DRAFT

Indian River Geomorphic Assessment and Sheldon Jackson Hatchery Diversion Evaluation

Prepared for:

Sitka Sound Science Center
834 Lincoln Street, Suite 200
Sitka, Alaska 99835

U.S. Fish and Wildlife Service
4700 BLM Road
Anchorage, AK 99507

Prepared by:

Inter-Fluve, Inc.
501 Portway Avenue, Suite 101
Hood River, OR 97031

November 1, 2019

Contents

Introduction 1
Existing information 1
Site investigations and project kick off meeting 2
Project Kick off meeting 2
Field work: 4
Stream walk 4
Pebble counts 4
Survey 4
Project reaches 5
LiDAR and site survey: 7
Hydrology: 7
Hydraulics: 8
Model Domain and Computation Parameters 8
Boundary Conditions 8
Roughness 9
Results: existing conditions 9
Geomorphology 9
Qualitative Geomorphic Analyses 10
Historical Aerials 11
Field Reconnaissance 11
Spatial Data Review 16
Summary and Key Points from Qualitative Analyses 18
Quantitative Geomorphic Analyses 18
Sediment Balance Modeling 19
Peak Flow Sediment Analysis 24
Summary and Key Points from Quantitative Analyses 24
Implications for Project Alternatives 26
Alternatives: 28
References: 29
Appendices 30

DRAFT

Introduction

The Indian River Working Group has been studying the complex conditions of the Indian River including: characterizing the watershed and river system, water rights and water use, fisheries resources, sedimentation and flooding, and channel stability. This work is well documented in the *Indian River Watershed Collaborative Management Strategy* by Steve Paustian and Jennifer Hamblen (2018) and includes a number of management objectives to provide a framework to better understand the river system, manage available resources and consider alternatives and enhancement options to provide better ecological function, stream process, and meet water rights and flow needs for the various stakeholders. The current study addresses objectives specific to river geomorphology, diversion and fish passage alternatives.

Sitka Sound Science Center (SSSC) in partnership with U.S. Fish and Wildlife Service (USFWS) have contracted Inter-Fluve, Inc. (Inter-Fluve) to conduct a geomorphic assessment of Indian River in the vicinity of a boulder dam diverting flow to the SSSC fish hatchery, identify alternatives for improved sediment transport and fish passage through the Sheldon Jackson Hatchery diversion reach of Indian River.

This working draft preliminary memorandum summarizes site investigations, survey, field observations, stakeholder concerns, integration of 2018 LiDAR with survey, hydraulic modeling, and sediment transport analyses. Alternatives analysis will be the next phase. Inter-Fluve's principal investigators are Dan Miller, P.E., Engineer and Luke Swan, Geomorphologist; with assistance by Greg Koonce, Fisheries Biologist and Principal Emeritus.

Special thanks go to members of the local expert advisory group who made their time and knowledge available to us. Special thanks also go to Cora Siebert and William Coltharp of SSSC for their coordination and assistance with field work during our week on site.

Existing information

A wealth of existing information was available for Indian River. This information was reviewed and will continue to be consulted as the project progresses. This information will not be reiterated here. A brief summary of primary resources follows.

- As noted above, an excellent summary of the watershed and multifaceted issues is presented in the *Indian River Watershed Collaborative Management Strategy* by Paustian and Hamblen, 2018.
- Hydrologic conditions of Sitka area drainages including Indian River are documented in chapter 3 of the *City and Borough of Sitka Stormwater Management Plan* by TetraTech, 2013.

DRAFT

- Water quality and stream flow data collected at the existing USGS gage is documented in the *Water Quality and Streamflow of the Indian River, Sitka, Alaska, 2001-02*. Scientific Investigation Report 04-5023 by USGS, 2004. Contemporary data is available online.
- *Indian River Intake Screen, Trip Report*. HDR, 2012.
- A number of articles on fisheries, and working group meeting presentations were also very useful.

Site investigations and project kick off meeting

Inter-Fluve conducted a site visit August 5-9, 2019. Work tasks included an introductory stream walk, a kick off meeting with the local expert advisory group, detailed stream walk, survey and review meeting. USGS records indicated that Indian River stream flows dropped from 31 cfs to 23 cfs through the week. Low flows provided ideal conditions to access the stream for data collection and survey.

Project Kick off meeting

Following an introductory stream walk, a project kick off meeting was held with the Indian River local expert advisory group. The purpose of the meeting was to learn from local knowledge of the river system, and to hear their concerns and goals for enhancements. The time and information shared was greatly appreciated. Meeting notes are included in Appendix 1, and summarized here.

National Park Service (NPS). Brinnen Carter has been the Resource Manager at the Sitka National Historic Park for about six years. The Indian River is a major natural resource and a core of the Park. This location has been a draw to humans for thousands of years. An objective is to have an ecologically functioning stream with upstream and downstream passage of salmonids and as natural stream processes as possible. Current erosion and channel incision are concerns. Contributing factors to erosion may include past mining near the river mouth and ADOT&PF work on the Sawmill Creek Road Bridge. Water rights are a concern with a desire to have sufficient flow during low flow periods for ecological function. NPS has funded data collection along Indian River and welcomes continuing conversations with other stakeholders.

US Forest Service (USFS): Aaron Prussian, Marty Becker and Steve Paustian (retired) know the watershed well. Neil Stichert attended by phone. Observations of sources of sediment entering Indian River include bank erosion about one-quarter mile upstream of the City intake, some landslide activity from Mount Verstovia, various debris torrents evident in LiDAR data and a high density of source areas hidden below tree canopy bleeding sediment into the system throughout the watershed. Sediment wedges have been observed migrating downstream.

Sitka Tribe of Alaska (STA): Jeff Feldpausch indicated goals include river ecological health, sediment transport and water rights. Concerns include upstream development with possible increases of nutrient loading, increased temperatures and potential of flooding into infrastructure.

Sitka Sound Science Center (SSSC): Lisa Busch, Ron Heintz, William Coltharp, Blake Conaway and Cora Siebert are with the SSSC. In addition, Angela Bowers of UAS was a former aquaculture director at SSSC.

DRAFT

Blake has been the SSSC facilities manager for three years. His objective is to maintain flow to the facility. If maintenance is a strategy for dealing with flooding and channel instabilities he would like to have some guidance provided on when and how to manage deposited sediments in the dam impoundment.

Angela Bowers was the former SSSC aquaculture director during the 2015 flood that moved boulders from the dam and flushed sediments. 2007 was the last dredging prior to the 2015 event.

Lisa Busch is the executive director of SSSC and mentioned that objectives include being a good neighbor, maintaining a safe environment and providing natural process.

William Coltharp is the current aquaculture director, has been in Sitka since 1980 and was also the aquaculture director in the '90s. For operation of the hatchery, year round flow is necessary for attracting adults, incubating and hatching eggs and raising and imprinting juveniles. A DNR study of the hatchery water supply measured about 20 cfs flow. Flow records are available. The original log dam diversion for hydropower still in place in the1980s seemed to pass sediments more readily than the current dam. Three repairs were made to the dam and diversions in the '90s. An infiltration gallery was installed in '97 to draw water during turbid flow events but was out of service six months later when a major valve broke. Sediment is dredged on an as needed basis every several years. Sediment is not passed downstream of the dam to continue down Indian River due to permitting restrictions by the Corps of Engineers. Flows in Indian River seem to be more flashy now than in the past.

Sitka Hydrologic Sciences: Steve Paustian is a retired USFS hydrologist with extensive knowledge of Indian River extending back to the 1980s. He helped the USGS with gage installations for temperature and water quality data collection. Two USGS gages are located on Indian River with various periods of record. The current gage is located upstream of the Sawmill Creek Road Bridge. Steve observed that there seem to be more high and low flow extremes and that Indian River is very dynamic and flashy with no apparent stable condition. Goals include improve ecologic function, maintain fisheries and the hatchery, improve function of the stream, and identify conditions that would trigger maintenance.

Southeast Alaska Land Trust: SE Trust is the landowner on which the dam is located. Krista Garrett teleconferenced into the meeting and expressed support of the study and continued conversations with stakeholders.

USFWS: Franklin Dekker is USFWS's project manager and expressed USFWS' support of continuing the working group and local expert advisory group's efforts to better understand the Indian River and identify solutions.

City and Borough of Sitka: The study team met with Shilo Williams separately to describe the project purpose and learn about CBS's uses and needs of the Indian River. The City's primary water source is from Sawmill Creek. An emergency water source is maintained via an existing infiltration gallery on Indian River at the end of Indian River Road. The infiltration gallery pipes are currently exposed in the

bed of Indian River. A boulder dam is positioned to back water and submerge the pipes when withdrawals are necessary. Chlorine is added at the upstream end of the distribution system – however a boil water notice is issued due to insufficient residence time for chlorine to effectively disinfect the supply water while it is in the existing distribution system. The existing pipe system is adequate for the City's emergency water but has no excess capacity for delivery of water for other uses. A ground water resource study was conducted but was unable to locate adequate supply to serve as the municipal water supply.

In summary, the primary goals relevant to this study include:

- Maintain flow uses including diversion, City backup municipal supply, instream flow conditions. (Note, management of water use and water rights is outside the scope of this study.)
- Enhance or improve ecological function.
- Enhance fish habitat and reduce low flow hypoxic conditions
- Improve upstream and downstream fish passage.
- Reduce channel instability including sediment deposition and lateral stream migration.
- Improve stream process by reducing sediment deposition issues.
- Reduce or minimize flooding and erosion
- Minimize instream maintenance disturbance

Field work:

Stream walk

Following the project kick off meeting, a detailed stream walk was conducted from the Sawmill Creek Road Bridge to approximately 1300 feet upstream of the City intake. Indian River through Sitka National Historic Park was also viewed, but no data was collected within the park. River geomorphic conditions were noted and photographed. The survey data collection strategy and coverage was refined during the stream walk.

Pebble counts

Gradation of stream bed substrate was characterized by pebble counts collected from gravel bars and riffles at six locations as shown on Figure 1. Pebble counts are used to define gradation of the surficial stream substrate. For this study sediment was selected from areas along gravel bars and riffles that contain bed load material. One hundred particles are blindly selected on a grid within the defined area and the particle sizes enumerated into size class bins using a gravelometer. The resulting particle count by size class provides a grain size distribution that is useful in the sediment transport analysis to estimate mobility of stream bed substrate and estimate sediment transport rates in the geomorphic analyses. Pebble count data are summarized in Appendix 2.

Survey

Topographic and bathymetric survey data were collected using Inter-Fluve's total station. Survey was collected based on project relative vertical datum and horizontal datum to be later translated to

DRAFT

established datum based on surveyed existing benchmarks. Survey coverage from the Sawmill Creek Road Bridge to upstream of the City Intake included detailed profile and cross sections at select locations to characterize geomorphic conditions of a particular stream reach or feature. Detailed topography and bathymetry were collected at the dam and impoundment. An upstream subreach was identified to represent supply conditions with cross sections and profile survey data collected.

Low flows allowed wading survey of the majority of the study reach. SSSC provided an inflatable boat to assist with survey through pools too deep to wade. Cora Siebert and William Coltharp (SSSC) assisted with survey and were bear guard for the duration of our field work.

Existing benchmarks included an ADOT&PF brass cap set in an air relief valve station concrete pad southeast of the Sawmill Creek Road Bridge and a US Bureau of Reclamation brass cap located in bedrock at the USGS gage. These monuments were included in the survey. Elevation data were obtained for these benchmarks and used to adjust the Inter-Fluve relative elevations. Unfortunately, horizontal coordinates with datum information was not available for these monuments. Thus, the Inter-Fluve survey was manually adjusted to approximate horizontal location matching to the dam fish ladder and approximate features near the City intake that were evident in the LiDAR. NPS ground based LiDAR was collected along Indian River through the park and GPS survey included four Inter-Fluve control points. Horizontal correlation will be refined pending NPS LiDAR survey and GPS surveyed coordinates of control points in common with both surveys.

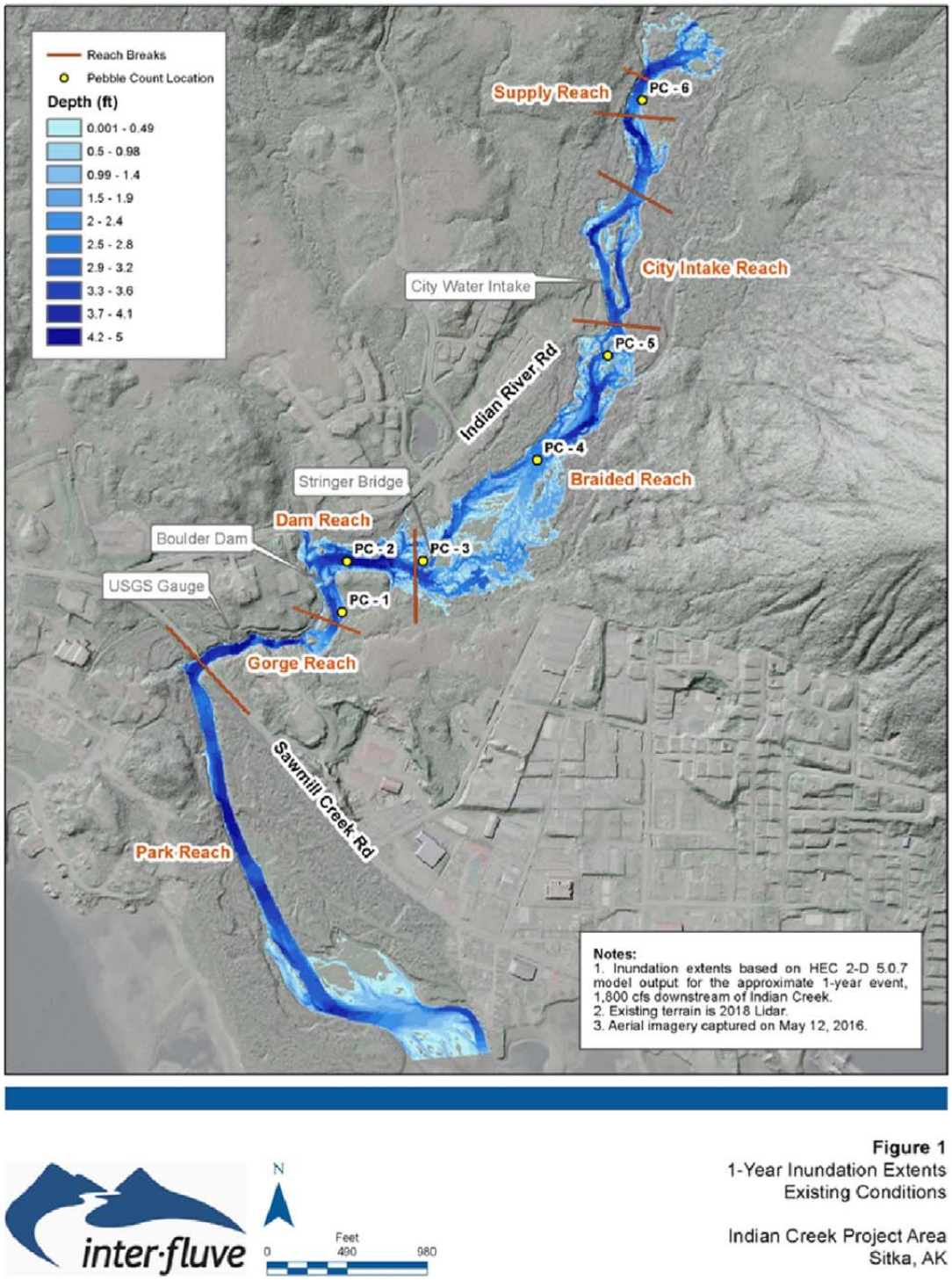
Project reaches

A number of reaches with similar characteristics were identified within the project study area. These are shown on Figure 1 and described as follows:

- **Park Reach:** the Park Reach extends from tide water up to the Sawmill Creek Road Bridge and passes through the Sitka National Historic Park. This reach is single thread, plane bed, incised and lacking in large woody material usable as habitats. A footbridge exists midway along this reach. Indian River enters this reach below the Sawmill Creek Road Bridge takes a sharp turn to the left causing flow to impact the river right bank, rebound and impinge on the river left bank immediately downstream. The left bank exhibits active erosion.
- **Gorge Reach:** the Gorge Reach extends from the Sawmill Creek Road Bridge upstream through a bed rock gorge to approximately 250 feet downstream from the boulder diversion dam. At the downstream end of this reach is a boulder riffle, the crest of which is the hydraulic control to the USGS gage located in the pool immediately upstream. The remainder of this reach is steep gradient, bedrock bounded confined channel that transports sediment with only limited occurrences of deposited pocket gravels.
- **Dam Reach:** the Dam Reach includes the gravel bar immediately downstream of the boulder diversion dam, the dam and diversion, the impoundment and extends upstream to about 750 feet upstream of the dam. The upstream limit is at the downstream end of the braided reach and downstream of the abandoned log stringer bridge.

DRAFT

Figure 1 – reaches and PC locations.



- **Braided Reach:** the Braided Reach extends for approximately 2,200 feet upstream from the Dam Reach to about 400 feet downstream from the City intake. A number of subreaches exist within the Braided Reach including:
    - Braided subreach with log stringer bridge – occurs along approximately 1000 feet of the downstream end of the Braided Reach. The main stem has filled with sediment resulting in flows having avulsed creating left and right side channels around the main stem. The log stringer bridge is located near the downstream end of the river right side channel which was conveying the majority of the flow during fieldwork. This side channel has not yet filled with sediment. Limited sediment deposition was noted upstream of the log bridge suggesting that the bridge by itself likely is either not or only a minor contributor to braiding of this reach. The left side channel system is an low gradient, low relieve flood plain area with multiple flow threads and is likely still a young feature that has not established a dominant channel.
    - Single thread – approximately 600 feet from mid-reach and upstream is predominantly a single thread channel with wide exposed gravel bars.
    - Braided subreach with large woody material dominated side channels – the remaining upstream end of the Braided Reach is multi-threaded channels with large woody material dominating the main stem diverting flow towards river right.
- **City Intake Reach**: the City Intake Reach extends from approximately 400 feet downstream of the intake to approximately 600 feet upstream of the intake. This reach includes a primary main stem channel and a secondary side channel on river left that has flow and sediment inflow limited by large woody material near its inlet. The main stem is incised and has left the infiltration gallery pipes exposed.
- **Supply Reach:** the Supply Reach was identified to be comparatively stable with little evidence of excessive deposition or erosion. This reach was selected as having geomorphic characteristics that most likely pass sediment supplied from upstream. The apparent stability of this reach to pass supplied sediments provides the best available insight into the flow, energy and sediment dynamic of sediment likely supplied to the study reach.

LiDAR and site survey:

2018 LiDAR topography of the study area was provided. The Inter-Fluve survey was based on relative datum and was translated as described above and overlain onto the LiDAR. For the scope of this study only the dam impoundment bathymetric surface was spliced into the LiDAR terrain included in the HEC-RAS 2D modeling and CADD drawings. Other survey data including profile and cross sections will provide input to the hydraulic modeling and geomorphic analysis.

Hydrology:

Two USGS gages are located on Indian River. Gage 15087690 located approximately 4600 feet upstream of the City intake, records flows from a 10.3 square mile drainage area and has a period of record from August 28, 1980 to March 31, 2006. The currently active gage 15087695 located approximately 220 feet

upstream of the Sawmill Creek Road Bridge, records flows from a 12.1 square mile drainage area and has a period of record from February 9, 2016 to the present. Steve Paustian observed that the gage near the Sawmill Creek Road Bridge lacks flow measurements during high flow events necessary to calibrate the gage stage recordings to flow values (personal communication, August 6, 2019).

For the initial HEC-RAS analysis, peak Indian River flows for a number of flow events were estimated using USGS regional regression equations (Curran et al, 2003).

Flow event	2-year	5-year	10-year	25-year	50-year	100-year
Peak discharge (cfs)	2446	3334	3923	4644	5178	5679

More detailed hydrology analyses will be included in the ongoing sediment transport analysis including flow frequency data. Prior hydrology analyses will also be considered.

Hydraulics:

A two-dimensional (2D) hydraulic model of the project site was developed using the U.S. Army Corps of Engineers HEC-RAS 5.0.7 software, which can compute hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. The 2D model was used to assess channel/floodplain interactions for existing conditions under a range of flow scenarios.

Results of the existing conditions 2D model results are shown in Appendix 3 with a subset of model output for flow depth, velocities and profiles along the Indian River.

Model Domain and Computation Parameters

The modeled area extends from the mouth of Indian River at Sitka Sound and extends upstream 10,000 feet along the river thalweg alignment to upstream of the City intake structure. The modeled area was set to fully encompass model estimates of inundation width. The model terrain is based on the 2018 LiDAR data and includes the dam impoundment bathymetry collected by Inter-Fluve and SSSC staff on August 7th, 2019. The computational domain consists of 14485 grid cells with a maximum size of 20 feet by 20 feet.

Break lines were added along stream banks, channel thalweg and topographic breaks, to provide increased resolution and to align cell faces along high ground and appropriately represent the underlying terrain and associated roughness characteristics. The boulder dam crest was modeled as a weir using the model option for 2D Area Connection.

Boundary Conditions

The upstream boundary condition was a synthetic inflow hydrograph that includes flows ranging from low flow and increasing up through the return period flows summarized above. The inflow hydrograph was defined as a “stepped” hydrograph with increasing discharge values. Flow step duration was maintained long enough to allow flows to fully pass through the modeled area and reach a steady-state at that flow step, before rising to the next step.

The downstream boundary condition was set to an assumed tidal elevation of 0.0-ft elevation.

Roughness

A spatially varying roughness layer was developed by digitizing various land cover regions based on aerial imagery, ground photos, and topography data in ArcGIS Software. These regions were assigned a corresponding roughness (Manning's n) coefficient based on field observations and professional judgment summarized in the table below. Manning's n values ranged from 0.035 to 0.08 within the computational domain.

Summary of hydraulic roughness values assigned to land cover classifications

Description	Manning's n
Stream	0.038
Open water	0.035
Pond	0.035
Pond/grass	0.045
Road	0.05
Riparian	0.08
Shrub	0.08
Short forest	0.08
Tall forest	0.075
Mixed	0.06

Results: existing conditions

Results of the existing conditions 2D model results are shown in Appendix 3 with a subset of model output for flow depth and velocities.

Geomorphology

The geomorphology of the study site was investigated using an analysis framework created to address those project goals that directly relate to physical processes (acknowledging that biogical processes are closely related to physical processes):

- Reduce channel instability including sediment deposition and lateral stream migration;

- Improve stream process by reducing sediment deposition issues;
- Reduce or minimize flooding and erosion; and,
- Minimize instream maintenance disturbance.

Given the focus of each of these objectives on sediment dynamics, the analysis consists of a sediment transport model housed within a framework that combines qualitative and quantitative analyses to reduce the uncertainties inherent to sediment transport modeling.

Qualitative analyses included in the framework consist of historical aerial interpretation, anecdotal observations from project stakeholders, field observations, and review of spatial data (e.g., aerial photography, LiDAR, hydraulic model outputs). Quantitative analyses include magnitude frequency analysis, spatially-distributed shear stress calculations, and sediment transport modeling. Both categories of data (qualitative and quantitative) were analyzed with reference to different time scales, differentiating between long-term trends or 'average' behavior and discrete events. Results of each analysis were then viewed comparatively, creating a multiple-lines-of-evidence geomorphic assessment framework within which alternatives can be evaluated relative to the project objectives (Figure 1).

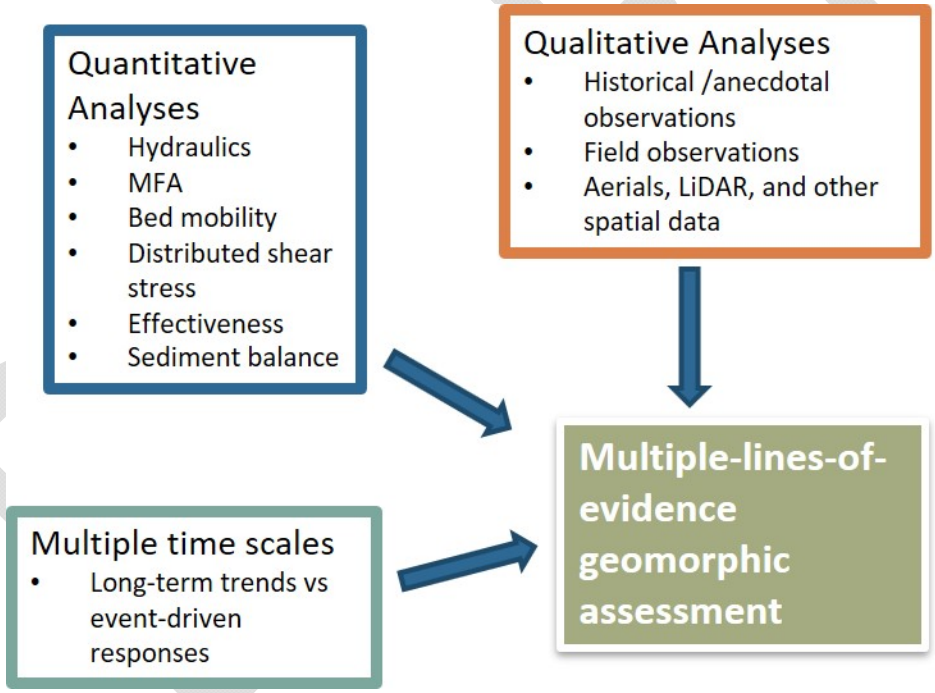


Figure 1. Schematic of geomorphic assessment framework used to examine geomorphic trends and characteristics at the site.

The following section details the methods and results of the geomorphic analysis, first discussing the qualitative components of the assessment and then the quantitative. Finally, a discussion section relates assessment results to the project objectives and implications for alternative development.

Qualitative Geomorphic Analyses

Qualitative geomorphic analyses included review of historical aerial photographs, literature provided by SSSC and project stakeholders, anecdotal observations from project stakeholders communicated during

a project stakeholder meeting that occurred on August 6, 2019, field observations made during the week of August 5, 2019, and review of existing spatial data (e.g., aerial photography, LiDAR, hydraulic model outputs).

Historical Aerials

A review of provided historical aerial photographs provides evidence of past human alterations to the area. Historical aerial photographs were reviewed from 1929, 1948, and 1979, with attention paid to those visible actions that may have impacted sediment dynamics in the Indian River. Human impacts to the area are visible in the 1929 aerial (Figure 2), but impacts to the channel are directly evident. Some level of alteration is presumed because of the presence of two bridges, and linear features in the nearshore area. By 1948, gravel mining in the estuary and nearshore environments was visible and extensive; braiding and exposed gravel bars are also visible along the main channel for the extent captured in the aerial. Increased gravel mining is visible in the 1958 aerial, as is manipulation of the Indian River floodplain and active channel. Extensive gravel bars are visible, and the river is being encroached upon by the Indian River Road and development along it. Between 1959 and 1979 an obvious shift in the channel position in the estuary has taken place, likely a result of gravel mining and expansion of the trailer park (also discussed in Stark et al., 2012). It is estimated that 3 million cubic yards of gravel was removed from the Indian River, and these actions, considered in concert with other influences (e.g., logging, wood jam removal, bank armoring) discussed in Stark et al., 2012, provide evidence of mechanisms that likely explain the incision observed in the park reach[1,2].

Field Reconnaissance

Field reconnaissance and survey of the site was performed during the week of August 5, 2019. In addition to the channel total station survey, observations regarding the character of the channel and riparian area, relative to sediment dynamics, were recorded. Pebble counts were taken at select locations to characterize the caliber of the bed sediments, and results are shown in Figure 3. Key observations include regarding sediment composition, transitions in channel confinement ratios and slopes, and evidence of anthropogenic modifications that may be currently influencing the geomorphology. Key field observations include:

- In depositional areas of the project reach, sediment is sub-angular and poorly sorted, and contains a high proportion of fines. It appears that the channel is being inundated by sediment during higher magnitude floods which is causing the active channel to avulse and/or migrate across the floodplain (Figure 4B). The depositional, or 'braided', reach is acting like an alluvial fan – frequently shifting position across the valley in response to a change in gradient and substantial sediment load. Active bank erosion is present in some locations, but largely slowed by vegetation. Considered together, these observations suggest that substantial sediment is being supplied to channel via mass wasting (e.g., landslides) of the valley slopes. Several recent

[1] Stark et al., 2012 provides a more thorough review and precise timeline of human alterations of the Indian River and adjacent riparian area.

[2] Isostatic rebound rates, while quite large in some areas of SE AK, do not appear to be able to explain, but may have contributed to the observed channel incision. In the Sitka region, total land emergence is less than 1 meter (Motyka et al., 2007), and uplift rates are near 0 mm/yr (Larsen et al., 2005).

landslides are visible on current imagery and project stakeholders have confirmed the presence of mass wasting in the upper watershed;

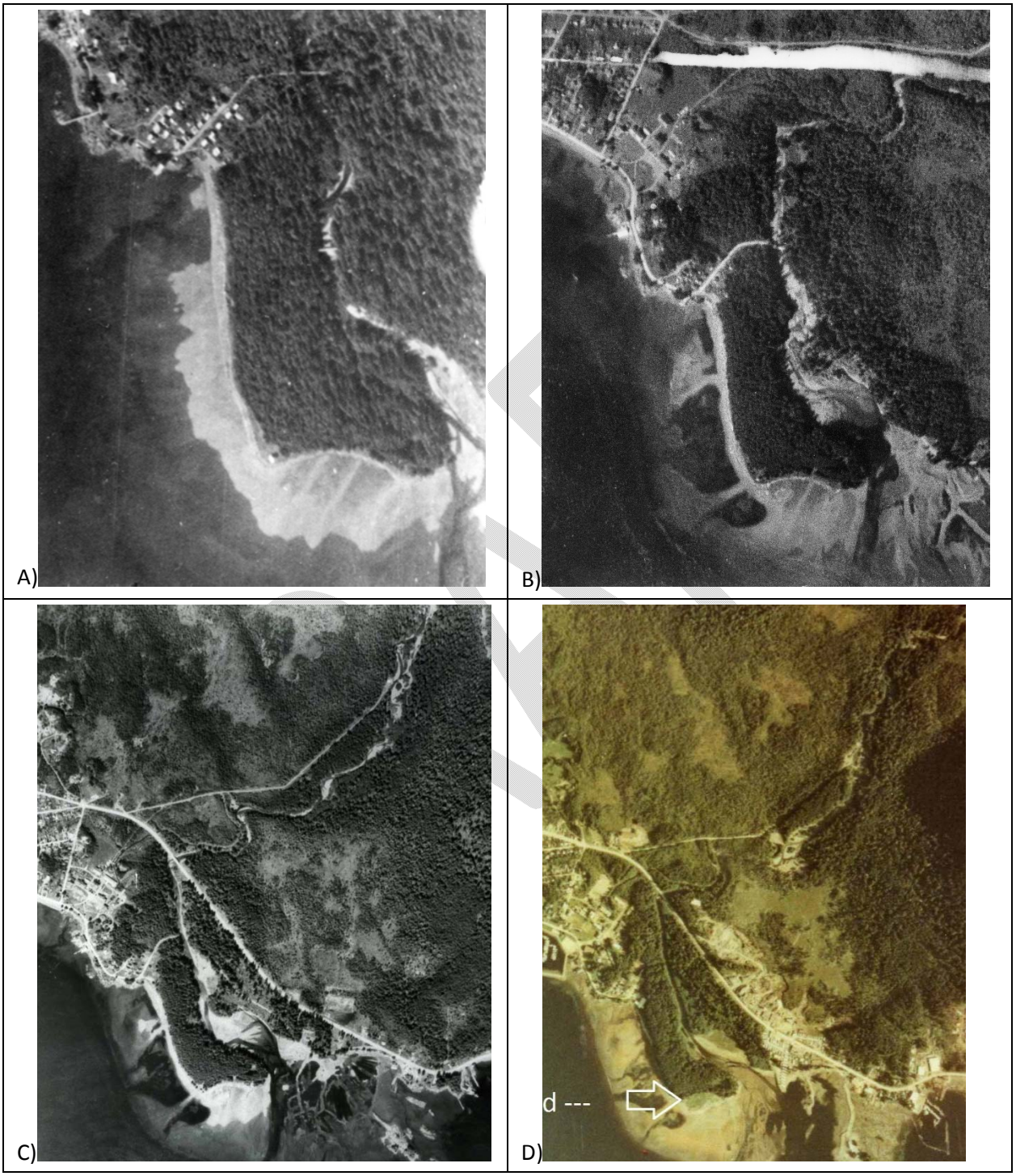


Figure 2. Historical aerial photographs from A) 1929, B) 1948, C) 1958, and D) 1979. Note that annotation on photo in D) is pre-existing and not relevant to this discussion.

- Moving downstream through the project reach, the valley constricts and the channel enters a narrow and steep, bedrock canyon (Figure 4C). The dam is located at this transition in valley confinement; thus, the hydraulic effects of the dam appear to be localized, extending upstream for a short distance. This steeper, high-confined section quickly gives way to a more gently sloped channel that remains confined and has a simple, homogenous character. This transition in valley configuration, moving from unconfined and lower gradient to high confinement and high gradient exhibits a strong control on sediment dynamics. Sediments are impounded in the upstream area, with those that make it to the canyon reach being efficiently transported to the estuary.
- Development along Indian River Road appears to be at risk to flooding and/or channel avulsion as a result of the amount of sediment aggrading in the 'braided' reach. Removal of the largest trees and log jams from the channel and riparian area as a result of past land use practices may be contributing to the sediment aggradation problem by increasing the efficiency at which sediment is transported to the lower energy, 'braided', reach adjacent to the road. Alternatively, the aggradation may be a result of increased sediment supply as a result of a recently increased rate of mass wasting (as communicated by project stakeholders) in the watershed.

DRAFT

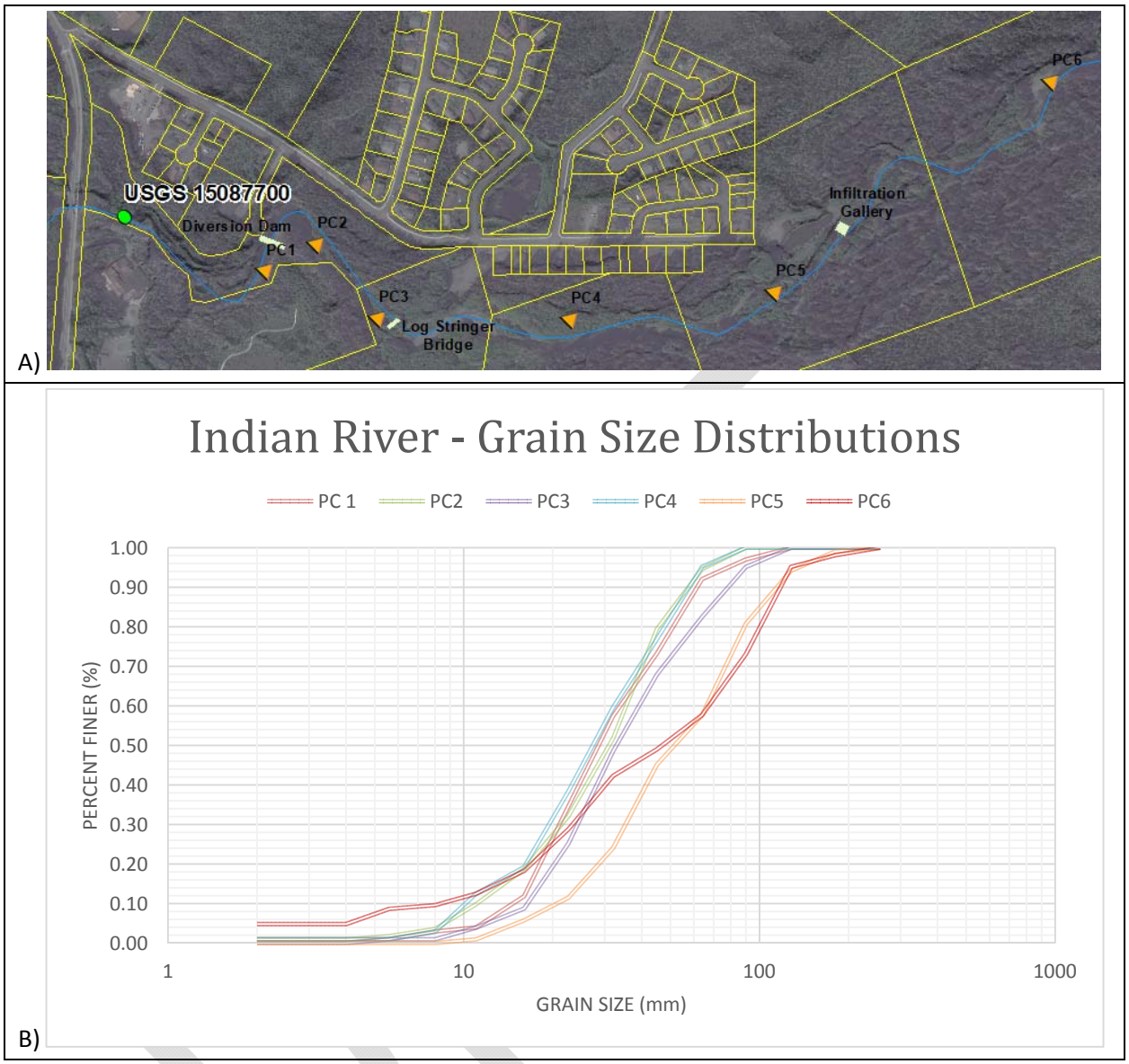


Figure 3. Pebble count locations (A) and grain size distributions (B) for sampled bed sediments. Pebble count locations are shown with orange triangles. Flow direction is right to left. Median grain size diameters range from 1.1 inches to 2.1 inches.

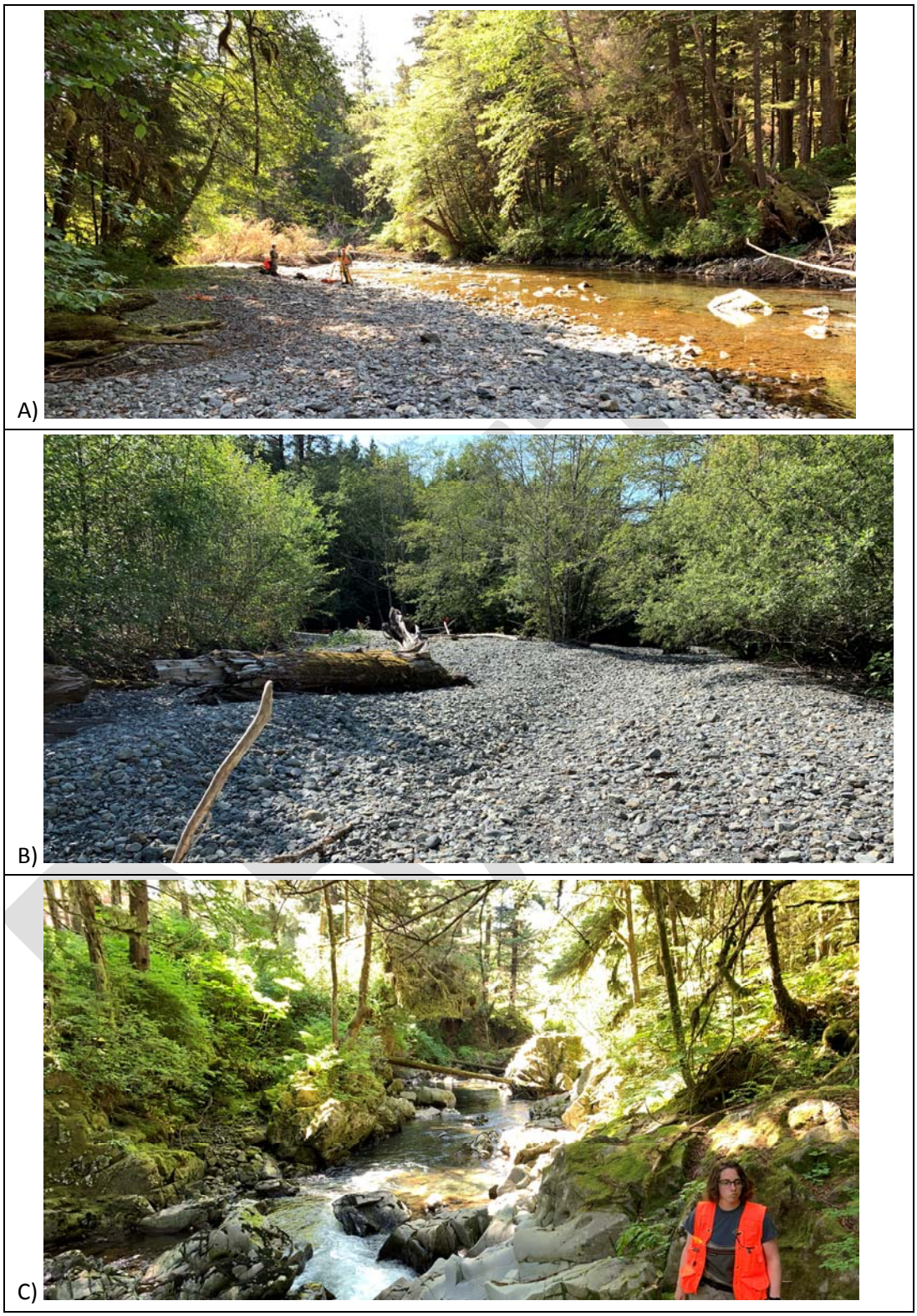


Figure 4. Representative photos of the transition in channel confinement through the project site. A) shows the upstream supply reach that appears to be adjusted to the water and sediment regimes. B) The 'braided' reach. Note the piles of sediment at the vegetated margin indicted that sediment is inundating the riparian vegetation. C) The confined bedrock reach located downstream of the 'braided' reach. The bedrock exerts a strong influence on sediment dynamics.

Spatial Data Review

LiDAR data, collected in 2018, was investigated to understand reach-scale changes in channel confinement, slope, and channel pattern. In light of the field observations discussed above and examination of the LiDAR, sub-reaches were delineated on the basis of the above factors and to facilitate the sediment balance modeling discussed below (Figure 5). (Note that these are slightly different from those presented above in anticipation of the sensitivity of the sediment modeling discussed below.) Sub-reach 3 was further divided to isolate the impacts of the dam on the sediment balance. Sub-reach 1 begins at a reduction in slope in the bedrock section and extends down to the estuary. Sub-reach 2 is the bedrock reach, extending up to the dam. Sub-reach 3 is the 'braided' section of channel. Sub-reach 4 captures a change in confinement, and sub-reach 5 represents a change in slope and channel pattern.

To further understand the changes in confinement and slope through the project reach, confinement ratio (calculated as the ration of valley width to channel width) was plotted with slope (Figure 6). Sub-reaches 4 and 5 have similar confinement ratios (~9) and slight differences in slope. Sub-reach 3 has a large increase in confinement ratio in 3b (~15, moving down the channel), which rapidly decreases in 3a. Slope in 3a is quite low and controlled by the dam (~0.004 ft/ft) before spiking in Sub-reach 2 at ~0.028 ft/ft. Slope decreases in Sub-reach 1, while the confinement ratio remains fairly low.

DRAFT

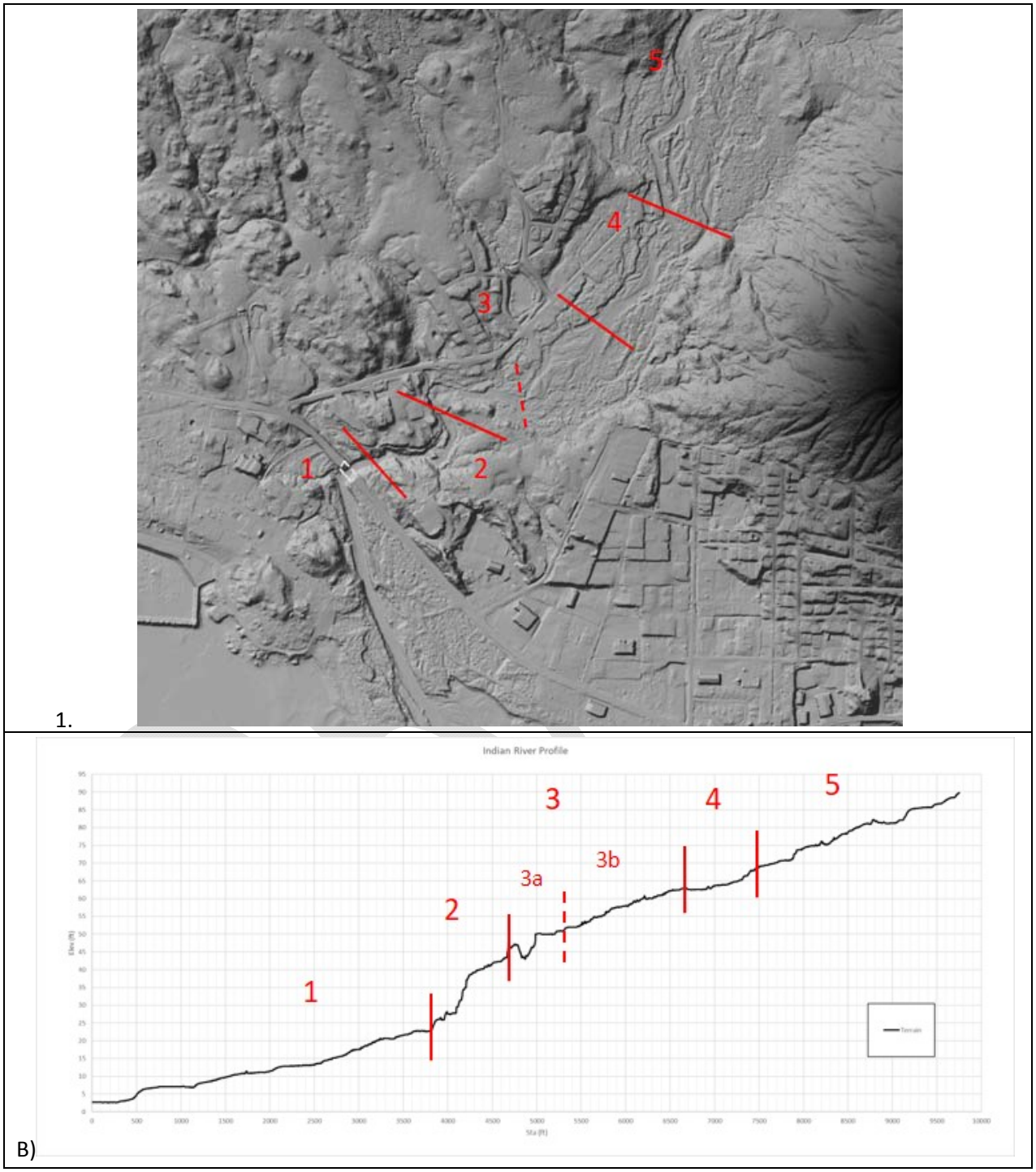


Figure 5. Sub-reach delineations in A) planview and B) profile view.

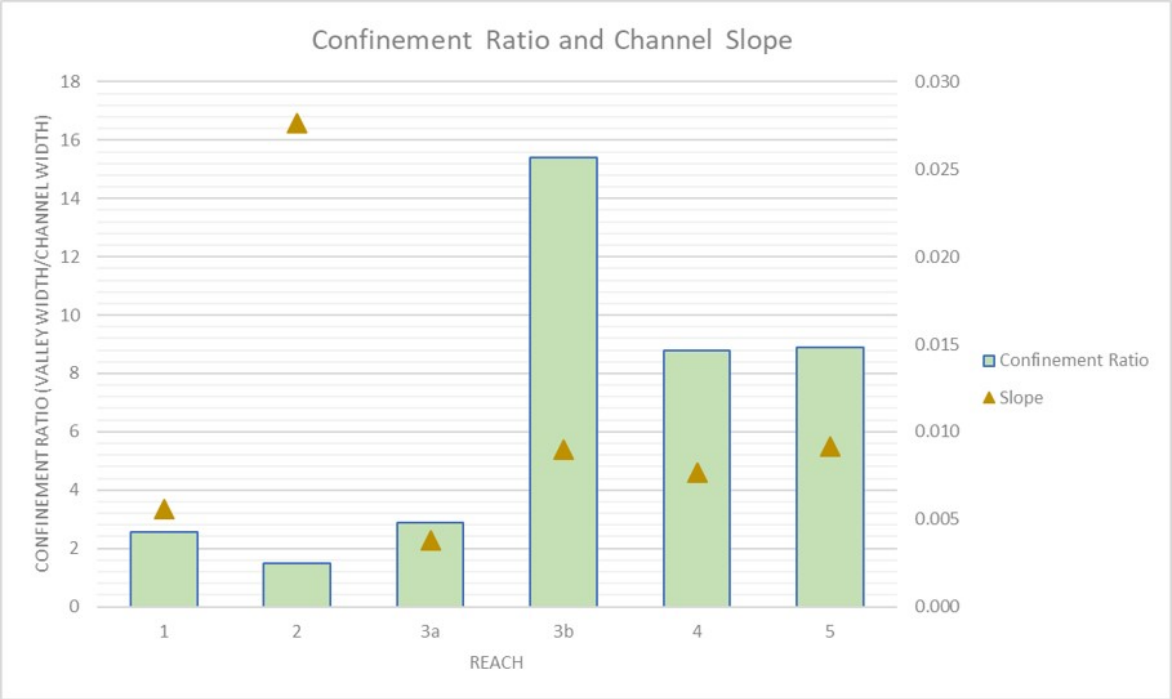


Figure 6. Confinement ratios and slopes from the sub-reaches identified in Figure 5.

Summary and Key Points from Qualitative Analyses

The following summary and key points from the qualitative analyses were then used to provide the context within which the sediment transport calculations (discussed below) were performed and interpreted. Key points include:

1. There appears to be more sediment being delivered to and stored in the 'braided' area than the channel has capacity to process. An increase in sediment supply may be responsible, and anthropogenic modifications (e.g., encroachment, logging, simplification) may be exacerbating the response. The degree to which each of these are factors is unknown.
2. The dam is impounding a substantial portion of the sediment being delivered to it, but so is the 'braided' reach above that is not likely hydraulically influenced by the dam. At the reach scale, this is likely a result of a reduction in channel slope and an increase in confinement ratio, relative to the reach above it.
3. The bedrock is exerting a strong control over channel slope and confinement which has the effects of impounding sediment upstream and efficiently transporting sediment downstream.
4. Anthropogenic modifications, including a large gravel mining operation in the nearshore area, may explain the observed incision and erosion in the park reach (i.e., Sub-reach 1).

Quantitative Geomorphic Analyses

The Quantitative geomorphic analysis was focused on understanding the balance in sediment transport along between the project sub-reaches on long-term and event-based time scales. In order to understand long-term trends, a sediment balance model was created focusing on comparing the time-integrated sediment transport capacity, or effectiveness, between the sub-reaches. To investigate the

response to individual floods, spatially-distributed shear stress calculations from the 2D hydraulic model were used to examine bed mobility and sediment continuity.

Sediment Balance Modeling

As a result of the uncertainty in sediment transport calculations, the methodology developed in Soar and Thorne, 2001 was used to develop the sediment transport model. To remove the errors in the transport calculations, Soar and Thorne (2001) recommended comparing the results in a relative manner by differencing successive, reach-scale sediment yield metrics. This creates a sediment *balance* that, when used with other lines of evidence, can be used to examine the geomorphic trajectory of a reach of stream. This approach was employed for this project and the sediment balance model was developed using the grain size data and sub-reach delineations described above, following guidance in Bledsoe et al., 2016 which developed specific application guidance for the concepts in Soar and Thorne, 2001. Given the reach-scale nature of the project and accompanying 2D hydraulic model, all calculations were performed using the CSR Tool developed in Bledsoe et al., 2016.

To build the sediment balance model, a flow duration curve was built from gauge data, sediment transport capacity was calculated using equations from Parker (1990) and Wilcock & Crowe (2003), and the results were compared between reaches.

Gauge records are inconsistent for the study site, and it was communicated by project stakeholders that the rating curves developed for the gauges did not include higher magnitude flow rates. Two gauges have been in operation at the site at various times. USGS 15087690 was located well upstream of the City infiltration gallery and recorded streamflow from 08/28/1980 to 09/30/1993 and 09/30/1998 to 03/31/2006. USGS 15087700 is located just upstream of the bridge on Sawmill Creek Road and recorded data from 09/30/1998 to 09/29/2003 and 02/10/2016 to the present. Data from both gauges were combined into a single flow record by basin-area scaling USGS 15087690 (10.1 square mile watershed area) to USGS 15087700 (12 square mile watershed area). Figure 7 shows the resulting flow duration curve which plots discharge per square mile against the percent of time the flow is exceeded.

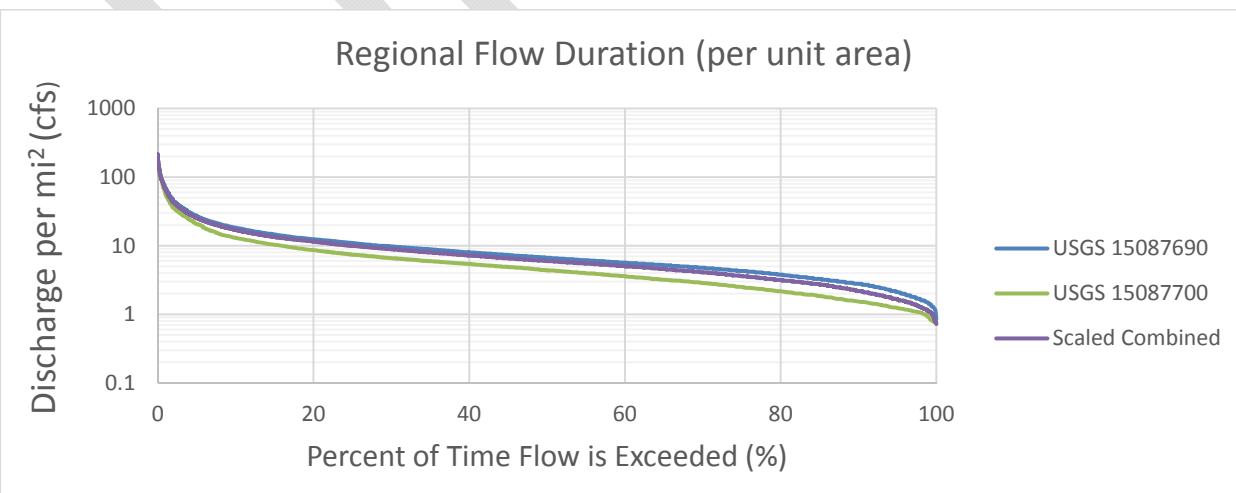


Figure 7. Flow duration curves for USGS 15087690, USGS 15087700, and the basin-area scaled and combined data set.

The flow duration curve is then sampled and used to develop a probability distribution, binning the flows into 25 bins, after Biedenharn et al., 2000 (Figure 8).

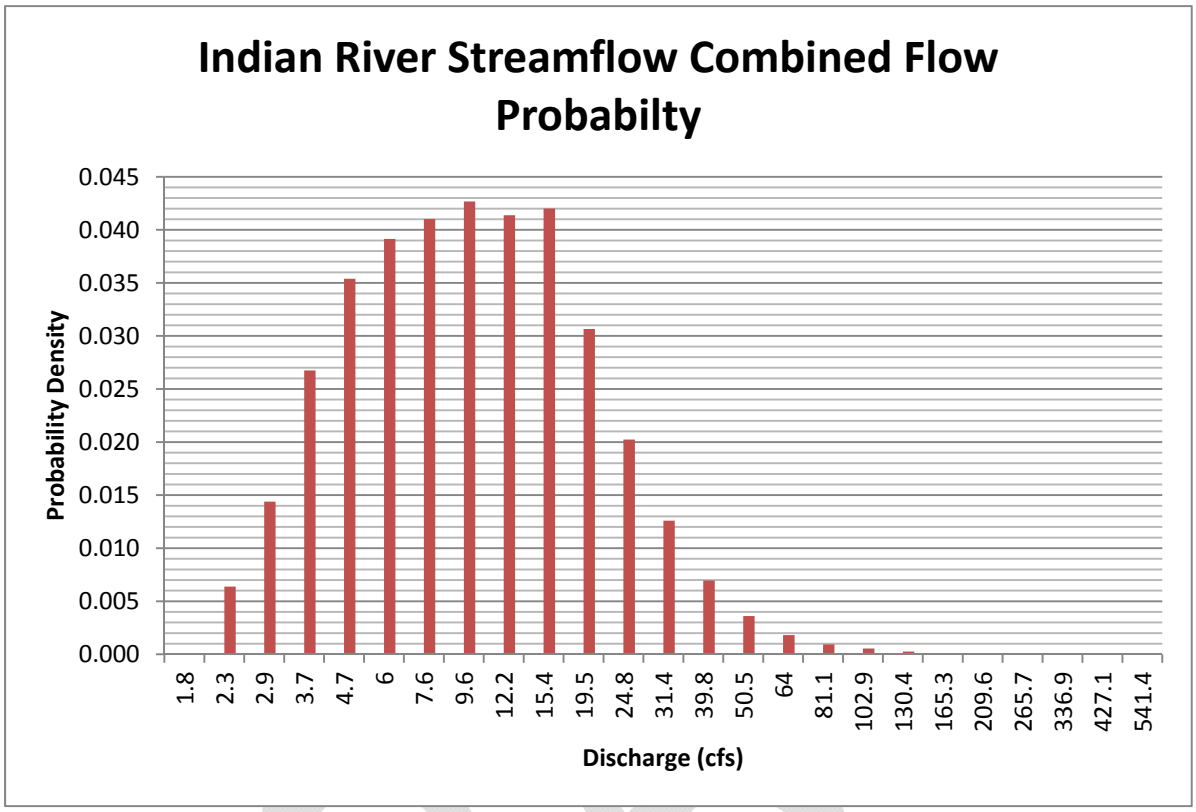


Figure 8. Indian River flow probability distribution developed from the combined flow duration curve in Figure 7.

At-a-station hydraulic properties for flow rates characterizing each of the flow bins defined by the probability distribution above were then calculated using Manning's equation. Channel geometry of a representative cross section for each reach was developed using the field survey and LiDAR data. The calculations are applied to a simplified trapezoidal channel, so flow areas for the larger magnitude flow rates were compared with 2D hydraulic model output. All calculations were performed using the CSR Tool developed in Bledsoe et al., 2016 which uses the Limerinos equation for grain roughness. Bank and overbank roughness values were the same as those used for the 2D model.

The resulting hydraulic properties developed for flow rates representing each bin were then used to calculate sediment transport capacity rates for each bin (Figure 9A). Two established bedload transport equations were used: 1) Parker 1990, and 2) Wilcock & Crowe 2003. Both equations are appropriate for gravel bed streams; the primary differences between the two are in how the sand fraction is handled and the Wilcock & Crowe relationship incorporates a hiding function that accounts for the ability of smaller particles to show reduced mobility as they deposit in the hydraulic shadow of the larger grains. While these calculations attempt to predict transport capacity, the actual amount of sediment transported will depend on the amount of sediment supplied to the reach. Therefore, it is best to consider the capacity calculations as sediment transport *potential*.

Effectiveness, or the time-integrated sediment transport capacity, is then calculated as the sum of the probability of a particular flow bin times the sediment transport capacity of each flow bin (Figure 9B). By incorporating measures of frequency and magnitude, the effectiveness calculation reduces the dominance of larger magnitude flows as they are scaled by their probability of occurrence. In this manner, the results can be considered indicative of long-term trends or 'average' conditions.

Effectiveness curves were developed for each of the sub-reaches and compared with the adjacent upstream reach, developing an effectiveness balance (Figure 10). Results are shown from the Parker (1990) and Wilcock & Crowe (2003) equations for comparison, but the differences between the two are not significant for this analysis. More weight is placed on the relative relationship between sub-reaches and the overall trends than any specific result. As a check on the effectiveness calculations, specific stream power, or stream power per unit width, was also calculated for each reach as the product of the specific gravity of water, discharge, and slope, divided by channel width.

Results, depicted in Figure 10, show decreasing effectiveness moving from the supply reach in Sub-reach 5 to the dam in sub-reach 3a. Effectiveness then spikes in the steep, confined bedrock section (Sub-reach 2). Of note, nearly 98% of the sediment potentially supplied to Sub-reach 4 is deposited in Sub-reach 4 while the remaining is deposited in Sub-reach 3. Over the long term, there is a potential for 4-6 tons/day to be impounded by the dam. These general patterns align well with the field observations.

The balance (Figure 10B) depicts excess or deficit transport capacity between reaches. If the downstream reach has less capacity than the reach supplying sediment to it, it may be likely to store sediment and aggrade. If the downstream reach has more sediment transport capacity than the reach supplying sediment to it, it may be likely to evacuate sediment and degrade. Aggradational tendencies (i.e., a

DRAFT

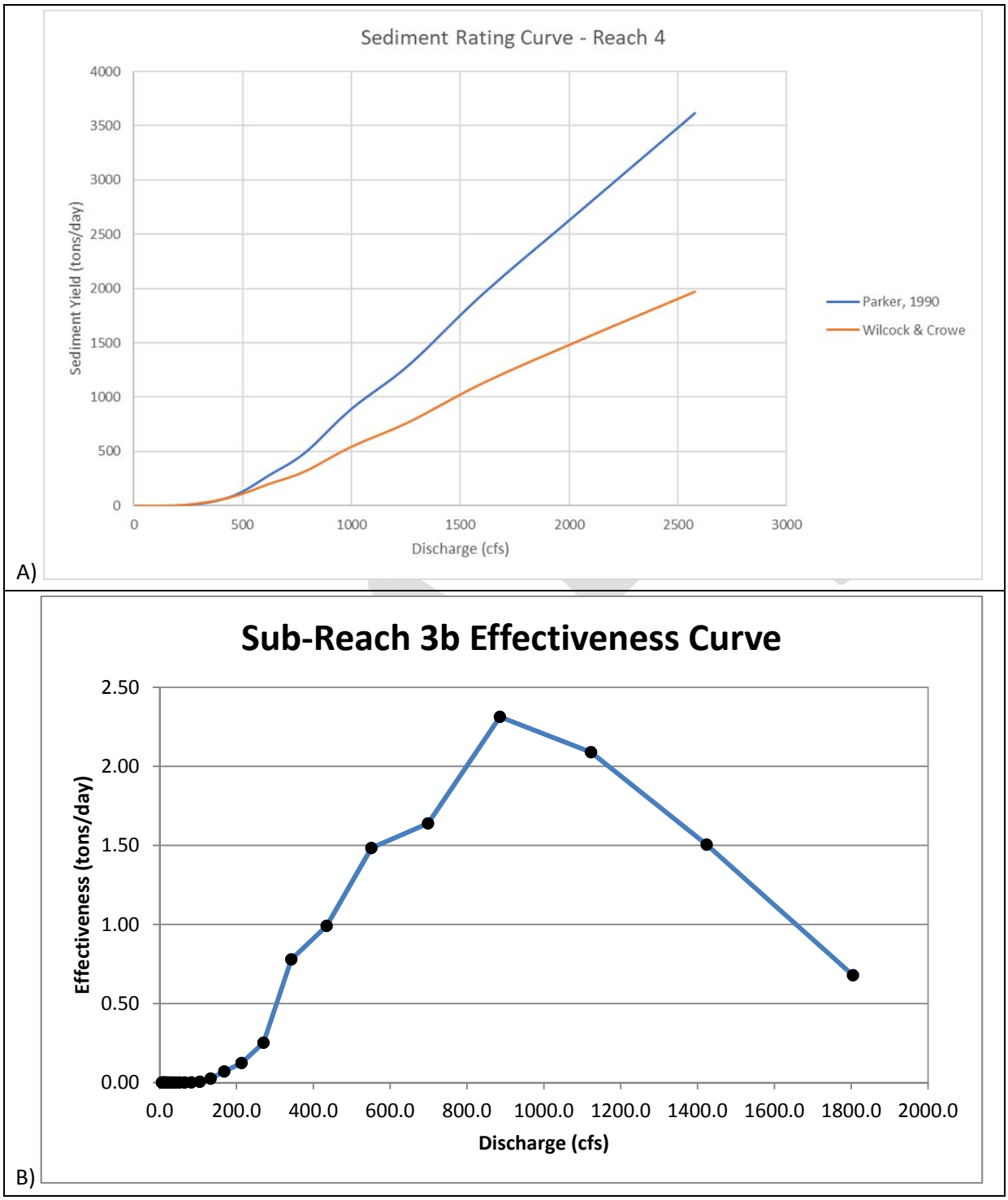


Figure 9. Example sediment rating curve (A) and effectiveness curve (B) calculated for two of the project sub-reaches.

positive balance) are shown in Sub-reaches 1, 3, and 4; a degradational tendency (i.e., a negative balance) is shown in Sub-reach 2. With the exception of Sub-reach 1, these results are expected, matching observations made in the field and from the spatial data. The result for Sub-reach 1 is

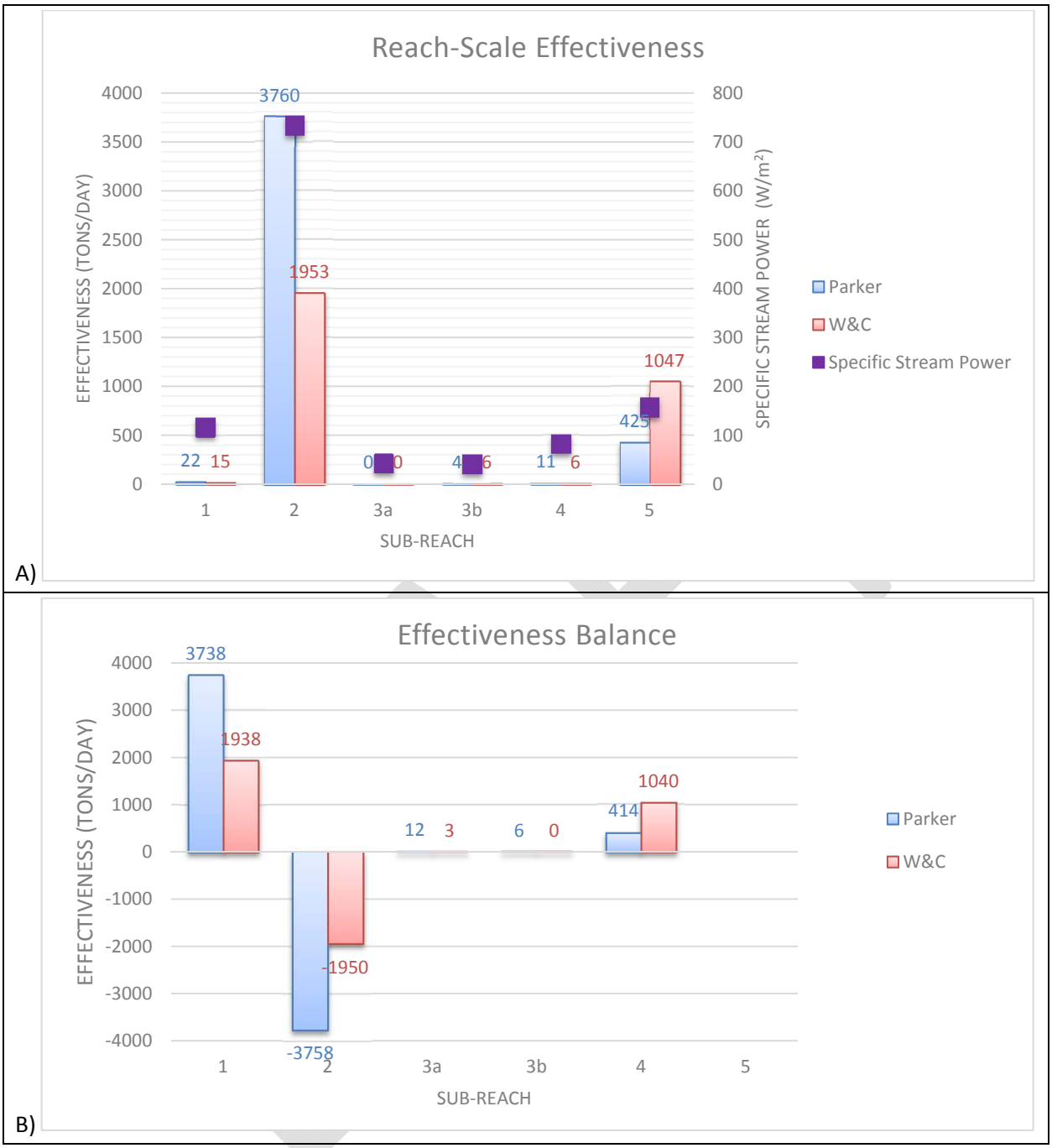


Figure 10. Reach-scale effectiveness comparison showing effectiveness and specific stream power in (A) and the effectiveness balance in (B). Blue bars were calculated with the Parker (1990) equation while orange bars were calculated with the Wilcock & Crowe (2003) equation. Relative differences in specific stream power between reaches are also reflected in the effectiveness results. As expected, a large spike in specific stream power and effectiveness is seen in sub-reach 2, the bedrock reach. Effectiveness is quickly reduced in the downstream direction, moving from sub-reach 5 to sub-reach 4, and then to sub-reach 3. The results indicate that some sediment is transported to the dam impoundment area, but much of it is likely to be stored before reaching the dam. The balance shown in (B) suggests that sub-reaches 3 and 4 will have aggradational tendencies while sub-reach 2, the bedrock reach, will be degradational. These results match observations from the field visit. The balance result in sub-reach 1, suggesting aggradation, is misleading as it is being affected by the lack of sediment supply to sub-reach 2.

potentially misleading because sediment only makes it past the dam at higher magnitude flows. Without a supply, there is no/minimal sediment to store.

The results of the sediment balance model suggest that while the dam is impounding some material, most of the sediment storage occurring over the long term is taking place in the braided reach (Sub-reach 3), triggered by changes in slope and valley confinement. Changes in land use and/or anthropogenic modifications may also be influencing sediment dynamics, but those variables are not explicitly captured in the sediment balance model.

Peak Flow Sediment Analysis

While the above analysis captures long-term trends in sediment dynamics, individual flood flows are not well represented but have the ability to transport much sediment. Spatially distributed shear stress datasets from the 2D hydraulic model were used to examine sediment continuity at select flood flows. From the shear stress outputs, an incipient motion, or the point at which movement of a grain of sediment begins, was used to calculate the largest grain size that the flow would be capable of moving. This is commonly referred to as the critical grain size and was calculated by solving for D_{crit} in the equation:

$$\tau_c = \tau_c^*(1.65\gamma(D_{crit}))$$

where τ_c is critical shear stress (exported from the hydraulic model), τ_c^* is critical dimensionless shear stress (set to 0.035 to match the threshold of movement used in the Parker and Wilcock & Crowe sediment transport equations), γ is the specific weight of water, and D_{crit} is critical grain size.

Outputs from select flow rates are shown in Figure 11 and Figure 12. To ease interpretation, the results are classified based on the Wentworth scale, grouping individual results into common size classes. Figure 11A shows the results from the 1.5-year return period flow and Figure 11B depicts the 5-year return period peak flow. Figure 12A shows the 10-year return period peak flow, and Figure 12B shows the 25-year return period peak flow. As flow rates increase to the 25-year return period peak flow cobble-sized sediment (represented by dark blue) is potentially transported through the 'braided' section (Sub-reach 3) to the dam, and the impoundment may convey large gravels (light blue). The median grain size (D_{50}) sampled from the bar below the dam was approximately 1 inch, or large gravel, but the D_{84} is in the cobble range. Therefore, the results may slightly underpredict the conveyance of the dam impoundment as large gravels and some cobbles are clearly making it over the dam. This result is expected as the model does not capture the dam impoundment filling up during flood events which results in less trapping efficiency and increased transport over the dam. Once sediment makes it over the dam, the results suggest that it is likely transported through the bedrock reach, downstream into the estuary.

Summary and Key Points from Quantitative Analyses

The following summary and key points from the quantitative analyses, when considered within the context of the qualitative analyses discussed above, shed light on the sediment dynamics of the project reach:

1. Patterns of effectiveness generally align well with field and spatial data observations. Effectiveness is relatively low in the braided reach where much deposition was observed. Effectiveness was relatively high in the steep, bedrock section of the project reach. At the reach-scale, the sediment balance model seems to be correctly characterizing geomorphic trends.
2. Over the long term, nearly 98% of the sediment potentially supplied to Sub-reach 4 is deposited in Sub-reach 4 while the remaining is deposited in Sub-reach 3. Over the long term, there is a potential for 4-6 tons/day to be supplied to the dam impoundment. This suggests that changes in slope and valley configuration exert a stronger control over the depositional nature of Sub-reach 3 than the dam.
3. At flood flows, larger sediments (e.g., cobbles) are transported across Sub-reach 3 to the dam impoundment. Depending on the magnitude of the flow, some of this material is conveyed over the dam. This suggests that the dam impoundment fills up with sediment during floods and will require maintenance.
4. Larger magnitude flood events have the competence to move bedload past the dam, but if that happens it is likely to be transported through Sub-reach 1, all the way to the estuary. As a result,

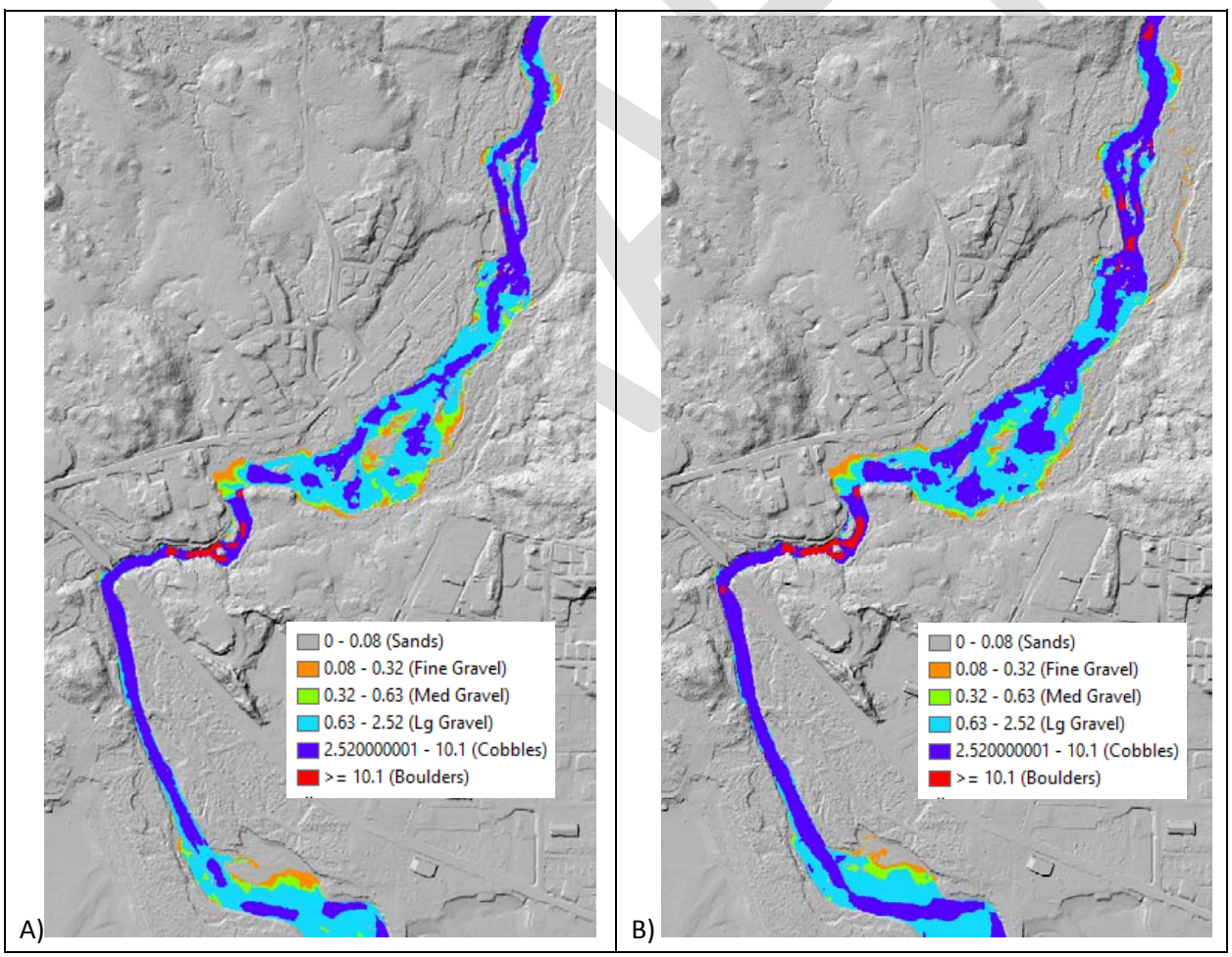


Figure 11. Results of the critical grain size calculation for the A) 1.5-year return period peak flow and B) the 5-year return period peak flow.

Sub-reach 1 is unlikely to store sediment and may continue to erode.

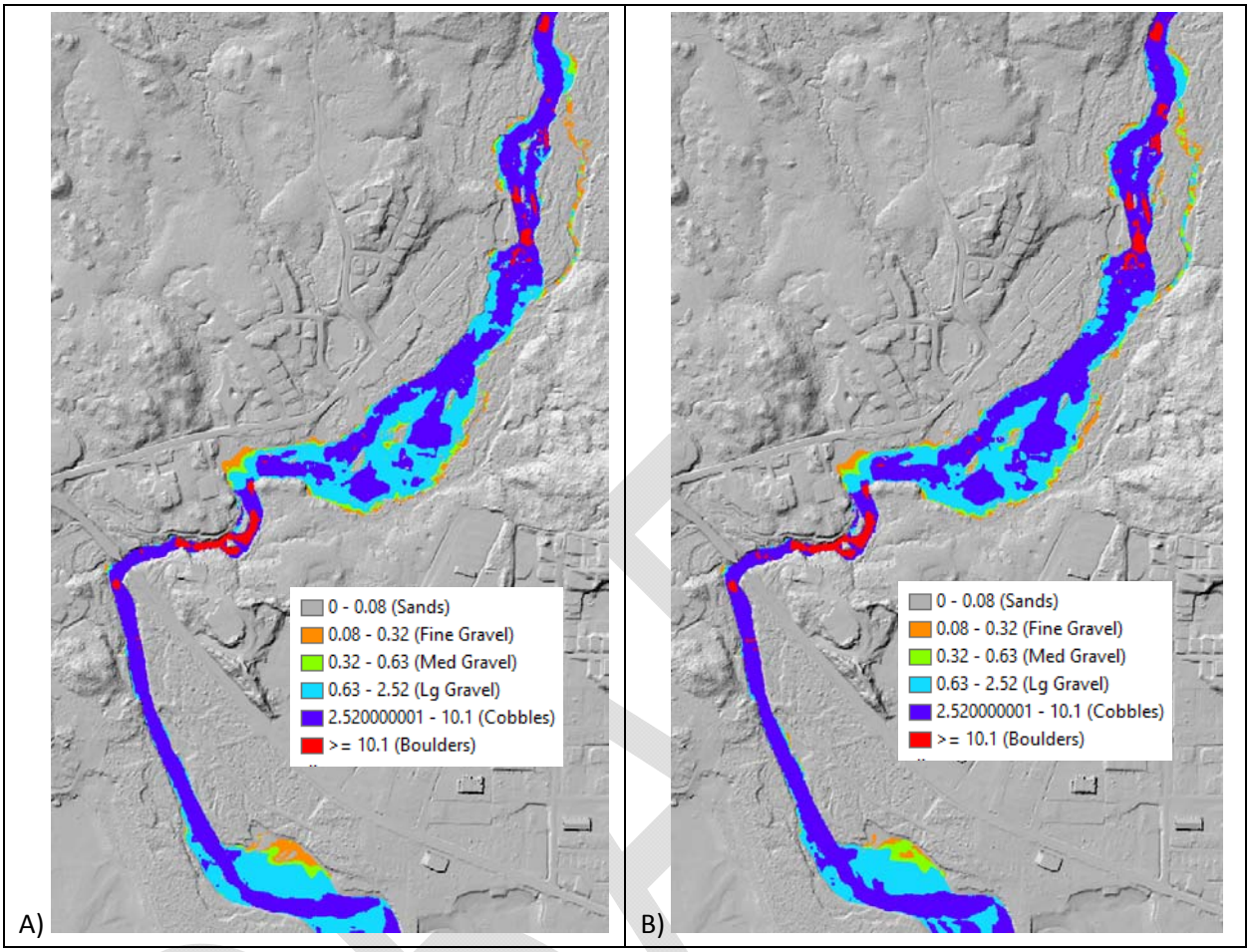


Figure 12. Results of the critical grain size calculation for the A) 5-year return period peak flow and B) the 10-year return period peak flow.

Implications for Project Alternatives

To support the development of alternatives the hydraulic and sediment models were used to examine the effects of simply removing the dam. For the hydraulic modeling, the dam was removed from the terrain model and a channel was created at a constant slope to tie the upstream and downstream grades together. For the sediment transport model, the slope of Sub-reach 3a was increased using the base of the dam as the downstream elevation instead of the dam crest.

The results of the sediment balance modeling are shown in Figure 13. Effectiveness in Sub-reach 3a increases under the removal scenario, while it decreases in Sub-reach 2. This is caused by the change in slope and suggests an increase in sediment transport through the dam impoundment under the removal scenario. The sediment balance in Sub-reach 3a then trends toward degradation as the capacity becomes greater than that of Sub-reach 3b. This suggests an improvement in sediment continuity through the dam location, but that sediment will still be stored in Sub-reach 3b. This increased

continuity is also seen in the updated critical grain size calculations (Figure 14). At the 1.5-year return period peak flow, large gravels, and potentially cobble are predicted to be transported through the impoundment reach.

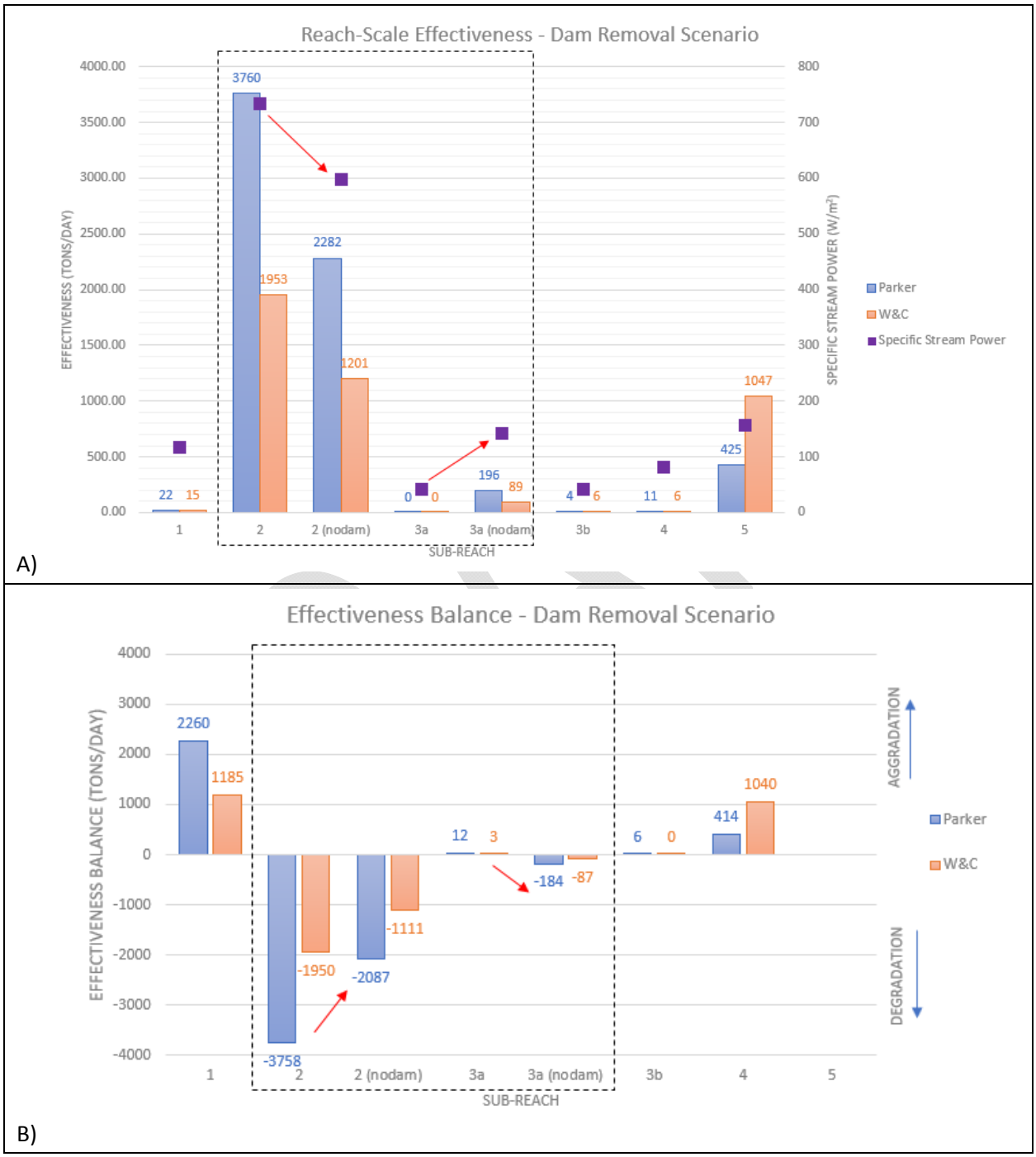


Figure 13. Effectiveness (A) and sediment balance (B) results from the dam removal scenario. The dash box highlights the sub-reaches affected by removal in the analysis. Red arrows highlight the direction of change.

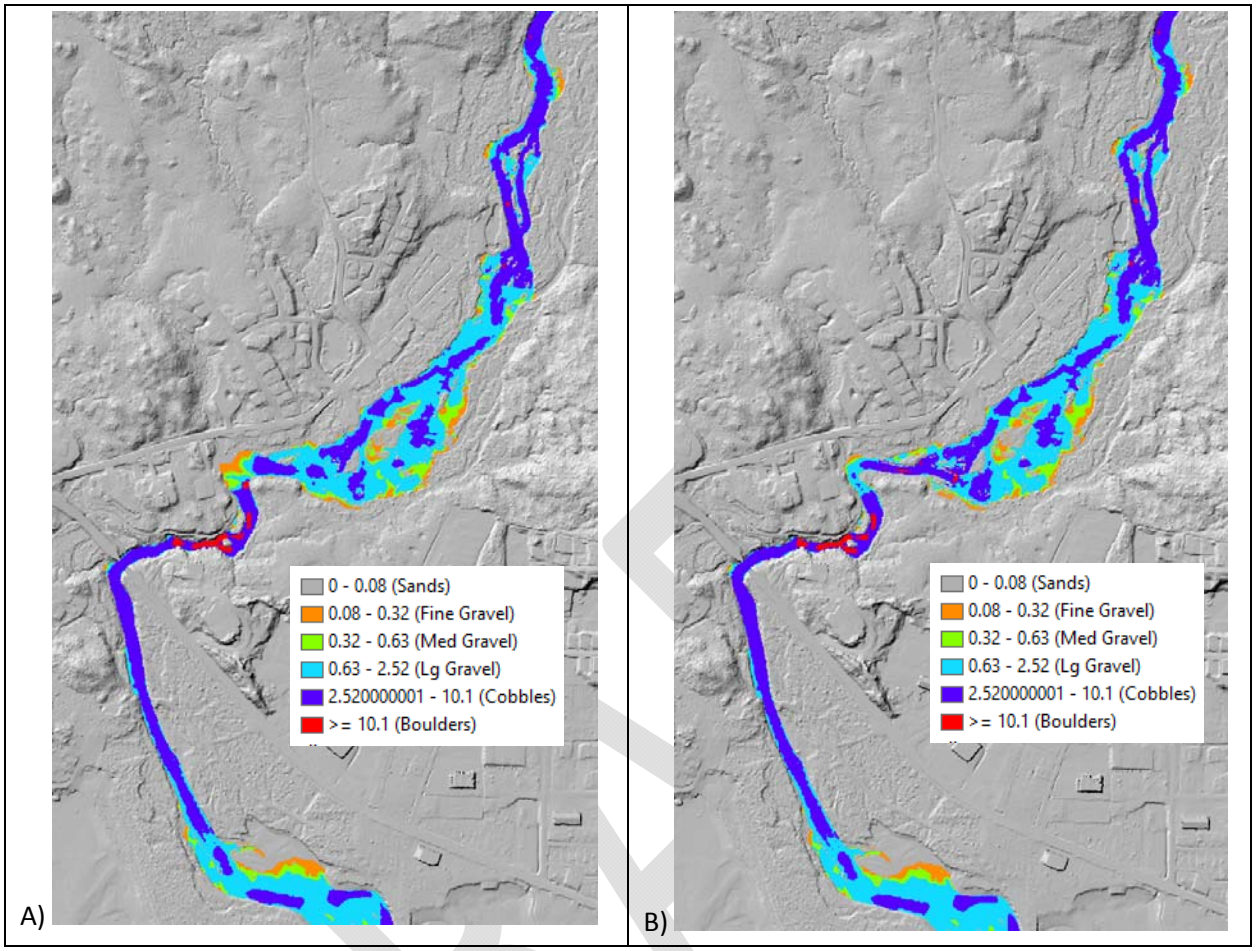


Figure 14. Critical grain size calculations for the 1.5-year return period peak flow under existing conditions (A) and the dam removal scenario (B).

In summary, simply removing the dam will help increase sediment continuity through the project reach, but is not likely to solve the excess supply and deposition problem seen in the 'braided' reach. This means that maintenance will be required at the dam site and has implications for the development along Indian River Road. If the point of diversion was to be moved to another location in the project reach, optimal areas are those less impacted by the sediment deposition. These include the bedrock section of channel located downstream from the current location and potentially the area upstream near the City's infiltration gallery.

Alternatives:

The next phase of the study is to compile a suite of alternatives for consideration. A brief narrative and sketches will be prepared to describe the alternative. A companion decision matrix will be developed to aid the stakeholders in selecting up to three alternatives for more detailed analysis. Analysis and discussion of the three alternatives will aid the stakeholders in selecting a preferred alternative.

References:

Biedenharn, D.S., R.R. Copeland, C.R. Thorne, P.J. Soar, R.D. Hey, and C.C. Watson. 2000. "Effective Discharge Calculation: A Practical Guide." Technical Report No. ERDC/CHL TR-00-15, U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS.

Bledsoe, B., D. Baker, P. Nelson, T. Rosburg, J. Sholtes, and T. Stroth. 2016. Design Hydrology for Stream Restoration and Channel Stability at Stream Crossings. Technical Report, National Cooperative Highway Research Program (NCHRP) Project 24-40, Washington, DC, September, 329 p

HDR, 2012. *Indian River Intake Screen, Trip Report*.

Larsen, C.F., Motyka, R.J., Freymueller, J.T., Echelmeyer, K.A., & Ivins, E.R. 2005. Rapid viscoelastic uplift in southeast Alaska caused by post-Little Ice Age glacial retreat.

Motyka, Roman & Larsen, Christopher & Freymueller, Jeffrey & Echelmeyer, Keith. 2007. Post Little Ice Age Glacial Rebound in Glacier Bay National Park and Surrounding Areas. 6.

Parker, G. 1990. "Surface-based Bedload Transport Relation for Gravel Rivers." Journal of Hydraulic Research, Vol. 28, No. 4, pp. 417–436.

Paustian, Steve and J Hamblen. June 2018. *Indian River Watershed Collaborative Management Strategy*.

Stark, K. J., C. Lee, J. M. Sopcak, K. Kilkus, A. Nadeau, and S. Amberg. 2012. Sitka National Historical Park Natural Resource Condition Assessment. Natural Resource Report NPS/SITK/NRR—2012/525. National Park Service, Fort Collins, Colorado.

Summit. 2004. *City and Borough of Sitka, Indian River Corridor and Watershed Master Plan*

TetraTech, 2013. *City and Borough of Sitka Stormwater Management Plan*

US Army Corps of Engineers. HECRAS version 5.0.7 (March 2019).

USGS. Curran, et al. 2003. WRIR 03-4188. Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada.

USGS, 2004. *Water Quality and Streamflow of the Indian River, Sitka, Alaska, 2001-02*. Scientific Investigation Report 04-5023

Wilcock, P.R., and J.C. Crowe. 2003. "Surface-based Transport Model for Mixed-size Sediment." Journal of Hydraulic Engineering, Vol. 129, No. 2, pp. 120–128.

DRAFT

Appendices

Appendix 1 – Kick off meeting notes

Appendix 2 – Pebble count

Appendix 3 – HECRAS 2D model results for main stem Indian River

DRAFT

Appendix 1 – Kick off meeting notes

DRAFT

Indian River Geomorphic Assessment and Diversion Alternatives

Project Kickoff meeting 8/6/2019, Sitka Sound Science Center

Attendees:

- Sitka Tribal Association: Jeff Feldpausch
- National Park Service, (Brinnen Carter),
- USFS: Aaron Prussian, Marty Becker, Neil Stichert (phone)
- Sitka Hydro Science: Steve Paustian
- UAS: Angela Bowers
- SE Trust: Krista Garrett
- SSSC: Lisa Busch, William Coltharp, Cora Siebert, Black Conaway, Ron Heintz (phone)
- USFWS: Franklin Dekker
- Inter-Fluve: Dan Miller, Luke Swan

Brinnen Carter, NPS:

- Has been at the park for 6 years as the Resource Manager.
- Indian River is a major natural resource for the park. Defines the central core. Has been a draw to Sitka for thousands of years. Is a core natural resource. The battle of 1804. Natural and scenic resource.
- Observed changing rates of erosion of Indian River through the park. Not sure if erosion is accelerating or steady process.
- Objective is an ecological functioning river with upstream and downstream passage for salmon.
- Protect as best as possible.
- Sediment conveyance as natural as possible. Reduce human impacts and improve natural process.
- Continue discussion with partners on other issues such as water rights.
- Water rights are a concern. Desire sufficient flow for ecological function during low flows.
- Erosion seems to occur when flows are at or above 5,000cfs.
- After large flows, gravels up to 15 cm form a bar at the mouth about 20-30cm deep. Could hear gravels moving through the stream during the 2015 event that was greater than 5,000cfs.
- ADOT&PF bridge reconstruction 4-5 years ago included riprap along the banks. Not sure if changes have affected hydraulics. At flood, flows downstream of the SMCR Bridge can pile up on the right bank and redirect into the left bank causing slumping. Estimate 25-30feet of lateral migration of 12-15 ft tall banks. Erosion is active.
- NPS has funded data collection for land slide, LiDAR. Will be collecting SX10 ground based LiDAR of the river channel through the park up to the USGS gage station.
- Revetment on west side of river 500meters north of MHT mouth to 1804 battleground placed 1984-85. Toe of revetment is eroding. Drawings are available.

Aaron Prussian and Marty Becker, USFS:

- Aaron manages the headwaters and trail.
- Indian River is a well functioning watershed.
- There is bank erosion about one-quarter mile upstream of the City intake
- Some landslide activity off mount Verstovia.
- Identified debris torrents from LiDAR analysis. Age unknown.
- Observed sediment wedges migrating downstream
- Glacial snow avalanches with debris reworked by high flows.
- A lot of source areas beneath tree canopy with high density of delivery channels bleeding sediment into the river system.

Jeff Feldpausch: Sitka Tribe of Alaska:

- Goals: ecological health, sediment transport, water rights
- Development upstream. Concerns about nutrient loading, warm, dry, low flows observe algae
- Water temperatures can get high. Important to have adequate flow.
- Concerned about flood control and possibility of flows backing up into houses upstream of dam if the dam is raised.
- Concerned about erosion control and lateral migration.
- Protect cultural resources.

Blake Conaway, SSSC Facilities Manager.

- Been with SSSC for 3 years, in Sitka for 10 years.
- Goal: maintain water flow
- Looking for guidance – such as generalized maintenance schedule recommendations.
- Observed an oxbow forming along river left with gravel buildup.

Angie Bowers, UAS

- Former SSSC aquaculture director during working group
- Been in the area since fall 2015
- Sediment at intake builds up. Last dredging occurred more than 5 years ago.
    - Blake recalled 125cy was dredged.
    - Bill recalled 2019 dredged to infiltration gallery and 2007 was the previous dredging.
- 2015 flood moved rocks from the dam and flushed sediments.

Lisa Busch, SSSC

- Geology background. Been in Sitka for 30 years.
- Objective: be a good neighbor, safe, natural process.

William “Bill” Coltharp, SSSC

- Aquaculture director
- Been in the area since 1980. Aquaculture manager in the ‘90s
- Lots of concerns – primarily fish related
    - Year round flow
    - Attraction flow
    - Spring – imprinting. Has observed fish redirect following flume work
- Dam history
    - Original log dam diversion for hydro in the early 1980s seemed to allow gravel to pass and had similar footprint
    - Three repairs in the ‘90s
    - Infiltration gallery built in ’97 to with draw during turbid flows. Six months of service and a valve broke and hasn’t been used since.
    - Dredged material is not placed downstream of the dam – ADFG would like it to be, Corps says no.
    - Ice has formed inside the pipe. Ice dams are rare.
- Need constant flow. DNR measured 20 cfs.
- Seen lots of change including upstream development. Flow hydrographs seem flashier now than before.
- Fall 2019 flood event formed a gravel bar on river left.
- Flow use:
    - Gravity system.
    - Attractant flow first of July. Open tanks
    - 900-1000gpm for juveniles and eggs
    - 250gpm spilled for adult holding

Steve Paustion, USFS retired, Sitka Hydro Science

- Retired Tongass hydrologist
- Indian River in the ‘80s: helped with USGS gage temperature and water quality data. Station was mothballed.
- NPS, CBS – current gage has been operating 8-10years. Discontinued.
- NPS reactivated gage the past 5-6 years.
- 3-4 years of detailed data may be available in a spreadsheet from Bill Johnson in Juneau.
- Observed there are more high and low extremes. Potentially climate change.
- Engineering studies have been done of the subdivision about stormwater issues and controls. Nothing egregious stands out. Fine sediment is accounted for with traps and ditch lines.
- Old logging road stringer bridge is trapping bedload, multiple channels
- Very dynamic, very flashy, no stable condition.

- Challenges – diversions and routing sediment
- Goal: improve ecology, maintain fisheries, hatchery, function of stream.
- USGS data: stage data is useful. Lacks high flow measurements.
- USGS contact: Randy Host
- DNR, Juneau contact: Terry Schwartz completed low flow measurements
    - Lisa: NWS has river gage flood forecasting associated with Harbor Mountain weather station
- Upper gaging station has a long history
    - Ed Neal compared gages, enough change that limited general trends comparison. Specific events might be comparable.
- Consider conditions to trigger maintenance issues.

Appendix 2 – Pebble count

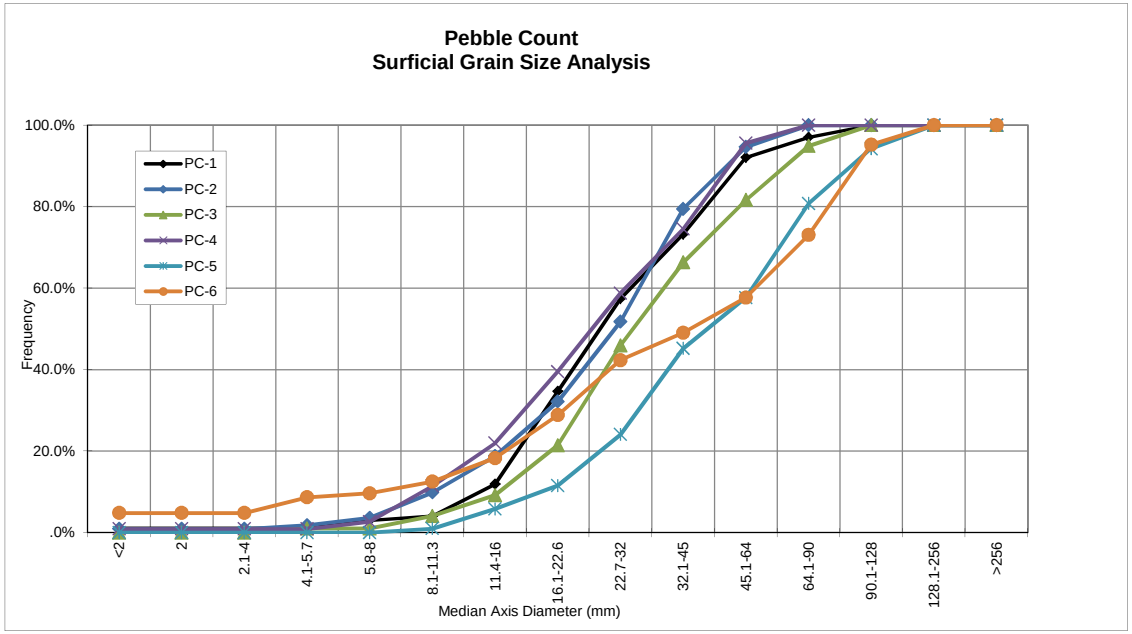
DRAFT

Indian River - Pebble Count: Summary Plots

Sediment Grain Size Analysis

Pebble Count Data

Class (Wentworth)	*Size Class mm*	*Size upper bound*	*Cumulative % - summary*					
			Sample:	*PC-1*	*PC-2*	*PC-3*	*PC-4*	*PC-5*	*PC-6*
Sand	<2	0		1.0%	.9%	.0%	.9%	.0%	4.8%
Sand	2	2		1.0%	.9%	.0%	.9%	.0%	4.8%
Very Fine Gravel	2.1-4	4		1.0%	.9%	.0%	.9%	.0%	4.8%
Fine Gravel	4.1-5.7	5.7		1.0%	1.8%	1.0%	.9%	.0%	8.7%
Fine Gravel	5.8-8	8		3.0%	3.6%	1.0%	2.6%	.0%	9.6%
Medium Gravel	8.1-11.3	11.3		4.0%	9.8%	4.1%	11.4%	1.0%	12.5%
Medium Gravel	11.4-16	16		11.9%	18.8%	9.2%	21.9%	5.8%	18.3%
Coarse Gravel	16.1-22.6	22.6		34.7%	32.1%	21.4%	39.5%	11.5%	28.8%
Coarse Gravel	22.7-32	32		57.4%	51.8%	45.9%	58.8%	24.0%	42.3%
Very Course Gravel	32.1-45	45		73.3%	79.5%	66.3%	74.6%	45.2%	49.0%
Very Course Gravel	45.1-64	64		92.1%	94.6%	81.6%	95.6%	57.7%	57.7%
Small Cobble	64.1-90	90		97.0%	100.0%	94.9%	100.0%	80.8%	73.1%
Small Cobble	90.1-128	128		100.0%	100.0%	100.0%	100.0%	94.2%	95.2%
Large Cobble	128.1-256	256		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Small Boulders	>256	0		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Total	684.6							



Indian River: Pebble Count, PC-1

Sediment Grain Size Analysis

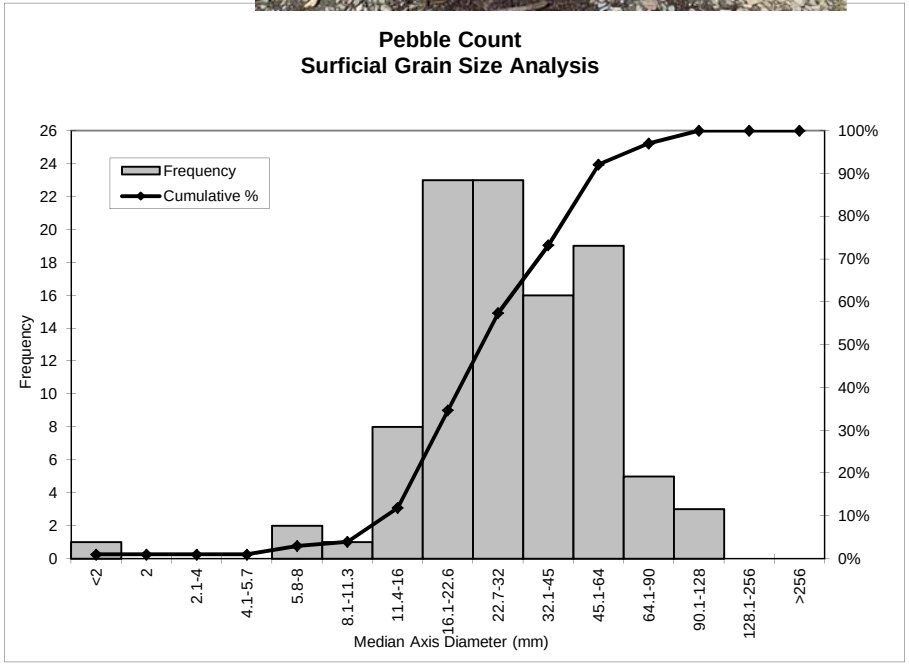
Bar below dam	Identifier
August 6, 2019	Date
DM, LS, FD, CS, BC	Personnel
Indian River	Stream
n/a	Approximate Depth of Flow at Thalweg (ft)
stream bed substrate	Longitudinal Description (Pool, Riffle, Bend, Crossing)
surficial material	Sample Type: Armor Layer or Subarmor

Gravel bar downstream from dam on river left. View looking upstream

Substrate:

Pebble Count Data

Class (Wentworth)	*Size Class mm*	*Frequency*	*Cumulative %*
Sand	<2	1	1.0%
Sand	2	0	1.0%
Very Fine Gravel	2.1-4	0	1.0%
Fine Gravel	4.1-5.7	0	1.0%
Fine Gravel	5.8-8	2	3.0%
Medium Gravel	8.1-11.3	1	4.0%
Medium Gravel	11.4-16	8	11.9%
Coarse Gravel	16.1-22.6	23	34.7%
Coarse Gravel	22.7-32	23	57.4%
Very Course Gravel	32.1-45	16	73.3%
Very Course Gravel	45.1-64	19	92.1%
Small Cobble	64.1-90	5	97.0%
Small Cobble	90.1-128	3	100.0%
Large Cobble	128.1-256	0	100.0%
Small Boulders	>256	0	100.0%
	Total	101	



Indian River: Pebble Count, PC-2

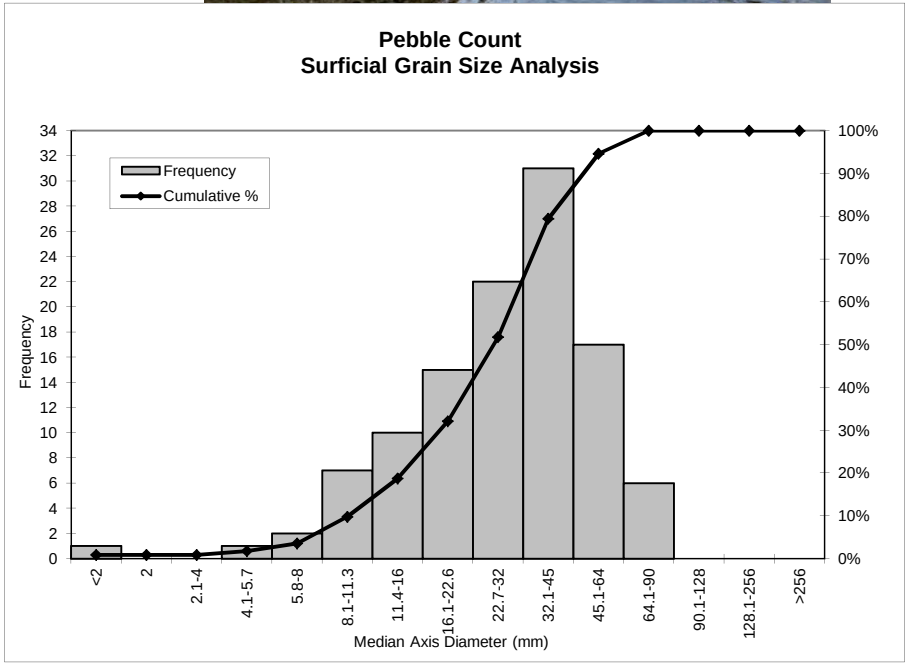
Sediment Grain Size Analysis

Riffle into dam pond	Identifier
August 6, 2019	Date
DM, LS, FD, CS, BC	Personnel
Indian River	Stream
n/a	Approximate Depth of Flow at Thalweg (ft)
stream bed substrate	Longitudinal Description (Pool, Riffle, Bend, Crossing)
surficial material	Sample Type: Armor Layer or Subarmor

Riffle entering dam impoundment. View looking downstream

Pebble Count Data

Class (Wentworth)	*Size Class mm*	*Frequency*	*Cumulative %*
Sand	<2	1	.9%
Sand	2	0	.9%
Very Fine Gravel	2.1-4	0	.9%
Fine Gravel	4.1-5.7	1	1.8%
Fine Gravel	5.8-8	2	3.6%
Medium Gravel	8.1-11.3	7	9.8%
Medium Gravel	11.4-16	10	18.8%
Coarse Gravel	16.1-22.6	15	32.1%
Coarse Gravel	22.7-32	22	51.8%
Very Course Gravel	32.1-45	31	79.5%
Very Course Gravel	45.1-64	17	94.6%
Small Cobble	64.1-90	6	100.0%
Small Cobble	90.1-128	0	100.0%
Large Cobble	128.1-256	0	100.0%
Small Boulders	>256	0	100.0%
	Total	112	



Indian River: Pebble Count, PC-3

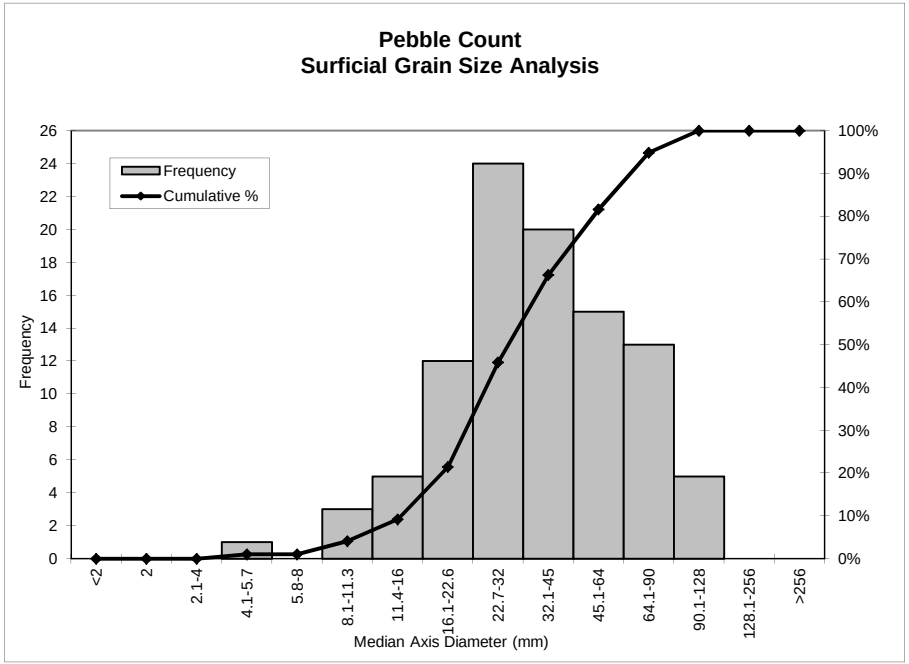
Sediment Grain Size Analysis

Bar below stringer br	Identifier
August 6, 2019	Date
DM, LS, FD, CS, BC	Personnel
Indian River	Stream
n/a	Approximate Depth of Flow at Thalweg (ft)
stream bed substrate	Longitudinal Description (Pool, Riffle, Bend, Crossing)
surficial material	Sample Type: Armor Layer or Subarmor

Gravel bar downstream of log stringer bridge on river right. View looking upstream.

Pebble Count Data

Class (Wentworth)	*Size Class mm*	*Frequency*	*Cumulative %*
Sand	<2	0	.0%
Sand	2	0	.0%
Very Fine Gravel	2.1-4	0	.0%
Fine Gravel	4.1-5.7	1	1.0%
Fine Gravel	5.8-8	0	1.0%
Medium Gravel	8.1-11.3	3	4.1%
Medium Gravel	11.4-16	5	9.2%
Coarse Gravel	16.1-22.6	12	21.4%
Coarse Gravel	22.7-32	24	45.9%
Very Course Gravel	32.1-45	20	66.3%
Very Course Gravel	45.1-64	15	81.6%
Small Cobble	64.1-90	13	94.9%
Small Cobble	90.1-128	5	100.0%
Large Cobble	128.1-256	0	100.0%
Small Boulders	>256	0	100.0%
	Total	98	

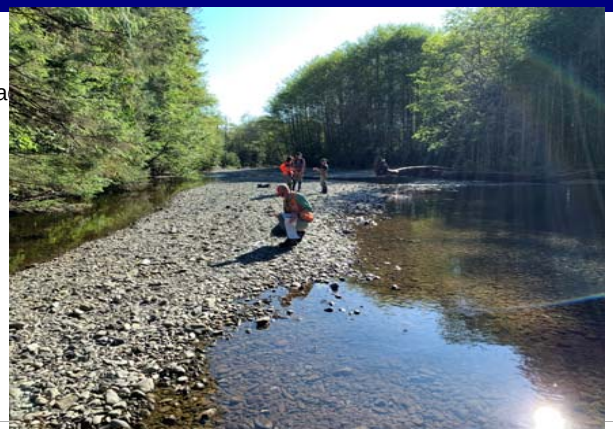


Indian River: Pebble Count, PC-4

Sediment Grain Size Analysis

Mainstem at bifurcation into braided reach	Identifier
August 6, 2019	Date
DM, LS, FD, CS, BC	Personnel
Indian River	Stream
n/a	Approximate Depth of Flow at Thalweg (ft)
stream bed substrate	Longitudinal Description (Pool, Riffle, Bend, Crossing)
surficial material	Sample Type: Armor Layer or Subarmor

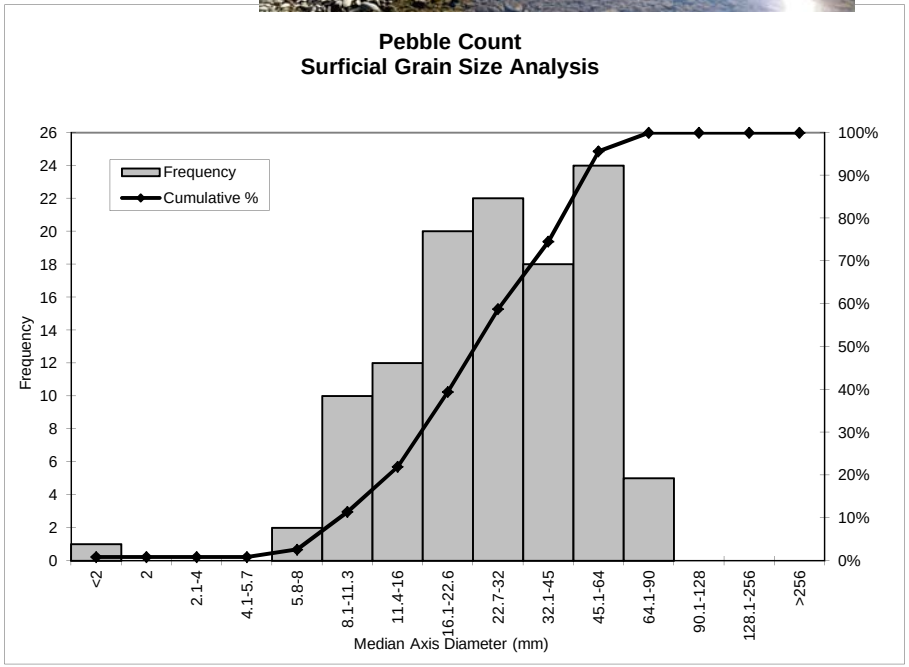
Longitudinal bar on mainstem at bifurcation into braided rea side channels. View looking downstream.



Substrate

Pebble Count Data

Class (Wentworth)	*Size Class mm*	*Frequency*	*Cumulative %*
Sand	<2	1	.9%
Sand	2	0	.9%
Very Fine Gravel	2.1-4	0	.9%
Fine Gravel	4.1-5.7	0	.9%
Fine Gravel	5.8-8	2	2.6%
Medium Gravel	8.1-11.3	10	11.4%
Medium Gravel	11.4-16	12	21.9%
Coarse Gravel	16.1-22.6	20	39.5%
Coarse Gravel	22.7-32	22	58.8%
Very Course Gravel	32.1-45	18	74.6%
Very Course Gravel	45.1-64	24	95.6%
Small Cobble	64.1-90	5	100.0%
Small Cobble	90.1-128	0	100.0%
Large Cobble	128.1-256	0	100.0%
Small Boulders	>256	0	100.0%
	Total	114	



Indian River: Pebble Count, PC-5

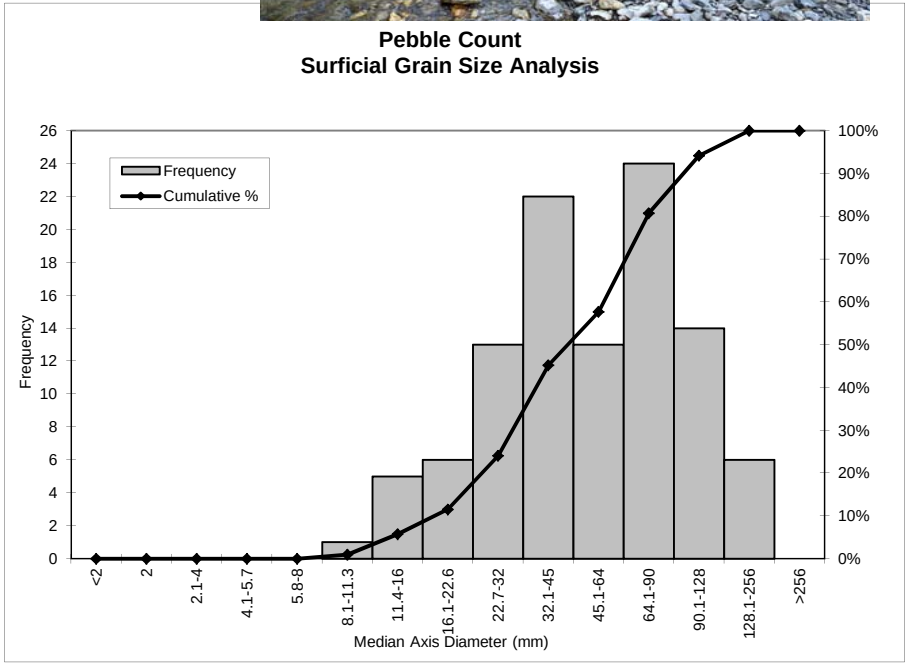
Sediment Grain Size Analysis

Riffle below City Intake	Identifier
August 6, 2019	Date
DM, LS, FD, CS, BC	Personnel
Indian River	Stream
n/a	Approximate Depth of Flow at Thalweg (ft)
stream bed substrate	Longitudinal Description (Pool, Riffle, Bend, Crossing
surficial material	Sample Type: Armor Layer or Subarmor

Riffle in primary channel of multi-threaded, LWM controlle channels. Approx. 450-ft Downstream of City intake. View looking upstream

Pebble Count Data

Class (Wentworth)	*Size Class mm*	*Frequency*	*Cumulative %*
Sand	<2	0	.0%
Sand	2	0	.0%
Very Fine Gravel	2.1-4	0	.0%
Fine Gravel	4.1-5.7	0	.0%
Fine Gravel	5.8-8	0	.0%
Medium Gravel	8.1-11.3	1	1.0%
Medium Gravel	11.4-16	5	5.8%
Coarse Gravel	16.1-22.6	6	11.5%
Coarse Gravel	22.7-32	13	24.0%
Very Course Gravel	32.1-45	22	45.2%
Very Course Gravel	45.1-64	13	57.7%
Small Cobble	64.1-90	24	80.8%
Small Cobble	90.1-128	14	94.2%
Large Cobble	128.1-256	6	100.0%
Small Boulders	>256	0	100.0%
	Total	104	

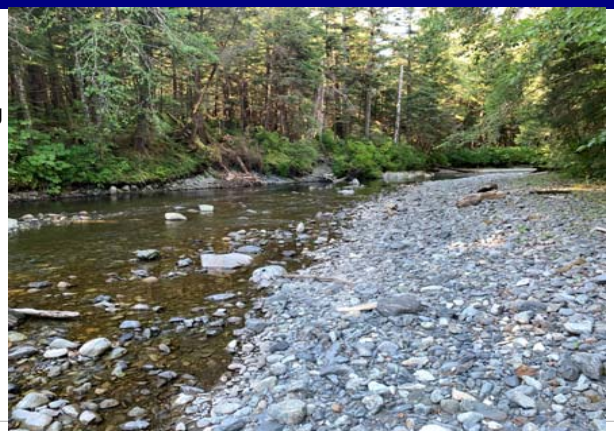


Indian River: Pebble Count, PC-6

Sediment Grain Size Analysis

Bar at Supply Rch XS	Identifier
August 6, 2019	Date
DM, LS, FD, CS, BC	Personnel
Indian River	Stream
n/a	Approximate Depth of Flow at Thalweg (ft)
stream bed substrate	Longitudinal Description (Pool, Riffle, Bend, Crossing)
surficial material	Sample Type: Armor Layer or Subarmor

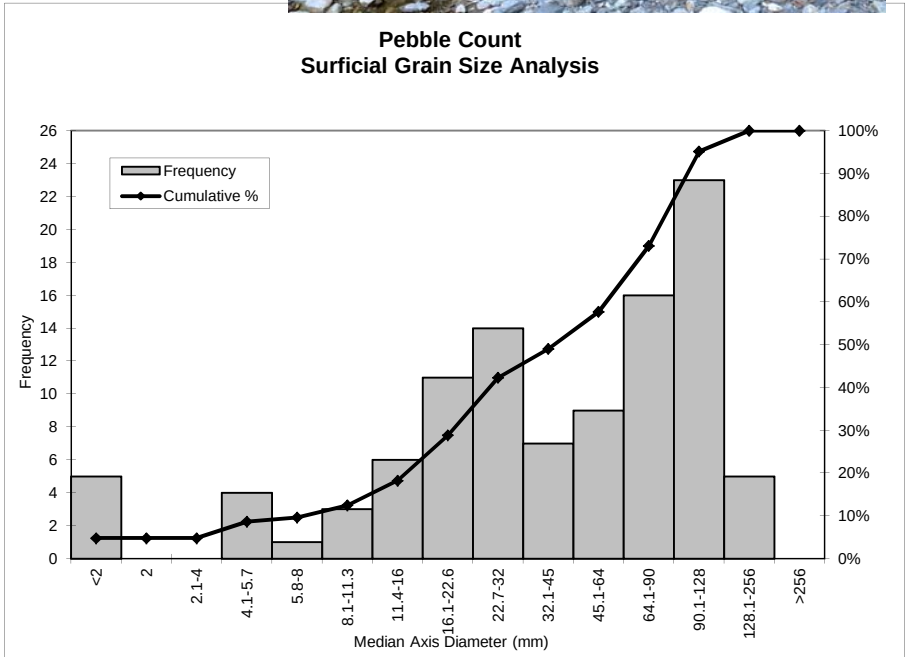
Gravel bar along river left at Reference reach for sediment supply conditions. View looking upstream



Substrate:

Pebble Count Data

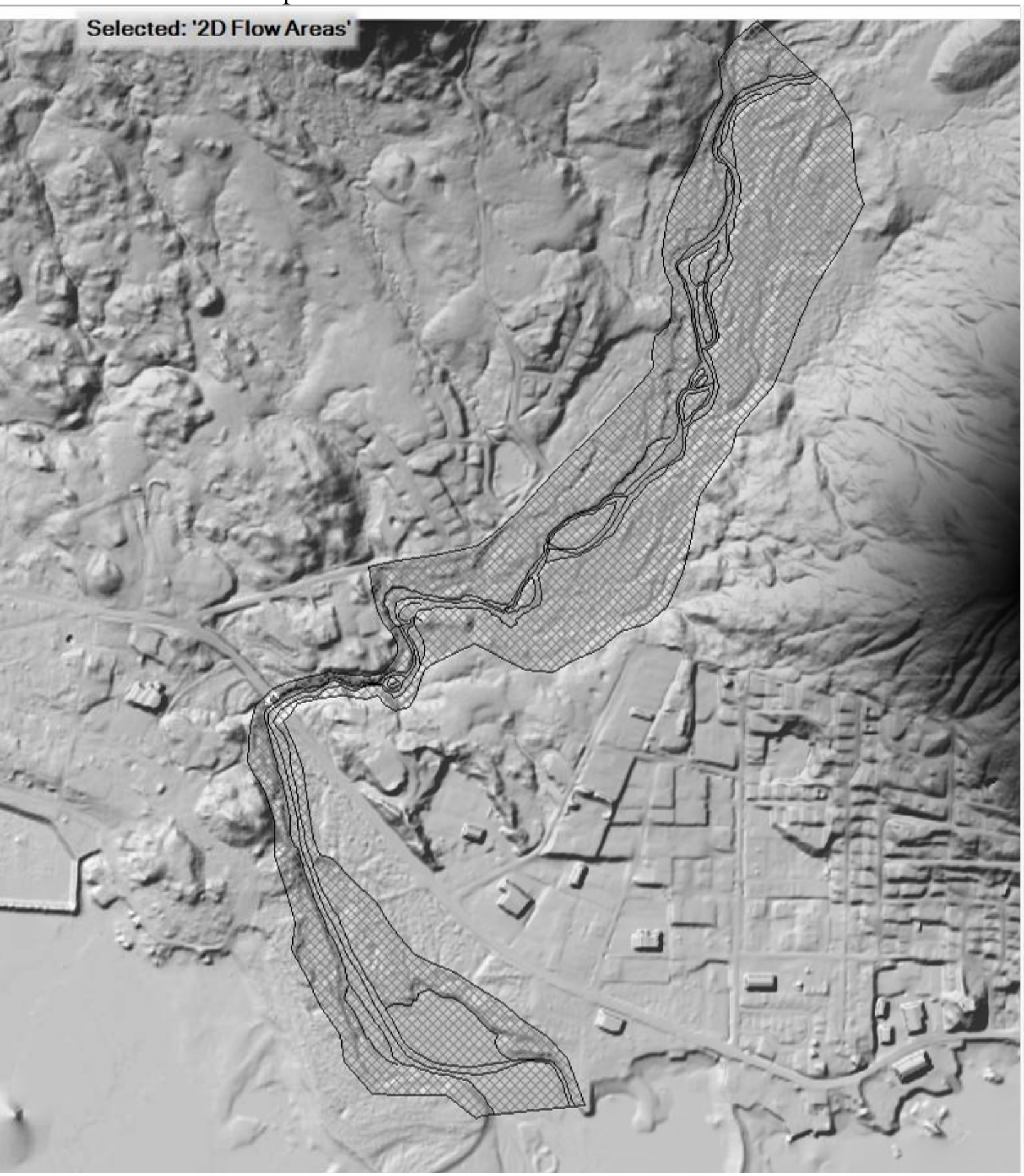
Class (Wentworth)	*Size Class mm*	*Frequency*	*Cumulative %*
Sand	<2	5	4.8%
Sand	2	0	4.8%
Very Fine Gravel	2.1-4	0	4.8%
Fine Gravel	4.1-5.7	4	8.7%
Fine Gravel	5.8-8	1	9.6%
Medium Gravel	8.1-11.3	3	12.5%
Medium Gravel	11.4-16	6	18.3%
Coarse Gravel	16.1-22.6	11	28.8%
Coarse Gravel	22.7-32	14	42.3%
Very Course Gravel	32.1-45	7	49.0%
Very Course Gravel	45.1-64	9	57.7%
Small Cobble	64.1-90	16	73.1%
Small Cobble	90.1-128	23	95.2%
Large Cobble	128.1-256	5	100.0%
Small Boulders	>256	0	100.0%
	Total	104	



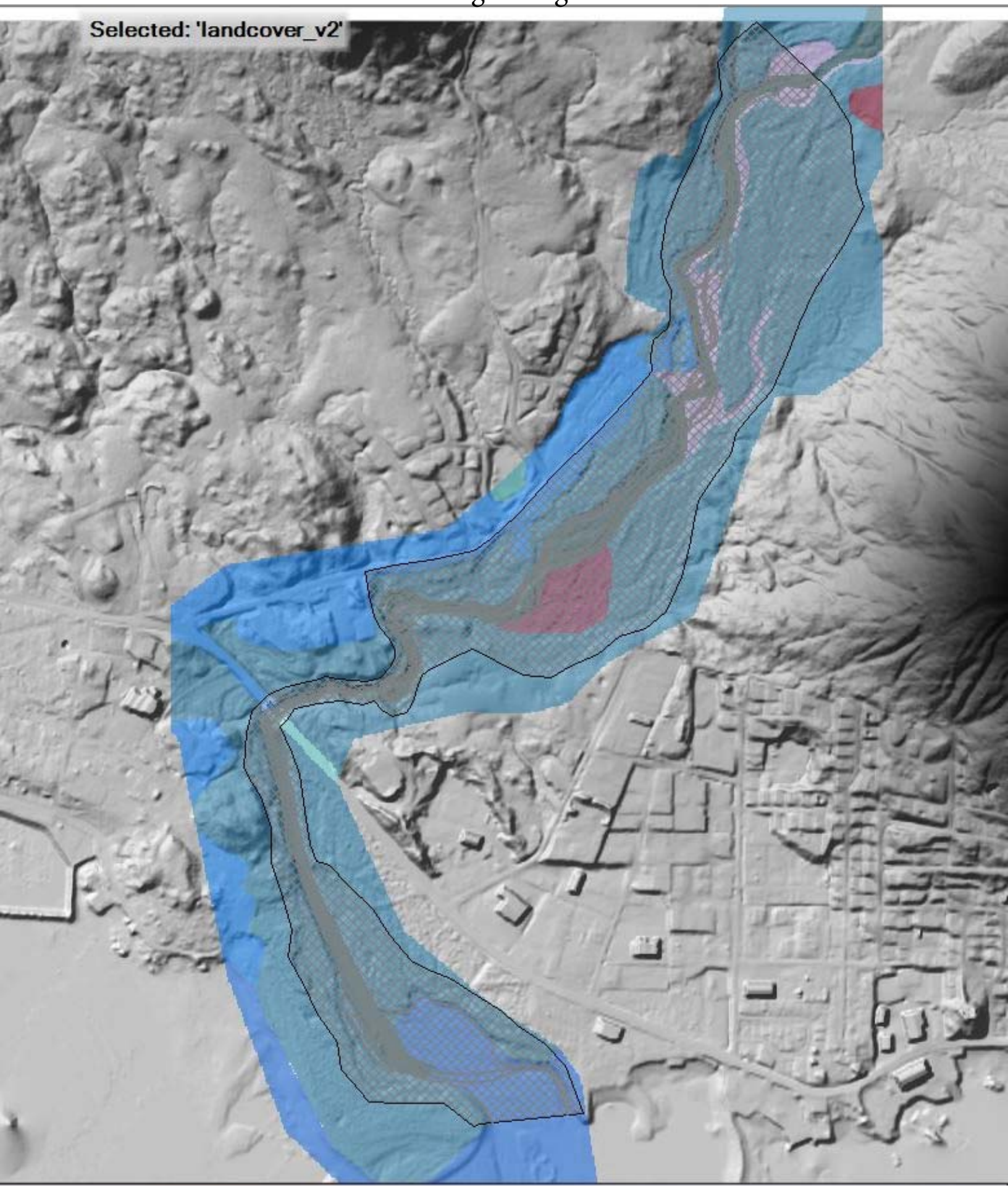
Appendix 3 – HECRAS 2D model results for main stem Indian River

DRAFT

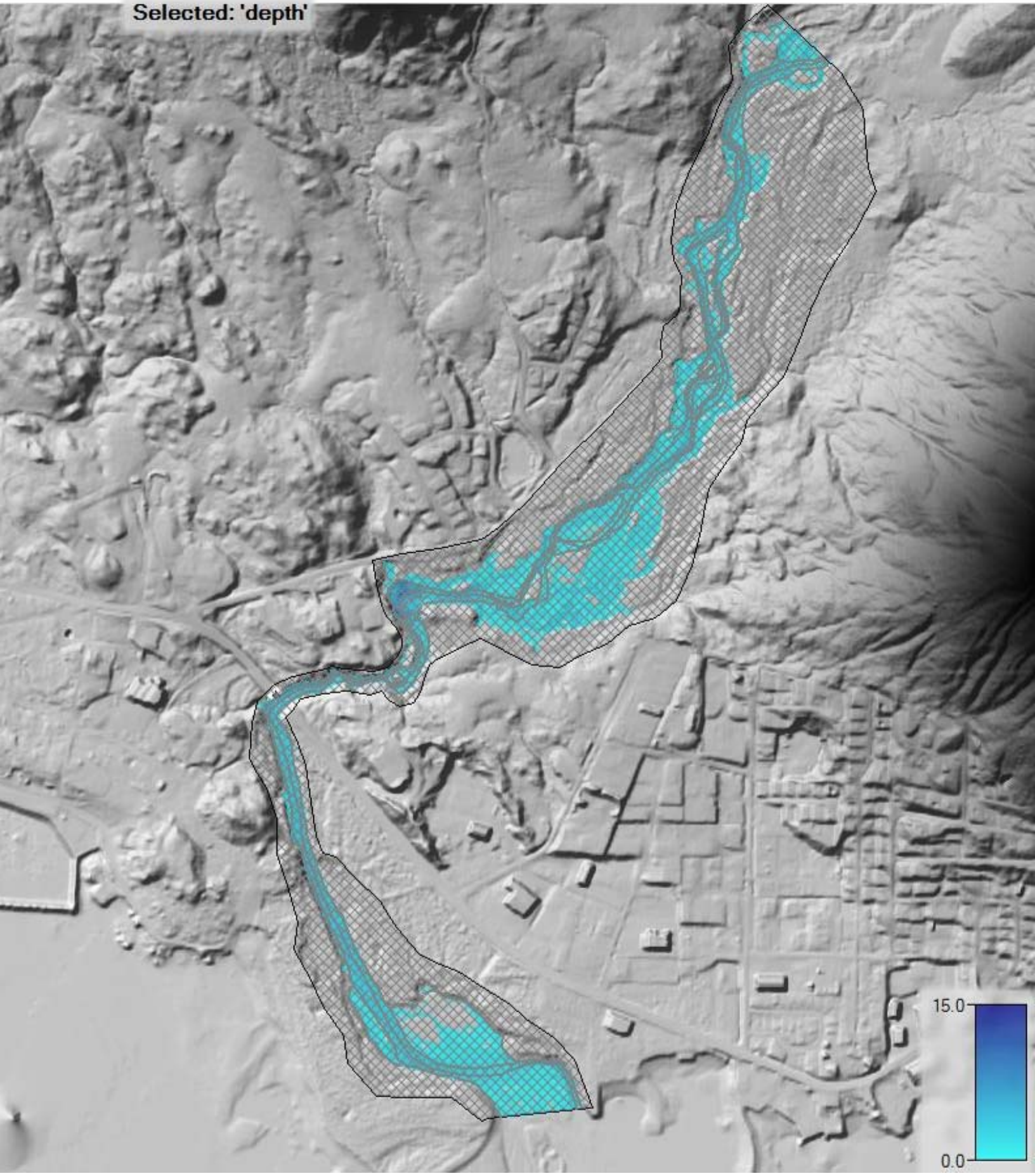
HEC-RAS 2D Computational mesh and breaklines



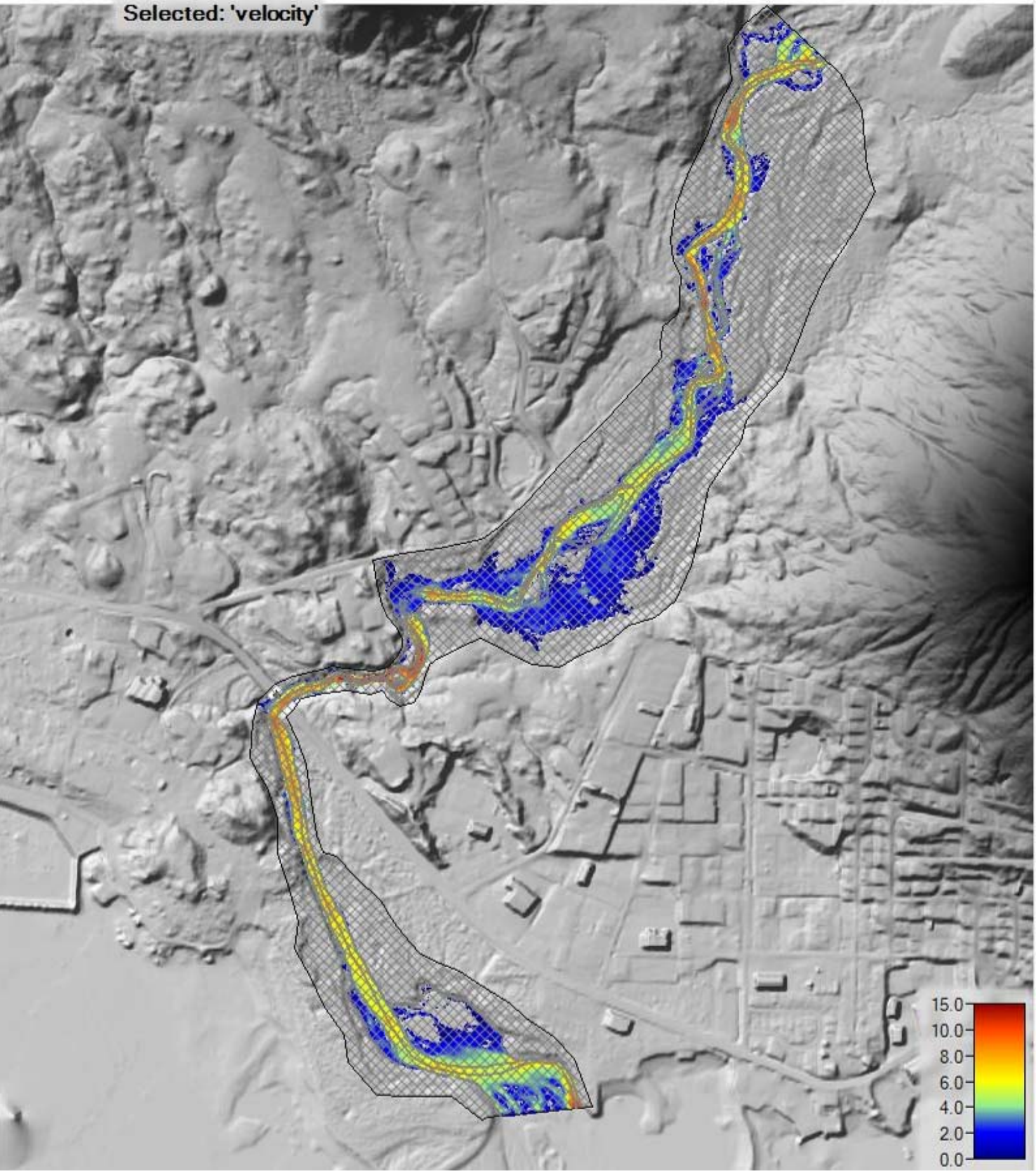
HEC-RAS 2D Landcover - Manning's n regions



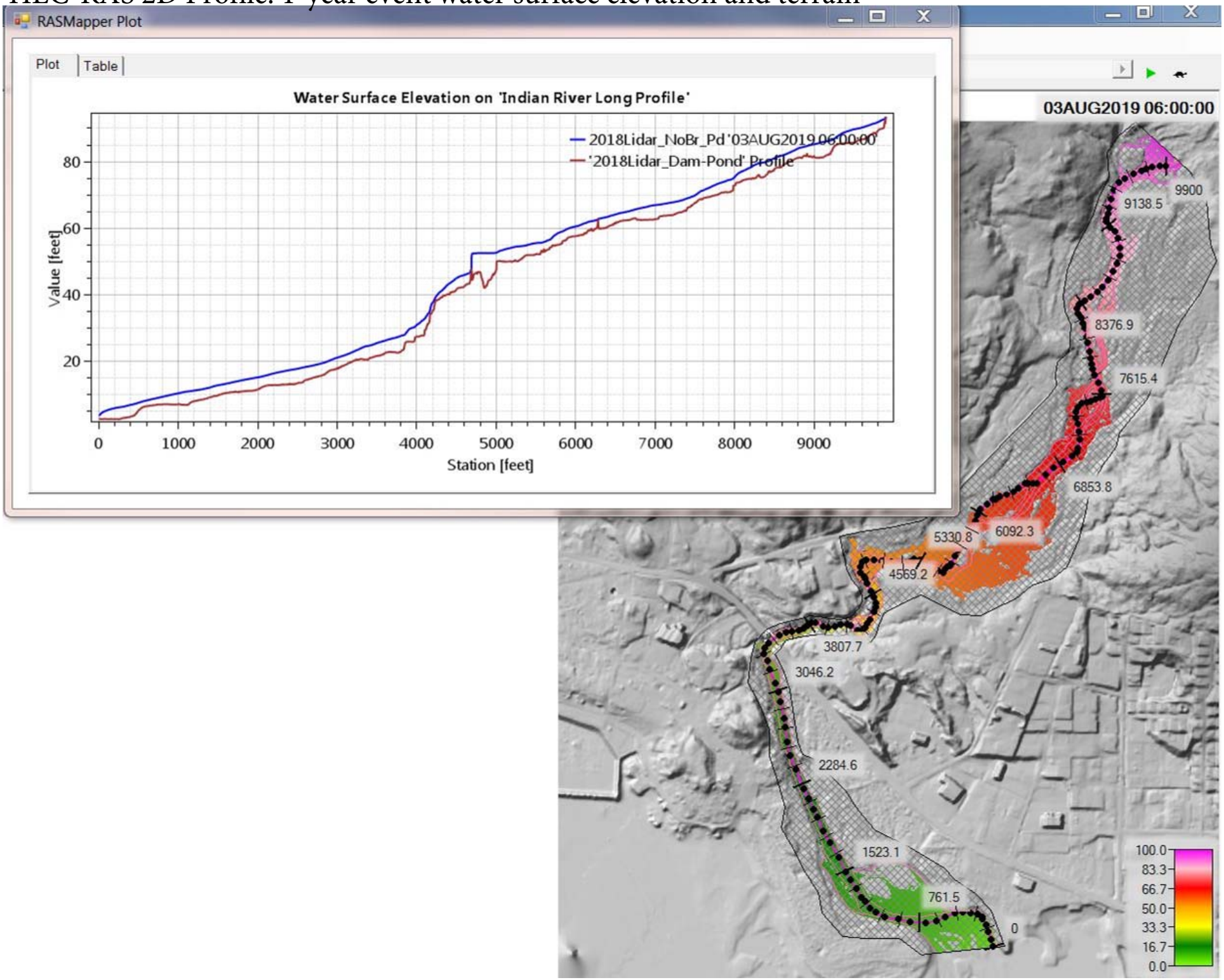
HEC-RAS 2D 1-year event flow depth



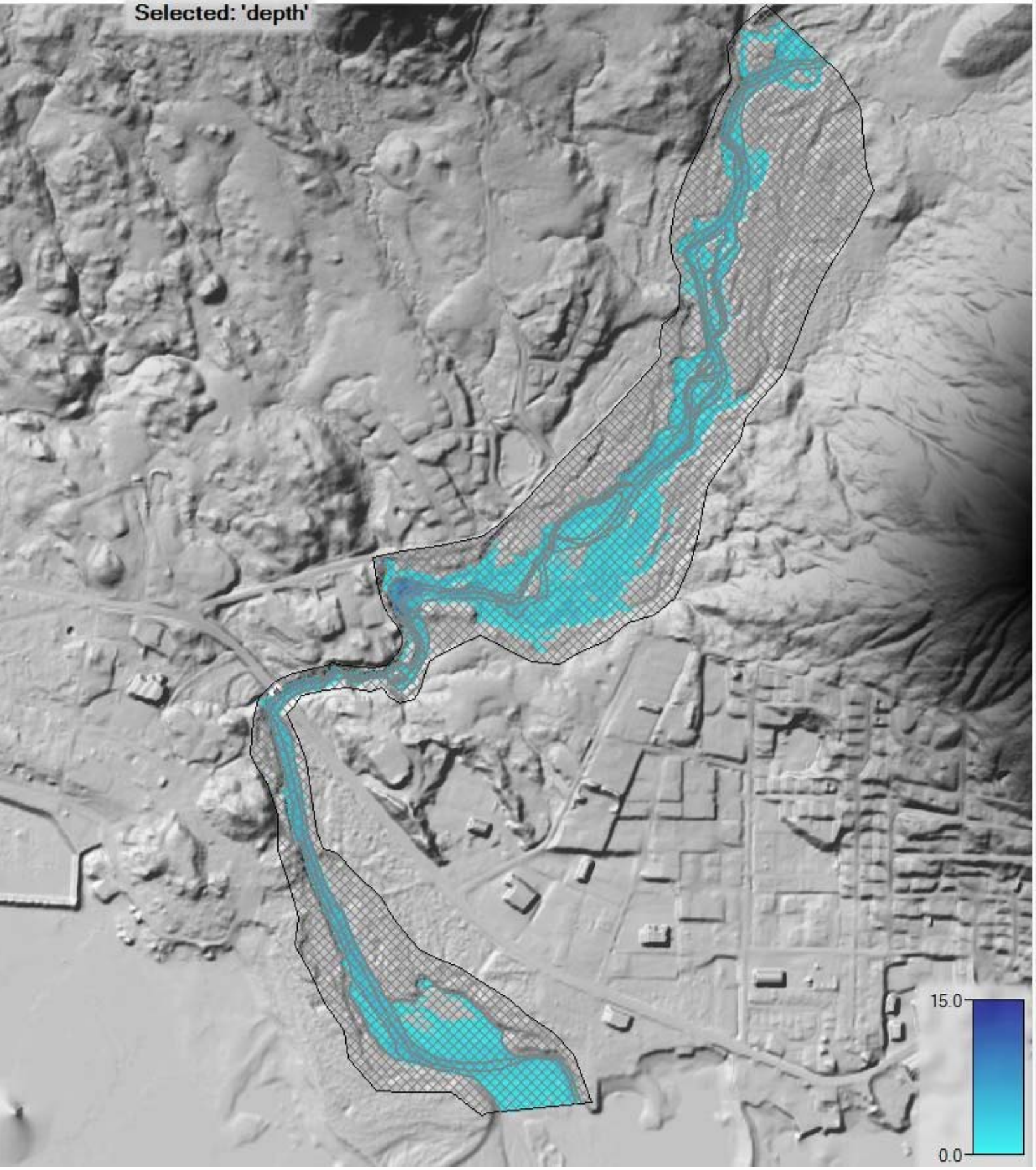
HEC-RAS 2D 1-year event flow velocity



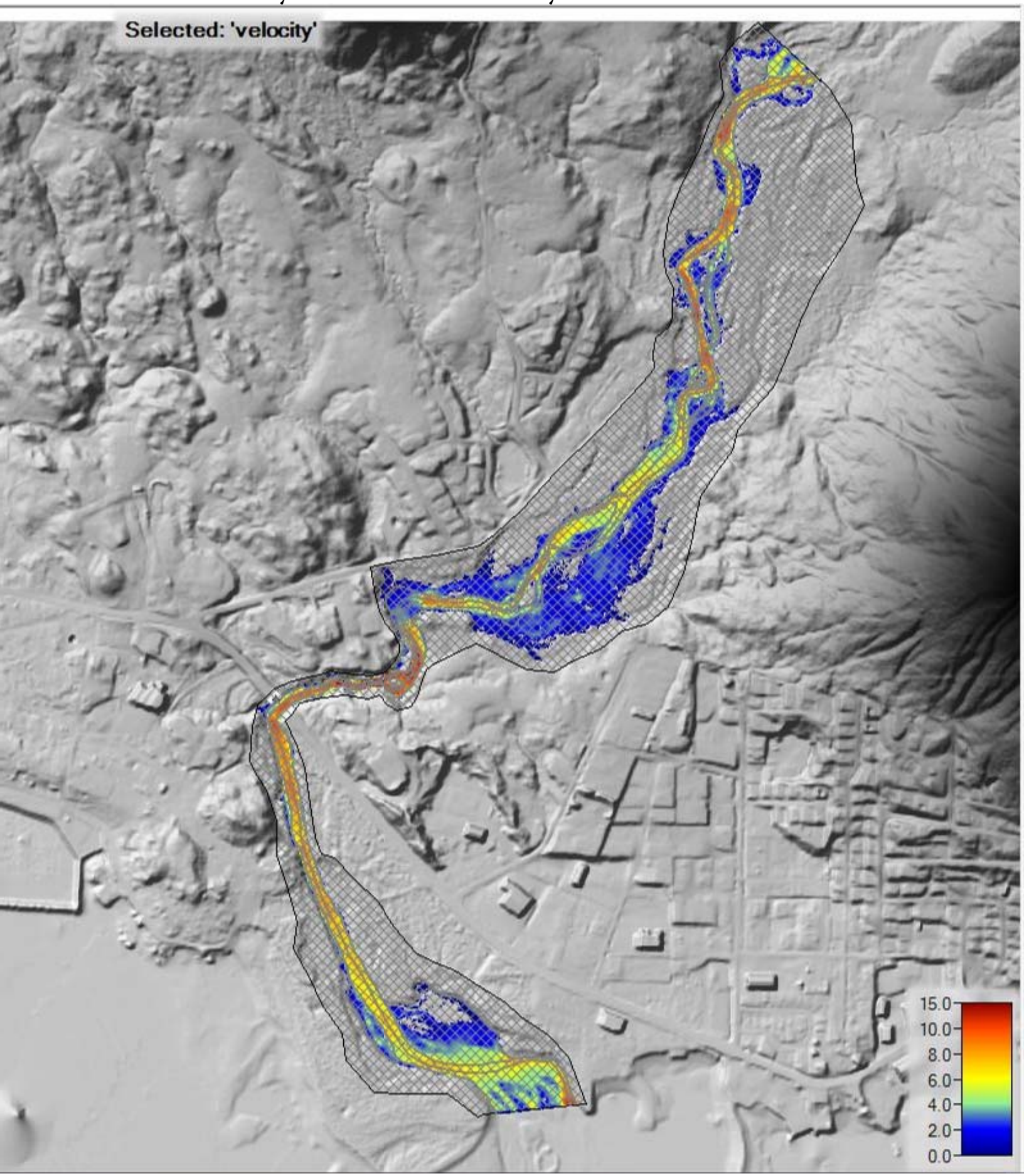
HEC-RAS 2D Profile: 1-year event water surface elevation and terrain



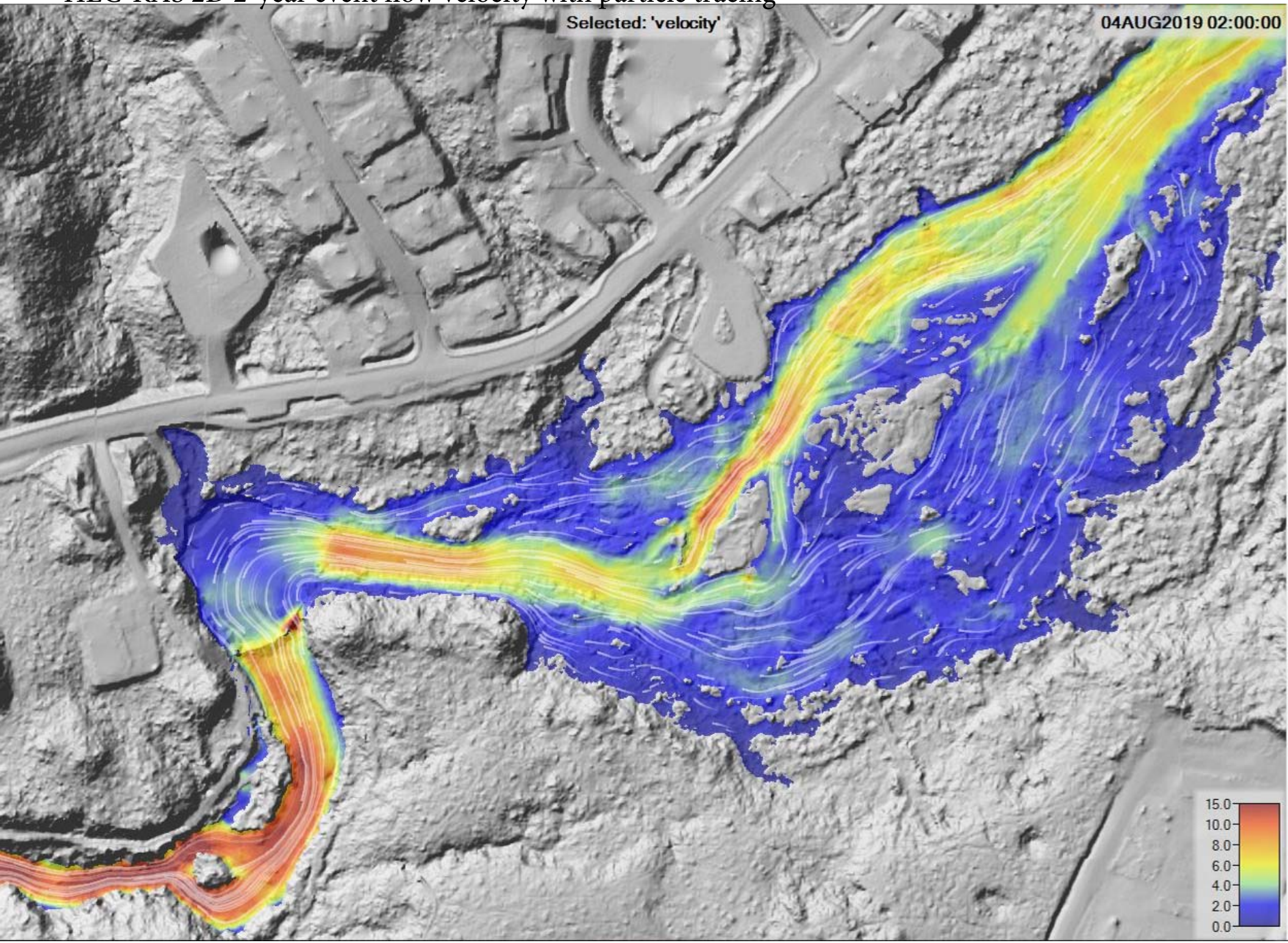
HEC-RAS 2D 2-year event flow depth



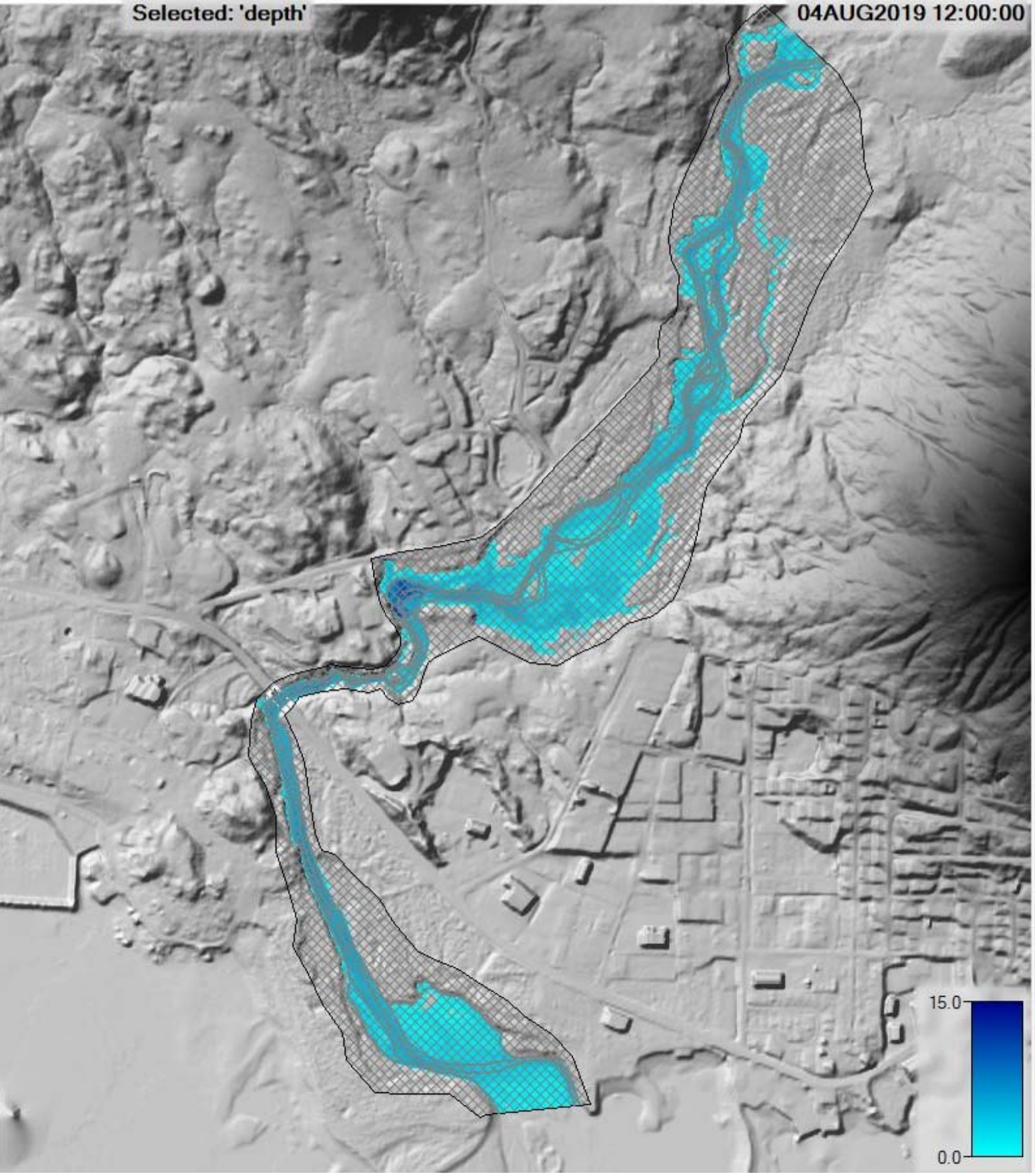
HEC-RAS 2D 2-year event flow velocity



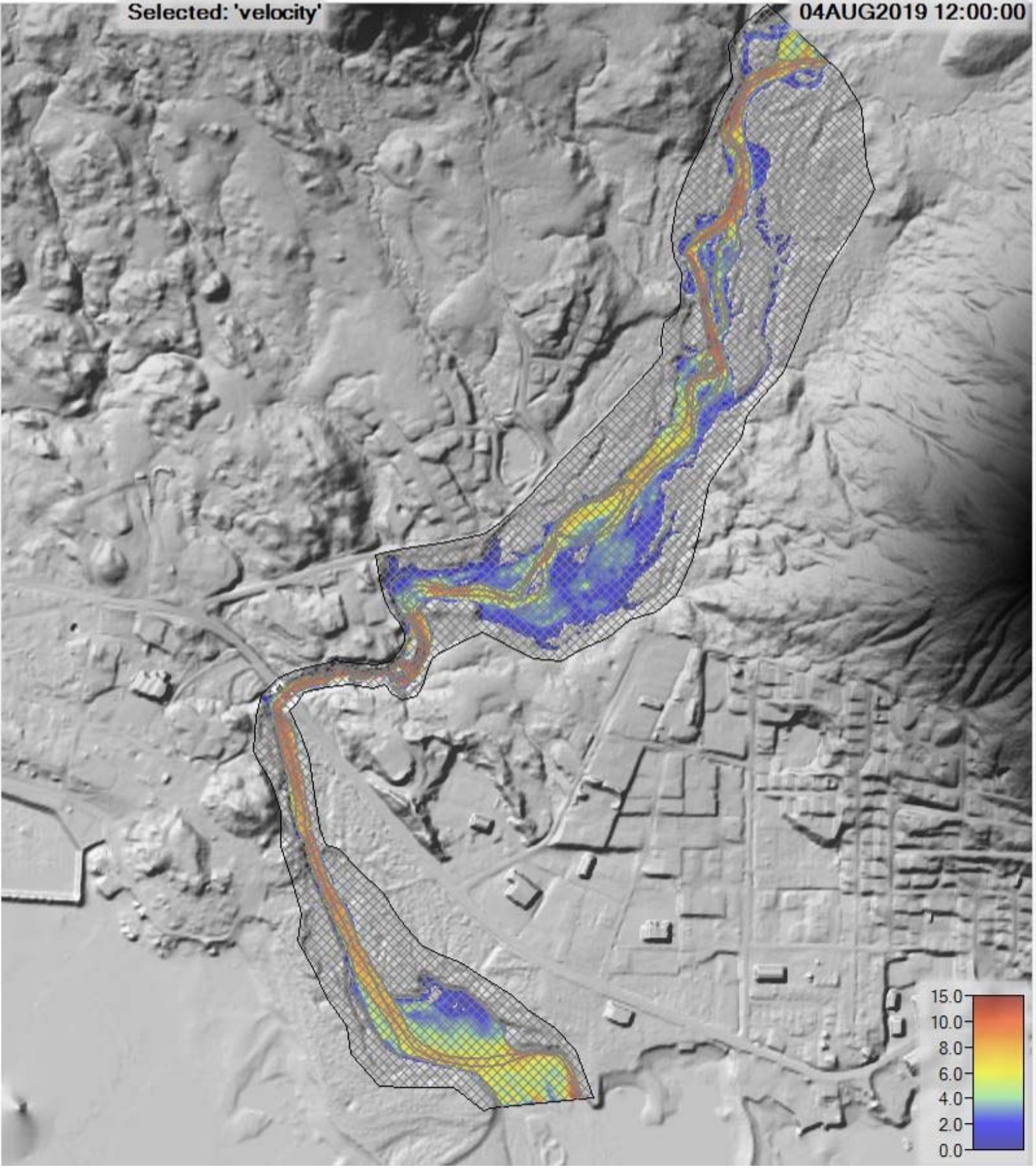
HEC-RAS 2D 2-year event flow velocity with particle tracing



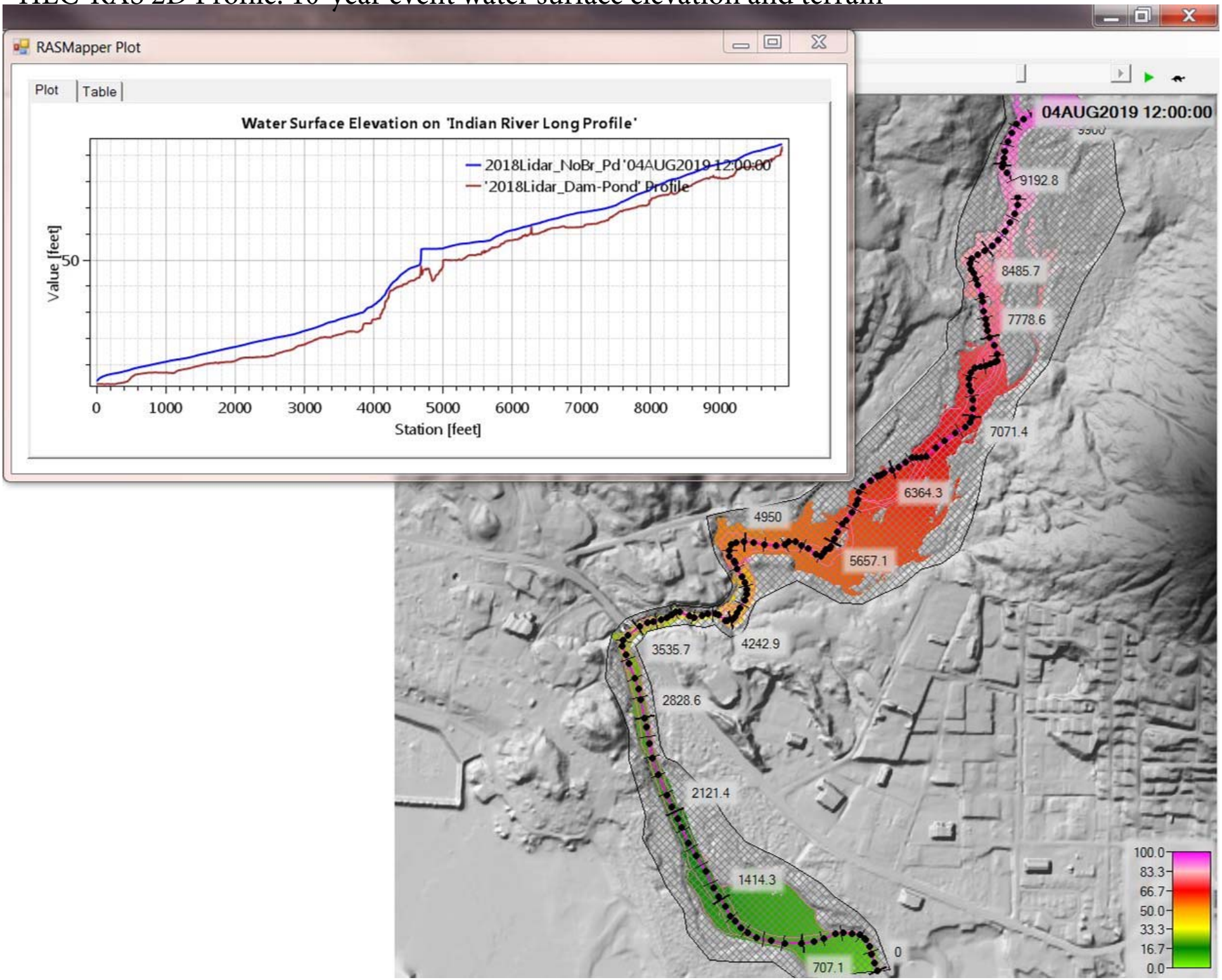
HEC-RAS 2D 10-year event flow depth



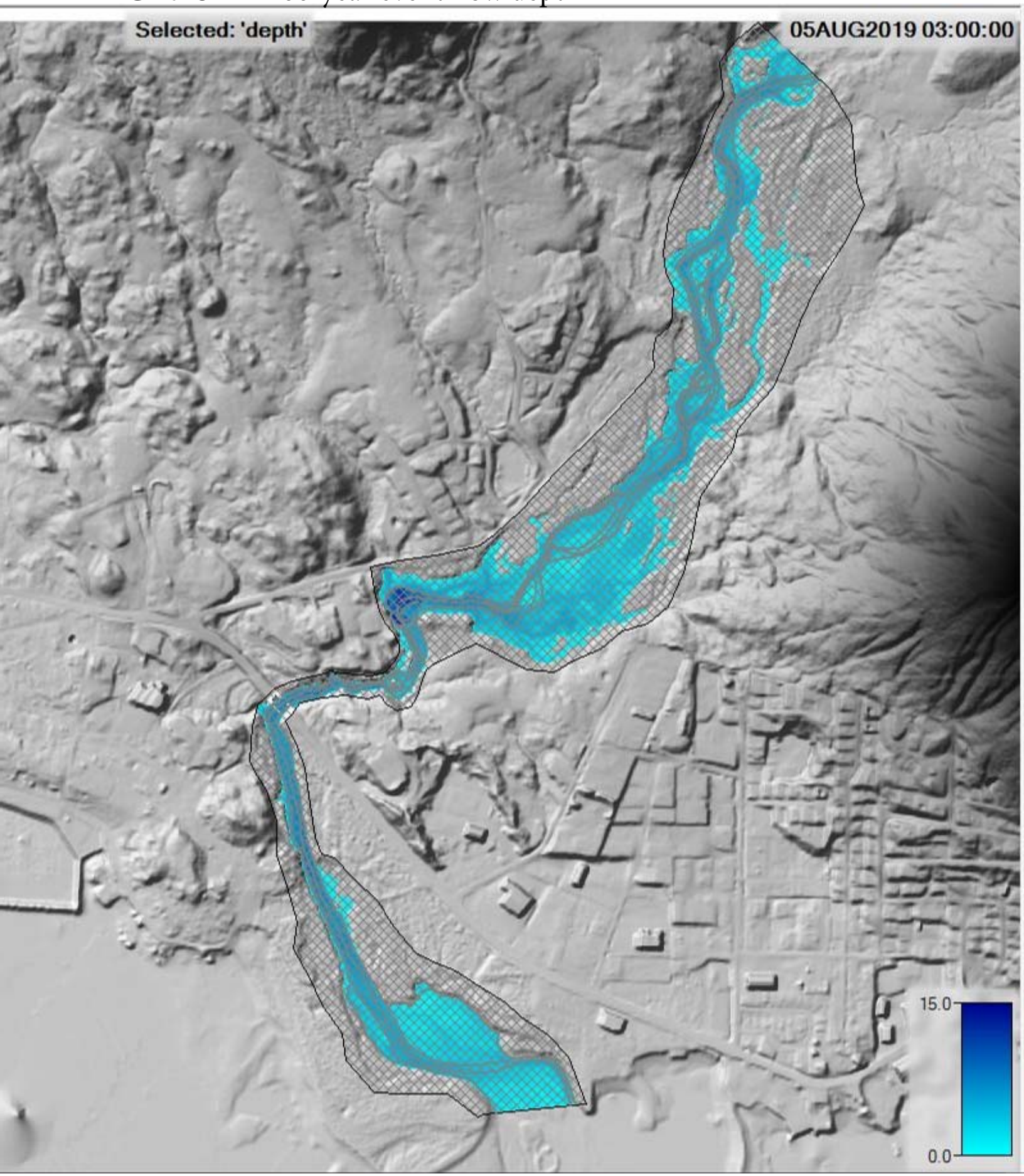
HEC-RAS 2D 10-year event flow velocity



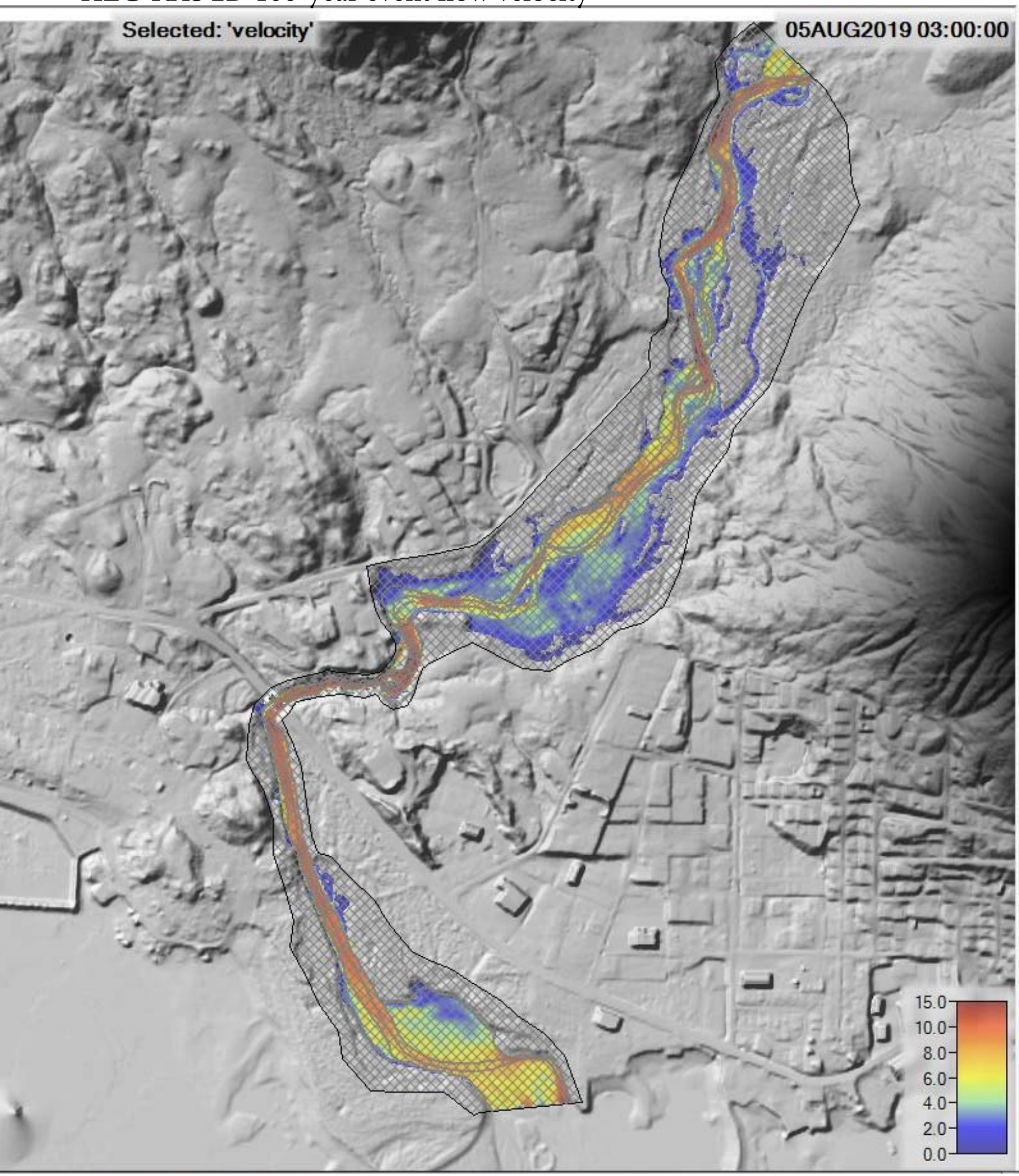
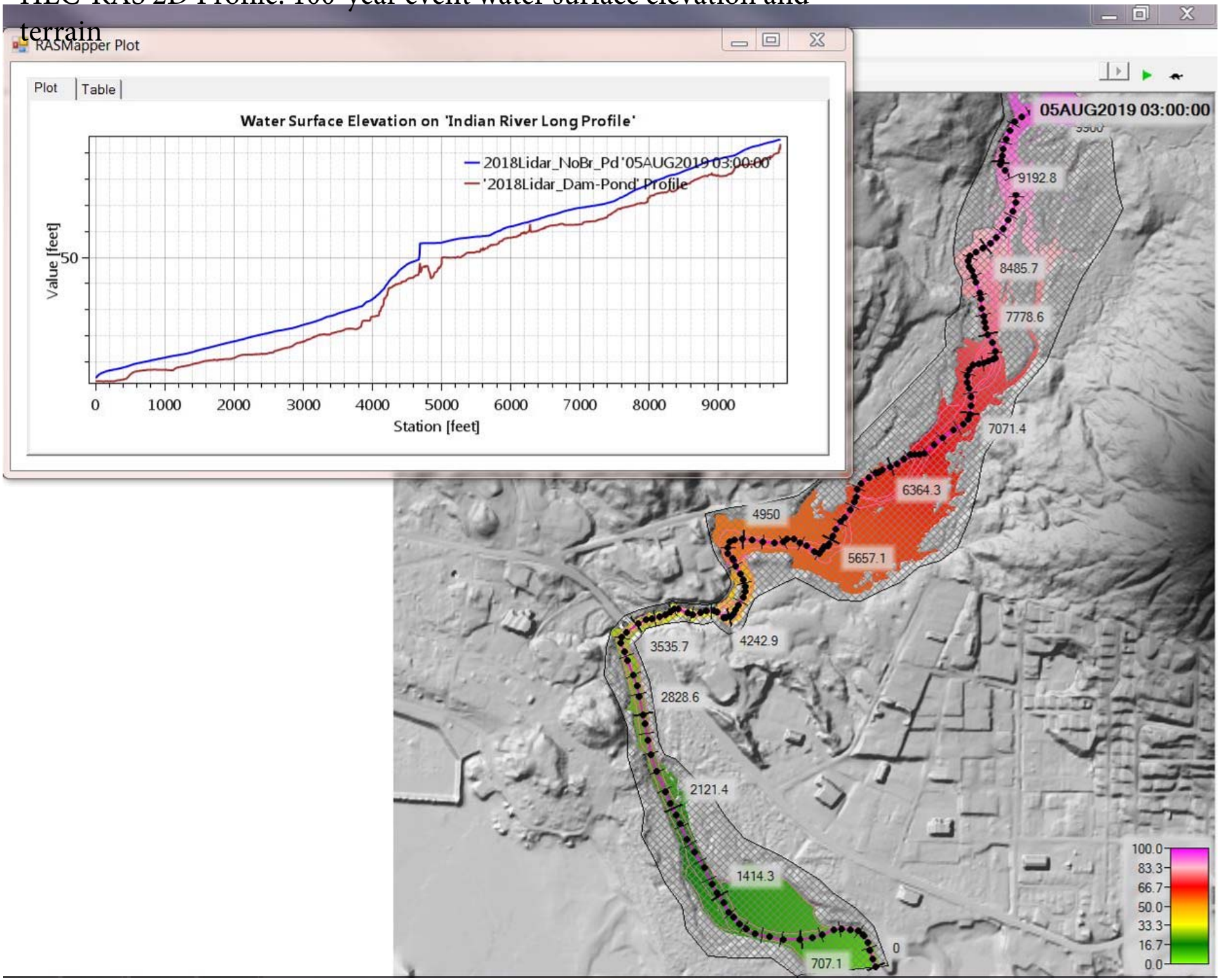
HEC-RAS 2D Profile: 10-year event water surface elevation and terrain



HEC-RAS 2D 100-year event flow depth



HEC-RAS 2D 100-year event flow velocity



HEC-RAS 2D Profile: 100-year event water surface elevation and terrain