KINEROS2 A DISTRIBUTED KINEMATIC RUNOFF & EROSION MODEL:

Major model components and limitations

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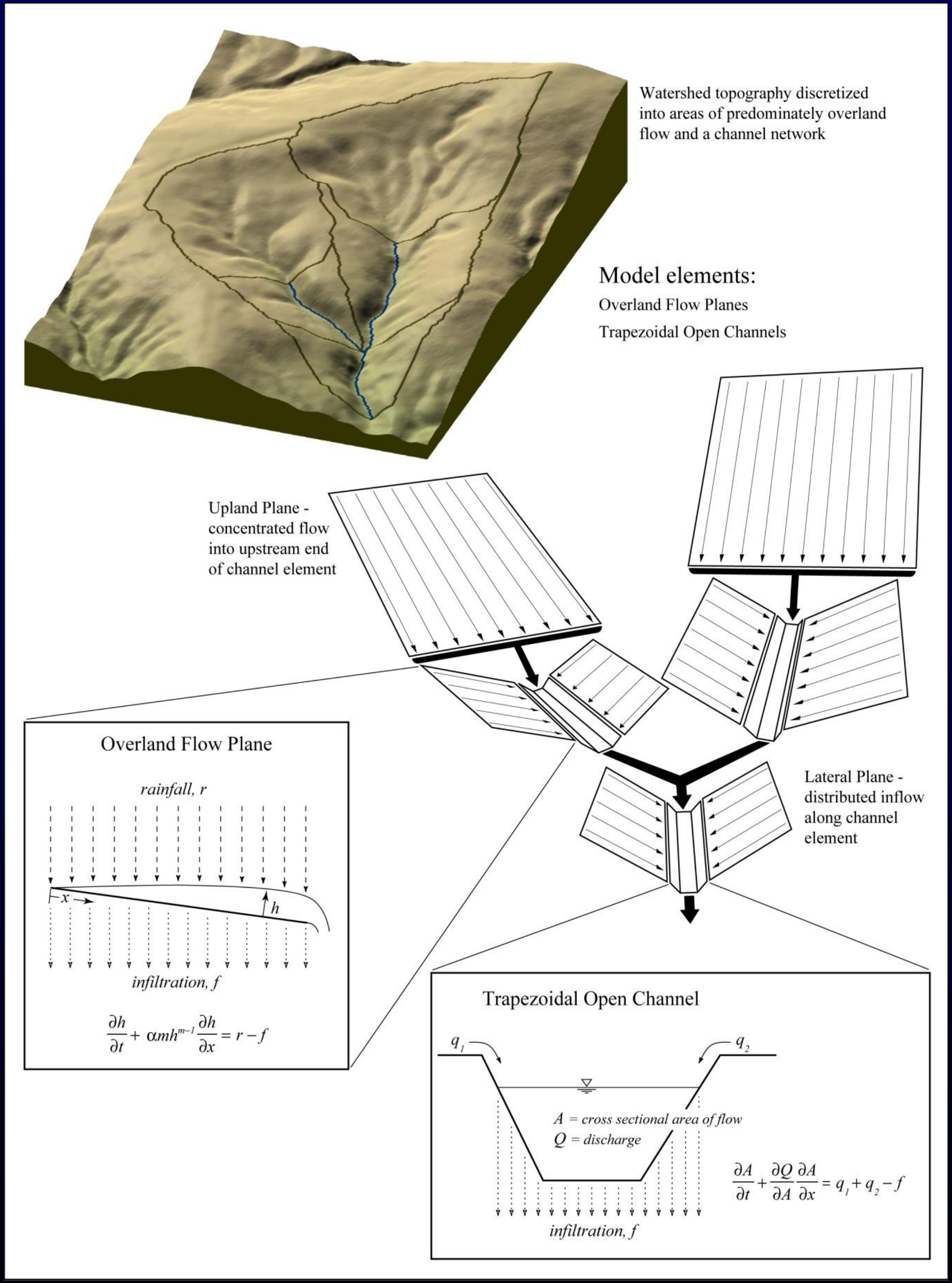
SedHyd

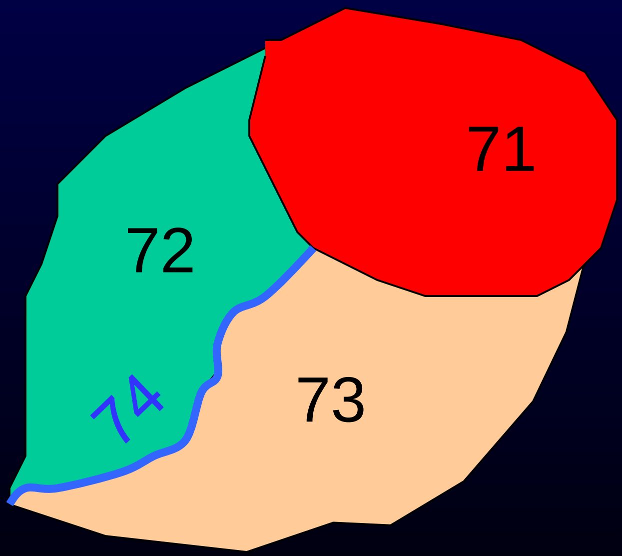
OVERVIEW

- Background
- Model Features
- Sensitivity
- Flood Forecasting
- Model Limitations
- Conclusions

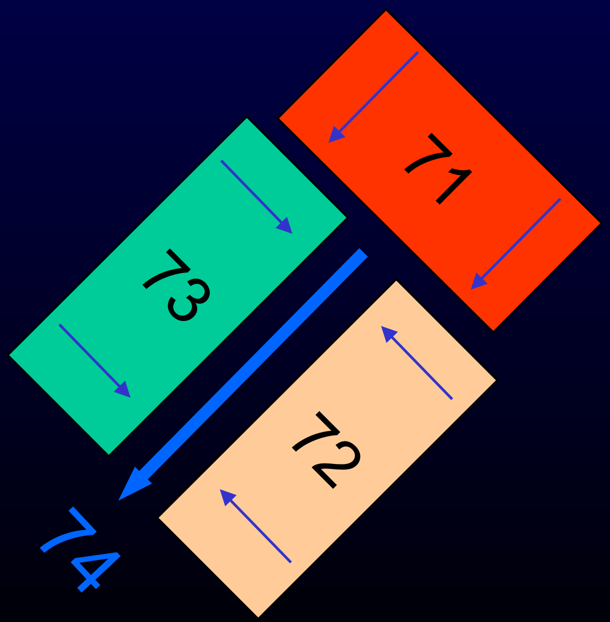


Kinematic Runoff and Erosion Model (KINEROS2)

- Event-based (< minute time steps)
- Distributed: physically-based model with dynamic routing – both for overland flow and erosion
- Has been used in urban environments
- Hydrology, erosion, sediment transport (plus N&P with OPUS version)
- Usually applied to smaller watersheds (< 100-200 km^2)

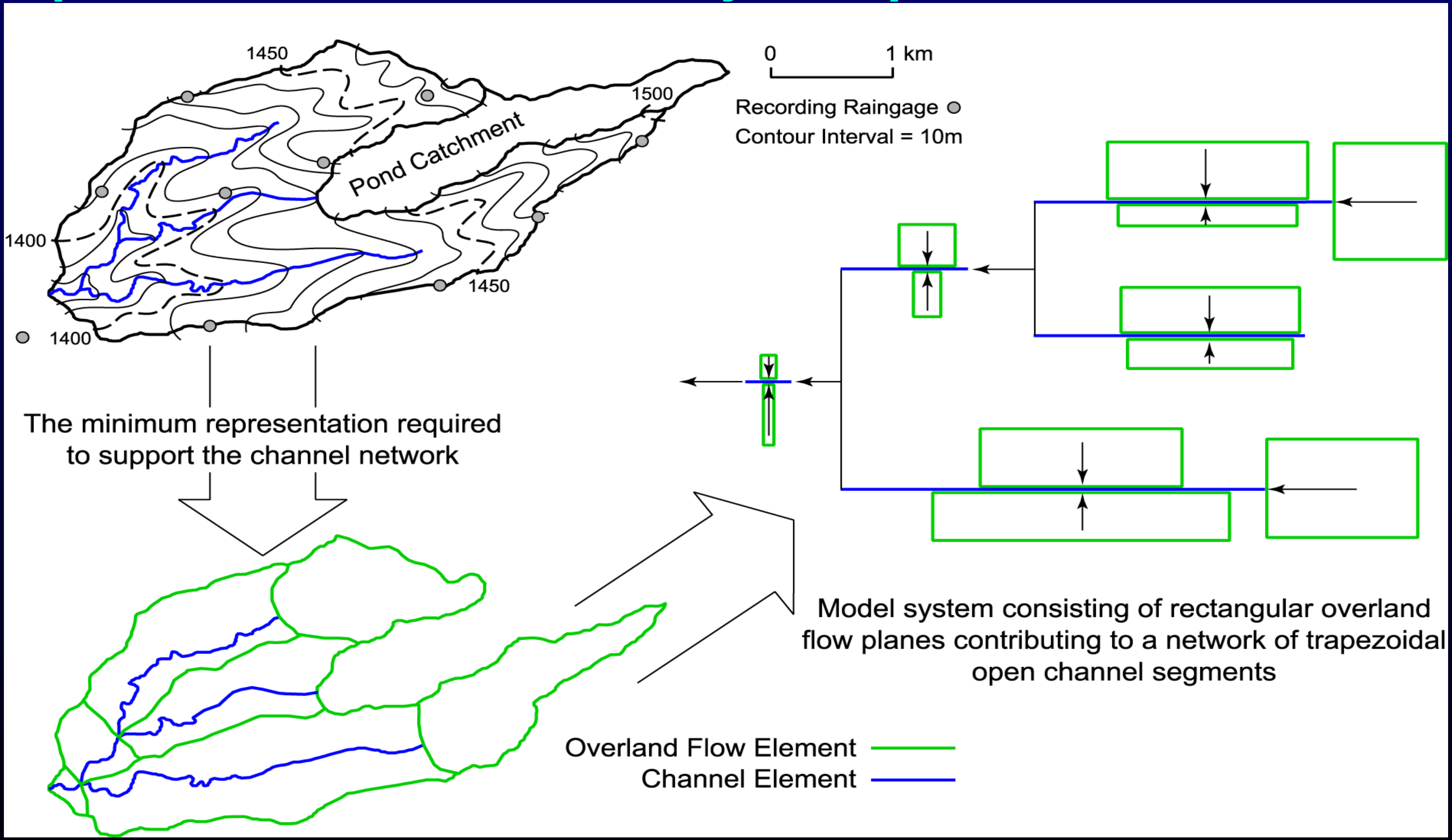


Abstract Routing Representation



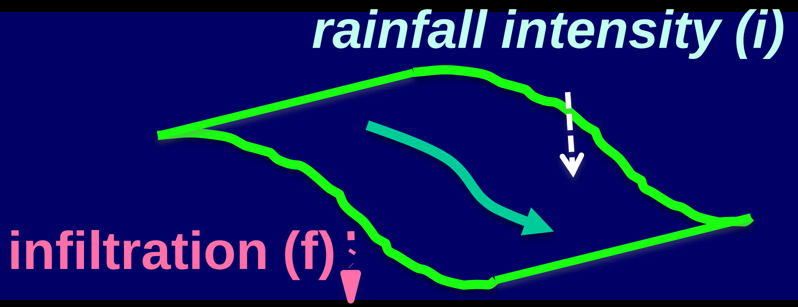
K2 FEATURES

- Approx. watershed by cascade of overland flow elements, channels, impoundments
- Space-time rainfall intensity interpolation

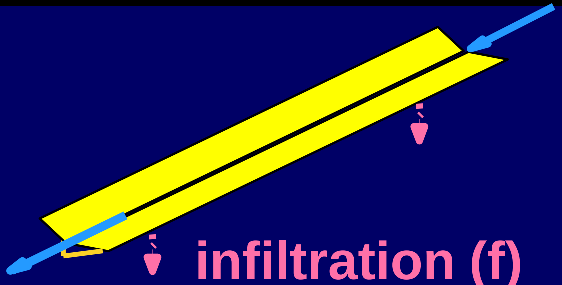


K2 Model Element Types

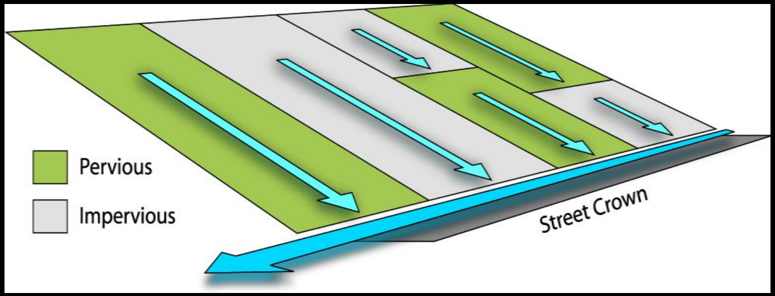
- Overland Flow Element
  - Planar or curvilinear
  - Multiple - cascading



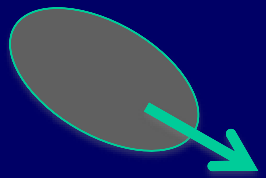
- Channel - Trapezoidal
  - Simple or compound



- Urban Element
  - Flow & Channel (1/2 street)



- Pond Element
  - Geometry +
  - Outflow rating

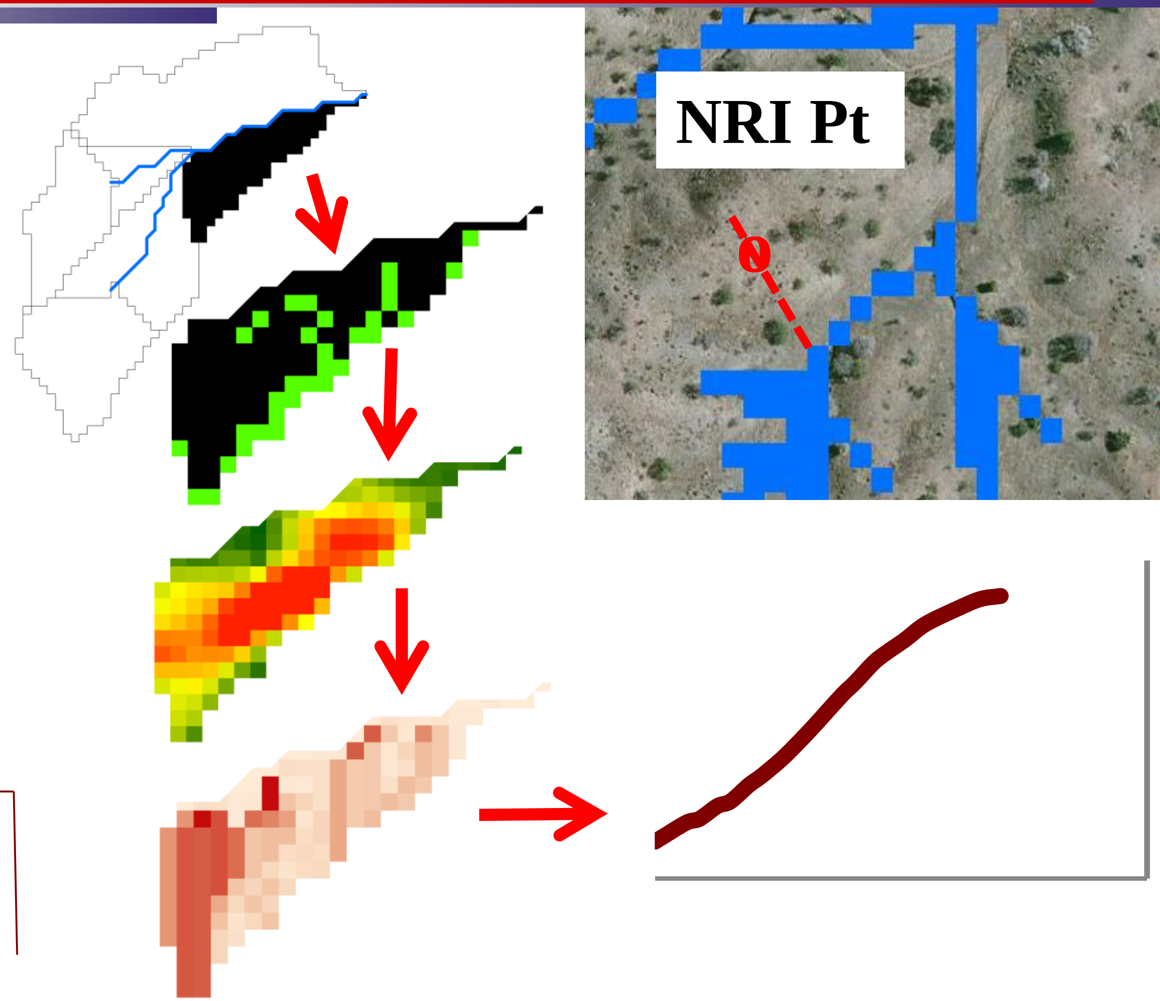


- Injection Element
  - Introduce a known discharge

Representative Slope Profile and Flow Length

$$S_i = \frac{\sum_{p=1}^{n} s_{pi} * k_p}{\sum_{p=1}^{n} k_p}, \quad k_p = a_p * l_p$$

- Calculate a weight grid for every cell on the hillslope
- Calculate a weighted slope for each cell - S_i



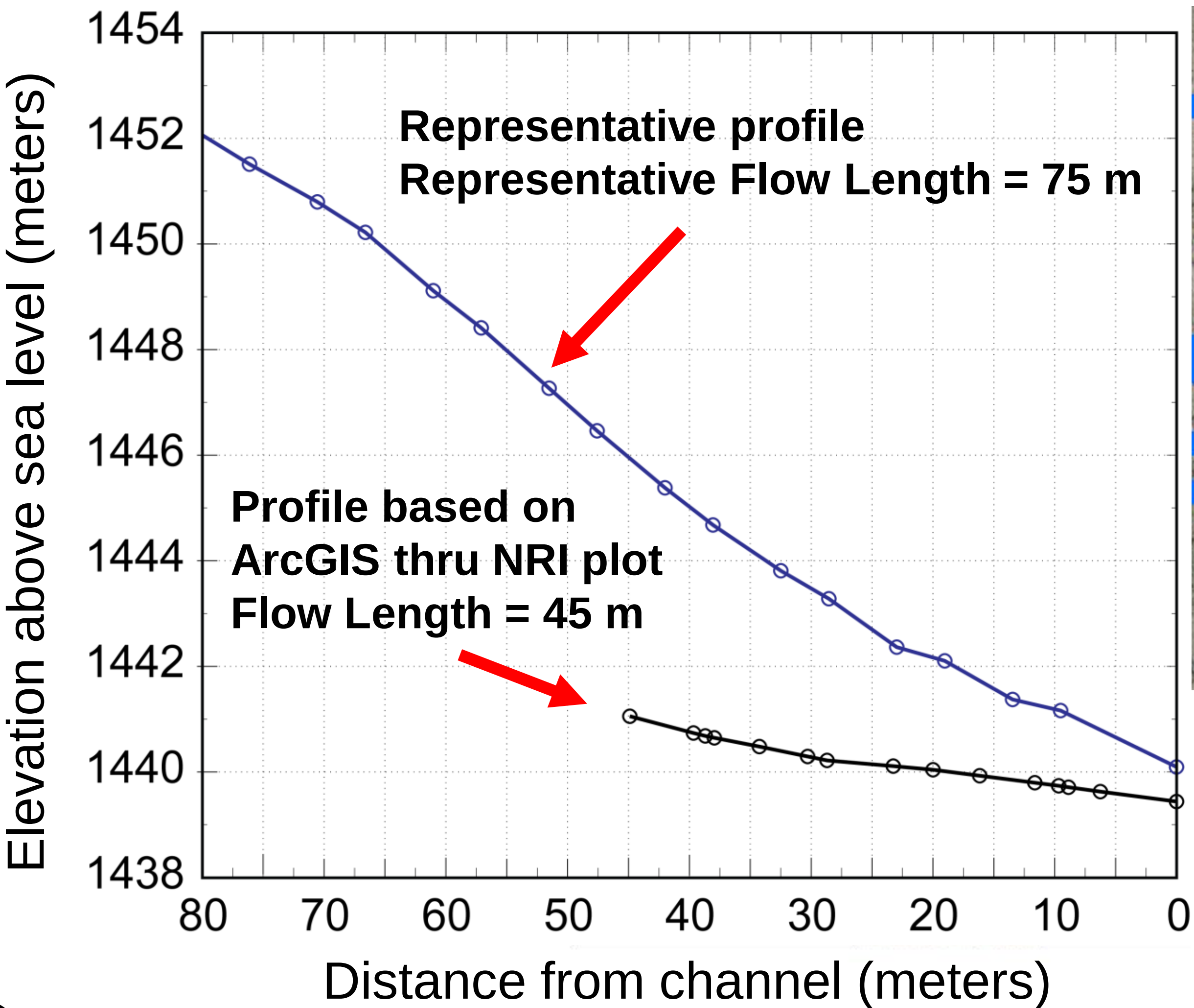
$$L_r = \frac{\sum_{p=1}^{n} l_p * a_p}{\sum_{p=1}^{n} a_p}$$

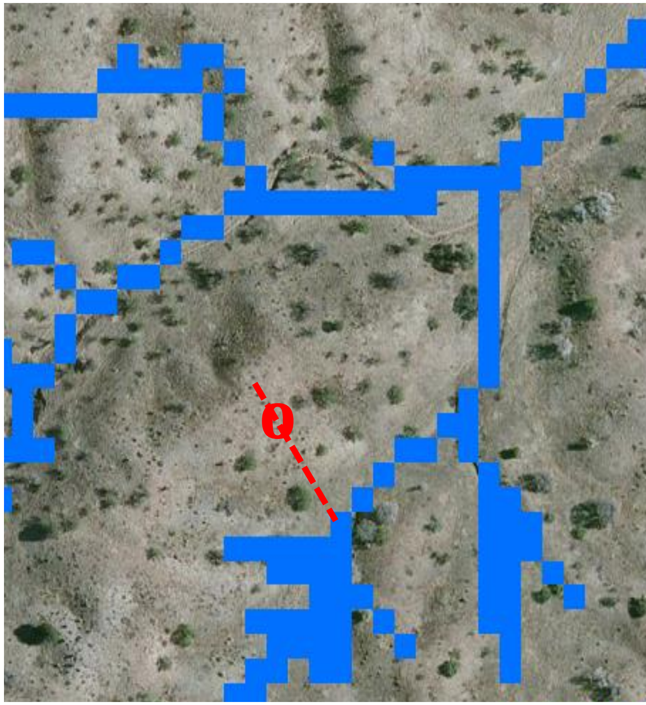
- Calculate a weighted length for each flow path
- L_r is the representative flow length

(Flanagan et al. 2011)

ARS USDA

Hillslope profiles from DEM at NRI point

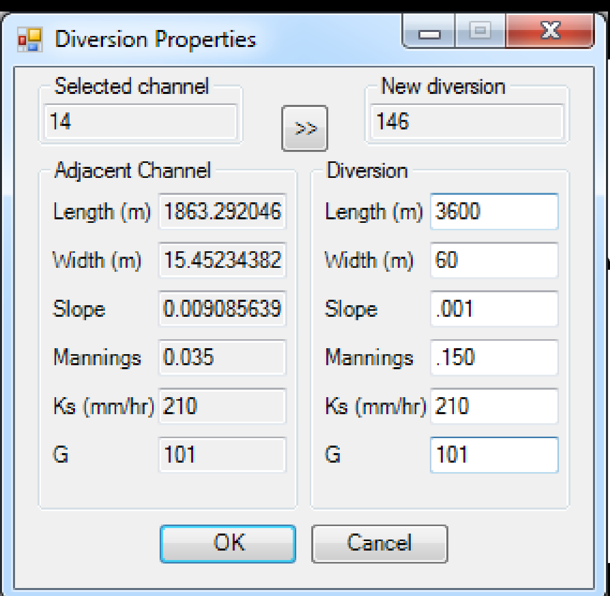


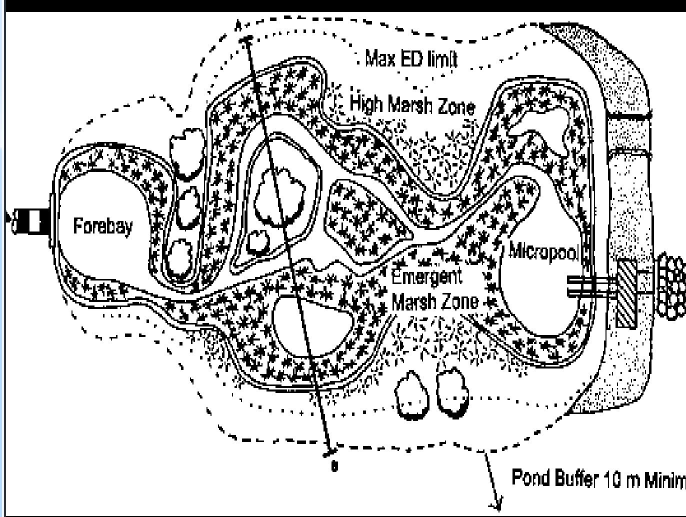


Computed based on the weighted flow length method (Flanagan et al. 2011)

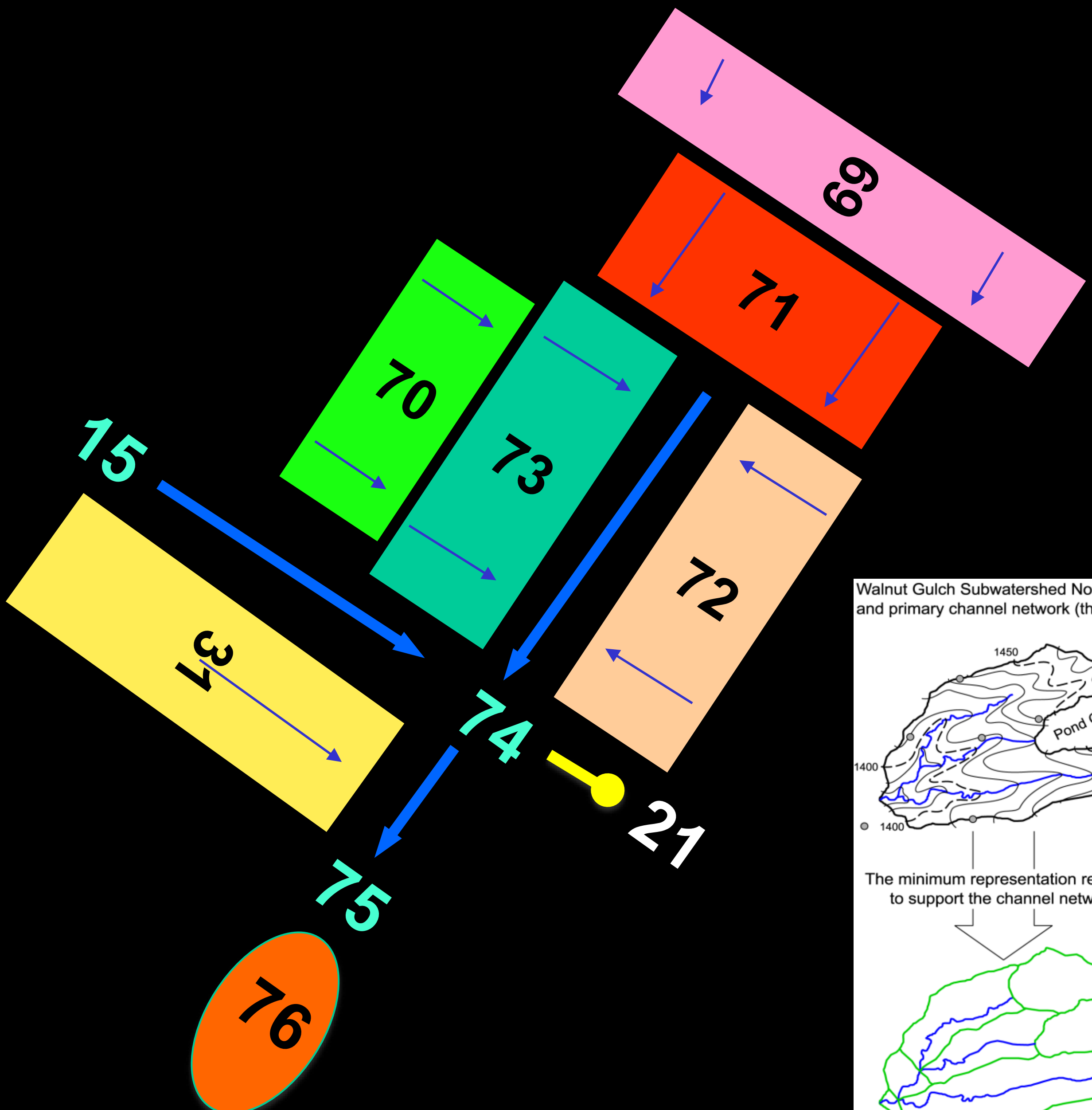
K2 Model Element Types (Cont.)

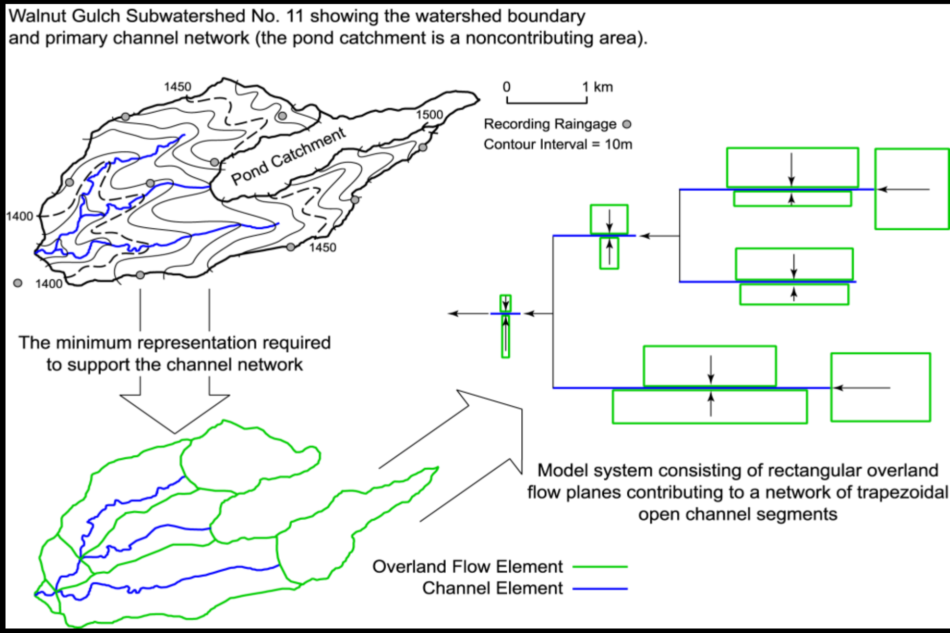
- Diversion Element - allows simulation of wetlands
  - Modify channel length to represent sinuosity
  - Modify channel width as surrogate for braided channels
  - Modify channel slope to affect stream energy
  - Modify channel roughness to affect stream velocity
  - Modify channel KS to increase infiltration capacity





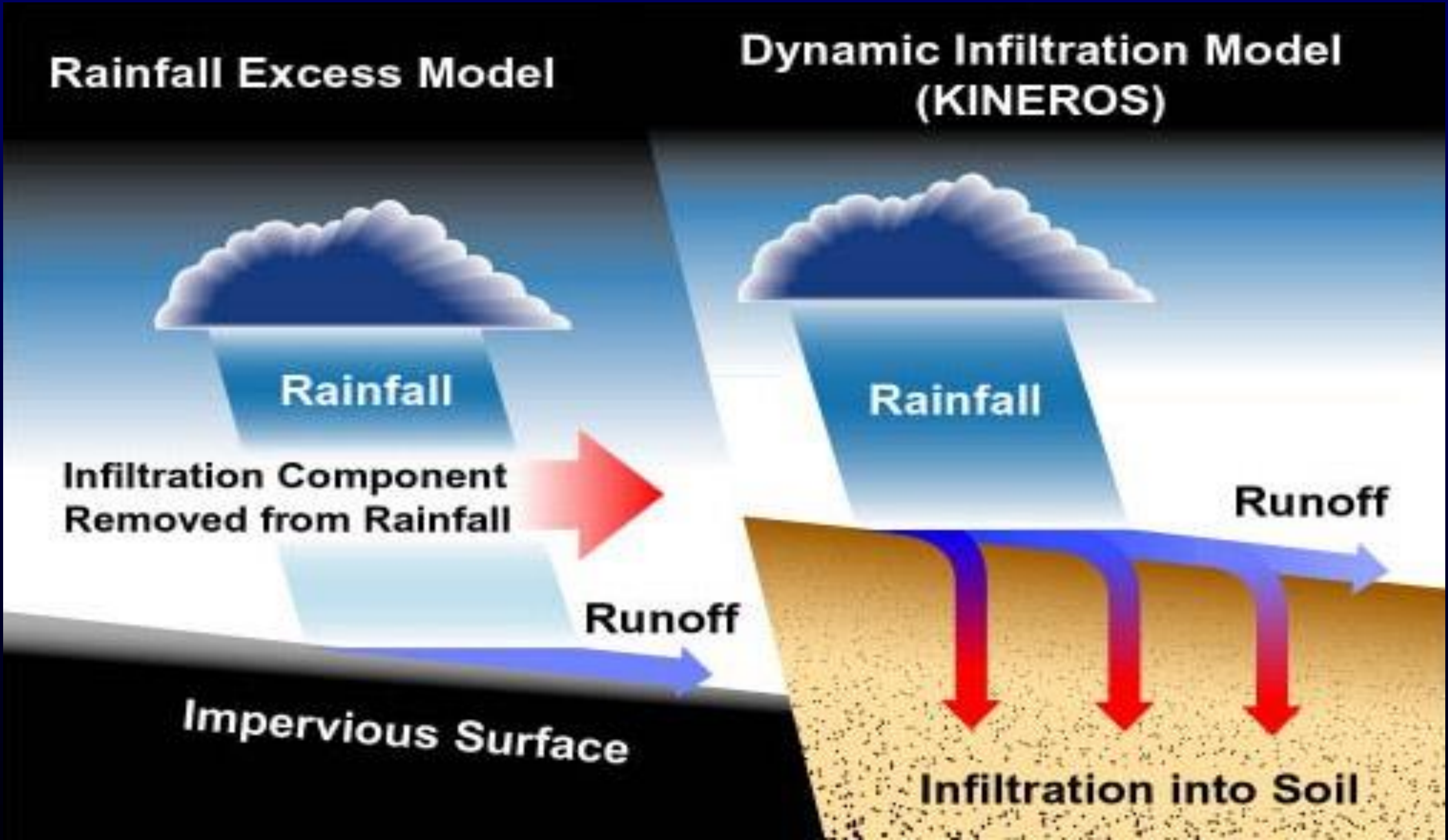
Flexible Element Configurations





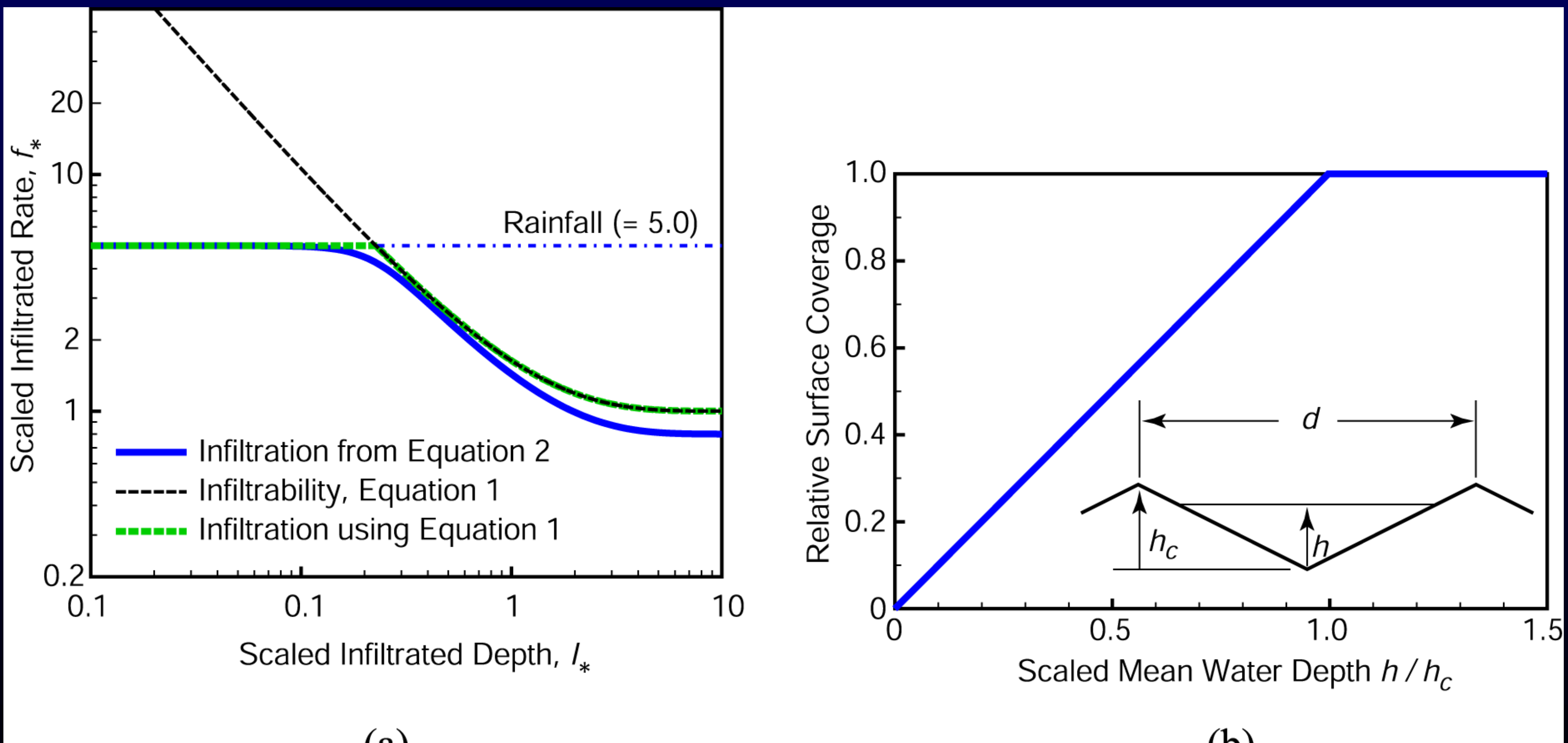
Interactive Infiltration

- **Coupled Infiltration – Routing (Runoff – Runon)**



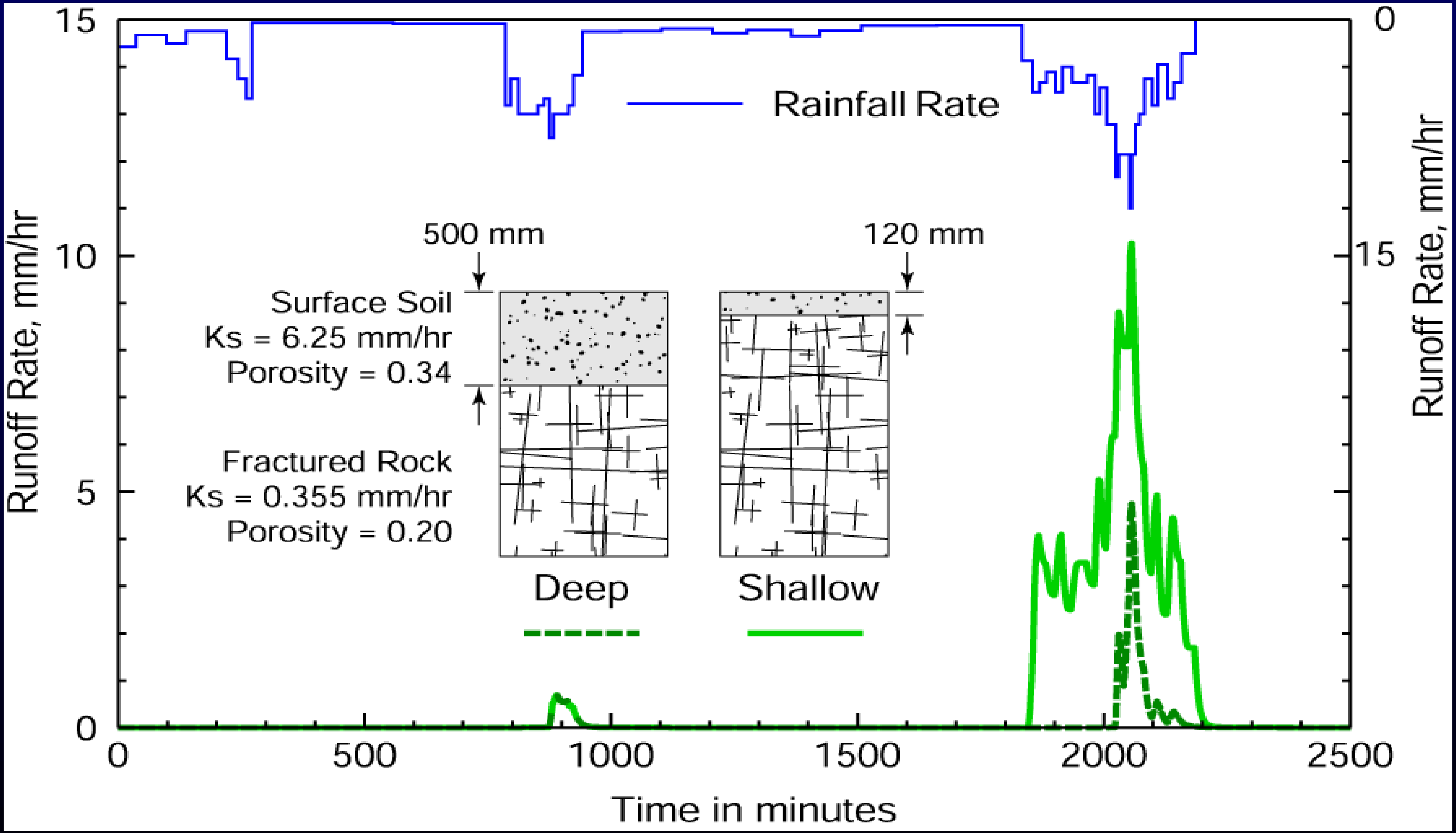
Spatial Variability of Infiltration

- Small scale spatial variability of infiltration represented in distribution sense and parameterized for numerical efficiently
- Microtopography represented



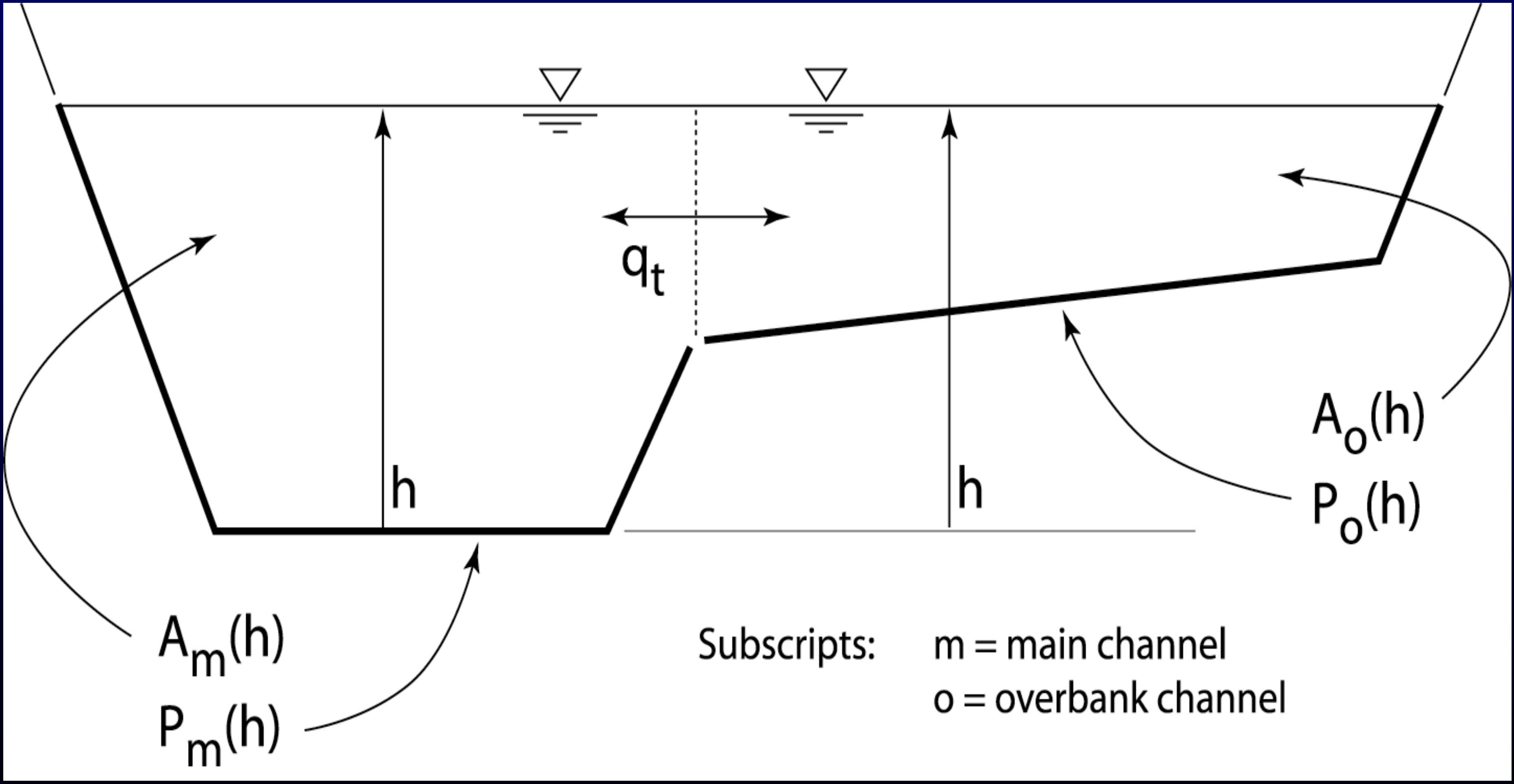
Two Layer Infiltration

- Infiltration with two-layer soil profile
- Soil moisture re-distribution during storm hiatus



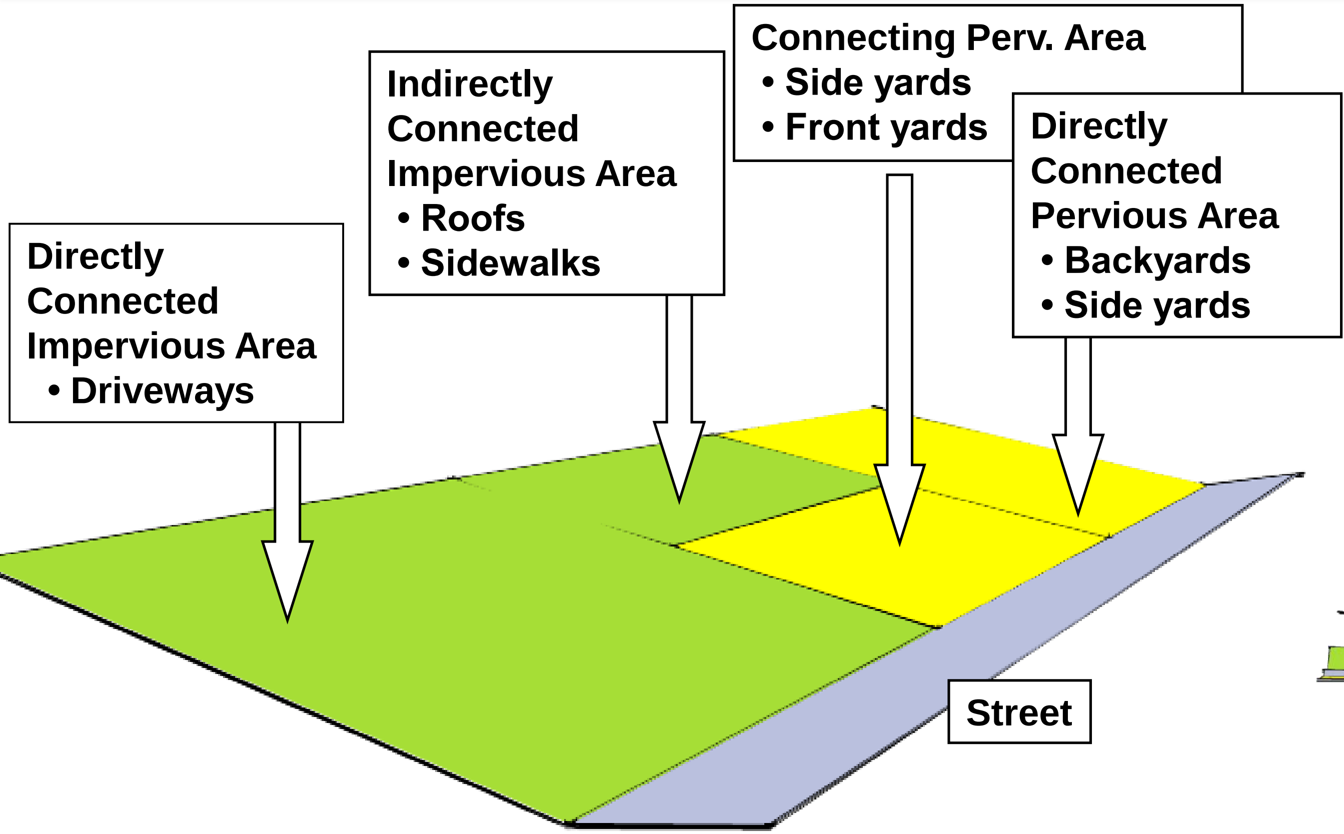
Compound Channel Routing

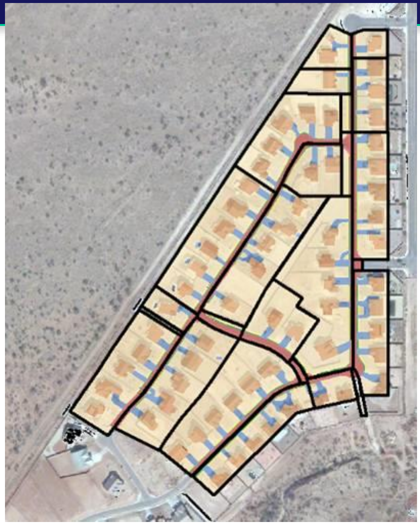
- Compound channel routing with distinct main and overbank channel infiltration

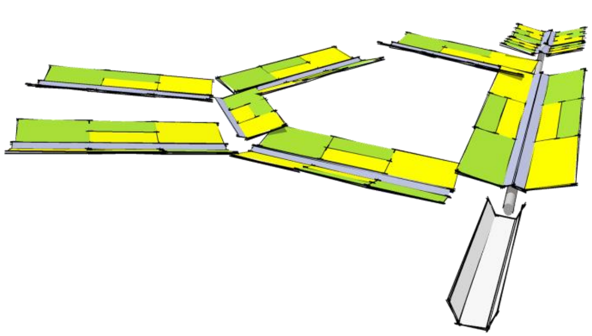


Urban Element

- Simplifies urban modeling
- Is an abstaction representing contributing areas along one side of a street, and one half of the street itself

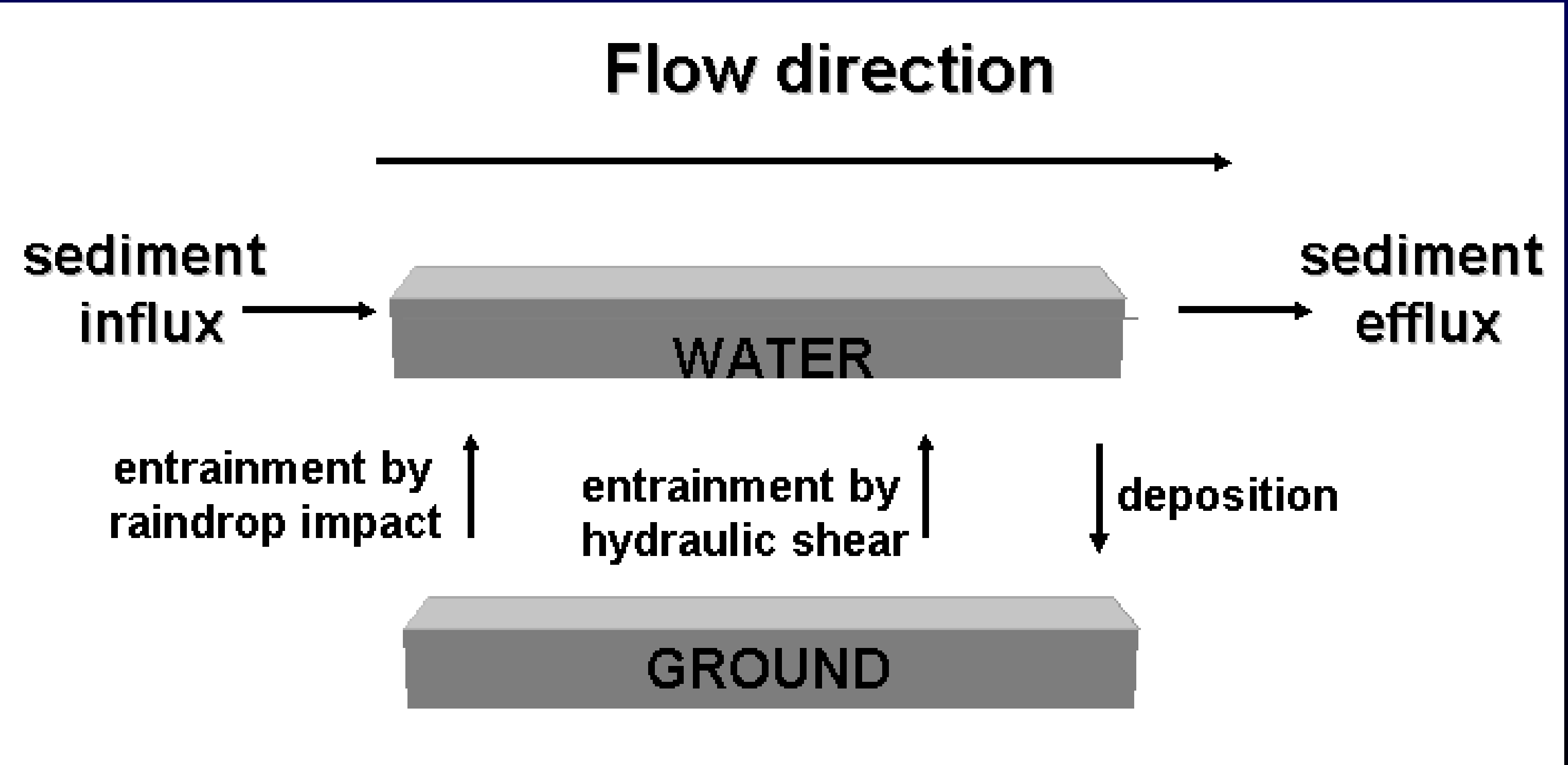






Erosion – Sediment Transport

- Multiple particle class size sediment routing (non-interactive)
- Entrainment by rainsdrop impact and hydraulic shear
- WEPP and RHEM (stream power) erosion models are also being incorporated



KINEROS2 Parameters

- Geometric (position, length, slope, width)
  - From DEM and watershed discretization
- Hydraulic Roughness, microtopo, and interception
  - From soils and cover (literature)
- Infiltration (Ksat, porosity, suction term, rock, residual and maximum fillable porosity)
  - Soils data modified by cover (literature and experimental data)
- Erosion Parameters (splash, cohesion, pave, sediment fractions)
  - Soils data (literature and experimental data)
- Channel Parameters (and culverts)
- Pond/Detentions Structures
- Urban Elements

KINEROS2 Parameter Estimation in AGWA

➢ Parameters based on soil texture

Texture	Ksat	Suction	Porosity	Smax	CV	Sand	Silt	Clay	Dist	Kff
Clay	0.6	407.0	0.475	0.81	0.50	27	23	50	0.16	0.34
Fractured Bedrock	0.6	407.0	0.475	0.81	0.50	27	23	50	0.16	0.05
Clay Loam	2.3	259.0	0.464	0.84	0.94	32	34	34	0.24	0.39
Sandy Clay Loam	4.3	263.0	0.398	0.83	0.60	59	11	30	0.40	0.36
Silt	6.8	203.0	0.501	0.97	0.50	23	61	16	0.23	0.49
Loam	13.0	108.0	0.463	0.94	0.40	42	39	19	0.25	0.42
Sandy Loam	26.0	127.0	0.453	0.91	1.90	65	23	12	0.38	0.32
Gravel	210.0	46.0	0.437	0.95	0.69	27	23	50	0.16	0.15

➢ Parameters based on land cover classification (NALC)

Land Cover Type	Interception (mm/hr)	Canopy (%)	Manning's *n*
Forest	1.15	30	0.070
Oak Woodland	1.15	20	0.040
Mesquite Woodland	1.15	20	0.040
Grassland	2.0	25	0.050
Desertscrub	3.0	10	0.055
Riparian	1.15	70	0.060
Agriculture	0.75	50	0.040
Urban	0.0	0.0	0.010

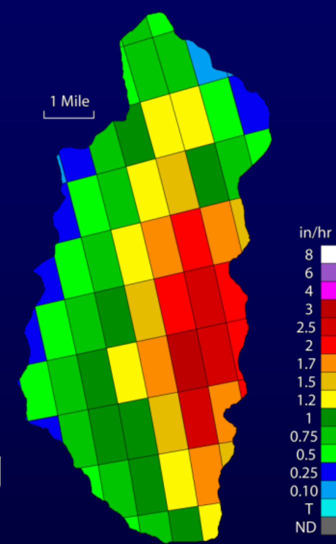
Hydrologic Modeling & AGWA

Flash Flood Forecasting

- **Real time, using Doppler weather radar**
  - **Can include predicted rainfall (QPF)**
  - **Multiple Z-R relationships simultaneously**
- **Spatially distributed model, using short (3-5 min) time steps, ideal for fast-responding basins**
- **Can be calibrated using archived radar data and discharge data at forecast points**

AGWA Parameterization Intersected with Polarimetric Radar Grid

Doppler Weather Radar



Predicted Rainfall

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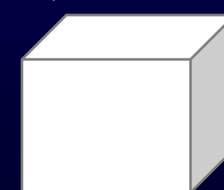
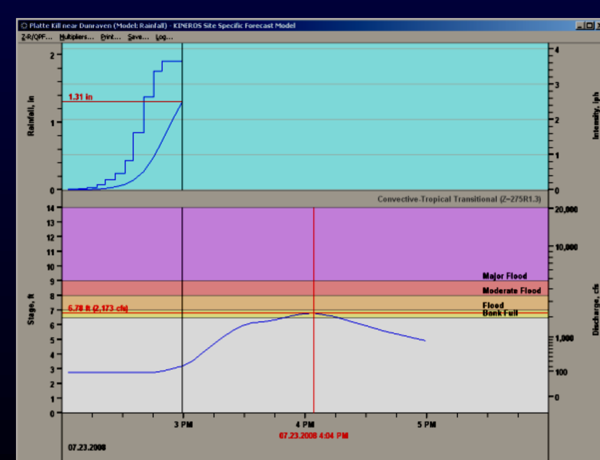


KINEROS2



Graphical User Interface

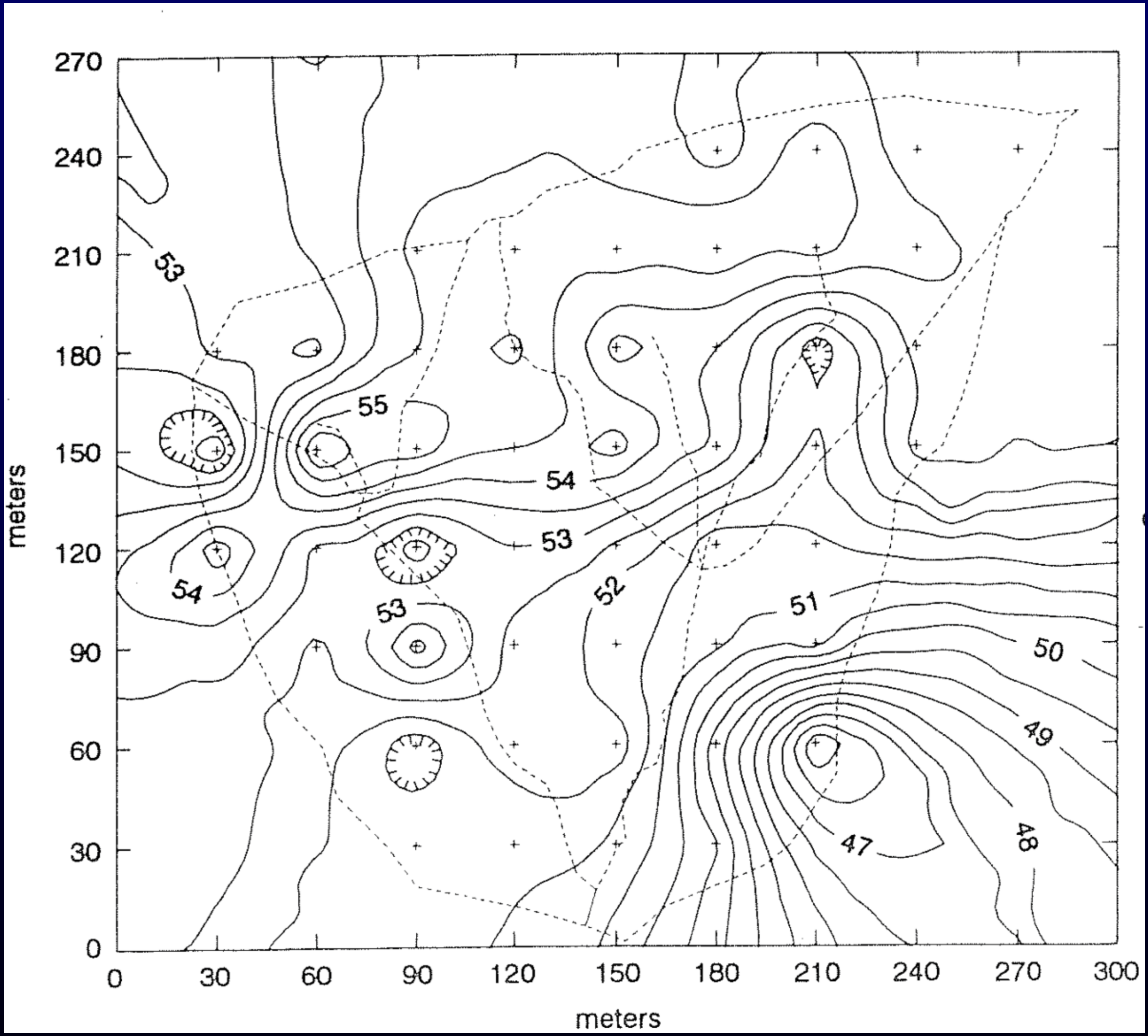
K2 SENSITIVITY

- **Relative ranking of most sensitive inputs and parameters**
  - **Rainfall Inputs (emphasis in arid and semi-arid areas)**
  - **Saturated Hydraulic Conductivity**
  - **Hydraulic Roughness**
- **All a function of watershed geometric complexity**

Small Scale Rainfall Variability

Lucky Hills-104

- 4.4 hectare area
- 48 non-recording gauges (30 x 30 m grid)
- 9 recording gauges
- Total Event Depth Contours (Aug 12, 1990)
  - Aver. – 52.9 mm
  - Range – 10.6 mm

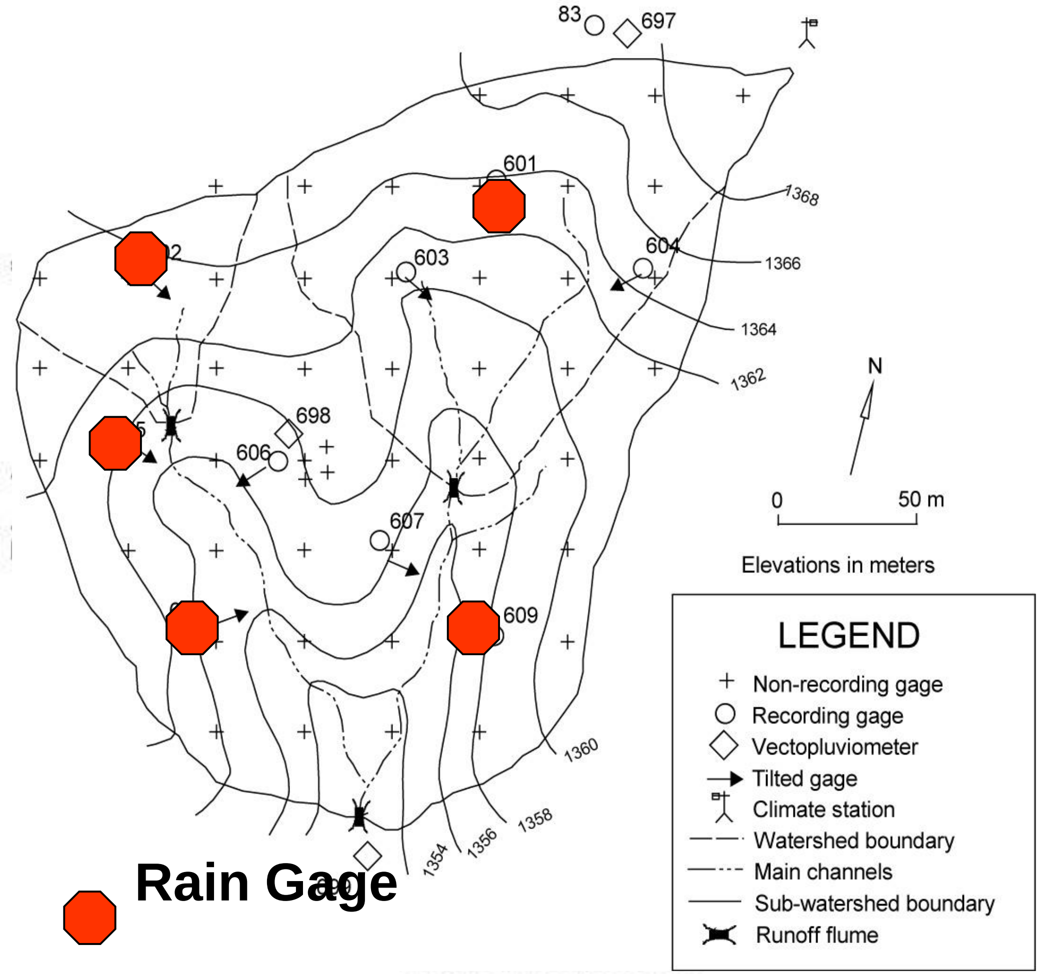


Goodrich et al., 1995 – J Hyd.

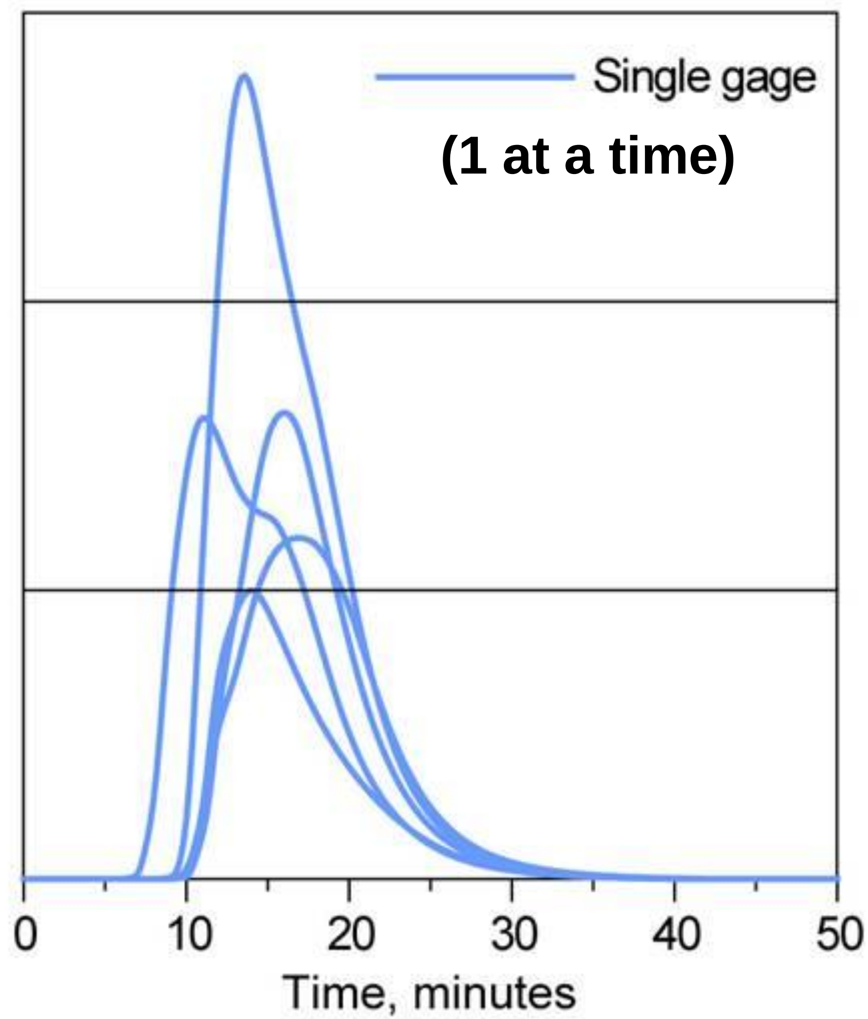
Uncertainty in Runoff Simulation due to Rainfall Variability

Small scale spatial variability of rainfall (on the order of ~150 m)

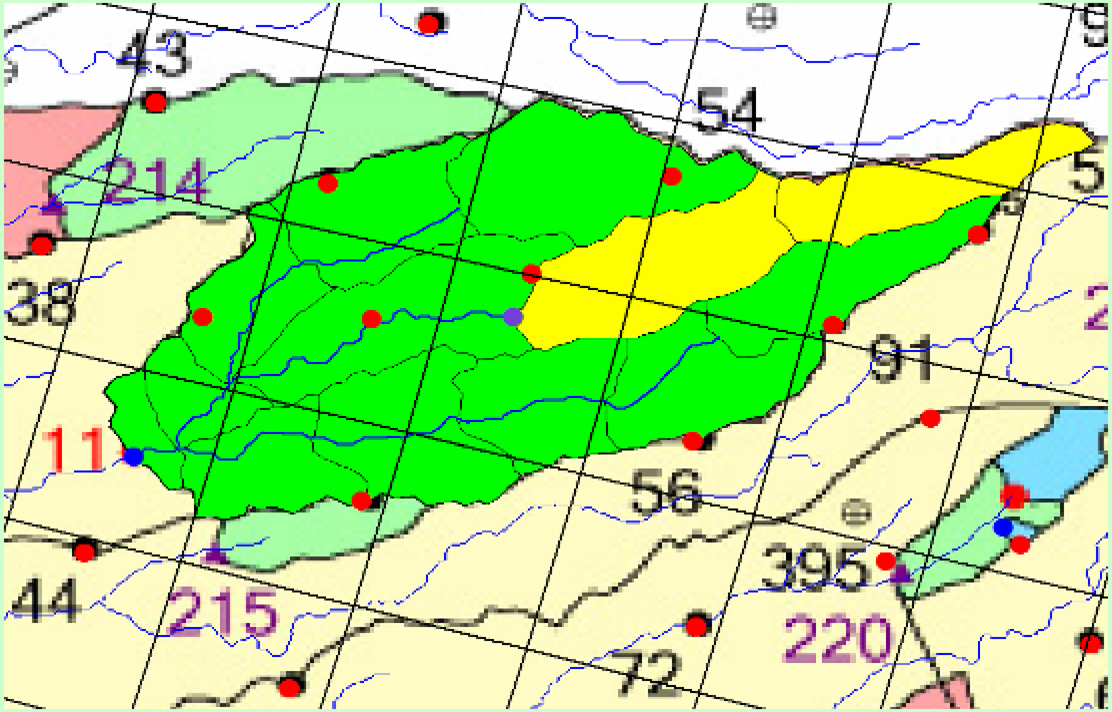
Walnut Gulch – Lucky Hills #104 (4.4 ha)



Modeled runoff (KINEROS)



Small test basin setup: Walnut Gulch Flume 11 (WG11)



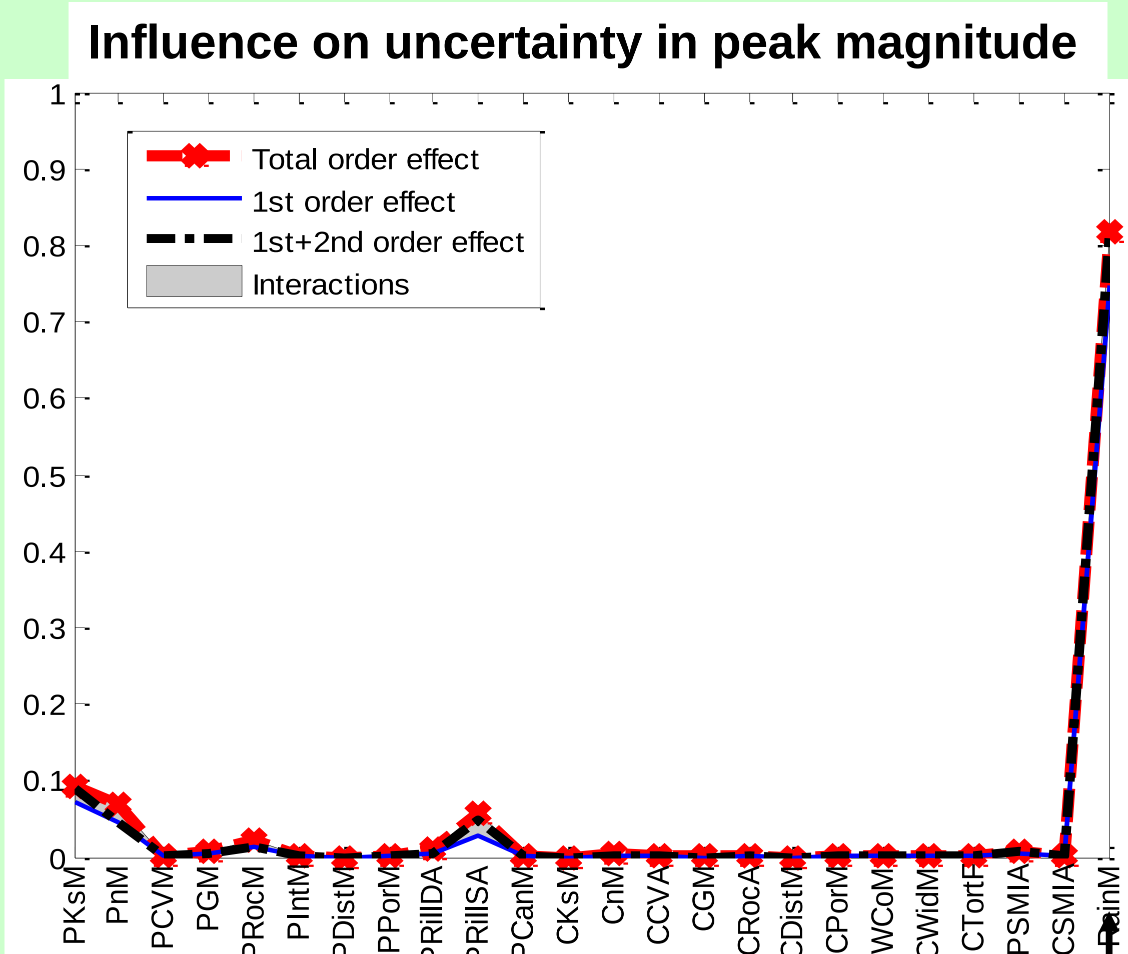
- Hillslope elements
- Channels
- Watershed Outlet
- Rain Gage
- Stock pond outlet
- Radar Bin

- 6.5 km² area
- Almost spatially homogenous parameters (from AGWA)

Model run setup

- Monte-Carlo simulations (~100,000)
- 23 parameter modifiers (Hillslope, Channel & Initial conditions)
- Successful forecasts: ‘behavioral envelope’
    - e.g. van Straten and Keesman, 1991

Relative Influence of Radar Rain Depth Bias



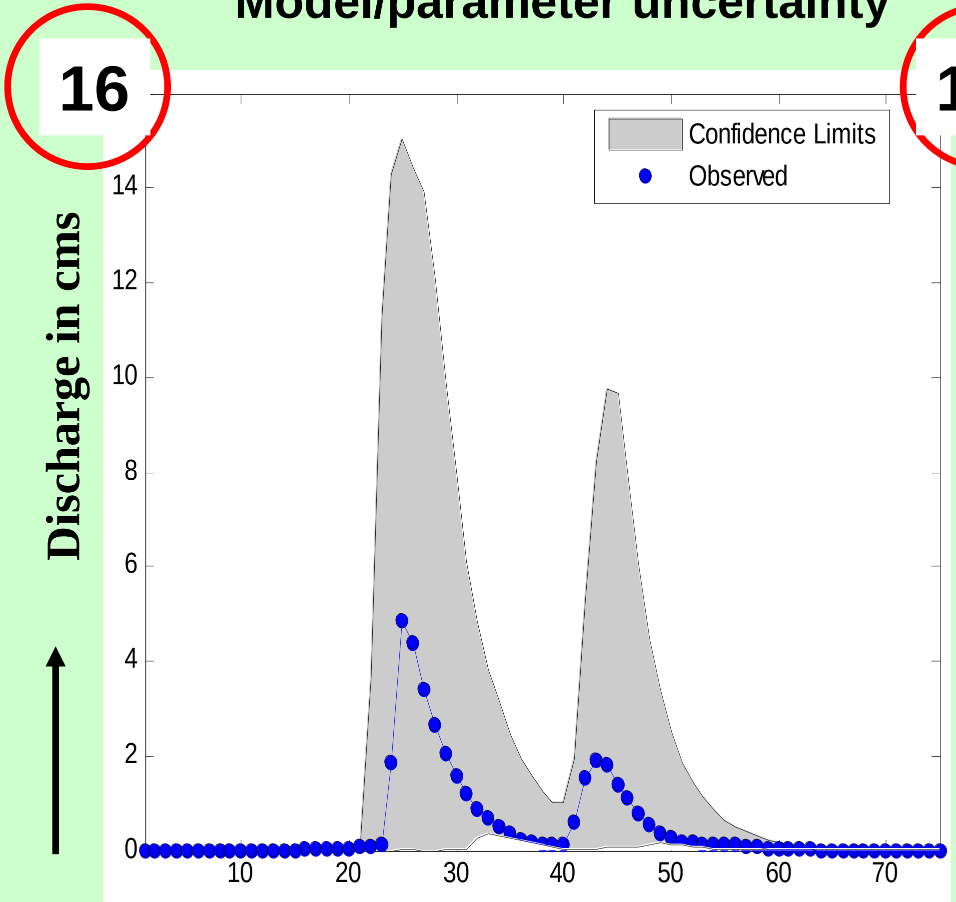
Rain depth bias

July 29, 2006 storm

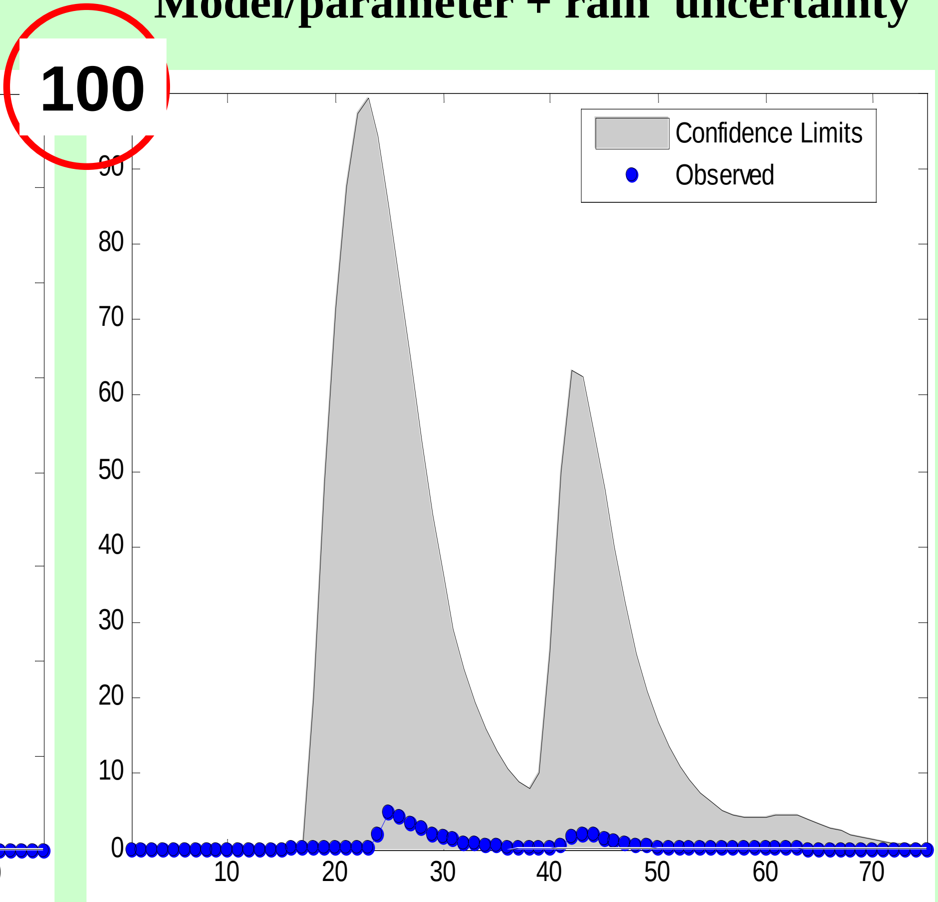
Model/parameter & rain uncertainty

July 29, 2006 storm
90% confidence interval

Model/parameter uncertainty



Model/parameter + rain uncertainty



Discharge in cms

Radar Time Steps

Additional Limitation – Cannot model backwater or presurrized culvert flow

What Could Possibly Go Wrong??

PLENTY

SYSTEMIC ERRORS

These are "hidden" & include:

- **Poor conceptual model**
- **Programming errors**
  - ***AGWA, SWAT, KINEROS2***
- **Poor process representation**
- **Errors in GIS data**
  - ***Land cover, soils***
- **Assumptions in the look-up tables**

PROCESSING ERRORS

These are "visible" & include:

- **Errors in GIS data**
  - ***DEM***
- **Lack of input data**
  - ***GIS, rainfall***
- **AGWA fails to characterize watershed**

KINEROS2 Strengths

- Readily available inputs
- Physical-based model
- High resolution both spatial and temporal
- Can simulate detailed flood routing
- Can simulate detailed sediment budget

Weaknesses

- More parameters to estimate
- Currently not continuous in the current AGWA release
- Subsurface flow component weak, works better in streams with negligible base flow
- Currently improving snow melt component
- Will not model "small events" where the runoff to rainfall ratios are small (most any model)

CONCLUSIONS - Cautions

- KINEROS2 – Evolved from a research model to one gaining wider applicability
- K2 most sensitive to rainfall input and Infil. Par.
- In a water limited area with small runoff to rainfall ratios, runoff modeling is difficult and highly dependent of the quality of model input
- The model representation of the watershed must keep up with changes in the watershed characteristics due to land use changes (i.e. urbanization, change in agriculture, fires, etc.)