Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries
(Study 9.12)

Fish Passage Criteria Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2014

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
2-D	Two dimensional
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
CDFG	California Department of Fish and Game
ft	feet
ISR	Initial Study Report
Q1	First quarter
TM	Technical Memorandum
USFS	United States Forest Service

1. INTRODUCTION

The Initial Study Report (ISR) for Study 9.12, Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries Part A: Sections 1-6, 8-10, outlined the approach for selecting target fish species and passage criteria for the fish passage barrier analysis. AEA proposed a draft target species list and depth, leaping and velocity criteria in a technical team meeting on March 19, 2014. During and following the technical team meeting, AEA received input from the licensing participants. This Technical Memorandum (TM) presents a proposed final list of fish species that will be included in the fish barrier analysis as well as depth, leaping and velocity passage criteria for selected fish species.

2. FISH SPECIES AND PASSAGE CRITERIA SELECTION

Anadromous and resident fish species require access to a range of habitats to complete their life cycle for spawning, incubation and rearing. Moreover, passage of returning adults or outmigrating juveniles must be achieved during specific periods. The movement of fish between the mainstem Susitna and off-channel habitats and tributaries requires adequate depth, velocity and gradient conditions that can be attained by species with varying capabilities and at different life stages. Depth barriers can prevent or delay fish passage between the mainstem Susitna and off-channel habitats such as sloughs and side channels. Depth and velocity barriers may affect fish passage at the mouth of tributaries to access tributary habitats. Lastly, cascades and waterfalls are the main physical barriers within tributaries and are evaluated with respect to the species-specific swimming and leaping abilities.

2.1. Fish Species Selection

The fish community of the Susitna River includes approximately 19 documented fish species. Within this community, some fish species exhibit life history patterns that rely on multiple habitats during freshwater rearing, and therefore may be more sensitive to changes in access to side channels, sloughs, and/or tributary habitats. A subset of species was selected for the fish passage barrier analysis based on passage sensitivity, species presence in the Middle and Upper Susitna, and the locations of potential barriers (Table 5.1-1). Following the technical team meeting on March 19, 2014, additional species were recommended by licensing participants including Arctic lamprey, Bering cisco, eulachon, northern pike, and humpback whitefish. AEA examined the distribution of these additional species, and it was determined that Bering cisco and eulachon were not present in the study area of the Middle River and Upper River. Consequently, Arctic lamprey and humpback whitefish, which are present in the Middle River were added to the final list that now includes eleven species in total (Table 5-1).

2.2. Passage Criteria for the Selected Fish Species

A literature review of passage criteria was conducted for selected fish species and adult and juvenile life stages. Salmonid passage criteria are well researched and some criteria exist for all salmonid species. Passage criteria for many non-salmonids have not been extensively researched, and in some cases, criteria do not currently exist. Where criteria for selected species were not available, closely related "surrogate" species were substituted. Basic categories of fish passage criteria for use in this study include water depth, fish swimming ability (as related to velocity criteria), and fish leaping ability. Depth criteria will be used to assess fish passage into, within, and out of side channels, sloughs, and tributaries. Leaping criteria will be used to evaluate the vertical and horizontal distances fish must leap to pass a physical barrier. The velocity component of passage at a physical or depth barrier will be applied where velocity may influence successful passage.

2.2.1. Depth Criteria for Adult Upstream Migration and Downstream Migration

Minimum depth criteria for fish passage have been reported for many fish species. While the majority of studies focus on the design of fish ladders, culverts or other man-made structures, fewer studies focus on fish passage in natural channels (R2 Resource Consultants 2007). The criteria chosen for minimum depth requirements vary by study. A minimum depth may be chosen that a fish species can successfully swim through (Furniss 2008), or a minimum depth may be considered that is required to fully submerge the species (Powers and Orsborn 1985). In other studies, a body depth plus an additional depth to account for fish behavior, injury prevention or substrate composition is suggested (for example 2.5 times the caudal fin depth; ADF&G 2001). Overall, minimum depth varies with fish size and life stage. A range of minimum depth criteria from the literature for selected fish species and life stages are presented in Table 5-2.

2.2.2. Leaping Criteria for Adult Upstream Migration

The ability of a fish to pass a vertical barrier is determined by species- and life stage-specific endogenous factors such as burst speed, swimming form, and leaping capability. Exogenous factors include water depth, stream flow, and barrier geometry. Powers and Orsborn (1985) present a detailed analysis of passage at physical barriers to upstream migration by salmon and trout. Powers and Orsborn (1985) present criteria for Chinook, coho, sockeye, pink, and chum salmon passage at waterfalls and cascades. Other sources of leaping height criteria are available from Reiser and Peacock (1985) and the USFS (2001). Table 5-3 presents the leaping criteria from these sources.

Leaping curves and jumping equations assume that the depth of the pool the fish must leap from is adequate. Reiser and Peacock (1985) also suggest a ratio of 1:1.25 (barrier height/leaping pool depth) and a pool depth of at least 2.5 meters (8.2 ft). Aaserude and Orsborn (1985) concluded that for optimum leaping conditions the depth of the leaping pool must be on the order of, or greater than, the length of the fish attempting to pass. These general guidelines are incorporated into the USFS 2001 Aquatic Habitat Management Handbook for the Alaska Region and presented in Table 5-4.

An additional impediment to upstream passage is a gradient over reach distance. Fish passage may occur at steeper gradients over shorter reaches (e.g. > 50 ft at 20 percent gradient for Chinook, coho and sockeye), but the gradient for successful passage decreases with increasing reach length (see Table 5-4). The USFS (2001) gradient criteria indicate that Dolly Varden have the greatest ability to attain steep gradients for short distances, followed by Chinook, coho and sockeye, and pink and chum salmon are the poorest leapers. Overall, a combination of waterfall height, pool depth, and cascade length and gradient above and below waterfalls are used to evaluate the impediments for fish passage in Study 9.12.

2.2.3. Velocity Criteria

Stream velocities higher than a fishes swimming speed can create barriers to upstream migration. If velocity barriers to upstream adult migration currently exist or if they are created by the Project, they would likely occur as temporary barriers during high flow in tributaries. Gradients or channel constrictions at the entrances to sloughs and side channels are likely not sufficient to create velocity barriers to adult fish or juveniles with or without the Project. Furthermore, in natural river and stream systems, rapids will often have areas of flow that are below the maximum velocity criteria. Velocity only becomes an effective barrier when flow is concentrated in a chute and its combined length and velocity overcome the fish’s swimming ability, and the geometry of the channel does not enable the fish to leap over or otherwise avoid the velocity barrier (R2 Resource Consultants 2007).

Modes of fish swimming can be classified as one of three categories: sustained, prolonged, or burst swimming (Beamish 1978). Sustained swimming is that which can be maintained indefinitely (more than 200 minutes) and is also referred to as cruising speed. Prolonged swimming is a more moderate speed than sustained speed that can be maintained for a specific period of time (20 seconds to 200 minutes). Burst swimming is the fastest speed achievable and can only be maintained for short durations (less than 20 seconds) as it utilizes more anaerobic metabolism than the other swimming modes. Similar to the Fish Passage Study 9.11, the Fish Passage Barrier Study 9.12 focused on burst swimming and prolonged swimming. Prolonged swimming is an indication of a fish’s ability to traverse longer reaches, whereas burst swimming provides an indication of the ability of fish to traverse discrete high velocity areas. We recommend that high-end prolonged speed and burst speed are applicable to fish passage in higher velocity and gradient reaches found in Susitna River tributaries. A literature review of prolonged and burst speeds for adult and juvenile fish species are reported in Table 5-5.

3. APPLICATION OF PASSAGE CRITERIA

The application of depth and velocity criteria for fish passage has been examined extensively with respect to man-made structures, but few established criteria exist for evaluating natural channels. Thompson (1972) presented the most widely used approach to evaluate passage for a river or stream reach. The critical passage section of the reach is identified by a transect that follows the shallowest course from bank to bank. A flow is considered adequate for passage when minimum depth and maximum velocity criteria are met for at least 25 percent of the total transect width and for a continuous portion for at least 10 percent of the total width. Other studies have suggested that the Thompson (1972) method is relatively conservative and that narrower passage widths may be used for successful fish passage (Mosley 1982). Mosley (1982) noted that while it is possible for fish to pass reaches shallower than minimum depth criteria, abrasion and loss of spawning condition was observed. The Thompson (1972) method has been applied in California streams with a regression method to identify flow rates that meet the minimum continuous and total passable widths (CDFG 2013).

ADF&G (1984) determined that depth of water and length of passage reach were the most significant factors affecting migrating fish in sloughs and side channels. Multiple cross section profiles perpendicular to the channel were surveyed and the deepest point representing the thalweg was identified. Longitudinal thalweg profiles were mapped by connecting the deepest point along the entire length of each slough and side channel site during low water conditions. Passage curves representing passage depth requirements as a function of reach length were developed for chum salmon for uniform (<3 inches) and non-uniform (>3 inches) substrates (ADF&G 1984, Study 9.12 ISR (Figures 4.2-1 and 4.2-2)). Using this “passage reach” concept, the minimum depth required for successful passage increases with reach length. Overall, three categories of passage were developed ranging from “successful”, “successful with difficulty and exposure”, to “unsuccessful”. For example, over a 0 to 200 ft reach length the minimum depth for the “successful with difficulty and exposure” category, ranged from 0.18 to 0.32 ft and 0.3 to 0.41 ft for uniform and non-uniform substrates, respectively. In contrast, the minimum depth for the more conservative “successful” category, ranged from 0.30 to 0.41 ft and 0.41 to 0.54 ft for uniform and non-uniform substrates, respectively.

The approaches outlined above provide a basis for applying depth criteria to sloughs and side channels in Focus Areas of the Susitna River. The final approach will be refined to account for the range of target species in Table 5-1 and will be based on 2-D model results from the Fluvial Geomorphology Modelling Study 6.6. For the side channels and sloughs, results from the 2-D hydraulic models will provide comparisons of existing conditions and with-Project conditions over a range of discharges. The 2-D model results for evaluating passage into tributaries will include the potential for fan growth, changes in slope and length of the tributary channel within the fan, and the location and elevation of the intersection of topset and forest slopes. This information would be combined with hydraulic and hydrologic information for the mainstem and tributary to evaluate potential with-Project changes to tributary access. Lastly, the Study 7.6 Ice Processes Study will use the River2D model in Focus Areas during the ice-cover period in coordination with the 2-D hydraulic model to evaluate how ice conditions may influence fish passage between the mainstem Susitna River and sloughs or side-channels.

Overall, model outputs will be used to evaluate minimum water depth and corresponding discharge at key areas for passage between mainstem and off-channel habitats. ADF&G (1984) evaluated breaching and backwater conditions at the heads and mouths of sloughs and side channels that were considered critical points for fish access in Focus Areas. Similarly, 2-D model coverage across Focus Areas FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-115 (Slough 6A), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), FA-144 (Slough 21), FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam) will enable mapping of the minimum depths across key access points as well as the longitudinal extent of depth in the upstream and downstream direction. The spatial distribution of minimum water depth and corresponding flow rates will be used to determine the duration of successful or unsuccessful passage conditions. These passage conditions will be compared with the periodicity of anadromous migration as well as known patterns of resident fish movement.

The final approach that will be used in this study is being refined in coordination with the Study 6.6 Fluvial Geomorphology Modelling and the Study 7.6 Ice Processes. The first step will be to test the methodologies for the 2-D model runs for FA-128 (Slough 8A) in Q1 2015 with the results presented in the AEA (2014b) technical memorandum. Subsequent analysis will include model output from River2D in Focus Areas during the ice-cover period.

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5. TABLES

Table 5-1. AEA proposed species list, additional species suggested by licensing participants, and preliminary species list following consultation during fisheries technical meeting on March 19, 2014.

AEA Proposed Species List	Additional Species Suggested by Licensing Participants	Species List Following Consultation
Chinook salmon	Arctic lamprey	Chinook salmon
Chum salmon	Bering cisco[1]	Chum salmon
Coho salmon	Eulachon[1]	Coho salmon
Pink salmon	Northern pike[1]	Pink salmon
Sockeye salmon	Humpback whitefish	Sockeye salmon
Arctic grayling		Arctic grayling
Burbot		Arctic lamprey
Dolly Varden		Burbot
Rainbow trout		Dolly Varden
		Humpback whitefish
		Rainbow trout

[1] Species not added due to absence from study area

Table 5-2 Depth criteria reported in the literature for selected fish species and adult and juvenile life stages

Species	Life Stage	Depth Criteria	
		Feet	References
Arctic grayling	*adult*	0.6	ADFG (2001)
	juvenile	0.4	ADFG (2001)
Dolly Varden	*adult*	0.2 - 1.0	ADFG (2001)
	juvenile	0.2	Bugert et al. (1991)
Chinook salmon	*adult*	0.8 - 0.9	CDFG (2013), Thompson (1972)
	juvenile	0.3	CDFG (2013)
Coho salmon	*adult*	0.6 - 0.7	CDFG (2013), Thompson (1972)
	juvenile	0.3	CDFG (2013)
Chum salmon	*adult*	0.6 - 0.8	CDFG (2013), Thompson (1972)
	juvenile	0.3	CDFG (2013)
Pink salmon	*adult*	0.6 - 0.8	CDFG (2013), Thompson (1972)
	juvenile	0.3	Nordlund, B. (2008)
Sockeye salmon	*adult*	0.6 – 0.7	Bates et al. (2003)
	juvenile	0.3	CDFG (2013)
Rainbow trout	*adult*	0.5 - 0.7	Snider (1985), CDFG (2013)
	juvenile	0.3	CDFG (2013)

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Table 5-3 Pacific salmon leaping height capabilities from three sources.

Species	Leaping Height (in feet)		
	Powers and Orsborn (1985)[1]	Reiser and Peacock (1985)	USFS (2001)
Dolly Varden	-	-	6
Chinook	7.5	7.9	11.0
Chum	3.5	4.0	4.0
Coho	7.5	7.3	11.0
Pink	3.5	4.0	4.0
Sockeye	7.5	6.9	10.0

Note: Assumes a trajectory of 80^0 with a condition factor of 1.0. Maximum leaping height is less at a lower trajectory and lower fish condition factor.

Table 5-4 Pool depth and gradient criteria adapted from the Forest Service Handbook (FSH) 2090.21 Adult Salmonid Migration Blockage Table.

	Species				
Criterion	Chinook	Coho	Sockeye	Pink/Chum	Dolly Varden
Pool depth A blockage may be presumed if pool depth is less than the following, and the pool is unobstructed by boulders or be bedrock:	1.25 x jump height, except that there is no minimum pool depth for falls: (a)<4 feet (1.2,) in the case of coho and steelhead; and (b)<2 feet (0.6m) in the case of other anadromous fish species.				
Steep channel A blockage may be presumed if channel steepness is greater than the following without resting places for fish:	>225 feet (68.6m) @ 12% gradient >100 feet (30.5m) @ 16% gradient >50 feet (15.2m) @ 20% gradient			>100 feet (30.5m) @ 9% gradient	>50 feet (15.2m) @ 30% gradient

Table 5-5 Swimming capabilities and velocity criteria reported in the literature for selected fish species including adult and juvenile life stages.

Species	Life Stage	Prolonged Speed		Burst Speed	
		ft/s	References	ft/s	References
Arctic Grayling	*Adult*	1.4 - 4.1	Katapodis (1992)	6.9 - 13.9	Bell (1991)
	Juvenile	0.5 - 0.8	Deegan et al. (2005)	*NR*	*NR*
Arctic Lamprey	*Adult*	0.2 - 0.8	*Robinson and Bayer (2005), *Clemens (2012)	2.5 to 10	*Mesa et al. (2003), *Keefer (2010)
	Juvenile	0.3 - 0.6	*Sutphin and Hueth (2010)	1.0 to 2.5	*Sutphin and Hueth (2010)
Burbot	*Adult*	1.3 - 2.6	Jones et al. (1974), Schwalme et al. (1985)	1.1 to 4.0	Bell (1991)
	Juvenile	1.1 - 1.3	Jones et al. (1974)	*NR*	*NR*
Dolly Varden	*Adult*	2.0 - 3.3	**Beamish (1980)	4.2 to 7.5	+Mesa (2004)
	Juvenile	0.5-1.6	+Mesa (2004)	*NR*	*NR*
Humpback whitefish	*Adult*	1.0 - 2.3	Jones et al. (1974), Beamish (1980)	3.0 - 4.0	Bell (1991)
	Juvenile	0.2 to 1.3	Jones et al. (1974)	*NR*	*NR*
Chinook salmon	*Adult*	2.9 - 11.0	Bell (1991)	11.0 - 22.1	Bell (1991)
	Juvenile	0.5 - 0.9	Furniss et al. (2008)	2.0 - 2.3	Randall et al. (1987)
Coho salmon	*Adult*	3.1 - 10.9	Lee et al. (2003)	11.7 - 21.0	Bell (1991)
	Juvenile	0.4 - 2.1	Bell (1991)	*NR*	*NR*
Chum salmon	*Adult*	1.7 - 5.1	Aaserude and Orsborn (1985)	6.0 - 12.6	Powers and Orsborn (1985)
	Juvenile	0.4 - 0.6	Smith and Carpenter (1987)	*NR*	*NR*
Pink salmon	*Adult*	2.9 - 11.0	Lee et al. (2003), Bell (1991)	11.0 – 21.0	Bell (1991)
	Juvenile	0.4 - 0.5	Smith & Carpenter 1987	7.7 – 11.0	Powers & Orsborn (1985)
Sockeye salmon	*Adult*	4.0 – 8.8	Bell (1991)	10.0 - 21.9	Bell (1991), Bainbridge (1960)
	Juvenile	1.4 - 2.1	Bell (1991)	*NR*	*NR*
Rainbow trout	*Adult*	2.1 - 2.6	Furniss (2008)	14.0 - 20.3	Bell (1991)
	Juvenile	1.0 - 2.0	Bainbridge (1960)	2.4 - 7.2	Bainbridge (1960)

*for Pacific lamprey
**for Arctic char
+for Bull trout
NR = no reference available

APPENDIX A: NOTES FROM TECHNICAL TEAM MEETING MARCH 19, 2014

Meeting Notes
Fisheries Technical Meeting
03/19/2014

LOCATION: **Alaska Energy Authority – Board Room**
813 West Northern Lights Blvd.
Anchorage, AK 99503

TIME: **1:00 p.m. – 4:30 p.m. (AKST)**

SUBJECT: **Study 9.12 - Fish Barriers Study**

Goal **Collaboration on topics as identified in the Study Plan**

ATTENDEES: **Kathryn Peltier** McMillen, **Scott Crowther** Ratepayers, **MaryLouise Keefe** R2, **Betsy McGregor** AEA, **Lori Verbrugge** USFWS, **Phil Hilgert** R2, **Bill Fullerton** Tetra Tech, **Kevin Petrone** R2

ON PHONE: **Betsy McCracken** USFWS, **Matt Cutlip** FERC, **Nick Jayjack** FERC, **Matt Love** VNF, **Sharon Kramer** CIRI fisheries consultant, **Stormy Haught** ADF&G, **Kai Steimle** R2, **Dara Glass** CIRI **Joe Klein** ADF&G, **Sue Walker** NMFS (part of meeting), **David Pizzi** Tetra Tech

The purpose of this meeting was to collaborate with licensing participants on topics identified in the Study Plan and during the December 2013 TWG meetings. Through this collaboration, AEA hopes to include input from licensing participants into the final ISR section 7 (plans for completing the study). Comments and suggestions are welcomed by AEA and can be provided by contacting Betsy McGregor (BMcGregor@aidea.org).

The following meeting notes are intended to capture any significant discussion/information in addition to the materials provided on the Project website (http://www.susitna-watanahydro.org/). The meeting agenda and materials are available under the "previous meetings" tab (link provided under the meetings tab) on the Project website.

Study 9.12 Fish Passage Barriers Presentation - Kevin Petrone

Betsy McCracken said that the USFWS will be submitting formal suggestions/comments to the final ISR.

Target/Priority Species - Based on the criteria explained in slide 4, slide 5 indicates the proposed target species for the Fish Passage Barrier Study. Some of these species can be targeted for specific reaches since their presence has not been documented throughout all reaches of the study area.

- Stormy Haught suggested that humpback whitefish be considered for Lower River reaches.

- Betsy McCracken suggested considering eulachon in the Lower River reaches. Stormy Haught indicated that eulachon would be limited to the mainstem and would not be entering tributaries.
- Betsy McCracken explained that arctic lamprey require unique passage requirements and should be approached with methods specific to the species. Stormy Haught agreed with this suggestion. MaryLouise Keefe indicated that AEA will be in contact Betsy McCracken regarding lamprey details.
- Betsy McCracken suggested focusing some efforts on predicting the reduction of passage for northern pike. Stormy Haught confirmed that northern pike are mostly sedentary, but move throughout systems on occasion; not yet above ~ River Mile 60. Phil Hilgert suggested that once potential Project- induced passage barrier changes are evaluated, tributaries impassable for northern pike could be identified. Stormy later added that northern pike are not good swimmers and will be restricted by velocity barriers which may not restrict other species.
- Betsy McCracken suggested targeting Bering cisco in the Lower River, although she is unsure if they access tributaries.
- Scott Crowther said that he has caught rainbow trout in Susitna Lake and Lake Louise (near the headwaters of the Susitna River). MaryLouise Keefe explained that thus far, those populations do not show signs of entering the study area and seem to be isolated. The study area's upper extent ends just upstream of the inundation zone near the confluence of the Oshetna River.

Kevin Petrone explained that the study is currently focused on Middle and Upper River segments. Based on information from the open water flow routing model (expected in time for the Proof of Concept meeting this spring), the Lower River may be included in this study. If the Lower River were to be added, suggestions related to Lower River species would be considered.

Species-specific Passage Criteria – Slides 6-22 explain the passage criteria which will be determined for each target species. Details are provided in the fish passage feasibility draft ISR (Study 9.11).

- Slide 8 does not include burbot which have a prolonged speed of 1 foot per second (fps) and burst speed of 1-4 fps.
- Kevin Petrone proposed that burst speeds be used as criteria to determine movement in evaluating velocity barriers. In response to MaryLouise, Kevin will look into the literature to see if velocity barrier lengths are a factor. Sharon Kramer mentioned that fish are able to take "breaks" in low velocity pockets. Bill Fullerton explained that the model resolution is approximately 2 meters at slough mouths within Focus Areas. This will not identify things such as a 1-foot boulder with a small eddy with a low velocity pocket.
- Matt Cutlip asked if models will be verifying the "Gradients or channel constrictions at entrances to sloughs and side channels not sufficient to create velocity barriers for adult or juvenile fish" component of the study. Kevin explained that models will be evaluating this, but other criteria are expected to play a larger role in increasing/decreasing barriers.
- Based on the information in slide 11, the study is considering a 12-foot elevation difference a definitive barrier (1 foot over the max. leap height).
- MaryLouise Keefe mentioned that there were no leaping criteria found for some species and asked if Betsy McCracken knew of any surrogates used. Most criteria were determined for culverts and the criteria may be different for natural systems. Stormy Haught said that

steelhead may be used as a surrogate for rainbow trout. MaryLouise added that juvenile steelhead would be comparable in size to adult rainbow.

- Betsy McCracken and Sharon Kramer will look to see if they can provide suggestions for surrogates.
- Depth criteria are from the ADF&G/DOT culvert document and are presented on slide 16.
- Data provided on slides 19-20 are only from the Fish Distribution and Abundance in the Middle and Lower River Study (Study 9.6). Juvenile screw trap counts and Salmon Escapement (Study 9.7) data will be added to these tables and reposted. Otolith analyses for humpback whitefish and Dolly Varden are not yet available to determine the upper extent of species anadromy.
- Data for the studies are provided in the respective draft ISR. Summaries are in the draft ISR text or appendices with more detailed data provided on GINA (link in draft ISR).
- MaryLouise explained that lamprey were found throughout the river and since most were juvenile fish they were unable to be identified to species. Very few Bering cisco, less than 10 total, were found in the Lower River late in the summer.
- Periodicity on slide 22 reflects data from the 1980s. This table will be updated with current data throughout the study.

Application of Passage Criteria – Slides 23-27 present the proposed application of the passage criteria. The approach is being proposed, and details will be refined as data is available.

- The figures on slides 25-27 are from the 1980s studies. The dotted line on slides 25-26 should be located at 0.41 feet on the Y axis.
- The 1980s used chum as a surrogate for all salmon species because they have a deep body and are weak swimmers; assuming that if chum could pass, other salmonids could pass. Sue Walker said that there is no need to limit analyses to one surrogate and that more specific analyses per habitat is needed.
- Kevin Petrone explained that the details of the approach will be discussed when sediment model results are available (not expected for a while).
- Phil Hilgert said that it is important to determine the timing/duration below a minimum passage depth to accurately influence operations.

Geomorphological Assessment and Modeling – Bill Fullerton presented slides 28 – 38 to discuss the geomorphology studies (Study 6.6) in relation to fish passage. Data provided in slides 31, 34, and 37 do not include escapement data. These data will be added to the presentation tables and the online presentation will be updated.

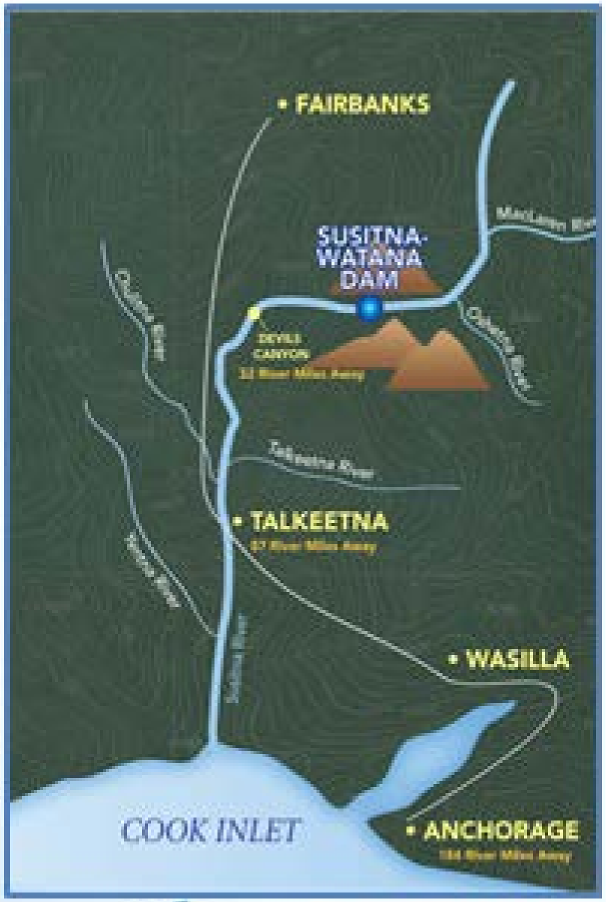
In slide 31, the fish species acronyms follow ADF&G standards and are defined as follows:
SCK – Chinook salmon; GBR – Burbot; CDV – Dolly Varden; WRN – Round whitefish; GRA – Arctic grayling

- Lori Verbrugge asked what variables are being considered when selecting tributaries (as indicated in green on slides 31, 34, and 37). Bill Fullerton said that the presence of fish is the primary factor. The red highlighted tributaries are not proposed for studies of delta formation and potential barrier impacts mostly because the drainage areas are small (thus low potential to produce the quantity of sediment to form deltas) or existing barriers at elevations above the reservoir pool will limit access to habitat. Tributaries without highlighting (white) do not have a clear basis for recommending further study, so the licensing participants were asked for input. Note that all tributaries in Focus Areas will have sediment modeling applied.

- Unnamed tributary 115.4 on slide 37 has a pseudo-lake at the mouth so it is not considered a significant contributor of sediment. Also, Whiskers Creek's sediment influence is masked by Whiskers Slough.

Action Items	**Responsibility**
If the Lower River is added to Fish Passage Barriers Study Area: Consider the following target species: • humpback whitefish • eulachon (mainstem) • Bering cisco; Identify tributaries where accessibility by northern pike may change.	AEA
Add lamprey to the target species lists for Middle and Upper River as applicable based on fish distribution data.	AEA
Determine if velocity barrier length is a needed factor for fish passage criteria.	R2
Coordinate with Betsy McCracken regarding potential need and criteria for lamprey.	R2
Identify surrogate species and their passage criteria that can be used in this study.	Licensing participants
Add 2013 rotary screw trap and fish escapement data to the presentation and repost to website.	AEA

APPENDIX B: PRESENTATION FROM TECHNICAL TEAM MEETING MARCH 19, 2014



Fisheries Technical Meeting

Study 9.12 Fish Passage Barriers

March 19, 2014

Prepared by
R2 Resource Consultants, Inc. & Tetra Tech, Inc.

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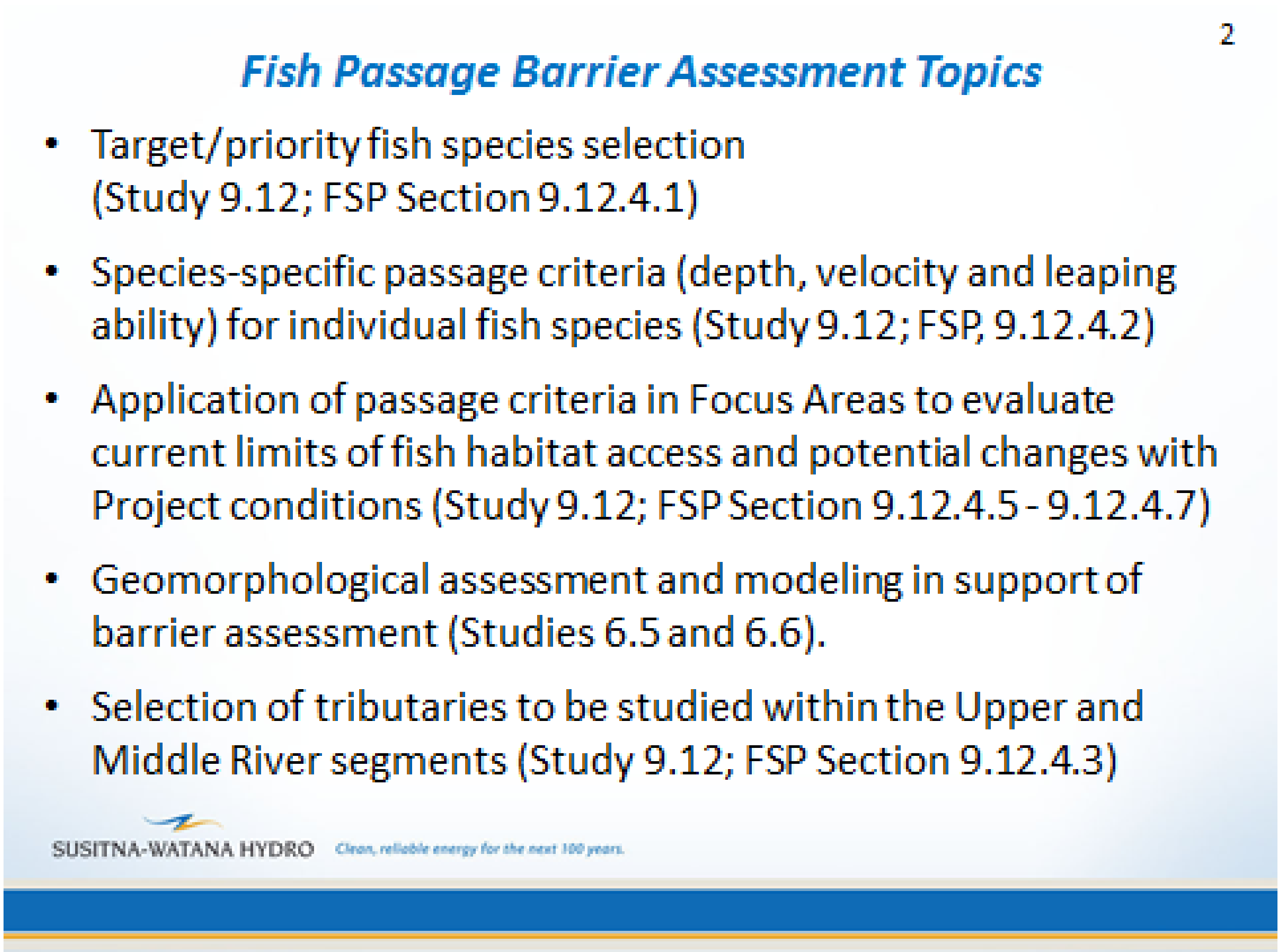
2
Fish Passage Barrier Assessment Topics
• Target/priority fish species selection (Study 9.12; FSP Section 9.12.4.1)
• Species-specific passage criteria (depth, velocity and leaping ability) for individual fish species (Study 9.12; FSP, 9.12.4.2)
• Application of passage criteria in Focus Areas to evaluate current limits of fish habitat access and potential changes with Project conditions (Study 9.12; FSP Section 9.12.4.5 - 9.12.4.7)
• Geomorphological assessment and modeling in support of barrier assessment (Studies 6.5 and 6.6).
• Selection of tributaries to be studied within the Upper and Middle River segments (Study 9.12; FSP Section 9.12.4.3)
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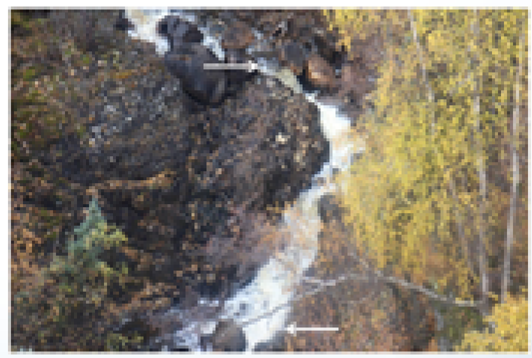
3

9.12 Fish Passage Barriers – Objectives

- *Locate and categorize existing barriers in selected Middle and Upper River tributaries*
- *Evaluate potential changes to existing barriers within the influence of the Project*
- *Evaluate potential Project-induced creation of barriers*



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4

Susitna Fish Species
Arctic grayling
Dolly Varden
Humpback whitefish
Round whitefish
Burbot
Longnose sucker
Sculpin
Eulachon
Bering cisco
Threespine stickleback
Arctic lamprey
Chinook salmon
Coho salmon
Chum salmon
Pink salmon
Sockeye salmon
Rainbow trout
Northern pike
Lake trout

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Target Species Selection

- 9.12 Study Plan - select same species or a sub-set of those selected for IFS Study 8.5
- Apply same 3 criteria for target fish species selection from Study 9.11 (Fish Passage Feasibility Study):
  - ***Exhibits migratory and/or anadromous behavior*** most significant for species for which migration is necessary to complete its life cycle.
  - ***High relative abundance***
  - ***Important to commercial, sport, or subsistence fisheries***

5

Proposed Fish Passage Species List

Susitna Fish Species
Arctic grayling
Dolly Varden
Humpback whitefish
Round whitefish
Burbot
Longnose sucker
Sculpin
Eulachon
Bering cisco
Threespine stickleback
Arctic lamprey
Chinook salmon
Coho salmon
Chum salmon
Pink salmon
Sockeye salmon
Rainbow trout
Northern pike
Lake trout

→

Arctic grayling
Dolly Varden
Burbot
Chinook salmon
Coho salmon
Chum salmon
Pink salmon
Sockeye salmon
Rainbow trout

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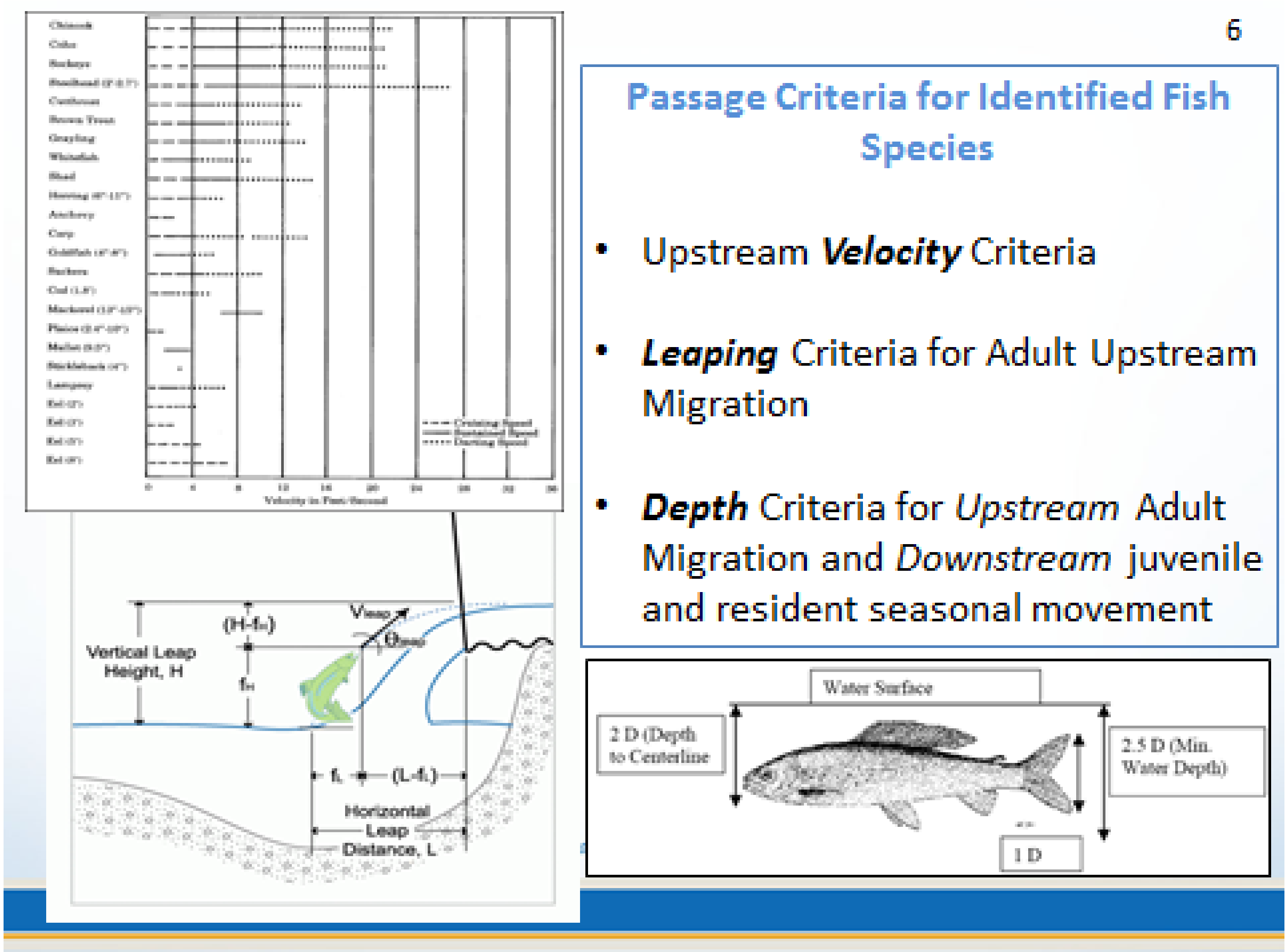
6
Passage Criteria for Identified Fish Species
• Upstream Velocity Criteria
• Leaping Criteria for Adult Upstream Migration
• Depth Criteria for Upstream Adult Migration and Downstream juvenile and resident seasonal movement
Vertical Leap Height, H
Horizontal Leap Distance, L
Water Surface
2 D (Depth to Centerline
2.5 D (Min. Water Depth)
1 D

7

Velocity Criteria

Category	Period	Definitions
Sustained speed	> 200min	Maintained indefinitely w/o fatigue, purely aerobic
Prolonged speed	20s to 200min	Short periods of travel at high speeds, aerobic to anaerobic
Burst speed	< 20s	Max swimming speed or jumping, inducing fatigue, anaerobic

U_{crit} (critical swimming speed) max swimming speed a fish can maintain for a period of time (e.g. 10min, 20min, …) under laboratory conditions. Top end of prolonged speed/aerobic range. Useful for understanding fish passage through culverts

- **Prolonged** swimming and **U_{crit}** indicative of fish ability to travel long distances upstream and how fish condition may change in upper reaches of Susitna
- **Burst** swimming speed useful to understand fish movement across discrete rapids/riffles or high velocity areas

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7

8

Fish Swimming Performance

COMMON NAME		PROLONGED SPEED		BURST SPEED	
		ft/s	References	ft/s	References
Arctic grayling	*adult*	1.4 - 4.1	Katapodis (1992)	6.9 - 13.9	Bell (1991)
	juvenile	0.5 - 0.8	Deegan et al. (2005)	NA	
Dolly Varden	*adult*	2.0 - 3.3	Jones et al. (1974), Beamish (1980)	3.6 - 4.4	Beamish 1980
	juvenile	0.5-1.6*	Mesa (2004) *for Bull Trout*	NA	
Chinook salmon	*adult*	2.9 - 11.0	Bell (1991)	11.0 - 22.1	Bell (1991)
	juvenile	0.5 - 0.9	Furniss et al. (2008)	2.0 - 2.3	Randall et al. (1987)
Coho salmon	*adult*	3.1 - 10.9	Lee et al. (2003)	11.7 - 21.0	Bell (1991)
	juvenile	0.4 - 2.1	Bell (1991)		
Chum salmon	*adult*	1.7 - 5.1	Aaserude/Orsborn (1986), Smith/Carpenter (1987)	6.0 - 12.6	Powers and Orsborn 1985
	juvenile	0.4 - 0.6	Smith and Carpenter (1987)	NA	
Pink salmon	*adult*	2.9 - 11.0	Lee et al. (2003), Bell (1991)	11.0 – 21.0	Bell (1991)
	juvenile	0.4 - 0.5	Smith & Carpenter 1987	7.7 – 11.0	Powers & Orsborn (1985); Hawkins & Quinn (1996)
Sockeye salmon	*adult*	4.0 – 8.8	Bell (1991)	10.0 - 21.9	Bell (1991), Bainbridge (1960)
	juvenile	1.4 - 2.1	Bell (1991)		
Rainbow trout	*adult*	2.1 - 2.6	Furniss (2008)	14.0 - 20.3	Bell (1991)
	juvenile	1.0 - 2.0	Bainbridge 1960	2.4 - 7.2	Bainbridge 1960

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Velocity Criteria (cont)

9

- Swimming speed proportional to fish length

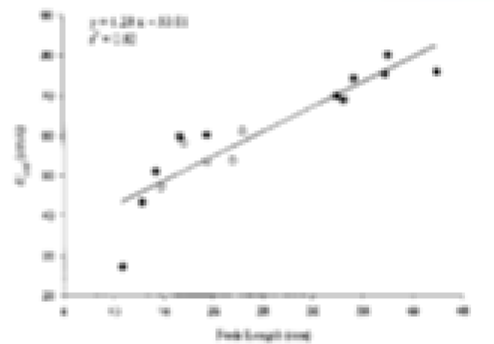
  Adult speed > Juvenile speed
- Gradients or channel constrictions at entrances to sloughs and side channels not sufficient to create velocity barriers for adult or juvenile fish
- Velocity barriers most likely a factor in tributaries where steep gradients create uniform, high velocity flows in chutes and waterfalls and at tributary mouths before entering the main channel *(Devils Canyon velocity not measured due to safety concerns)*
- Which swimming speed category best represents limitations for fish passage in Susitna River and its tributaries?

Criteria Suggestion - high-end prolonged speed and burst speed represent the fish speeds required to attain chutes and waterfalls in major tributaries

Hunter and Mayor (1998)
Swim Speed Equation

$$V = aL^{b}t^{-c}$$

V = swim speed of fish relative to the water
L = length of the fish
t = time to exhaustion
a,b,c = regression constants



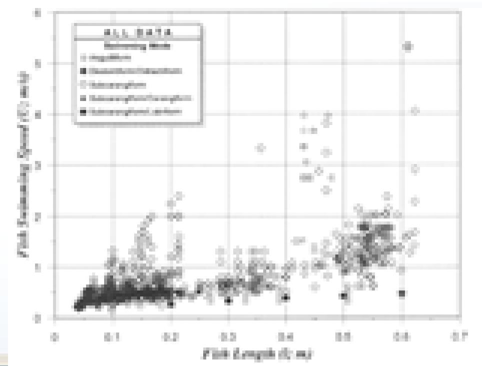
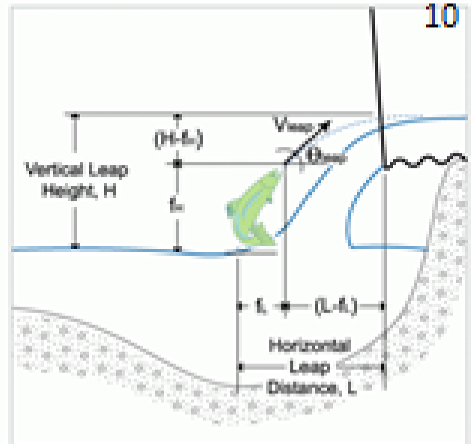


Fig. 1. Swimming speed vs fish length by swimming mode.

9

Leaping Criteria

- Ability of fish to pass a vertical barrier is determined by:
  - species- and life stage-specific factors such as burst speed, swimming form, and leaping capability.
  - water depth, stream flow, and barrier geometry
- Leaping curves and jumping equations assume pool depth below barrier is adequate
  - 1:1.25 barrier height/leaping pool depth (Powers Orsborn 1985)
  - Pool depth at least 2.5m (Reiser and Peacock 1985)
- Other barrier considerations – stream gradient
  - 8% sustained slope (CA Habitat Restoration Manual)
  - >20% for 30ft (OR Dept of Forestry)
  - w/o pools >12% for 30ft adult salmon
  - >20% for 160m (WA Dept F&W)



USFS Fish Xing Leaping equations

$$H = V_{leap}(\sin\theta_{leap})\ t + \frac{1}{2} g\, t^2$$

$$L = V_{leap}(\cos\theta_{leap})\ t$$

Where:
H = Vertical leap distance
L = Horizontal leap distance
Vleap = Leap velocity
θleap = Leap angle
g = Gravitational acceleration
t = Time

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10

11

Leaping Criteria – literature values

COMMONNAME		LEAPING CRITERIA	
		ft	References
Arctic grayling	*adult*	NA	
	juvenile		
Dolly Varden	*adult*	NA	
	juvenile		
Chinook salmon	*adult*	7.5, 7.9, 11.0	Powers and Orsborn (1984), Reiser and Peacock (1985), USFS (2001)
	juvenile		
Coho salmon	*adult*	7.5, 7.3, 11.0	Powers and Orsborn (1984), Reiser and Peacock (1985), USFS (2001)
	juvenile		
Chum salmon	*adult*	3.5, 4.0, 4.0	Powers and Orsborn (1984), Reiser and Peacock (1985), USFS (2001)
	juvenile		
Pink salmon	*adult*	3.5, 4.0, 4.0	Powers and Orsborn (1984), Reiser and Peacock (1985), USFS (2001)
	juvenile		
Sockeye salmon	*adult*	7.5, 6.9, 10.0	Powers and Orsborn (1984), Reiser and Peacock (1985), USFS (2001)
	juvenile		
Rainbow trout	*adult*	NA	
	juvenile		

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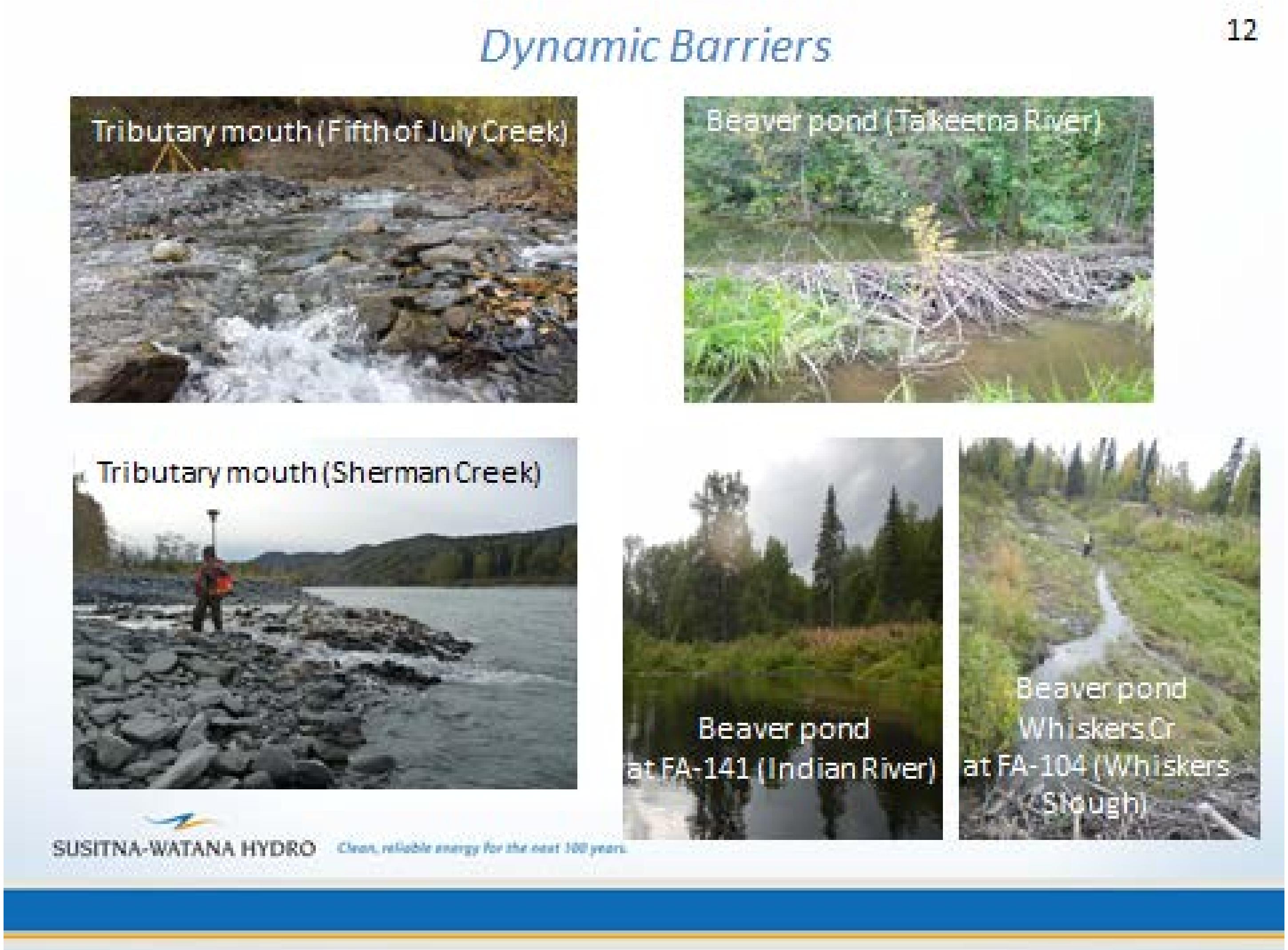
Dynamic Barriers
12
Tributary mouth (Fifth of July Creek)
Beaver pond (Talkeetna River)
Tributary mouth (Sherman Creek)
Beaver pond
at FA-141 (Indian River)
Beaver pond
Whiskers Cr
at FA-104 (Whiskers
Slough)
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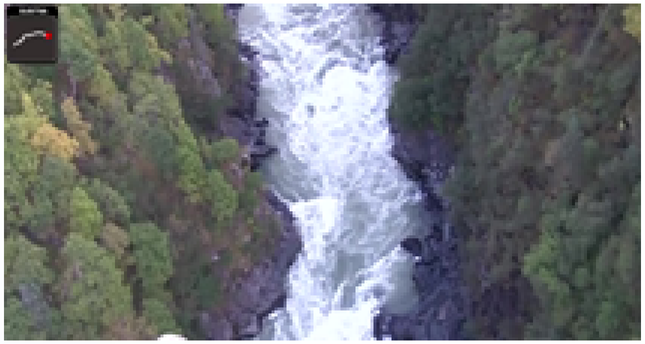
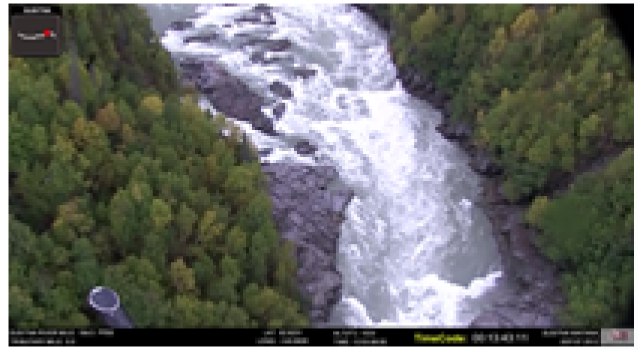
13

Velocity Barriers – Devils Canyon

passage of adult salmon addressed by Study 9.7 (Salmon Escapement)



Impediment 1 (PRM 154.8) – Sept 11, 2012
11,600 cfs at Gold Creek
8,840 cfs at Tsusena



Impediment 3 (PRM 164.5) - Sept 7, 2012
16,500 cfs at Gold Creek
11,800 cfs at Tsusena

- Movement of radio tagged fish will be compared to discharge during spawning period by the Salmon Escapement Study 9.7
- *2012 results – of 313 Chinook salmon radio tagged in Middle River, four passed through impediment 3*
- *2013 results – of 449 large Chinook salmon radio tagged in Middle River, three passed through impediment 3*

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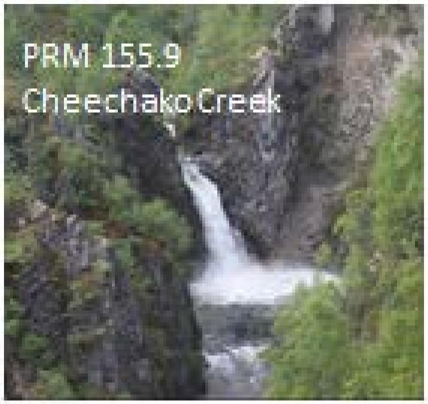
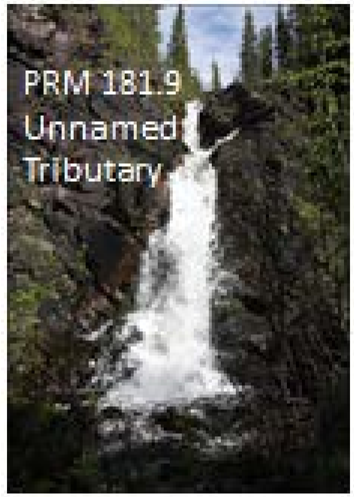
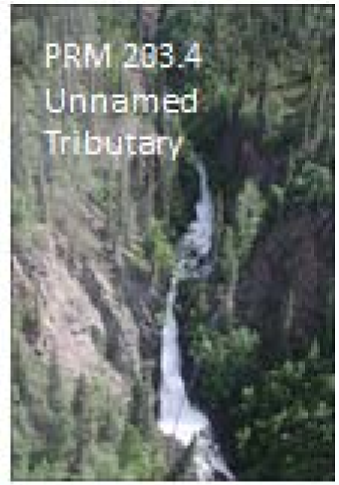
14

Permanent Barriers

Waterfall >12ft







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15

Depth Criteria

- Water depth required to fully submerge the fish species
- Body depth of the fish plus some additional depth to account for a number of factors that could affect passage, such as:
  - Variation in individual size, behavior, and performance;
  - Possible obstacles that must be passed like debris or sediment deposits;
  - The ability to move to some degree in a vertical plane for predator avoidance, or injury prevention (i.e., no contact with solid surfaces)
- "the minimum water depth necessary to minimize wave induced swimming forces is two and one half times the height of the caudal fin" (ADF&G and AKDT&PF 2001).

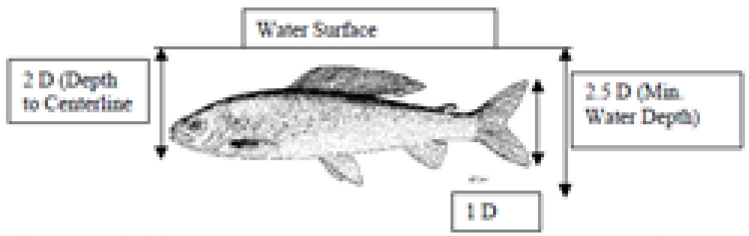

Figure A-2. Minimum water depths for fish passage (D = height of caudal fin).

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15

16

Depth Criteria – literature values

COMMON NAME		DEPTH CRITERIA	
		Ft	**References**
Arctic grayling	*adult*	0.6	ADFG (2001)
	juvenile	0.4	ADFG (2001)
Dolly Varden	*adult*	0.2 - 1.0	ADFG (1985)
	juvenile	0.2	Bugert et al. (1991)
Chinook salmon	*adult*	0.8 - 0.9	OSGC (1963), R2 CDFG 2013
	juvenile	0.3	R2 CDFG (2013)
Coho salmon	*adult*	0.6 - 0.7	R2 CDFG (2013)
	juvenile	0.3	R2 CDFG (2013)
Chum salmon	*adult*	0.6 - 0.8	Thompson (1972), Bates et al. (2003)
	juvenile	0.3	Young, C. (2009)
Pink salmon	*adult*	0.6 - 0.8	Thompson (1972), Bates et al. (2003)
	juvenile	0.3	Nordlund, B. (2008)
Sockeye salmon	*adult*	0.6 – 0.7	Bates et al. (2003)
	juvenile	0.3	Nordlund, B. (2008)
Rainbow trout	*adult*	0.5 - 0.7	Snider (1985), R2 CDFG (2013)
	juvenile	0.3	R2 CDFG (2013)

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17
Potential Depth Barrier
Whisker Slough Mouth
at FA-104 (Whiskers Slough)
upstream view
downstream view
July 18 2013, Susitna R at Gold Creek 16,000-20,000 cfs
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18

Passage Criteria and Fish Abundance/Habitat Use

- Fish **abundance** and **habitat** use considerations
  - Upper River
    - Arctic Grayling (all habitats; MC, SC, BW, CWP, SS)
    - Chinook and Dolly Varden - less abundant
  - Middle River
    - Tributaries – Chinook, Coho, Chum, Pink
    - Sloughs – Chum, Sockeye, some Pink
    - Side Channel/Mainstem - limited use by Chum, Coho, Sockeye
- **Periodicity** – adult anadromous migration, and resident/juvenile migrations
- ***Leaping*** and ***Velocity*** criteria – tributary vertical barriers and mouths
- ***Depth*** Criteria – Focus Areas and Tributary Mouths
  - Upstream – adult anadromous migration
  - Downstream – anadromous juvenile and migratory resident movement between summer rearing and overwintering habitats

18

19

Study 9.5/9.6 FDA Adult and Juvenile Resident Fish Counts by Macrohabitat 2013

Macrohabitat	Dolly Varden	Burbot	Arctic grayling	Rainbow trout
	Upper River			
Black River		11	108	
Clearwater Plume		18	17	
Goose Creek			1502	
Jay Creek	137	3	42	
Kosina Creek			180	
Main Channel		58	270	
Oshetna River		16	227	
Side Channel		3	17	
Side Slough	15		29	
Tsisi Creek			198	
Unnamed Tributary 194.8	71		16	
Upland Slough		1	19	
Watana Creek	520		1008	
	Middle River Above Devils Canyon			
Backwater	1	5	110	
Chinook Creek	63			
Clearwater Plume	2	3	299	
Fog Creek	256			
Main Channel	3	13	141	
Side Channel		6	150	
Side Slough	11	13	727	
Tributary Mouth	2	4	42	
Tsusena Creek	4		74	

Macrohabitat	Dolly Varden	Burbot	Arctic grayling	Rainbow trout
	Middle River Below Devils Canyon			
Backwater	4	38	21	4
Clearwater Plume		4	33	13
Main Channel	4	52	41	24
Side Channel	7	35	16	6
Side Slough	3	39	49	22
Side Slough Beaver Complex		19	2	6
Tributary	16	37	101	141
Tributary Mouth	27	4	49	17
Upland Slough		39	1	12
Upland Slough Beaver Complex	8	82	2	26

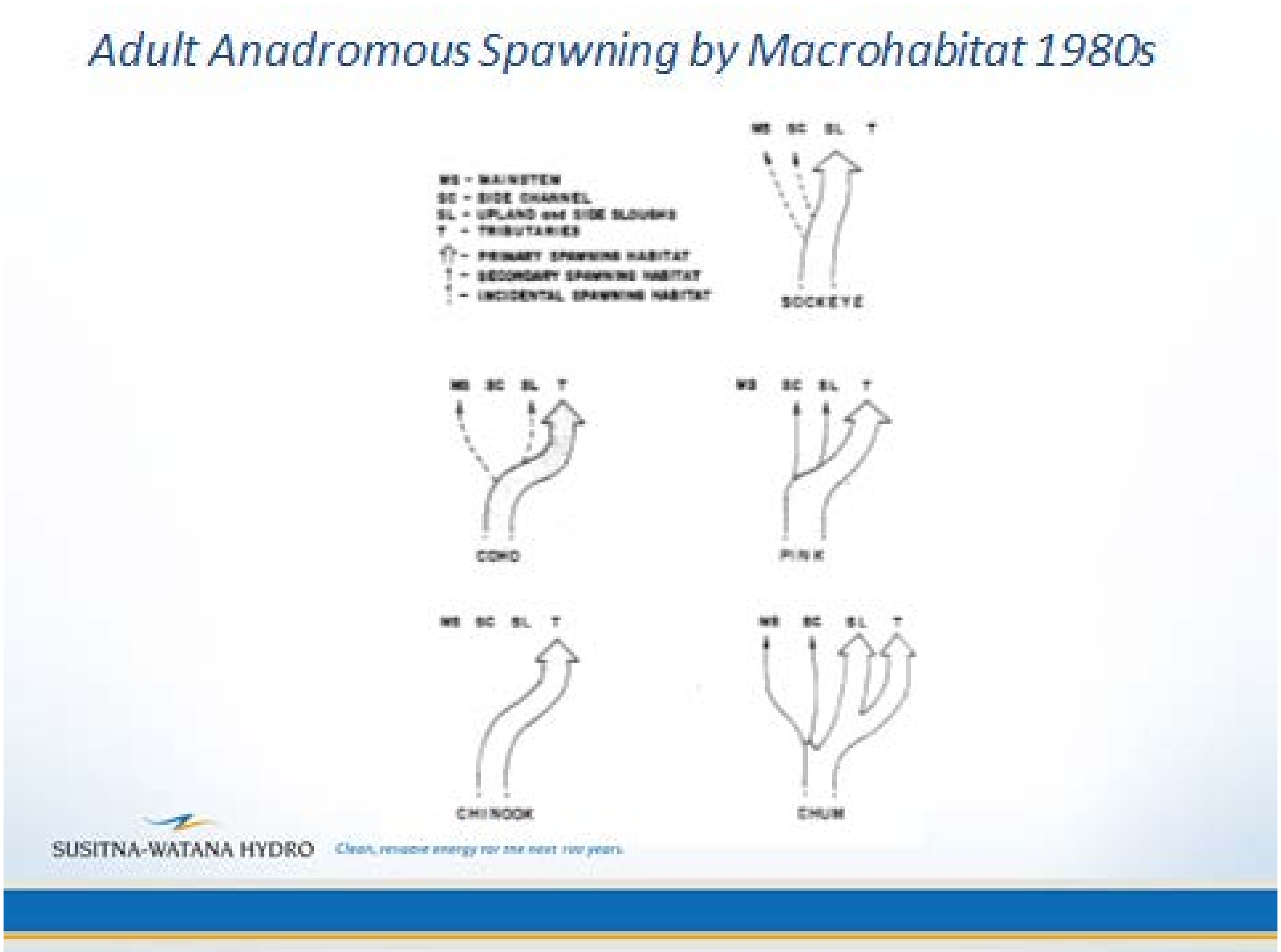
Preliminary data, may not contain all data sources, subject to QC

Study 9.5/9.6 FDA Juvenile Anadromous Fish Counts by Macrohabitat 2013

Macrohabitat	Chinook	Chum	Coho	Pink	Sockeye
	Upper River				
Black River	69				
Clearwater Plume					
Goose Creek					
Jay Creek					
Kosina Creek	116				
Main Channel					
Oshetna River	2				
Side Channel					
Side Slough					
Tsisi Creek					
Unnamed Tributary 194.8					
Upland Slough					
Watana Creek					
	Middle River Above Devils Canyon				
Backwater	1				
Chinook Creek					
Clearwater Plume					
Fog Creek					
Main Channel					
Side Channel					
Side Slough					
Tributary Mouth					
Tsusena Creek					

Macrohabitat	Chinook	Chum	Coho	Pink	Sockeye
	Middle River Below Devils Canyon				
Backwater	30		104	4	98
Clearwater Plume	5		49		8
Main Channel	6		5		1
Side Channel	121	17	321		174
Side Slough	77		412	1	235
Side Slough Beaver Complex	62	4	217		992
Tributary	170	1	880		40
Tributary Mouth	12	6	309		17
Upland Slough	22		205		10
Upland Slough Beaver Complex	543	1	2947		29

Preliminary data, may not contain all data sources, subject to QC


Adult Anadromous Spawning by Macrohabitat 1980s
MS - MAINSTEM
SC - SIDE CHANNEL
SL - UPLAND and SIDE SLOUGHS
T - TRIBUTARIES
- PRIMARY SPAWNING HABITAT
- SECONDARY SPAWNING HABITAT
- INCIDENTAL SPAWNING HABITAT
MS SC SL T
SOCKEYE
MS SC SL T
COHO
MS SC SL T
PINK
MS SC SL T
CHINOOK
MS SC SL T
CHUM
SUSITNA-WATANA HYDRO

1980s periodicity and habitat observations

22

	Presence (p 101, Table 8.1-1)					Peak Use Period (All River) (p 83, Table 5-1)					Spawning Habitat (Primary and/or Secondary) (p 105, Fig. 5-1)			
	Presence (p 101, Table 8.1-1)					Peak Use Period (All River) (p 83, Table 5-1)					Spawning Habitat (Primary and/or Secondary) (p 105, Fig. 5-1)			
Common Name	Lower River	Lower Middle	Upper Middle	Upper River	Tribs	June	July	Aug.	Sept	Oct.	Main-stem	Side Channel	Side Slough	Trib
Arctic grayling	x	x	x	x	x									
Dolly Varden	x	x	x		x									
Chinook salmon	x	x	x	x	x									1
Chinook salmon, Spawning														
Coho salmon	x	x			x									1
Coho salmon, Spawning														
Chum salmon	x	x			x						2	2	1	1
Chum salmon, Spawning														
Pink salmon	x	x			x							2	2	1
Pink salmon, Spawning														
Sockeye salmon	x	x			x	A A B				B			1	
Sockeye salmon, Spawning						A		A B		B				
Rainbow trout	x	x			x									

Key	
	Off-Peak Use, Adult
	Peak Use, Adult Migration
	Off-Peak Use, Spawning
	Peak Use, Spawning

Notes: 1st (A) and 2nd (B) run Sockeye exhibit distinct timing of adult migration and spawning, and use separate areas for spawning.

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Passage Criteria Application

- **Depth Criteria** application
  - 1980s depth x distance curves for uniform and non-uniform substrate with Chum as surrogate for salmonids 0.41 ft uniform, 0.54 ft non-uniform
  - Lang et al. (2004) determined the limiting depth to be the shallowest point over a riffle following the thalweg in the stream wise direction
  - Min depth for 25% total, full 10% of transect width (Thompson 1972)

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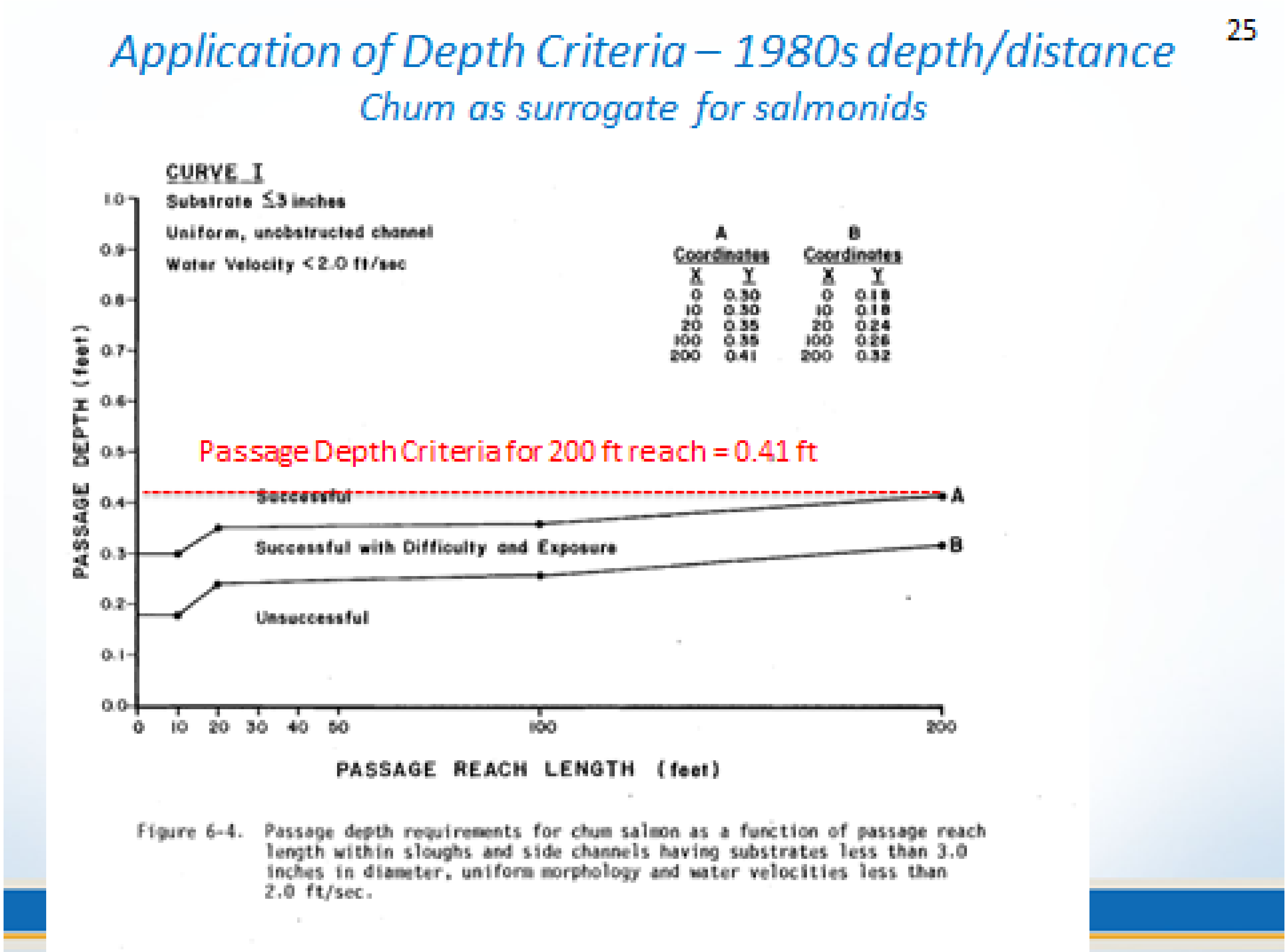
Passage Criteria Application

- **Integration with modeling**
  - Fluvial Geomorphology Study 6.5 - depth threshold magnitude and frequency with 2-D model runs including upstream/downstream velocity, hydraulic dynamics and sediment aggradation/degradation, channelization and tributary mouth barriers, formation and removal of barriers under project conditions
  - Ice Processes Study 7.6 - address juvenile fish passage during ice-cover periods with 1-D and 2-D models including ice formation and breakup; ice thickness, elevation, and blockage of off-channels and tributary deltas; passageways beneath ice and changes in ice-free at slough entrances

24


25
Application of Depth Criteria – 1980s depth/distance
Chum as surrogate for salmonids
CURVE I
Substrate ≤3 inches
Uniform, unobstructed channel
Water Velocity < 2.0 ft/sec
A Coordinates
X Y
0 0.30
10 0.30
20 0.35
100 0.35
200 0.41
B Coordinates
X Y
0 0.18
10 0.18
20 0.24
100 0.26
200 0.32
Passage Depth Criteria for 200 ft reach = 0.41 ft
Successful
Successful with Difficulty and Exposure
Unsuccessful
A
B
PASSAGE DEPTH (feet)
PASSAGE REACH LENGTH (feet)
Figure 6-4. Passage depth requirements for chum salmon as a function of passage reach length within sloughs and side channels having substrates less than 3.0 inches in diameter, uniform morphology and water velocities less than 2.0 ft/sec.

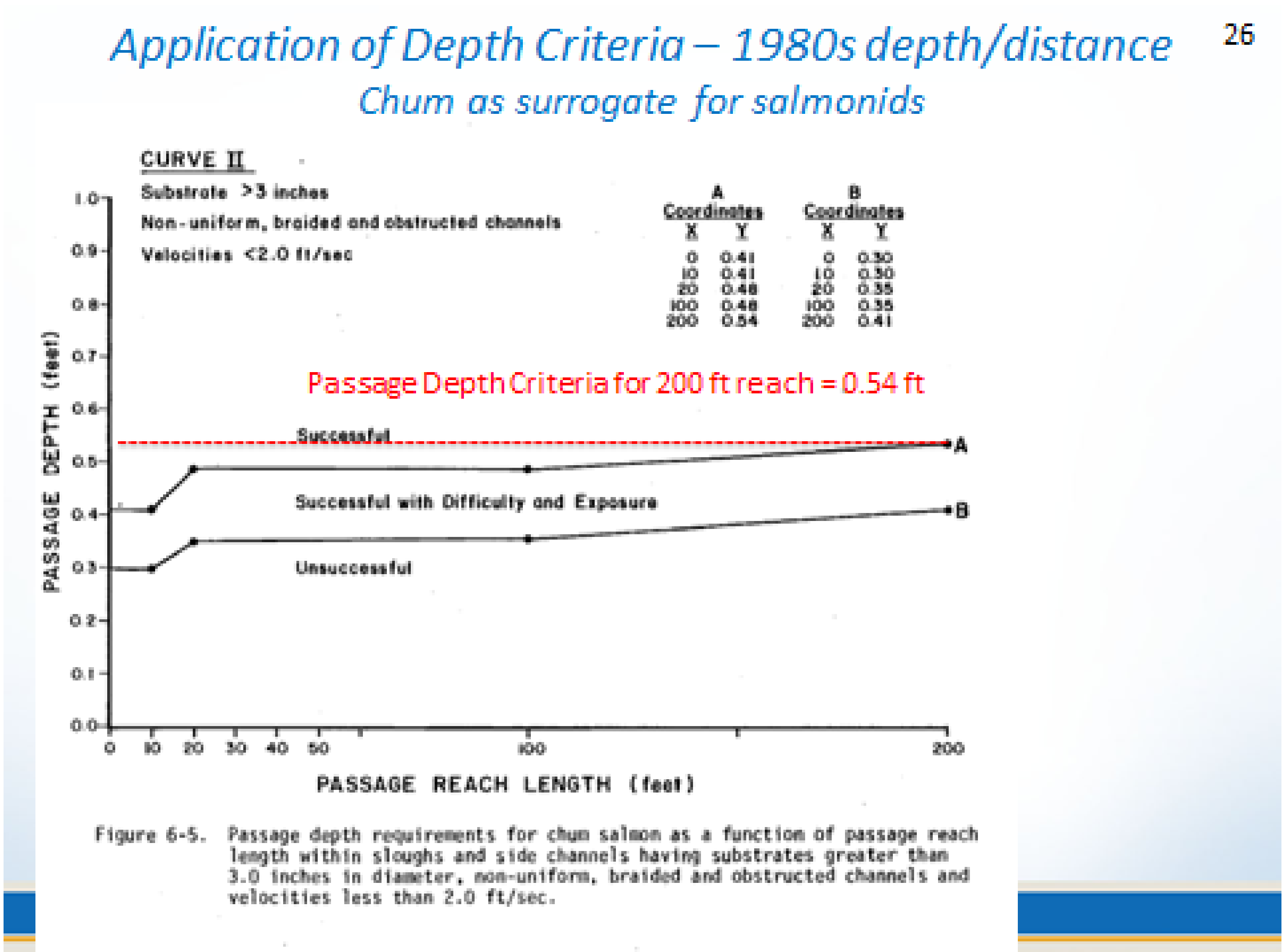
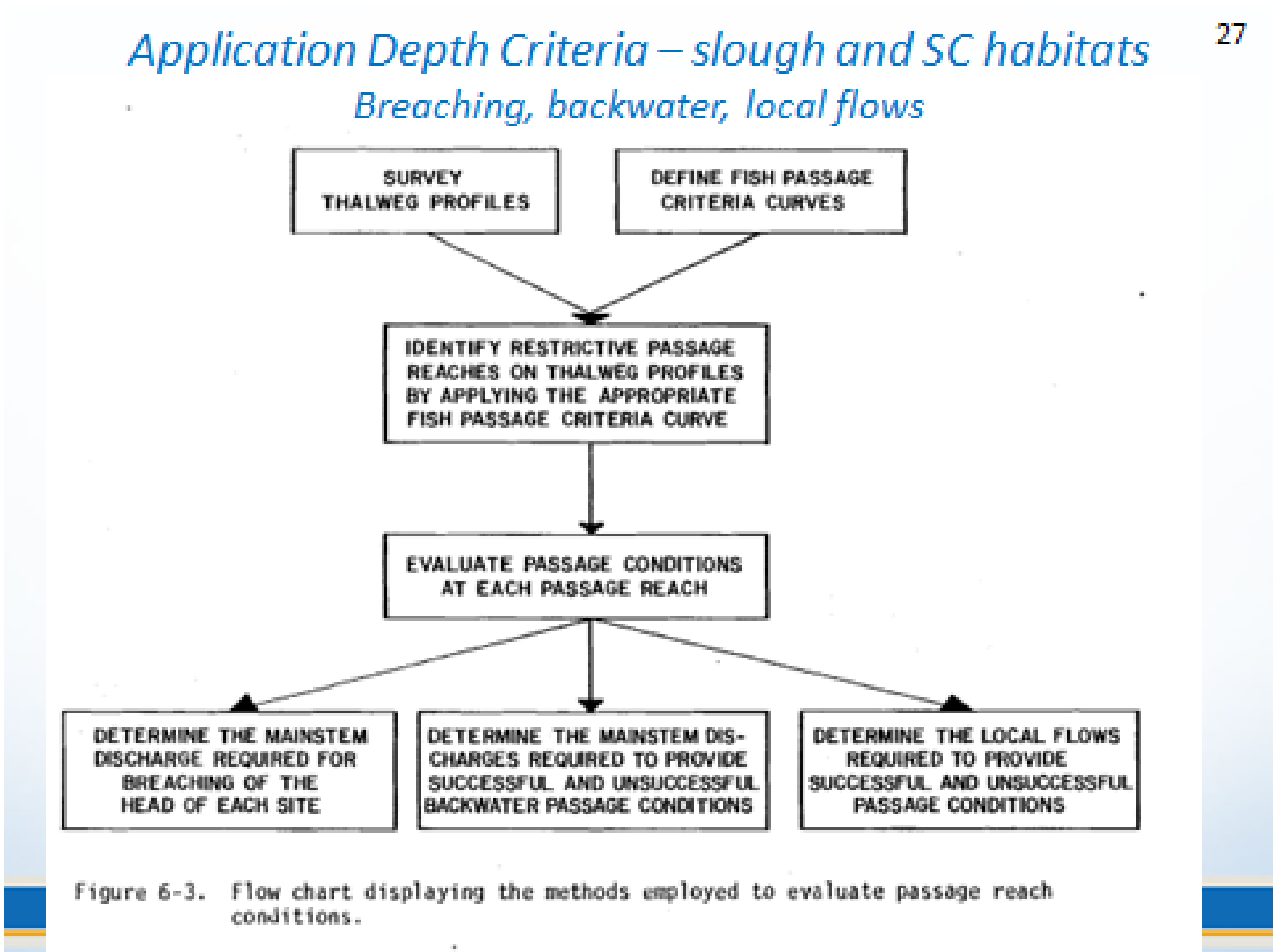
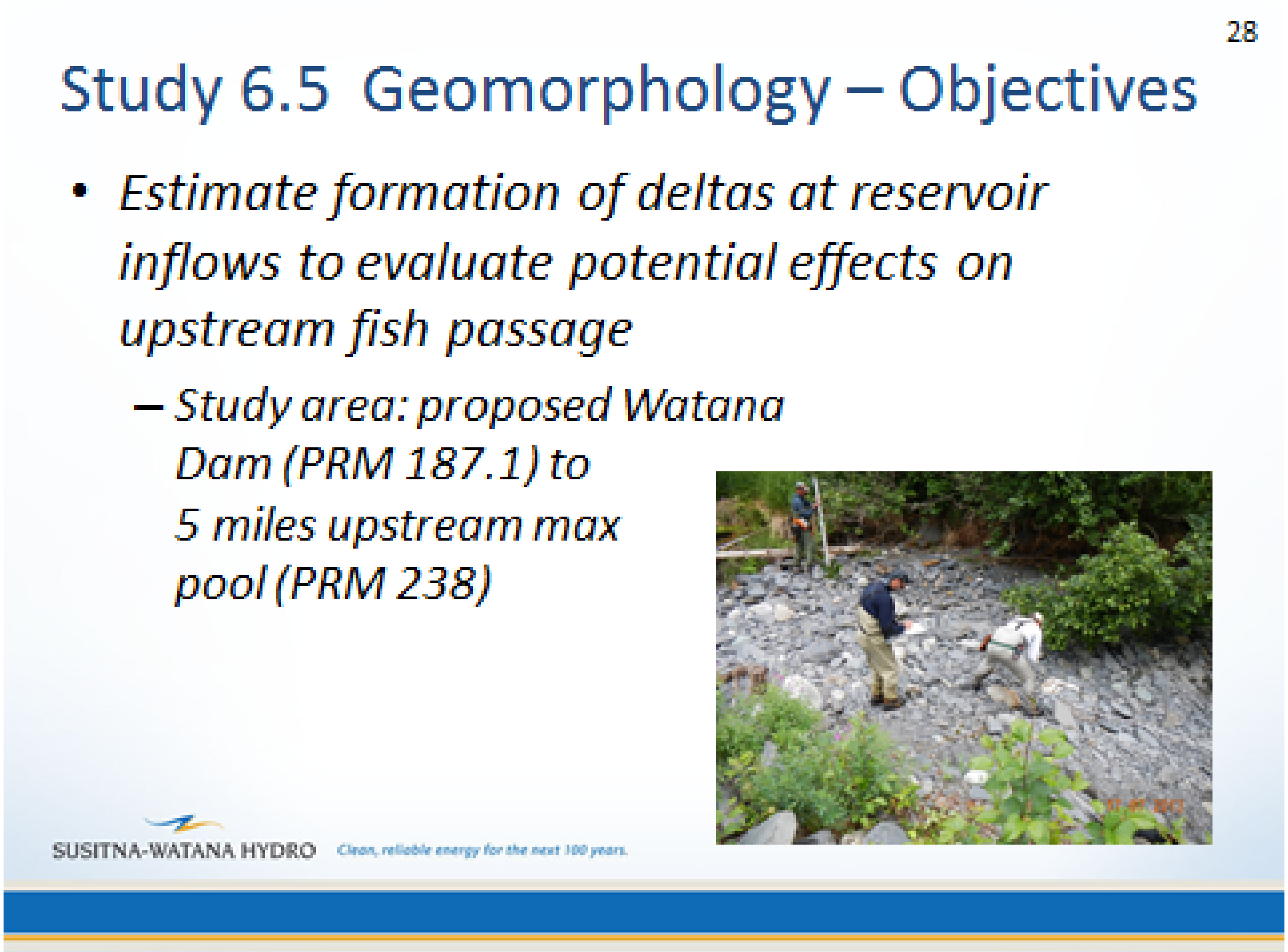


Figure 6-5. Passage depth requirements for chum salmon as a function of passage reach length within sloughs and side channels having substrates greater than 3.0 inches in diameter, non-uniform, braided and obstructed channels and velocities less than 2.0 ft/sec.


Application Depth Criteria – slough and SC habitats
Breaching, backwater, local flows
27
SURVEY THALWEG PROFILES
DEFINE FISH PASSAGE CRITERIA CURVES
IDENTIFY RESTRICTIVE PASSAGE REACHES ON THALWEG PROFILES BY APPLYING THE APPROPRIATE FISH PASSAGE CRITERIA CURVE
EVALUATE PASSAGE CONDITIONS AT EACH PASSAGE REACH
DETERMINE THE MAINSTEM DISCHARGE REQUIRED FOR BREACHING OF THE HEAD OF EACH SITE
DETERMINE THE MAINSTEM DISCHARGES REQUIRED TO PROVIDE SUCCESSFUL AND UNSUCCESSFUL BACKWATER PASSAGE CONDITIONS
DETERMINE THE LOCAL FLOWS REQUIRED TO PROVIDE SUCCESSFUL AND UNSUCCESSFUL PASSAGE CONDITIONS
Figure 6-3. Flow chart displaying the methods employed to evaluate passage reach conditions.


28
Study 6.5 Geomorphology – Objectives
• Estimate formation of deltas at reservoir inflows to evaluate potential effects on upstream fish passage
– Study area: proposed Watana Dam (PRM 187.1) to 5 miles upstream max pool (PRM 238)
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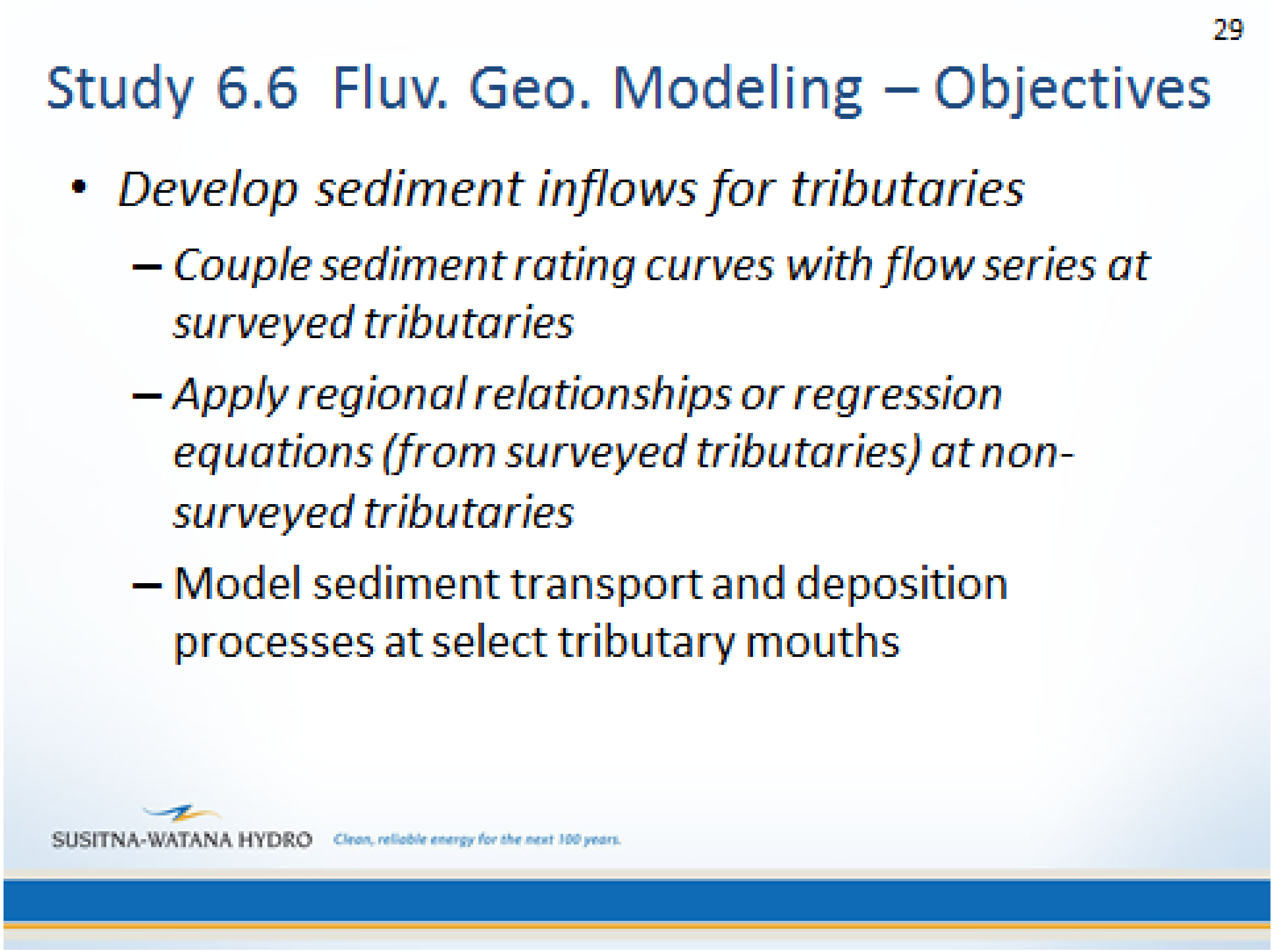
29
Study 6.6 Fluv. Geo. Modeling – Objectives
• Develop sediment inflows for tributaries
– Couple sediment rating curves with flow series at surveyed tributaries
– Apply regional relationships or regression equations (from surveyed tributaries) at non-surveyed tributaries
– Model sediment transport and deposition processes at select tributary mouths
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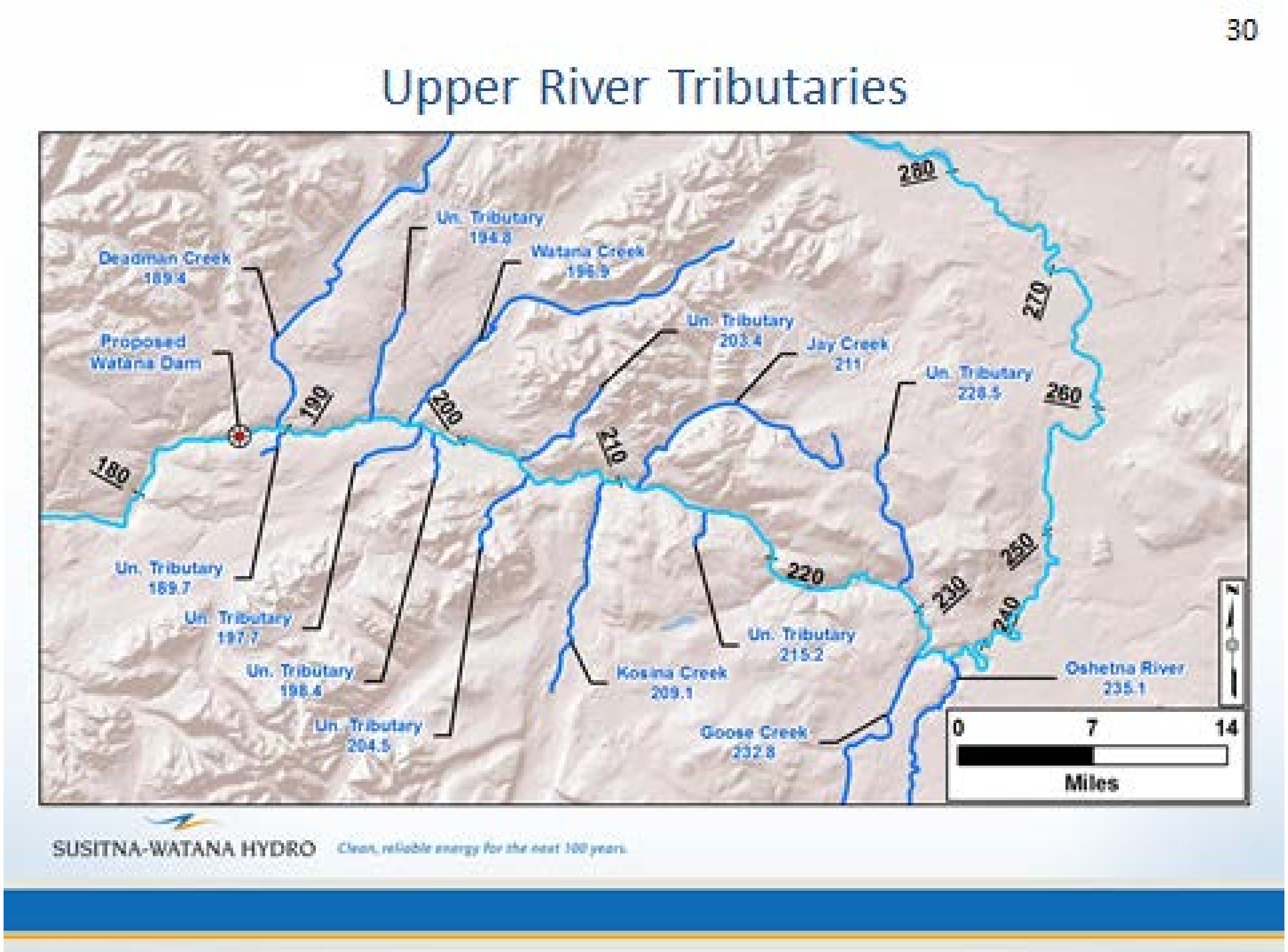
30
Upper River Tributaries
Deadman Creek
189.4
Un. Tributary
194.8
Watana Creek
196.9
Proposed
Watana Dam
Un. Tributary
203.4
Jay Creek
211
Un. Tributary
228.5
Un. Tributary
189.7
Un. Tributary
197.7
Un. Tributary
198.4
Un. Tributary
204.5
Kosina Creek
209.1
Un. Tributary
215.2
Goose Creek
232.8
Oshetna River
235.1
180
190
200
210
220
230
240
250
260
270
280
0
7
14
Miles
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Recommended Selection of Upper River Tributaries

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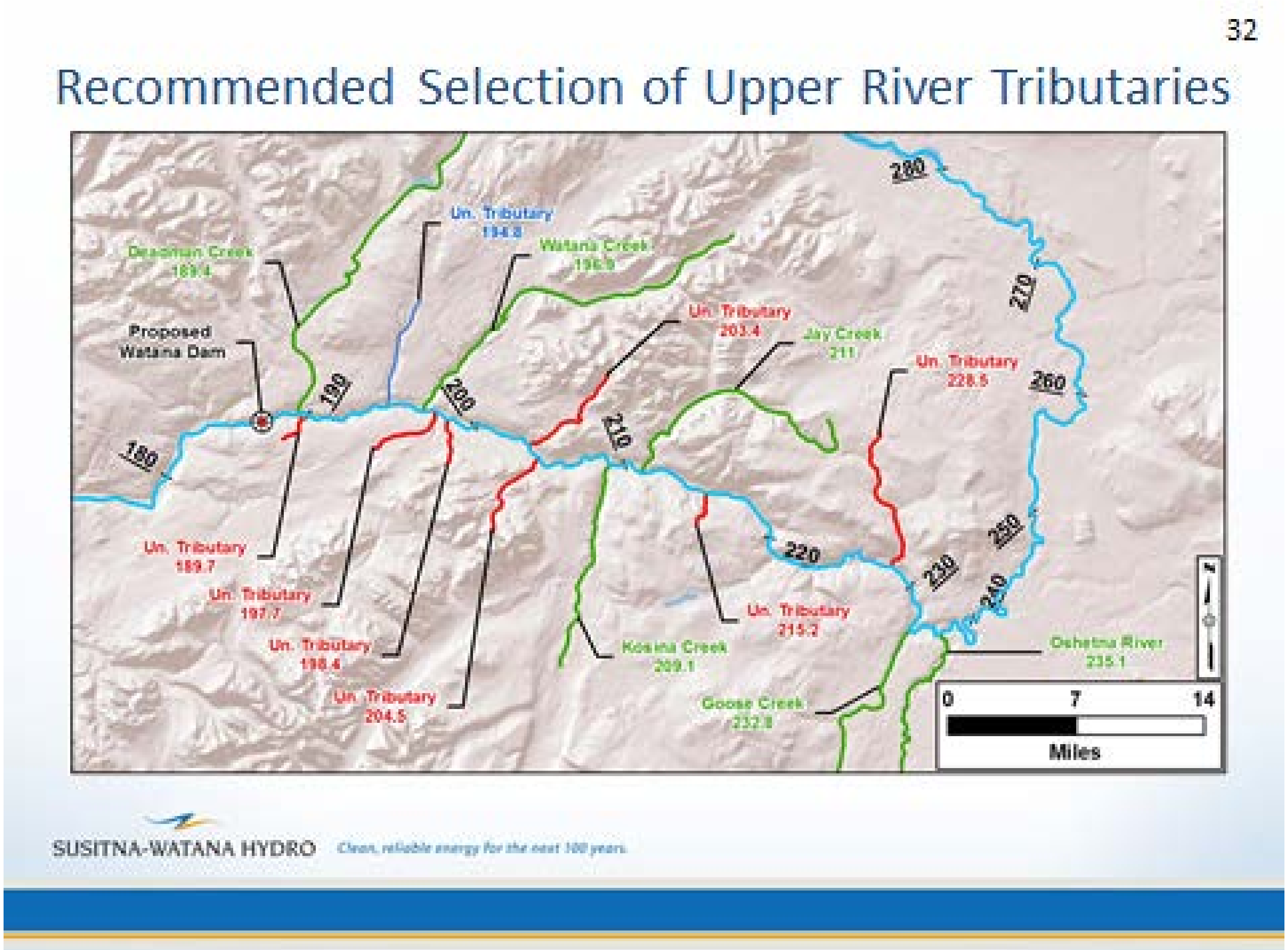
Tributary	PRM	D.A. (mi^2)	Bank	2012/2013 Fish Distribution: Chinook	Burbot	Dolly Varden	Round Whitefish	Arctic Grayling	Barriers Eliminated by Reservoir[1]: Type	Trib RM	Elevation[2]	Rationale for Exclusion
Oshetna R.	235.1	556.4	L	x		x	x	x				
Goose Cr.	232.8	106.5	L	x	x		x	x				
Un. Tributary	228.5	46.3	R									TOB @ 2,375'
Un. Tributary	215.2	2.3	L									TOB @ 2,200'
Jay Cr.	211.0	62.4	R		x	x	x	x				
Kosina Cr.	209.1	402.5	L	x	x	x	x	x				
Un. Tributary	204.5	12.3	L						cmpd.	0.4 & 0.6	1830&1925	Steep ch.
Un. Tributary	203.4	13.5	R									TOB @ 2,030'
Un. Tributary	198.4	1.8	L			x						Small D.A.
Un. Tributary	197.7	8.1	L						falls	1.3	1550	Steep ch.
Watana Cr.	196.9	176.4	R	x	x	x	x	x				
Un. Tributary	194.8	23.2	R			x		x				
Un. Tributary	189.7	1.5	L						chute	0.4	1550	Small D.A.
Deadman Cr.	189.4	175.4	R		x	x	x	x	falls	0.6	1760	

[1] Identified fish passage barriers potentially inundated by the proposed Watana Reservoir
Reservoir max pool = 2,050 feet (NAVD88) with upper extent at PRM 232.5,
Reservoir low pool = 1,850 feet (NAVD88) with upper extent at PRM 222.5

[2] Elevation at the top of the barrier, as estimated using 2011 MatSu LIDAR (feet, NAVD88)

Indicates candidate tributary recommended for delta modeling (green)

Indicates candidate tributary recommended for exclusion from delta modeling (red)


32
Recommended Selection of Upper River Tributaries
Un. Tributary
194.8
Watana Creek
196.9
Deadman Creek
189.4
Proposed
Watana Dam
Un. Tributary
203.4
Jay Creek
211
Un. Tributary
228.5
280
270
260
250
240
230
220
210
200
190
180
Un. Tributary
189.7
Un. Tributary
197.7
Un. Tributary
198.4
Un. Tributary
204.5
Kosina Creek
209.1
Un. Tributary
215.2
Goose Creek
232.8
Oshetna River
235.1
0
7
14
Miles
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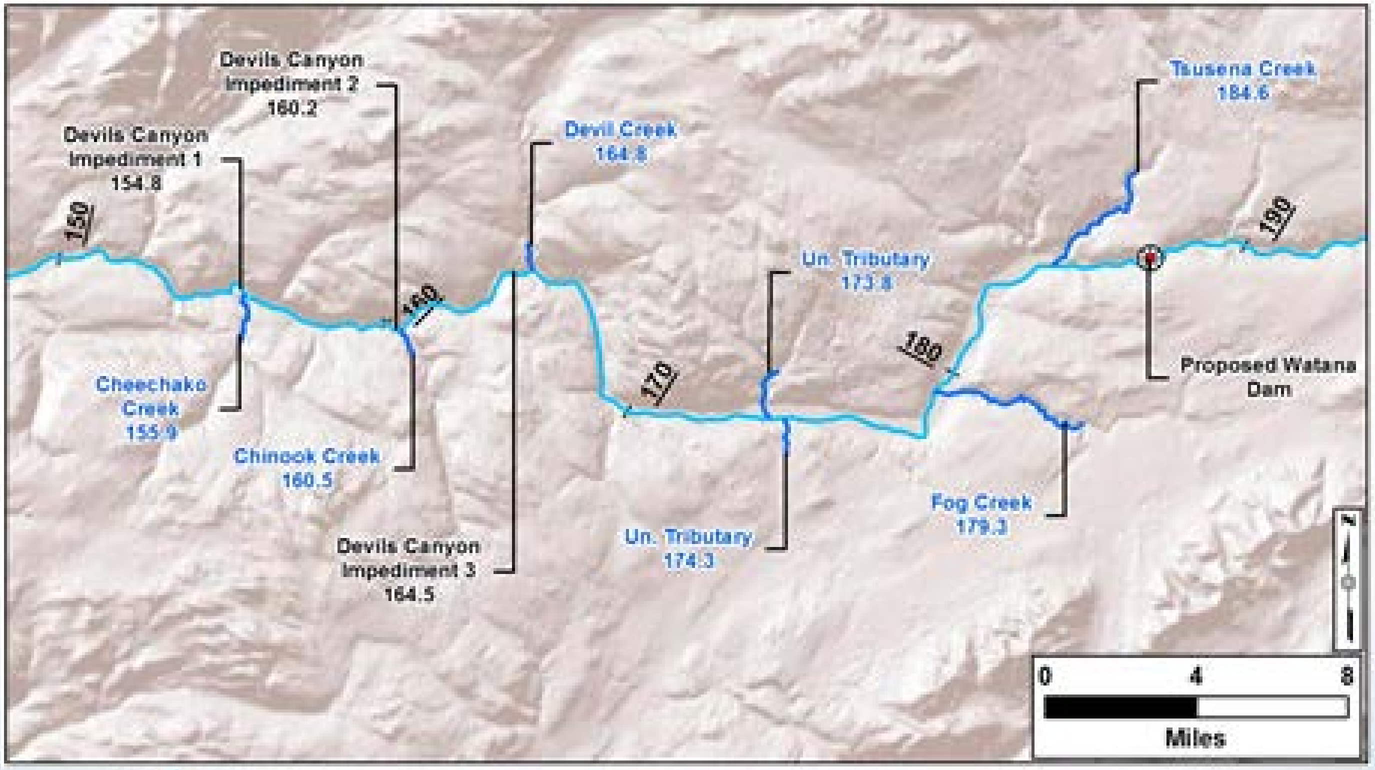
Middle River Tributaries Upstream and Within Devils Canyon



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Recommended Selection of Middle River Tributaries Upstream and Within Devils Canyon

Tributary	PRM	D.A. (mi^2)	Lake Presence[1] Trib RM	Lake Presence[1] Area (ac)	Focus Area	Evidence of Active Fan	2012/2013 Fish Distribution No. of Resident Species	2012/2013 Fish Distribution No. of Salmon Species	Interest[2]
Upstream of Devils Canyon									
Tsusena Cr.	184.6	145.4			184	Yes	4	1	S,B,F
Fog Cr.	179.3	149.7				Yes	4	1	S,B,F
Un. Tributary	174.3	4.4	1.0 & 1.8	62.3 & 23.5	173	No			S
Un. Tributary	173.8	8.6			173	Yes	4		S,F
Within Devils Canyon									
Devil Cr.	164.8	74.4				No		1	B
Devils Canyon Impediment 3 (PRM 164.5)									
Chinook Cr.	160.5	24				Yes	2	1	S,B,F
Devils Canyon Impediment 2 (PRM 160.2)									
Cheechako Cr.	155.9	34.4				No		1	B
Devils Canyon Impediment 1 (PRM 154.8)									

[1] Large lakes near the tributarymouth trap sediment and prevent formation of fans

[2] S = sediment supply (Study6.6); B = fish passage barrier (Study 9.12); F = depositional fan (Study6.5)

Indicates candidate tributaryrecommended for delta modeling

Indicates candidate tributaryrecommended for exclusion from delta modeling

Basis of recommendation for exclusion

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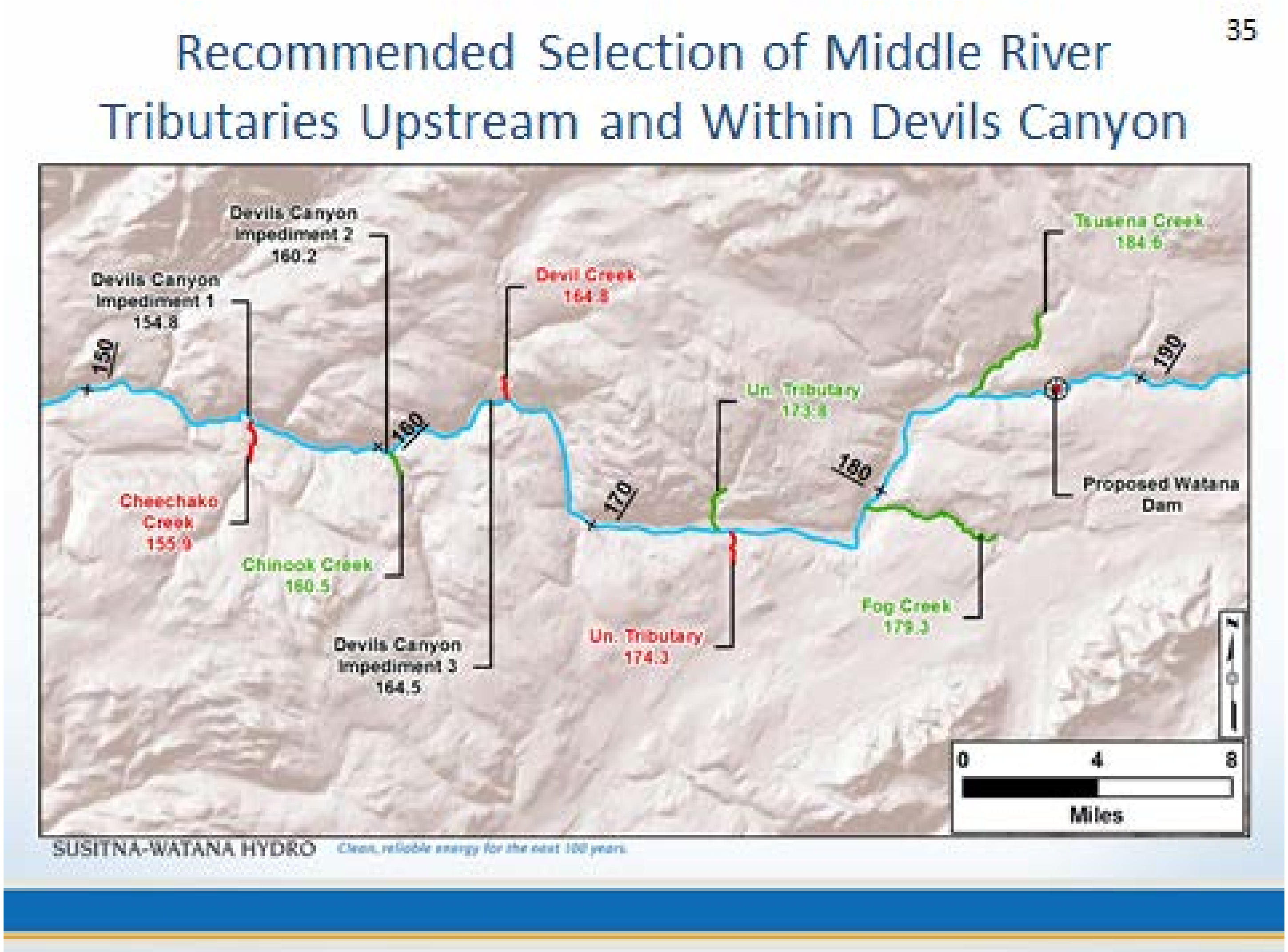
35
Recommended Selection of Middle River Tributaries Upstream and Within Devils Canyon
Devils Canyon Impediment 2 160.2
Devils Canyon Impediment 1 154.8
Devil Creek 164.8
Tsusena Creek 184.6
150
160
170
180
190
Un. Tributary 173.8
Proposed Watana Dam
Cheechako Creek 155.9
Chinook Creek 160.5
Fog Creek 179.3
Un. Tributary 174.3
Devils Canyon Impediment 3 164.5
0 4 8
Miles
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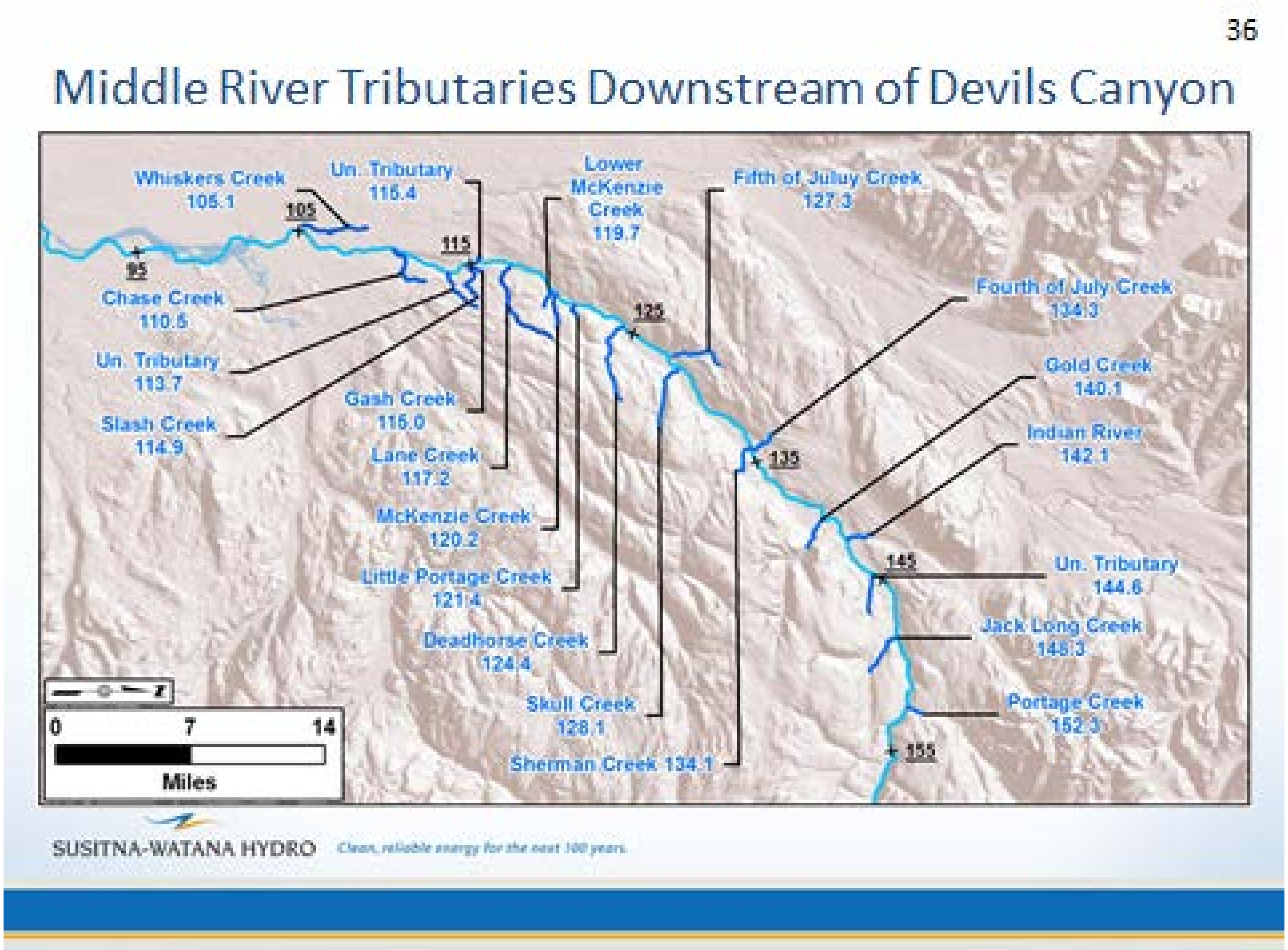
36
Middle River Tributaries Downstream of Devils Canyon
Whiskers Creek 105.1
Un. Tributary 115.4
Lower McKenzie Creek 119.7
Fifth of Juluy Creek 127.3
105
95
115
125
Chase Creek 110.5
Un. Tributary 113.7
Slash Creek 114.9
Gash Creek 115.0
Lane Creek 117.2
McKenzie Creek 120.2
Little Portage Creek 121.4
Deadhorse Creek 124.4
Skull Creek 128.1
Sherman Creek 134.1
Fourth of July Creek 134.3
Gold Creek 140.1
Indian River 142.1
135
145
Un. Tributary 144.6
Jack Long Creek 148.3
Portage Creek 152.3
155
0 7 14
Miles
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Recommended Selection of Middle River Tributaries Downstream of Devils Canyon

Tributary	PRM	D.A. (mi²)	Lake Presence[1]		Focus Area	Evidence of Active Fan	2012/2013 Fish Distribution		Interest[2]
			Trib RM	Area (ac)			No. of Resident Species	No. of Salmon Species	
Portage Cr.	152.3	179.1			151	Yes	2	5	S,F
Jack Long Cr.	148.3	18.1				No		2	B
Un. Tributary[4]	144.8	6.0			144	Yes			S,F
Indian River	142.1	81.9			141	Yes	9	5	S,F
Gold Cr.	140.1	24.8				Yes	1	3	S,B,F
Fourth of July Cr.	134.3	23.4				Yes	2	5	S,B,F
Sherman Cr.	134.1	7.1				Yes		1	S,B,F
Skull Cr.	128.1	4.3			128	Yes	4	4	S,F
Fifth of July Cr.	127.3	7.1				Minimal	3	4	S,B,F
Deadhorse Cr.	124.4	4.7				Yes			S,B,F
Little Portage Cr.	121.4	2.6	0.9	7.4		No			B
McKenzie Cr.	120.2	2.1				No			B
L. McKenzie Cr.	118.7	2.3	1.2 & 1.3	17.5 & 29.6		No			B
Lane Cr.	117.2	11.4				Yes	1	4	S,B,F
Un. Tributary	116.4	2.7			116	No	4	3	n/a
Gash Cr.	115.0	1.6	0.8	18.8	115	No	6	1	S
Slash Cr.	114.6	1.3			113	No			S
Un. Tributary	113.7	2.0			113	Yes	4	1	S,F
Chase Cr.	110.5	4.8	1.3	26.5		No	6	2	B
Whiskers Cr.	105.1	18.2			104	No	9	5	S

[1] Large lakes near the tributary mouth trap sediment and prevent formation of fans

[2] S = sediment supply (Study 6.6); B = fish passage barrier (Study 9.12); F = depositional fan (Study 6.5)

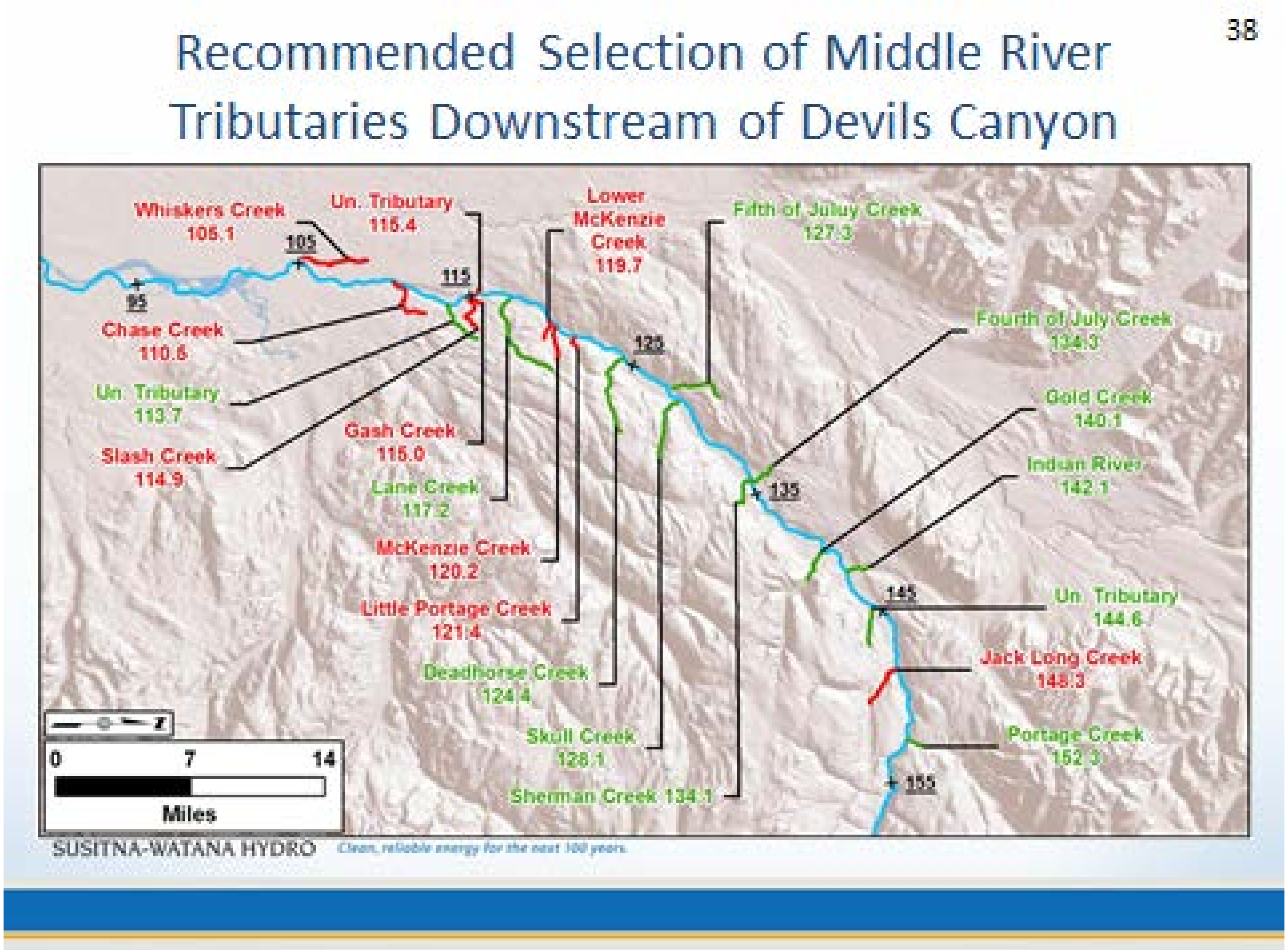
[3] No surface flow at mouth during July 2013 survey

SUSITNA

Indicates candidate tributary recommended for delta modeling

Indicates candidate tributary recommended for exclusion from delta modeling

Basis of recommendation for exclusion


38
Recommended Selection of Middle River Tributaries Downstream of Devils Canyon
Whiskers Creek 105.1
Un. Tributary 115.4
Lower McKenzie Creek 119.7
Fifth of Juluy Creek 127.3
105
95
115
120
135
145
155
Chase Creek 110.8
Un. Tributary 113.7
Slash Creek 114.9
Gash Creek 115.0
Lane Creek 117.2
McKenzie Creek 120.2
Little Portage Creek 121.4
Deadhorse Creek 124.4
Skull Creek 128.1
Sherman Creek 134.1
Fourth of July Creek 134.3
Gold Creek 140.1
Indian River 142.1
Un. Tributary 144.6
Jack Long Creek 148.3
Portage Creek 152.3
0 7 14
Miles
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DISCUSSION
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