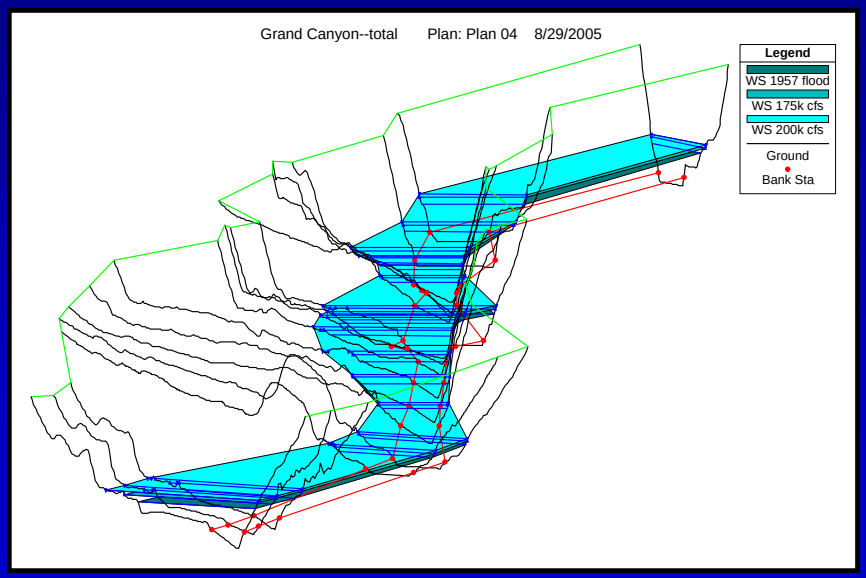
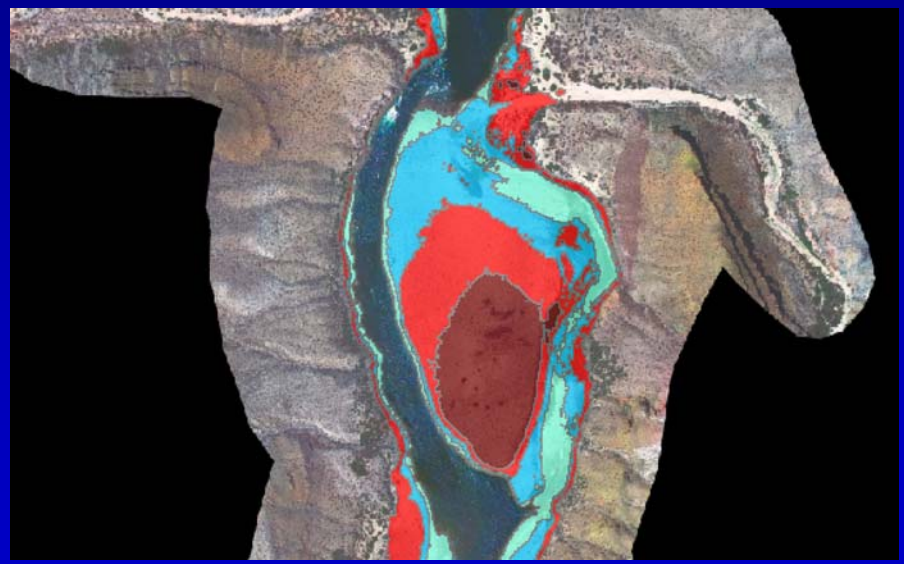
An Improved STARS Model:

Predicted Grand Canyon water-surface elevations and virtual shorelines for flows up to 200,000 cfs





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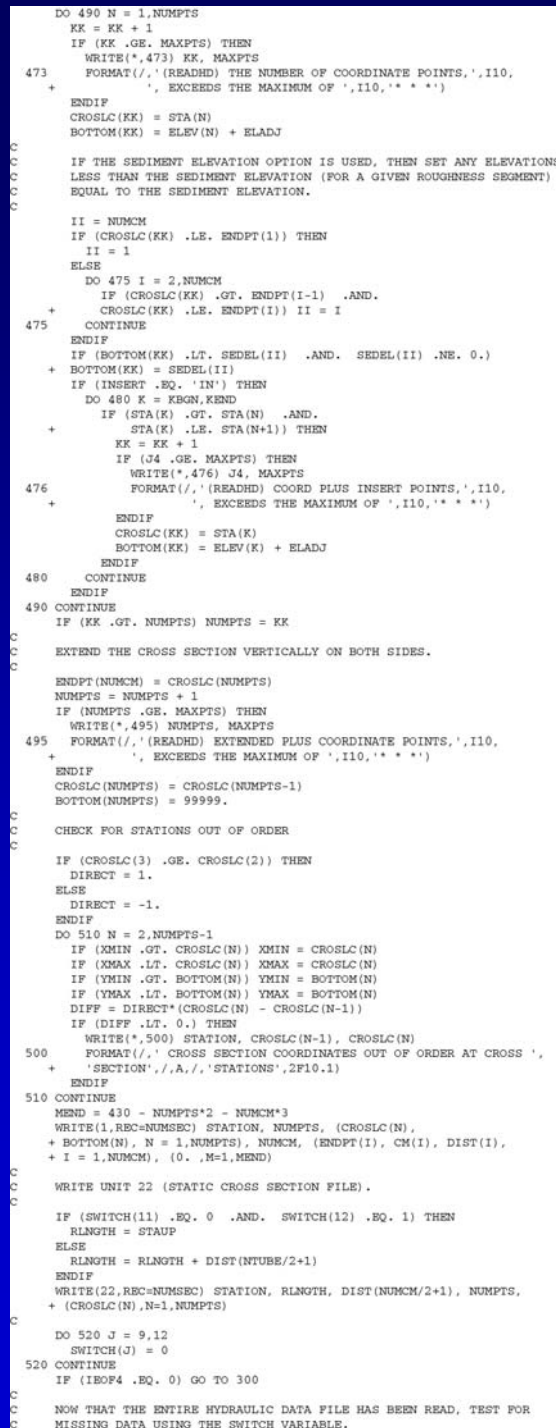
Original STARS Model

Randle and Pemberton, 1987

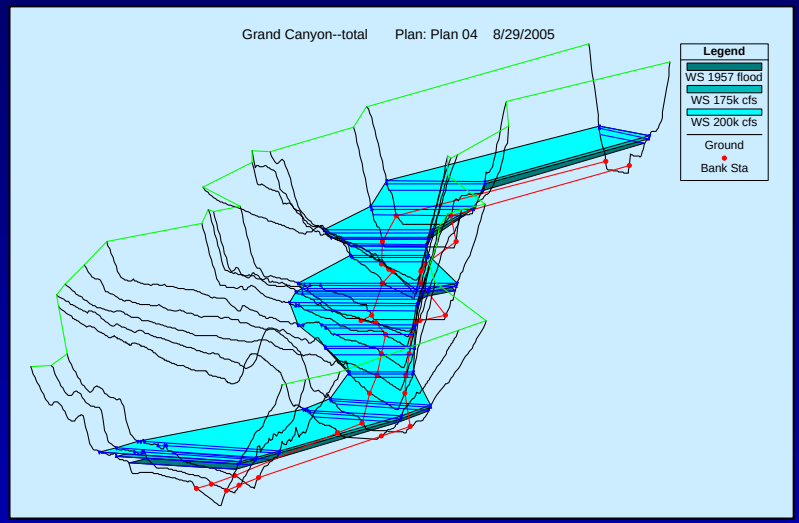
- 1-D Step Backwater
- Fortran mainframe code
- 708 Cross Sections (509 Interpolated)
- 1923 USGS WS Profile to calibrate
- Critical Flow at each rapid (cascade of weirs)
- Discharge up to 30,000 cfs

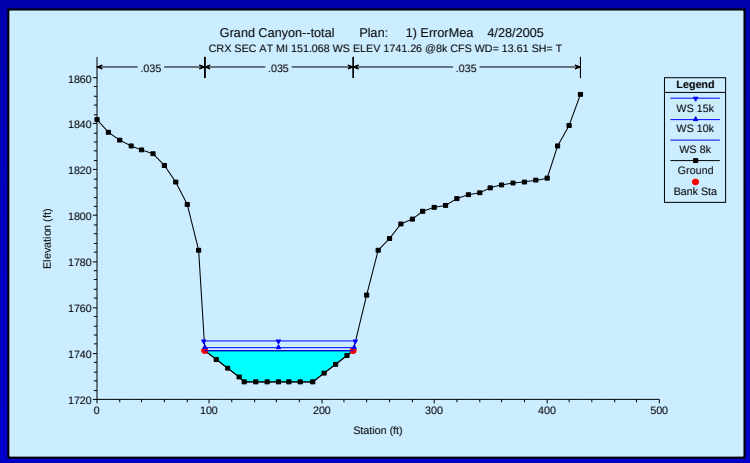


```
      DO 490 N = 1,NUMPTS
        KK = KK + 1
        IF (KK .GE. MAXPTS) THEN
          WRITE(*,473) KK, MAXPTS
473       FORMAT(/,'(READHD) THE NUMBER OF COORDINATE POINTS,',I10,
     +           ', EXCEEDS THE MAXIMUM OF ',I10,'* * *')
        ENDIF
        CROSLC(KK) = STA(N)
        BOTTOM(KK) = ELEV(N) + ELADJ

C
C       IF THE SEDIMENT ELEVATION OPTION IS USED, THEN SET ANY ELEVATIONS
C       LESS THAN THE SEDIMENT ELEVATION (FOR A GIVEN ROUGHNESS SEGMENT)
C       EQUAL TO THE SEDIMENT ELEVATION.
C
        II = NUMCM
        IF (CROSLC(KK) .LE. ENDPT(1)) THEN
          II = 1
        ELSE
          DO 475 I = 2,NUMCM
            IF (CROSLC(KK) .GT. ENDPT(I-1)  .AND.
     +        CROSLC(KK) .LE. ENDPT(I)) II = I
475       CONTINUE
        ENDIF
        IF (BOTTOM(KK) .LT. SEDEL(II)  .AND.  SEDEL(II) .NE. 0.)
     +  BOTTOM(KK) = SEDEL(II)
        IF (INSERT .EQ. 'IN') THEN
          DO 480 K = KBGN,KEND
            IF (STA(K) .GT. STA(N)  .AND.
     +          STA(K) .LE. STA(N+1)) THEN
              KK = KK + 1
              IF (J4 .GE. MAXPTS) THEN
                WRITE(*,476) J4, MAXPTS
476             FORMAT(/,'(READHD) COORD PLUS INSERT POINTS,',I10,
     +                 ', EXCEEDS THE MAXIMUM OF ',I10,'* * *')
              ENDIF
              CROSLC(KK) = STA(K)
              BOTTOM(KK) = ELEV(K) + ELADJ
            ENDIF
480       CONTINUE
        ENDIF
490   CONTINUE
      IF (KK .GT. NUMPTS) NUMPTS = KK

C
C     EXTEND THE CROSS SECTION VERTICALLY ON BOTH SIDES.
C
      ENDPT(NUMCM) = CROSLC(NUMPTS)
      NUMPTS = NUMPTS + 1
      IF (NUMPTS .GE. MAXPTS) THEN
        WRITE(*,495) NUMPTS, MAXPTS
495     FORMAT(/,'(READHD) EXTENDED PLUS COORDINATE POINTS,',I10,
     +         ', EXCEEDS THE MAXIMUM OF ',I10,'* * *')
      ENDIF
      CROSLC(NUMPTS) = CROSLC(NUMPTS-1)
      BOTTOM(NUMPTS) = 99999.

C
C     CHECK FOR STATIONS OUT OF ORDER
C
      IF (CROSLC(3) .GE. CROSLC(2)) THEN
        DIRECT = 1.
      ELSE
        DIRECT = -1.
      ENDIF
      DO 510 N = 2,NUMPTS-1
        IF (XMIN .GT. CROSLC(N)) XMIN = CROSLC(N)
        IF (XMAX .LT. CROSLC(N)) XMAX = CROSLC(N)
        IF (YMIN .GT. BOTTOM(N)) YMIN = BOTTOM(N)
        IF (YMAX .LT. BOTTOM(N)) YMAX = BOTTOM(N)
        DIFF = DIRECT*(CROSLC(N) - CROSLC(N-1))
        IF (DIFF .LT. 0.) THEN
          WRITE(*,500) STATION, CROSLC(N-1), CROSLC(N)
500       FORMAT(/,' CROSS SECTION COORDINATES OUT OF ORDER AT CROSS ',
     +    'SECTION',/,A,/,'STATIONS',2F10.1)
        ENDIF
510   CONTINUE
      MEND = 430 - NUMPTS*2 - NUMCM*3
      WRITE(1,REC=NUMSEC) STATION, NUMPTS, (CROSLC(N),
     + BOTTOM(N), N = 1,NUMPTS), NUMCM, (ENDPT(I), CM(I), DIST(I),
     + I = 1,NUMCM), (0. ,M=1,MEND)

C
C     WRITE UNIT 22 (STATIC CROSS SECTION FILE).
C
      IF (SWITCH(11) .EQ. 0  .AND.  SWITCH(12) .EQ. 1) THEN
        RLNGTH = STAUP
      ELSE
        RLNGTH = RLNGTH + DIST(NTUBE/2+1)
      ENDIF
      WRITE(22,REC=NUMSEC) STATION, RLNGTH, DIST(NUMCM/2+1), NUMPTS,
     + (CROSLC(N),N=1,NUMPTS)

C
      DO 520 J = 9,12
        SWITCH(J) = 0
520   CONTINUE
      IF (IEOF4 .EQ. 0) GO TO 300

C
C     NOW THAT THE ENTIRE HYDRAULIC DATA FILE HAS BEEN READ, TEST FOR
C     MISSING DATA USING THE SWITCH VARIABLE.
```

The New Model

- ISTAR 2002 DEM
- Hec-Ras (1-D step backwater)
- 2700 Cross Sections
- Lee's Ferry to Diamond Creek





- Calibrated at 8k cfs (00/02 data)
- Critical Flow at each rapid
- Discharge up to 200,000 cfs

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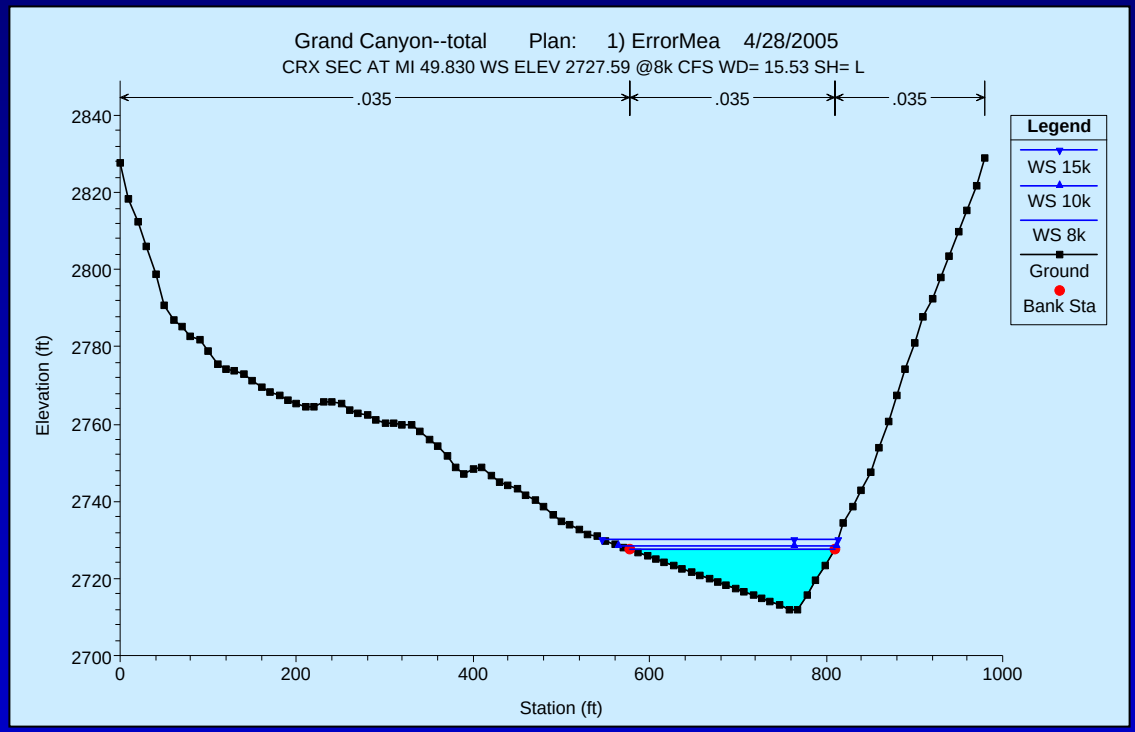
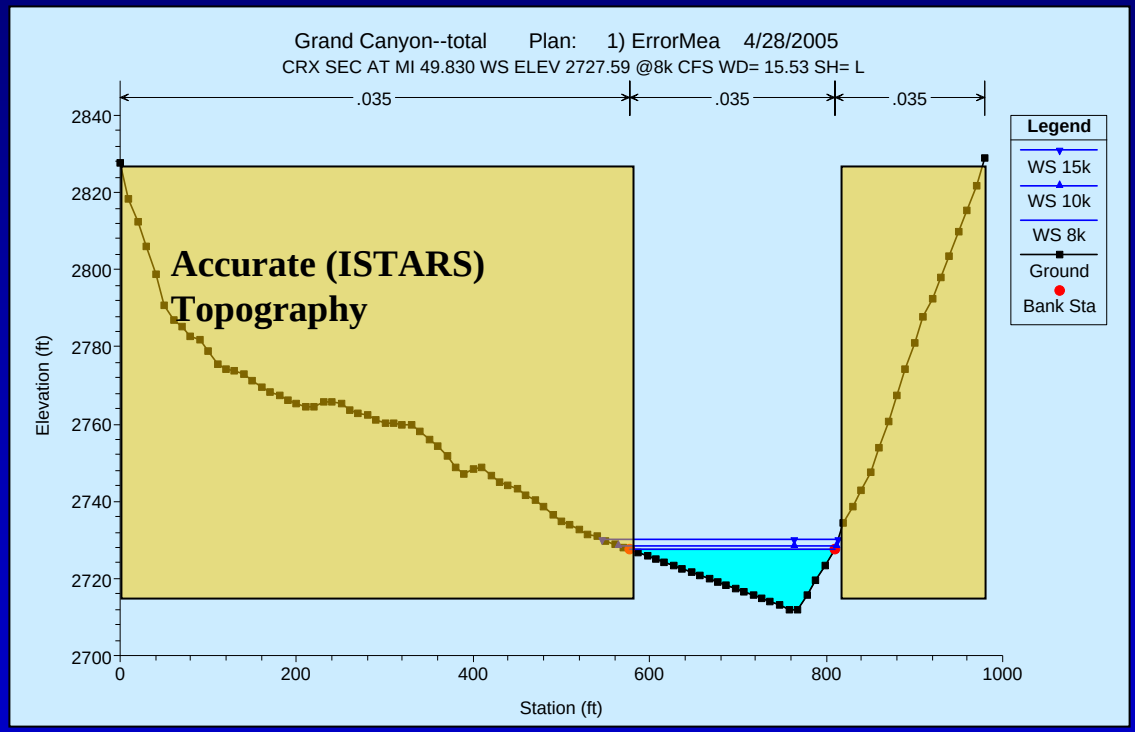
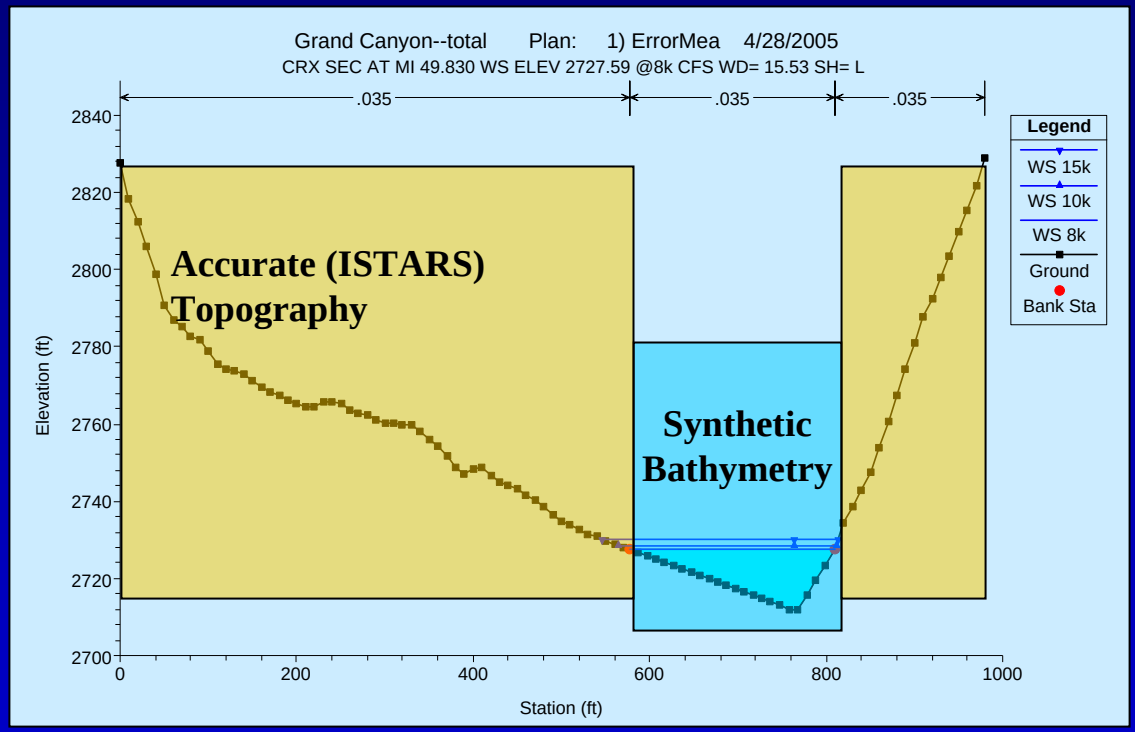
Cutting Cross Sections



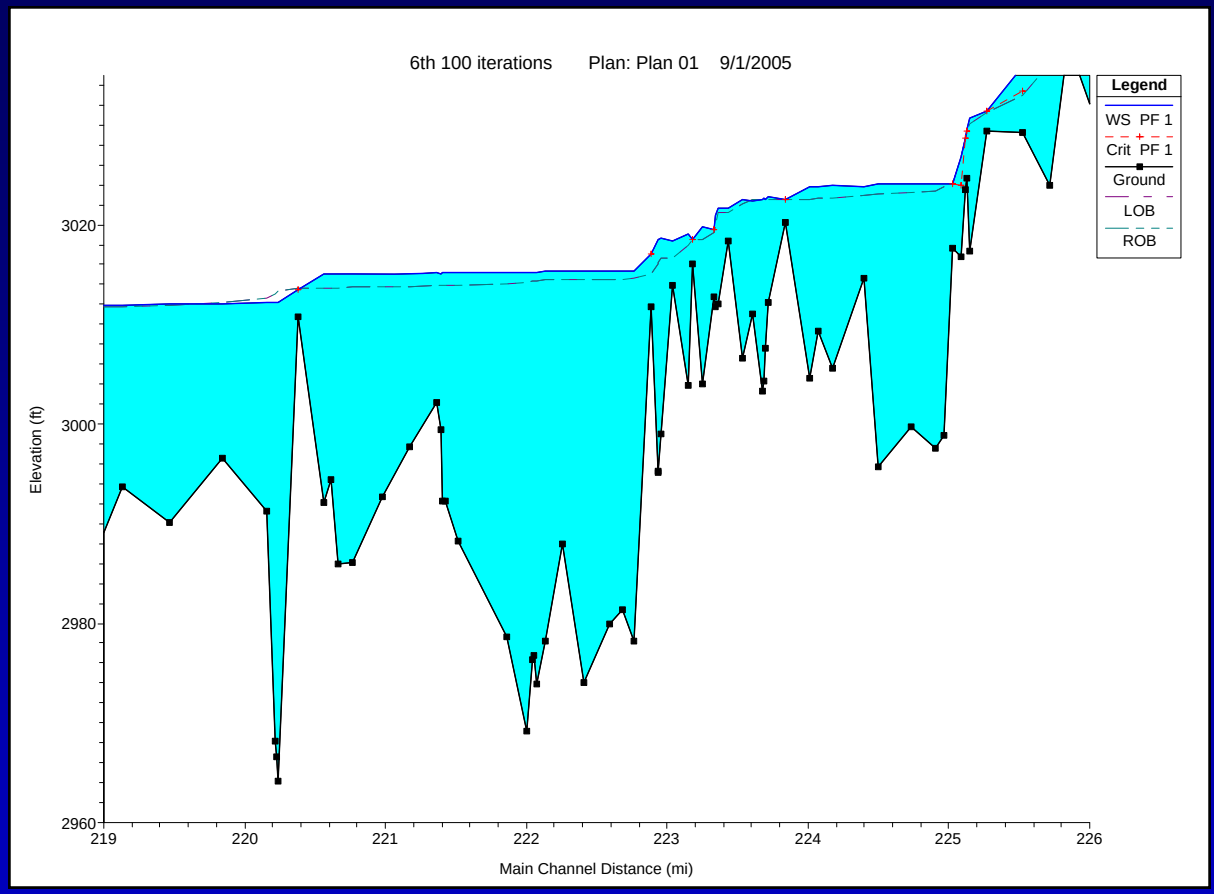
Cutting Cross Sections



Cutting Cross Sections



Bathymetry



- Trapezoidal Shape
- Thalweg Depth adjusted up/down
- Accuracy in pools = 0.1 foot

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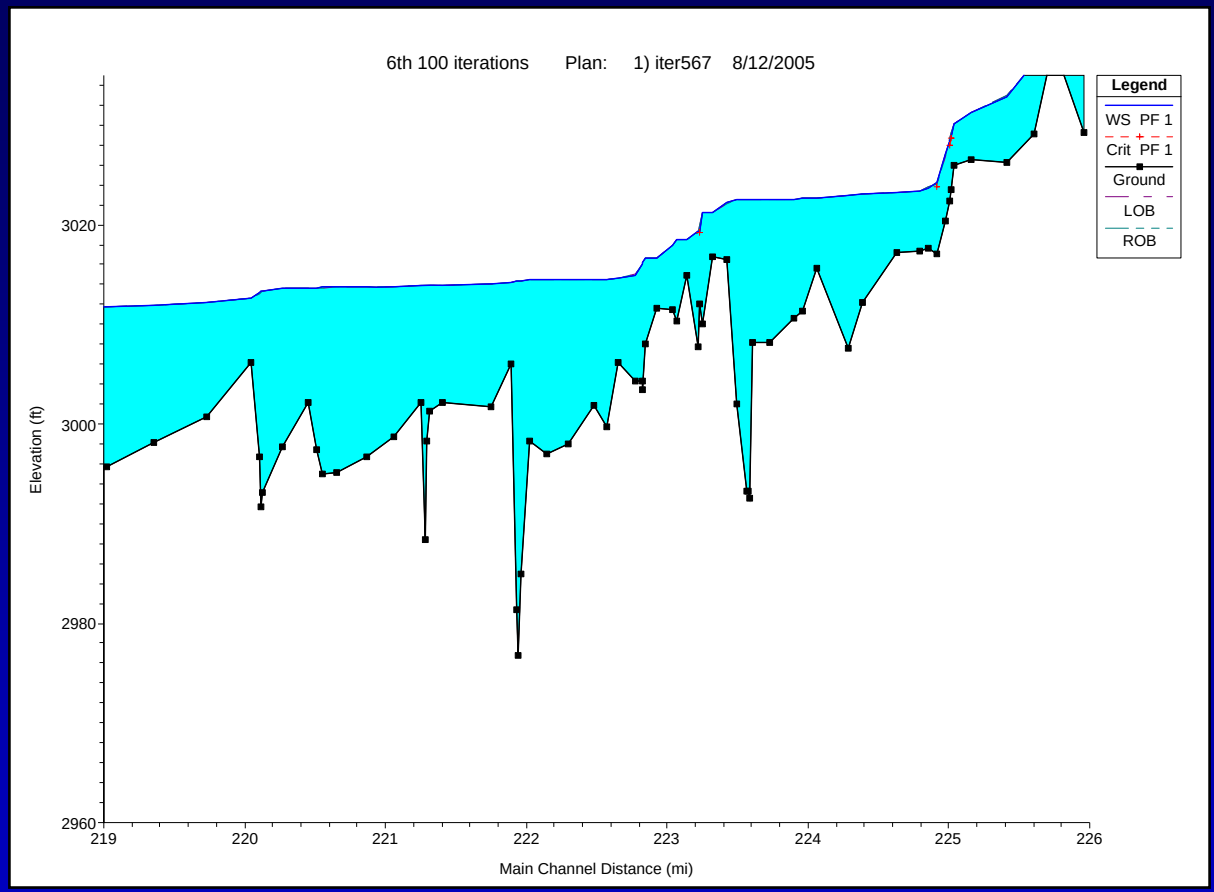
Bathymetry



- Trapezoidal Shape
- Thalweg Depth adjusted up/down
- Accuracy in pools = 0.1 foot

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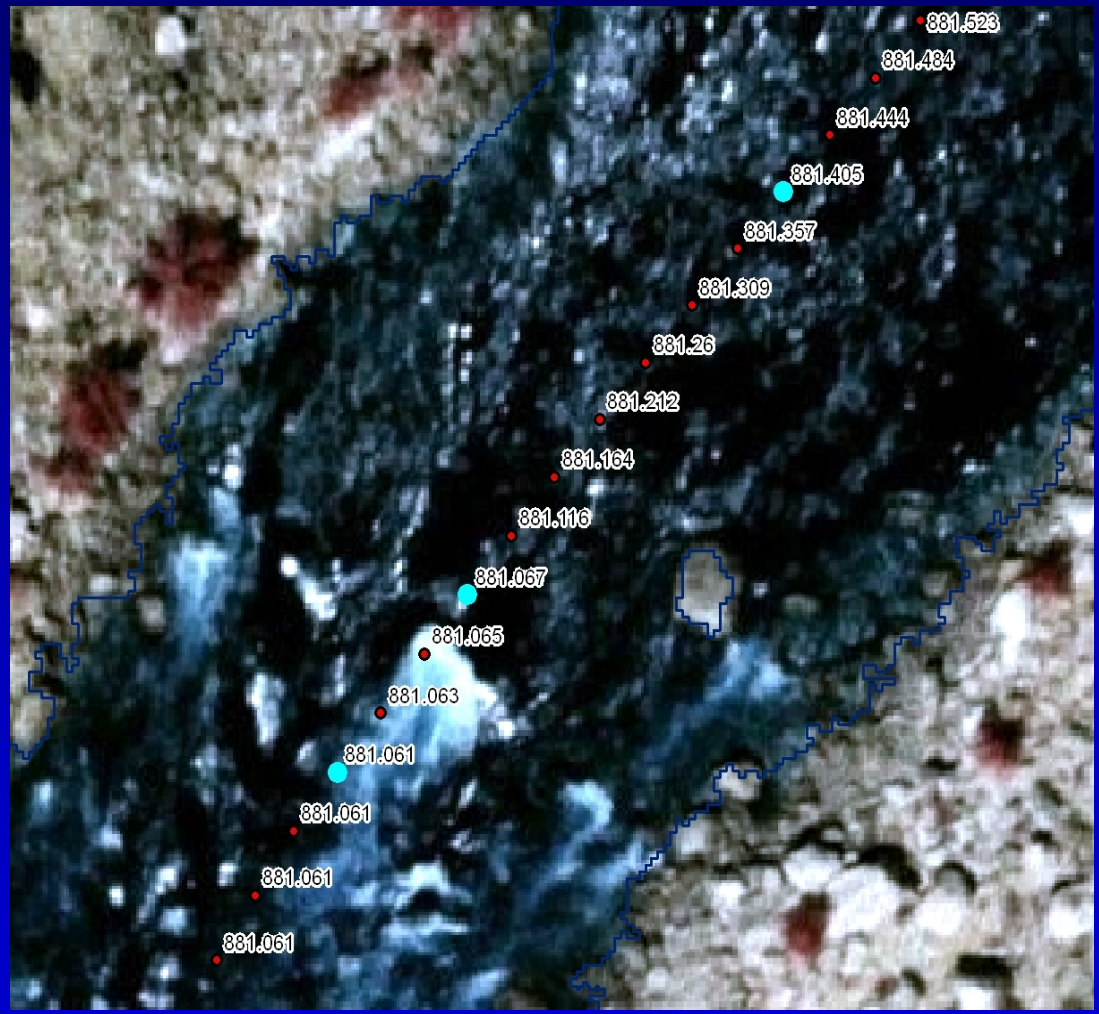
Constructing Virtual Shoreline (e.g. 45,000 cfs)

Model Calibration Cross-Sections with 45,000 cfs Elevations (Blue Points).

Linear Interpolation of 45,000 cfs Elevation Values at 5-Meter Intervals Along River Centerline (Red Points).



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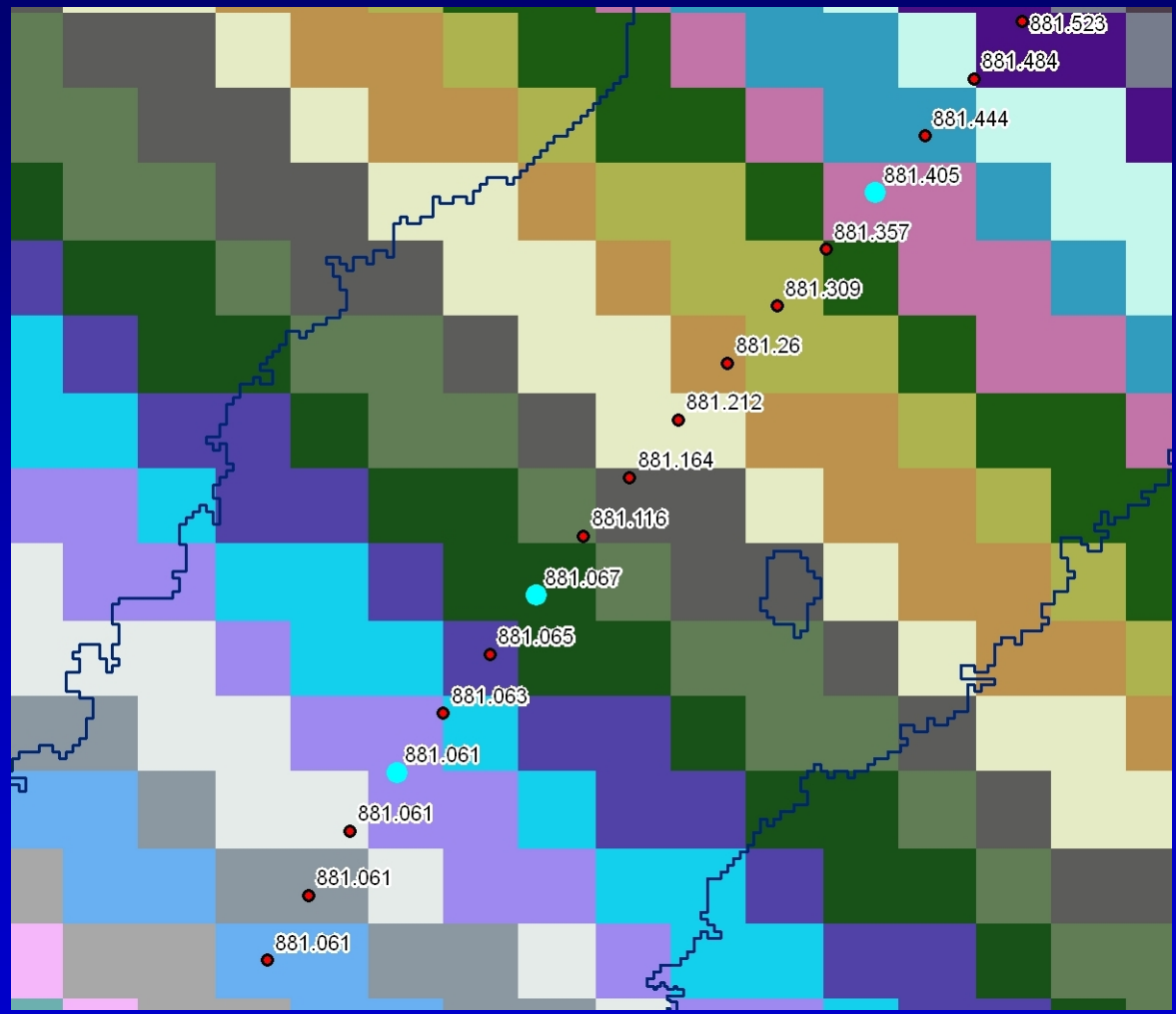
Constructing Virtual Shoreline (e.g. 45,000 cfs)

5-Meter Grid Cells for Entire DEM are Assigned to Nearest 5-Meter Node Along River Centerline (Colored Squares).

Control and Interpolated 45,000 cfs Elevation Values for Each Node are Assigned to Each Grid Cell.



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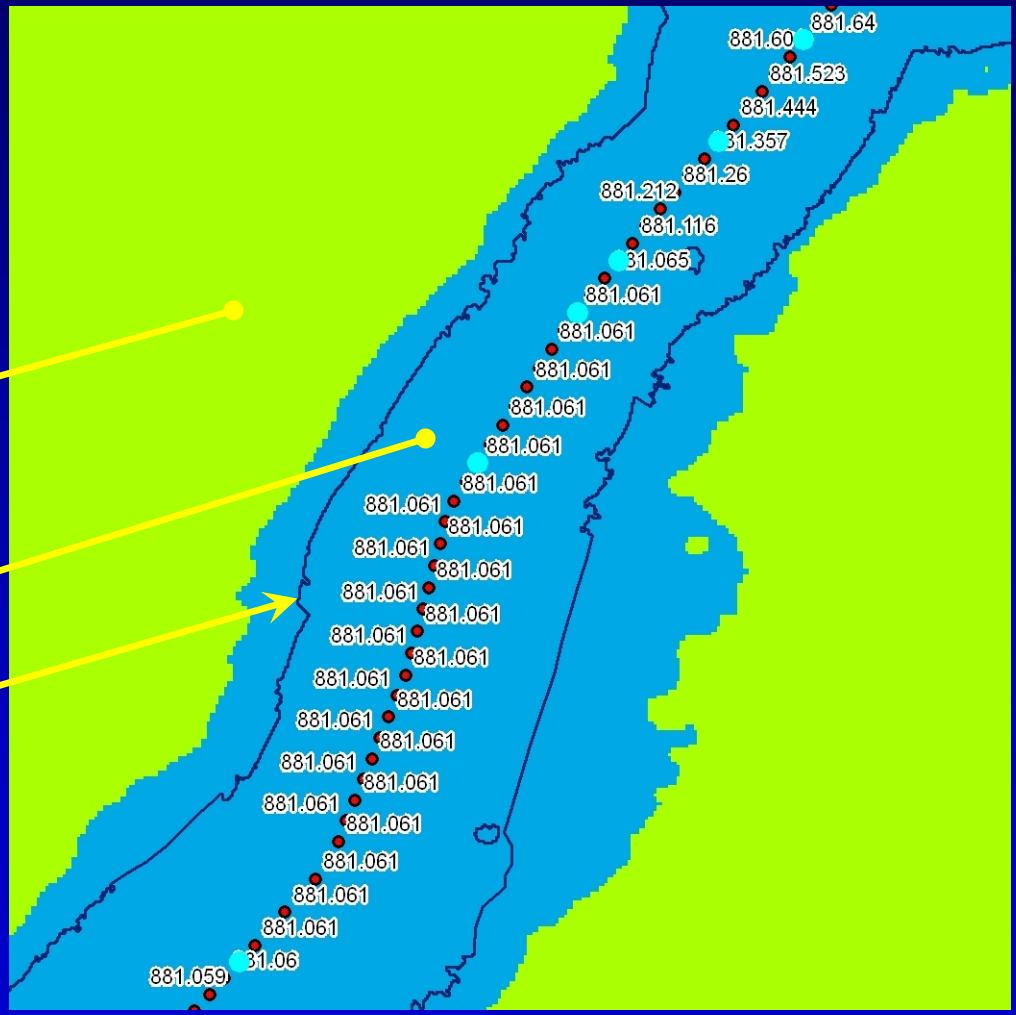
Constructing Virtual Shoreline (e.g. 45,000 cfs)

The Grid Containing 45,000 cfs Centerline Elevation Values is Subtracted from the May, 2002 ISTAR DEM.

- **Positive Values (Green) are Above the 45,000 cfs Water Surface.**
- **Negative Values (Blue) are Below the 45,000 cfs Water Surface.**
- **The Dark Blue Line is the 8,000 cfs Shoreline.**



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Constructing Virtual Shoreline (e.g. 45,000 cfs)

Negative Grid Cells (Areas Below the 45,000 cfs Water-Surface Elevation) are Converted to a Polygon, Whose Boundaries Represent the 45,000 cfs Shoreline.

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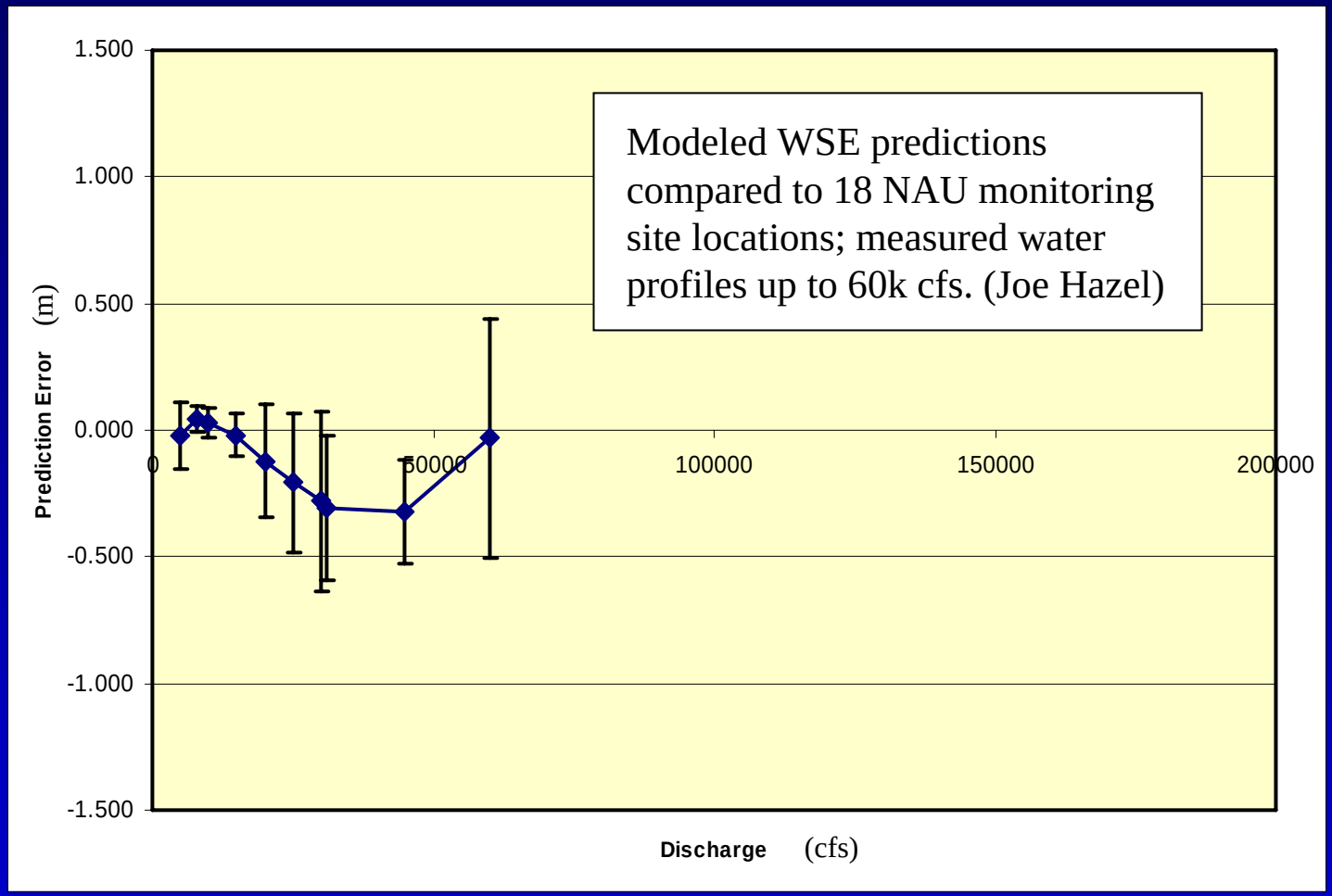
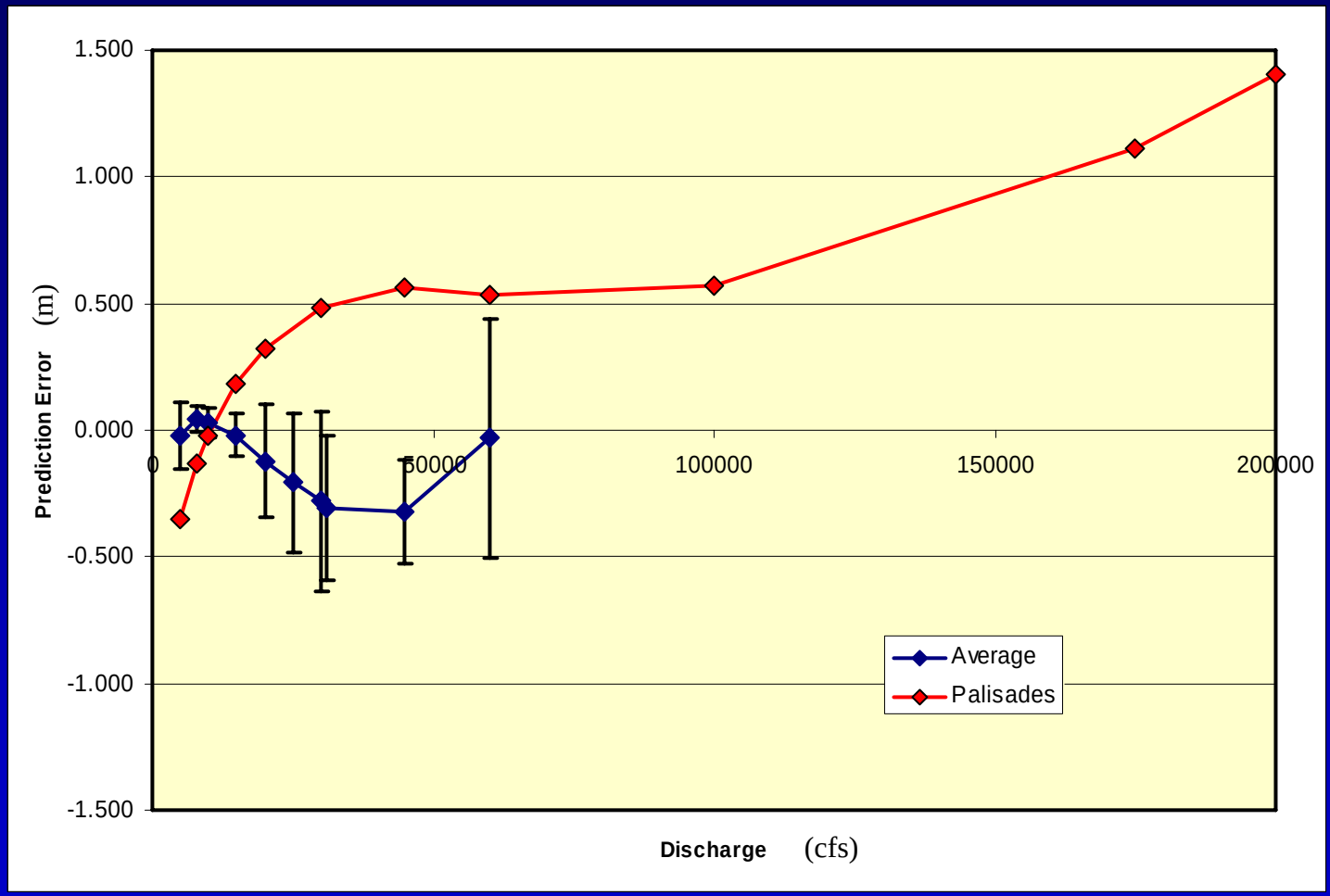
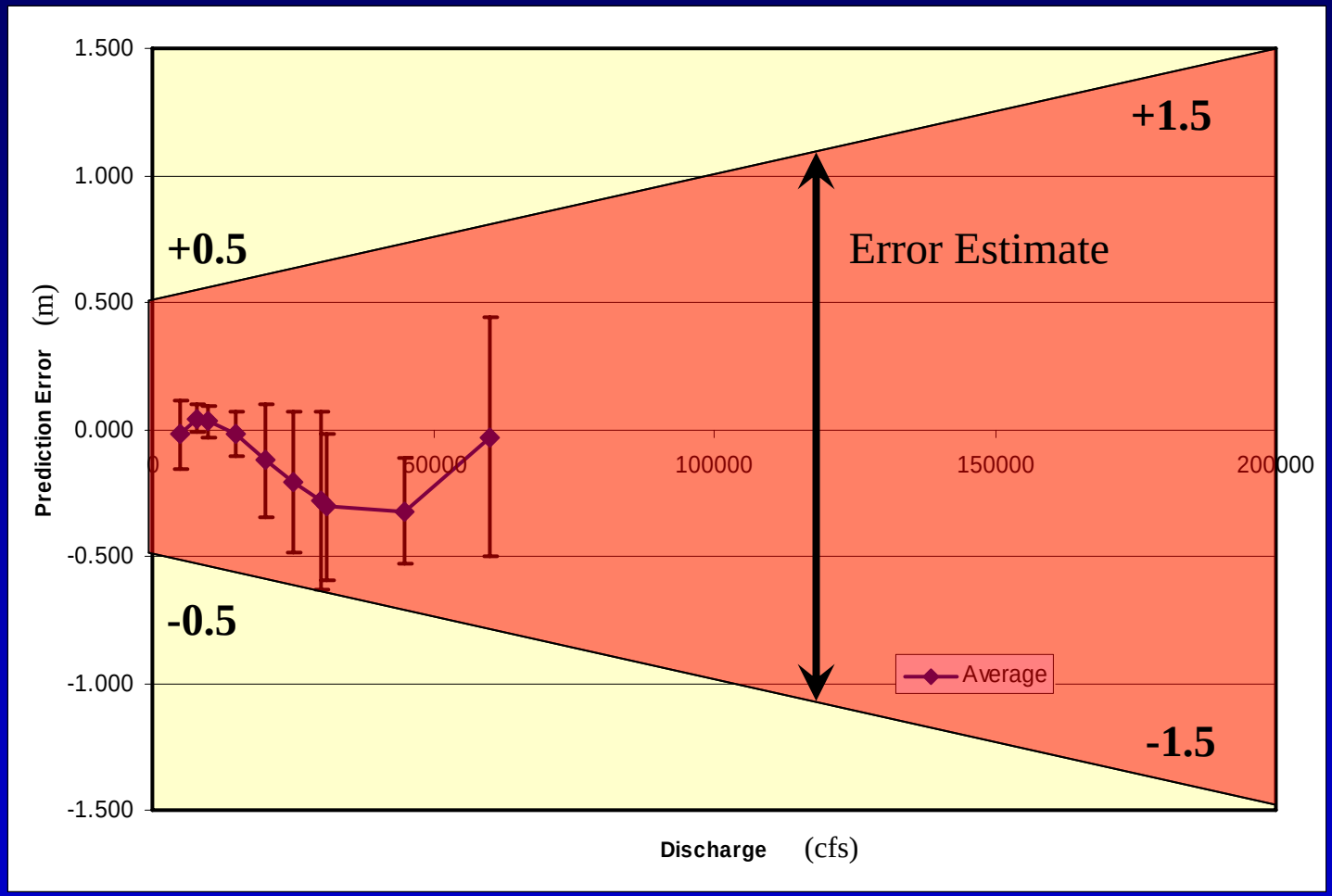
Model Prediction Accuracy



High Water Comparison at Palisades



Prediction Error of model



NAU Beach Study Site 43.4

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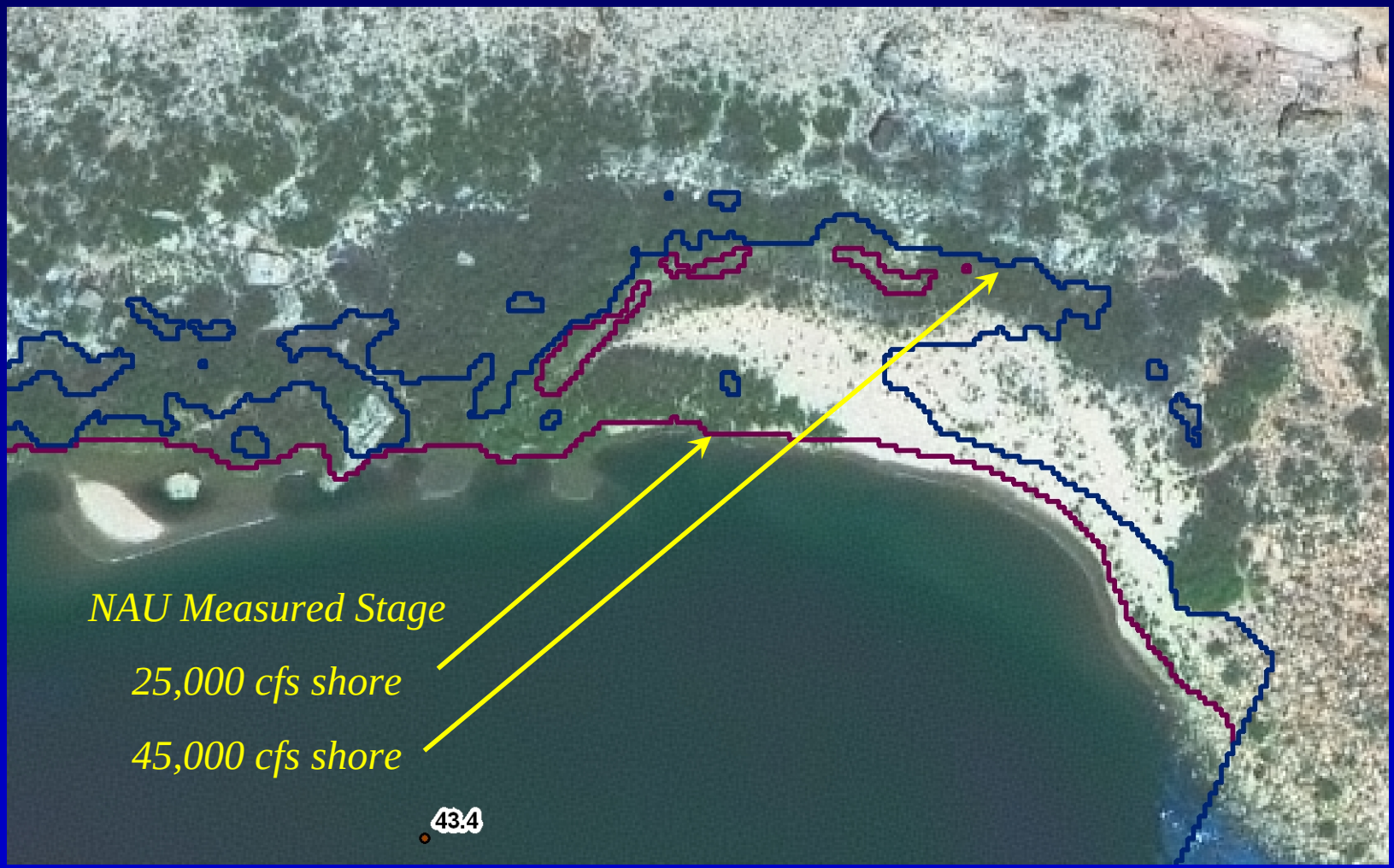

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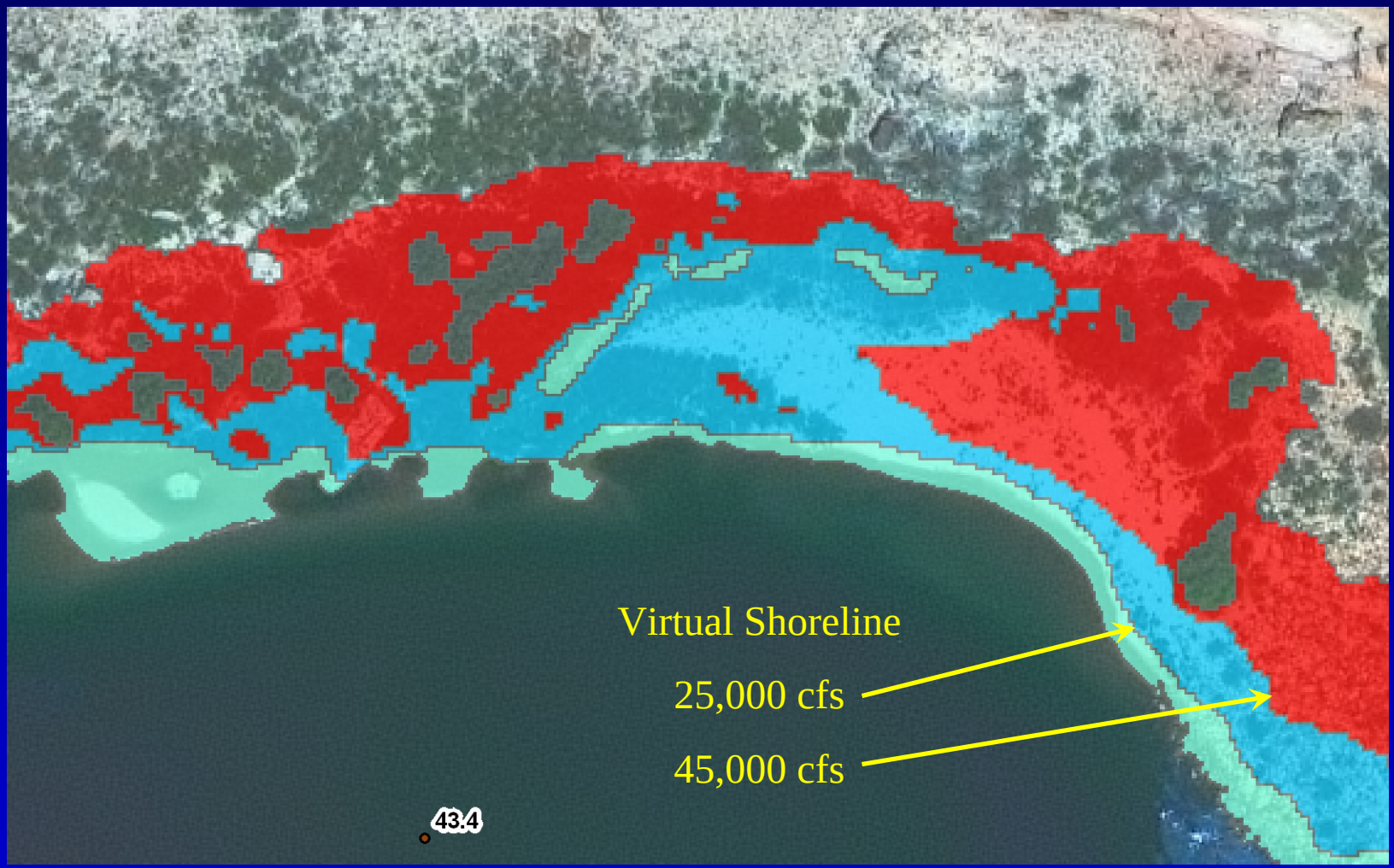
NAU Beach Study Site 43.4



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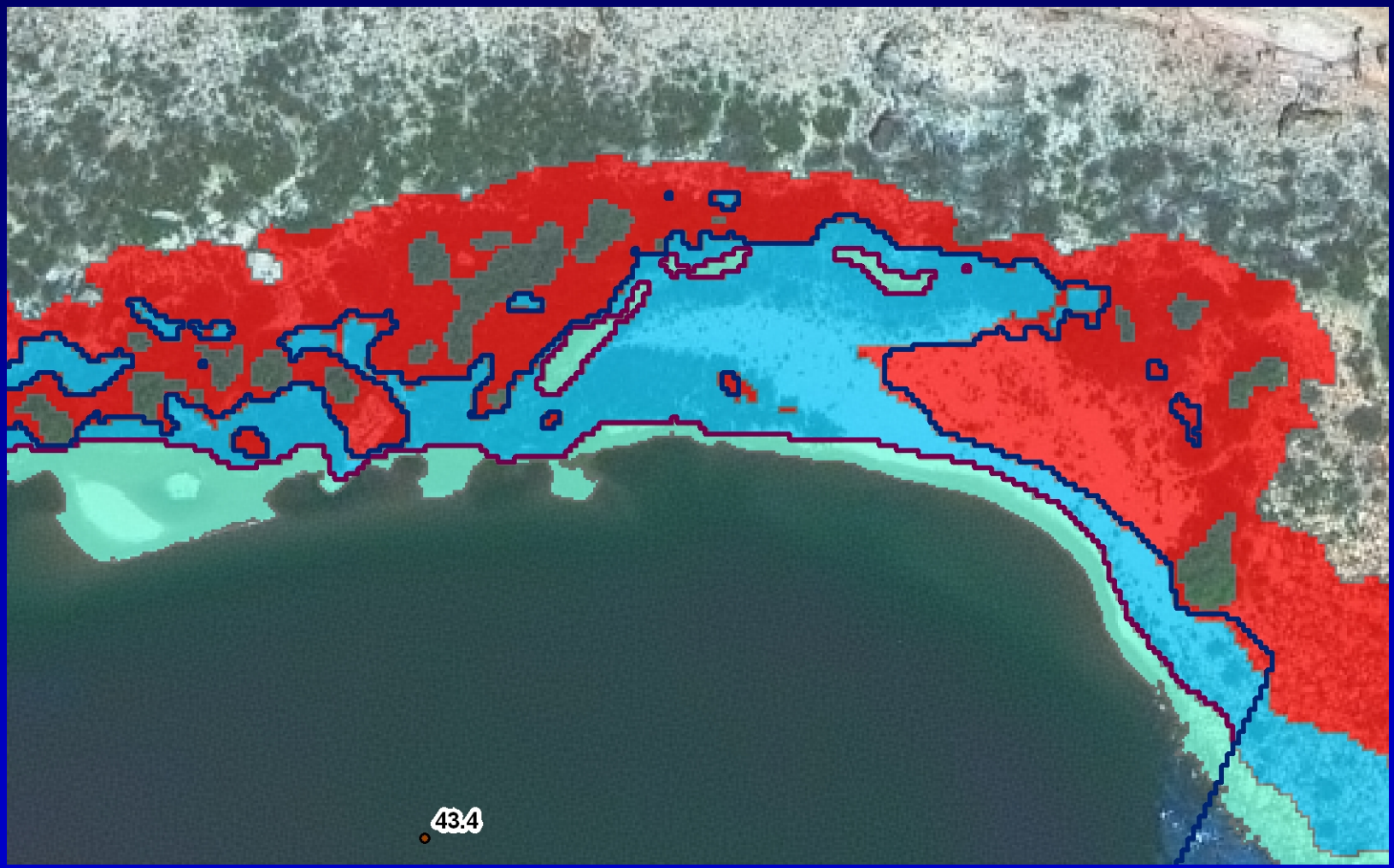

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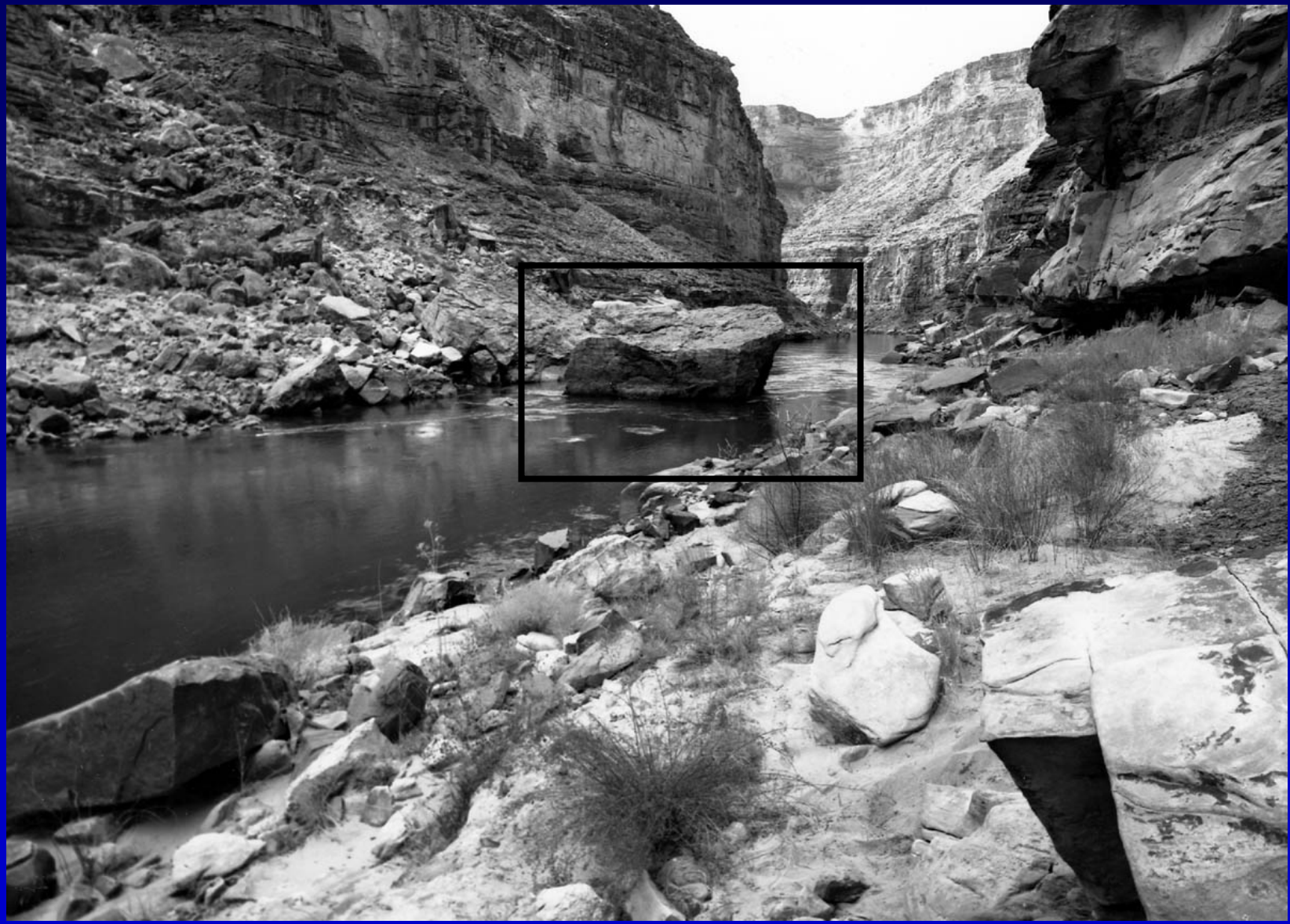

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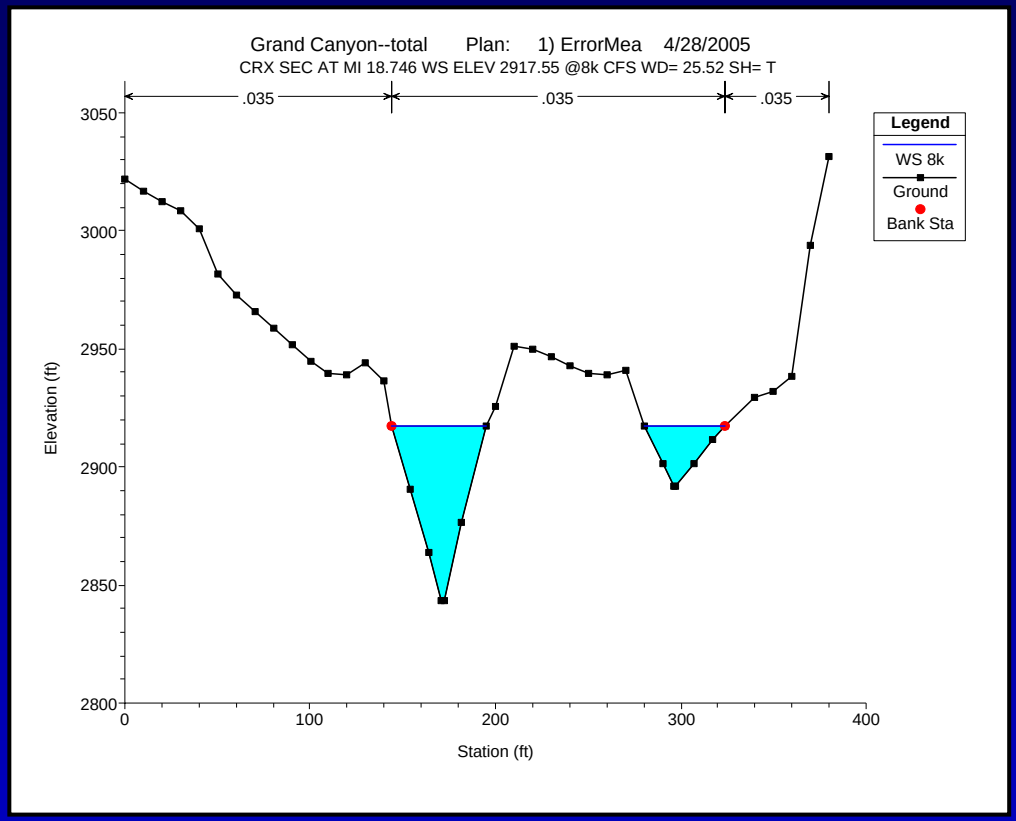

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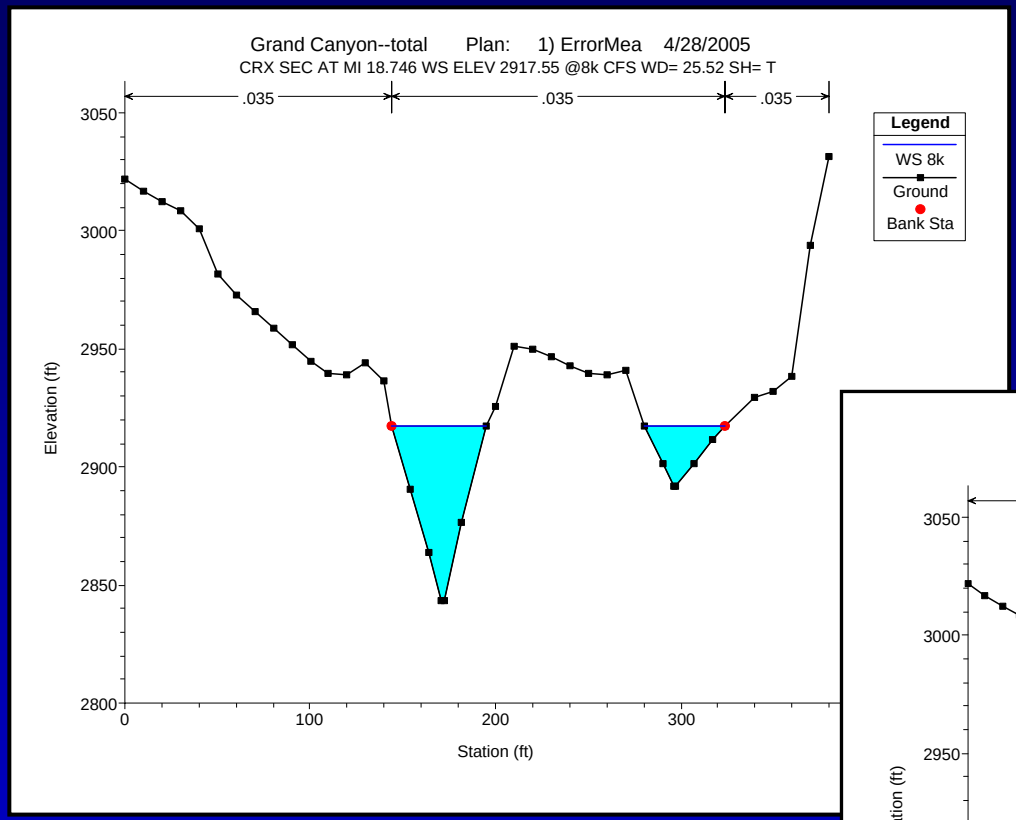
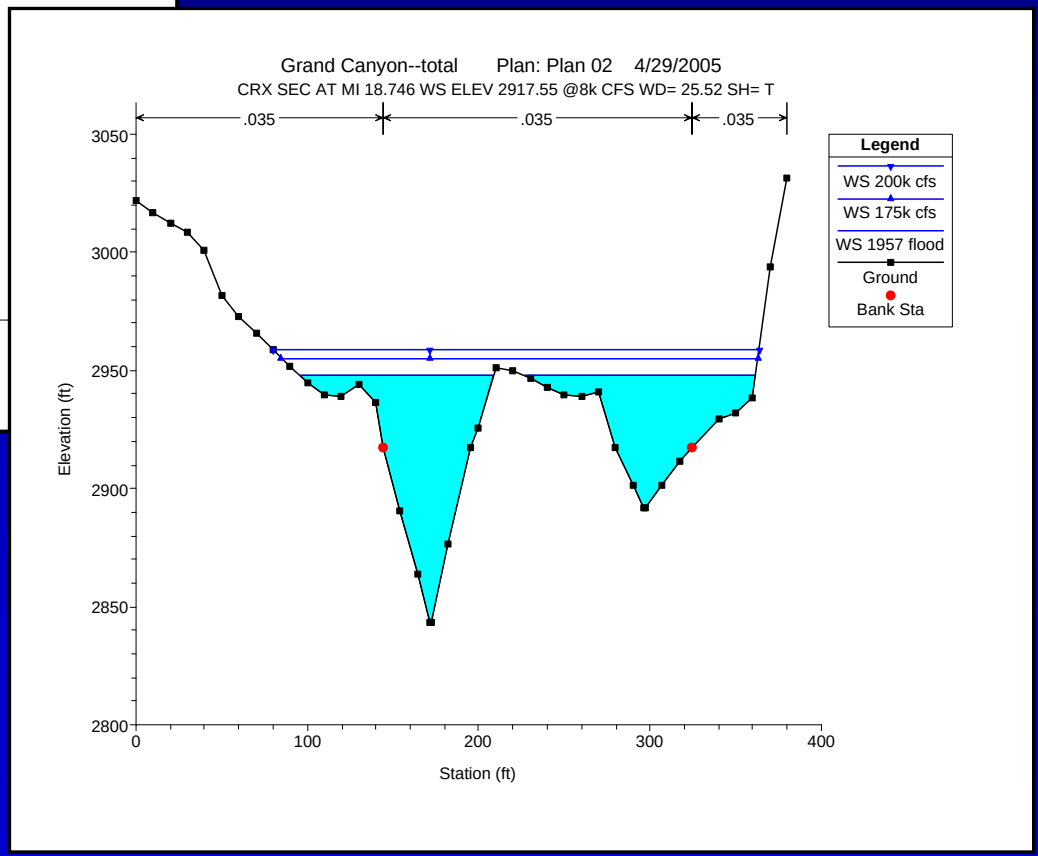
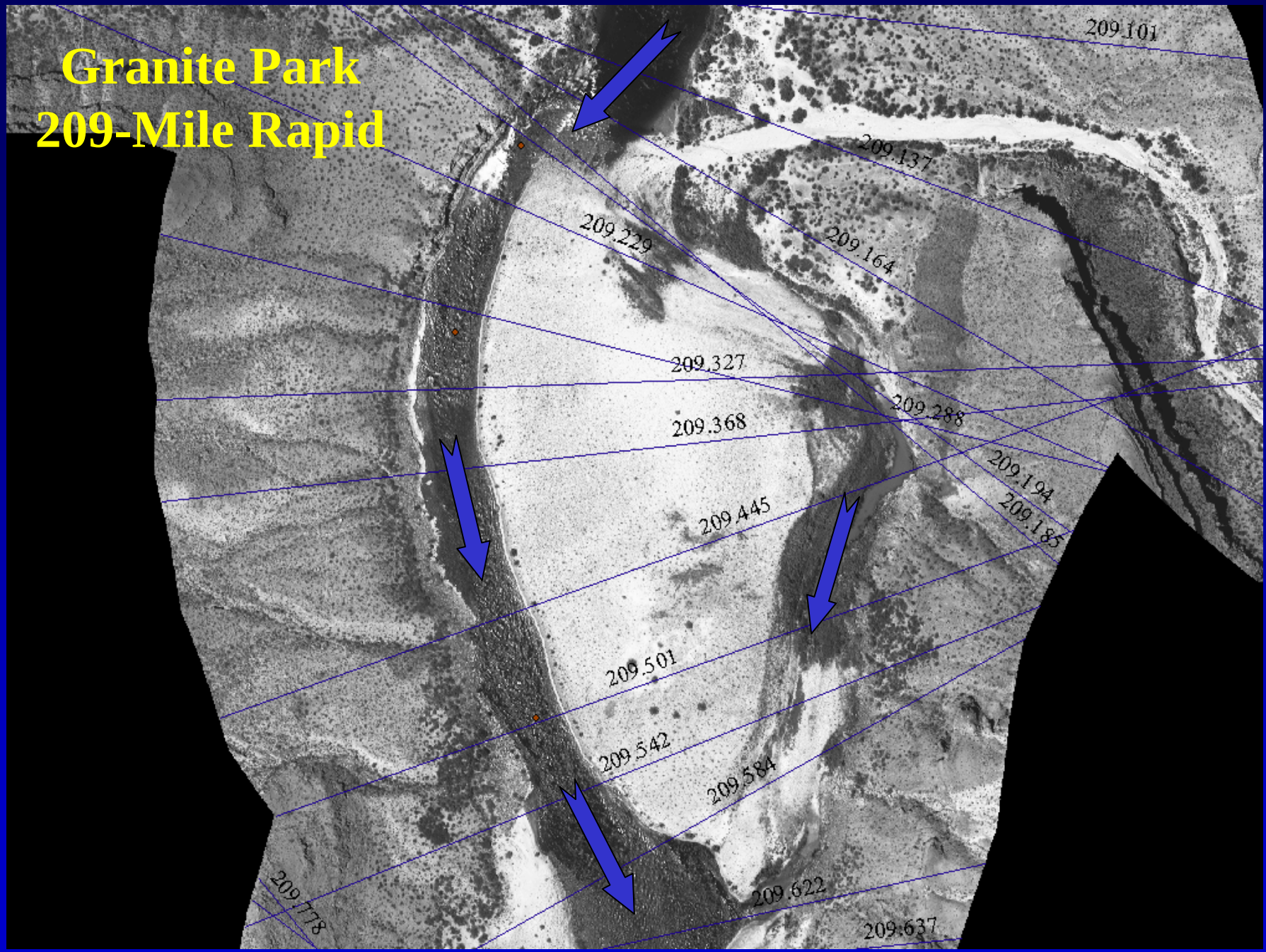
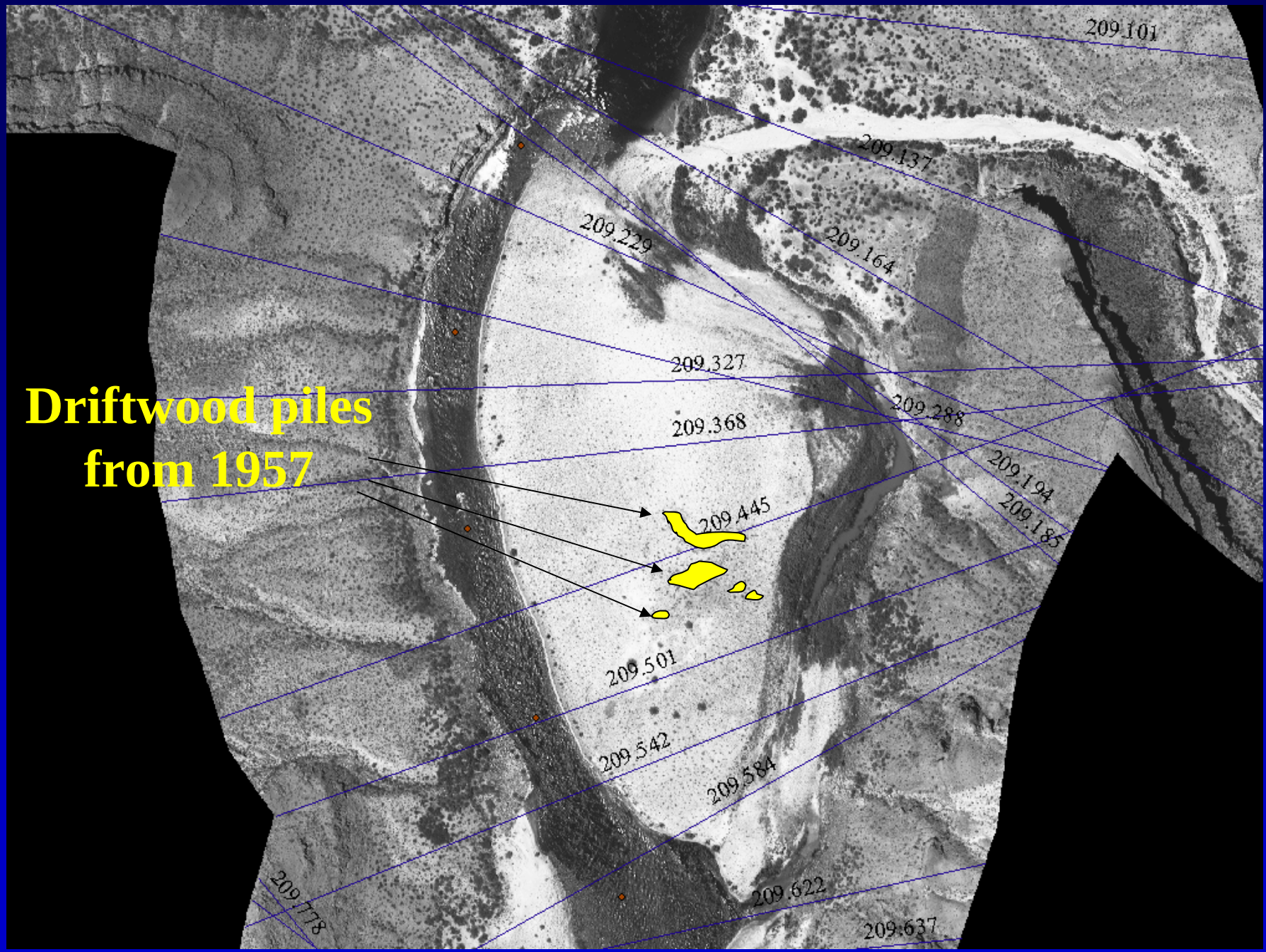
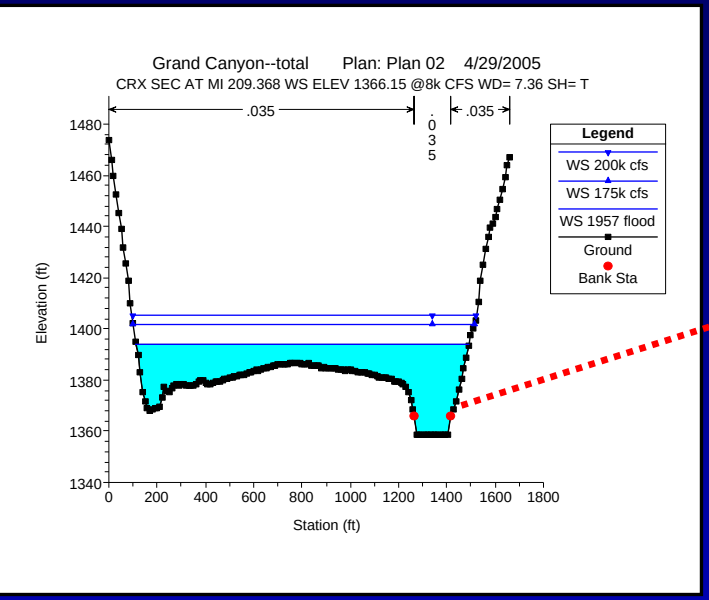


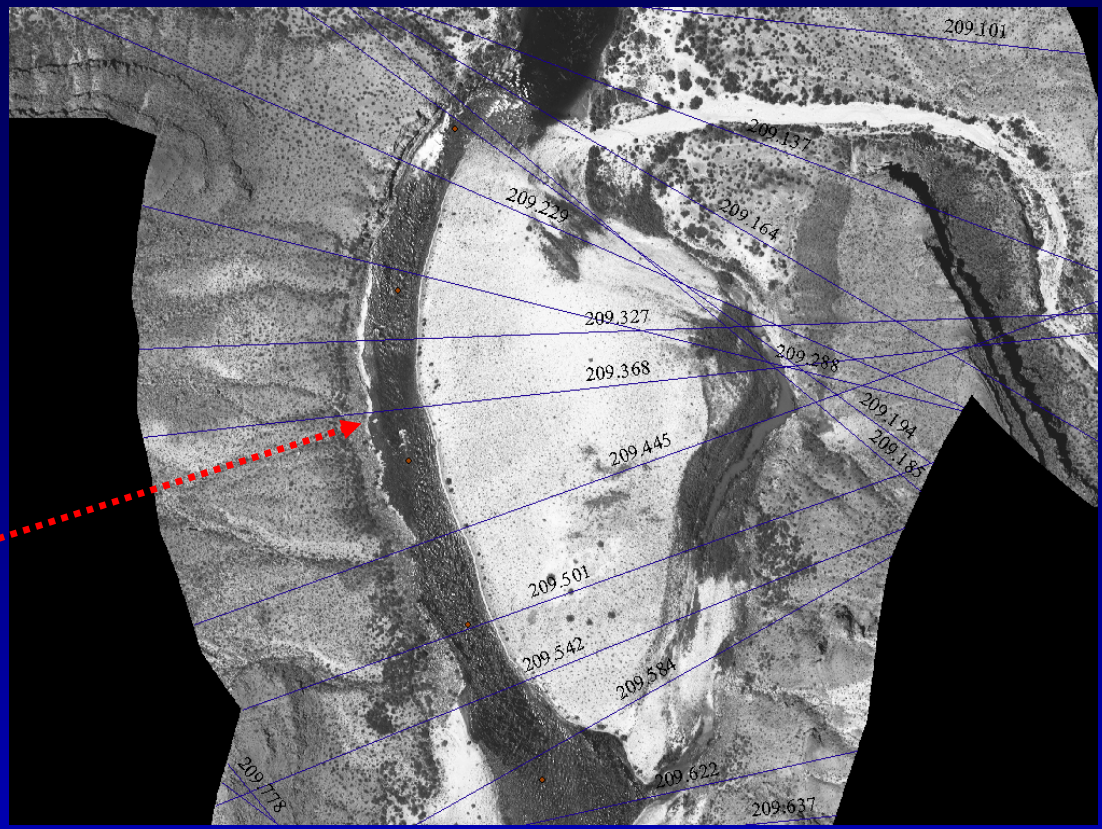



Granite Park
209-Mile Rapid
209.101
209.137
209.164
209.229
209.327
209.288
209.368
209.194
209.185
209.445
209.501
209.542
209.584
209.622
209.637
209.778

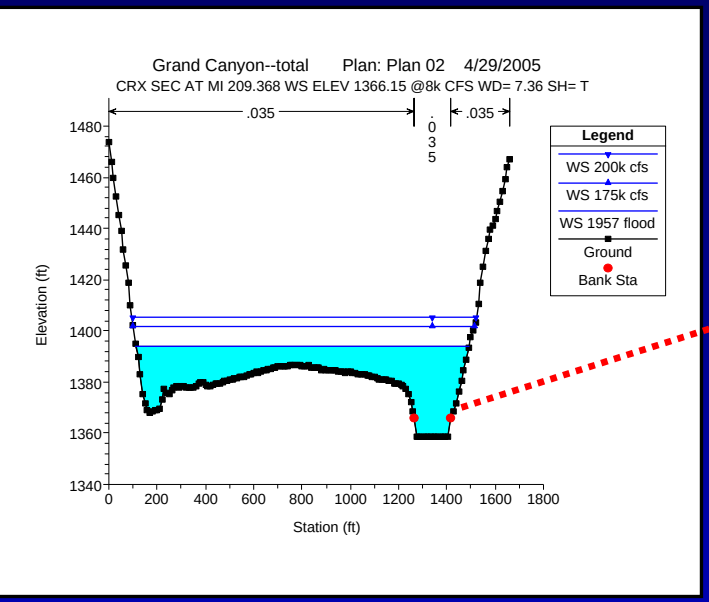

Driftwood piles
from 1957
209.101
209.137
209.164
209.229
209.327
209.288
209.368
209.194
209.185
209.445
209.501
209.542
209.584
209.622
209.637
209.778

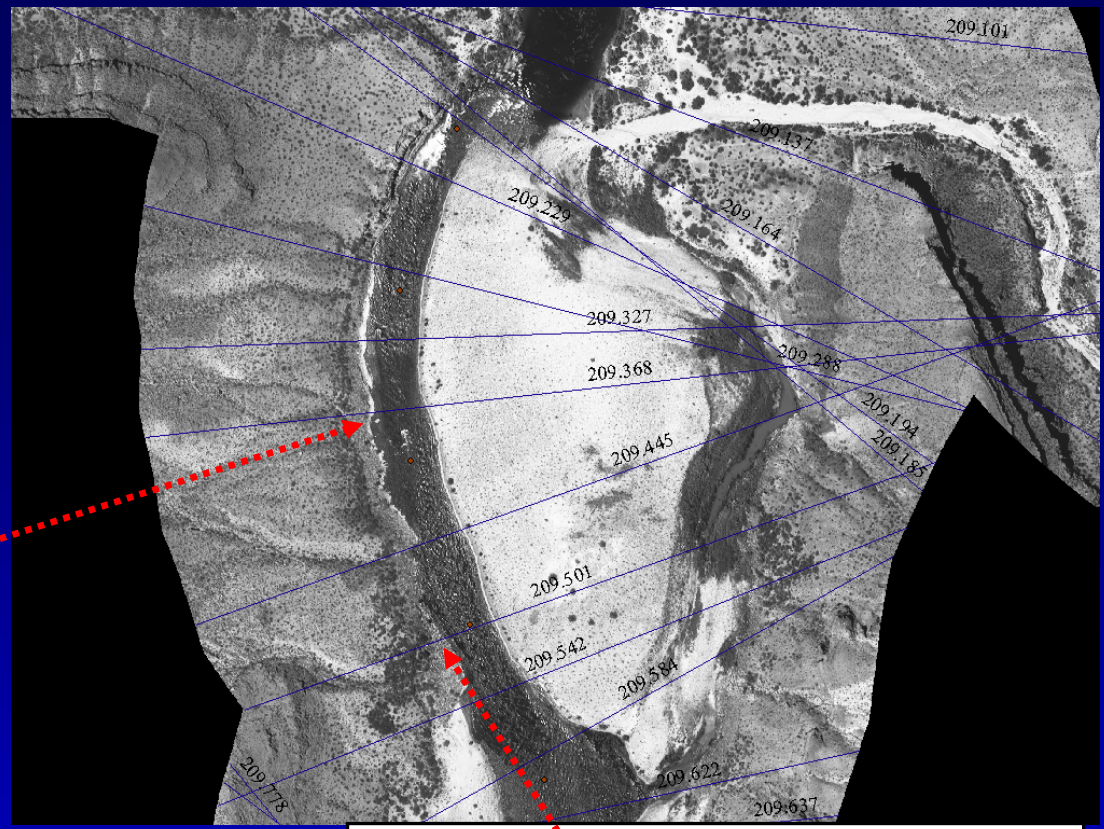
GC Hec-Ras Model at 209-Mile

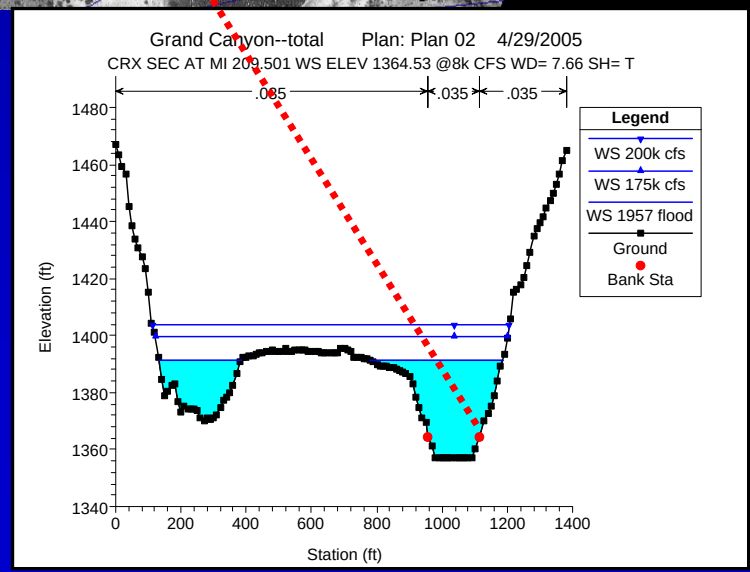




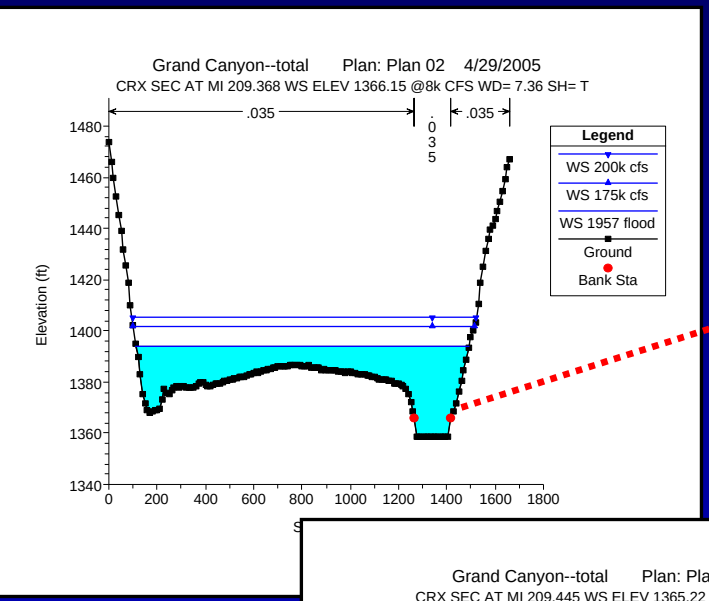
GC Hec-Ras Model at 209-Mile

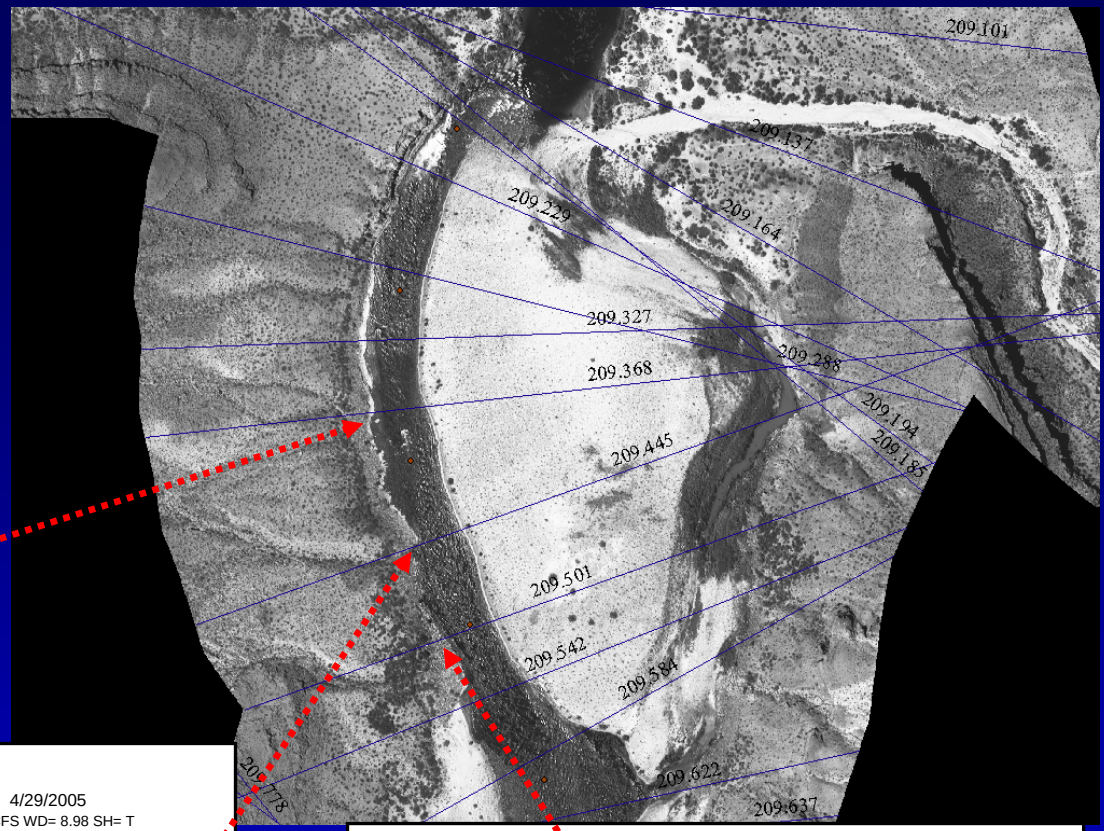


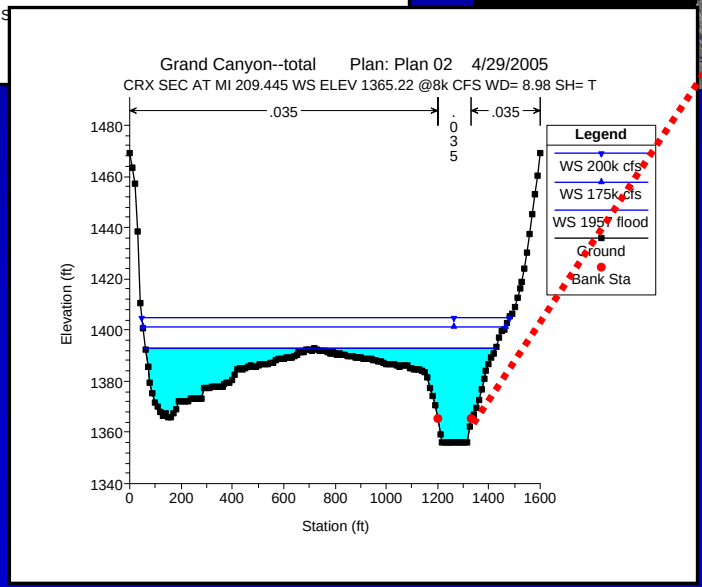


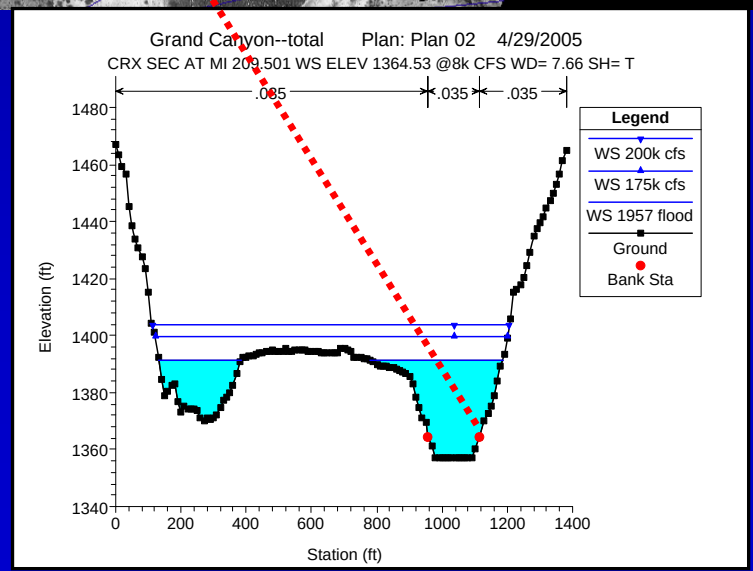


GC Hec-Ras Model at 209-Mile

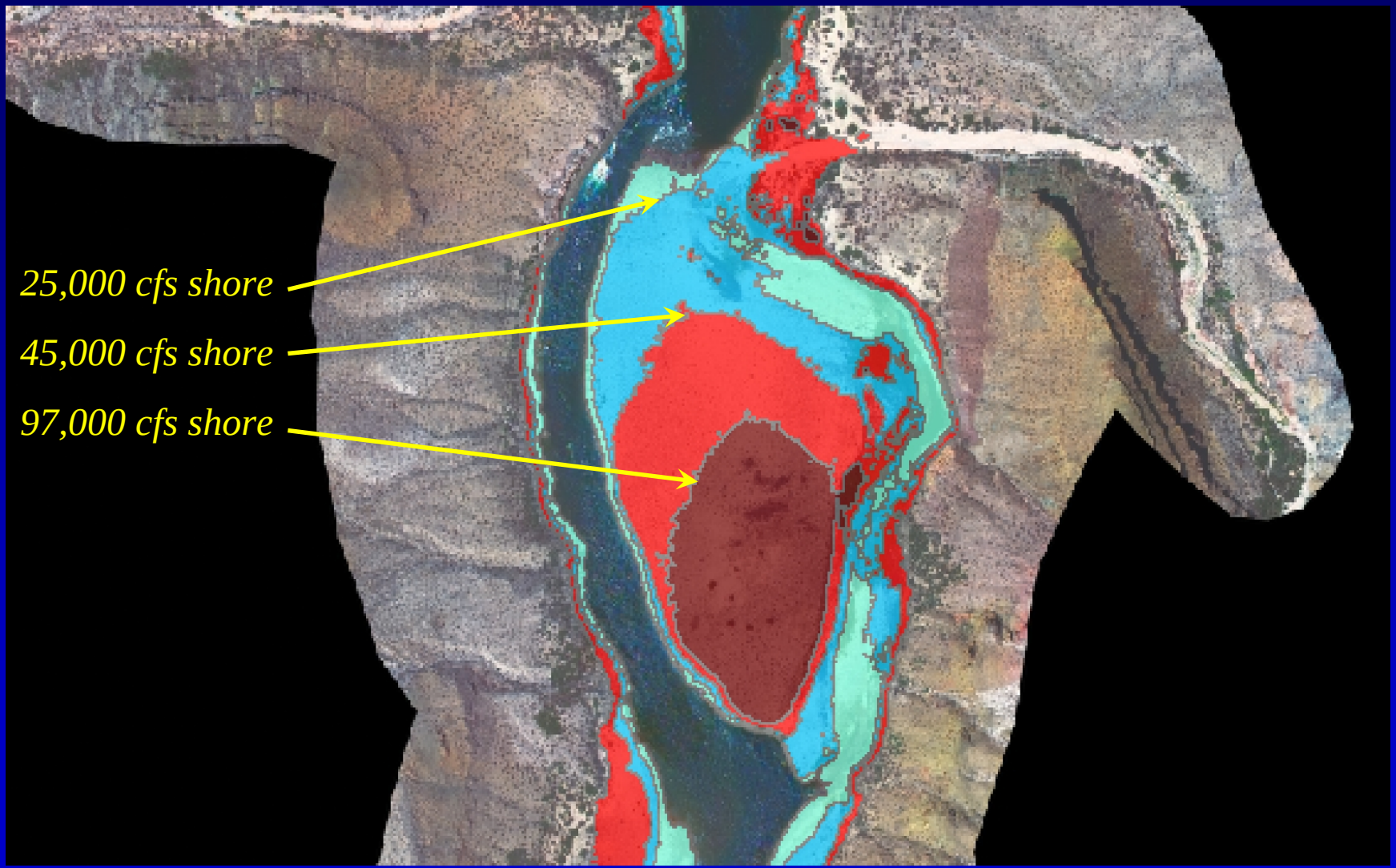








Virtual Inundation Shoreline at 209-Mile



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Conclusions

- New 1-D Hydraulic model (with GUI) to replace STARS
- Uses 2002 DEMs with modern water-surface profile
- Predict water-surface elevations and virtual shorelines in Grand Canyon for any flow up to 200k for the purposes of:

  >Predicting relative inundation of variable flows on archaeological sites.
  >Producing stage-discharge relationships throughout Canyon.
  >Providing statistical tabulations of changes in physical and biological parameters by stage for monitoring purposes.

- Error of new model ranges from ±0.5 m to ±1.5 m

Thanks to Joe Hazel and the Namdor Team for measuring and providing calibration data.
Thanks also to Tim Randle (BOR) for provide base data, process insight, and advice early in project.

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