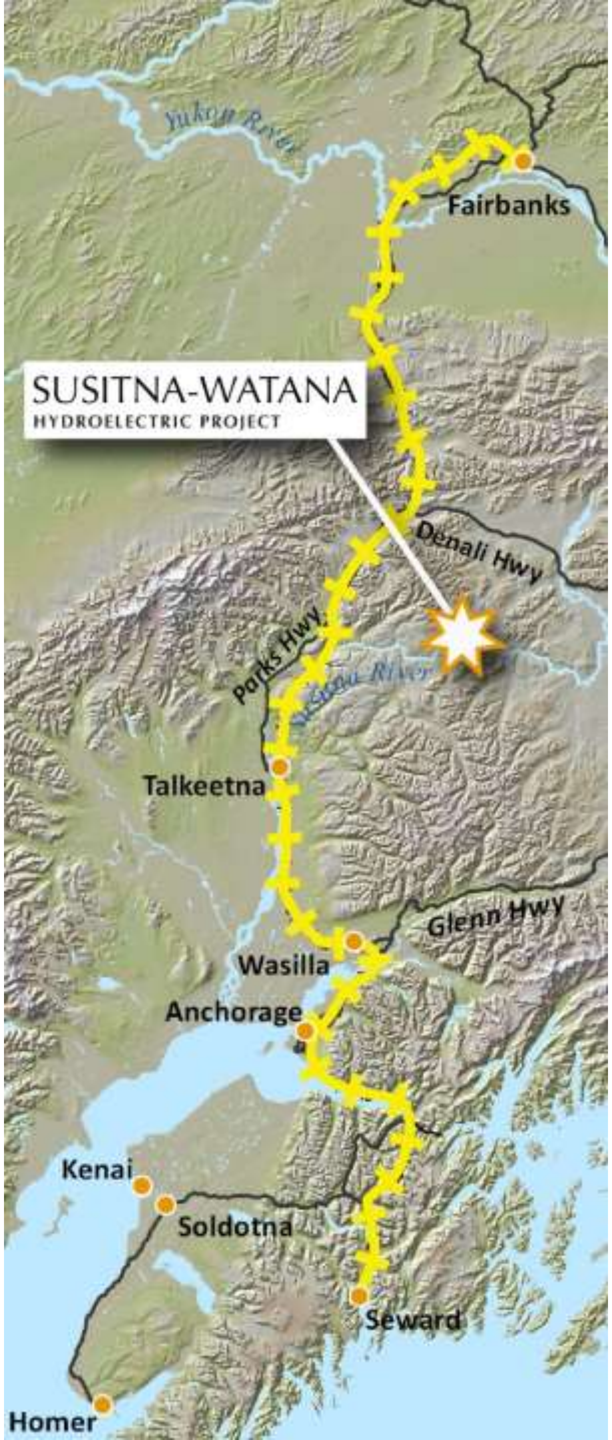

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HYDROELECTRIC PROJECT

Water Resources
Technical Work Group Meeting
1st Quarter 2013
Ice Processes

March 28, 2013

Prepared by HDR Alaska, Inc.

ALASKA ENERGY AUTHORITY

Ice Processes Presentation Outline

- FERC Study Plan Determination delayed until April 1st
- 2012 Study Results Summary
  - Previous Studies
    - Observed Processes
    - Prediction of effects
  - Open Leads
  - Breakup Progression and Ice Jams
  - Freeze-up Progression
- 2013 1st Quarter Work to Date

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Existing Information

- All measurements and observation locations are compiled into an Access database and are sorted by river mile.
  - Freeze-up and breakup progression observations, 1980-1985
  - Open lead mapping in the Middle River, 1983
  - Winter flow observations at Lower River fish habitat sites
  - Ice thickness and stage measurements in Lower River and Middle River
  - Frazil ice density, porosity, and structure
  - Observations of geomorphic and sediment transport effects of ice jams

- Model predictions of post-project ice cover progression, ice thickness and elevation, and the open-water lead downstream of the dam site.

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Existing Information

Alaska Energy Authority

Susitna River Ice Processes Study

Historic Susitna River Ice Events

Susitna River Bridge - May 16, 1921

Search Historic Informatio

Historic River Mile Data Search

Find Data

Clear River Mile Search

Historic River Mile Observation Search

Find Observations

Clear River Mile Search

View/Print Historic Report

Open Data Report

Print Data Rep

Open Observation Report

Print Observati

Historic Events References

Open Full Reference Citations

Print Full Re Citatio

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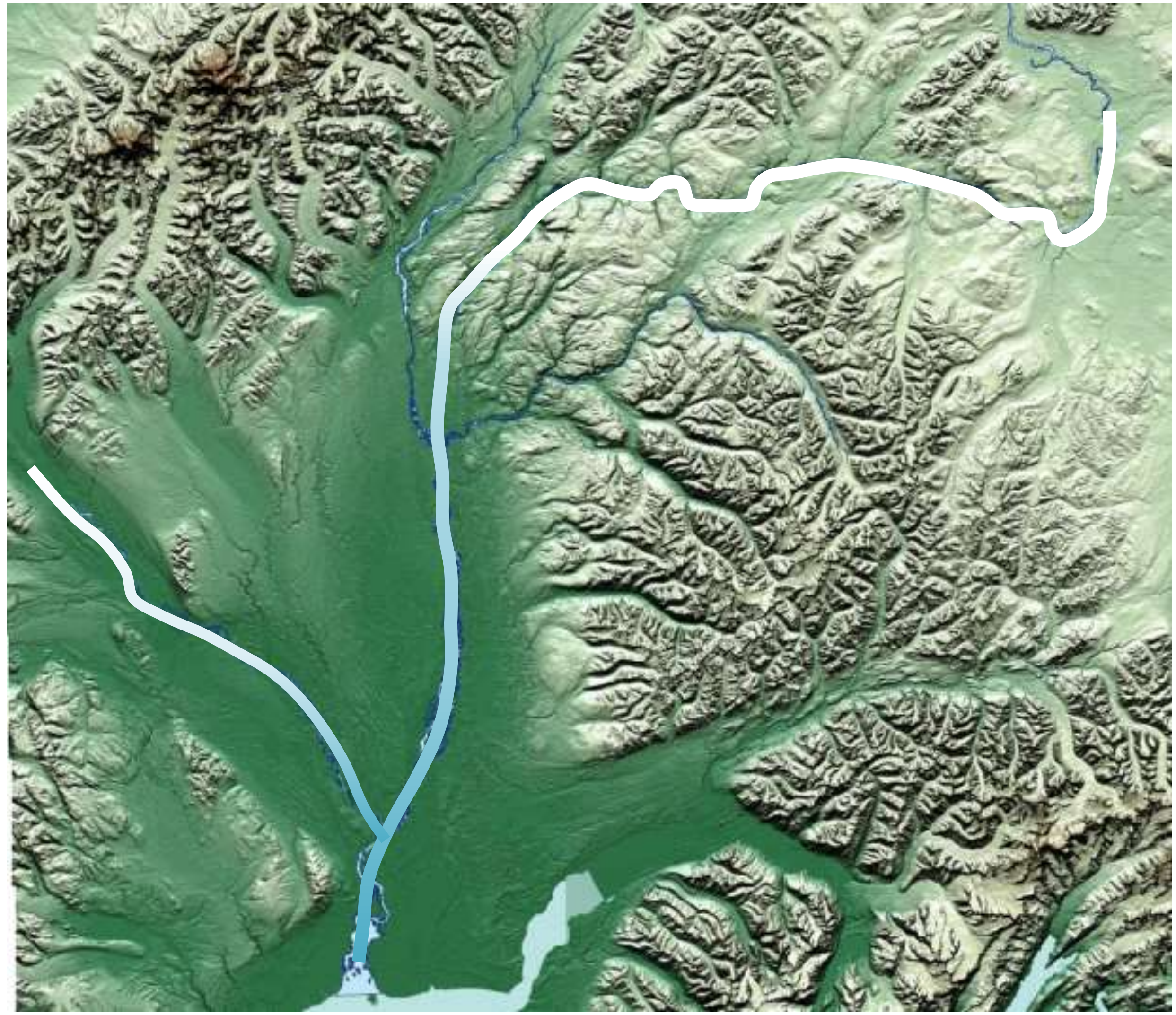
Susitna River Freeze Up Process – Frazil Production

- River cools to 32 degrees
- Frazil appears, flows downstream
- Border ice grows
- Upper and Middle Susitna Rivers and Yentna River are dominant frazil sources. Chulitna and Talkeetna produce minor frazil volumes.



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Susitna/Talkeetna Relative Frazil Volumes

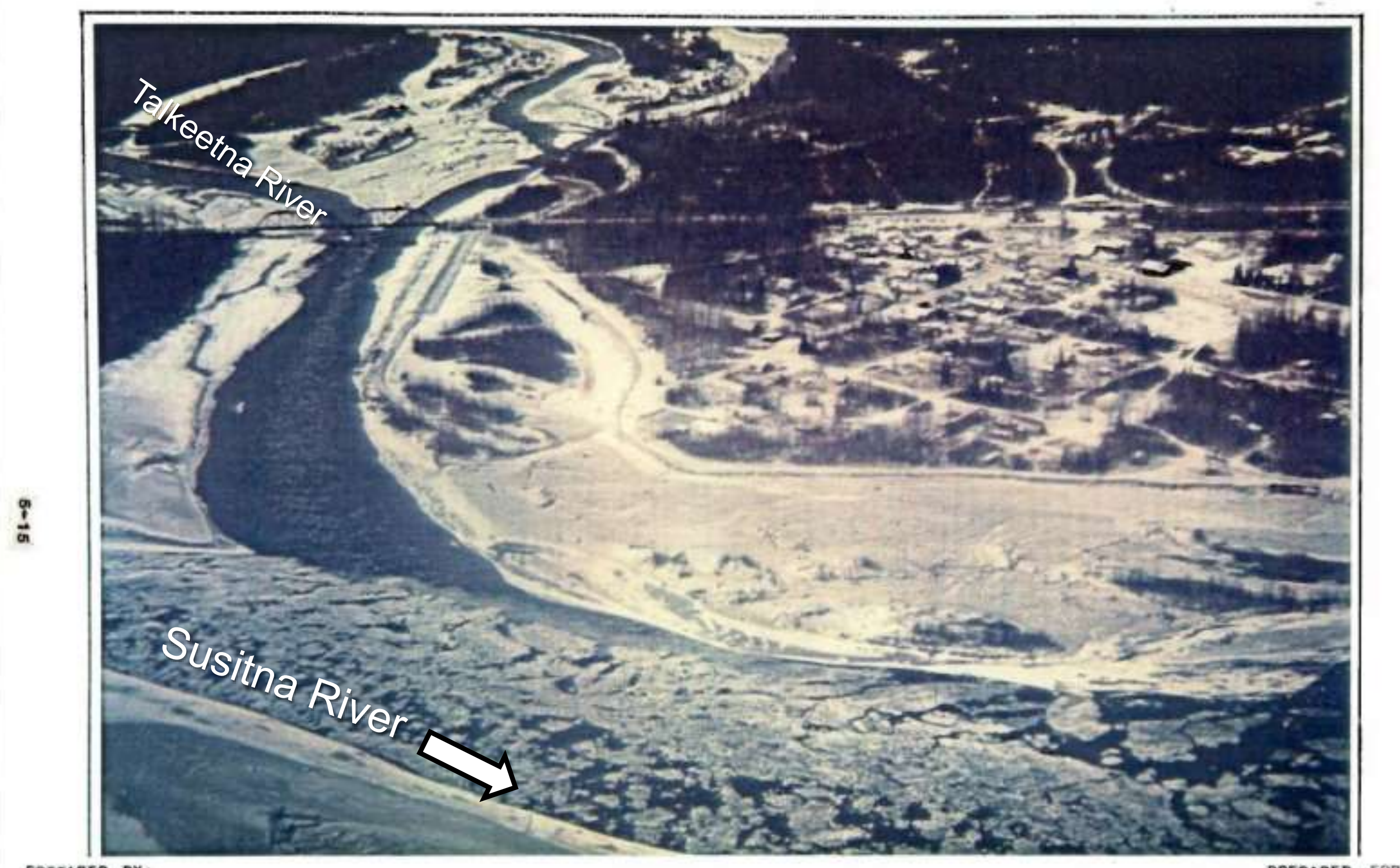

FIGURE 5.2
TALKEETNA RIVER CONFLUENCE SHOWING
RELATIVE CONTRIBUTIONS OF ICE.
SUSITNA RIVER IS ENTERING FROM THE LOWER LEFT
NOVEMBER 2, 1981

R&M 1982

Susitna River Freeze Up Process – Frazil Production and Border Ice Growth

FIGURE 5.4
October 17, 1983. Low air temperatures and minimal solar radiation influence the water surface in the upper river canyons. These factors together with high turbulence generates large volumes of frazil slush in October. This is near the mouth of Jay Creek, looking downstream.

R&M 1984

FIGURE 6.2
October 17, 1983. Border ice begins to develop on the middle river. This is near the Chulitna confluence, flow is right to left.

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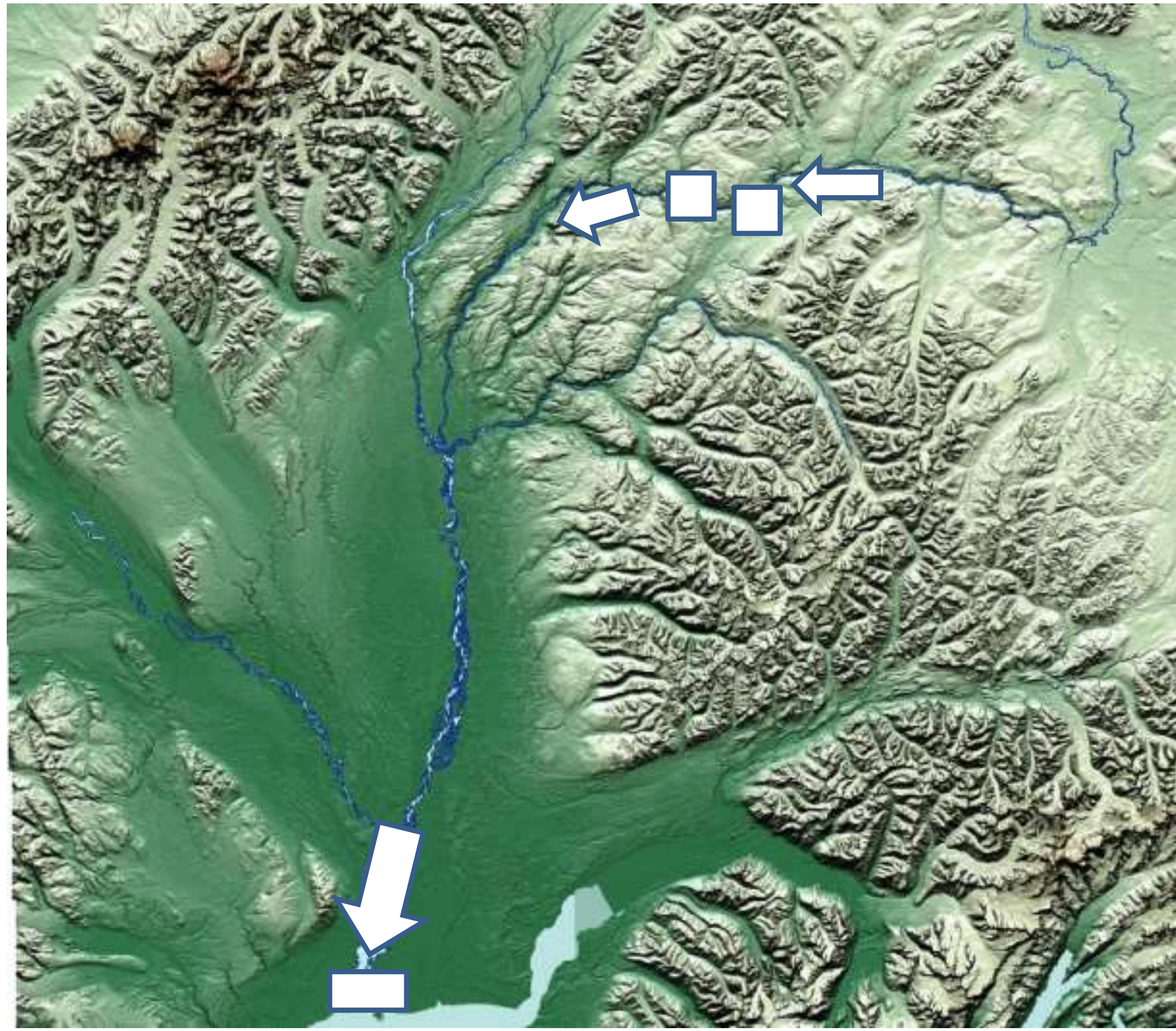
Susitna River Freeze Up Process - Bridging

- Ice bridges over Devil Canyon first, but frazil is transported beneath the bridges and cover does not progress upstream.
- Ice bridges near tidewater, blocks frazil from flowing out to Cook Inlet, and cover progresses upstream.
- In low water years, intermediate bridges may form, cutting off frazil from Middle River.



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Devil Canyon Bridge, October

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Ice Bridge near Tidewater, October

FIGURE 6.6
October 28, 1983. High tides occurred during this time in October. The slush ice velocity slowed to the point that friction along the bank and within the ice pack exceeded the friction imparted by the slow moving water, and the flowing slush stopped moving. Looking upstream at river mile 9 ice bridge.

R&M 1984

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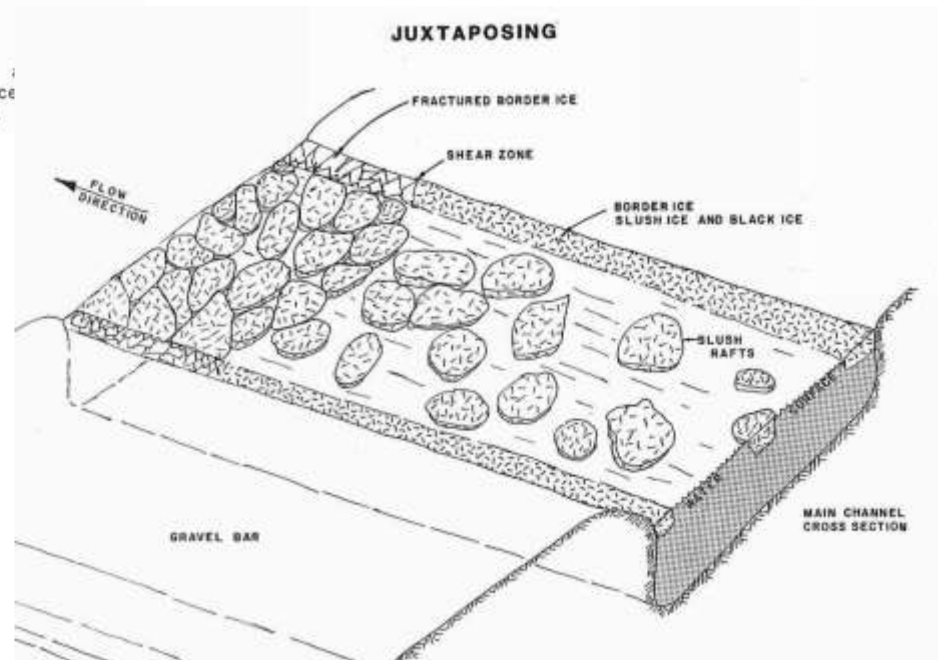
Ice Cover Progression

s6/mm72

FIGURE 6.9
November 1, 1983. The ice cover lengthens or progresses upstream a
accumulates along the "leading edge". Water level rises due to displace
ice and resistance to flow. This is near river mile 31, flow is left to right.

Juxtaposition – rapid ice cover progression in lower gradient reaches. Surface velocities must be under ~3 feet/sec for ice to accumulate.



R&M 1984

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Ice Cover Progression

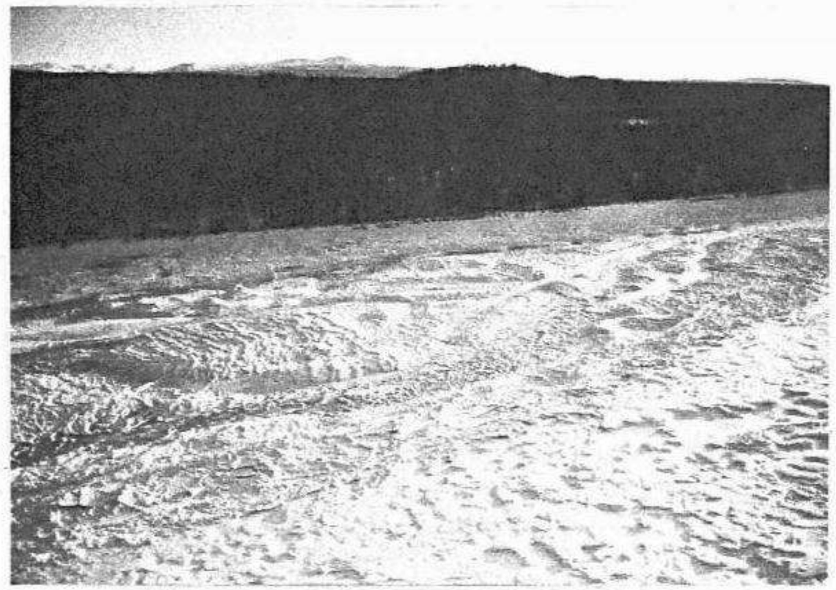
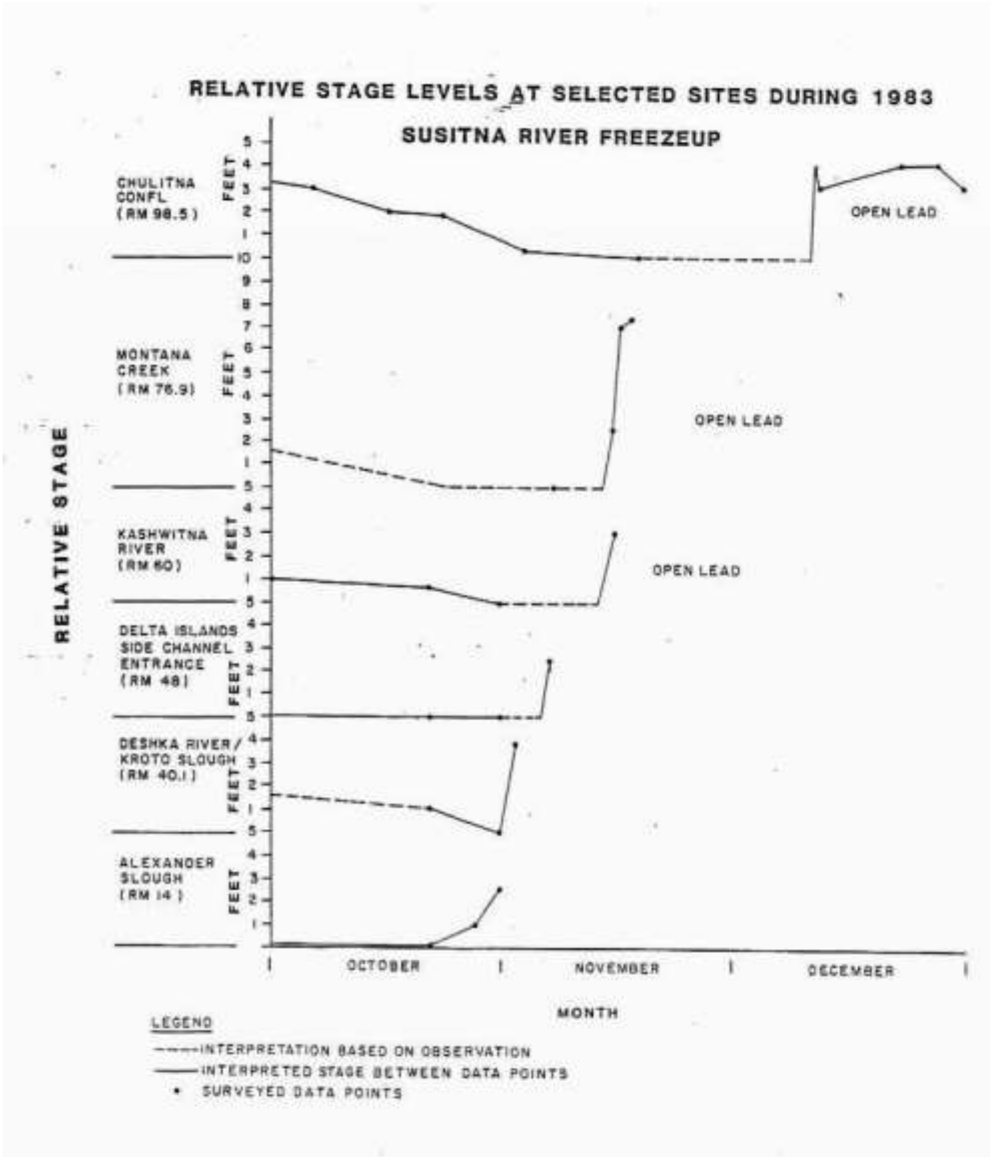


FIGURE 6.35
December 28, 1983. Near LRX-9. This ice cover is deteriorating as evidenced by the sagging cover over the flowing water. A lead will eventually open up in the sagged portion of the section. Flow is left to right.

Hydraulic Thickening – ice cover compresses and thickens before progressing upstream in steeper reaches. The thicker ice slows water velocities upstream to less than 3 feet/second to allow ice to accumulate. Creates a hummocky cover, and more staging than juxtaposition.

Ice Cover Progression - Staging



R&M 1984

As ice fills the channel, the water surface rises upstream and velocity slows. The steeper the reach, the thicker the ice, the higher the water must rise in order to allow the ice cover to progress. Once the ice cover has progressed past a point, the water surface drops as the underside of the ice cover is smoothed and open leads develop. Staging up to 7 feet was observed in1983 in the Lower River.

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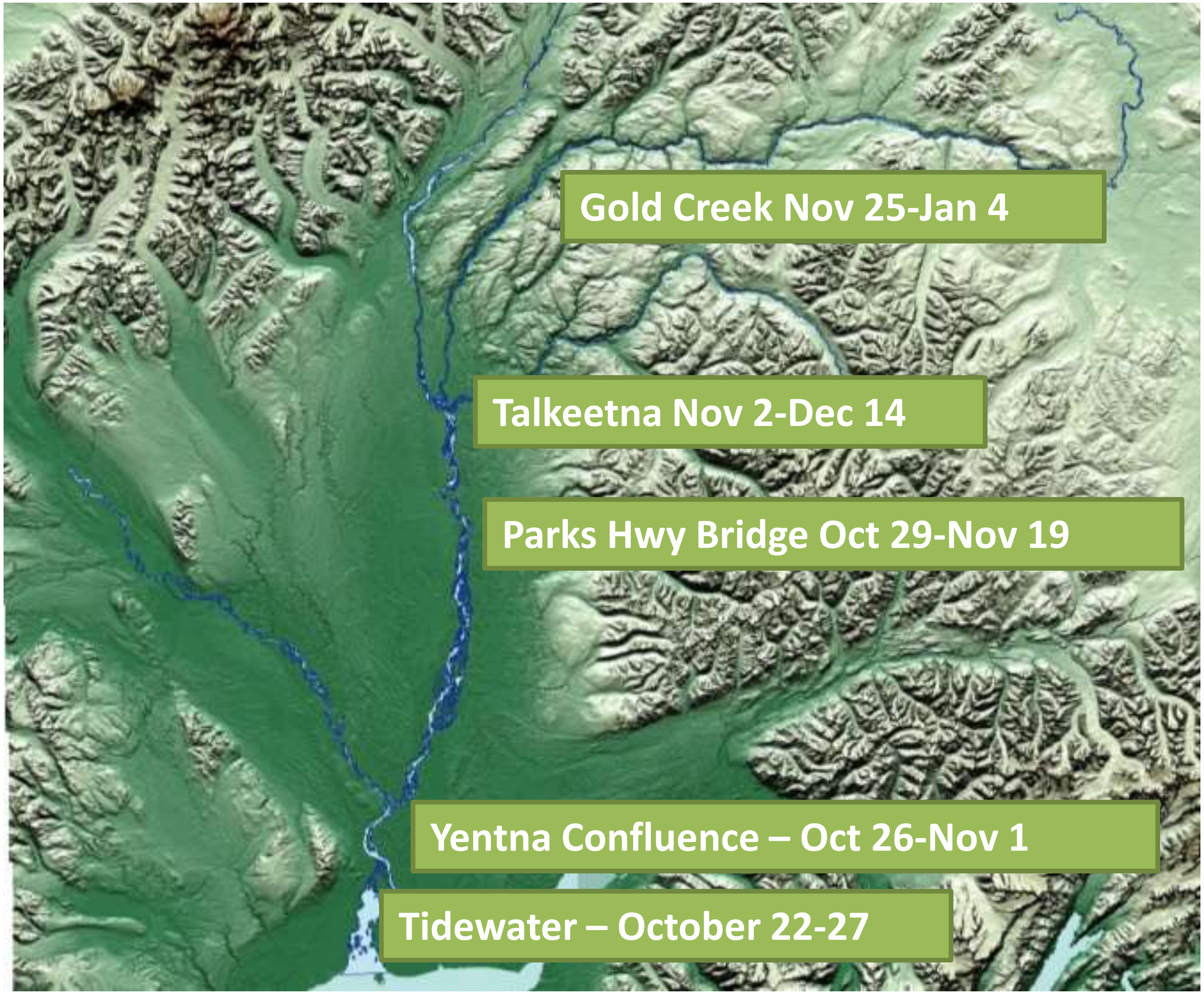
Ice Cover Progression – Timing (1980-1985)



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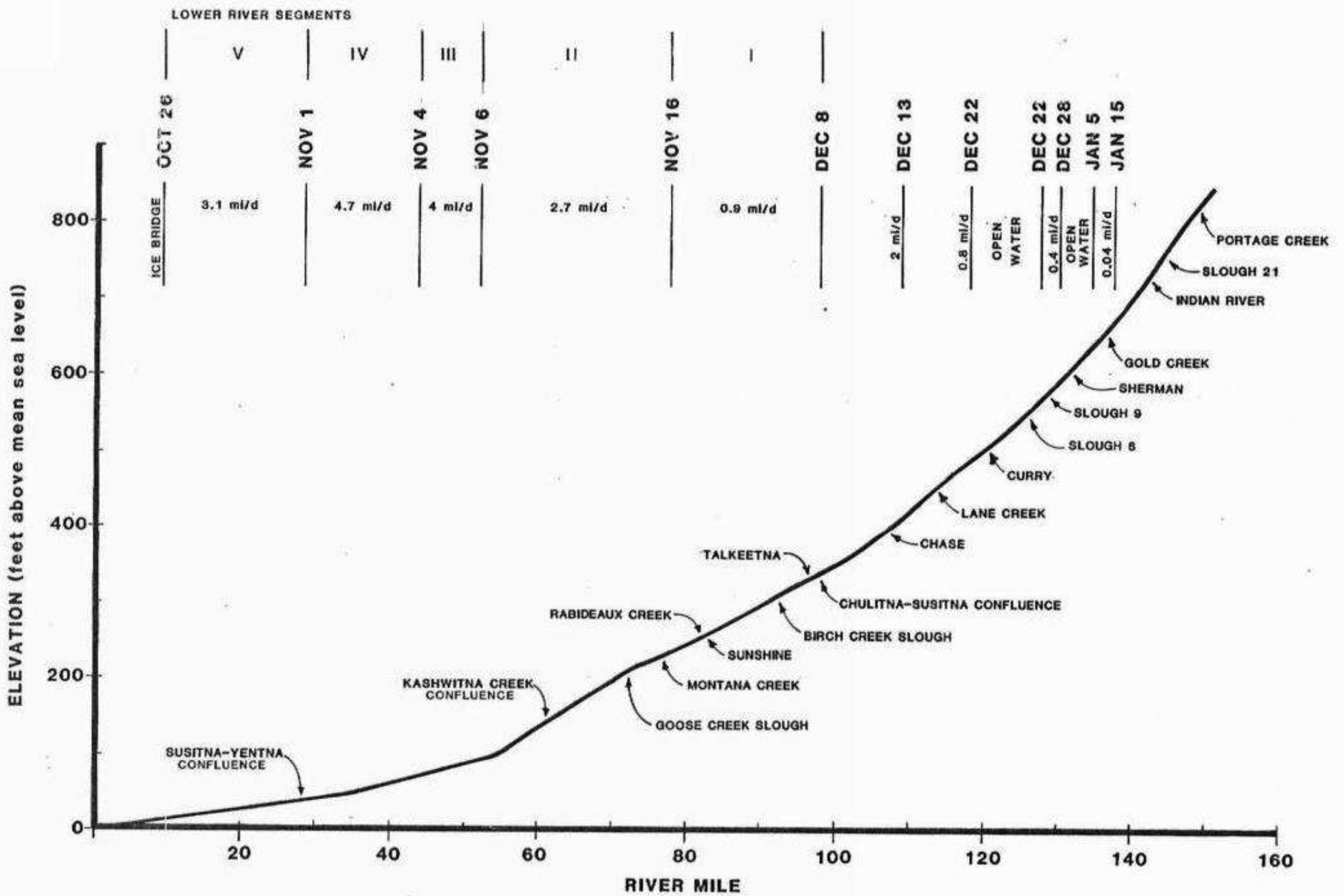
Ice Cover Progression - Timing



SUSITNA RIVER ICE LEADING EDGE PROGRESSION RATES (miles/day) RELATIVE TO THE THALWEG PROFILE FROM RIVER MILE 0 (Cook Inlet) TO RIVER MILE 155 (DEVIL CANYON)

R&M 1984

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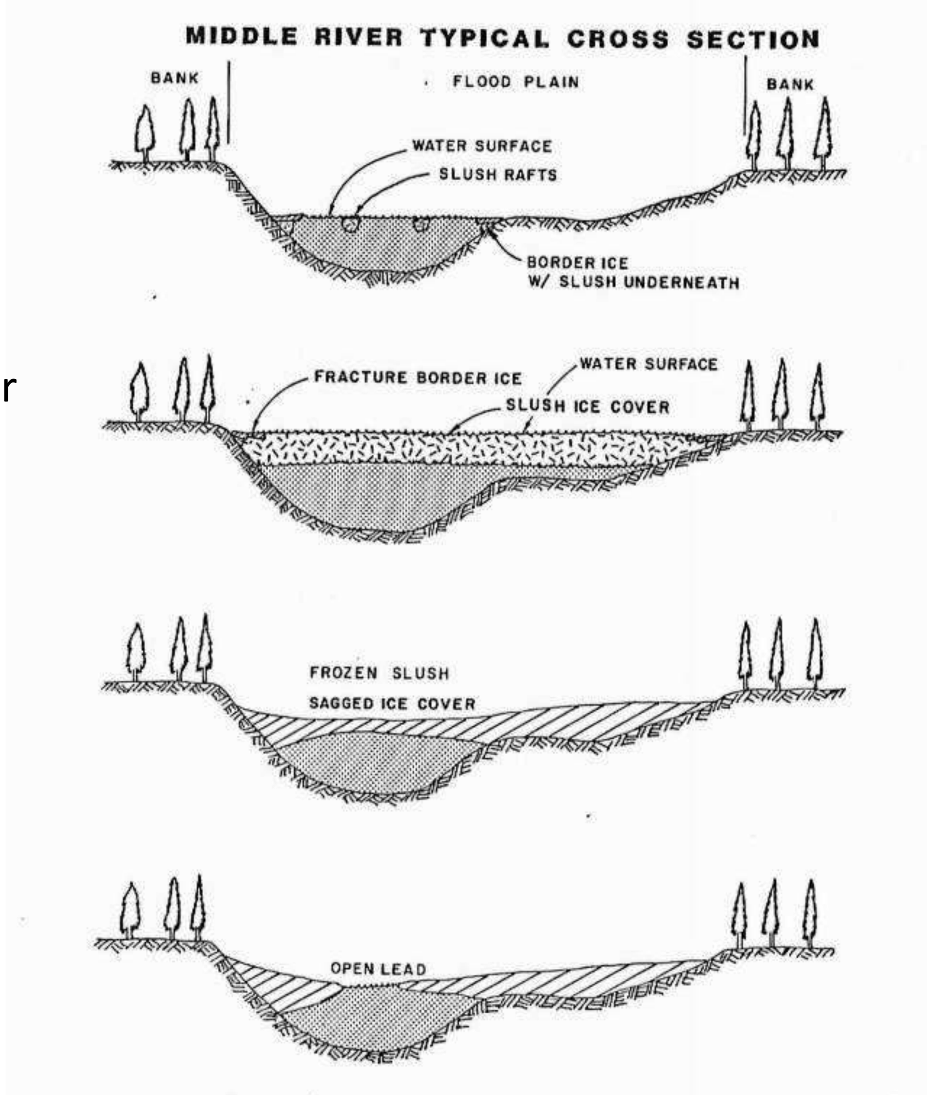
Ice Covered Conditions

- Ice cover increases drag and decreases channel area
- Stage (water surface elevation) increases and velocity decreases for the same discharge
- As discharge decreases, the ice cover over the active channel sags.
- Increased stage during ice cover in the main channel may drive upwelling groundwater into lateral habitats (Trihey 1982 found that at one location, an ice-covered flow of 1500-2500 cfs had an stage equivalent to 18,000 cfs under open water.)



R&M 1984

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Open Leads

- Open leads were observed all study years, but were systematically mapped between Sunshine and Devil Canyon in March, 1983.
- Some reaches were found to have recurrent velocity leads, although the configuration of leads varied between years.
- Thermal leads occurred in side sloughs every year of the study.

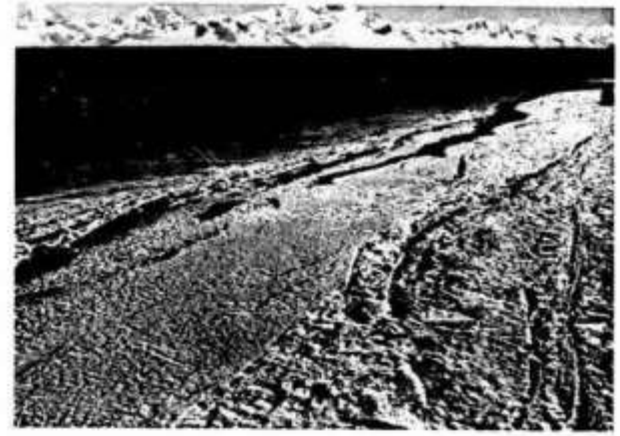

PHOTO 4.13
Susitna River at river mile 106 on November 17, 1982. Flow is from the upper right to lower left. Ice cover has telescoped to cover the river channel from bank to bank. Note the sagging ice cover over the narrow winter channel and the open leads created by turbulent flow.

PHOTO 4.14
Open leads on February 2, 1983 at river mile 103.5, view looking downstream. Note the slush ice cover developing in the foreground.

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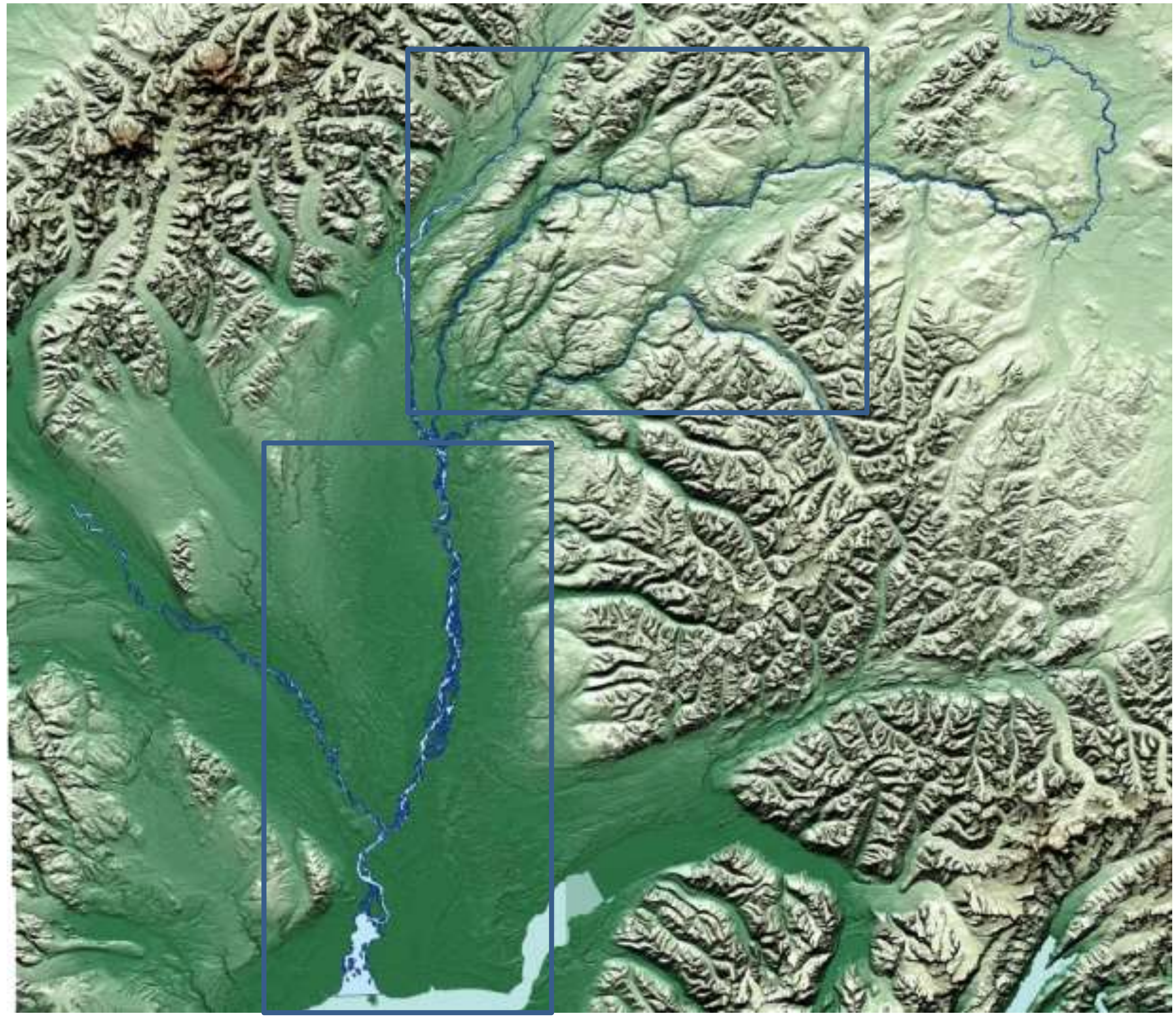
1980-1985 Susitna River Breakup Chronology

- The Lower River is exposed to the most solar radiation and warmest temperatures, and melts out first (late April to early May)
- The Middle River breaks up as upper basin snowmelt increases. Breakup dates in the Middle River ranged from May 8 to May 24 between 1975 and 1985.
- Upper River breakup was presumed to occur after the Middle River.



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1980-1985 Susitna River Breakup Processes

- Thermal breakup in Lower River combined with the unconfined channel geometry resulted in few observed overbank events during breakup.
- Middle River breakup varied in severity depending on weather in April and May. The most dynamic breakups were driven by rapid flow increases lifting and physically breaking the ice cover.
- The timing and progression of jamming in the Middle River does not appear to be systematic, although jams tend to occur in the same places.

RM 108, ARRC Photos

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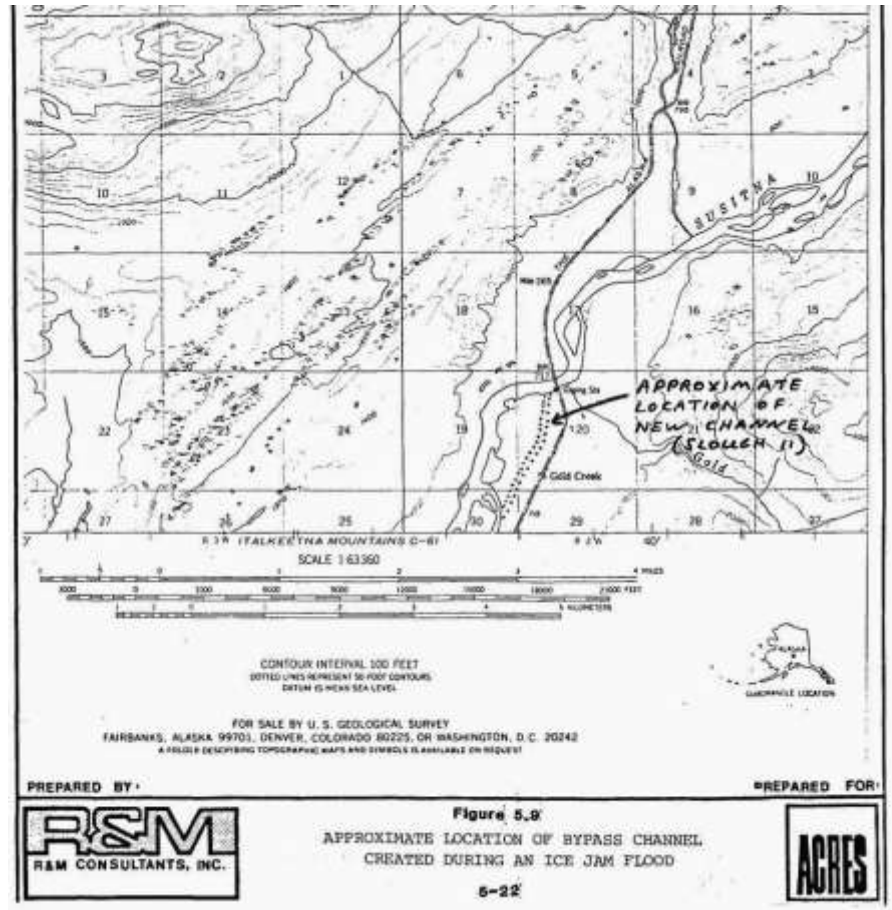
Effects of Breakup on Habitat, Vegetation and Geomorphology

- In the Middle River, breakup jams have created new side channels/sloughs, (Slough 11 formed in 1976) and significantly scoured existing lateral habitats.
- In the Middle River, ice jams were correlated with deep scour holes in the main channel.
- Ice jam breakouts often drove ice overbank and damage trees and railroad tracks in the Middle River.



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1985 Modeling Results and Predicted Project Effects (Middle River – Watana Only)

- The dam would release above-freezing water, creating an open reach extending 40-50 miles downstream of the dam (ice cover would end just downstream of Gold Creek in warm years, downstream of Portage Creek in cold years)
- The formation of an ice cover at Talkeetna would be delayed by 2-4 weeks (3 weeks on average).
- Within the open-water reach, stages would be lower than or equal to natural ice-covered conditions.
- Within the ice-covered reach, stages would be 2-7 feet higher than natural conditions.
- The increased stage may result in breaching of slough berms in the ice-covered reach of the Middle River.
- Breakup would occur 2-3 weeks earlier, and breakup jams in the Middle River would be decreased in severity.

1980's Modeling Results and Predicted Project Effects (Middle River – Watana Only)

TABLE 3

SUSITNA HYDROELECTRIC PROJECT
MAXIMUM SIMULATED WINTER RIVER STAGES
1981-82 WEATHER CONDITIONS (AVERAGE WINTER)
THREE-STAGE PROJECT vs NATURAL CONDITIONS

SLOUGH OR SIDE CHANNEL	RIVER MILE	THRESHOLD ELEVATION	NATURAL CONDITIONS	WATANA ONLY STAGE I		WATANA AND DEVIL CANYON STAGE II		WATANA AND DEVIL CANYON STAGE III	
				CASE E-VI	CASE E-I	CASE E-VI	CASE E-I	CASE E-VI	CASE E-I
Whiskers	101.5	367	$\boxed{368}$	$\boxed{370}$	$\boxed{370}$	$\boxed{370}$	$\boxed{370}$	$\boxed{370}$	$\boxed{370}$
Gash Creek	112.0	Unknown	455	457	458	459	458	457	457
6A	112.3	(Upland)	467	459	461	461	461	459	460
8	114.1	476	472	475	$\boxed{478}$	$\boxed{478}$	$\boxed{478}$	474	475
MS II	115.5	482	$\boxed{484}$	$\boxed{487}$	$\boxed{490}$	$\boxed{487}$	$\boxed{487}$	$\boxed{486}$	$\boxed{486}$
MS II	115.9	487	490	$\boxed{489}$	$\boxed{493}$	$\boxed{490}$	$\boxed{490}$	$\boxed{487}$	$\boxed{488}$
Curry	120.0	Unknown	523	526	526	521	520	518	522
Moose	123.5	Unknown	549	556	556	551	551	546	545
8A West	126.1	573	571	$\boxed{575}$	$\boxed{574}$	$\boxed{573}$	$\boxed{573}$	569	569
8A East	127.1	582	$\boxed{583}$	$\boxed{585}$	$\boxed{585}$	$\boxed{584}$	$\boxed{584}$	581	582
9	129.3	604	$\boxed{606}$	$\boxed{607}$	$\boxed{607}$	$\boxed{605}$	$\boxed{606}$	603	603
9 u/s	130.6	Unknown	620	620	621	619	619	617	617
4th July	131.8	Unknown	629	633	632	630	630	628	628
9A	133.7	651	$\boxed{651}$	$\boxed{656}$	$\boxed{656}$	649	649	650	650
10 u/s	134.3	657	$\boxed{657}$	$\boxed{664}$	$\boxed{663}$	655	655	656	656
11 d/s	135.3	Unknown	670	675	674	667	667	668	668
11	136.5	687	683	$\boxed{688}$	$\boxed{687}$	682	682	684	684
17	139.3	Unknown	UPSTREAM BOUNDARY OF NATURAL SIMULATIONS	715	715	714	714	715	715
20	140.5	730		729	729	728	728	729	729
21 (AB)	141.8	747		747	747	746	746	747	747
21	142.2	755		753	753	752	752	753	753
22	144.8	780		787	786	785	785	787	787
LRX 3 Ice Front Starting Date			11 18	12 10	12 10	12 29	12 29	1 2	1 1
Max. Ice Front Extent (River Mile)			137 4/	139	139	133	133	114	120
Melt Out/Breakup Date			5 10	4 28	4 29	3 26	3 28	3 5	3 6

UPSTREAM EXTENT OF ICE COVER PROGRESSION

NOTES:

1. LOCATIONS WHERE MAXIMUM RIVER STAGE OVERTOPS A KNOWN SLOUGH THRESHOLD ELEVATION
2. ALL RIVER STAGES IN FEET MSL
3. "INFLOW MATCHING" POWER INTAKE OPERATING POLICY IS ASSUMED FOR PROJECT SIMULATIONS
4. ICE COVER FOR NATURAL CONDITIONS EXTENDS UPSTREAM OF GOLD CREEK (RIVER MILE 137) BY MEANS OF BORDER ICE BRIDGING

Predicts breaching of Whiskers Slough, MSII, 8A, 9, 9A, 10, 11.

Harza-Ebasco 1985

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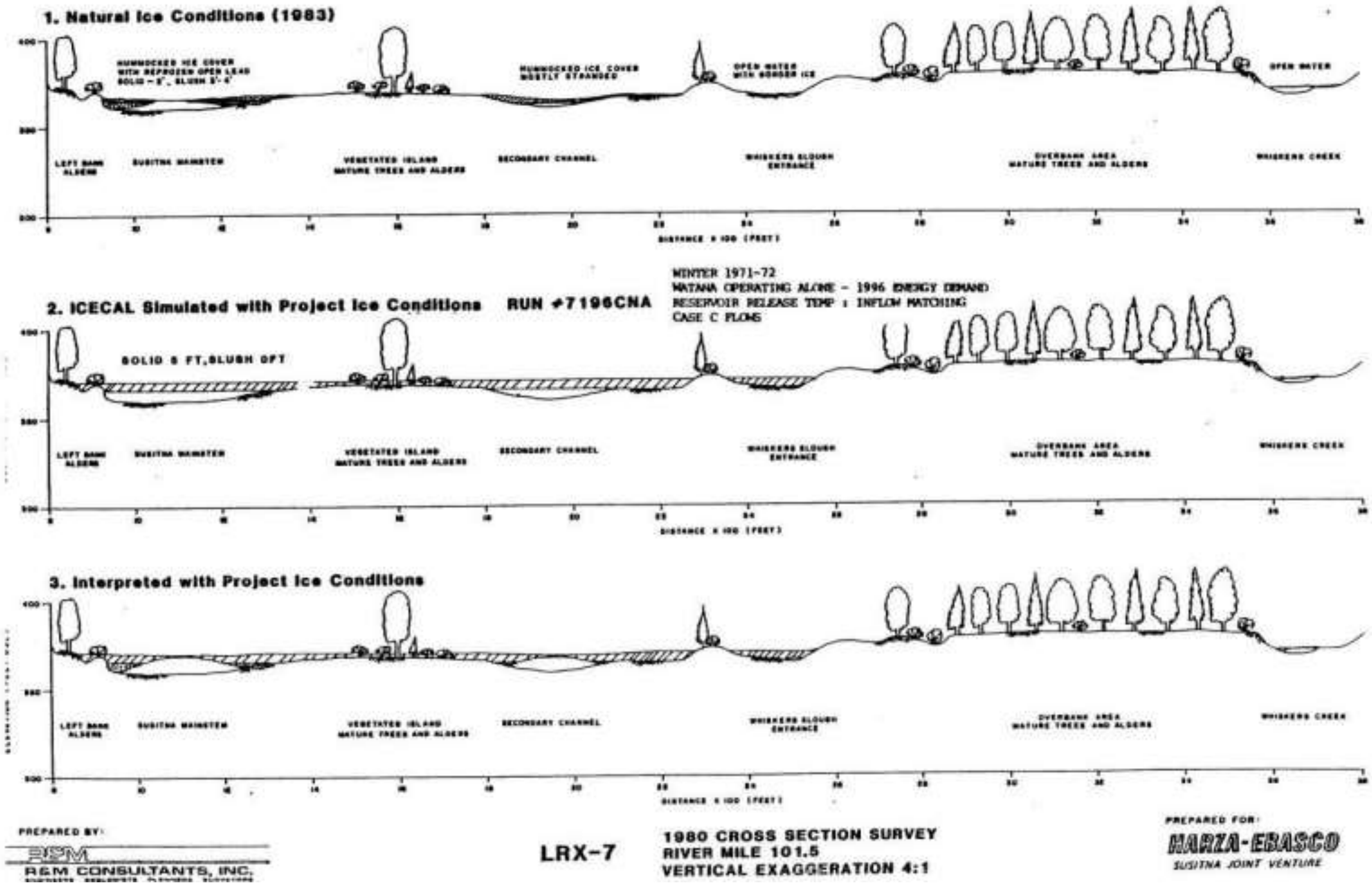
HYDROELECTRIC PROJECT

1980's Modeling Results and Predicted Project Effects
Whiskers Slough



AEIDC 1985

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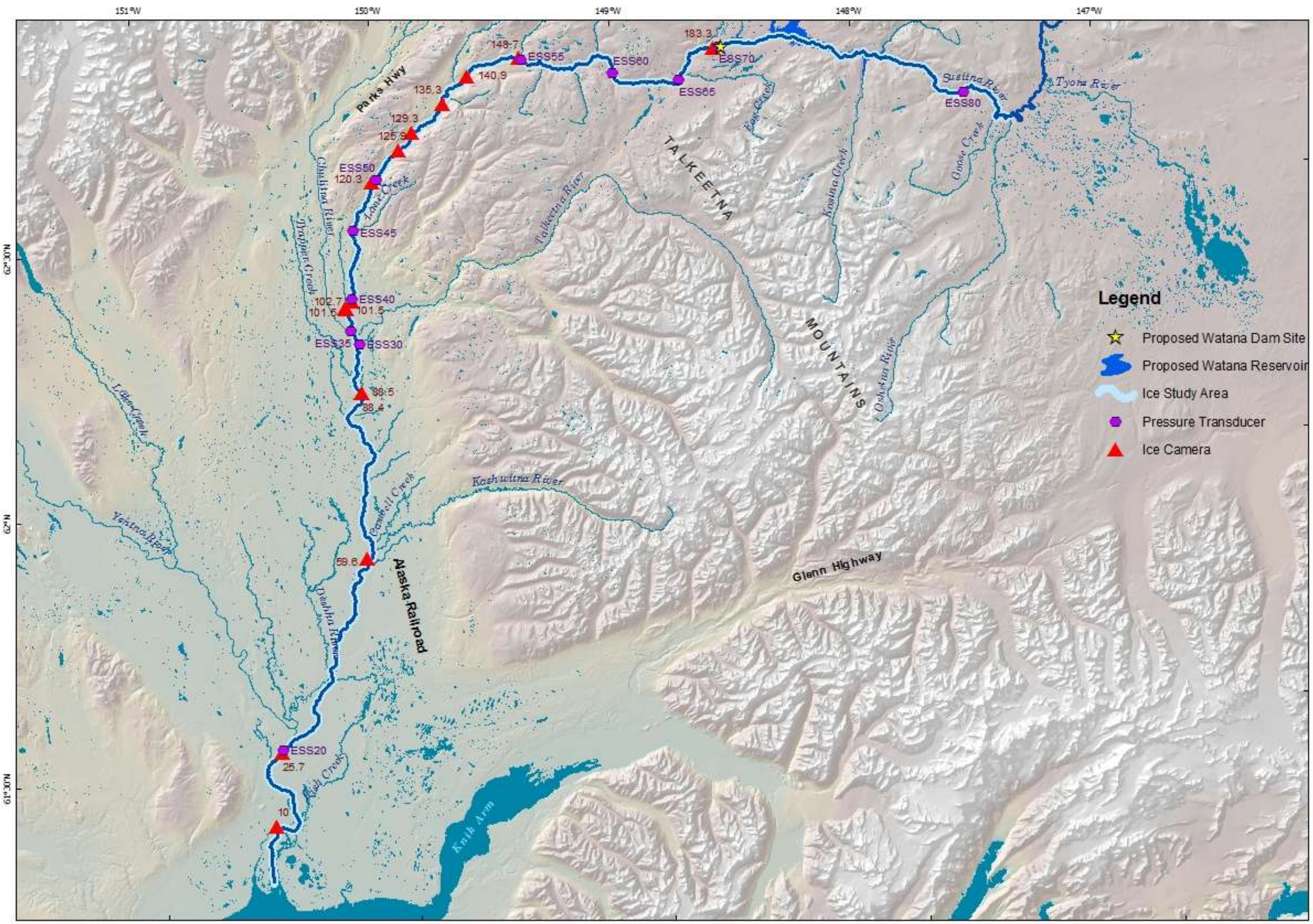
2012 Study Area



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2012 Open Leads

- Mapped from mouth to Oshetna Confluence
- Thermal leads
- Velocity Leads
- Some unknown
- Many locations similar to 1983 mapping (Middle River Sloughs)

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2012 Open Leads – Lower River

Thermal lead with tannic staining,
RM 15, PRM 19.6

Mid-river gravel bar seep, RM 32, PRM 36

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2012 Open Leads – Lower River

Velocity Leads near Talkeetna, RM 97, PRM 100.5

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2012 Open Leads – Middle River Thermal

Slough 8A, RM 126, PRM 130

Slough 1, RM 135, PRM 139

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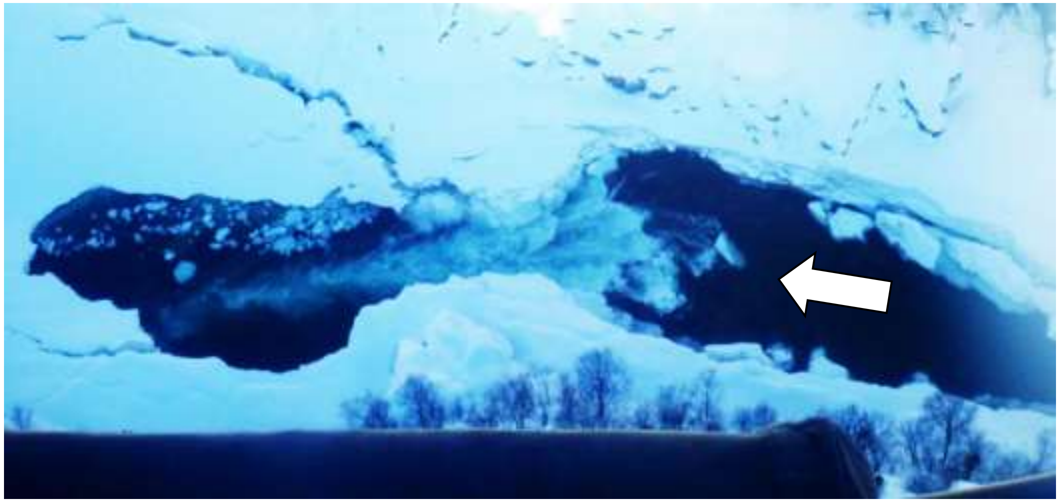
2012 Open Leads – Middle River Velocity



Devil Canyon, RM 152, PRM 156

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2012 Open Leads – Middle River above Devil Canyon

RM 170 Velocity lead opening up, April 2012

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2012 Open Leads – Upper River

Vee Canyon, RM 222, PRM 224

Oshetna Confluence, RM 232, PRM 234

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2012 Breakup Observations

- Very mild breakup occurred from April 25th to May 5th.
- Long period of diurnal melt/freeze allowed snowpack to slowly run off while the ice weakened.

Lead opening up on April 23, 2012, RM 133, PRM 136

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2012 Breakup Near Mouth

RM 10, PRM 15, April 27th (above) and April 30th (right)

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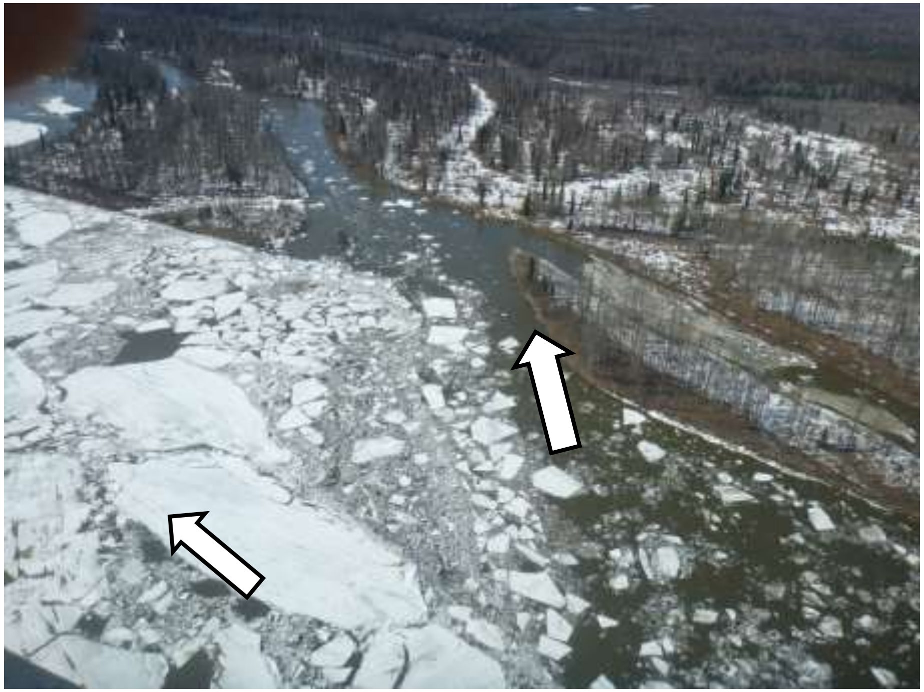
2012 Breakup Observations – Lower River

RM 62, PRM 66 Ice jam, April 30, 2012



RM 32, PRM 36 Ice jam, April 30, 2012

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2012 Post-Breakup – Lower River

RM 26, PRM 30 stranded ice, May 9, 2012

RM 10, PRM 15 eroded bank, May 10, 2012

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2012 Breakup – Gold Creek/Slough 11 RM 134-136, PRM 137.5-140

April 19th

April 27th

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2012 Breakup Observations – Gold Creek/Slough 11 Jam Moved Downstream to RM 129, PRM 132.5

May 2nd, Slough 11

May 2nd, Slough 9

2012 Breakup – Gold Creek/Slough 11

May 2nd, Slough 11 Entrance

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2012 Breakup – Slough 9

Side channel entrance post-breakup, May 9th

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2012 Breakup – Devil Canyon

Leads opening, April 27th

Remains of ice shelf, May 2. Ice cover Composed of rounded fine slush balls.

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2012 Breakup – Upper River

Vee Canyon, RM 221.5, PRM 223.4 April 27th

RM 221, PRM 223, May 9th

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2012 Breakup – Watana Dam Site Area

Stranded ice chunks, above and "bulldozed" soil, right.
May 9, RM 183, PRM 186

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2012 Breakup Summary

- Dominantly thermal breakup, within normal timeframe.
- Very little observed damage to vegetation
- Very little potential for slough scouring or channel change
- Minor sediment deposition and erosion

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2012 Freeze-up Conditions

- Much higher than average flows during early ice formation (October 12th flows were twice average at Gold Creek and Sunshine, and near proposed project flows)
- Colder than average November, warmer December and January
- Unusually high water as ice front reached Talkeetna
- Progression followed patterns observed in the 1980's.

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Frazil Ice, October 16th, Whiskers Slough

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Frazil Ice and Border Ice October 26th

Slough 6A, RM 112, PRM 115.5

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2012 Freeze-up – Devil Canyon October 22

Lower Devil Canyon Ice Bridge, RM 151, PRM 155

Middle Devil Canyon Ice Bridge, RM 155, PRM 158.5

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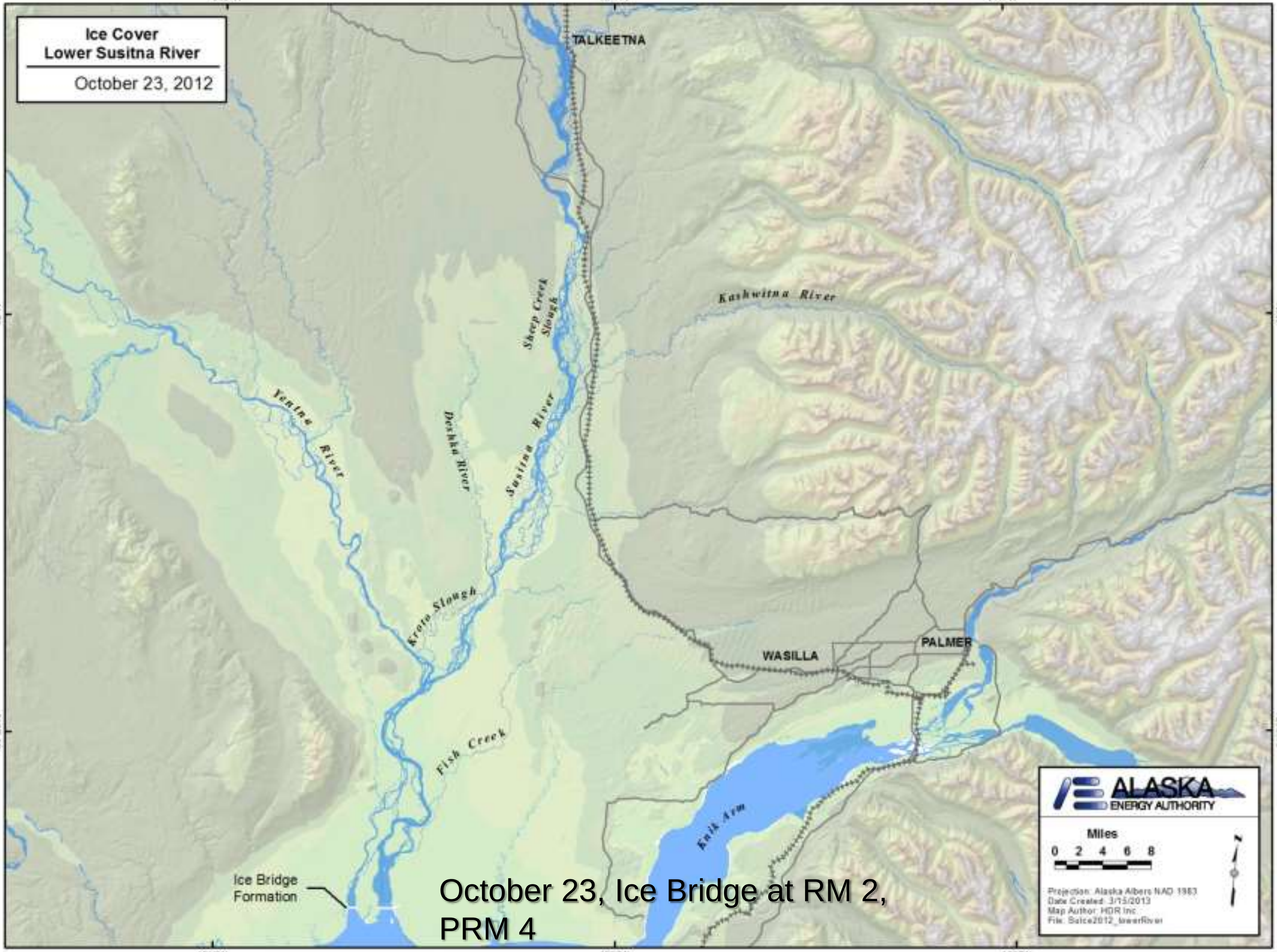
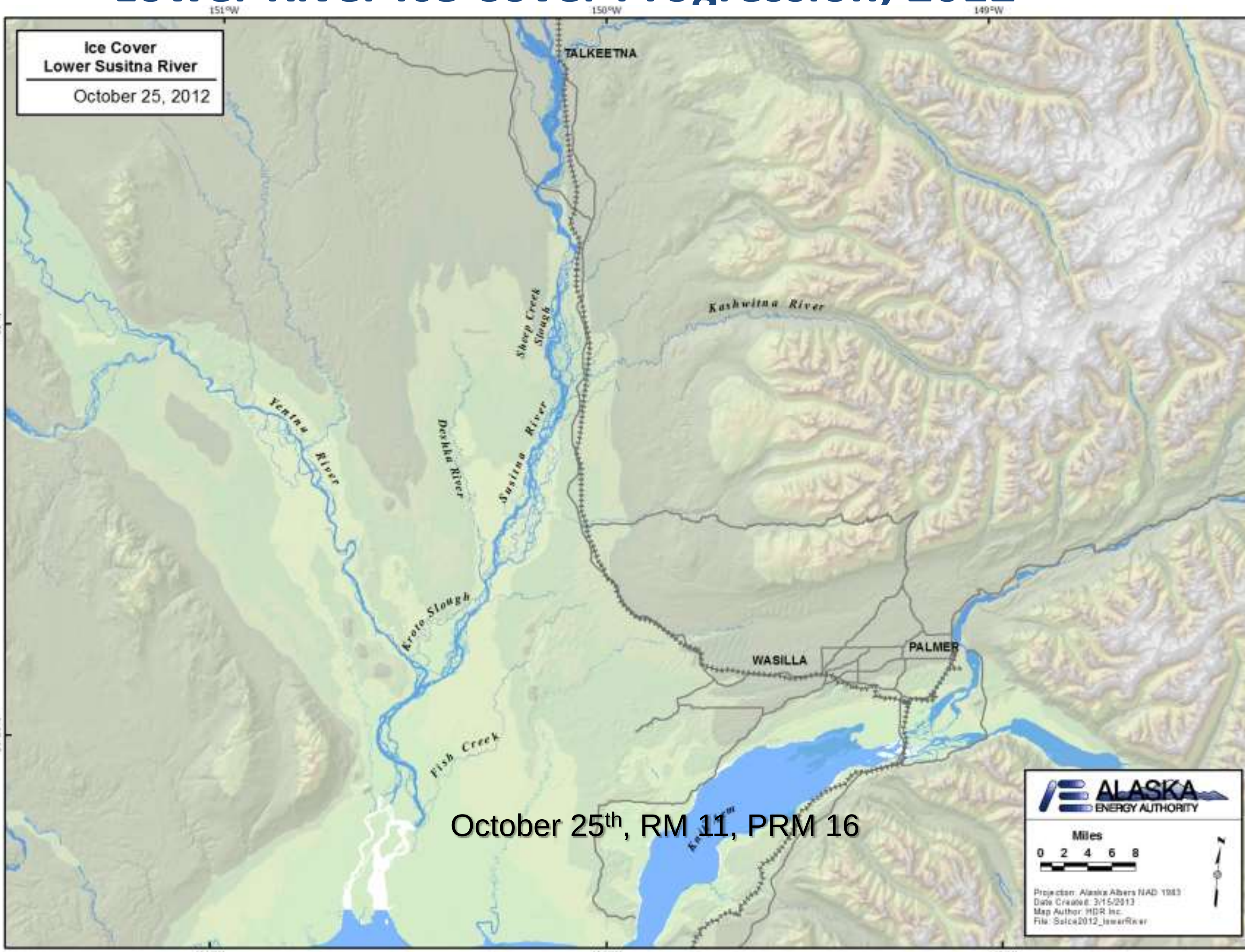
Bridge near Tidewater, October 23

Lower River Ice Cover Progression, 2012



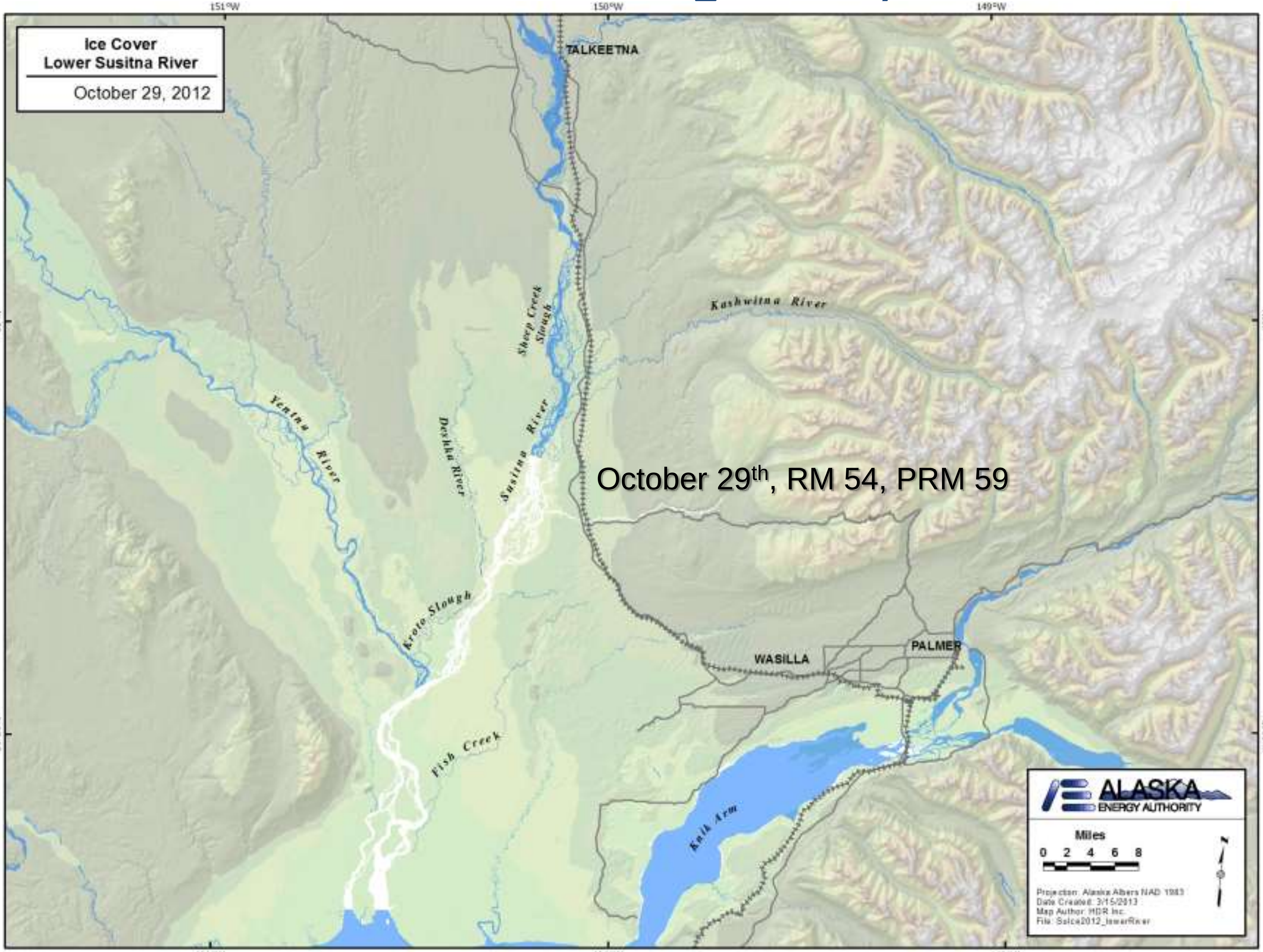
October 23, Ice Bridge at RM 2, PRM 4

Lower River Ice Cover Progression, 2012

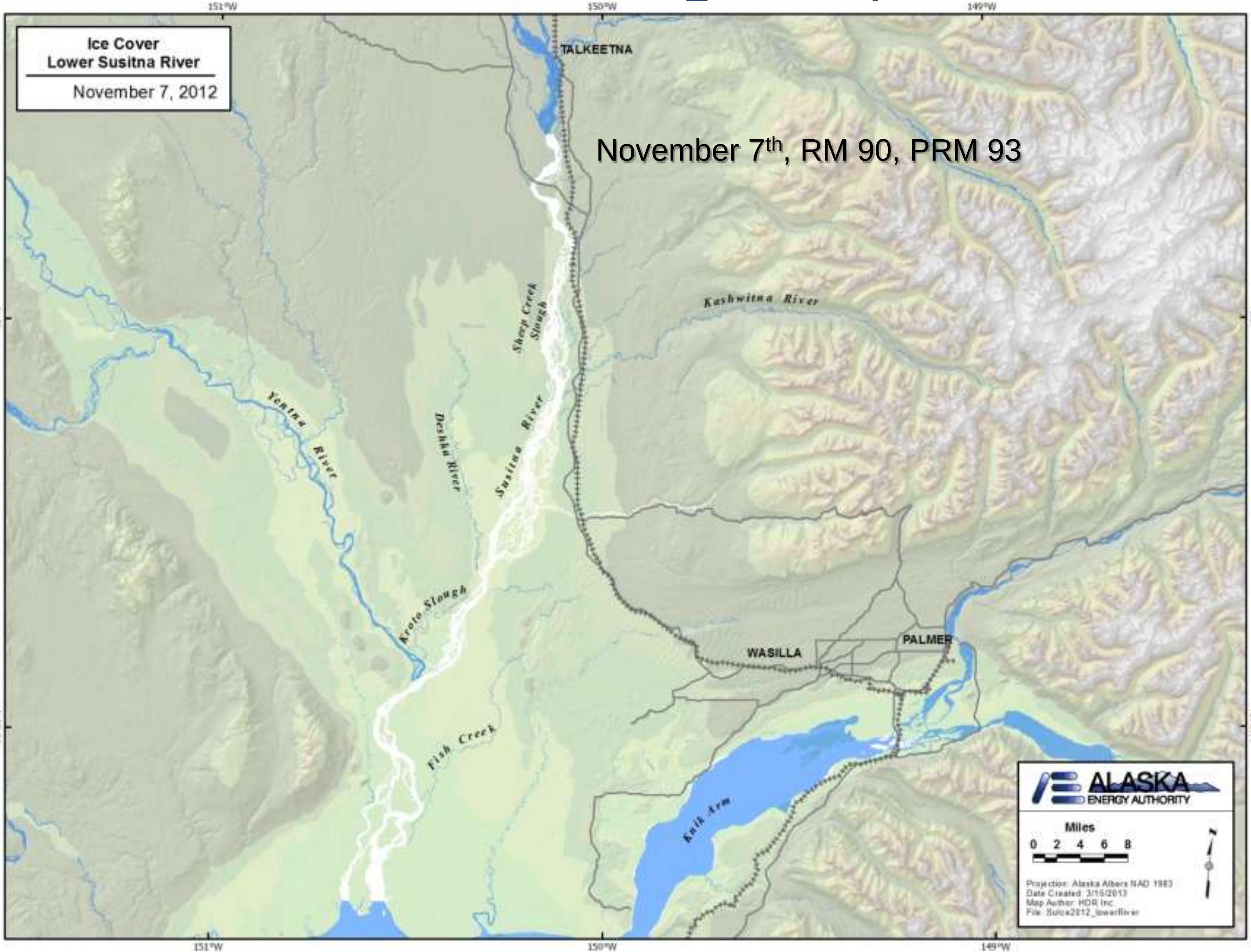


October 25th, RM 11, PRM 16

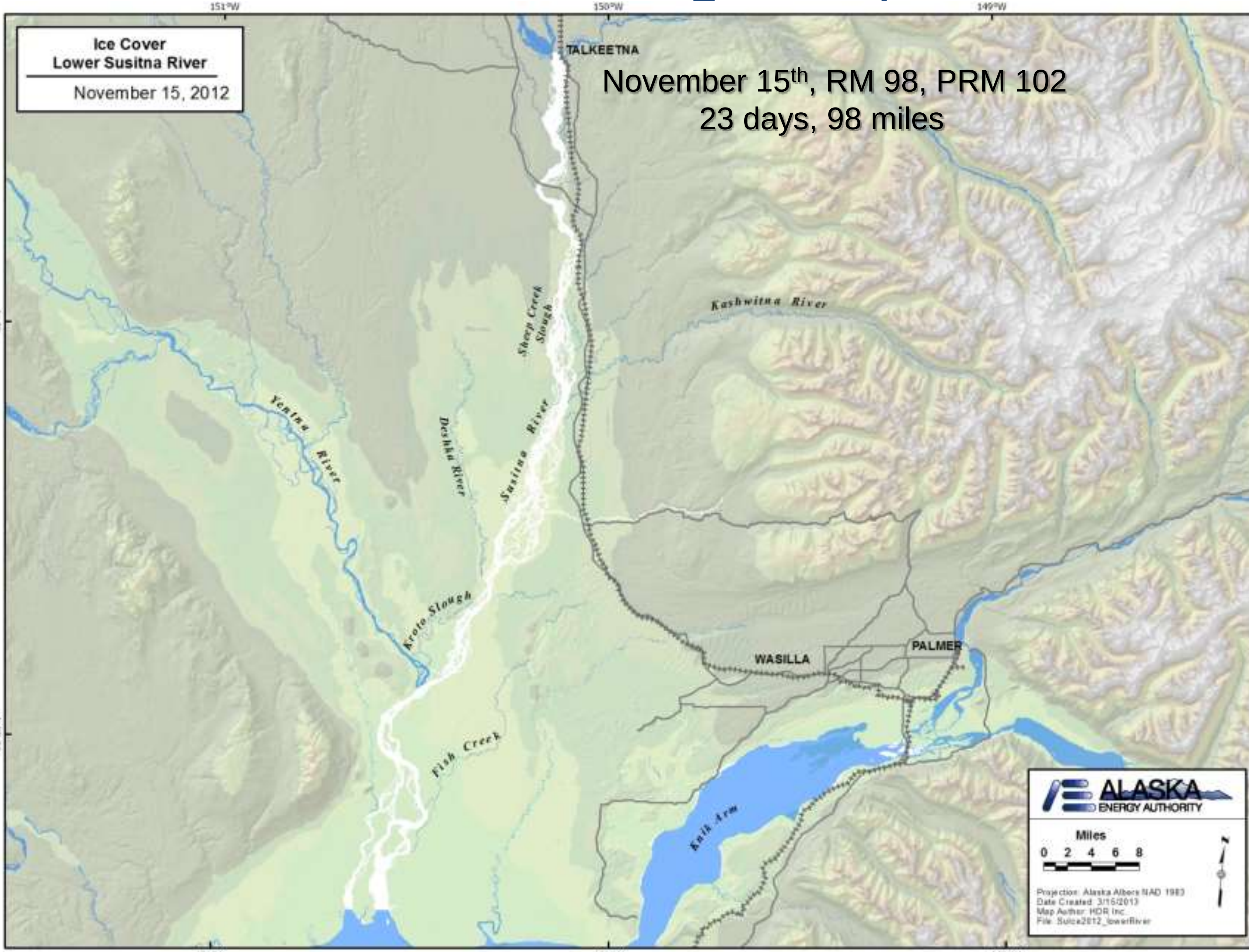
Lower River Ice Cover Progression, 2012



Lower River Ice Cover Progression, 2012



Lower River Ice Cover Progression, 2012



2012 Freeze-up Observations – Lower River

- Ice cover progressed rapidly at first then slowed – 11-12 miles/day up past the Yentna, 7 miles/day past Sunshine, 4 miles/day to Talkeetna.
- Staging flooded gravel bars and braidplain, but not vegetation.
- Cover was largely juxtaposed below Yentna, hummocky through Delta Islands and Sunshine.

Ice cover leading edge, RM 68, PRM 72.4

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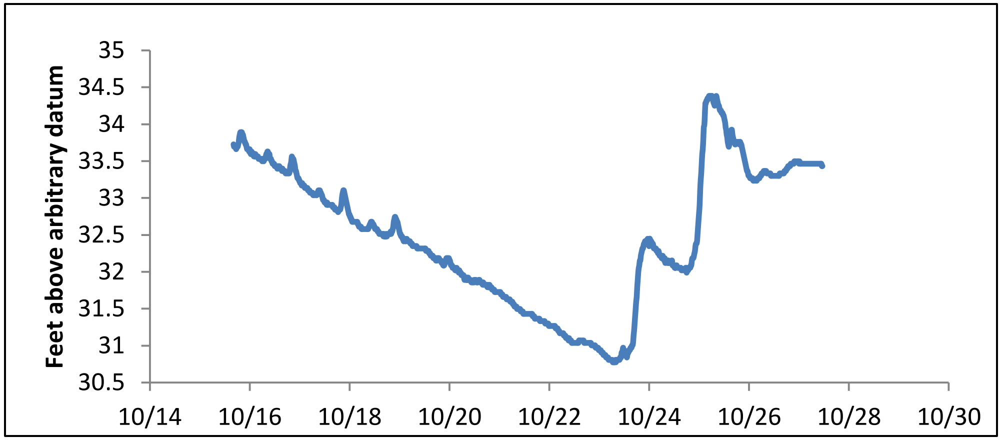
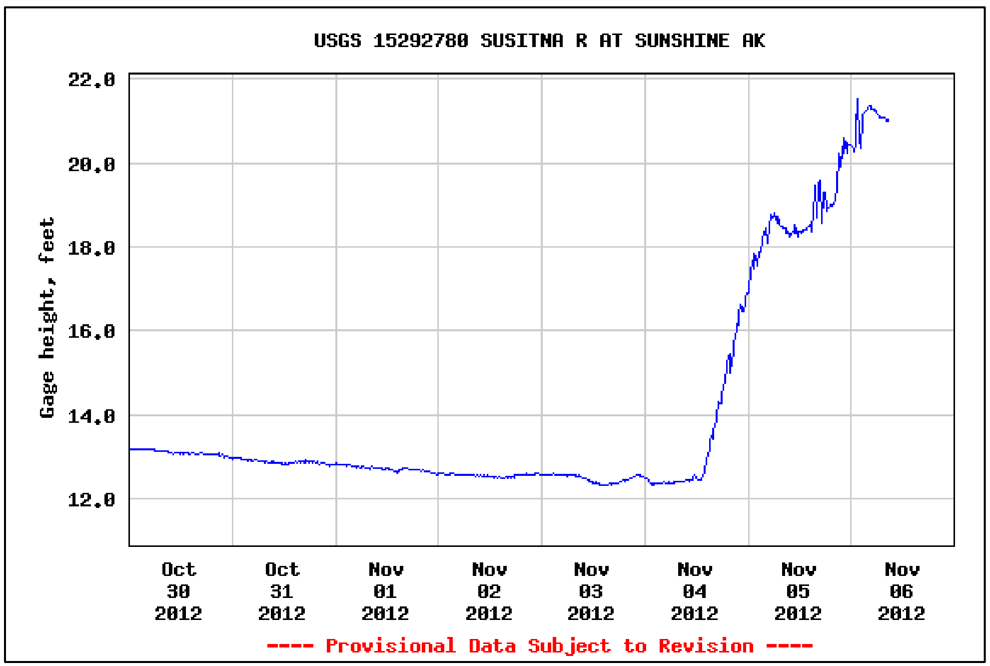
2012 Freeze-up Observations – Lower River Staging



Water level rose 4 feet at ESS10 (RM 15, PRM) as ice front progressed



Water level rose 8 feet at the USGS gage at the Parks Highway Bridge as ice front progressed

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2012 Freeze-up – Lower River Staging

Flooded gravel bars at RM 54, PRM 59 on October 29th

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2012 Freeze-up – Lower River Staging at Sunshine

Parks Highway Bridge, November 1st

Parks Highway Bridge, November 7th

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2012 Freeze-up Flooding Talkeetna Area, Nov 15th

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2012 Freeze-up Flooding Talkeetna Area, Nov 15th

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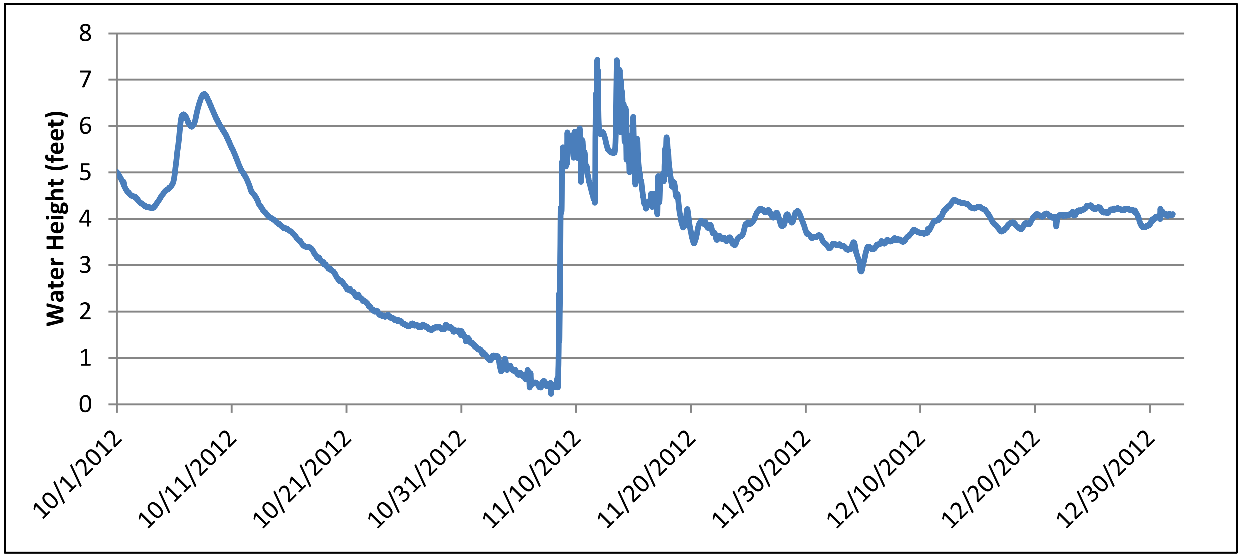
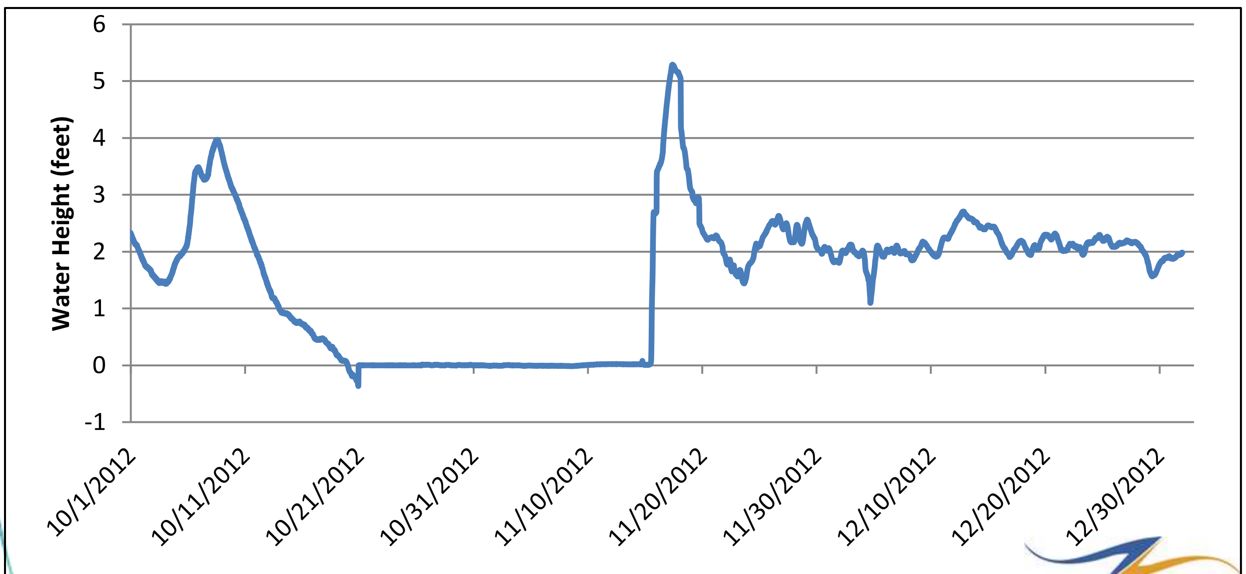
2012 Freeze-up Staging, Talkeetna Area





Pressure transducer readings indicate 7 feet of rise at ESS30 (RM 97, PRM 100.3) above and at least 5 feet at ESS35 (RM 99, PRM 102.3) below.

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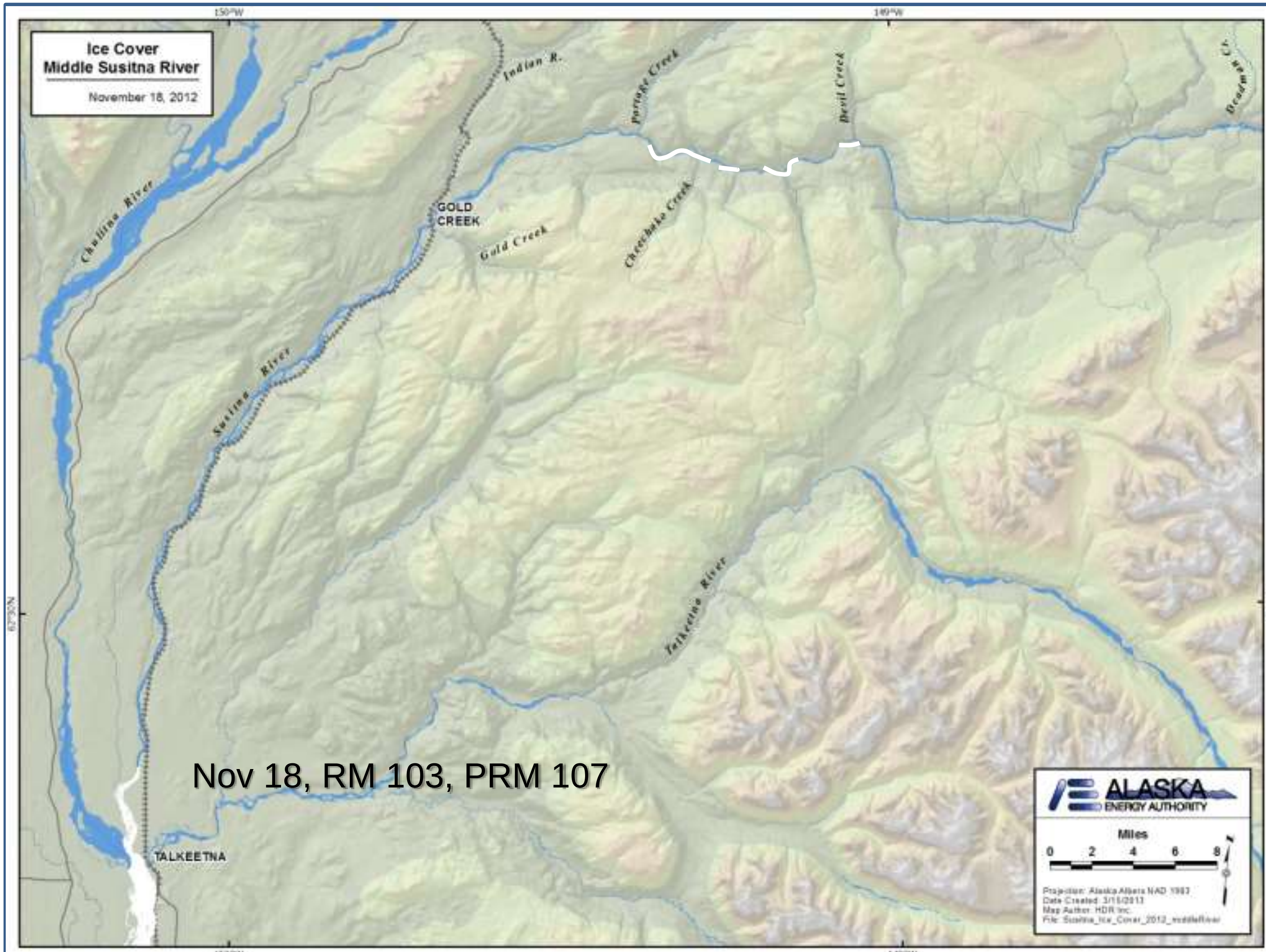
2012 Freeze-up Progression – Middle River



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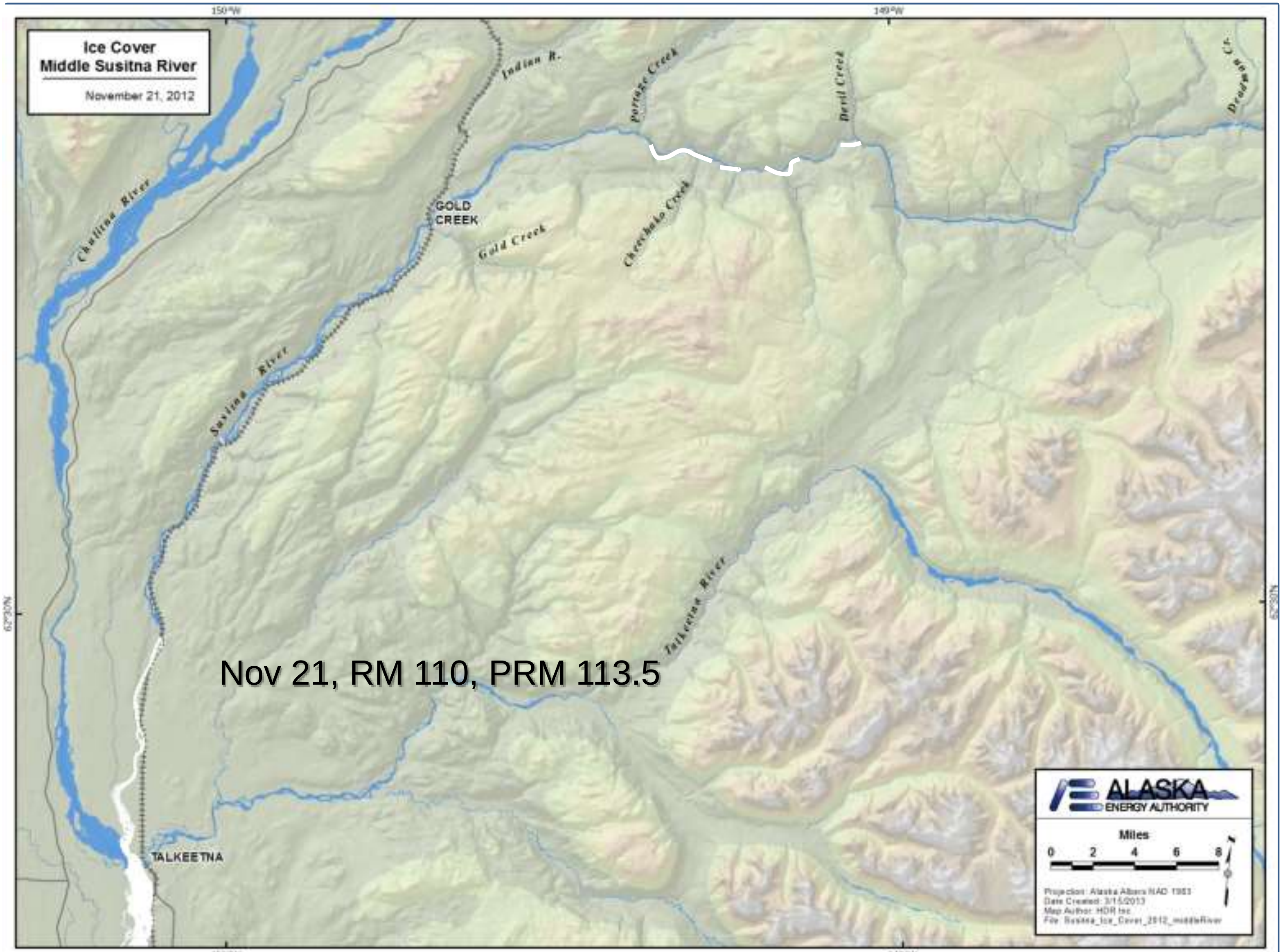
2012 Freeze-up Progression – Middle River



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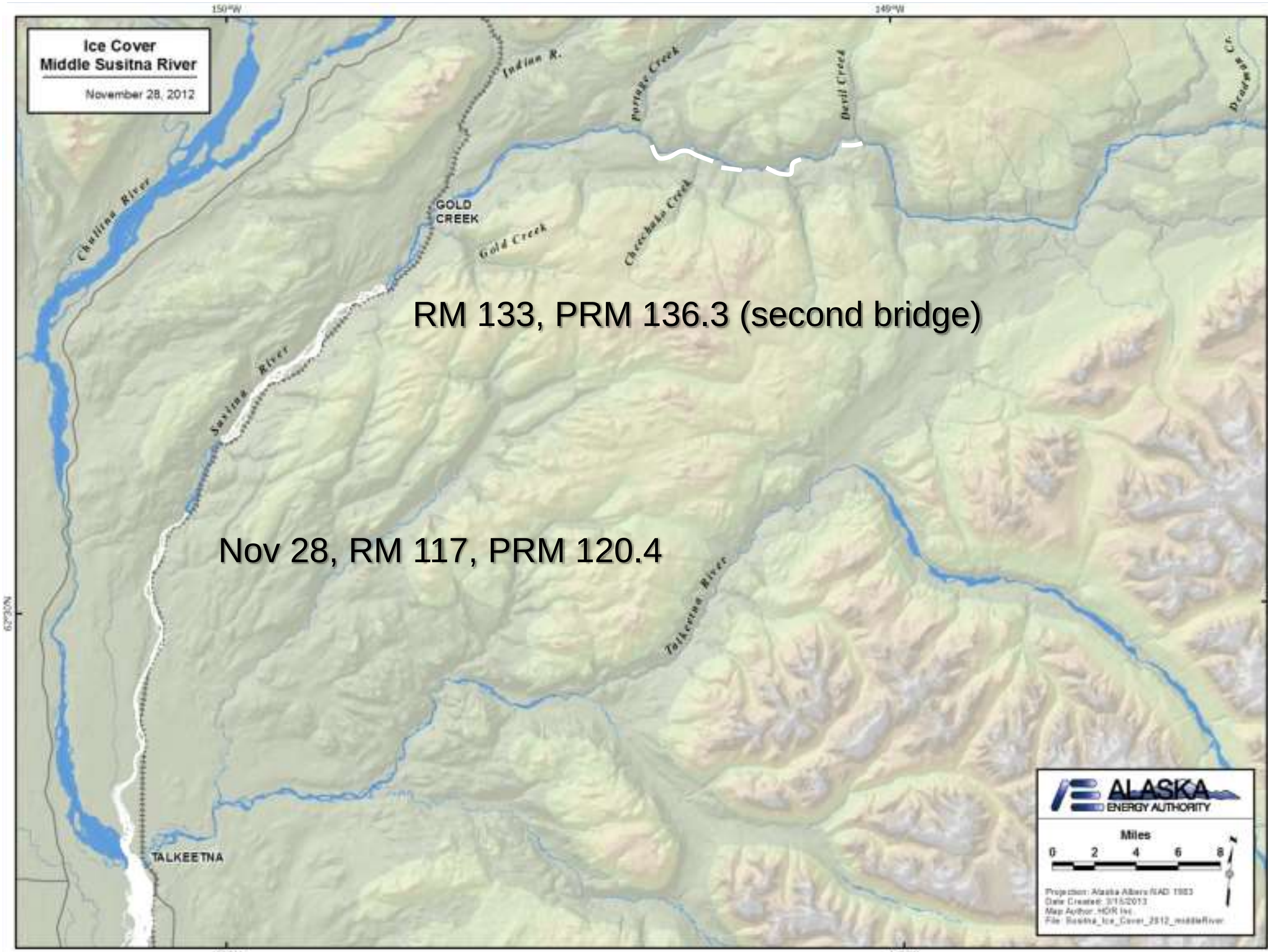
2012 Freeze-up Progression – Middle River



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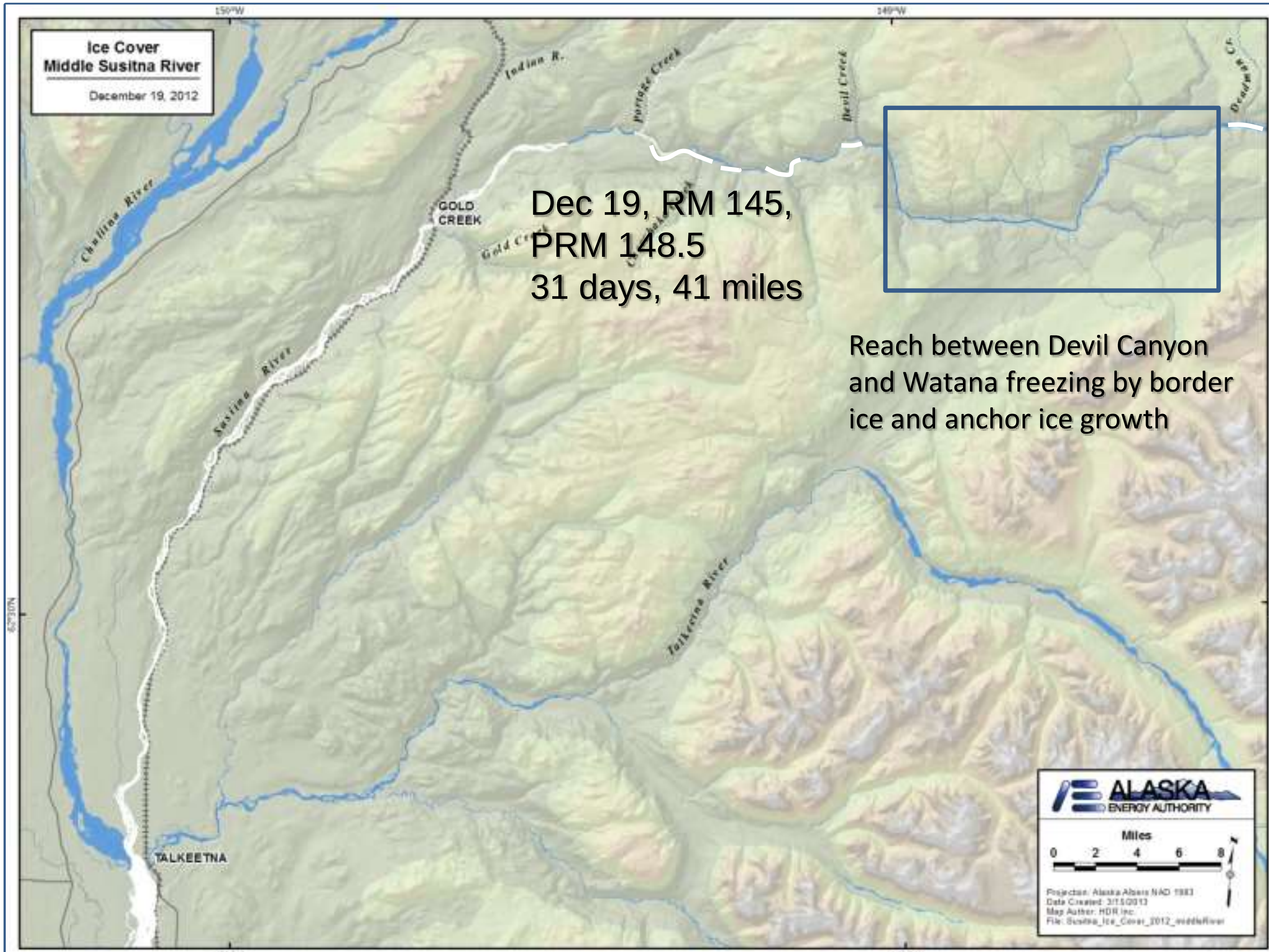
2012 Freeze-up Progression – Middle River



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2012 Freeze-up – Slough 6A, RM 112, PRM 115.5

October 26th

November 15th

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2012 Freeze-up – Slough 6A, RM 112, PRM 115.5

November 28th

Anchor Ice, Middle River Above Devil Canyon

RM 172, PRM 175, November 15th , 2012

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2012 Freeze-up Observations – Upper River

Above, Upper River ice bridge, RM 194, PRM 196.6, November 15th

Right, Upper River ice front, RM 215, PRM 217.5, November 15th

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2012 Freeze-up Observations – Upper River

Oshetna River breakout flood, November 15th

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2012 Study Summary

- Mapped open leads from mouth to Oshetna confluence. Determined that most thermal leads are in the same location as in the 1980's, while velocity leads are in the same general locations.
- Observed a very mild breakup, which may be similar to post-project conditions in that flow did not increase rapidly and ice breakup was mostly thermal.
- Mild breakup meant few observed effects on channel morphology, vegetation, or fish habitat.
- Observed a freeze-up with unusually high initial flows, similar to post-project conditions, although flows dropped rapidly.
- Documented Upper River ice cover formation.
- Progression of freeze-up and breakup was within the range of those documented 1980-1985.

Ice scar near Whiskers Creek. This did not happen in 2012.

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Ice Process Studies: 1st Quarter Activities, 2013

- Measured thickness, elevation, and discharge (January and March)
- Processed freeze-up videos
- Continued freeze-up reconnaissance until January 9th
- Started developing Lower River HEC-RAS models with ice cover
- Started review of cold-regions hydropower projects
- Mapped open leads, March

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