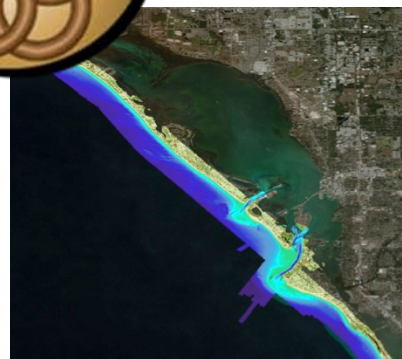
Reservoir Sediment Modeling:

Modeling reservoir deposition and management with 1D morphological models.

Stanford Gibson, PhD.
Hydrologic Engineering Center

RSM



University of Kansas
LEEP2 Building – Room G415
June 11-15, 2018

ERDC
Engineer Research and Development Center

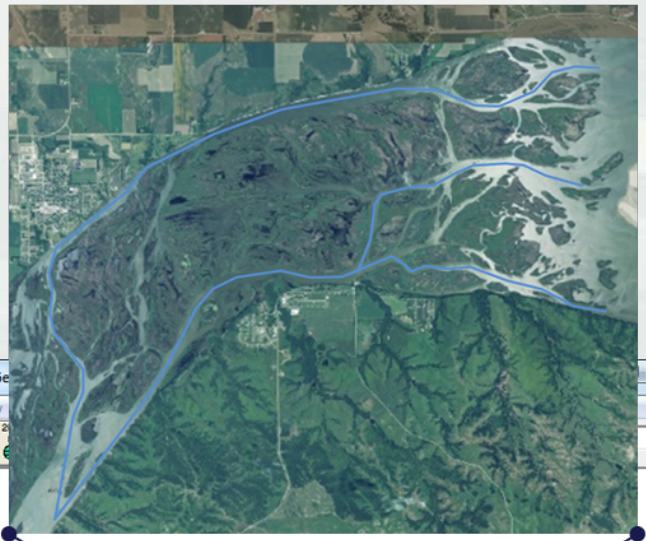
Why Model?

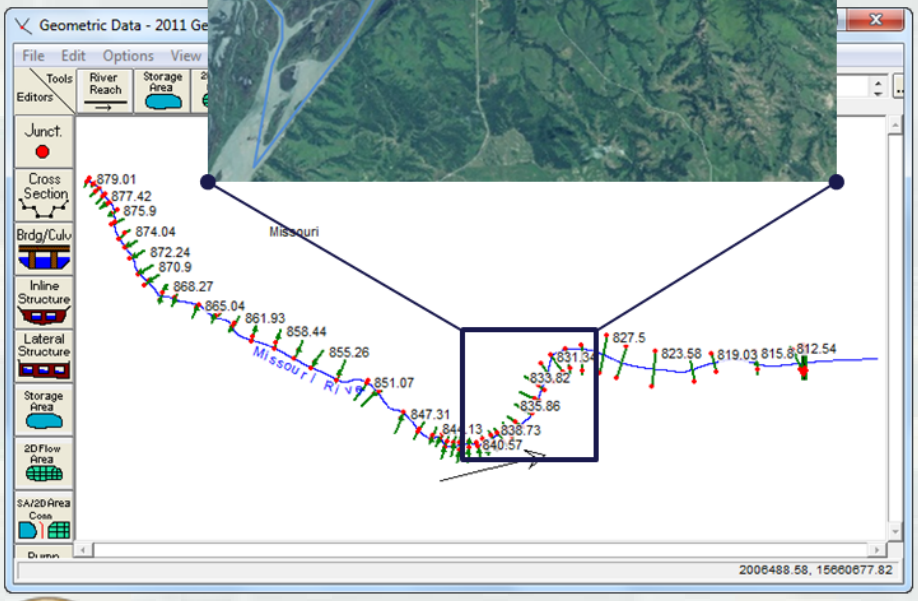
1. More precise answers to “How Much” sediment or “How Long” will it take to fill the reservoir.

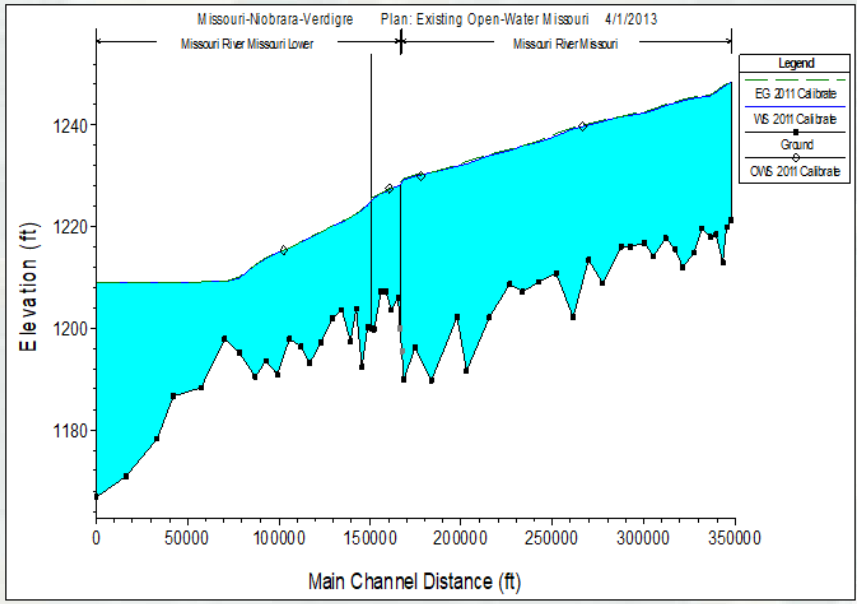
2. Answer the “Where” questions; determine the location of deposits in reservoir.

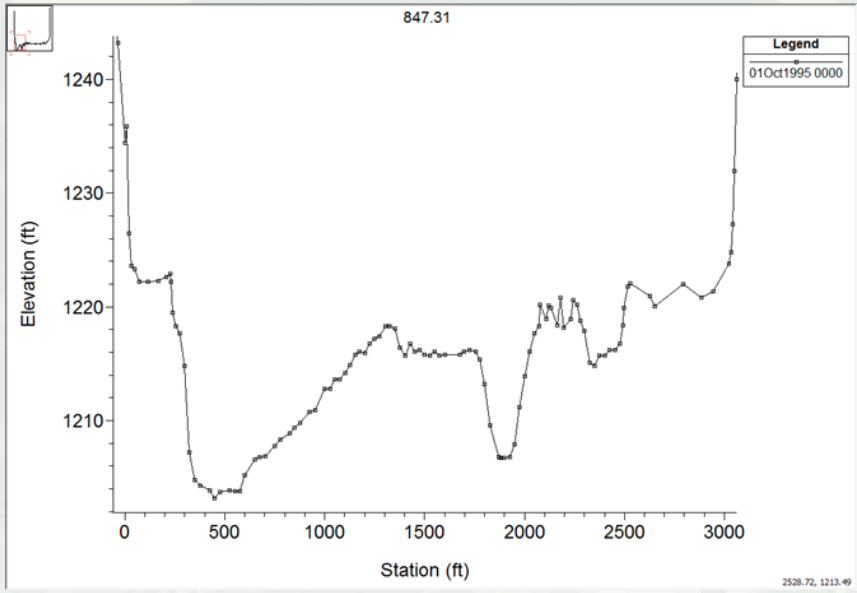
3. Simulate alternatives.

HEC-RAS
1D Hydraulic Modeling



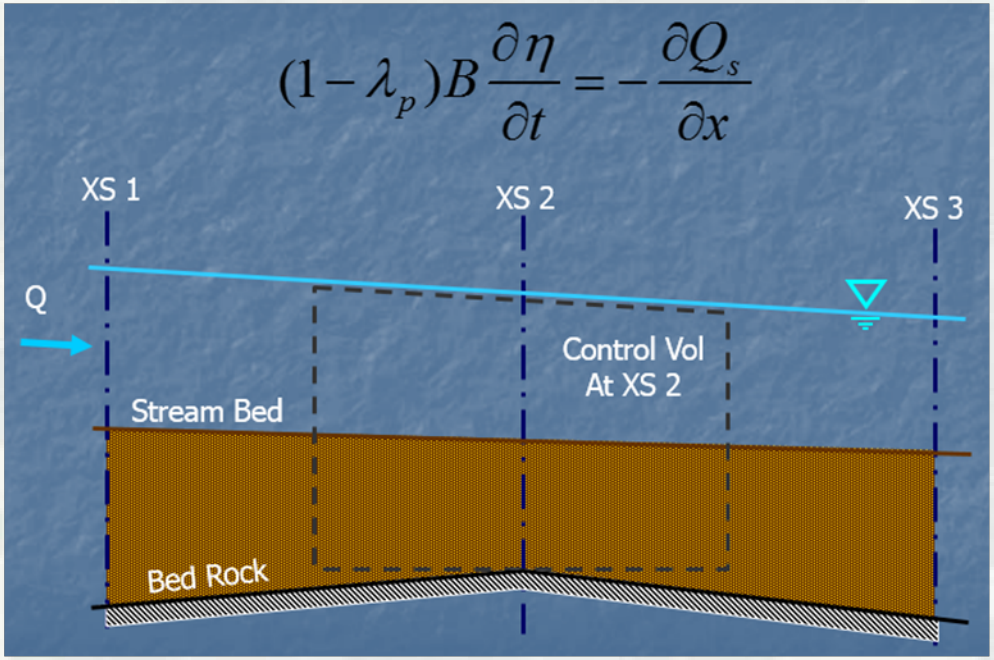


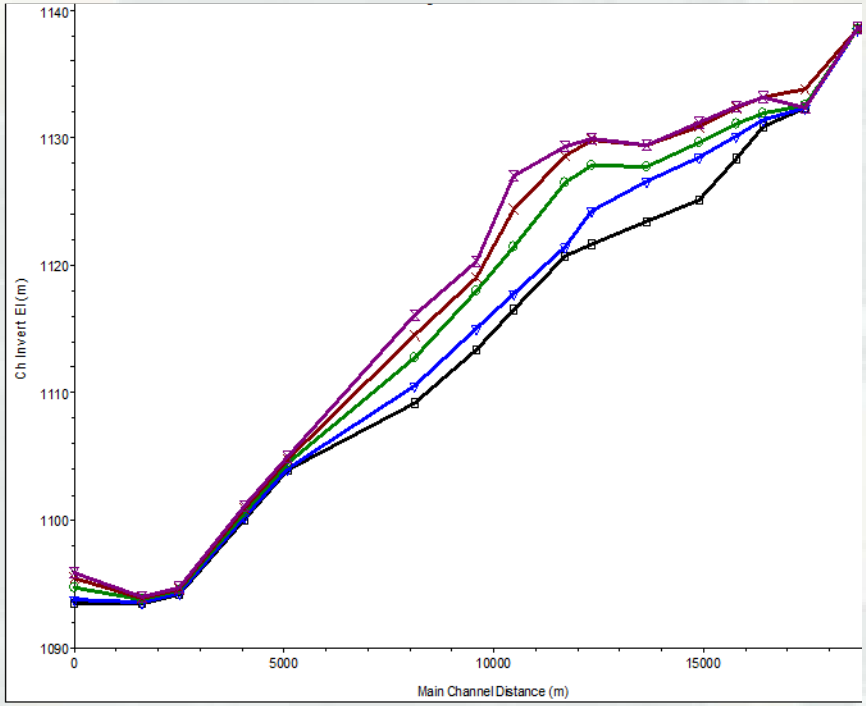


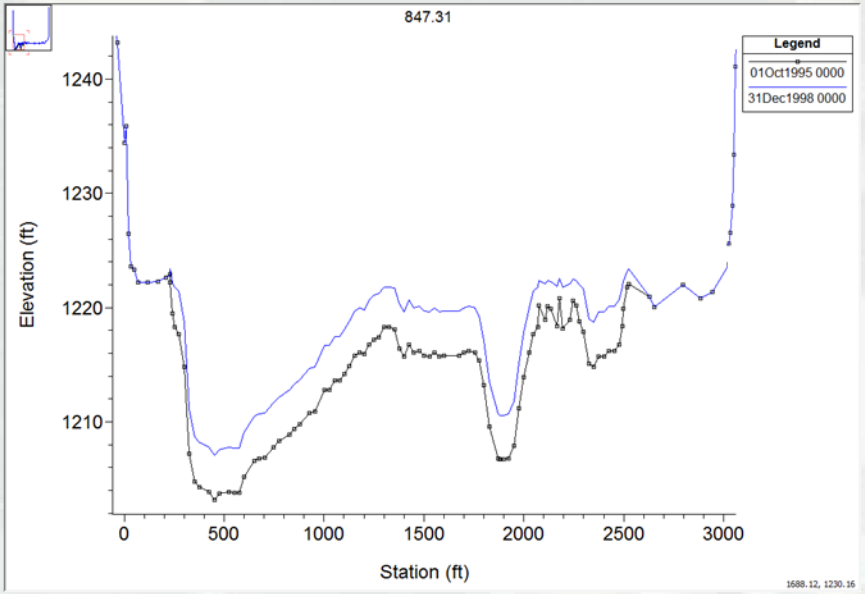


HEC-RAS
1D Sediment Model

$$(1-\lambda_p)B\frac{\partial \eta}{\partial t} = -\frac{\partial Q_s}{\partial x}$$







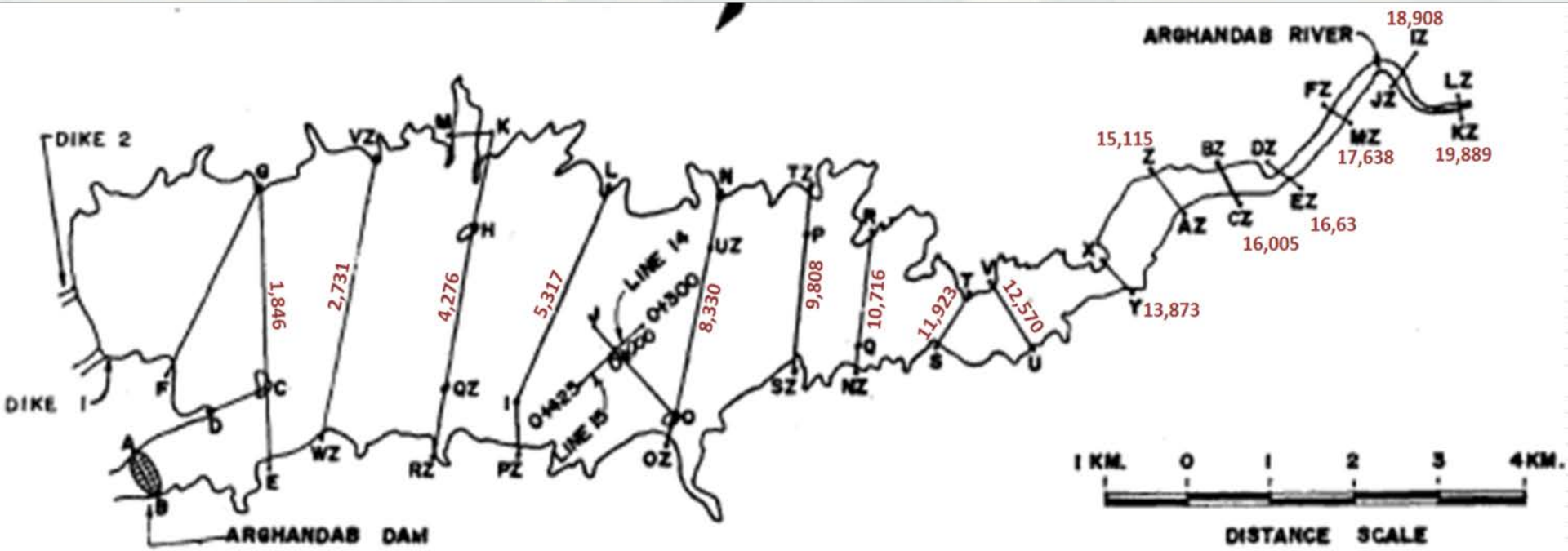
Model Components and Data Requirements

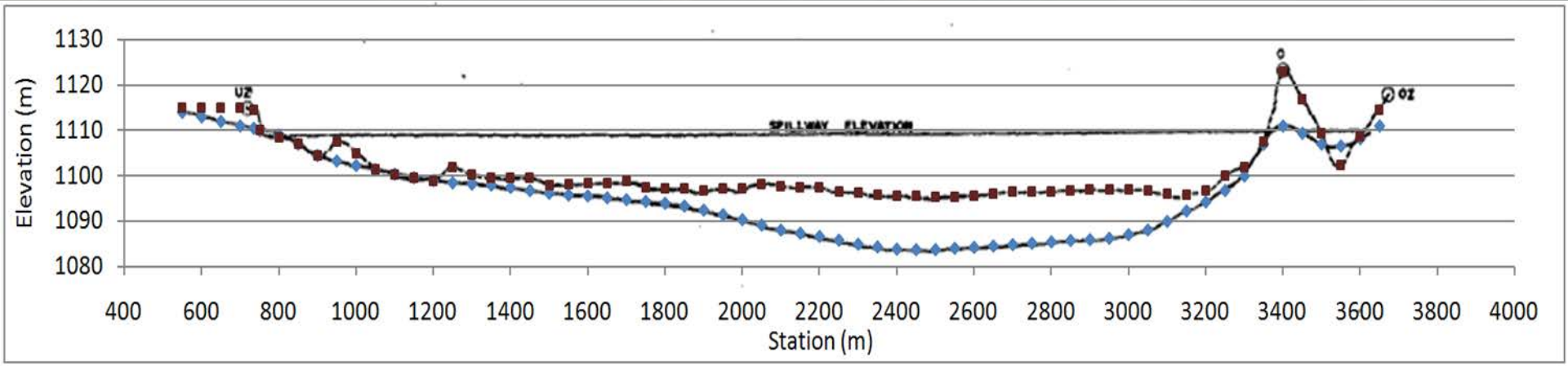
1. Geometry Data

2. Flow Data

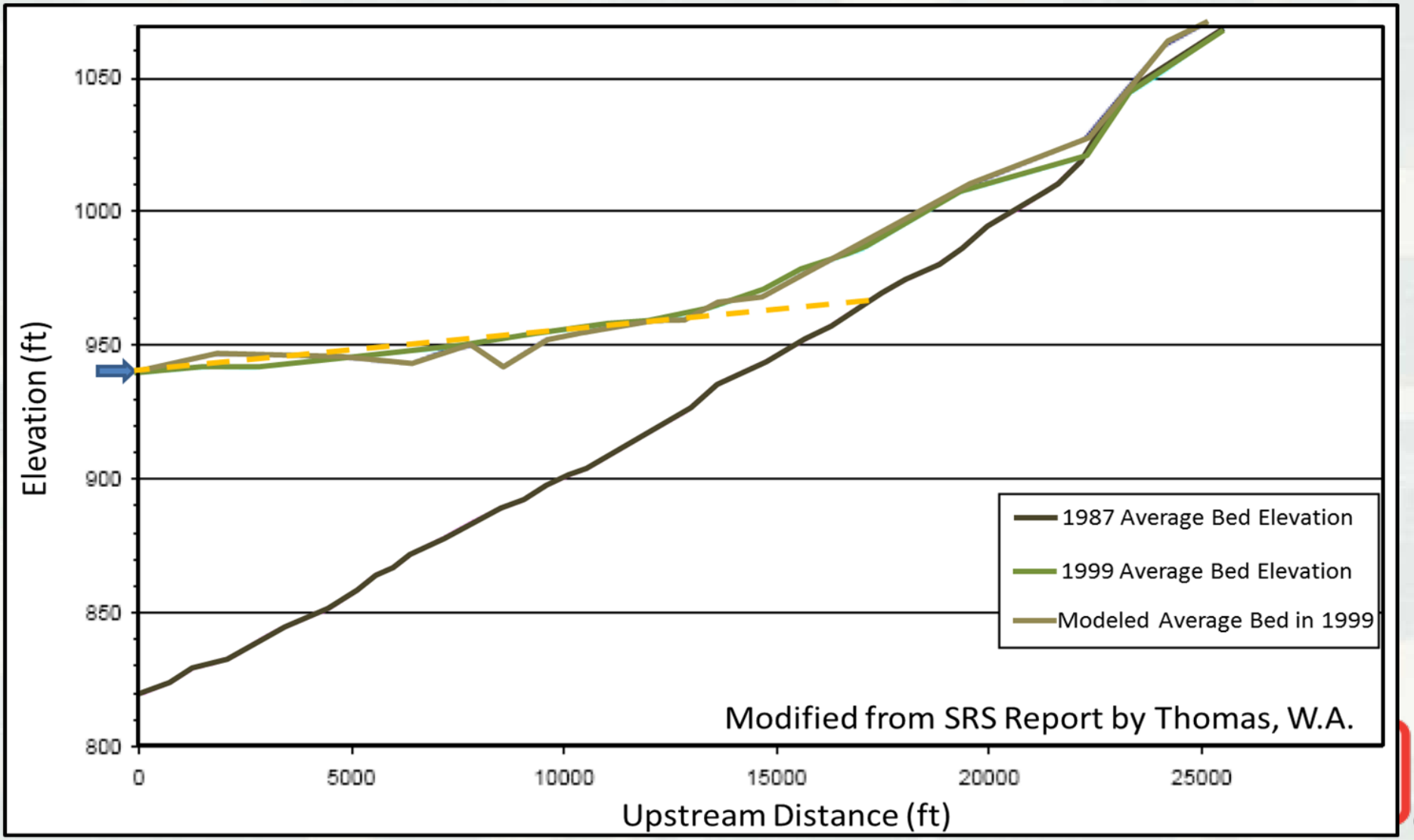
3. Sediment Data

1. Geometry Data

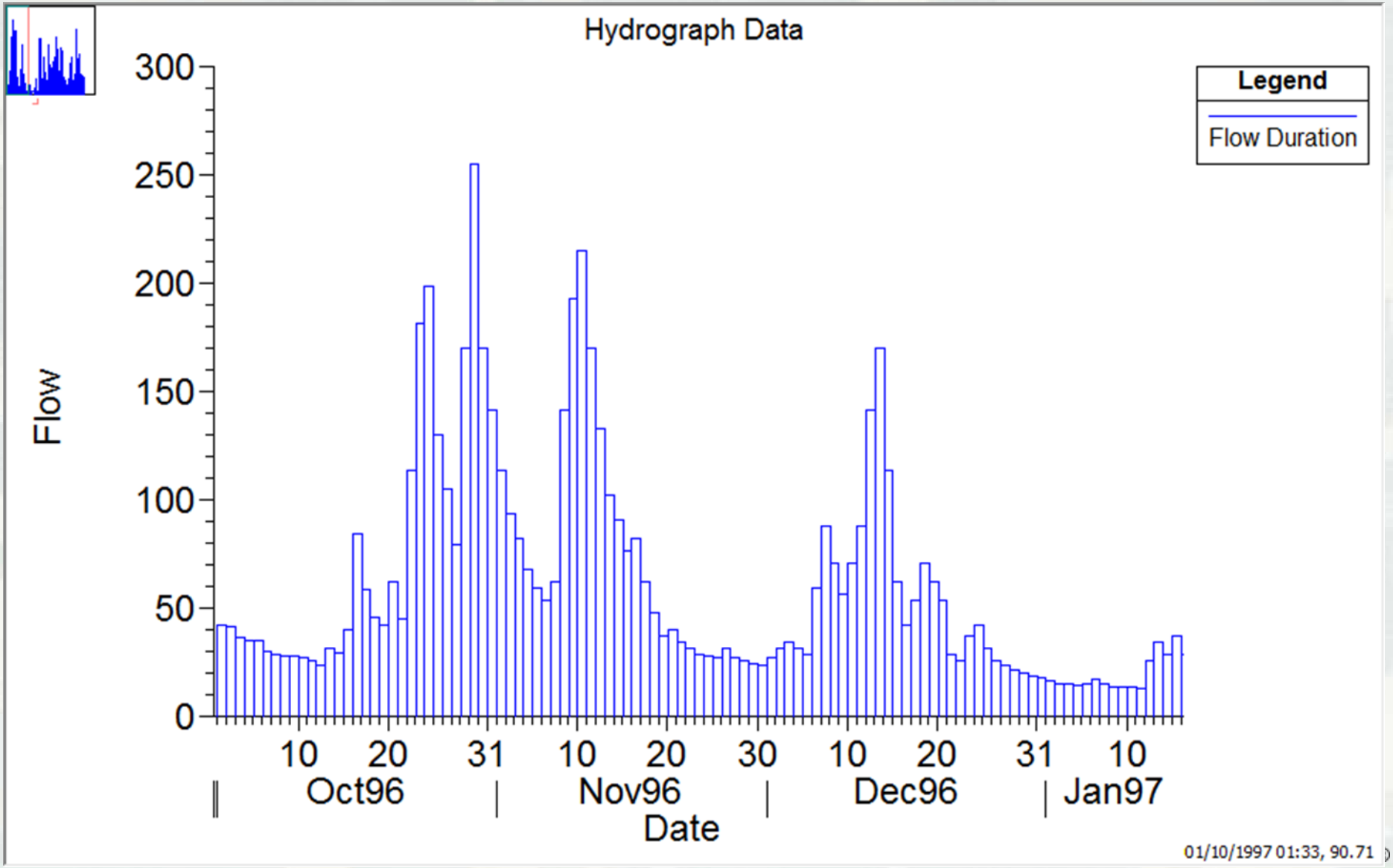




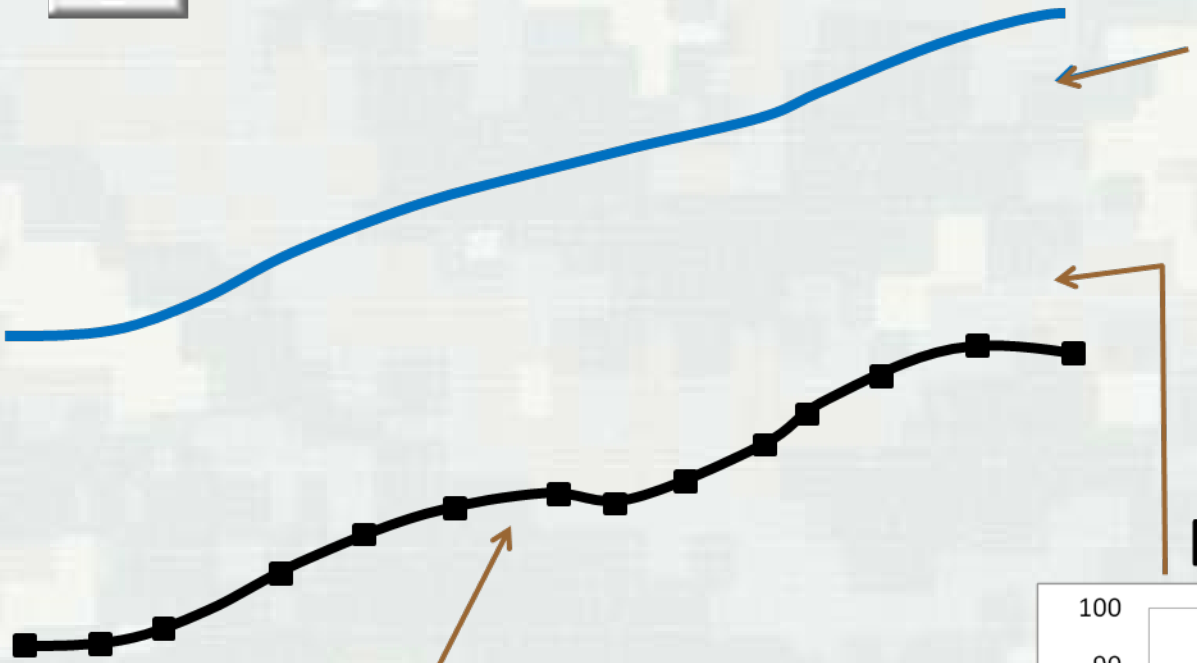
Model Domain: How Far Upstream?



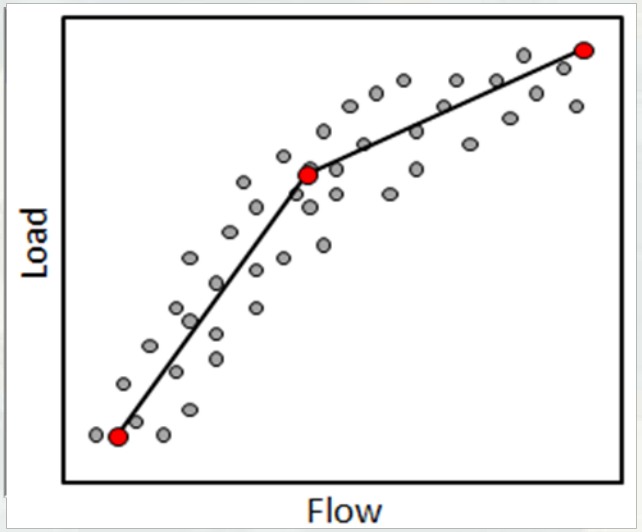
2. Flow Data


Hydrograph Data
Legend
Flow Duration
Flow
300
250
200
150
100
50
0
10
20
31
10
20
30
10
20
31
10
Oct96
Nov96
Dec96
Jan97
Date
01/10/1997 01:33, 90.71

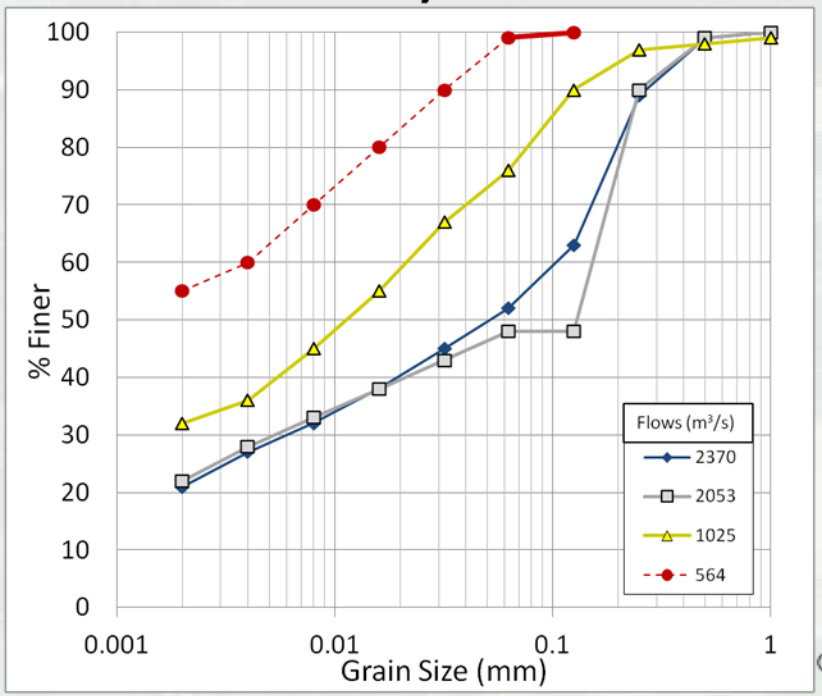
3. Sediment Data



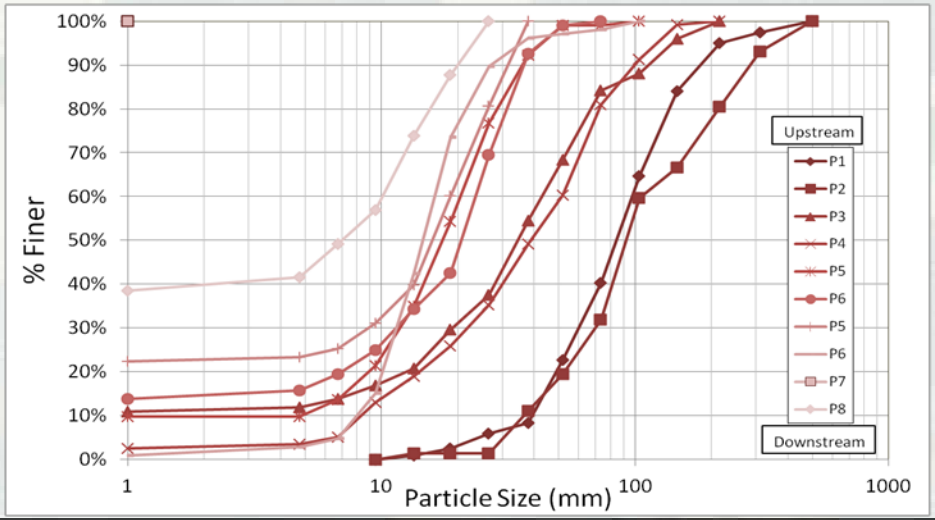
Boundary Load



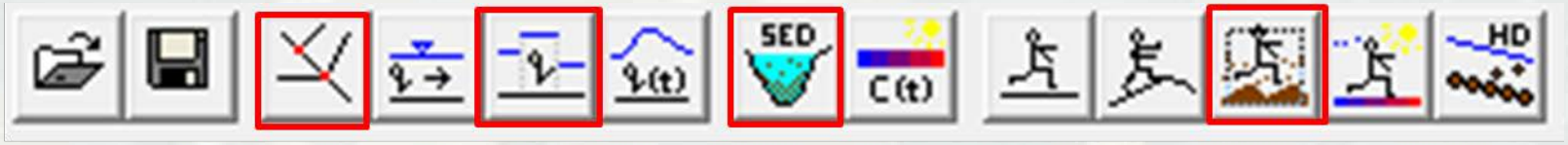
Boundary Gradations



Bed Gradation



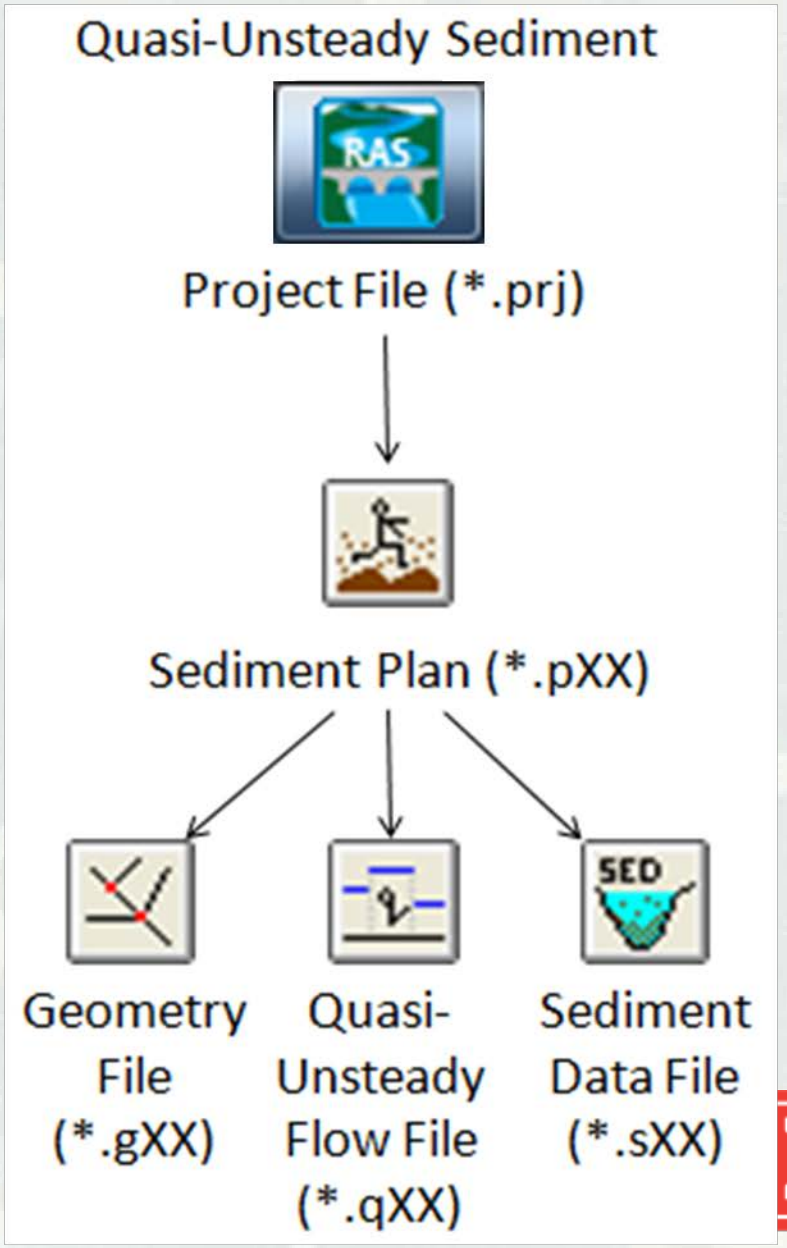
Input Data	Calibration Data
Hydraulic Data • Flow (maninstem and tributaries) -Calibration period flows -Estimate of future flows • Downstream boundary condition	**Hydraulic Calibration Data** • High water marks • Internal gage data (stage time series) • Velocity measurements
Sediment Load at Model Boundaries • Flow-Load rating curve • Suspended load and bed load • Main stem and tributary loads	**Volume Change** • Repeated Cross Sections • Repeated bathymetry
Load Gradation at Model Boundaries • Most sediment models require boundary loads subdivided by grain class	Downstream or Mid-Model Loads or Gradations • Sediment models can be calibrated against load measured in the model domain. This is not as reliable as calibrating to bed change
Bed Gradations • Collect enough bed gradations to capture trends and variablitiy • If the bed is armored, collect separate cover and subsurface gradations	Bed Gradations • If bed gradations changed during the calibration period (e.g. reservoir deposition) current bed gradations and trends can be a calibration parameter (Gibson and Pridal, 2015)
Cohesive Critical Shear and Erodibility Data • Models designed to predict cohesive erosion must estimate the critical shear and erodibility of the sediment. • These paremeters can vary over 5 orders of magnitude and must either be measured or become a calibration parameter.	Scour chain data • Measure of net bed change during an event or time window.



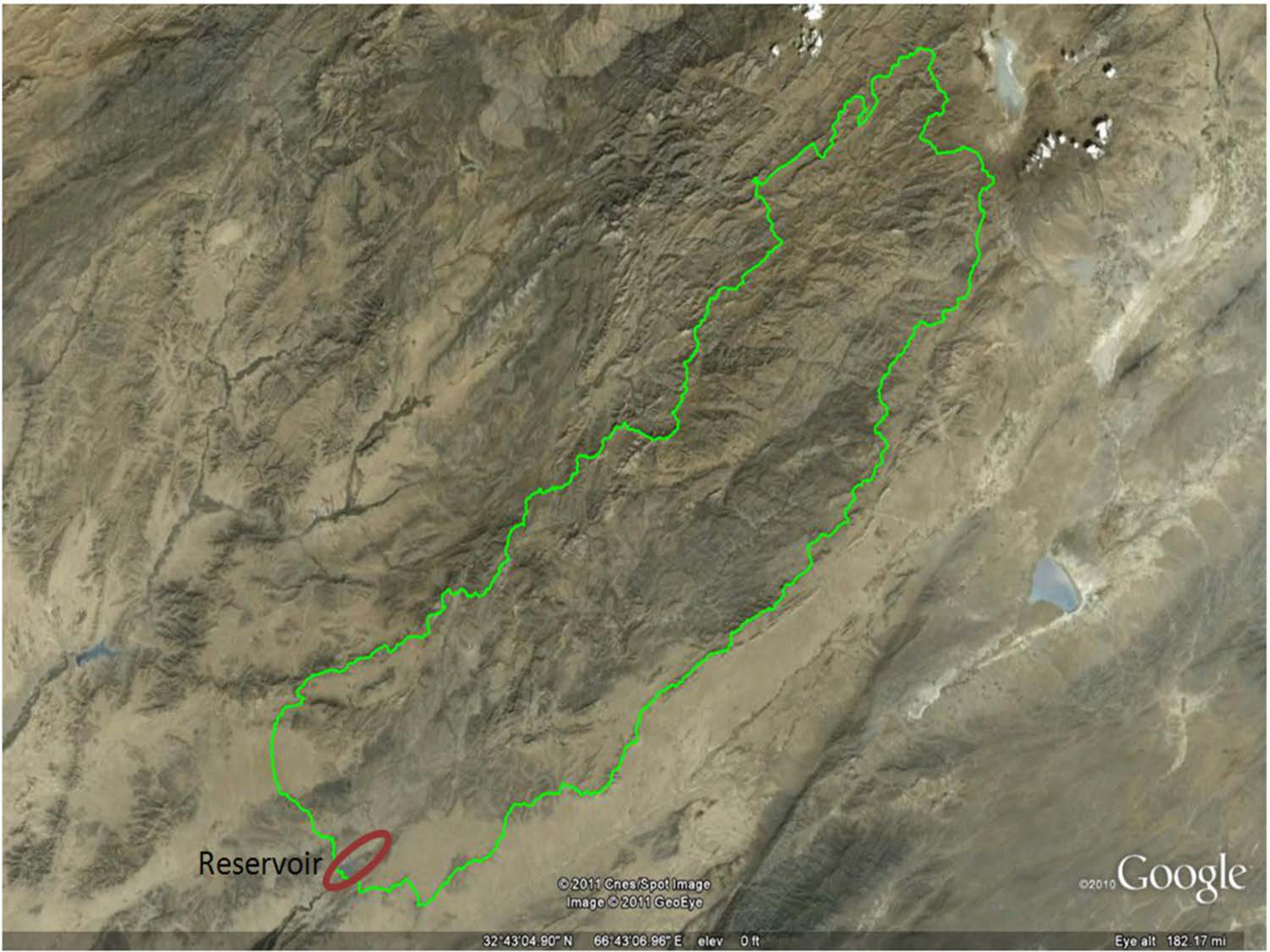
Elements of an HEC-RAS Model

- Geometry
- Flows
- Sediment

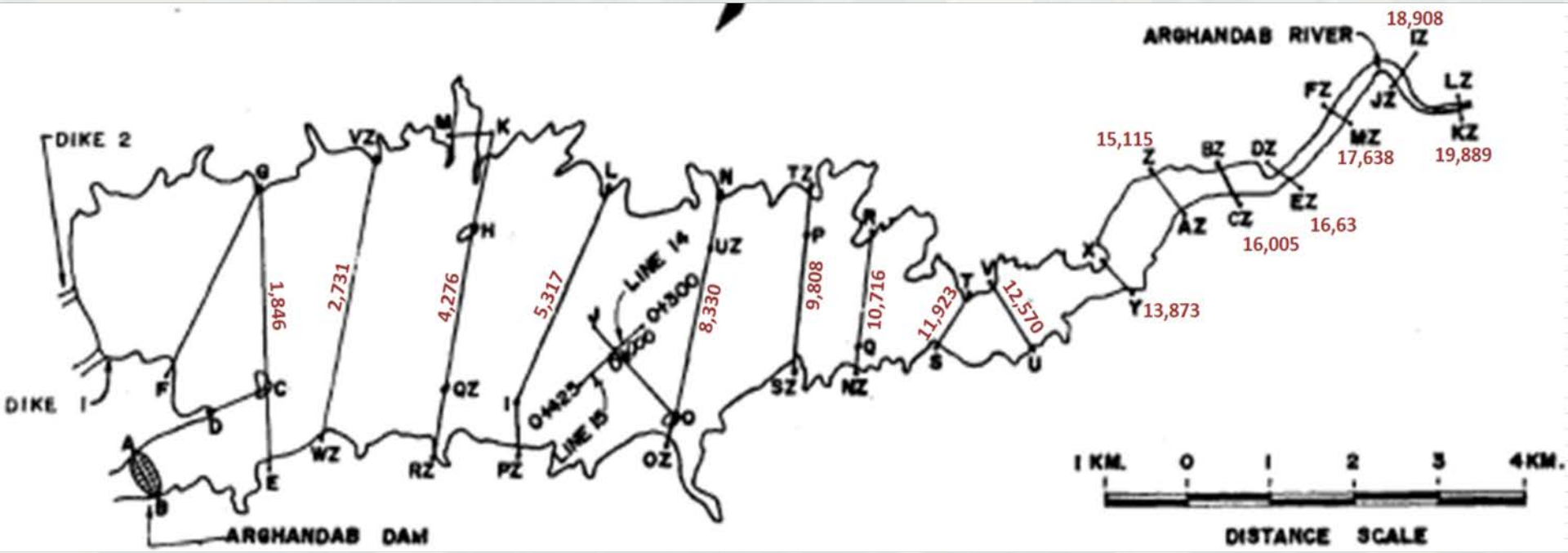
Plan

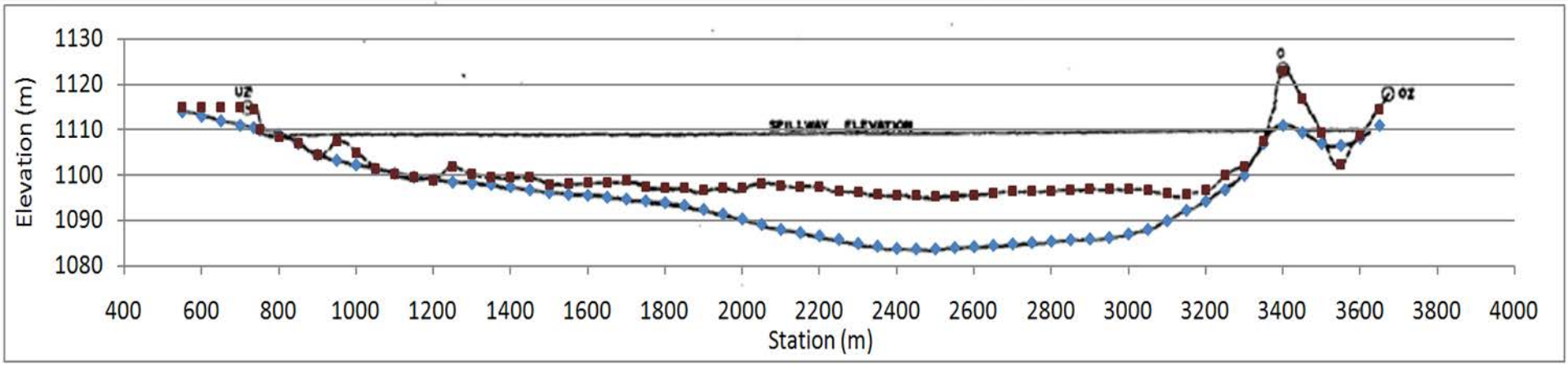


Reservoir Management
Volume Projections - Argandab Reservoir

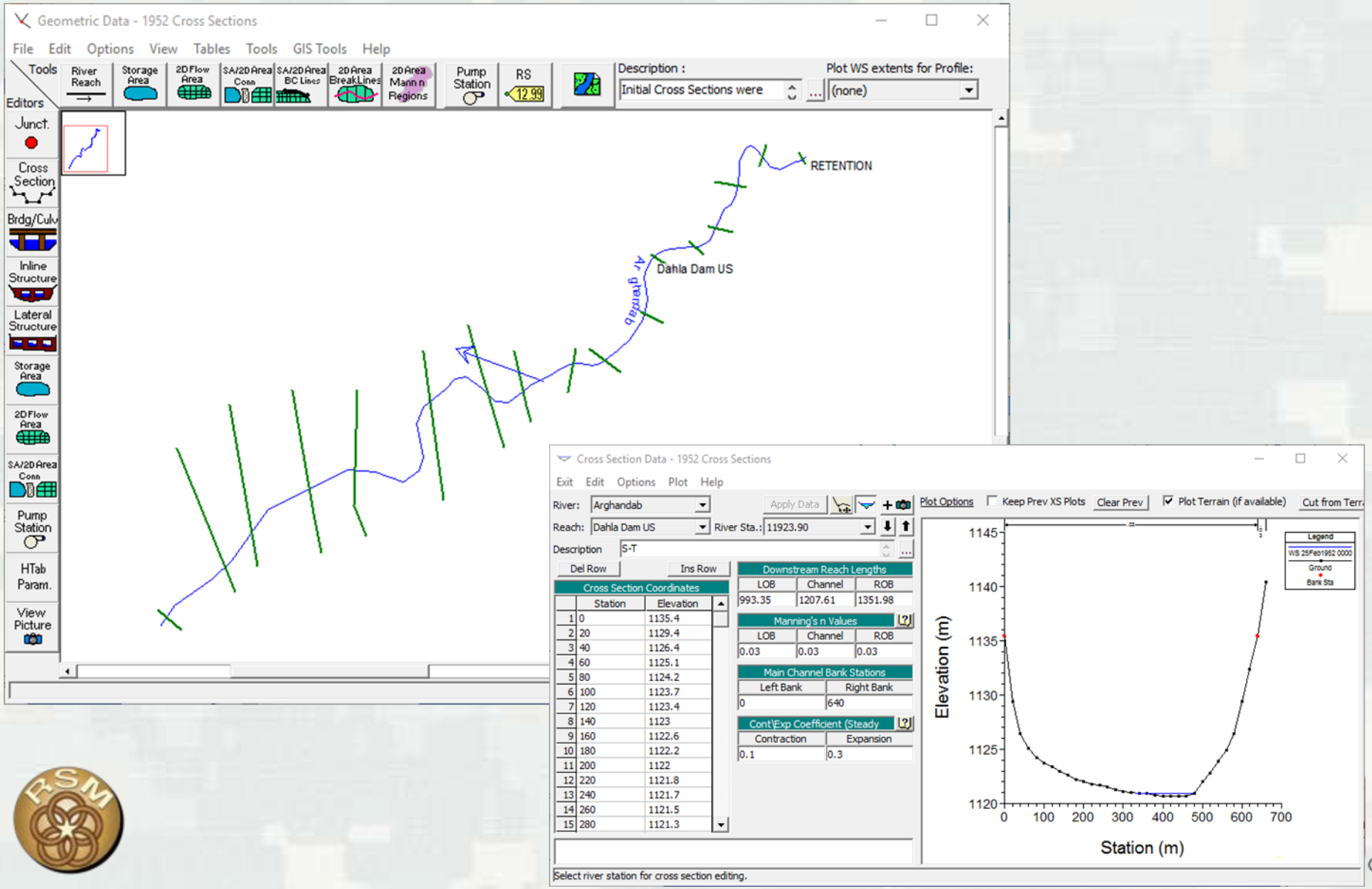

Reservoir
© 2011 Cnes/Spot Image
Image © 2011 GeoEye
©2010 Google
32°43'04.90" N 66°43'06.96" E elev 0 ft
Eye alt 182.17 mi

Geometry – Cross Sections



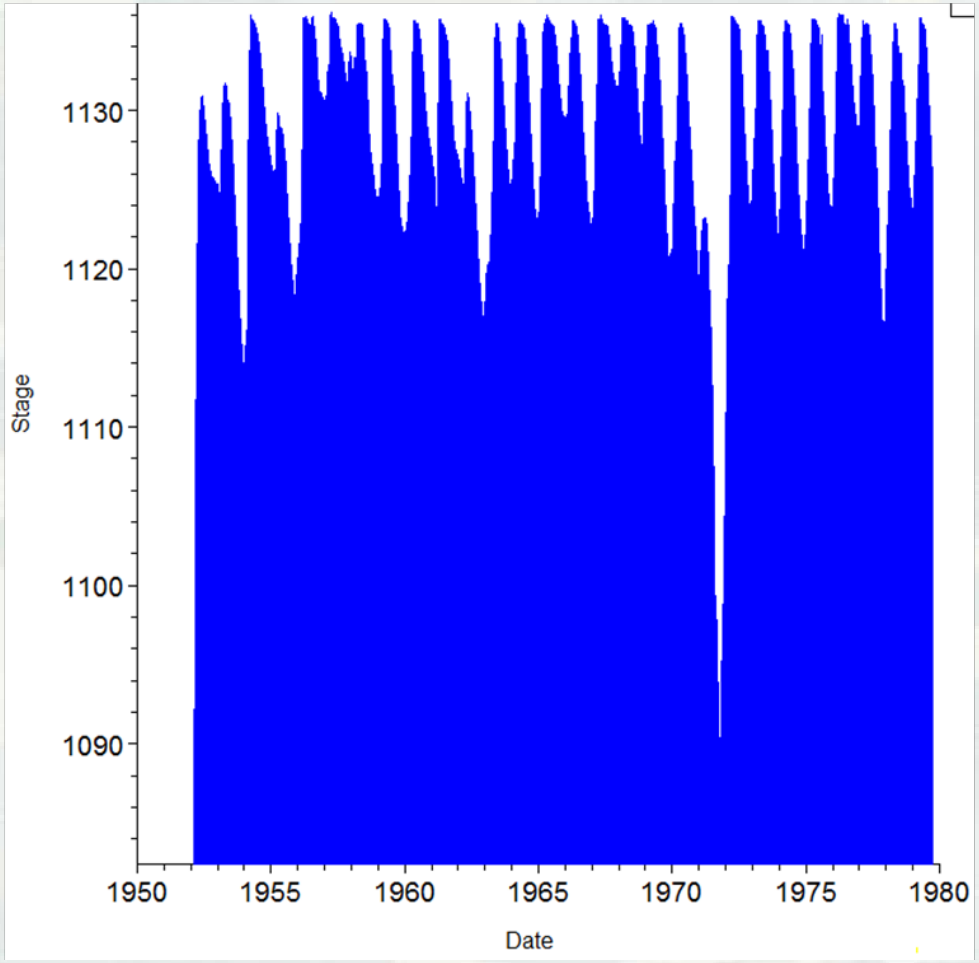


Geometry – Cross Sections

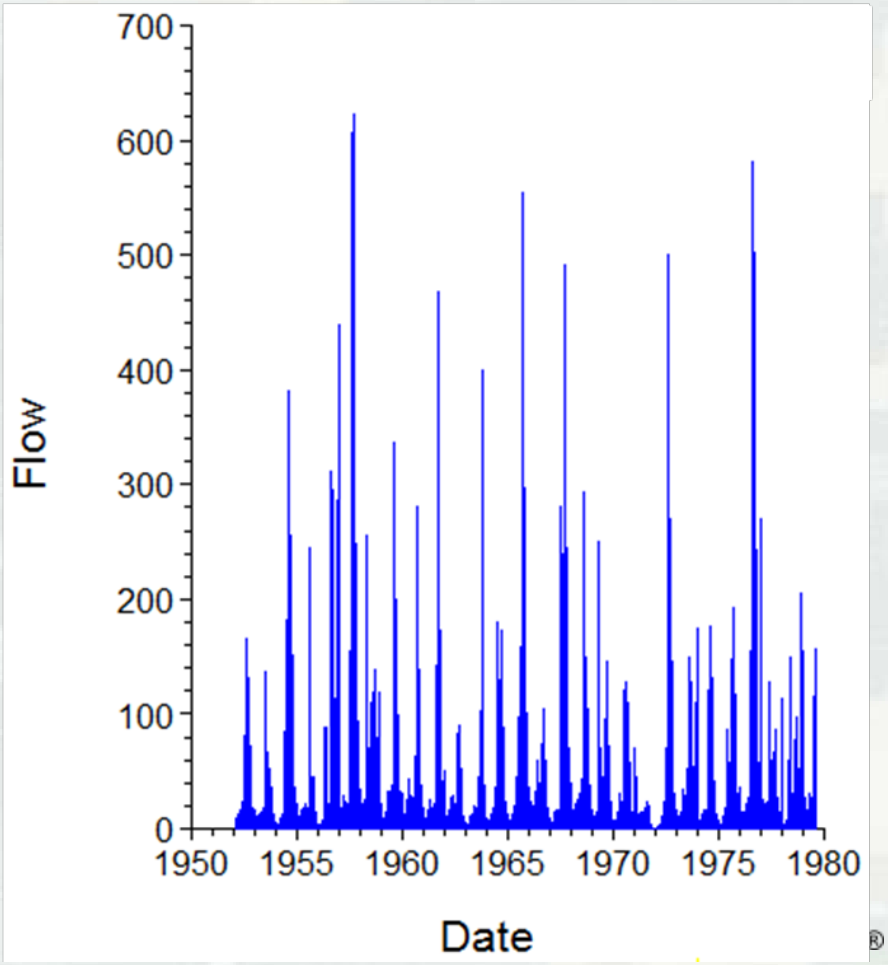


Flow Data

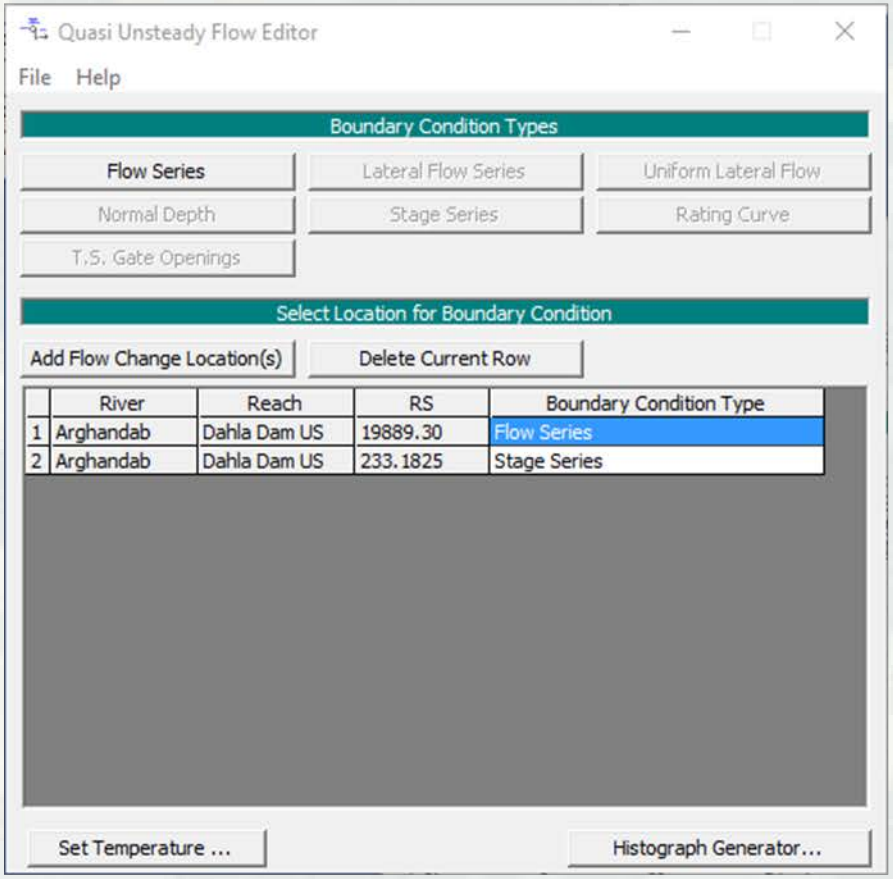
Downstream Boundary Condition
Reservoir Stage

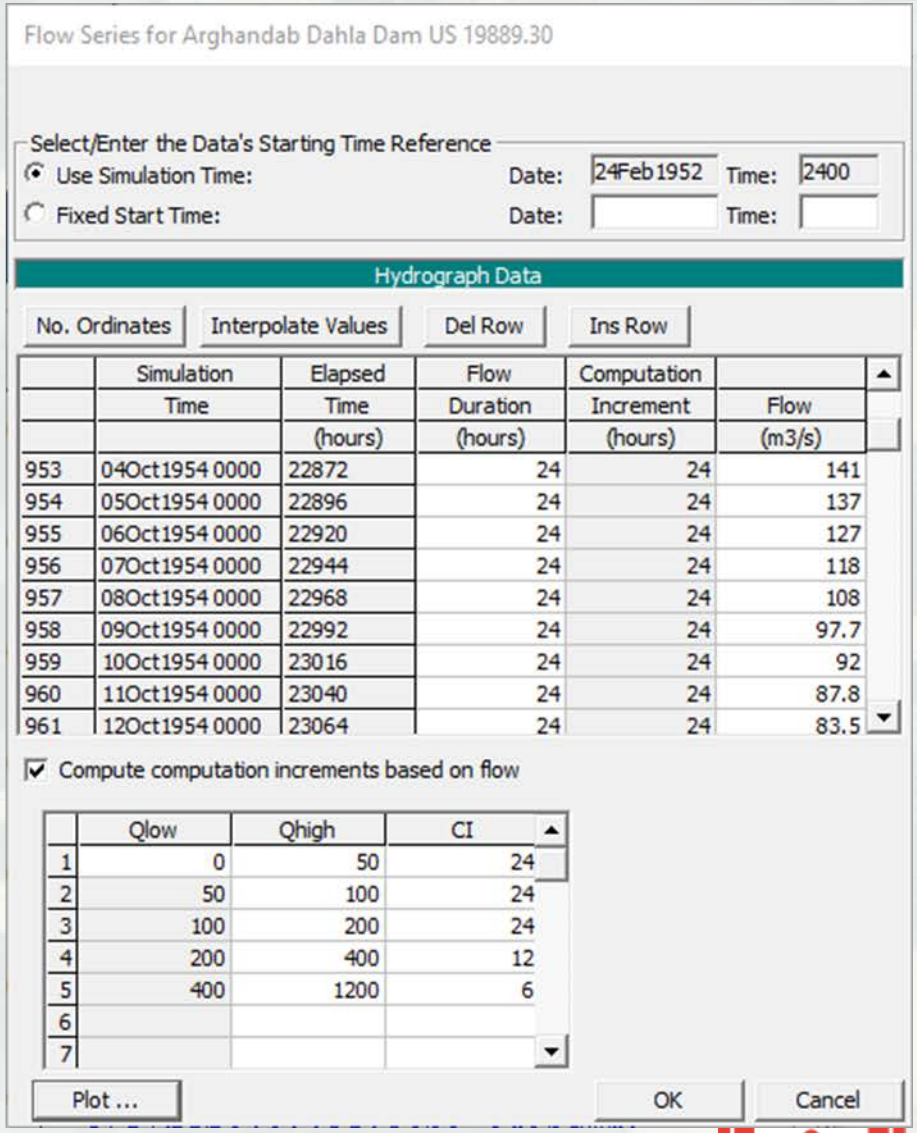


Upstream Boundary Condition
Flow Series



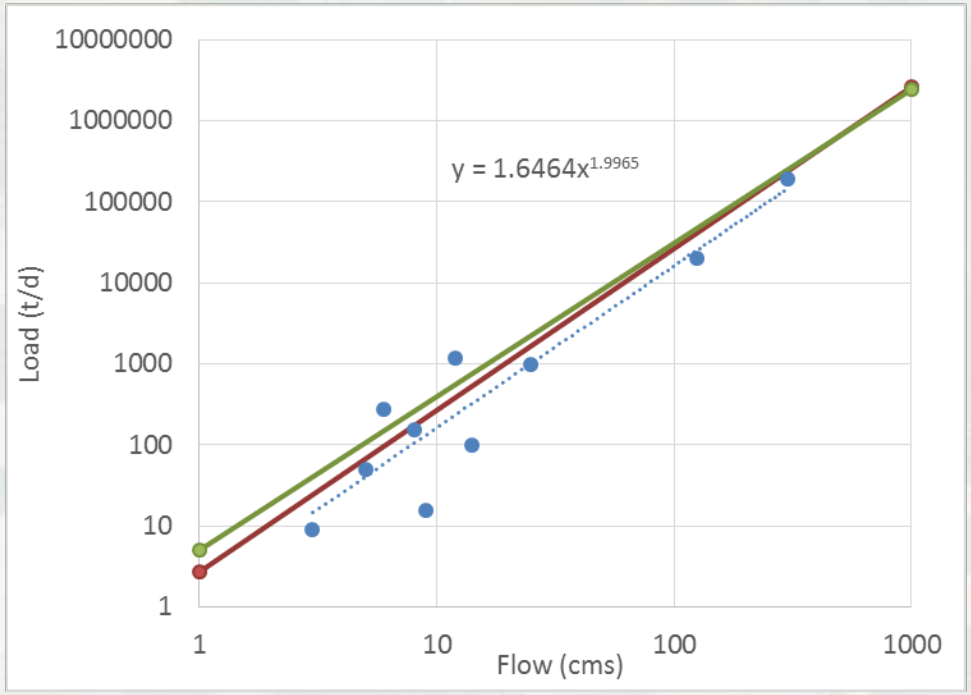
Flow Data


Quasi Unsteady Flow Editor
File Help
Boundary Condition Types
Flow Series
Lateral Flow Series
Uniform Lateral Flow
Normal Depth
Stage Series
Rating Curve
T.S. Gate Openings
Select Location for Boundary Condition
Add Flow Change Location(s)
Delete Current Row
River Reach RS Boundary Condition Type
1 Arghandab Dahla Dam US 19889.30 Flow Series
2 Arghandab Dahla Dam US 233.1825 Stage Series
Set Temperature ...
Histograph Generator...

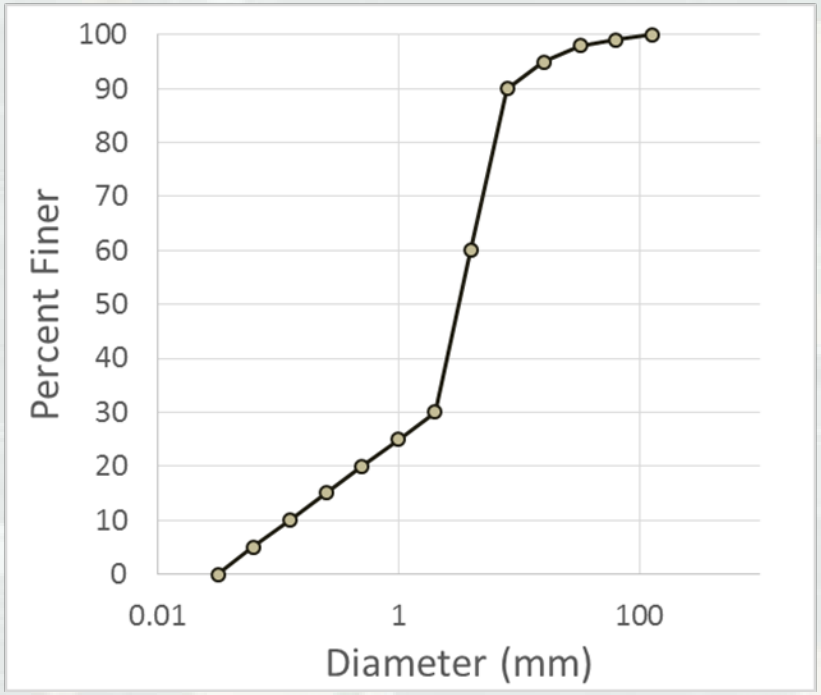

Flow Series for Arghandab Dahla Dam US 19889.30
Select/Enter the Data's Starting Time Reference
Use Simulation Time: Date: 24Feb1952 Time: 2400
Fixed Start Time: Date: Time:
Hydrograph Data
No. Ordinates
Interpolate Values
Del Row
Ins Row
Simulation Time | Elapsed Time (hours) | Flow Duration (hours) | Computation Increment (hours) | Flow (m3/s)
953 04Oct1954 0000 22872 24 24 141
954 05Oct1954 0000 22896 24 24 137
955 06Oct1954 0000 22920 24 24 127
956 07Oct1954 0000 22944 24 24 118
957 08Oct1954 0000 22968 24 24 108
958 09Oct1954 0000 22992 24 24 97.7
959 10Oct1954 0000 23016 24 24 92
960 11Oct1954 0000 23040 24 24 87.8
961 12Oct1954 0000 23064 24 24 83.5
Compute computation increments based on flow
Qlow Qhigh CI
1 0 50 24
2 50 100 24
3 100 200 24
4 200 400 12
5 400 1200 6
6
7
Plot ...
OK
Cancel

Sediment Data

Flow-Load Rating Curve



Bed Gradation



Sediment Data

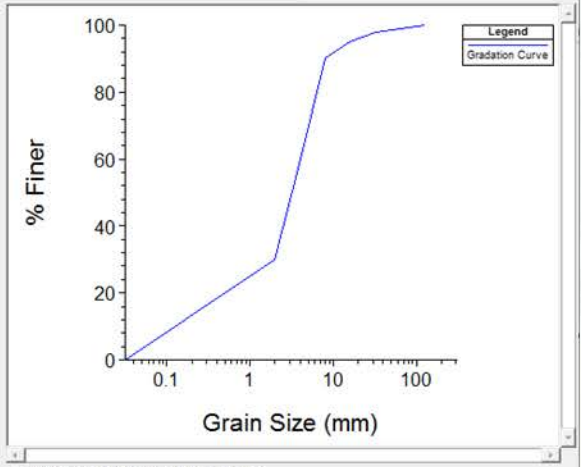
Bed Gradation

View

Bed Gradation Template: Coarse Initial bed

Enter Multiple Gradations in a Table...

	Class	diam (mm)	% Finer
1	Clay	0.004	
2	VFM	0.008	
3	FM	0.016	
4	MM	0.032	0
5	CM	0.0625	5
6	VFS	0.125	10
7	FS	0.25	15
8	MS	0.5	20
9	CS	1	25
10	VCS	2	30
11	VFG	4	60
12	FG	8	90
13	MG	16	95
14	CG	32	98
15	VCG	64	99
16	SC	128	100
17	LC	256	
18	SB	512	
19	MB	1024	
20	LB	2048	



% Finer Grain Class % Convert: %finer<-->%

Set Sample Specific Cohesive Parameters

OK Close

Sediment Data - Calibration Workshop Solution

File Options View Help

Initial Conditions and Transport Parameters | Boundary Conditions | USDA-ARS Bank Stability and Toe Erosion Model (BSTEM) (Beta)

River: Arghandab

Reach: Dahla Dam US

Number of mobile bed channels: 1

Transport Function: Laursen (Copeland)

Sorting Method: Thomas (Ex5)

Fall Velocity Method: Ruby

Define/Edit Bed Gradation

Define Layers

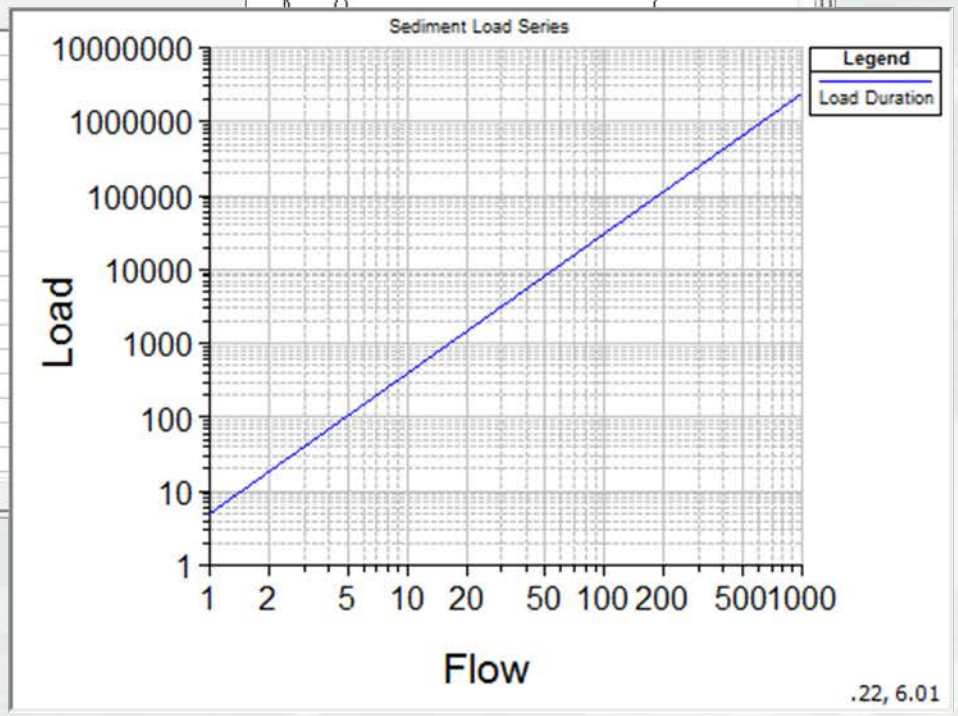
	River	Reach	RS	Invert	Max Depth	Min Elev	Left Sta	Right Sta	Bed Gradation
1	Arghandab	Dahla Dam US	19889.30	1136.9	0		-14.11	186.07	Coarse Initial bed
2	Arghandab	Dahla Dam US	18908.08	1137.5	0		25	450	Coarse Initial bed
3	Arghandab	Dahla Dam US	17638.36	1132.4	0		0	200	Coarse Initial bed
4	Arghandab	Dahla Dam US	16637.84	1130.9	0		20	280	Coarse Initial bed

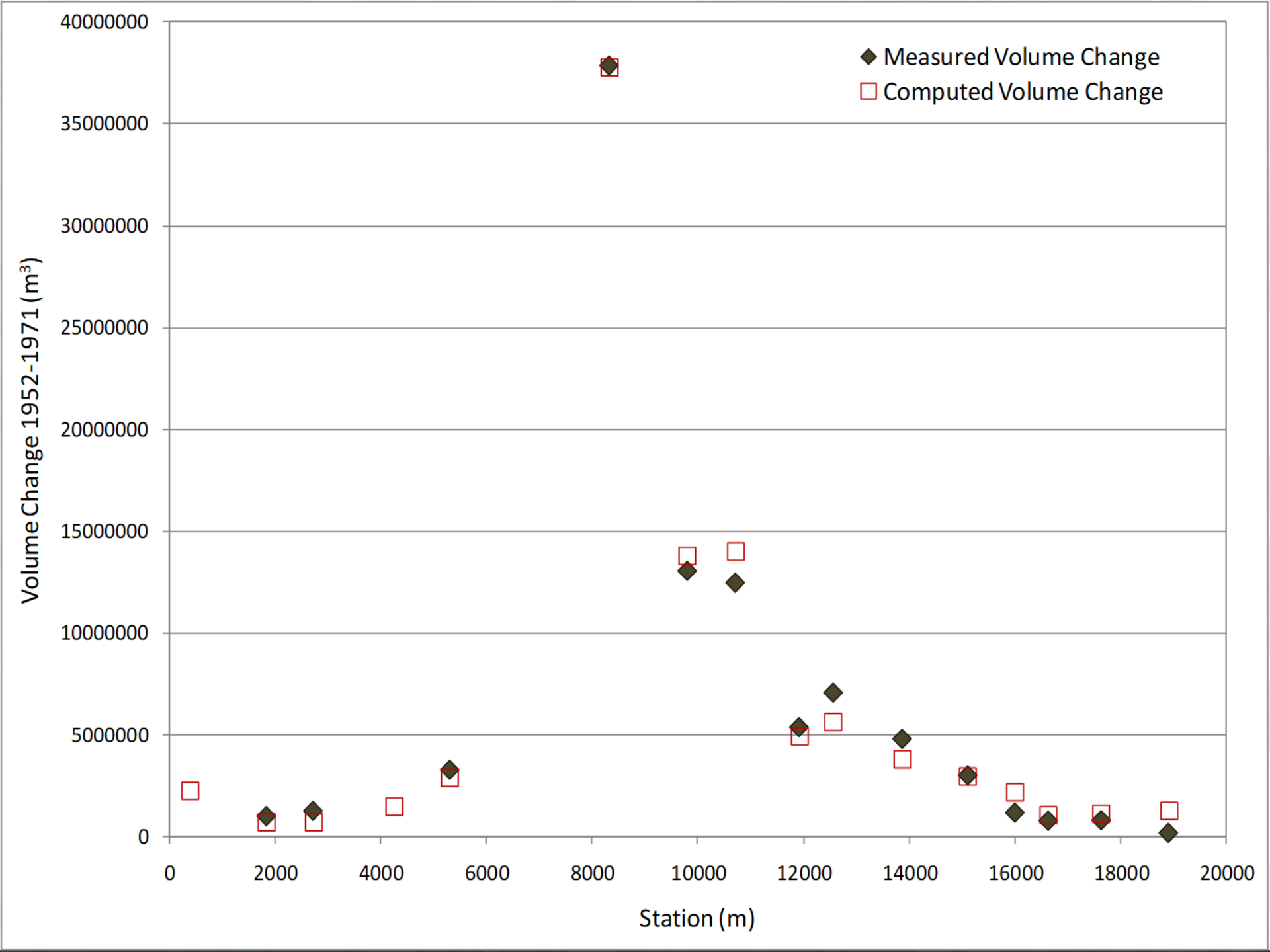
Rating Curve for Arghandab Dahla Dam US 19889.30

Number of flow-load points: 2 sets

	Flow (m3/s)	1
	Total Load (tonnes/day)	5
1	Clay (0.002-0.004)	0.2
2	VFM (0.004-0.008)	0.3
3	FM (0.008-0.016)	0.2
4	MM (0.016-0.032)	0.2
5	CM (0.032-0.0625)	0.1
6	VFS (0.0625-0.125)	
7	FS (0.125-0.25)	
8	MS (0.25-0.5)	
9	CS (0.5-1)	
10	VCS (1-2)	
11	VFG (2-4)	
12	FG (4-8)	
13	MG (8-16)	
14	CG (16-32)	
15	VCG (32-64)	
16	SC (64-128)	

Define Diversion Load Plot ...




Measured Volume Change
Computed Volume Change
Volume Change 1952-1971 (m³)
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Station (m)