



Flood wave characteristics and sediment transport during storm events at a channel confluence of the Anacostia River



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Introduction

- Geomorphic studies of channel confluences have focused on confluence hydraulics and consequences for channel morphology.
- There have been fewer studies on the variability of confluence responses and the consequences for flooding and sedimentation hazards.
- Additionally, geomorphic research has been primarily conducted in non-urbanized environments.
- With annual discharges increasing due to human influence and climate change, analysis of urban systems at flood stage should be conducted

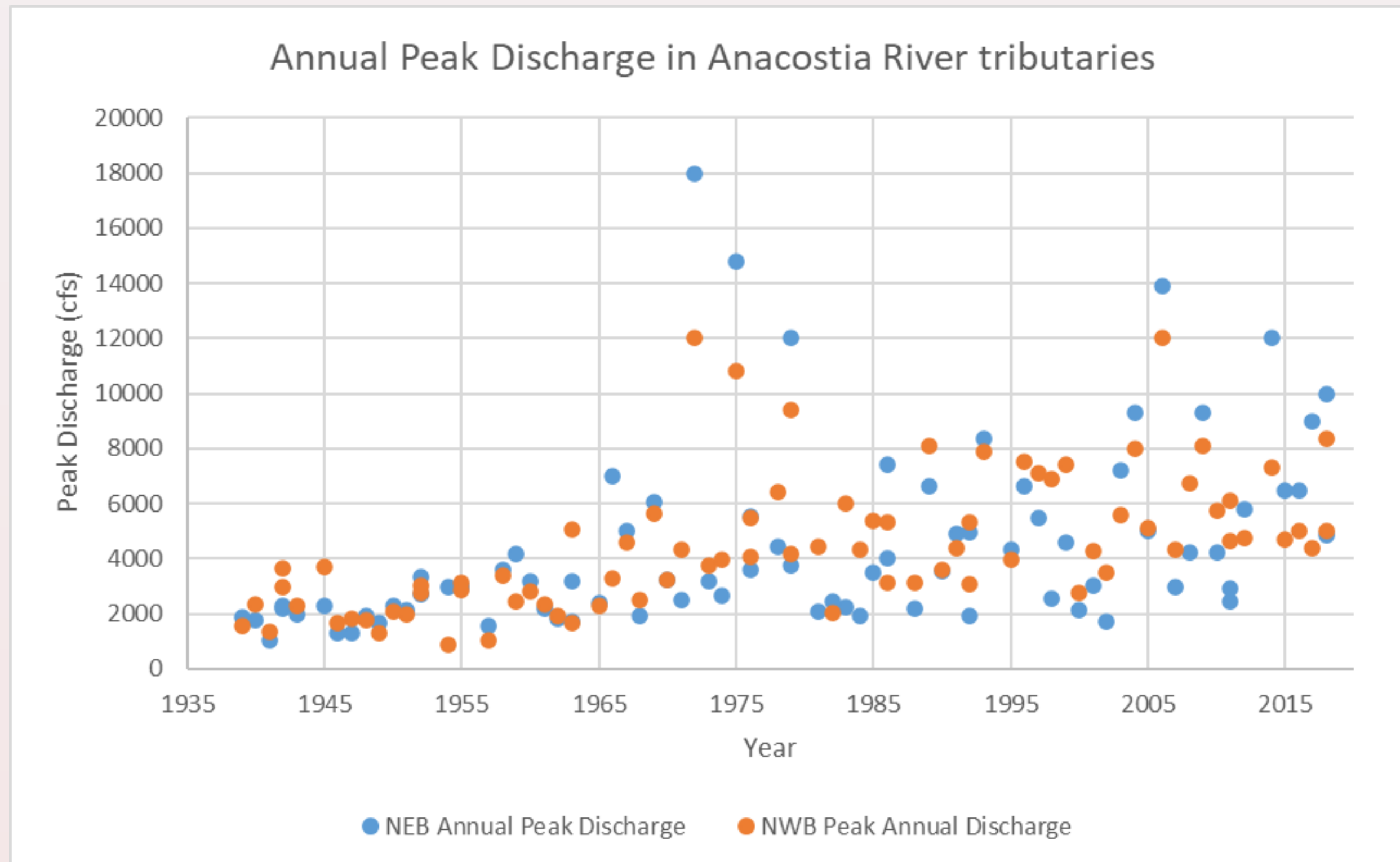


Figure 1: Annual peak discharge of the Northeast Branch and Northwest Branch. The annual peak in each branch is trending to increase every year. Data retrieved from the USGS.

Hypotheses

1. Synchronous flood waves occur during a majority of storms at the Northeast Branch-Northwest Branch confluence, with asynchronous flow being less frequent.
2. The runoff response (volume/basin area) of the Northwest Branch is greater than the runoff of the Northeast Branch in the majority of storms. (This may contribute to synchronicity)
3. Seasonal variations in storm intensity and sediment supply behaviors affects the grain composition of the gravel beds and seasons with more frequent storms deposit fine subsurface materials.

Study Site Location

Confluence of the Northeast Branch and Northwest Branch of the Anacostia. (Bladensburg, Maryland)

Northeast Branch

Drainage Basin Area: **127.9 km²**

Slope: **0.0012**

Flows through the Piedmont Province

Northwest Branch

Drainage Basin Area: **188.6 km²**

Slope: **0.0016**

Flows through the Coastal Plane Province

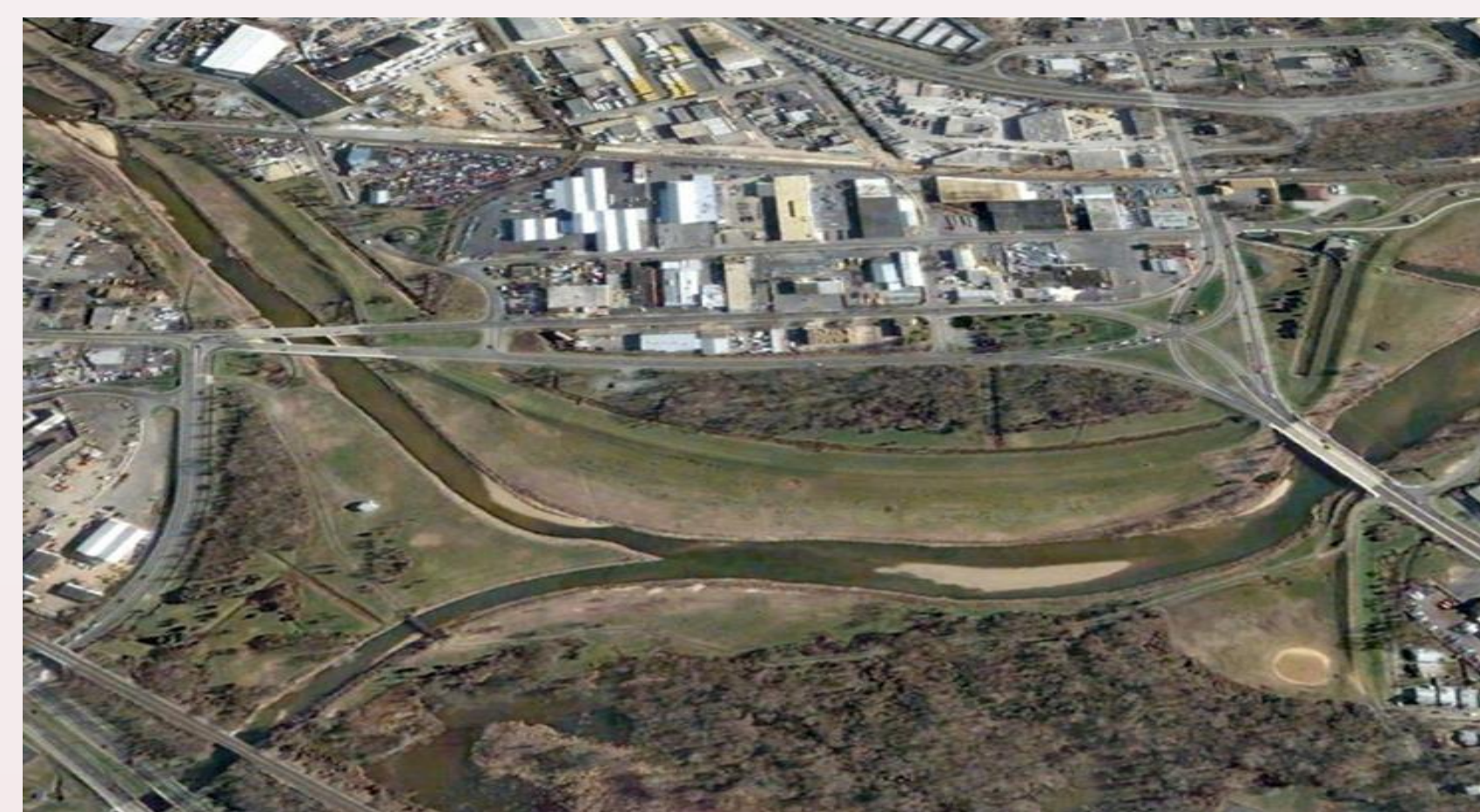


Figure 2: Satellite image of the confluence of the Northeast and Northwest Branch

Methods

- Surveys of surface gravels using the Wolman pebble count method to determine which grains regulate gravel bar mobilization
- Sieve analysis of subsurface materials deposits to determine composition of gravel bed materials .
- Analysis of USGS field measurements to identify the discharge required to exceed the critical shear stress that regulates mobilization in each tributary.
- Analysis of USGS data to determine what storm events exceeded the critical shear stress required for sediment transportation

Discharge and Critical Shear Stress

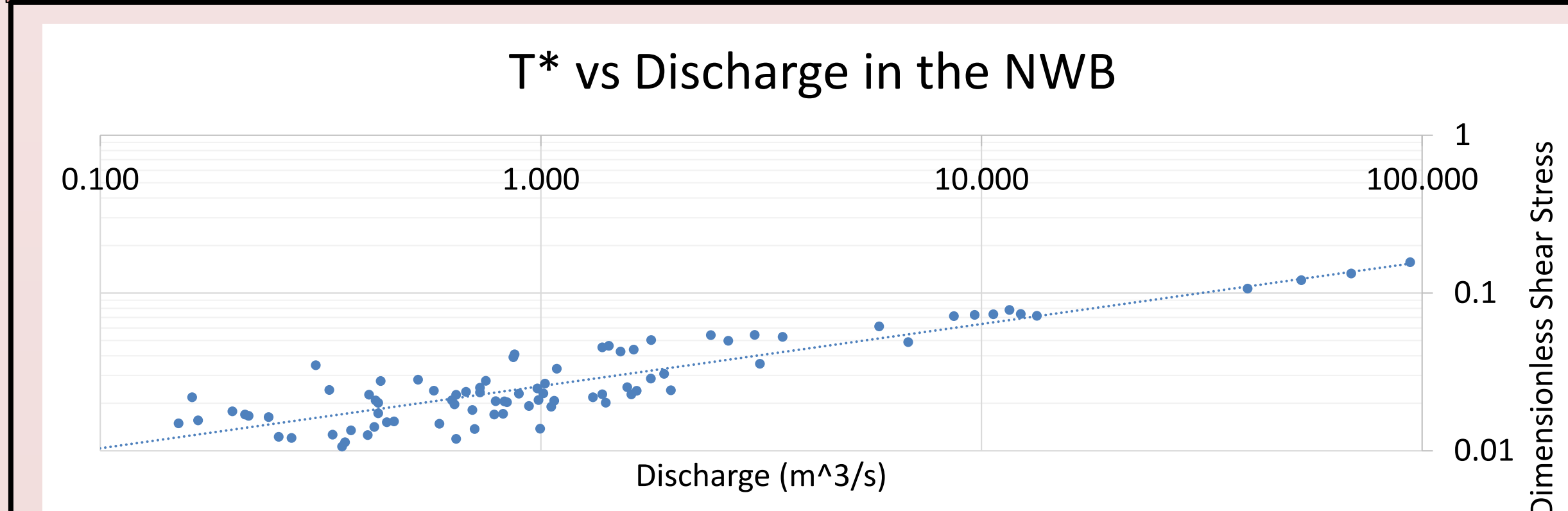


Figure 3: Calculated relationship between discharge and critical shear stress in the NWB

Storm Event Analysis Summary

Date of Event	Event Duration (hours)	Peak NWB Discharge (m ³ /s)	Peak NEB Discharge (m ³ /s)	Lag Time Between Peak Flood Waves (minutes)	Tributary to Peak first	Tributary with the longest transportation duration	NWB Runoff (mm)	NEB Runoff (mm)
Aug 4-5 2020	23.5	213.1	120.56	37.2	NWB	NEB	26.63	20.52
Aug 6 2020	8.75	37.64	42.73	85.1	NEB	NWB	6.05	4.21
Aug 7-8 2020	6.75	21.88	20.26	65.9	NEB	NWB	2.11	1.03
Aug 12-13 2020	4.75	21.88	86.88	24	NEB	NEB	1.87	4.75
Aug 16 2020	12.25	23.83	60	37	NWB	NEB	4.89	6.97
Sept 3-4 2020	13.5	155.93	114.9	21	NWB	NEB	13.98	14.83
Sept 10-11 2020	11.5	455.63	233.19	5.8	Synchronous	Equal	83.73	21.83
Oct 12 2020	4.5	22.61	19.98	53.1	NEB	NWB	2.26	1.69
Oct 29-30 2020	13.5	57.45	90.56	14.6	Synchronous	NEB	16.3	20.12
Nov 11-12 2020	26	71.32	130.18	76.6	NWB	NEB	57.02	28.1
Nov 30 - Dec 1 2020	20.5	49.81	103.01	16.9	NEB	NEB	12.88	17.17
Dec 5 2020	16.25	28.3	47.26	5	Synchronous	NEB	6.78	8.64
Dec 14-15 2020	17	30.56	50.66	20	NEB	NEB	8.57	9.42
Dec 16-17 2020	21.25	36.22	67.64	20.4	NWB	NEB	11.13	14.69
Dec 24-25 2020	27.75	64.52	82.07	41	NWB	NEB	23.52	21.55
Jan 1-2 2021	18.5	30.56	50.37	35	NWB	NEB	8.56	9.32
Feb 15-16 2021	21	40.19	63.11	20.5	NEB	NEB	11.43	13.08

Table 1: Summary of storm events analyzed. A total of 17 storm events were identified to exceed the critical shear stress required for sediment mobilization.

Runoff Ratios, Lag Time and the September 10th-11th Event

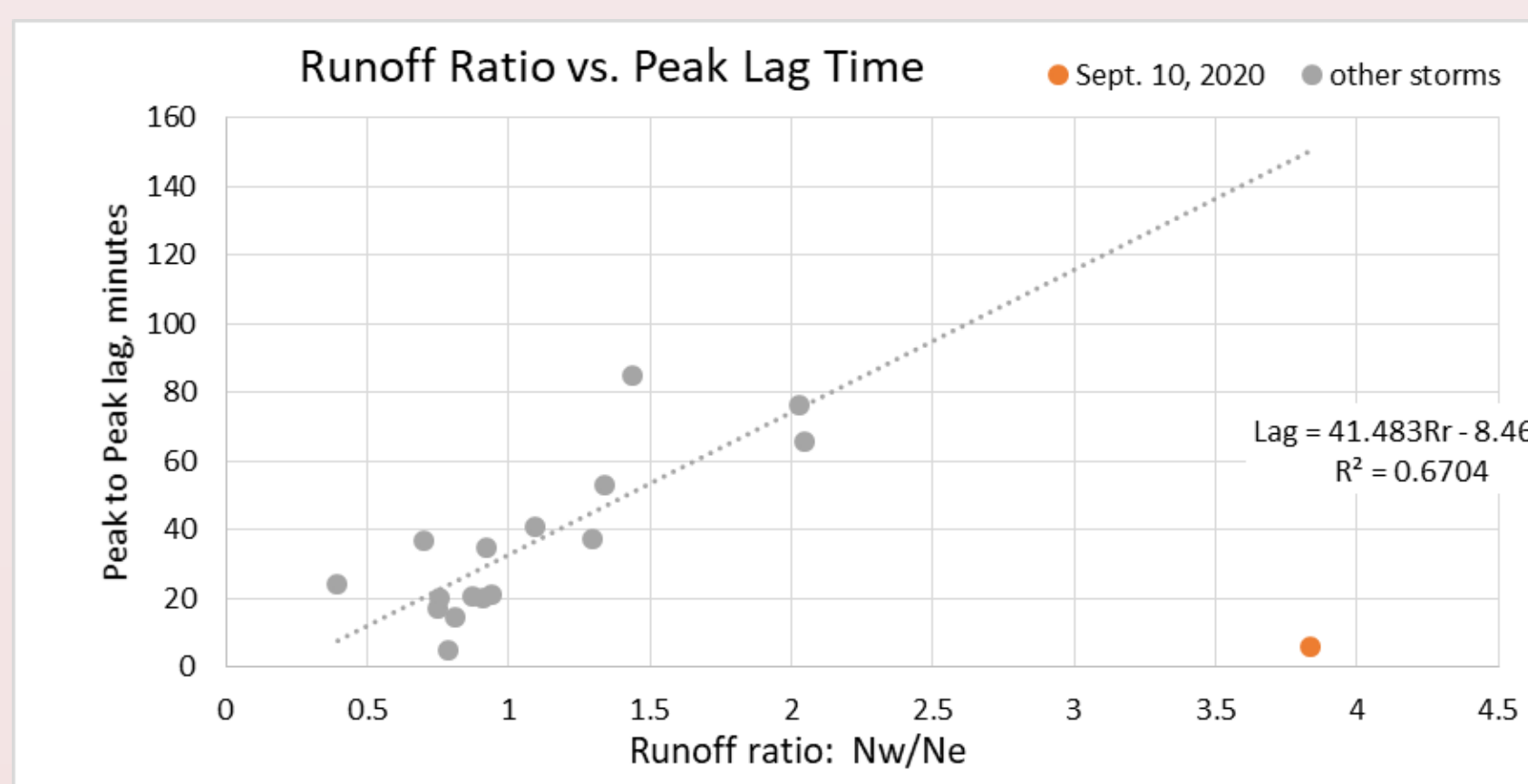


Figure 4: Lag time between flood wave peaks vs Runoff Ratio. The September 10-11th storm is plotted in orange.

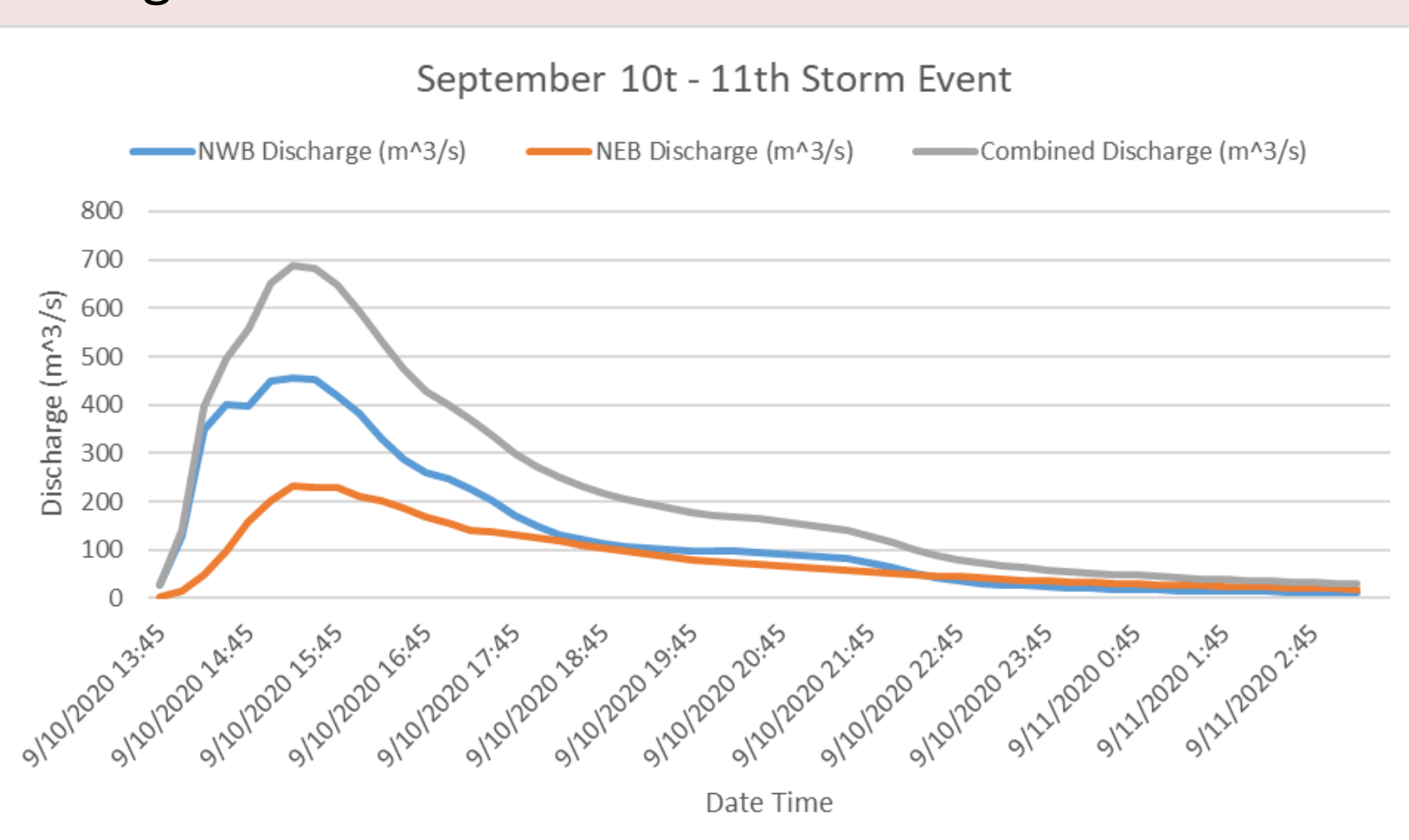


Figure 5: Hydrograph of the September 10th-11th 2020.

- Runoff ratios directly compare the rainfall collected in each of the drainage basins.
- Ratios greater than 1, Northwest Branch generated most runoff
- Ratios less than 1, Northeast Branch generated most runoff
- A clear relationship exist between lag time and the runoff ratio
- September 10th-11th event a outlier to this trend

September 10th-11th Storm Event

- This storm event with the annual maximum in both the Northeast and Northwest Branch
- The Northwest Branch generated almost 4 times more runoff than the Northeast Branch
- Suggests that the Northwest Branch drainage basin is extremely efficient at transporting runoff

Subsurface Grain Size Composition

- Analysis of subsurface sediments of gravel bars indicated that there was a shift in composition to coarser sediments from October 2020 to February 2021.
- This is theorized to be due to the increased storm duration in the winter.

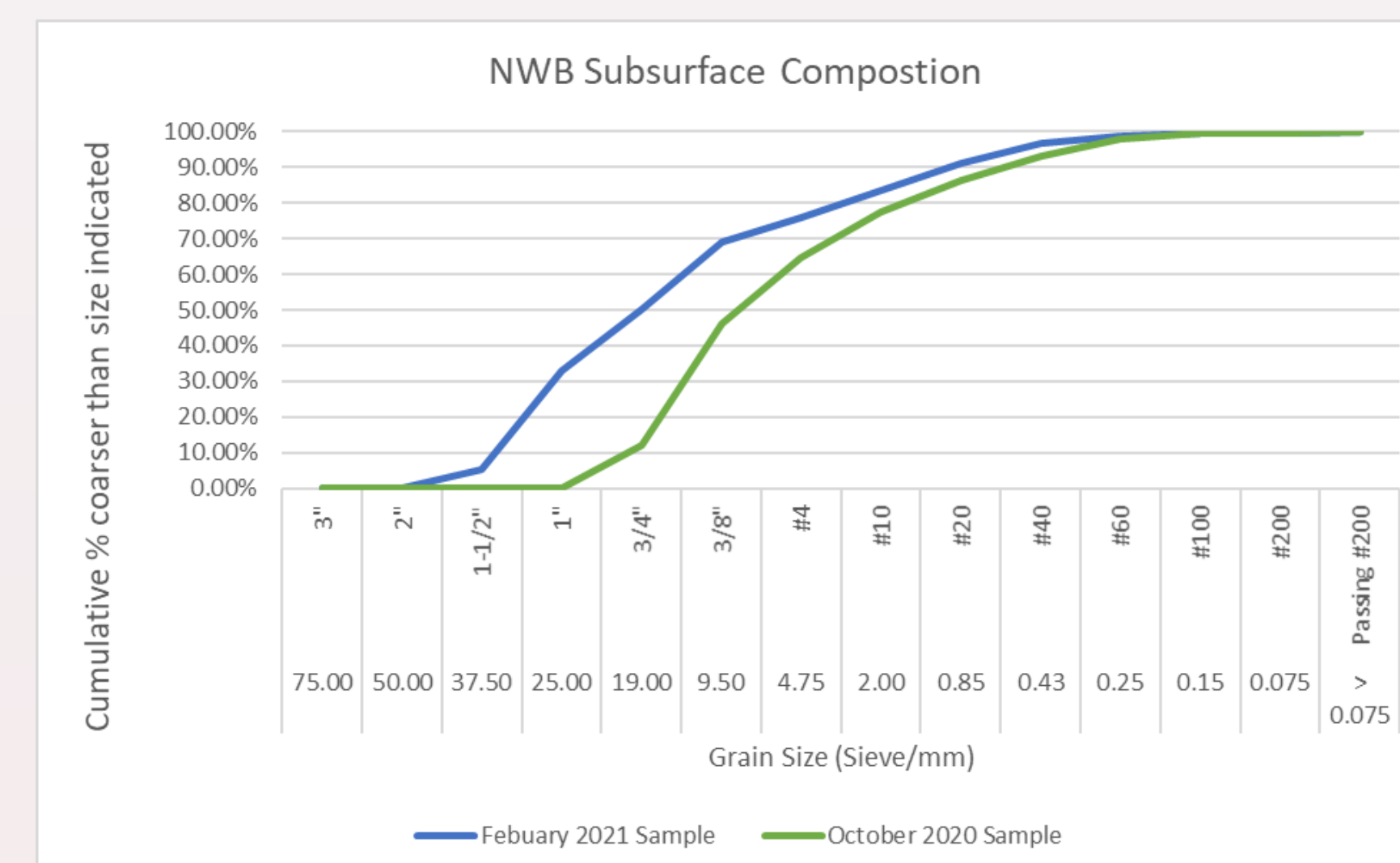


Figure 6: Sieve analysis results of gravel bar materials of the Northwest Branch.

Discussion

- The velocity of waves is clearly linked to the intensity of storms.
- While not commonly synchronous, wave peaks arrive at channel confluences within short intervals of one another frequently
- The Northwest Branch drainage basin is more efficient at runoff transportation, the Northeast Branch maintains extended periods of sediment mobilization.
- The September 10th-11th storm suggest there may be a threshold where the Northwest Branch becomes even more efficient in transporting runoff
- Subsurface analysis indicates there is little fine materials stored within gravel bars, which is likely due to the number of sediment mobilizing storms that occur.

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