Engineer's Manual for PondSim.XLS

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Abstract

PondSim is an Excel workbook for the simulation of water flow in a set of ponds–the managed units at Quivira National Wildlife Refuge. For each day, the volume of water in the pond is calculated as the sum of the previous day's volume of water and the net inflow of the previous day's gains and losses. From the volume, the area and water level of the pond are calculated by looking the volume up in a volume-elevation-area table. Ponds can gain or lose water through rainfall, evaporation, groundwater, and surface-water. Fluxes can be explicitly entered (for example, inflow along a river) or calculated from other data, such as finding evaporation as the product of area and evaporation rate or outflow through a control structure using formulas involving water level, structure dimensions, and structure status. Adjusting the structure state allows simulation of management strategies. Adjusting model parameters–such as channel loss factors and control structure dimensions–to match observed losses and flows allows calibration of the model.

This document supplements the User's manual by explaining how to "program" the model to include new structures or reservoirs and how to adjust model parameters, both to match observations and to simulate proposed modifications to channels, reservoirs, and water control structures.

Introduction

PondSim is an Excel workbook for the simulation of water flow in a set of ponds at the Quivira National Wildlife Refuge. PondSim is a mass-balance model: for each day, for each pond, the volume of water in the pond is calculated as the sum of the previous day's volume of water and the net inflow of the previous day's gains and losses. From the volume, the area and water level of the pond are calculated by looking the volume up in a volume-elevation-area table. This water level and area are then used in calculating the next step's net inflow. Ponds can gain or lose water through rainfall, evaporation, groundwater, and surface-water. Fluxes can be explicitly entered (for example, inflow along a river) or calculated from other data, such as finding evaporation as the product of area and evaporation rate or outflow through a water control structure using formulas involving water level, structure dimensions, and structure status.

PondSim uses formulas, model parameters, user-input, and a number of assumptions to calculate water budgets. For each day, PondSim calculates a water budget for each pond. The water budget is only as good as the assumptions, user-input, model parameters, and formulas that went into the model: if the water budgets are inaccurate, these need to be changed.

In many ways, PondSim is like a financial-planning program that lets the user simulate different investment options (management strategies) by apportioning assets (water) among different investment opportunities (ponds) with different yields (pond capacity curves), risks (no analogue), and fees (channel seepage, groundwater losses, and evaporative losses) where both fees and yields are uncertain and changing. As engineer, you can adjust the "economy" to match historical observations (calibration), better match measured dimensions on the Refuge, and examine what-if scenarios for possible works of civil engineering. Examples include adjusting parameters on water control structure formulas or seepage loss parameters to match observed behavior; adjusting model parameters to match dimensions of water control structures at the Refuge; and adjusting seepage loss parameters to simulate adding a clay lining to a channel.

Overview of PondSim

Each pond in PondSim gets a separate worksheet. This worksheet contains information about that pond, including

1. Formulas for calculating the volume of water in the pond, the elevation of the pond surface, and the area of the pond	Model Formula.
2. Structure state information	Model Input Daily
3. Flows into and out of the pond	Model Formula or Model Input Daily.
4. Structure dimensions	Model Parameter
5. Volume-elevation-area curve	Model Parameter

Each day is represented by a row in the worksheet. Columns are provided for fluxes of water and data necessary for calculating them. For example, a stop-log board-gate gets a column for flux out the structure (from a formula), and auxiliary columns for input board-height, elevation of the top of the boards, water depth at the structure, and transmission losses in the channel downstream from the structure. In addition to the main part of the spreadsheet that forms the model, the top 12 or so rows are reserved for labels, directions, and control-structure information.

PondSim calculates four source terms for water at each time step: evaporation, rainfall, groundwater, and surface water flows. Surface water flows are lossy: surface flows include transmission losses (or gains). Where surface water fluxes can be calculated with a simple formula, such as through a stop-log board-gate, these formulas are used. In other cases, such as partial flow through a culvert with no freefall at the outlet, a simple, closed analytical formula does not exist the user must directly enter a flux. (A possible modification to the model is to provide approximate formulas or rating curves to calculate these fluxes from input more palatable to the user.)

In addition to the pond sheets, there is a Weather sheet that contains date and weather forecasts (rainfall and evapotranspiration), and separate sheets for some complex channels. Sheets showing a network diagram and maps of Quivira are included for convenience. The user can add more sheets for notes or other purposes.

Each Pond sheet is organized similarly. Column A contains a simple copy of the date. Column B contains the water-surface elevation, usually based on the volume. (For the first step, the volume is based on the elevation.) Column C contains the area based on the volume, and column D contains the volume. Column E contains an error status if more water is leaving the pond than can be allowed.

The net inflow is calculated in column G. Net surface water inflows are calculated in column H, in a formula that varies with the channels water control structures entering and leaving the pond. Columns I and J calculate influx due to rainfall and evaporation, respectively, and Column K contains net groundwater inflow, based on terms in columns M, N, and O. Column Q and right-ward contain surface water flows and auxiliary columns for calculating surface water flows.

Elevation and area are found in the volume-elevation-area curve, located in A106-Dxxx, where xxx depends on the pond. The table, referred to as the VZAV curve, is laid out in the form Volume-Elevation-Area-Volume to allow looking up volume and area based on elevation as well as looking up elevation and area based on volume. Modifying a VZAV curve requires not only altering the data in the lookup table, but also requires altering the formulas that use it, in columns B-D.

Volumetric fluxes are calculated in acre-feet per day, areas in acres, and elevations in feet. Where the user enters a volumetric flux, such as for flow in a channel, the volumetric flux is in acre-feet per day. For areal fluxes, such as evaporation, rainfall, and groundwater discharge, inches per day seems more natural and is used. (The time-step is somewhat difficult to change, due to an implicit (*1 day) in formulas that calculate today's volume from yesterday's volume and yesterday's flux rate.)

Modifying PondSim

This section gives directions for modifying PondSim, for calibration purposes, alteration or adjustment of control structures, or to alter the network.

Changing a pond-capacity curve for a pond involves re-stating the curve as a volume-elevation-area-volume table and minor editing of some formulas. Changing water control structure parameters only requires changing some cells. Changing the type of a water control structure involves adding columns to calculate flow through the new structure and altering the pond's formula for calculating net influx. Adding a pond to the network involves adding a whole new sheet and changing formulas for the sheets that drain into and out of the new pond.

The volume-elevation-area curve influences the model heavily and needs to be accurate and current. The VZA curve is used to calculate initial volume in the pond from elevation, evaporation from the pond (ET*Area), rainfall (Rainfall*Area), and groundwater influxes (GroundWaterInflux*Area). The most useful increase in accuracy is probably in good volume-elevation-area curves. If the VZA relationship is inaccurate, the entire model is inaccurate.

VOLUME-ELEVATION-AREA CURVES

Elevation and area are found in the volume-elevation-area curve, located in A106-Dxxx, where xxx depends on the size of the volume-elevation-area curve. The table, referred to as the VZAV curve, is laid out in the form Volume-Elevation-Area-Volume to allow looking up volume and area based on elevation as well as looking up elevation and area based on volume. Modifying a VZAV curve requires not only altering the data in the lookup table, but also requires altering the formulas that use it, in columns B-D. These look like

```
=VLOOKUP(D13,$A$106:$C$245,2,TRUE)
```

which is an instruction to lookup the value of cell D13 in the table in A106:C245 and get the value in the second column (TRUE specifies that this is a sorted table). This finds the elevation for a particular volume. When you add a new VZAV table, you need to adjust the formula references to the VZAV table ($A$106:$C$245): if you keep the upper left cell of the table in A106, you can simply do an Edit|Replace of 245 with the appropriate row number.

The formula used does not interpolate values because interpolation from a lookup table is too time-consuming for the program to be interactive.) This means that elevation and area in the pond are quantized: they assume only discrete levels found in the VZAV table. When you modify a pond-capacity curve, you need to generate enough points that the quantization is insignificant, but few enough that the program is fast. On my computer, I found that about 100 to 300 entries is a good compromise. The spreadsheet PondVZA5.xls can be used to generate such a table. To do so, place the source Elevation-Volume-Area curve on the sheet, with the first elevation value located in cell A4, then run the macro AACreateCompleteVZAVTable (you may want to get some coffee while this runs), copy the new VZAV table to the SimPond sheet of interest, and adjust the cell

As an alternative to using a lookup table for the pond, you could use analytical formulas, such as polynomials, to calculate volume from elevation, elevation from volume, and area from volume. There is a limit of 256 characters in a formula, so a nested set of IF statements for each elevation band should not be used. Because Excel appears to calculate x^b as $e^{b \ln x}$, avoid using formulas like =J$8*B14^2 + J$9*B14: instead use =J$8*(B14*B14) + J$9*B14 (avoid ^ for integral powers, and use explicit multiplication instead).

Since these formulas are used each time the user makes any modification to the spreadsheet, they must be fast: avoid user-defined functions and trigonometric or other transcendental functions.

EVAPORATION

Evaporation from a pond is calculated as the product of pond area and evapotranspiration rate. If you need to simulate non-open water for a pond, you might want to add a multiplier (0-1) to the front of the formula.

RAINFALL

Rainfall is calculated as the product of pond area and rainfall rate. Due to the nature of Quivira (sandy soils in a semi-arid environment), there is no allowance for surface water runoff in the model. If you need to simulate runoff, there are two approaches: simply increase the rainfall amount by incorporating a multiplier (>1) in the rainfall flux term, or explicitly calculate the runoff using a formula such as the SCS method and multiply by the non-filled portion of the drainage basin.

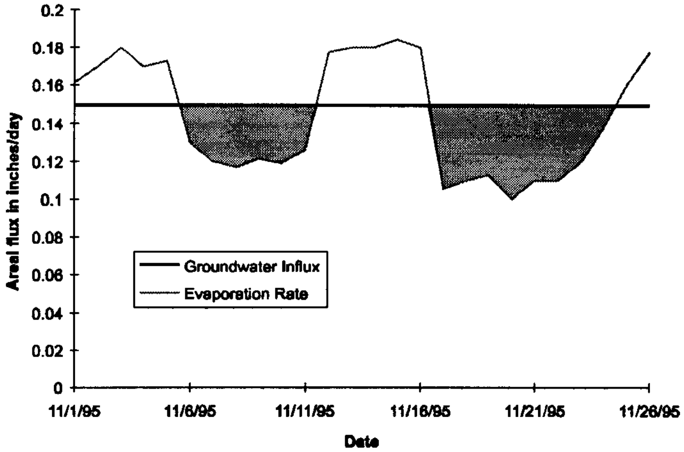
GROUNDWATER

Groundwater is calculated as the sum of two terms, one for groundwater seeping directly into a pond, and another for water discharging into a pond's drainage basin. Both terms depend on the groundwater flux rate, located in cell M9 of each worksheet. Adjusting the rate of groundwater influx (negative for outflow) is simply a matter of changing the value of cell M9. The groundwater flow rate in cell M9 is specified as an areal flux rate in inches per day, in the same form as rainfall or evaporation.

Groundwater can discharge subaqueously or subaerially. If water discharges subaqueously, it is immediately "available" in the pond, so subaqueous groundwater flow is the product of areal flux rate and submerged-pond-area.

If water discharges subaerially, its rate must exceed the evaporatranspiration rate in order to become surface flow. This is illustrated in the conceptual diagram below: groundwater discharge becomes surface-flow only if the discharge rate exceeds the evaporation rate, and the amount of surface-flow is the groundwater discharge rate minus the evaporation rate (the gray area in the diagram).

Conceptual Diagram of Groundwater Discharge Truncated by Evaporation Rate



Based on recent mass-balance studies of water fluxes in the south-central Kansas region (Quinodoz and Buddemeier, 1997) and analysis of satellite images of Quivira National Wildlife Refuge (Pouch, 1997), an areal flux rate of 0.17"/day into Little Salt Marsh and the Northern Groundwater Discharge Zone (Big Salt Marsh, North Lake, North Flats, and Units 57 and 58) gives good agreement with the amounts of groundwater flow discharged and of surface water flow gained in the Quivira area.

An alternative to using the constant fluxes shown would be to use pond-level and groundwater head outside the pond to calculate the flux using Darcy's law. Such a formula would have the form

```
=(GWHead-PondHead)*K/L *U
```

where K is the hydraulic conductivity, L is the distance over which the head-drop occurs, and U is for units conversion.

WATER CONTROL STRUCTURES

The central purpose of SimPond is to allow the user to simulate management strategies by adjusting the state water control structures (open/closed, board-gate height, direct entry of discharges). To make this as convenient as possible, formulas were provided for common control structures if a simple, analytical formula could be used to calculate the flux through a structure. These are based on idealized structures and probably need to be adjusted. (Formulas are based on those of Moffett and Chadwick (1986) or Resnick and Halliday (1977): any standard hydraulics or hydrology textbook will also contain the formulas.)

Calculating flux requires knowledge of hydraulic slope. For waterfall-style flow, only the water level in the source pond matters, and formulas can be developed. For other features, such as a partially submerged culvert without a "waterfall," there is no easy way to calculate the flux, and in cases like this, the user needs to enter the flux directly.

In general, formulas for flux through a water control structure have the form $Q = kA\sqrt{s} = \left(\frac{kA}{L}\right)\sqrt{\Delta H}$, where s is the hydraulic slope, k and A are geometric factors that depend on the constriction and its state, and L is the length over which a head-drop of ΔH occurs. If ΔH can be easily calculated (waterfall conditions), an analytical formula can be found. If ΔH cannot be calculated (the head on the downflow side is not known), a simple formula cannot be found and the user must provide fluxes based on experience.

Because calculating flux through a constriction is surprisingly imprecise under a wide range of circumstances, it may prove useful to add control-sections to channels to allow measurement of flow and adjust controls to match the flow to the desired level, rather than trying to calculate flow through a structure. For example, adding V-notch or square-notch weir structures along with stage-gages to channels immediately downstream from water control structures would allow flow measurements from staff-gauge height, and the structure could be adjusted to produce the desired flow.

Altering Water Control Structures

Adjusting water control structure parameters only involves editing the cell containing the model parameter.

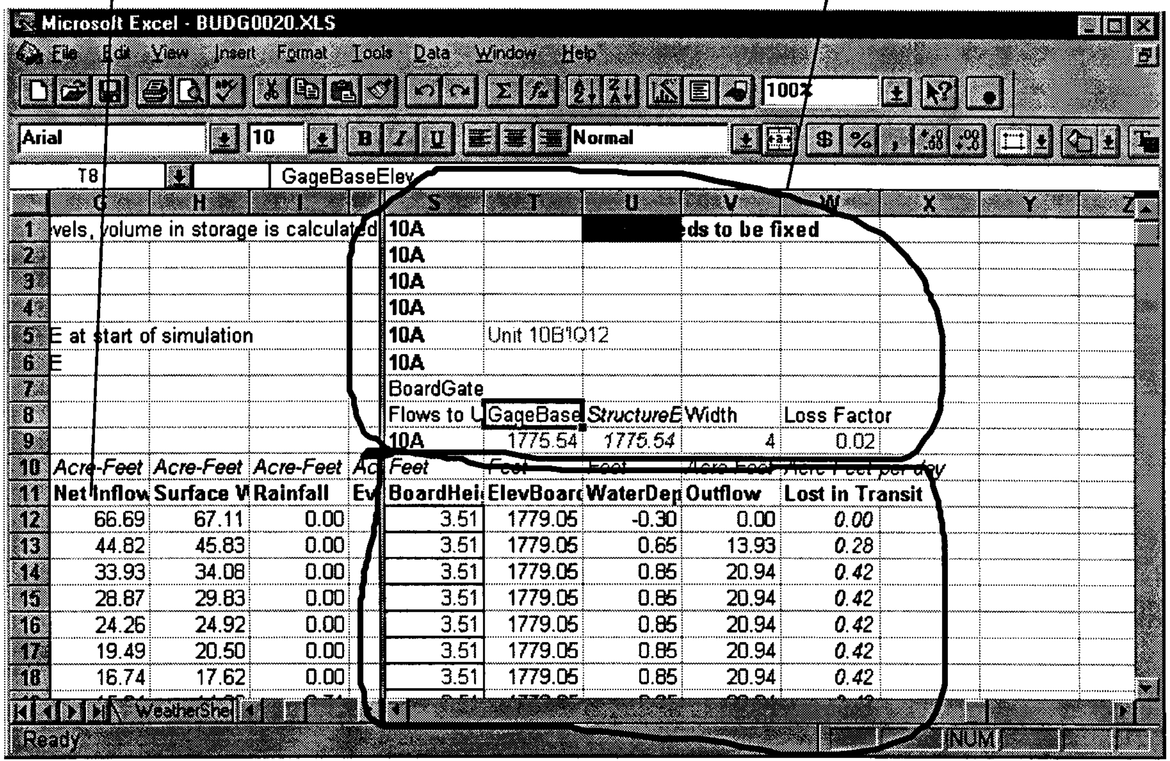
Adding a water control structure is more involved. You always add a set of columns for the new structure and alter the formula for net surface water inflow. If the water flows into another pond, you need to alter the sink-pond's worksheet to include a column for the influx (source_outflux-transmission_losses) and alter the sink-pond's formula for net surface water inflow. (The net surface water inflow is in the column labeled "Surface Water" NET located in column H at time of shipment.)

Removing a water control structure involves 1) changing the source-pond's surface water formula, 2) changing the sink-pond's surface water formula, 3) deleting the columns for the structure on both the source and sink pond's.

Changing a water control structure is the equivalent to adding one and removing another.

Although these directions sound confusing, these operations are actually much easier. When you actually have the spreadsheet in front of you, they make more sense.

For major alterations of a water control structure (such as adding one, removing one, or changing it from a board-gate to a valve-and-pipe), you need to add/remove/change the columns for the water control itself and the formulas that depend on it (the source-pond's net surface inflow and, if there is a sink-pond, the sink-pond's surface inflow.



Net surface water inflow to a pond. Add sources and subtract sinks

Parameters, labels, and notes for a water control structure

A formula-assemblage representing the control

T8 GageBaseElev

	G	H	I		S	T	U	V	W
1	vels, volume in storage is calculated				10A		[redacted]	ds to be fixed	
2					10A				
3					10A				
4					10A				
5	E at start of simulation				10A	Unit 10B1Q12			
6	E				10A				
7					BoardGate				
8					Flows to U	GageBase	*StructureE*	Width	Loss Factor
9					10A	1775.54	*1775.54*	4	0.02
10	*Acre-Feet*	*Acre-Feet*	*Acre-Feet*	*Ac*	*Feet*	*Feet*	*Feet*	*Acre-Feet*	*Acre-Feet per day*
11	**Net Inflow**	**Surface W**	**Rainfall**	**Ev**	**BoardHei**	**ElevBoard**	**WaterDep**	**Outflow**	**Lost in Transit**
12	66.69	67.11	0.00		3.51	1779.05	-0.30	0.00	*0.00*
13	44.82	45.83	0.00		3.51	1779.05	0.65	13.93	*0.28*
14	33.93	34.08	0.00		3.51	1779.05	0.85	20.94	*0.42*
15	28.87	29.83	0.00		3.51	1779.05	0.85	20.94	*0.42*
16	24.26	24.92	0.00		3.51	1779.05	0.85	20.94	*0.42*
17	19.49	20.50	0.00		3.51	1779.05	0.85	20.94	*0.42*
18	16.74	17.62	0.00		3.51	1779.05	0.85	20.94	*0.42*

Board-gates

Stop-log board-gates are sharp-crested weirs. Flow through a sharp-crested weir is calculated as

$$Q=15.9088(0.407+0.0533*H\_Local/BoardDepth)*Area\ Sqrt(H\_Local)$$

$$Area=H\_Local*WidthOfWeir$$

where *H_Local* is the distance from the water surface to the top of the boards, *BoardDepth* is the distance form the top of the boards to the bottom of the boards, and *WidthOfWeir* is the width that water flows through. All input units are in feet and the outflow is calculated in acre-feet per day.

The column-assemblage includes the board-height, the board-top-elevation, the water depth (H_Local), and the outflow.

Pipes

Flux through a completely submerged pipe with free outflow can be calculated as $Q = K\sqrt{H_{Local}}$, where *K* is a constant that depends on the pipe's diameter, length, and material and H_{Local} is water depth referenced to the bottom of the pipe. *K* can be found using an orifice formula or using a modification of the Hazen-Williams formula. Initially, all pipes in the model were described as freefall orifices due to lack of information on pipe lengths. Some of these have been modified to reflect lengths of the pipes. Other pipes are probably partially-full culverts and should be replaced by stipulated fluxes.

Pipes and pipe-valve combinations are controlled by the user with a column for Open/Closed.

Screwgate and Pipe Culvert			
Unit 7	1782.39	Loss Factor	
Pipe factor .	42.00	0	
Feet	*Acre-Feet per day*	*Acre-Feet per day*	
State	**Outflow**	**Lost in Transit**	(Local head)
Closed	0.00	*0.00*	1.31
Closed	0.00	*0.00*	1.18
Open	43.87	*0.00*	1.09
Closed	0.00	*0.00*	0.94
Closed	0.00	*0.00*	0.88

The following is the standard formula for pipe flow used in SimPond
`=IF(AND(AI14="OPEN",$B14-AJ$8>0),MIN(AJ$9*SQRT($B14-AJ$8), $D14),0)`

The main part of the formula is `AJ$9*SQRT($B14-AJ$8)` , which is $K\sqrt{H_{Local}}$ for a full pipe. The pipe factor, *K*, in this formula located in cell AJ9, can be calculated for orifice flow as *0.086774*D*D*, where *D* is diameter in inches and the resulting formula gives *Q* in acre-feet per day.

The Hazen-Williams formula, $Q = 0.435Cd^{2.63}\left(\frac{H_{Local}}{L}\right)^{0.53}$, where d is diameter in feet, L is pipe length in feet, Q is in cubic feet per second, and C is a material constant, has, for use in this model, been approximated as

$Q = 0.219Cd^{2.63}\left(\frac{H_{Local}}{L}\right)^{0.5} = \left[\frac{0.219Cd^{2.63}}{\sqrt{L}}\right]\sqrt{H_{Local}}$, where the term in brackets is a constant for a given structure and the constant is changed to 0.219 to produce flows in acre-feet per day. C ranges from 70 (rough) to 150 (smooth); 120 is a good guess for steel or concrete.

For a short length of pipe, the orifice flow formula gives a pipe-factor surprisingly close to the Hazen-Williams formula. A multiplicative constant or additive constant on head may be needed to adjust the model to conform to observations.

Culverts

Flux through a partially submerged pipe (culvert) can be calculated using the Manning formula for open-channel flow. Few simplifying assumptions can be made for a culvert, because the area varies as a (double-trigonometric) function of water depth and the outflow is typically not freefall: flow through the culvert depends on the water depth in the outlet, and the water depth in the outlet depends on the downstream channel and flow through the culvert. In the sample spreadsheet Controls.XLS, a formula cluster is provided that calculates flow through a partially full pipe with a freefall outlet. No culverts are implemented as such in the model.

Spillway

In SimPond, a spillway is an infinite capacity method to take all excess water out of a pond if the volume exceeds a threshold, as shown in the formula

```
=MAX((D13+J13+K13+I13)-Q$9,0)
```

where the term `D13+J13+K13+I13` is the volume in storage plus the inflows (rainfall, ET, and groundwater) and `Q$9` is the maximum volume of water in the pond (volume at spill threshold). If the potential spillage is negative, this function returns zero. Effectively, this is like the overflow-drain on a sink: as long as water doesn't enter the pond faster than it can leave through the spillway, the formula is accurate enough.

A spillway might be used to represent flow through a partially full culvert or outflow along a stream channel from a lake.

Manual Entry of Flux

When all else fails, go to manual override. For many structures, no simple, analytical formula exists. In these cases, the user needs to enter a flux in acre-feet per day.

ONE-TIME-ONLY ADJUSTMENT OF BASE ELEVATIONS

For all time-steps except the first, PondSim calculates today's water volume as the sum of yesterday's water volume and yesterday's net flux. From the volume, it calculates elevation and area.

For the first day, it calculates the water volume from the elevation. To make PondSim easy to use, the elevation is entered as a height above some local reference point (in cell B5): usually, this will simply be the water-level read directly off a gauge. In order to covert this to water-surface elevation, and hence volume, the zero-elevation of the gauge needs to be entered (in cell B6). The initial water-surface elevation is calculated in cell B7 and repeated in B12.

As shipped, the reference elevation is a formula that points at the lowest elevation in the volume-elevation-area curve. This should be changed to the zero-elevation of the gauge of the user's choice. The user can change this elevation later if need be.

INCREASING THE NUMBER OF TIME STEPS

As shipped, PondSim had formulas in place for a 31 day simulation. To extend the possible length of simulation, you need to visit each sheet and copy row 42 to row 43-{LastRowNeededForLongerSimulation}.

ADDING WATER SOURCE TERMS

The modular, open construction of PondSim allows you to add new water source terms, such as runoff. To do so, add columns to the pond sheet to calculate the new term and modify the net inflow formula found in column G to include it.

Calibration

The point of calibration is to make a model match observations. Calibration requires observations, and lots of them. Calibrating PondSim requires observations of pond water levels, evaporation rates, and surface water transfers, or data from which these can be derived, such as stop-log board-gate settings. The largest obstacle to calibrating PondSim has been the lack of knowledge about inter-pond surface water flows. In many cases, it may be necessary to build control-structures used to measure water flows in order to calibrate the model or accurately determine water use.

Before deciding to devote effort to calibrating the model, decide how accurate the model needs to be and what you are willing to pay for that accuracy. If you spend too much labor on choosing the best investment, you can lose money in labor and lost opportunities: if you jump at the first investment with a high yield (and high risk), you can lose money there as well. Consideration should be given to both the costs and benefits of improved accuracy. It is very easy to be seduced by accuracy, but if the model meets the user's needs as-is, excess effort spent on calibration is wasted.

Accurate measurements and records of water transfers between ponds and measurements of stream flow are needed to produce a calibrated model. This may be difficult or impossible at QNWR, where hydraulic conditions change rapidly, or it may prove to be more expensive to gather the necessary data than the improvement in accuracy justifies.

The model parameters found by calibration apply to the conditions under which the observations were made. At Quivira, it may be necessary to calibrate seepage and groundwater terms on a seasonal basis.

OVERVIEW OF CALIBRATION

Calibrating a model is the process of adjusting model parameters to match observations. When you calibrate a model, you need to decide which observations will be matched (flows on the channels, water-surface elevations, water volumes) and how to weight these in combination. It is often possible to achieve a very good match between water levels and a very bad match with fluxes, or vice versa, so it is important to know what your objectives are.

The structure of PondSim allows for easy calibration: each pond is a separate, isolated entity and can be calibrated individually. For example, to calibrate groundwater influxes to Unit 57, you need observations of water levels and surface-water transfers into and out of Unit 57, as well as evaporation and rainfall for the period of observation. Since the total water in Unit 57 is what was there before and what came in, and you already have all the terms except groundwater. By observing the pond water level, you can determine how much water has come in, which must be the groundwater term. (If this is small relative to the uncertainty of the other terms, such as evaporation and rainfall, the groundwater component is negligible and should be ignored.)

To re-visit the financial planning analogy, calibration is the process of using historical records of economic events to predict future yield, risk, and fees. In order to do this, you need accurate bookkeeping and records of balances and all transactions.

In a dynamic setting such as Quivira National Wildlife Refuge, where vegetation growth and sedimentation play an active role hydrologic events, it may not be possible or worthwhile to calibrate the model.

CALIBRATING SPECIFIC TERMS

For most, if not all, parameters, accurate measurements of surface water flow are needed. Presently, these are difficult to perform because the channels are oddly-shaped natural features with awkward mathematics. One solution to this would be building sharp-crested weirs (or some other control section where flow through the section can be easily measured from water levels) with freefall (or other easy boundary condition) on the downstream end, so that fluxes can be determined by measuring water level in the control section.

Evaporation and Rainfall

More measurement sites are almost always better, and weather is no exception. Rain gauges closer to ponds could improve the accuracy of the direct interception component of the hydrologic budgets, and evaporating pans at strategic location could improve the accuracy of the evaporation component. Either change would require modifying pond worksheets to use the correct ET or rainfall value.

Water Control Structures

Many water control structures are far from ideal, and calculating flow through them can be difficult. As mentioned earlier, constructing control sections with "good" geometry to allow flow measurement would improve knowledge of other terms. Since all water control structure are governed by formulas of the form K*A*Sqrt(H_Local), measuring flux and H_Local and graphing Q vs. Sqrt(H_Local) should allow easy calculation of K for that structure.

Transmission loss in channels

Conceptually, this quite easy. You measure water flow at the start and end of channel, and figure out how outflow relates to inflow by graphing them. If you're lucky, there is a simple linear relationship between the two, such that

`Outflow=TransmissionLossFactor*Inflow-TransmissionLossOffset`

and you might even find that TransmissionLossFactor or TransmissionLossOffset is zero.

In practice, you need to be able to measure the flow at both ends easily. This requires either much labor or control sections for flux measurement at both ends of the channel. See the note at the beginning of "Calibrating Specific Terms."

Seepage losses on a channel change with vegetation growth, changes in channel geometry due to erosion and sedimentation, and changes in the condition of the bed material, so calibration may need to be done repeatedly with varying conditions.

Groundwater

Groundwater is perhaps the most difficult component to estimate in a water budget and can only be determined by controlling for the other fluxes quite accurately and using the difference to find the groundwater term. The easiest way to determine the surface water terms for a pond is to make them zero by shutting off inflows and outflows. Observations of water level, evaporation, and rainfall, should be recorded and plotted against date. The slope of the curve of water level versus date gives the areal flux into the pond. Adjusting this to account for rainfall and evaporation gives the groundwater areal flux in inches per day. If this is smaller than the uncertainty in rainfall or evaporation, it should probably be set to zero.

Summary

SimPond has a modular design that makes it easy to use, easy to understand, and easy to maintain and calibrate. By adjusting cells in the spreadsheet, you can calibrate and adjust the model. By altering column-clusters, you can change the add water control structures or modify water control structures. By adding worksheets and adjusting formulas, you can add ponds.

In addition to the calculations directly in SimPond, the user can add auxiliary calculations such as total evaporation for each day or water "depth" in a pond as well as graphs of interest to the user.

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