow	=	91.77	0.00
Calc. flow and efficiency at 95 % rated flow	=	93.55	0.00
Calc. flow and efficiency at 90 % rated flow	=	94.15	0.00
Calc. flow and efficiency at 85 % rated flow	=	94.32	0.00
Calc. flow and efficiency at 80 % rated flow	=	94.35	0.00
Calc. flow and efficiency at 75 % rated flow	=	94.35	0.00
Calc. flow and efficiency at 70 % rated flow	=	94.35	0.00
Calc. flow and efficiency at 65 % rated flow	=	94.35	0.00
Calc. flow and efficiency at 60 % rated flow	=	94.35	0.00
Calc. flow and efficiency at 55 % rated flow	=	94.35	0.00
Calc. flow and efficiency at 50 % rated flow	=	94.34	0.00
Calc. flow and efficiency at 45 % rated flow	=	94.25	0.00
Calc. flow and efficiency at 40 % rated flow	=	93.88	0.00
Calc. flow and efficiency at 30 % rated flow	=	89.58	0.00
Calc. flow and efficiency at 20 % rated flow	=	67.02	0.00



This completes the program description. Prior to downloading the program, the user has to register, so that they can be notified of updates and revisions. The program developers hope that users will provide comments for improving the program and sufficient data on equipment quotations so that the program-calculated equipment costs remain current.

The program has been updated for 2009 with some revisions to the operating envelope for the turbines to increase the allowable flow, to include very large turbines, such as those at Three Gorges in China. Also, the submergence for SAXO units was revised to allow use of such units in a horizontal configuration. The powerhouse length (at right angles to the flow) has also been added to the data computed by the program.