

7.3 Sediment Delivery Analysis

In order to evaluate potential changes in sedimentation patterns that could occur due to impacts from the FCP and LPP alignments, sediment assessment models were constructed using the SIAM (Sediment Impact Assessment Model) feature in HEC-RAS. SIAM compares the annual sediment transport capacity of a reach to the annual sediment supply and provides an indication of whether aggradation, degradation, or equilibrium may occur. A schematic showing the sediment balance algorithm in SIAM is provided in Figure 7-1.

The SIAM feature was applied for all general study reaches under current conditions. For the LPP alignment scenario, SIAM was applied for the diversion channel and those rivers that would be affected by the LPP diversion. These include: Red River, Sheyenne River, Wild Rice River, and Maple River. Although the LPP alignment crosses the Rush and Lower Rush Rivers it is expected that the diversion would have no impact on the upper reaches (Rush 2 and Lower Rush 2). The diversion is designed to intercept all flow in the lower reaches of Rush 1 and Lower Rush 1, negating the need for comparison; therefore, no SIAM modeling was conducted for either the Rush River or Lower Rush River. Similarly, for the FCP alignment SIAM was applied for the diversion channel plus those rivers that could be impacted by the FCP diversion. These include: Red River, Rush River, Sheyenne River, and Wild Rice River. Though the FCP alignment does not intersect the Rush River, Sheyenne River or Wild Rice River, minor changes in the hydraulic model output were noted for the downstream reaches of these rivers due to backwater effects on the Red River and Sheyenne River from the FCP alignment.

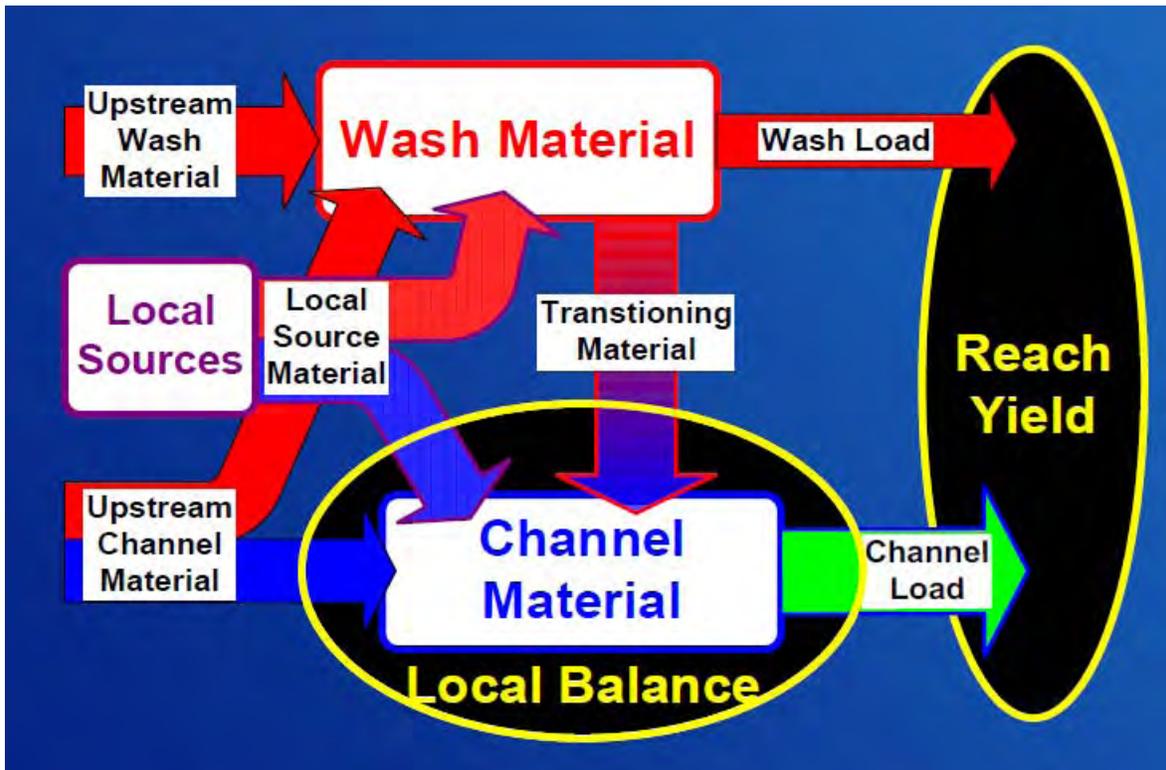


Figure 7-1. SIAM Sediment Balance Schematic (Mooney, 2006)

7.3.1 Sediment Reaches

Sediment reaches in SIAM should be based on similar sediment and hydraulic properties, recognizing any significant geomorphic changes, changes in channel gradient, planform and geometry, and shifts in sediment composition. Based on these parameters and field observations, the SIAM sediment reach divisions were based on the general study reaches that were selected using similar criteria. The FCP diversion channel was subdivided into four sediment reaches based on channel gradient and changes in the channel geometry. The LPP diversion was subdivided into twelve sediment reaches based on changes in channel gradient and locations of significant flow changes, and structures that significantly impact hydraulic properties. Diversion channel sediment reaches are shown in Figure 7-2.



Figure 7-2. LPP and FCP Diversion SIAM Sediment Reaches

7.3.2 SIAM Input Data

The input required to the SIAM module includes cross section data for the study reach, annualized flow-duration data, bed material gradations, an appropriate sediment transport function, wash load criteria, and annualized sediment input volumes (broken down by grain size fractions). The SIAM modeling was conducted using the modified HEC-RAS bank full models used to create the elevation-duration curves described in section Section 4.4.2.

7.3.2.1 Annualized Flow Distributions

Sediment transport estimates developed by SIAM are based on annualized flow-duration curves created from mean daily discharges. The flow-duration curves provided by the St Paul District and those developed by WEST for the detailed study reaches, used in developing the elevation-duration curves, were input into SIAM. The various flows that define the flow-duration curves were automatically imported by HEC-RAS into SIAM. The corresponding exceedence percentage was used to compute the number of days in a year that each discharge value applies (Table 7-1 & Table 7-2). The total duration must equal 365 days because SIAM predicts annual trends. The discharges associated with each profile in Table 7-1 & Table 7-2 for current and future conditions can be found in Appendix Q.

Table 7-1. Duration of SIAM Discharge Profiles for Study Rivers

Profile (% time equaled or exceeded)	Duration (days)							
	Buffalo River	Lower Rush River	Maple River	Red River	Rush River	Sheyenne River	Wild Rice River	Wolverton Creek
0.001%	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
0.05%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.10%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.15%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.20%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.25%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.30%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.35%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.40%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.45%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.50%	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.60%	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
0.70%	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
0.80%	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
0.90%	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1.00%	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1.20%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
1.40%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
1.60%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
1.80%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2.00%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2.20%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2.40%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2.60%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2.80%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
3.00%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
3.50%	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
4.00%	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
4.50%	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
5.00%	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
6.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
7.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
8.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
9.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65

10.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
11.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
12.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
13.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
14.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
15.00%	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
20.00%	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25
25.00%	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25
30.00%	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25
35.00%	18.25	255.50	18.25	18.25	18.25	18.25	18.25	18.25
40.00%	18.25		18.25	18.25	18.25	18.25	18.25	18.25
45.00%	18.25		18.25	18.25	219.00	18.25	18.25	18.25
50.00%	18.25		18.25	18.25		18.25	18.25	18.25
55.00%	18.25		18.25	18.25		18.25	18.25	18.25
60.00%	18.25		18.25	18.25		18.25	18.25	18.25
65.00%	18.25		18.25	18.25		18.25	18.25	18.25
66.67%	6.08		6.08	6.08		6.08	6.08	6.08
70.00%	12.17		12.17	12.17		12.17	121.66	12.17
75.00%	18.25		18.25	18.25		18.25		109.50
80.00%	18.25		18.25	18.25		18.25		
85.00%	18.25		73.00	18.25		18.25		
90.00%	18.25			18.25		18.25		
95.00%	18.25			18.25		18.25		
99.00%	18.25			18.25		18.25		
Total Flow Duration (days)	365.0	365.0	365.0	365.0	365.0	365.0	365.0	365.0

Table 7-2. Duration of SIAM Discharge Profiles for LPP and FCP Diversion Canals

Profile (% time equaled or exceeded)	Duration (days)		Profile (% time equaled or exceeded)	Duration (days)	
	LPP Diversion	FCP Diversion		LPP Diversion (continued)	FCP Diversion (continued)
0.001%	0.004	0.37	2.60%	0.73	
0.05%	0.18	17.89	2.80%	0.73	
0.10%	0.18	18.25	3.00%	0.73	
0.15%	0.18	18.25	3.50%	1.83	
0.20%	0.18	18.25	4.00%	1.83	
0.25%	0.18	18.25	4.50%	1.83	
0.30%	0.18	18.25	5.00%	1.83	
0.35%	0.18	18.25	6.00%	3.65	
0.40%	0.18	18.25	7.00%	3.65	
0.45%	0.18	18.25	8.00%	3.65	
0.50%	0.18	18.25	9.00%	3.65	
0.60%	0.37	36.50	10.00%	3.65	
0.70%	0.37	36.50	11.00%	3.65	
0.80%	0.37	109.50	12.00%	3.65	
0.90%	0.37		13.00%	3.65	
1.00%	0.37		14.00%	3.65	
1.20%	0.73		15.00%	3.65	
1.40%	0.73		20.00%	18.25	
1.60%	0.73		25.00%	18.25	
1.80%	0.73		30.00%	18.25	
2.00%	0.73		35.00%	18.25	
2.20%	0.73		40.00%	18.25	
2.40%	0.73		45.00%	219.00	
			Total Flow Duration (days)	365.0	365.0

7.3.2.2 Bed Material Gradations

Development of the SIAM model required bed material gradation information for each reach. The sediment size distribution gained from the bed core samples collected during the field investigation were entered into HEC-RAS as the percent of the total sediment gradation finer than a particular sediment class particle diameter by weight (e.g., see Figure 7-3). Twenty

sediment size classifications are available in SIAM ranging from clay (0.004 mm) to large boulders “LB” (2,048 mm). The bed material gradations for each general study reach were based on the sieve analysis results from the bed core samples collected in the detailed study reaches during the field investigation. Although boring sample data is available along the proposed diversion alignments, the boring logs provide only general material descriptions along with geotechnical data. As no sieve analysis was conducted on the boring material, detailed grain size distributions were not available. The general grain class distribution (%sand, %silt, % clay) for each diversion sediment reach was based on the published STATSGO (NRCS, 2012) soil data for the soil type within each sediment reach. Only grain sizes of sand size and larger are considered in the SIAM mass balance (see wash load discussion below); therefore the detailed size distributions for the silt and clay soils (which make up the vast majority of the local sediment) are not needed. The sand portion of the bed sediment along the diversion channel alignments were assumed to be evenly distributed among the five sand grain classes (very fine sand, fine sand, medium sand, coarse sand, very coarse sand).

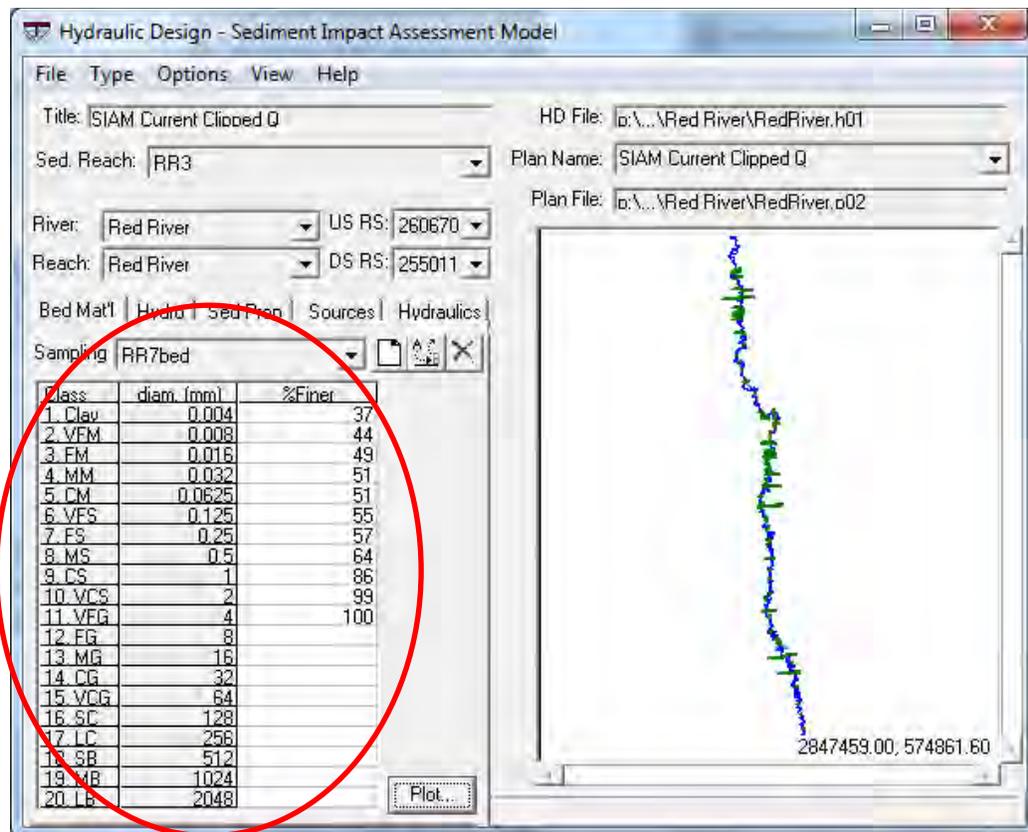


Figure 7-2. Example SIAM Bed Material Gradation in HEC-RAS

7.3.2.3 Sediment Transport Function and Wash Load

Historically, dozens of transport functions have been developed and it is well known that sediment transport is very sensitive to many variables (USACE, 2010c). Accordingly, it is important that the transport function chosen for the analysis should have been developed using similar sediment gradation and hydraulic conditions to what is found in the project area. SIAM includes six different functions to compute sediment transport capacity over a range of bed material sizes, including Ackers-White, Engelund-Hansen, Laursen-Copeland, Meyer-Peter

Müller, Toffaleti, and Yang. The dominant bed and bank material for the Red River and its tributaries is cohesive clay. None of the transport functions available in SIAM were developed based on clay size materials. Of the six available transport functions, all but Laursen-Copeland were developed from data based on sand or larger sized particles, making them poor choices for this analysis. While Laursen-Copeland was developed for material sizes that extend to the range of coarse silt, finer silts and clay size particles are outside the range of applicability. The Laursen-Copeland function was selected for all sediment reaches; however, it should be noted that applying this function to predominantly clay-sized material gives results that are extrapolated well beyond the range of the data used to derive the functions. This could result in the compounding of extrapolation errors in addition to the already significant uncertainty that is associated with sediment transport calculations.

Further complicating the available transport functions is the cohesive nature of the clay sediments. While the standard sediment transport module (HEC-6) in HEC-RAS does provide the ability to enter erosion parameters manually for cohesive sediments (should that data be known), this feature is not available in SIAM. It would be expected that SIAM would over predict the erosion and transportation of cohesive sediments.

The maximum wash load threshold is also required in SIAM. Wash load is sediment in transport derived from sources other than the bed (Biedenharn et al., 2006). SIAM does not apply standard transport equations to compute a mass balance for wash load material (USACE, 2010). Instead, the program automatically passes any particle equal to or smaller than the maximum wash load through the system. Although there is no universally accepted method of selecting a wash load threshold, the material is often considered the fine-sized silt and clay material (particles less than 0.0625 mm in diameter). Einstein (1950) defined wash load as the grain size of which 10 percent of the bed mixture is finer; however, as the dominant sediment in the Red River system are clay sized particles and the sediment load is close to 99% suspended load (USGS, 2011b), the Einstein guideline is not considered to be applicable. Based on an evaluation of the suspended and bedload sediment collection data from the USGS for the project site, the wash load threshold was set at 0.0625mm, corresponding to coarse silt. As a result, the problematic silt- and cohesive clay-sized materials that dominate the system are finer than the wash load threshold and are therefore excluded from the mass balance.

7.3.2.4 Sediment Sources

In order to compare sediment transport capacity to sediment supply, SIAM requires sediment supply data to be input for each reach. The sediment supply data are entered by source as annual sediment loads in tons per year per grain class. Three primary sediment sources were identified: channel banks, ground surface, and upstream or tributary inflows.

Typically, estimates of bank erosion can be calculated based on annual erosion and/or migration rates as were discussed in Section 6.1.8 of this report. These calculations all resulted in zero or near zero erosion rates. It was therefore assumed that the contribution of bank sediments to the channels due to channel migration occur too slowly to be worth considering as a sediment supply source in the SIAM modeling. As discussed in section Sections 6.1.8, a cyclic pattern of bank deposition, failure, and erosion was observed based on the field investigations and aerial imagery analysis; however, quantifying the net loss rate of sediment from the banks was not considered

possible. Therefore, while it is understood that this cycle contributes a portion of the annual sediment supply to the channel, no estimates of the contributions were included in SIAM. It is assumed that annual sediment contributions from the banks are minimal due to the slow rate of this process, the cohesive nature of the dominant bank sediments, and the very small percentage of the bank material that is not considered wash load.

The primary sediment supply for the Red River and its tributaries is considered to be the surrounding agricultural fields that compose the majority of the watershed. Sediment is transported from the surrounding fields to the channels through sheet erosion, rills and gullies, drainage canals, and through subsurface drains (e.g. Figure 7-4). Accurately determining surface sediment contribution is difficult. Soil loss equations such as the Revised Universal Soil Loss Equation (RUSLE, Renard, et al., 1997) can provide estimates of soil losses due to rainfall erosion; however, they do not consider wind erosion and also do not give direct sediment yield estimates (Novotny and Olem, 1994). Furthermore, while they can provide estimates of soil losses, soil loss equations such as RUSLE require detailed information on crops, rotation practices, plowing and irrigation methods, and conservation practices that can make application over large areas particularly problematic. The U.S.D.A. Agricultural Non-Point Source Pollution Model (AnnAGNPS) is based on the RUSLE, but is expanded to predict sediment yield by using the Natural Resource Conservation Service Technical Report 55 rain fall-runoff model (TR55). While this model does provide an estimate of sediment yield, it requires a large set of input data and is a significant undertaking.



Figure 7-3. Sediment Deposition in Wolverton Creek at a Drain Tile Outlet

According to the USGS, sediment transported by the Red River and its tributaries during the 2010 and 2011 high flow periods was comprised of 99% suspended load and 1% bedload. Annual surface sediment contribution for SIAM was estimated using the sediment transport

rating curves discussed in Section 4.2.2. While suspended and bedload data were collected for most of the study streams during the 2010 and 2011 high flow events, little or no data was available for lower discharges at most locations. Only three gages had a range of sediment measurements that were considered reasonable for creating a sediment rating curve. For each of these three gage sites (Red River at Hickson, Red River at Fargo, and Sheyenne at Kindred), the sediment rating curve was multiplied by the annualized flow duration curve to arrive at an annual total sediment load in tons per year. Despite the availability of good sediment data for the 2010 and 2011 flood season for the remaining sampling locations, the flows during which sediment measurements were taken occur relatively infrequently and make up only a small portion of the annual flow-duration curve; therefore, calculating an annualized sediment yield would require significant extrapolation of sediment transport over the majority of the annual flow-duration curve. The results of the estimates are presented in Table 7-3. For comparative purposes, published studies detailing soil loss estimates for the region were reviewed. A study of sediment production for the south branch of the Buffalo River watershed using AnnAGNPS resulted in an estimate annual sediment yield of 0.05 tons/acre/yr (Lauer et al., 2006).

Table 7-3. Estimated Annual Sediment Load

Location	Annual Sediment Load	
	(tons/yr)	(tons/acre/yr)
Red River at Hickson	51,445	0.02
Red River at Fargo	95,555	0.03
Sheyenne River at Kindred	61,434	0.03
	Average	0.03

The selected value of 0.03 tons/acre/year for annual surface contribution was used to estimate two sets of sediment inputs for SIAM, the inflowing sediment load to the most upstream sediment reach of each stream and the inflowing sediment load for each individual sediment reach. The sediment inflow to the upstream end of the uppermost reach of each river is based on the entire contributing watershed area upstream of the inflow point (Figure 7-11). The sediment inflow to the downstream sediment reaches is based on the contributing surface area to each individual sediment reach. The Contributing surface area and annual sediment yield for each sediment reach are provided in Table 7-4.

Tributary sediment inflows were based on SIAM model output for each tributary. Therefore, contributing tributary areas were excluded from the surface area computed for each sediment reach. For example, although sediment reach Sheyenne River 3 (SR3) is below the Maple River, which contributes to SR3, the surface area contributing to SR3 excludes the Maple River basin surface area. Instead, only the portion of the sediment from the Maple River basin that could be passed annually through its downstream most reach (MR1) based on SIAM results, was used as input into SR3.

Table 7-4. Sediment Inflows for each General Study Reach

Sediment Reach	Contributing Surface Area (acres)	Annual Sediment Yield (tons)
Ground Surface Inputs		
Buffalo River - 1	2,690	269
Lower Rush River - 1	2,240	224
Lower Rush River - 2	3,328	333
Maple River - 1	5,888	589
Maple River - 2	11,392	1,139
Red River - 1	10,893	10,828
Red River - 2	643,346	64,335
Red River - 3	38,919	338,243
Red River - 4	9,631	963
Red River - 5	57,124	137,185
Red River - 6	6,648	7,443
Red River - 7	12,096	1,210
Red River - 8	23,152	2,315
Rush River - 1	2,176	218
Rush River - 2	12,160	1,216
Sheyenne River - 1	25,837	2,577
Sheyenne River - 2	14,496	11,346
Sheyenne River - 3	3,812	4,278
Sheyenne River - 4	1,337	95,082
Sheyenne River - 5	15,903	1,590
Sheyenne River - 6	17,107	1,711
Sheyenne River - 7	13,224	1,322
Sheyenne River - 8	5,028	503
Wild Rice River 1	717	72
Wild Rice River 2	20,224	2,022
Wild Rice River 3	21,632	2,163
Wild Rice River 4	35,412	3,541
Wild Rice River 5	27,092	2,709
Wild Rice River 6	1,135	114
Wolverton Creek 1	283	28
Wolverton Creek 2	9,822	982
Upstream Inflow Contribution		
Buffalo River - 1	633,084	63,308
Lower Rush River - 2	33,856	3,386
Maple River - 2	931,776	93,178
Red River - 8	2,105,592	210,559
Rush River - 2	84,672	8,467
Sheyenne River - 8	2,170,091	217,009
Wild Rice River - 6	1,176,351	117,635
Wolverton Creek - 2	55,968	5,597

Since SIAM requires the annual sediment supply to be parsed by grain size, the total supply for each general study reach was distributed based on the 2010/2011 USGS sediment sample distributions. A composite grain size distribution was created for each reach by weighting the mean of the bedload and suspended load samples based on a ratio of 99.5% suspended load and 0.5% bedload. The upstream inflow to sediment reach Red River 8 was based on a ratio of 96% suspended load to 4% bedload. An example grain size distribution for the Maple River is provided in Table 7-5. Grain size distributions for the other study reaches are located in Appendix J.

Table 7-5. Sample Grain Size Distribution for the Maple River

Grain Size	Suspended Sediment	Bedload	Weighted by %		Final weighted	Final field input values for SIAM			
			SS (99.5%)	Bedload (0.5%)		(reach)->	MR1	MR2	Upstream MR2
(mm)	(% finer)	(% finer)	(% finer)	(% finer)	(% finer)	(acres)->	5,888	11,392	931,776
0.0625*	97	11	96.52	0.06	96.57		170.6	330.0	26994.5
0.125	98	17	97.51	0.09	96.60		0.1	0.1	8.4
0.25	100	28	99.50	0.14	96.66		0.1	0.2	15.4
0.5	100	52	99.50	0.26	99.76		5.5	10.6	867.9
1		75	0.00	0.38	99.88		0.2	0.4	32.1
2		91	0.00	0.46	99.96		0.1	0.3	22.4
4		98	0.00	0.49	99.99		0.1	0.1	9.8
8		100	0.00	0.50	100.00		0.0	0.0	2.8
* Though the SIAM grain size distribution continues down to 0.004mm, none of the USGS suspended sediment samples contained enough material to determine individual grain class below 0.0625mm						Sum	176.6	341.8	27953.3

7.3.2.5 Sediment Input Distribution

Under the current condition models, sediment inputs in SIAM are a combination of upstream inflow (at the upstream most sediment reach), surface inputs from the area contributing to each sediment reach, and any sediment inflows from tributaries (based on the SIAM results for that tributary). Schematics of assumed sediment inputs for the Red River and Sheyenne River are provided as Figure 7-4 and Figure 7-5.

For the FCP models all sediment inputs are the same as current conditions except for the Red River. A constant discharge is assumed along the length of the protected portion of the Red River between the Wild Rice River and the Sheyenne River. To maintain consistency with this assumption, no external (surface) sediment inputs are assumed to be contributing along the protected portion of the Red River (RR3 through RR5). A schematic of inputs for the Red River under the FCP scenario is provided as Figure 7-6. Similarly, for the FCP scenario it has been assumed that no additional inflows occur along the length of the FCP diversion channel. To maintain consistency with this assumption, no additional external (surface) sediment inputs are assumed to be contributing along the FCP diversion. Only sediment from the Red River that enters the FCP diversion channel at its upstream end was included (Figure 7-7).

The FCP diversion intercepts flood waters from the Red River. These floodwaters are routed to the diversion over a weir control structure with downstream flow to the Red River being controlled by adjustable gates. While SIAM can do simple accounting of sediment supply and capacity downstream along a watercourse, it does not have the ability to route and distribute sediment between divergent reaches such as the Red River and the FCP diversion channel. Ultimately the exact impact of the flow control structure on sediment routing is unknown and it was conservatively assumed that all sediment in the Red River would continue being transported downstream of the diversion into the next sediment reach and that no sediment would be diverted to the diversion channel.

For the FCP diversion model it was assumed that the Red River would be transporting only very fine sand and smaller sized material in suspension. Therefore, only these grain sizes would be able to flow over the weir into the diversion channel. The larger particle sizes were assumed to be moving as bedload and therefore would be prevented from entering the diversion channel via the entrance weir.

For the LPP scenario it is assumed that there is a constant discharge along the length of the protected portion of the Red River between its confluence with Wild Rice River and its confluence with the Sheyenne River. Accordingly, it is assumed that no surface sediment inputs contribute to the protected portion of the Red River (RR2 through RR6) aside from what is transported into the Red River via the Wild Rice River and the Sheyenne River (Figure 7-8). A similar assumption of consistent discharge and no surface sediment inputs is made for the protected portions of the Sheyenne River (SR1 through SR6) with the exception of the discharge and sediment contributed by the Maple River (Figure 7-9). The LPP diversion channel intercepts floodwaters from the Red River, Sheyenne River, Wild Rice River, Maple River, Lower Rush River and Rush River. For the Red, Sheyenne, Wild Rice and Maple Rivers, it was

conservatively assumed that all sediment would continue being transported downstream of the diversion into the next sediment reach and that no sediment would be diverted to the diversion channel.

For the LPP diversion model it was assumed that only very fine sand and finer material would be in suspension in the Sheyenne, Wild Rice and Maple Rivers. Therefore only these grain sizes would be able to flow over the associated weir into the diversion channel. The larger particle sizes were assumed to be moving as bedload and therefore would be prevented from entering the diversion channel via the entrance weir. Since the LPP diversion intercepts 100% of the discharge from the Rush and Lower Rush Rivers, it was assumed that all sediment grain sizes could pass from these rivers into the diversion channel (Figure 7-10).

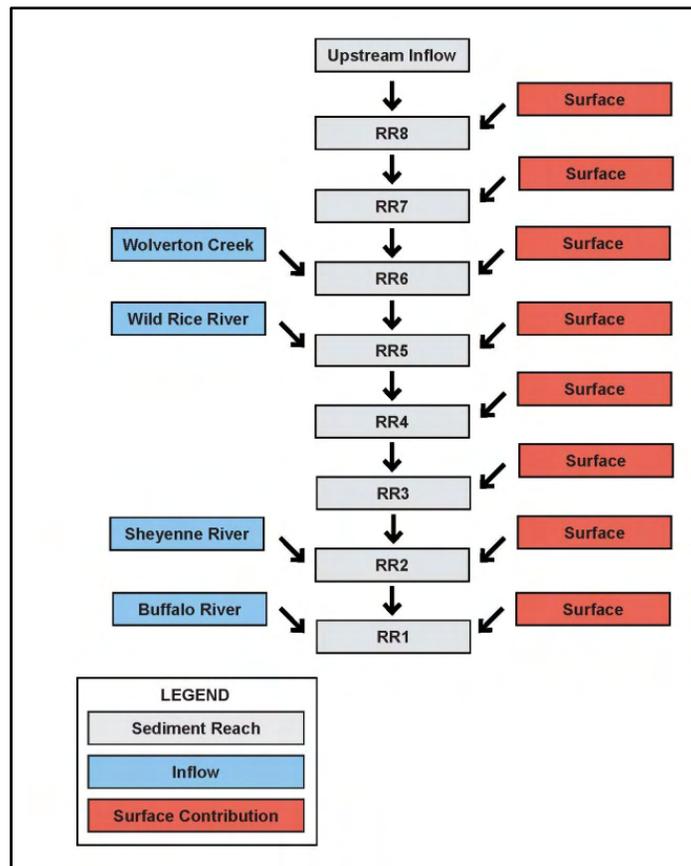


Figure 7-4. Red River Sediment Inputs (Current Condition)

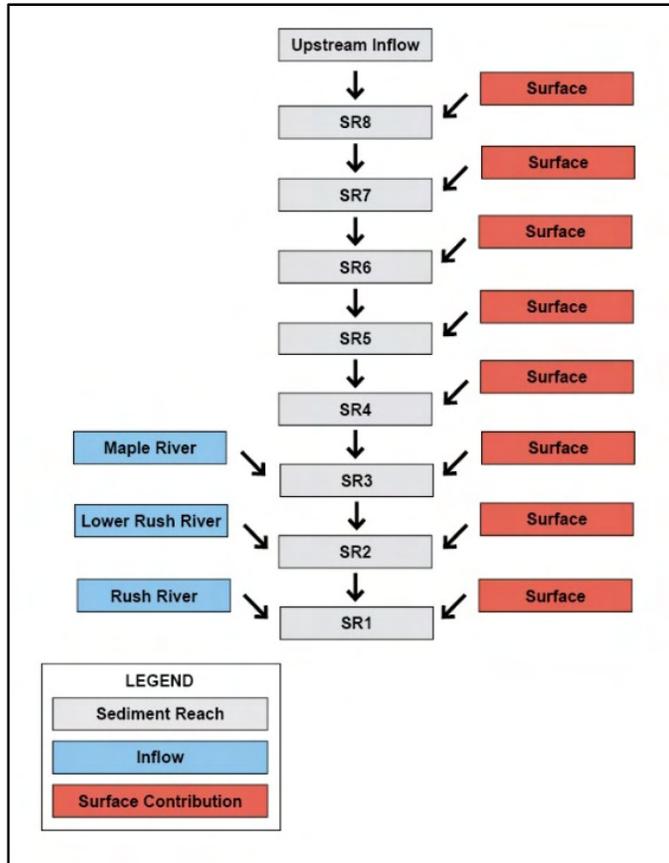
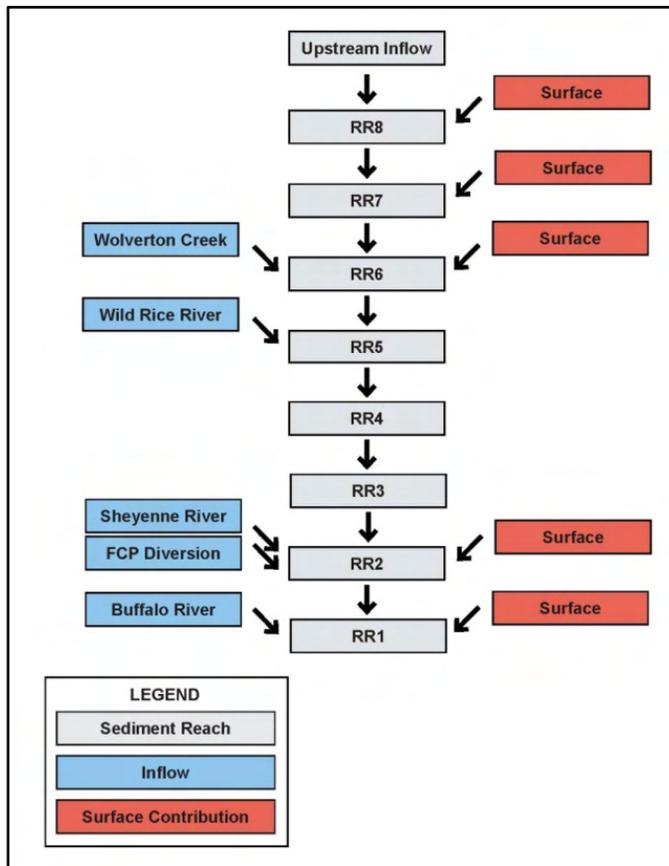


Figure 7-5. Sheyenne River Sediment Inputs (Current and FCP)



5

Figure 7-6. Red River Sediment Inputs (FCP Condition)

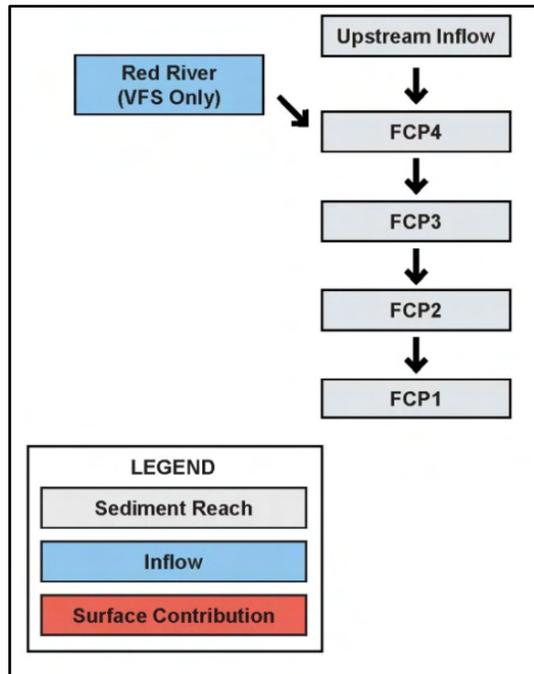


Figure 7-7. FCP Diversion Sediment Inputs

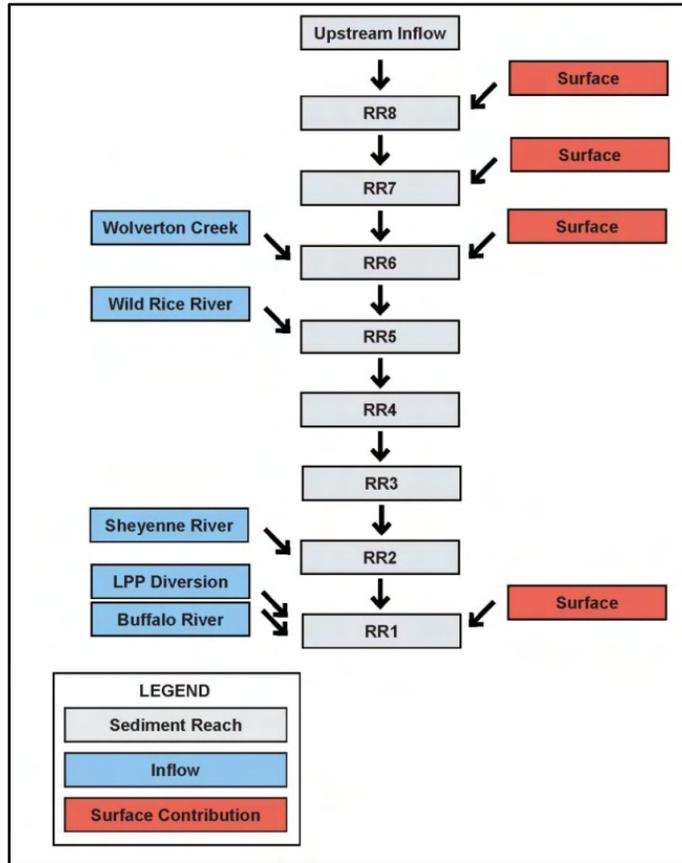


Figure 7-8. Red River Sediment Inputs (LPP Condition)

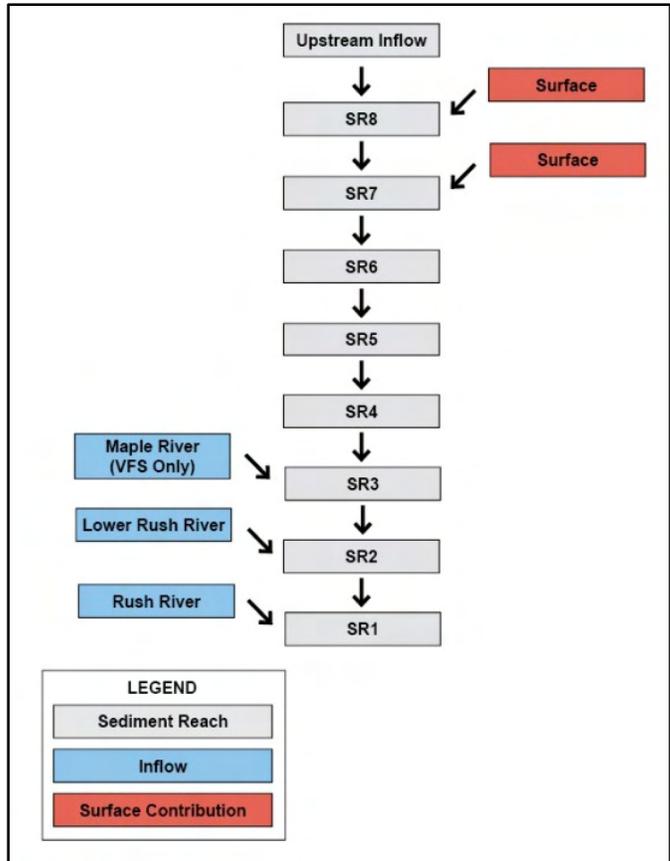


Figure 7-9. Sheyenne River Sediment Inputs (LPP Condition)

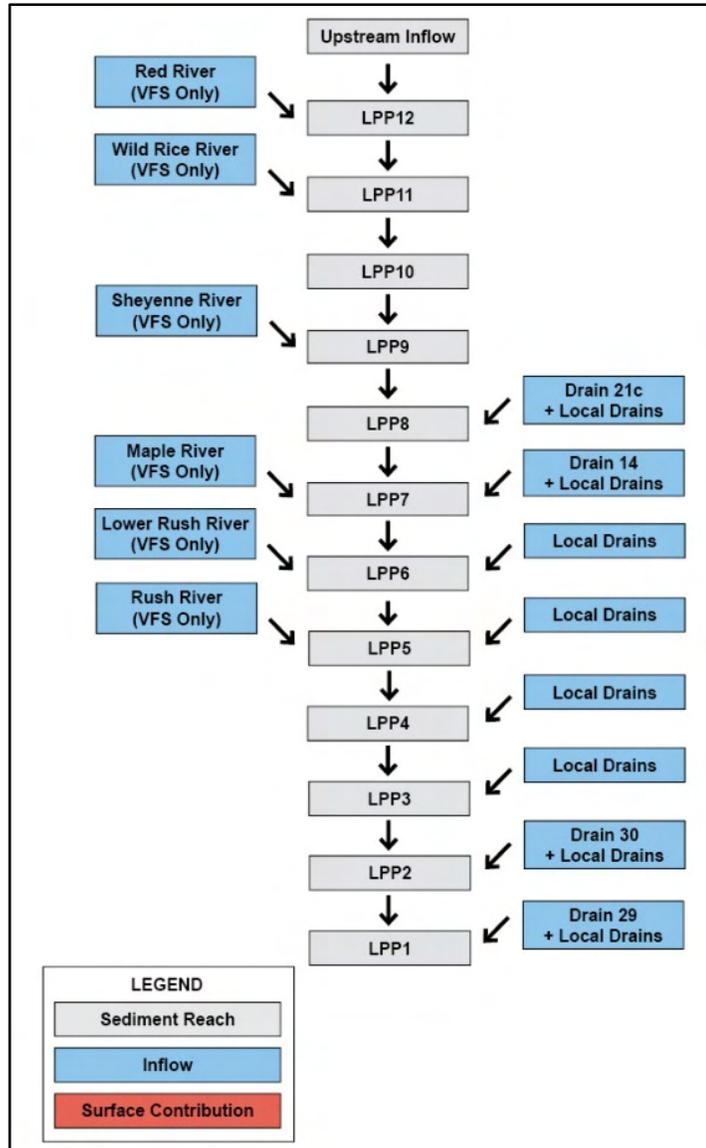


Figure 7-10. LPP Diversion Sediment Inputs

7.4 SIAM Results

A summary of the local sediment balance results from SIAM are provided in Table 7-6 through Table 7-11. The local sediment balance value indicates whether deposition (positive value) or erosion (negative value) of the sediment reach occurs. Please note that SIAM is not a sediment routing model and that results from SIAM represent general trends of surplus and deficit only and not actual volumes of eroded or deposited material. While SIAM is a very useful sediment management tool, the following limitations should be considered when reviewing the results (Little and Jonas, 2010):

- Channel geometry is not updated in SIAM based on erosion or deposition (i.e., hydraulics are not updated or changed over time during a model run)
- No time frame for sediment impacts is computed
- Reach-averaged values are used in all computations (localized effects of hydraulic structures are not considered and include the numerous dams, weirs and gates located throughout the Red River and its tributaries)
- There is no limitation on bed material supply (i.e., SIAM assumes erosion will continue indefinitely from the bed until the sediment transport capacity is satisfied)

Compounding these issues are uncertainties in annual sediment loads which were discussed previously. It is understood that the majority of the sediments found in the system are much smaller in size than was used to develop the available sediment transport functions in SIAM and are therefore based on extrapolations. Furthermore, SIAM does not have the ability to address cohesive sediment, which is a distinguishing characteristic of the majority of the sediment in the study reaches. Lastly, while SIAM limits its calculations to the channel portion of the model cross sections, the HEC-RAS models used for the analysis are simplified versions of the unsteady HEC-RAS models provided by the St. Paul District, which have extremely complex overbank hydraulics and flood storage. The discharge duration curves used in the SIAM models have been limited at their upper ends (as described in Section 4.4.2) at the point where the flood discharges are large enough to produce possibly erroneous results in the simplified hydraulic models. This effectively removes a portion of the annual sediment transport capacity from the models that would occur during larger flood events. While the effective annual durations of these extreme events are relatively short, this does potentially affect the SIAM results. Additionally, the increased water surface elevations due to flood staging for those reaches of Wolverton Creek, Wild Rice River and Red River that are located in the staging area upstream of the LPP alignment, were not considered in the SIAM analysis because the simplified bankfull models are not able to accurately represent the potentially complex hydraulic conditions associated with the storage of flood waters. Accordingly, the results presented herein are considered adequate for the determination of general trends and for comparisons between the LPP, HCP and current conditions results but should not be used to estimate actual sediment transport volumes.

It should also be noted that model boundary effects are likely to have an impact on results for some of the sediment reaches. Typically, with subcritical HEC-RAS modeling the location of the upstream limit of the hydraulic model can coincide with the beginning of the area of interest, as the upstream boundary limit will not affect results. However, when using the SIAM module

the location of the upstream limit of the model in relation to the overall length of the river can be of greater importance depending on local hydraulic conditions and the magnitude of the available upstream sediment inflows. As previously discussed, two sediment sources were entered into SIAM for all sediment reaches. Surface sediment based on the basin area contributing along the length of the sediment reach was input for all reaches. The upstream most sediment reach on each river also included sediment inflow from upstream which, for lack of better information, was based on the entire contributing drainage area upstream of that point (Figure 7-11). For example, the basin area that contributes to the upper end of the Wild Rice study reach (Wild Rice 6) is 1,176,350 acres. Based on 0.03 tons/acre/yr the calculated annual upstream sediment inflow at this point is 35,291 tons. Of this, 1,198 tons are of a grain size greater than the wash load threshold of 0.0625 mm (only sediment larger than the washload threshold is part of the sediment mass balance). The surface sediment inflow component for Wild Rice 6 is 34 tons with only 1 ton being above the washload threshold. The total non-washload component for both sources amounts to 1,199 tons of which 948 tons are deposited based on SIAM results. The calculated deposition is partially an artifact of the arbitrary location for the start of the analysis and the spike in available sediment. Had the model boundary been located further upstream, SIAM would likely have deposited some of this material upstream of Wild Rice 6, possibly resulting in a different SIAM result. While the nature of SIAM precludes trying to interpret results as volumes of sediment, it is still important to consider the possible effect of the boundary location on the SIAM result. An artificially large supply from upstream could result in SIAM predicting deposition when in fact this may not be occurring.

The SIAM local balance results for the Existing Conditions, FCP, and LPP diversion alternatives are provided in Table 7-4 through Table 7-13 and in Figure 7-13 through Figure 7-15. A summary of predicted trends between the FCP and LPP alignments and Existing Conditions is presented in Table 7-16. For the purposes of this discussion, trend shifts between Existing Conditions and the FCP and LPP diversion alternatives are defined as a shift from aggradation to degradation or vice versa, not as changes in magnitude of aggradation or degradation. Figure 7-16 and Figure 7-17 show the sediment trend shifts that are predicted to occur under the FCP and LPP alignment alternatives, respectively.

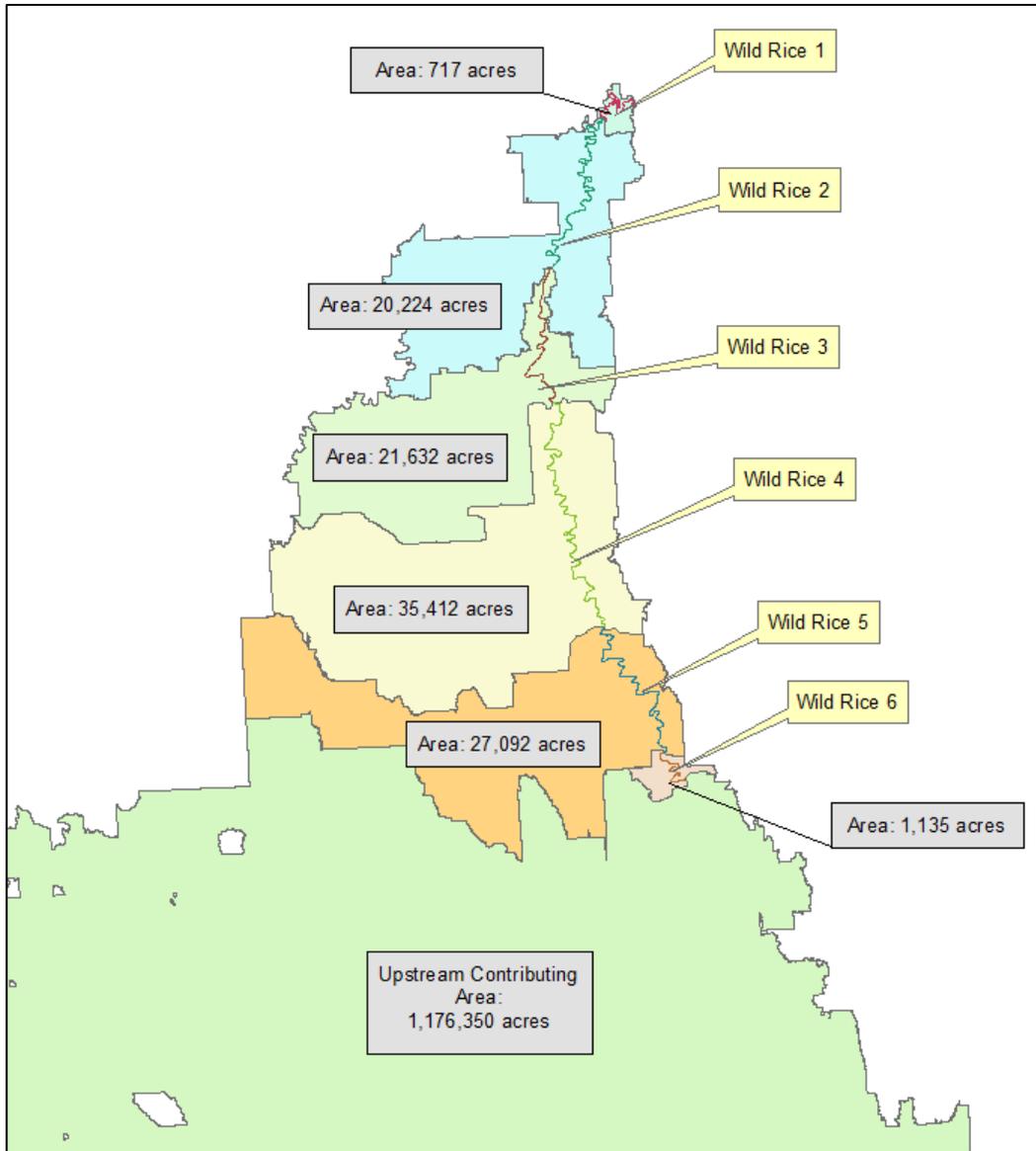


Figure 7-11. Wild Rice Sediment Contributing Basins

For the Buffalo River, SIAM predicts a sediment deficit and net erosion. The LPP and FCP diversions will not impact the Buffalo River and therefore no SIAM modeling was conducted.

Table 7-4. Local Sediment Balance Results for Buffalo River

Study Reach	Local Sediment Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Buffalo River 1	-246	-0.01	1/	1/	1/	1/
	Net Deposition: -246	Average: -0.01	Net Deposition: 1/	Average: 1/	Net Deposition: 1/	Average: 1/

1/ Not affected by diversion channel - not modeled in SIAM

For the Lower Rush River, SIAM predicts some aggradation in the upstream reach (possibly influenced by boundary conditions) and minor degradation in the downstream reach. The FCP diversion will not impact the Lower Rush River and therefore no SIAM modeling was conducted. The LPP diversion will intercept 100% of the flow from the Lower Rush River. Therefore, SIAM modeling was not conducted.

Table 7-5. Local Sediment Balance Results for Lower Rush River

Study Reach	Local Sediment Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Lower Rush River 1	-5.53	0.00	1/	1/	1/	1/
Lower Rush River 2	261	0.01	2/	2/	1/	1/
	Net Deposition: 255	Average: 0.01	Net Deposition: 1/	Average: 1/	Net Deposition: 1/	Average: 1/

1/ Not affected by diversion channel - not modeled in SIAM

2/ No upstream inflow to reach, local inflow unknown - not modeled in SIAM

For the Maple River, SIAM predicts net degradation in both sediment reaches, with more significant degradation occurring in the Reach 1. For the LPP scenario, SIAM predicts a decrease in degradation for Reach 2 and minimal change in Reach 1 when compared with current conditions. The reduction in degradation in Reach 2 is an artifact of the truncated duration curves described earlier. Because of backwater effects from diversion channel flood flows under the LPP scenario go out of bank at lower recurrence intervals than under current conditions. Accordingly, to prevent erroneous results in the hydraulic model the duration curve for the LPP condition was truncated at smaller flows (resulting in lower cumulative annual flows). This results in an artificially lower annual transport capacity and less degradation of the channel in

Reach 2. The FCP diversion will not impact the Maple River and therefore no SIAM modeling was conducted.

Table 7-6. Local Sediment Balance Results for Maple River

Study Reach	Local Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Maple River 1	-23,500	-0.65	-22,200	-0.61	∅	∅
Maple River 2	-1,364	-0.04	-822	-0.02	∅	∅
	Net Deposition: -24,864	Average: -0.34	Net Deposition: -23,022	Average: -0.32	Net Deposition: ∅	Average: ∅

∅ Not affected by bypass canal - not modeled in SIAM

For the Red River under current conditions, SIAM predicts degradation in Reaches 1, 3, 4 and 8 and aggradation in Reaches 2, 5, 6 and 7. The most significant aggradation is predicted to occur in Reach 2 which is located immediately downstream of confluence with the Sheyenne River. For the LPP scenario, SIAM predicts the sedimentation patterns will remain generally consistent for all reaches except that the aggradation in Reach 2 will be reduced. This reduction in aggradation is an artifact of the assumption that there is no surface sediment contribution along the protected portion of the Red River. The lack of surface sediment for this reach results in a much lower value of aggradation compared to current conditions

For the FCP alignment alternative, sedimentation patterns are predicted to remain relatively consistent compared to current conditions, though Reach 2 shows a noticeable increase in aggradation. This increase is the result of increased sediment loading from the FCP diversion channel. While the steeper channel gradient in the lower reach of the diversion channel (FCP1) is likely to result in degradation which will cause significant additional sediment inputs to Red River Reach 2, the magnitude of the change predicted by SIAM is likely an artifact of the unlimited bed sediment supply assumed made by the model. Under flood conditions, the downstream most reach (FCP1) of the diversion channel has a relatively large sediment transport capacity compared to the upstream reaches. Also, since it is assumed that there are no significant lateral sediment inputs to the diversion channel, there is significant excess transport capacity in FCP1 compared to the upstream sediment supply. As previously discussed, SIAM assumes an unlimited supply of bed material is available to be removed from the bed. Therefore, the excess transport capacity is satisfied by erosion of the bed. While some degradation of Reach FCP 1 would be expected under these conditions, the cohesive nature of the clay soils underlying the diversion channel and the limited supply of sand found within these soils would likely preclude the relatively large amount of degradation predicted by SIAM. Consequently, the relatively large amount of aggradation predicted for Red River Reach 2 would not occur.

Table 7-7. Local Sediment Balance Results for Red River

Study Reach	Local Sediment Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Red River 1	-30,000	-0.46	-25,300	-0.39	-19,900	-0.30
Red River 2	91,900	1.64	10,700	0.19	248,000	4.41
Red River 3	-38,200	-0.35	-22,700	-0.21	-20,300	-0.19
Red River 4	-723	-0.02	-851	-0.02	-811	-0.02
Red River 5	843	0.01	196	0.00	458	0.01
Red River 6	12,600	0.18	11,000	0.16	11,000	0.16
Red River 7	47,400	0.64	45,700	0.62	45,700	0.62
Red River 8	-49,500	-0.36	-46,000	-0.33	-45,900	-0.33
	Net Deposition: 34,320	Average: 0.16	Net Deposition: -27,255	Average: 0.00	Net Deposition: 218,247	Average: 0.54

For the Rush River, SIAM predicts aggradation in the upstream reach and degradation in the downstream reach. The FCP scenario was modeled in SIAM as there were some very minor backwater effects from the Sheyenne River under this scenario. However, SIAM predicted identical results for the FCP alignment alternative as for existing conditions. The LPP diversion will intercept 100% of the flow from the Rush River. Therefore, SIAM modeling was not conducted.

Table 7-8. Local Sediment Balance Results for Rush River

Study Reach	Local Sediment Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Rush River 1	-39	0.00	^{1/}	^{1/}	-39	0.00
Rush River 2	158	0.00	^{2/}	^{2/}	158	0.00
	Net Deposition: 119	Average: 0.00	Net Deposition: ^{1/}	Average: ^{1/}	Net Deposition: 119	Average: 0.00

^{1/} Not affected by diversion channel - not modeled in SIAM

^{2/} No upstream inflow to reach, local inflow unknown - not modeled in SIAM

For the Sheyenne River under Existing Conditions, SIAM predicts degradation in Reaches 2, 3, 4 and 7 and aggradation in Reaches 1, 5, 6 and 8. For the LPP alignment alternative, SIAM

predicts degradation in Reaches 2, 4, and 7 and aggradation in Reaches 1, 3, 5, 6, and 8. The trend shift from degradation to aggradation in SR3 is likely due to the reduction transport capacity as the majority of the Maple River flows that join the Sheyenne at the upstream end of SR3 are intercepted by the LPP diversion.

The exception to this trend in the protected portion of the Sheyenne is Reach 3, for which aggradation is predicted. The aggradation noted in Reach 3 is the result of sediment inflow from the Maple River. While SIAM predicts equilibrium for several of the Sheyenne reaches, this should be considered cautiously, as this is partially a function of the underlying assumptions regarding sediment inputs. While it is assumed that there are no local sediment inputs in the protected area aside from the Maple River, it is likely that some sediment will be contributed to the river which could result in aggradation. However, given that the local soils only contain a minimal component of material larger than the washload threshold, aggradation is expected to be minimal. The increase in deposition predicted for SR8 is again an artifact of having a different truncation point on the LPP discharge duration curve than on the Current Conditions discharge duration curve, as was discussed previously in the Maple River results.

For the FCP diversion alternative, the diversion channel only affects the Sheyenne River along its downstream reaches due to minor backwater effects associated with the diversion channel inflows to the Red River. Sediment inputs for the Sheyenne under the FCP scenario are the same as under current conditions and the predicted SIAM trends for the Sheyenne River are predicted to be essentially the same as Existing Conditions.

Table 7-9. Local Sediment Balance Results for Sheyenne River

Study Reach	Local Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Sheyenne River 1	9,383	0.16	3565	0.06	9,365	0.16
Sheyenne River 2	-4,365	-0.49	-1364	-0.15	-4,387	-0.49
Sheyenne River 3	-9,386	-0.28	12600	0.37	-9,401	-0.28
Sheyenne River 4	-23,200	-1.00	-25100	-1.08	-23,200	-1.00
Sheyenne River 5	2,378	0.07	2156	0.07	2,378	0.07
Sheyenne River 6	10,700	0.18	8097	0.13	10,700	0.18
Sheyenne River 7	-7,398	-0.17	-4956	-0.11	-7,398	-0.17
Sheyenne River 8	8,566	0.09	8731	0.09	8,566	0.09
	Net Deposition:	Average:	Net Deposition:	Average:	Net Deposition:	Average:
	-13,322	-0.18	3,729	-0.08	-13,377	-0.18

For Wild Rice River under Existing Conditions, SIAM predicts aggradation in Reach 1 and Reach 4 through 6, and degradation in Reaches 2 and 3. For the LPP and FCP alignment

alternatives, sedimentation patterns are predicted to remain relatively consistent compared to current conditions.

Table 7-10. Local Sediment Balance Results for Wild Rice River

Study Reach	Local Sediment Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Wild Rice River 1	948	0.02	529	0.02	962	0.04
Wild Rice River 2	-510	-0.02	-282	-0.01	-709	-0.01
Wild Rice River 3	-506	-0.01	-293	-0.01	-527	-0.02
Wild Rice River 4	232	0.01	171	0.00	233	0.00
Wild Rice River 5	437	0.03	348	0.01	437	0.01
Wild Rice River 6	590	0.07	741	0.05	589	0.04
	Net Deposition:	Average:	Net Deposition:	Average:	Net Deposition:	Average:
	1,191	0.02	1,214	0.01	985	0.01

For Wolverton Creek under Existing Conditions, SIAM predicts aggradation in the upstream reach and degradation in the downstream reach. SIAM modeling was not conducted for the LPP diversion condition as the diversion is not expected to impact the lower reach of Wolverton Creek, while Reach 2 is located in the staging area for which SIAM modeling is not possible due to the uncertainties involved with channel hydraulics under inundated conditions. The FCP diversion will not impact Wolverton Creek and therefore no SIAM modeling was conducted and no changes in sedimentation trends are expected.

Table 7-11. Local Sediment Balance Results for Wolverton Creek

Study Reach	Local Sediment Balance : Bed Material					
	Current		LPP		FCP	
	- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)		- = Degradation (red) + = Aggradation (blue)	
	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)	(tons/yr)	(tons/ft/yr)
Wolverton Creek 1	565	0.07	1/	1/	2/	2/
Wolverton Creek 2	-653	-0.03	1/	1/	2/	2/
	Net Deposition:	Average:	Net Deposition:	Average:	Net Deposition:	Average:
	-88	0.02	1/	1/	2/	2/

^{1/} Not modeled in SIAM

^{2/} Not affected by diversion channel - not modeled in SIAM

For the FCP diversion channel, SIAM predicts degradation along sediment Reaches 1, 3 and 4, and aggradation in Reach 2. Notably, significantly greater degradation is predicted for Reach 1 than for the other reaches of the FCP diversion. This is due to the increase in bed slope and velocities at the downstream end of the channel. The magnitude of the predicted degradation is partially an artifact of the unlimited bed assumption as was discussed previously in the Red River results.

Table 7-12. Local Balance Results for FCP Alignment

Study Reach	US XS	DS XS	Local Balance : Bed Material	
			FCP Alignment	
			- = Degradation (red) + = Aggradation (blue)	
			(tons/yr)	(tons/ft/yr)
FCP 1	8744	271	-174,000	-20.54
FCP 2	56554	9849	19,900	0.43
FCP 3	127463	57375	-27,500	-0.39
FCP 4	130278	128453	-6,011	-3.29
			Net Deposition: -187,611	Average: -5.95

For the LPP diversion channel, SIAM predicts degradation for Reaches 1-3 and 9, and aggradation for Reaches 4-8 and 10-12.

Table 7-13. Local Balance Results for LPP Alignment

Study Reach	US XS	DS XS	Local Balance : Bed Material	
			LPP Alignment	
			- = Degradation (red)	
			+ = Aggradation (blue)	
			(tons/yr)	(tons/ft/yr)
LPP 1	5500	100	-152	-0.03
LPP 2	19000	6500	-102	-0.01
LPP 3	41000	20000	-50	0.00
LPP 4	53000	42000	31	0.00
LPP 5	67390	53500	1,481	0.11
LPP 6	71000	67550	51	0.01
LPP 7	81230	72000	400	0.04
LPP 8	118500	81370	78	0.00
LPP 9	143000	119500	-94	0.00
LPP 10	152440	143500	17	0.00
LPP 11	170100	152600	294	0.02
LPP 12	184590	171975	6,585	0.52
			Net Deposition:	Average:
			1,660	0.01

Table 7-14. Summary of Predicted Changes between Future Alignments and Existing Conditions

Study Reach	Trend Change for LPP Conditions	Trend Change for FCP Conditions
Buffalo River 1	no change	no change
Lower Rush River 1	not compared	no change
Lower Rush River 2	no change	no change
Maple River 1	no change	no change
Maple River 2	no change	no change
Red River 1	no change	no change
Red River 2	no change	no change
Red River 3	no change	no change
Red River 4	no change	no change
Red River 5	no change	no change
Red River 6	no change	no change
Red River 7	aggradation to degradation	no change
Red River 8	no change	no change
Rush River 1	not compared	no change
Rush River 2	no change	no change
Sheyenne River 1	no change	no change
Sheyenne River 2	no change	no change
Sheyenne River 3	degradation to aggradation	no change
Sheyenne River 4	no change	no change
Sheyenne River 5	no change	no change
Sheyenne River 6	no change	no change
Sheyenne River 7	no change	no change
Sheyenne River 8	no change	no change
Wild Rice River 1	no change	no change
Wild Rice River 2	no change	no change
Wild Rice River 3	no change	no change
Wild Rice River 4	no change	no change
Wild Rice River 5	no change	no change
Wild Rice River 6	no change	no change
Wolverton Creek 1	no change	no change
Wolverton Creek 2	not compared	no change

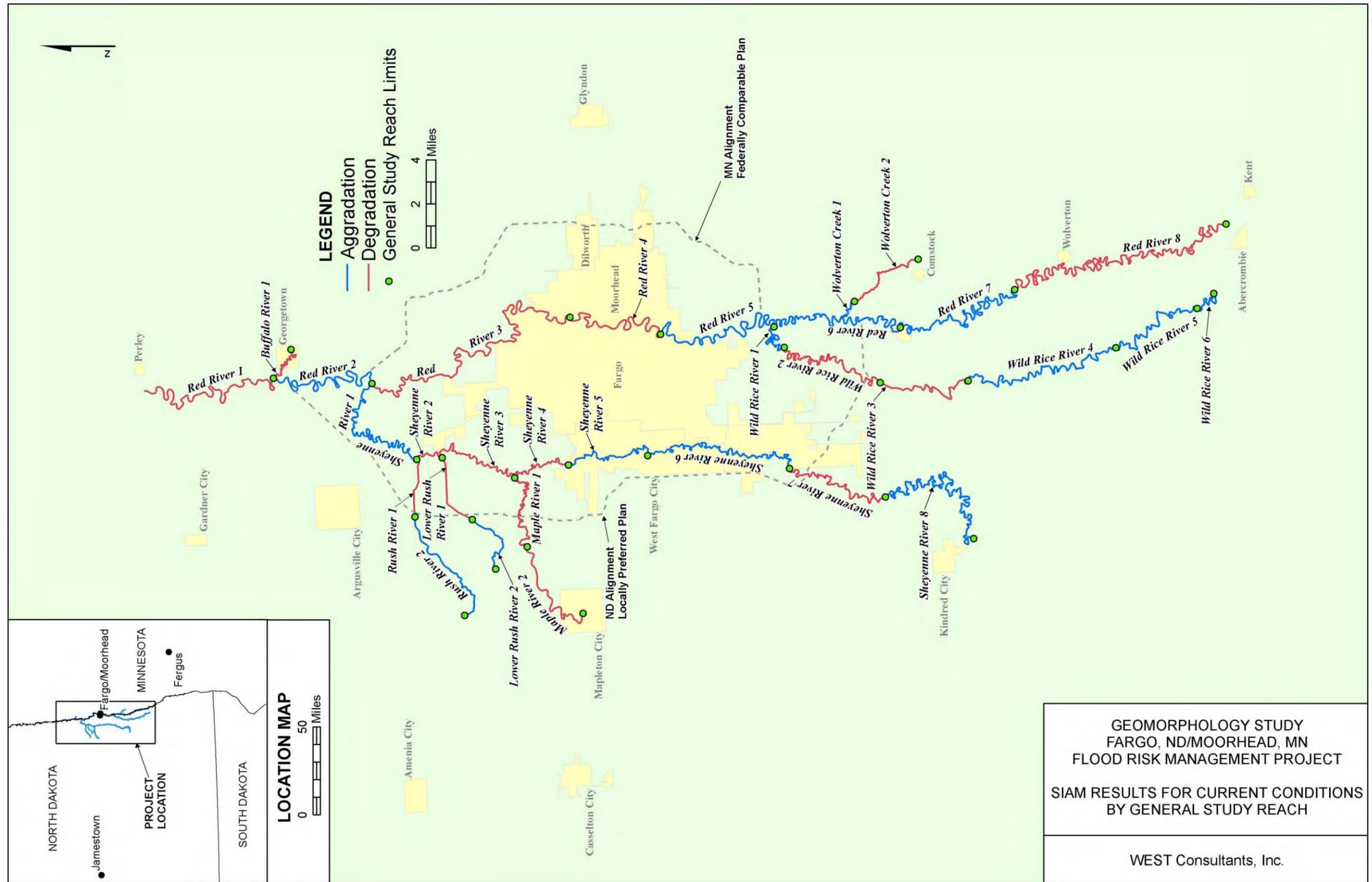


Figure 7-12. Predicted SIAM Trends (Current Conditions)

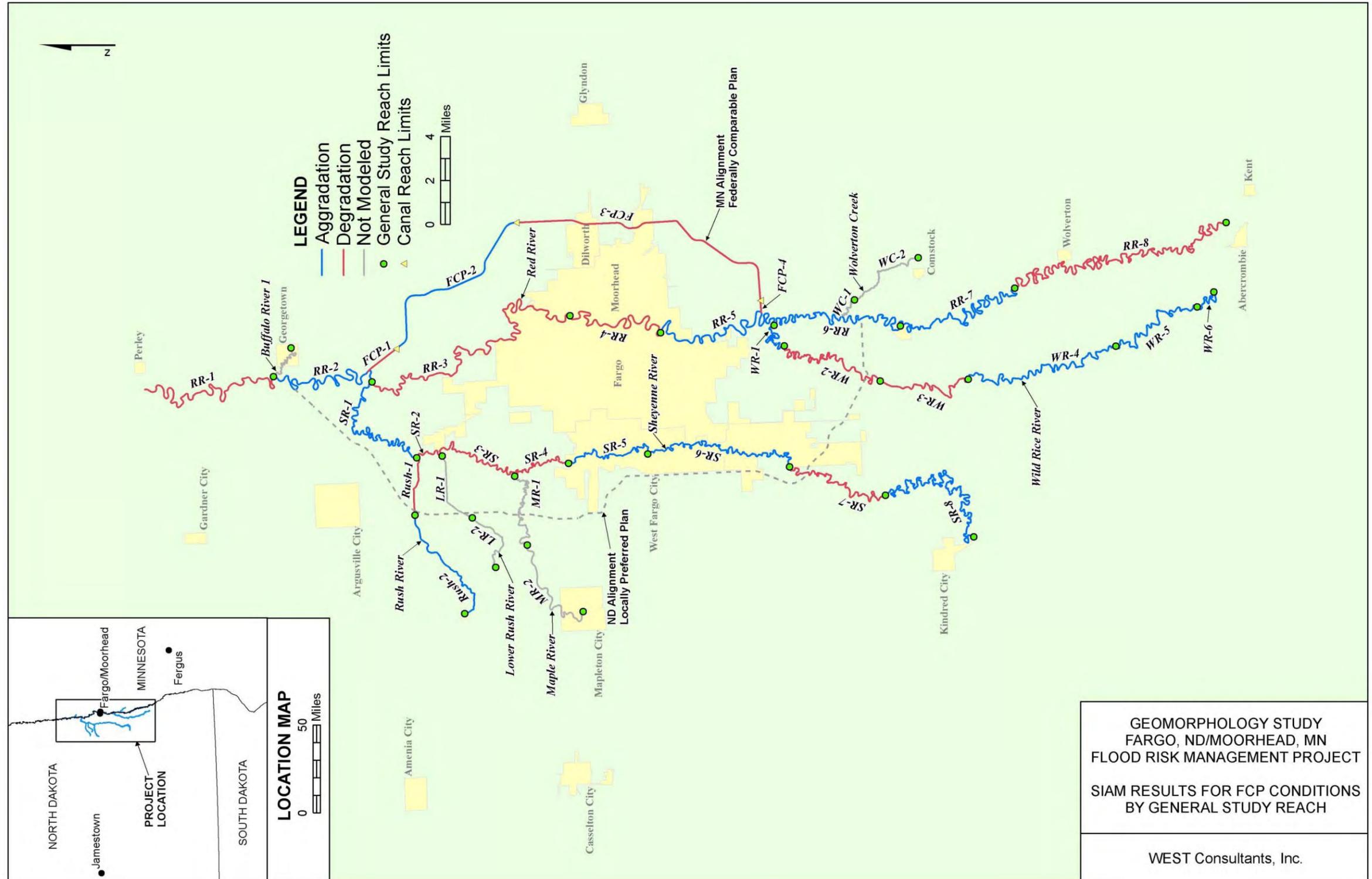


Figure 7-13. Predicted SIAM Trends (FCP Conditions)

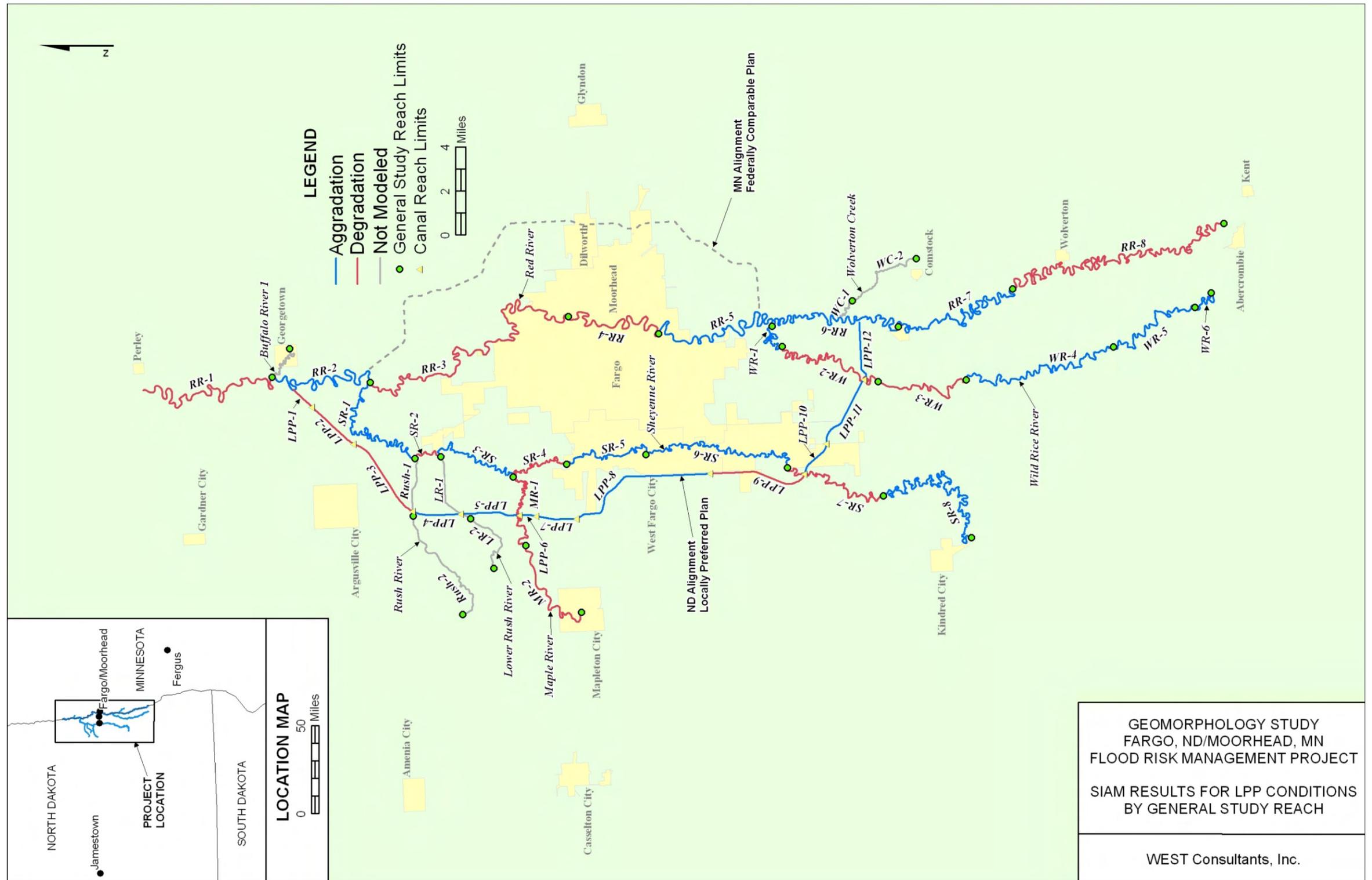


Figure 7-14. Predicted SIAM Trends (LPP Conditions)

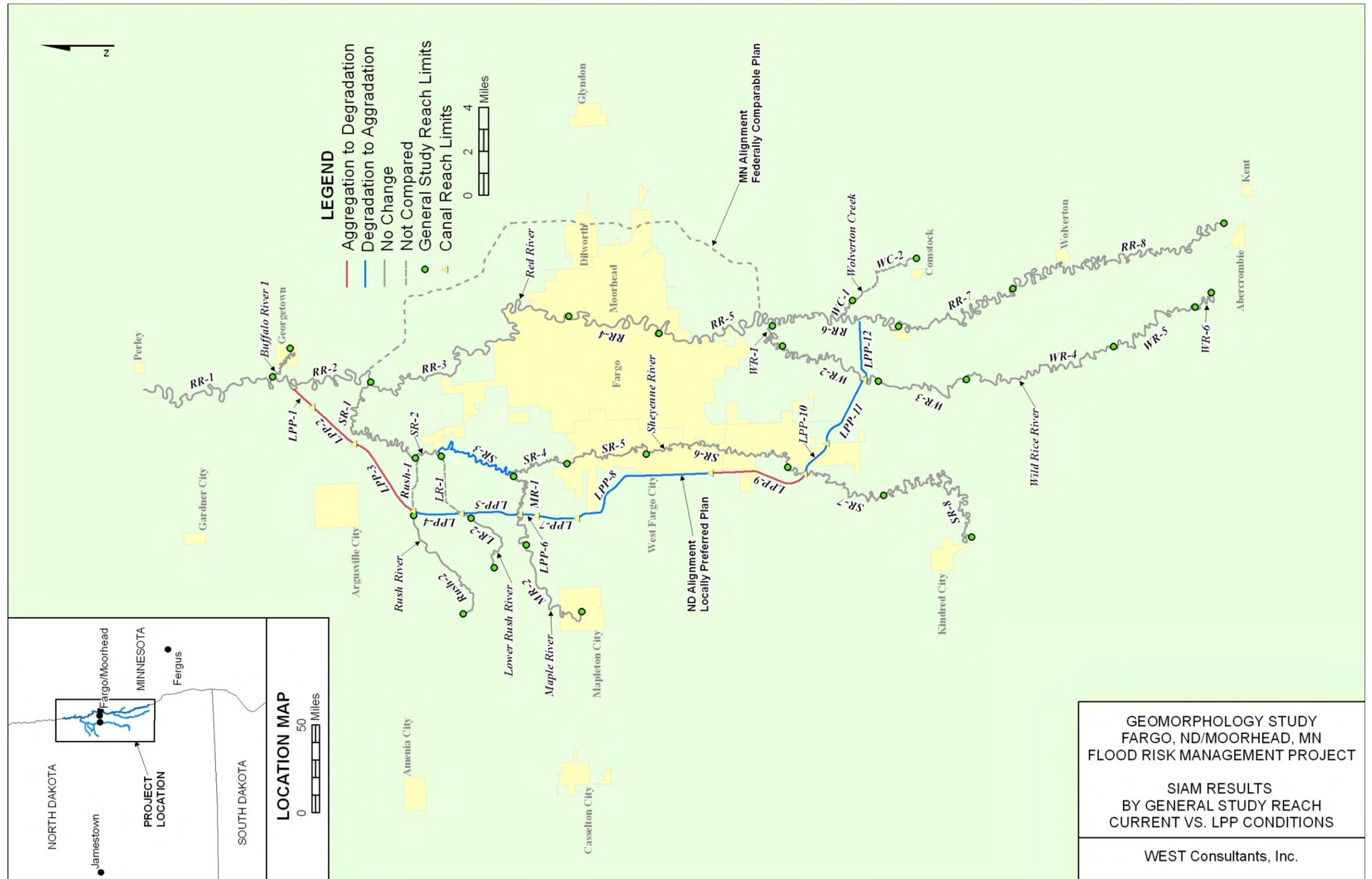


Figure 7-15. Predicted Shift in Trends between LLP and Current Conditions

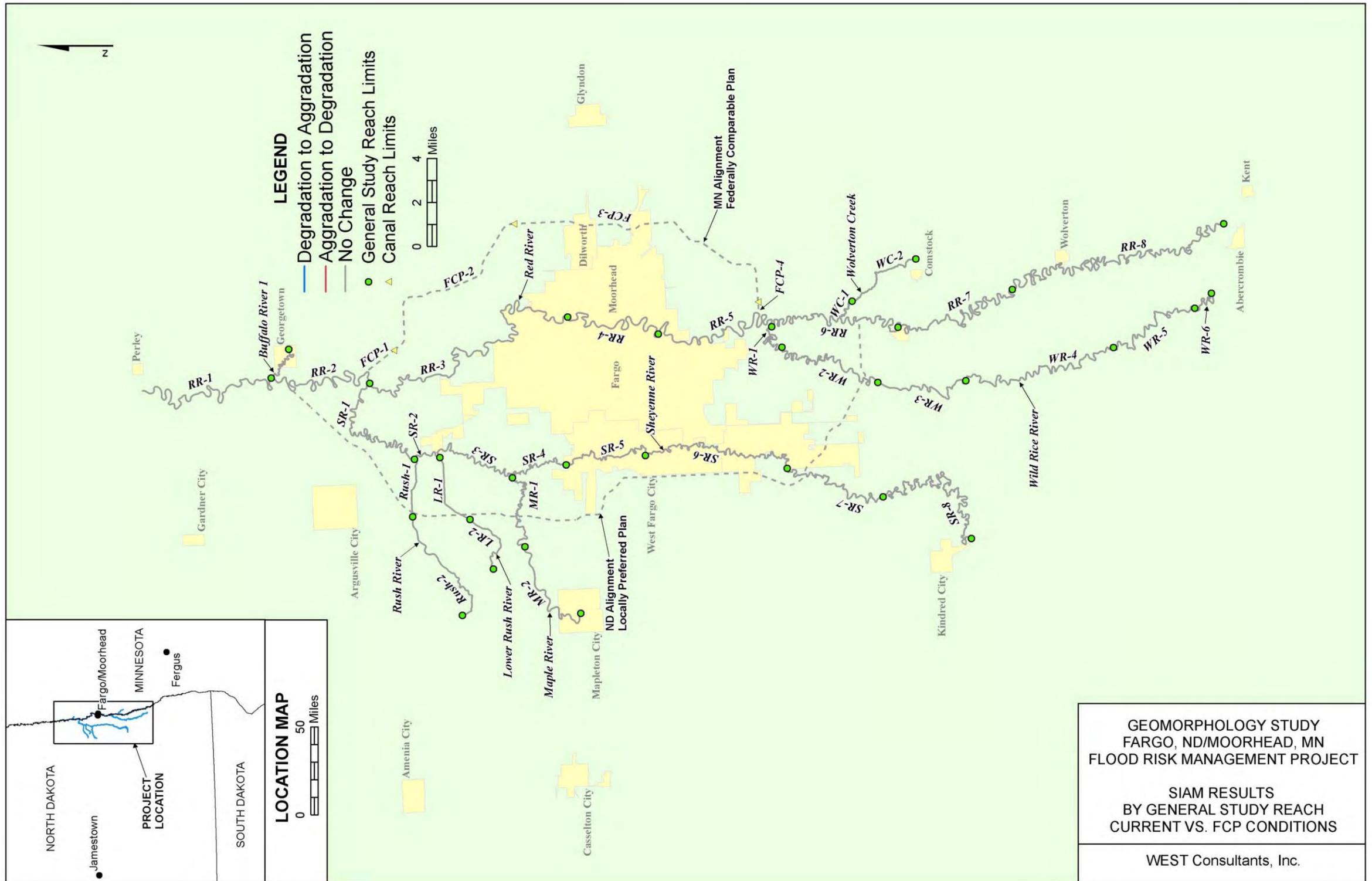


Figure 7-16. Predicted Shift in Trends between FCP and Current Conditions

7.5 Sediment Impact Analysis Conclusions

The main purpose of SIAM analysis is to understand if the FCP and LPP alignment alternatives would result in significant alterations to the sediment transport conditions along the study streams. The results of the analysis allow for a better understanding of the potential for the various sediment reaches to shift sedimentation trends from aggradation to degradation or vice versa. Although the output of the SIAM analysis provide magnitudes of aggradation or degradation, it should be recognized that the model's inherent limitations and the simplifying assumptions required for data input yields values that are not expected to be representative of actual sediment transport rates. Conclusions regarding the results of the SIAM analysis are as follows:

7.5.1 FCP scenario

For the FCP alignment alternative, the SIAM model results indicate that there will be no sedimentation trend shifts for any of the study streams. The magnitude of deposition and erosion for most of the sediment reaches are generally similar between the Existing Conditions and FCP alignment alternative. However, Red River Reach 2 is predicted to have a significant increase in deposition for the FCP alternative. This increase is the result of increased sediment loading from the FCP diversion channel. While the steeper channel gradient in the lower reach of the diversion channel (FCP1) is likely to result in degradation, which will cause significant additional sediment inputs to Red River Reach 2, the magnitude of the change predicted by SIAM is likely an artifact of the unlimited bed sediment supply assumed made by the model.

Under flood conditions, the downstream most reach (FCP1) of the diversion channel has a relatively large sediment transport capacity compared to the upstream reaches. Also, since it is assumed that there are no significant lateral sediment inputs to the diversion channel, there is significant excess transport capacity in FCP1 compared to the upstream sediment supply. As previously discussed, SIAM assumes an unlimited supply of bed material is available to be removed from the bed. Therefore, the excess transport capacity is satisfied by erosion of the bed. While some degradation of Reach FCP 1 would be expected under these conditions, the cohesive nature of the clay soils underlying the diversion channel and the limited supply of sand found within these soils would likely preclude the relatively large amount of degradation predicted by SIAM. Consequently, the relatively large amount of aggradation predicted for Red River Reach 2 would not occur. However, the results do suggest that FCP Reach 1 would likely require mitigation to increase its long-term stability.

7.5.2 LPP Scenario

For the LPP alignment alternative, the SIAM model results indicate that there will be no sedimentation trend shifts for any of the study streams except the Sheyenne River. For the Sheyenne River, SIAM predicts that all of the protected reaches (SR1 – SR6) with the exception of SR3 will experience equilibrium conditions. However, some amount of sediment deposition is likely to occur within these reaches. Deposition would be expected to occur immediately downstream of local inflow drains which are not accounted for in the SIAM model. The deposition predicted for SR3 is due to the introduction of sediments from the Maple River into

the Sheyenne which has no bedload transport capability due to reduced flows under the LPP scenario.