Rapid Assessment Flooding Tool (RAFT)

ASFPM Conference, Phoenix, Arizona - June 20, 2018

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Acknowledgments

FEMA Region 10 – Ted Perkins

Oregon Silver Jackets

- Julie Ammann, Ryan Cahill, USACE – Portland
- Andy Bryant, NWRFC
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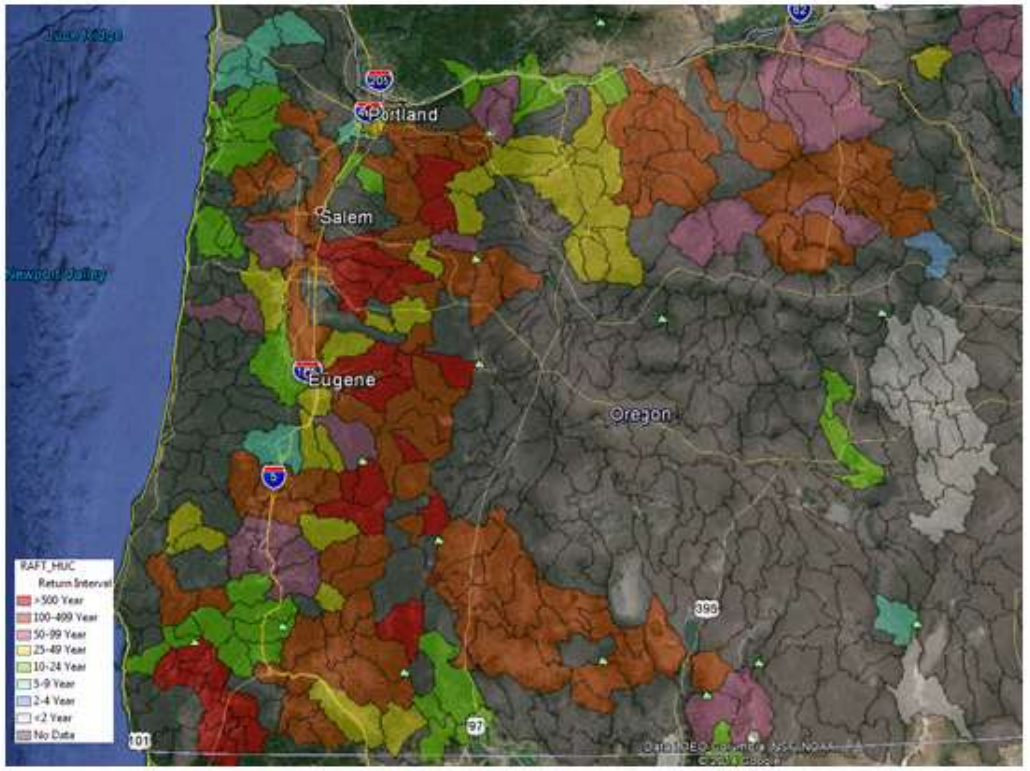
- Anu Acharya, Oregon Water Resources Dept

Washington Silver Jackets

- Travis Ball USACE – Seattle
- Mark Mastin, WA USGS

Idaho Silver Jackets

- Tracy Schwarz USACE –Walla Walla



Flood Risk Communication & RAFT

STARR II Strategic Alliance for Risk Reduction

RAFT Origins in Region 10

Current Flood Risk Information

What Flood Risk Information is used for

Why Flood Frequency tells the best story from a national assessment perspective

December 2015 Flood Event with RAFT

How we expanded this nationally

Next Steps

Origin of Need - Response

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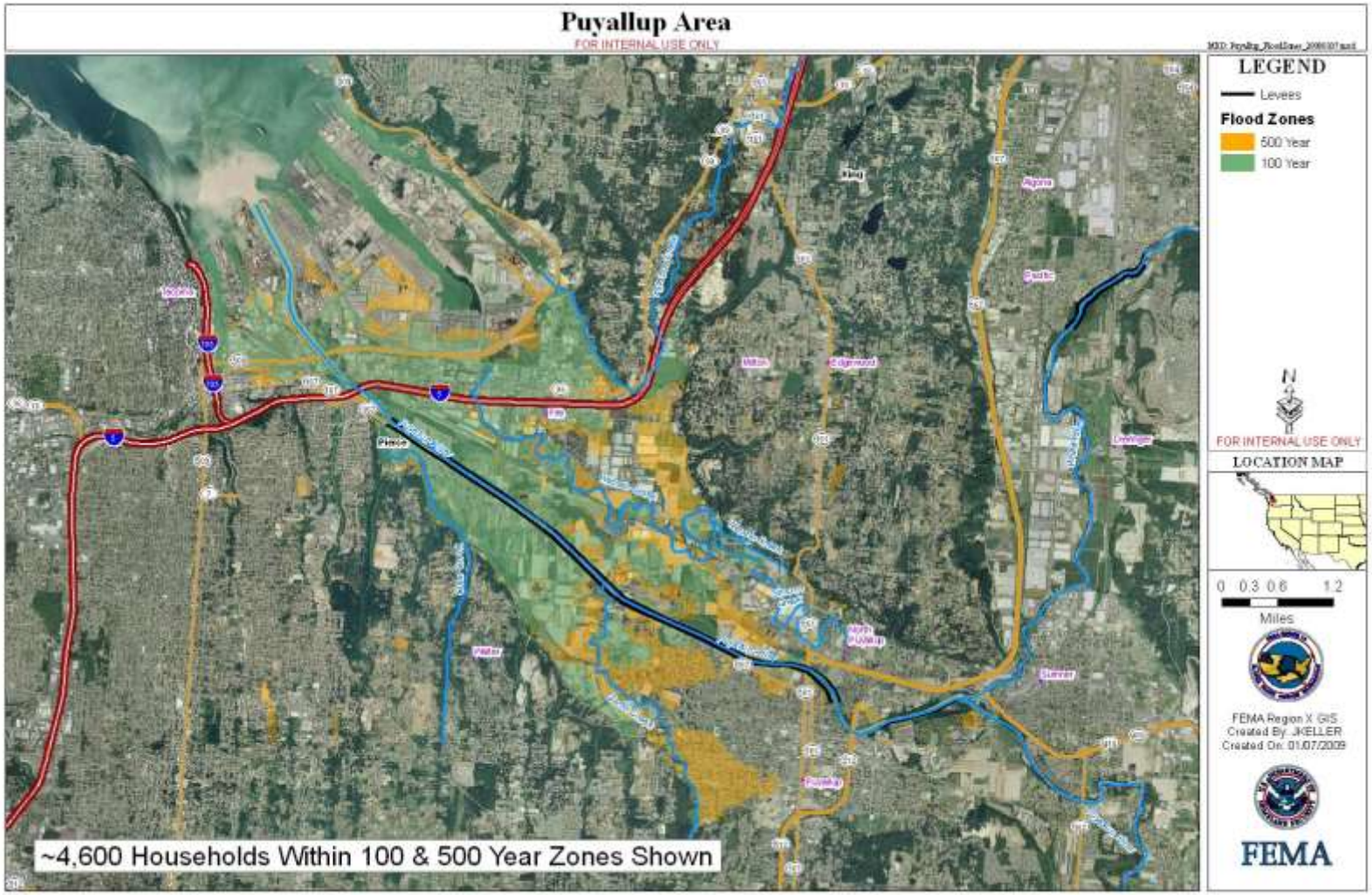

Origin of Need

Origin of Need - Recovery

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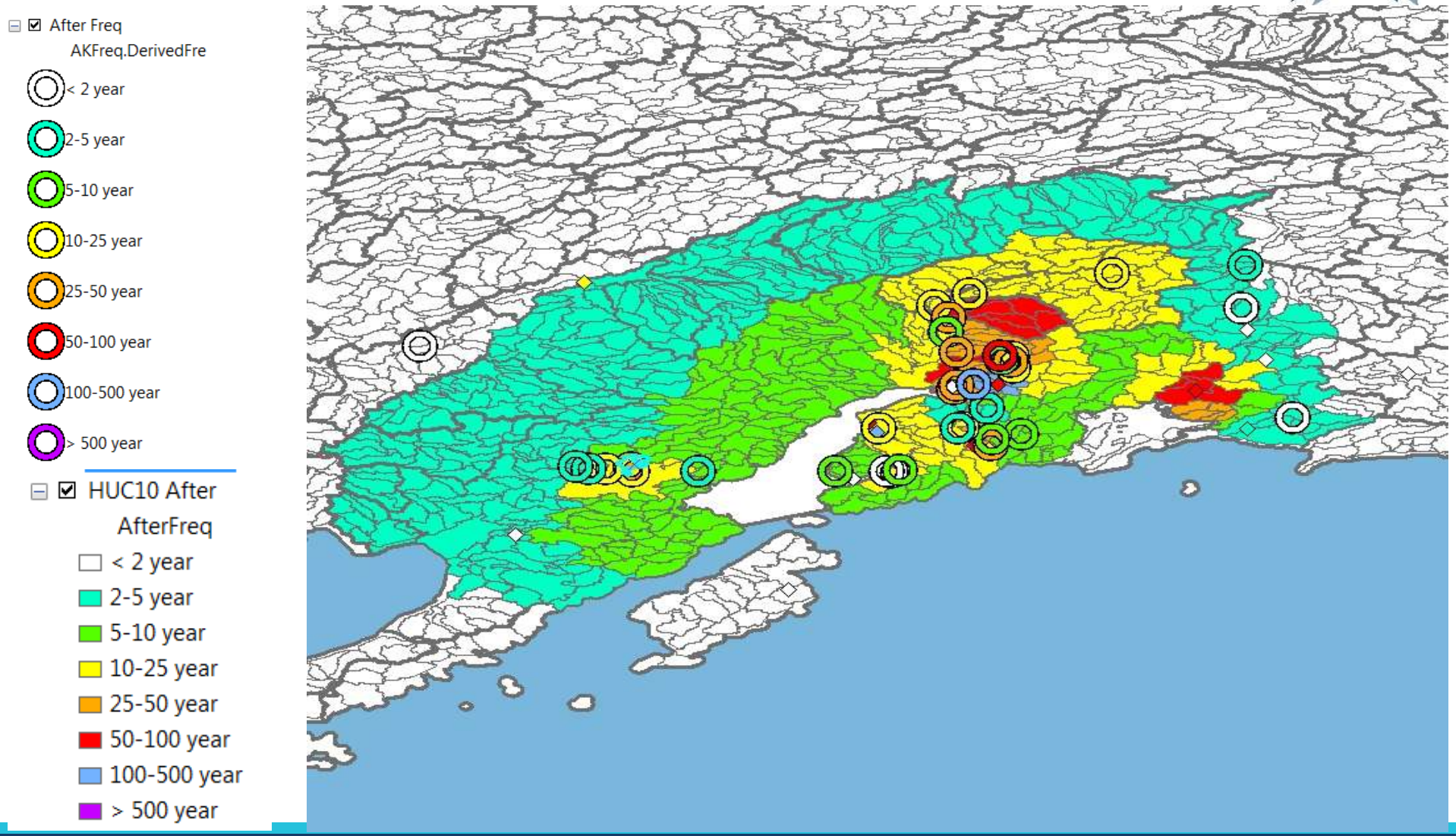
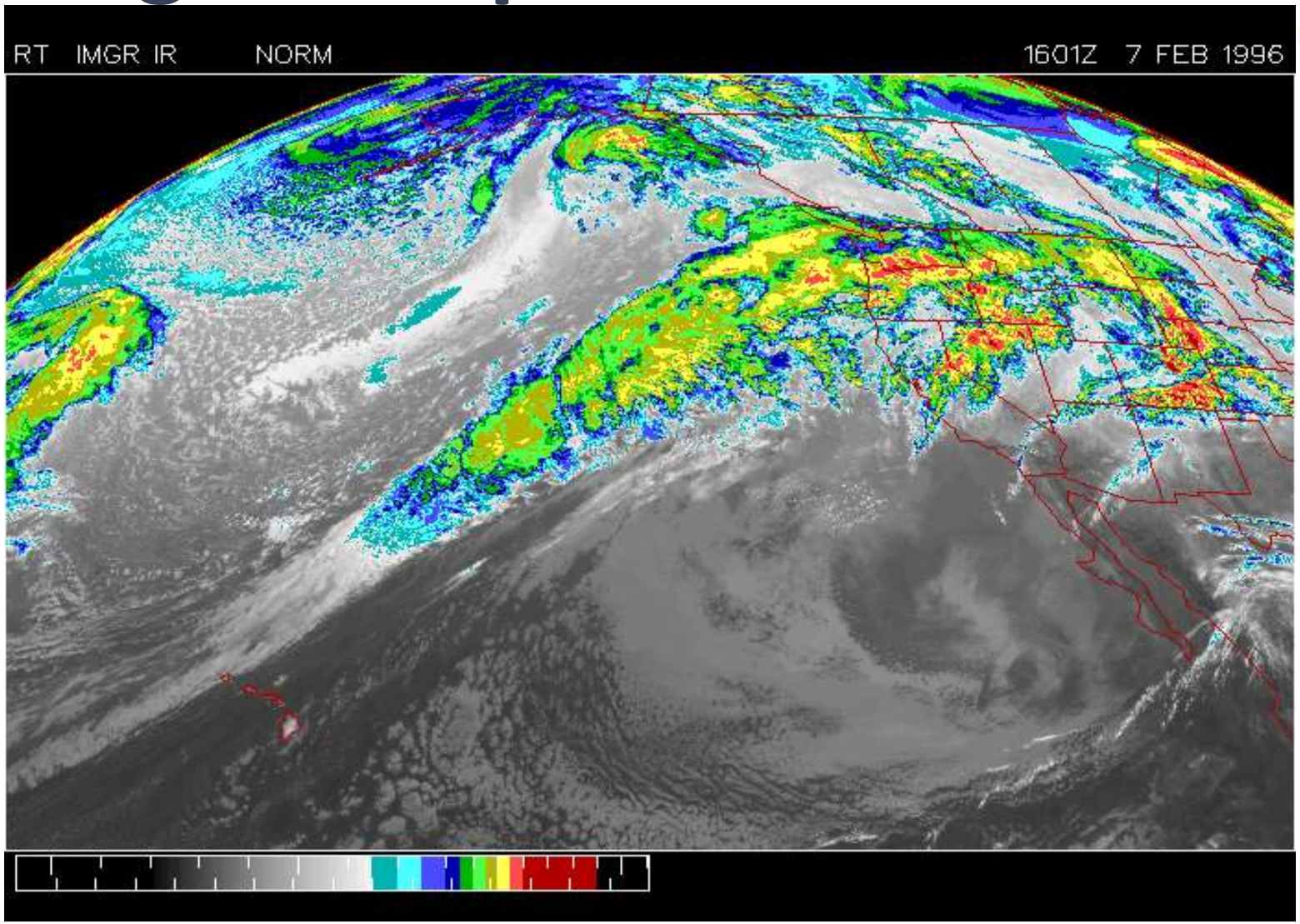
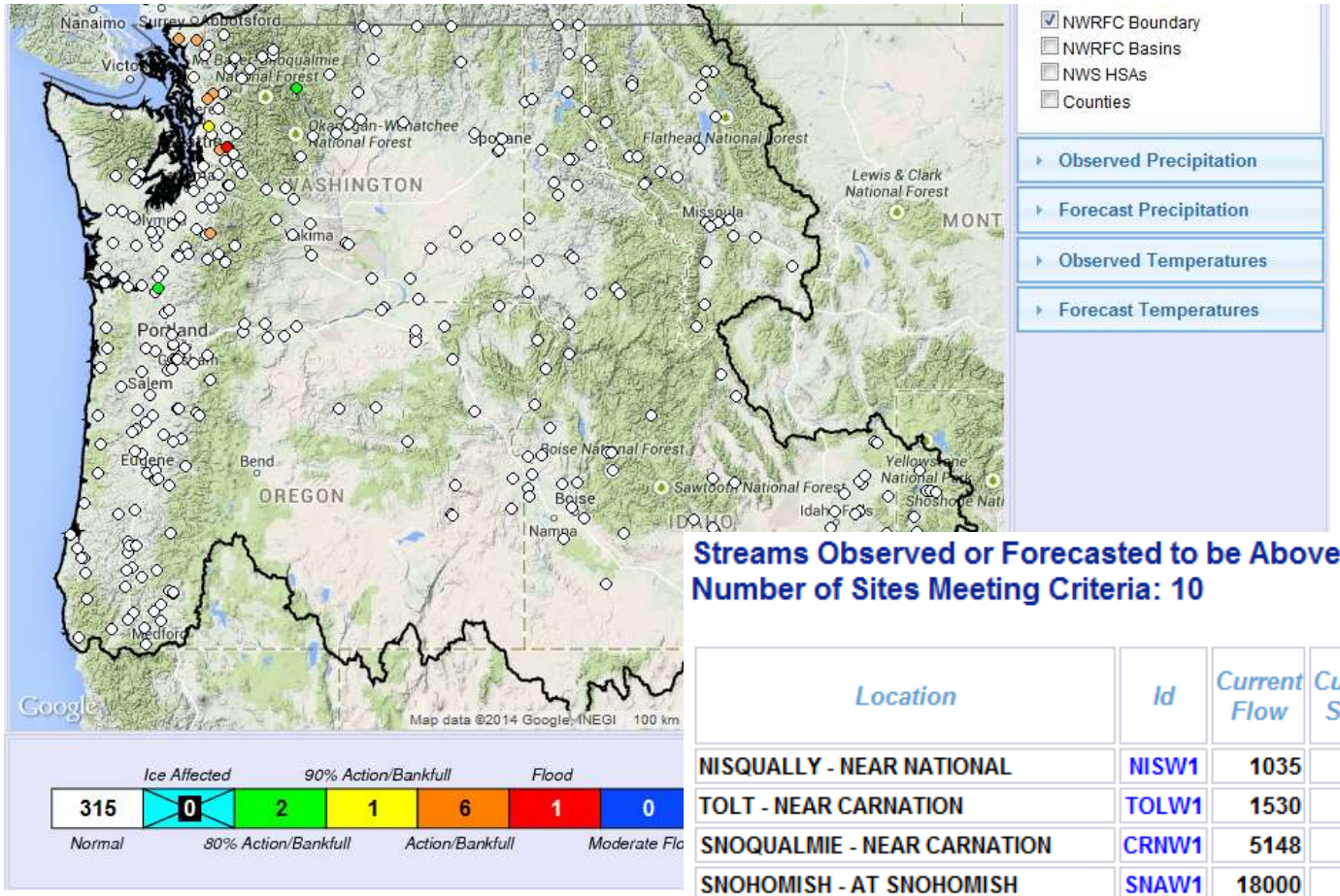


Diagnosing the Impact





Streams Observed or Forecasted to be Above a Minimum Criteria
Number of Sites Meeting Criteria: 10

Location	Id	Current Flow	Current Stage	Flood Stage	Action Stage	Day 1-3 Forecast Max Stage	Day 4-10 Trend Max Stage
NISQUALLY - NEAR NATIONAL	NISW1	1035	6.06		7.50	8.36	6.66
TOLT - NEAR CARNATION	TOLW1	1530	6.93		7.74	9.72	6.13
SNOQUALMIE - NEAR CARNATION	CRNW1	5148	47.91	54.00	51.00	52.61	48.19
SNOHOMISH - AT SNOHOMISH	SNAW1	18000	13.04	25.00	23.00	22.78	17.38
NF STILLAGUAMISH - NEAR ARLINGTON	ARGW1	2768	4.69	13.00	10.70	11.33	4.81
STILLAGUAMISH - NEAR ARLINGTON	ARLW1	8382	5.06	14.00	12.50	13.00	4.14
NOOKSACK - AT CEDARVILLE	NRKW1	5093	141.58	146.50	144.80	145.49	143.38
NOOKSACK - AT FERNDALE	NKSW1	6183	8.82	19.00	17.00	17.23	12.44
STEHEKIN - AT STEHEKIN	STHW1	1197	19.89	24.00	22.00	21.52	20.98
COWLITZ - AT KELSO	KELW1		13.50	21.50	18.00	15.72	14.76

http://www.nwrfc.noaa.gov/rfc/

Terminology

Record

Major Flood

Moderate Flood

Flood

Action/Bankfull

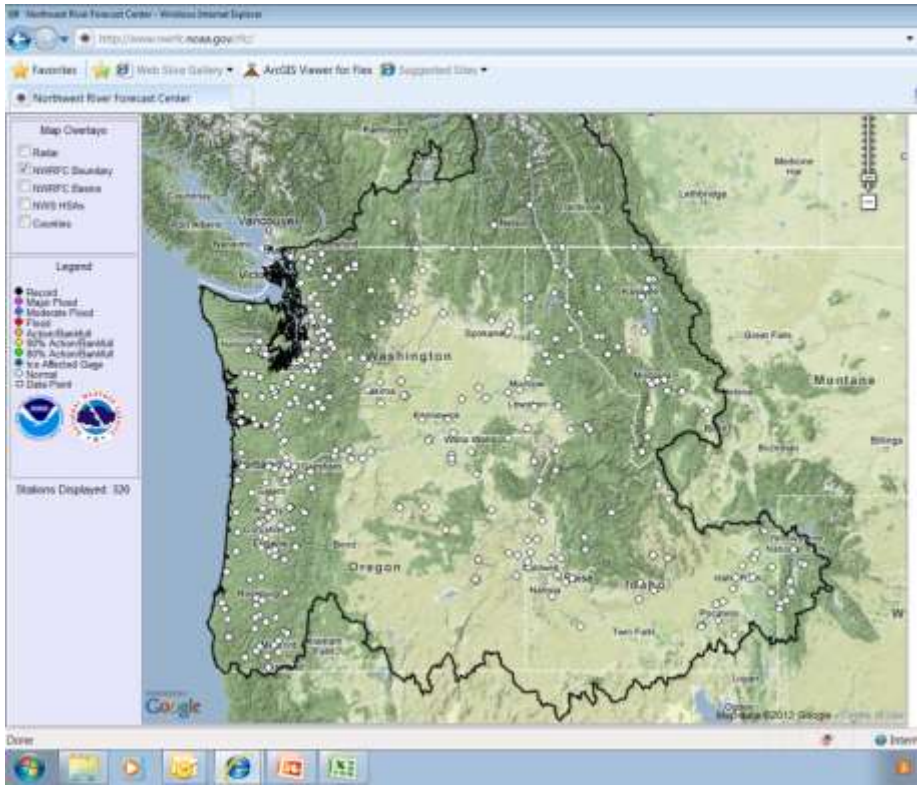
90% Action/Bankfull

80% Action/Bankfull

Ice Affected Gage

Normal

Data Point



Design Standards

Culverts 10- to 100-year

Bridges 25- to 100-year

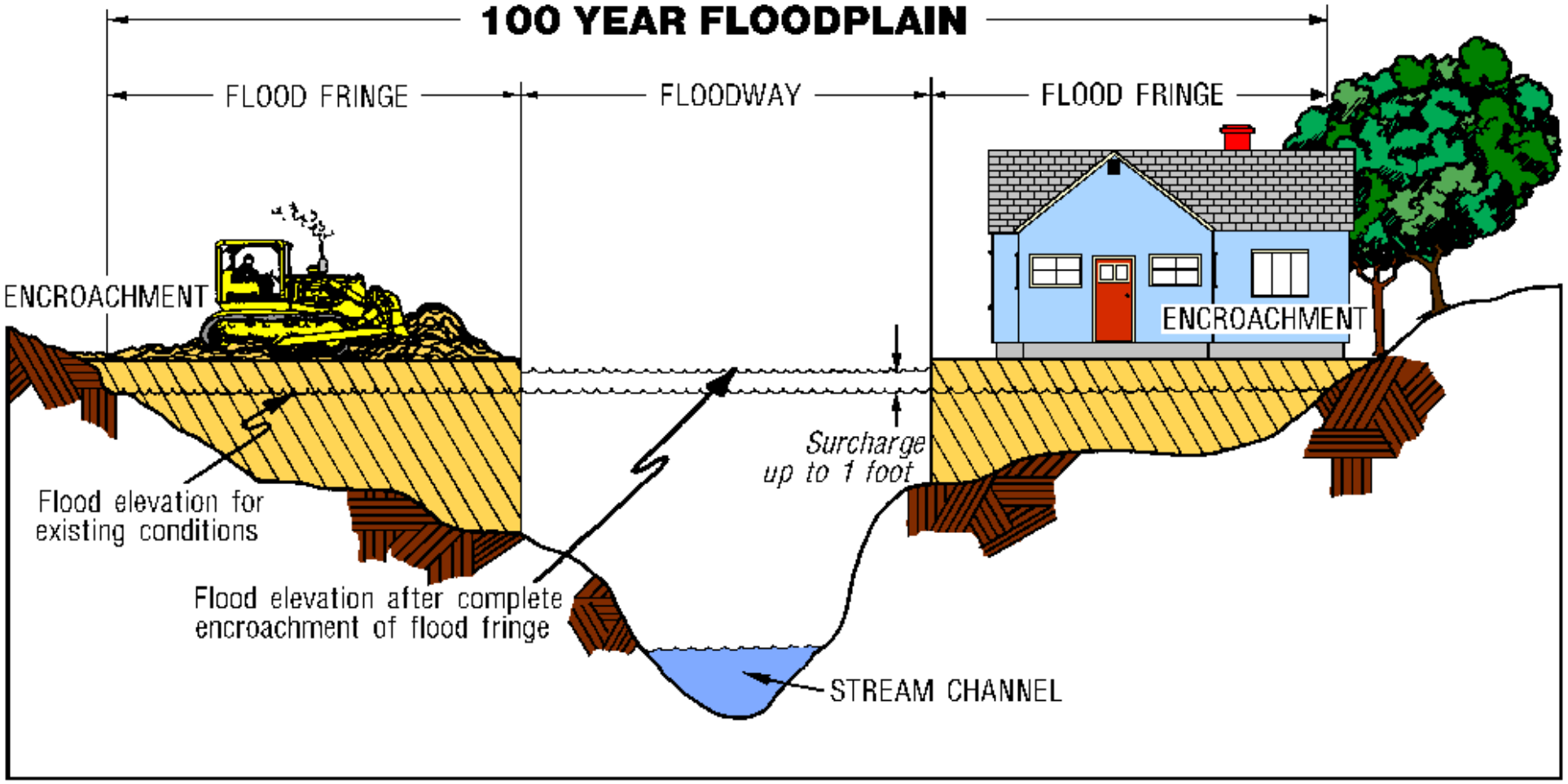
Levees 10- to 500-year

Dams

- Flood Control 10- to 500-year
- Safety – Probable Maximum Flood

Type of Structure	MRI (Years)[1]	Hydrology Method	Recommended Design Tools and Software[4]
Gutters	10	Rational	Inlet Spreadsheet
Storm Drain Inlets • On longitudinal slope • Vertical curve sag	 10 50	 Rational Rational	 Inlet Spreadsheet Sag Spreadsheet
Storm Drains • Laterals • Trunk lines	 25 25	SBUH/SCS	StormShed or Storm Drain Spreadsheet[5]
Ditches[2]	10	SBUH/SCS	StormShed
Standard Culverts • Design for HW/D ratio[3] • Check for high flow damage	 25 100	Published flow records, Flood reports (FIS), USGS Regression, or Rational Method	HY-8 or HEC-RAS
Bottomless Culverts • Design for HW depth[3]	 100	Same as standard culverts (except rational method)	HY-8 or HEC-RAS
Bridges • Design for flow passage and foundation scour • Check for high flow damage	 100 500	Same as standard culverts (except rational method)	HEC-RAS (1D) or FESWMS (2D)
Stormwater Best Management Practices (BMPs)	See HRM		MGSFlood WWA StormShed EWA

Floodplain Development Standards



100-year Levees(?)

Accredited:

Multnomah County (Portland/Fairview/Gresham/Sauvie Island), OR and Longview, WA on Columbia River

Bothell Annex, WA on North Creek

Tukwila, WA on Green River

Renton, WA on Cedar River

Yakima, WA on Yakima and Naches River

Startup, WA on Skykomish River

Castle Rock, WA on Cowlitz River

Lower Elwha Klallam Tribe on Elwha River

Reedsport, OR on Umpqua River and Scholfield Creek

St. Maries, ID on St. Joe River

Coeur D'Alene, ID on Lake Coeur D'Alene and Spokane River (500-year)

Pocatello, ID on Portneuf River (500-year?)

Need Documentation:

Kennewick, Pasco, and Richland, WA on Columbia River (500-year)

Aberdeen/Cosmopolis, WA on Chehalis River

Colfax, WA on SF Palouse River

Vail, OR on Malheur River

Pendleton, OR on Umatilla River

De-Accredited or soon to be:

Auburn/Kent/Renton, WA on Green River

Puyallup/Fife, WA on Puyallup River

Kelso/Longview/Lexington, WA on Cowlitz River

Clatskanie/Rainier/Scappoose, OR and Washougal, WA on Columbia River

Jefferson County , ID on Snake River

Clark Fork, ID on Lightning Creek

Pendleton, OR on Umatilla River

Milton-Freewater, OR on Walla Walla River

Connecting Data – Multiple Sources

NWRFC – Forecast Location, Predicted Stage – Flood Category

USGS – Gage #, Real-Time Flow-Stage

USGS Rating Curves – Stage/Flow

AHPS – Stage/Impact

FEMA Risk MAP and Hazus Data – Flow/Impact

USACE GI Studies – Frequency/Impact

Atmospheric River – December 2015

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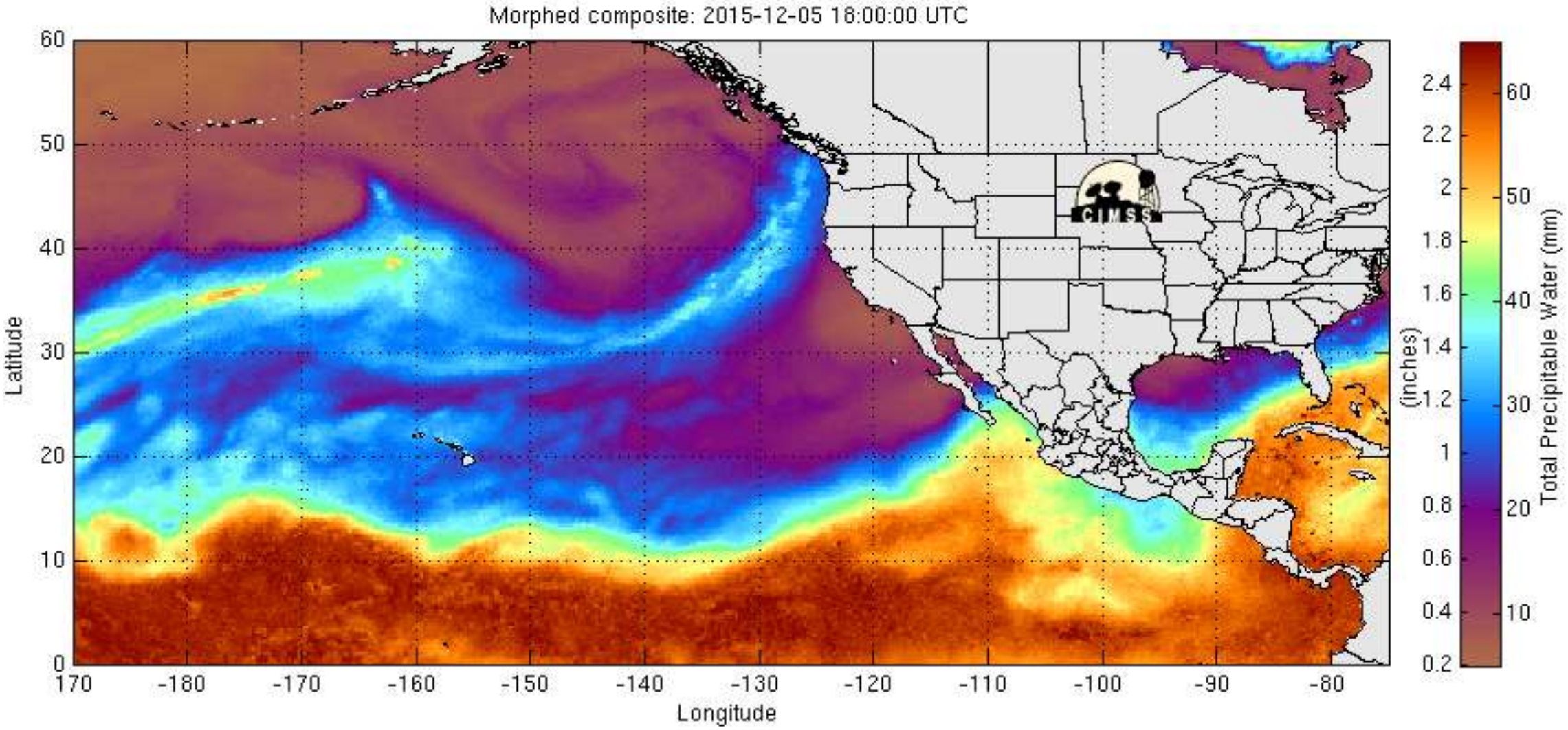
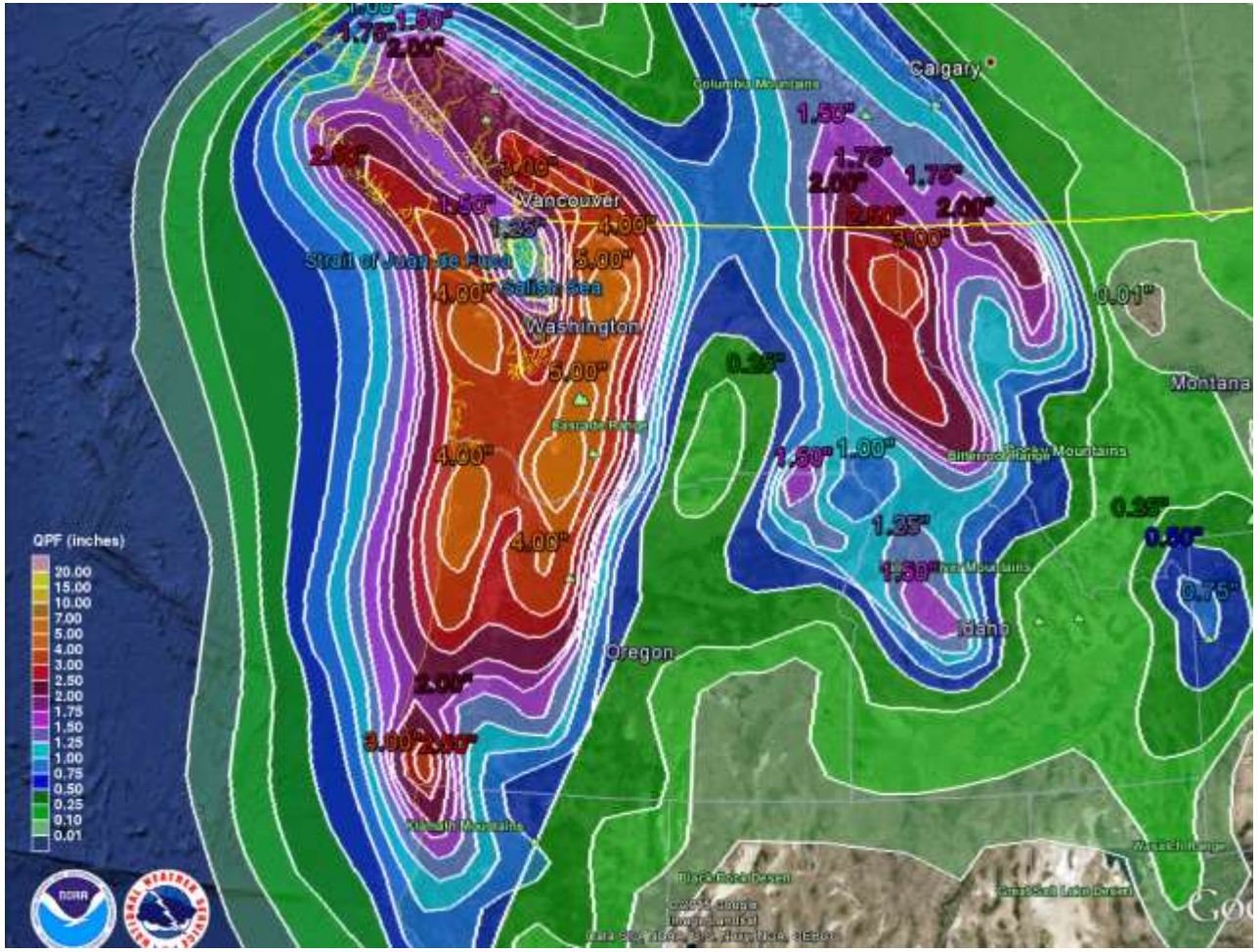
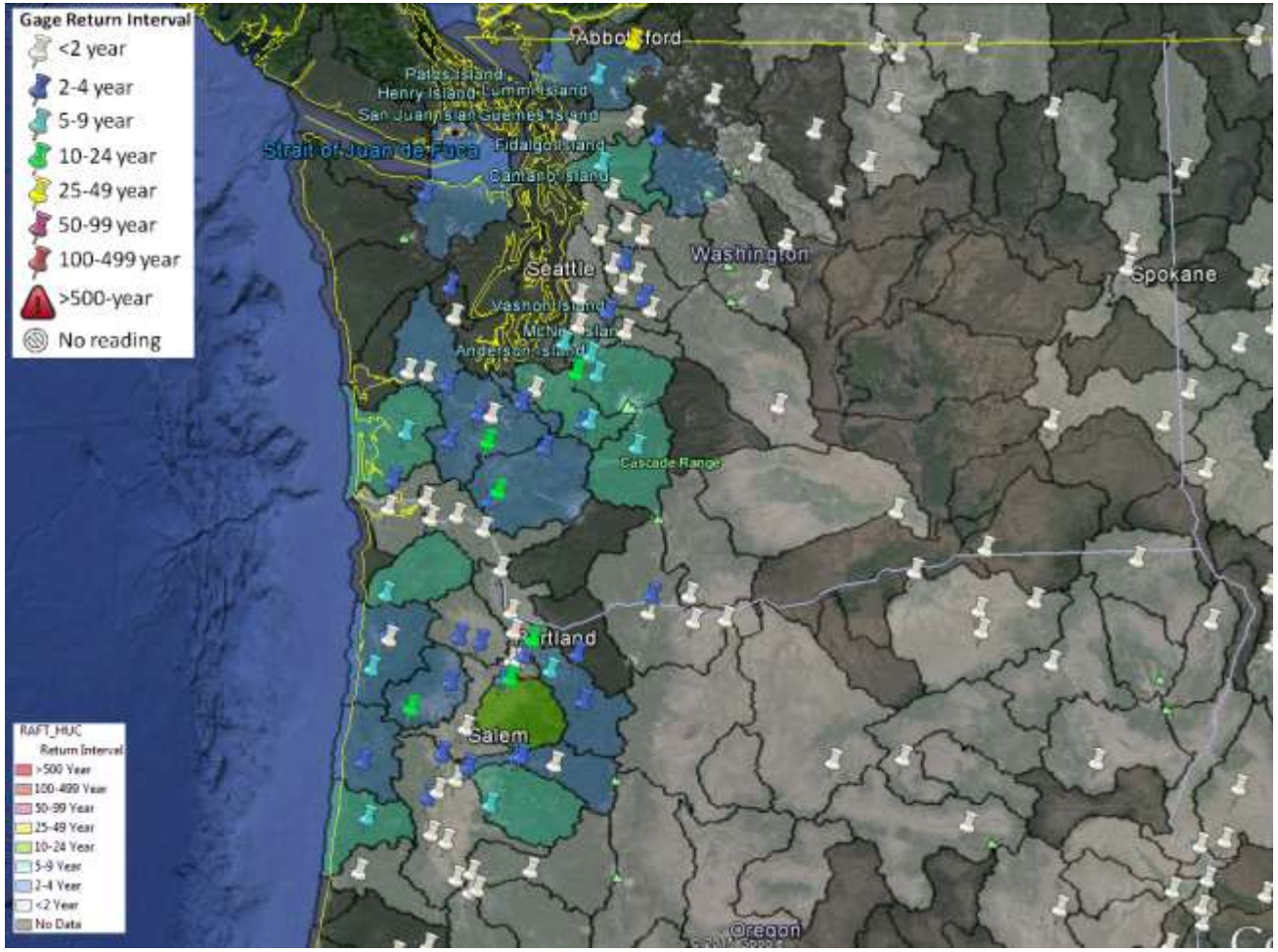


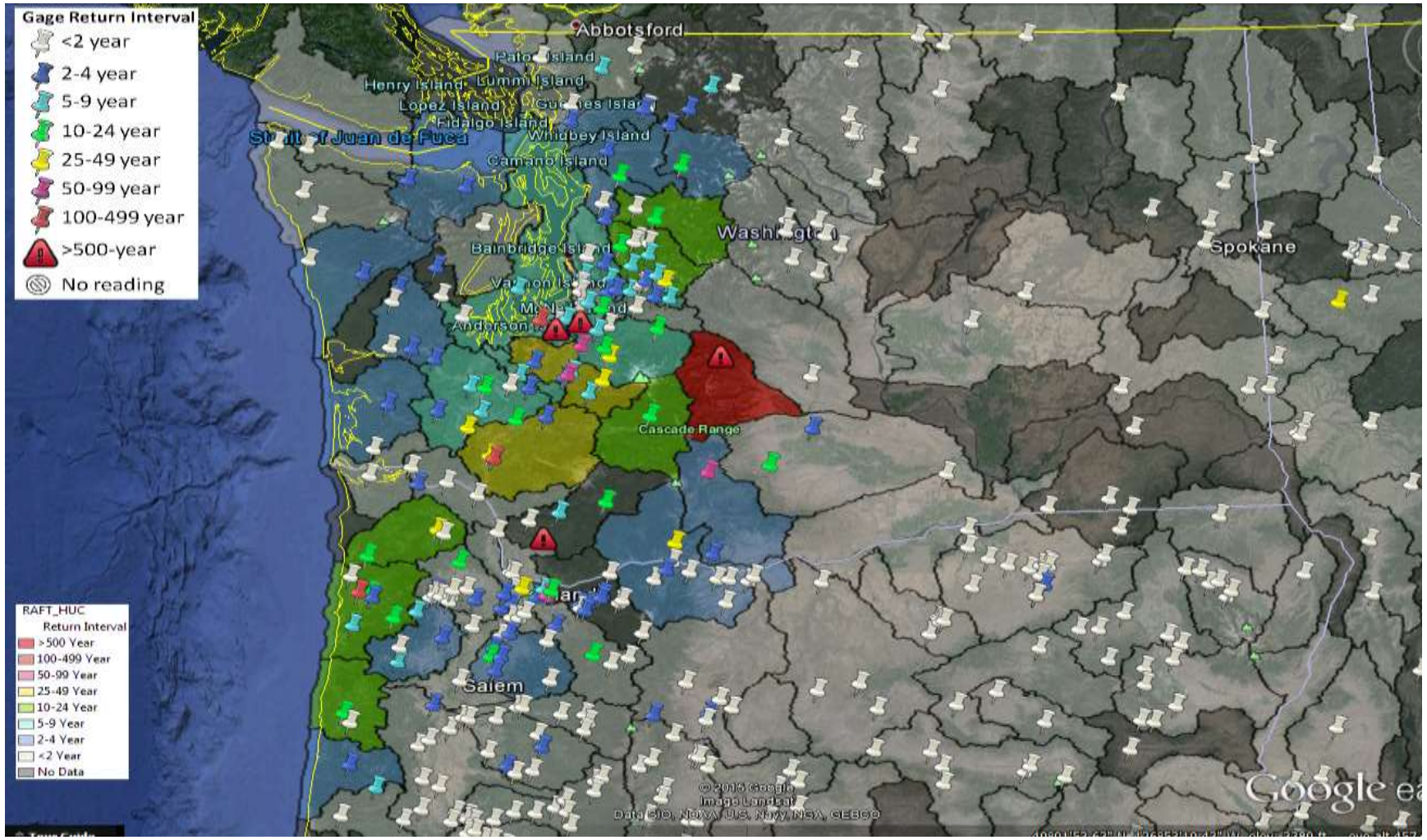
NWS River Forecast Center 48-hour QPF – 12/7/15



RAFT Output on December 7, 2015 – Forecast



RAFT Output on December 10, 2015 – Peak Observed



RAFT Output on December 10, 2015 – Observed

GageName	DSOrderNum	State	County	River	Observed Data Time	Observed Stage (ft)	Observed Flow (cfs)	Frequency	Return Interval	Impacts
NORTH FORK CLOVER CREEK NEAR PARKLAND, WA	12090400	WA	Pierce	NF CLOVER	12/9/15 4:30 AM	9.15	321	Too High	>100 yr	No Impacts Defined
AMERICAN - NEAR NILE	12488500	WA	Yakima	AMERICAN	12/9/15 2:15 PM	76.9	3939	Too High	>100 yr	No Impacts Defined
EF LEWIS - NEAR HEISSON	14222500	WA	Clark	EF LEWIS	12/9/15 1:15 AM	22.43	22389	Too High	>100 yr	No Impacts Defined
TOUTLE - AT TOWER BRIDGE	14242580	WA	Cowlitz	TOUTLE	12/9/15 3:15 AM	20.13	64482	0.23%	431.0	No Impact for this stage
LEACH CR AT MEADOW PARK GC AT UNIVERSITY PLACE, WA	12091290	WA	Pierce	LEACH	12/8/15 3:15 PM	1.96	253	0.90%	111.4	No Impacts Defined
KLICKITAT - NEAR GLENWOOD	14107000	WA	Yakima	KLICKITAT	12/9/15 10:15 AM	5.47	5100	1.17%	85.8	No Impacts Defined
PUYALLUP - NEAR ORTING	12093500	WA	Pierce	PUYALLUP	12/9/15 6:30 AM	11.19	17243	1.27%	78.8	No Impact for this stage
MASHEL RIVER NEAR LA GRANDE, WA	12087000	WA	Pierce	MASHEL	12/9/15 1:30 AM	7.74	7660	1.67%	59.9	No Impacts Defined
JOHNSON CR - AT GRESHAM	14211400	OR	Multnomah	JOHNSON CREEK	12/7/15 12:45 PM	11.78	1750	1.69%	59.0	No Impacts Defined
SF CHEHALIS - NEAR WILDWOOD	12020800	WA	Lewis	SF CHEHALIS	12/9/15 4:30 AM	362.36	4677	2.02%	49.5	No Impacts Defined
PUYALLUP - NEAR ELECTRON	12092000	WA	Pierce	PUYALLUP	12/9/15 4:15 AM	9.96	12419	2.38%	42.1	No Impacts Defined
COWLITZ - AT CASTLE ROCK	14243000	WA	Cowlitz	COWLITZ	12/9/15 8:00 AM	52.34	92391	2.65%	37.7	Above 51 feet, flooding of buildings and residential areas begins, especially west of the river along Hwy 411 and around Four Corners. Also expect widespread flooding of low-lying agricultural land.
JOHNSON CREEK - AT MILWAUKIE	14211550	OR	Clackamas	JOHNSON CREEK	12/8/15 12:45 AM	31.25	2360	3.00%	33.3	No Impacts Defined
ST MARIES - NEAR SANTA	12414900	ID	Benewah	ST MARIES	12/8/15 2:30 AM	12.16	10168	3.01%	33.3	No Impacts Defined
NEHALEM - NR VERNONIA	14299800	OR	Columbia	NEHALEM	12/9/15 1:30 AM	14.47	9553	3.28%	30.5	Above 13.5 feet, Expect minor flooding of lower areas in and near Vernonia. Some roads near the river may be flooded.
NISQUALLY - NEAR NATIONAL	12082500	WA	Pierce	NISQUALLY	12/9/15 1:00 AM	12.75	16030	3.59%	27.9	No Impact for this stage
CEDAR - NEAR CEDAR FALLS	12115000	WA	King	CEDAR	12/9/15 6:00 AM	8.86	6916	3.79%	26.4	No Impacts Defined
WHITE SALMON - NEAR UNDERWOOD	14123500	WA	Skamania	WHITE SALMON	12/9/15 9:45 AM	10.62	10660	3.90%	25.7	No Impacts Defined
ZOLLNER CREEK NEAR MT ANGEL, OR	14201300	OR	Marion	ZOLLNER CREEK	12/9/15 8:45 PM	16.68	1700	4.21%	23.7	No Impacts Defined
CLACKAMAS - THREE LYNX	14209500	OR	Clackamas	CLACKAMAS	12/5/15 2:36 PM	15.68	36303	4.44%	22.5	No Impacts Defined
JOHNSON CREEK - AT SYCAMORE	14211500	OR	Multnomah	JOHNSON CREEK	12/7/15 5:45 PM	15.33	2468	4.47%	22.3	Above 14 ft, Expect widespread flooding of residential and commercial areas along johnson creek.
MUDDY - NEAR COUGAR	14216500	WA	Skamania	MUDDY	12/9/15 12:30 AM	28.61	15718	4.49%	22.3	No Impacts Defined
GREENWATER - AT GREENWATER	12097500	WA	Pierce	GREENWATER	12/9/15 8:00 AM	8.17	4619	4.85%	20.6	No Impacts Defined
WILSON - NEAR TILLAMOOK	14301500	OR	Tillamook	WILSON	12/9/15 1:00 AM	20.62	31686	4.85%	20.6	Above 19.0 ft, expect widespread flooding in Tillamook and surrounding areas, along with the Wilson River RV park east of Tillamook. Hwy 101 through the northern portion of Tillamook has historically been closed at this and higher stages. The worst of the flooding can be expected during high tides.
NEWAUKUM CREEK - NEAR BLACK DIAMOND	12108500	WA	King	NEWAUKUM	12/9/15 1:00 AM	3.62	1615	4.89%	20.4	No Impacts Defined
CARBON - NEAR FAIRFAX	12094000	WA	Pierce	CARBON	12/9/15 5:30 AM	14.84	10222	5.15%	19.4	the Carbon River will flood the residential areas near Crocker and sections of the Carbon River Rd
BEAVER CREEK - AT TROUTDALE	14142800	OR	Multnomah	BEAVER CREEK	12/7/15 12:45 PM	14.38	1140	5.45%	18.3	No Impacts Defined
SKOOKUMCHUCK - NEAR BUCODA	12026400	WA	Thurston	SKOOKUMCHUCK	12/9/15 4:30 PM	16.6	7800	5.45%	18.3	the Skookumchuck River in Thurston County will flood several residential and business areas around Bucoda. Flood waters will cover many roads
NEHALEM - FOSS	14301000	OR	Tillamook	NEHALEM	12/9/15 1:15 AM	23.41	47164	5.75%	17.4	Above 20 ft, flooding of some buildings in the town of Nehalem begins, with the situation worsening during the high tide. Also expect widespread low land flooding and numerous flooded rural roads from the Foss gauging station downstream to Nehalem.
TUCCA CREEK - NEAR BEAVER	14303200	OR	Tillamook	TUCCA CREEK	12/7/15 4:15 PM	12.64	568	5.82%	17.2	No Impacts Defined
SNOQUALMIE - NEAR CARNATION	12149000	WA	King	SNOQUALMIE	12/9/15 5:15 PM	59.78	58547	6.21%	16.1	the Snoqualmie River will cause major flooding from Fall City downstream through Carnation and Duvall. Deep and swift flood waters will inundate many farms...residential areas...and roads. Flooding will occur all along the river including headwaters...tributaries...and other streams within and near the Snoqualmie River Basin.
EAST FORK DAIRY CREEK NEAR MEACHAM CORNER, OR	14205400	OR	Washington	EF DAIRY CREEK	12/9/15 2:00 AM	9.66	1920	6.62%	15.1	No Impacts Defined

RAFT Output on December 10, 2015 – Observed

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GageName	Gage #	State	County	Subbasin (HUC-8)	Observed Data Time	Observed Stage (ft)	Observed Flow (cfs)	Observed Ranking	Years of Record	Date of Highest Flood Event	Flow of Highest Flood Event (cfs)	Stage of Highest Flood Event (ft)
NORTH FORK CLOVER CREEK NEAR PARKLAND, WA	12090400	WA	Pierce	Puget Sound	12/9/15 4:30 AM	9.15	321	5	35	4/5/91	474	9.37
AMERICAN - NEAR NILE	12488500	WA	Yakima	Naches	12/9/15 2:15 PM	76.9	3939	5	75	12/26/80	6280	77.99
EF LEWIS - NEAR HEISSON	14222500	WA	Clark	Lewis	12/9/15 1:15 AM	22.43	22389	2	83	2/8/96	28600	25.26
TOUTLE - AT TOWER BRIDGE	14242580	WA	Cowlitz	Lower Cowlitz	12/9/15 3:15 AM	20.13	64482	1	32	2/8/96	61800	24.91
LEACH CR AT MEADOW PARK GC AT UNIVERSITY PLACE, WA	12091290	WA	Pierce	Puget Sound	12/8/15 3:15 PM	1.96	253	4	8	11/6/06	399	2.44
KLICKITAT - NEAR GLENWOOD	14107000	WA	Yakima	Klickitat	12/9/15 10:15 AM	5.47	5100	2	56	2/8/96	5500	5.7
PUYALLUP - NEAR ORTING	12093500	WA	Pierce	Puyallup	12/9/15 6:30 AM	11.19	17243	3	82	11/6/06	21500	12.4
MASHEL RIVER NEAR LA GRANDE, WA	12087000	WA	Pierce	Nisqually	12/9/15 1:30 AM	7.74	7660	2	39	12/11/46	7980	9.3
JOHNSON CR - AT GRESHAM	14211400	OR	Multnomah	Lower Willamette	12/7/15 12:45 PM	11.78	1750	1	15	1/2/09	1600	11.38
SF CHEHALIS - NEAR WILDWOOD	12020800	WA	Lewis	Upper Chehalis	12/9/15 4:30 AM	362.36	4677	5	16	12/3/07	12200	365.98
PUYALLUP - NEAR ELECTRON	12092000	WA	Pierce	Puyallup	12/9/15 4:15 AM	9.96	12419	3	76	2/8/96	16000	10.94
COWLITZ - AT CASTLE ROCK	14243000	WA	Cowlitz	Lower Cowlitz	12/9/15 8:00 AM	52.34	92391	5	87	12/23/33	139000	31.6
JOHNSON CREEK - AT MILWAUKIE	14211550	OR	Clackamas	Lower Willamette	12/8/15 12:45 AM	31.25	2360	1	24	2/8/96	2170	30.27
ST MARIES - NEAR SANTA	12414900	ID	Benewah	St. Joe	12/8/15 2:30 AM	12.16	10168	3	48	2/9/96	12300	13.75
NEHALEM - NR VERNONIA	14299800	OR	Columbia	Nehalem	12/9/15 1:30 AM	14.47	9553	3	13	12/3/07	17600	18.61
NISQUALLY - NEAR NATIONAL	12082500	WA	Pierce	Nisqually	12/9/15 1:00 AM	12.75	16030	4	71	11/6/06	21800	13.14
CEDAR - NEAR CEDAR FALLS	12115000	WA	King	Lake Washington	12/9/15 6:00 AM	8.86	6916	4	65	11/22/59	9490	11.34
WHITE SALMON - NEAR UNDERWOOD	14123500	WA	Skamania	Middle Columbia-Hood	12/9/15 9:45 AM	10.62	10660	6	91	2/8/96	45200	19.16
ZOLLNER CREEK NEAR MT ANGEL, OR	14201300	OR	Marion	Molalla-Pudding	12/9/15 8:45 PM	16.68	1700	2	20	11/19/96	1890	16.93
CLACKAMAS - THREE LYNX	14209500	OR	Clackamas	Clackamas	12/5/15 2:36 PM	15.68	36303	3	97	12/22/64	68200	21.7
JOHNSON CREEK - AT SYCAMORE	14211500	OR	Multnomah	Lower Willamette	12/7/15 5:45 PM	15.33	2468	3	73	12/22/64	2620	14.68
MUDDY - NEAR COUGAR	14216500	WA	Skamania	Lewis	12/9/15 12:30 AM	28.61	15718	3	56	2/8/96	30600	33.26
GREENWATER - AT GREENWATER	12097500	WA	Pierce	Puyallup	12/9/15 8:00 AM	8.17	4619	7	71	12/2/77	10500	9.8
WILSON - NEAR TILLAMOOK	14301500	OR	Tillamook	Wilson-Trusk-Nestuccu	12/9/15 1:00 AM	20.62	31686	8	83	11/6/06	38600	22.89
NEWAUKUM CREEK - NEAR BLACK DIAMOND	12108500	WA	King	Duwamish	12/9/15 1:00 AM	3.62	1615	5	69	2/8/96	2640	3.95
CARBON - NEAR FAIRFAX	12094000	WA	Pierce	Puyallup	12/9/15 5:30 AM	14.84	10222	6	72	11/6/06	14500	16.93
BEAVER CREEK - AT TROUTDALE	14142800	OR	Multnomah	Lower Columbia-Sandy	12/7/15 12:45 PM	14.38	1140	1	15	1/19/12	1090	12.61
SKOOKUMCHUCK - NEAR BUCODA	12026400	WA	Thurston	Upper Chehalis	12/9/15 4:30 PM	16.6	7800	7	47	Feb. 08, 1996	11300	17.87
NEHALEM - FOSS	14301000	OR	Tillamook	Nehalem	12/9/15 1:15 AM	23.41	47164	4	74	2/8/96	70300	29.56
TUCCA CREEK - NEAR BEAVER	14303200	OR	Tillamook	Wilson-Trusk-Nestuccu	12/7/15 4:15 PM	12.64	568	3	30	2/6/96	680	4.3
SNOQUALMIE - NEAR CARNATION	12149000	WA	King	Snoqualmie	12/9/15 5:15 PM	59.78	58547	7	84	1/8/09	82900	62.21
EAST FORK DAIRY CREEK NEAR MEACHAM CORNER, OR	14205400	OR	Washington	Tualatin	12/9/15 2:00 AM	9.66	1920	2	11	12/3/07	2000	9.2

Other Possible Outputs

STARR II Strategic Alliance for Risk Reduction

HUCs				Linked Gages/Frequencies							Likely Impacted	Likely Impacted		Contracts in Force/ Housing Units
HUCID	HUCName	State	County	GageName	Frequency	Return Interval	Contracts in Force (NFIP)	Housing Units in SFHA	Population in SFHA	Housing Units	Population			Percentage
17030002	Naches	WA	Yakima_King_Kittitas_Lewis_Pierc	AMERICAN - NEAR NILE	Too High	100 yr	247	633	1288	633	1288			39%
17080005	Lower Cowlitz	WA	Cowlitz_Lewis_Skamania	COWLITZ - AT CASTLE ROCK	2.7%	38 yr	617	1024	2306	146	328			60%
17110015	Nisqually	WA	Lewis_Pierce_Thurston	NISQUALLY - NEAR NATIONAL	3.6%	28 yr	408	773	1849	60	144			53%
17080006	Lower Columbia	OR_WA	Clatsop_Lewis_Pacific_Wahkiakun	TONGUE POINT TIDE GAGE	4.6%	22 yr	513	1235	2624	59	125			42%
17100203	Wilson-Trusk-Nestuccu	OR	Lincoln_Polk_Tillamook_Yamhill_\	WILSON - NEAR TILLAMOOK	4.8%	21 yr	1494	1849	2435	79	104			81%
17100202	Nehalem	OR	Clatsop_Columbia_Tillamook_Was	NEHALEM - FOSS	5.8%	17 yr	719	996	1774	30	54			72%
17100204	Siletz-Yaquina	OR	Benton_Lincoln_Polk_Tillamook	SILETZ - AT SILETZ	7.2%	14 yr	1272	1644	2566	32	50			77%
17110009	Skykomish	WA	Chelan_King_Kittitas_Snohomish	SKYKOMISH - NEAR GOLD BAR	7.4%	14 yr	954	1884	4010	34	73			51%
17080004	Upper Cowlitz	WA	Yakima_Lewis_Skamania_Pierce	COWLITZ - AT PACKWOOD	9.6%	10 yr	316	702	768	8	8			45%
17110014	Puyallup	WA	Yakima_King_Kittitas_Pierce	PUYALLUP - AT PUYALLUP	10.7%	9 yr	2477	3153	7724	0	0			79%
17100103	Upper Chehalis	WA	Cowlitz_Grays Harbor_Lewis_Pacif	CHEHALIS - NEAR GRAND MOUND	17.1%	6 yr	2190	3275	7980	0	0			67%
17110012	Lake Washington	WA	King_Kittitas_Snohomish	CEDAR - AT RENTON	18.2%	6 yr	2438	5342	11363	0	0			46%
17110019	Puget Sound	WA	Grays Harbor_Island_Jefferson_Kir	HUGE CREEK - NEAR WAUNA	18.7%	5 yr	4268	9614	19377	0	0			44%
17110016	Deschutes	WA	Lewis_Thurston	DESCHUTES - NEAR RAINIER	19.2%	5 yr	184	470	1021	0	0			39%
17100307	Upper Rogue	OR	Douglas_Jackson_Klamath	ROGUE - NEAR EAGLE POINT	21.8%	5 yr	354	654	1325	0	0			54%
17110006	Sauk	WA	Chelan_Skagit_Snohomish	SAUK - NEAR SAUK	22.5%	4 yr	31	206	292	0	0			15%
17070105	Middle Columbia-Hood	OR_WA	Clackamas_Hood River_Multnoma	HOOD - NEAR TUCKER BRIDGE	23.8%	4 yr	162	528	1104	0	0			31%
17060204	Lemhi	ID	Beaverhead_Custer_Lemhi	LEMHI - NEAR LEMHI	24.6%	4 yr	17	58	101	0	0			29%
17100102	Queets-Quinault	WA	Grays Harbor_Jefferson_Mason	QUINAULT - AT QUINAULT LAKE	26.9%	4 yr	204	167	216	0	0			122%
17110020	Dungeness-Elwha	CN_WA	Clallam_Jefferson	ELWHA - AT MCDONALD BRIDGE NEAR PORT ANGELE	30.4%	3 yr	408	541	952	0	0			75%
17100106	Willapa Bay	WA	Grays Harbor_Lewis_Pacific_Wahk	WILLAPA - NEAR WILLAPA	31.5%	3 yr	1046	2108	3319	0	0			50%
17090008	Yamhill	OR	Lincoln_Polk_Tillamook_Yamhill_\	S YAMHILL - AT MCMINNVILLE	32.7%	3 yr	643	1906	5081	0	0			34%
17100104	Lower Chehalis	WA	Grays Harbor_Jefferson_Mason_Th	CHEHALIS - AT PORTER	35.2%	3 yr	364	1445	3266	0	0			25%
17090009	Molalla-Pudding	OR	Clackamas_Marion	MOLALLA - NEAR CANBY	37.4%	3 yr	472	974	2726	0	0			48%
17110007	Lower Skagit	WA	Skagit_Snohomish	SKAGIT - NEAR CONCRETE	46.7%	2 yr	3972	6858	17077	0	0			58%
17100205	Alsea	OR	Benton_Lane_Lincoln	ALSEA - NEAR TIDEWATER	48.4%	2 yr	902	1002	1409	0	0			90%

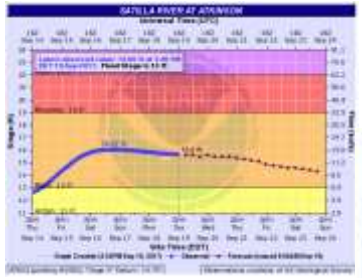
STARR II Strategic Alliance for Risk Reduction

Technical Background

RAFT NATIONAL DEPLOYMENT

RAFT Basics – Going National

National Weather Service (NWS)
River Forecast Center (RFC) Gages



USGS Flood Freq Curves (FFC)

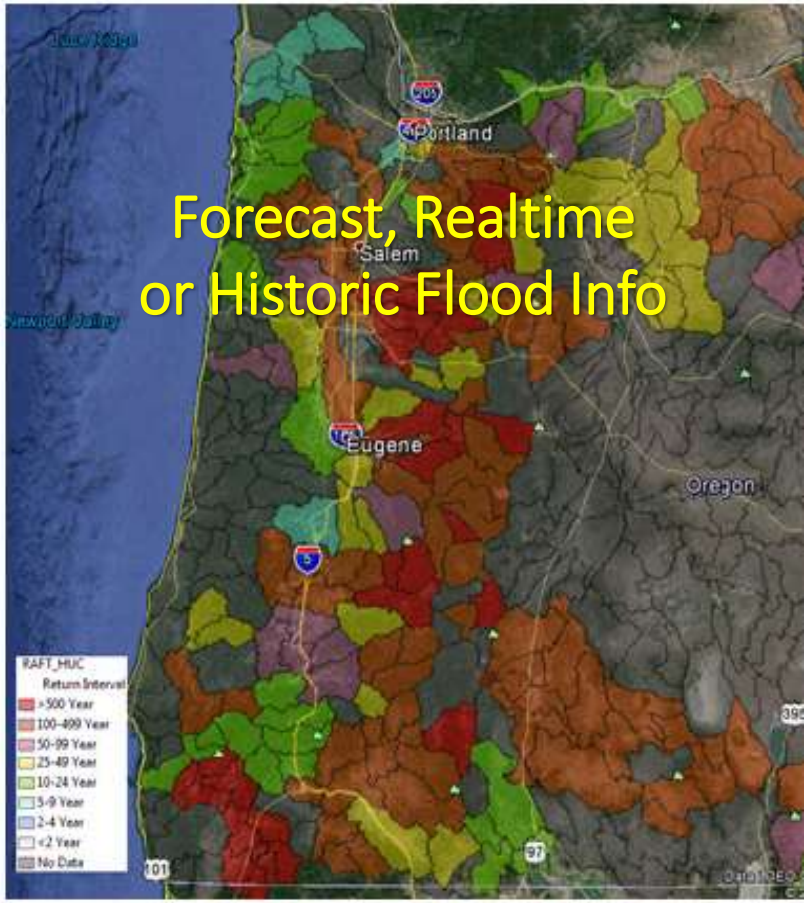
Table 4. Flood-frequency statistics for streamgages in California that were considered for use in the regression equations, 2006

[USGS, U.S. Geological Survey; S, estimated from the Bulletin 17B analysis of the streamgaging station; R, estimated from the regional regression equation; and W, weight

Station	2yr 50-percent			5yr 20-percent			10yr 10-percent			25yr 4-percent			50yr 2-pe	
	S	R	W	S	R	W	S	R	W	S	R	W	S	R
09423350	25	--	--	149	--	--	381	--	--	1,050	--	--	2,040	
09423400	2	--	--	11	--	--	30	--	--	88	--	--	178	
09424050	25	--	--	97	--	--	183	--	--	348	--	--	514	
09428570	11	--	--	64	--	--	164	--	--	446	--	--	854	
09429240	5	--	--	21	--	--	44	--	--	93	--	--	150	

Connect National Hydrography Dataset (NHD) streams to HUC watershed

Select the best gage for each HUC



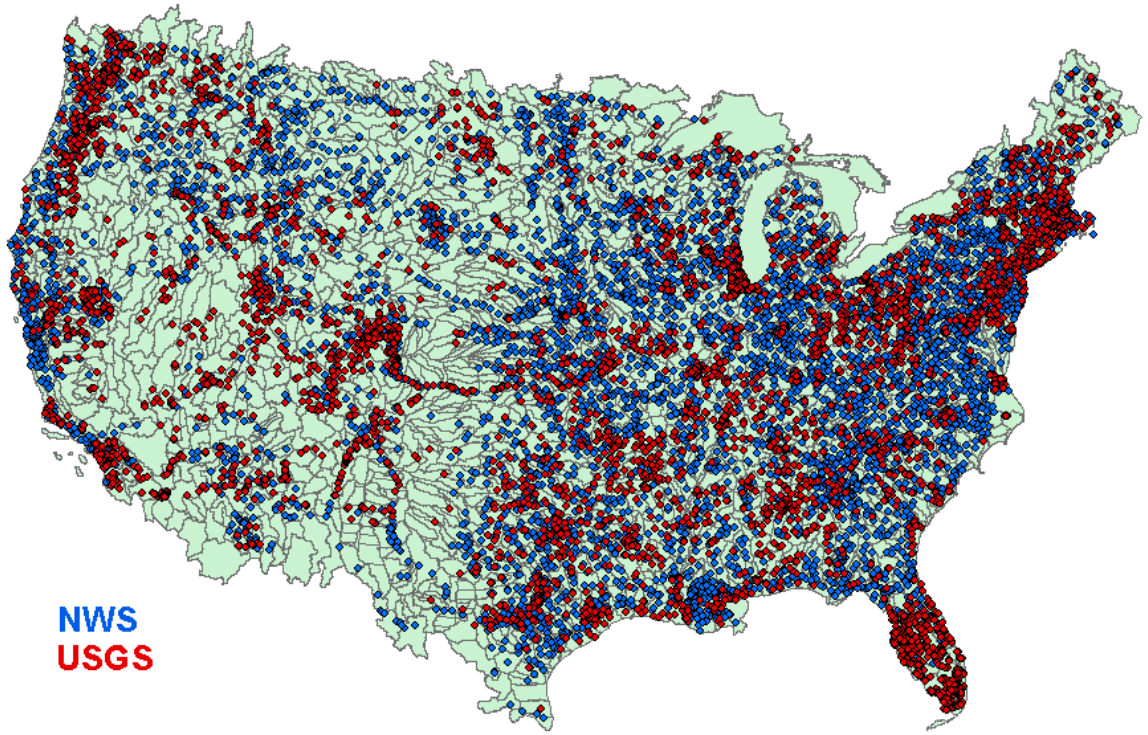
Taking RAFT National

Gage assignment cannot be done by hand – Too much data

11,308 - USGS gages

6,304 - NWS River Forecast gages

2,120 - HUC 8 watersheds



- Levees not included in national rollout

Data Preparation

STARR II Strategic Alliance for Risk Reduction

USGS Regional Regression Equation Reports

Convert from PDF and reformat data to a spreadsheet for import

Appendices contain individual gage data tables with the FFCs

Table 3. Flood-frequency discharges for the 290 U.S. Geological Survey streamgage stations on rural, unregulated streams in West Virginia and adjacent states.

[Identification number refers to the number in figure 3; %, percent; AOP, annual-occurrence probability; WV, West Virginia; MD, Maryland; VA, Virginia; OH, Ohio; PA, Pennsylvania; KY, Kentucky; East, Eastern Panhandle Region; Central, Central Mountains Region; West, Western Plateaus Region. Flood-frequency discharges are presented in the following estimate-type order: first line (Q_s), from the systematic and historical record using guidelines established by the Interagency Advisory Committee on Water Data (1982) with the West Virginia skew (Atkins and others, 2009); second line (Q_r), from the regionalized regression equation; and third line (Q_w), from weighting (1) the systematic and historical record using guidelines established by the Interagency Advisory Committee on Water Data (1982) with the West Virginia skew (Atkins and others, 2009) and (2) the regionalized regression equation, using the number of years of peak discharge and equivalent years of record. Shading indicates the 44 streamgage stations removed from consideration as part of the regional regression analysis]

Identification number	Streamgage station number	State	Region	Estimate type	1.1-year (90% AOP)	1.5-year (67% AOP)	2-year (50% AOP)	5-year (20% AOP)	10-year (10% AOP)	25-year (4% AOP)	50-year (2% AOP)	100-year (1% AOP)	200-year (0.5% AOP)	500-year (0.2% AOP)
1	01595000	MD	East	Q_s	1,700	2,600	3,280	5,390	7,130	9,760	12,100	14,700	17,700	22,300
				Q_r	993	1,620	2,120	3,840	5,390	7,780	9,820	12,100	14,600	18,200
				Q_w	1,640	2,530	3,170	5,080	6,590	8,890	10,900	13,200	15,800	19,800
										3,350	4,220	5,280	6,550	8,670
										4,920	6,200	7,610	9,150	11,400
										4,080	5,290	6,650	8,180	10,500
										24,100	31,200	39,900	50,600	68,600
										20,200	25,600	31,600	38,200	48,200
										22,500	28,400	35,200	43,200	55,800
										26,100	33,100	41,200	50,700	65,800
										24,800	31,500	38,900	47,100	59,500
										25,300	32,000	39,500	48,000	60,900
										4,260	5,300	6,530	7,960	10,200
										5,550	7,000	8,590	10,300	12,900
										4,710	6,010	7,500	9,160	11,700
										1,740	2,290	2,970	3,810	5,230
										2,230	2,790	3,420	4,090	5,090
										1,970	2,570	3,240	3,990	5,140
										11,600	15,000	19,000	23,900	32,000
										11,400	14,400	17,800	21,500	27,000
										11,500	14,600	18,100	22,100	28,100
										5,440	6,750	8,270	10,000	12,700
										7,720	9,740	12,000	14,400	18,100
										6,080	7,790	9,730	11,900	15,200
										3,530	4,400	5,360	6,430	8,020
										5,300	6,680	8,200	9,870	12,300
										4,560	5,880	7,340	8,920	11,200
										51,200	65,000	81,300	100,000	131,000
										46,800	59,600	73,800	89,700	114,000
										48,000	60,700	75,200	91,400	116,000

Table 4. Flood-frequency statistics for streamgages in California that were considered for use in the regression equations, 2006.
[USGS, U.S. Geological Survey; S, estimated from the Bulletin 17B analysis of the streamgaging station; R, estimated from the regional regression equation; and W, weighted estimate using equation 11; --, not applicable]

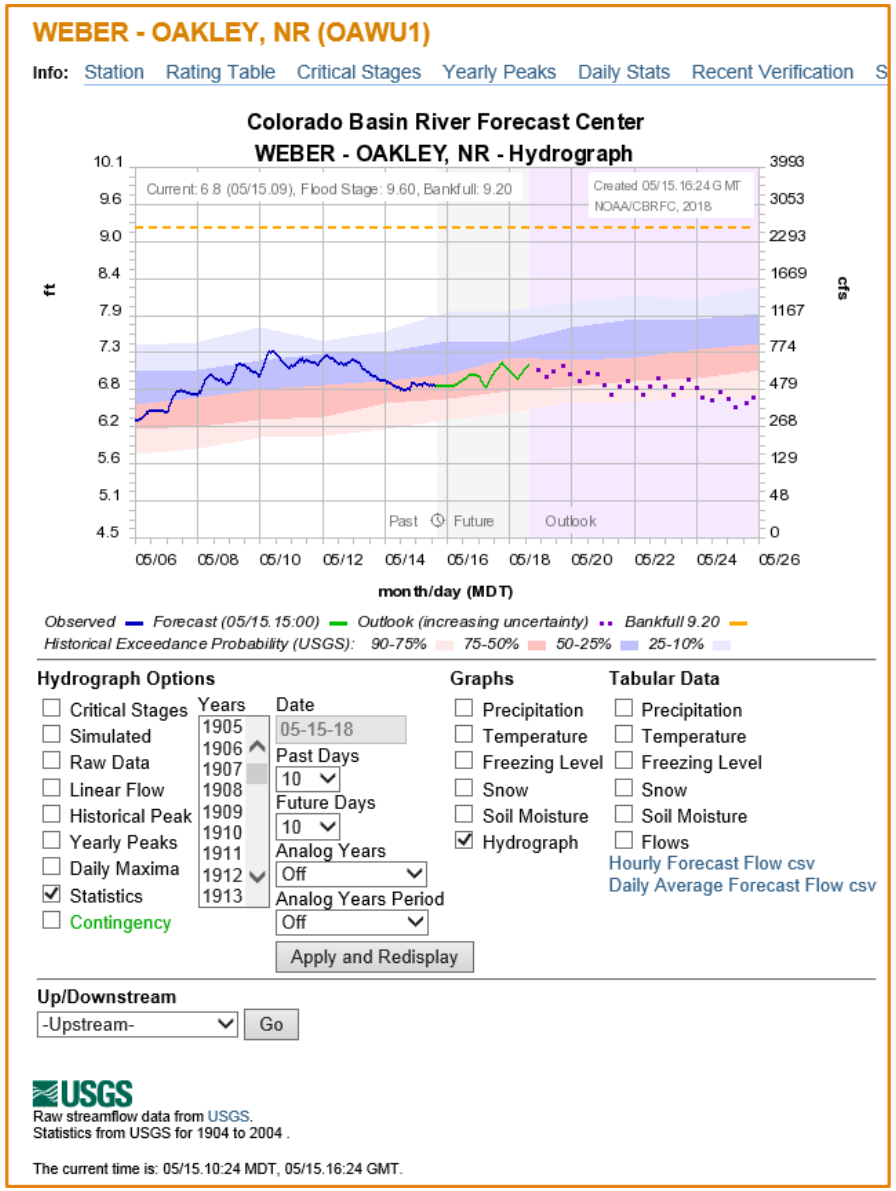
Station	2yr 50-percent			5yr 20-percent			10yr 10-percent			25yr 4-percent			50yr 2-percent			100yr 1-percent			200yr
	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S
09423350	25	--	--	149	--	--	381	--	--	1,050	--	--	2,040	--	--	3,700	--	--	6,420
09423400	2	--	--	11	--	--	30	--	--	88	--	--	178	--	--	337	--	--	609
09424050	25	--	--	97	--	--	183	--	--	348	--	--	514	--	--	720	--	--	968
09428570	11	--	--	64	--	--	164	--	--	446	--	--	854	--	--	1,540	--	--	2,630
09429240	5	--	--	21	--	--	44	--	--	93	--	--	150	--	--	228	--	--	333
10250800	90	--	--	550	--	--	1,460	--	--	4,230	--	--	8,520	--	--	16,100	--	--	29,100
10251400	6	--	--	36	--	--	89	--	--	233	--	--	432	--	--	751	--	--	1,240
10253350	222	--	--	878	--	--	1,680	--	--	3,210	--	--	4,750	--	--	6,640	--	--	8,900
10253700	16	--	--	51	--	--	87	--	--	150	--	--	208	--	--	275	--	--	352
10255230	2	--	--	11	--	--	28	--	--	73	--	--	137	--	--	239	--	--	399
10255650	15	--	--	88	--	--	227	--	--	630	--	--	1,220	--	--	2,230	--	--	3,860
10255730	24	--	--	157	--	--	454	--	--	1,500	--	--	3,350	--	--	7,040	--	--	14,200
10255800	374	--	--	1,590	--	--	3,150	--	--	6,180	--	--	9,270	--	--	13,100	--	--	17,700
10255810	23	--	--	150	--	--	414	--	--	1,260	--	--	2,650	--	--	5,210	--	--	9,770
10255820	2	--	--	11	--	--	27	--	--	69	--	--	128	--	--	222	--	--	366
10255850	50	--	--	279	--	--	665	--	--	1,650	--	--	2,940	--	--	4,910	--	--	7,810

Data Preparation

NWS River Forecast Center Gages

Scraping data from gage webpages

- Location
- Corresponding USGS gage



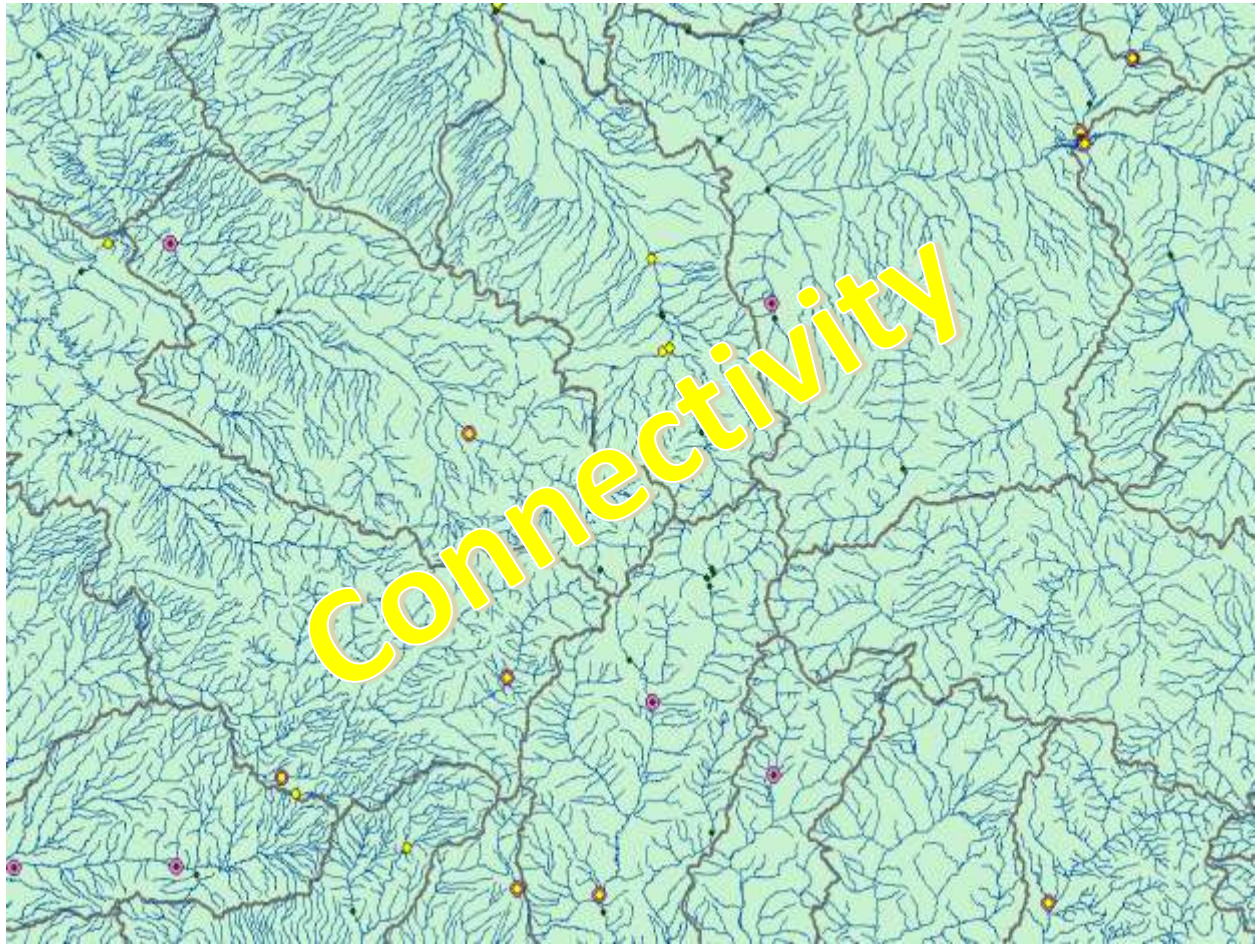
HUC8 Assignment

What we need:

USGS gages

NHD flowlines

HUC8



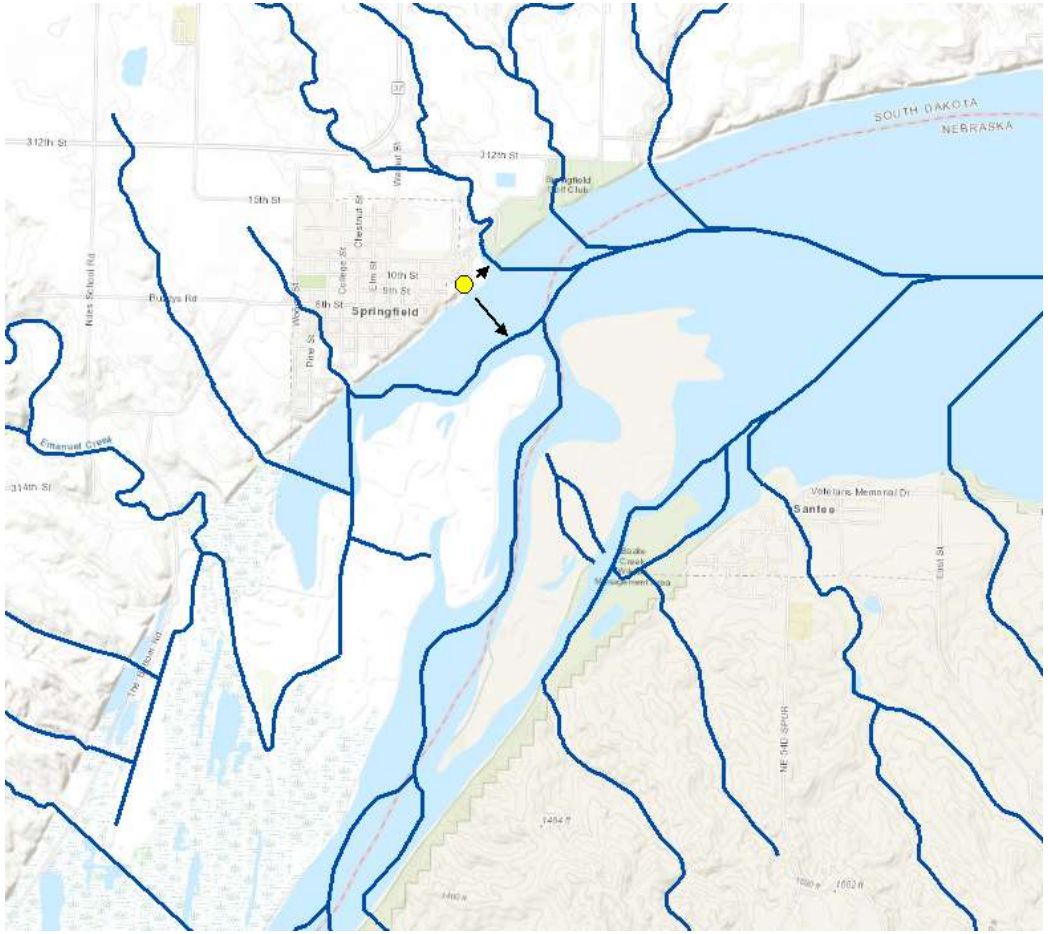
Data Verification

Use GIS processing to connect gages to NHD flowlines.

What reach is closest to the gage?

How far is the reach from the gage?

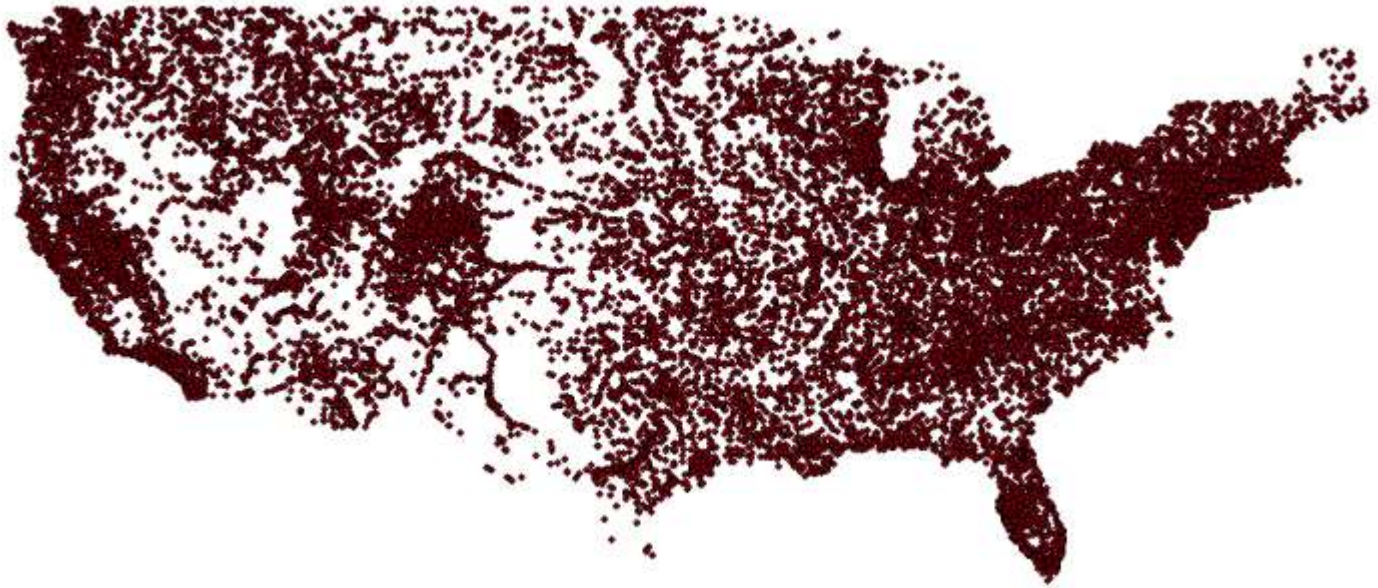
Is the Drainage Area correct?



Which gages can we use?

Over 26,000 USGS gages in the CONUS

Discard if not real-time, inactive, or not on flow network



Gage Categories

Total candidate gages in Continental US: 8,463

2,663 NWS gages with flood frequency curve (FFC)

866 USGS Realtime (RT) gages with FFC

These are preferred.

2,738 NWS gages without FFC

2,196 RT gages without FFC and in NHD

These provide limited data.

HUC8 Assignment Methodology

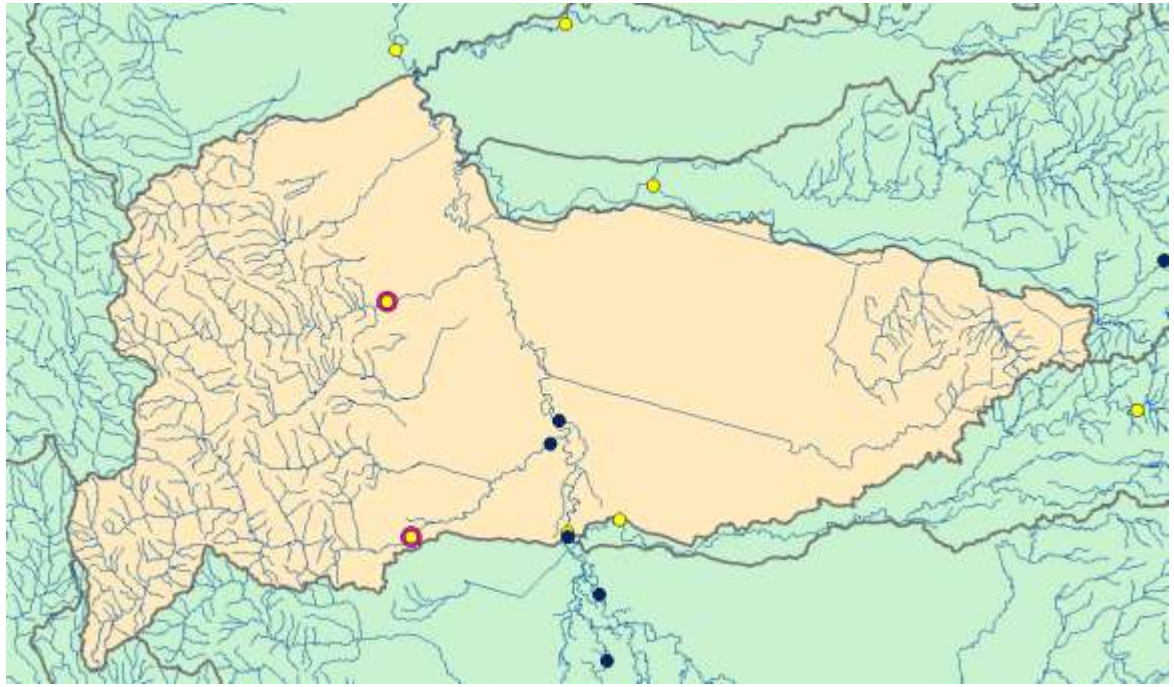
Is there a representative candidate?

- More than 30% of gage drainage area must be in the HUC.

More than one candidate?

- Chosen based first on type
  - Does it have a flood frequency curve (FFC)?
  - Prefer NWS gages over USGS Realtime only

More than one candidate of the same type?



Yellow – NWS gages

Pink – Gage with FFC

Gage-HUC8 Assignment Methodology

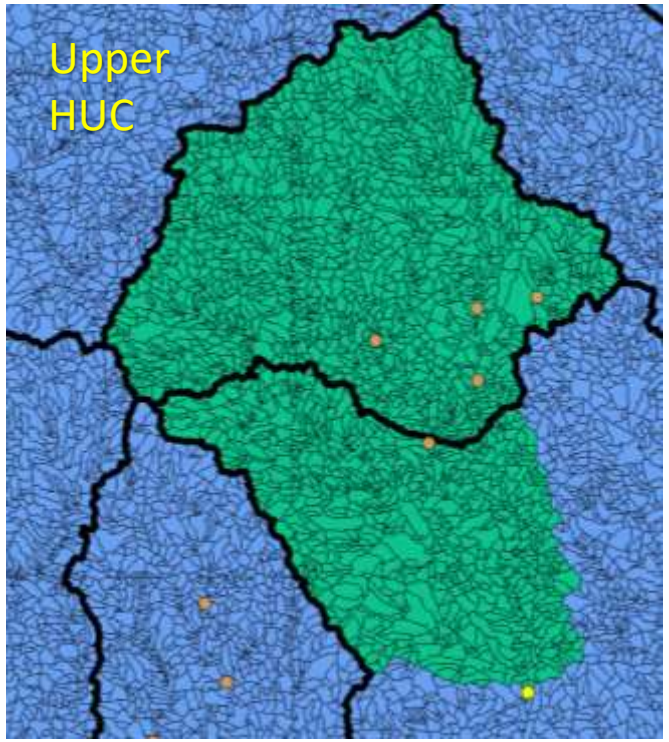
HUC8 Fraction

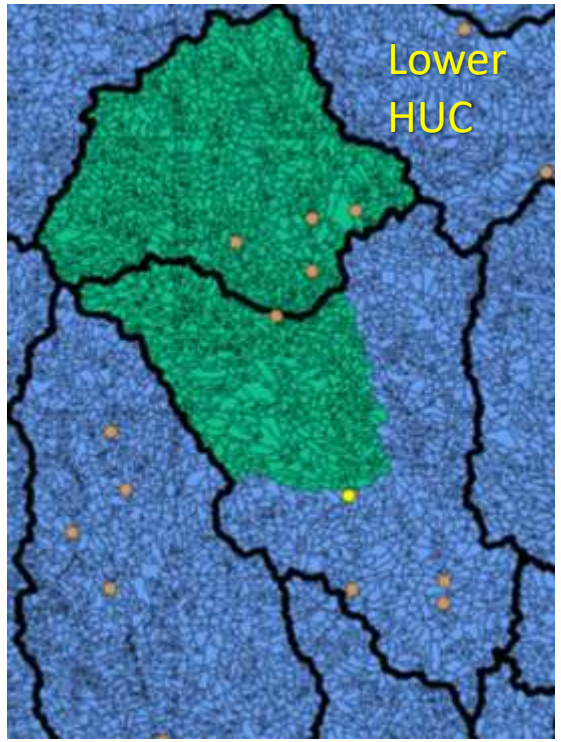
= % of HUC8 captured by the gage

Gage Fraction

= % of total contributing area

- within the HUC8





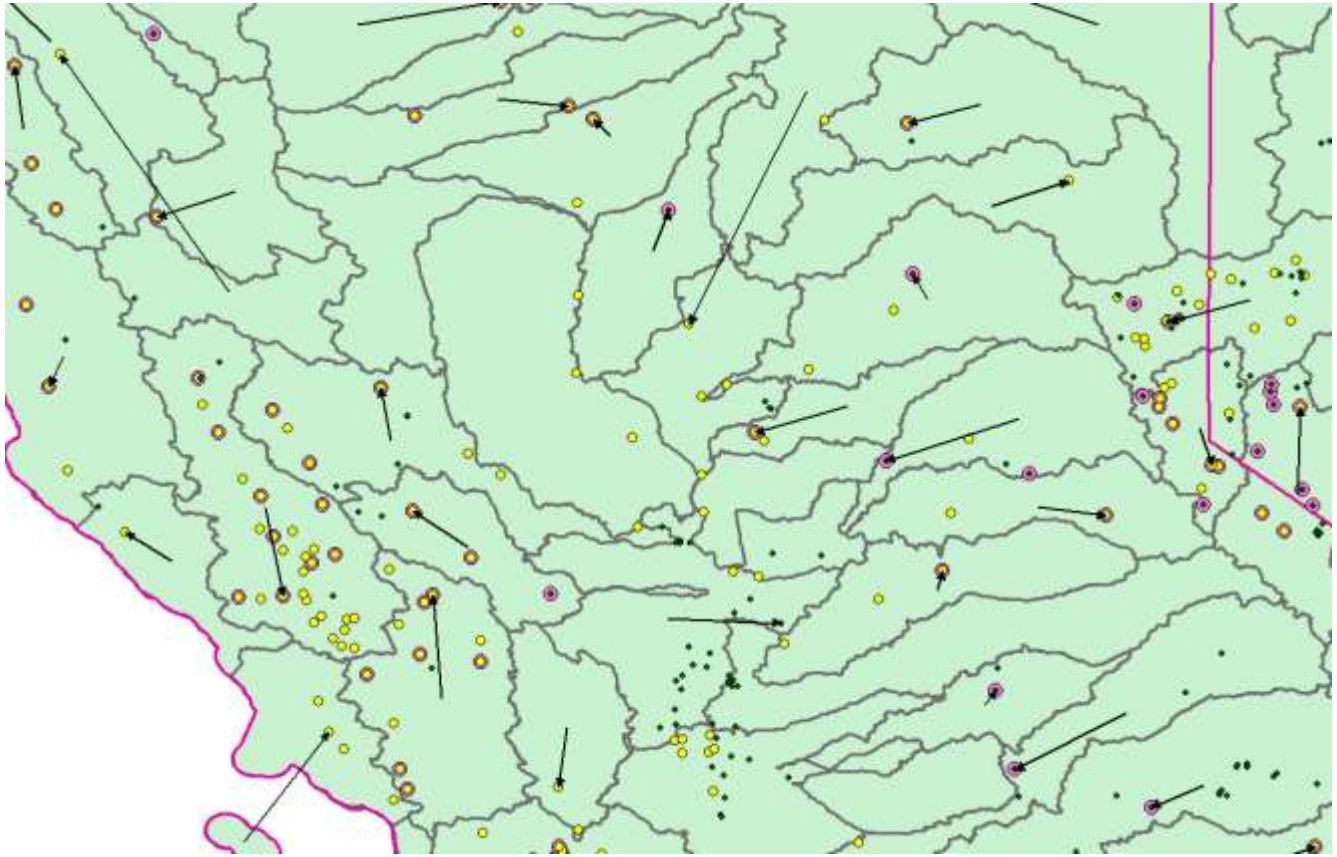
HUC8 fraction = 100%
Gage fraction = 60%

HUC8 fraction = 35%
Gage fraction = 40%

HUC8 Gage Assignments

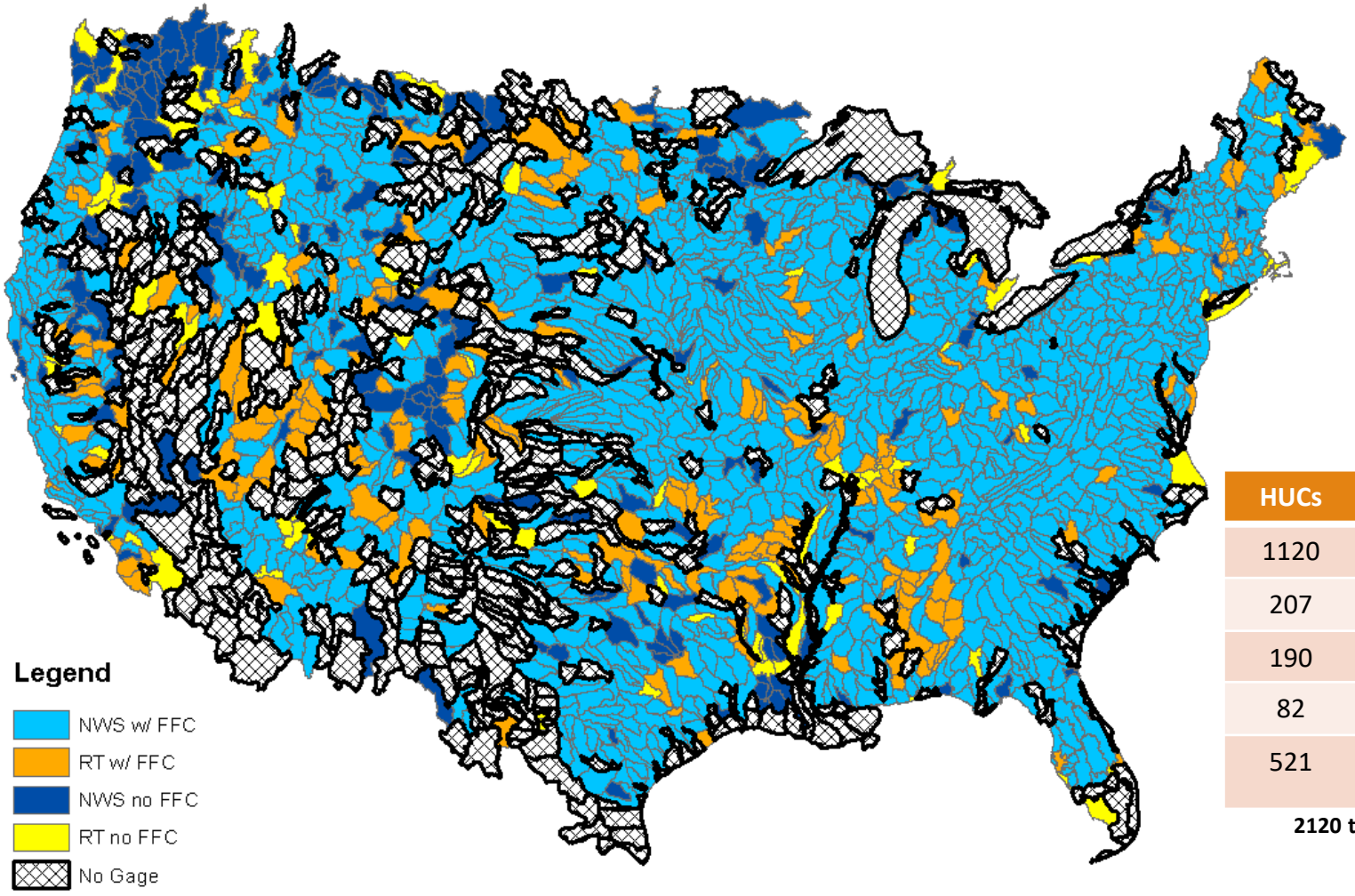
Yellow – NWS gages

Pink – Gage with FFC



HUC8 Assignments

STARR II Strategic Alliance for Risk Reduction

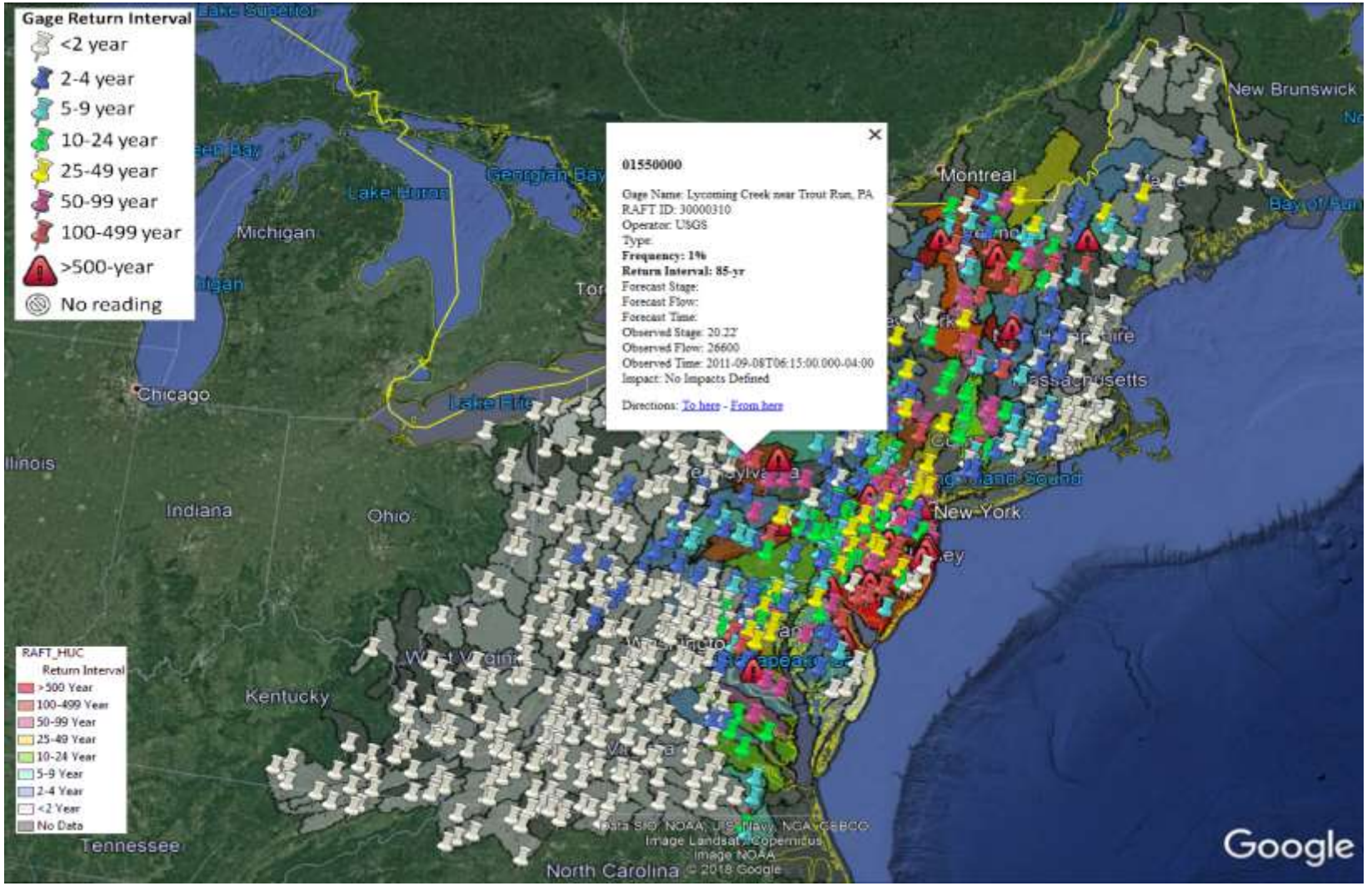


HUCs	Type	%
1120	NWS w/ FFC	52.8
207	RT w/ FFC	9.7
190	NWS no FFC	8.9
82	RT no FFC	3.9
521	No gage	24.6

2120 total HUC8s in CONUS

Hurricane Irene – Region I, II, & III

Historic Flood Frequencies for streamgages and HUC-8s



Hurricane Irene – Region I

STARR II Strategic Alliance for Risk Reduction

Historic Flood Frequencies for Regions 1 for streamgages

GageName	DSOrder Num	State	County	River	Observed Data Time	Observed Stage (ft)	Observed Flow (cfs)	Frequency	Return Interval	Impacts
Wild River at Gilead, Maine	1054200	ME	Oxford	0	2011-08-28T16:15:00	17.42	37800	Too High	>500 yr	No Impacts Defined
SAXTONS RIVER AT SAXTONS RIVER, VT	1154000	VT	Windham	Saxtons River	2011-08-28T14:30:00	19.58	21600	Too High	>500 yr	No Impacts Defined
DOG RIVER AT NORTHFIELD FALLS, VT	4287000	VT	Washington	Dog River	2011-08-28T19:45:00	17.26	22200	Too High	>500 yr	Devestating flooding throughout the Dog River valley. Route 12 will be inundated, with road damage and bridge washouts. Low structures along the Dog River will be inundated. Flooding will be comparable to Irene in 2011.
WILLIAMS RIVER NEAR ROCKINGHAM VT	1153550	VT	Windham	Williams River	2011-08-28T16:45:00	17.94	21300	0.26%	386.1	No Impacts Defined
WHITE RIVER AT WEST HARTFORD, VT	1144000	VT	Windsor	White River	2011-08-29T01:30:00	28.36	90100	0.29%	348.6	This is an extremely dangerous situation and will equal Irene in 2011 and the 1927 flood. If you live, work, or travel near the White river evacuate uphill now! The White River will cover the entire valley in some areas, and there will be widespread, devastating damage. Homes and businesses near the river will be inundated and some may be swept off their foundations. Portions of Routes 14 and 107 will be covered and will be damaged or destroyed.
MAD RIVER NEAR MORETOWN, VT	4288000	VT	Washington	Mad River	2011-08-28T20:15:00	19.26	24200	0.30%	333.2	About 4 feet of water will cover Route 100 south of Moretown, nearly reaching a trailer park.
BOUQUET RIVER AT WILLSBORO NY	4276500	NY	Essex	Boquet River	2011-08-29T07:45:00	12.35	16000	0.56%	178.7	No Impacts Defined
SOUTH RIVER NEAR CONWAY, MA	1169900	MA	Franklin	South River	2011-08-28T12:15:00	#N/A	9300	0.56%	177.1	No Impacts Defined
ESOPUS CREEK AT ALLABEN NY	1362200	NY	Ulster	0	2011-08-28T09:15:00	16.34	29300	0.63%	159.6	No Impacts Defined
AYERS BROOK AT RANDOLPH, VT	1142500	VT	Orange	Ayers Brook	2011-08-28T19:30:00	15.04	3920	0.66%	152.4	Flood of record 6/27/1998. Numerous roads under water. Extensive damage to roads in the upper reaches of the White River from Granville to Hancock.
PEMIGEWASSET RIVER AT WOODSTOCK, NH	1075000	NH	Grafton	Pemigewasset Ri	2011-08-28T17:52:00	16.97	53700	0.68%	147.1	Significant flooding along route 112. significant flooding along route 3 and route 175 from north woodstock to west campton. some flooding occurs at the riverfront condo development, the river green hotel and the saint andrews condos. water up to the low steel on the route 175 bridge in north woodstock.
Saco River near Conway, NH	1064500	NH	Carroll	Saco River	2011-08-29T00:27:00	17.23	58200	0.70%	143.7	17 feet, all of Transvale Acres flooded to west Side Road. Hillside Avenue, Washington Street, and East Side Drive flooded in Conway. Water just below covered bridge on East Side Road in Conway. Beach and Eastern Slope camping areas under 10 to 12 feet of water
POMPERAUG RIVER AT SOUTHBURY, CT	1204000	CT	New Haven	Pomperaug River	2011-08-28T13:30:00	17.45	14200	0.73%	137.8	No Impacts Defined
OTTER CREEK AT CENTER RUTLAND, VT	4282000	VT	Rutland	Otter Creek	2011-08-29T02:30:00	17.43	15700	0.78%	127.8	Many homes will be affected. Flood levels will be similar to those seen in June 1973 and September 1938.
HOOSIC RIVER NEAR EAGLE BRIDGE NY	1334500	NY	Rensselaer	Hoosic River	2011-08-29T00:30:00	19.24	44300	0.81%	124.1	Bottom frame of steel truss bridge. Gage house floor.
BUNNELL BROOK NEAR BURLINGTON, CT	1188000	CT	Hartford	Bunnell Brook	2011-08-28T11:30:00	8.86	1310	1.07%	93.5	No Impacts Defined
EAST BRANCH PEMIGEWASSET RIVER AT LINCOLN, NH	1074520	NH	Grafton	East Branch Pemi	2011-08-28T15:30:00	17.5	29300	1.17%	85.7	No Impacts Defined
MISSISQUOI RIVER NEAR NORTH TROY, VT	4293000	VT	Orleans	Missisquoi River	2011-08-29T03:30:00	13.93	10900	1.17%	85.4	Large sections of Route 100 will be flooded from Lowell downstream to Troy. Water will approach homes along River Road and Loop Road from Westfield to North Troy. Widespread flooding of farmlands from Lowell to North Troy.
ESOPUS CREEK AT COLDBROOK NY	1362500	NY	Ulster	Esopus Creek	2011-08-28T12:00:00	23.34	75800	1.20%	83.5	Boiceville business district underwater.
HUBBARD RIVER NEAR WEST HARTLAND, CT	1187300	CT	Hartford	Hubbard River	2011-08-28T10:45:00	11.01	4860	1.31%	76.2	No Impacts Defined
POULTNEY RIVER BELOW FAIR HAVEN, VT	4280000	NY	Washington	Poultney River	2011-08-29T10:00:00	23.28	12800	1.36%	73.6	Water approaches Greene Rd and Swamp Rd in Fair Haven.
NEW HAVEN RIVER @ BROOKSVILLE, NR MIDDLEBURY, VT	4282525	VT	Addison	New Haven River	2011-08-28T21:30:00	12.95	16700	1.42%	70.3	No Impacts Defined
METTAWEE RIVER NEAR MIDDLE GRANVILLE NY	4280450	NY	Washington	Mettawee River	2011-08-28T22:45:00	15.04	16800	1.58%	63.5	Major flood stage. Widespread flooding in Granville with numerous evacuations and Upper Turnpike Road under water.
WELLS RIVER AT WELLS RIVER, VT	1139000	VT	Orange	Wells River	2011-08-28T23:30:00	9.03	5170	1.59%	62.8	The villages of Wells River, South Ryegate, and Groton become isolated due to flooded roadways. Water reaches a depth of about 2 feet in downtown Wells River. Low lying buildings and roads along the Wells River in Groton, South Ryegate, and Wells River take on water, with significant flooding along route 302. Flooding is similar to Irene in 2011.
HOOSIC RIVER NEAR WILLIAMSTOWN, MA	1332500	MA	Berkshire	Hoosic River	2011-08-28T15:15:00	13.75	12900	1.61%	62.1	Flood of April 1987.
WALLOOMSAC RIVER NEAR NORTH BENNINGTON, VT	1334000	VT	Bennington	Walloomsac Rive	2011-08-28T15:30:00	12.82	9420	1.75%	57.0	Flood of record with Tropical Storm Irene in August 2011.
STILL RIVER AT ROBERTSVILLE, CT	1186500	CT	Litchfield	Sandy Brook	2011-08-28T13:15:00	11.01	12300	1.85%	54.1	No Impacts Defined

Hurricane Irene – Region I

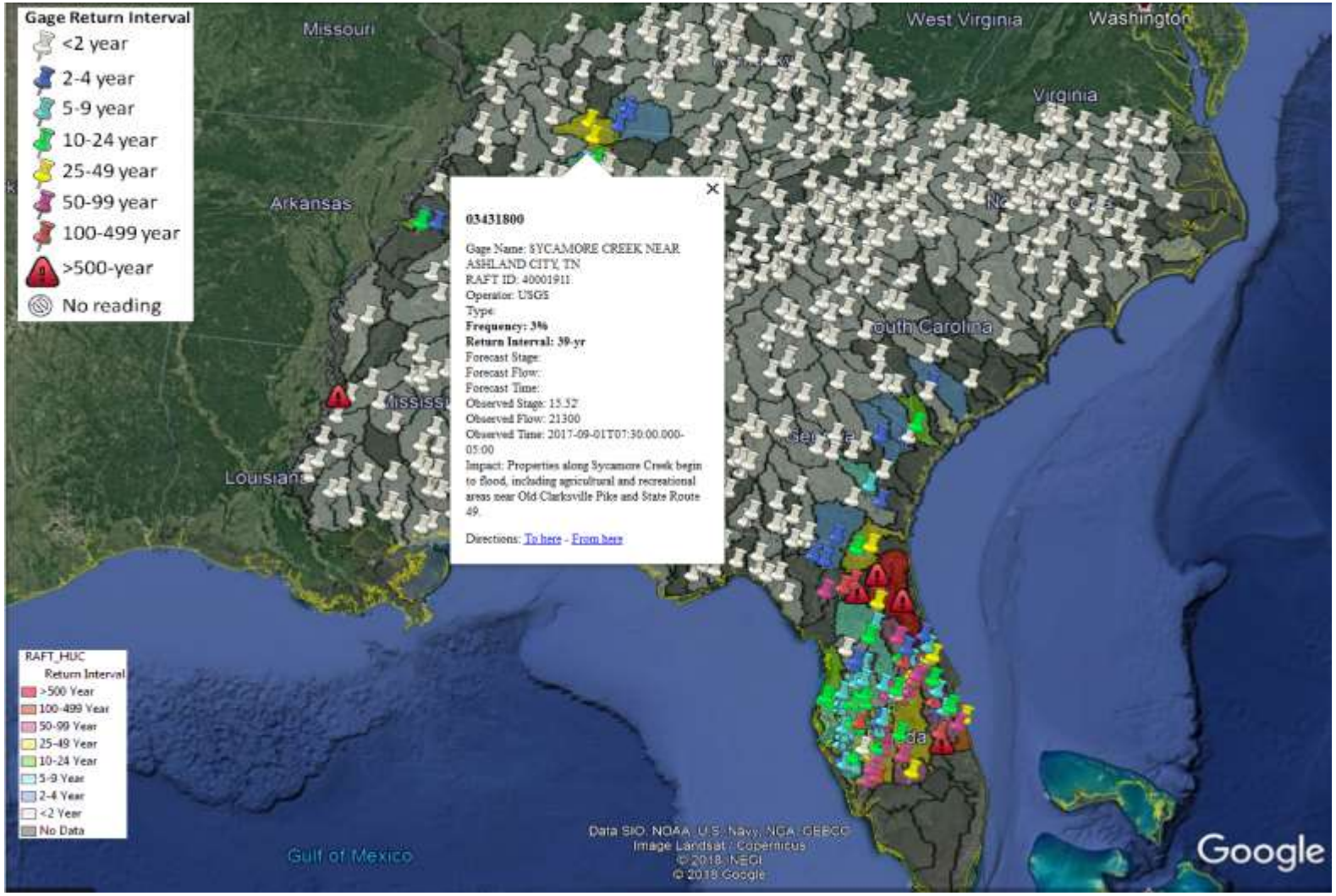
STARR II Strategic Alliance for Risk Reduction

Region 1 Housing Units, Population in Floodplain, and Insurance Penetration in 1% Chance Flood Event for Hurricane Irene HUC-8 watersheds where the observed event is greater than a 10% chance flood

HUCs				Linked Gages/Frequencies							Contracts in Force/ Housing Units
HUCID	HUCName	State	County	GageName	Frequency	Return Interval	Contracts in Force (NFIP)	Housing Units in SFHA	Population in SFHA		Percentage
1080107	West	New Hampshire_Ver	Bennington_Cheshire_	SAXTONS RIVER AT SAXTONS RIVER, VT	Too High	>500 yr	408	1541	2572		26%
1080105	White	Vermont	Addison_Orange_Rutla	WHITE RIVER AT WEST HARTFORD, VT	0.3%	349 yr	219	950	1663		23%
4150403	Winooski River	Vermont	Addison_Caledonia_Ch	MAD RIVER NEAR MORETOWN, VT	0.3%	333 yr	1218	3434	6942		35%
4150408	Lake Champlain	New York_Vermont	Addison_Chittenden_C	BOUQUET RIVER AT WILLSBORO NY	0.6%	179 yr	716	2780	4848		26%
2020003	Hudson-Hoosic	Massachusetts_New	Albany_Bennington_Be	HOOSIC RIVER NEAR EAGLE BRIDGE NY	0.8%	124 yr	1771	7076	14347		25%
4150407	Missiquoi River	Vermont	Franklin_Lamoille_Orle	MISSISQUOI RIVER NEAR NORTH TROY, VT	1.2%	85 yr	96	492	969		20%
2020006	Middle Hudson	Massachusetts_New	Albany_Berkshire_Colu	ESOPUS CREEK AT COLDBROOK NY	1.2%	83 yr	2786	9311	18251		30%
4150401	Mettawee River	New York_Vermont	Addison_Bennington_R	POULTNEY RIVER BELOW FAIR HAVEN, VT	1.4%	74 yr	234	1315	2548		18%
1080103	Waits	New Hampshire_Ver	Caledonia_Carroll_Coo	WELLS RIVER AT WELLS RIVER, VT	1.6%	63 yr	151	1278	2247		12%
1080207	Farmington	Connecticut_Massach	Berkshire_Hampden_H	STILL RIVER AT ROBERTSVILLE, CT	1.8%	54 yr	906	2896	6251		31%
4150500	St. Francois River	Maine_New Hampsh	Caledonia_Coos_Essex_	BLACK RIVER AT COVENTRY, VT	2.9%	35 yr	77	627	996		12%
1080104	Upper Connecticut-Masco	New Hampshire_Ver	Caledonia_Grafton_Ora	EAST ORANGE BRANCH AT EAST ORANGE, VT	4.0%	25 yr	161	744	1464		22%
1100005	Housatonic	Connecticut_Massach	Berkshire_Columbia_Di	HOUSATONIC RIVER AT GAYLORDSVILLE, CT	7.4%	13 yr	3954	11417	24757		35%
1040002	Lower Androscoggin	Maine_New Hampsh	Androscoggin_Carroll_(	Swift River near Roxbury, Maine	10.3%	10 yr	565	3927	6958		14%

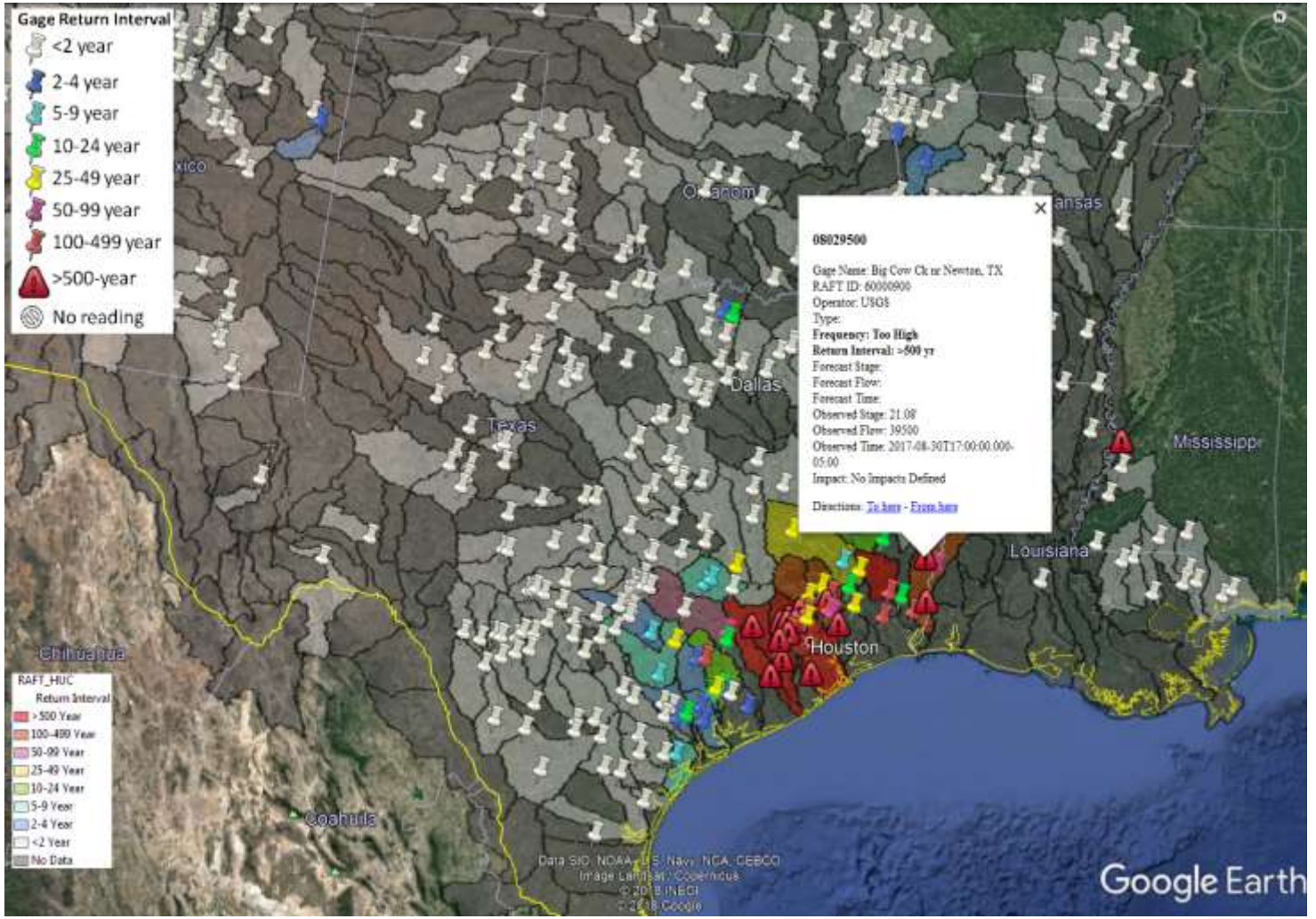
Hurricane Irma – Region IV

Historic Flood Frequencies for streamgages and HUC-8s



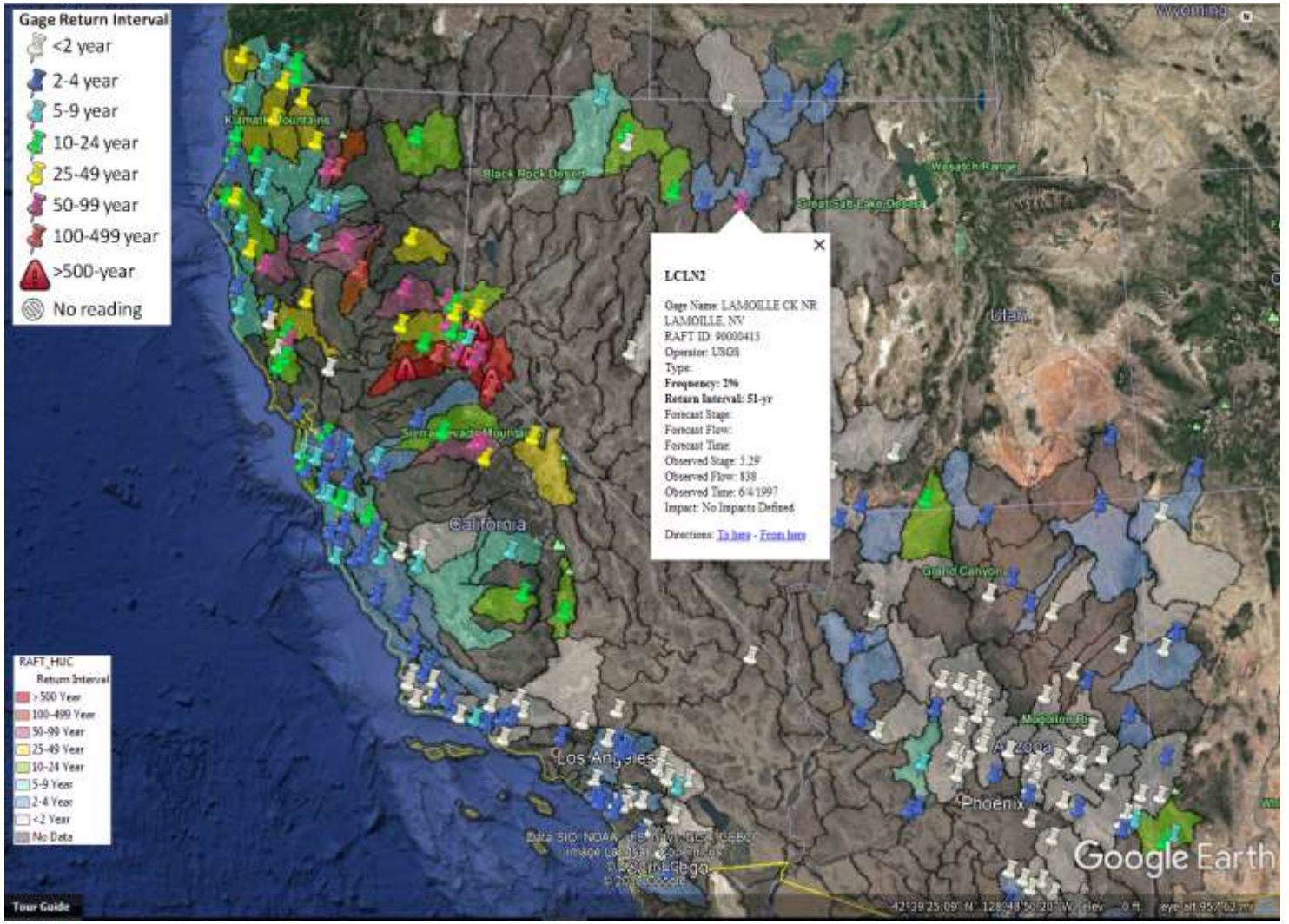
Hurricane Harvey – Region VI

Historic Flood Frequencies for streamgages and HUC-8s



Water Year 1997 – Region IX

Water Year 1997 Flood Frequencies for streamgages and HUC-8s



RAFT Walkthrough – Where's the Rain?

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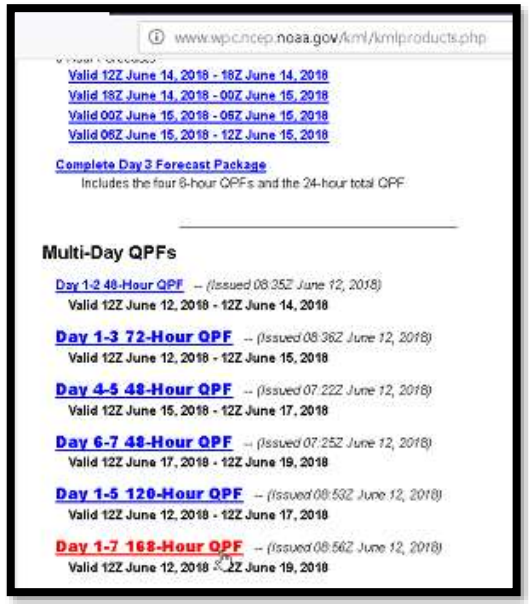
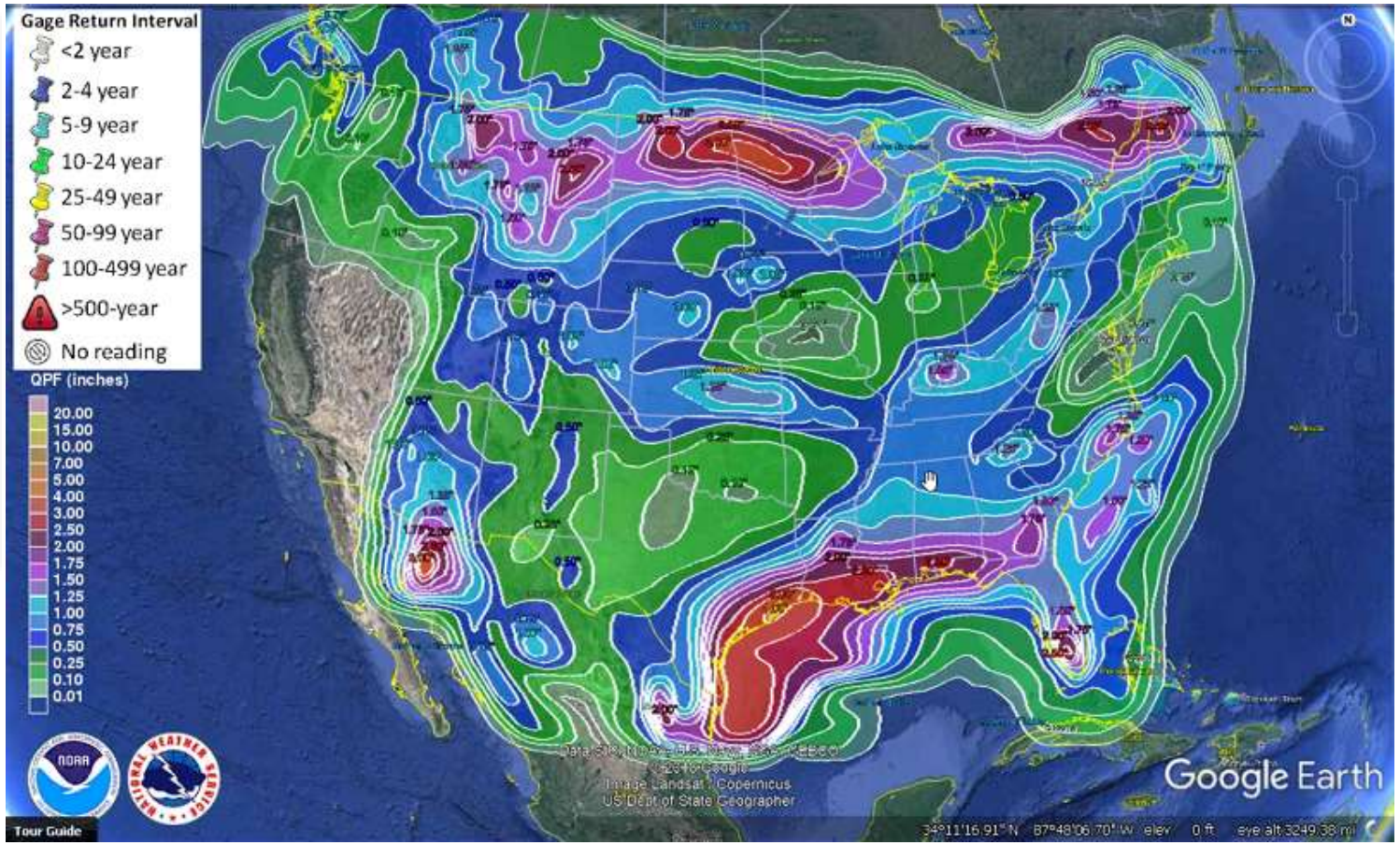
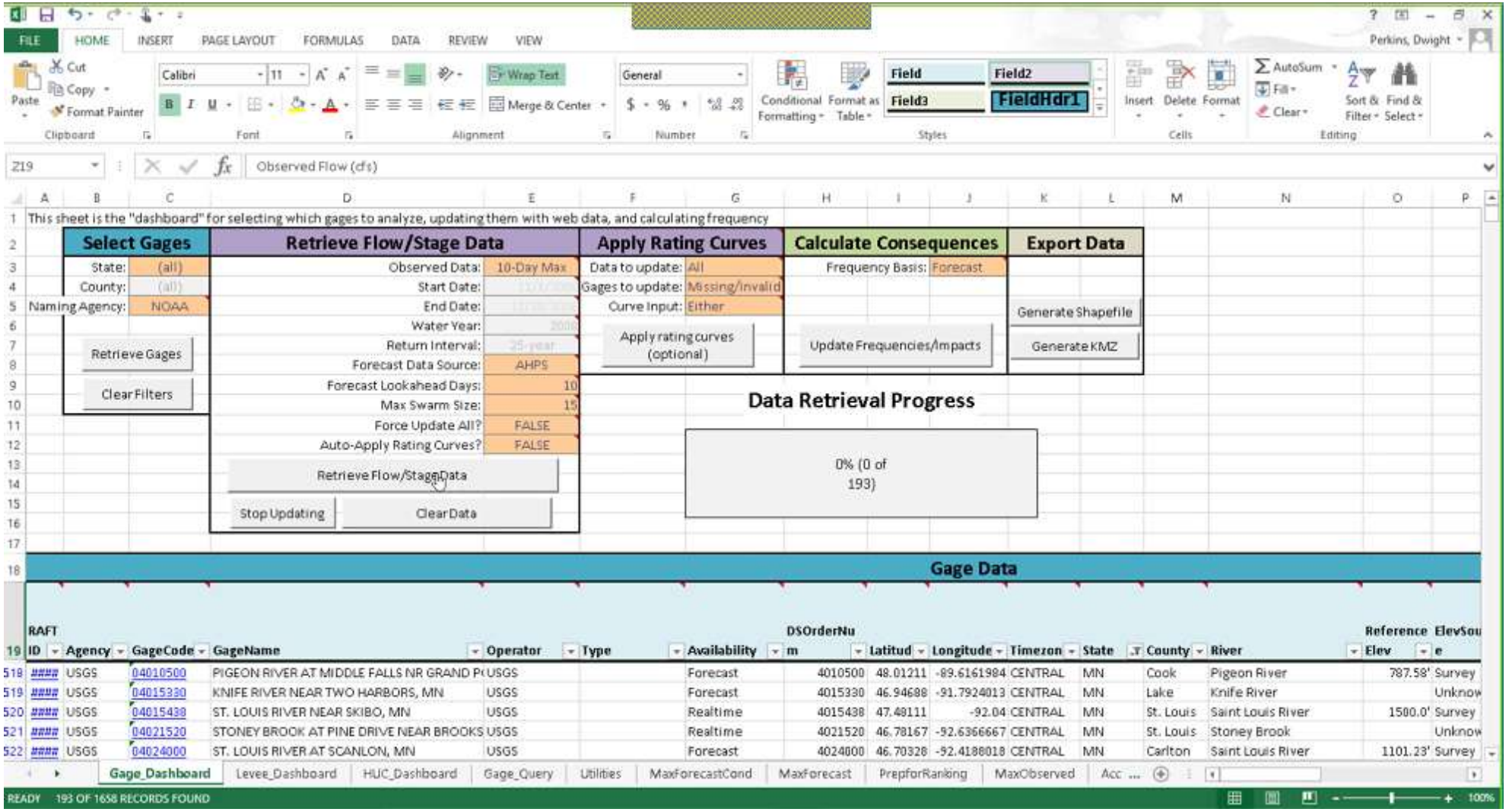




RAFT Tool – Gages – Get Data



RAFT Tool – Gages - Results

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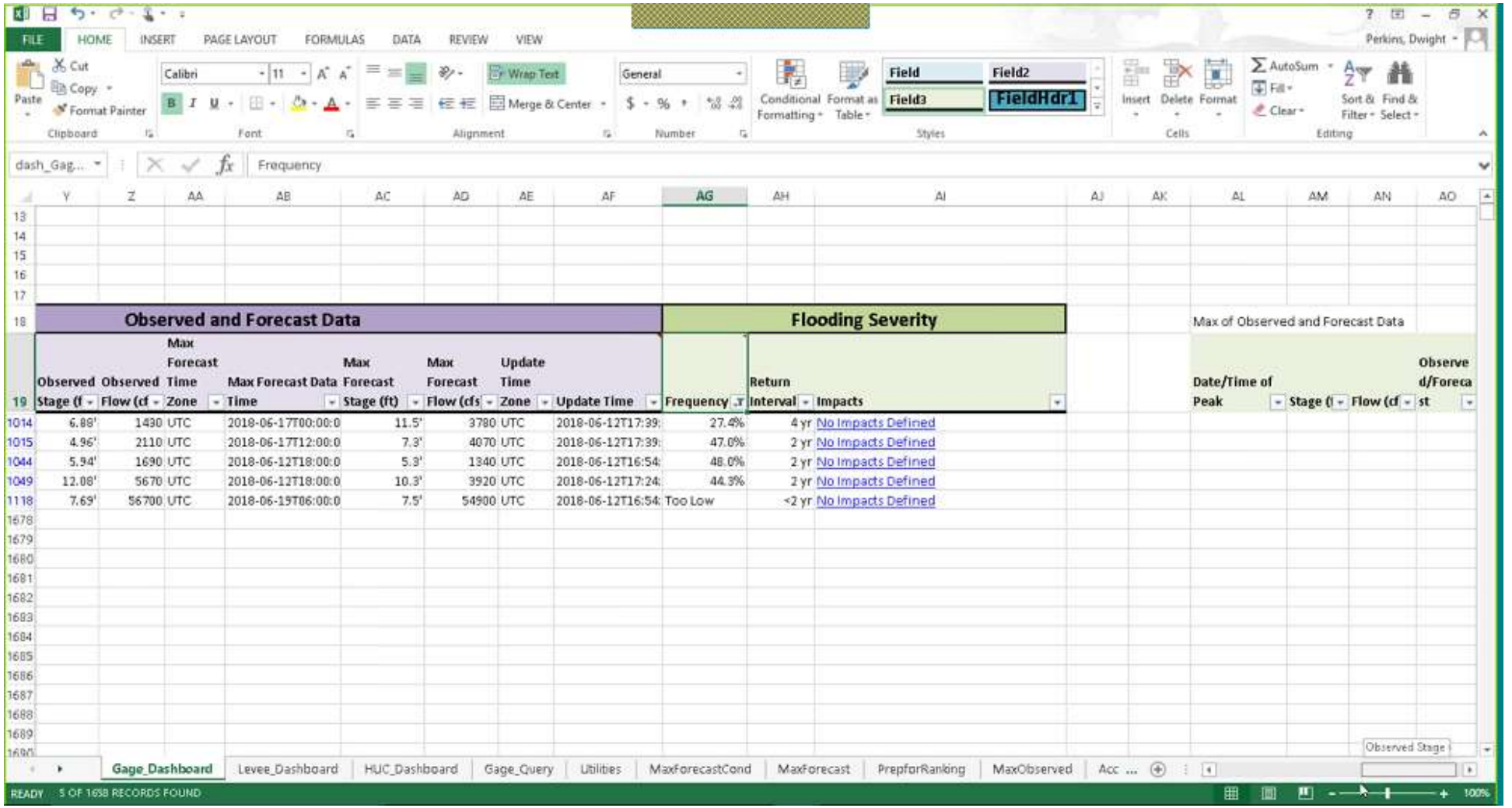
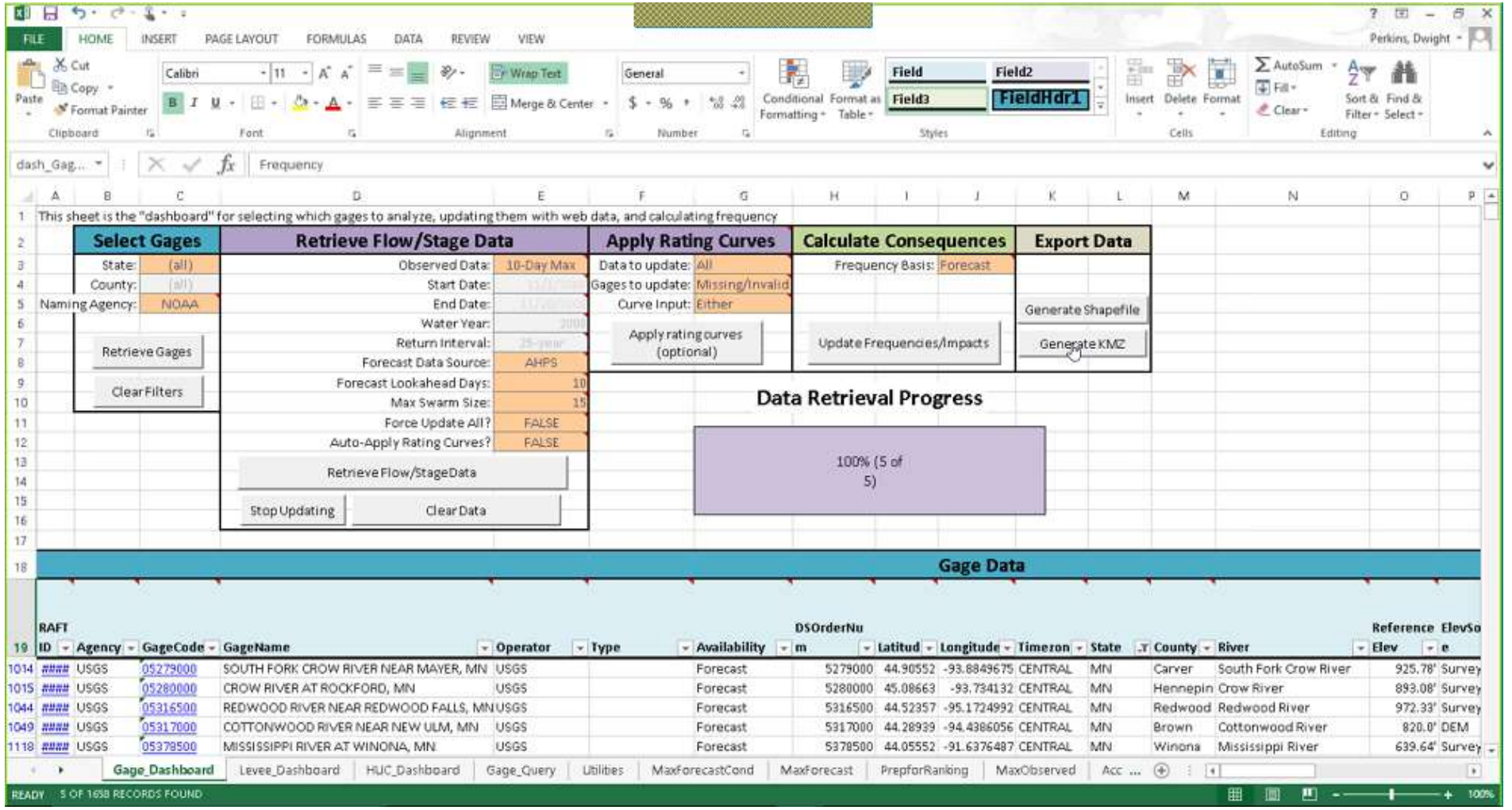


Observed and Forecast Data								Flooding Severity		
Observed Stage (f	Observed Flow (cf	Max Forecast Time Zone	Max Forecast Data Time	Max Forecast Stage (ft)	Max Forecast Flow (cfs	Update Time Zone	Update Time	Frequency	Return Interval	Impacts
6.88'	1430	UTC	2018-06-17T00:00:0	11.5'	3780	UTC	2018-06-12T17:39:	27.4%	4 yr	No Impacts Defined
4.96'	2110	UTC	2018-06-17T12:00:0	7.3'	4070	UTC	2018-06-12T17:39:	47.0%	2 yr	No Impacts Defined
5.94'	1690	UTC	2018-06-12T18:00:0	5.3'	1340	UTC	2018-06-12T16:54:	48.0%	2 yr	No Impacts Defined
12.08'	5670	UTC	2018-06-12T18:00:0	10.3'	3920	UTC	2018-06-12T17:24:	44.3%	2 yr	No Impacts Defined
7.69'	56700	UTC	2018-06-19T06:00:0	7.5'	54900	UTC	2018-06-12T16:54:	Too Low	<2 yr	No Impacts Defined

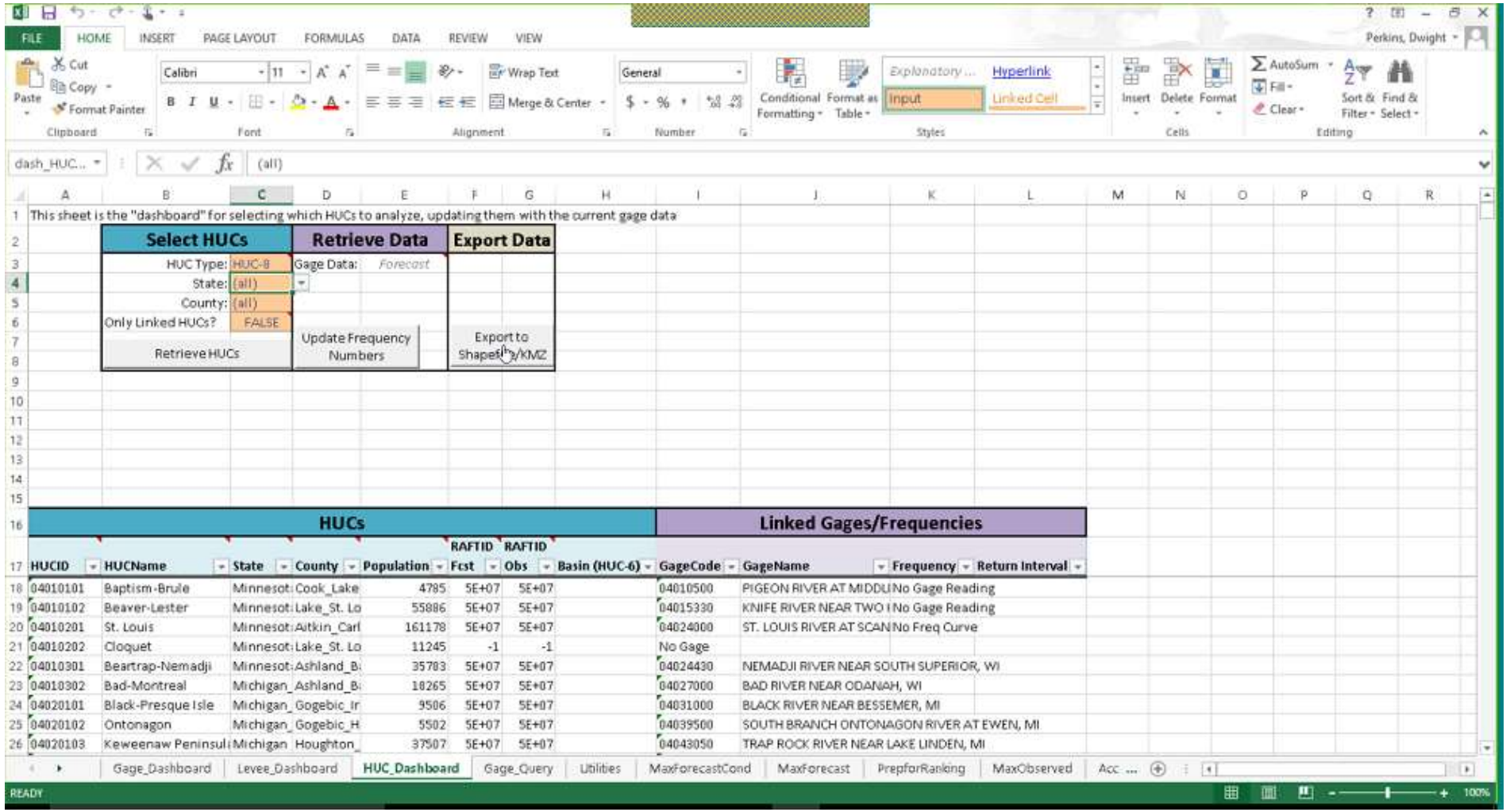
Max of Observed and Forecast Data

Date/Time of Peak	Stage (f	Flow (cf	Observed/Forecast

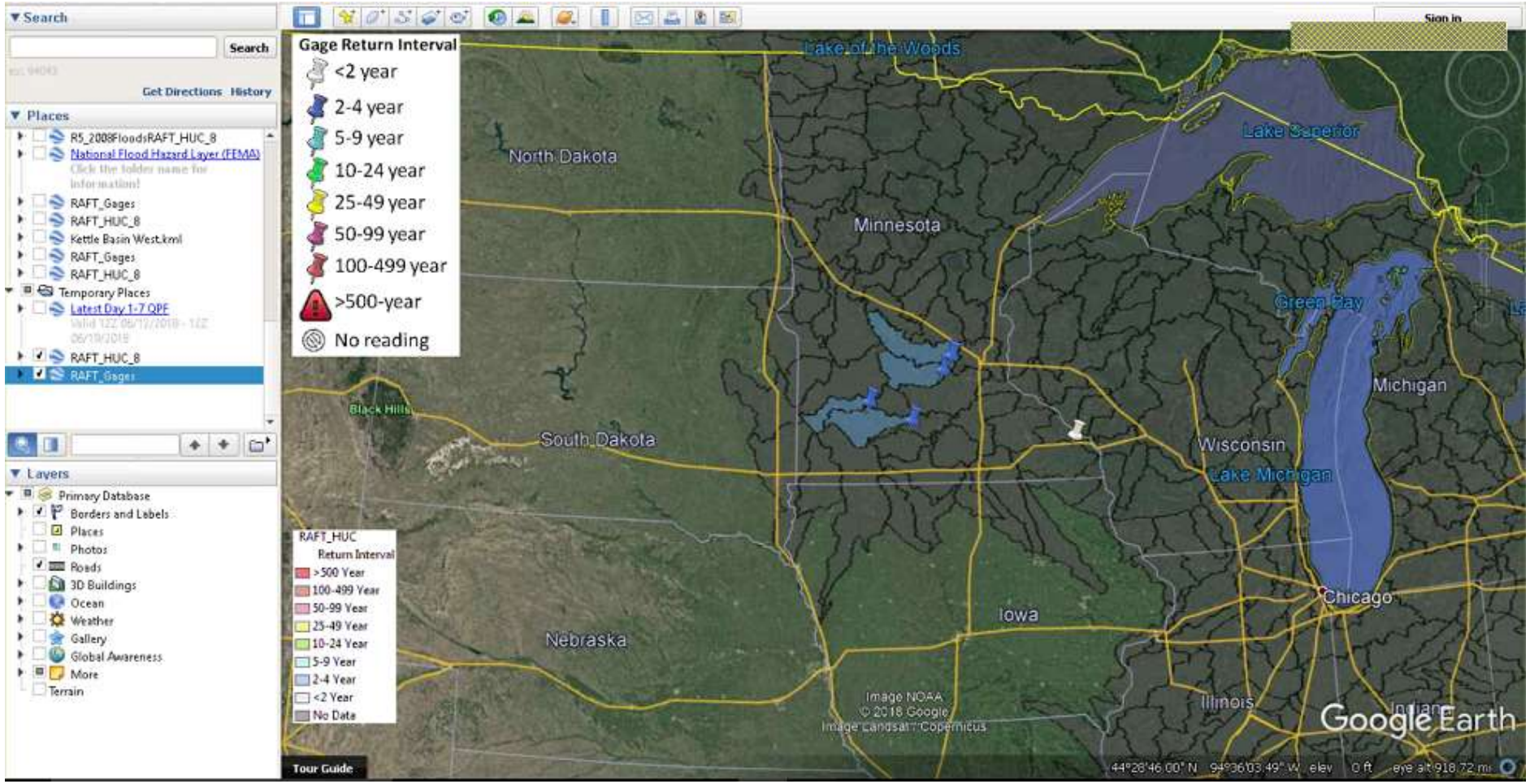
RAFT Tool – Gages – Export



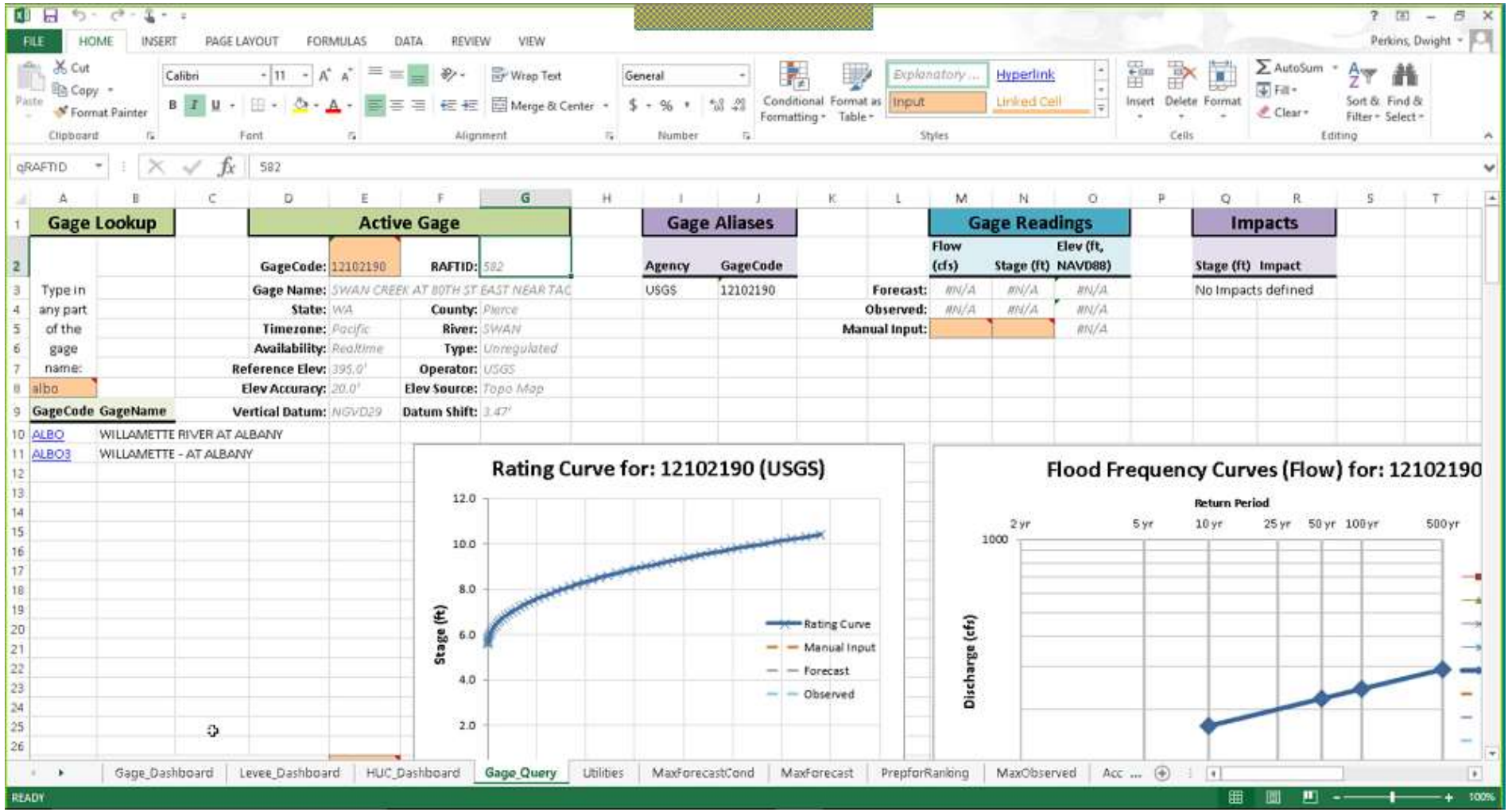
RAFT Tool – HUCs – Export



Results in Google Earth



Additional Dashboards - Gages



The Project Team

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