Washington State Department of Ecology
Water Resources Program / Dam Safety Office

Spreadsheets for
Hydraulic Computations for Drop Inlet Spillways

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Several spreadsheets are available to assist design engineers in performing the hydraulic computations related to drop inlet spillways. The calculations include the stage-discharge curve for the overall spillway, pressure sags and fluctuations in the outlet pipeline, and downstream tailwater conditions that may affect the hydraulic capacity of the spillway. The governing equations are summarized on the spreadsheets to facilitate their use for file documentation.

The stage-discharge curve considers five possible locations of hydraulic control:

- Weir flow at the riser crest
- Orifice flow at the riser crest
- Inlet control at the outlet pipe
- Outlet control at the outlet pipe due to the outlet pipe itself
- Outlet control at the outlet pipe due to downstream tailwater conditions

Most designers will recognize these concepts from the equations for stormwater detention pond flow control structures and for culverts and storm sewers. These spreadsheets help the designer consider all of these factors simultaneously when designing and analyzing their spillway.

The general theory for drop inlet spillways is discussed in Mel Schaefer's short course notes for shaft spillways (Schaefer, 1981). A copy is available as a companion paper (see Schaefer.pdf). I am indebted to Dr. Schaefer for the insights his paper provides into the hydraulics of drop inlet spillways and the key features these spillways need for dam safety, although there are a few areas where the computations in the spreadsheets differ somewhat from Dr. Schaefer's approach.

Spreadsheets

The template spreadsheets are listed below, along with a brief description of each spreadsheet. The spreadsheets are compiled in MS Excel format (the current version in use at the Washington State Department of Ecology as of this writing). These versions of the spreadsheets include provisions for using either U.S. customary units or metric units, with a view toward making them more available to the international dam safety community.

DropIn-1 calculates the stage-discharge curve for a drop inlet spillway with a circular riser, plus computes the pressure sag at the inlet to outlet pipe due to the venturi effect. This spreadsheet is eight pages long.

DropIn-TW offers a rough calculation of downstream tailwater conditions when the downstream channel may be approximated as a wide weir, a V-notch weir, or an orifice. This spreadsheet is four pages long. (Note: The designer may also use a canned hydraulics program to perform these computations.)

DropIn-3 calculates potential pressure fluctuations and flow surges in the outlet pipe, to further confirm the need for air venting of the outlet pipe. This spreadsheet is eight pages long.

DropIn-1d integrates downstream tailwater calculations into the stage-discharge computations of DropIn-1. This spreadsheet is 10 pages long. This expedites these computations when the spillway is under outlet control due to downstream tailwater conditions.

DropIn-3d integrates downstream tailwater calculations into the flow and pressure surge computations of DropIn-3. This spreadsheet is nine pages long. This expedites these computations when the spillway is under outlet control due to downstream tailwater conditions.

Two worked examples from previous dam safety projects are also included to illustrate how the template spreadsheets are used.

The general computation sequence and procedures are as follows:

1. Save a copy of the template spreadsheet to a new project-specific name before making any project-specific changes to that spreadsheet.
2. Use DropIn-1 to calculate a preliminary stage-discharge curve for the spillway. This preliminary run identifies the range of flows for tailwater computations.
3. Calculate the range of tailwater elevations and corresponding flows using DropIn-TW or a canned hydraulics program.
4. [optional step] Calculate the range of headwater elevations and corresponding flows for the outlet pipeline, typically done using culvert equations. For example, the HY-8 program from USDOT FHWA may be used for this. From these calculations, estimate a representative orifice coefficient to approximate inlet control conditions for the outlet pipe.
5. Enter the refined estimates for tailwater elevations and representative orifice coefficient into DropIn-1 or DropIn-1d to re-calculate the stage-discharge curve for the spillway.
6. Use DropIn-3 or DropIn-3d to calculate the possible range of flow surges and pressure fluctuations in the outlet pipe. The potential for low pressures to occur near the pipe inlet and for hydraulic transients (flow and pressure fluctuations) to develop confirms the need for air venting of the outlet pipe to relieve any negative pressures.

Using the spreadsheets

The spreadsheets are intended to be very interactive. The user should be sure to understand the calculations and their physical significance. As always, the design engineer retains full responsibility for making sure these calculations are correctly applied to their specific project.

Green and blue shading is used to help identify the cells where key information needs to be entered by the user. Many of the green cells have "dummy" values in them just as a check to make sure the spreadsheet does the calculations correctly. Most of the hydraulic coefficients (in blue cells) are reasonable values, but all the values for pipe sizes, pipe and riser elevations, etc. (in green cells) need to be replaced with project-specific values. The specific item of data needed is usually listed nearby so that a print-out of the spreadsheet will serve as clear file documentation of the calculations performed.

When the correct value has been entered into a particular cell (including accepting any suggested values in the blue-tinted cells), my usual practice is to get rid of the green or blue shading for that cell as an indication that the data input for that cell has been completed, although for illustrative purposes I elected not to do this in the worked example spreadsheets.

You may also need to delete some lines and/or autofill to add some lines (and adjust the data sources for the graphs) to make the spreadsheet fit your specific project. To some extent, each use of the spreadsheet has its own project-specific nuances and variations. Feel free to edit and revise these spreadsheets as appropriate for your own specific needs.

For each of these spreadsheets, page 1 serves primarily as an "executive summary" page for the computations, with most of the data input starting on page 2.

<u>Stage-discharge calculations (DropIn-1):</u>

Data for the dam, the spillway riser and the outlet conduit need to be entered in the appropriate cells on pages 2 and 3. The effective weir length % and effective orifice area % are intended to account for the physical configuration of the riser crest. Possible blockage by debris is considered as % obstruction (obstr) for both weir flow and orifice flow, and the percentages may be different for weir vs. orifice flow.

The system of units, either U.S. or metric, are entered in the far right column on page 2, with U.S. customary units shown as the default values. If metric units are used, simply autofill or copy and paste the metric values in cells N71 thru N80 into the cells M71 thru M80; most of the units shown next to the input cells will update automatically, but many of the column headings in the various tabular presentations will need to be manually updated to list the metric units.

The default weir and orifice coefficients are typical values consistent with stormwater management practice; for example, see Ecology (2019), Equations 6.6 and 6.4 in Section 6.2.6; see also Brater and King (1976). If desired, the designer or analyst may use other values in lieu of these.

"Convergence" occurs when weir flow from opposite sides of the riser intersects at the center of the riser to essentially provide a water seal near the riser crest. This phenomenon is described in more detail in USBR (1987) on pages 407 to 409. For weir flow convergence, the distance to intersection L_o is typically either 0.5 or 1.0 times the riser diameter or width, depending on whether flow occurs from opposite sides to intersect in the center, or flow occurs from one side and must cross the entire riser width to intersect the opposite wall.

Inlet control at the entrance to the outlet pipe is approximated by an orifice equation. The orifice coefficient may be selected based on a separate comparison with culvert equations, or the default value may be used. Provision is also made to consider the effects of a deflector plate across the top of the pipe inlet as described in Schaefer (1981). A deflector plate will lower the orifice centroid elevation and crown elevation, and reduce the cross-section area of flow. (Head is measured from the orifice centroid for flow calculations; water levels below the pipe or orifice crown are too shallow for orifice flow or inlet control to occur.) The hydraulic

coefficients for the deflector plate may be estimated from tables for circular conduits or channels flowing part full. For example, see Tables 7-8 and 7-4 in the Handbook of Hydraulics, 6th ed. (Brater and King, 1976). See also separate guidance for air vents available from Dam Safety's web site.

For computing head losses in the outlet conduit during full pipe flow conditions, the default values for entrance and exit loss coefficients are typical values, may be adjusted as appropriate by the designer or analyst. A column is provided on page 4 for the user to insert flow-specific tailwater (TW) elevations based on computations for the downstream channel or hydraulic control (calculated by canned hydraulics program or separate spreadsheet such as DropIn-TW), with a further criterion that TW elevation should be at or above the pipe crown, and for spill-ways that discharge to an up-flow energy dissipator, at or above the overflow (rim) elevation.

On page 2, low-level inflow to the riser (for example, flow through the various orifices in the flow control structure) may be specified as a representative constant value, or may be omitted (presumed negligible and calculated as zero). In actual practice, flow through the orifices will diminish as the water level rises within the riser and decreases the driving head across the orifices. My experience using the spreadsheets has been that: (a) including low-level inflow may slightly over-estimate inflow to the riser near the transition to pipe control, which may calculate the transition one increment earlier than if it were omitted; and (b) omitting low-level inflow may slightly under-estimate the stage-discharge curve during weir flow, especially at lower water levels just above the riser rim, and may calculate the transition to pipe control one increment later than if it were included. The spreadsheets allow the designer to compute the stage-discharge curve with and without low-level inflow, or to try several representative values, to see how much difference it makes and which scenario they prefer to use for design purposes.

For each increment of water level (WL) in the pond or reservoir, the spreadsheet calculates the hydraulic head on the riser crest, head on the inlet to the outlet pipe, and head loss (HW – TW) through the outlet pipe. Based on these values, the spreadsheet calculates the corresponding weir flow and orifice flow at the riser crest, orifice flow into the outlet pipe, and full pipe flow for the outlet pipe. The minimum of these four flows is selected as the spillway discharge corresponding to the reservoir WL. The computations are summarized in a table on page 4 and also presented in graphical form on page 5. Space is provided in the far right column on page 4 for the designer or analyst to note key elevations such as changes in hydraulic control and overflow elevations for other hydraulic or physical features. The stage-discharge table and graph are also copied to page 1 to serve as an executive summary of the calculations.

As written, the spreadsheet provides equal increments of head ("H") or water level (input on page 4). Individual cells in the table on page 4 may be manipulated by the user to provide smaller increments where desired to obtain more detail around changes in hydraulic control.

For preliminary estimates of the stage-discharge curve, DropIn-1 estimates tailwater elevations as being relatively constant at the outlet pipe crown or energy dissipator overflow elevation.

Once the general range of spillway flows is known, the corresponding range of downstream tail-water elevations can be estimated, then factored back into the stage-discharge computations.

Tailwater computations (DropIn-TW):

These computations are typically performed using a canned hydraulics program or other hydraulics calculator. The DropIn-TW spreadsheet was developed for cases where a canned program is not readily available, or for use as a screening tool to see whether further refinement of downstream conditions or constrictions is needed.

The DropIn-TW spreadsheet considers downstream conditions and/or constrictions as roughly fitting into one of the following scenarios:

- Wide channel or overflow (approximated as a wide weir)
- Narrow or V-shaped channel (approximated as a V-notch weir)
- Culvert or storm sewer (approximated as an orifice)

A representative overflow elevation and channel dimension (width, side slope or diameter) should be entered for the most appropriate scenario in the top or middle of page 2, then autofilled into the Downstream Scenario section at the bottom of page 2. To do this, set the Downstream Scenario input cell equal to the appropriate scenario in the column above it, then autofill down to input the values for the respective parameters.

Consistent with the full pipe approximation for pipe outlet control, the spreadsheet recommends using the pipe crown at the outlet, or the energy dissipator overflow elevation, as the minimum TW elevation. For the computations on page 3, I usually select a starting Q of zero and a flow increment to obtain coverage in the table of the entire flow range of interest. Page 4 provides a table of detailed TW calculations to help expedite entry of flow-specific TW levels into the stage-discharge curve. On page 4, I usually select a starting Q near the upper end of the range where TW = pipe crown (since all TW levels below that are constant at the same value) and, again, a flow increment to obtain coverage in this table of the entire flow range of interest. Since there are more values in this table (page 4), the flow increment is smaller than on page 3.

Note that the purpose for calculating TW elevations is to feed this information back into the stage-discharge computations, as discussed in the next section.

Stage-discharge calculations (DropIn-1 or DropIn-1d):

After the preliminary run using DropIn-1, the analyst should note whether inlet or outlet control seems to be more limiting, that is, whether the values for Q_c are greater than or less than Q_p in the table on DropIn page 4 or DropIn-1d page 6. For cases where inlet control is more limiting ($Q_c < Q_p$), updating the data for TW levels with flow-specific values in DropIn-1 will usually have little or no impact on the corresponding values for discharge Q. This update to DropIn-1 will usually complete the stage-discharge computations for the spillway.

For cases where outlet control is more limiting ($Q_c > Q_p$), updating the data for TW levels with flow-specific values in DropIn-1 may significantly change the corresponding values for discharge

Q, especially for flows where the spillway may be in pipe outlet control. In such cases, entering correct TW levels becomes an iterative process. Unfortunately, the spreadsheet doesn't like circular cell references, and several of my attempts to use the iteration feature in Excel have not been successful either. To circumvent this apparent dilemma, for the range of TW levels above the pipe crown or other minimum TW level, each TW value must be manually revised until the resulting value for Q is consistent with the separate rating table of Q vs. TW. Spreadsheet DropIn-1d may help to expedite these computations.

Data input for DropIn-1d is the same as for DropIn-1 and DropIn-TW. The TW iterations are done in the table on page 5. For calculated TW levels that exceed the minimum TW level, each cell in the "use TW" column must be manually adjusted to equal the value in the adjacent "calc'd TW" column. If TW iterations are needed just for higher flows near the bottom of the table, auto-fill down from one of the minimum TW cells to correct the "dummy" values. The final stage-discharge computations are shown in the table on page 6 and in graphical form on page 7.

Pressure sag calculations (DropIn-1 or DropIn-1d):

The pressure sag computations in DropIn-1 use the same data for the dam, spillway and conduit as previously entered for the stage-discharge curve. The default value of 0.6 for the contraction coefficient (input on DropIn page 6 or DropIn-1d page 8), is suggested based on Henderson (1966), pages 175 to 178, consistent with Brater and King (1976), page 4-7. The designer or analyst may use another value for the contraction coefficient if they prefer.

Based on the range of flows calculated previously for the stage-discharge curve, the spreadsheet calculates corresponding headwater (HW) elevations within the riser for both inlet and outlet control, then selects the higher of the two values for further hydraulic grade line (HGL) computations. HW depth (measured from the pipe invert) represents the energy of the water in the riser pushing the water through the outlet pipe.

The spreadsheet then calculates entrance losses based on average velocity head in the outlet pipe, and the velocity head of the water at the vena contracta. HGL at the vena contracta represents the hydraulic energy (elevation head plus pressure head) remaining after the energy losses at the pipe entrance and the conversion to kinetic energy have been subtracted from the original HW depth. Note that HW and HGL are measured from the pipe invert. To examine the potential for low or negative pressures to occur at the top of the pipe, an "air grade line" (AGL) is calculated to show the HGL relative to the pipe crown. A negative AGL confirms the need for air venting to relieve negative pressures within the pipe. Computations for HGL and AGL are constrained to be greater than -33.9 feet of water equivalent (zero absolute pressure).

In DropIn1, results of the venturi pressure sag computations are presented in the table on page 7 and in graphical form on page 8. In DropIn1d, results of the venturi pressure sag computations are presented in the table on page 9 and in graphical form on page 10. Space is also provided in the far right column of page 7 or page 9 for the designer or analyst to note the range of flows and HW levels from the pipe crown to the dam crest.

Pressure sag calculations (DropIn-3 or DropIn-3d):

The pressure sag calculations here are similar to the calculations in the DropIn-1 spreadsheet, except they are incremented by flow ("Q" incr). Data for the dam, the spillway riser and the outlet conduit need to be entered in the appropriate cells. Default values for the orifice coefficient, the contraction coefficient, and the entrance and exit loss coefficients may be used, or other values may be used if preferred.

A starting discharge Q and flow increment (Q incr) need to be entered in the green-tinted cells on DropIn-3 page 3 or DropIn-3d page 4. The starting Q should be the discharge for HW depth near or greater than the outlet pipe diameter (i.e., HW elevation near or above the pipe crown elevation). I try to select a flow increment to obtain coverage in the table of the entire flow range of interest. Also on page 3 or page 4, a column is provided for the user to insert flow-specific TW elevations as calculated by a canned hydraulics program or separate spreadsheet such as DropIn-TW. As mentioned above, the minimum TW elevation should be the pipe crown or energy dissipator overflow elevation, as appropriate. Again, results of the venturi pressure sag computations are presented in table and graphical form on DropIn-3 pages 3 and 4, and on DropIn-3d pages 4 and 5.

Flow surge and pressure drop calculations (DropIn-3 or DropIn-3d):

The calculations on DropIn-3 page 3 or DropIn-3d page 4 presume the values for flow Q and HW depth (based on the higher HW elevation for inlet vs. outlet control) represent an equilibrium condition for the spillway. The flow surge and pressure drop calculations would then represent potential departures from these equilibrium conditions.

The pressure drop computations on DropIn-3 page 5 and DropIn-3d page 6 compare the equilibrium HW elevation with the HW elevation for full pipe flow for flow at equilibrium discharge. The difference in HW elevations represents a sudden, temporary pressure drop. (Note: If the pipe is outlet controlled, there is no flow surge or pressure drop, so dHW = zero.) The sudden pressure drop is superimposed on the pressure sag (residual HGL) to calculate the combined *HGL** as measured from the pipe invert, or *AGL** as measured from the pipe crown. Computations for *HGL** and *AGL** are constrained to be greater than -33.9 feet of water equivalent (zero absolute pressure).

The flow surge computations on DropIn-3 page 6 and DropIn-3d page 7 compare the equilibrium flow with full pipe flow for HW at equilibrium HW level. The difference in flows represents a sudden, temporary flow surge. (Note: If the pipe is outlet controlled, there is no flow surge or pressure drop, so dQ = zero.)

The flow surge computations are summarized in tabular and graphical form on DropIn-3 page 7 and DropIn-3d page 8. The pressure drop computations are summarized in tabular and graphical form on DropIn-3 page 8 and DropIn-3d page 9. The tables and graphs should update automatically as the "dummy" values in the template spreadsheet are replaced with project-specific data.

If the graphs for Equil Q vs. Alt Q and Equil HW vs. Alt HW show two separate lines, a High surge vulnerability is indicated. If the lines for Equil Q vs. Alt Q and Equil HW vs. Alt HW overlap to show just one line on the graph, a Low surge vulnerability is indicated. Entering a value of 1 or 0, as applicable, in the input cell for surge vulnerability will help calculate the required diameter for the air vent pipe. The value for surge vulnerability as input on the page for flow surges will copy to the page for pressure drops. This provides a visual check that the two calculations reach the same conclusion with regard to surge vulnerability.

These computations illustrate the potential for hydraulic transients to occur, and confirm the need for air venting of the outlet pipe to relieve any negative pressures that may develop in the outlet pipe. As will be discussed later, these computations also calculate the required diameter for the air vent pipe.

Examples

Two drop inlet spillways from previous projects illustrate how these spreadsheets may be used. Example 1 discharges to a storm sewer system that constricts the spillway capacity at higher flows. Example 2 discharges to an up-flow energy dissipator, which then overflows to a stream. At this time, only examples using calculations in U.S. units are available. I would be interested in feedback from anyone using these spreadsheets with calculations in metric units.

Example 1 spreadsheets:

- Ex1a-DropIn1, 9 pages. Preliminary stage-discharge curve. At higher flows, the spillway is under pipe outlet control. An extra page is added to also show the incorrect stage-discharge curve as calculated by a hydrology program that does not consider the outlet pipe or down-stream constrictions.
- Ex1b-DropTW, 4 pages. Tailwater computations for the downstream constriction.
- Ex1c-DropIn1d, 10 pages. Revised stage-discharge curve, with TW calculations integrated into the stage-discharge computations. Downstream TW levels restrict the spillway capacity even more than originally estimated. In the TW calculations on page 5, the TW elevations had to be expanded to 3 decimal places in order to get good agreement between the calculated and used values; this was a very iterative process. Also, the riser is located high on the embankment, with a portion of the rim right at ground level. Effective rim length of 75% takes into consideration this configuration of the riser rim.
- Ex1d-DropIn3, 8 pages. Pressure sag, potential flow surges and pressure fluctuations. Due to outlet control, the potential for flow surges is minimal. At higher flows, backwater from high TW levels will pressurize the outlet pipe.
- Ex1e-DropIn3d, 9 pages. Pressure sag, potential flow surges and pressure fluctuations, with TW calculations integrated into the computations. Due to outlet control, the potential for flow surges is minimal. At higher flows, backwater from high TW levels will pressurize the outlet pipe.

Example 2 spreadsheets:

- Ex2a-DropIn1, 9 pages. Preliminary stage-discharge curve. At higher flows, the spillway is under pipe inlet control. An extra page is added to also show the incorrect stage-discharge curve as calculated by a hydrology program that does not consider the outlet pipe or down-stream constrictions.
- Ex2b-DropTW, 4 pages. Tailwater computations for an up-flow energy dissipator 54 inches in diameter. Range of TW levels from low to high flows is about one foot difference.
- Ex2c-DropIn1, 8 pages. Final stage-discharge curve. Slightly higher TW levels do not affect stage-discharge curve. As in Example 1, this riser is also located high on the embankment, with a portion of the rim right at ground level. Effective rim length of 75% considers this configuration of the riser rim.
- Ex2d-DropIn3, 8 pages. Pressure sag, potential flow surges and pressure fluctuations. Potential for flow surges and pressure fluctuations is significant.

Air vent requirements

Conduits are particularly vulnerable to negative pressures when both ends of the pipe may be submerged. For drop-inlet spillways, the upstream end of the outlet conduit may be submerged by water backed up within the riser. The downstream end of the pipe may be submerged by back-water from the downstream channel or a downstream culvert, or by an up-flow energy dissipator or similar pipe outfall configuration.

This phenomenon of negative pressures in conduits is briefly mentioned for culverts in HDS-5 (FHWA, 1985, types of inlet control; for example, see Haan et al, 1994, page 160). Although the need for air venting is illustrated, a procedure to compute air demand or the size of vent pipe required for such culverts is not presented.

Several air vent sizing procedures are presented in the literature for dams and spillways:

- USDA-SCS, 1969: SCS uses a graphical procedure based on head and pipeline diameter. This approach is also recommended in Schaefer (1981).
- USBR, 1974: The Bureau of Reclamation uses a standard air vent diameter = 1/6 pipeline diameter, with a further limit of air vent > 4 inches diameter.
- USACE, 1980: The Army Corps of Engineers (USACE) has developed an equation for air demand based on water flow rate and Froude number. The air vent diameter is sized for air velocity < 150 ft/sec.

At this writing, two spreadsheets are in development and testing that would calculate air demand and required air vent size. One spreadsheet uses the Corps' air entrainment mechanism in conjunction with the venturi effect pressure sag to estimate air demand. The other spreadsheet uses the flow surges and pressure drops calculated in DropIn-3 as the mechanism for air demand. Both spreadsheets then calculate head losses in the air vent pipe to

verify whether adequate pressure is delivered to the outlet pipe. These spreadsheets are still undergoing internal peer review, so are not yet ready for wider distribution.

In the meantime, the following recommendations are offered with regard to the size of air vent pipe required for drop-inlet spillways:

Scenario **A**: Spillway appears vulnerable to potential flow surges and pressure drops as computed using DropIn-3 spreadsheet, and/or outlet pipe hydraulics indicate inlet control would be limiting as compared to outlet control at higher flows.

> Recommend air vent pipe = **1/6** outlet pipeline diameter, with 2-inch minimum air vent diameter.

Scenario **B**: Spillway does not appear vulnerable to potential flow surges and pressure drops per DropIn-3 computations, and/or outlet pipe hydraulics indicate outlet control would be limiting as compared to inlet control at higher flows.

> Recommend air vent pipe = **1/12** outlet pipeline diameter, with 2-inch minimum air vent diameter.

Scenario **C**: Outlet pipe hydraulics indicate neither end of the outlet pipe is likely to become submerged, even at high flows; HW/D << 1 and TW/D << 1 for all flows. **And:** Weir flow convergence does not occur at water levels below the dam crest elevation; no potential for water seal to develop at or near the riser crest.

> Air vent pipe may be omitted. Riser and outlet pipe are already open to the atmosphere during all flow scenarios.

Air vent design

The following features are suggested for incorporating the air vent pipe into the spillway design:

- Inverted inlet (facing down), screened.
- Inlet elevation at least 1.5 ft above peak water level from dam safety inflow design flood and at least 1.0 ft above dam crest elevation, whichever is higher.
- Air vent pipe strapped to the riser for support over most of its vertical length. May be located either within or outside the riser.
- Air vent connects or opens to the spillway outlet pipe crown roughly ½ pipe diameter from the inlet to the outlet pipe, or just behind a deflector plate.
- Deflector plate at the inlet to the outlet pipe is recommended for cases where the outfall from the outlet pipe is only partially submerged even during high TW conditions.

See also separate guidance for air vents available from Dam Safety's web site.

Summary comments

The spreadsheets presented here were developed and refined over a number of years, and have been used extensively in engineering reviews of proposals for new dams and in conjunction with periodic inspections of existing dams. These spreadsheets are intended to be public domain, so please feel free to edit and revise them as appropriate for your own specific needs. As always, the engineer retains full responsibility for making sure these hydraulic calculations are correctly applied to their specific project.

Engineers from the Dam Safety Office are available to provide technical assistance regarding dam design and construction and related engineering analyses, so please feel free to contact us early in the planning stages for your project.

Feedback and questions regarding these spreadsheets are welcome, and should be directed to Marty Walther, fax 360-407-7162, e-mail martin.walther@ecy.wa.gov, or regular mail to Washington State Department of Ecology, Dam Safety Office, PO Box 47600, Olympia, WA 98504.

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