Explanation and Use of the Blaney-Criddle Reuse Water Balance Model
A Microsoft Excel Ver. 4.0 Spreadsheet

OVERVIEW OF MODEL:

The Blaney-Criddle water balance model is a straight forward water balance model with the addition of vegetation water consumption. Evaporation, rain, effluent flow, and pond leakage form the basic aspects of the model, however the critical portion of the model is the Blaney-Criddle plant water consumption calculation.

Blaney and Criddle in the early 1960's worked on the quantitative estimation of vegetation water usages. This leads to the Blaney-Criddle method. The Blaney-Criddle formula is that the consumptive use (U) is equal to a seasonal coefficient (K) times a monthly consumptive use factor(F) (U=K*F). The monthly consumptive use factor (F) is a function of the mean monthly temperature in degrees Fahrenheit (t) times the monthly percent of day-time hours (p) divided by 100, expressed as (F= t*p/100). K is a factor relating the plant water usage for a specific species. K factors are generated under experimental conditions where F and U in the above formula are measured under tightly controlled conditions (K=U/F).

DATA ENTRY:

Data entry is divided into distinct parts of the spreadsheet. The basic facility data is entered into a block at the top left of the spreadsheet. The entry locations are highlighted with light green stippling to designate which cells of the spreadsheet are designed for the input of information. All other cells are calculated and should be protected from change. In the basic facility information block there are spaces to enter the facility name, its location, the daily average facility flow rate, the yearly evaporation rate, the acreage of ponds (and other free water surfaces), and the acreage of land to be irrigated.

An example of the basic information data block is below:

Facility Name:	**Valley Golf Village**
Location:	**Somewhere, AZ**
System average daily flow: (MG/D)	**0.4000**
Yearly evaporation rate: (in/year):	71.00
Total lake and free water surface area:	1.10
Landscape acreage:	160.00
Summer crop:	**Bermuda grass**
Winter crop:	**Rye grass**
Estimated Storage required (gal./mo.):	16,378,754
Water balance total/year:	(98,461,955)
A positive value indicates insufficient water usage, a negative value is indicated by (parentheses).	

The basic model is designated (set-up) for calculating turf irrigation. The standard turf plant configuration is a combination of Bermuda grass and rye grass. The Bermuda grass is the main summer specie and the rye grass provides for the winter water consumption.

The second data block is located along the top center of the spreadsheet. This entry block is the basis for the Blaney-Criddle water consumption calculations. The K value, Monthly % daytime hours of the year, and mean monthly temperatures are entered into this part of the spreadsheet. The K values entered into the basic model are for the Bermuda rye grass mix. Additional vegetative K values are available in the USDA, Agricultural Research Service, Conservation Research Report Number 29, 1981 and other sources.

The following is a reproduction of the water consumption data entry area:

Bermuda and Rye grass consumptive use calculation:			
	K Value	Monthly % daytime hours of the year	Mean monthly temperature (F)
January	0.65	7.10	51.3
February	0.70	6.91	55.1
March	0.75	8.35	59.8
April	0.75	8.80	68.0
May	0.74	9.71	76.5
June	1.06	9.71	85.2
July	1.17	9.88	91.4
August	1.10	9.34	89.3
September	0.90	8.35	83.9
October	0.80	7.90	72.7
November	0.75	7.02	60.3
December	0.70	6.93	52.6

The model has been designed to include water usage for the more common tree species planted in Arizona. Information on tree water consumption is entered into a third part of the spreadsheet located on the top right side. The program user enters the total number of each tree species being planted. The program calculates the total usage by species and total monthly usage by all of the trees. The following is a reproduction of the tree water consumption data input block:

Tree consumptive use calculation:			
	Number of trees in project area:	Gallons per day used per tree:	Total consumptive usage per day:
Cottonwood	0	400	0
Fan palm	0	40	0
Oleander	0	10	0
Eucalyptus	0	not currently available	0
Pine	0	50	0
Olive	0	130	0
Misc.	0	50	0
Desert	0	50	0
Rhus	0	20	0
Totals:	0		0

Below the three main data entry blocks is the final water balance tabulation area.
Within this final water balance tabulation area is an additional data entry area. This is where the monthly precipitation values are entered.

An excerpt of the water balance tabulation area is copied below showing the precipitation input area.

Rainfall inches per month:
0.82
0.71
0.83
0.38
0.15
0.12
0.88
1.27
0.79
0.57
0.58
0.96

CALCULATIONS:

There are two main parts to the calculations performed in the spreadsheet. So far only the Blaney-Criddle water balance calculation has been mentioned and described. In addition to this, the spreadsheet is designed to estimate the water storage needs for the facility involved in consumptive use irrigation. This part of the spreadsheet is only an estimate and is not intended to be a design calculation. A professional engineer needs to be consulted to design and evaluate the facility storage needs.

WATER BALANCE:

The water balance calculations sum: 1. (water available) the monthly effluent flow and the average monthly precipitation, and 2. (water usage) the average monthly evaporation, the monthly total pond leakage if allowable and approved by the Department, the monthly turf consumptive use, and the monthly tree consumptive use. An example of the water balance calculation block is on the next page.

	Monthly effluent available: gallons:	Rainfall inches per month:	Rainfall gallons per month:	Total evaporation: gallons per month:	System leakage and percolation if allowable: gallons per month:	Consumptive use of grasses: inches per acre:	Consumptive use of grasses: gallons per month:	Consumptive use of trees: gallons per month:	Total landscape water demand: gallons per month:	Total water available: gallons per month:	Net water balance: gallons per month:
January	12,400,000	0.82	3,586,886	63,830	0	2.37	10,285,307	0	10,285,307	15,923,056	5,637,749
February	11,200,000	0.71	3,105,719	90,889	0	2.67	11,578,596	0	11,578,596	14,214,830	2,636,234
March	12,400,000	0.83	3,630,629	141,741	0	3.74	16,269,609	0	16,269,609	15,888,888	(380,722)
April	12,000,000	0.38	1,662,216	193,675	0	4.49	19,497,595	0	19,497,595	13,468,541	(6,029,054)
May	12,400,000	0.15	656,138	265,075	0	5.50	23,880,345	0	23,880,345	12,791,062	(11,089,282)
June	12,000,000	0.12	524,910	291,031	0	8.77	38,097,186	0	38,097,186	12,233,879	(25,863,307)
July	12,400,000	0.88	3,849,341	291,031	0	10.57	45,900,478	0	45,900,478	15,958,310	(29,942,168)
August	12,400,000	1.27	5,555,300	265,075	0	9.17	39,858,342	0	39,858,342	17,690,224	(22,168,117)
September	12,000,000	0.79	3,455,659	202,327	0	6.31	27,391,710	0	27,391,710	15,253,332	(12,138,378)
October	12,400,000	0.57	2,493,323	155,801	0	4.59	19,960,881	0	19,960,881	14,737,523	(5,223,358)
November	12,000,000	0.58	2,537,066	96,297	0	3.17	13,792,529	0	13,792,529	14,440,769	648,241
December	12,400,000	0.96	4,199,282	63,830	0	2.55	11,085,243	0	11,085,243	16,535,451	5,450,208
SUMS:	146,000,000	8.06	35,256,468	2,120,602	0	63.90	277,597,821	0	277,597,821	179,135,866	(98,461,955)

ESTIMATION OF FACILITY STORAGE REQUIREMENT:

A. FIVE DAY EFFLUENT STORAGE:

The Arizona State reuse regulations (A.A.C. R18-9-702.F) require the facility to have a minimum of five days storage to prevent the discharge of effluent under certain conditions, (such as where the ground is already wet from rain or when the effluent quality will not meet permit requirements), unless other means of disposal are available.

If the facility is located in an area where the ground freezes, effluent irrigation is not allowed (during these periods) and the effluent must be stored or discharged under an NPDES permit.

If the facility has an NPDES permit to discharge the water, the reuse program does not mandate a five day storage requirement. However, if the facility discharges under an NPDES permit, the facility still has to meet those permit discharge limits and requirements. It is suggested that all facilities review and address their needs for effluent storage.

B. STORAGE FOR PRECIPITATION:

Normal precipitation is accounted for in the basic water balance calculation. However, to accommodate a precipitation event which would necessitate a full 5 days of storage, five days of rain is added to the storage requirement as a safety factor. This calculation is done by taking the maximum precipitation month (the wettest month) multiplying it by 5/30 and converting this to gallons per acre. Then the quantity of precipitation in gallons over the area (acreage) of the ponds is estimated. An alternate more conservative precipitation calculation (not contained in this model) would be to estimate the quantity of water from a 10 year 24 hour rain event over the pond areas. Additional consideration (not in this model) needs to be taken for surface runoff that may enter the effluent storage system. The Blaney-Criddle model presented here assumes that the impoundments are protected from this additional water source.

C. STORAGE OF UNUSED EFFLUENT (long term water balance)

The model presented here estimates a cumulative water balance over a five year period. It estimates the maximum unused monthly quantity of effluent.

This evaluation is tabulated below the main water balance calculation table. Along with this tabulation is a graphic presentation of this information. The tabulation and graph represent a five year period starting with the month of January (60 months).

In the foreground of the graph is the monthly water balance quantity either positive (all the water generated that month is unused) or negative (a deficit in the water balance). Behind this on the graph is the cumulative unused water quantity (the total of the month's water usage plus any water left in storage from the previous month). This visual presentation is intended to aid in the interpretation of the water balance calculations for the facility; it is not a design calculation. An engineer should be consulted to evaluate and design any water storage system.

D. ESTIMATED TOTAL STORAGE REQUIRED:

The total storage estimation is based on the total of the five day storage requirement, the five days of precipitation, and the storage of unused effluent.

Storage requirement estimation:	**FOR INTERNAL USE ONLY!**
	Storage required: gallons:
If five day storage required: (five days flow plus five days maximum rain):	2,006,322
Storage required based on long term water balance:	14,372,432

Estimated Total storage required:	16,378,754

DATA OUTPUT

If the user of this spreadsheet uses the Microsoft Excel Version 4.0 of the spreadsheet (blaney.xls), the output will be to three legal pages in landscape format. A copy of a typical output is attached. If the user intends to use on of the alternate file format copies provided, some additional reformatting will be necessary. The .WK3 format for Lotus users (two files) appears to contain all of the elements of the Excel Version 4.0 original spreadsheet, however, significant cell width and height reformatting will be necessary. Additionally, the format of the graph will potentially be different from the Excel Version 4.0 example.

If the user chooses to use the .DIF file format (Data Interchange Format) provided, significant reformatting of the spreadsheet will be required. Also, the .DIF format does not support the graphics of the original Excel version. Therefore, no graphic data presentation is contained in this file format version.

Summary-Disclaimer:

This program is intended to calculate the water balance for an Arizona State Reuse permit, utilizing the Blaney-Criddle method. It is only a tool. It does not relieve the user of any responsibility to provide good sound judgment and engineering for a reuse project. It is not an engineering design program and it should not be relied on to provide any engineering information.

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