

USING THE WINWRNSHYD PROGRAM AS A DIDACTIC TOOL

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ABSTRACT

The WinWrnsHyd computer program is a complete implementation of the hydrology section of the USEPA WRENSS procedure plus some additional routines related to forest growth. As such its principal use has been to estimate the changes in water yield associated with forest management activities. However, it is not limited to this use.

Forest harvest affects water yield by altering evapotranspiration, the differential accumulation and retention of snow, the timing of snow melt, the intensity of harvest, and the speed of vegetative regrowth. The WinWrnsHyd model simulates the magnitude of each of these factors and integrates the net result to give an estimate of annual water yield.

Hydrologists often examine each of these factors in isolation and it is not always clear what magnitude of the effect that each one has on the integrated whole. The WinWrnsHyd program can be set to produce a detailed table of seasonal values for each of these factors that can be displayed in tabular or graphical form. These tabulated values and/or graphs are a valuable aid in illustrating the relative magnitude of the influence of each factor.

INTRODUCTION

The hydrology chapter (Troendle and Leaf, 1980) of WRENSS (USEPA, 1980) provides hydrologic procedures to estimate the annual water yield from forested watersheds in WRENSS-defined climatic regions (Figure 1) where rain (Rain Dominated Procedure, RDP) or snowmelt (Snow Dominated Procedure, SDP) dominates the annual hydrograph. The rain dominated procedure is based on the PROSPER evapotranspiration model (Goldstein and Mankin, 1972, Goldstein et al., 1974); the snow dominated procedure on the WATBAL hydrologic model (Leaf and Brink, 1975). Both procedures operate the same conceptually (Figure 2) except that the snow dominated procedure pays particular attention to losses from and the spatial arrangement of snow on a watershed. Accumulation of snow in clearcuts and under the surrounding forest and wind-driven losses or transfers from the accumulated snowpack are major determinates of streamflow from snow dominated watersheds.

The WinWrnsHyd computer program has been developed for the US Forest Service as a complete MicrosoftTM AccessTM database implementation of the hydrology section (Chapter III, Troendle and Leaf, 1980) of the USEPA (1980) WRENSS handbook. WinWrnsHyd is only available for the WindowsTM operating system (all versions from Windows 95 through Windows Xp). Two versions of the rain and snow dominated water yield procedures given in the hydrology section (Troendle and Leaf, 1980) are included in WinWrnsHyd, 1) provision to examine the effect on water yield of a forested area at some point in time, i.e., a *snapshot*, and 2) provision to examine the effect of regrowth on water yield as a function of time, i.e., a *time series*. The snapshot version seeks to faithfully emulate the graphical procedure followed in the WRENSS handbook. There was no mention of a time series procedure in the WRENSS handbook. This feature and one to estimate peak flows (Swanson, 1997) were added by the author to assist in the analysis of past, present and future harvesting patterns on water yield. If used, the time series version requires regrowth equation for the tree species found in the applicable WRENSS-defined hydrologic/climatic region, (Figure 1).

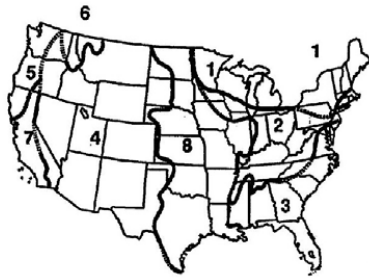
WinWrnsHyd operates with and simulates results in either SI or English units. The user must provide datasets that are consistent in whichever units are used, i.e., precipitation, water yield and silvicultural datasets must all be in the same type of units, either SI or English. The United States Forest Service, Rocky Mountain Station will publish WinWrnsHyd (Personal communication, C.A. Troendle) and it should be freely available in late 2005 or 2006.

Paper presented Western Snow Conference 2005

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WRENS HYDROLOGIC REGIONS U. S. A.

1. NEW ENGLAND
2. APPALACHIANS
3. SOUTHEAST
4. ROCKIES
5. NORTHWEST
6. CONTINENTAL
7. CENTRAL SIERRA
8. PLAINS (NO PROCEDURE FOR PLAINS AREA)



U. S. WRENS HYDROLOGIC REGIONS EXTRAPOLATED INTO CANADA



Figure 1. WRENS hydrologic regions in the US and Canada. The extrapolation of regions into Canada was based primarily on similarity of forest types.

Forestry Canada has made some changes to the hydrologic procedures which have been incorporated into WinWrnsHyd as user-selectable options. These are: a) provision to correct winter precipitation for the effect of wind on snow catch in gauges fitted with the commonly-used shields (Goodison, 1981); b) provision to estimate sublimation from the winter snowpack; c) provision to correct precipitation for elevation difference between a watershed and the gauge location; and d) automatic calibration of the model to a watershed with known or estimated annual yield. The calibration option can be used in lieu of, or in addition to, the snow catch and elevation options.

Various versions of computer programs for the hydrology section of the WRENS handbook are currently in use for estimating forest harvesting effects on streamflow in Canada. These use SI units only and have been developed with regrowth equations, precipitation datasets, water yield datasets, and peak flow equations specific to identified forest units in Alberta (WrnsAb2k, WrnsAbFh, WrnsDmi, WrnsFmf, WrnsRmFh,) and Manitoba (WrnsMb2k). Apparently the MS-DOS version (WrnsHyd), or at least the code from it, programmed by Forestry Canada has also been used to some degree by researchers and managers in the United States (Huff, et al., 2000, Huff, et al., 2002).

USING WINWRNSHYD

The principal use for WinWrnsHyd is to estimate the amount of annual yield and peak flow changes that will occur, or have occurred, under various forest harvest scenarios. Both the gross change and the details of the effects of climatic and silvicultural variables on snow accumulation, disposition and evapotranspiration can be examined. The rain and snow dominated procedures were derived from simulated results produced by two models; PROSPER, a plant-soil-water model was used to simulate the rain dominated procedure. WATBAL, a snow melt water balance model was used to simulate the snow dominated procedures. Although the two procedures originate from different models, they function similarly to the flow chart, Figure 2. The major difference between the two is the spatial arrangement of the snowpack in the snow dominated procedure and how that influences water availability to vegetation in cleared and treed areas of a watershed.

Both the rain and snow dominated routines in WinWrnsHyd allow a user to conduct either time-series or snapshot simulations.

Time Series Simulations

Time series simulations are a graphical display or numerical series of water yield increases from one or more hydrologic units of a watershed for a given time period, usually one rotation. They require real or estimated precipitation, plus basal area and tree height data that can be generated as a function of time. The time series procedure has become the standard for long-term planning of the intensity of forest harvest in Alberta and to some degree in Manitoba. Since time series simulations require species-specific growth functions, and site-specific peak flow functions, the Alberta and Manitoba programs cannot be used elsewhere without user modifications. However,

the time series procedure in WinWrnsHyd contains generic basal area and tree height growth functions that can be used in the absence of local ones, but local precipitation data and peak flow analyses must be provided by the user.

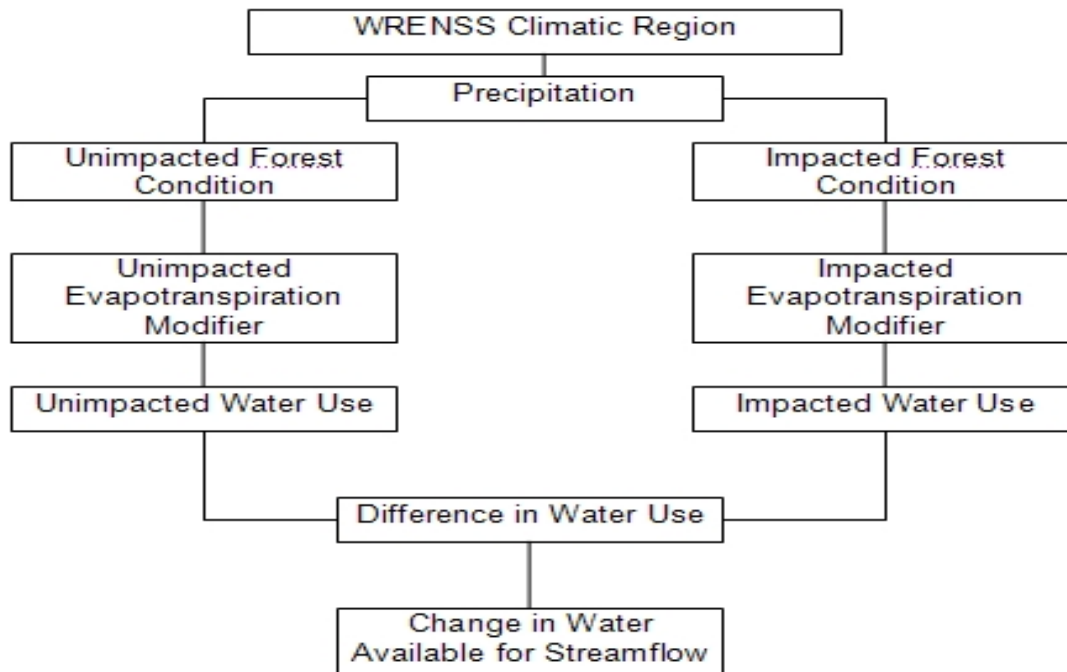


Figure 2. WRENSS flow chart (Adapted from Huff, et al. 2000). The rain and snow dominated procedures function similarly but the precipitation routines in the snow dominated procedure are more complex.

Snapshot Simulations

Snapshots are a description of the water yield of a watershed at a particular silvicultural state and point in time. The original graphical procedures of the WRENSS handbook produced snapshots, as did the Canadian Forestry Service’s WrnsHyd. Current GIS-based forest management models coupled with growth simulators provide silvicultural data at 10-to-20 year increments. The snapshot procedures are particularly amenable for use with these GIS-generated datasets. Local precipitation data must be supplied by the user.

ESTIMATING WATER YIELD CHANGE– RAIN DOMINATED PROCEDURES

The Needle Branch watershed in Oregon, documented in the WRENSS handbook (USEPA, 1980), is used to demonstrate the rain dominated procedure. The user-changeable portions of the procedure are leaf area index (LAI) and rooting depth. Of these, LAI has the greatest influence on water yield, (Figure 3) although rooting depth cannot be ignored. Leaf area index and rooting depth can be calculated as a function of time, (Variable rooting depth is a user-selectable option for time series simulations), or manually entered to test various combinations as to their effect on annual water yield with snap shot simulations (Figure 4).

ESTIMATING WATER YIELD CHANGE– SNOW DOMINATED PROCEDURES

The hydrology portion (Troendle and Leaf, 1980) of the WRENSS handbook (USEPA, 1980) did not contain a snow-dominated watershed to use as an example. Therefore I have created a fictitious one to illustrate the snow-dominated procedure results. The user-changeable portions of the snow-dominated procedure that affect the simulated results are clear-cut size, basal area and tree height regrowth (roughness). In the original WRENSS procedure, wind does not affect snow distribution or loss when clear-cuts are less than 15 tree heights in windward

width. In clear-cuts of width greater than 15 tree heights, regrowth and aerodynamic roughness affect the annual water yield, particularly during the first few years following harvest, as shown in Figure 5.

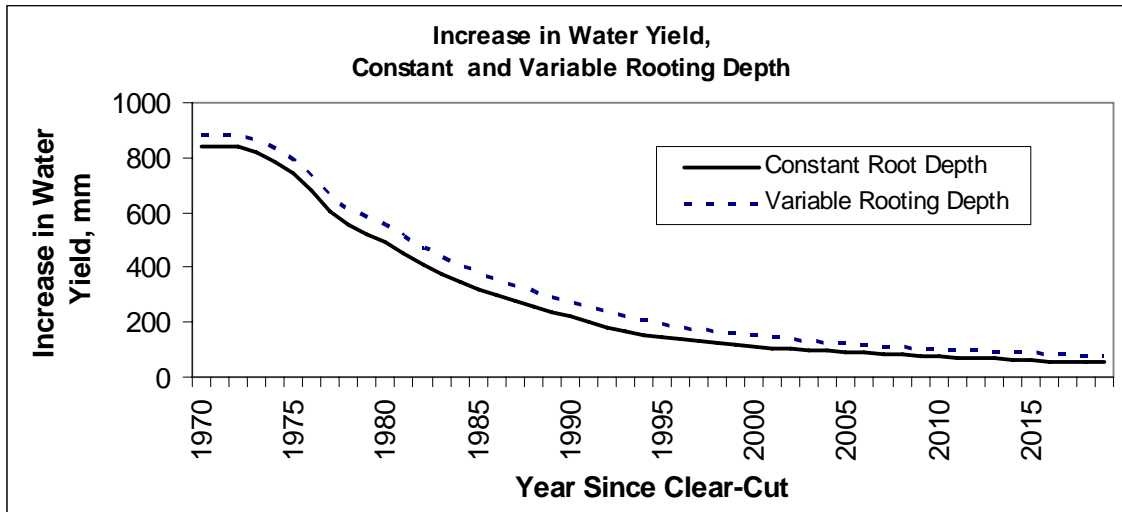


Figure 3. Water yield change, Rain Dominated Watershed, Pacific Northwest WRENSS region. Variable rooting depth, increases annual yield change by about 10% initially, increasing to about 40% at 50 years of regrowth. Constant root depth is 0.918 m. Variable rooting depth is calculated as a linear function of year since clear-cut starting at 0.4 m in 1970, increasing to 1.1 m in 50 years. LAI increases from 1 to 40 over this same 50 years, reducing the annual yield increase from approximately 850 mm to 50 mm.

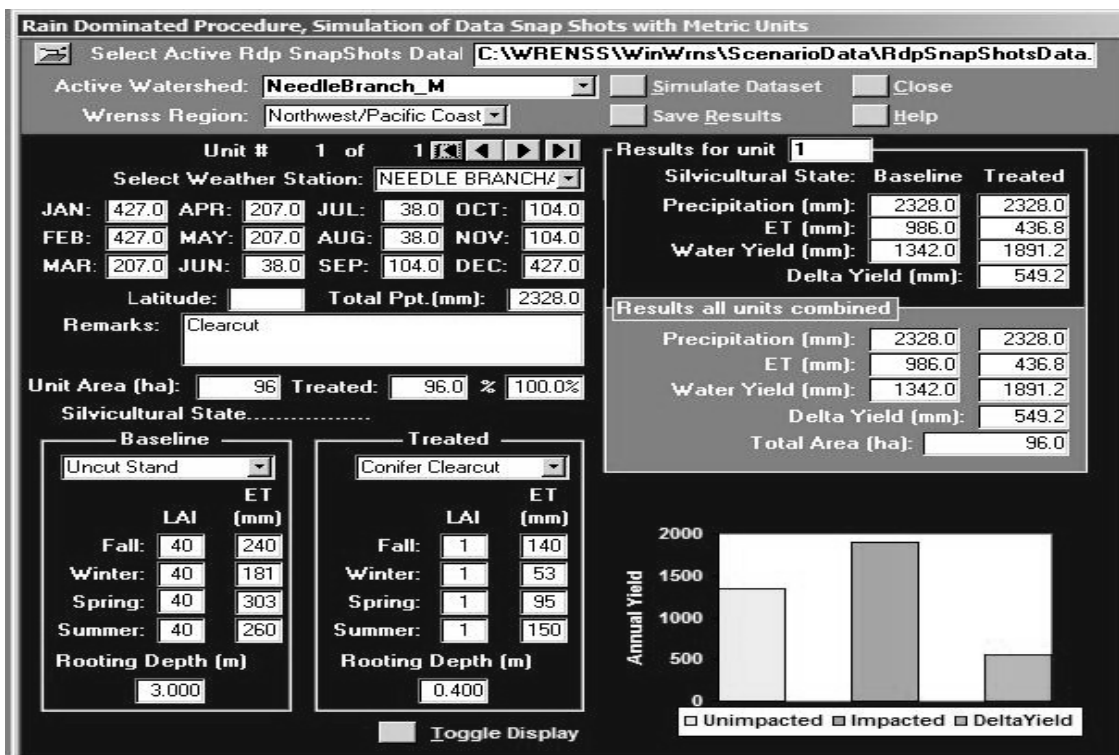


Figure 4. Rain Dominated Procedure snapshot simulation form. Results are displayed in numerical and graphical form as any variable is changed. In this case, rooting depth in the treated portion (clear-cut) has been reduced to the minimum specified for the Northwest/Pacific Coast WRENSS region, i.e., 0.4 m.

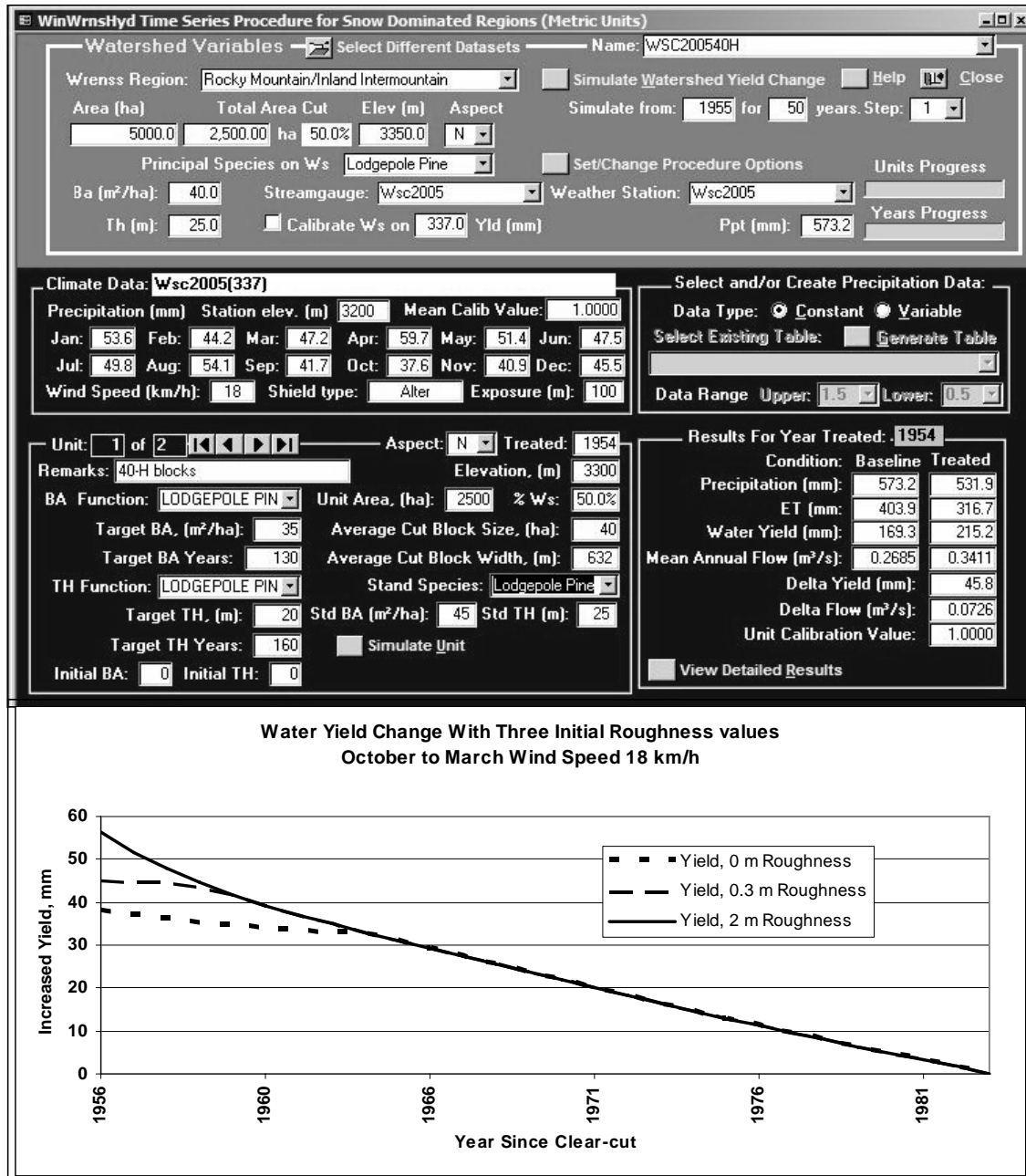


Figure 5. **Top** - time series form, watershed 50% harvested in a number of 40 ha clear-cut 632 m wide blocks. **Bottom** - simulated results. The differing response in the first years after harvest is a result of wind-driven snow scouring and sublimation loss. Snow ablation from wind scour or in situ sublimation can be controlled to some degree by modifying residual roughness height. Wind-driven snow scouring and sublimation will occur and reduce the initial water yield change unless initial roughness or the regeneration

Aerodynamic roughness can be created by leaving slash and other debris on the clear-cut. In the time series simulations, basal area and tree height growth are calculated as a function of time since harvest, and starting values for both can be entered. Initial values for tree height of 0, 0.3 and 2 m were used to simulate aerodynamic

roughness in Figure 5. Once tree height growth reaches a height greater than the depth of the snowpack, snow loss is no longer a factor in determining water yield change.

Basal area and tree heights can be also be entered manually on the snapshot form to simulate the results of various combinations on any year's annual water yield, as shown in Figure 6. To do this, one needs to determine the appropriate values to enter from some other source, such as a forest growth simulator model, or from GIS stand data at discrete time steps as was done by Troendle et al. (2003), at 20-year increments, as shown in Figure 7.

WinWrnsHyd SnapShots ActiveProcedure For Snow Dominated Regions, Metric Units

Select Active Sdp Unit Database Active Database: C:\WRENSS\WinWrns\ScenarioData\SdpSnapshotsData.n

Data Set: Select **Wsc2005_M** Wrenss Region: Rocky Mountain/Inland Intermountain

Sublimation? No Apportion as Rho? Yes Data Set Calibration Value: 1.0000

Gauge Corrections? No Apportion by Aspect? Yes Units Progress: ██████████

Scouring? No

Close Resimulate Save Results Help

Unit Parameters Unit # 1 of 5

Elevation, (m): 3300 Unit Area, (ha): 21.0 Aspect: N

Remarks: 1-H Clear cuts

Precip Stn Selector: Wsc2005AVG1940-1971

Precip (mm) Unit Calibration Value: 1.0000

Jan: 53.6	Feb: 44.2	Mar: 47.2	Apr: 59.7	Annual: 573.5
May: 51.4	Jun: 47.5	Jul: 49.8	Aug: 54.1	
Sep: 41.7	Oct: 37.6	Nov: 40.9	Dec: 45.5	

Wind Speed (km/h): 18 Shield: Alter Exposure (m): 100

Tree Height (m): 25.0 Unit Species: Lodgepo

	Unimpacted	Impacted
Toggle Results Display	Percent Cut 0.0%	50.0%
Simulate Unit	Target Ba (m ² /ha) 45.0	45.0
	Actual Ba (m ² /ha) 45.0	45.0
	Area Cut (ha) 0.0	10.5
	Ba In Cut (m ² /ha) 0.0	0.0
	Roughness Height (m) 25.0	0.0
	Windward Width (m) 0.0	25.0
	Block Size (ha) 0.0	0.2

Precipitation corrected for gauge catch (mm)

Jan: 53.6	Feb: 44.2	Mar: 47.2	Apr: 59.7	Annual: 573.2
May: 51.4	Jun: 47.5	Jul: 49.8	Aug: 54.1	
Sep: 41.7	Oct: 37.6	Nov: 40.9	Dec: 45.5	

Unimpacted Impacted

	100% F	0% C	50% F	50% C	Composite
Seasonal Precipitation, mm					
Season (1)	222	222	150	293	222
Season (2)	206	206	139	272	206
Season (3)	146	146	146	146	146

Uimp - limp

	100% F	0% C	50% F	50% C	Composite
Evapotranspiration, mm					
Season (1)	35.2	21.1	35.2	21.1	35.2
Season (2)	143	158	119	170	143
Season (3)	225	96.9	225	96.9	225

Water yield, mm

	100% F	0% C	50% F	50% C	Composite
Season (1)	187	201	115	272	187
Season (2)	62.4	48.1	20.4	102	62.4
Season (3)	-80	48.7	-80	48.7	-80

Impacted 239 Unimpacted 169 Delta Yld 70.1

Figure 6. Form for simulating snapshots of a watershed at a particular point in time, detailed results view. Values in most fields can be changed and the simulated results will be displayed immediately. Results may be saved for later analysis or to combine and display as a pseudo time series, e.g., Figure 7.

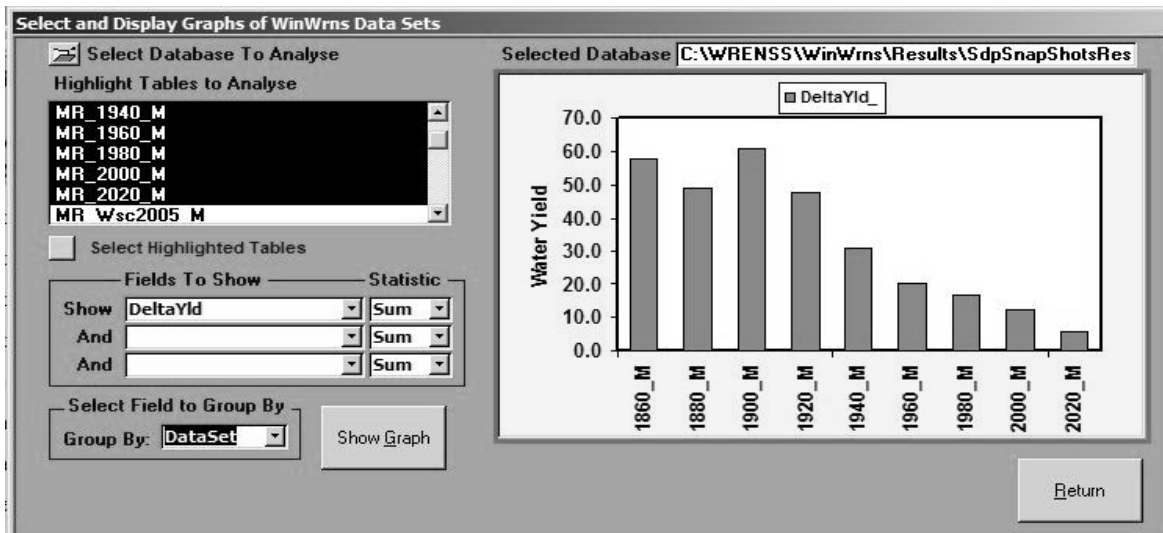


Figure 7. Results of simulation of datasets in 20-year time steps. Data from Troendle et al., 2003. (These results were obtained while the WinWrnsHyd program was still under development and should not be regarded as either correct or final.)

CONCLUSIONS

The simulation of annual water yields is the primary use for the WinWrnsHyd procedure. However, it can also be used as a teaching tool to elucidate the effect of changing single or multiple variables. Time series of water yield can be simulated with differing initial regrowth conditions. The snapshot procedure provides rapid visual and numerical display of the effect of changing any of the input data variables.

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