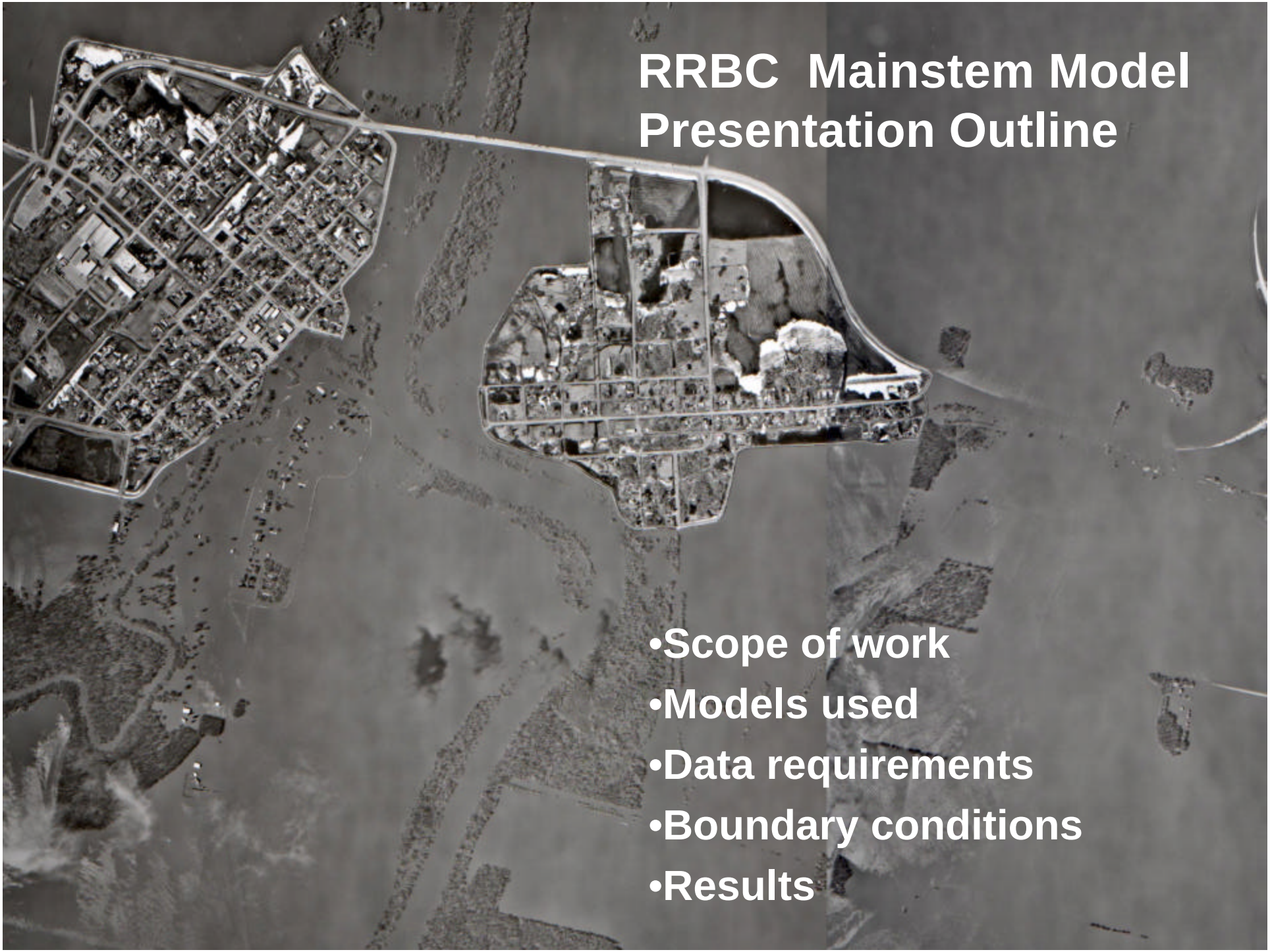

# RRBC Mainstem Model Presentation Outline

- Scope of work
- Models used
- Data requirements
- Boundary conditions
- Results

# Red River Model Development

- Modeling carried out under contract to the RRBC
- Primary objective of Phase 1 was to develop MIKE 11 and HEC-RAS models that will be effective as planning tools particularly for assessment of the effectiveness of storage projects on Red River tributaries.
- The scope included hydrologic analysis for establishing boundary conditions, particularly for ungaged areas
- and development of unsteady flow models for the main stem and tributary reaches below stream gaging stations

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# Mike11 Hydrodynamic Model

- Developed by the Danish Hydraulic Institute
- 1-Dimensional Hydrodynamic model designed to simulate flows, water levels, water quality, and sediment transport in rivers, channels, and estuaries
- Ability to model hydraulic structures such as weirs, culverts, and gates.

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# Mike11 Hydrodynamic Model

- Several options available for boundary conditions including recorded water levels, discharges, and Q-H relationships.
- Able to model with several parallel channels connected by link channels that typically represent dikes, levees, roads, or rail embankments
- The MIKE 11 model was developed from Lake Traverse to north of Emerson.
- This model overlaps with the Manitoba MIKE 11 model which extends north to Lake Winnipeg.

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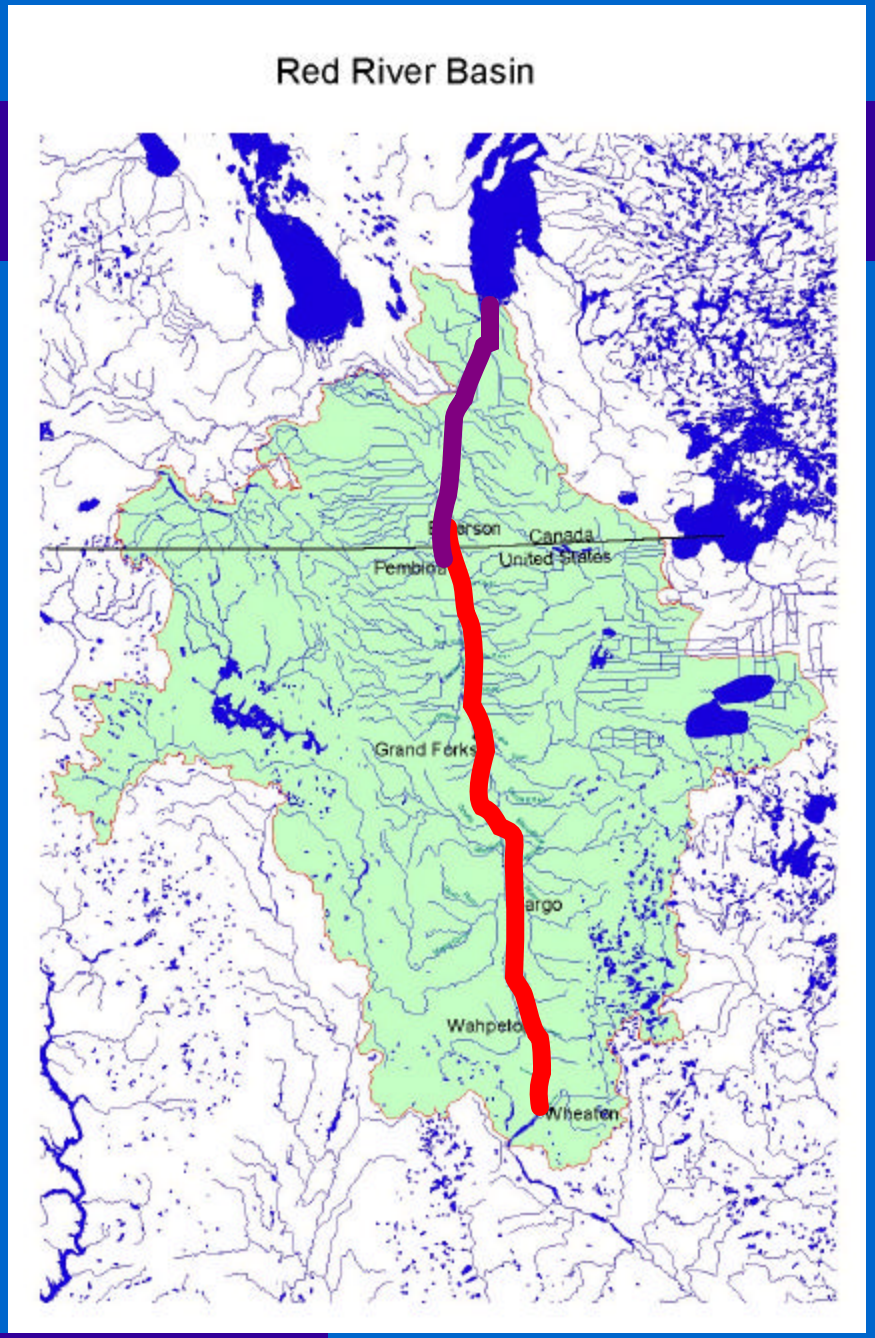
MIKE 11
MAINSTEM
MODELS



# HEC-RAS model

- The unsteady flow module of HEC-RAS version 3.01 was used to develop a model from Fargo to Emerson
- The unsteady flow module of HEC-RAS is based on the USACOE UNET model which has been applied on the Red River main stem
- HEC-RAS features and interface similar to MIKE 11
- The HEC-RAS model developed in this project will be linked to USACOE upstream models to provide a continuous unsteady HEC-RAS model from Lake Traverse to Emerson.

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# Data requirements

- Basic streamflow data available from USGS
- Ungaged areas were a major challenge. We added ungaged discharge to the main stem of the Red River at six locations between major calibration centers
- Cross sections were based on existing USACOE HEC-2 cross sections

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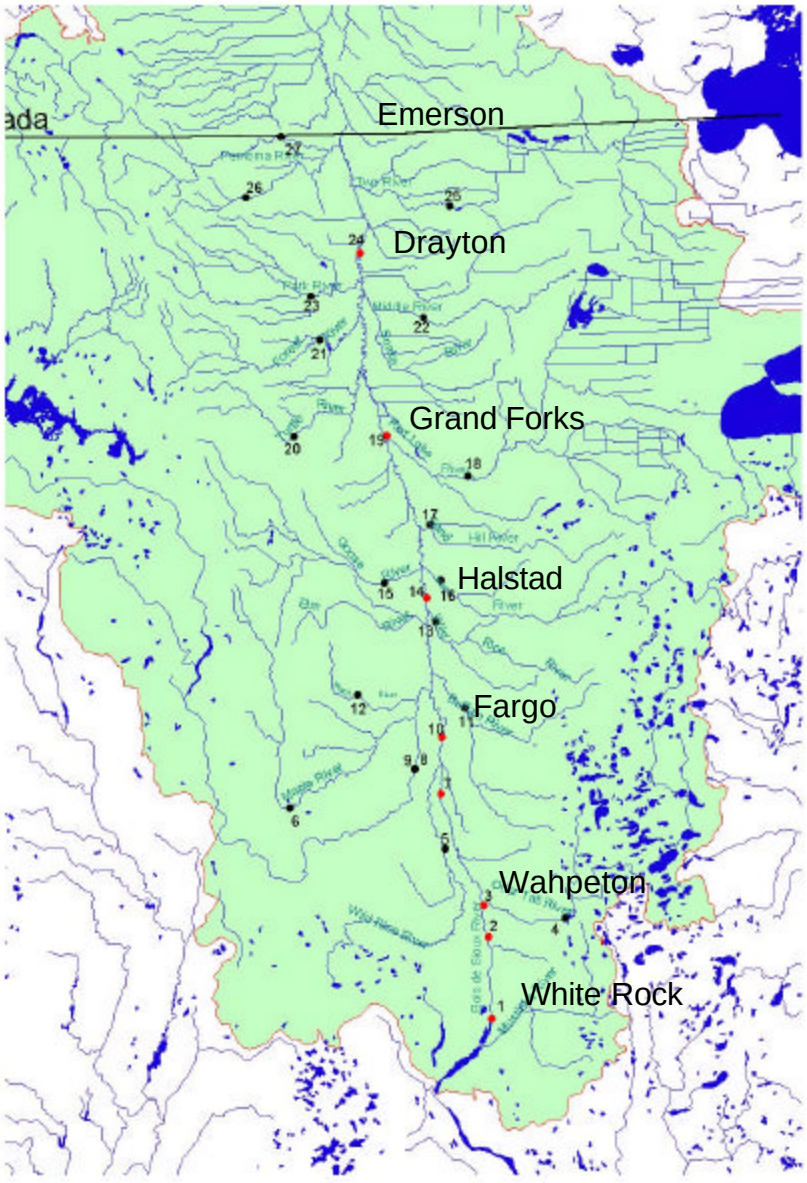
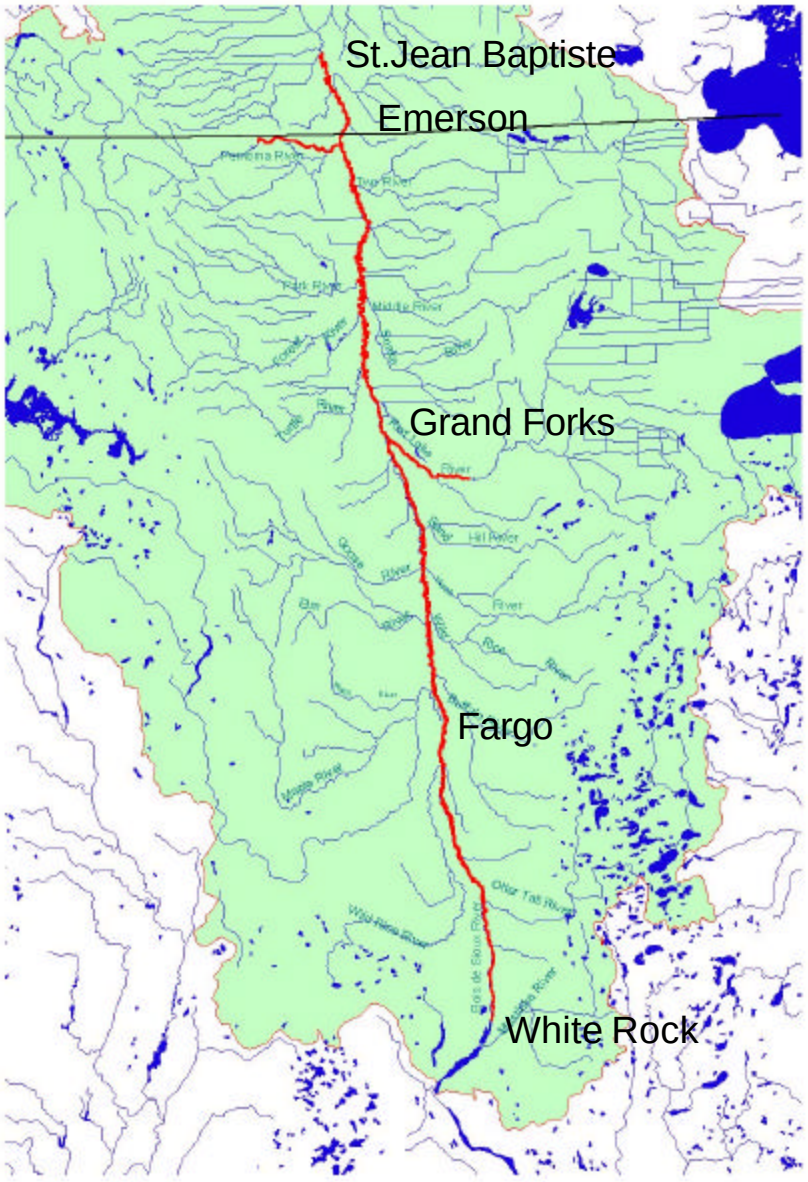
## Red River Basin Gaging Stations



# Model Extent



# Boundary conditions

- The following general boundary conditions used for the MIKE 11 model were:
  - Red River water levels at St.Jean Baptiste
  - Red River discharge data for Bois de Sioux River near White Rock north of Lake Traverse
  - Tributary flow data for active gages closest to the Red River with data from at least as far back as 1997
  - Ungaged tributary flow estimates between calibration centers

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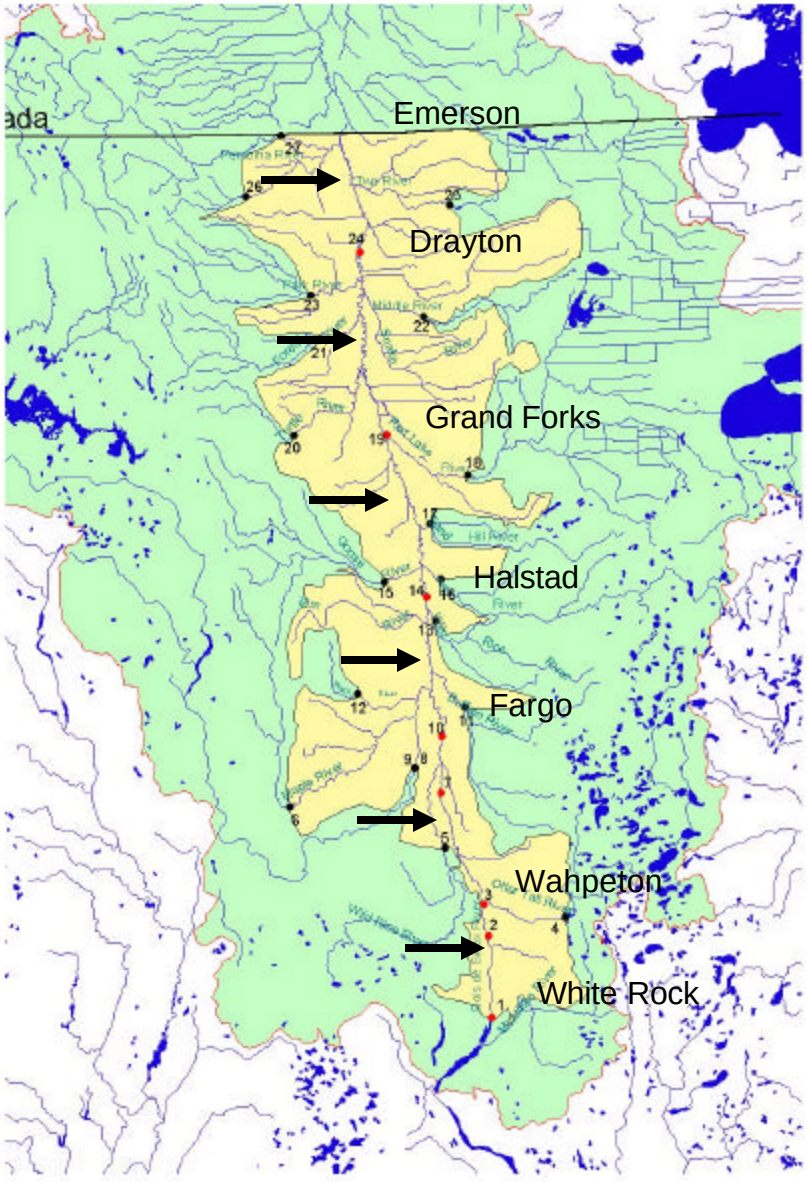
# Ungaged areas

- Although the ungaged areas account for only 25% of the total drainage area, the ungaged inflows generate 40-50% of the total flow volume upstream of Emerson.
- The primary reason is that the tributary catchment areas include significant non-contributing areas
- Another factor is likely to be more efficient runoff closer to the Red River particularly within inundated areas

# Ungaged areas

- The main stem of the Red River is gaged at key locations. The difference in flows between consecutive main stem gages minus the sum of tributary inflows is a measurement of the ungaged inflow
- During the calibration process the timing and distribution of ungaged flow estimates were modified to best match downstream recorded hydrographs.

## Red River Basin Ungaged Area



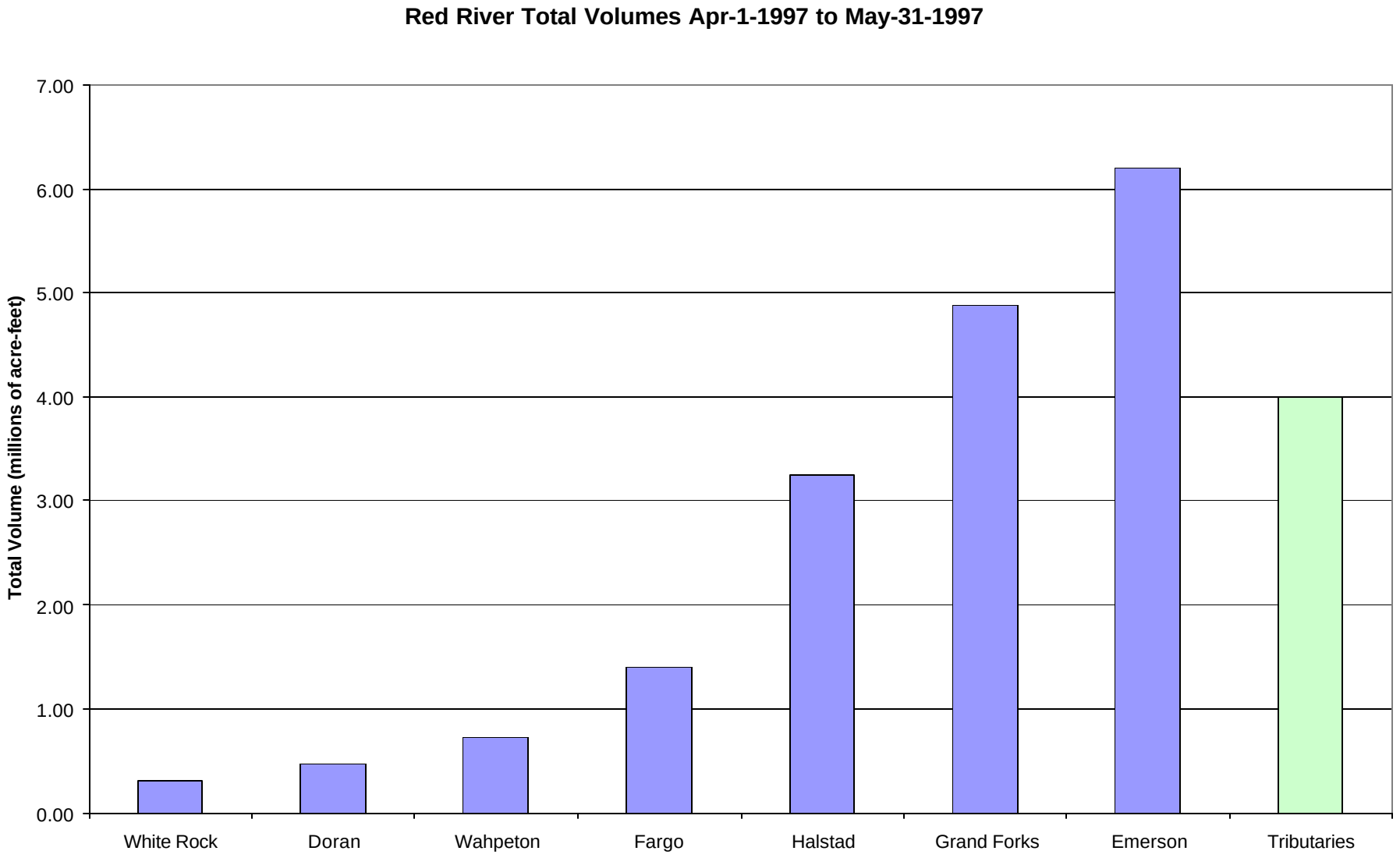
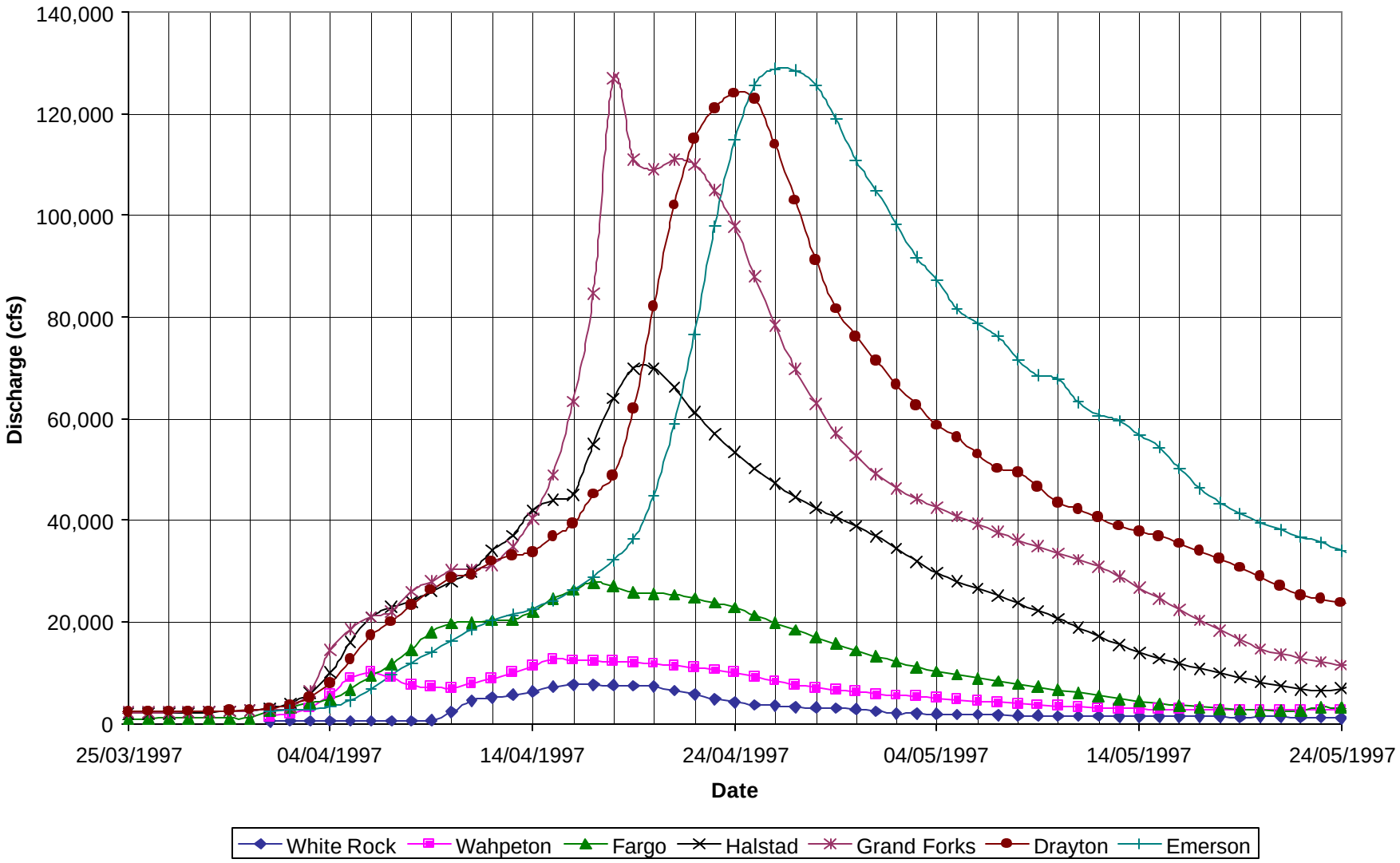

Red River Total Volumes Apr-1-1997 to May-31-1997
Total Volume (millions of acre-feet)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
White Rock
Doran
Wahpeton
Fargo
Halstad
Grand Forks
Emerson
Tributaries

**Figure 3.1 -1997 Red River Discharges White Rock - Emerson**



# Calibration and verification

- The MIKE 11 and HEC-RAS models were calibrated with 1997 data using USGS streamflow and water level data on the Red River main stem
- The calibrated models simulated water levels within one foot of then recorded values.
- The exception was at Wahpeton where ice jams have a significant impact on water levels
- Verification was carried out with different flood events
  - 1989, 1996, and 2001
- The verification results were generally as good as the calibration with one or two exceptions

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**Figure 3.18 - Grand Forks Discharges**

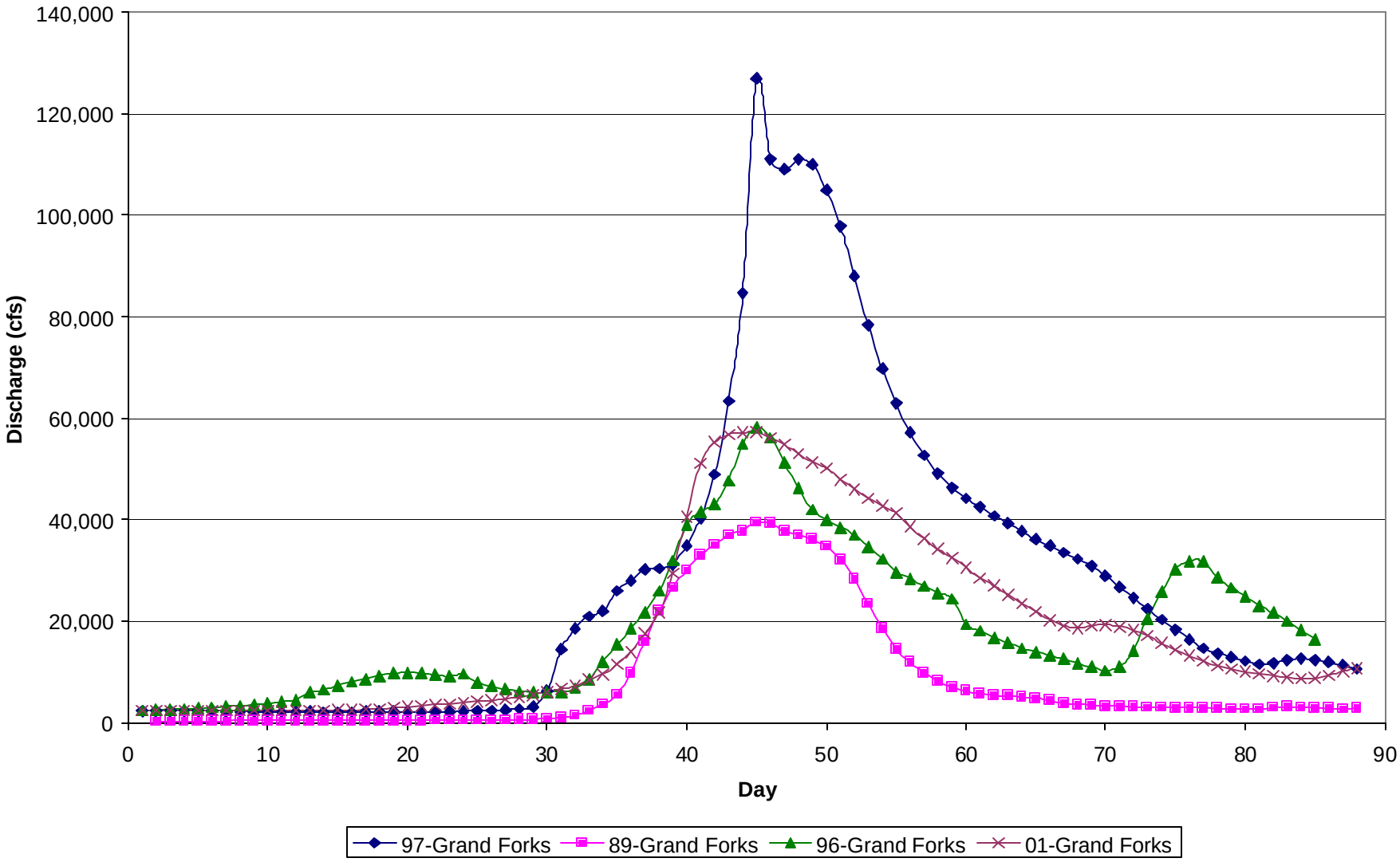
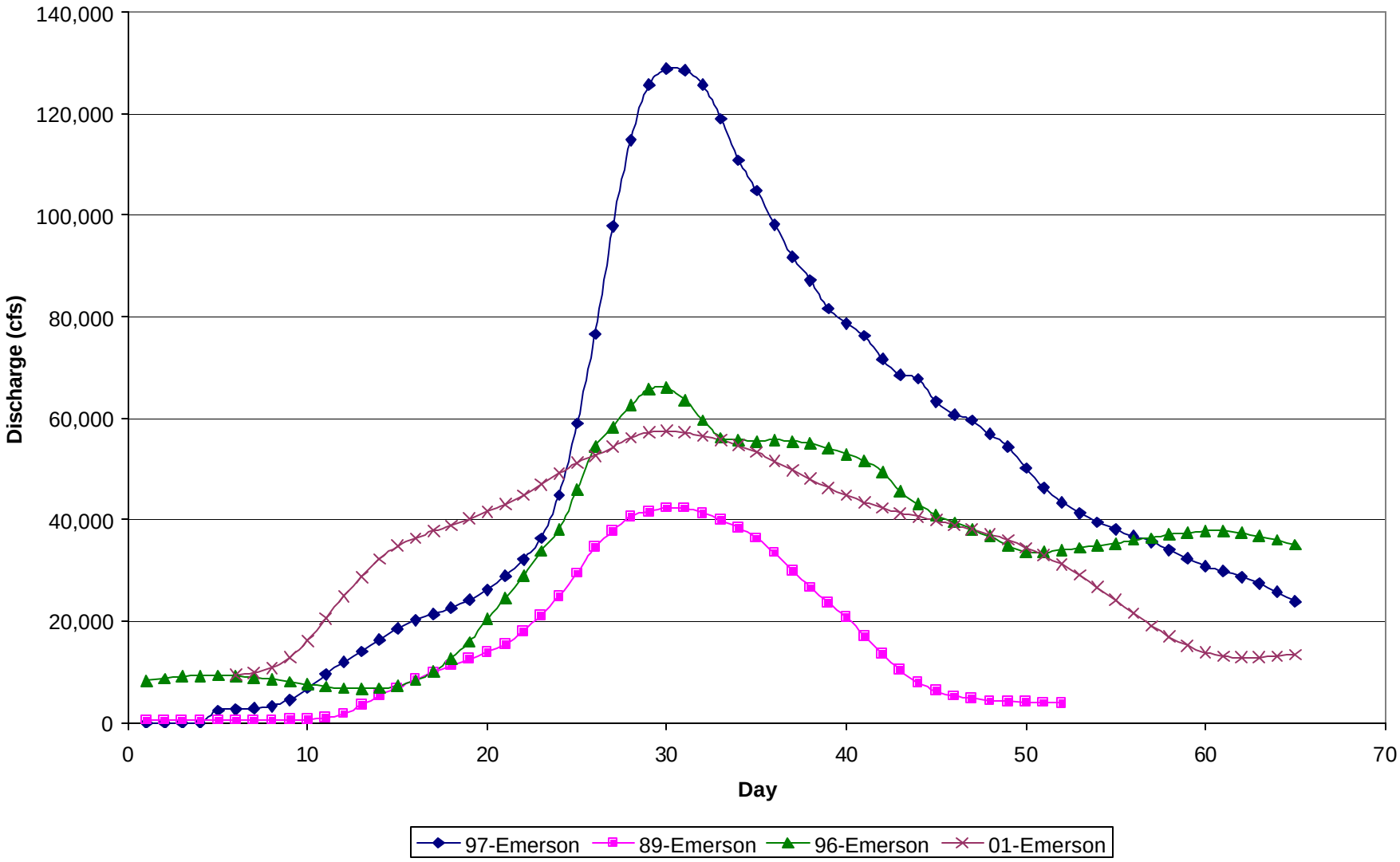
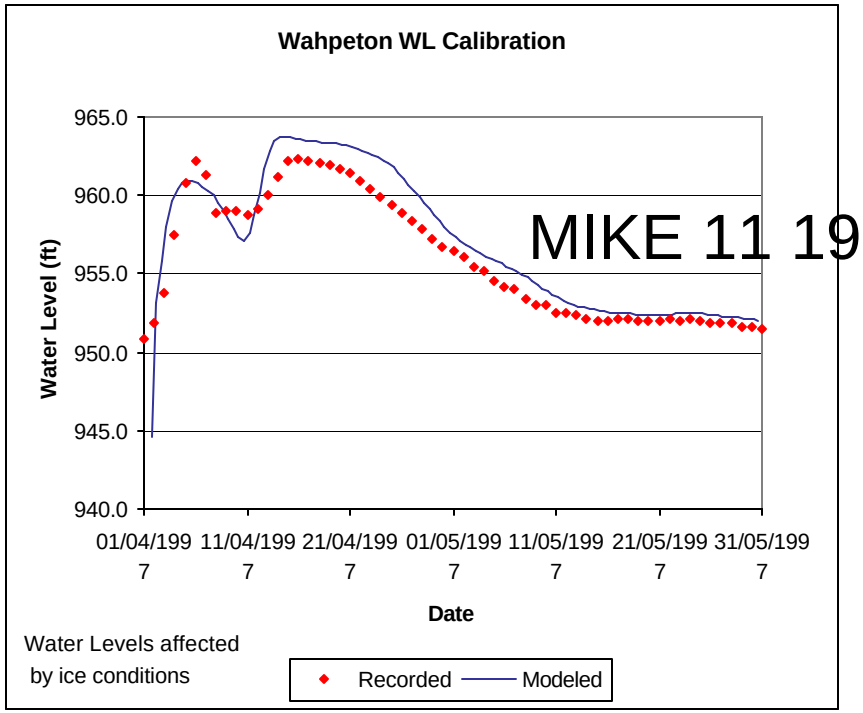
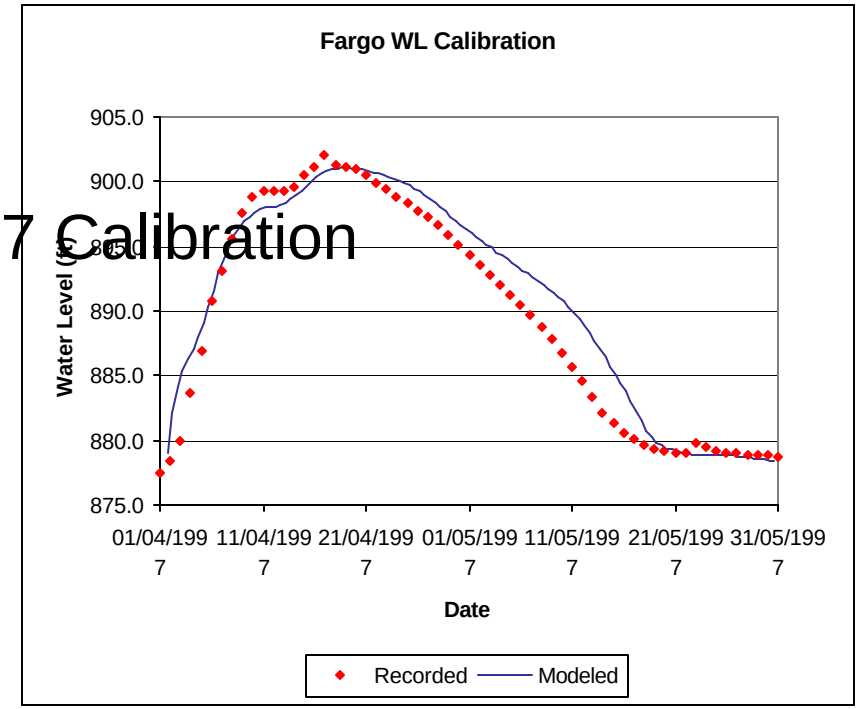


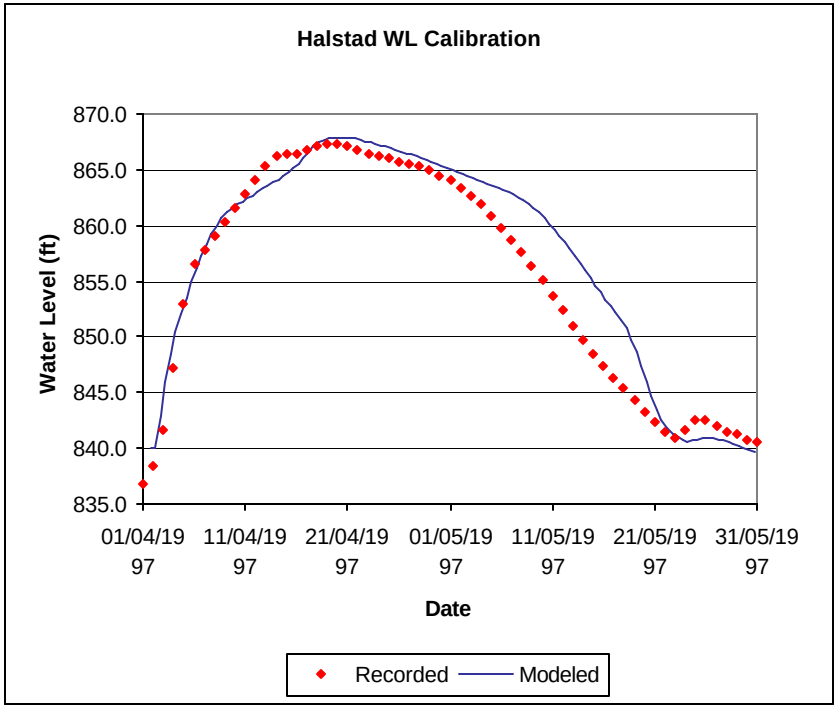
**Figure 3.19 - Emerson Discharges**

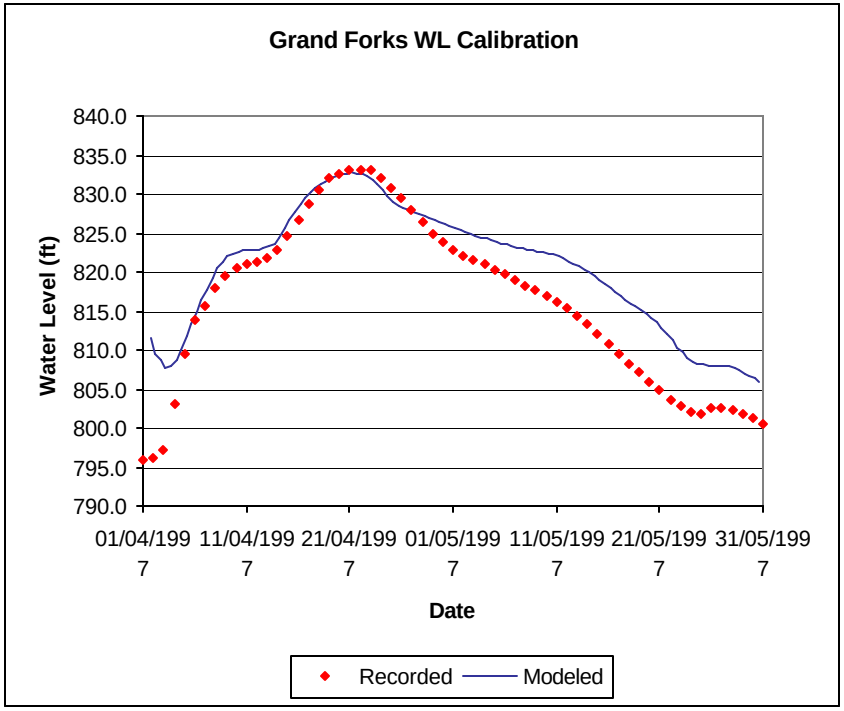


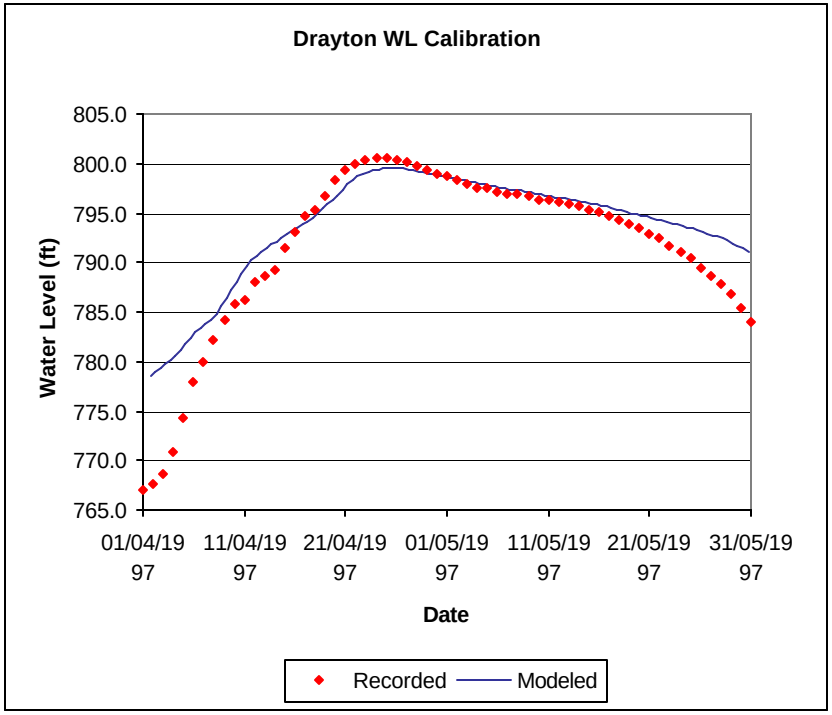
# MIKE 11 1997 Calibration

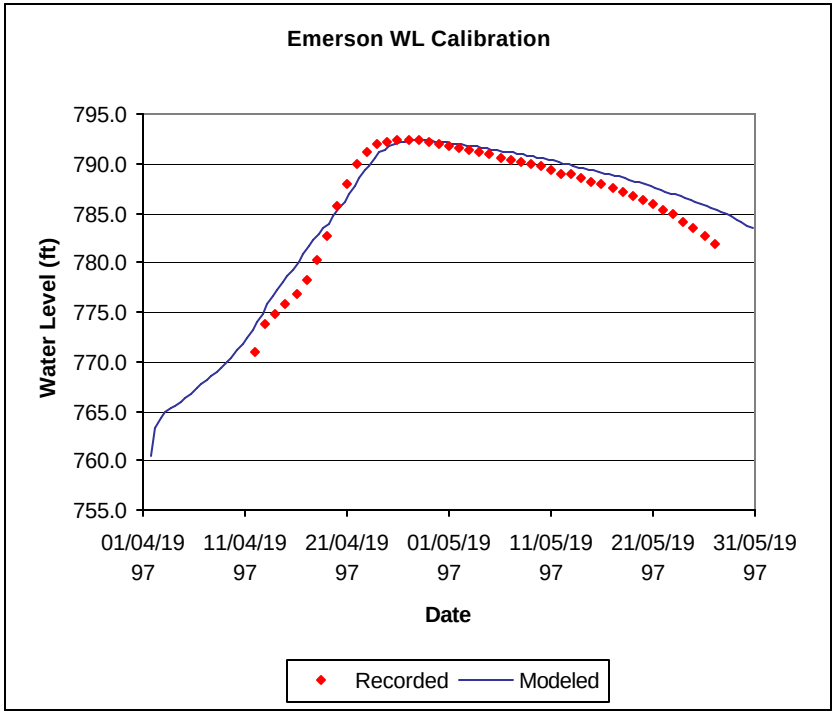


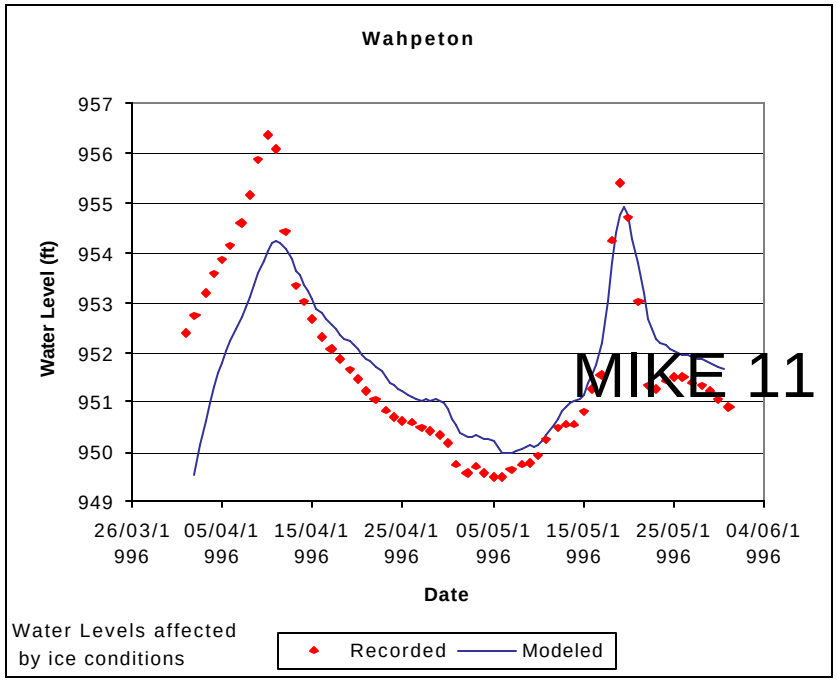



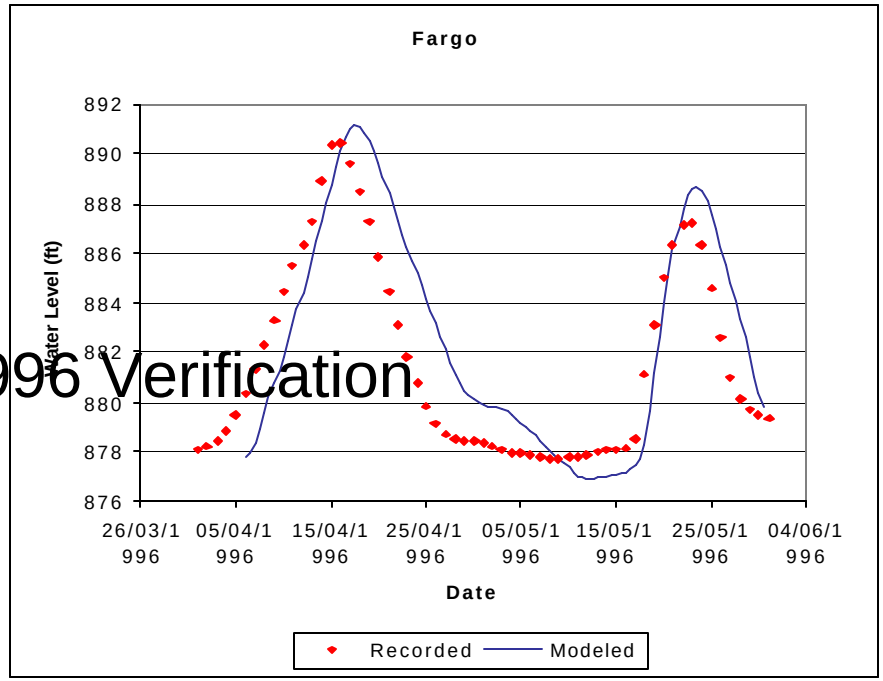



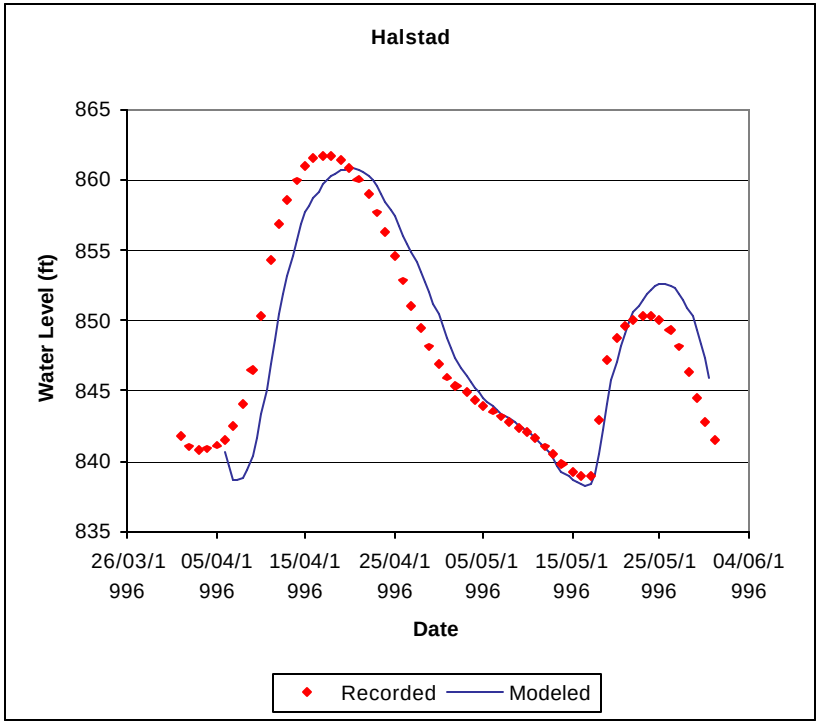

Drayton WL Calibration
Water Level (ft)
805.0
800.0
795.0
790.0
785.0
780.0
775.0
770.0
765.0
01/04/19 97
11/04/19 97
21/04/19 97
01/05/19 97
11/05/19 97
21/05/19 97
31/05/19 97
Date
Recorded
Modeled

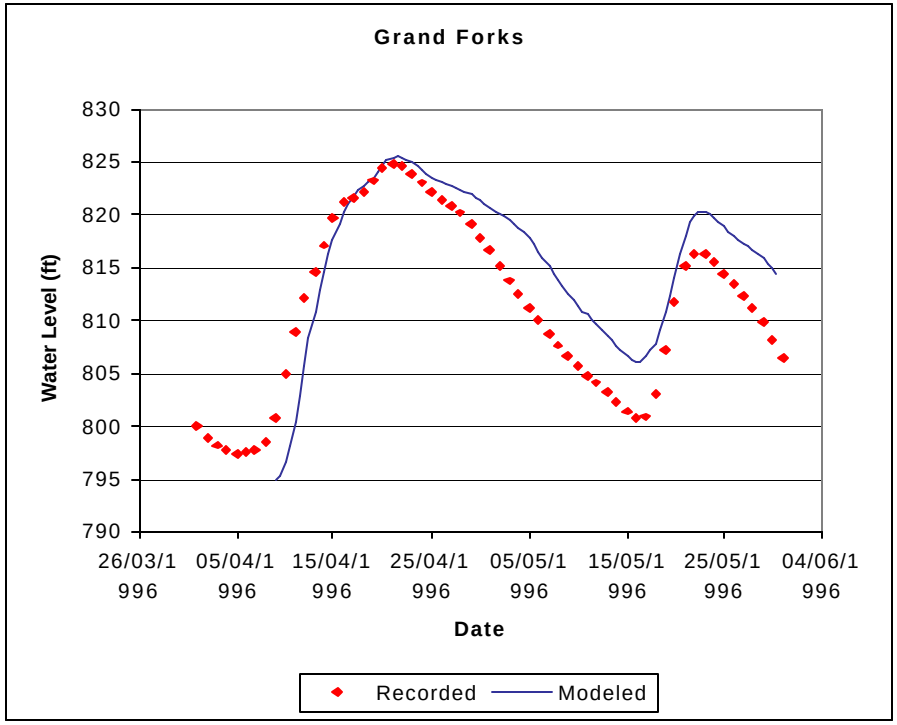

Emerson WL Calibration
Water Level (ft)
795.0
790.0
785.0
780.0
775.0
770.0
765.0
760.0
755.0
01/04/19 97
11/04/19 97
21/04/19 97
01/05/19 97
11/05/19 97
21/05/19 97
31/05/19 97
Date
Recorded
Modeled

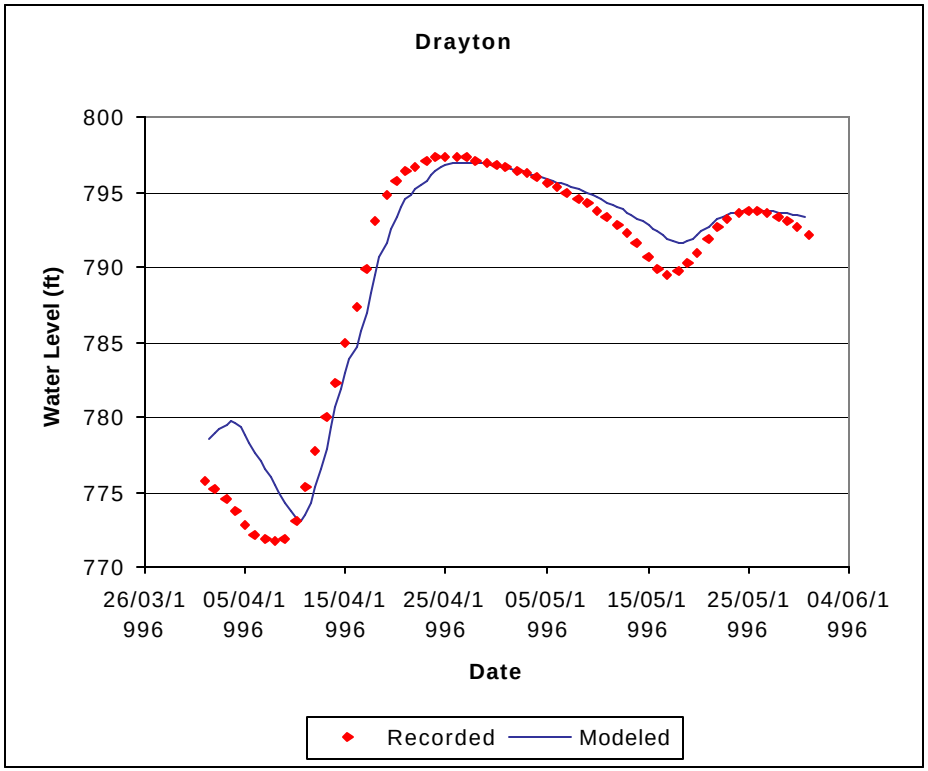
# MIKE 11 1996 Verification

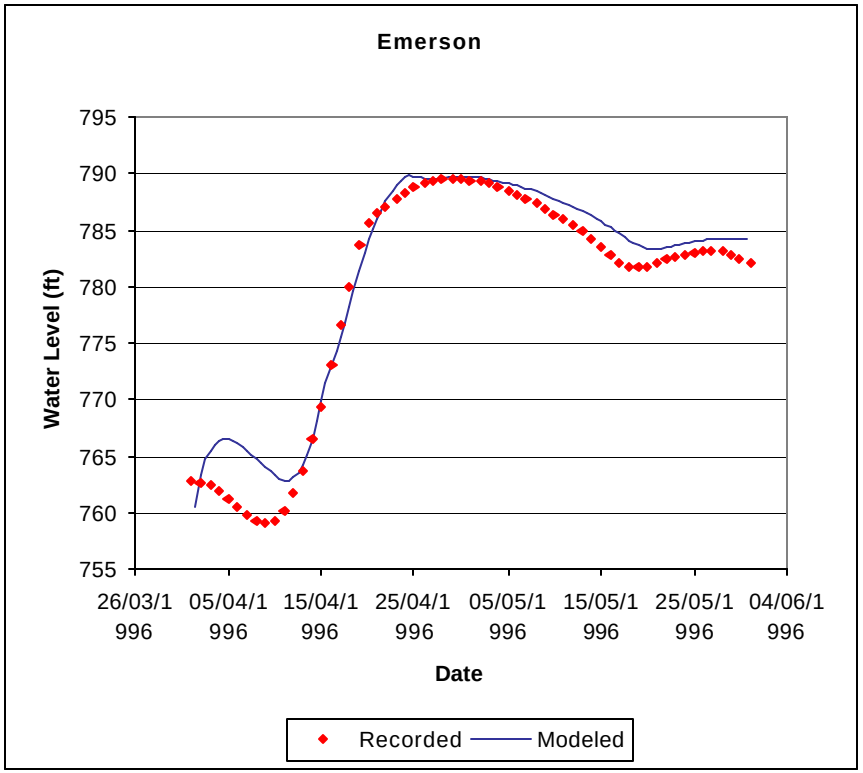


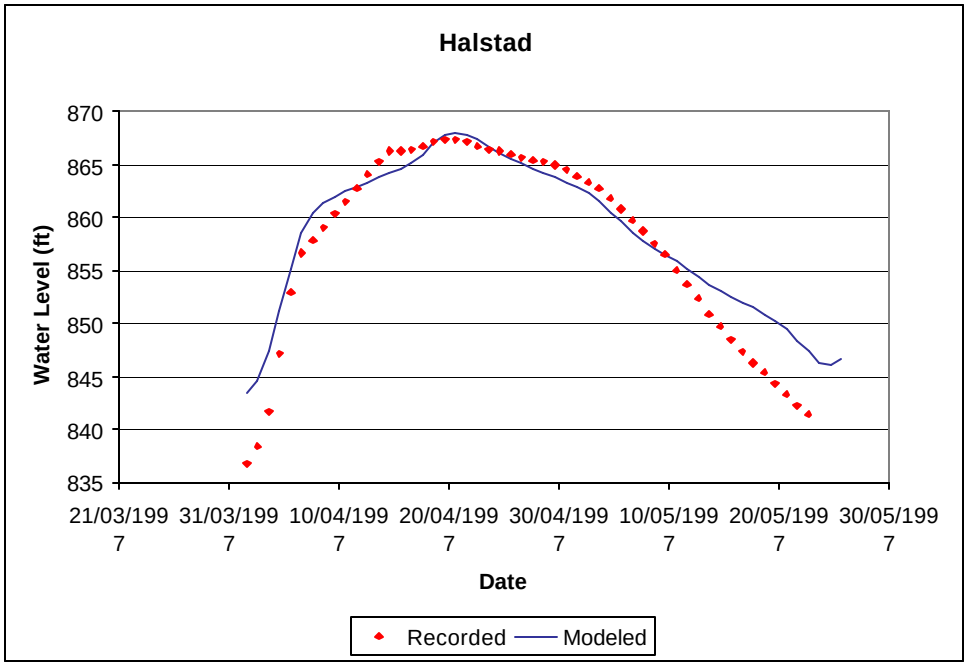



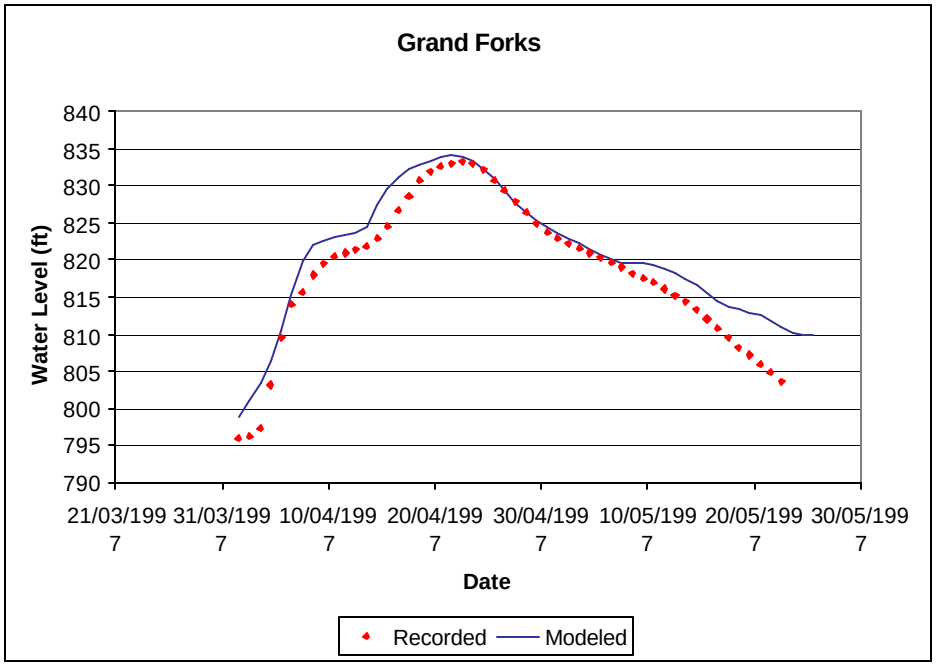



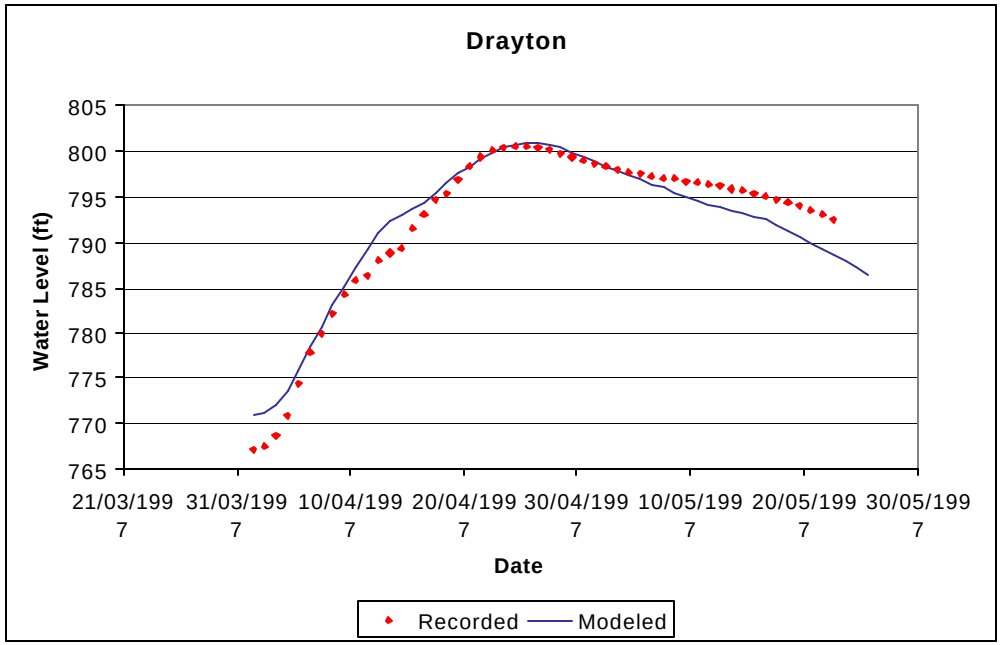

Drayton
800
795
790
785
780
775
770
Water Level (ft)
26/03/1996
05/04/1996
15/04/1996
25/04/1996
05/05/1996
15/05/1996
25/05/1996
04/06/1996
Date
Recorded
Modeled


Emerson
795
790
785
780
775
770
765
760
755
Water Level (ft)
26/03/1996
05/04/1996
15/04/1996
25/04/1996
05/05/1996
15/05/1996
25/05/1996
04/06/1996
Date
Recorded
Modeled

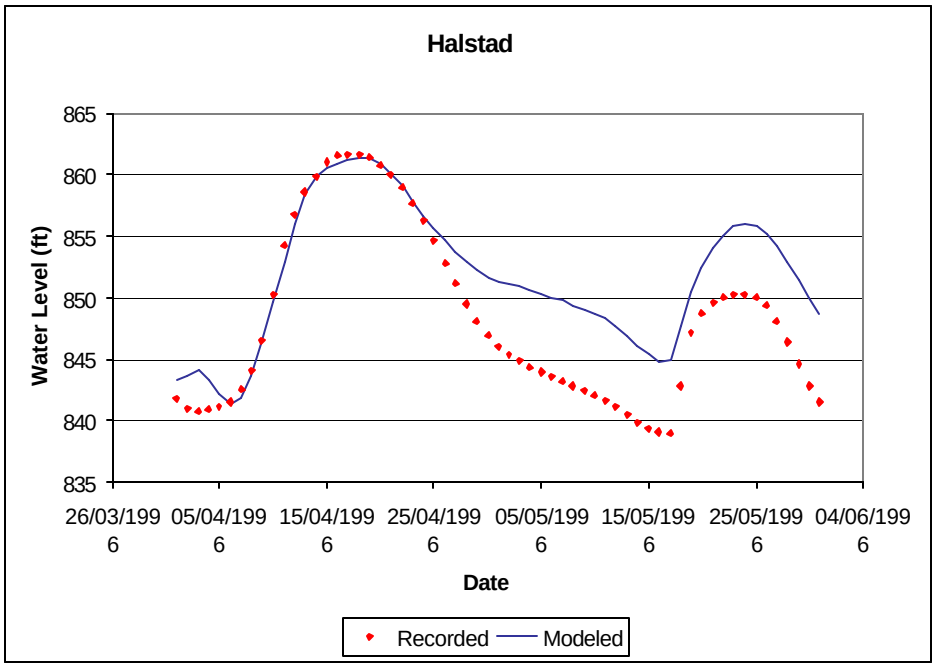
# HEC-RAS 1997 Calibration

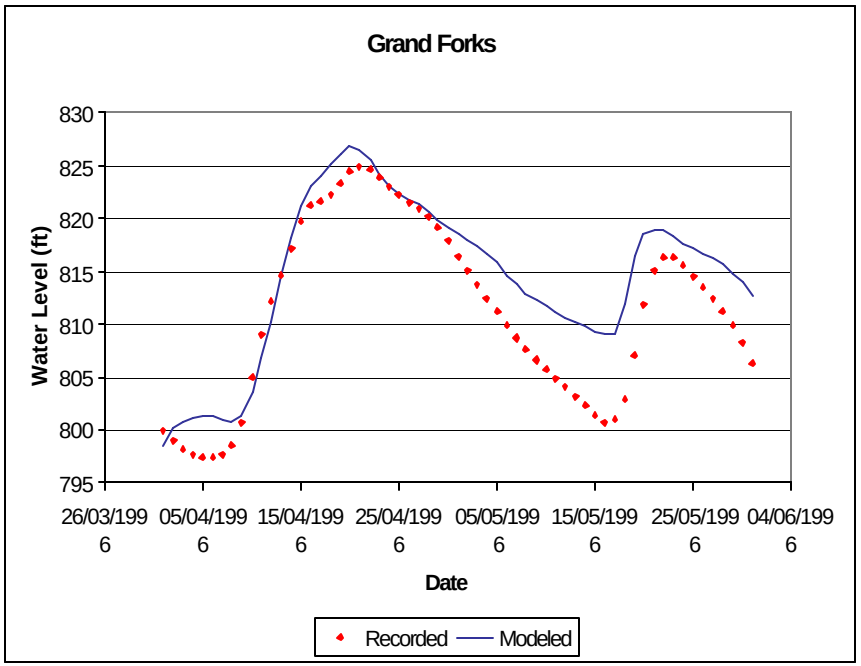


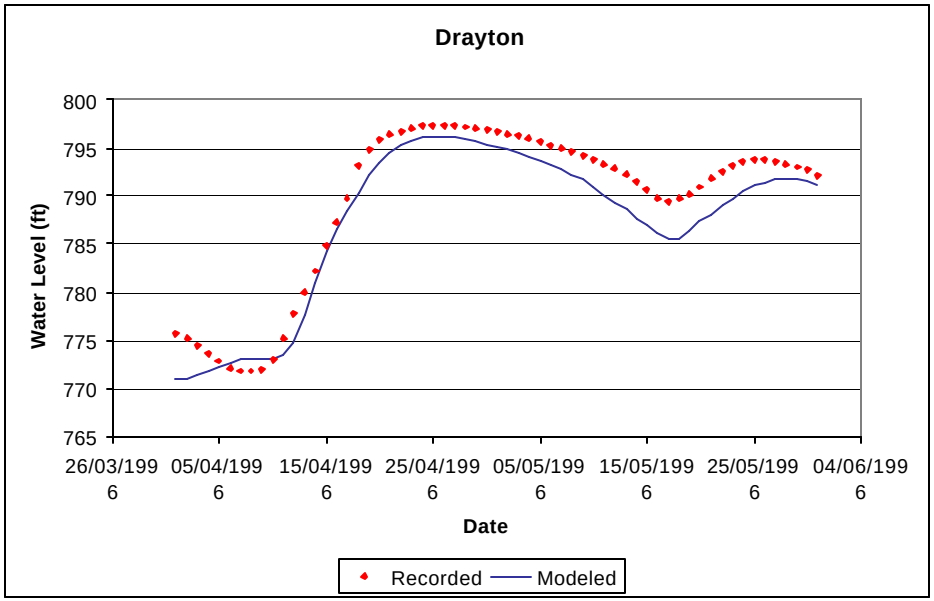



# HEC-RAS 1996 Verification



# Example storage project

- An example storage project was analyzed based on 370,000 acre feet of storage on the Red Lake River.
- The storage project reduced the discharge in the Red River main stem by about 16,000 cfs for the 1997 flood.
- The reduction in water levels was about 1.7 feet at Grand Forks with a reduction of about 0.4 feet at Emerson.

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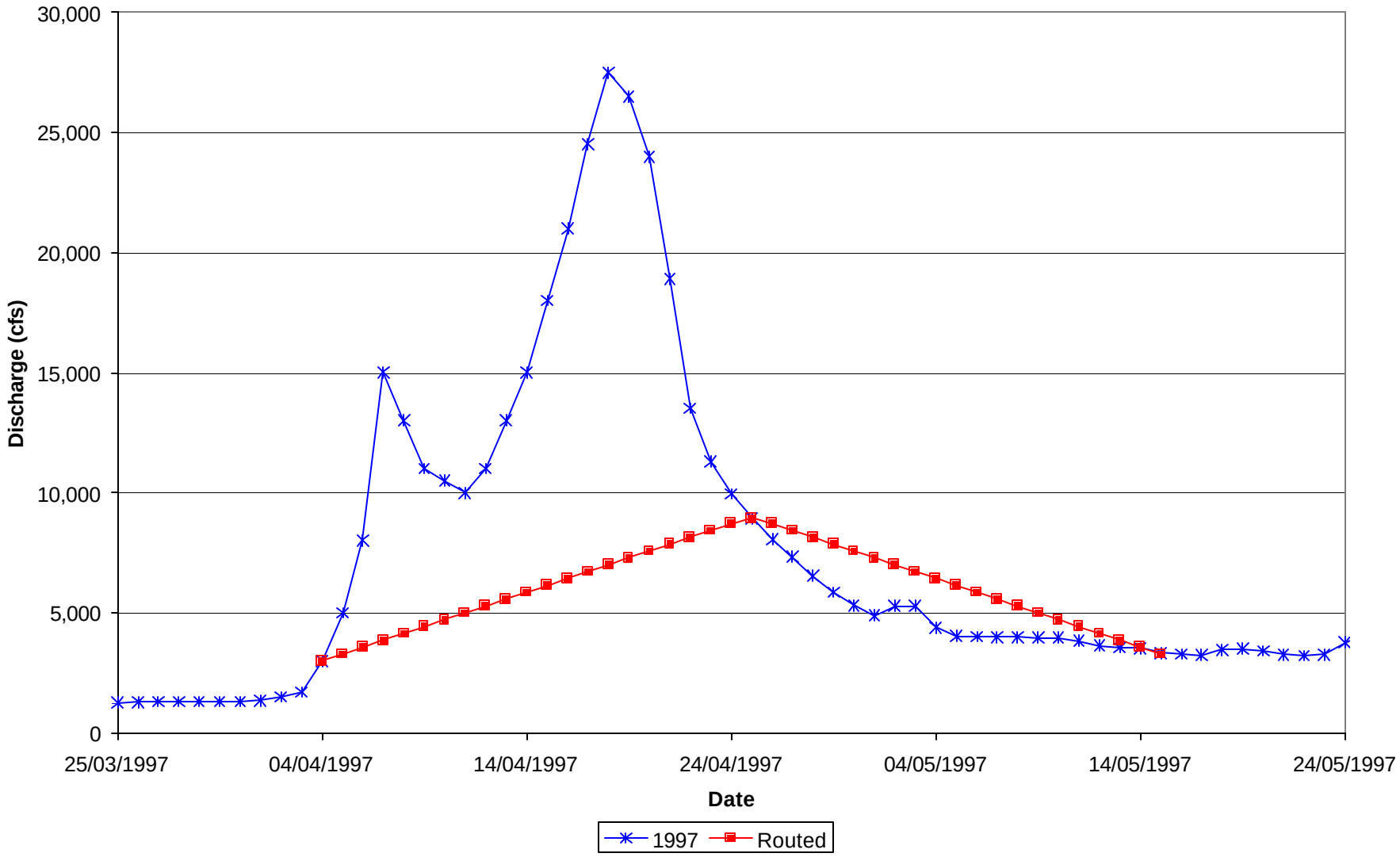
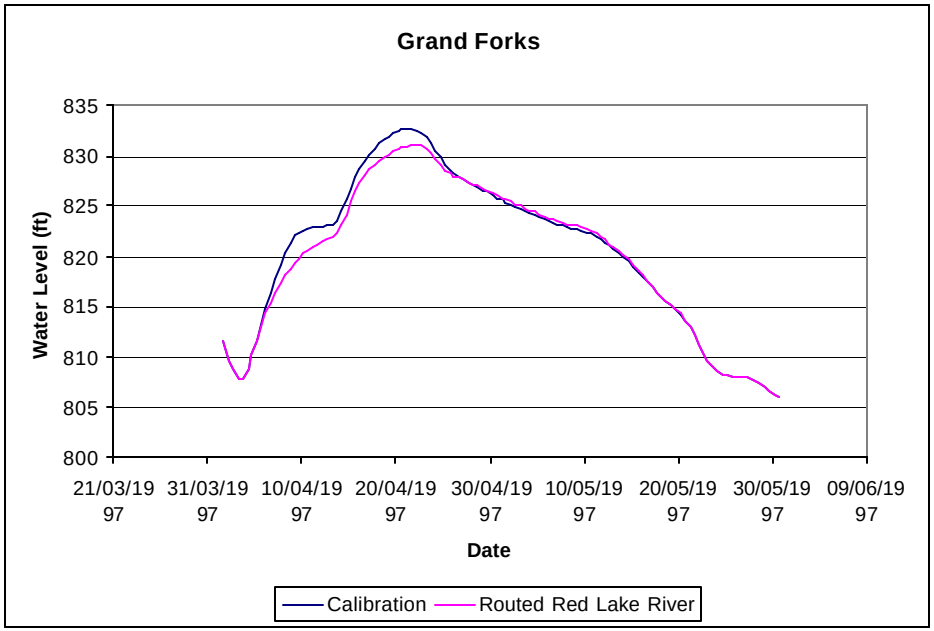
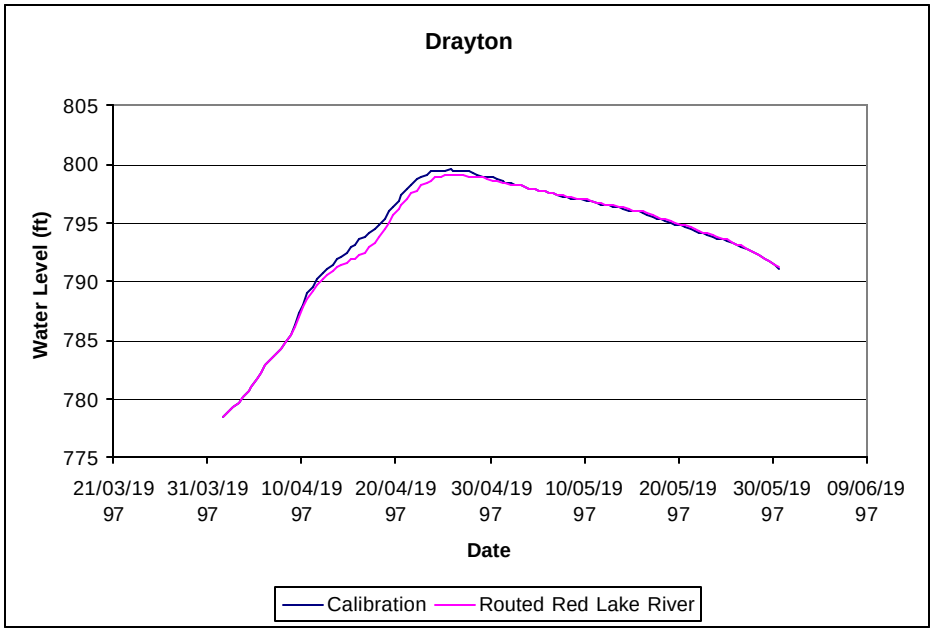
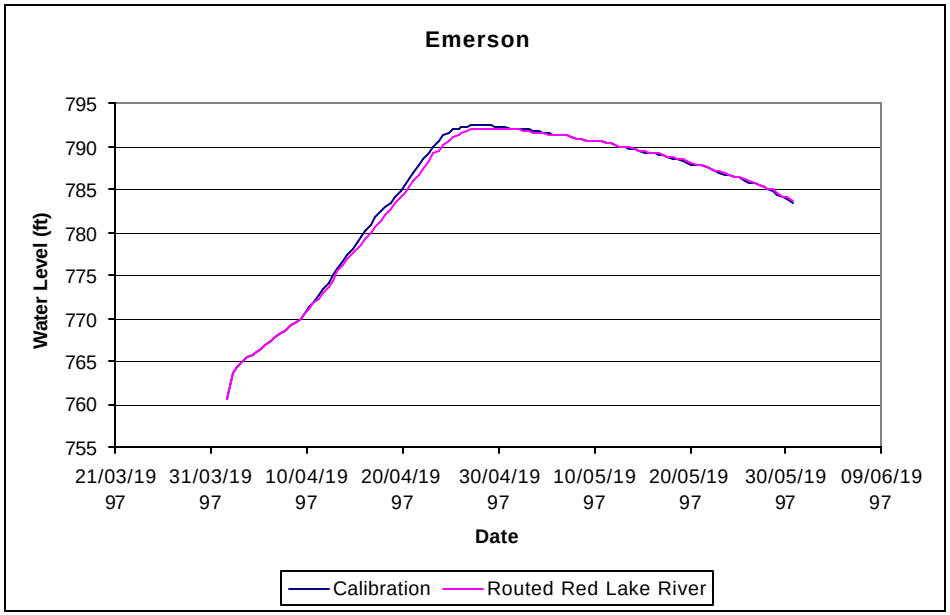
**Figure 6.1 - 1997 Discharges for the Red Lake River with an Example Storage Project**



# Effect of Example Storage Project on Water Levels



# Conclusions

- A Phase 1 unsteady flow model has been developed from Lake Traverse to north of Emerson using MIKE 11.
- A Phase 1 unsteady flow model has been developed from Fargo to Emerson using HEC-RAS.
- Both models provided a satisfactory calibration and verification.
- An example storage project demonstrated the use of the models for analyzing downstream flows and flood levels
- Both models are effective tools for flood mitigation planning in the upper Red River Basin.

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# Recommendations

- Consideration should be given to completing Phase 2 of the study.
- Phase 2 would include collection of additional survey data in particular:
  - Cross sections on  tributaries
  - LIDAR topographic data collection in floodplain areas
  - GPS surveys to define elevations of roads, dikes and railway embankments
- The Phase 2 model would be enhanced by modeling all tributaries below gaging stations and including additional detail in key impact areas.

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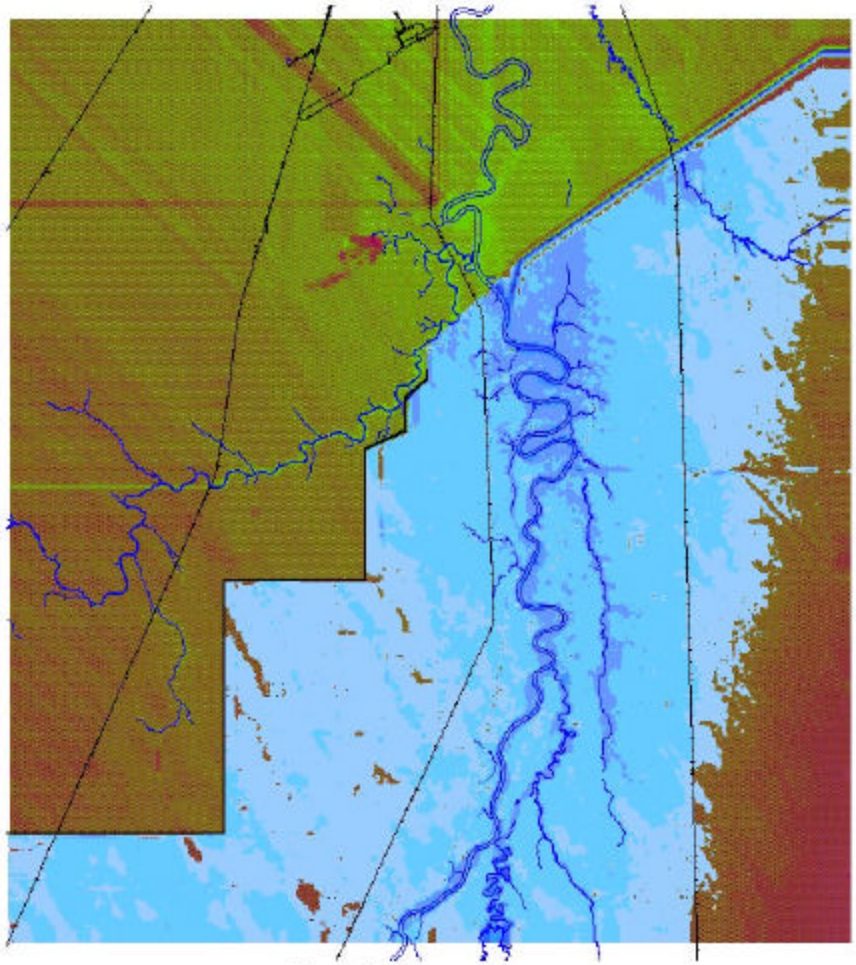
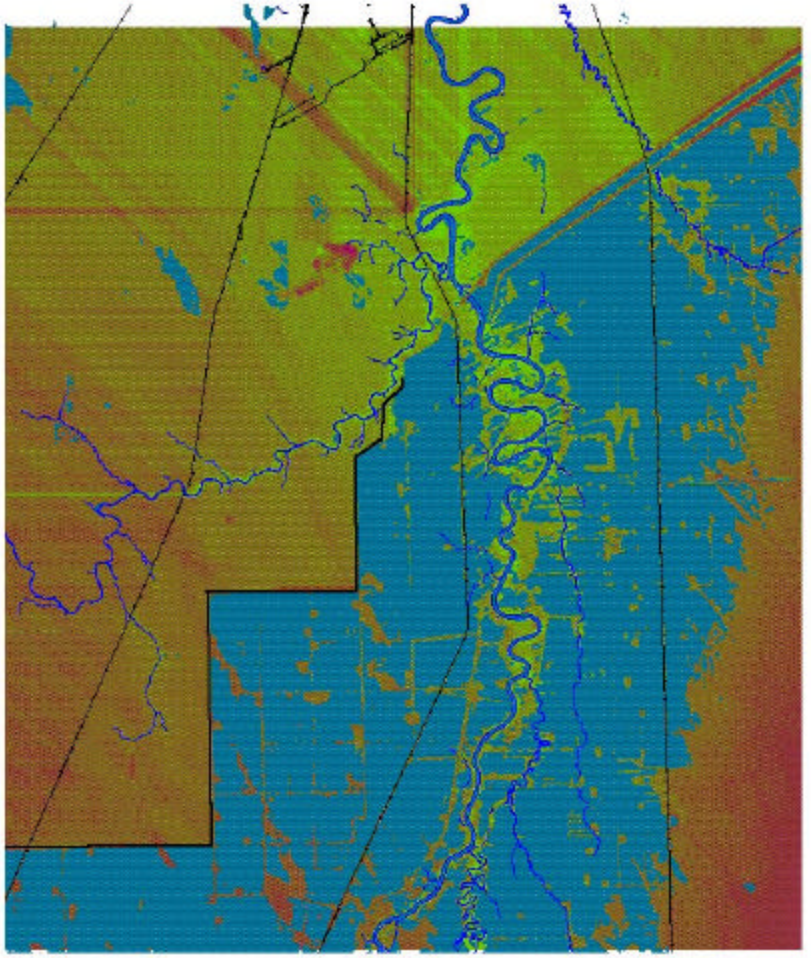
# Comparison of Flood Map with Satellite Image



Modelled
May 4, 1997



Satellite Image
May 4, 1997