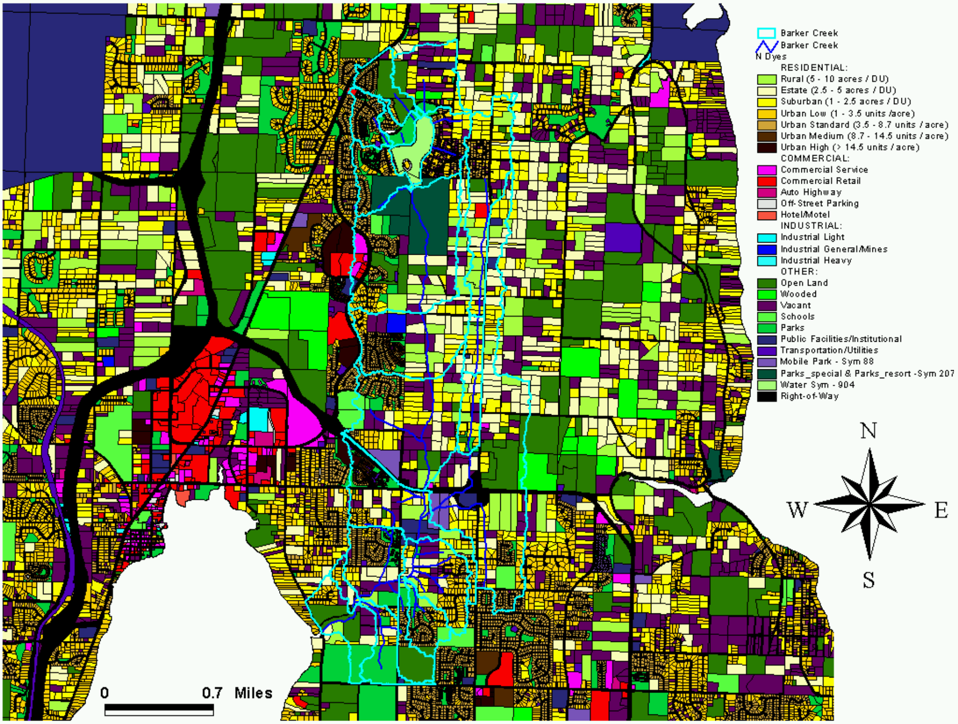
USE OF REGULARIZATION AS A METHOD FOR WATERSHED MODEL CALIBRATION

Brian Skahill
Watershed Systems Group
Hydrologic Systems Branch
Coastal and Hydraulics Laboratory
Brian.E.Skahill@erdc.usace.army.mil
601-634-3441

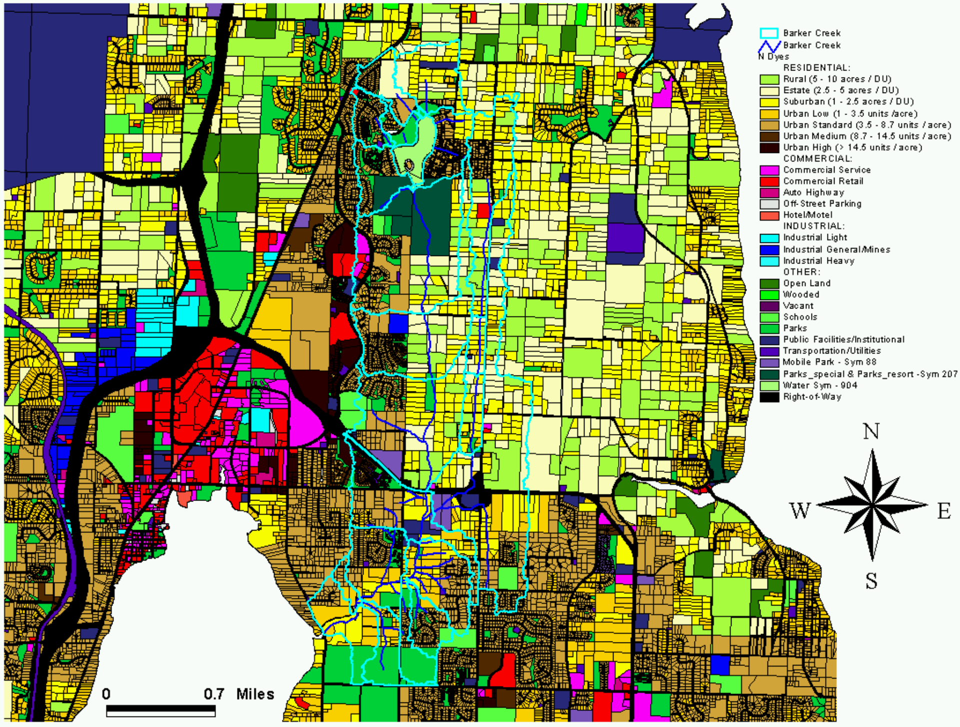
August 2005

MOTIVATION

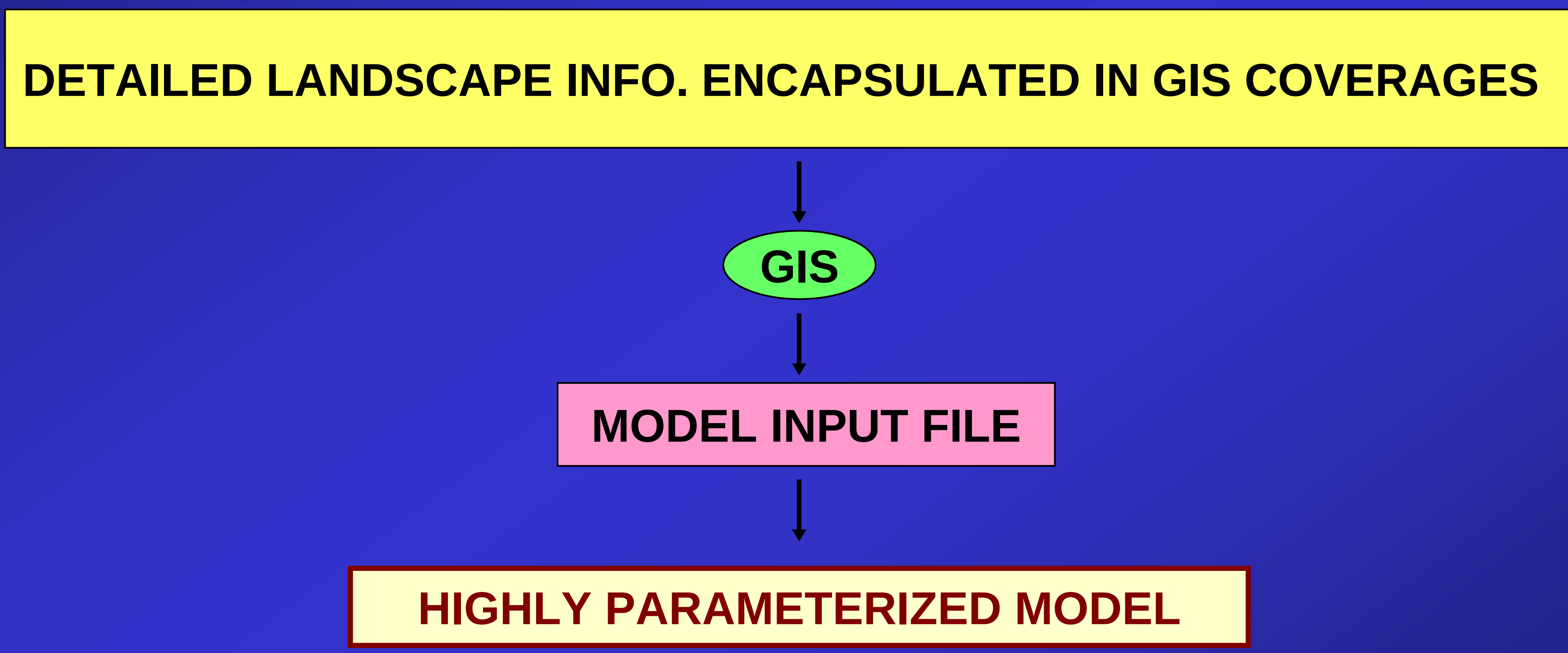
CURRENT



ALTERNATIVE FUTURE

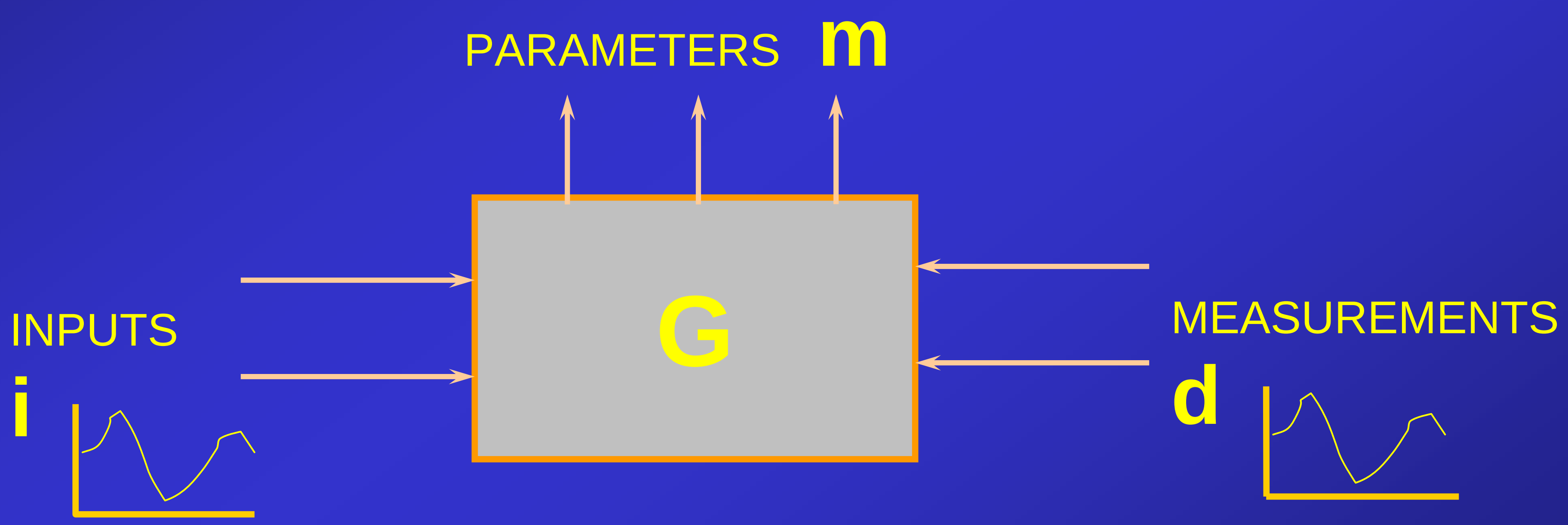


PROBLEM


DETAILED LANDSCAPE INFO. ENCAPSULATED IN GIS COVERAGES
GIS
MODEL INPUT FILE
HIGHLY PARAMETERIZED MODEL

CONTEXT

THE INVERSE PROBLEM

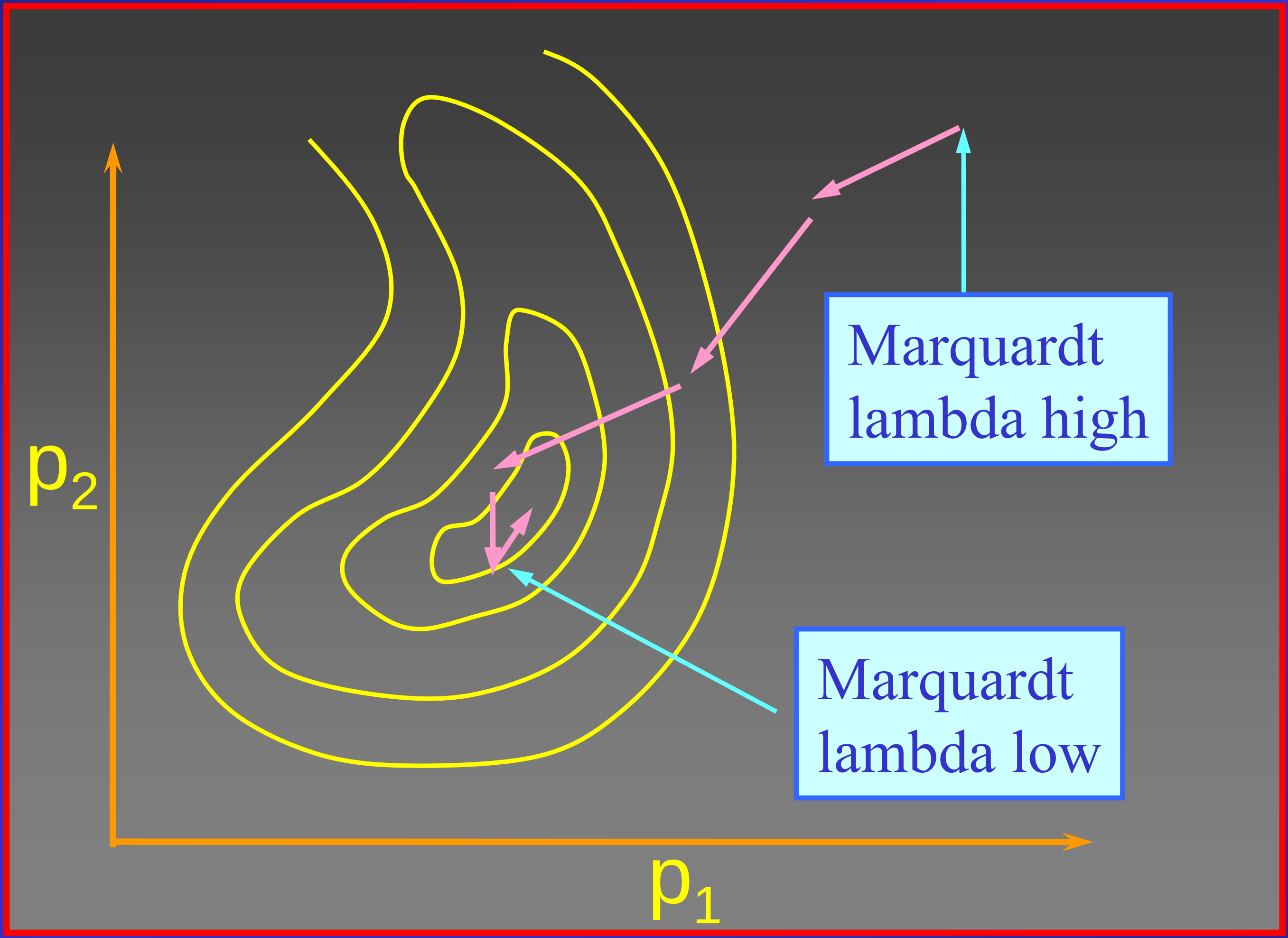


FIND m GIVEN d

CONTEXT

- MODEL TO MEASUREMENT MISFIT QUANTIFIED USING THE LEAST SQUARES SOLUTION
  - HOMOSCEDASCITY CAN BE ACHIEVED THROUGH TRANSFORMATION
  - SERIAL CORRELATION CAN BE ADDRESSED THROUGH EMPLOYMENT OF AN ARMA MODEL
  - IT IS THE MAXIMUM LIKELIHOOD SOLUTION

CONTEXT



US Army Corps of Engineers

Skahill, B., Doherty, J., (2005). "Efficient accommodation of local minima in watershed model calibration" Submitted for publication in Journal of Hydrology.

CONTEXT

$$\Phi = \Sigma\, (w_i r_i)^2$$

$$m - m_0 = (J^t Q J + \lambda I)^{-1} J^t Q (d - d_0)$$

US Army Corps
of Engineers

PROBLEM

- THE J^tQJ MATRIX IS ILL-CONDITIONED
  - WHICH OFTEN OCCURS AS MODEL COMPLEXITY GROWS

REGULARIZATION

- A MEASURE OR ADDITIONAL CONSTRAINT THAT IS TAKEN TO ENSURE THAT A STABLE SOLUTION IS OBTAINED TO AN OTHERWISE ILL-POSED INVERSE PROBLEM

EXAMPLE

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x}$$

$$C(0,t) = C_{in}(t)$$

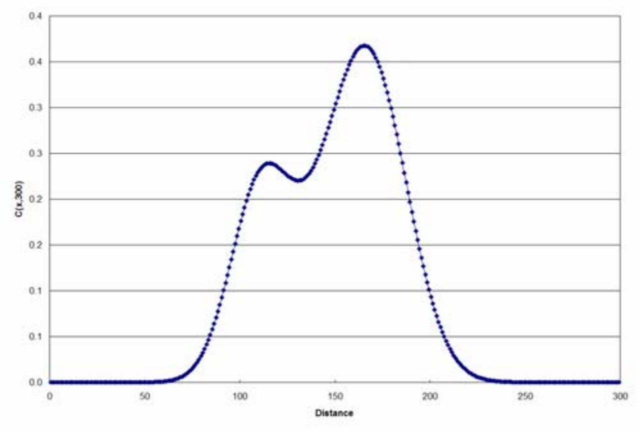
$$C(x,t) \to 0 \text{ as } x \to \infty$$

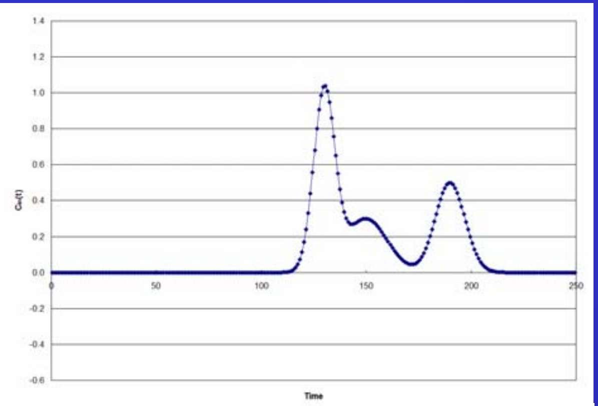
$$C(x,0) = C_0(x)$$

$$C(x,T) = \int_0^T C_{in}(t) f(x, T-t)\, dt,$$

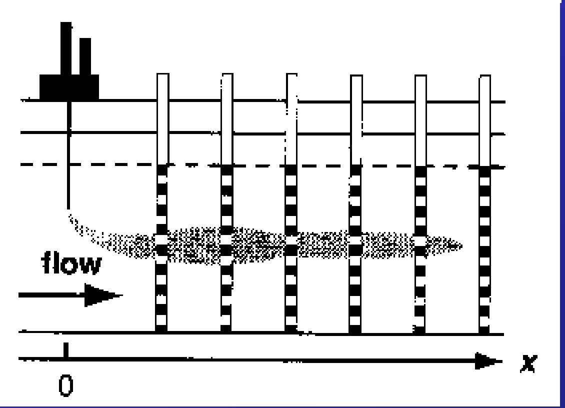
$\rightarrow$ **d = Gm**

$$f(x, T-t) = \frac{x}{2\sqrt{\pi D(T-t)^3}} \exp\left(-\frac{[x - v(T-t)]^2}{4D(T-t)}\right)$$





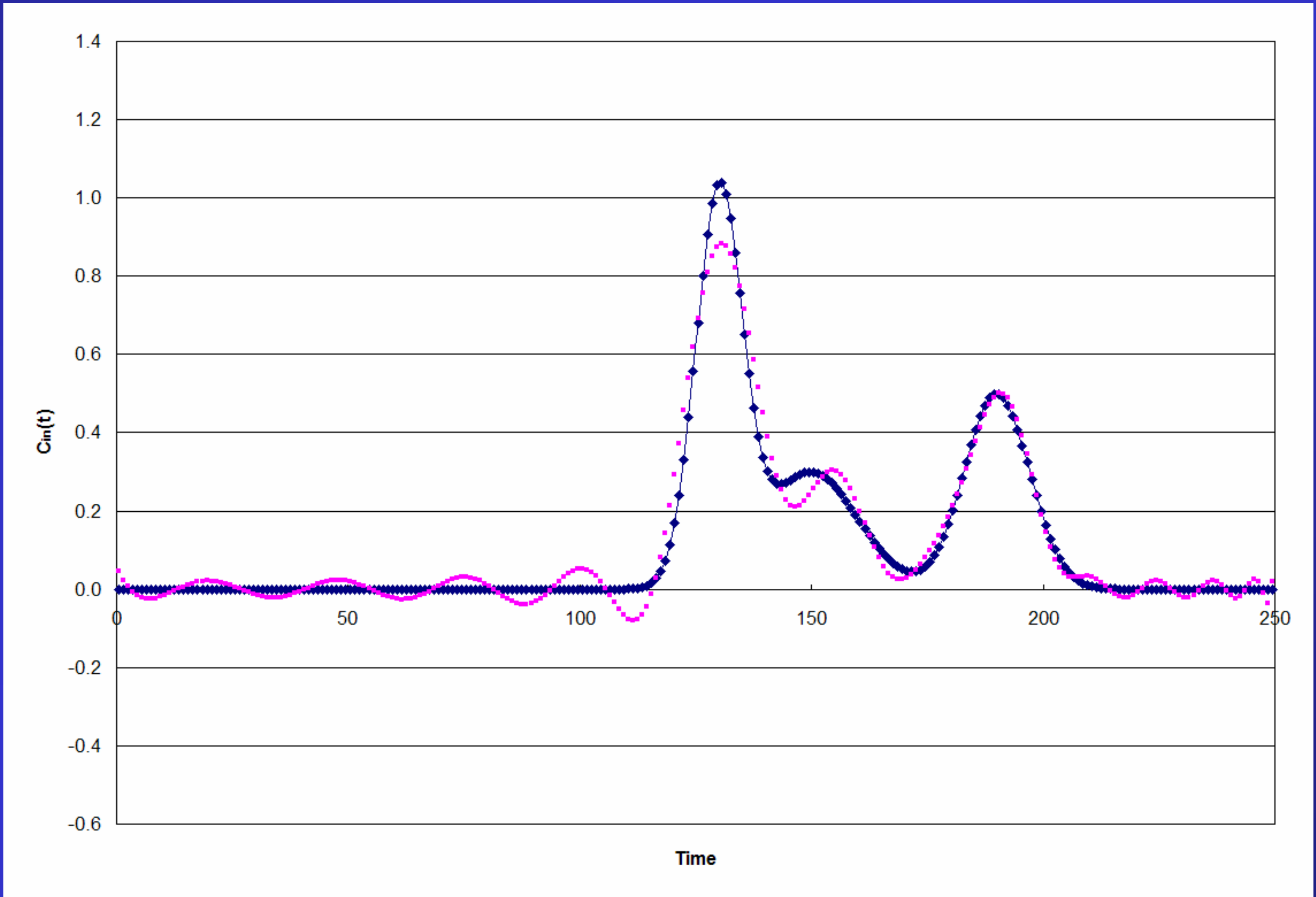
$$C_{in}(t) = \exp\left(-\frac{(t-130)^2}{2(5)^2}\right) + 0.3\exp\left(-\frac{(t-150)^2}{2(10)^2}\right) + 0.5\exp\left(-\frac{(t-190)^2}{2(7)^2}\right)$$



US Army Corps of Engineers

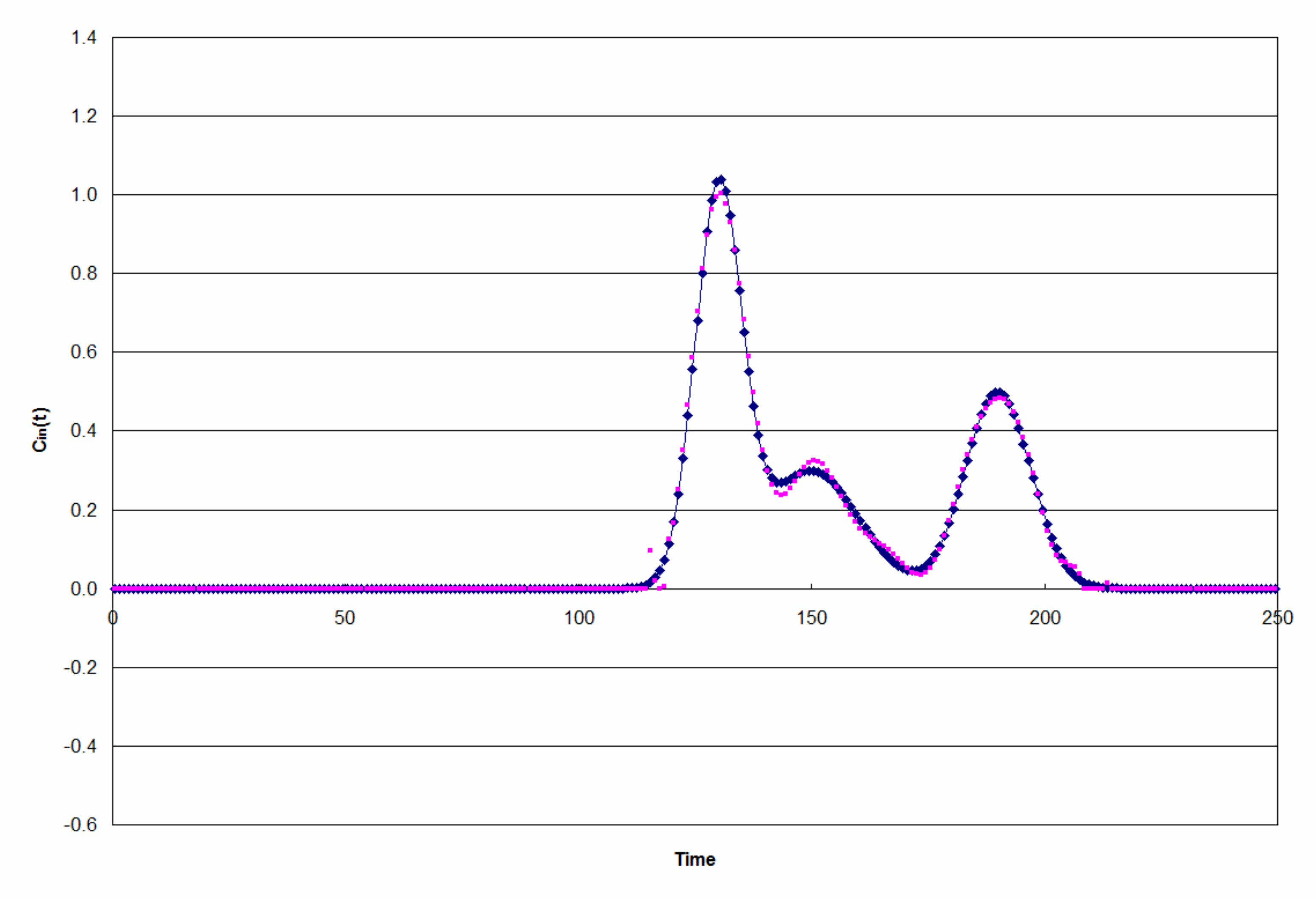
Skaggs, T.H., and Z.J. Kabala, Recovering the release history of a groundwater contaminant, *Water Resources Research*, 30(1), 71-79, 1994.

EXAMPLE



US Army Corps of Engineers

EXAMPLE

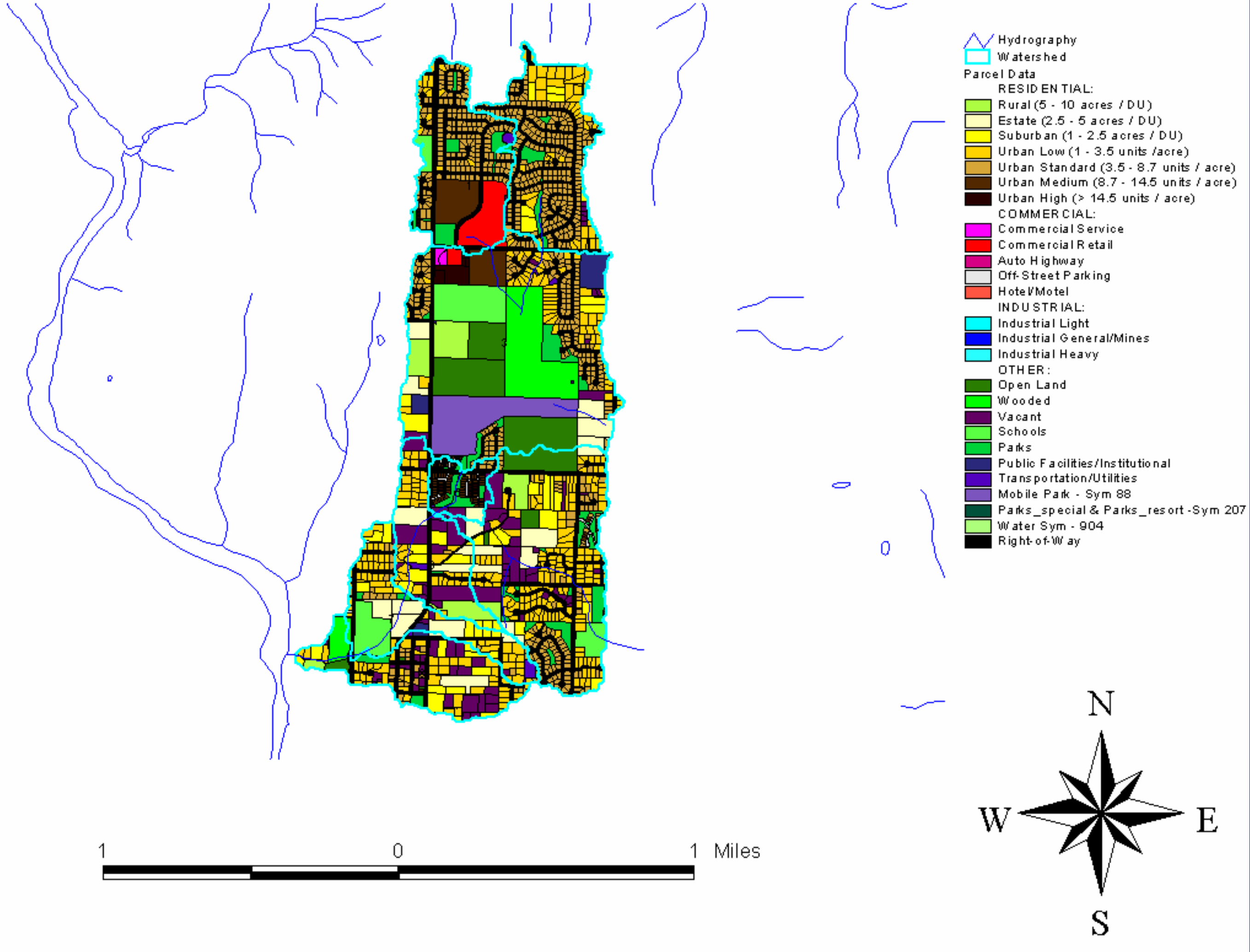


US Army Corps of Engineers

POINTS

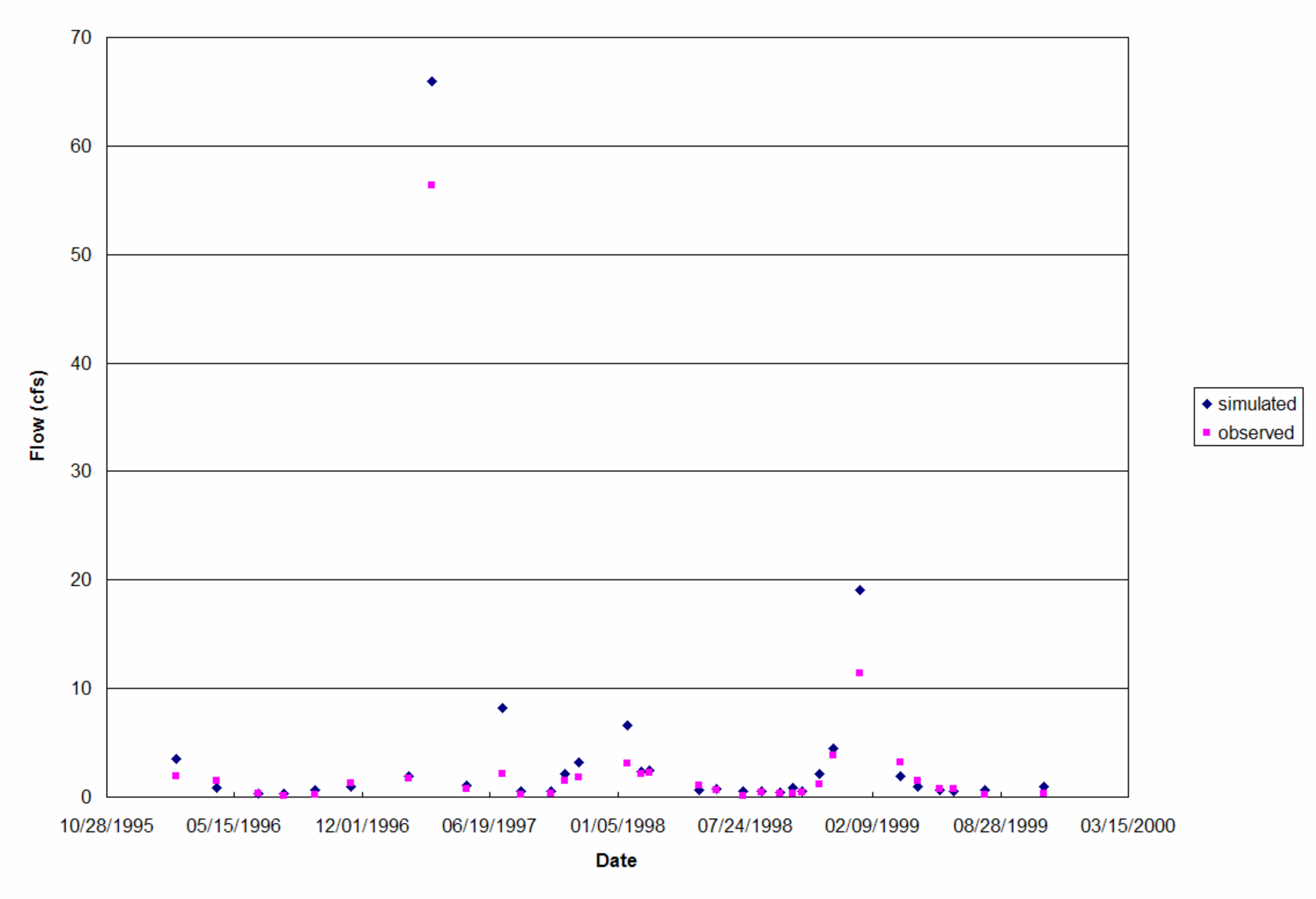
- WITH REGULARIZATION, THERE IS A TRADE OFF BETWEEN FITTING THE DATA IN EXCHANGE FOR SOLUTION STABILITY
- WITH TSVD, NO ABILITY TO INSIST ON THE OBSERVANCE OF SPECIFIED PARAMETER RELATIONSHIPS IN ATTAINING STABILITY

EXAMPLE



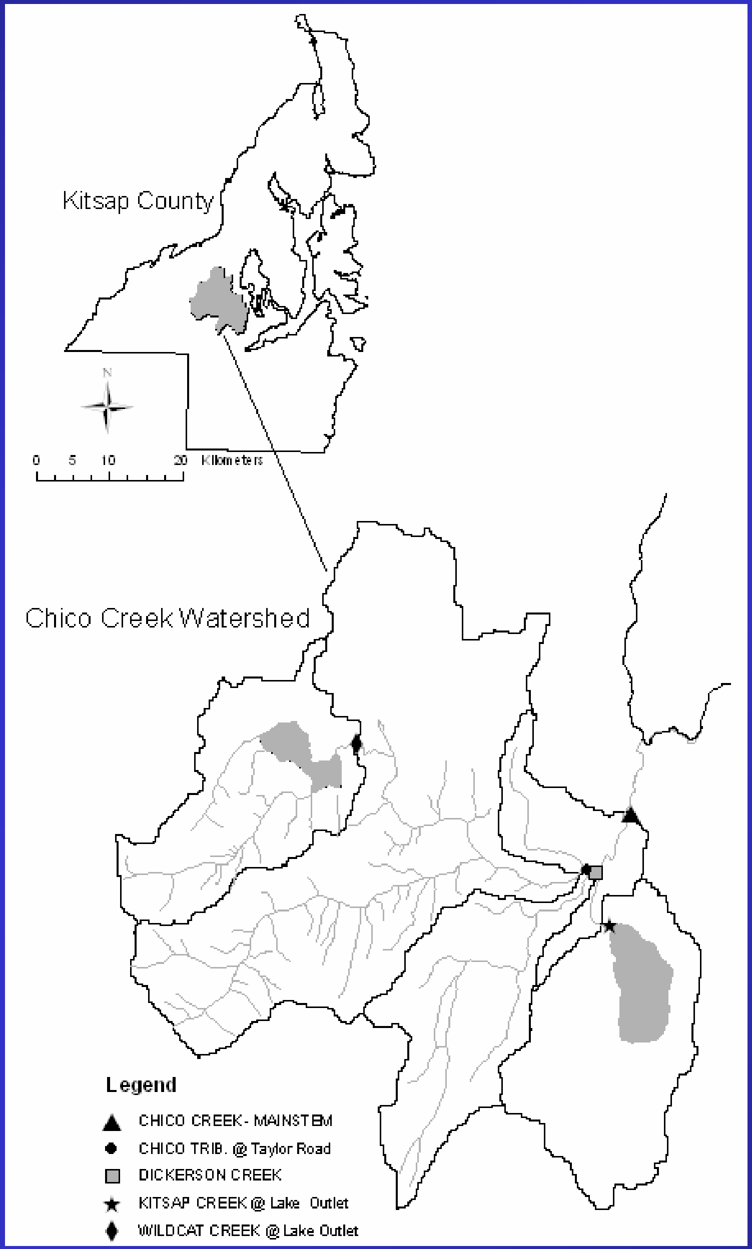
US Army Corps
of Engineers

EXAMPLE



US Army Corps of Engineers

EXAMPLE



Doherty, J., Skahill, B., (2005). "An Advanced Regularization Methodology for Use in Watershed Model Calibration" Submitted for publication in Journal of Hydrology.

EXAMPLE

Streamflow Gaging Station	Adaptive regularization	Hardwired parameter equality
Kitsap Creek	0.768	0.336
Wildcat Creek	0.918	0.879
Chico Creek (Taylor Road)	0.888	0.675
Dickerson Creek	0.936	0.879
Chico Creek (mainstream)	0.952	0.916
All gaging stations	0.917	0.846

Nash-Sutcliffe coefficients for log of daily flows based on simultaneous calibration through regularized inversion (column 2) and simultaneous calibration with hardwired parameter equality (column 3)

EXAMPLE

Parameter	Kitsap Ck.	Wildcat Ck.	Chico Ck. (Taylor Rd.)	Dickerson Ck.	Chico Ck. (mainstream)	Wildcat Creek only
AGWETP	2.08E-03	1.75E-03	1.55E-03	1.83E-03	1.92E-03	1.15E-03
AGWRC	0.985	0.982	0.964	0.984	0.975	0.981
DEEPFR	9.00E-03	7.37E-03	1.26E-02	7.53E-03	1.18E-02	0.18
INFILT	0.36	0.11	.091	0.12	0.19	0.093
INTFW	1.42	2.53	1.64	2.95	1.56	1.88
IRC	0.81	0.63	0.71	0.72	0.73	0.67
LZETP	0.28	0.41	0.57	0.12	0.59	0.36
LZSN	17.8	19.7	33.1	20.5	18.2	14.4
UZSN	3.94	3.45	5.08	4.75	2.82	3.26

Columns 2 – 6: Estimated values for subwatershed model parameters for attainment of best fit at all Chico Creek subwatershed streamflow gaging stations. Regularization was employed in the parameter estimation process. Column 7: calibration of the Wildcat Creek subwatershed model alone.

SUMMARY

- REGULARIZATION IS A MEASURE OR ADDITIONAL CONSTRAINT THAT IS TAKEN TO ENSURE THAT A STABLE SOLUTION IS OBTAINED TO AN OTHERWISE ILL-POSED INVERSE PROBLEM
- WITH REGULARIZATION, THERE IS A TRADE OFF BETWEEN FITTING THE DATA IN EXCHANGE FOR SOLUTION STABILITY
- REGULARIZATION ELIMINATES THE NEED FOR "PREEMPTIVE PARSIMONIZING" AHEAD OF THE CALIBRATION PROCESS
- THE RESULT IS A STABLE PROCESS THAT ALLOWS MAXIMUM RECEPTIVITY OF PARAMETERS TO BOTH "HARD INFORMATION" PROVIDED BY THE MEASUREMENT DATASET AND "SOFT DATA" EMBODIED IN A MODELER'S UNDERESTANDING OF THE AREA, ENCAPSULATED IN THE SET OF REGULARIZATION CONSTRAINTS

USE OF REGULARIZATION AS A METHOD FOR WATERSHED MODEL CALIBRATION

Brian Skahill

Watershed Systems Group

Hydrologic Systems Branch

Coastal and Hydraulics Laboratory

Brian.E.Skahill@erdc.usace.army.mil

601-634-3441

August 2005