



**U. S. Arid Land Agricultural Research Center
Maricopa AZ**

Predicting Irrigation-Induced Furrow Erosion with WinSRFR

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**Agricultural
Research
Service**



Magnitude of furrow-irrigation induced erosion

In the U.S., the greatest is in the Pacific Northwest.

Sojka et al (2007) report from the literature: 65 tons/acre in 1 hour (Israelson *et al*, 1946); 22 tons/acre in a 24-hour irrigation (Mech, 1959); 1/2 to 12 tons/acre per irrigation in Wyoming (Koluvek *et al*, 1993)

Upper quarter of a field can lose 3 to 30 times more soil than the average

Soil from the upper end of a field is often deposited in the lower portions, including infertile subsoil

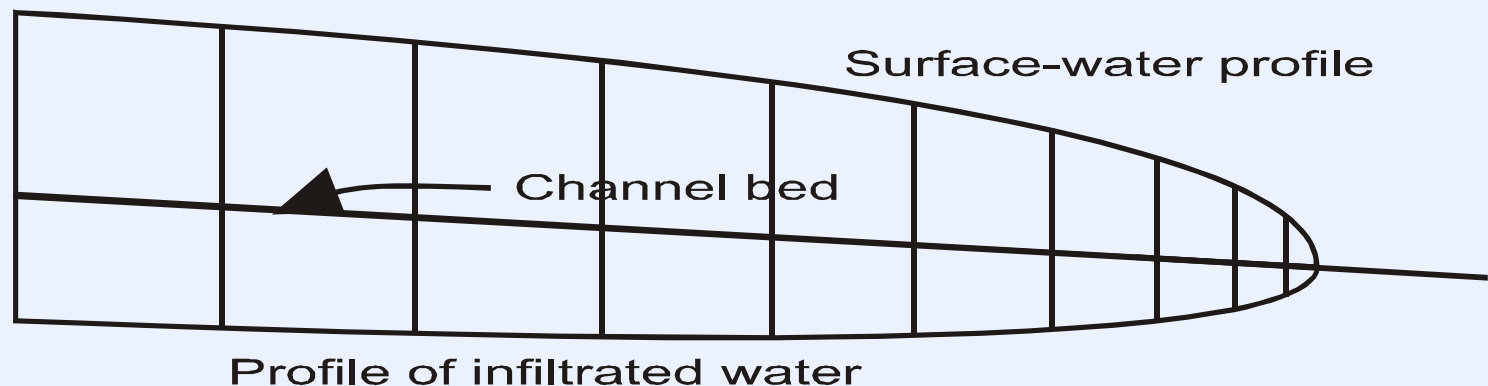
Carter (1985, 1986, 1993) reports 75% of Idaho furrow-irrigated fields lost entire A horizon in the upper reaches together with a 2 to 4-fold increase in “topsoil” at the lower ends, reducing productivity by 25% over pre-erosion values, and reducing yields by 20 – 50% in areas with lost top soil

Modeling can lead to rational recommendations for design and management of surface irrigation

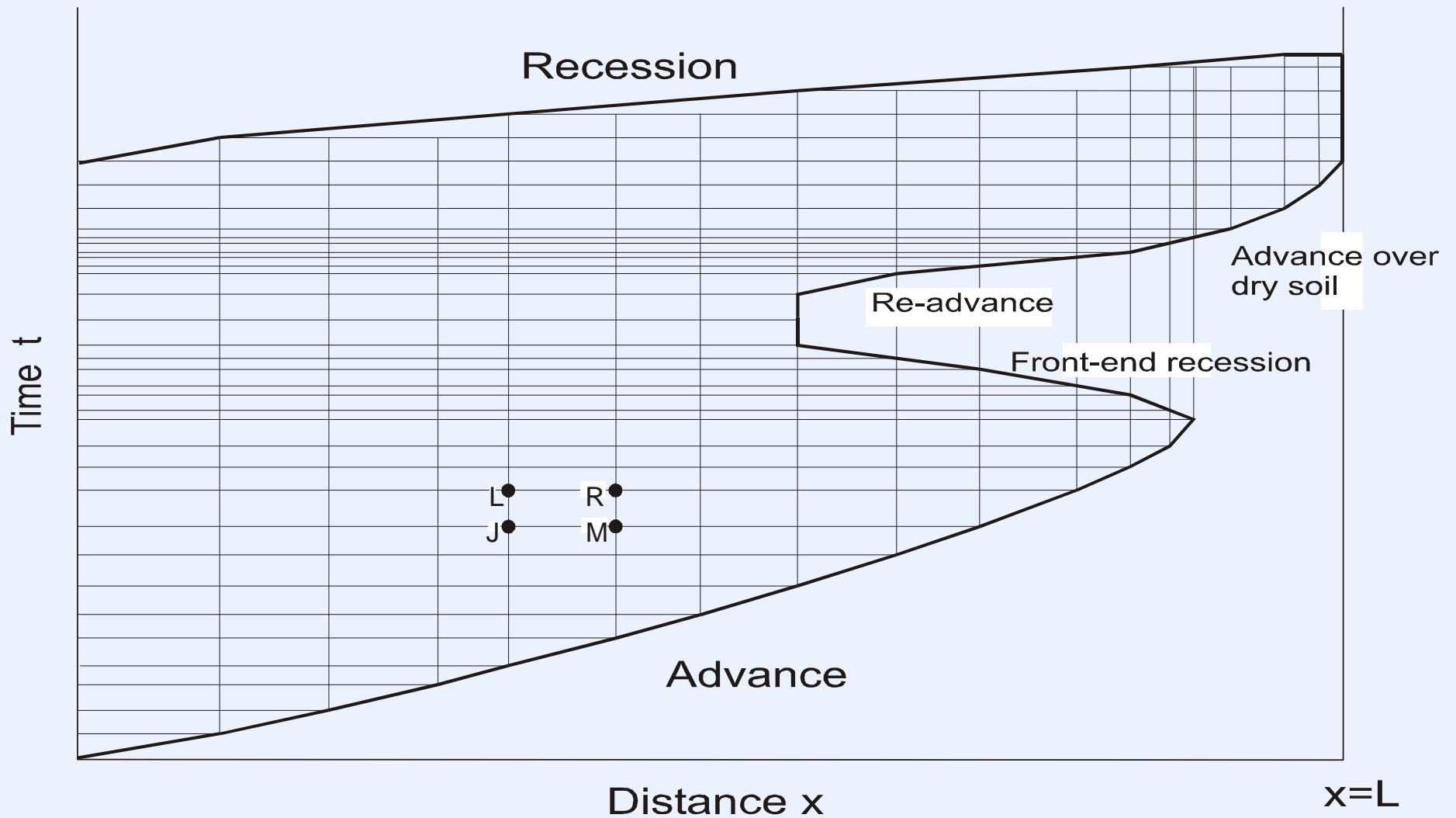
Sojka, R.E., Bjorneberg, D.L., Trout, T.J., Strelkoff, T.S., Nearing, M.A. 2007. The importance and challenge of modeling irrigation-induced erosion, *Journal of Soil and Water Conservation*, 62(3):153-162

Simulation of furrow flow

- Subdivide surface stream and infiltration profile into cells

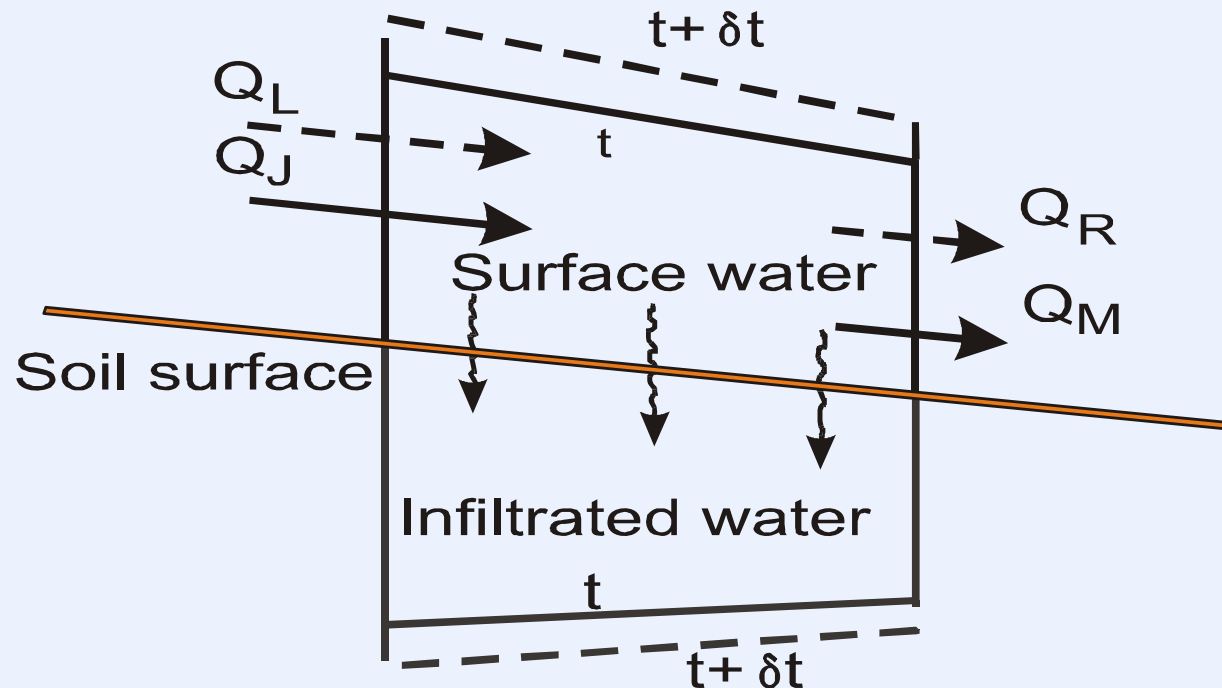


Mass and momentum conservation equations written for the cells are simultaneously solved over a sequence of time lines



Mass conservation of water

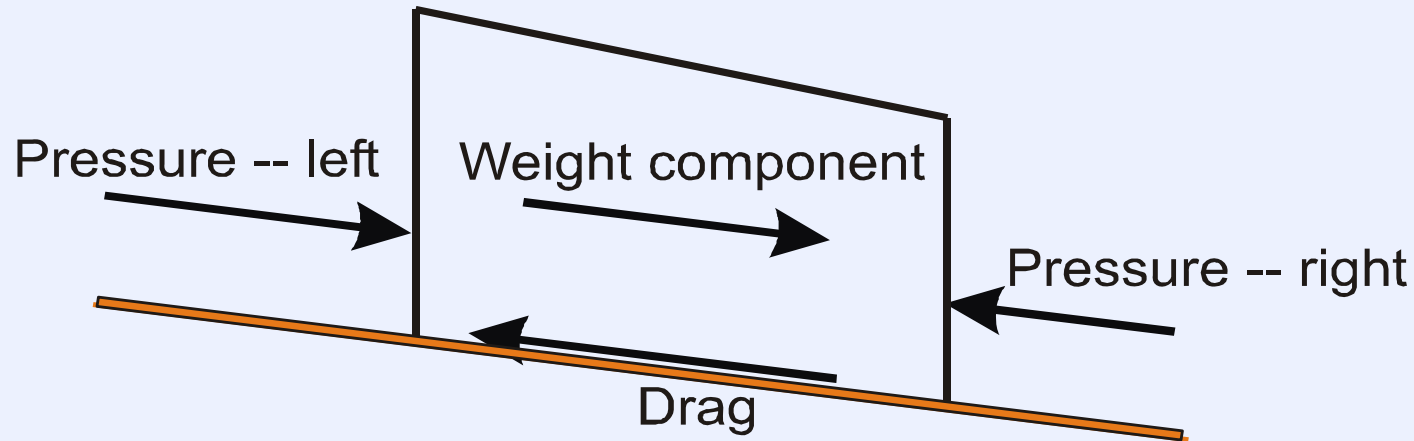
Empirical formulas define the infiltration (in lieu of a solution of the Richards equation)



Leads to an equation in terms of depth and flow rate at cell boundaries

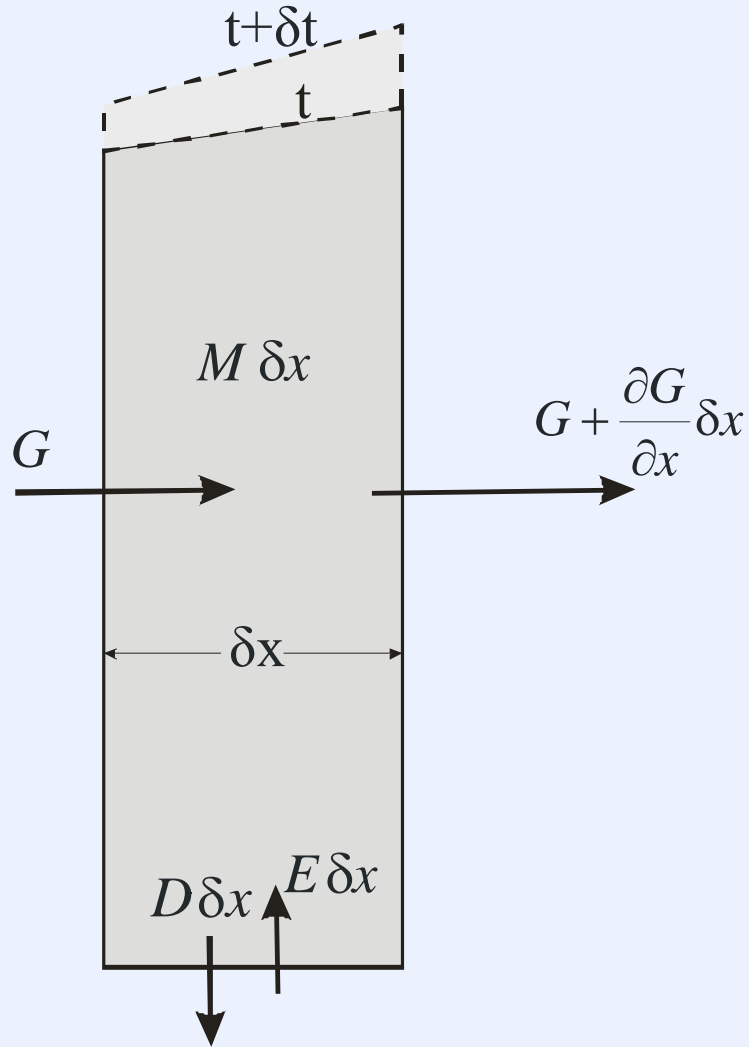
Forces entering into momentum equation

Empirical formulas define the hydraulic drag in terms of cross section, flow rate and geometry of roughness and vegetation



Leads to an equation in terms of depth and flow rate at cell boundaries

Following USDA, 1995 (WEPP), Fernandez, 1997,
 sediment-mass conservation assumed as a sequence of
 steady states



$$\frac{dG}{dx} = E - D$$

$$E = E_p W \left(1 - \frac{G}{T_c} \right)$$

$$E_p = K_r (\tau - \tau_c)$$

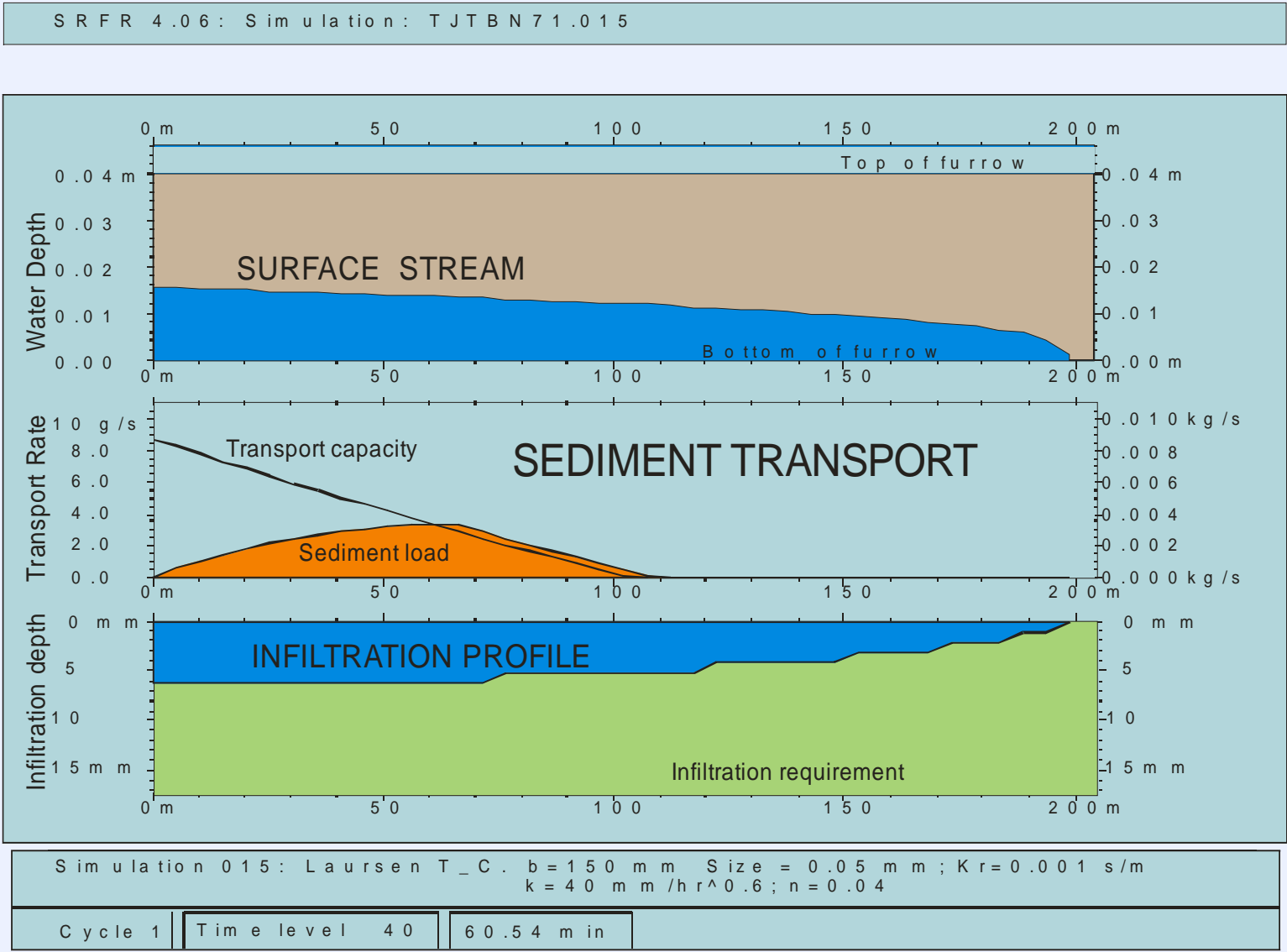
$$D = \frac{G - T_c}{\frac{y/2}{w/V}}$$

Input site-specific soil erodibility, K_r ,
 critical shear, τ_c

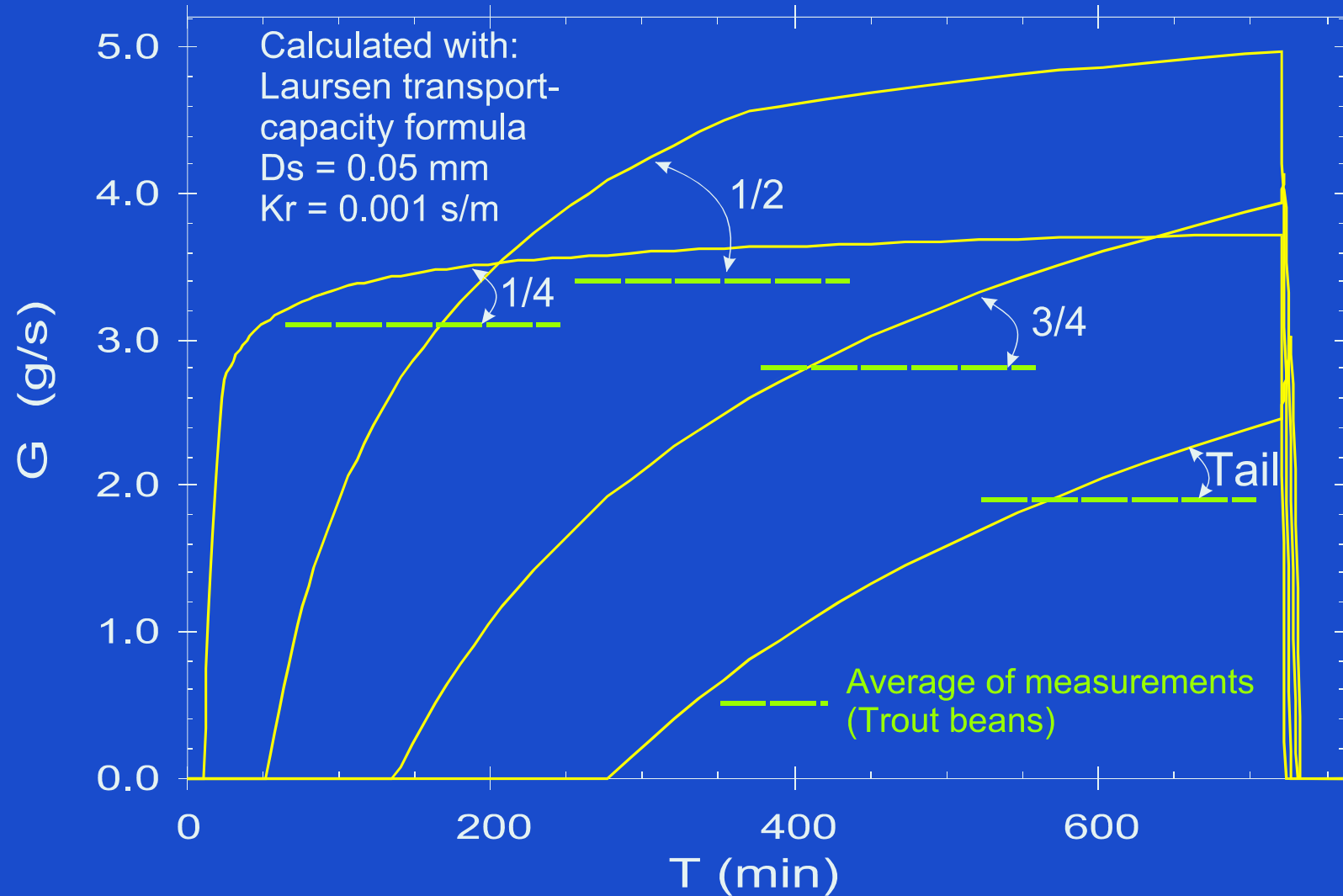
Input site-specific representative particle
 size, density

Empirical universal transport capacity
 formula, T_c (order of magnitude deviation)

Frame of animation from SRFr simulation of erosion, transport, deposition at 61 minutes

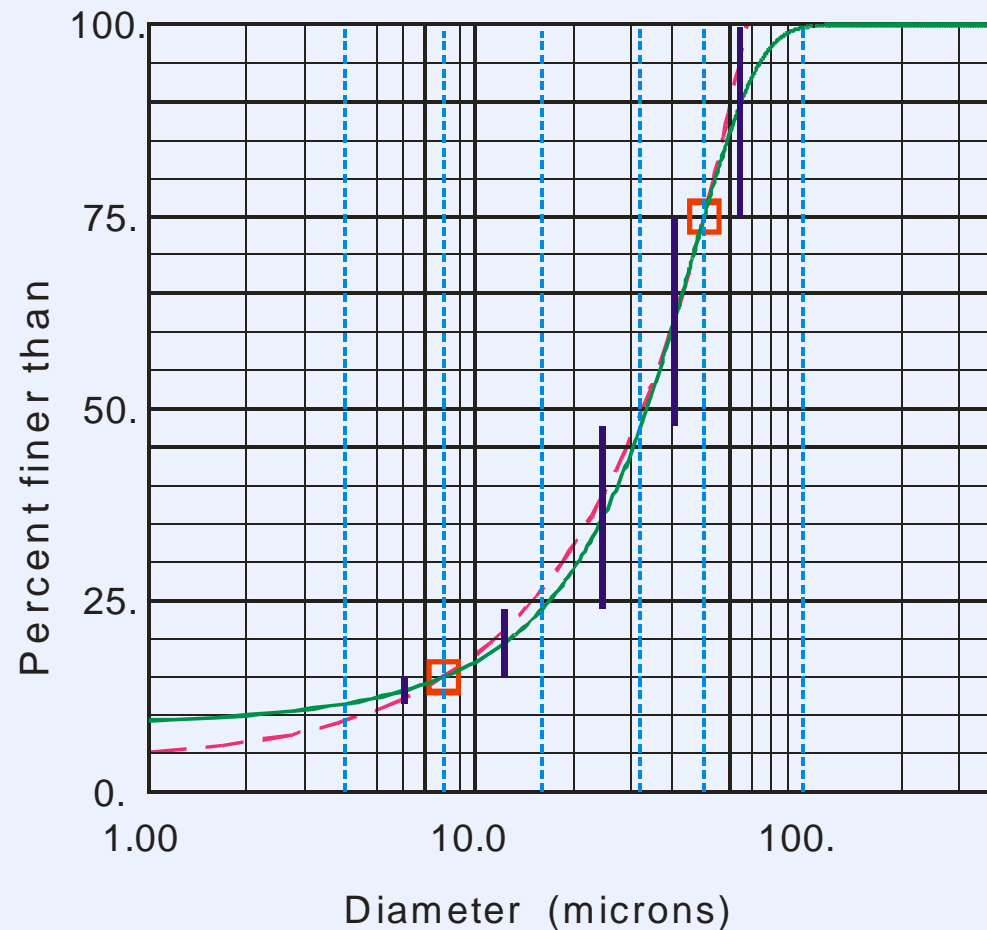


Sample comparison with field data: Hydrographs of Sediment Load

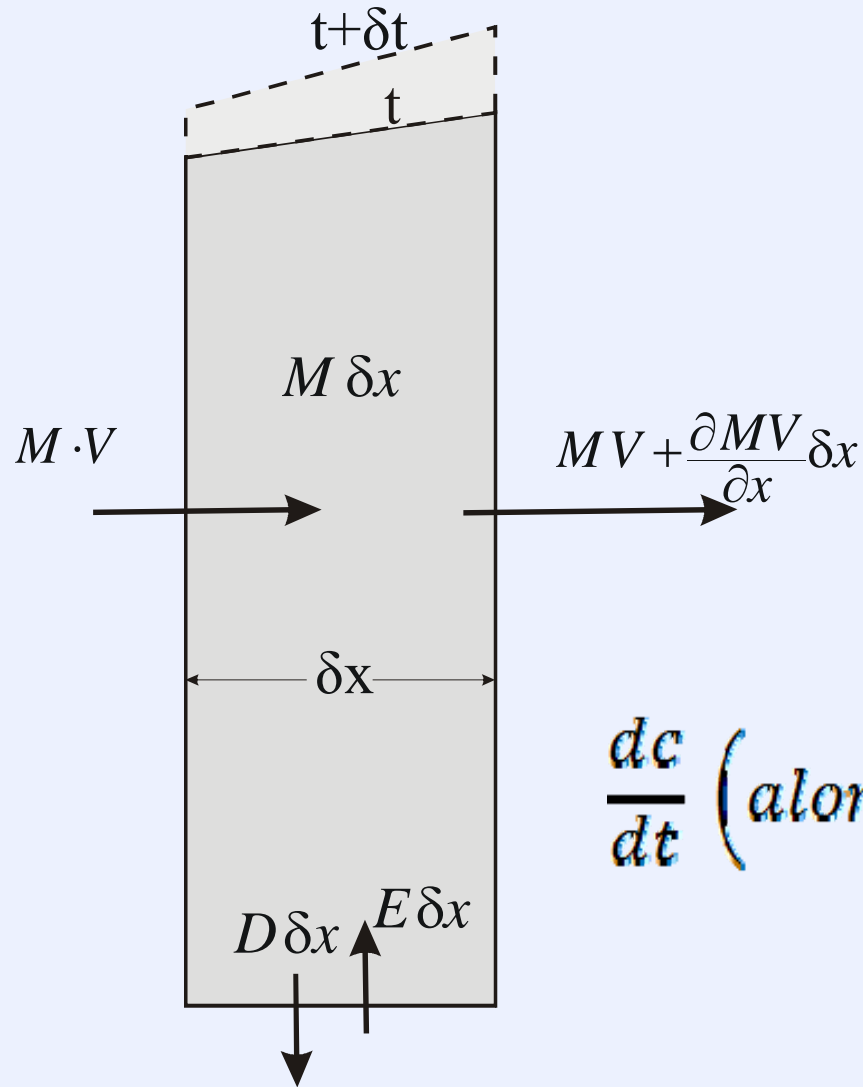


Simulation: TJTBN71.015
File: TJTBn71L.cdr

Continuous distribution fitted to field data:
(Red squares: 25% sand, 60% silt, 15% clay)
magenta: straight line fit; green: Gauss normal



Recognize unsteadiness



Mass conservation:

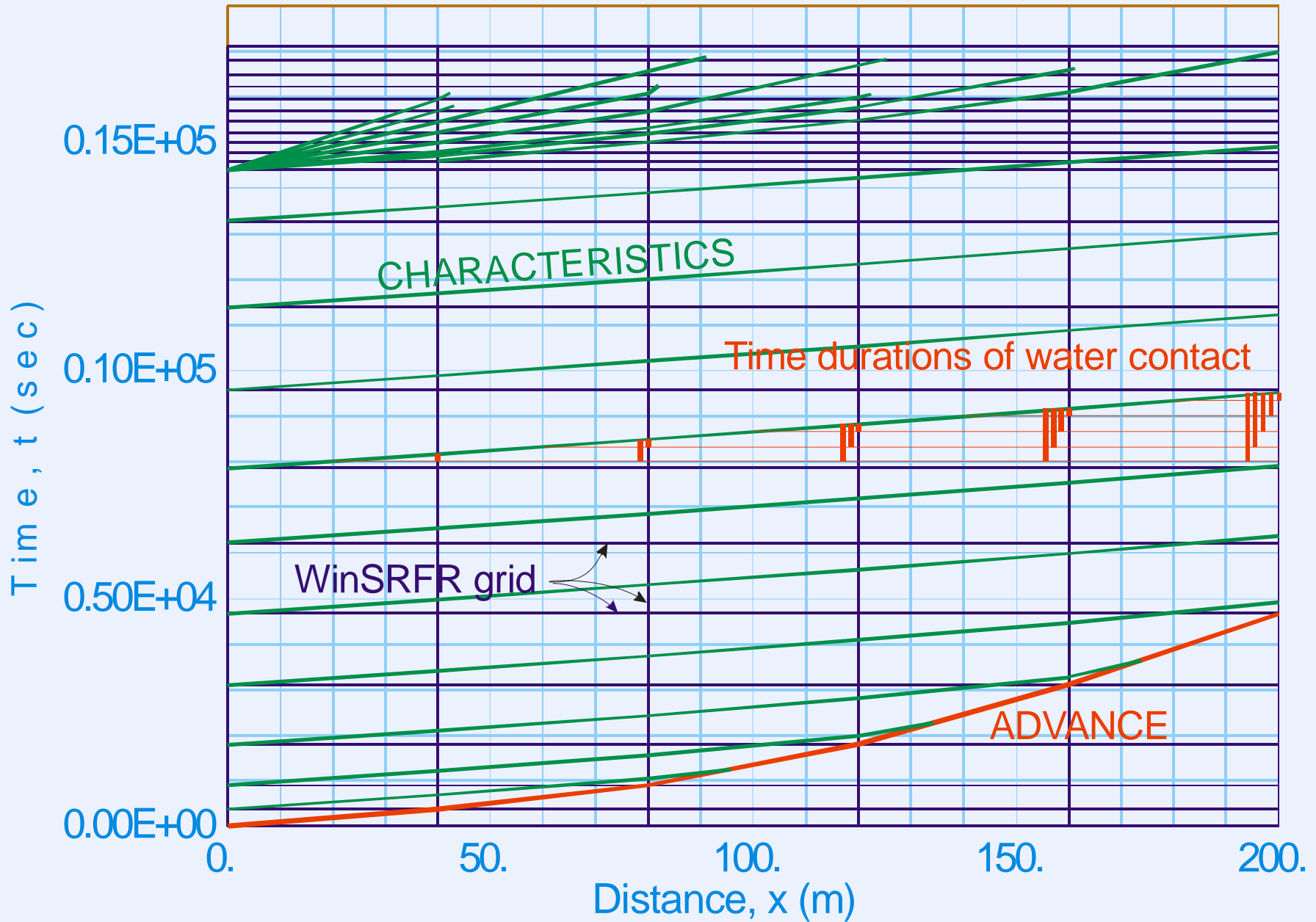
$$\frac{\partial M}{\partial t} + \frac{\partial(MV)}{\partial x} = E - D$$

$$M = A c$$

Leads to Characteristics:

$$\frac{dc}{dt} \left(\text{along } \frac{dx}{dt} = V \right) = \frac{E - D}{A} + c \frac{\partial A_z / \partial t}{A}$$

ADVECTION-EQUATION CHARACTERISTICS

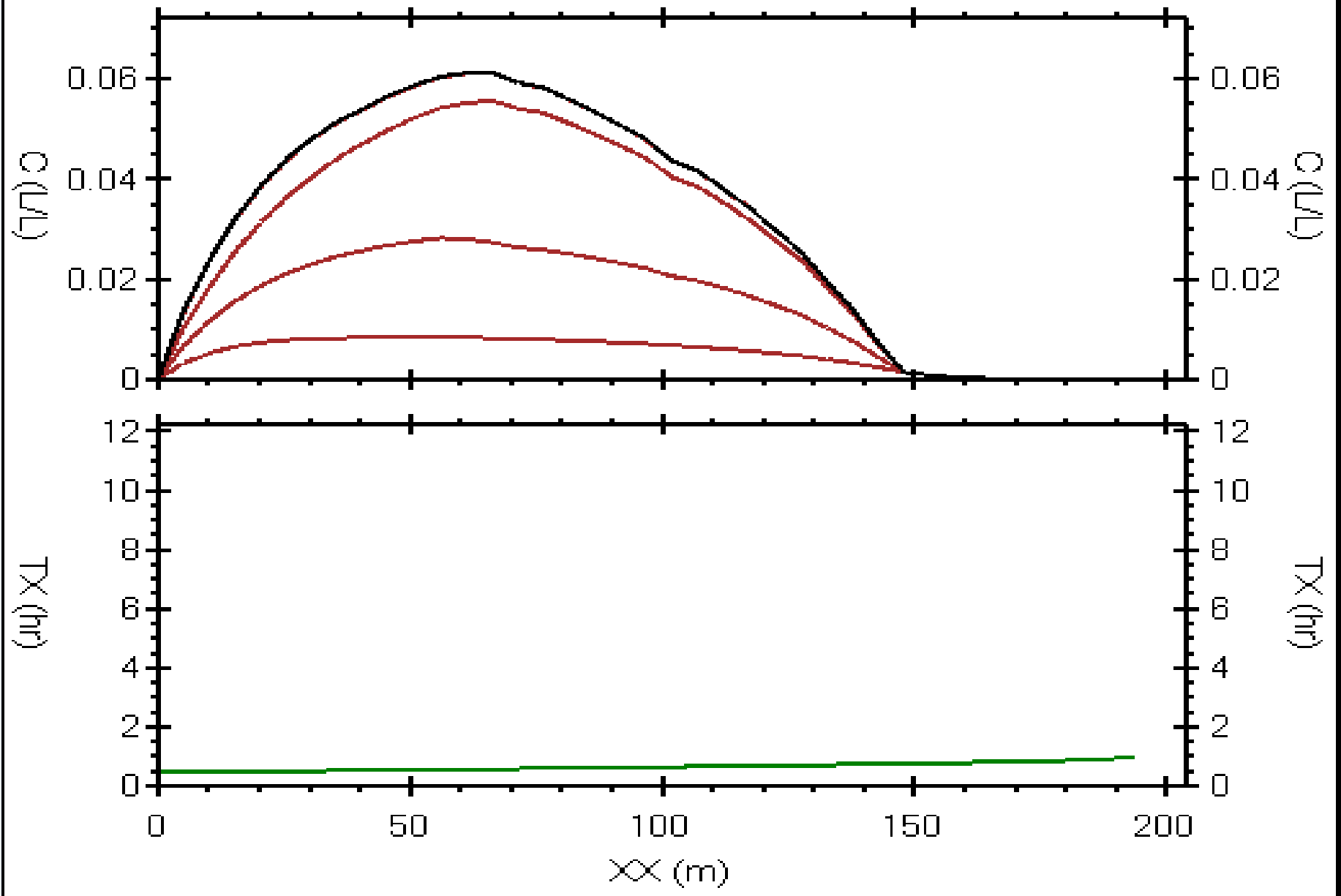


WinSRFR erosion component:

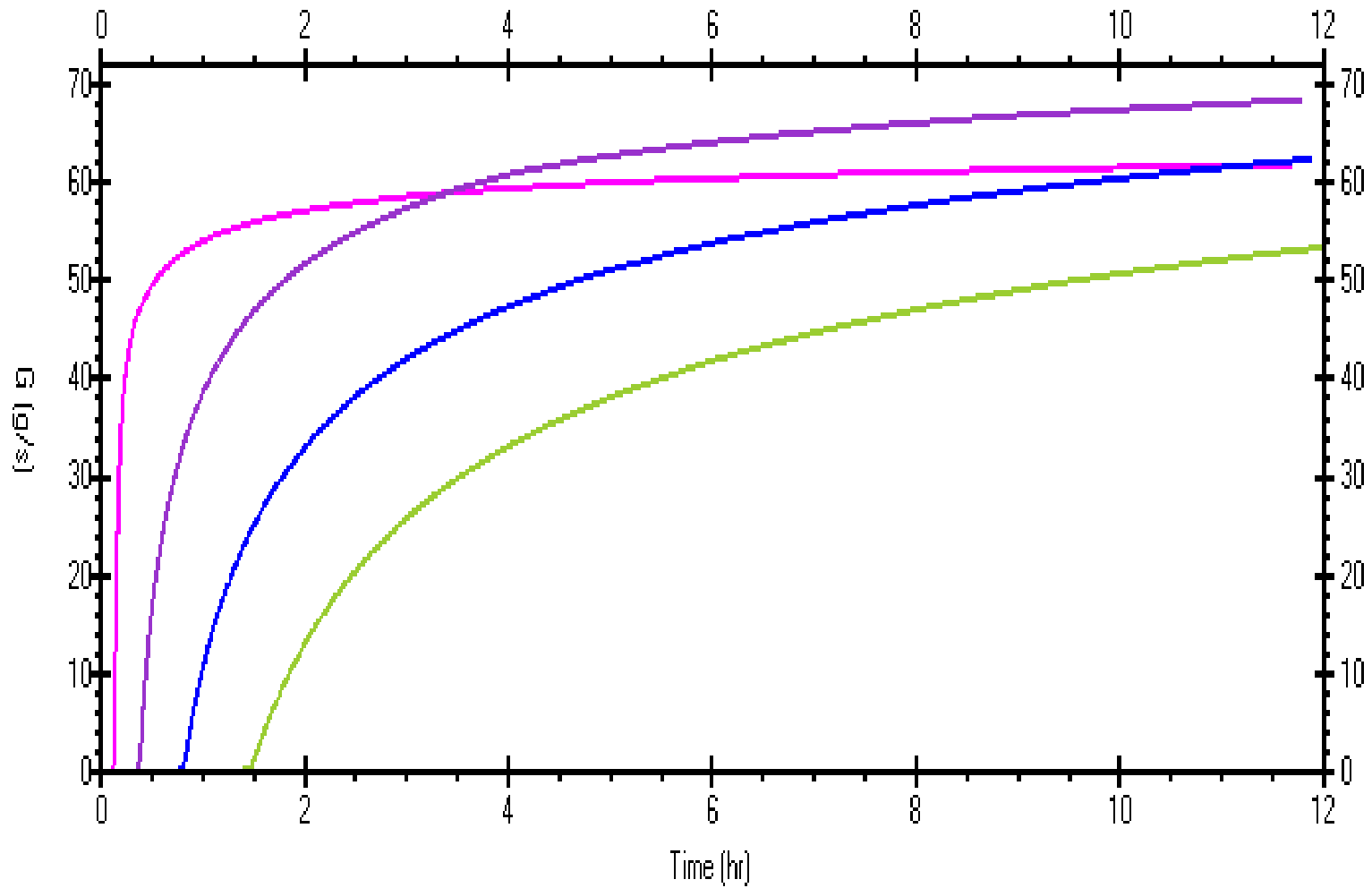
- Calculates theoretical continuous particle-size distribution based on % sand-silt-clay in field.
- Determines entrainment for each size fraction, accounting for the phenomenon of shielding – large particles, too heavy to be entrained, shielding smaller ones underneath.
- Calculates transport capacity of the flow and the transport of each fraction; added up for hydrographs of total load.
- Calculates total deposition as a function of location in furrow, $D(x)$

LINEAR. COARSE

Characteristic 26 - Sediment Concentrations



G Hydrographs - G(X,T)



- G [X=0 m]
- G [X=51 m]
- G [X=102 m]
- G [X=153 m]
- G [X=204 m]

WinSRFR 3.0.11 - Furrow Simulation

File Edit View Simulation Help

Farm: Event Analysis Examples, Field: Tests
 Folder: Irrigation Simulations, Simulation: Elliot-Walker (Two-Point) Analysis - Trapezoid Furrow

Erosion

Sediment Components

	Retained (%)	Sieve Size (microns)	Spec. Grav.
▶	25	50	2.65
	60	8	2.65

Edit Sand / Silt / Clay Sediment Components Table ...

Particle Size Distribution

Resolution Coarse (5)

Fit Piece-Wise Linear

Irrigation Water

Temperature 14 °C

Kinematic Viscosity 1.17e-06 m²/s

Soil Erodibility

DR = KR * (Tau-TauC)^{Beta} TauC: Critical shear stress

KR 0.00234 TauC 0.02097 N/m²

Beta 1

Compute TauC & Beta

Simulation World System Geometry Soil Crop Properties Inflow Management **Erosion** Execution Results

===> Proceed down these tabs verifying data is correct for your field. ===> User Level: Advanced

WinSRFR 3.0.11 - Furrow - Erosion Parameter Estimation

File Edit View Evaluation Help

Folder: Irrigation Evaluations, **Farm:** Event Analysis Examples, **Field:** Tests
Analysis: Elliot-Walker (Two-Point) Analysis - Trapezoid Furrow

Erosion

Sediment Components

	Retained (%)	Sieve Size (microns)	Spec. Grav.
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	60	8	2.65

Edit Sand / Silt / Clay Sediment Components Table ...

Particle Size Distribution

Resolution: Coarse (5)

Fit: Piece-Wise Linear

Irrigation Water

Temperature: 14 °C

Kinematic Viscosity: 1.17e-06 m²/s

Erosion Measurements

CG_m: 89 g/l

At: Time: 3 hr

Distance: 156.25 m

Soil Erodibility

DR = KR * (Tau-TauC)^{Beta} TauC: Critical shear stress

KR: 0.00234 TauC: 0.02097 N/m²

Beta: 1

Event World System Geometry Soil Crop Properties Inflow **Erosion** Execution Results

Results are available; View using the Results tab User Level: Advanced

Collaboration

Modeling: Bert Clemmens, Supervisory Research Hydraulic Engineer, Center Director (ARS, U.S. Arid Land Agricultural Research Center, Maricopa, AZ)

Laboratory Data and Field Verification: Dave Bjorneberg, Research Leader (ARS, Northwest Irrigation and Soils Research Laboratory, Kimberly, ID); Bert Clemmens

Programmer: J. L. Schlegel

IT: Bob Strand, Robert LaMorte