

MEMORANDUM FOR RECORD

SUBJECT: Missouri River bed changes 2009 to 2019

1. Introduction. Per the Regulatory framework for Missouri River dredging, the dredgers provide a bathymetric survey of the Missouri River every 4th year into a 5-year permit cycle. From June 29, 2019 to September 19, 2019, engineering contractor JD-MC Engineering, LLC performed a single-beam hydrographic survey of the Missouri River RM 0 to 498.17. The 2019 survey includes 5,276 cross sections with approximately 500 ft transect spacing. Daily flow at the locations of survey ranged from aprx. 120,000 to 253,000 cfs (see Figure 1).

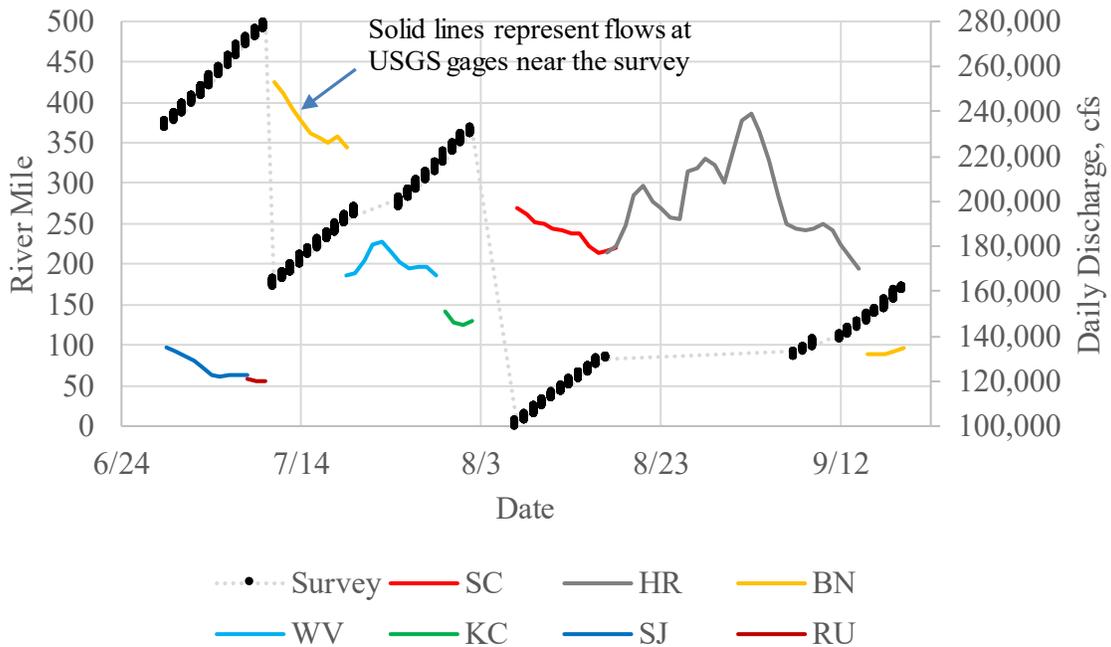


Figure 1. Survey locations and dates. Solid lines represent flows at USGS gages near the survey.

This memo documents technical analyses on the state of bed elevations and of bed elevation change evinced by the 2019 survey. Section 1 is an introduction. Section 2 discusses survey quality control. Section 3 presents the volume change from 2009 to 2019. Section 4 provides the average bed profiles over time. Section 5 presents the analysis of bed change from 2009 to 2019. Section 6 presents the upstream and downstream buffers as computed in USACE (2020). Section 7 discusses the implications for permitting of the potential data quality issues from RM 0 to 50. Section 8 concludes.

2. Data Quality. NWK-EDH-R performed quality control on the data submittal from JD-MC Engineering, including the following tests: Visual inspection of each cross section, point density, comparisons to previous surveys, comparison to targeted QA/QC surveys conducted by NWK-EDH-R, and analysis of the timing and flow rates on the survey days. JD-MC neglected to thin the data in the first submittal. On request, they thinned and resubmitted. The QA/QC indicated reasonable confidence in the thinned data submittal, with the exception of RM 0 to 50. The submitted sections for RM 0 to 50 were flagged for inconsistent and unrealistic cross section characteristics. The contractors indicated this was an error during the thinning process. JD-MC engineering reprocessed and resubmitted the data for the reach. The resubmitted section shapes match the initial, un-thinned data and appear reasonable compared to previous surveys, including at less moveable features such as revetments (see Figure 2). However, volume change analyses reveal a sudden shift in river bed change behavior from degradational to aggradational at RM 50 (see Figure 4).

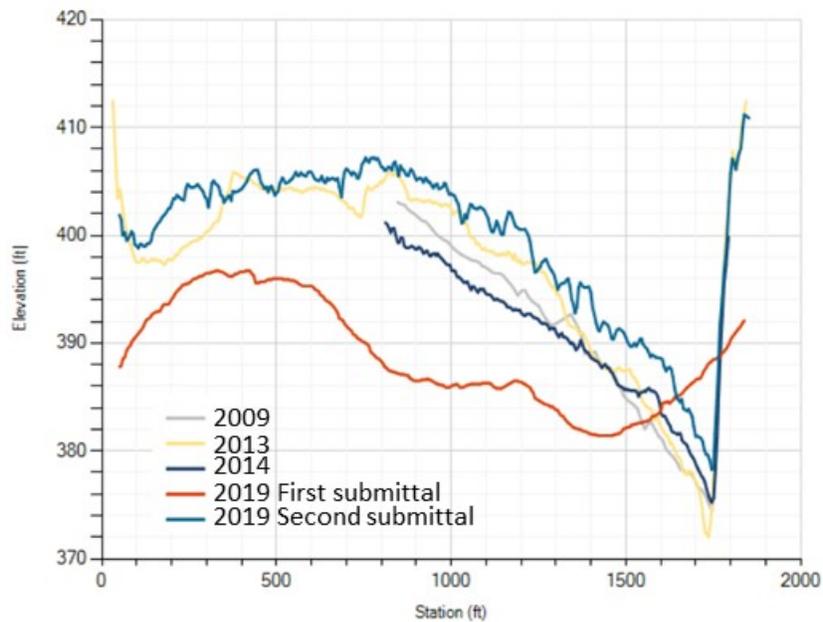


Figure 2. Cross Section at RM 4.61

Neither river flows nor timing of the surveys can explain why this reach reflects an upward shift in volume trend that is different from anywhere else on the river and is also inconsistent with past survey trends in this area. In addition, analysis of individual cross sections in the lower 50 miles shows deposition patterns not seen elsewhere on the river. EDHR performed a QA/QC survey from RM 33.39 to 26.96, a month after the 2019 survey of the reach, which allows an additional check. Figure 3 provides the longitudinal cumulative volume change curves from both surveys.

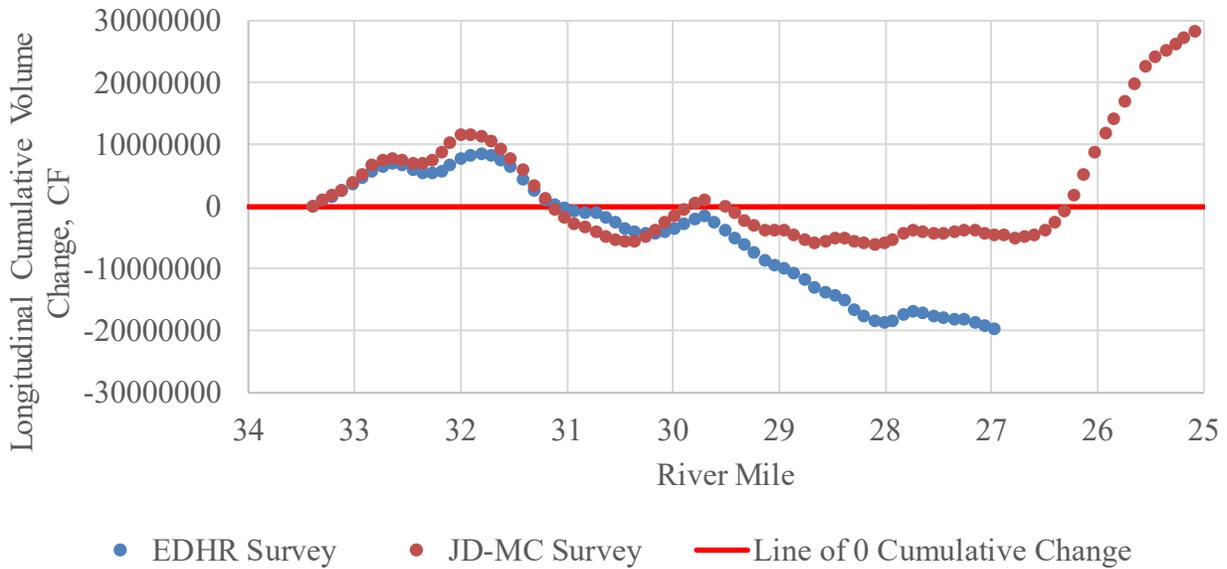


Figure 3. QA/QC of 2019 Survey near Jefferson City

As seen in Figure 3, the EDH-R data matches the dredgers data from RM 33 to RM 29.5, however the EDH-R data trends downward from RM 29.5 to RM 27 while the dredgers data trend is stable. The reason for the trend reversal and unique deposition patterns is unknown at this time and it is unknown if this trend will remain with the return of more normal stages on the Missouri and Mississippi Rivers. The discrepancy between the EDH-R and JC-MC surveys from RM 29.5 to RM 27 after only one month may indicate that the aggradation and unique depositional patterns are transient features of the flood 2019 flood event.

This document proceeds using the JD-MC survey, including the resubmitted RM 0 to 50.

3. Volume Change. Figure 4 presents the longitudinal cumulative volume change for the Missouri River from 2009 to 2019, including the intermediate volume changes from 2009 to 2012, 2013, 2014, and 2018. Two broad reaches exhibit significant degradation from 2009 to 2019: RM 500 to 307 and RM 176 to 50. The data indicate that the river has lost 36 million cubic yards of bed material from 2009 to 2019, compared to 13 million cubic yards of loss from 2009 to 2014. This indicates an additional loss of 23 million cubic yards since 2014. Figure 4 indicates a continued upstream migration of the degradation that had been in Kansas City, plus very significant recent degradation downstream of RM 365.86. Comparison with the 2018 survey indicates continued degradation from RM 500 to 50, but aggradation in the lower 50 miles.

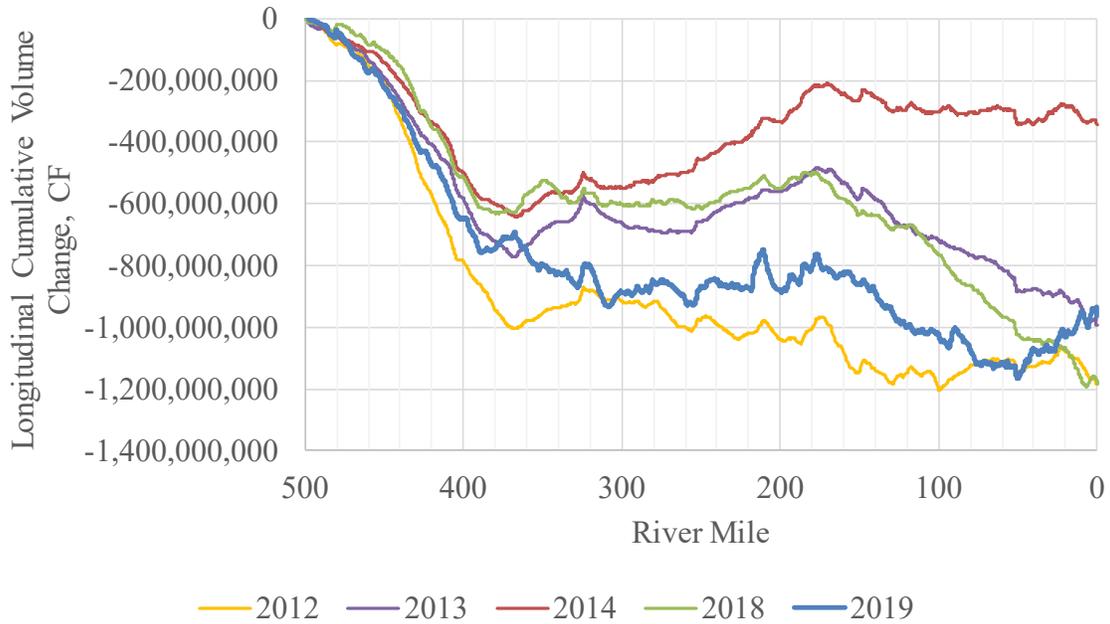


Figure 4. Longitudinal Cumulative Volume Change Since 2009

4. Bed Profiles. Figures 5 to 9 plot the average bed elevation for each cross section in the 2009, 2014, and 2019 surveys. The large upstream-to-downstream changes in bed elevation due to the slope of the river can obscure year-to-year changes due to the scale of the vertical axis. To better demonstrate temporal changes, these data are also plotted as departures from the 2009 averaged bed trend line (i.e. a straight line connecting the average bed elevations from the most upstream to the most downstream 5-mile reach.) Figures 10 and 11 plot the average bed elevation at individual cross sections, which demonstrates spatial variability within each year. Figures 12 and 13 plot 5-mile moving averages, which more easily displays spatial and temporal trends.

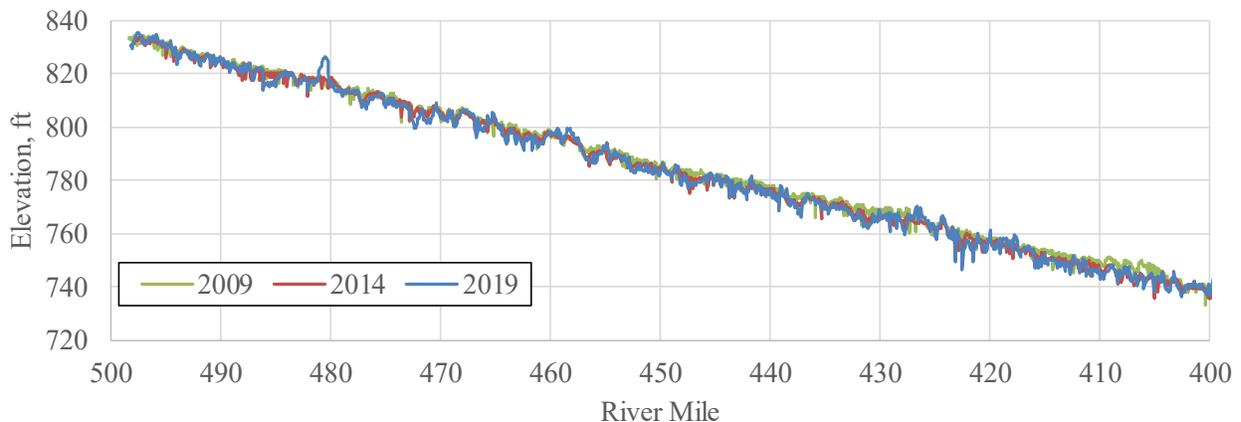


Figure 5. Average Bed Elevation Within the Rectified Channel Lines: RM 500 to 400

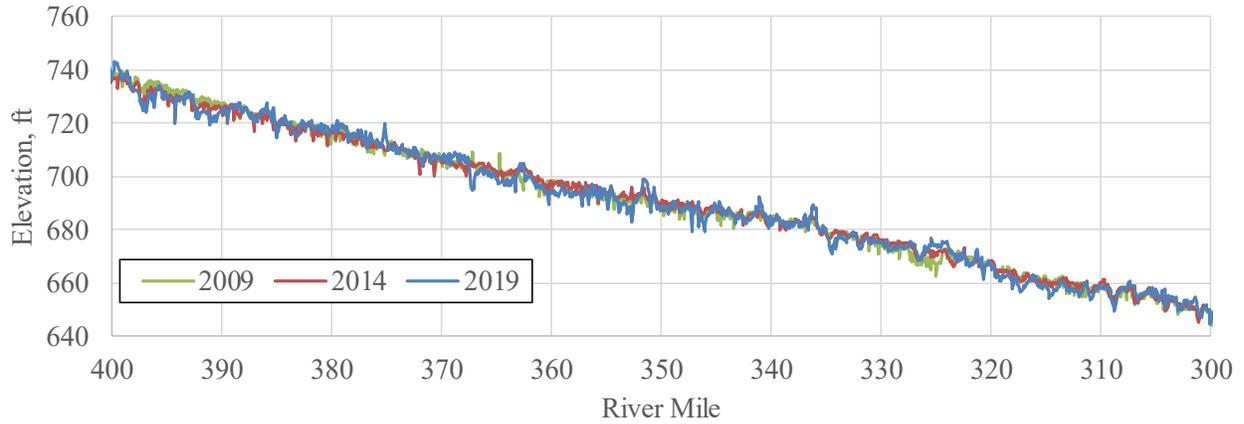


Figure 6. Average Bed Elevation Within the Rectified Channel Lines: RM 400 to 300

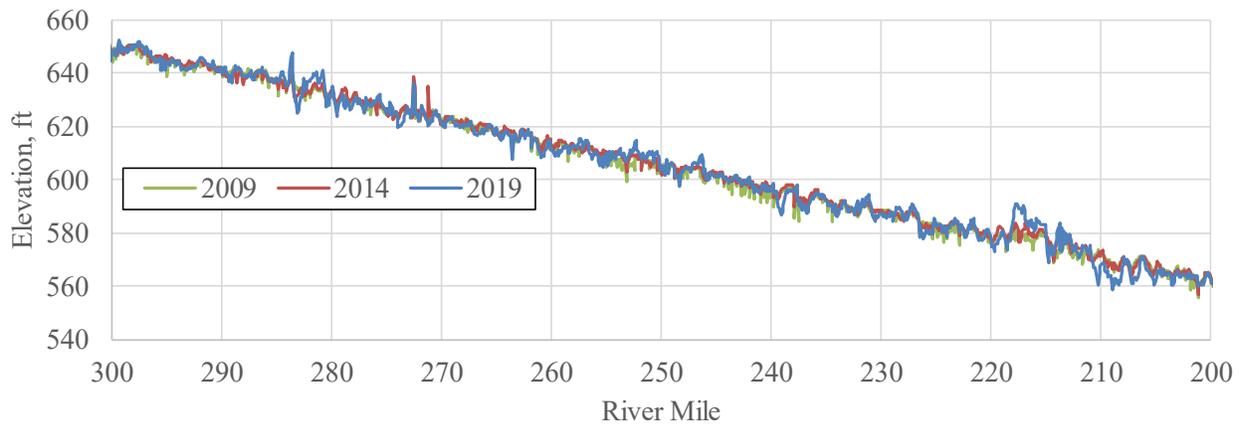


Figure 7. Average Bed Elevation Within the Rectified Channel Lines: RM 300 to 200

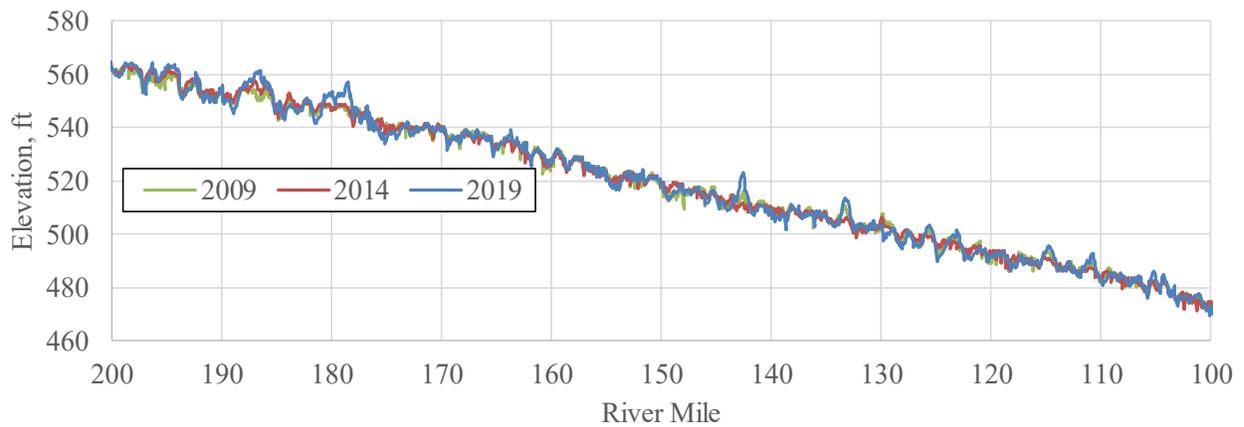


Figure 8. Average Bed Elevation Within the Rectified Channel Lines: RM 200 to 100

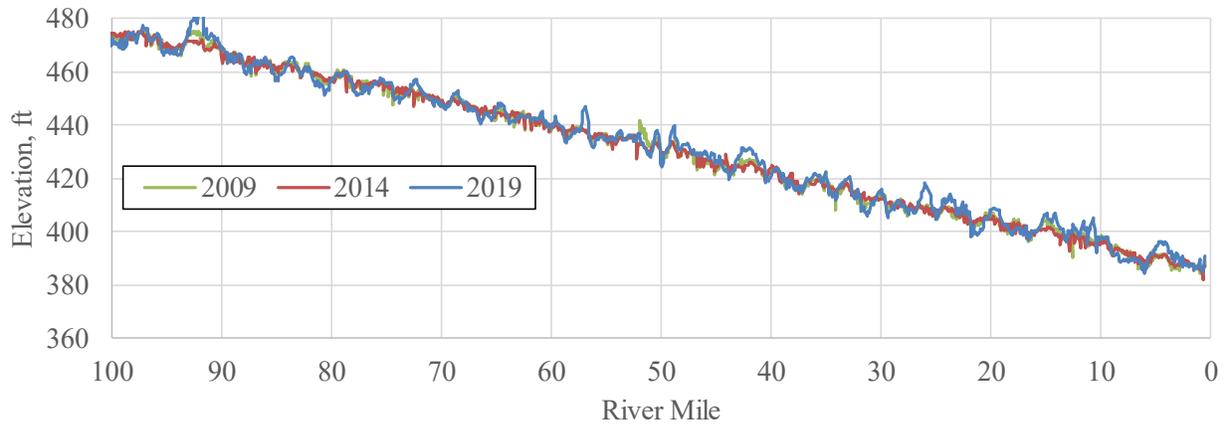


Figure 9. Average Bed Elevation Within the Rectified Channel Lines: RM 100 to 000

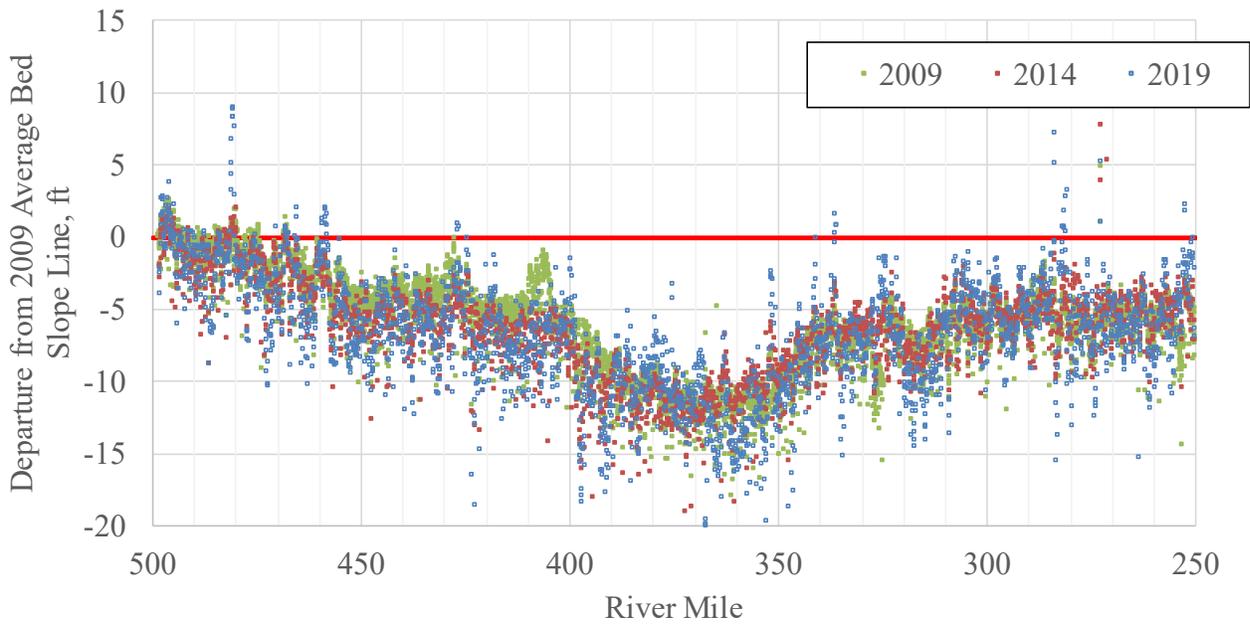


Figure 10. Departure from 2009 Average Bed Slope Line (Individual Cross Sections): RM 500 to 250. (Red line indicates zero change from 2009 average slope line.)

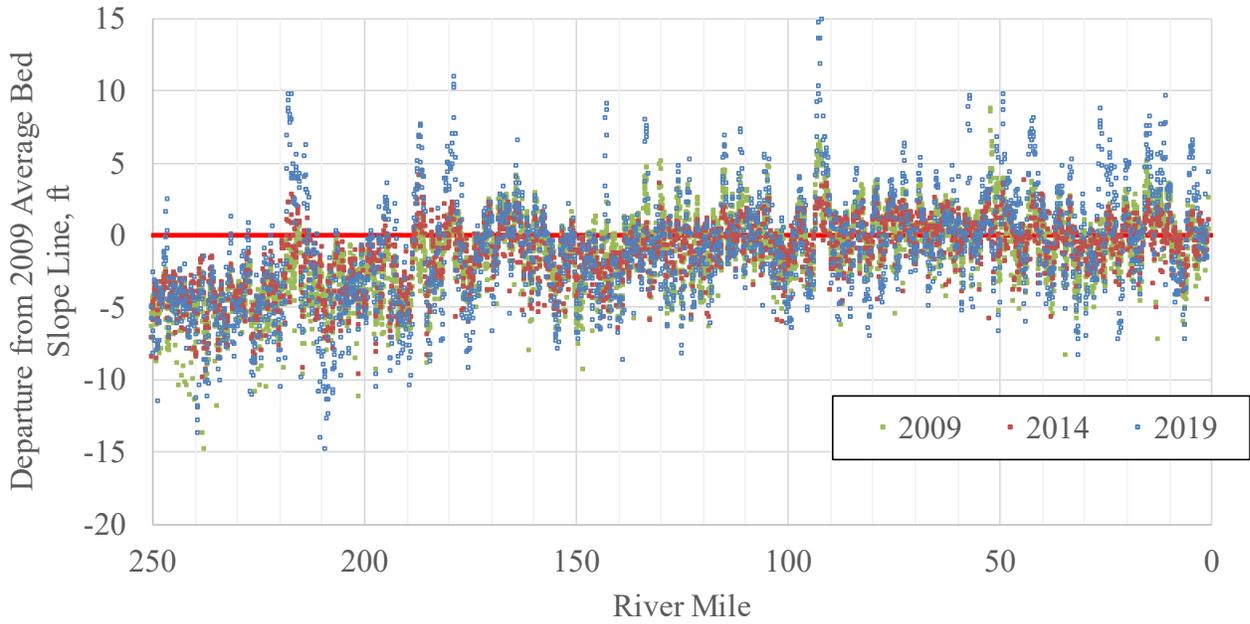


Figure 11. Departure from 2009 Average Bed Slope Line (Individual Cross Sections): RM 250 to 0. (Red line indicates zero change from 2009 average slope line.)

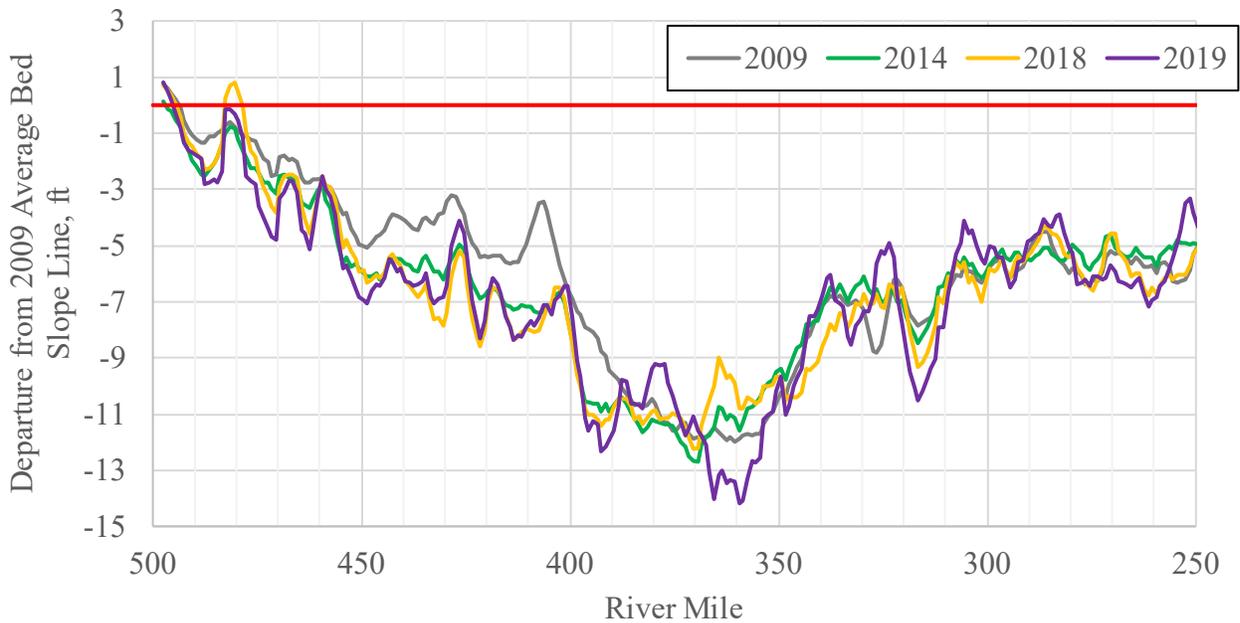


Figure 12. Departure from 2009 Average Bed Slope Line (5-Mile Moving Averages): RM 500 to 250. (Red line indicates zero change from 2009 average slope line.)

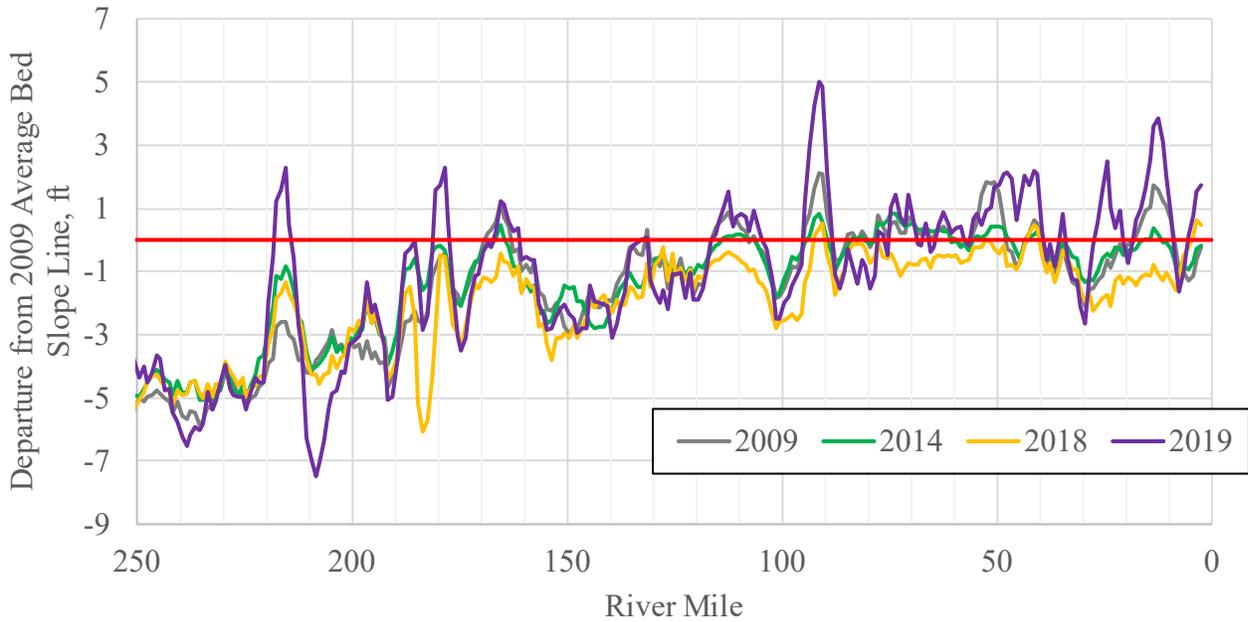


Figure 13. Departure from 2009 Average Bed Slope Line (5-Mile Moving Averages): RM 250 to 0. (Red line indicates zero change from 2009 average slope line.)

5. Bed Change from 2009. This section provides bed change analyses referenced against the 2009 survey. Bed change at a cross-section was computed by the same procedures as were used previously to analyze the 2014 survey to inform regulatory decision making (USACE 2015):

- 1- Compute the cross-sectional area change at each cross-section that exists in both surveys (2009 and 2019). Note: To ensure a valid comparison, only the lateral extent of the cross-section covered by both surveys was used to compute the area change. For reference, the average width for the common lateral extent from 2009 to 2019 is 998 feet, which is a sufficient width to describe the channel change. This step was automated by using the XS Viewer calculator on the Missouri River bathymetry database.
- 2- Divide the area change computed at each cross-section by the width to yield an average bed change at the cross-section.
- 3- Average the bed changes that occur between the upstream and downstream river miles for a particular reach or hotspot. Because the cross-sections are approximately evenly spaced, a mean rather than a distance-weighted average was used.

Figure 14 illustrates the 2009 to 2019 bed change at individual cross sections. Figures 15 and 16 display the 5-mile rolling average of bed change from 2009 to 2019 with the 2009 to 2014 and 2009 to 2018 changes provided for context. Figures 15 and 16 include additional lines for reference. The EIS threshold line indicates no additional degradation in the Kansas City dredging segment and 2 feet of degradation in all other segments.

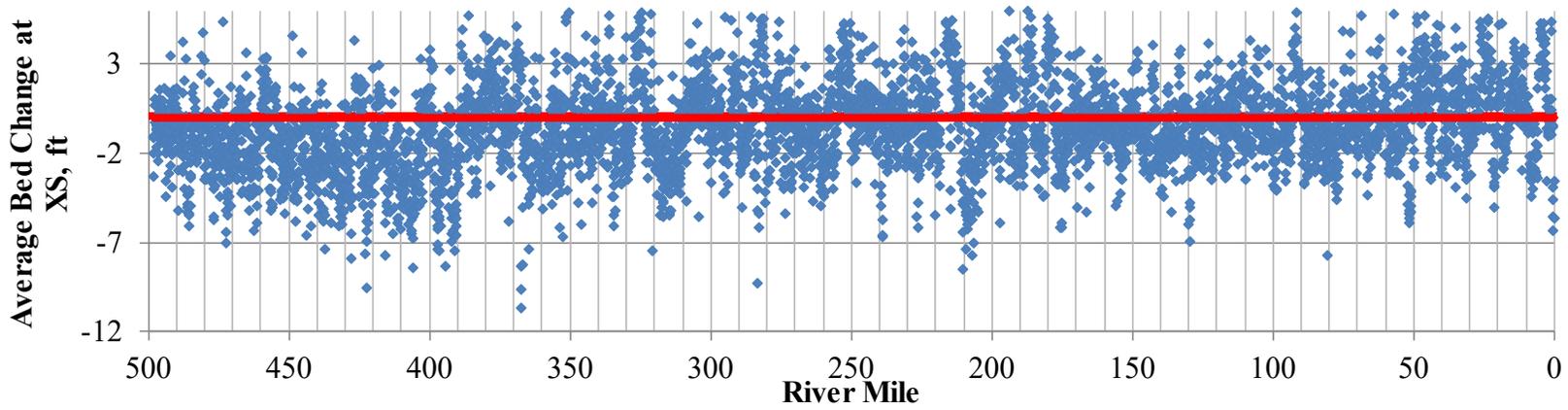


Figure 14. Average bed change 2009 to 2019 at individual cross sections. (Red line indicates no change from the 2009 survey).

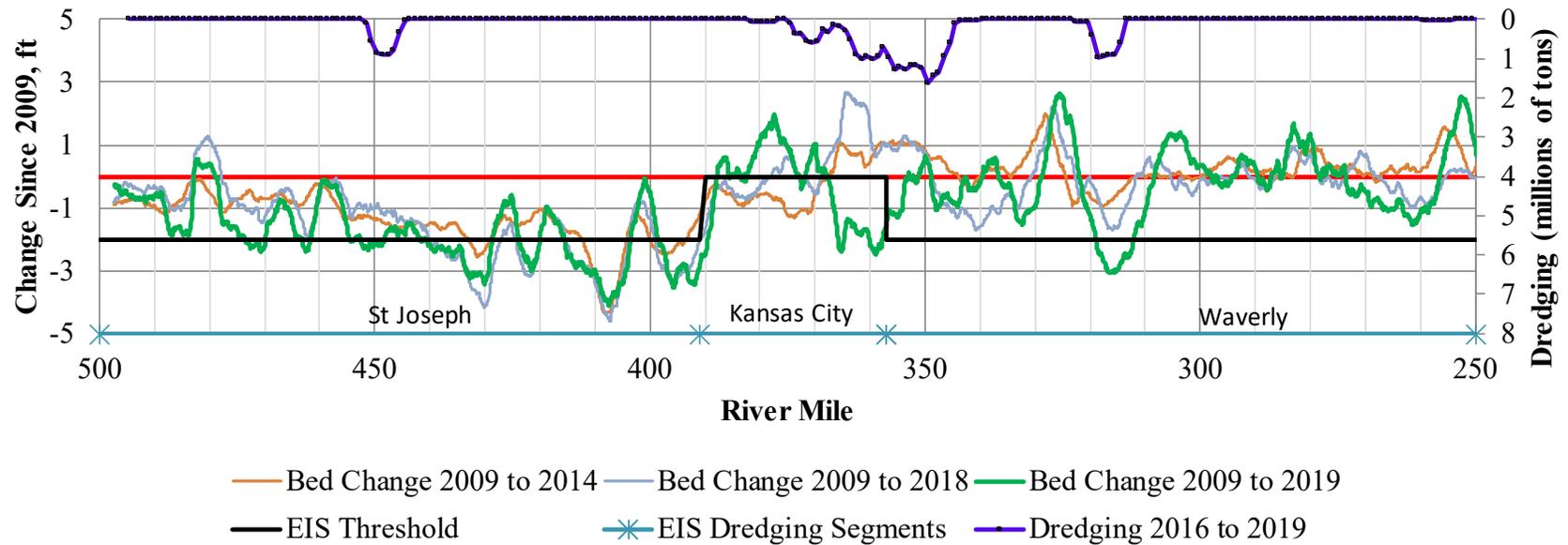


Figure 15. 5-mile moving average of bed change. Line represents the center of each 5-mile reach. (Red line indicates no change from the 2009 survey.)

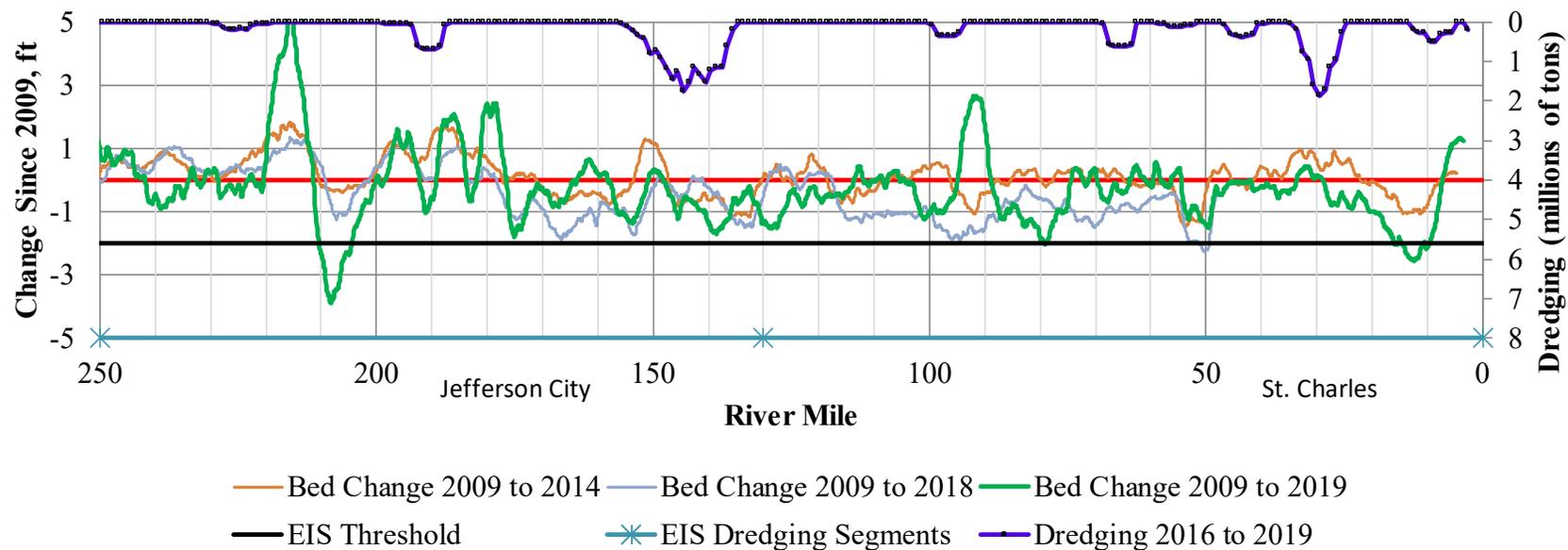


Figure 16. 5-mile moving average of bed change. Line represents the center of each 5-mile reach. (Red line indicates no change from the 2009 survey.)

Tables 1 and 2 present the average bed change over the larger segments and the hot-spots defined in the 2011 dredging EIS (USACE 2011) with the change from 2009 to 2014 and 2009 to 2018 provided for context.

Table 1. Average Bed Change over EIS Segments

Segment Name	St. Joseph	Kansas City	Waverly	Jefferson City	St. Charles
River Miles	391 to 498	357 to 391	250 to 357	130 to 250	0 to 130
2009 to 2014 (ft)	-1.40	-0.36	0.30	0.28	-0.04
2009 to 2018 (ft)	-1.62	0.18	-0.31	-0.17	-0.65
2009 to 2019 (ft)	-1.79	-0.38	-0.14	-0.04	0.06

Table 2. Average Bed Change over EIS Hotspot Reaches

Hotspot	Bed Change 2009 to 2014 (ft)	Bed Change 2009 to 2018 (ft)	Bed Change 2009 to 2019 (ft)
15 to 20	-0.16	-1.48	0.35
25 to 30	0.36	-0.69	1.07
30 to 35	0.87	0.41	0.03
90 to 95	-0.59	-1.14	2.47
95 to 100	0.54	-1.53	-1.04
140 to 145	-0.61	0.00	-0.75
145 to 150	0.87	-0.05	-0.20
355 to 360	0.97	0.96	-1.78
360 to 365	0.75	2.07	-1.75
365 to 370	-0.13	0.50	-0.08
370 to 375	-1.29	-0.35	-0.40
375 to 380	-0.55	0.15	1.96
380 to 385	-0.90	-0.86	-0.11
385 to 390	-0.33	-0.36	0.36
390 to 395	-2.07	-2.71	-3.36
445 to 450	-1.46	-1.30	-1.72
450 to 455	-1.36	-1.07	-2.04

As seen in Table 1, the St. Joseph reach was the most degradational of the larger authorized dredging segments, with an overall degradation of 1.79 feet since 2009. Of the hotspot locations, Hotspot 390 to 395 degraded the most, at 3.36 feet since 2009. Table 3 lists all of the individual 5-mile reaches on the lower Missouri River that have degraded more than the EIS threshold (any degradation in the Kansas City segment, 2 or more feet in any other segment since 2009).

Table 3. 5-mile Reaches with 2009 to 2018 Degradation Greater Than 2 ft. (Bed change in ft.)

RM Range	Bed Change						
76.5 to 81.5	-2.02	205.9 to 210.9	-3.83	311.9 to 316.9	-2.72	316.1 to 321.1	-2.33
76.6 to 81.6	-2.04	206 to 211	-3.73	312 to 317	-2.77	316.2 to 321.2	-2.31
76.7 to 81.7	-2.02	206.1 to 211.1	-3.67	312.1 to 317.1	-2.82	316.3 to 321.3	-2.20
202 to 207	-2.03	206.2 to 211.2	-3.66	312.2 to 317.2	-2.85	316.4 to 321.4	-2.04
202.1 to 207.1	-2.14	206.3 to 211.3	-3.58	312.3 to 317.3	-2.92	355.3 to 360.3	-2.00
202.2 to 207.2	-2.24	206.4 to 211.4	-3.56	312.4 to 317.4	-2.96	355.4 to 360.4	-2.14
202.3 to 207.3	-2.30	206.5 to 211.5	-3.51	312.5 to 317.5	-2.96	355.5 to 360.5	-2.23
202.4 to 207.4	-2.38	206.6 to 211.6	-3.37	312.6 to 317.6	-2.97	355.6 to 360.6	-2.22
202.5 to 207.5	-2.38	206.7 to 211.7	-3.10	312.7 to 317.7	-2.97	355.7 to 360.7	-2.30
202.6 to 207.6	-2.31	206.8 to 211.8	-2.93	312.8 to 317.8	-3.00	355.8 to 360.8	-2.20
202.7 to 207.7	-2.30	206.9 to 211.9	-2.81	312.9 to 317.9	-2.96	355.9 to 360.9	-2.18
202.8 to 207.8	-2.29	207 to 212	-2.76	313 to 318	-3.04	356 to 361	-2.25
202.9 to 207.9	-2.29	207.1 to 212.1	-2.68	313.1 to 318.1	-2.99	356.1 to 361.1	-2.32
203 to 208	-2.29	207.2 to 212.2	-2.57	313.2 to 318.2	-3.02	356.2 to 361.2	-2.33
203.1 to 208.1	-2.32	207.3 to 212.3	-2.47	313.3 to 318.3	-3.03	356.3 to 361.3	-2.41
203.2 to 208.2	-2.36	207.4 to 212.4	-2.38	313.4 to 318.4	-3.04	356.4 to 361.4	-2.44
203.3 to 208.3	-2.43	207.5 to 212.5	-2.31	313.5 to 318.5	-3.04	356.5 to 361.5	-2.47
203.4 to 208.4	-2.46	207.6 to 212.6	-2.30	313.6 to 318.6	-3.03	356.6 to 361.6	-2.44
203.5 to 208.5	-2.51	207.7 to 212.7	-2.24	313.7 to 318.7	-3.08	356.7 to 361.7	-2.35
203.6 to 208.6	-2.55	207.8 to 212.8	-2.13	313.8 to 318.8	-3.08	356.8 to 361.8	-2.31
203.7 to 208.7	-2.63	309.7 to 314.7	-2.11	313.9 to 318.9	-3.07	356.9 to 361.9	-2.33
203.8 to 208.8	-2.72	309.8 to 314.8	-2.20	314 to 319	-3.08	357 to 362	-2.34
203.9 to 208.9	-2.84	309.9 to 314.9	-2.31	314.1 to 319.1	-3.06	357.1 to 362.1	-2.28
204 to 209	-3.00	310 to 315	-2.35	314.2 to 319.2	-3.04	357.2 to 362.2	-2.28
204.1 to 209.1	-3.08	310.1 to 315.1	-2.41	314.3 to 319.3	-3.03	357.3 to 362.3	-2.22
204.2 to 209.2	-3.18	310.2 to 315.2	-2.45	314.4 to 319.4	-2.97	357.4 to 362.4	-2.22
204.3 to 209.3	-3.26	310.3 to 315.3	-2.46	314.5 to 319.5	-2.90	357.5 to 362.5	-2.20
204.4 to 209.4	-3.35	310.4 to 315.4	-2.55	314.6 to 319.6	-2.90	357.6 to 362.6	-2.02
204.5 to 209.5	-3.40	310.5 to 315.5	-2.56	314.7 to 319.7	-2.86	357.7 to 362.7	-1.91
204.6 to 209.6	-3.43	310.6 to 315.6	-2.57	314.8 to 319.8	-2.77	357.8 to 362.8	-1.84
204.7 to 209.7	-3.49	310.7 to 315.7	-2.58	314.9 to 319.9	-2.72	357.9 to 362.9	-1.80
204.8 to 209.8	-3.47	310.8 to 315.8	-2.57	315 to 320	-2.73	358 to 363	-1.73
204.9 to 209.9	-3.49	310.9 to 315.9	-2.52	315.1 to 320.1	-2.69	358.1 to 363.1	-1.68
205 to 210	-3.50	311 to 316	-2.51	315.2 to 320.2	-2.62	358.2 to 363.2	-1.66
205.1 to 210.1	-3.50	311.1 to 316.1	-2.45	315.3 to 320.3	-2.59	358.3 to 363.3	-1.70
205.2 to 210.2	-3.52	311.2 to 316.2	-2.45	315.4 to 320.4	-2.51	358.4 to 363.4	-1.69
205.3 to 210.3	-3.70	311.3 to 316.3	-2.49	315.5 to 320.5	-2.47	358.5 to 363.5	-1.70
205.4 to 210.4	-3.82	311.4 to 316.4	-2.54	315.6 to 320.6	-2.44	358.6 to 363.6	-1.73
205.5 to 210.5	-3.82	311.5 to 316.5	-2.59	315.7 to 320.7	-2.43	358.7 to 363.7	-1.74
205.6 to 210.6	-3.84	311.6 to 316.6	-2.67	315.8 to 320.8	-2.51	358.8 to 363.8	-1.75
205.7 to 210.7	-3.86	311.7 to 316.7	-2.69	315.9 to 320.9	-2.43	358.9 to 363.9	-1.81
205.8 to 210.8	-3.88	311.8 to 316.8	-2.73	316 to 321	-2.38	359 to 364	-1.80

RM Range	Bed Change						
359.1 to 364.1	-1.86	363.4 to 368.4	-1.88	385.4 to 390.4	-0.11	389.7 to 394.7	-3.38
359.2 to 364.2	-1.85	363.5 to 368.5	-1.77	385.5 to 390.5	-0.20	389.8 to 394.8	-3.40
359.3 to 364.3	-1.85	363.6 to 368.6	-1.58	385.6 to 390.6	-0.34	389.9 to 394.9	-3.36
359.4 to 364.4	-1.83	363.7 to 368.7	-1.43	385.7 to 390.7	-0.46	390 to 395	-3.36
359.5 to 364.5	-1.76	363.8 to 368.8	-1.28	385.8 to 390.8	-0.59	390.1 to 395.1	-3.39
359.6 to 364.6	-1.84	363.9 to 368.9	-1.14	385.9 to 390.9	-0.76	390.2 to 395.2	-3.40
359.7 to 364.7	-1.84	364 to 369	-1.09	386 to 391	-0.97	390.3 to 395.3	-3.37
359.8 to 364.8	-1.79	364.1 to 369.1	-0.95	386.1 to 391.1	-1.07	390.4 to 395.4	-3.35
359.9 to 364.9	-1.76	364.2 to 369.2	-0.93	386.2 to 391.2	-1.22	390.5 to 395.5	-3.27
360 to 365	-1.75	364.3 to 369.3	-0.75	386.3 to 391.3	-1.40	390.6 to 395.6	-3.17
360.1 to 365.1	-1.72	364.4 to 369.4	-0.62	386.4 to 391.4	-1.56	390.7 to 395.7	-3.06
360.2 to 365.2	-1.65	364.5 to 369.5	-0.59	386.5 to 391.5	-1.68	390.8 to 395.8	-2.98
360.3 to 365.3	-1.56	364.6 to 369.6	-0.45	386.6 to 391.6	-1.71	390.9 to 395.9	-2.89
360.4 to 365.4	-1.55	364.7 to 369.7	-0.34	386.7 to 391.7	-1.79	391 to 396	-2.81
360.5 to 365.5	-1.54	364.8 to 369.8	-0.28	386.8 to 391.8	-1.86	391.1 to 396.1	-2.84
360.6 to 365.6	-1.52	364.9 to 369.9	-0.21	386.9 to 391.9	-1.93	391.2 to 396.2	-2.85
360.7 to 365.7	-1.48	365 to 370	-0.08	387 to 392	-2.02	391.3 to 396.3	-2.84
360.8 to 365.8	-1.58	365.1 to 370.1	-0.05	387.1 to 392.1	-2.17	391.4 to 396.4	-2.79
360.9 to 365.9	-1.56	365.2 to 370.2	-0.05	387.2 to 392.2	-2.28	391.5 to 396.5	-2.84
361 to 366	-1.45	365.3 to 370.3	-0.07	387.3 to 392.3	-2.38	391.6 to 396.6	-2.83
361.1 to 366.1	-1.42	369.4 to 374.4	-0.11	387.4 to 392.4	-2.48	391.7 to 396.7	-2.89
361.2 to 366.2	-1.40	369.5 to 374.5	-0.17	387.5 to 392.5	-2.50	391.8 to 396.8	-2.88
361.3 to 366.3	-1.38	369.6 to 374.6	-0.20	387.6 to 392.6	-2.55	391.9 to 396.9	-2.94
361.4 to 366.4	-1.38	369.7 to 374.7	-0.26	387.7 to 392.7	-2.55	392 to 397	-2.94
361.5 to 366.5	-1.37	369.8 to 374.8	-0.33	387.8 to 392.8	-2.48	392.1 to 397.1	-2.89
361.6 to 366.6	-1.39	369.9 to 374.9	-0.35	387.9 to 392.9	-2.49	392.2 to 397.2	-2.91
361.7 to 366.7	-1.44	370 to 375	-0.40	388 to 393	-2.49	392.3 to 397.3	-2.93
361.8 to 366.8	-1.46	370.1 to 375.1	-0.20	388.1 to 393.1	-2.49	392.4 to 397.4	-2.95
361.9 to 366.9	-1.49	370.2 to 375.2	-0.01	388.2 to 393.2	-2.54	392.5 to 397.5	-3.02
362 to 367	-1.60	370.3 to 375.3	-0.02	388.3 to 393.3	-2.63	392.6 to 397.6	-3.06
362.1 to 367.1	-1.77	370.7 to 375.7	-0.03	388.4 to 393.4	-2.82	392.7 to 397.7	-3.16
362.2 to 367.2	-1.95	370.8 to 375.8	-0.01	388.5 to 393.5	-2.91	392.8 to 397.8	-3.29
362.3 to 367.3	-2.17	380 to 385	-0.11	388.6 to 393.6	-2.96	392.9 to 397.9	-3.39
362.4 to 367.4	-2.29	380.1 to 385.1	-0.16	388.7 to 393.7	-2.98	393 to 398	-3.45
362.5 to 367.5	-2.27	380.2 to 385.2	-0.17	388.8 to 393.8	-3.03	393.1 to 398.1	-3.52
362.6 to 367.6	-2.38	380.5 to 385.5	-0.07	388.9 to 393.9	-3.15	393.2 to 398.2	-3.54
362.7 to 367.7	-2.41	380.6 to 385.6	-0.08	389 to 394	-3.20	393.3 to 398.3	-3.55
362.8 to 367.8	-2.40	380.7 to 385.7	-0.11	389.1 to 394.1	-3.23	393.4 to 398.4	-3.45
362.9 to 367.9	-2.37	380.8 to 385.8	-0.09	389.2 to 394.2	-3.28	393.5 to 398.5	-3.42
363 to 368	-2.33	380.9 to 385.9	-0.11	389.3 to 394.3	-3.43	393.6 to 398.6	-3.34
363.1 to 368.1	-2.23	381 to 386	-0.01	389.4 to 394.4	-3.45	393.7 to 398.7	-3.30
363.2 to 368.2	-2.17	382.9 to 387.9	-0.05	389.5 to 394.5	-3.43	393.8 to 398.8	-3.26
363.3 to 368.3	-1.99	383 to 388	-0.06	389.6 to 394.6	-3.41	393.9 to 398.9	-3.22

RM Range	Bed Change						
394 to 399	-3.17	403.2 to 408.2	-3.50	407.5 to 412.5	-2.99	411.8 to 416.8	-2.57
394.1 to 399.1	-3.16	403.3 to 408.3	-3.63	407.6 to 412.6	-2.98	411.9 to 416.9	-2.51
394.2 to 399.2	-3.12	403.4 to 408.4	-3.69	407.7 to 412.7	-3.02	412 to 417	-2.52
394.3 to 399.3	-2.95	403.5 to 408.5	-3.77	407.8 to 412.8	-3.03	412.1 to 417.1	-2.52
394.4 to 399.4	-2.86	403.6 to 408.6	-3.81	407.9 to 412.9	-3.05	412.2 to 417.2	-2.53
394.5 to 399.5	-2.67	403.7 to 408.7	-3.79	408 to 413	-3.07	412.3 to 417.3	-2.56
394.6 to 399.6	-2.70	403.8 to 408.8	-3.77	408.1 to 413.1	-3.07	412.4 to 417.4	-2.53
394.7 to 399.7	-2.60	403.9 to 408.9	-3.76	408.2 to 413.2	-3.14	412.5 to 417.5	-2.58
394.8 to 399.8	-2.47	404 to 409	-3.70	408.3 to 413.3	-3.07	412.6 to 417.6	-2.50
394.9 to 399.9	-2.39	404.1 to 409.1	-3.66	408.4 to 413.4	-3.08	412.7 to 417.7	-2.38
395 to 400	-2.38	404.2 to 409.2	-3.71	408.5 to 413.5	-3.05	412.8 to 417.8	-2.30
395.1 to 400.1	-2.34	404.3 to 409.3	-3.76	408.6 to 413.6	-3.01	412.9 to 417.9	-2.20
395.2 to 400.2	-2.23	404.4 to 409.4	-3.85	408.7 to 413.7	-2.99	413 to 418	-2.11
395.3 to 400.3	-2.23	404.5 to 409.5	-3.88	408.8 to 413.8	-3.01	417.6 to 422.6	-2.10
395.4 to 400.4	-2.20	404.6 to 409.6	-3.90	408.9 to 413.9	-3.07	417.7 to 422.7	-2.27
395.5 to 400.5	-2.18	404.7 to 409.7	-4.01	409 to 414	-3.07	417.8 to 422.8	-2.37
395.6 to 400.6	-2.18	404.8 to 409.8	-4.01	409.1 to 414.1	-3.08	417.9 to 422.9	-2.45
395.7 to 400.7	-2.19	404.9 to 409.9	-4.04	409.2 to 414.2	-3.04	418 to 423	-2.54
395.8 to 400.8	-2.14	405 to 410	-4.09	409.3 to 414.3	-2.98	418.1 to 423.1	-2.59
395.9 to 400.9	-2.08	405.1 to 410.1	-4.01	409.4 to 414.4	-2.93	418.2 to 423.2	-2.67
396 to 401	-2.02	405.2 to 410.2	-3.96	409.5 to 414.5	-2.90	418.3 to 423.3	-2.65
401 to 406	-2.04	405.3 to 410.3	-3.98	409.6 to 414.6	-2.86	418.4 to 423.4	-2.73
401.1 to 406.1	-2.20	405.4 to 410.4	-3.94	409.7 to 414.7	-2.81	418.5 to 423.5	-2.69
401.2 to 406.2	-2.30	405.5 to 410.5	-3.96	409.8 to 414.8	-2.82	418.6 to 423.6	-2.79
401.3 to 406.3	-2.37	405.6 to 410.6	-3.95	409.9 to 414.9	-2.81	418.7 to 423.7	-2.86
401.4 to 406.4	-2.56	405.7 to 410.7	-3.92	410 to 415	-2.75	418.8 to 423.8	-2.94
401.5 to 406.5	-2.77	405.8 to 410.8	-3.93	410.1 to 415.1	-2.78	418.9 to 423.9	-2.98
401.6 to 406.6	-2.89	405.9 to 410.9	-3.84	410.2 to 415.2	-2.77	419 to 424	-3.00
401.7 to 406.7	-2.98	406 to 411	-3.78	410.3 to 415.3	-2.74	419.1 to 424.1	-2.96
401.8 to 406.8	-2.99	406.1 to 411.1	-3.69	410.4 to 415.4	-2.79	419.2 to 424.2	-2.94
401.9 to 406.9	-3.00	406.2 to 411.2	-3.70	410.5 to 415.5	-2.80	419.3 to 424.3	-2.87
402 to 407	-3.08	406.3 to 411.3	-3.72	410.6 to 415.6	-2.88	419.4 to 424.4	-2.81
402.1 to 407.1	-3.20	406.4 to 411.4	-3.58	410.7 to 415.7	-2.86	419.5 to 424.5	-2.75
402.2 to 407.2	-3.28	406.5 to 411.5	-3.42	410.8 to 415.8	-2.83	419.6 to 424.6	-2.67
402.3 to 407.3	-3.39	406.6 to 411.6	-3.30	410.9 to 415.9	-2.90	419.7 to 424.7	-2.60
402.4 to 407.4	-3.38	406.7 to 411.7	-3.27	411 to 416	-2.93	419.8 to 424.8	-2.55
402.5 to 407.5	-3.44	406.8 to 411.8	-3.32	411.1 to 416.1	-2.90	419.9 to 424.9	-2.64
402.6 to 407.6	-3.44	406.9 to 411.9	-3.36	411.2 to 416.2	-2.81	420 to 425	-2.72
402.7 to 407.7	-3.41	407 to 412	-3.30	411.3 to 416.3	-2.72	420.1 to 425.1	-2.69
402.8 to 407.8	-3.41	407.1 to 412.1	-3.23	411.4 to 416.4	-2.68	420.2 to 425.2	-2.68
402.9 to 407.9	-3.38	407.2 to 412.2	-3.18	411.5 to 416.5	-2.72	420.3 to 425.3	-2.62
403 to 408	-3.41	407.3 to 412.3	-3.09	411.6 to 416.6	-2.67	420.4 to 425.4	-2.55
403.1 to 408.1	-3.45	407.4 to 412.4	-3.11	411.7 to 416.7	-2.64	420.5 to 425.5	-2.50

RM Range	Bed Change						
420.6 to 425.6	-2.42	429.7 to 434.7	-3.08	434 to 439	-2.31	438.4 to 443.4	-2.01
420.7 to 425.7	-2.36	429.8 to 434.8	-3.18	434.1 to 439.1	-2.24	438.6 to 443.6	-2.01
420.8 to 425.8	-2.31	429.9 to 434.9	-3.17	434.2 to 439.2	-2.31	438.8 to 443.8	-2.07
420.9 to 425.9	-2.28	430 to 435	-3.16	434.3 to 439.3	-2.29	438.9 to 443.9	-2.04
421 to 426	-2.23	430.1 to 435.1	-3.26	434.4 to 439.4	-2.37	439 to 444	-2.06
421.1 to 426.1	-2.15	430.2 to 435.2	-3.22	434.5 to 439.5	-2.35	439.1 to 444.1	-2.07
421.2 to 426.2	-2.14	430.3 to 435.3	-3.20	434.6 to 439.6	-2.39	445.8 to 450.8	-2.05
421.3 to 426.3	-2.04	430.4 to 435.4	-3.14	434.7 to 439.7	-2.39	445.9 to 450.9	-2.09
426.2 to 431.2	-2.10	430.5 to 435.5	-3.12	434.8 to 439.8	-2.33	446 to 451	-2.11
426.3 to 431.3	-2.25	430.6 to 435.6	-3.05	434.9 to 439.9	-2.35	446.1 to 451.1	-2.16
426.4 to 431.4	-2.36	430.7 to 435.7	-3.06	435 to 440	-2.31	446.2 to 451.2	-2.19
426.5 to 431.5	-2.45	430.8 to 435.8	-3.01	435.1 to 440.1	-2.26	446.3 to 451.3	-2.16
426.6 to 431.6	-2.57	430.9 to 435.9	-2.95	435.2 to 440.2	-2.27	446.4 to 451.4	-2.15
426.7 to 431.7	-2.79	431 to 436	-2.97	435.3 to 440.3	-2.22	446.5 to 451.5	-2.16
426.8 to 431.8	-3.02	431.1 to 436.1	-2.89	435.4 to 440.4	-2.29	446.6 to 451.6	-2.17
426.9 to 431.9	-3.09	431.2 to 436.2	-2.80	435.5 to 440.5	-2.25	446.7 to 451.7	-2.17
427 to 432	-3.10	431.3 to 436.3	-2.72	435.6 to 440.6	-2.26	446.8 to 451.8	-2.20
427.1 to 432.1	-3.17	431.4 to 436.4	-2.66	435.7 to 440.7	-2.26	446.9 to 451.9	-2.13
427.2 to 432.2	-3.23	431.5 to 436.5	-2.59	435.8 to 440.8	-2.27	447 to 452	-2.11
427.3 to 432.3	-3.28	431.6 to 436.6	-2.48	435.9 to 440.9	-2.24	447.1 to 452.1	-2.11
427.4 to 432.4	-3.37	431.7 to 436.7	-2.36	436 to 441	-2.26	447.2 to 452.2	-2.09
427.5 to 432.5	-3.45	431.8 to 436.8	-2.34	436.1 to 441.1	-2.26	447.3 to 452.3	-2.10
427.6 to 432.6	-3.43	431.9 to 436.9	-2.25	436.2 to 441.2	-2.28	447.4 to 452.4	-2.16
427.7 to 432.7	-3.37	432 to 437	-2.26	436.3 to 441.3	-2.29	447.5 to 452.5	-2.13
427.8 to 432.8	-3.27	432.1 to 437.1	-2.22	436.4 to 441.4	-2.34	447.6 to 452.6	-2.20
427.9 to 432.9	-3.25	432.2 to 437.2	-2.30	436.5 to 441.5	-2.38	447.7 to 452.7	-2.20
428 to 433	-3.17	432.3 to 437.3	-2.34	436.6 to 441.6	-2.41	447.8 to 452.8	-2.26
428.1 to 433.1	-3.16	432.4 to 437.4	-2.32	436.7 to 441.7	-2.39	447.9 to 452.9	-2.22
428.2 to 433.2	-3.11	432.5 to 437.5	-2.32	436.8 to 441.8	-2.34	448 to 453	-2.20
428.3 to 433.3	-3.08	432.6 to 437.6	-2.35	436.9 to 441.9	-2.31	448.1 to 453.1	-2.21
428.4 to 433.4	-3.12	432.7 to 437.7	-2.36	437 to 442	-2.31	448.2 to 453.2	-2.15
428.5 to 433.5	-3.06	432.8 to 437.8	-2.42	437.1 to 442.1	-2.31	448.3 to 453.3	-2.08
428.6 to 433.6	-3.05	432.9 to 437.9	-2.41	437.2 to 442.2	-2.29	448.4 to 453.4	-2.13
428.7 to 433.7	-3.07	433 to 438	-2.43	437.3 to 442.3	-2.25	448.5 to 453.5	-2.16
428.8 to 433.8	-3.10	433.1 to 438.1	-2.44	437.4 to 442.4	-2.22	448.6 to 453.6	-2.31
428.9 to 433.9	-3.13	433.2 to 438.2	-2.46	437.5 to 442.5	-2.19	448.7 to 453.7	-2.34
429 to 434	-3.16	433.3 to 438.3	-2.53	437.6 to 442.6	-2.16	448.8 to 453.8	-2.32
429.1 to 434.1	-3.16	433.4 to 438.4	-2.54	437.7 to 442.7	-2.19	448.9 to 453.9	-2.29
429.2 to 434.2	-3.12	433.5 to 438.5	-2.52	437.8 to 442.8	-2.10	449 to 454	-2.28
429.3 to 434.3	-3.13	433.6 to 438.6	-2.39	437.9 to 442.9	-2.09	449.1 to 454.1	-2.27
429.4 to 434.4	-3.06	433.7 to 438.7	-2.40	438 to 443	-2.04	449.2 to 454.2	-2.24
429.5 to 434.5	-3.05	433.8 to 438.8	-2.39	438.1 to 443.1	-2.05	449.3 to 454.3	-2.22
429.6 to 434.6	-3.06	433.9 to 438.9	-2.39	438.2 to 443.2	-2.05	449.4 to 454.4	-2.23

RM Range	Bed Change	RM Range	Bed Change
449.5 to 454.5	-2.25	467.8 to 472.8	-2.30
449.6 to 454.6	-2.30	467.9 to 472.9	-2.32
449.7 to 454.7	-2.21	468 to 473	-2.36
449.8 to 454.8	-2.18	468.1 to 473.1	-2.36
449.9 to 454.9	-2.11	468.2 to 473.2	-2.38
450 to 455	-2.04	468.3 to 473.3	-2.32
451 to 456	-2.03	468.4 to 473.4	-2.33
451.3 to 456.3	-2.06	468.5 to 473.5	-2.28
451.4 to 456.4	-2.07	468.6 to 473.6	-2.12
451.5 to 456.5	-2.08	468.7 to 473.7	-2.06
451.6 to 456.6	-2.07	468.8 to 473.8	-2.06
451.7 to 456.7	-2.05	468.9 to 473.9	-2.07
451.8 to 456.8	-2.01	469 to 474	-2.13
451.9 to 456.9	-2.05	469.1 to 474.1	-2.17
452 to 457	-2.01	469.2 to 474.2	-2.20
459.3 to 464.3	-2.13	469.3 to 474.3	-2.20
459.4 to 464.4	-2.22	469.4 to 474.4	-2.21
459.5 to 464.5	-2.27	469.5 to 474.5	-2.21
459.6 to 464.6	-2.33	469.6 to 474.6	-2.24
459.7 to 464.7	-2.34	469.7 to 474.7	-2.26
459.8 to 464.8	-2.35	469.8 to 474.8	-2.22
459.9 to 464.9	-2.34	469.9 to 474.9	-2.25
460 to 465	-2.41	470 to 475	-2.28
460.1 to 465.1	-2.39	470.1 to 475.1	-2.25
460.2 to 465.2	-2.37	470.2 to 475.2	-2.18
460.3 to 465.3	-2.27	470.3 to 475.3	-2.15
460.4 to 465.4	-2.24	470.4 to 475.4	-2.12
460.5 to 465.5	-2.21	470.5 to 475.5	-2.14
460.6 to 465.6	-2.19	470.6 to 475.6	-2.13
467.4 to 472.4	-2.09	470.7 to 475.7	-2.12
467.5 to 472.5	-2.19	470.8 to 475.8	-2.10
467.6 to 472.6	-2.24	470.9 to 475.9	-2.07
467.7 to 472.7	-2.32	471.8 to 476.8	-2.00

Most of the reaches in Table 3 are adjacent to, and form a contiguous reach with, other reaches that have likewise exceeded the degradation threshold. Table 4 lists the upper and lower river mile extents within which all 5-mile reaches have exceeded the degradation thresholds.

Table 4. Reaches Exceeding Degradation Threshold

RM 76.5 to 81.7
RM 202 to 212.8
RM 309.7 to 321.4
RM 355.3 to 375.8
RM 379.9 to 444.1
RM 445.8 to 457
RM 459.3 to 465.6
RM 467.4 to 475.9

6. Upstream and Downstream Buffers. USACE (2020) indicates that at medium flows the most concentrated effects of dredging occur within 3.3 miles upstream and 6.5 miles downstream of the dredging site. Incorporating these buffers to prevent damage in degraded areas involves adding the respective distances upstream (6.5 miles) and downstream (3.3 miles) of the degraded reaches. Applying these buffer distances to the reaches in Table 4 yields the overall reaches in Table 5. All river miles within the limits set forth in Table 5 include either a 5-mile reach that has exceeded the degradation threshold or fall in the buffer of such a reach.

Table 5. Reaches Exceeding the Degradation Threshold with Upstream and Downstream Buffers

RM 73.2 to 88.2
RM 198.7 to 219.3
RM 306.4 to 327.9
RM 352 to 482.4

Comparison of Table 5 with dredging locations in Figure 15 and 16 indicate that these reaches incorporate large portions of the St. Joseph, Kansas City, and Waverly dredging segments including reaches where dredging occurred in the current permit cycle, and a smaller portions of the Jefferson City and St. Charles segment where no dredging occurred in the current permit cycle.

7. Summary. The 2019 survey evinces continued degradation on the lower 500-miles of the Missouri River compared to the 2014 survey, with an additional 23 million cubic yards of degradation since 2014, and a total loss of 35.8 million cubic yards since 2009.

From RM 500 to RM 50, the river further degraded from 2018 to 2019, which is consistent with other flood periods. Over the full 500 miles, however, the river gained volume, due to the stark depositional trend in the lower 50 miles. Determining the cause of this deposition is beyond the scope of this memo.

The St. Joseph segment indicates a continuing degradation trend consistent with an upstream-migrating headcut. The downstream portion of the Kansas City segment (downstream from the Kansas River) exhibits significant new degradation. Numerous 5-mile reaches have exceeded

the degradation thresholds (no additional degradation in the Kansas City segment and no more than 2 feet in all other segments). Applying the upstream and downstream buffers given in USACE (2020) to the reaches exceeding the thresholds incorporates significant portions of the St. Joseph (91.4 miles), Kansas City (34 miles), and Waverly (26.5 miles) segments including areas where dredging occurred in the current permit cycle, and portions of the Jefferson City (20.6 miles) and St. Charles (15 miles) segment where no dredging has occurred in the current permit cycle.

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References

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