HydroHelp

A SERIES OF EXCEL PROGRAMS

DEVELOPED FOR

PRE-FEASIBILITY ASSESSMENT

OF

HYDROELECTRIC SITES

BY

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HydroHelp series – a brief description.

The HydroHelp series of programs has been developed to allow engineers to obtain an initial assessment of a hydro-electric site, with a minimum of site data. All programs use Microsoft Office, Excel 2003 on Windows XP. Some data on charts may be lost if run on older versions of Microsoft Windows. The programs do NOT include any hydrologic or financial analysis. Several versions of the programs are being produced, as follows:-

1. The HydroHelp Beta SH (small hydro) series is designed for individuals and small consultants. It will be distributed at the August 1st "Innovative Small and Medium Hydropower Technologies" seminar at HydroVision 2006, in Portland Oregon. The programs contain a lock on the product of flow multiplied by head, which causes the program to crash if used on powerplants larger than 50MW. The number of embankment dams is limited to 2. The programs are protected, and all algorithms are hidden.

2. The HydroHelp Beta LH (large hydro) series is designed for large consultants, and covers all sizes of hydro projects since there is no lock on the product of flow times head. The programs are protected, and all algorithms are hidden. The number of embankment dams is limited to 2.

3. The HydroHelp Professional series is also designed for large consultants, and covers all sizes of hydro projects. The only difference is that the programs are not protected, and all algorithms are visible. There is no limit to the number of embankment dams.

There are presently 4 programs in each series, all for developments with surface powerplants:-

- HydroHelp 1TS for turbine selection.
- HydroHelp 2F for Francis turbine powered developments.
- HydroHelp 3I for impulse turbine powered developments.
- HydroHelp 4K for Kaplan turbine powered developments.

Two more programs are being developed, and will be available shortly. These are:-

- HydroHelp 5PT for Pump-turbine developments.
- HydroHelp 6UF for underground Francis turbine developments.

The user starts with program #1 which provides the user with the best turbine suitable for the flow, head and number of units desired in the powerplant. Selection is based on more than simple suitability. For example, the program will not select a propeller turbine where there is only one

unit in a low head plant, a Kaplan unit would be recommended instead. The user then proceeds to the next program, #2 for Francis turbines, #3 for impulse turbines or #4 for Kaplan turbines, based on the type of unit selected in the first program.

Programs 2 to 4 guide the user through the design process, providing the user with prompts in the adjacent "Comment" cell, as to the options available, and the best choice. All the user has to do is hold the cursor over an adjacent yellow "Comment" cell, and a box opens to provide detailed instructions on data entry. For this reason, the programs do not require a manual. The programs are intended for use by relatively inexperienced hydro engineers, by providing an "expert guide" throughout the project design process. The programs calculate quantities and costs, based on the data input, for all work and all electro-mechanical equipment, from initial clearing to the substation and transmission line.

Programs 2 to 4 have an input sheet where all input data is grouped. Although there is a large amount of data input, 186 to 235 items in each program, all data can be derived from maps and a casual site inspection with a GPS position locator, without having to resort to surveys and geotechnical investigations. The end result is a detailed pre-feasibility cost assessment. Typical input data would be length of pipeline, whether buried or above ground, length of tunnel, crest length of dam, headwater and tailwater elevations. The programs calculate all basic structure dimensions, from wave heights and the corresponding average rip-rap size on the dam, to the capacity of the powerhouse crane, governor open-close times, and provide a chart on suitability for isolated operation. Schematics are provided for surge and waterhammer levels. Sufficient dimensions are shown on typical sections of the required structures, to allow a draftsman to produce general drawings for the project. Charts are provided for turbine efficiency and for overall project efficiency, including conduit losses. In the cost sheet, the associated program-calculated quantities are shown, along with a suggested unit cost (for North American projects) so that the user can input an appropriate unit cost. The suggested unit cost is based on work quantity, use of union or non-union labor and the site frost days. More frost days and smaller quantity produce higher suggested unit costs. The user has the option of entering other unit costs. Water to wire costs for the generating equipment are developed, along with cost of all ancillary electromechanical equipment, from intake gates to spillway gates and powerplant elevators.

The programs contain design options for use by utilities or entrepreneurs. For utilities, the quantities for the concrete structures are larger, since utilities prefer to provide more space for repair bays and around equipment. Other options are also available, such as whether to use a surge tank or a relief valve on a long conduit, and program or manual optimization of the conduit size from intake to turbine. Optimization of unit size and number of units is easily attained, assisted by an energy cost index where the user can immediately see the effect of increasing or decreasing conduit size or number of units.

The programs include several safety overrides such as preventing the use of too small pipelines. All programs require some iteration of data, but this task is easily accomplished by following the adjacent instructions. For example, the programs calculate the head loss in the conduit and corresponding net head on the turbine at full load. The user has to change the assumed net head until it matches the calculated head. Another example would be the design of a sand settling basin, where the user has to increase the basin volume until a match is obtained with the program

calculated required volume. The programs have been successfully tested on several projects of varying capacity and head, from small hydro sites, to very large mega-projects. Experience has indicated that data input for program 1 requires a few minutes and for programs 2 to 4 requires about 2 to 3 hours per development. These times can be expected to reduce as the user develops familiarity with the programs. Program descriptions follow.

1. HydroHelp 1TS Beta 2 (Turbine selection program) Size 1.9Mb with 21 inputs.

Input data on lines 4 to 14 on page 1, and 52 to 58 on page 2. Program selects best turbine from a range of 15 reaction turbines and 13 impulse turbine types. Selection is based on two criteria, minimum equipment cost, and minimum equipment plus powerhouse cost. The latter criterion is to prevent selection of an inappropriate unit where there is a large rise in powerhouse tailwater at flood. For example a horizontal axis unit with a large footprint, instead of a vertical axis with a small footprint unit would cost more to protect from high tailwaters. The program provides a tabulation of all suitable units, and the user can de-select any unit, forcing the program to move on to the second best unit. An efficiency-flow chart is provided for the selected unit. After the turbine has been selected, the user moves on to one of the next three programs.

2. HydroHelp 2F Beta 2 (Projects with Francis turbines) Size 57.4Mb with 235 inputs.

The program produces 36 pages of detailed data on the project. All inputs have been grouped together on a 7-page input sheet. Adjacent to most input cells there is a yellow “Comment” cell, where the user can obtain advice on the input. The program produces charts of; (1) turbine efficiency-flow and (2) efficiency-power, (3) overall efficiency-flow, (4) generator power-flow, (5) suitability for “off-grid” or isolated operation, and (6) turbine-conduit efficiency to flow at constant head. There are options for single or multiple conduits. The program optimizes the conduit diameter, while offering the user a manual conduit optimization option, with an index of cost/kWh to assist optimization. Conduit losses (above-ground or buried pipelines/penstocks, tunnels and shafts) are calculated, and included in the estimate of energy. There are options for site dewatering by diversion through pipes, tunnels or spillway ogees. There are options for the inclusion of a surge tank, and/or a relief valve, and their sizes are calculated. Such details as turbine governor open-close times, powerhouse crane span, and wave run-up on the dam, (concrete, rock or homogeneous) are all determined. Harmonic interactions between the sound wave travel times for the penstock and draft tube surge frequency are calculated. 27 generic drawings are provided with dimensions for all structures, especially the powerhouse, shown in plan and section for both vertical and horizontal axis units. The input sheet for unit costs has a suggested unit cost for each unit of work, for USA and Canada, based on the quantity of work, and some other factors. Finally there is a detailed 3-page cost estimate with unit prices and quantities. Construction time and required operating hours are all calculated, producing an estimate of annual operating costs. The last page includes a preliminary screening, indicating whether the site is attractive.

3. HydroHelp 3I. Beta 1 (Projects with impulse turbines) Size 6.6Mb with 186 inputs.

The program follows the same format as HydroHelp 2, with an output of 23 pages. All inputs have been grouped together on a 6-page input sheet. However, in this case, the program selects the optimum impulse turbine from a list of 13 different types, ranging from small horizontal single jet units to large vertical axis 6-jet turbines. Turgo and Banki turbines are included. The selected turbine can be de-selected, if the choice is not suitable for other reasons. Charts are provided for overall efficiency-flow with the selected turbine, and the isolated speed operation characteristic. The professional version of the program provides efficiency-flow and efficiency-power for all turbine types. The program also determines whether plastic pipe can be used for the low-pressure section of the conduit, and if so, reduces the conduit cost. There are options for weir spillways and low level outlets. The conduit size can be optimized manually, and there is an index of cost per kWh to assist in the optimization. There is an option for the inclusion of a surge tank, and size is calculated. 15 dimensioned generic drawings for all structures are provided. The input sheet for unit costs has a suggested unit cost for each unit, for USA and Canada, based on the quantity of work, and some other factors. Finally there is a detailed 3-page cost estimate with unit prices and quantities. Construction time and required operating hours are all calculated, producing an estimate of annual operating costs. The last page includes a preliminary screening, indicating whether the site is attractive.

4. HydroHelp 4K Beta 2 (Projects with Kaplan turbines) Size 18.2Mb with 204 inputs.

The program follows the same format as HydroHelp 2, with an output of 26 pages. However, in this case, the program selects the optimum Kaplan turbine from a list of 8 different types ranging from horizontal axis bulb units and inclined axis SAXO units to large vertical axis concrete semi-spiral casing turbines. The selected turbine can be de-selected, if the choice is not suitable for other reasons. The program includes charts for; (1) turbine efficiency-flow for the selected unit, and (2) the speed regulation characteristic. There are options for site dewatering by diversion through pipes, tunnels or spillway ogees. The professional version of the program provides efficiency-flow and efficiency-power charts for all turbine types. 40 generic drawings are provided with dimensions for all structures, especially the different types of powerplants, shown in plan and section for both vertical and horizontal axis units. Finally there is a detailed 3-page cost estimate with unit prices and quantities. Construction time and required operating hours are all calculated, producing an estimate of annual operating costs. The last page includes a preliminary screening, indicating whether the site is attractive.

5. HydroHelp 5PT Beta 1 (Pump-turbine projects) Size 10.1Mb with 174 inputs.

This program has been developed for assessing the cost of pump-turbine projects using Francis reversible pump-turbines. It is only available as a professional version. It offers the option of underground or surface lower reservoirs, and daily or weekly pumping cycles. There are 2 charts showing pump and turbine efficiency plotted against flow and power,

along with 16 dimensioned generic drawings. The powerhouse is underground. Power demand and generation is calculated, along with the overall generating efficiency factor, taking into account conduit and transformer losses.

6. HydroHelp 6UF Beta (Underground Francis turbine projects) Size 23Mb with 264 inputs.

This program is identical to HydroHelp 2, with the exception of the powerhouse, which is placed underground. It is only available as a professional version. It offers the option of upstream or downstream transformer galleries, and free-flow or pressure tailrace tunnels. There are 5 charts plotting efficiency of turbine and conduit versus flow and power, and one chart showing the speed regulation characteristic. There are 36 dimensioned generic drawings, and provision for 3 embankment dams, with the option of adding more as required.

Programs 2 to 6 have a large data input sheet which is not intended for printing. It includes all instructions on data entry. Data entry cells are blue, comment cells are yellow, and red cells on the same line indicate that either iteration is needed or there is a restriction on the data range, where the data must be below or above a number provided in an adjacent cell. For example, the program will calculate the upper surge level in a surge tank, and if the tank is in rock, the level of rock at the tank, must be above the upper surge level. There are several warnings to check the more important data entry if this is outside defined limits – for example, if the turbine net head has not been iterated close to the program-defined head, a warning will be shown. Another example is excessive speed rise on load rejection triggers a warning, with instructions for correction of data entry.

For printing the output, there are several options as follows:-

- Print a one-page executive summary.
- Print the executive summary and the detailed 3 page cost estimate.
- Print a complete output of 23 to 36 pages.

All programs have an un-numbered cover sheet, indicating the estimated project cost, generation and power output. The next (first) page is a summary of principal data, suitable for inclusion in an executive summary of the project. The program output pages include all pertinent input data, as defined by blue cells, calculated structure and equipment dimensions, quantities, charts, structure drawings with dimensions, and conclude with a detailed estimate of quantities, unit costs, cost extensions and cost of all electro-mechanical equipment, substations and transmission lines. Overheads for site surveys, engineering, and interest based on an estimate of construction time, are also included. Calculations are “off page” and hidden, except in the professional version. The programs are large, ranging in size from 1.9Mbytes for HydroHelp 1TS to 57.4Mbytes for HydroHelp 2F.

Experience has indicated that users have their own programs for undertaking a financial analysis. However, to assist the optimization processes within the HydroHelp programs, a simple cost per kWh index is included, along with an estimated time for capital recovery. With the latter, a final comment on development prospects is shown, ranging from “Too optimistic - check input data” to “Not worth further investigation”.

All algorithms (except 2) used and developed for the programs are based on published data. The two unpublished algorithms are for dam design and for the weight of structural steel in a powerhouse superstructure. The dam program is currently being tested at a Canadian University. The structural steel program is based on unpublished statistics from the Montreal Engineering Company Limited “Manual of hydraulic engineering practice”, second edition, August 1980.

Based on early comments from users, the following changes have been made to Programs 2 and 4, both re-issued as follows:-

HydroHelp 2. Beta 2 Options unlocked, comment revised. The option of adding another embankment dam has been added, showing how the addition of multiple dams is added in the Pro version of the software. River diversion options have been enhanced to include -

1. No diversion, for projects where powerplants are added to existing dams.
2. Diversion through spillway ogee, or a concrete pipe through the dam, or an unlined tunnel in competent rock for both embankment dams and concrete dams.

HydroHelp 4. Beta 3 Option of adding another embankment dam has been added, showing how the addition of multiple dams is added in the Pro version of the software. River diversion options have been enhanced to include -

1. No diversion, for projects where powerplants are added to existing dams.
2. Diversion through spillway ogee, or a concrete pipe through the dam, or an unlined tunnel in competent rock for both embankment dams and concrete dams.
3. Links on dam and conduit sheets corrected, and cell for main dam foundation level added to input sheet.

Since the diversion options are many, correct selection warnings have been added to the input sheet, to warn of combinations such as diversion through an ogee, where there is no spillway, and incorrect sizing of the diversion conduit.

SUGGESTIONS FOR PROGRAM USERS

1. Before starting.

Make a sketch of the project, showing location of all structures and pertinent water and ground levels. This will help to avoid such mistakes as entering a river level above a dam full reservoir level, or a ground level well below a structure foundation level.

2. Site photographs.

Take ample photos, particularly of sideslopes along pipelines and penstocks. It is common to overestimate the steepness of terrain, and this can be avoided by printing the sideslope photo, and measuring the sideslope.

3. River diversion.
There are many options in the program, so it is prudent to make a note of how the diversion will be accomplished. For example, the program will malfunction (division by zero) if diversion is through open spillway ogees, and there is no spillway.

4. Dam.
The main difficulty with the dam, is assessing the foundation, particularly the permeability. If sound rock is visible, there are no problems. If abutments are steep, and there is alluvium in the river bed, it is likely that there is a deep deposit. Project the abutment sideslopes down to their intersection, to obtain likely depth of alluvium. If shallow, less than about one-quarter of dam height, assume excavation down to sound rock. If deeper, assume use of a cut-off wall. If in doubt, try both options to see which is less expensive.

5. Tunnels.
Assume at least 15% lining in sound rock – required to cover fault zones. Although the lining cost is based on concrete, look at moneys as being an allowance for covering faults with whatever is necessary, such as fiber reinforced gunnite. More permeable rock, such as sandstone, will require full lining.

6. Pipelines and penstocks.
Experience has indicated that excavation and fill quantities in buried conduits are always more than estimated. This is due to the roughness of the terrain, and the inability of the conduit to exactly follow the contour. Do not underestimate the roughness factor.

7. Quantities.
Review the estimate sheet, and look for negative quantities. These are obviously not correct, and result from incorrect data entry. Negative quantities could also cause parts of the program to crash on division by zero.

8. Costs.
For users outside USA and Canada, the suggested costs are not applicable. In such cases, find out the local costs, and try to "benchmark" the program by using it on an existing local hydro development where the costs are known.
