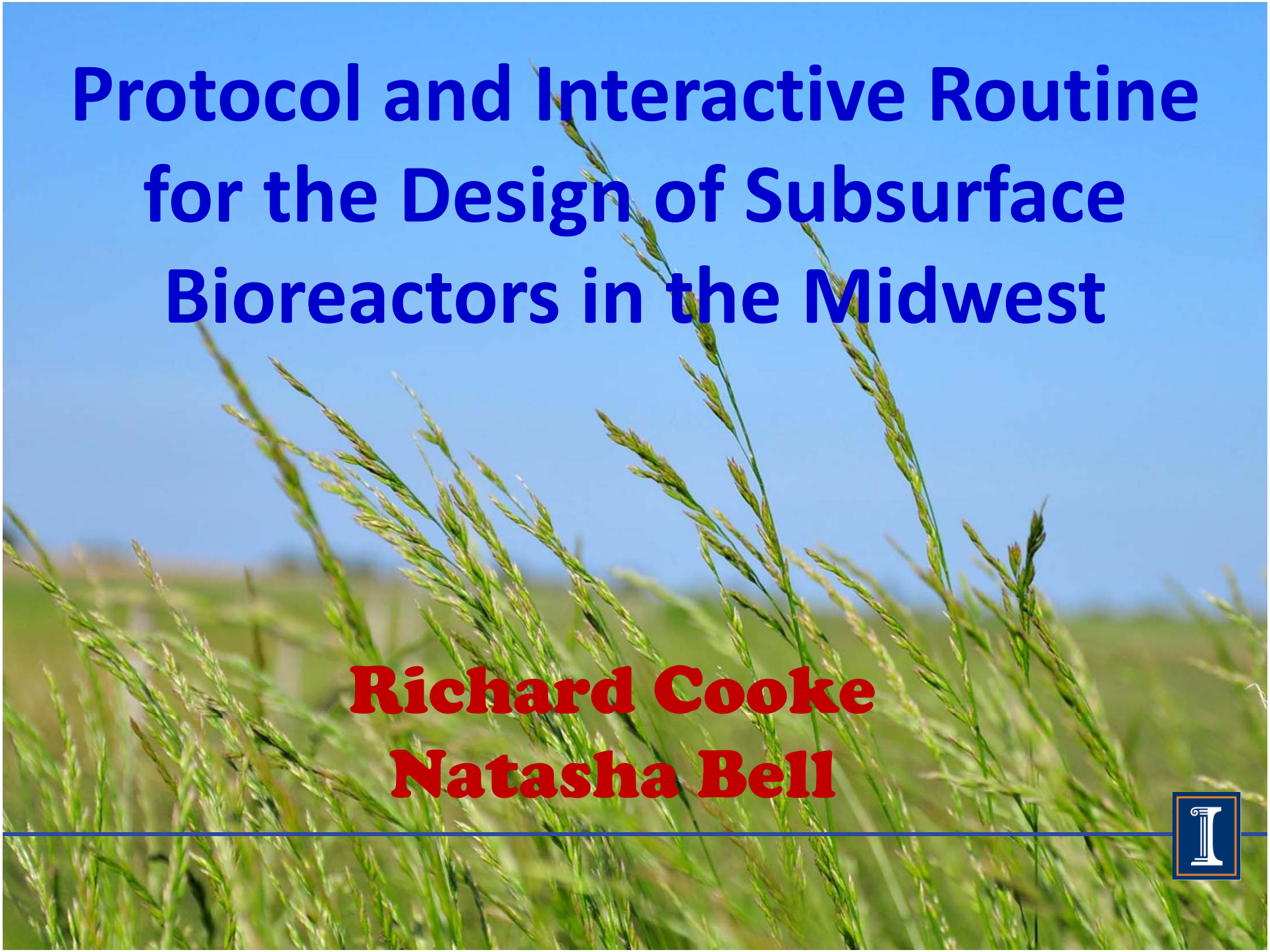
Protocol and Interactive Routine for the Design of Subsurface Bioreactors in the Midwest



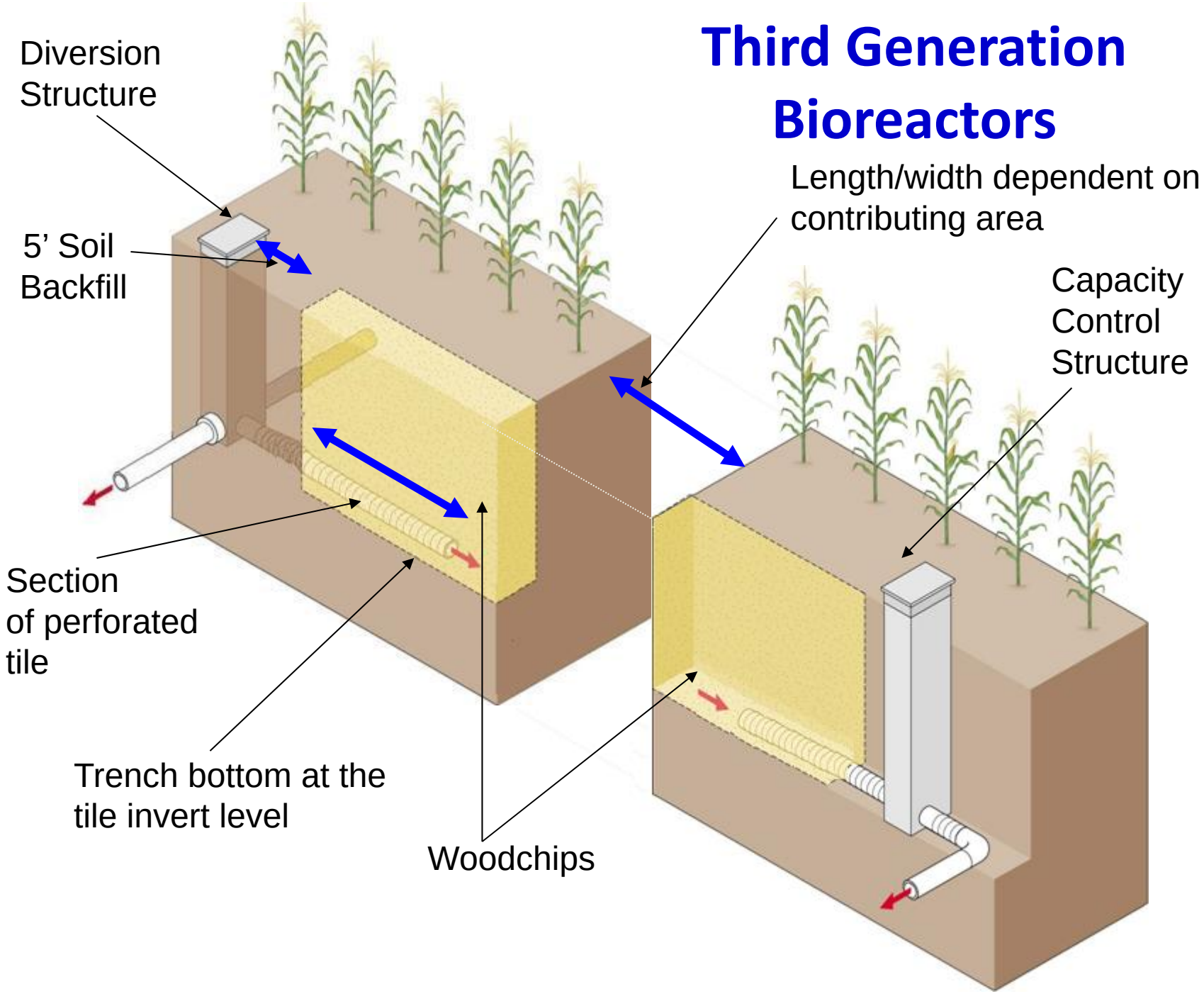
Richard Cooke
Natasha Bell

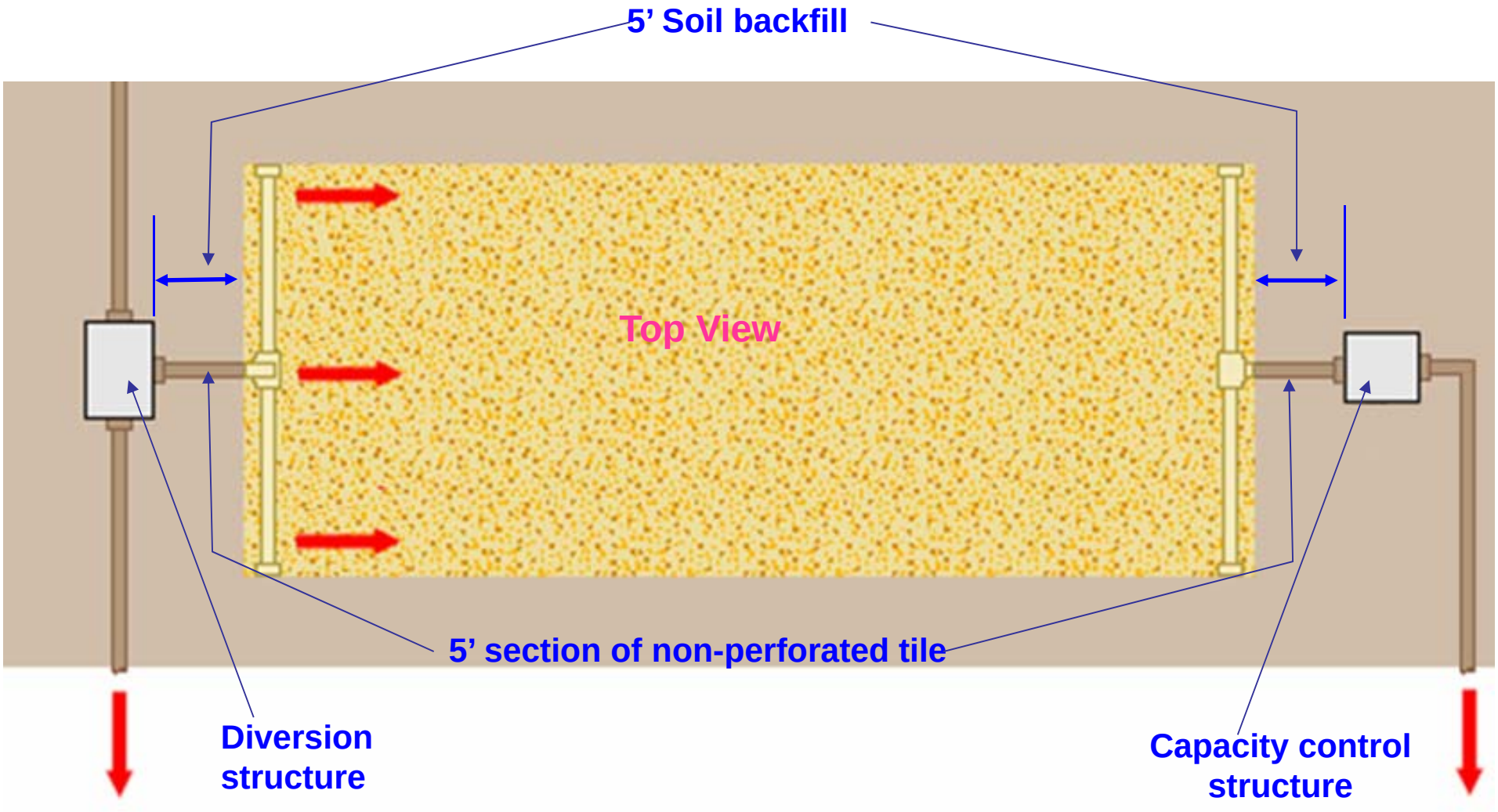
The layman finds such a law as $\frac{\partial \theta}{\partial t} = D \frac{\partial^2 \theta}{\partial x^2}$ **much less simple than "it oozes," of which it is the mathematical statement. The physicist reverses this judgment, and his statement is certainly the more fruitful of the two, so far as prediction is concerned. It is, however, a statement about something very unfamiliar to the plainman (*sic*).**

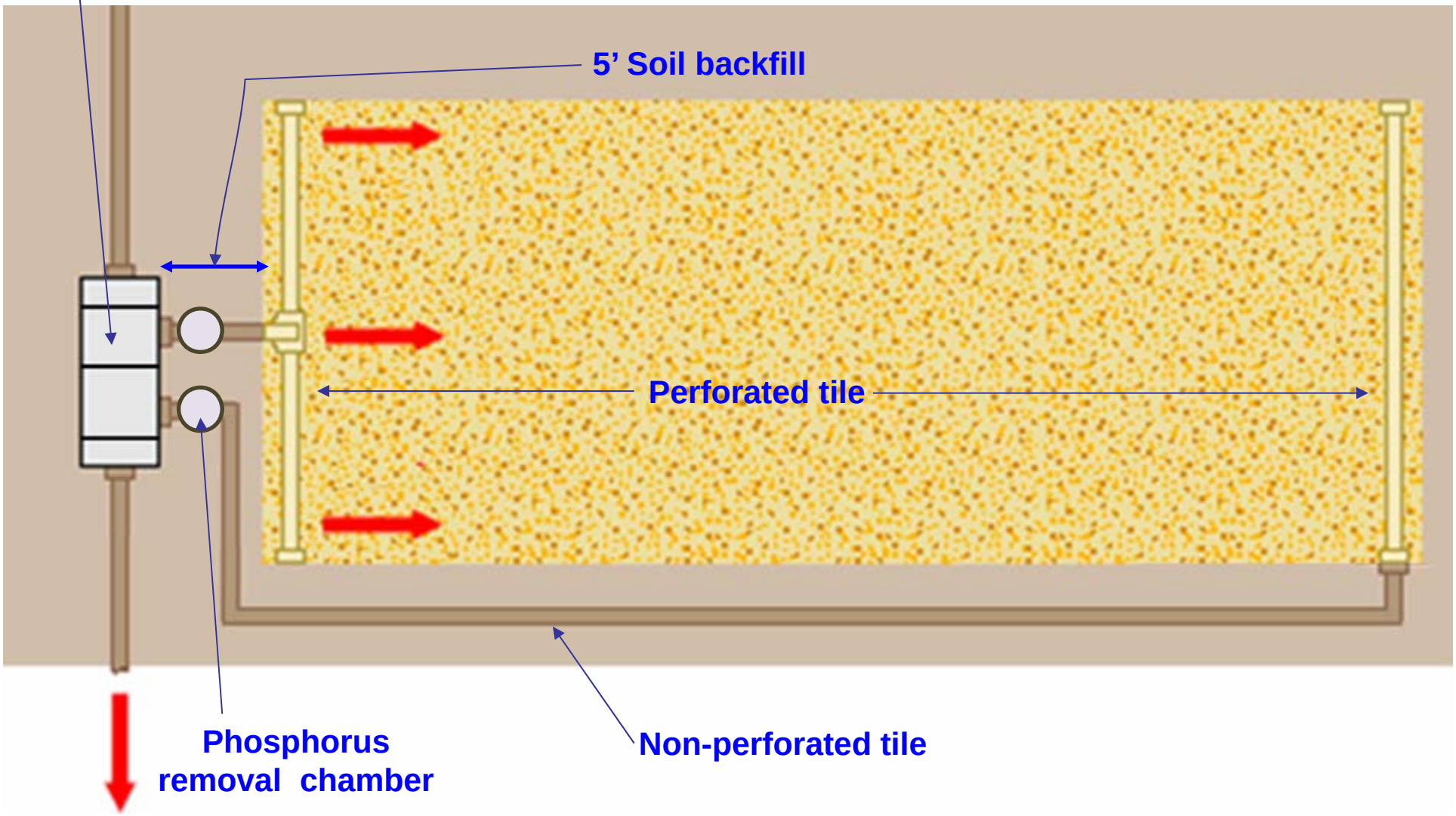
J. B. S. Haldane

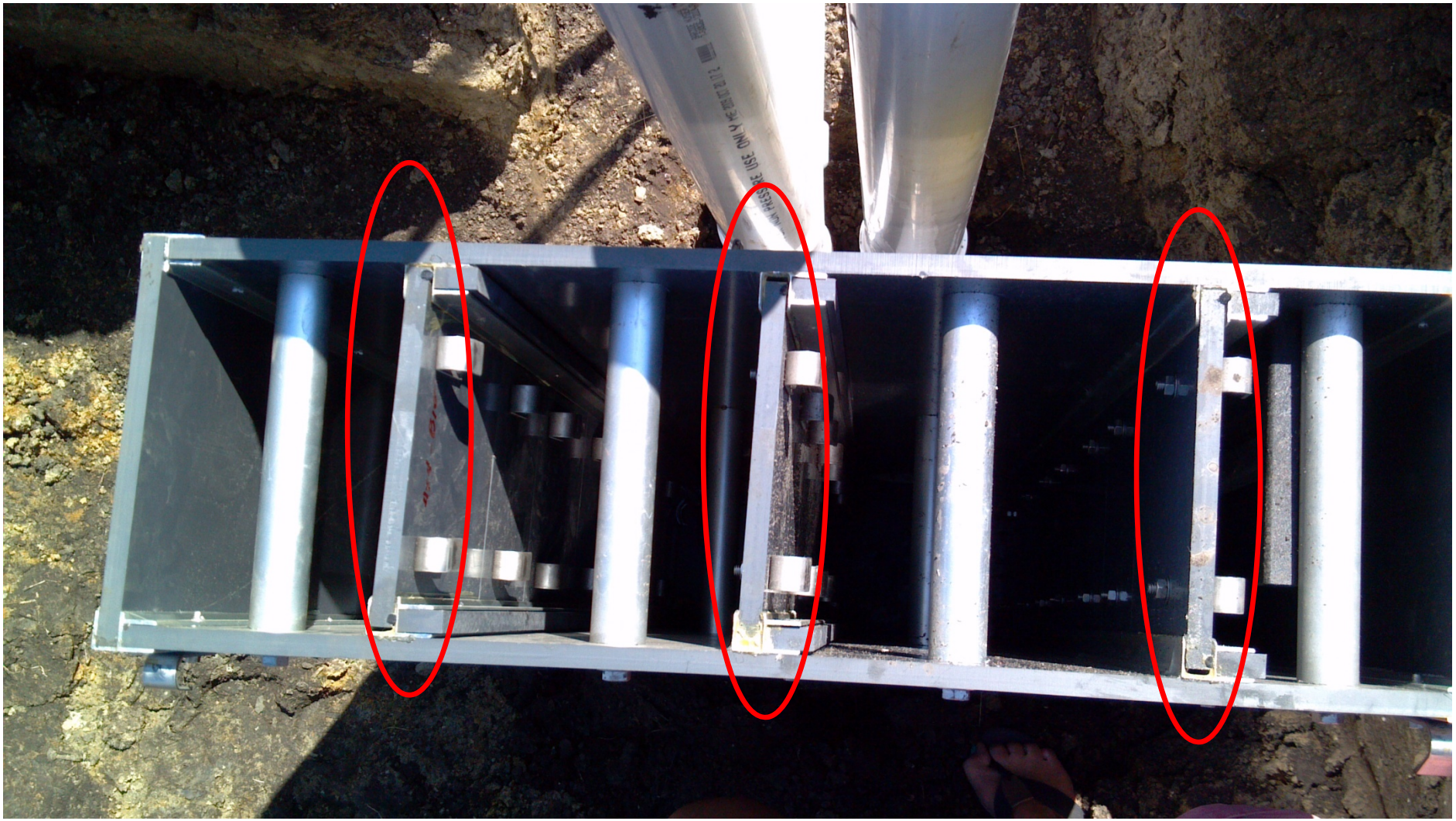
Possible Worlds and Other Papers (1927)

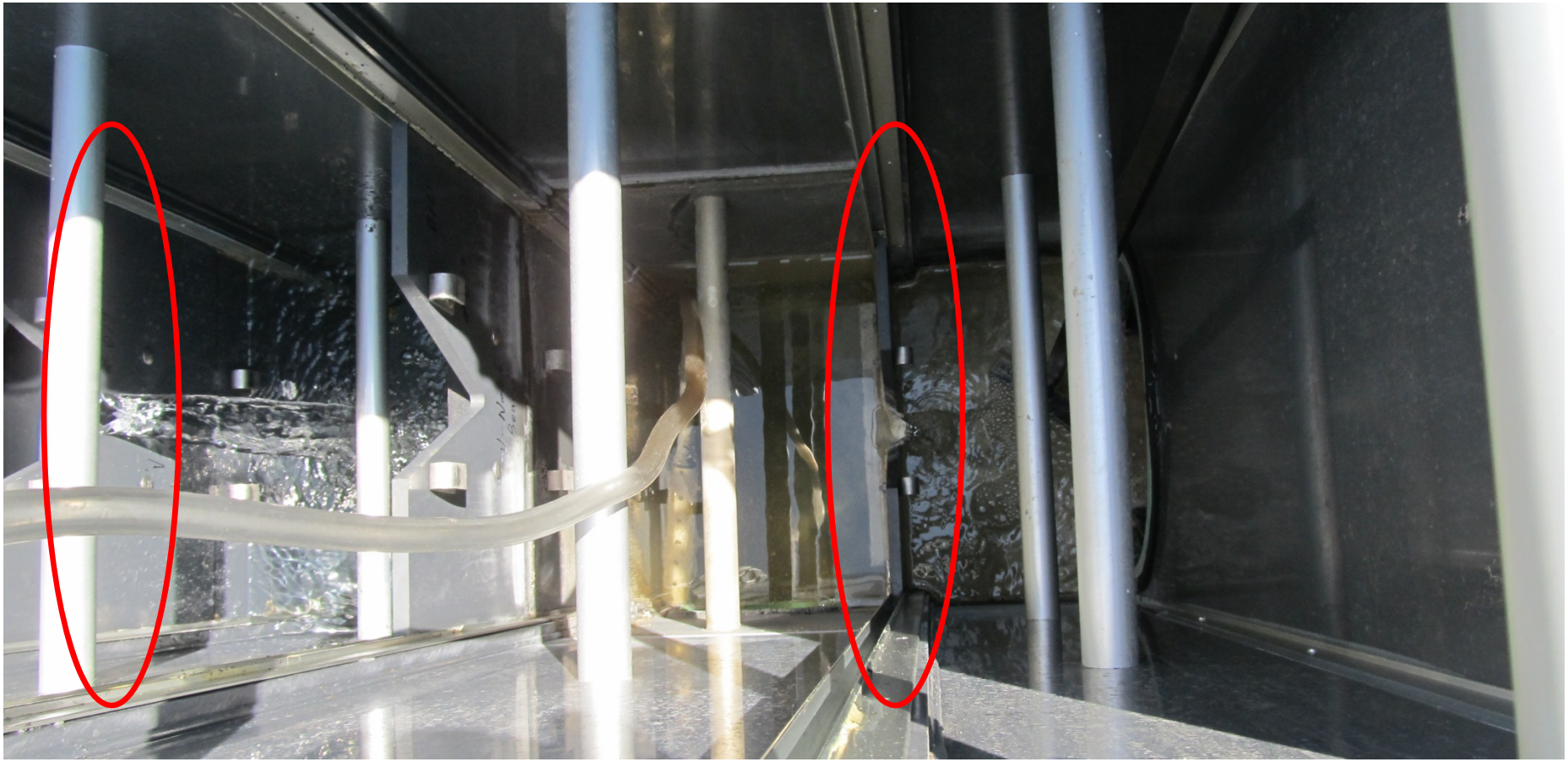
Third Generation Bioreactors



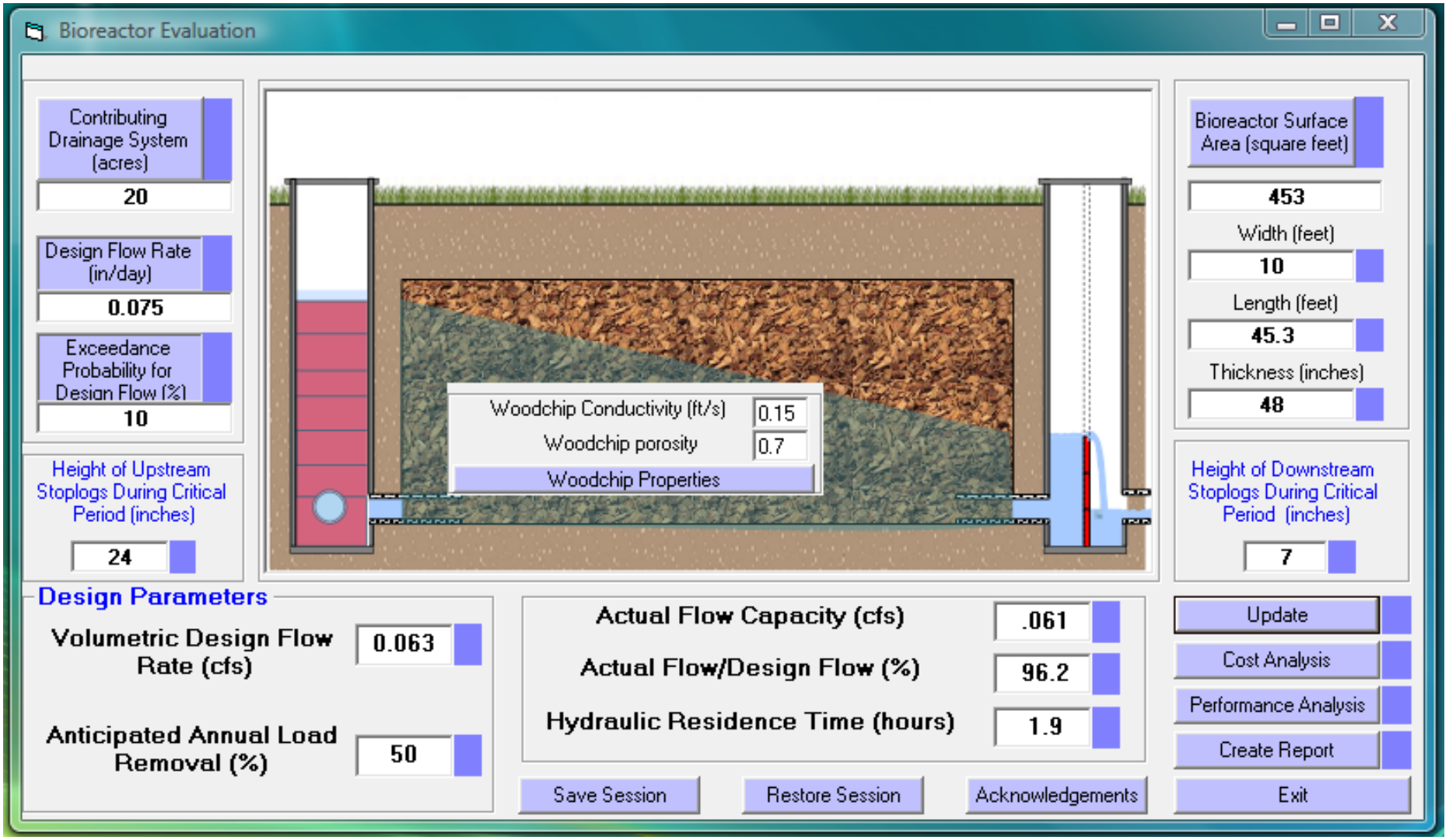

5’ Soil backfill
Top View
5’ section of non-perforated tile
Diversion structure
Capacity control structure


Combination structure
5’ Soil backfill
Perforated tile
Phosphorus removal chamber
Non-perforated tile

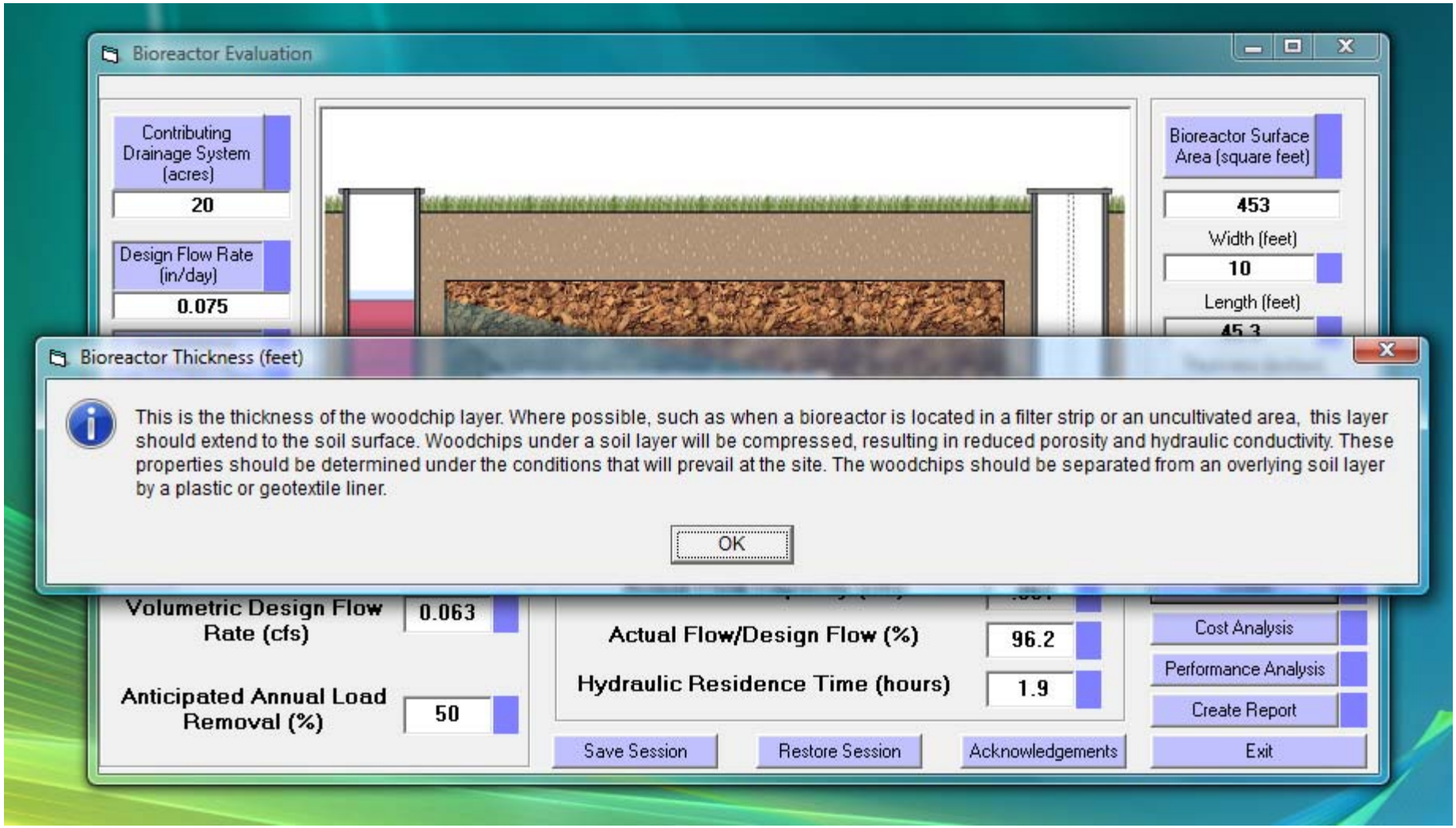




Main Interface

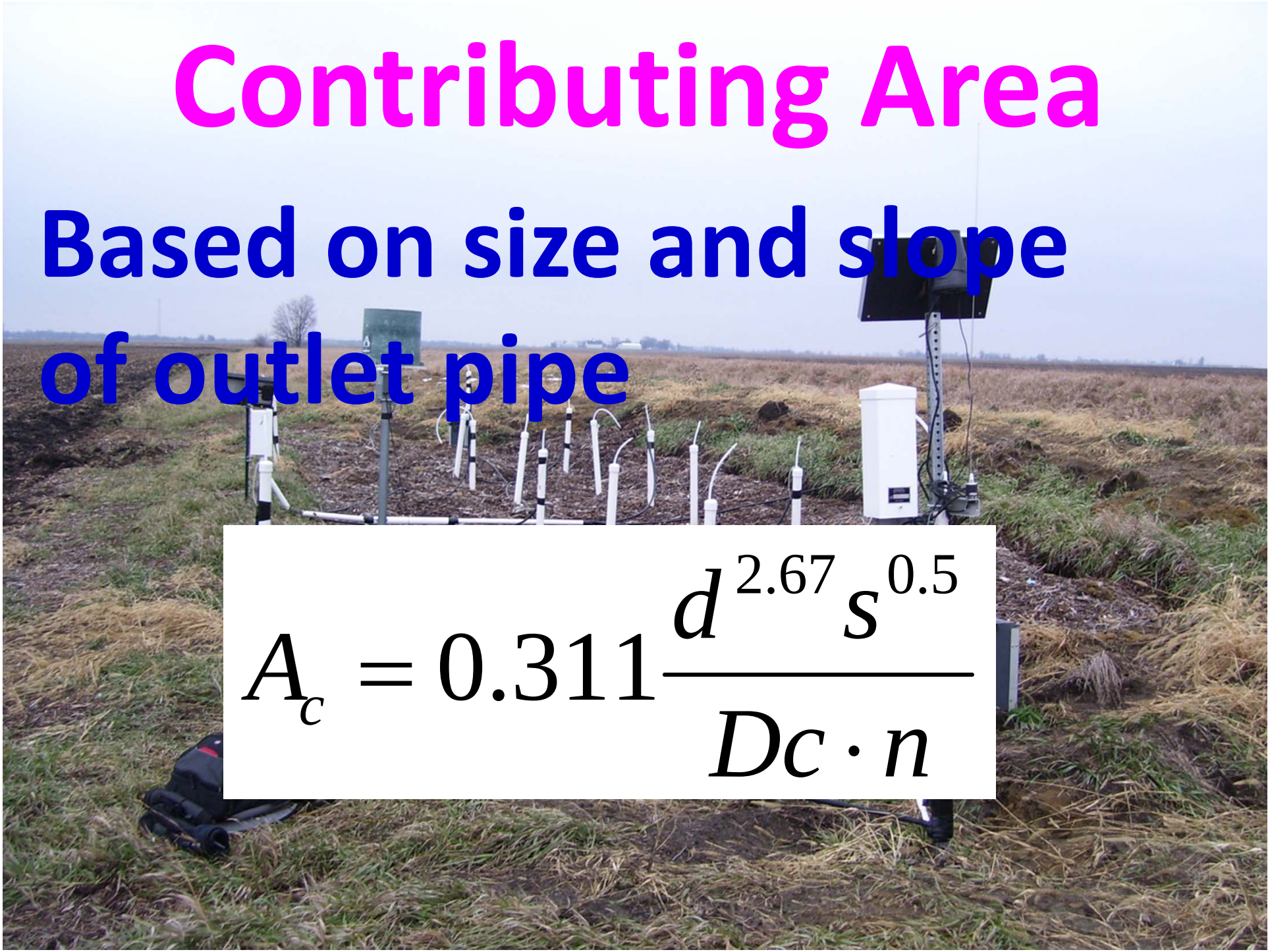


Popup Help Screens



Contributing Area

Based on size and slope of outlet pipe



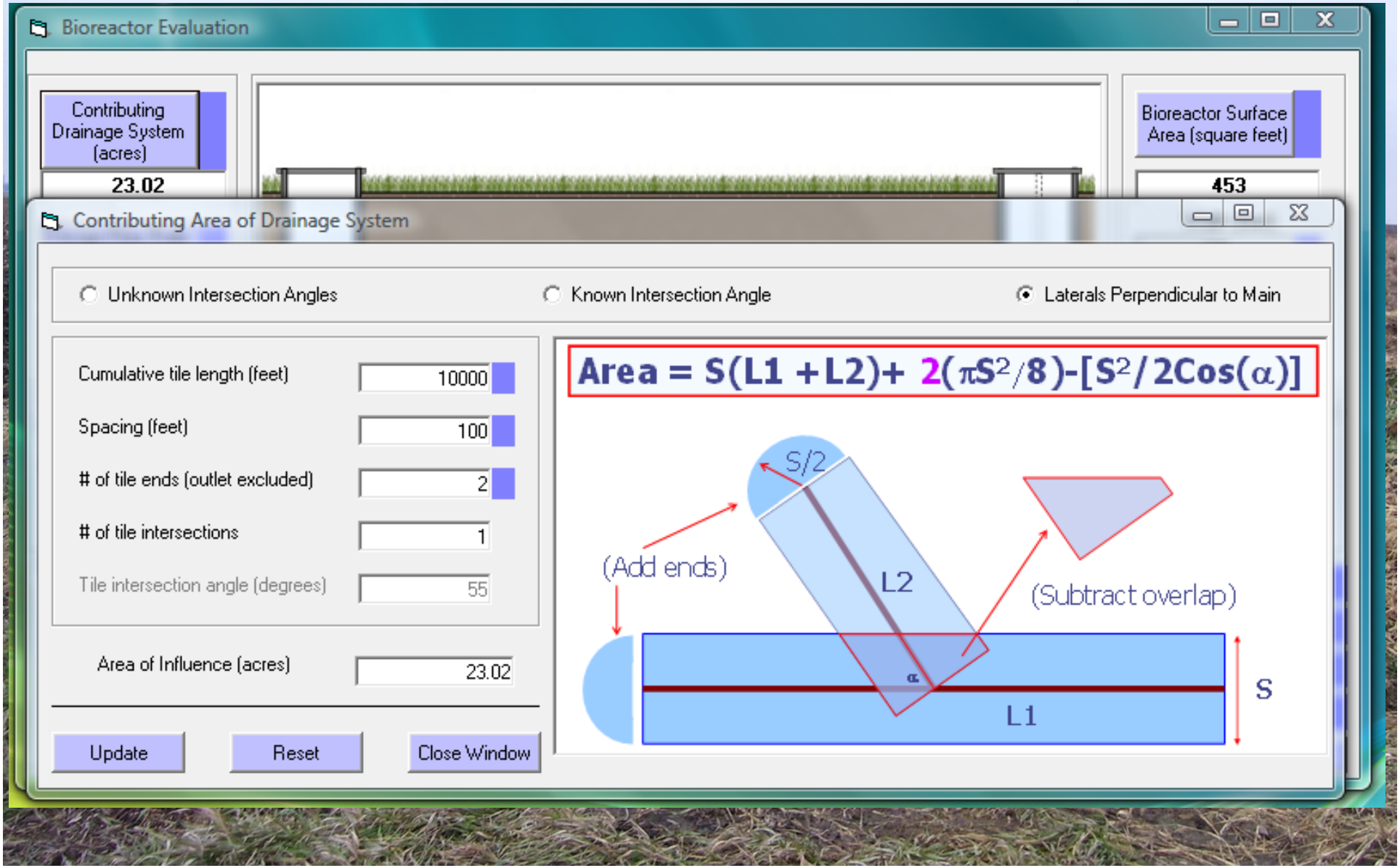
$$A_c = 0.311 \frac{d^{2.67} s^{0.5}}{Dc \cdot n}$$

Contributing Area

Based on tile lengths and intersection angles

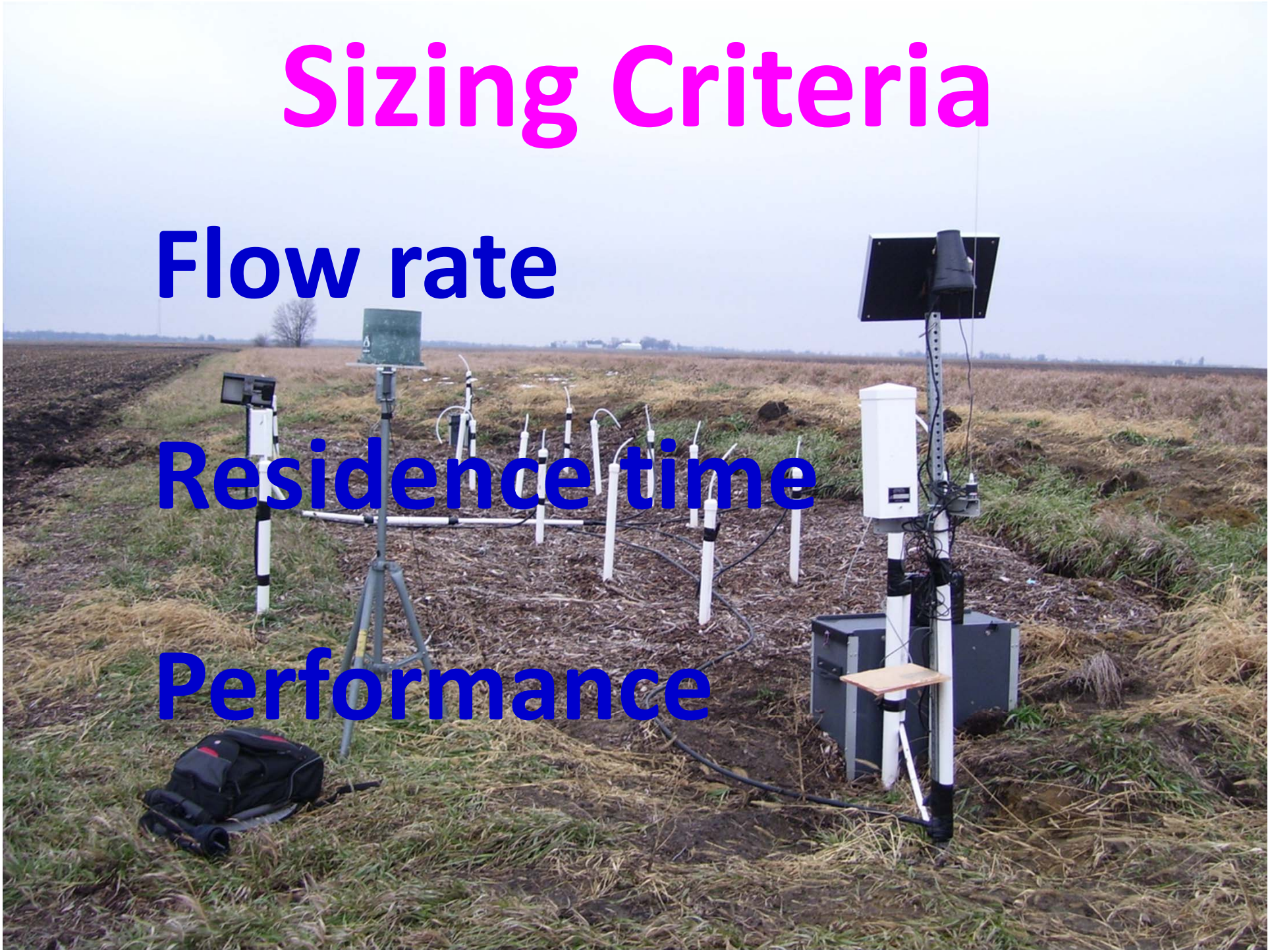
$$A_c = SL + \left(\frac{\pi E}{8} - \frac{I}{\cos(\alpha)} \right) S^2$$

Contributing Area



Woodchip Properties

Sizing Criteria



Flow rate

Residence time

Performance

Design Flow Rate

10-year, 24 hour drain outflow event

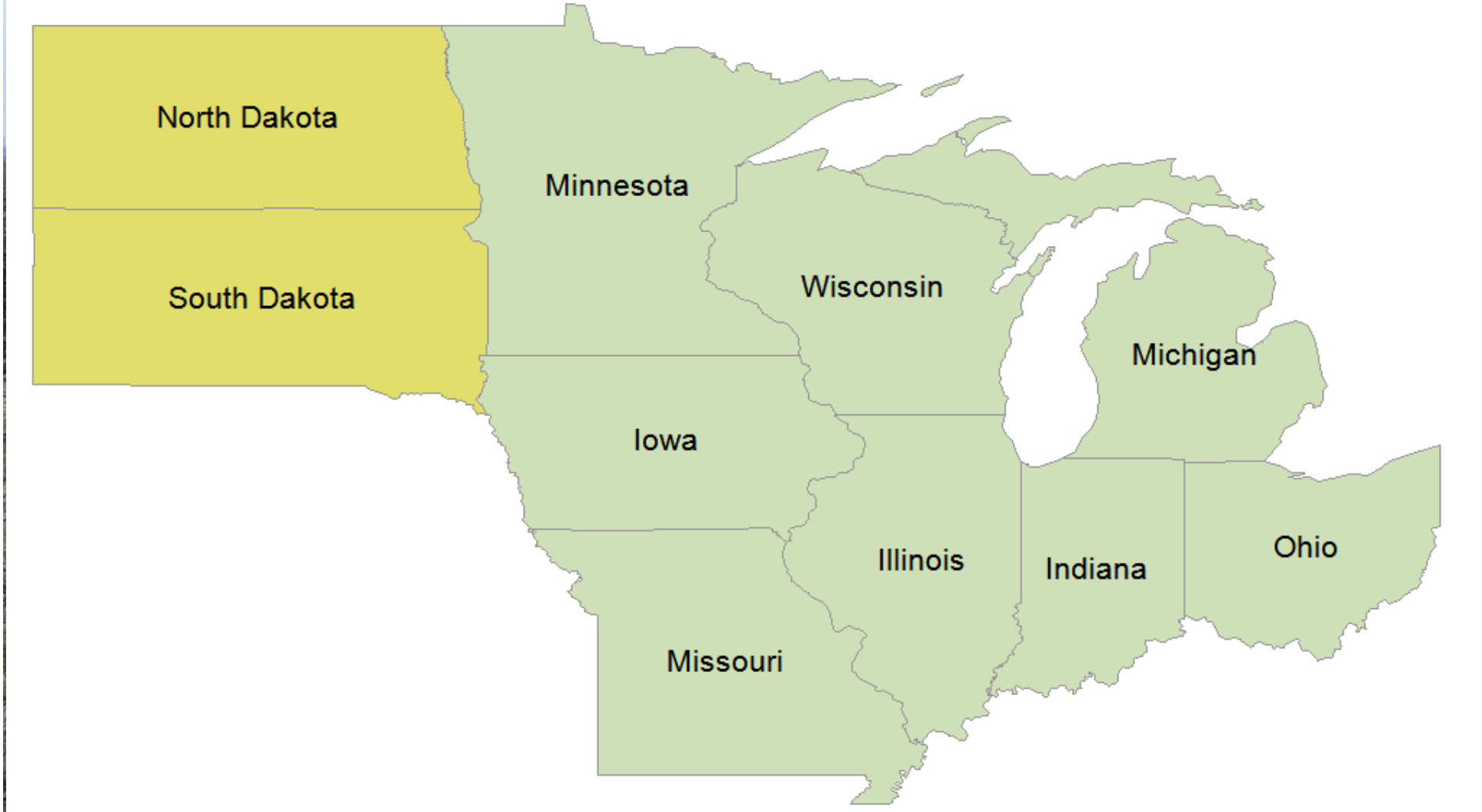
- Grassed waterways (NRCS-412)
- Constructed wetlands (NRCS-656)

Design Flow Rate

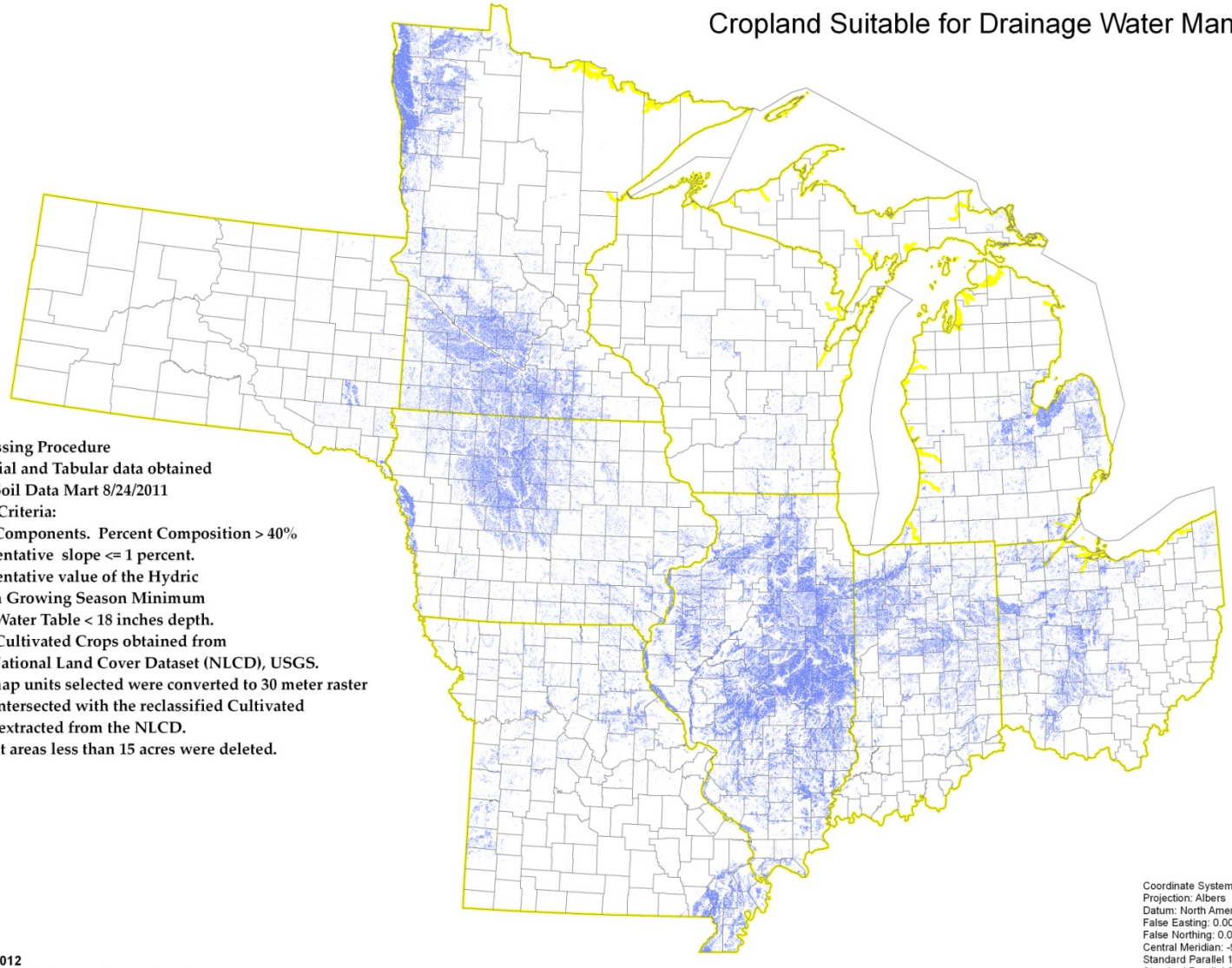
DRAINMOD Simulations

- Weather
- Soils
- Drainage System Layout

Midwest Database



NRCS Midwest DWM States



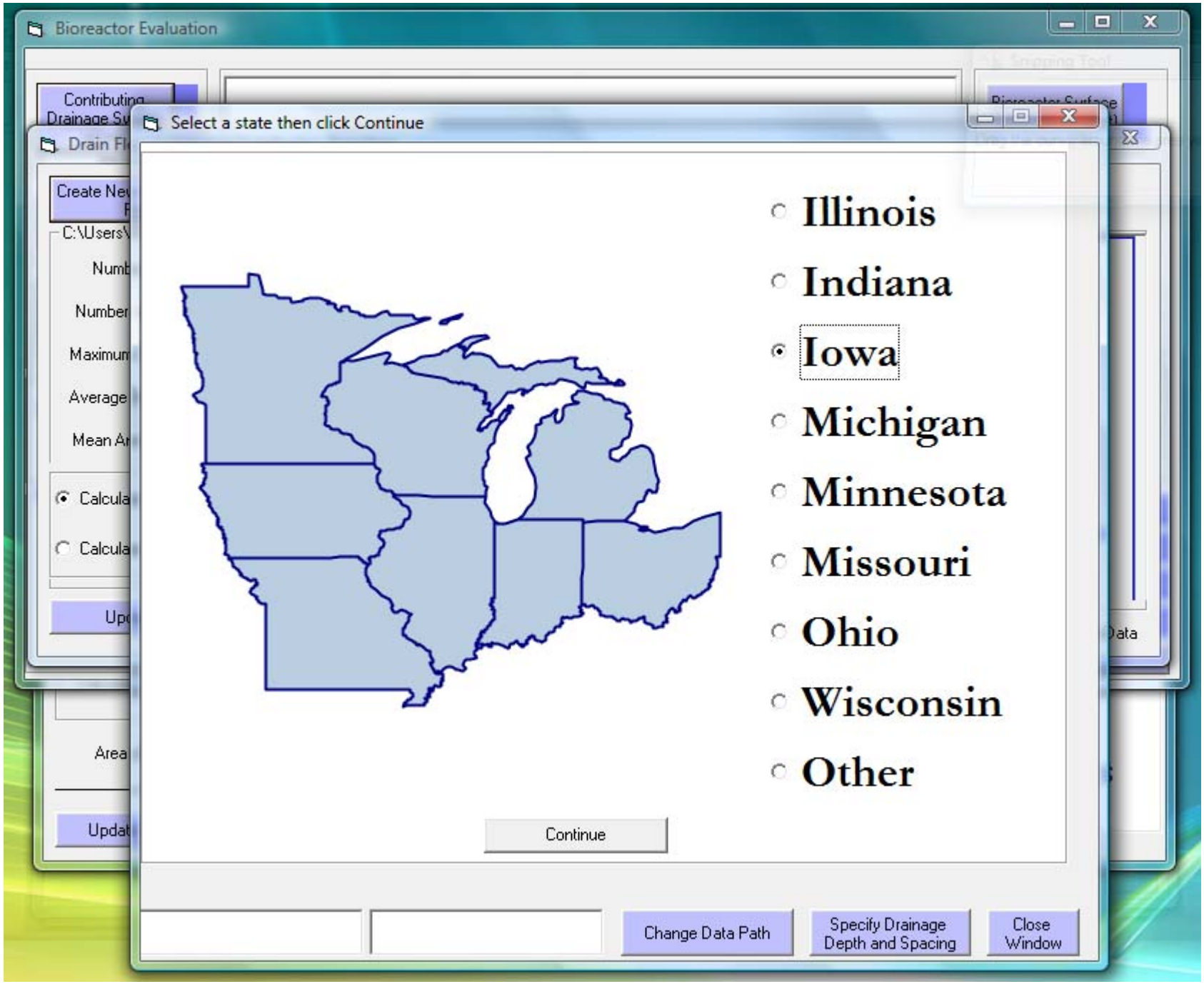
Illinois 10,289,165 Ac
Indiana 2,752,251 Ac
Iowa 4,076,072 Ac
Missouri 1,844,238 Ac
Michigan 1,259,731 Ac
Minnesota 6,308,982 Ac
Ohio 2,146,231 Ac
South Dakota 228,842 Ac
Wisconsin 309,427 Ac

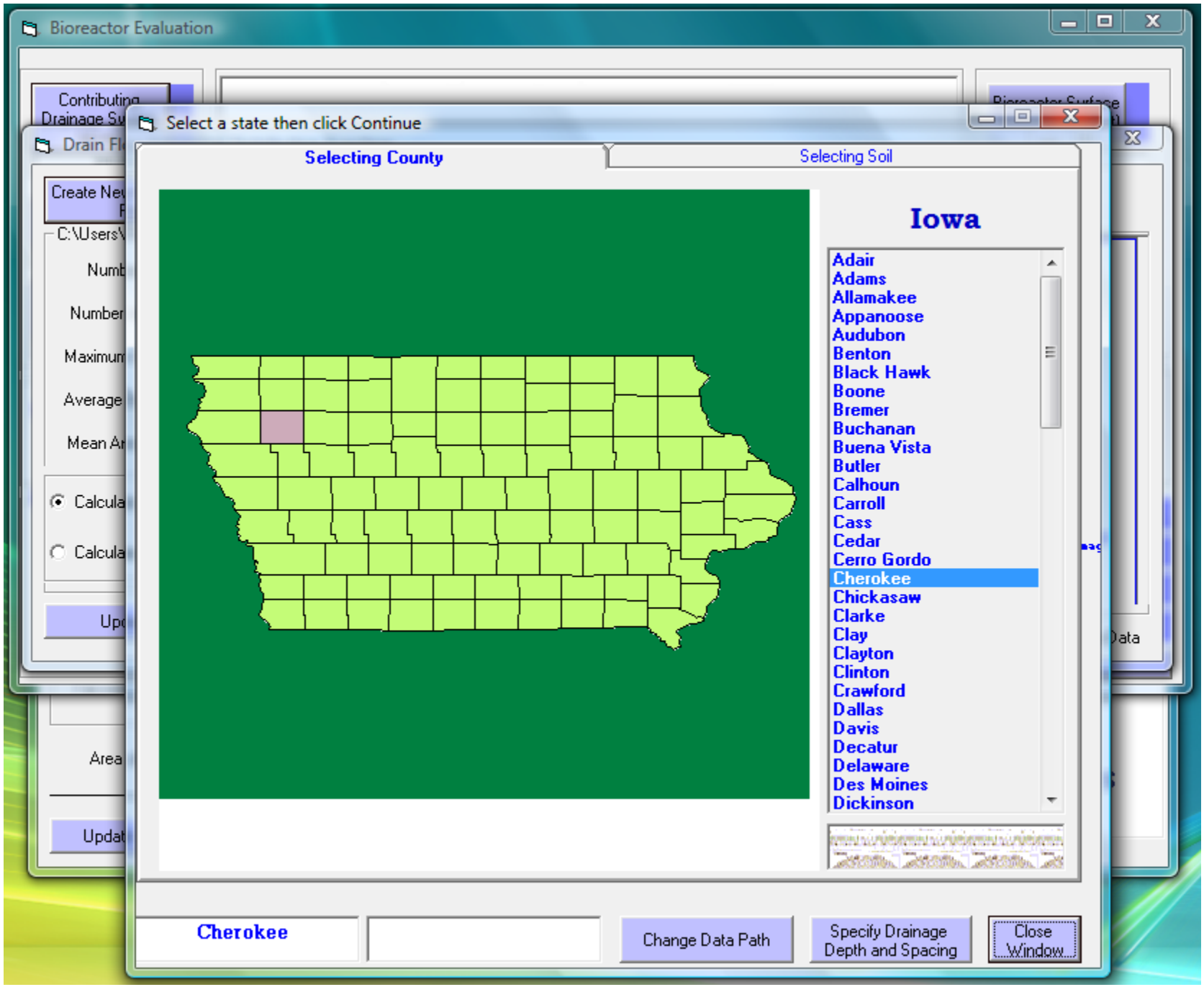
Geoprocessing Procedure
Soils Spatial and Tabular data obtained
from the Soil Data Mart 8/24/2011
Selection Criteria:
1. Major Components. Percent Composition > 40%
2. Representative slope <= 1 percent.
3. Representative value of the Hydric
Definition Growing Season Minimum
Depth of Water Table < 18 inches depth.
Extent of Cultivated Crops obtained from
the 2006 National Land Cover Dataset (NLCD), USGS.
The soil map units selected were converted to 30 meter raster
data and intersected with the reclassified Cultivated
Cropland extracted from the NLCD.
Coincident areas less than 15 acres were deleted.

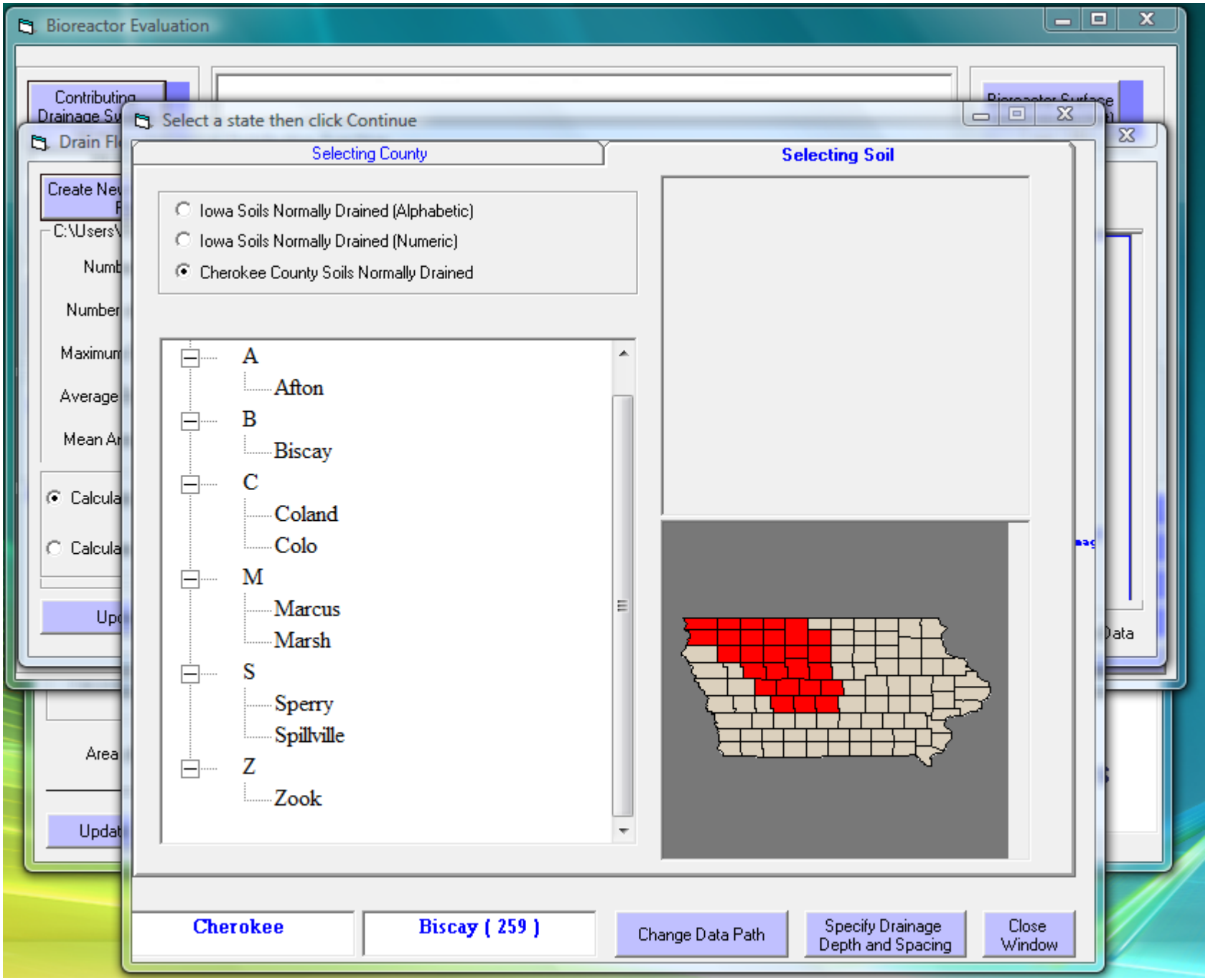
Coordinate System: USA Contiguous Albers Equal Area Conic USGS version
Projection: Albers
Datum: North American 1983
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: -96.0000
Standard Parallel 1: 29.5000
Standard Parallel 2: 45.5000
Latitude Of Origin: 23.0000
Units: Meter

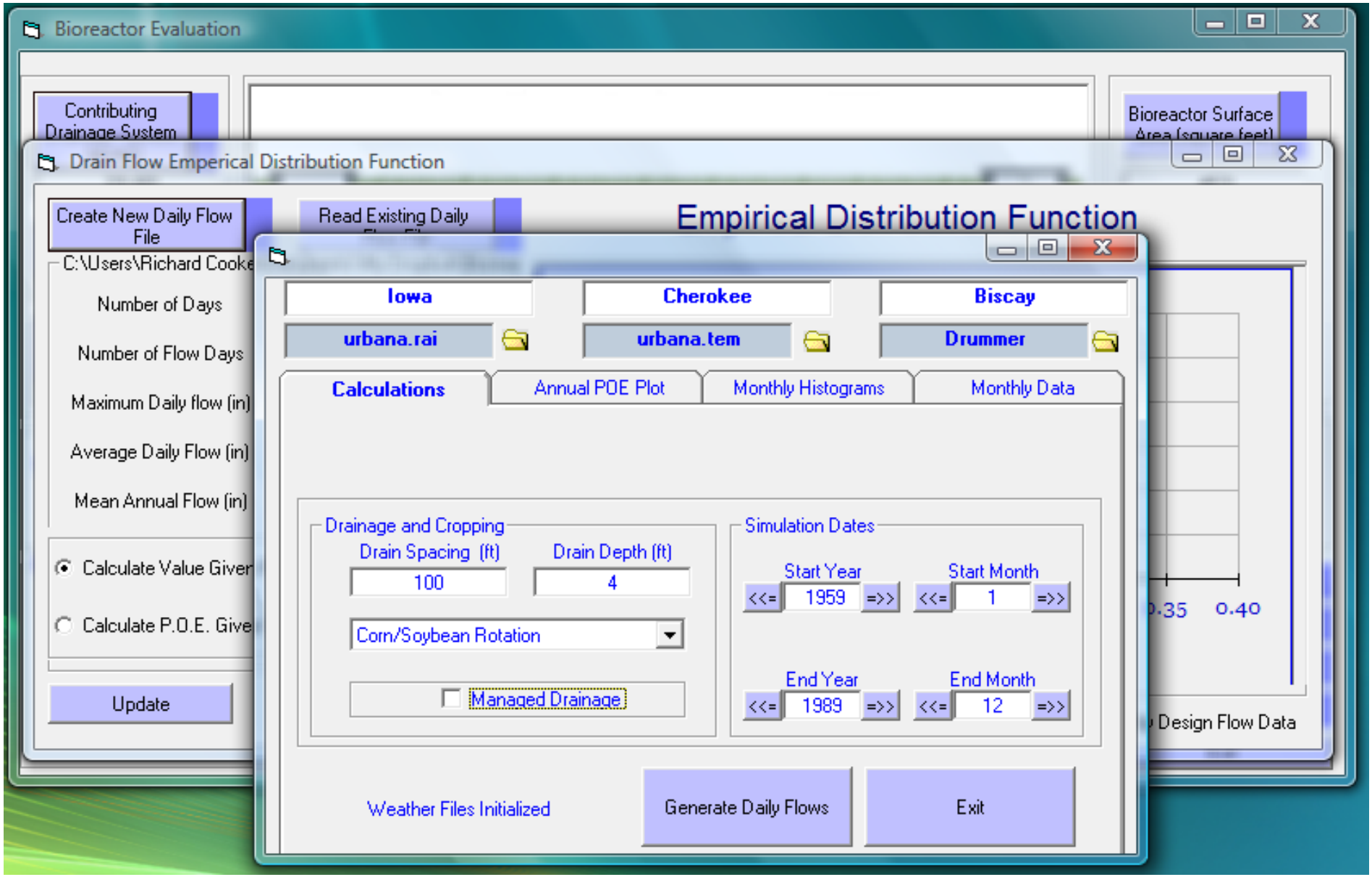
1:6,000,000

February 1, 2012
Central National Technology Support Center
Fort Worth, TX Map 2012- 41

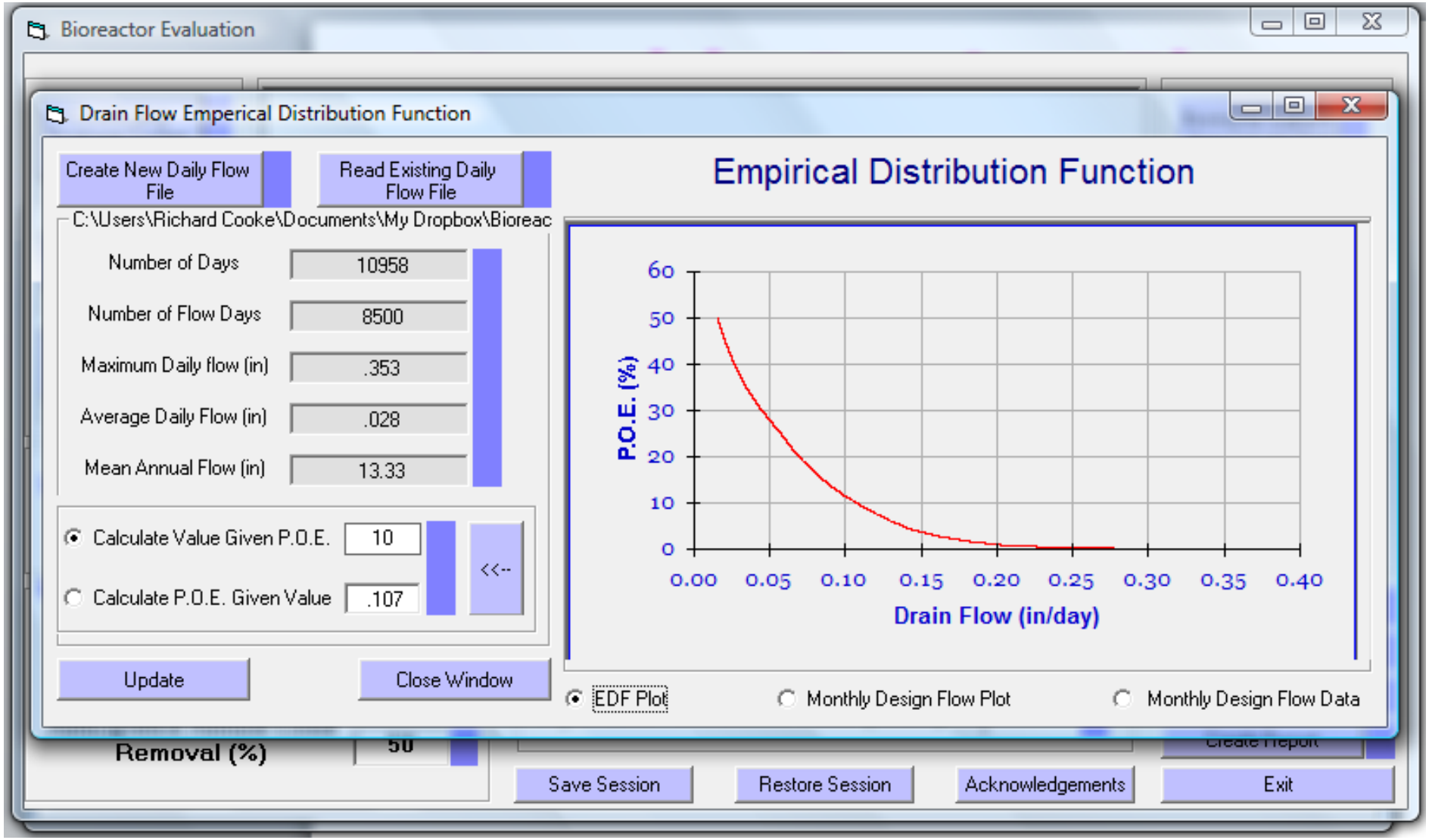

Bioreactor Evaluation
Select a state then click Continue
Illinois
Indiana
Iowa
Michigan
Minnesota
Missouri
Ohio
Wisconsin
Other
Continue
Change Data Path
Specify Drainage Depth and Spacing
Close Window


Bioreactor Evaluation
Select a state then click Continue
Selecting County
Selecting Soil
Iowa
Adair
Adams
Allamakee
Appanoose
Audubon
Benton
Black Hawk
Boone
Bremer
Buchanan
Buena Vista
Butler
Calhoun
Carroll
Cass
Cedar
Cerro Gordo
Cherokee
Chickasaw
Clarke
Clay
Clayton
Clinton
Crawford
Dallas
Davis
Decatur
Delaware
Des Moines
Dickinson
Cherokee
Change Data Path
Specify Drainage Depth and Spacing
Close Window

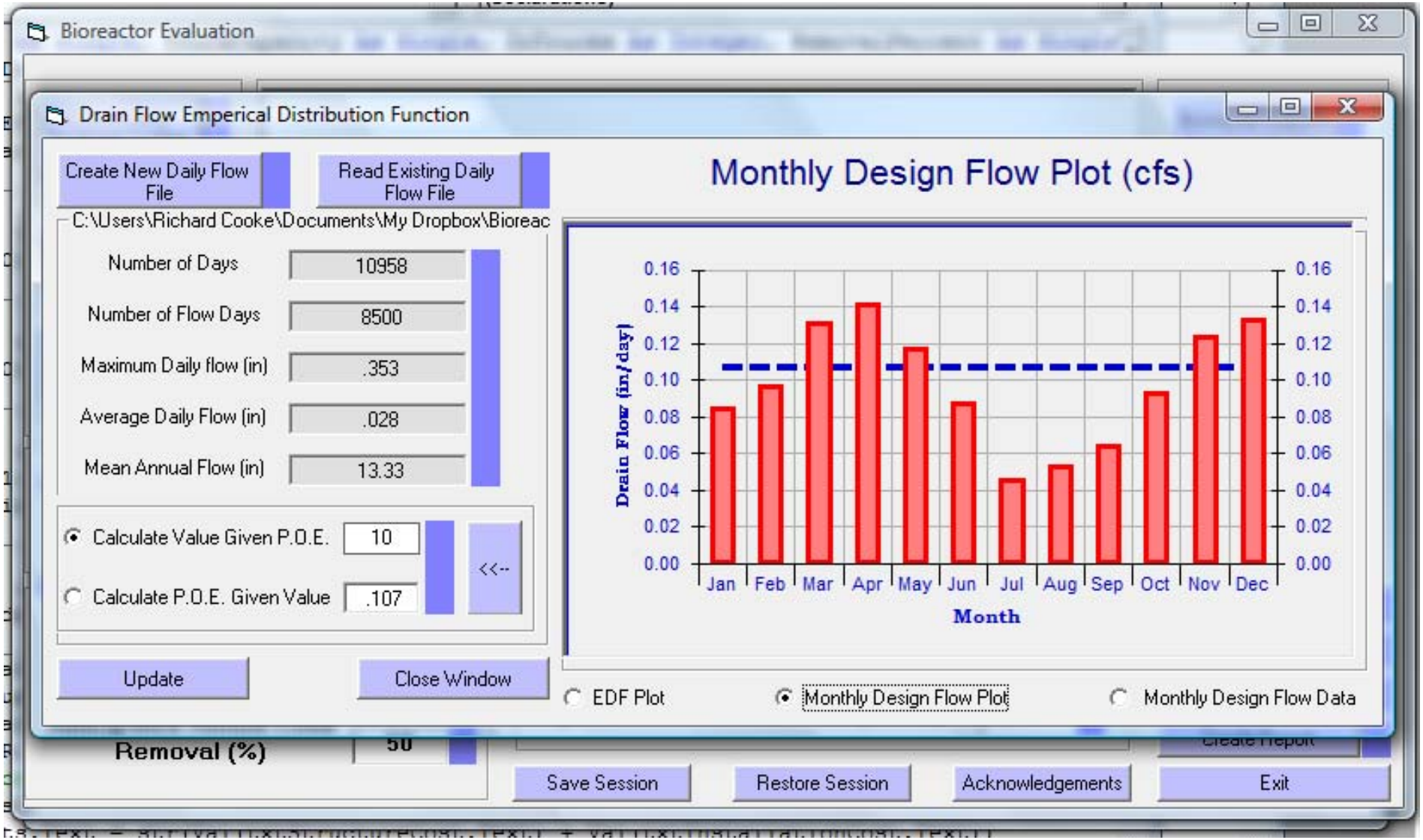

Bioreactor Evaluation
Select a state then click Continue
Selecting County
Selecting Soil
Iowa Soils Normally Drained (Alphabetic)
Iowa Soils Normally Drained (Numeric)
Cherokee County Soils Normally Drained
A
Afton
B
Biscay
C
Coland
Colo
M
Marcus
Marsh
S
Sperry
Spillville
Z
Zook
Cherokee
Biscay (259)
Change Data Path
Specify Drainage Depth and Spacing
Close Window


Bioreactor Evaluation
Contributing Drainage System
Bioreactor Surface Area (square feet)
Drain Flow Emperical Distribution Function
Create New Daily Flow File
Read Existing Daily
Empirical Distribution Function
C:\Users\Richard Cooke
Number of Days
Number of Flow Days
Maximum Daily flow (in)
Average Daily Flow (in)
Mean Annual Flow (in)
Calculate Value Given
Calculate P.O.E. Given
Update
Iowa
Cherokee
Biscay
urbana.rai
urbana.tem
Drummer
Calculations
Annual POE Plot
Monthly Histograms
Monthly Data
Drainage and Cropping
Drain Spacing (ft)
100
Drain Depth (ft)
4
Corn/Soybean Rotation
Managed Drainage
Simulation Dates
Start Year
<<=
1959
=>>
Start Month
<<=
1
=>>
End Year
<<=
1989
=>>
End Month
<<=
12
=>>
0.35
0.40
Design Flow Data
Weather Files Initialized
Generate Daily Flows
Exit

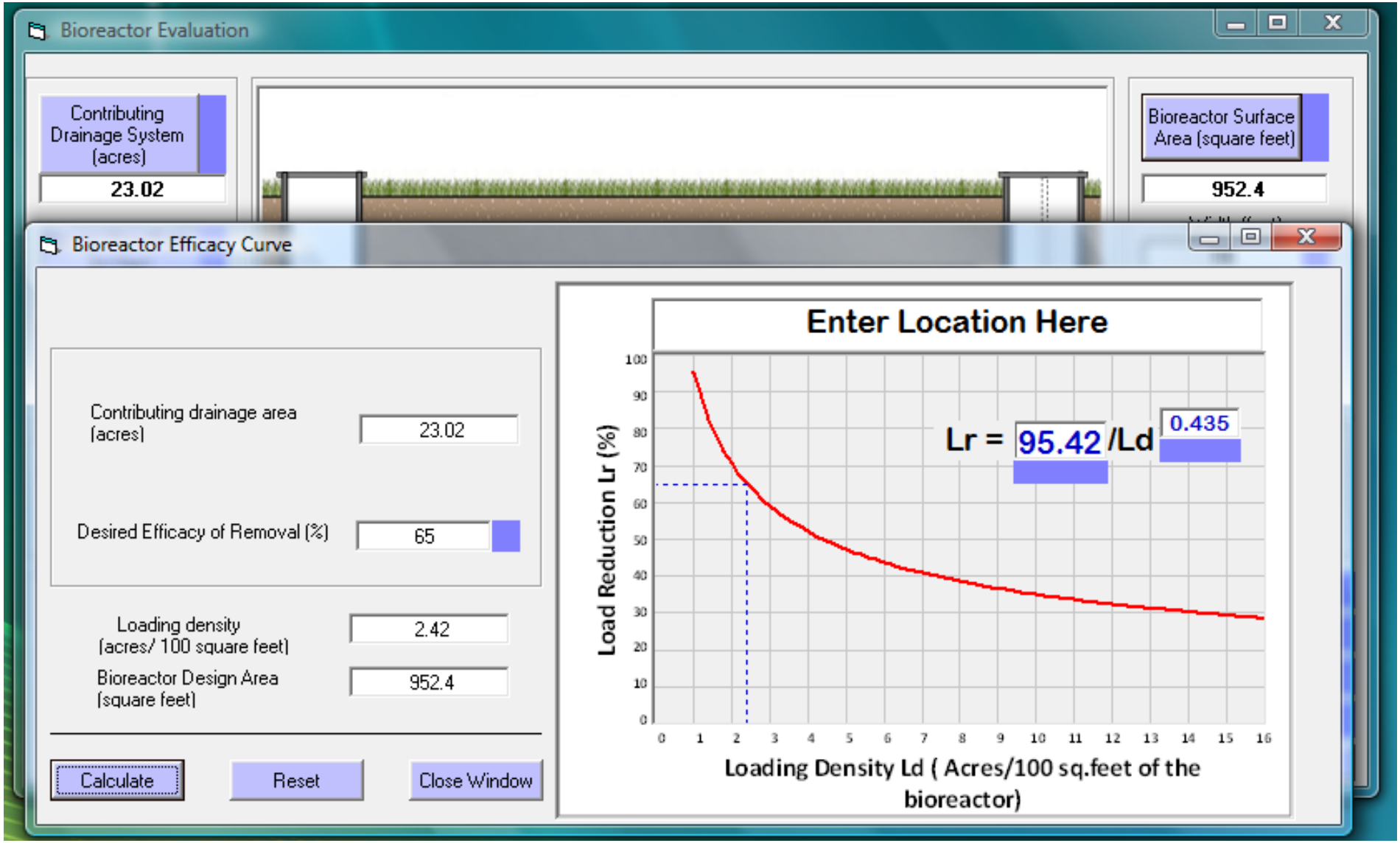
EDF for Daily Flow



Monthly Design Flows

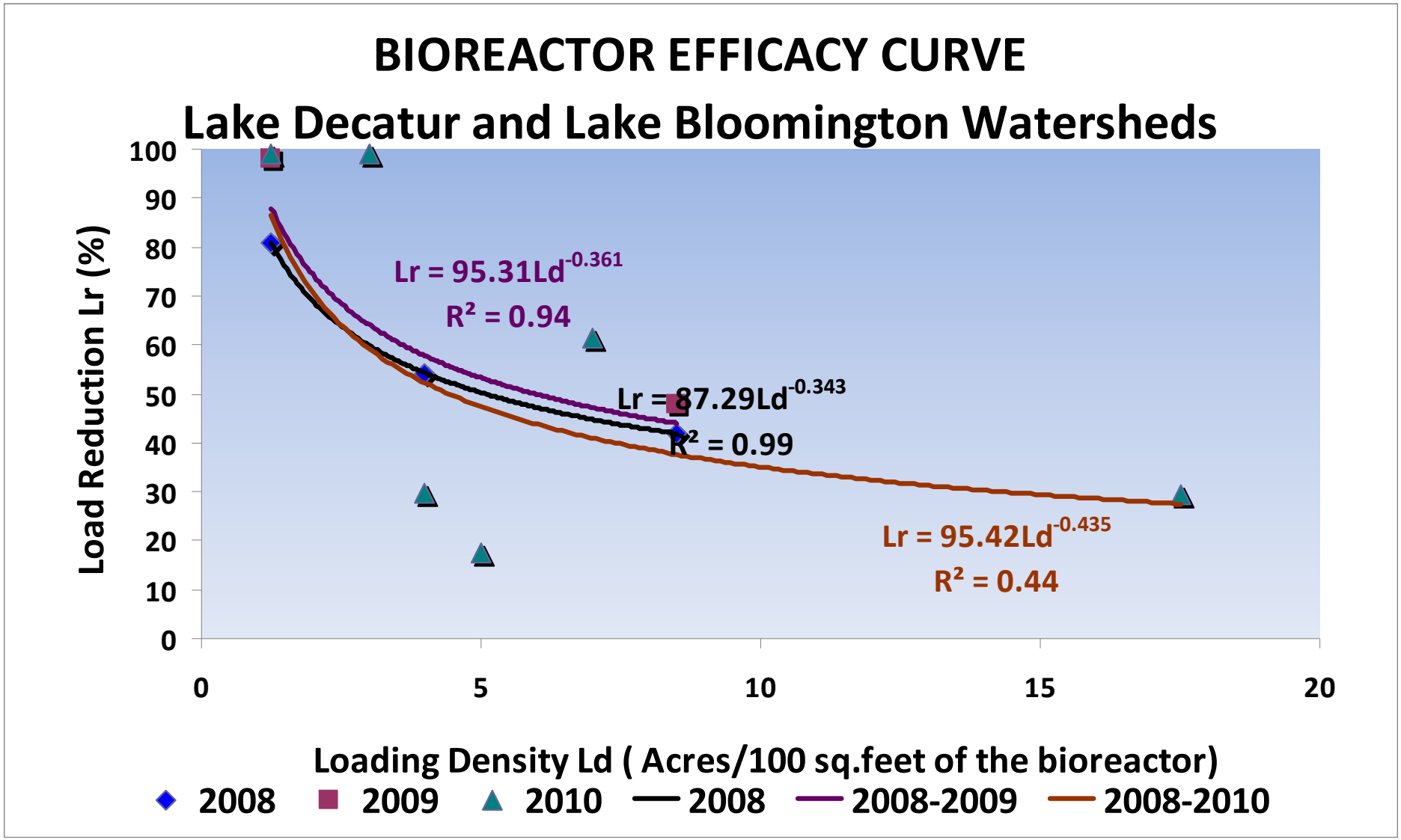


Performance Curve

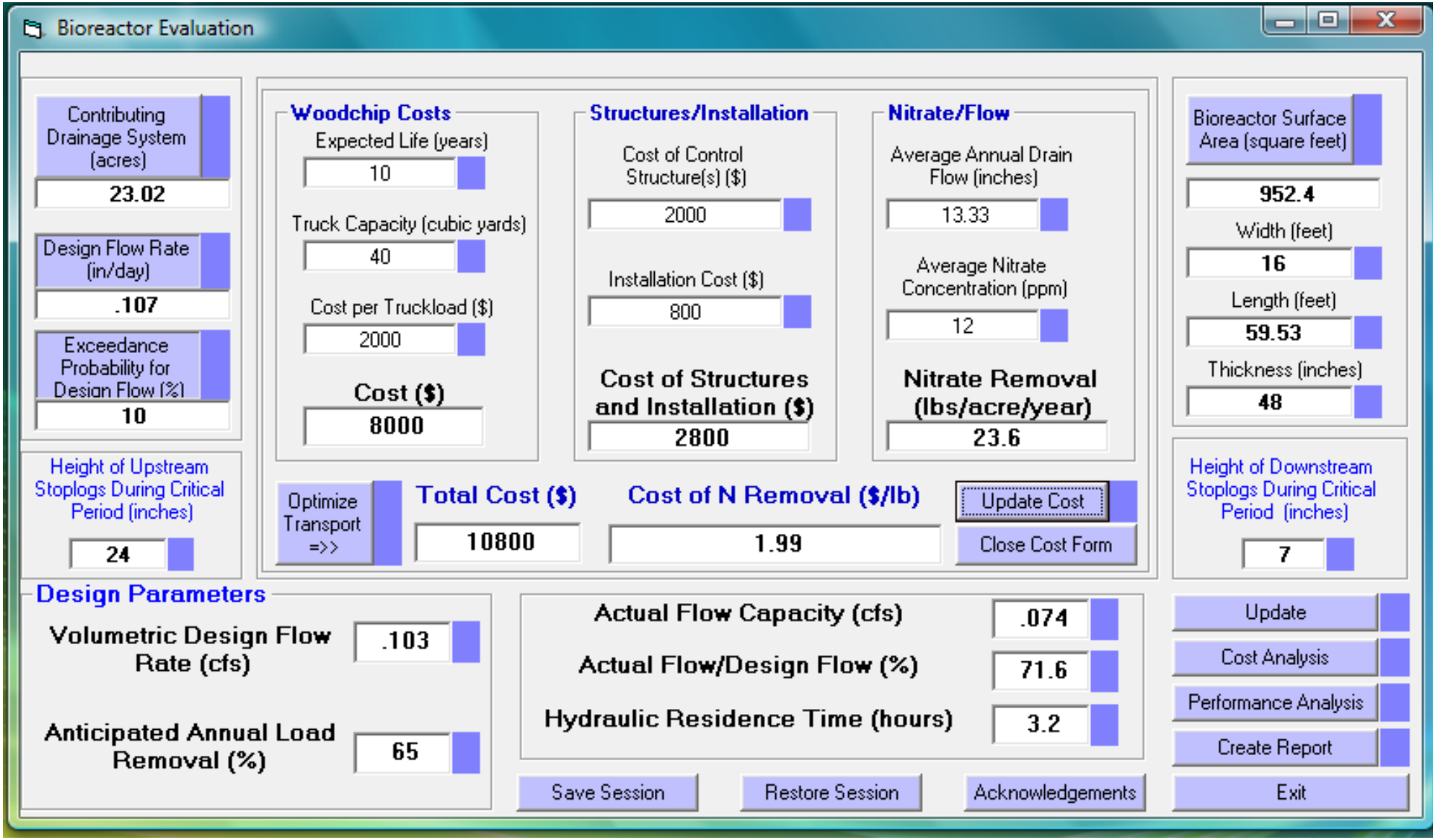


Site	Drainage Area (acres)	Bioreactor Area (square feet)	Loading Density (acres/100 sq. feet)
Decatur West	5	400	1.25
De Land West	28	930	3.00
Amenia	15	400	3.75
Decatur East	16	400	4.00
Bloomington North	20	400	5.00
De Land North	39	560	7.00
De Land East	34	400	8.50
Mount Zion	70	400	17.5

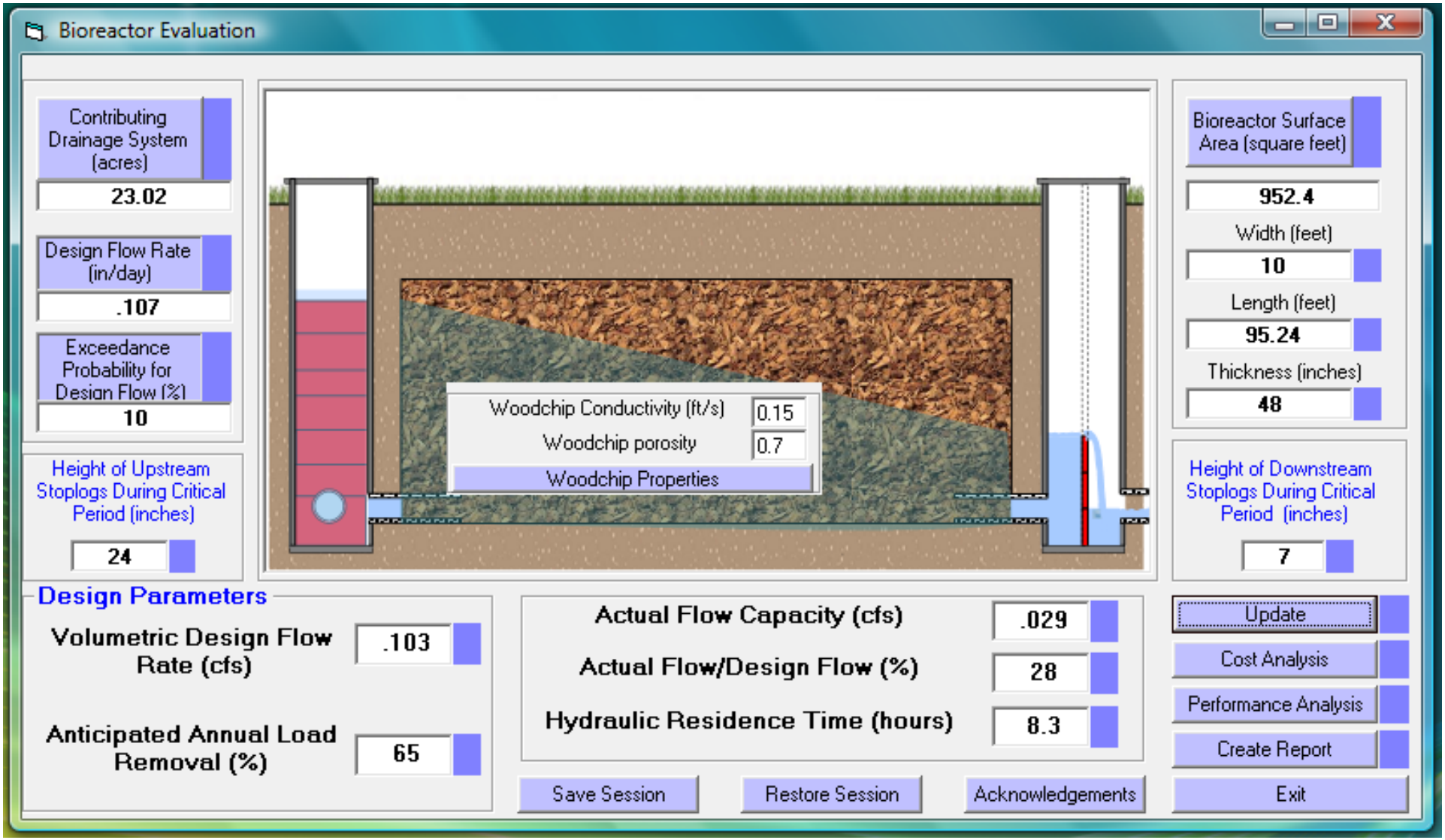
Illinois Performance Curve



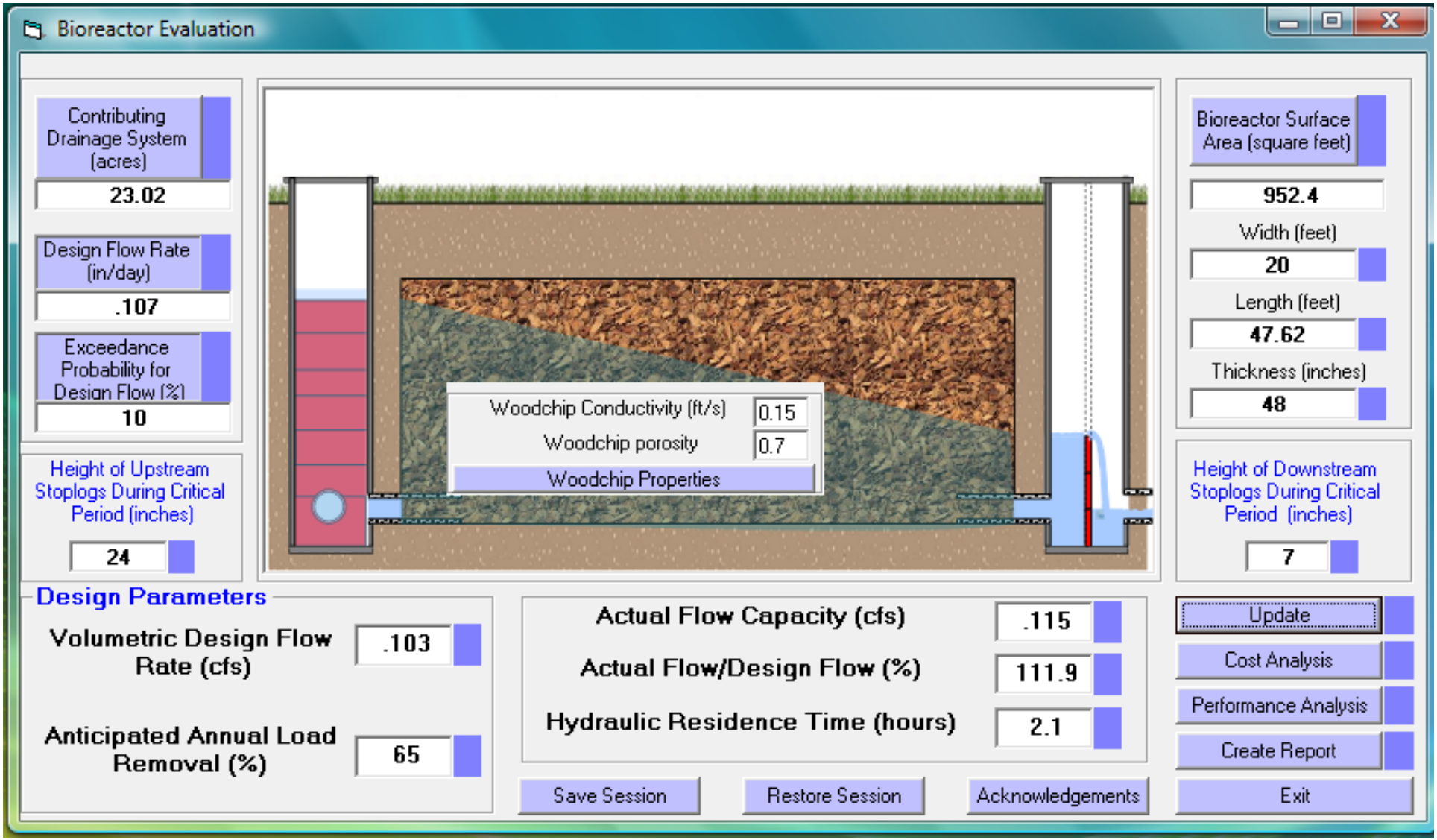
Cost Analysis



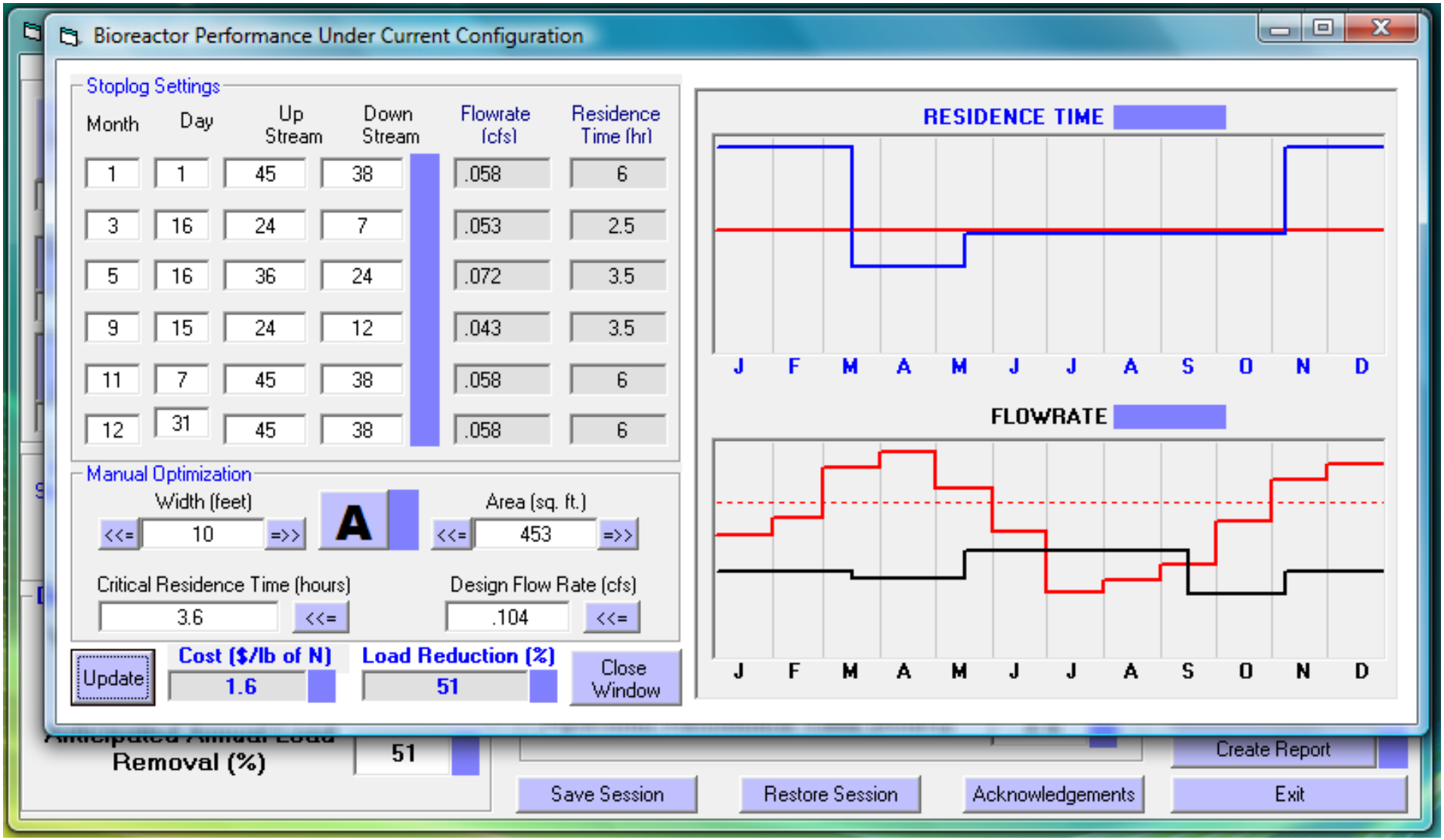
Length/Width Effects



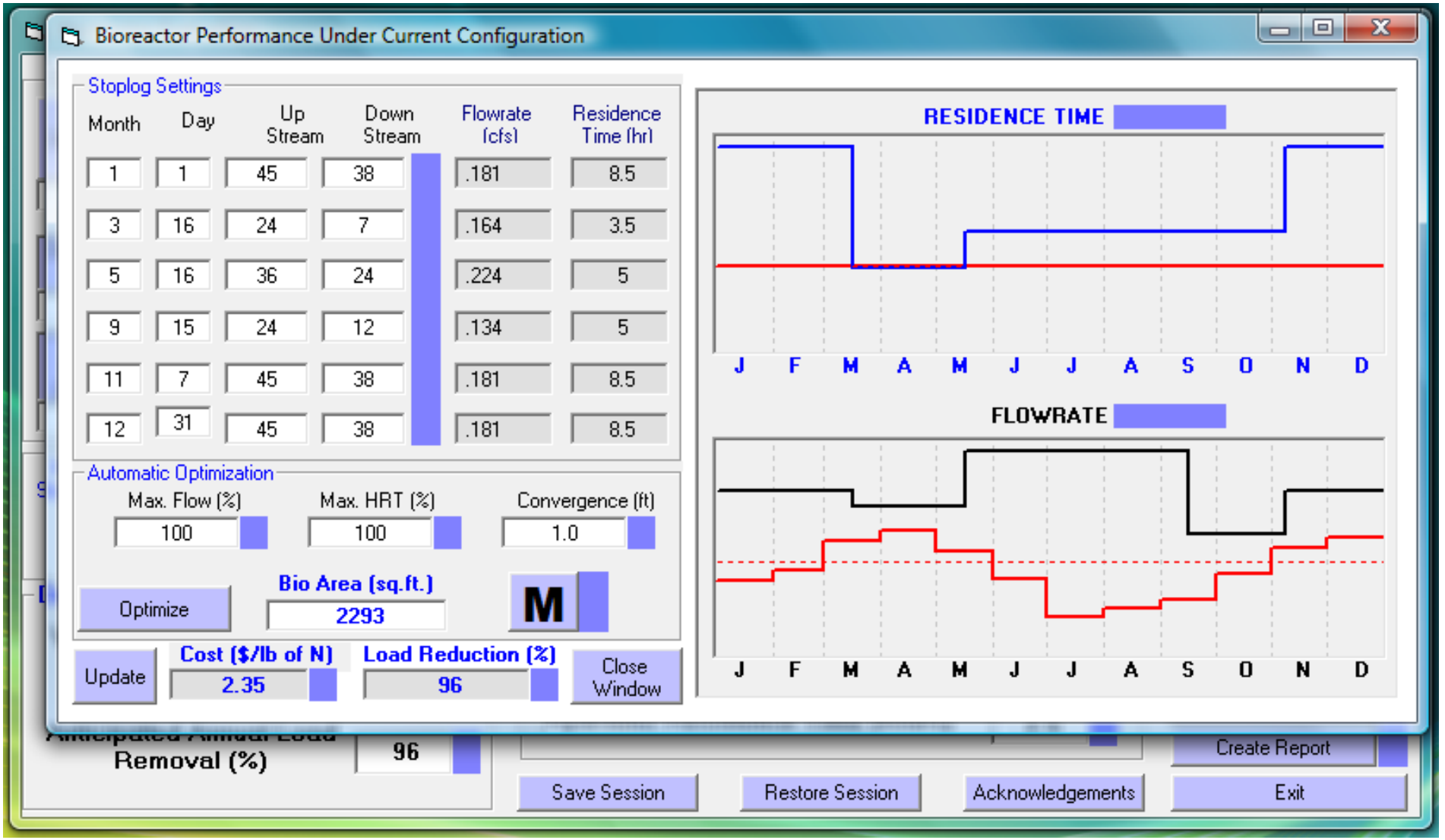
Length/Width Effects



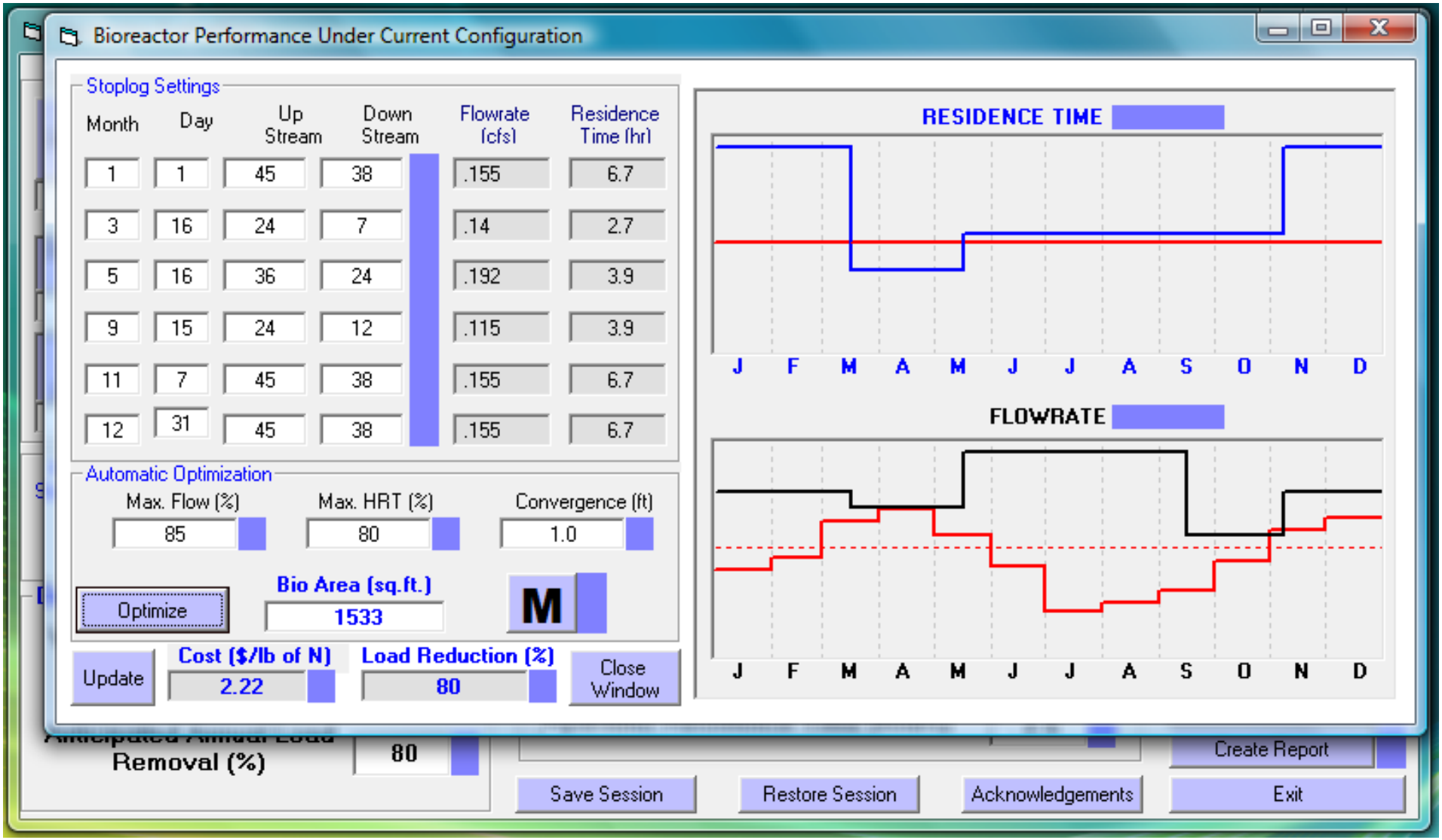
Manual Optimization



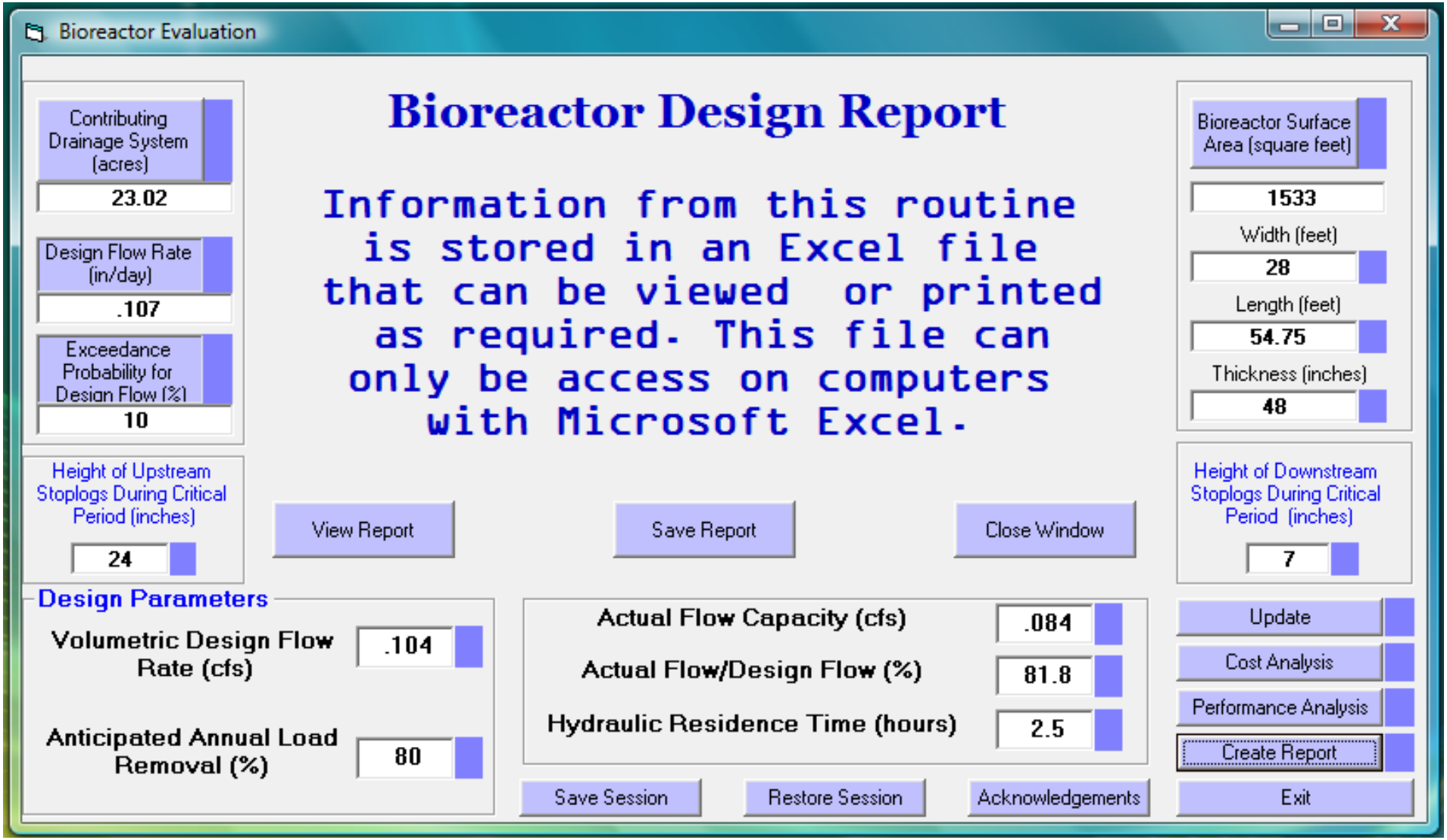
Automatic Optimization



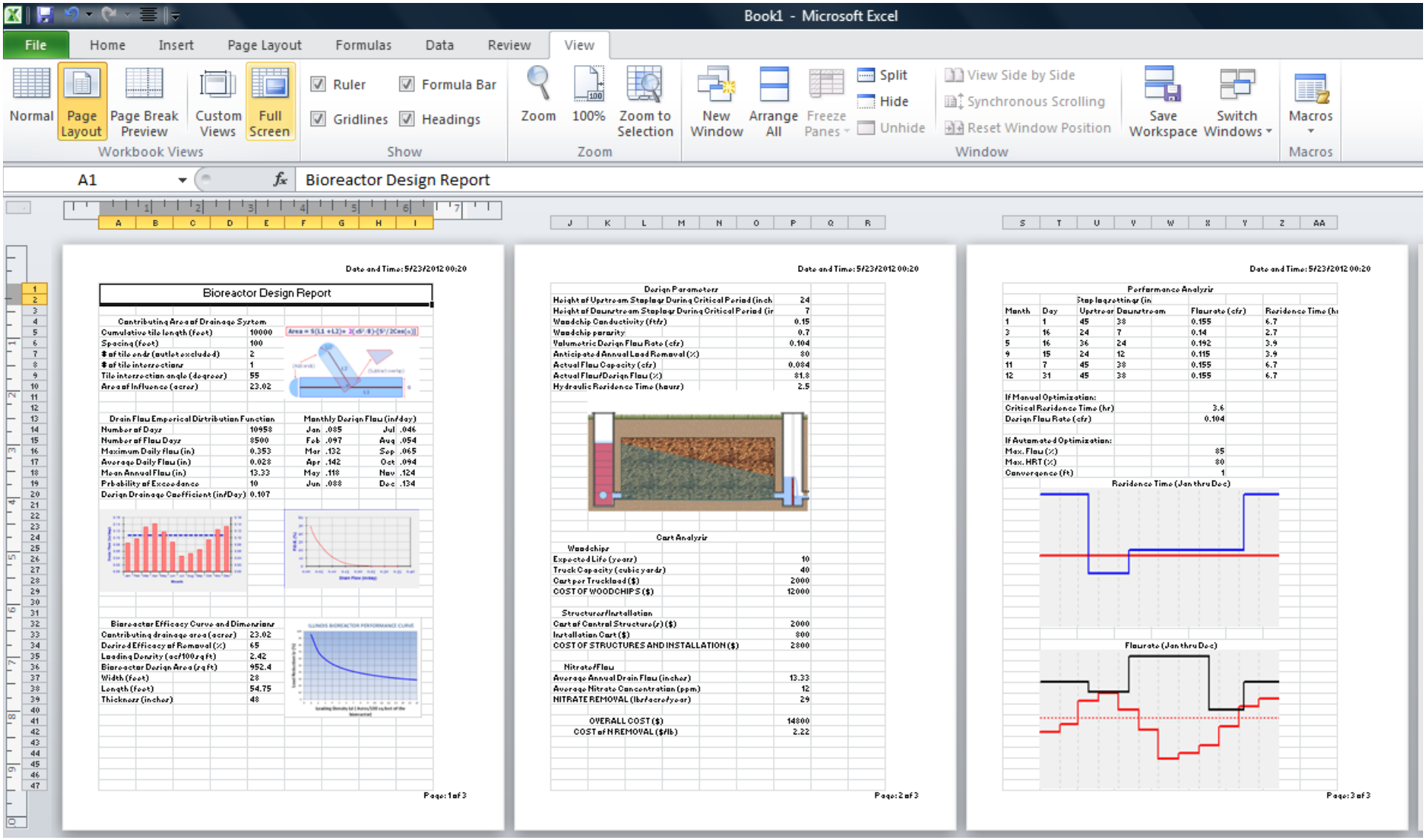
Incorporating Performance



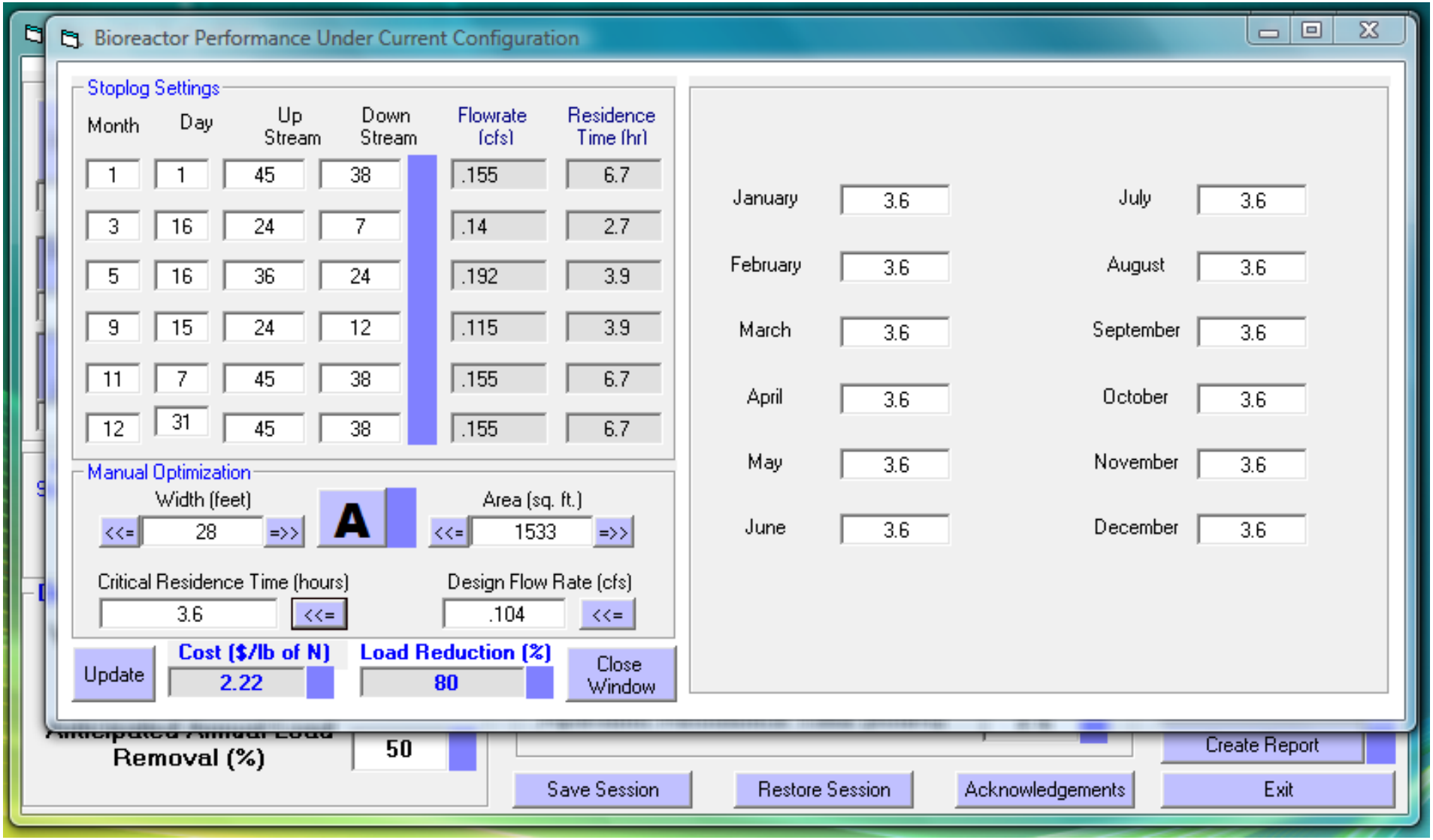
Report Generation



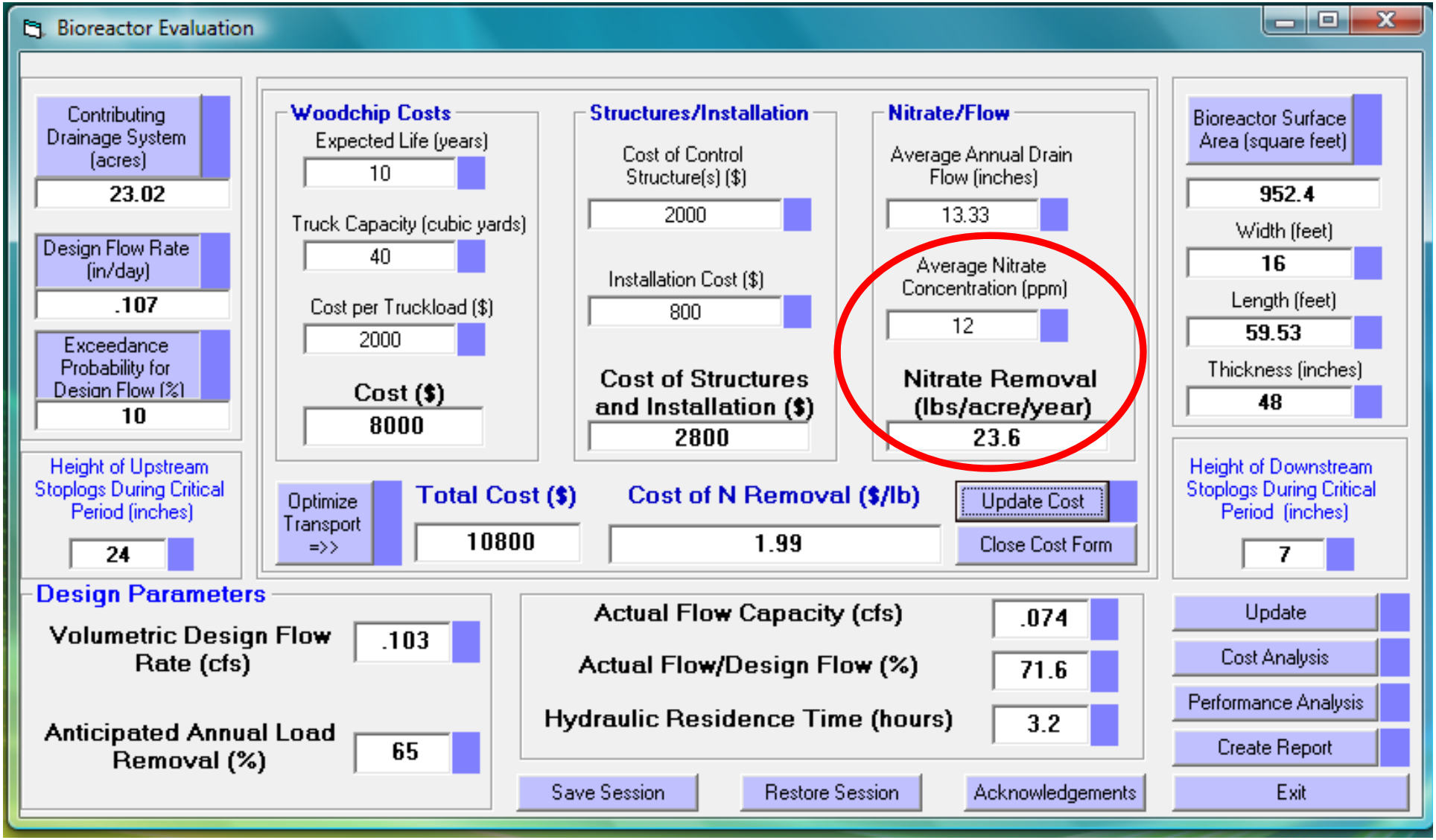
Report Generation



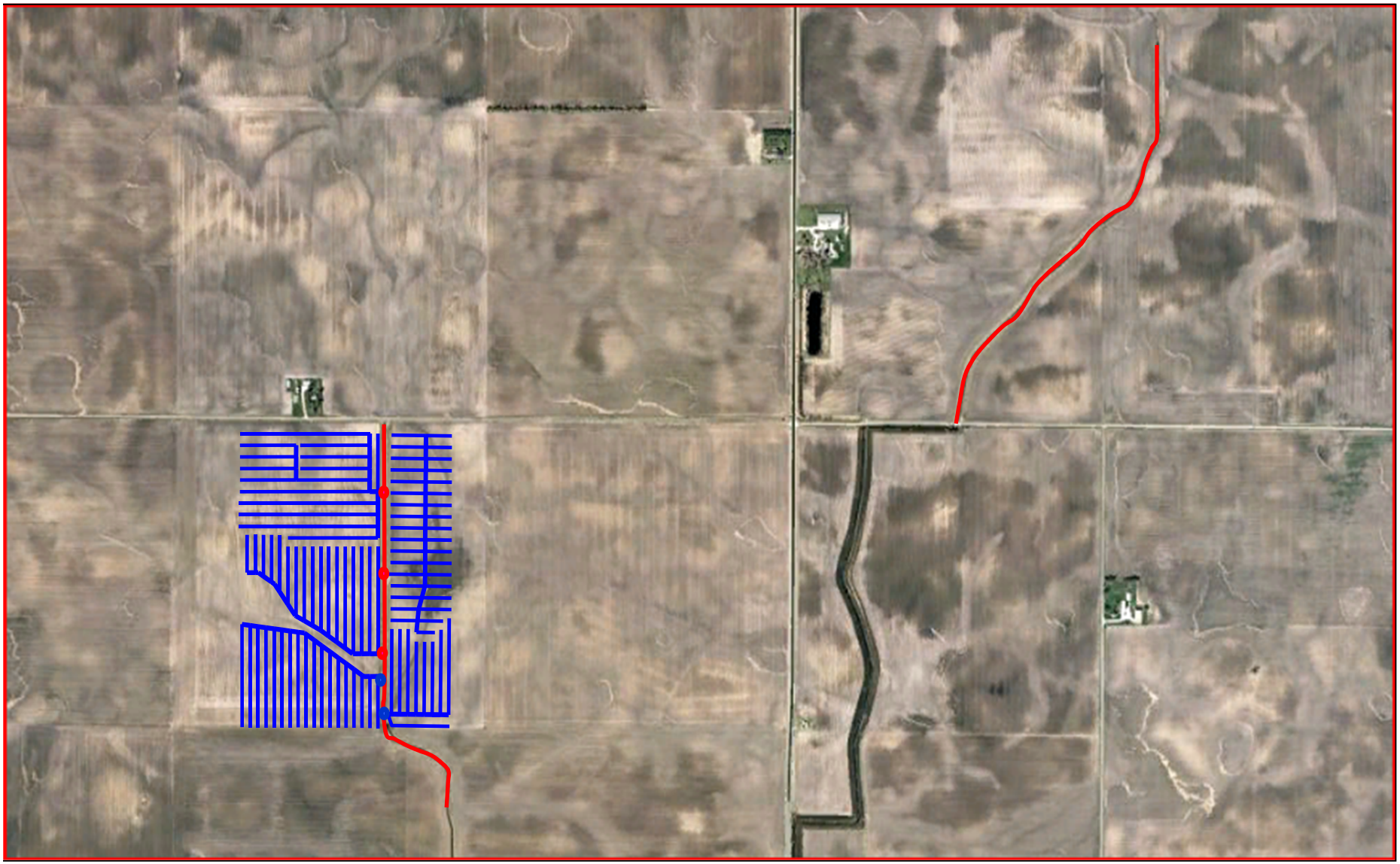
Future Work: Residence Time



Future Work: Nitrate Loads



Future Work: Long-term Trends

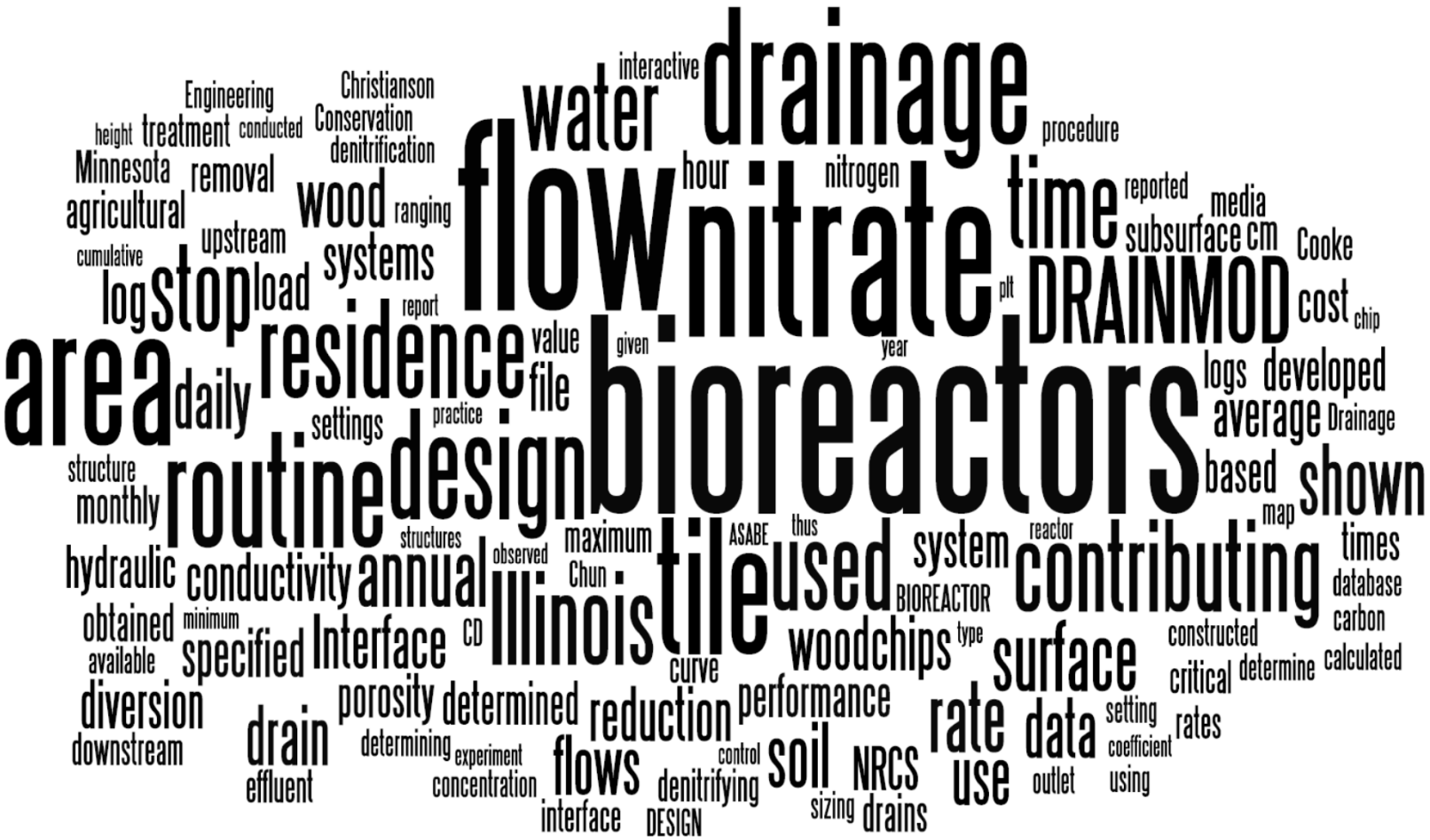


Acknowledgements

This routine was developed for the Illinois NRCS as part of a Conservation Innovation Grant titled "The Development of Performance Curves for Bioreactors in Illinois." Supplemental funding was provided by The Sand County Foundation. The bioreactors were constructed with funds provided by the Environmental Protection Agency.

Close Window

Thank You


drainage
flow
nitrate
water
bioreactors
area
residence
routine
design
tile
Illinois
used
contributing
DRAINMOD
time
shown
annual
surface
woodchips
rate
data
soil
NRCS
use
drain
flows
reduction
performance
porosity
determined
diversion
specified
Interface
conductivity
hydraulic
obtained
monthly
daily
stop
load
log
wood
systems
removal
treatment
Minnesota
agricultural
denitrification
Christianson
Conservation
Engineering
interactive
procedure
hour
nitrogen
reported
media
subsurface
cm
Cooke
cost
chip
developed
logs
average
Drainage
based
map
times
database
carbon
calculated
critical
determine
constructed
rates
setting
coefficient
using
outlet
drains
sizing
DESIGN
interface
denitrifying
control
concentration
experiment
determining
effluent
downstream
curve
type
BIOREACTOR
reactor
ASABE
thus
maximum
observed
Chun
structures
CD
minimum
available
structure
settings
practice
file
value
given
year
report
ranging
upstream
cumulative
height
conducted
plt