SKAGIT RIVER HYDROLOGY
INDEPENDENT TECHNICAL REVIEW

by

Northwest Hydraulic Consultants

March 2007

Scope:

Provide independent technical review of hydrologic analyses for Skagit River.

Recommend “most justifiable and defensible Skagit River hydrology…”

Approach:

Phase 1 - preliminary data review and informational interviews.

Phase 2 - focused review of selected issues to improve confidence in characterization of flood hydrology

Flood of December 1921

Peak discharge estimates for other historic events rely on December 1921 estimate.

Key to determination of 100-year discharge.

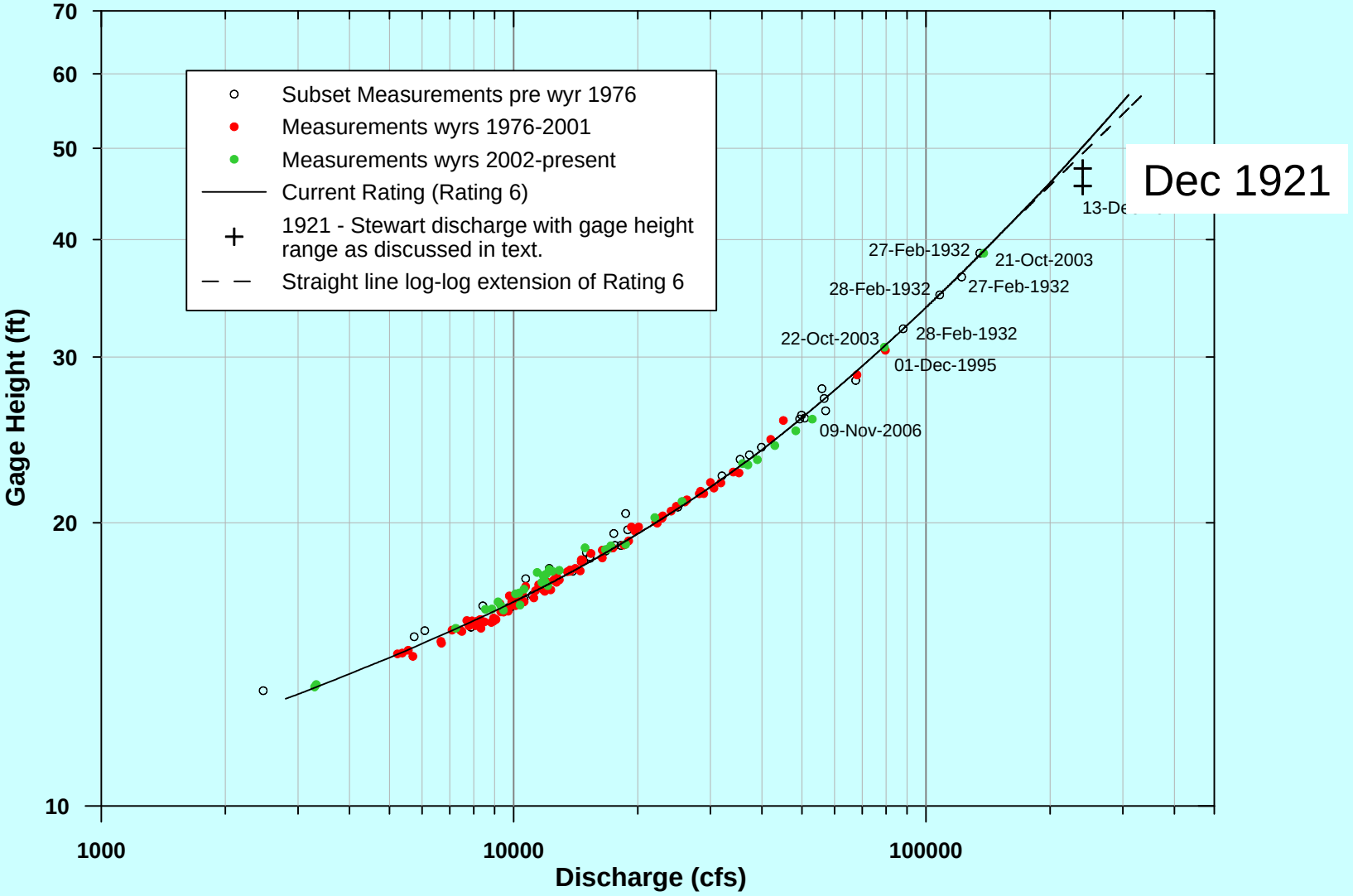
Issues:

- **Verification of Manning's roughness**
- **Consistency of historic data with stage-discharge rating**
- **Consistency of historic data with evidence of non-inundation**
- **Consistency of historic data from Concrete and Sedro Woolley**

Verification of Manning's Roughness

	Roughness	Peak Discharge (Dec 1921)
Stewart (1924)	0.033	240,000
Benson (1952)	0.030	225,000
Mastin and Kresch (2005)	0.024 to 0.032	266,000 to 215,000
NHC (2006)	0.030	n/a

Consistency of historic data with stage-discharge rating
for Skagit River at Concrete



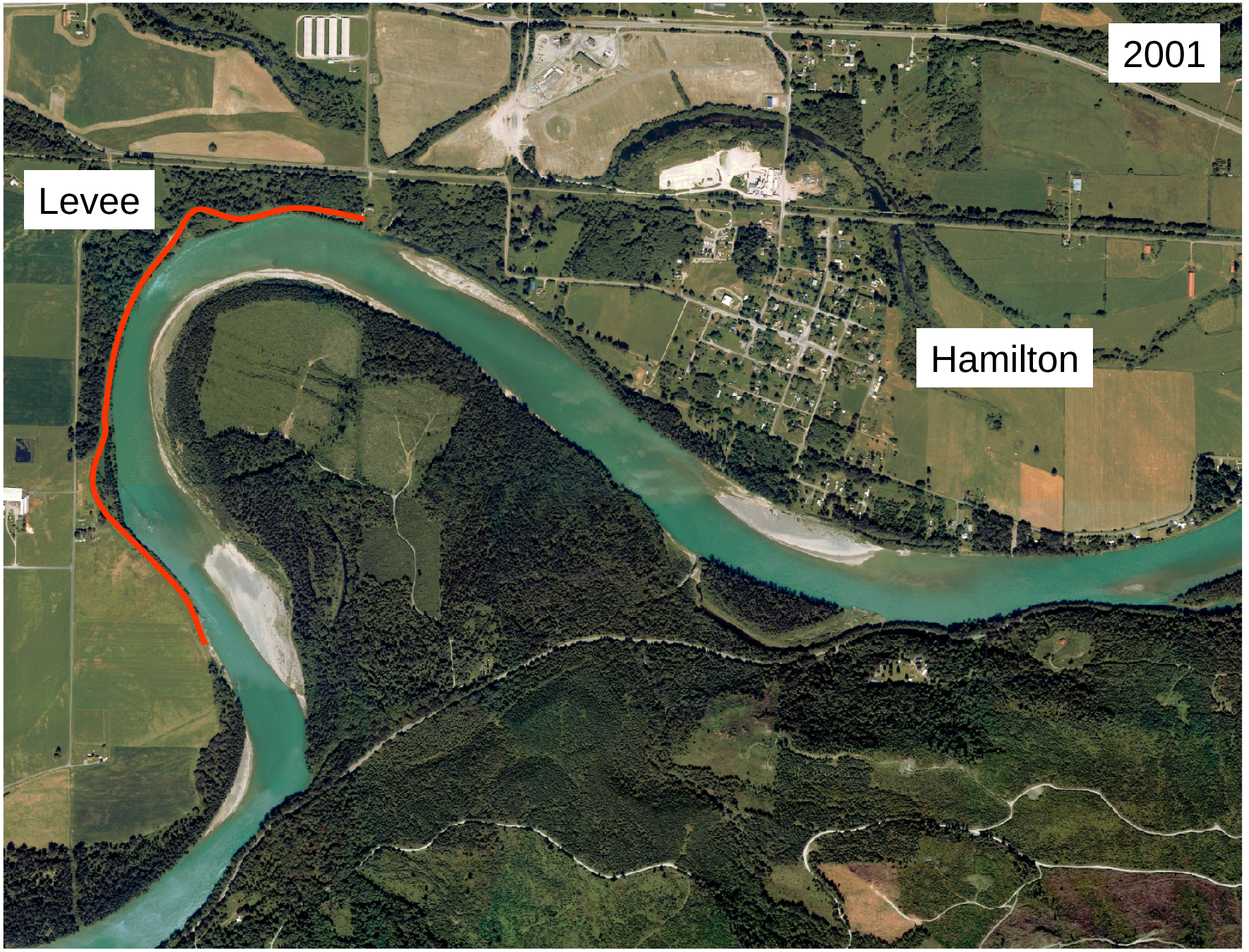
Assumptions	**Peak Gage Height or Discharge (December 1921)**	
	Gage Height (feet)	**Discharge (cfs)**
Gage height reported by Stewart with discharge from Rating 6	47.6	215,000
Gage height adjusted for 2 ft fall to new gage site with discharge from Rating 6	45.6	196,000
Discharge reported by Stewart with gage height from Rating 6	50.2	240,000

Consistency of historic data with flooding in Hamilton

Issue: Smith House flooded in 1995 (160,000 cfs) but anecdotal reports say it did not flood during historic events - reported peak flows of 260,000 cfs (1910), 220,000 cfs (1918), 240,000 cfs (1922).

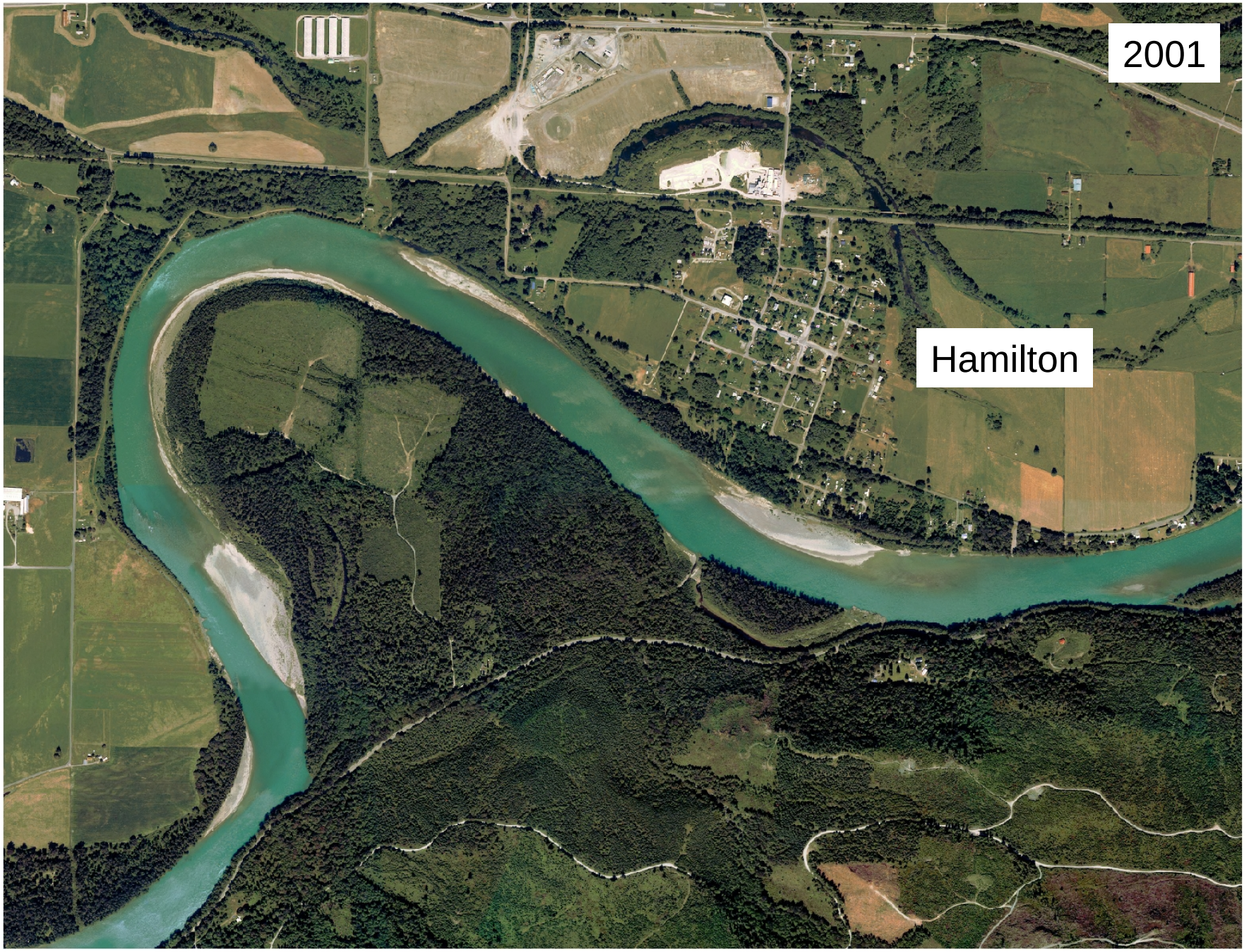
Possible Explanations:

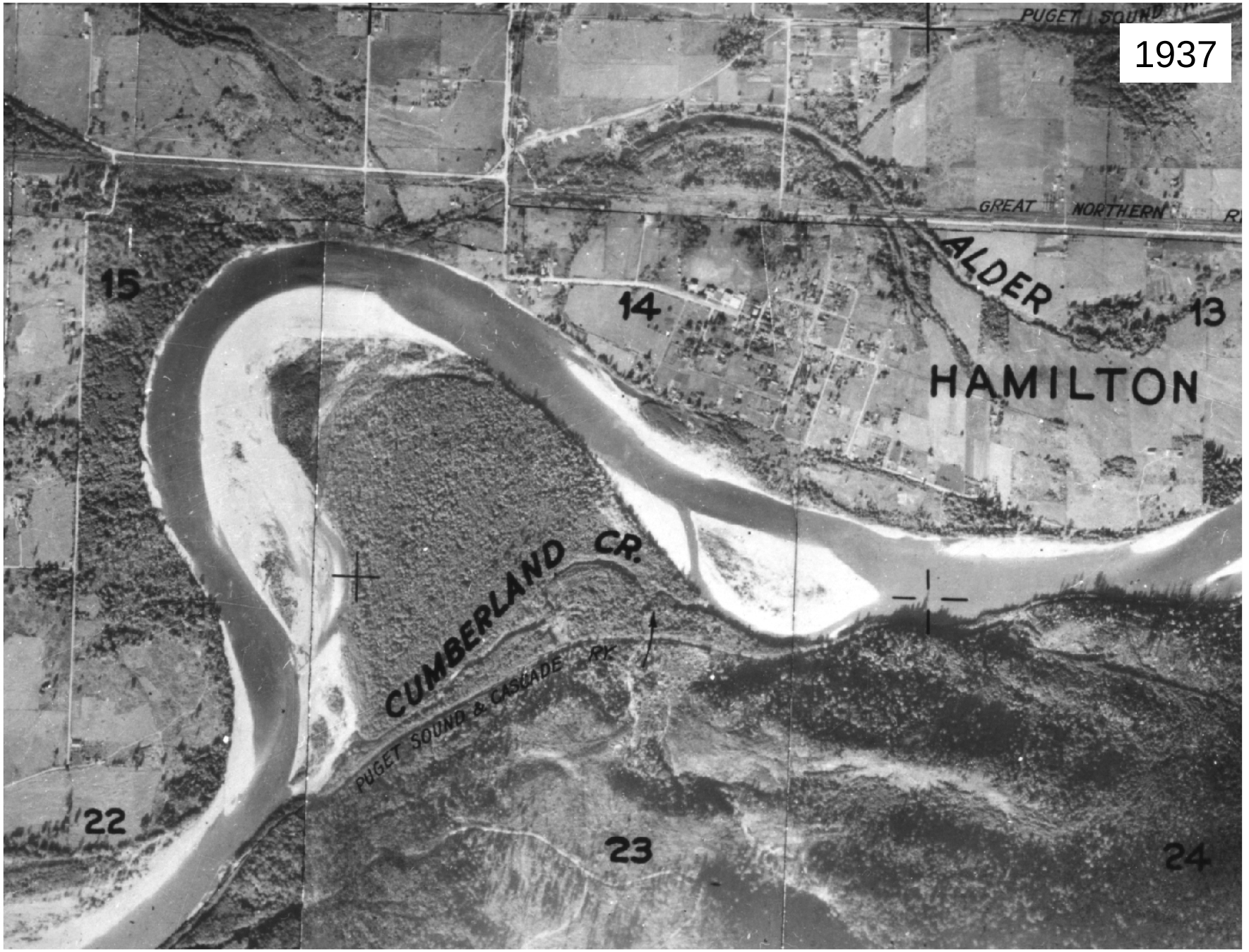
1) **Anecdotal reports are incorrect and house in fact flooded.**
2) **Reported historic peak discharges are too large.**
3) **River has changed since 1922 and historically carried greater flows at lower water levels.**
4) **Combination of 2) and 3)**


2001
Levee
Hamilton

Effect of Cockreham Levee on Water Levels in Hamilton Assuming 1975 Channel Geometry

Flood	Discharge (cfs)	Water Surface Elevation in Hamilton (ft)	
		Without Levee	With Levee
December 1921	240,000	102.7	103.9
November 1995	160,000	99.1	99.7


2001
Hamilton


1937
PUGET SOUND
GREAT NORTHERN R
ALDER
15
14
13
HAMILTON
CUMBERLAND CR.
PUGET SOUND & CASCADE RY
22
23
24

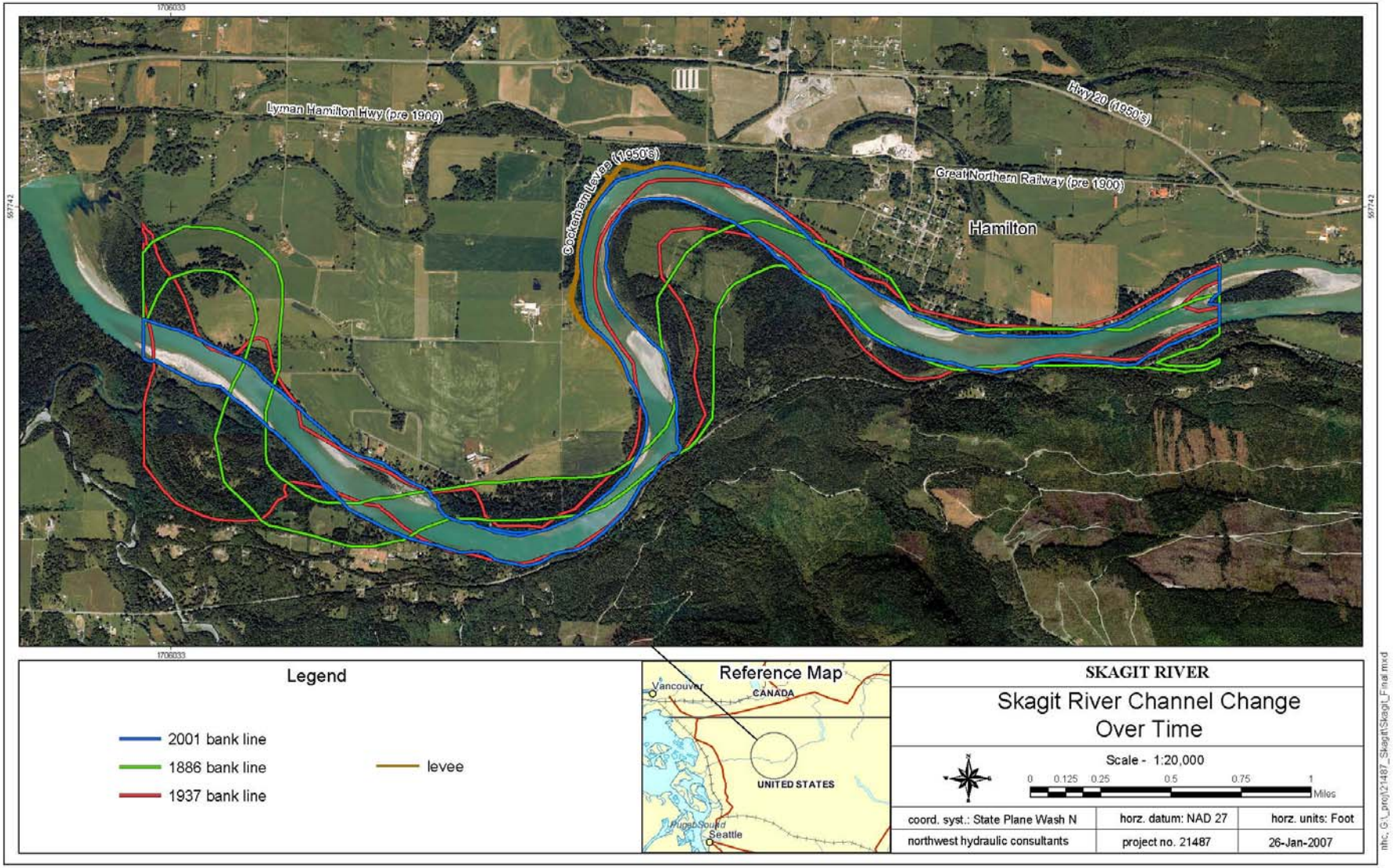

Lyman Hamilton Hwy (pre 1900)
Cockerham Levee (1950's)
Hwy 20 (1950's)
Great Northern Railway (pre 1900)
Hamilton
Legend
2001 bank line
1886 bank line
1937 bank line
levee
Reference Map
Vancouver
CANADA
UNITED STATES
Puget Sound
Seattle
SKAGIT RIVER
Skagit River Channel Change Over Time
Scale - 1:20,000
0 0.125 0.25 0.5 0.75 1
Miles
coord. syst.: State Plane Wash N
horz. datum: NAD 27
horz. units: Foot
northwest hydraulic consultants
project no. 21487
26-Jan-2007
nhc, G:_proj\21487_Skagit\Skagit_Final.mxd

Figure 3

Peak flow attenuation Concrete to Sedro Woolley

Date	Peak Discharge (cfs)		Difference	
	Concrete	Sedro Woolley	(cfs)	(%)
Historic Events (WSP 1527)				
19 November 1897	275,000	190,000	-85,000	-31
30 November 1909	260,000	220,000	-40,000	-15
30 December 1917	220,000	195,000	-25,000	-11
13 December 1921	240,000	210,000	-30,000	-13
Modeled Event				
100-yr regulated	235,400	242,000	+6,600	+3

Peak flow attenuation Concrete to Sedro Woolley

Issue:

- **Peak flow attenuation from historic data much greater than indicated by model results.**

Possible Explanations:

- **Model unreliable – but extensive tests indicate that reported attenuation of historic peaks is too large.**
- **Peak flows at Concrete too high.**
- **Peak flows at Sedro Woolley too low – but Sedro Woolley gauge site very poor and opinion of USGS review in 1950's was that reported peak flows for SW were too high.**

Uncertainty in historic discharge estimates:

- “n” verification study indicates published peaks too high

- Discharge estimates inconsistent with rating curve.

- No account for drop in water level between old and new gage sites.

Other factors:

- Evidence of non-inundation in Hamilton inconclusive because of changes in river channel.

- Reported peak flow attenuation between Concrete and Sedro Woolley excessive but no confidence in peak flow estimates at Sedro Woolley.

Uncertainty in historic discharge estimates (cont.)

Preliminary estimate of range of discharges:

Date	Low	Published	High
Nov 1897	213,000	275,000	310,000
Nov 1909	195,000	260,000	278,000
Dec 1917	166,000	220,000	235,000
Dec 1921	182,000	240,000	257,000

Flood Frequency Analyses

Corps analysis uses HEC-FFA (Bulletin 17B):

- **limited options for handling historic data**
- **standard approach approved by Federal Govt.**

Alternative analysis using Expected Moments Algorithm (EMA) :

- **allows for uncertainty in historic values**
- **developed by USBR**
- **under review for update to Bulletin 17B**

Exploratory Flood Frequency Analyses with EMA (Unregulated Peak Flows at Concrete)

Assumptions	**Q_{100} (cfs)**
Base Case with historic period back to 1898:	284,000
Extend historic period back to 1870:	276,000
Extend historic period and allow for uncertainty in historic peak discharge estimates:	240,000 to 250,000

Principal Conclusions and Recommendations

- Estimates of peak discharges for historic floods should continue to be used in analyses of flood hazard.

- Uncertainty in the magnitude of historic floods should be accounted for in future analyses.

- Consideration should be given to use of more rigorous flood frequency analysis techniques using EMA.