APPENDIX D

TECHNICAL REVIEW – COMMENTS & RESPONSES

Review of Yellowstone River HEC-RAS and Mapping

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February 26, 2015

Responses submitted by Laurel Hamilton, USACE Omaha District, May 2015 & June 2016

Scope

Conditions

Developed/ regulated

Undeveloped/ unregulated

(Developed/ unregulated and undeveloped/regulated were not reviewed)

Counties

Sweet Grass County

Stillwater County

Yellowstone County

Treasure County

Rosebud County

Custer County

Prairie County

Dawson County

Richland/McKenzie Counties

Files Received

The USGS received an external drive with 1.04 TB of data in a directory "**YELLOWSTONE CORRIDOR HYDRAULICS**"; and in the following subdirectories (subdirectories in **bold**):

_Metadata

_Supporting Data

Aerials (files showing locations/dates of acquisition)

Bathymetry (Merrick/DNRC reports documenting methods/materials, raw data)

Bridges (Bridge summary sheets containing survey data, photos)

HWM (HWM forms w/photos, shapefile)

Hydrology (Hydrology reports and appendixes; calcs % diff between USGS draft and final Q's)

Mapping (Hydraulic engineer's notes on mapping procedures for mappers and reviewers)

Files:

Hydraulics - Data Submittal.docx

**HydroTasks_Yellowstone Corridor.xls (summary spreadsheet, USEFUL)

Modeling Mapping Approach for Yellowstone River.docx

Scope of Work for West Consultants (FINAL) 28Jul2011.docx

Scope of work_Hydraulics for TAC.docx

WEST - QCP - Task Order 16 - Yellowstone River.pdf

** WEST Consultants - Modeling Mapping Report.pdf (Reviewed)

** Yellowstone Corridor Report - DRAFT (revised).pdf (VERY USEFUL)

Yellowstone Corridor Report for Fisheries FINAL.pdf (not reviewed, included in other report)

All Counties

Riparian and Land Use (not reviewed, background used to develop manning's n's)

Files:

Flood extent and other shapefiles:

Counties.dbf, prj, sbn, sbx, shp, xml, shx

Dev_Reg_100yr.dbf, prj, sbn, sbx, shp, xml, shx

Dev_Reg_2yr.dbf, etc.

Dev_Reg_5yr.dbf, etc.

Dev_Unreg_100yr.dbf, etc.

Dev_Unreg_2yr.dbf, etc.

Dev_Unreg_5yr.dbf, etc.

fl_1999_2001_route_primary.dbf, etc.

PhysFeatLine.dbf, etc.

reach_polys.dbf, etc.

Undev_Reg_100yr.dbf, prj, sbn, sbx, shp, shx

Undev_Reg_2yr.dbf, etc

Undev_Reg_5yr.dbf, etc

Undev_Unreg_100yr.dbf, etc

Undev_Unreg_2yr.dbf, etc

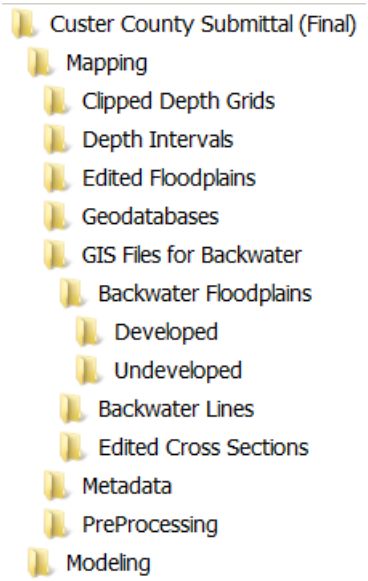
Undev_Unreg_5yr.dbf, etc.

Yellowstone River Miles.xlsx (Xsect No./RM)

Yellowstone River Reaches.pdf

Yellowstone_River_Miles.dbf, etc.

Custer County Submittal (Final) (directories and files under other county directories are similar)



Dawson County (Final)

Prairie County Submittal (Final)

Richland McKenzie County Submittal (Final)

Rosebud County Submittal (Final)

Stillwater County (Final)

Sweet Grass County (Final)

Treasure County Submittal (Final)

Yellowstone County (Final)

All Counties - Summary of HEC-RAS and Mapping Review

Topographic Data

TINs or DEMs were not supplied along with the review files. Shapefiles, HEC-RAS cross sections, and in some cases depth grids were viewed and checked for reasonableness.

Cross Sections

Cross sections looked reasonable, they extended above maximum WSELs. Bank stations were mostly consistent within each county; Yellowstone County bank stations were set high (above the 5-yr and even at about the 100-yr), other counties bank stations were set at the channel (~1.5-2 yr, at the break in slope).

Structures

Bridges and cross sections in HEC-RAS were visually compared with shapefiles and background maps in ArcMap, for the 100-yr flow, and other flows for some counties. Also spot checked survey measurements and HEC-RAS pier widths. Some discrepancies between the survey and HEC-RAS pier widths were noted in Yellowstone County.

RESPONSE: Sensitivities were conducted and showed minimal impact.

Ineffective Flow Areas and Levees

Levees, roads etc. were modeled as keeping flow from areas behind those features, even when they might not have been certified. This seems reasonable for the cumulative effects analyses.

In general ineffective flow areas were input very well. Exceptions are noted under discussions for each county, but it's possible that given the wide range of flows modeled the ineffective flow areas are as representative of actual conditions as possible, and that further refinements would not result in much change. It's also possible that the HEC-RAS locations of ineffective flow would correspond better with the elevation data (not reviewed) than the background maps used for the review. The background maps are more recent than the surveys and HEC-RAS modeling and mapping.

For Treasure, Rosebud, Custer, Prairie, and Richland/McKenzie county models, 2 different geometry files were created for developed and undeveloped conditions and unregulated and regulated flows; one for high flows and one for low flows, in order to represent ineffective flow areas for different river stages.

RESPONSE: WEST Consultants Inc. were contracted to perform these counties and felt a separate high flow and low flow geometry would represent the system more adequately. In most locations, the resulting water surface differences were minimal.

Roughness Values

Conveyance calculations at breaks in n values only; composite main channel n if channel side slope greater than 5:1. Manning's n values appear reasonable, some high in Yellowstone County (>0.05: 143932.9 RM 387.59, 78400.21 RM 346.93, 38239.27 RM 322.13; 38090.48 RM 322.03) in channel

(because bank stations are set high, even as high as the 50-yr/ 100-yr at many sections). A value of 0.028 was used for the low flow (water covered) channel.

RESPONSE: The Yellowstone County geometry was taken from the model submitted to FEMA. N-values were not adjusted.

Split Flow around Islands and in Braided Reaches

Some reaches have split flow but were modeled as continuous/connected flow across cross sections (see USACE report p.9). As a result the water surface elevations and velocities through some braided flow/island reaches might not reflect actual conditions. Modeling the divided flow through these numerous reaches (and with multiple discharges) likely would have doubled the effort (at least) for the modeling and mapping, so the uniform flow approach is reasonable for the large scale of the Yellowstone Corridor studies. However, users intending to analyze velocities/water surface elevations for detailed studies along braided flow/island reaches might consider performing sensitivity analyses to check that the HEC-RAS and mapping results are accurate enough for their applications.

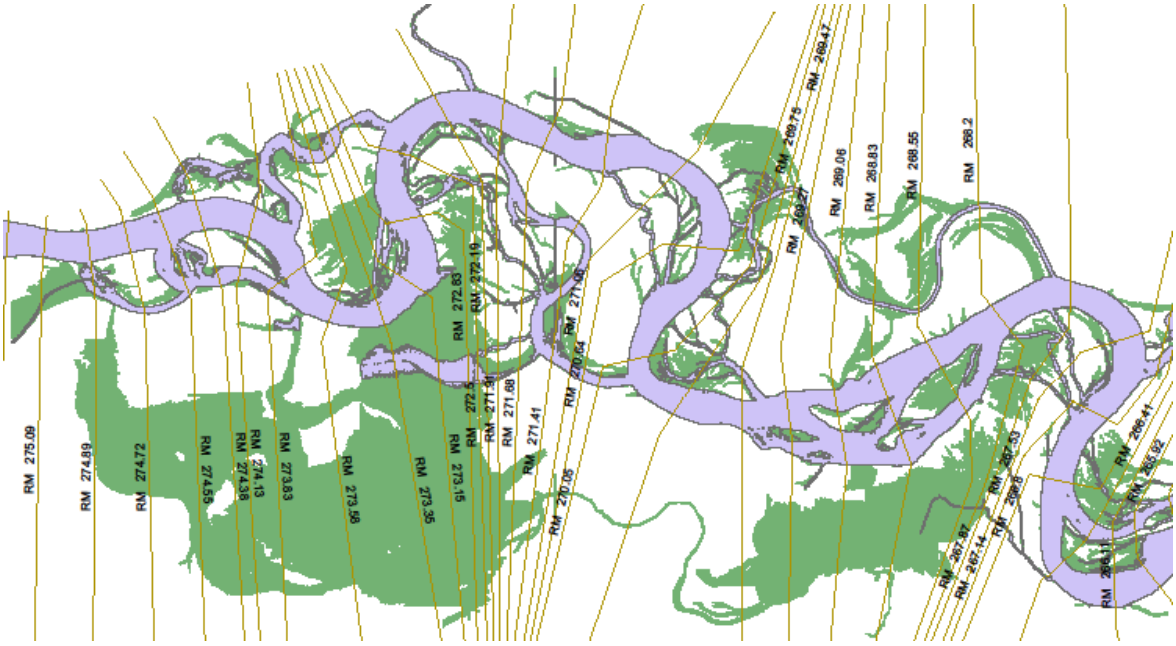
RESPONSE: Agreed. The model's applicability should be evaluated prior to its use in any study different than the intended.

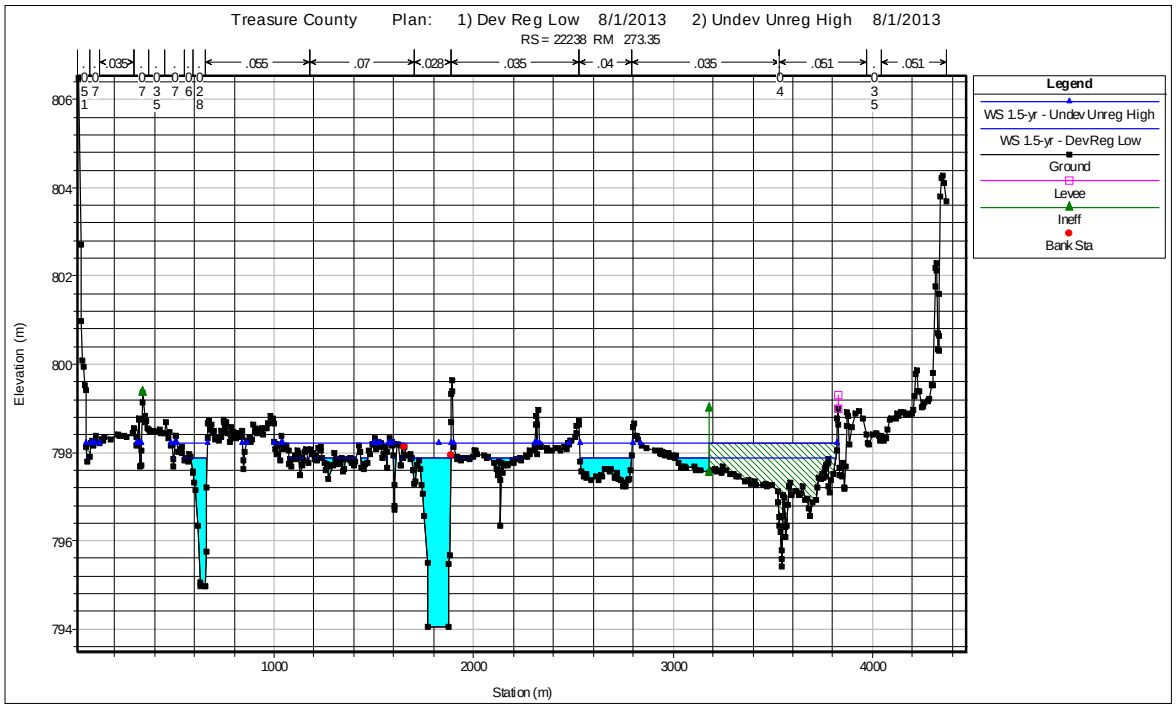
For example for the following reaches in Yellowstone County:

> 145547 RM 388.5 to 141479 RM 386.0 (upstream from bridge at Laurel; (some split flow could occur upstream from this reach)
>
> 86034.59 RM 351.67 (DS Huntly Bridge) to 77706.60 RM 346.49 (not as much divided flow for the 1% ACE for this reach)
>
> Several reaches between XSECT 44588.61 RM 326.07 to XSECT 25782.69 RM 314.35

The two following images show another example of divided low flows (1.5 yr) modeled as uniform across entire cross section containing multiple low flow channels in Treasure County XSECT 222238 RM 273.35 – downstream. The channels are far apart, and the water surfaces in one are likely not the same as water surfaces in another:

1.5 yr Developed/Regulated and Undeveloped/Unregulated





Hydrology

Looks good.

RESPONSE: It is also important to note that the discharges used in HEC-RAS were the draft hydrology values which did change by a small percentage in some locations. This difference is considered negligible.

Boundary Conditions

Used known WSEL from downstream model s or normal depth – look good.

Mapping

Visually compared flood widths in HEC-RAS cross sections to shapefiles and (in some cases) depth grids, for a low flow (1.5-yr or 2-yr) and for the 100-yr and either the 200-year or the 500-year. Focused on the Developed/Regulated condition, but also looked at the Undeveloped/Unregulated condition. Looks good, with few exceptions noted for individual counties, below.

Sweet Grass County

HEC-RAS

Low flow channel was estimated / calibrated to FEMA HEC-RAS (which included low flow channel bathymetry but was unavailable/not approved at time of CES HEC-RAS), per Laurel Hamilton email 12/12/2014.

RESPONSE: A trapezoidal channel low flow channel was incorporated and calibrated to the low flow channel extents of the aerial imagery. Once the FEMA model, which included bathymetry, was released, it was used for additional calibration.

Cross Sections

The estimated low flow channel invert is not smooth, the dips and sharp peaks could be causing flow at some cross sections to go critical or the program to not achieve balance. The natural channel thalweg profile can be uneven, but usually just in one part of a very irregular channel, as opposed to the estimated rectangular section. During calibration low flow channels were adjusted section – by – section instead of in groups?

RESPONSE: Correct – Low flow calibration occurred at and between each cross section.

Also, appears that surveyed cross sections at bridges were replaced by estimated low flow channel? US/DS cross sections at the bridges should be the same, but they have different inverts.

RESPONSE: Surveyed bridge cross sections were not incorporated in the model for consistency.

Section 193601 RM 439.01 invert looks high, no balance

Section 28852 RM 440.8 no balance

Section 31350 RM 441.27 no balance, looks high/shallow

Section 39363 RM 442.78 no balance, looks high/shallow (LOB channel lower than main channel?)

Section 48863 RM 444.6 "dip" 1.4 in invert?

Section 51873 2 m high spot in profile? Invert looks high, close to crit.

Section 55871 RM 445.94 high invert in profile, no balance

Section 64001 RM 447.49 very shallow 1.5 ft (0.5 m) low flow channel, is this realistic?

Sections 137683 RM 461.52 low spot in profile, US section no balance

Section 162845 RM 466.25 no balance, ROB section cut along channel; invert looks high us

Section 168362 high spot no balance

Profile from 170840 RM 467.78 US to bridge too much variation?

Section 3787 RM 436.29 cut along channel in ROB, some is ineffective so maybe this is OK?

Section 160351 RM 465.79 distance to downstream/upstream sections =1264/760 m

Section 164108 RM 466.49 and 3 sections downstream HL>1 m

Undev/Unreg Section 48367 RM 444.5 why is Undev ground 1 m above developed ground, but cross section looks fine? Section is fine but Undeveloped bank stations are not set correctly.

Also see bank station Section 49316 RM 444.69

RESPONSE: Agreed. Critical depth does occur at several locations and could be addressed further; however may not be a result of the channel invert. Channel invert variation were necessary when using a trapezoidal method to ensure adequate flow capacity and water surface elevation. Cross sections with a noticeably low or high invert in most cases still represent the overall cross sectional flow area.

Split Flow

Not modeled.

Structures

Section 67729 RM 448.2 Bridge sections should be same invert elevation? Why wasn't bridge survey used for section?

Section 132957 RM 460.59 Bridge sections should be same invert elevation? Why wasn't bridge survey used for section?

BR Exit 362 Section 179860 RM 469.47 why wasn't bridge survey used for section. Survey min. elev. 4087.69 ft = 1245.9 m but HEC-RAS 1247.9 m? All bridges should have used survey sections.

Undeveloped geometry at 2 DS bridges is different invert

Exit 362 Bridge HEC-RAS piers 1.07 m, in survey 2.2 m, other bridges look OK

Big Timber Br OF - Q US/BR/DS LOB OK

RESPONSE: It was not believed that adding the two internal cross section as surveyed would have much of an effect since the bathymetry immediately upstream and downstream was estimated. However, a sensitivity was run using the surveyed cross sections at the Exit 362 bridge. The 500-yr increased stage by 3.5 in and the 100yr increased by 2.3 inches.

Ineffective Flow Areas and Levees

>80% change in top width active at Sections 179726, 132836, 86230, 68815, 67729, 57365

Mostly looks good.

RESPONSE: Agreed. Active top width should be a gradual change. In some cases ineffective flow placement was exaggerated to address water surface dips and crossing in the vicinity.

Hydrology
OK

Boundary Conditions
OK

Downstream boundary condition = know WSEL from Stillwater County model. Sweet Grass downstream WSEL RM 435.42 = to upstream Stillwater section with same RM; then Stillwater furthest upstream section "set" wsel = to corresponding Sweet Grass Section. OK.

Calibration
No calibration data provided by USACE. No USGS streamgage rating curve data available in Sweet Grass County. Compared 1997 flood aerial upstream from Reed Point to 5-yr floodplain (5-yr is lower than 1997 flood flow approximately 10-yr) and looks good.

Mapping
Sections on map RM 462.32/462.16 not in HEC-RAS. HEC-RAS includes Section 144435 RM 462.72 with long distance= 1011 to downstream section.

RESPONSE: Cross section was removed from the FEMA model, and thus removed from this model for consistency. Cross section shapefile was not updated for review. FINAL SHAPEFILE HAS BEEN UPDATED.

Stillwater County

HEC-RAS

Cross Sections

Low flow bathymetry surveyed.

Section 86078.99 RM 407.71 to 84433.26 RM 407.41 channel appears to have shifted right at 407.71 and left downstream after LiDAR/survey/FP mapping (looking at ESRI basemap "World Imagery")

RESPONSE: High water occurred during 2011 and some channel shifting was observed in recent aerials.

Structures

Bridges look good.

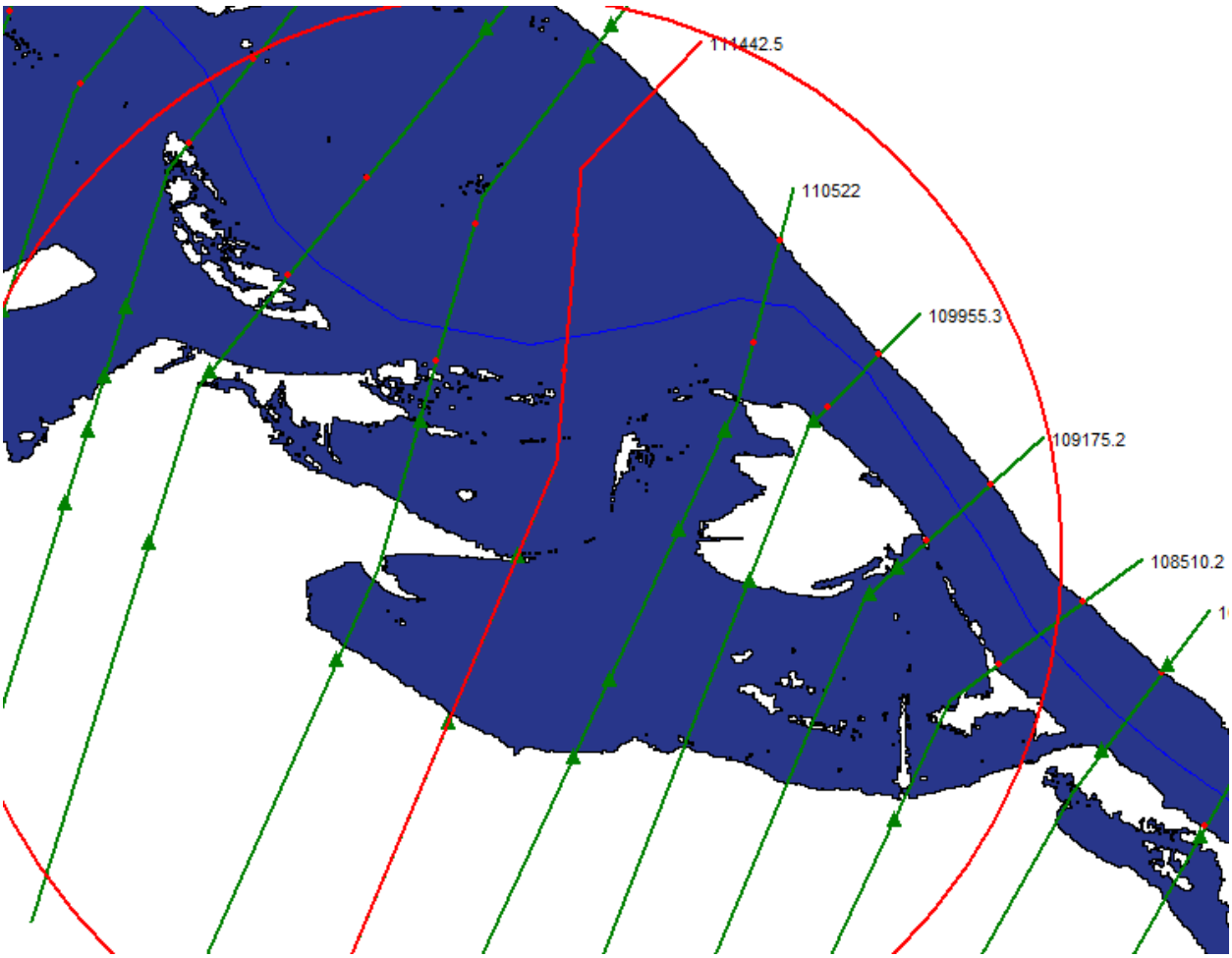
Why Contraction/Expansion coefficient 0.5/0.7 at Columbus bridge?

RESPONSE: Profile dipping was occurring immediately upstream of the bridge (possibly due to the river skew). Several modeling adjustments were made, including the increased contraction/expansion coefficient, and the profile dip was remedied.

Ineffective Flow Areas and Levees

Sections 111442.5 412.49 - 108510.2 411.92 more of ROB should be ineffective? Looks like Q cannot get into ROB from US?

RESPONSE: Some flow is conveyed through the ROB (see image below of the 100yr); however Ineffective flow placement could further be evaluated near XS 108510.2 (RM 411.92).



Hydrology
OK

Boundary Conditions
OK

Calibration
See Columbus Bridge 2011 flood photo comparison (attached); looks good.

Could not find any other calibration data.

Mapping
See comment under Cross Sections.

Yellowstone County

HEC-RAS

Cross Sections

Undeveloped geometry flowline is 200 m longer than developed geometry at RM 355.68 and upstream. *Per Laurel Hamilton's 9/15/2014 email, when she corrected the reach lengths for the undeveloped geometry, the change in wsel was minimal, except for the 2 cross sections upstream which were 16 inches higher in the uncorrected version.*

RESPONSE: During conversion to the undeveloped geometry, an error in reach length occurred when adjusting the diversion dam and adjacent cross sections. The Undeveloped geometry is 205 m longer at the location of the dam. A sensitivity was conducted to adjust the reach length and shown on the right. The "UndevB_Rev3" has the additional 200m length and shows a higher stage 0.47 m (18.5 inches) than the correct length. Increased stages greater than 0.1m (4 inches) occur upstream a distance of 2015 ft. The stages are conservative, and do not affect any residences or structures.

Reach	River Sta	Profile	Plan	Q Total	Cum Ch Len	W.S. Elev
				(m3/s)	(m)	(m)
allupstream	94148.77	100-yr	UndevB_Rev3	2214.38	94896.11	927.05
allupstream	94148.77	100-yr	Undev_B_length	2214.38	94691.05	927.05
allupstream	94030.68	100-yr	UndevB_Rev3	2214.38	94778.02	926.96
allupstream	94030.68	100-yr	Undev_B_length	2214.38	94572.95	926.95
allupstream	93912.76	100-yr	UndevB_Rev3	2214.38	94660.10	926.88
allupstream	93912.76	100-yr	Undev_B_length	2214.38	94455.03	926.87
allupstream	93782.14	100-yr	UndevB_Rev3	2214.38	94529.48	926.73
allupstream	93782.14	100-yr	Undev_B_length	2214.38	94324.42	926.71
allupstream	93670.16	100-yr	UndevB_Rev3	2214.38	94417.51	926.55
allupstream	93670.16	100-yr	Undev_B_length	2214.38	94212.45	926.52
allupstream	93525.27	100-yr	UndevB_Rev3	2214.38	94272.61	926.38
allupstream	93525.27	100-yr	Undev_B_length	2214.38	94067.55	926.33
allupstream	93386.36	100-yr	UndevB_Rev3	2214.38	94133.70	926.19
allupstream	93386.36	100-yr	Undev_B_length	2214.38	93928.63	926.14
allupstream	93264.31	100-yr	UndevB_Rev3	2214.38	94011.66	926.13
allupstream	93264.31	100-yr	Undev_B_length	2214.38	93806.60	926.08
allupstream	93150.71	100-yr	UndevB_Rev3	2214.38	93898.07	926.06
allupstream	93150.71	100-yr	Undev_B_length	2214.38	93693.01	925.99
allupstream	93034.25	100-yr	UndevB_Rev3	2214.38	93781.60	925.83
allupstream	93034.25	100-yr	Undev_B_length	2214.38	93576.53	925.73
allupstream	92927.46	100-yr	UndevB_Rev3	2214.38	93674.82	925.58
allupstream	92927.46	100-yr	Undev_B_length	2214.38	93469.76	925.19
allupstream	92825.82	100-yr	UndevB_Rev3	2214.38	93573.18	925.53
allupstream	92825.82	100-yr	Undev_B_length	2214.38	93368.12	925.06
allupstream	92688.73	100-yr	UndevB_Rev3	2214.38	93167.30	924.72
allupstream	92688.73	100-yr	Undev_B_length	2214.38	93231.03	924.85
allupstream	92419.94	100-yr	UndevB_Rev3	2214.38	92962.24	924.37
allupstream	92419.94	100-yr	Undev_B_length	2214.38	92962.24	924.37

Bank stations set high (>100-yr flood wsel) at most cross sections. This is acceptable as conveyance is calculated at breaks in Manning's n values. Bank stations would probably need to be changed for FW analyses.

Some reaches have split flow but modeled as uniform across cross sections. This is discussed in the USACE report and in this report above in the section *All Counties - Summary of HEC-RAS and Mapping Review*. As a result the water surface elevations and velocities through some of the reaches might not reflect actual conditions (looking at 100 yr), for example for the following reaches:

> 145547 RM 388.5 to 141479 RM 386.0 (upstream from bridge at Laurel; (some split flow could occur upstream from this reach)
>
> 86034.59 RM 351.67 (DS Huntly Bridge) to 77706.60 RM 346.49 (not as much divided flow for the 1% ACE for this reach)
>
> Several reaches between 44588.61 RM 326.07 to 25782.69 RM 314.35

At Sect 98813 200 yr WSEL < 100 yr, defaulted to critical depth, because of large R.O.B. area, model cannot solve

RESPONSE: Agreed. Ineffective flow placement should be further evaluated.

Structures

Laurel Bridge, Duck Cr Br., E. Billings I90, E. Billings RR: top of pier approx. measurement used for HEC-RAS pier widths, instead of bridge survey. Piers wider at base.

Bridge Pier	HEC-RAS width	Survey width	Difference
Laurel No. 2 (RR)	2.33 m	2.53 m	0.2 m
Duck Cr. No. 3	0.914	Base 1.19/Top 0.88	Base 0.28/Top 0/Ave 0.12
E. Billings I90 No. 2/3	1.219	Base 3.33/Top 1.52	Base 2.11/Top 0.3/Ave 1.2
E. Billings RR No. 1-4	Base 2.44/Top 2.13	Base 2.95/Top 2.17	Base 0.51/Top 0

RESPONSE:

Laurel Bridge: Review unclear. Survey data shows the RR bridge averages 2.67m Base/1.73m Top; HWY bridges average 2.3m Base/1.33m Top. The four pier widths modeled are 2.286 for two piers and 2.332 m for the other two piers. It appears the modeler used the highway bridge piers to be more conservative of using the 4 piers opposed to 2.

Duck Creek & Billings I90 & Billings RR: Agree that piers bases are slightly smaller than surveyed. A sensitivity was performed with the pier width adjustments the Billings I90 bridge had a max increase occurring at the 500-yr of 1.6 inches and the other bridges showed no detectable difference in stage.

Laurel Bridge: intake W=~6.5 m not blocked out of cross section

RESPONSE: The channel for water intake is not included in the bathymetry or lidar (shows water surface elevation), and the perpendicular channel area is to be modeled as ineffective. Within the channel, less than 0.5 m depth would need to be blocked for the short distance and impacts are expected to be negligible.

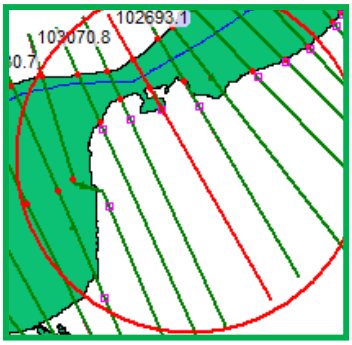
Huntley Diversion Dam RM 355.68: BOR data says 10 ft high, structure in HEC-RAS ~3 ft with channel slope d/s. Structure in HEC-RAS looks lower. *Per USACE modeler's response (Laurel Hamilton's email 12/15/2014), the diversion was fit to the TIN as best as possible.*

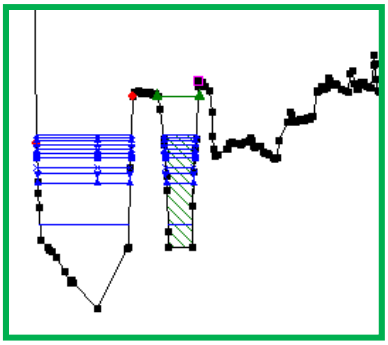
RESPONSE: Huntley diversion dam is a total of 3m in height but has a large notch noted as fish passage where the height is 1m.

Ineffective Flow Areas and Levees

Area in ROB not in floodplain at RM 362.13, are there breaks in this levee?

RESPONSE: There does not appear to be breaks in the levee. Levee features follow high ground and appear to adequately represent the area. See below images.





At Sect 87857.09 RM 352.79 the 500 yr effective flow WS extends 2,000 m into ROB, confined to channel upstream/downstream; that should be ineffective flow.

RESPONSE: Agreed. The 500-yr overtops the levee at this location. A sensitivity run showed that the water surface at this location increases 0.1m (3.9 inches)

Hydrology
Good

Boundary Conditions
Used known WSELs from Treasure County, Good.

Calibration – notes not provided, I looked at USACE HWM data (provided by USACE) and aerial photographs (found at Montana NRIS)
HWM MR11-WT1-MT-1014-007 Huntley, 1909 cms (at Billings gage?) EL 918 m, looks good compared with Section 87677.1.

HWM MR11-WT1-MT-1015-007 US , 1909 cms (~50yr 1973 cms) EL 944 m, looks good compared with Section 106893.3.

Comparison with 1997 aerial photo at South Billings Blvd. Bridge (Reach B1) looks pretty good.

Comparison with 1997 aerial photo upstream from Pompey's Pillar (Reach B7-B8) looks pretty good, except that houses and fields ~ cross sections RM 330.93 – 330.48 are shown in FP on 50-yr FP map but don't appear to have flooded in 97 flood photo.

RESPONSE: Calibration was also checked against FEMA maps at Huntley, Billings and Laurel and compared well.

Mapping
Per Laurel, do not use Billings mapping data (shapefiles, grids) which covers the area behind the interstate. These were developed based on LiDAR, but subsequent topographic surveys by DNRC showed the area to be higher than the floodplain. Therefore FEMA maps and Corridor maps show this area not in the floodplain.

Spot checked HEC-RAS results with flood extents for 100-yr Developed/Regulated, Good. Also cursory review of Undeveloped/Unregulated. OK.

Per 12/11/2014 telcon, Laurel checked corridor mapping with FEMA FIRM, Good.

Did not check mapping for other conditions.

RESPONSE: The Billings area showed wet based on the Lidar data; however, it was understood that FEMA LOMRs were granted based on spot surveys that showed higher elevations. (Surveys were likely performed by residents' contractors and not DNRC).

Treasure County

HEC-RAS

Cross Sections
Look good.

Split Flow
Another example of divided flow modeled as uniform across entire cross section containing multiple low flow channels sect 222238 RM 273.35 – downstream (see discussion and graphics above in the section *All Counties - Summary of HEC-RAS and Mapping Review*).

Structures
Compared survey measurements to pier widths, look good. No skew angles, looks good.

Ineffective Flow Areas and Levees
Seem reasonable.

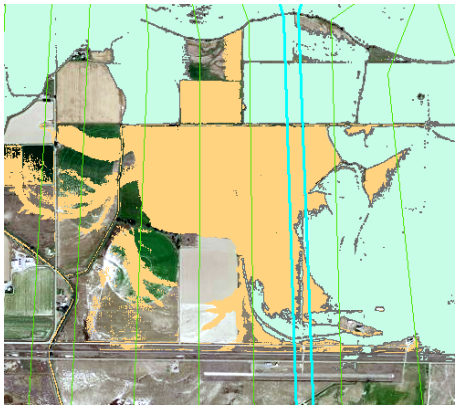
Hydrology
Good.

Boundary Conditions
Known WSELs from Rosebud – look good.

Calibration
Didn't check calibration, but West report tables indicate calibration was good.

Mapping
Sect 23892 RM 274.38 – RM 274.13 should floodplain extend further into the ROB? That area is modeled as ineffective flow in HEC-RAS, it's hard to tell on the imagery and with the cross sections if the flow can reach that area.

RESPONSE: This was an area identified as backwater and remapped with the lower, downstream stages shown in green. In the image to the right, the original mapping is shown in peach. The inundation is disconnected due to the agricultural levees. The backwater elevation used is where it connects to the main channel (several cross sections downstream [to the right of] the blue highlighted cross sections.



Rosebud County

HEC-RAS

Low flow model 5% duration through 100-yr

High flow model 200- and 500-yr

Cross Sections

Estimated LF channel, resulting channel has invert at bridges up to 6 m lower than channel US/DS. USGS Bridge surveys from the 1990's don't show any appreciable scour or differences between bridge thalweg and upstream/downstream channel thalwegs. However, per the West Consultants report, calibration to the water surface elevation at the date of the aerial photos showed that the conveyance of the estimated LF channel is equivalent to the actual channel.

RESPONSE: Bridge cross sections also show variations along the channel cross section. Overall, the underwater cross sectional area is similar between the bridge surveys and the low-flow trapezoidal cut, resulting in the acceptable low-flow calibration results.

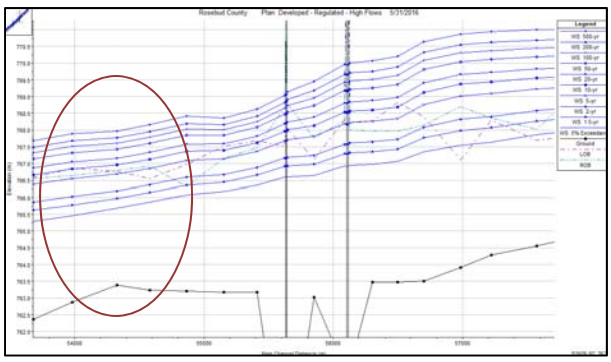
Split Flow

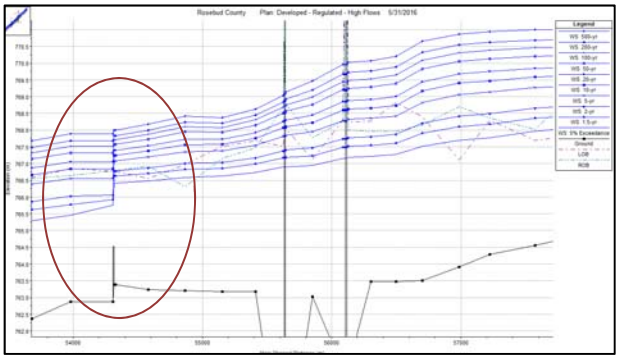
Not modeled, see discussions above.

Structures

The Cartersville Diversion Dam was not included in the model (54570 RM 238.73). *Per Laurel Hamilton email (2/4/2015) looks like diversion dam did show up in LiDAR/original cross sections, but channel invert was lowered during calibration.*

RESPONSE: The diversion dam is a rock structure that shifts from impacts of high water and ice. Rock is replaced when needed; therefore dimensions are not consistent. A detailed survey of the structure was not conducted; lidar did capture the crest elevation at the time of the flight. Due to the crest's low elevation, the diversion dam was not expected to impact the water stages. To confirm this, a sensitivity was run and comparison shows that discharges less than the 2 yr are impacted by the dam but impacts only extend ~1400 ft upstream. Therefore structure was not incorporated into the model.





Bridges OK

Ineffective Flow Areas and Levees

Cross section 66538 (RM 2466.22) RB ineffective flow station possibly should be set closer to channel; because downstream there is no flow in most of ROB (100 yr, probably 50-500 yr?). That might fix the default to critical depth at this section. If that ineffective flow station is moved, also would need to adjust ineffective flow station at upstream sections; slightly higher WSELs would result.

RESPONSE**:** Agreed. Very limited flow appears to occur over the agricultural levees at the 100-yr without ineffective flow area placement. A sensitivity was performed and shows a stage increase of 0.35 m (13.8 inches); higher stages may result in more levee overtopping and therefore more conveyance and less need for ineffective flow area. Additional ineffective flow area placement should be evaluated.

Hydrology

OK

Boundary Conditions

Know WSEL OK

Calibration

Low flow channel WSEL, looks OK, but est. channel invert higher than surveyed invert at bridges (up to 6 m).

Calibration to HWM OK per West Consultants Report. I found 4 of the HWM's in the HEC-RAS model, Table 3 in App. A Rosebud County corresponds to 20 yr flow = 2234 cms; in HWM documentation Q= 2096 cms. OK. Rough check of gage rating looks good.

Mapping

Appendix D Rosebud County discussion notes a low spot in the levee (per the LiDAR) that the 500-yr can overtop by a few inches, however Forsyth inundation is not shown in final floodplain shapefiles*. Per telcon with Laurel, the levee engineers stated that the low spot does not exist. A structure near the levee might have confused the levee elevation during LiDAR cleanup. Therefore this is OK.*

RESPONSE: A levee survey conducted subsequent to draft modeling and mapping confirmed that the levee protects against the 500-yr stages. The bad lidar data points may be due to the data processing when the neighboring structure elevation points were removed. Final modeling and maps show that inundation does not occur behind the levee.

Custer County

HEC-RAS

Low flow model 5% duration through 100-yr

High flow model 200- and 500-yr

Cross Sections

Low flow channel was estimated, calibrated per West Consultants report (see discussion under Rosebud County). Spacing, 8 sects >400 m, otherwise spacing <500 m except for 52809 and 51406. Longer spacing distances where channel is sinuous and cross section lines are crowded at overbanks.

Split Flow

Not modeled.

Structures

Should Paragon Bridge cross section 49458 RM 189.65 be skewed ~25 degrees per the survey notes? The piers are aligned with flow, no pier skew needed.

RESPONSE: There deck appears to be about 16 degrees. This skew increases stages 0.02 ft at this location and is considered negligible.

Fort Keogh Bridge at 44553 RM 186.62 should be skewed ~ 50 degrees? Piers also?

RESPONSE: Agreed. Bridge piers and deck should be skewed approximately 25 degrees. Note that the rail road bridge and piers were removed around 2012.

Ineffective Flow Areas and Levees

Cross section 69219 RM 201.97 100-yr = Levee (LB) top elevation, area behind levee should be shown as inundated?

RESPONSE: Agricultural levees are overtopped for the 100-yr. The area behind the levee was modeled as ineffective to represent stable expansion and contraction of flow between cross sections.

Cross section 38020 RM 182.54 (Mile City): why isn't ditch or low flow channel in ROB shown as inundated? Is it blocked?

RESPONSE: The ROB channel is an interior drainage channel and does not convey channel flow.

Hydrology

OK in model.

Tables 2-1 and 4 in West Consultants report show incorrect flows for the 5% duration (but correct values are in model.)

Boundary Conditions

OK

Calibration

Per West Consultant's report 2011 flood calibration OK. Rough check of HEC-RAS rating at USGS gage OK.

Mapping

OK

Prairie County

HEC-RAS

Low flow model 5% duration through 100-yr

High flow model 200- and 500-yr

Cross Sections

Low flow channel was estimated, calibrated per West Consultants report (see discussion under Rosebud County). Spacing, 13 sections >400 m, 3>500 m. Longer spacing distances where channel is sinuous and cross section lines are crowded at overbanks.

Split Flow

Not modeled

Structures

OK

Ineffective Flow Areas and Levees

Cross section 46219 RM 149.27 downstream from Powder confluence, appears that the ineffective flow station should be further to left, as it includes channel of Powder

RESPONSE: This areas is right at the confluence with the Powder River. Flows less than the 50-yr may benefit from having the ineffective areas located closer to the channel. However, at the 100-yr which was the target discharge for modeling, the portions of the Powder channel become inundated and its channel would help convey flow. A sensitivity run confirms the 100-yr stage at RM 149.27 and 149.48 change 0.02 meters or less.

Hydrology

OK

Boundary Conditions

Normal depth, but ds WSELs = Dawson County us WSELs

Calibration –West report and aerial photographs

West Consultant report states the HWM's were not sufficient for calibration, but they calibrated the low flow channel. Very rough comparison of Cross section 26627 (RM 137.04) and data from USGS streamgage 06326530 (Terry; Hwy 235 Bridge) looks OK.

2011 Flood Aerial photo (No. 679-103, 5/25/2011 from MDT) of Hwy 235 Bridge downstream from Terry (per MDT QGlendive on 5/24/2011 = 4,531 cms; corresponds with 200 – 500 yr flow (Regulated Conditions)) compares well with 100-yr/200-yr FP mapping. Mapping shows more FP in ROB US from bridge, but flow in photo could have been lower.

2011 Flood Aerial photo no. 679-105 (5/25/2011 photo date, from MDT) of Milwaki Road – Calypso Bridge at Terry (per MDT QGlendive on 5/24/2011 = 4,531 cms; corresponds with 200 – 500 yr flow (Regulated Conditions)) compares well with 100-yr/200-yr FP mapping.

Mapping

OK

Dawson County

HEC-RAS

Cross Sections
Look good.

Split Flow
Modeled as connected water surfaces elevations across entire channel, see discussion in section *All Counties - Summary of HEC-RAS and Mapping Review* above.

Structures
Look good, RM 94.55 BNSF pier widths = 9m, probably to represent skewed piers.

RESPONSE: Yes, the bridge opening and deck were skewed 35-degrees. As a result, the pier widths were recomputed by RAS.

Ineffective Flow Areas and Levees
Look good (rough visual check).

Hydrology
Good.

Boundary Conditions
Downstream - known WSELs from Richland county model, good.

USACE Report Table 8. P. 19 lists Prairie WSELs as US BC for Dawson model, but I don't see that WSEL listed as a boundary condition in the HEC-RAS model. However the WSEL's look to be equal.

RESPONSE: Prairie WSELs as an upstream condition is identified in the Flow file under "Set Internal Changes in WS and EG"

Calibration
Spreadsheet "Dawson Gage Height Calibration_revised.xls" shows good agreement between HEC-RAS results and USGS rating and NWS (?) rating (or perhaps this is the USGS rating w/the NWS datum). The modeler used datum of 2040 ft and subtracted 39 ft. Glendive gage 06327500.

2011 Flood Aerial photo (No. 679-79, 5/25/2011 from MDT) of I-94 Bridge at Glendive (per MDT QGlendive on 5/24/2011 = 4,531 cms; corresponds with 200 – 500 yr flow (Regulated Conditions)) compares well with 100-yr and 200-yr FP mapping, except for hexagonal field left of channel upstream from bridge is shown inundated in 200-yr FP map but does not appear to have been flooded in aerial photo.

2011 Flood Aerial photo (No. 679-80, 5/25/2011 from MDT) of bridges upstream from I-94 Bridge at Glendive (per MDT QGlendive on 5/24/2011 = 4,531 cms; corresponds with 200 – 500 yr flow (Regulated

Conditions)) compares well with 100-yr and 200-yr FP mapping, except for hexagonal field discussed above.

Mapping

Looked at 100-yr and 2-yr regulated/developed and unregulated/undeveloped. Look good.

Richland/McKenzie County

HEC-RAS

Low flow model 5% duration through 50-yr

High flow model 100-, 200- and 500-yr

Mannings n's

OK

Cross Sections

OK, see notes on ineffective flow below.

Split Flow

Not modeled, see notes in other sections.

Structures

OK

Ineffective Flow Areas and Levees

The following apparent discrepancies were noted between what appears to be ineffective flow on the map and ineffective flow per the HEC-RAS model. However, as stated above, elevation data or contours were not included in the review, only background imagery. In addition the background map is more recent than the survey and HEC-RAS modeling.

Section 89479 RM 88.78 ROB should be ineffective flow, looks discontinuous; also part of section cut along (not perpendicular to) small channel, large topwidth change between this section and US section (1.2:1 expansion?)

RESPONSE: RM 55.78 is connected to ROB side channels at 2-yr flows. Agreed, additional ineffective flow areas could be placed; however a sensitivity of additional ineffective showed a 100-yr stage difference at RM 55.78 and 55.96 of 0.04 meters.

Section 87382 RM 54.48 much of ROB should be ineffective? Also large change in topwidth between this section and US section

RESPONSE: Agreed, a portion of the ROB should be ineffective flow area; however a sensitivity of additional ineffective showed a 100-yr stage difference at RM 54.48 to 55.61 of 0.03 meters.

Section 85882 RM 53.55 - 52.98 - Section 84682 52.79 consider ineffective Q LOB, because dead-ends ds at RM 52.61

RESPONSE: Agreed, a portion of the LOB should be ineffective flow area; a sensitivity of additional ineffective showed a 100-yr stage difference at RM 52.61 to 53.73 of 0.12 meters (4.7 inches)

Section 84082 RM 52.42 LOB some channels are not continuous and should be ineffective

RESPONSE: Agreed, a portion of the LOB should be ineffective flow area; a sensitivity of additional ineffective showed a 100-yr stage difference at RM 52.61 to 51.13 of 0.13 meters (5.1 inches)

Section 83798 RM 52.24 cut along the channel in LOB

RESPONSE: Agreed, the cross section is cut along a perpendicular channel; however, a sensitivity of additional ineffective showed a 100-yr stage difference at RM 52.24 to 52.42 of 0.01 meters.

Section 79348 RM 49.5/78981 RM 49.26/ 49.26 middle part ineffective - doesn't look continuous

RESPONSE: Agreed, the immediate LOB should be ineffective; however, a sensitivity of additional ineffective showed a 100-yr stage difference at RM 49.08 to 49.5 of 0.01 meters.

Sect 102900 RM 64.12/ 102601 RM 63.92/ 102302 RM 63.74 cut diagonal to flow in ROB channel

RESPONSE: Agreed, the immediate LOB should be ineffective; however, a sensitivity of additional ineffective showed a 100-yr stage difference at RM 64.12 to 63.74 of 0.06 meters.

Section 92205 RM 57.46 left-most channel too big, cut along channel not perpendicular

RESPONSE: Agreed, a portion of the LOB channel should be ineffective; however, a sensitivity of additional ineffective showed a 100-yr stage difference at RM 57.63 to 57.26 of 0.01 meters.

Can Q get from 63402 RM 39.5 to 63102 RM 39.31 ROB? Looks like it's blocked, should be ineffective?

RESPONSE: There is some connection starting at the 5-yr. Additional ineffective placement may better represent the area.

Sections 27539 RM 17.36 to Section 23241 RM 14.61 - can Q be continuous in ROB? Looks like should be ineffective?

RESPONSE: Agreed, a portion of the ROB should be ineffective; a sensitivity of additional ineffective in a portion of the cross sections showed a 100-yr stage difference at RM 19.03 to 14.05 of 0.08 meters (3.2 inches)

Hydrology

OK

Boundary Conditions

OK

Calibration

West reports HWMs were questionable, but West calibrated at the gage within 0.3 m. Rough comparison of USGS streamgage 06329500 Yellowstone R near Sidney, MT rating to Cross section 49308 RM 30.79 looks OK.

Comparison of 200-yr FP with 2011 aerial flood photo at Sydney Bridge from MDY (No. 679-29, taken 5/25/2011, 200 yr Sydney Regulated Conditions < Q Glendive = 4191 cms < 500 yr Sydney Regulated conditions) looks good.

Mapping

OK