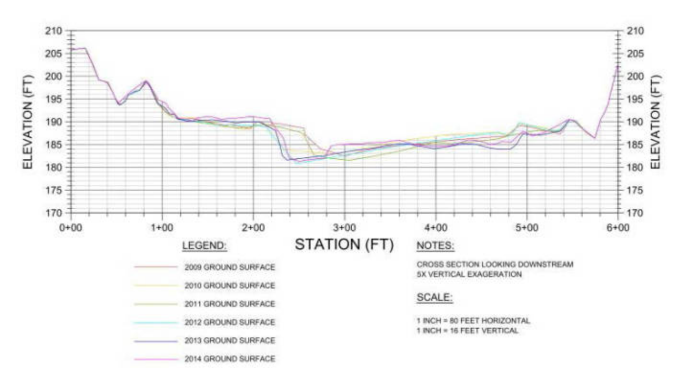
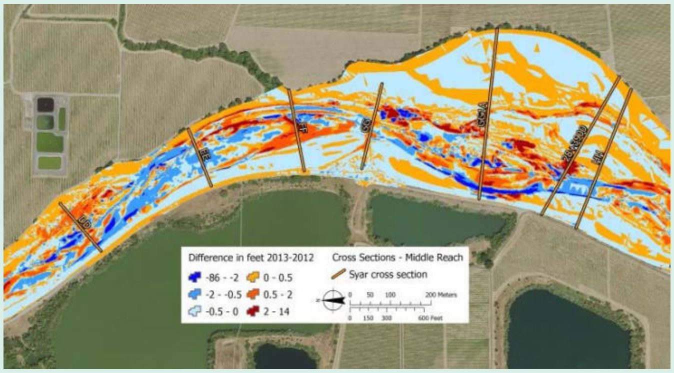
FINAL TECHNICAL REPORT ◦ MAY 2016

Sonoma County Aggregate Resources Management Plan: 2009–2014 Russian River Monitoring Results





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Cover graphics:

Upper left: Photographic view of the Lower Alexander Valley Reach near the Alexander Valley Road bridge (taken June 10, 2015 by Stillwater Sciences).

Top right: Comparison of surveyed channel cross-sections at station 51+0000 along the Lower Alexander Valley Reach (graphic produced by Stillwater Sciences).

Bottom left: Map-view comparison of 2012 and 2013 topographic surfaces near station 28+0900 along the Middle Reach (graphic produced by Stillwater Sciences).

Bottom right: Photographic view of the S-8 gravel bar downstream of the Highway 128 bridge in the Lower Alexander Valley Reach (taken June 10, 2015 by Stillwater Sciences).

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Executive Summary

This report has been prepared by Stillwater Sciences on behalf of the County of Sonoma's Permit and Resource Management Department (PRMD). The purpose of this report is to provide the PRMD with objective, multi-disciplinary, scientific analysis to help them review, analyze, and report on annual, in-channel gravel mining plans and monitoring data. In addition, the information herein will assist the County evaluate the effectiveness of mining methods, standards, and mitigations, and assess the status and trends of the Russian River within each mining reach. This report describes channel conditions within each of the two monitoring reaches—the Lower Alexander Valley and Middle reaches (Figure 1)—with active and/or proposed surface mining operations during the 2009–2014 time period. Because mining in the reaches has not been active since before 2009, this report does not directly evaluate the effects of mining activities on channel morphology. This report also differs from past monitoring reports by not including evaluations of groundwater-level and aquatic habitat changes, as these data were not collected by the gravel operators during the reporting period.

In-channel gravel mining along the Russian River over the past decades has been limited to the Upper Alexander Valley, Lower Alexander Valley, and Middle reaches. Gravel mining has not occurred in these three reaches since 2006, 2002, and 2007, respectively.

Sediment transport remains quite active in the Lower Alexander Valley and Middle reaches despite the influences of various land-use activities that alter run-off and sediment delivery processes. During the 2009–2014 period, the potential for geomorphic change during larger run-off events was limited to water years (WYs) 2010, 2011, and 2013. Evaluation of changes in cross-sectional areas at nine cross-sections in the Lower Alexander Valley Reach and 27 cross-sections in the Middle Reach indicated a modest amount of net sediment aggradation. However, results from evaluation of 2009–2013/2014 changes in thalweg and water-surface elevations indicate net erosion from the two reaches. Bank retreat rates and quantities have generally outpaced bank/bar accretion at the cross-sections in both reaches. Evaluation of volumetric changes in sediment storage reveal conflicting results when applying two different methods: one using the cross-sectional areas and the second using spatially comprehensive topographic surfaces. The former method estimated net accumulation of sediment (*i.e.*, aggradation) in both reaches, while the latter and spatially more comprehensive method estimated net loss of sediment (*i.e.*, degradation) from both reaches.

The overall trends of accumulation and loss in the two monitoring reaches were found to vary considerably during the 2009–2014 period depending on the spatial and temporal extents that each data source represented, *and* on the particular evaluation method employed. Within those portions of the two monitoring reaches that were monitored during 2009–2014, the overall finding is that they experienced net sediment loss on the order of -10,000 to -100,000 cubic yards (using the topographic surfaces as opposed to the cross-sections), with attendant lowering of the thalweg elevation and widening of the active channel.

We recommend continued monitoring of channel topography to quantify and track geomorphic changes over time. We further recommend that all datasets provided to the SRC for evaluation in future monitoring reports should include sufficient technical information documenting specific data collection and processing methods. An uncertainty analysis should also be performed by the SRC to assess the uncertainty of the field-based measurements, which will provide needed confidence to the computed results.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym or abbreviation [A]	Definition
%	percent
AEA	average end area
ac	acres
ARM	Aggregate Resource Management
AV	Alexander Valley
cfs	cubic feet per second
CGS	California Geological Survey
DEIR	Draft Environmental Impact Report
DTM	digital terrain model
ENSO	El Niño–Southern Oscillation
ft	feet
GIS	geographic information system
in	inch
km	kilometer
m	meter
mi	mile
mm	millimeter
N/A	not applicable
NAD	North American Datum
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
PRMD	Permit and Resource Management Department (of Sonoma County)
R^2	coefficient of determination
RM	river mile
SED	surface elevation differencing
SMARA	Surface Mining and Reclamation Act
SMRO	Surface Mining and Reclamation Ordinance
SRC	Scientific Review Consultants
TIN	triangular irregular network
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
WSEL	water surface elevation
WY	water year
yd	yard
yr	year

Table footnotes:
[A] Symbology used in mathematical equations is defined in the text adjacent to the associated equation(s).

GLOSSARY OF KEY TERMS

Keyword	Definition
aggradation	The process involving the deposition of sediment on the landscape, but most commonly in a stream channel.
alluvial	Having originated through the transport by and deposition from running water.
AutoCAD	A commercial software application used for 2D and 3D computer-aided design (CAD) and drafting developed by Autodesk.
bank/bar accretion	The process of lateral migration of a riverbank and/or point bar toward the river centerline and away from the adjacent floodplain driven by sediment deposition.
bank retreat	The process of lateral migration of a riverbank away from the river centerline and toward the adjacent floodplain driven by sediment erosion.
bedload	Sediment transporting along the streambed by rolling, sliding, and saltating (jumping). Includes coarser grains larger than 0.0625 mm in diameter, such as sand, gravel, cobbles, and boulders; however, sand-sized particles can often be transported as suspended bed material load in higher energy flows, thus making them part of the bed material load.
bulk density	The mass of a material (rock or sediments) divided by the total volume they occupy [in units of mass per length cubed, *i.e.*, M/L^3].
channel	Natural or artificial waterway of perceptible extent that periodically or continuously contains moving water.
channel migration	Lateral movement of the active channel, usually in response to large flow events.
bankfull discharge	Discharge that just overtops a river or stream channel banks onto the adjacent floodplain. Bankfull discharges commonly occur approximately every 1 to 2 years for most humid-region rivers of the world, with a median recurrence interval of about 1.5 years and is generally considered to be the primary channel-forming discharge in humid environments. This common assumption does not consistently apply in the Russian River watershed.
cobble	Substrate particles 64–256 mm in diameter. Often subclassified as small (64–128 mm) and large (128–256 mm) cobble.
deposition	The process whereby Earth materials accumulate, which is commonly achieved by the mechanical settling of sediment from suspension in water or the accumulation of coarse materials as delivered by ice, water, or wind.
discharge (stream)	The volume of flow passing a stream cross section in a unit of time [unit of L^3/T].
erosion	The process whereby Earth materials are loosened, dissolved, or worn away, and simultaneously transported away from the material source by natural agencies, such as abrasion, solution, transportation, and weathering, but is most commonly achieved mechanically by ice, water, or wind, or even biogenic agents (*e.g.*, tree throw, gopher burrowing).
geographic information system (GIS)	A computer system capable of storing and manipulating spatial data. A geographic information system has four major components: a data input subsystem, a data storage and retrieval subsystem, a data manipulation and analysis subsystem, and a data reporting subsystem.
gravel	Substrate particles 2–64 mm in diameter.
incision	The process whereby a channel (stream or trench) vertically erodes downward resulting in a lower bed elevation.
riparian vegetation	Vegetation growing on or near the banks of a stream or other body of water in soils that exhibit some wetness characteristics during some portion of the growing season.
sand	Substrate particles 0.062–2 mm in diameter.

Keyword	Definition
sediment	Fragments of rock, soil, and organic material transported and deposited in beds by wind, water, or other natural phenomena.
sediment delivery	The process whereby sediment is transported from a production source to a given location in the drainage network. The *sediment delivery rate* is the total delivery over a given time period; usually reported in mass per year [*M/T*].
sediment recharge	The total amount of sediment transported to a point over a given time period; usually reported in mass per year [*M/T*].
sediment storage	The process by which sediment is delivered to a location and is then stored there for a period of time (*e.g.*, days to millennium, or even beyond).
sediment transport	The process involving the movement of sediment.
silt	Substrate particles 0.004–0.062 mm in diameter.
Suspended-sediment load	Sediment that transports continuously in suspension within the water column. Under most flow conditions, commonly comprises particles finer than about 0.0625 mm (*i.e.*, silt and clay-sized particles), but can also include coarser sediment (*e.g.*, sand) in higher energy flows.
thalweg	A longitudinal line following the deepest points along the streambed.
water surface elevation	The elevation of the water surface in an open channel.
water year (WY)	The 12-month period for any given year from October 1 through September 30.

UNIT CONVERSION FACTORS

Most values presented in this report are reported in the U.S. Customary system. This table presents conversion factors of the commonly used U.S. Customary system units to metric units.

U.S. Customary Units	Multiply by	Metric Units
in (inches)	2.54	cm (centimeters)
ft (feet)	0.3048	m (meters)
mi (mile)	1.609	km (kilometers)
mi^2 (square miles)	2.59	km^2 (square kilometers)
ft^3 (cubic feet)	0.028	m^3 (cubic meters)
af (acre feet)	1,233.5	m^3 (cubic meters)
yd^3 (cubic yards)	0.765	m^3 (cubic meters)
tn (tons)	0.907	t (tonnes)

1 INTRODUCTION

The County of Sonoma's Permit and Resource Management Department (PRMD) regulates surface mining activities under the Surface Mining and Reclamation Ordinance (SMRO), Chapter 26A of the county's zoning code, which complies with the Surface Mining and Reclamation Act of 1975 (SMARA) (California Public Resources Code, Division 2, Chapter 9, Section 2710 et seq.). The purpose of SMRO is to protect the quality of the County's environment, to protect against land uses incompatible with preservation and utilization of natural resources, and to assure the community of an adequate supply of these resources for present and future generations. Surface mining operations must also comply with the County's Aggregate Resource Management (ARM) Plan (Sonoma County 2010), which is intended to meet future aggregate needs while promoting their efficient use and avoiding or minimizing significant impacts to the environment. The ARM Plan includes a comprehensive mitigation and monitoring program to allow the PRMD to verify compliance with permit conditions, operation standards, and reclamation plans. Based on review of annual reports submitted by each operator, the PRMD provides an Annual Report to the entire Planning Commission and Board of Supervisors that presents an account of the year's mining-compliance activities.

Stillwater Sciences was contracted to serve as the PRMD's Scientific Review Consultants (SRC) to assist in development of their Annual Report. Specifically, the SRC is charged with providing the PRMD with objective, multi-disciplinary, scientific analysis to help review, analyze, and report on annual mining plans and monitoring data. In addition, the information contained in the annual report will be used by the County for the purpose of evaluating the effectiveness of mining methods, standards, and mitigations, and assess the status and trends of the Russian River within each mining reach.

Stillwater Sciences has prepared this Monitoring Report to provide the PRMD with the following:

- Presentation of the results of instream monitoring activities for each year of mining, including the past non-mining years of 2009–2014, since the last annual Monitoring Report was produced (Entrix 2010);
- Description of the status and trends within the Middle Reach and Lower Alexander Valley Reach with respect to channel morphology, aquatic and riparian habitat, and lateral bank erosion;
- Evaluation of the effectiveness of existing mining methods, mitigations, and standards at each instream mining site at avoiding or minimizing adverse impacts, meeting the ARM Plan and site-specific objectives, complying with mining standards, and site-specific performance standards adopted with the permit approvals within each reach, as appropriate; and
- Recommendations, as appropriate, of continuing existing mining methodologies, mitigations, and standards or revising them to better achieve the goal of adverse environmental impacts while meeting ARM Plan and permit objectives.

This report thus describes channel conditions within each of the two monitoring reaches with active and/or proposed surface mining operations (Table 1), but does not directly evaluate the effects of mining activities as none occurred during the 2009–2014 time period for which this report is based. Locations of the two reaches are shown in Figure 1.

Table 1. Reaches of the Russian River assessed in this Monitoring Report.

Monitoring Reach	Approx. River Mile (RM) Segment [A]	Segment Landmarks	Operator
Middle	23.0–33.9	Wohler Rd near town of Forestville–Digger Bend (near City of Healdsburg)	Syar Industries
Lower Alexander Valley	45.9–56.2	Alexander Valley Rd (Jimtown Bridge)–North of Town of Geyserville	

Table footnotes:
[A] Source: ARM Plan (Sonoma County 2010) and 2008 Monitoring Report (Entrix 2010)

This Monitoring Report relies upon monitoring data collected annually by each operator and provided to the PRMD, in addition to supplemental information provided in related documents, including the draft environmental impact report (DEIR) for the "Syar Alexander Valley Instream Mining Project and Sonoma County ARM Plan Amendments" (AECOM 2010). As the PRMD's SRC, Stillwater Sciences is charged with compiling and analyzing the operator-provided monitoring information, which can include aerial photographs, topographic data, aquatic and biotic surveys, and any other available information. This Monitoring Report is intended to primarily present an assessment of the current status and long-term trends of the channel morphology in each monitoring reach (Section 2).

This Monitoring Report should also present an assessment of aquatic and biotic habitats in the mining areas based on available monitoring reports submitted by the operators. The assessment is to evaluate whether mining operations as regulated are having a beneficial, neutral, or adverse effect on the surrounding aquatic and riparian habitat, and the fish, fowl, and other wildlife associated with such habitats. This annual report does not, however, report on aquatic or riparian habitat conditions as these monitoring data have not been collected and/or provided to the PRMD during the time period for which this report considers (*i.e.*, 2009–2014). Subsequent annual reports may include an assessment of aquatic and biotic habitats should the supporting monitoring information become available.

Past monitoring reports have also included an assessment of groundwater-level changes in the monitoring reaches. However, this monitoring component of the ARM Plan monitoring program has since been discontinued by the PRMD based on the recommendation made in the 2008 annual monitoring report (Entrix 2010). The justification for this recommendation was based on the lack of a correlation found between changes in groundwater levels and channel morphology. Therefore, this monitoring report does not include discussion of groundwater monitoring.

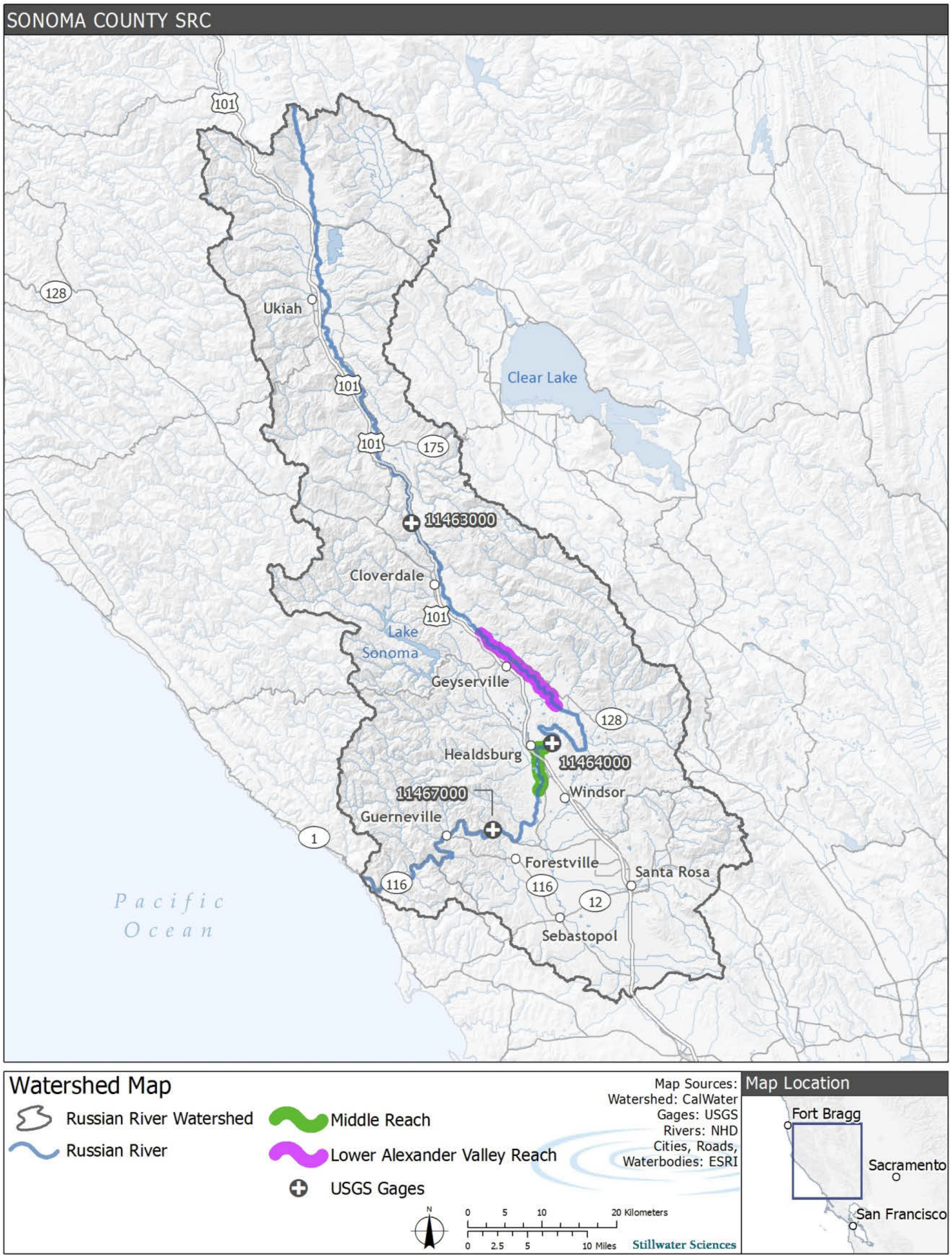


Figure 1. Location of the Russian River watershed and monitoring reaches.

2 GEOMORPHIC CONDITIONS AND MONITORING

This section summarizes current status and long-term trends of the Russian River's morphology in the two monitoring reaches. The section describes the physical setting, in-channel gravel mining production, and the channel monitoring activities. The following channel attributes are to be considered in an annual monitoring report, to the extent available data has been provided by the PRMD and gravel operators:

- Level of Russian River flood flows compared to the dominant discharge,
- Amount of gravel recharge or replenishment,
- Amounts of instream extraction (*no mining during 2009–2014*),
- Annual net changes in gravel recharge or depletion volume in channel,
- Change in flood channel capacity,
- Changes in thalweg elevations,
- Comparison of low-flow channel elevation to baseline reference elevation,
- Identification of degrading and aggrading areas,
- Occurrences of noted bank erosion adjacent to the mining sites and/or within ¼-mile of permitted and vested mining sites (*no mining during 2009–2014*),
- Influence of mining operations on aquatic and biotic habitats (*no mining during 2009–2014; no information provided on aquatic and biotic habitats*),
- Comparison of trends in mining versus non-mining areas where such comparisons can help ascertain any effects of mining activities and standards on channel morphology, and
- Compliance with site-specific performance standards adopted by the permit approvals.

2.1 Physical Setting

The morphology of the Russian River channel, and in turn its supported aquatic habitats, is controlled by both natural and anthropogenic (human-induced) forces. This section briefly describes these forces to the extent they relate to geomorphic processes in the project area.

2.1.1 General watershed characteristics

The Russian River watershed lies within the northern portion of the California Coast Range—a northwest-trending series of tectonically active mountains and basins along the coast from Santa Barbara north to the Oregon border. The 1,485 square mile (mi^2; 3,846 square kilometer [km^2]) watershed is bounded to the east by the Mayacamas Mountain range and to the west by a series of smaller, coastal ranges. The Russian River flows generally southward from its steep headwaters in central Mendocino County, through an alternating complex of sinuous, confined canyons and broad, alluvial valley bottoms, and out to the Pacific Ocean. In all, the 110-mi (177 km) long river drops over 2,000 feet (ft; 610 meters [m]) as it meanders through rich agricultural lands and past growing urban centers near Ukiah, Cloverdale, Geyserville, Healdsburg, Windsor, and Forestville. While land-use developments have altered runoff process in portions of the watershed, the river continues to receive storm-induced pulses of water and sediment from its vast network of steep tributaries and, where space allows, deposit coarse sediments in the river corridor that provide the source of instream aggregate production.

2.1.2 Geology

The river and its major tributaries flow across various geologic terrains that strongly influence the morphologic character of the river corridor. Sediments delivered to the river originate from geologically old and structurally weak lithologies of alternating sequences of sedimentary (sandstone and shale) and meta-sedimentary (mélange, serpentinite) and meta-volcanic (greenstone) units from the Jurassic to Cretaceous periods (Blake et al. 2002, CGS 2010). This lithologic assemblage is part of the Franciscan and Great Valley complexes, both composed of basement rocks from the upper mantle and ocean crust (Coast Range Ophiolite) and marine sediment rocks formed in a marine basin during Mesozoic subduction of the Pacific plate beneath the North American plate. Those portions of the assemblage within the watershed have been intruded by much younger, more competent rocks of volcanic origin consisting of andesite and basalt. Quaternary-aged, weakly consolidated alluvial units composed of sandstone and conglomerates are present in the alluvial valleys of the watershed, and similarly aged landslides are also common on the steeper slopes of this terrain (Blake et al. 2002, CGS 2010). The stream channel and floodplain deposits throughout the Middle and Lower Alexander Valley reaches are composed of poorly sorted (well graded) to well sorted (poorly graded) silt, sand, gravel and cobble (Blake et al. 2002, CGS 2010).

2.1.3 Climate and hydrology

The river's hydrologic nature is Mediterranean with cool, often wet winters and warm, dry summers. The Coast Range receives highly variable annual rainfall depending on each storm's frequency and magnitude and on the landscape relief; mean annual rainfall across the entire watershed varies between 30 and 78 inches (in), as reported by the U.S. Department of Agriculture (USDA) for the period 1981–2010 (PRISM 2015). A clear pattern of increased rainfall with elevation is expressed across the watershed, as the valley lowlands receive about half the rainfall received near the river's headwaters. The majority of rainfall occurs between November and April. Since water year (WY) 2008, the Coast Range has experienced a range of water-year types, with a significant drought occurring since WY 2012. Periodicity in the pattern of the wet/dry years is correlated to the El Niño-Southern Oscillation (ENSO) climatic phenomenon, which typically has a 1–1.5 year duration and a 3–8 year recurrence period (NOAA NWS CPC 2015). Average daily rainfall since WY 2008, as reported at the Cloverdale atmospheric monitoring station (NOAA NCDC 2015a,b), has been slightly less than the historical average: 0.11 in/day versus 0.12 in/day (Figure 2).

The seasonal rainfall pattern is apparent in examination of the river's mean monthly runoff, as depicted graphically in Figure 3, where January and February experience the highest mean monthly flows over a given water year (October 1–September 30), and June through October experience the lowest flows. Also visible in Figure 3 is the doubling of river flow between the upstream and downstream gaging stations as a product of tributary and spring input. Average daily flows are about 900 cubic feet per second (cfs) at Cloverdale, 1380 cfs at Healdsburg, and 2,200 cfs at Guerneville, respectively (Figure 4a). Since WY 2008, mean daily flows have been less than the historical levels: 560 cfs at Cloverdale, 870 at Healdsburg, and 1370 cfs at Guerneville. Overall, for 90 percent of the time, mean daily flows in the river are less than about 140 and 130 cfs at Cloverdale and Guerneville, respectively (Figures 4a and 4b). These discharges coincide with the observed transition to low flows at around 150 cfs that can be interpreted through examination of the exceedance curves from each gaging station, where the transitions are marked by fairly abrupt changes in the shapes of each curve (see Figure 4a). Baseflows are affected by water storage at Lake Mendocino (since 1958) and Lake Sonoma (since 1983), and numerous smaller diversions for irrigation and municipal use (USGS 2010). Water is also diverted into the watershed from the Eel River via the East Fork Russian River that flows into Lake Mendocino.

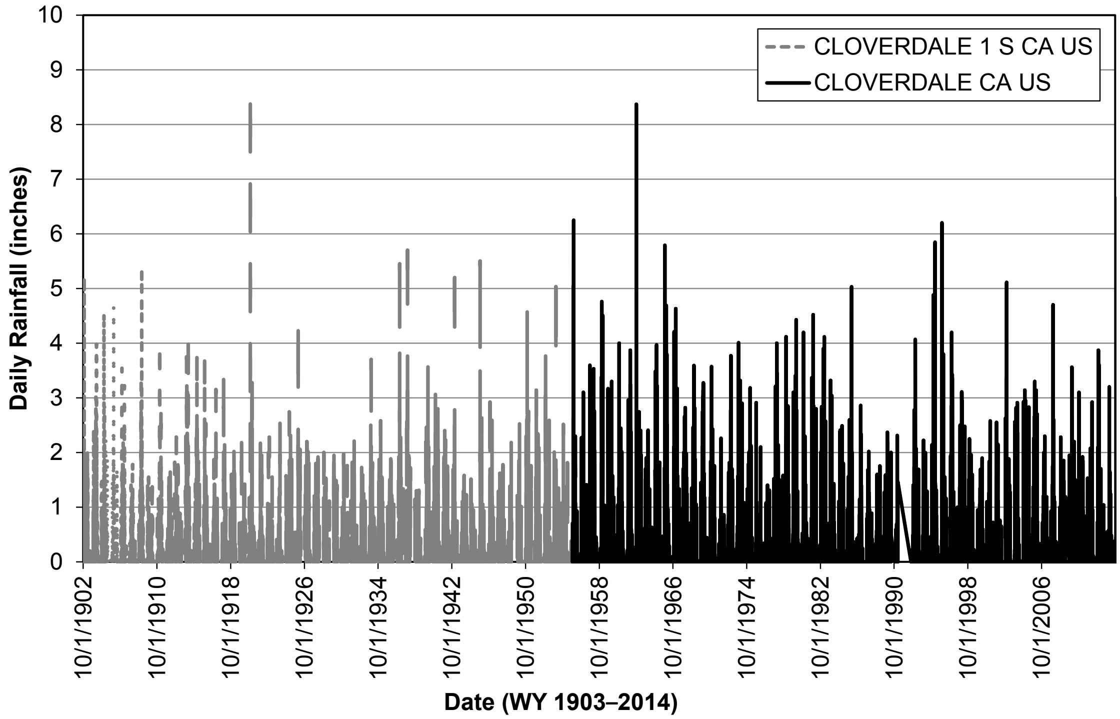


Figure 2. Daily rainfall recorded in the Russian River watershed at the Cloverdale atmospheric monitoring station during water year 1903–2014.

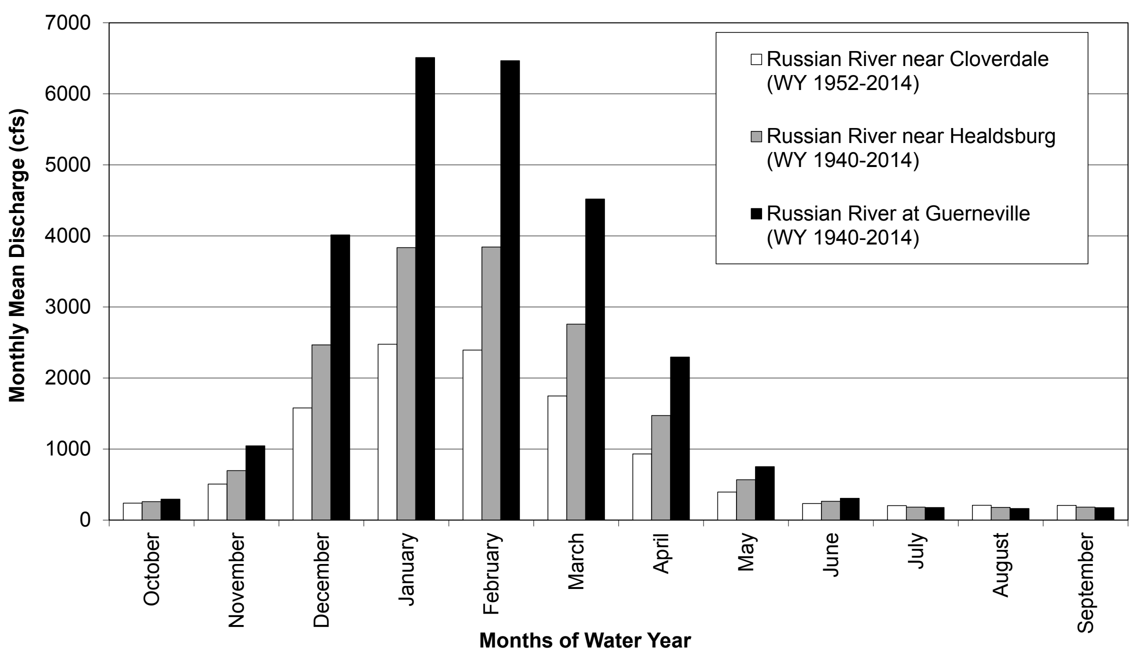
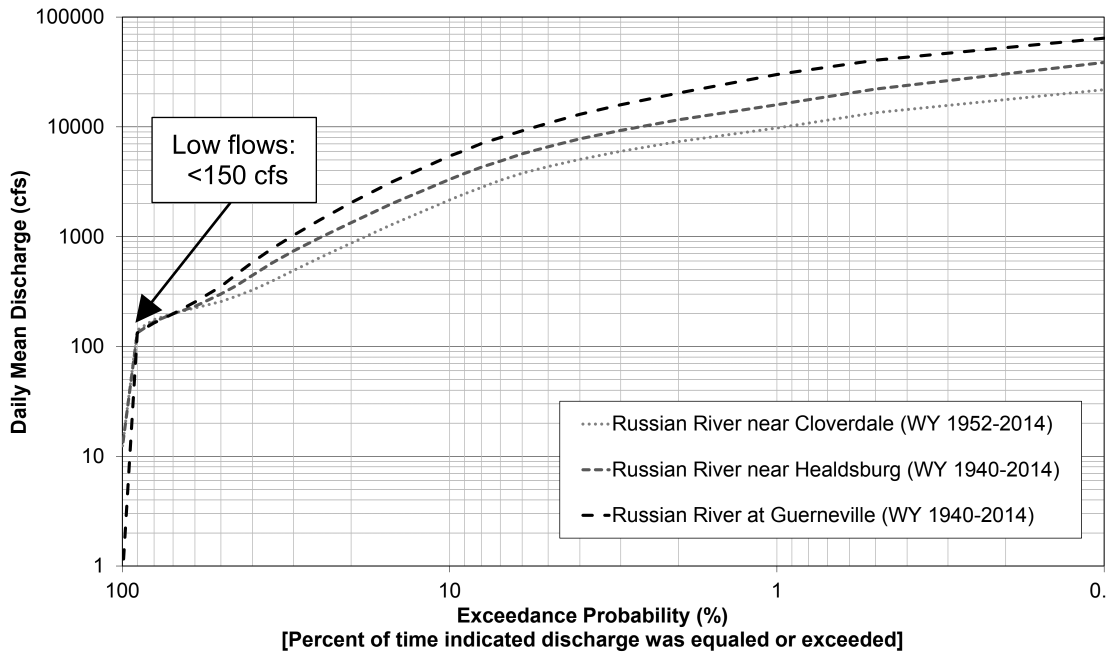


Figure 3. Monthly mean discharge characteristics of the Russian River based on compilation of available long-term river-gaging stations through water year 2014.

a)



b)

Parameter			Stream Gage Location		
			Russian River near Cloverdale	Russian River near Healdsburg	Russian River at Guerneville
Water Years			1952–2014	1940–2014	1940–2014
Number of Samples			23,071	27,394	27,394
Flow (cfs)	Mean		918	1,382	2,208
	Std. Dev.		2,054	3,391	5,823
	Minimum		12	12	1
	Exceedance probability (%)	100%	12	12	1
		90%	141	133	133
		80%	176	168	164
		70%	200	198	198
		60%	224	232	254
		50%	256	300	351
		40%	326	445	585
		30%	491	740	1,030
		20%	872	1,340	2,040
		10%	2,160	3,320	5,420
		5%	4,344	6,582	10,800
		1%	9,768	15,900	30,000
		0.1%	21,800	38,642	64,221
		0.01%	42,800	69,300	97,700
	Maximum		42,800	69,300	97,700

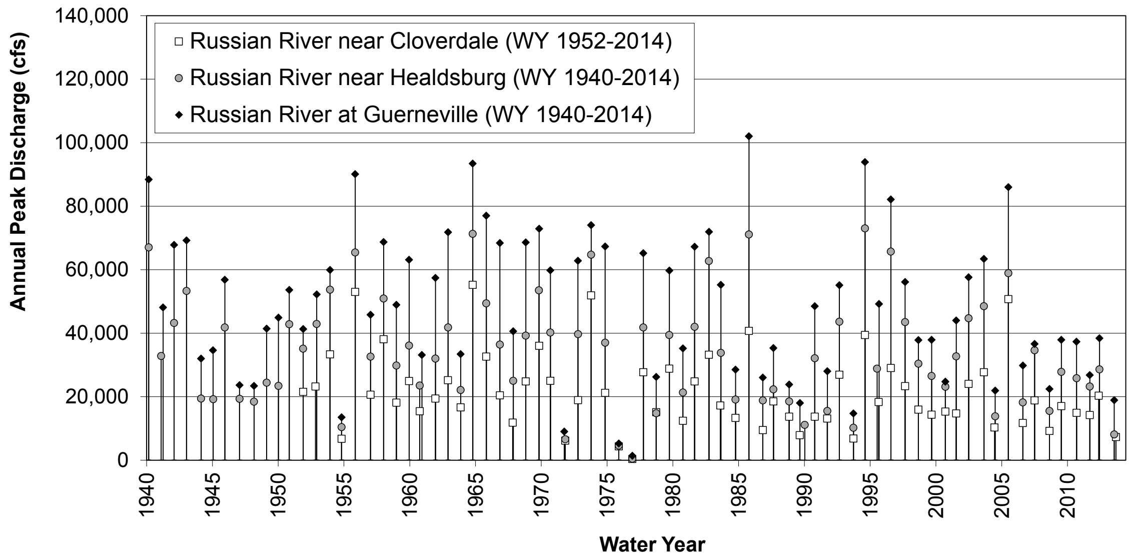
Figure 4. Daily mean flow characteristics of the Russian River based on compilation of available long-term river-gaging records through water year 2014. Data presented above includes mean daily flow duration curves (a) and statistics (b).

Annual peak flows in the Russian River have been substantial in comparison with the mean daily flows (*e.g.*, 2,200 versus 102,000 cfs at Guerneville) (Figure 5a). Since the mid-20th century, the largest floods recorded (*i.e.*, in excess of 80,000 cfs as recorded near Guerneville) occurred in WY 1940, 1956, 1965, 1986, 1995 1997, and 2006. The largest flood recorded at Guerneville during this period peaked at 102,000 cfs on February 18, 1986, having a return period of about 25 years (Figure 5b). Since WY 2008, the monitoring reaches have experienced peak flows of 20,300 cfs on December 2, 2012 at Cloverdale, 28,600 cfs on December 23, 2012 at Healdsburg, and 38,400 cfs on December 24, 2012 at Guerneville, all of which were part of WY 2013. The magnitudes of these recent peak flows are less than the estimated 2-year recurrence periods for the three gages (see Figures 5b and 5c).

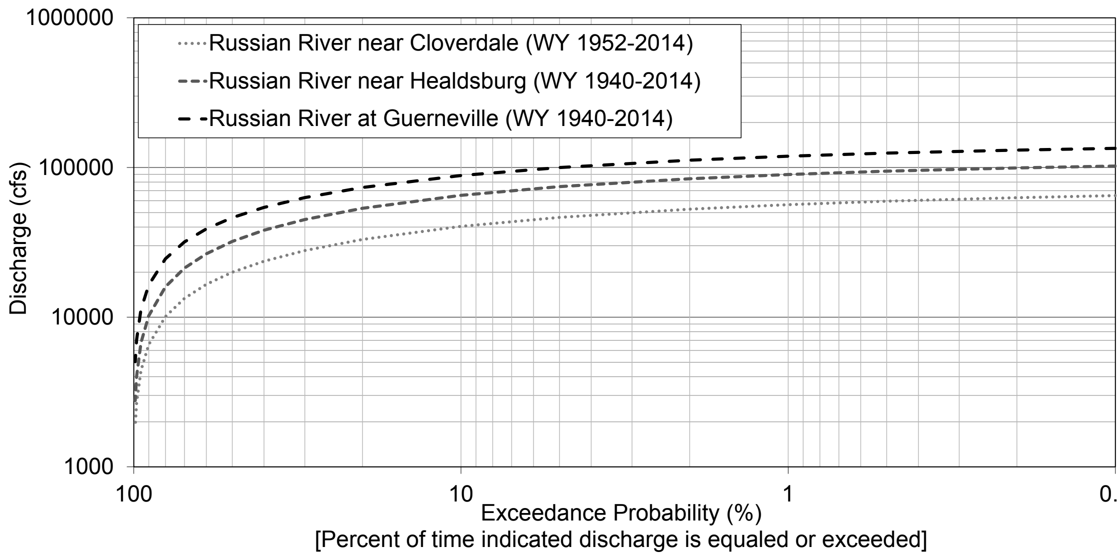
Total annual run-off, as a sum of daily mean flows, during WY 2009–2014 was greatest during WYs 2010 and 2011, estimated at about 1.4 and 1.9 million acre-feet, respectively (Table 2). Only the annual run-off recorded in WY 2011 exceeded the long-term average annual run-off estimated for WY 1983–2014. The initial year of 1983 was selected here because it coincides with the filling of Lake Sonoma—the last water-storage reservoir constructed in the watershed. Annual run-off during WYs 2009, 2012, and 2014 were each less than about half of the long-term annual average. These patterns closely match the Department of Water Resources' published classifications of water-year types in the Sacramento River Valley, which described WY 2009 as dry, WY 2010 as below normal, WY 2011 as wet, WY 2012 as below normal, WY 2013 as dry, and WY 2014 as critically dry (CDWR 2015).

Rainfall and runoff patterns in the watershed are expected to shift as a result of ongoing changes in climate across the western U.S. While the available literature for climate-change effects in California suggest large spatial variability in hydrologic responses, management of natural resources in the Coast Ranges can at least plan for atmospheric warming that has been forecasted in nearly all projections (CCCC 2012). One pertinent study recently conducted by the USGS and Sonoma County Water Agency specifically for the Russian River Valley predicted longer and drier summers during the 21st Century regardless of whether total annual precipitation increases or decreases (Flint and Flint 2012). The study's authors attributed this phenomenon to increased air temperature with attendant increases in evapotranspiration rates.

a)



b)



c)

USGS 11463000 RUSSIAN RIVER NEAR CLOVERDALE, CA		USGS 11464000 RUSSIAN RIVER NEAR HEALDSBURG, CA		USGS 11467000 RUSSIAN RIVER NEAR GUERNEVILLE, CA	
[WY 1952–2014]		[WY 1940–2014]		[WY 1940–2014]	
Return Period	Discharge (cfs)	Return Period	Discharge (cfs)	Return Period	Discharge (cfs)
1.2	10,100	1.2	16,000	1.2	24,500
2	20,000	2	32,100	2	46,300
5	33,100	5	53,400	5	73,600
10	40,500	10	65,100	10	88,400
20	46,400	20	74,500	20	100,000
50	52,700	50	84,200	50	112,000
100	56,400	100	89,900	100	119,000
200	59,600	200	94,500	200	124,800
500	62,900	500	99,400	500	130,800
1000	64,900	1000	102,300	1000	134,400

Figure 5. Annual peak discharge characteristics of the Russian River based on compilation of available long-term streamflow gaging records through water year 2014. Data presented above includes annual peak streamflow events (a), flood frequency analysis curves [Log-Pearson III method] (b), and flood frequency return periods (c).

Table 2. Total annual run-off recorded in the Russian River watershed during WY 2009-2014.

Stream Gage Location	Total Annual Run-off (acre-feet)						Annual Average Run-off during WY 1983–2014 (acre-feet)
	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014	
Russian River near Cloverdale	230,953	541,829	791,088	314,632	407,343	149,621	621,562
Russian River near Healdsburg	389,946	899,960	1,186,627	483,344	610,483	226,824	943,035
Russian River at Guerneville	580,748	1,412,192	1,890,577	687,074	974,194	388,042	1,503,514

2.1.4 Characteristics of the "dominant discharge"

The dominant discharge is a hydrologic parameter initially considered in the previous annual monitoring reports (*e.g.*, Entrix 2010) for the purpose of evaluating the potential for geomorphic change during a given year of the ARM Plan monitoring program. The term "dominant" discharge, also referred to as "effective" discharge, is generally defined as the river flow that transports the most sediment over time and, thus, achieves the most geomorphic work (Wolman and Miller 1960, Emmett and Wolman 2001). For lowland, alluvial rivers in humid and temperate climes, the dominant discharge is most commonly associated with an intermediate discharge equivalent to bankfull stage (*e.g.*, 1–2-yr recurrence interval): increasing sediment transport with increasing flow, coupled with the rapidly decreasing durations of large (and thus uncommon) flows, produce a maximum total sediment load (calculated as the product of the sediment transport rate and flow frequency) at flows neither very small (because little sediment is moved) nor very larger (because they occur so rarely and so briefly)—thus, "intermediate." In contrast, coarse-bedded rivers in drier climes like those in California and the southwest region have been shown to be sensitive primarily to larger and infrequent flood events (*i.e.*, >2-yr recurrence interval) (*e.g.*, Downs et al. 2013, Bunte et al. 2014).

Computation of the dominant discharge for any given river system requires field-collected measurements of the total load of sediment transport, which is composed of suspended (*i.e.*, fine) and bedload (*i.e.*, coarse) materials. While suspended sediment measurements have been collected by the USGS at several of the Russian River's long-term stream gaging stations, no bedload measurements have been collected and, thus, estimation of the river's dominant discharge cannot be readily determined using standard methods. Past studies have attempted to estimate the dominant discharge for the monitoring reaches, however, based on interpretation of geomorphic indicators, such as gravel bar formation. The bankfull discharge was deemed representative of the river's dominant discharge, which correlates with a flow having about a 1.2-yr recurrence interval (PWA 1993 and Syar 2005 as cited in AECOM 2010, Entrix 2010).

Table 3 summarizes the number of days during WY 2009–2014 when daily mean flows recorded at each of the three streamflow gaging stations equaled or exceeded the previously estimated dominant discharge values. Longer-term annual averages for the period of WY 1983–2014 are also provided for context, which ranged between 2.6 and 3.7 days per year, depending on the specific gaging station. The initial year of 1983 was selected here because it coincides with the filling of Lake Sonoma. The results presented in Table 3 indicate that there have been few opportunities (≤5 days/year) for geomorphic change during WY 2009–2014, but that this seemingly low frequency is consistent with the longer-term annual average between 1983 and 2014. Since WY 2008, the greatest number of days equaling or exceeding dominant discharge values occurred in WYs 2010, 2011, and 2013. These results correspond with the total annual run-off amounts presented above in Table 2, where WY 2011 was the only year that exceeded the long-term annual average, while WYs 2010 and 2013 were below the average, and WYs 2009, 2012, and 2014 were significantly drier.

Table 3. Dominant discharge exceedance frequency at the three Russian River streamflow gaging stations.

Stream Gage Location	Dominant Discharge (cfs) [A]	Computed Exceedance Probability (%) [B]	Computed Recurrence Interval (years) [B]	Number of Days Equaled or Exceeded [C]						
				2009	2010	2011	2012	2013	2014	Annual Average in 1983–2014
Russian River near Cloverdale	9300	82	1.2	0	4	5	1	4	0	3.7
Russian River near Healdsburg	16,000	80	1.3	0	3	4	1	4	0	3.2
Russian River near Guerneville	31,000	71	1.4	0	2	1	0	1	0	2.6

Table footnotes:
[A] Source: 2008 Monitoring Report (Entrix 2010)
[B] Computed by Stillwater Sciences based on full period of record through WY 2014
[C] Computed by Stillwater Sciences for individual water year since WY 2008 and for period WY 1983–2014

2.1.5 River Morphology

The morphology of the river corridor has experienced substantial change—both naturally and anthropogenically induced—since European-American settlement of the region in the 1800s, as summarized in several previous studies, including Syar's DEIR (AECOM 2010). Human-induced changes have stemmed from land-cover alterations, dams and diversion construction, floodplain-channel encroachment, instream gravel mining, and flood control. Cumulatively these activities have diminished several geomorphic attributes, including (but not limited to) channel-floodplain connectivity, sediment-transport rates, channel sinuosity, riparian vegetation coverage and composition, and large woody debris recruitment and loading.

The valley portions of the Russian River, including the two monitoring reaches, are about 1-mi wide and support an alluvial, gravel-bed river channel that continues to actively meander across its floodplain where not constrained by bridges, bank revetments, and levees. The 11-mi long

Middle Reach hosts a geomorphically active river channel that is narrower than in the Alexander Valley (~400-ft average width), relatively straight (~1.4 sinuosity), and low-gradient (~0.1%). The channel is composed of alternate sequences of pools and coarse point bars. The upstream end of the reach runs adjacent to the City of Healdsburg while the remainder of the reach is bordered by agricultural fields and terrace pits. A narrow, mature riparian forest is still present along the active river channel. The largest tributary joining the river in this reach is Dry Creek, which is regulated by Warm Springs Dam.

The 18-mi long Lower Alexander Valley Reach is functionally similar to, but wider (~1,000-ft average width) than the Middle Reach. The active channel follows a generally straight (~1.2 sinuosity) and low-gradient (~0.1% slope) course past agricultural fields and few man-made constrictions. The channel planform still maintains several high amplitude, actively migrating meander bends. The channel is composed of alternate sequences of pools and coarse point bars, and is fringed by a narrow, mature riparian forest. Tributaries joining the river in this reach are few and small, the largest being Gill Creek.

Sediment transport remains active throughout much of the watershed, especially in the monitoring reaches, despite the interception of bed-material load in the watershed's reservoirs. The total suspended-sediment load (*i.e.*, sand, silt, and clay) for the watershed, as gaged at the Guerneville streamflow station, has been estimated to be approximately 1,000,000 tons annually (Farnsworth and Warrick 2007). This estimate was based on suspended-sediment measurements made intermittently by the USGS during 1965–1995. The corresponding total sediment load (*i.e.*, suspended and bed-material) of the river is not known, however, as field-based data collection efforts have not included direct sampling of bedload-transport rates. Studies conducted in support of the original ARM Plan estimated annual gravel replenishment in the entire Alexander Valley to be approximately 100,000 tons (Sonoma County 1994 as cited in AECOM 2010). Additional discussion on gravel removal and replenishment is discussed below.

2.2 In-Channel Gravel Mining Production

The PRMD publishes an annual report on aggregate production in Sonoma County, which contains instream gravel extraction from 1981 through the present year (Sonoma County 2014). The results specific to the Middle Reach and both Lower and Upper Alexander Valley reaches are summarized in Table 4. During 2009–2014, since the last annual monitoring report, there was no gravel mining in any of the monitoring reaches of the Russian River. Recommencement of instream mining in the Lower Alexander Valley may possibly occur in 2016 pending County approval of mining plans.

Table 4. Reported in-channel gravel production values for the Russian River.

Year [A]	In-Channel Gravel Production by Reach [B]				Total In-Channel Gravel Production in the Alexander Valley and Middle Reaches [C]	
	Upper Alexander Valley [D]	Lower Alexander Valley [E]	Total Alexander Valley	Middle		
	(in thousand tons)				(in thousand tons)	(in thousand cubic yards)
1981			544	210	964	643
1982			542	323	1,188	792
1983			494	99	692	461
1984			967	379	1,725	1,150
1985			590	235	1,060	707
1986			1,016	40	1,096	731
1987			886	40	966	644
1988			955	5	965	643
1989			905	0	905	603
1990			365	0	365	243
1991			345	0	345	230
1992			859	0	859	573
1993			376	0	376	251
1994	275	40	315	0	315	210
1995	200	440	640	0	640	427
1996	<250	0	<250	0	<250	<167
1997	425	310	735	0	735	490
1998	<275	0	<275	0	<275	<183
1999	75	115	190	0	190	127
2000	25	65	90	0	90	60
2001	0	10	10	0	10	7
2002	<165	5	<170	<295	<465	<310
2003	<210	0	<210	0	<210	<140
2004	<80	0	<80	0	<80	<53
2005	0	0	0	0	0	0
2006	<60	0	<60	0	<60	<40
2007	0	0	0	<185	<185	<123
2008	0	0	0	0	0	0
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
1981–2014 Average			<594	<90	<761	<507
1981–2014 Total			<21,393	<3,244	<27,402	<18,269

Table footnotes:

[A] Data sources: years 1981–2008 from the 2008 Monitoring Report (Entrix 2010), years 2009–2013 from the 2013 Aggregate Production Report (Sonoma County 2014), and year 2014 from PRMD (D. Schiltgen, pers. comm., 2015).

[B] Gravel extraction totals are considered proprietary data and not subject to publication pursuant to Sonoma County Board of Supervisor's Resolution No. 96-1361 and State law. Where only one operator had reported extraction for their respective area, these figures have been rounded up and a less than symbol ("<") has been used for the purposes of this table.

[C] Conversion of tons to cubic yards assumes a bulk density of 1.5 tons per cubic yard (yd^3), per the 2008 Monitoring Report (Entrix 2010).
[D] The Upper Alexander Valley Reach totals include amounts along the lower portion of Big Sulphur Creek, per the 2013 Aggregate Production Report (Sonoma County 2014).
[E] Gravel extraction amounts reported from the Lower Alexander Valley Reach for 2001 and 2002 were based on estimates from stockpiles that were mined in previous years, per the 2008 Monitoring Report (Entrix 2010).

2.3 Monitoring Activities

In this section we summarize the monitoring activities conducted between 2009 and 2014 in the Lower Alexander Valley and Middle reaches. Annual data collection activities included aerial photography flights and topographic surveys in portions of the two river reaches. These data were collected by the gravel operators and their contractors. We have attempted to summarize data collection and post-processing methods to the extent that information was included with the monitoring data.

The following presents accounts of changes to channel morphology in the two monitoring reaches using information on cross-section and longitudinal profiles, reference water surface elevations, bank erosion, and sediment volumes.

2.3.1 Change in channel geometry

The geometry, or shape, of the river channel is subject to adjustments in response to natural events that deliver or scour bed and bank sediment, and to land-use activities that alter runoff and sediment supply and storage. Two-dimensional views of the river provide a reliable means to detect and track changes in channel geometry over space and time. Cross-sections of the river channel can be aligned perpendicular to the high-flow channel orientation to provide a view of the channel topography both above and below the water surface. Adjustments in the cross-section dimensions over time can indicate widening or narrowing, deepening or shallowing, and/or channel migration. A thalweg (*i.e.*, line of lowest elevation that runs parallel to the river course) profile of a river is sometimes referred to as the longitudinal profile. Adjustments in the thalweg elevation over time can indicate channel deepening or shallowing. Together, changes in cross-section geometry and thalweg elevation can indicate changes in sediment storage.

The nine channel cross-sections surveyed in the Lower Alexander Valley Reach during 2009–2014 are shown in Figure 6. The 27 cross-sections surveyed in the Middle Reach during 2009–2013 are shown in Figure 7. A tabular summary of all cross-sections is presented in Table 5. The methods used to generate and subsequently evaluate the cross-sections and thalweg (longitudinal) profiles are briefly summarized below. Results on the change in channel geometry gleaned from our evaluation of the cross-section and thalweg profiles are also presented below.

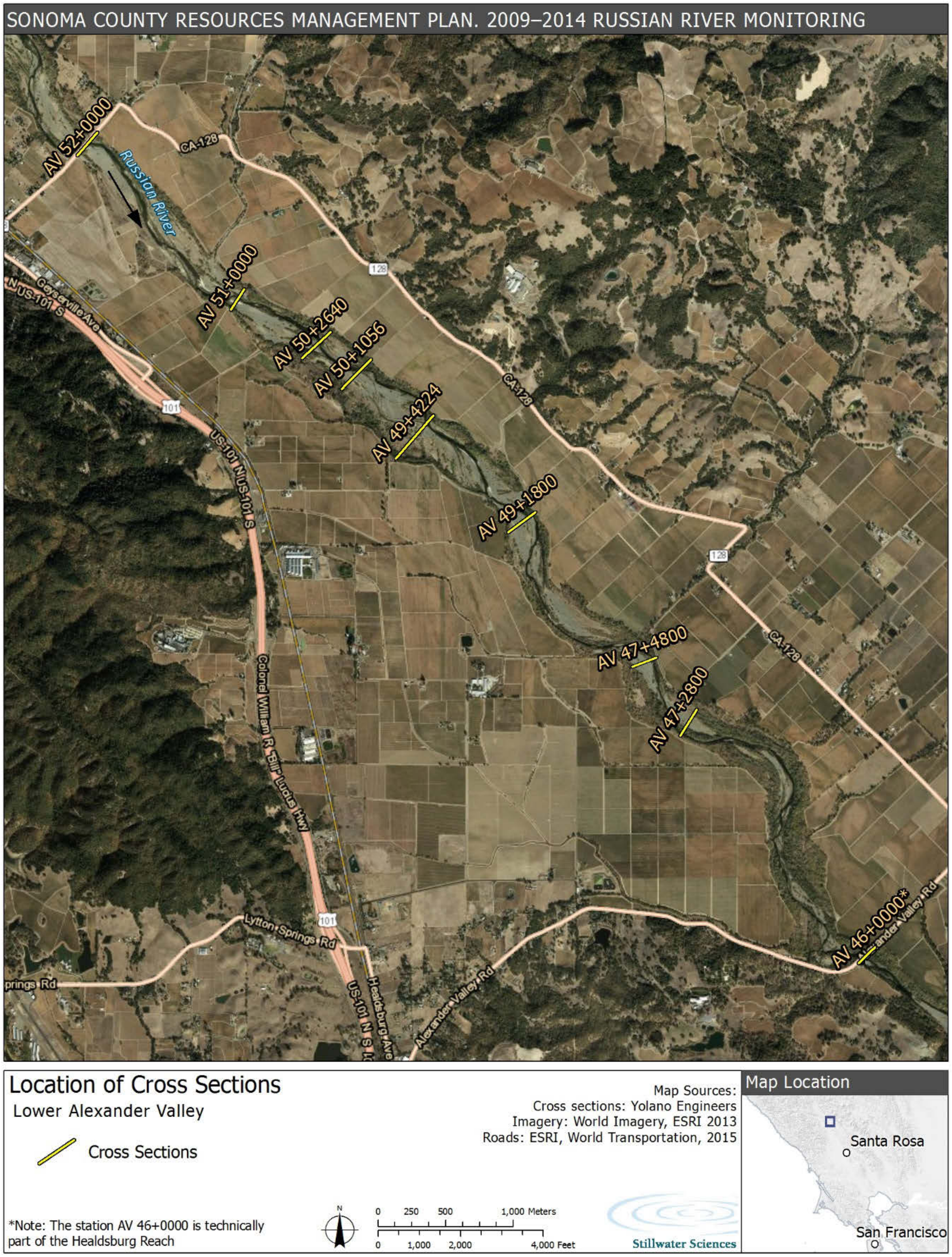


Figure 6. Locations of channel cross-sections in the Lower Alexander Valley Reach evaluated in this monitoring report.

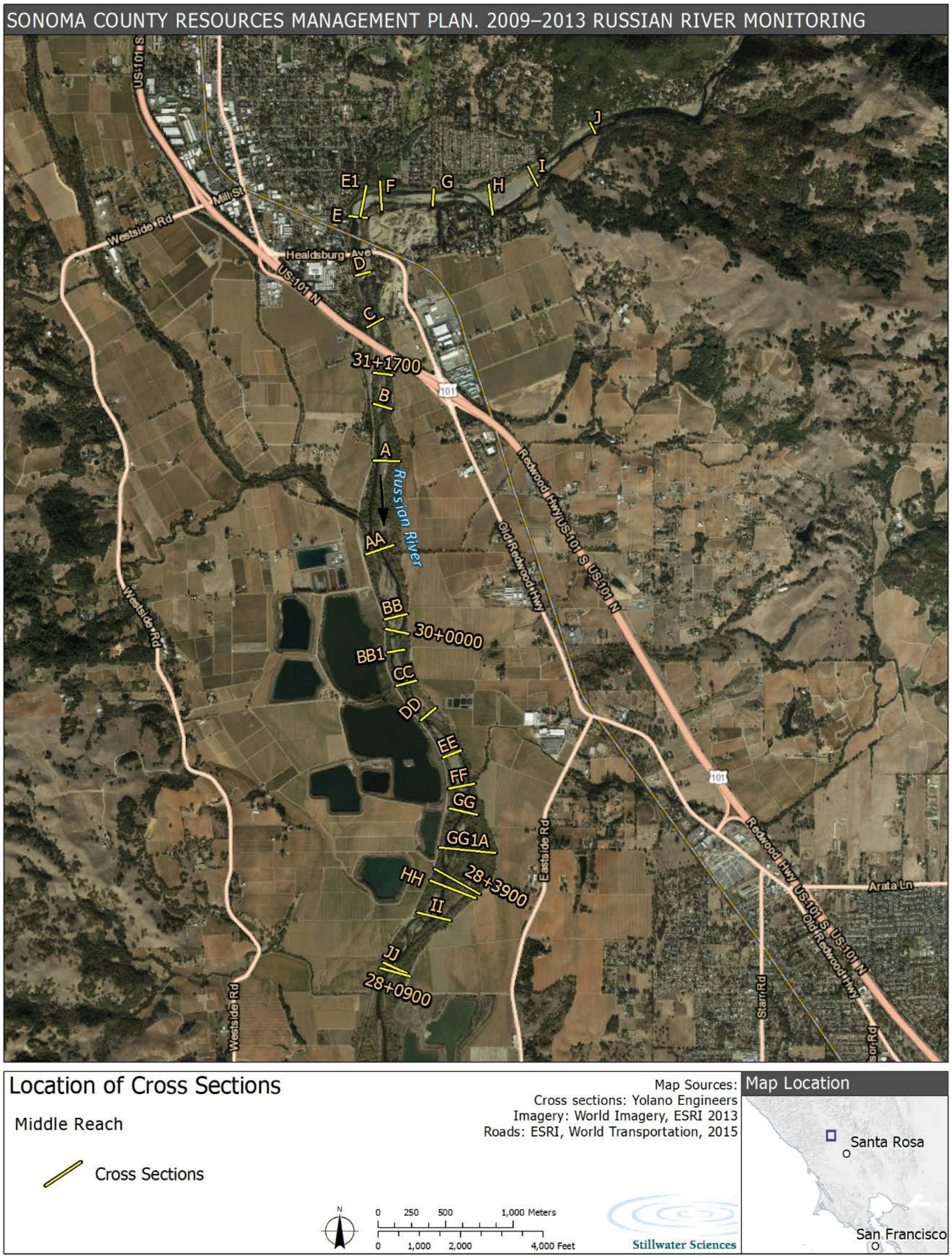


Figure 7. Locations of channel cross-sections in the Middle Reach evaluated in this monitoring report.

Table 5. Summary of channel cross-sections surveyed in Lower Alexander Valley and Middle Reaches between 2009 and 2014.

Reach	Cross-section Identification (listed upstream to downstream order) [A]	River Mile
Lower Alexander Valley Reach (RM 46–52)	AV 52+0000 (Geyserville Bridge)	52.0
	AV 51+0000 (1500' U/S from Smith's Levee)	51.0
	AV 50+2640 (300' U/S from Smith's Levee)	50.5
	AV 50+1056 (Smith's Levee)	50.2
	AV 49+4224 (800' D/S from Smith's Levee)	49.8
	AV 49+1800 (DeWitt Gravel)	49.3
	AV 47+4800 (Gird Creek)	47.9
	AV 47+2800 (SCPD)	47.5
	AV 46+0000 (Jimtown Bridge)	46.0
Middle Reach (RM 28.2–33.4)	J (176170)	33.4
	I (174130)	33.0
	H (172960)	32.8
	G (171490)	32.5
	F (170410)	32.3
	E1 (169960)	32.2
	E (169270)	32.1
	D (167910)	31.8
	C (166730)	31.6
	31+1700 (Below Hwy. 101 Bridge)	31.3
	B (164460)	31.2
	A (162940)	30.9
	AA (161040)	30.5
	BB (158860)	30.1
	30+0000 (Basalt Pit)	30.0
	BB1 (158070)	29.9
	CC (157020)	29.7
	DD (156120)	29.6
	EE (154920)	29.3
	FF (154200)	29.2
	GG (153570)	29.1
	GG1A (152620)	28.9
	28+3900 (SCPD)	28.7
	HH (151690)	28.7
	II (150870)	28.6
	JJ (149570)	28.3
	28+0900 (SCPD)	28.2

Table footnotes:
[A] Data collected by Yolano Engineers and provided by PRMD. Table compiled by Stillwater Sciences.

2.3.1.1 Data collection methods

The cross-section and thalweg data were collected and processed by Yolano Engineers (a Syar Industries subsidiary) and provided to us by the PRMD. The annual datasets consisted of topographic surfaces and elevation profiles derived from the digital terrain models (DTMs) generated for each reach. These data were compiled in AutoCAD Civil 3D software (*i.e.*, .dwg file format). All supporting ortho-rectified aerial photographs were also provided with each annual dataset. Information documenting the data collection and post-processing methods were not included with the datasets.

According to the 2008 Monitoring Report, in-channel surveys of cross-sections and thalweg profiles have recently been prepared using DTM-generated topography. This approach differs from the methods used prior to 2008 that relied solely upon field-based surveys employing total-station equipment. The current approach applied again in 2009–2014 reportedly involved collection of aerial photography of the monitoring reaches, typically in spring, to create the complete DTMs using photogrammetry techniques. Limited field surveys were conducted to provide control points to improve accuracy of the DTM elevations. The field surveys also supplemented elevation data in areas obscured by dense vegetation or under water on the aerial photographs.

The DTM is initially processed automatically using the stereo-paired aerial photographs. Break lines in the ground topography are manually added to the DTM where shown to have been omitted in the automation process. A continuous, bare-earth surface is created from the DTM using an interpolated triangulated irregular network (TIN). Elevation profiles in cross-section and longitudinal view are then extracted from the TIN surface. The locations of the cross-sections and longitudinal (thalweg) profiles are based on fixed end-point coordinates that remain static over time, which allows a means to compare changes in channel geometry each year.

The 2008 Monitoring Report noted that all cross-sections had been aligned perpendicular to the high-flow channel orientation and extended across the majority of the active channel. The cross-section and thalweg profile data were recorded in feet and geographically referenced horizontally to California State Plan, Zone 2, 1983 North American Datum (NAD83), and vertically to the 1988 North American Vertical Datum (NAVD88).

The datasets from 2009–2013/2014 included cross-sections having stationing coordinates (in feet) relative to the left streambank station looking downstream, where the left bank is located at 0 ft and stationing increases towards the right bank. The stationing for the thalweg profiles began downstream and progressed upstream. The horizontal datum of NAD83 was only recorded in the 2009 dataset for the Lower Alexander Valley Reach, while all other datasets lack a recorded horizontal datum. Additionally, all datasets lack a recorded vertical datum. We have assumed that all datasets use the same horizontal datum (NAD83) and vertical datum (NAVD88) based on an assumed consistency with the 2008 datasets evaluated in the 2008 Monitoring Report, and because we determined that unchangeable surfaces, such as higher floodplains, appear to have the same elevations and lateral positions for each cross-section and thalweg profile in 2009–2013/2014.

The datasets provided for this monitoring report included fewer cross-sections than were evaluated in the 2008 Monitoring Report. For the Lower Alexander Valley Reach, only seven of the 28 cross-sections recommended to be surveyed during non-mining years are currently available for use in the present analysis (see Appendix H in Entrix 2010). Two additional cross-sections, AV 49+1800 and 47+4800, were included in the datasets even though they were recommended to be surveyed during mining years. For the Middle Reach, only nine of the 23 cross-section recommended to be surveyed during non-mining years were made available. The other 18 cross-sections included were recommended for mining years.

2.3.1.2 Cross-section change results

As stated above, a total of nine ARM Plan cross-sections were provided for the Lower Alexander Valley Reach for years 2009 through 2014, and 27 sections were provided for the Middle Reach for years 2009 through 2013 (see Table 5). Statistics on the spacing between the cross-sections provided for each monitoring reach are summarized in Table 6. According to the 2008 Monitoring Report, the spacing between cross-sections has been lower when more cross-sections were surveyed during mining years.

Table 6. Distances between ARM Plan cross-sections.

Monitoring Reach	All Provided Cross-Sections (miles) [A]	
Lower Alexander Valley (evaluated extent: RM 46–52)	2009–2014	
	Max	1.53
	Min	0.3
	Median	0.48
	Mean	0.75
Middle (evaluated extent: RM 28.2–33.4)	2009–2013	
	Max	0.43
	Min	0.02
	Median	0.19
	Mean	0.2

Table footnotes:
[A] Data collected by Yolano Engineers and provided by PRMD. Analysis conducted and statistics compiled by Stillwater Sciences.

To aid with the analysis of cross-section changes, we assembled the TIN surfaces into a single AutoCAD file and re-exported the elevation profiles for those cross-sections contained in the source datasets. Cross-sectional areas were measured in AutoCAD and represented that area bounded by the given cross-section's ground surface elevation, left and right stations, and base elevation. The areas were then increased by adding that portion of a given cross-section between its base elevation and sea level at 0-ft elevation (NAVD88). This additional step provided the means to compare the 2009–2013/2014 cross-sectional areas with those from 2008 presented in the 2008 Monitoring Report. However, the differences between the 2009 and 2008 results for five of the nine cross-sections from the Lower Alexander Valley Reach and one of the 27 cross-sections from the Middle Reach were not within the same order of magnitude as the other changes. We inferred that these apparent discrepancies indicated that the cross-section endpoints provided to us in the source datasets were not the same as those used in the 2008 dataset.

Where applicable, changes in cross-sectional area were determined by subtracting the previous year's area from the current. A positive sign in the comparison indicates an increase in cross-sectional area below the ground surface due to sediment deposition along the bed or banks. Whereas, a negative sign in the comparison indicates a decrease in cross-sectional area below the ground surface due to sediment loss along the bed or banks. An increase in area potentially indicates sediment aggradation in the section, while a decrease indicates degradation. Further, a decrease in the area of a cross-section could indicate bank erosion and/or channel incision. These processes are discussed further in the thalweg and bank erosion change sections below. The results of the cross-sectional areas and year-to-year changes in areas are summarized in Appendix

A. Graphical plots of each cross-section location are presented in Appendix B. Year-to-year changes in cross-sectional areas in the two reaches are summarized in Tables 7 and 8.

In the Lower Alexander Valley Reach, the annual changes in cross-sectional areas varied by location with alternating patterns of aggradation and degradation over the evaluation period (see Table 7). Only four of the cross-sections could be utilized for a comparison between 2008 and 2009 conditions, the results of which indicate a consistent trend of aggradation, with an average change of +500 ft^2 for that 1-year period. Changes in area at the other five cross-sections cannot be computed, as described above. The average annual changes in area for all nine cross-section stations during 2009–2014 fluctuated from negative to positive values of approximately equivalent magnitude (*i.e.*, ~100–200 ft^2). The largest increase, or sediment accumulation, was +659 ft^2 at station AV 49+1800, which occurred during 2009–2010. The largest decrease, or sediment loss, was -554 ft^2 at station AV 50+2640, which occurred during 2010–2011. The 2009–2014 reach-wide average change in area from all nine cross-section stations was only +18 ft^2, which signifies a modest degree of sediment accumulation. The sub-total change in area during 2009–2014 was about +800 ft^2.

Annual changes in cross-sectional area also varied significantly by location in the Middle Reach during evaluation period. All but one of the stations contained useable cross-sectional area data from 2008, which provided a means to evaluate changes in areas from 2008 to 2013. As stated above, no data were provided for 2014. Similar to the Lower Alexander Valley Reach results, the change in cross-sectional areas during 2008–2009 were mostly positive, which contributed to an annual average change of +122 ft^2. Also, the average annual changes in area for all 27 cross-section stations during 2009–2013 similarly fluctuated from positive to negative values of approximately equivalent magnitude (*i.e.*, ~20–40 ft^2). The largest increase was +696 ft^2 at station 30+0000, which occurred during 2012–2013. The largest decrease was -638 ft^2 at station II, which occurred during 2009–2010. The 2008–2013 reach-wide average change in area was +28 ft^2, which, like revealed in the results from the Lower Alexander Valley Reach during 2009–2014, is indicative of a modest amount of sediment accumulation. The sub-total change in area during 2008–2013 was about +3,600 ft^2.

Additionally, the 2009–2013 reach-wide average changes in cross-sectional areas in the Lower Alexander Valley and Middle reaches were only -14 ft^2 and +4 ft^2, respectively. And, the sub-total changes in area in the two reaches during 2009–2013 was about -500 ft^2 and +500 ft^2. Given that the reach-wide average values are relatively small compared with the maximum range of annual variability, there appears to be an approximate balance in sediment flux through these two reaches during their evaluation periods.

The results from 2009–2013/2014 are consistent with the trends and range of values noted in the 2008 Monitoring Report (Entrix 2010). For example, the long-term averages of area changes during 1994–2008 in the Lower Alexander Valley and Middle reaches were estimated to be 26 ft^2 and 73 ft^2, respectively. Thus, the changes in cross-sectional area observed in the 2009–2013/2014 period are within the range of historical variability.

Table 7. Change in cross-sectional area in the Lower Alexander Valley reach.

Cross-section	Change in Cross-sectional Area (ft^2)						*Average Change (ft^2)*
	2008–2009 [A]	**2009–2010**	**2010–2011**	**2011–2012**	**2012–2013**	**2013–2014**	***2009–2014***
52+0000	N/A[B]	-91	-311	56	-340	-11	*-139*
51+0000	N/A[B]	-10	-294	41	-189	375	*-15*
50+2640	N/A[B]	364	-554	398	-314	237	*26*
50+1056	N/A[B]	-132	-10	172	-398	299	*-14*
49+4224	838	74	-51	25	223	182	*91*
49+1800	254	659	146	238	-513	-8	*104*
47+4800	322	212	26	-83	126	238	*104*
47+2800	586	4	42	284	-168	-62	*20*
46+0000	N/A[B]	129	-199	245	-320	52	*-19*
Summary of Changes (2009–2014)							
Total Change in Cross-sectional Area (ft^2)		1,209	-1,205	1,376	-1,893	1,302	*158*
Average Change in Cross-sectional Area (ft^2)		134	-134	153	-210	145	*18*
Number of Cross-sections with Increased Area		6	3	8	2	6	*25*
Number of Cross-sections with Decreased Area		3	6	1	7	3	*20*

Table footnotes:
[A] 2008 data from the 2008 Monitoring Report (Entrix 2010). See Appendix A for total cross-sectional areas.
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Table 8. Change in cross-sectional area in the Middle reach.

Cross-section	Change in Cross-sectional Area (ft^2)						*Average Change (ft^2)*
	2008–2009 [A]	**2009–2010**	**2010–2011**	**2011–2012**	**2012–2013**	**2013–2014** [C]	***2008–2013***
J	283	-313	-160	340	-142	---	*2*
I	-42	70	-239	189	-167	---	*-38*
H	377	200	-78	206	-381	---	*65*
G	128	123	-227	177	-159	---	*8*
F	-49	234	-139	-12	-14	---	*4*
E1	200	216	139	25	36	---	*123*
E	30	0	180	-76	88	---	*44*
D	168	94	-237	61	51	---	*27*
C	28	166	-93	-268	112	---	*-11*
31+1700	-42	-20	39	-75	35	---	*-13*
B	147	23	71	-98	190	---	*67*
A	258	25	-144	47	145	---	*66*
AA	21	195	-100	-53	-18	---	*9*
BB	144	-118	191	-120	-67	---	*6*
30+0000	107	-384	-6	-746	696	---	*-67*
BB1	-48	144	-107	104	163	---	*51*
CC	53	-170	277	-103	-47	---	*2*
DD	145	16	145	-7	23	---	*64*
EE	363	81	256	-24	-207	---	*94*
FF	81	-35	390	94	174	---	*141*
GG	167	-239	5	39	107	---	*16*
GG1A	-80	-331	78	91	-100	---	*-68*
28+3900	38	86	2	175	453	---	*151*
HH	199	-64	198	2	-168	---	*33*
II	297	-638	471	-460	94	---	*-47*
JJ	198	-118	97	-45	-57	---	*15*
28+0900	N/A[B]	-215	26	19	66	---	*-26*

Summary of Changes (2008–2013)

Total Change in Cross-sectional Area (ft^2)	3,171	-972	1,035	-518	906	---	*113*
Average Change in Cross-sectional Area (ft^2)	122	-36	38	-19	34	---	*28*
Number of Cross-sections with Increased Area	21	14	16	14	15	---	*80*
Number of Cross-sections with Decreased Area	5	12	11	13	12	---	*53*

Table footnotes:
[A] 2008 data from the 2008 Monitoring Report (Entrix 2010). See Appendix A for total cross-sectional areas.
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.
[C] --- = no data provided by PRMD.

2.3.1.3 Thalweg change results

Changes in thalweg elevations in the two ARM Plan monitoring reaches were evaluated by two separate methods using data provided by PRMD.

The first method compared thalweg elevations, or lowest points, along the previously introduced cross-sections, which provided a means to compare the 2009–2013/2014 conditions to past years evaluated in the 2008 Monitoring Report. Changes in thalweg elevation were determined by subtracting the previous year's elevation from the current. A positive sign in the comparison indicates a rising of the thalweg elevation due to sediment deposition upon the channel bed. A negative sign in the comparison indicates a lowering of the thalweg elevation due to sediment loss from the channel bed. A complete tabular summary of thalweg elevations at the nine cross-sections in the Lower Alexander Valley Reach and 27 cross-sections in the Middle Reach since 1994 is presented in Appendix C. Annual changes in thalweg elevations in the two reaches from 1994–2013/2014 are summarized in Tables 9 and 10. Graphical plots of the thalweg elevations at the cross-sections in 1994 and 2009–2014 are presented in Figures 8 and 9. Graphical plots of the thalweg changes in 1994 and 2009–2014 are presented in Appendix D.

The results of applying the first method reveal that both reaches experienced a cumulative decrease, or lowering, of thalweg elevations from between 1994 and 2013/2014 (see Tables 9 and 10). During this period, reach-wide average elevations fluctuated between positive and negative values on the order of about 1 ft. The greatest change in the Lower Alexander Valley Reach was +1.67 ft during 2009–2010, while the greatest change in the Middle Reach was +1.20 ft during 2010–2011. Since 2008, the elevations at a station have ranged between -3 and +4 ft in the Lower Alexander Valley Reach and between -7 and +8 ft in the Middle reach. Overall, the two reaches have experienced a net decrease in thalweg elevations of about -1 ft since 2008.

The annual channel-bed slopes of the two reaches are approximated by the trendlines plotted in Figures 8 and 9 based on linear regressions of the thalweg elevation points and their corresponding river-mile position during. All regressions have a high correlation (*i.e.*, $R^2>0.90$), thus making them useful for comparative analysis. The changing positions of the annual trendlines and their associated slopes clearly indicate that a general shallowing of reach-wide slope has occurred in both reaches since 1994. In the Lower Alexander Valley Reach, the upstream portion has lowered while the downstream portion has risen during 1994–2014, though annual readjustments are apparent. In the Middle Reach, the downstream portion has risen during 1994–2013, while the bed positions in the upstream portion have fluctuated about the 1994 level.

Table 9. Change in thalweg elevation at nine cross-sections in the Lower Alexander Valley Reach.

Year	Number of Cross-Sections with Same or Increased Thalweg Elevation	Number of Cross-Sections with Decreased Thalweg Elevation	Average Change in Thalweg Elevation (feet)
1994	3	4	0.13
1995	3	6	-0.40
1996	6	3	0.78
1997	4	5	-0.72
1998	3	6	-0.76
1999	1	3	-0.43
2000	2	2	1.00
2001	6	2	0.36
2002	5	4	0.28
2003	2	7	-0.70
2004	5	4	0.01
2005	3	6	-0.01
2006	5	3	0.47
2007	4	5	0.16
2008	2	7	-0.50
2009	3	6	0.02
2010	8	0	1.67
2011	2	6	-0.87
2012	2	7	-0.80
2013	4	5	-0.34
2014	3	6	-0.55
Cumulative Change 1994–2014	*76*	*97*	*-1.20*

Table 10. Change in thalweg elevation at 27 cross-sections in the Middle Reach.

Year	Number of Cross-Sections with Same or Increased Thalweg Elevation	Number of Cross-Sections with Decreased Thalweg Elevation	Average Change in Thalweg Elevation (feet)
1994	15	11	-0.10
1995	18	9	0.31
1996	15	12	0.24
1997	19	7	0.23
1998	4	0	0.60
1999	0	4	-0.95
2000	2	2	-0.18
2001	3	1	-0.08
2002	1	3	-0.20
2003	19	8	0.94
2004	13	14	-0.79
2005	7	20	-0.57
2006	21	6	0.79
2007	11	16	-0.19
2008	15	12	-0.17
2009	16	11	-0.24
2010	9	18	-0.31
2011	22	5	1.20
2012	9	18	-1.07
2013	16	11	0.32
Cumulative Change 1994–2013	*235*	*188*	*-0.22*

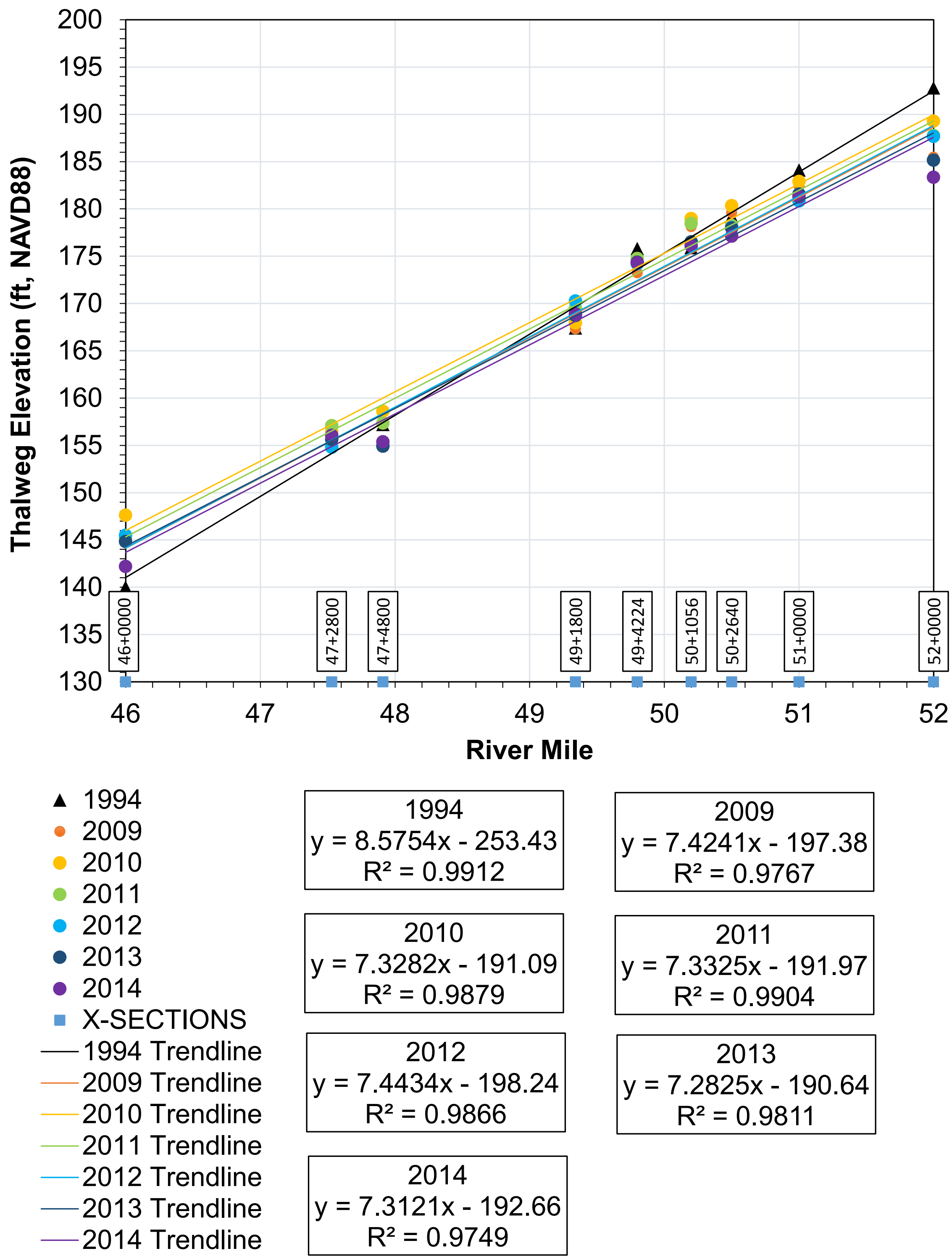


Figure 8. Thalweg elevations at nine cross-sections in the Lower Alexander Valley Reach.

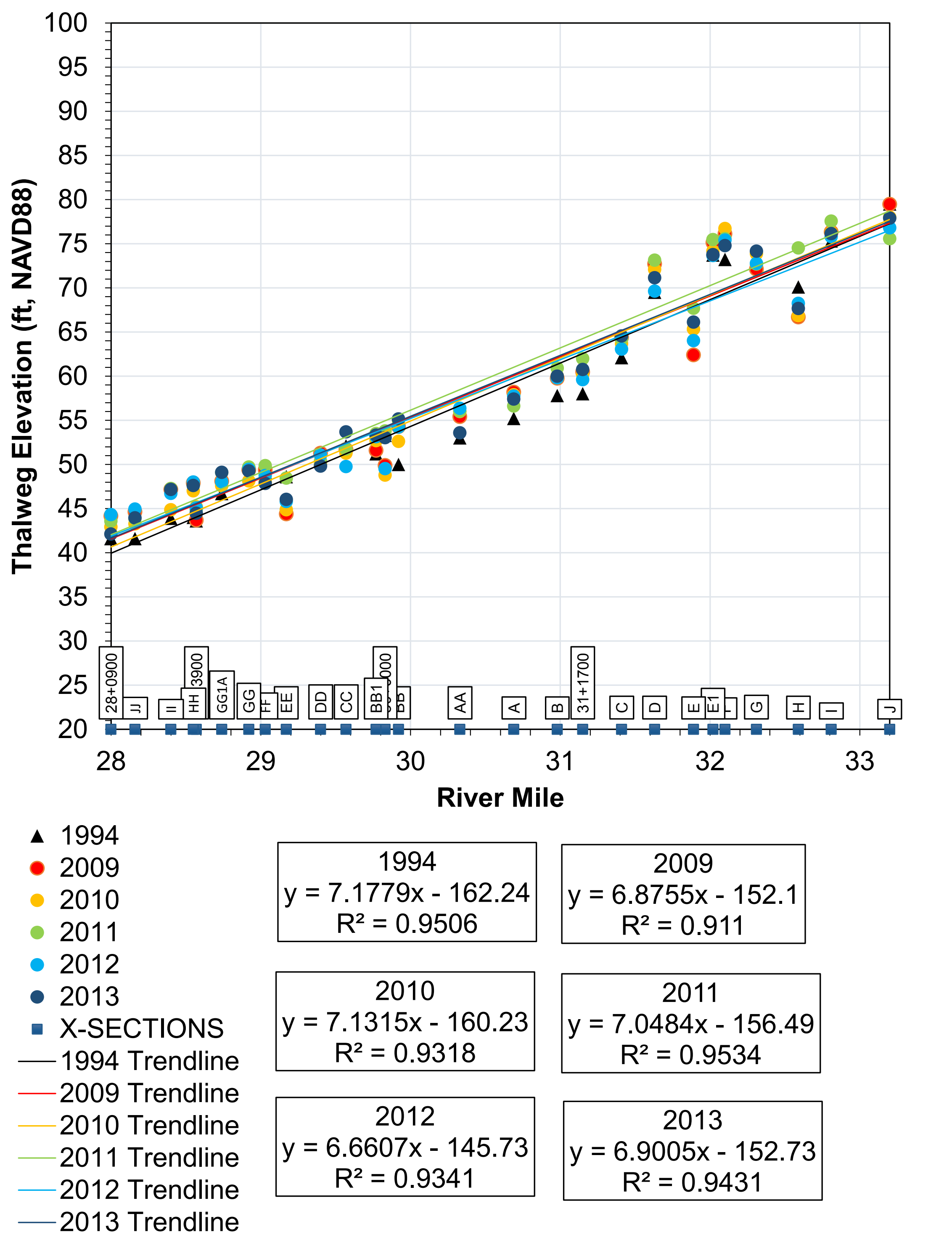


Figure 9. Thalweg elevations at 27 cross-sections in the Middle Reach.

The second method employed here to evaluate changes in thalweg elevations utilized continuous longitudinal profiles of the entire river thalweg in each monitoring reach. The purpose of this additional analysis was to evaluate the thalweg changes using a more detailed dataset and identify any differences between the two approaches. The continuous profiles were extracted from the DTM-generated TIN surfaces in AutoCAD Civil 3D software. The upstream start point for each annual profile was kept constant to enable a spatial comparison over time. The upstream start of the Lower Alexander Valley Reach profile coincided with the upstream extent of the 2009 TIN surface, which begins well upstream of the cross-section station 52+0000. Thus, the spatial extent is greater than the profile view shown above in Figure 8. The spatial extent of the continuous thalweg profile generated for the Middle Reach is the same as the profile extent shown above in Figure 9. Graphical plots depicting the continuous thalweg profiles in the two reaches are presented below in Figures 10 and 11.

The plotted thalweg-elevation profiles in Figures 10 and 11 depict a more detailed representation of the bed elevations and their changes between 2009 and 2013/2014. Comparisons of the continuous profiles in each reach reveal annual adjustments of bed elevation and reach-scale slope. Trendlines were added to the plotted data to approximate the channel-bed slopes in each reach. All regressions have a high correlation (*i.e.*, $R^2>0.90$). A summary of trendline statistics using the two methods to evaluate thalweg elevations is presented in Table 11. The annual results from each method are similar within each reach, indicating that the less-detailed cross-section based approach was sufficient to characterize reach-scale changes in thalweg elevation since 2009. Overall, the results from both approaches indicate that the thalweg slope has become less steep during the recent period.

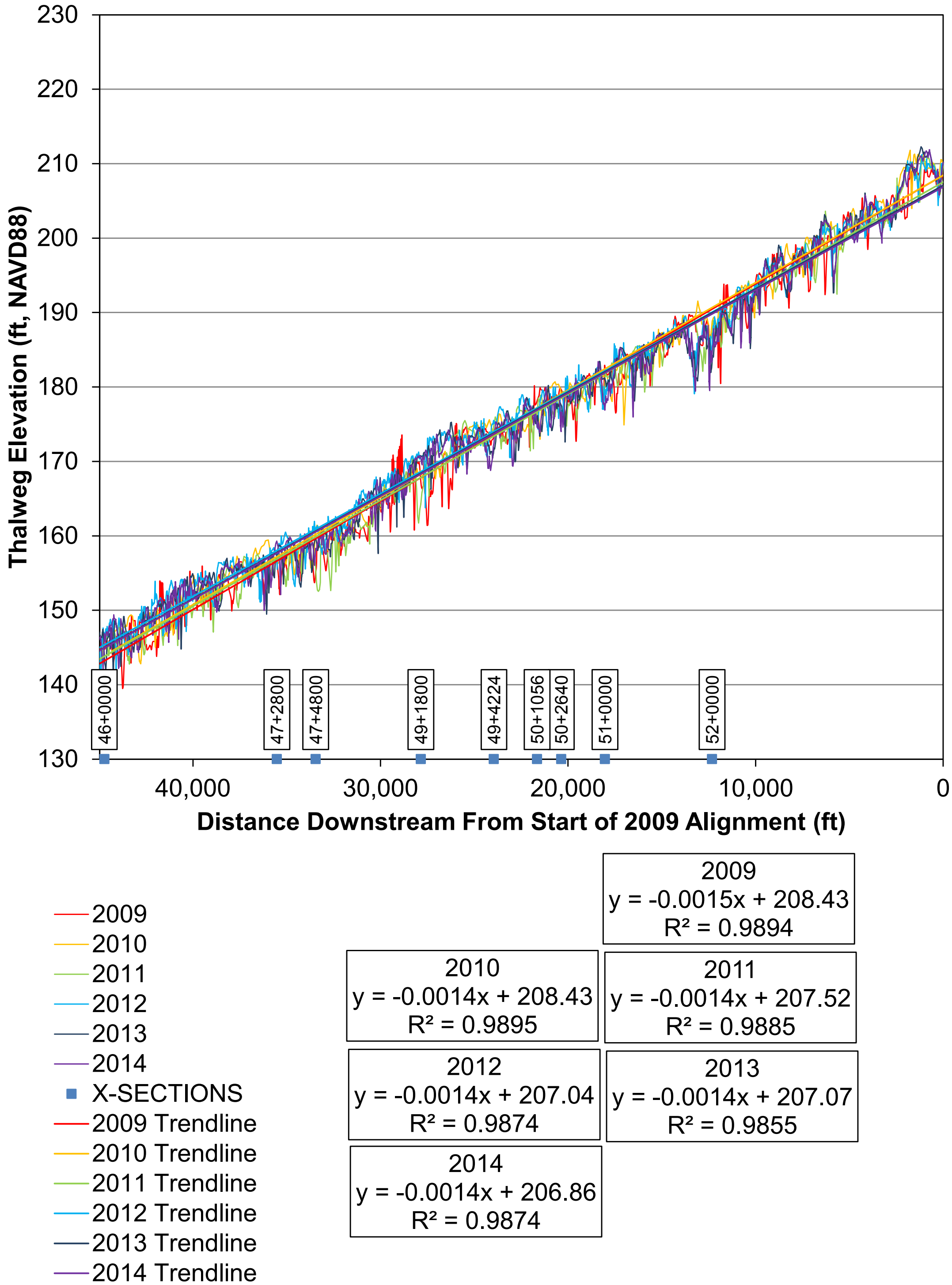


Figure 10. Continuous thalweg-elevation profile in the Lower Alexander Valley Reach.

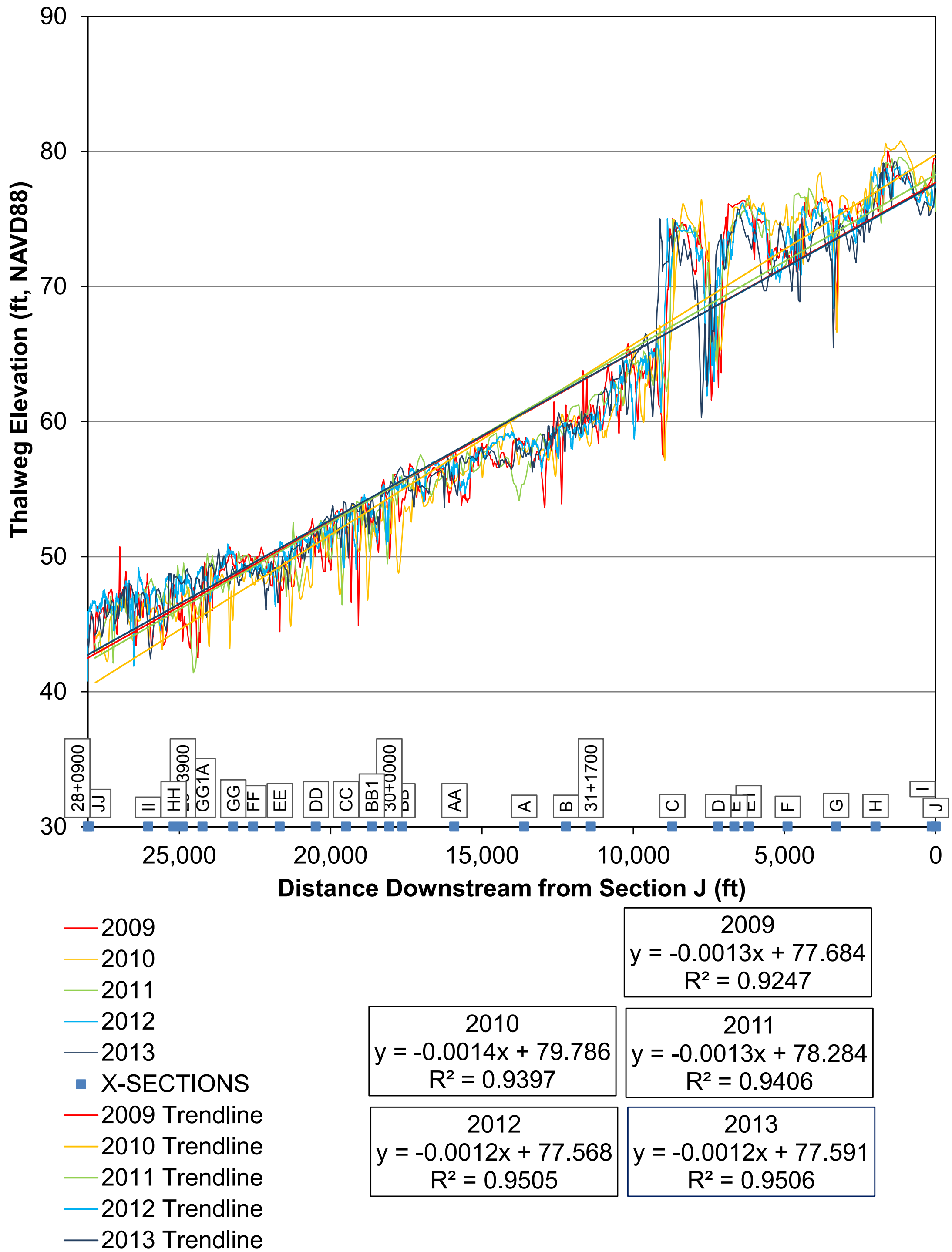


Figure 11. Continuous thalweg-elevation profile in the Middle Reach.

Table 11. Thalweg-elevation trendline slopes for the Lower Alexander Valley and Middle reaches.

Reach	Year	Trendlines from Cross-section Points along Thalweg Profiles			Trendlines from Continuous Thalweg Profiles	
		Equation (based on river-mile stations)	Equation (based on station points converted to feet)	Coefficient of Determination (R^2)	Equation (based on station positions in feet)	Coefficient of Determination (R^2)
Lower Alexander Valley Reach	2009	y = 7.42x - 197	y = 0.0014x - 197	0.98	y = -0.0015x + 208	0.99
	2010	y = 7.33x - 191	y = 0.0014x - 191	0.99	y = -0.0014x + 208	0.99
	2011	y = 7.33x - 192	y = 0.0014x - 192	0.99	y = -0.0014x + 207	0.99
	2012	y = 7.44x - 198	y = 0.0014x - 198	0.99	y = -0.0014x + 207	0.99
	2013	y = 7.28x - 191	y = 0.0014x - 191	0.98	y = -0.0014x + 207	0.99
	2014	y = 7.31x - 193	y = 0.0014x - 193	0.97	y = -0.0014x + 207	0.99
Middle Reach	2009	y = 6.88x - 152	y = 0.0013x - 152	0.91	y = -0.0013x + 78	0.92
	2010	y = 7.13x - 160	y = 0.0014x - 160	0.93	y = -0.0014x + 80	0.94
	2011	y = 7.05x - 156	y = 0.0013x - 156	0.95	y = -0.0013x + 78	0.94
	2012	y = 6.66x - 146	y = 0.0013x - 146	0.93	y = -0.0012x + 78	0.95
	2013	y = 6.90x - 153	y = 0.0013x - 153	0.94	y = -0.0012x + 78	0.95

2.3.1.4 Long-term thalweg change results (1982–2013/2014)

Thalweg elevation data from years 1982, 1986, and 1989 that were presented in the 2008 Monitoring Report (Entrix 2010) can be used to evaluate longer-term changes in channel morphology. These older data were derived from cross-section profiles in the two monitoring reaches. According to the 2008 Monitoring Report, there are eight cross-sections in the Upper and Lower Alexander Valley reaches and nine cross-sections in the Middle Reach available for those three years pre-dating 1994 (see Table 7 in Entrix 2010). Of these longer-term monitoring stations, there are six available for the Lower Alexander Valley Reach and three for the Middle Reach for comparison with post-2008 thalweg elevations. The thalweg elevations for 1982, 1986, 1989, 1994, and 2013/2014 are summarized for these stations in the two reaches in Tables 12 and 13. The changes in thalweg elevation between 1982 and 1994, 1982 and 2013/2014, and 1994 and 2013/2014 are also included in these tables.

The majority of thalweg comparison points decreased in elevation during the three time periods evaluated for the two reaches (see Tables 12 and 13). In the Lower Alexander Valley Reach, the average change from the six thalweg points was -2.3 ft between 1982 and 1994, and -4.6 between 1982 and 2014. In the Middle Reach, the average change from the three thalweg points was -5.0 ft between 1982 and 1994, -3.6 ft between 1982 and 2013, but +1.4 ft between 1994 and 2013 (ARM Plan implementation period). While the number of thalweg points used here is considerably less than those used in the analyses presented above, the comparisons to older data from 1982 still indicate similar trends wherein the Lower Alexander Valley Reach (at the six long-term comparison points) has been experiencing annual fluctuations in bed elevation with overall reach-average lowering while the Middle Reach (at the three long-term comparison points) appears to have reversed that trend after 1994.

Table 12. Long-term thalweg elevations and differences for the Lower Alexander Valley Reach.

Cross-section Intercept along Thalweg	Thalweg Elevation per Year (ft, NGVD29) [A]					Change in Thalweg Elevation (ft)		
	1982	1986	1989	1994	2014	1982 & 1994 [A]	1982 & 2014	1994 & 2014
52+0000	188.8	190.3	190.3	190.0	180.6	1.2	-8.3	-9.5
51+0000	184.3	180.8	181.0	181.3	178.5	-3.0	-5.8	-2.8
50+2640	182.3	175.0	175.0	176.4	174.3	-5.9	-8.0	-2.1
50+1056	179.5	175.3	172.0	173.1	173.3	-6.4	-6.2	0.2
49+4224	168.0	171.0	167.5	173.0	171.5	5.0	3.5	-1.5
46+0000	142.0	142.3	138.5	137.2	139.4	-4.8	-2.6	2.2
Average Change in Thalweg Elevation						-2.3	-4.6	-2.2
Number of Thalweg Points with Same or Increased Elevations						2	1	2
Number of Thalweg Points with Decreased Elevations						4	5	4

Table footnotes:

[A] 1982–1994 data from the 2008 Monitoring Report (Entrix 2010). All elevations referenced to National Geodetic Vertical Datum of 1929 (NGVD29) to enable comparison between historic and contemporary data. Transformations of post-1994 data were confirmed using NOAA's online VERTCON software. Thalweg elevations reported for 1995–2013 are presented in Appendix C.

Table 13. Long-term thalweg elevations and differences for the Middle Reach.

Cross-section Intercept along Thalweg	Thalweg Elevation per Year (ft, NGVD29) [A]					Change in Thalweg Elevation (ft)		
	1982	1986	1989	1994	2013	1982 & 1994 [A]	1982 & 2013	1994 & 2013
31+1700	59.3	55.2	56.3	55.2	57.9	-4.1	-1.4	2.7
28+3900	47.7	44.9	43.4	40.8	41.7	-6.9	-6.0	0.9
28+0900	42.7	41.1	40.3	38.8	39.3	-3.9	-3.4	0.5
Average Change in Thalweg Elevation						-5.0	-3.6	1.4
Number of Thalweg Points with Same or Increased Elevations						0	0	3
Number of Thalweg Points with Decreased Elevations						3	3	0

Table footnotes:

[A] 1982–1994 data from the 2008 Monitoring Report (Entrix 2010). All elevations referenced to National Geodetic Vertical Datum of 1929 (NGVD29) to enable comparison between historic and contemporary data. Transformations of post-1994 data were confirmed using NOAA's online VERTCON software. Thalweg elevations reported for 1995–2013 are presented in Appendix C.

2.3.2 Change in reference water surface elevation

Another means to evaluate changes in channel dimensions over space and time is to monitor changes to a reference water surface elevation (WSEL). While the thalweg elevation is a useful indicator of the lowest elevation of the channel bed, the reference WSEL can reveal geomorphic changes across the entire wetted, low-flow channel width. The WSEL is typically measured during summer low-flow conditions, and can indicate aggradation or degradation of channel bed features based on the assumption that the WSEL runs parallel to the bed elevation. This assumption, however, only holds true if flow conditions at the time of the survey are consistent from year to year. Also, significant changes in channel geomorphology between sections can influence WSELs, forcing discharge through different cross-sectional areas and consequently raising or lowering the water surface proportionally.

Reference WSELs in 1997 for many of the cross-section stations evaluated above were provided in the 2008 Monitoring Report (Entrix 2010). Reference WSELs from 1997 were available for four of the nine Lower Alexander Valley Reach cross-sections and 25 of the 27 Middle Reach sections. We compared the 1997 reference WSELs to those derived from cross-section data in the 2009–2013/2014 datasets provided by PRMD. The annual WSELs were represented as polylines along both riverbanks in the TIN surface. Information on the corresponding river discharge was not provided with the 2009–2013/2014 datasets, nor was a discharge attributed to the 1997 reference WSELs in the 2008 Monitoring Report. Therefore it was not possible to confirm whether the WSELs from any year were based on a similar discharge.

The WSELs from 1997 and 2008–2013/2014 are summarized in Tables 14 and 15. Also presented are the WSEL differences between 1997 and each of the more recent years. The reach-average WSEL changes in the Lower Alexander Valley Reach ranged from -1.9 ft to +1.0 ft, while the changes in the Middle Reach ranged from -3.4 ft to +2.8 ft. The average change between 1997 and each of the years between 2008 and 2014 in the Lower Alexander Valley Reach was approximately zero, while the difference between 1997 and 2014 was -1.1 ft. In the Middle Reach, the average change between 1997 and each of the years between 2008 and 2013 was +0.1 ft, while the difference between 1997 and 2013 was -0.7 ft. These results indicate virtually no change in WSELs based on the average 1997–2013/2014 results. Since 2009, however, there has been a steady, albeit low-magnitude, decline in WSELs through to 2013/2014 in both reaches. It should be further noted that the calculated changes in WSELs at most cross-sections for most years may be too small to provide an accurate characterization of aggradation and degradation over time.

Table 14. Water surface elevations and changes for the Lower Alexander Valley Reach.

Cross-section	WSEL (ft, NAVD88) [A]								Change in WSELs Since 1997 (ft)						
	1997 Reference [B]	2008 [B]	2009	2010	2011	2012	2013	2014	1997 & 2008 [B]	1997 & 2009	1997 & 2010	1997 & 2011	1997 & 2012	1997 & 2013	1997 & 2014
52+0000	N/A[C]	N/A[C]	190.6	193.2	191.3	190.7	189.9	190.0	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]
51+0000	N/A[C]	N/A[C]	183.4	183.5	183.3	182.7	182.6	182.0	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]
50+2640	N/A[C]	N/A[C]	181.4	182.3	181.1	181.1	181.0	180.7	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]
50+1056	N/A[C]	N/A[C]	180.8	180.6	180.6	179.3	178.2	177.6	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]
49+4224	176.8	176.5	176.5	177.7	177.5	176.2	177.3	175.8	-0.3	-0.3	0.9	0.7	-0.6	0.5	-1.0
49+1800	172.1	171.7	171.9	171.8	173.2	171.9	170.8	170.3	-0.4	-0.2	-0.3	1.0	-0.2	-1.4	-1.9
47+4800	161.2	161.9	161.0	162.2	162.4	161.5	161.1	160.8	0. 7	-0.2	1.0	1.2	0.3	-0.1	-0.4
47+2800	158.9	158.7	159.1	159.8	160.0	159.1	158.7	157.8	-0.2	0.2	0.9	1.1	0.2	-0.2	-1.1
46+0000	N/A[C]	N/A[C]	147.4	148.7	148.5	147.9	147.7	147.2	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]
Average Change in Reference WSEL									-0.1	-0.1	0.6	1.0	-0.1	-0.3	-1.1
Number of Cross-sections with Same or Increased WSEL									1	1	3	4	2	1	0
Number of Cross-sections with Decreased WSEL									3	3	1	0	2	3	4

Table footnotes:
[A] WSEL = water surface elevation; datum of 1997 elevations is assumed to be NAVD88.
[B] 1997 and 2008 data from the 2008 Monitoring Report (Entrix 2010).
[C] N/A = no data available for 1997 because these cross-sections were not considered in the original ARM Plan; values for 2009–2014 have been provided here for future reference.
[D] --- = no data provided by PRMD (see Table 15).

Table 15. Water surface elevations and changes for the Middle Reach.

Cross-section	WSEL (ft, NAVD88) [A]								Change in WSELs Since 1997 (ft)						
	1997 Reference [B]	2008 [B]	2009	2010	2011	2012	2013	2014 [D]	1997 & 2008 [B]	1997 & 2009	1997 & 2010	1997 & 2011	1997 & 2012	1997 & 2013	1997 & 2014 [D]
J	81.2	81.6	81.6	81.6	81.6	80.3	80.1	---	0.4	0.4	0.4	0.4	-0.9	-1.1	---
I	78.9	80.1	79.8	80.7	80.1	80.0	79.3	---	1.1	0.9	1.8	1.2	1.1	0.4	---
H	78.4	78.3	78.4	78.4	78.0	78.0	76.0	---	0.0	0.0	0.1	-0.4	-0.4	-2.3	---
G	78.3	77.9	77.5	78.1	77.5	77.5	76.0	---	-0.4	-0.8	-0.1	-0.8	-0.7	-2.2	---
F	77.2	77.8	77.5	77.8	77.5	77.4	76.0	---	0.6	0.3	0.6	0.3	0.2	-1.2	---
E1	76.5	76.2	76.1	77.4	76.4	76.6	75.9	---	-0.4	-0.5	0.8	-0.2	0.0	-0.6	---
E	76.9	75.6	75.5	76.4	75.5	76.4	75.8	---	-1.3	-1.4	-0.4	-1.3	-0.5	-1.0	---
D	76.2	75.4	75.3	76.0	75.3	75.3	75.2	---	-0.8	-0.9	-0.2	-0.9	-0.9	-1.0	---
C	67.7	66.4	66.2	67.3	65.3	65.6	65.4	---	-1.4	-1.5	-0.5	-2.4	-2.2	-2.4	---
31+1700	65.3	62.6	61.9	62.9	62.8	61.5	62.0	---	-2.7	-3.4	-2.4	-2.5	-3.8	-3.3	---
B	63.4	61.4	61.0	62.1	62.1	60.8	60.9	---	-2.0	-2.3	-1.3	-1.3	-2.6	-2.4	---
A	60.8	60.4	60.4	61.2	60.3	60.5	60.0	---	-0.4	-0.5	0.4	-0.5	-0.3	-0.8	---
AA	59.3	59.1	58.1	60.1	59.4	58.5	58.3	---	-0.2	-1.1	0.8	0.1	-0.8	-1.0	---
BB	57.4	57.3	57.4	58.4	58.2	57.8	57.2	---	-0.1	0.0	1.0	0.8	0.4	-0.2	---
30+0000	57.1	57.1	57.2	58.0	58.0	56.7	56.4	---	0.0	0.1	0.9	0.9	-0.4	-0.7	---
BB1	57.4	57.2	56.6	57.6	57.1	56.2	55.7	---	-0.2	-0.8	0.2	-0.3	-1.2	-1.7	---
CC	55.6	56.1	55.7	56.4	55.5	55.5	55.5	---	0.5	0.1	0.8	-0.1	-0.2	-0.1	---
DD	54.0	54.0	53.9	54.7	54.0	53.8	52.9	---	0.0	0.0	0.8	0.1	-0.1	-1.0	---
EE	51.8	52.9	52.9	53.9	53.1	52.7	51.5	---	1.2	1.2	2.1	1.4	0.9	-0.3	---
FF	51.6	52.1	52.9	52.8	53.0	51.8	51.5	---	0.6	1.4	1.2	1.4	0.2	-0.1	---
GG	51.2	52.1	51.9	52.6	51.9	51.8	51.2	---	1.0	0.8	1.4	0.7	0.6	0.1	---
GG1A	49.7	50.8	50.6	51.8	51.6	51.3	51.1	---	1.1	1.0	2.2	1.9	1.7	1.4	---
28+3900	49.5	50.7	50.4	51.3	51.5	51.2	50.6	---	1.3	1.0	1.9	2.1	1.8	1.2	---
HH	49.5	50.6	50.4	51.3	51.7	50.9	50.6	---	1.1	0.9	1.8	2.2	1.4	1.1	---
II	48.4	50.1	50.3	51.0	51.2	50.5	50.6	---	1.7	1.9	2.6	2.8	2.1	2.1	---
JJ	N/A[C]	N/A[C]	48.2	48.7	48.0	47.4	47.1	---	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	---
28+0900	N/A[C]	N/A[C]	48.2	48.7	48.0	47.3	47.1	---	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	N/A[C]	---
Average Change in Reference WSEL									0.02	-0.1	0.7	0.2	-0.2	-0.7	---
Number of Cross-sections with Same or Increased WSEL									13	13	19	14	11	6	---
Number of Cross-sections with Decreased WSEL									12	12	6	11	14	19	---

See footnotes for Table 14.

2.3.3 Change in bank position (bank erosion)

Erosion, or retreat, of the riverbanks has been evaluated during past years of the ARM monitoring program via field-based visual observations, as described in the 2008 Monitoring Report (Entrix 2008). No reports on observed bank erosion have been prepared since before 2008. The 2008 Monitoring Report did, however, present an evaluation of bank erosion at select locations in the Lower Alexander Valley and Middle reaches based on review of aerial photographs collected in 2007 and 2008.

In general, bank retreat and accretion are caused by lateral movement of the channel through its floodplain. Typically, when the channel is migrating laterally, erosion occurs on one bank while the opposite bank and/or bar complex experiences accretion, or deposition. In turn, channel constriction and expansion result from relative accretion and erosion, respectively, on both banks. Adjustments in bank and bar positions are also linked to vertical adjustment of the channel bed. For example, as a bar builds in elevation, the cross-sectional area available for high-water flow decreases, which typically results in channel adjustments involving lateral retreat of the riverbank via erosion.

For the evaluation of bank erosion activity occurring in the two monitoring reaches between 2009 and 2014, we have quantified movement in riverbank position using the cross-section profiles provided by PRMD. Determining the amount of bank movement at each cross-section first required establishment of a fixed elevation from which to reference bank position along the cross-section for all years. The reference elevation unique to each cross-section station was set as the average WSEL at that section over the 2009–2013/2014 time period. Stationing along each cross-section began on the left bank side and increased towards the right bank (see horizontal stationing on cross-section plots presented in Appendix B). The previous year's bank position along the horizontal axis was then subtracted from the current year's position to compute a change in bank position that could later be attributed to either bank erosion or bank/bar accretion. For evaluation of the left bank, positive values computed from the annual comparison indicate that the bank position moved towards the river's centerline and away from the floodplain (*i.e.*, bank and/or bar accretion), while negative values indicate bank movement away from the river's centerline and toward the floodplain (*i.e.*, bank retreat). For the right bank evaluation, positive values indicate that the bank position moved away from the river's centerline and toward the floodplain (*i.e.*, bank retreat), while negative values indicate bank movement toward the river's centerline and away from the floodplain (*i.e.*, bank and/or bar accretion).

Summaries of the bank position changes during 2009–2013/2014 in the two reaches are presented in Tables 16 and 17. Detailed summaries of bank positions and their changes are presented in Appendix E. Graphical depictions of the cross-sections are presented in Appendix B.

In the Lower Alexander Valley Reach, more cross-sections experienced greater bank retreat, or erosion, than bank/bar accretion, or deposition. The greatest amount of left-bank and right-bank retreat occurred at cross-sections 47+2800 (159 ft) and 52+0000 (223 ft), respectively. The reach-average left-bank and right-bank retreat over the 2009–2014 period was 31 and 32 ft, respectively. The greatest reach-average retreat of both banks occurred between 2010 and 2011. Overall, the results reveal that there was a greater amount of bank retreat than bank/bar accretion, which indicates general widening of the channel at the point intersected by the reference WSELs.

Most of the 27 cross-sections in the Middle Reach experienced greater bank retreat than bank/bar accretion during the 2009–2013 period. Bank retreat was greatest on river left of cross-section 30+0000 (86 ft) and on river right of cross-section II (138 ft). The reach average retreat on both banks between 2009 and 2013 was only 1 ft, which indicates a closer balance between total bank retreat and bank/bar accretion despite the annual variability observed at most cross-sections.

In summary, the results from both reaches indicate a pattern of site-specific adjustments that generally oscillate between overall average bank retreat and bank/bar accretion from 2009–2013/2014. Localized and momentary channel incision and aggradation are apparent at multiple sections, which are linked to the lateral adjustments.

Table 16. Riverbank position changes for the Lower Alexander Valley Reach.

Cross-Section	Mean WSEL (ft) [A]	Change in Left Bank Position (ft) [B]					Change in Right Bank Position (ft) [C]				
		2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
52+0000	190.9	40.1 accrete	-34.3 retreat	35.5 accrete	-49.1 retreat	7.1 accrete	79.3 retreat	46.5 retreat	64.0 retreat	34.8 retreat	-1.2 accrete
51+0000	182.9	-5.8 retreat	-21.6 retreat	-27.3 retreat	-7.1 retreat	6.6 accrete	-20.8 accrete	56.7 retreat	-36.6 accrete	-19.6 accrete	-7.4 accrete
50+2640	181.3	11.3 accrete	-47.2 retreat	4.6 accrete	-2.4 retreat	1.6 accrete	-1.7 accrete	30.7 retreat	-25.2 accrete	-17.2 accrete	7.5 retreat
50+1056	179.5	2.3 accrete	-14.8 retreat	-0.8 retreat	-3.6 retreat	2.9 accrete	-7.2 accrete	22.4 retreat	3.1 retreat	-5.1 accrete	-20.8 accrete
49+4224	176.8	3.4 accrete	-3.5 retreat	5.5 accrete	-0.6 retreat	-3.1 retreat	-8.1 accrete	93.6 retreat	-102 accrete	-30.1 accrete	150.7 retreat
49+1800	171.6	2.2 accrete	5.3 accrete	31.1 accrete	-36.0 retreat	-0.1 retreat	-2.2 accrete	-118 accrete	81.8 retreat	37.5 retreat	-11.4 accrete
47+4800	161.5	10.5 accrete	-8.6 retreat	1.4 accrete	-9.2 retreat	9.8 accrete	-0.5 accrete	1.9 retreat	8.4 retreat	-5.3 accrete	-12.4 accrete
47+2800	159.1	0.9 accrete	-0.6 retreat	-1.7 retreat	-0.1 retreat	-157 retreat	-0.6 accrete	6.8 retreat	-26.3 accrete	26.9 retreat	2.3 retreat
46+0000	147.9	38.5 accrete	-46.6 retreat	8.9 accrete	-37.6 retreat	11.6 accrete	-39.3 accrete	39.9 retreat	-10.0 accrete	27.3 retreat	-2.3 accrete
Average Change in Lateral Movement (ft)		11.5 accrete	-19.1 retreat	6.4 accrete	-16.2 retreat	-13.4 retreat	-0.1 accrete	20.0 retreat	-4.7 accrete	5.5 retreat	11.7 retreat
Number of Bank-position Comparisons with Lateral Movement Toward Left Bank (retreat)		1	8	3	9	3					
Number of Bank-position Comparisons with Lateral Movement Toward Right Bank (retreat)							1	8	4	4	3

Table footnotes:

[A] WSEL = water surface elevation based on an assumed vertical datum of NAVD88. See Appendix E for detailed tabular summary of riverbank positions.

[B] Stationing along cross-sections began on the left bank side and increased towards the right bank. Positive values in the left bank columns indicate bank-position movement toward the river's centerline and away from the floodplain (*i.e.*, bank and/or bar accretion), while negative values indicate bank movement away from the river's centerline and toward the floodplain (*i.e.*, bank retreat).

[C] Positive values in the right bank columns indicate bank-position movement away from the river's centerline and toward the floodplain (*i.e.*, bank retreat), while negative values indicate bank movement toward the river's centerline and away from the floodplain (*i.e.*, bank and/or bar accretion).

Table 17. Riverbank position changes for the Middle Reach.

Cross-Section	Mean WSEL (ft) [A]	Change in Left Bank Position (ft) [B]					Change in Right Bank Position (ft) [C]				
		2009–2010	2010–2011	2011–2012	2012–2013	2013–2014 [D]	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014 [D]
J	81.0	-47.8 retreat	-5.4 retreat	2.7 accrete	-9.1 retreat	---	3.5 retreat	-6.8 accrete	-19.5 accrete	90.7 retreat	---
I	80.0	-1.6 retreat	4.8 accrete	-18.4 retreat	-1.9 retreat	---	1.0 retreat	-92.5 accrete	91.2 retreat	0.1 retreat	---
H	77.8	16.6 accrete	-15.1 retreat	0.0	-10.0 retreat	---	14.3 retreat	61.3 retreat	-10.3 accrete	8.7 retreat	---
G	77.3	-6.7 retreat	25.4 accrete	36.3 accrete	-39.2 retreat	---	5.0 retreat	2.6 retreat	-3.5 accrete	-1.4 accrete	---
F	77.2	-3.4 retreat	2.6 accrete	3.4 accrete	34.4 accrete	---	-26.4 accrete	5.4 retreat	2.8 retreat	0.7 retreat	---
E1	76.5	16.2 accrete	94.2 accrete	-39.7 retreat	94.5 accrete	---	-11.4 accrete	12.4 retreat	4.0 retreat	1.5 retreat	---
E	75.9	-6.5 retreat	6.2 accrete	12.0 accrete	-8.3 retreat	---	4.6 retreat	1.7 retreat	0.1 retreat	1.7 retreat	---
D	75.4	17.4 accrete	7.2 accrete	53.1 accrete	-62.4 retreat	---	11.5 retreat	1.3 retreat	0.0	-2.8 accrete	---
C	65.9	34.9 accrete	-29.8 retreat	-0.5 retreat	0.0	---	-0.1 accrete	4.9 retreat	0.0	0.0	---
31+1700	62.2	0.0	0.0	-5.4 retreat	0.0	---	3.4 retreat	16.2 retreat	-44.8 accrete	13.8 retreat	---
B	61.4	0.0	0.0	0.0	0.0	---	1.6 retreat	0.5 retreat	-0.2 accrete	-4.3 accrete	---
A	60.5	2.5 accrete	-5.0	0.5 accrete	0.3 accrete	---	8.3 retreat	4.7 retreat	-3.8 accrete	-0.2 accrete	---
AA	58.9	12.4 accrete	10.3 accrete	-3.8 retreat	-18.5 retreat	---	-8.8 accrete	32.8 retreat	7.0 retreat	-2.6 accrete	---
BB	57.8	-8.3 retreat	-7.6 retreat	-7.9 retreat	-5.8 retreat	---	9.9 retreat	-35.1 accrete	-2.3 accrete	-12.3 accrete	---
30+0000	57.3	-10.5 retreat	-3.9 retreat	-60.4 retreat	-11.3 retreat	---	3.9 retreat	-5.1 accrete	-31.6 accrete	-45.3 accrete	---
BB1	56.6	4.0 accrete	-28.1 retreat	36.6 accrete	-26.4 retreat	---	-4.3 accrete	10.0 retreat	0.5 retreat	2.8 retreat	---
CC	55.7	-12.5 retreat	24.6 accrete	-18.9 retreat	-25.5 retreat	---	-1.5 accrete	2.5 retreat	1.1 retreat	-1.1 accrete	---
DD	53.9	-3.8 retreat	22.4 accrete	-5.0 retreat	14.8 accrete	---	7.6 retreat	-0.5 accrete	-4.3 accrete	7.7 retreat	---
EE	52.8	-2.3 retreat	0.7 accrete	-5.1 retreat	-0.4 retreat	---	-1.9 accrete	3.3 retreat	3.5 retreat	4.8 retreat	---
FF	52.4	-11.7 retreat	7.7 accrete	-12.9 retreat	7.0 accrete	---	6.3 retreat	-0.2 accrete	1.0 retreat	1.1 retreat	---
GG	51.9	2.8 accrete	-6.9 retreat	2.9 accrete	-1.1 retreat	---	23.3 retreat	-24.5 accrete	-2.2 accrete	1.8 retreat	---
GG1A	51.3	-23.9 retreat	50.1 accrete	-18.7 retreat	60.0 accrete	---	7.9 retreat	-5.5 accrete	13.1 retreat	14.3 retreat	---
28+3900	51.0	-4.6 retreat	8.5 accrete	0.1 accrete	-4.5 retreat	---	6.0 retreat	0.7 retreat	-2.6 accrete	0.1 retreat	---
HH	51.0	-2.1 retreat	77.3 accrete	-69.4 retreat	-14.3 retreat	---	8.1 retreat	-0.8 accrete	0.1 retreat	-3.3 accrete	---
II	50.7	-12.9 retreat	-20.2 retreat	-4.9 retreat	-5.0 retreat	---	8.0 retreat	-158 accrete	4.9 retreat	7.1 retreat	---
JJ	47.9	-25.0 retreat	24.2 accrete	-17.5 retreat	-2.5 retreat	---	2.1 retreat	-4.3 accrete	11.4 retreat	-3.3 accrete	---
28+0900	47.9	-18.2 retreat	17.8 accrete	-18.3 retreat	3.3 accrete	---	5.9 retreat	4.2 retreat	1.4 retreat	-2.9 accrete	---

Cross-Section	Mean WSEL (ft) [A]	Change in Left Bank Position (ft) [B]					Change in Right Bank Position (ft) [C]				
		2009–2010	2010–2011	2011–2012	2012–2013	2013–2014 [D]	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014 [D]
Average Change in Lateral Movement (ft)		-3.5 retreat	9.7 accrete	-5.9 retreat	-1.2 retreat	---	3.3 retreat	-6.2 accrete	0.6 retreat	2.9 retreat	---
Number of Bank-position Comparisons with Lateral Movement Toward Left Bank (retreat)		17	9	16	17	---					
Number of Bank-position Comparisons with Lateral Movement Toward Right Bank (retreat)							20	16	14	15	---

Table footnotes:

[A] WSEL = water surface elevation based on an assumed vertical datum of NAVD88. See Appendix E for detailed tabular summary of riverbank positions.

[B] Stationing along cross-sections began on the left bank side and increased towards the right bank. Positive values in the left bank columns indicate bank-position movement toward the river's centerline and away from the floodplain (*i.e.*, bank and/or bar accretion), while negative values indicate bank movement away from the river's centerline and toward the floodplain (*i.e.*, bank retreat).

[C] Positive values in the right bank columns indicate bank-position movement away from the river's centerline and toward the floodplain (*i.e.*, bank retreat), while negative values indicate bank movement toward the river's centerline and away from the floodplain (*i.e.*, bank and/or bar accretion).

[D] --- = no data for 2014 provided by PRMD.

2.3.4 Volumetric change in sediment storage

Yearly patterns of aggradation and degradation throughout the monitoring reaches due to sediment scour, deposition, or in-channel mining can be further assessed through computation of volumetric changes in sediment storage. During mining years, the total sediment recharge capacity of the river is determined by summing the volume of gravel mined with the total change in volume in the channel between cross-section stations. Because mining was not active during the monitoring years evaluated in this report, the evaluation of changes in sediment volume presented here emphasizes how the river system has naturally stored sediment independent of the direct influence of mining. We employed two different methods to evaluate changes in sediment volume, the first of which utilized the two-dimensional cross-sections previously introduced, and the second utilized the three-dimensional channel-bed surfaces.

2.3.4.1 Volumetric changes from cross-sections

Evaluation of net change in sediment storage volume on a reach scale was previously conducted for the 2008 Monitoring Report (Entrix 2010) using the cross-section profiles. The approach utilized the standard "Average End Area Method," or AEA method, for calculating the volumetric change in sediment storage between two paired cross-sections. The calculation formula is as follows:

$$V_{AEA} = \mathrm{L}\frac{(\Delta A_2 + \Delta A_1)}{2}$$

Where:

ΔA_1 is the annual change in cross-sectional area at the first cross-section in ft^2
ΔA_2 is the annual change in cross-sectional area at the second cross-section in ft^2
L is the distance between the paired cross-sections in ft
V_{AEA} is the volume of sediment aggradation or degradation in cubic feet (ft^3) and subsequently converted to cubic yards (yd^3)

The volumetric change in sediment storage between paired cross-sections relied directly upon the annual change in area at each cross-section (see Section 2.3.1.2 above). As such, a positive sign in the comparison indicates an increase in channel volume below the ground surface due to sediment deposition along the bed or banks. Whereas, a negative sign in the comparison indicates a decrease in channel volume below the ground surface due to sediment loss along the bed or banks.

The AEA method is very convenient because it only requires cross-sectional information and the river mile distance between the paired cross-sections. The simplified interpolation, however, results in only an approximation of the actual volumetric change between cross-sections and, thus, does not capture any geomorphic changes occurring between the cross-sections. The results from applying this method can also be skewed over longer river segments between more distant sections regardless of the magnitude of average annual change in cross-sectional area.

The results of the reach-wide volumetric changes using the AEA method are presented in Tables 18 and 19. The results reported for 1994–2008 in the Lower Alexander Valley Reach have been adjusted to account for that portion of the reach between stations RM 46.00 and 52.00 where cross-sections from 2009–2014 have been provided. Similarly, the results reported for 1994–2008 in the Middle Reach have been adjusted to focus only that portion between stations RM 28.17 and 33.37. The approximate amounts of in-channel gravel mined annually in each reach have also been provided in the tables. Finally, the approximate sediment recharge rates, which account for the total volume of gravel mined, are presented in the tables. The approximate recharge rates for 2002–2003 and 2007–2008 in the Middle Reach, however, may be inflated by some quantity of gravel mined outside of the evaluated reach (*i.e.*, downstream of RM 28.17). All gravel mined in the Lower Alexander Valley Reach is known to have occurred within the focus area of this report (*i.e.*, RM 46.00–52.00). Comprehensive summaries of the annual changes in cross-sectional area and sediment storage between 1993 and 2013/2014 are presented in Appendix F.

Because the evaluation was based on changes in cross-sectional area, the results of volumetric changes during 2008–2013/2014 presented in Tables 18 and 19 vary similarly to those presented above in Tables 7 and 8. Sediment storage in both reaches varied annually with some years experiencing net gain and other years experiencing net loss.

In the Lower Alexander Valley Reach, the cumulative change for 2008–2014 in the reach was about +321,000 yd^3, which equates to an average annual recharge rate of +53,500 yd^3/yr (see Table 18). In comparison, the 1994–2008 average annual recharge rate including gravel mined was much greater (+126,000 yd^3/yr); the rate without the gravel mined contribution was +78,900 yd^3/yr.

This result indicates that the rate of annual recharge has decreased since 2008 compared with the historical average, which corresponds with a series of relatively low-flow winter seasons and reduced bedload transport.

The Middle Reach also experienced net aggradation during 2008–2013, amounting to approximately +103,000 yd^3 (see Table 19). This amount equates to an average annual recharge rate of +20,600 yd^3/yr, which is substantially less than the 1994–2008 average rate of +147,500 yd^3 (inclusive of gravel mined).

Table 18. Changes in sediment volume in the Lower Alexander Valley Reach.

Year		Volumetric Change in Sediment Storage within RM 46.00–52.00 (yd^3)		
		Approximate Change Based on AEA Method [A]	**Approximate In-Channel Gravel Mined [B]**	**Approximate Sediment Recharge After Mining**
1994–1995		396,458	27,000	423,000
1995–1996		-8,065	293,000	285,000
1996–1997		-111,278	0	-111,000
1997–1998		213,380	207,000	420,000
1998–1999		250,083	0	250,000
1999–2000		-115,209	77,000	-38,000
2000–2001		-5,015	43,000	38,000
2001–2002		144,496	7,000	151,000
2002–2003		-109,447	3,000	-106,000
2003–2004		383,238	0	383,000
2004–2005		-37,762	0	-38,000
2005–2006		163,394	0	163,000
2006–2007		19,436	0	19,000
2007–2008		-79,063	0	-79,000
2008–2009		163,404	0	163,000
2009–2010		194,660	0	195,000
2010–2011		-112,190	0	-112,000
2011–2012		175,494	0	175,000
2012–2013		-245,745	0	-246,000
2013–2014		145,086	0	145,000
Cumulative Change	1994–2008	1,104,646	657,000	1,762,000
	2008–2014	320,709	0	321,000
	1994–2014	1,425,355	657,000	2,082,000

Table footnotes:

[A] Data sources: years 1994–2008 adapted from the 2008 Monitoring Report (Entrix 2010) and adjusted to accommodate that portion of the monitoring reach between stations 46+0000 and 52+0000; years 2009–2014 summarized in Appendix F.

[B] Values based on in-channel gravel production summarized in Table 3; conversion of tons to cubic yards (yd^3) assumes a bulk density of 1.5 tons per cubic yard, per the 2008 Monitoring Report (Entrix 2010).

Table 19. Changes in sediment volume in the Middle Reach.

Year		Volumetric Change in Sediment Storage within RM 28.17–33.37 (yd³)		
		Approximate Change Based on AEA Method [A]	Approximate In-Channel Gravel Mined [B]	Approximate Sediment Recharge After Mining
1994–1995		437,555	0	438,000
1995–1996		147,754	0	148,000
1996–1997		373,901	0	374,000
1997–1998		168,275	0	168,000
1998–1999		131,653	0	132,000
1999–2000		-34,111	0	-34,000
2000–2001		161,611	0	162,000
2001–2002		248,540	0	249,000
2002–2003		56,534	197,000	254,000
2003–2004		399,451	0	399,000
2004–2005		-310,803	0	-311,000
2005–2006		101,491	0	101,000
2006–2007		61,189	0	61,000
2007–2008		-198,312	123,000	-75,000
2008–2009		123,677	0	124,000
2009–2010		-32,672	0	-33,000
2010–2011		15,889	0	16,000
2011–2012		-29,490	0	-29,000
2012–2013		26,007	0	26,000
Cumulative Change	1994–2008	1,744,728	320,000	2,065,000
	2008–2013	103,411	0	103,000
	1994–2013	1,848,139	320,000	2,168,000

Table footnotes:

[A] Data sources: years 1994–2008 adapted from the 2008 Monitoring Report (Entrix 2010) and adjusted to accommodate that portion of the monitoring reach between stations 28+1700 and 33+3700; years 2009–2013 summarized in Appendix F.

[B] Values based on in-channel gravel production summarized in Table 3; conversion of tons to cubic yards (yd^3) assumes a bulk density of 1.5 tons per cubic yard, per the 2008 Monitoring Report (Entrix 2010); gravel mined areas partially extended downstream of station 28+1700.

2.3.4.2 Volumetric changes from surface differencing

We initiated a secondary evaluation of volumetric changes in sediment storage in the two monitoring reaches by calculating the difference in surface elevations from the DTMs derived from the repeat photogrammetric surveys. The “Surface Elevation Differencing Method,” or SED method, was conducted using ArcGIS 3D Analyst software. Spatially discrete zones of erosion and deposition are identified by overlapping DTMs of different years. In comparison to the cross-section data, the DTM data provides a great deal more information about geomorphic change along the active river corridor, including between cross-sections. This method has been previously applied in limited application in the monitoring reaches to evaluate volumetric changes at gravel bars. For example, the 2006–2007 Monitoring Report (Entrix 2009) presented maps depicting bar elevation changes between 2002 and 2007 along a five-mile section of the Middle Reach. Also, the 2010 DEIR (AECOM 2010) presented maps depicting surface elevation changes between 1994 and 2007 at project bars in the Lower Alexander Valley Reach.

The volumetric changes between 2009 and 2013/2014 computed using the SED method are presented in Tables 20 and 21. The tables further differentiate the contributions of sediment loss (erosion) and gain (deposition). Maps depicting the annual changes of surface elevations in each reach are presented in Appendix G.

Use of the SED method found that the Lower Alexander Valley Reach experienced alternating patterns of net erosion and deposition between 2009 and 2014 (see Table 20). The greatest net sediment loss occurred during the wetter years of 2010 and 2011 (-257,000 yd^3), while the greatest net sediment gain occurred during the following year (2011–2012: +224,000 yd^3). The cumulative change in sediment volume during the entire 2009–2014 period was -13,000 yd^3.

The Middle Reach also experienced alternating patterns of net erosion and deposition between 2009 and 2013 (see Table 21). Further, the greatest net sediment loss similarly occurred during 2010–2011 (-67,000 yd^3) and the greatest net sediment gain occurred during the 2011–2012 (+28,000 yd^3). The cumulative change in sediment volume during the entire 2009–2013 period was -125,000 yd^3.

Table 20. Volumetric changes of sediment storage in the Lower Alexander Valley Reach using the SED and AEA methods.

Time Period		Volumetric Change in Sediment Storage (yd^3)			
		Using the SED Method			Using the AEA Method
		Erosion	Deposition	Total	Total
2009–2010		-260,000	+347,000	+88,000	+195,000
2010–2011		-416,000	+158,000	-257,000	-112,000
2011–2012		-155,000	+379,000	+224,000	+175,000
2012–2013		-333,000	+203,000	-130,000	-246,000
2013–2014		-176,000	+238,000	+62,000	+145,000
Cumulative Change:	2009–2014	-1,338,000	+1,325,000	-13,000	+157,000

Table 21. Volumetric changes of sediment storage in the Middle Reach using the SED and AEA methods.

Time Period		Volumetric Change in Sediment Storage (yd^3)			
		Using the SED Method			Using the AEA Method
		Erosion	Deposition	Total	Total
2009–2010		-274,000	+228,000	-46,000	-33,000
2010–2011		-247,000	+180,000	-67,000	+16,000
2011–2012		-180,000	+208,000	+28,000	-29,000
2012–2013		-184,000	+144,000	-40,000	+26,000
Cumulative Change:	2009–2013	-884,000	+760,000	-125,000	-20,000

Volumetric changes in sediment storage estimated from the AEA method using the cross-section data are also presented in Tables 20 and 21 for the purpose of comparing the SED and AEA methods. The annual total changes in sediment storage using the two methods are depicted graphically in Figure 12. Overall, the AEA method results differ significantly from the volumes estimated using the SED method. In the Lower Alexander Valley Reach both methods resulted in the same years having either net erosion or deposition. In the Middle Reach the annual patterns of net erosion and deposition were not estimated similarly by the two methods. The cumulative volumetric change in the Lower Alexander Valley Reach of -13,000 yd^3 contrasts sharply with the volumetric change of +157,000 estimated using the AEA method. While both the SED and AEA methods estimated cumulative sediment loss in the Middle Reach, their magnitudes were significantly different (*i.e.*, -125,000 yd^3 versus -20,000 yd^3). These significant differences in results highlights the sensitivity of computing changes in sediment storage to the particular method employed.

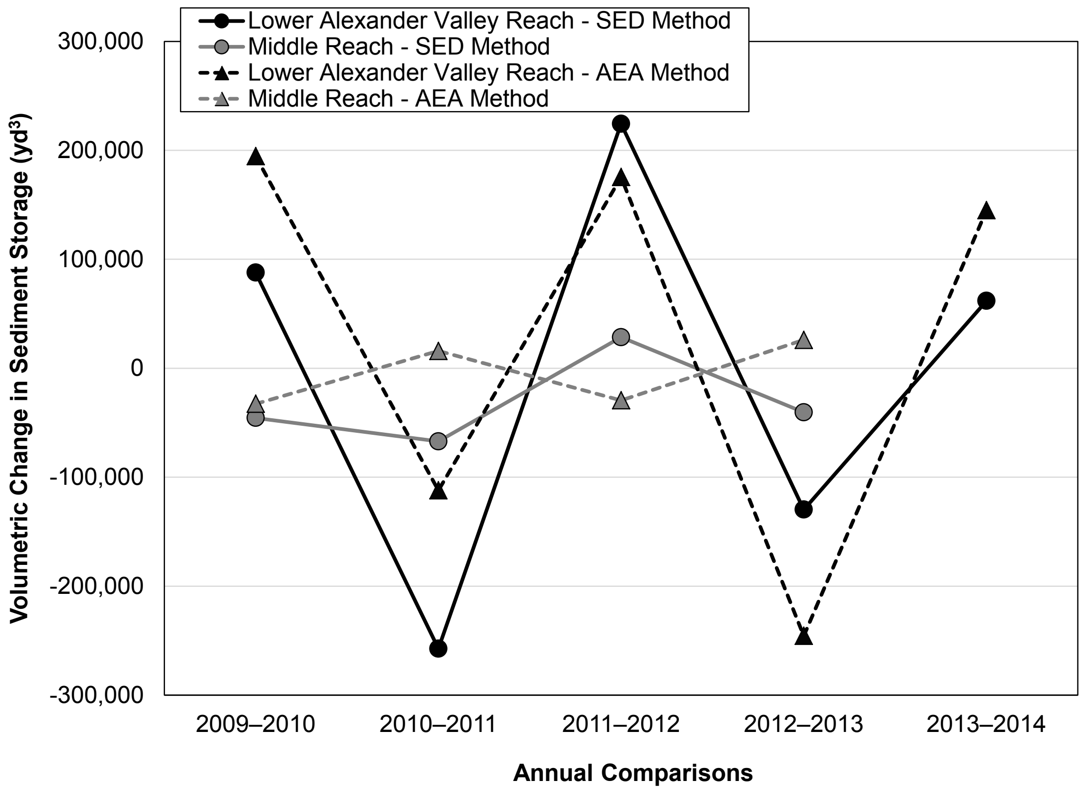


Figure 12. Comparison of volumetric changes in sediment storage in the Lower Alexander Valley and Middle reaches using the SED and AEA methods.

An additional evaluation of volumetric changes was performed for a portion of the Russian River situated immediately upstream of station 52+0000 in the Lower Alexander Valley Reach. The DTM provided by PRMD for years 2009 through 2014 extended approximately 12,300 ft (~2.3 river miles) upstream of station 52+0000. This additional extent is shown as the orange-colored, hatched area in Figure 13. We evaluated this portion of the river for the purpose of further evaluated spatial trends of geomorphic change throughout the river corridor. The results of this additional evaluation are summarized in Table 22.

Sediment storage changes upstream of station 52+0000 exhibited different trends of erosion and deposition during 2009–2014 compared with the changes occurring between stations 52+0000 and 46+0000 (see Tables 20 and 22). The greatest net loss of sediment occurred between 2009 and 2010 (-199,000 yd^3) and the greatest net gain of sediment occurred between 2013 and 2014 (+192,000 yd^3). The cumulative change in sediment volume in this portion of the reach during the entire 2009–2014 period was +32,000 yd^3. Adding these cumulative changes to those presented above for the reach portion between stations 52+0000 and 46+0000 results in a combined volumetric change of +19,000 yd^3, indicating net sediment gain over this longer extent of the Lower Alexander Valley Reach. Overall, consideration of these results highlights the extreme spatial and temporal variability of geomorphic change throughout the river corridor, and the finding of whether net sediment gain or loss has occurred depends greatly upon the data sources used and their location in the river corridor.

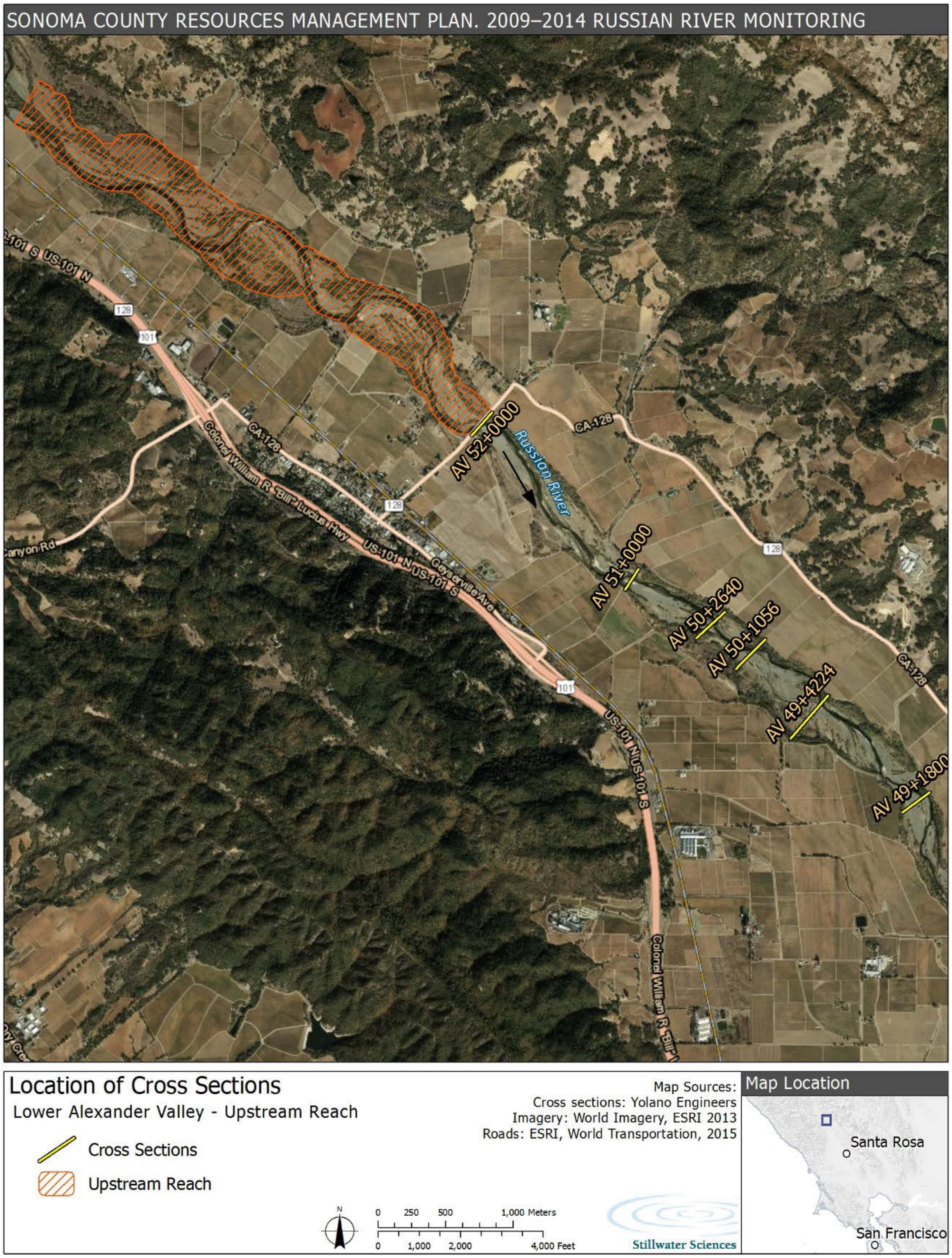


Figure 13. Portion of the Russian River situated immediately upstream of station 52+0000 in Lower Alexander Valley Reach utilized for the additional evaluation of changes in sediment storage.

Table 22. Volumetric changes of sediment storage in the river immediately upstream of station 52+0000 in Lower Alexander Valley Reach.

Time Period		Volumetric Change in Sediment Storage (yd^3)		
		Erosion	Deposition	Total
2009–2010		-306,000	+107,000	-199,000
2010–2011		-219,000	+186,000	-38,000
2011–2012		-105,000	+158,000	+53,000
2012–2013		-238,000	+257,000	+20,000
2013–2014		-52,000	+244,000	+192,000
Cumulative Change:	2009–2014	-920,000	+952,000	+32,000

3 SYNTHESIS

The following summarizes the key findings of our review of geomorphic information provided by the PRMD and the gravel operators for the periods of 2009–2014 in the Lower Alexander Valley Reach and 2009–2013 in the Middle Reach of the Russian River. This section concludes with a summary of our recommendations for future ARM monitoring and reporting activities.

3.1 Key Findings

- In-channel gravel mining along the Russian River has been limited to the Upper Alexander Valley, Lower Alexander Valley, and Middle reaches. Gravel mining has not occurred in these three reaches since 2006, 2002, and 2007, respectively (see Table 4).
- Total annual run-off during WY 2009–2014 was greatest during WYs 2010 and 2011, though WY 2011was the only year between WY 2009-2014 when the annual run-off exceeded the longer-term annual average between WY 1983 and 2014 (see Table 2). Run-off during WYs 2009, 2012, and 2014 were each less than about half of the long-term annual average indicating that these were relatively drier water years. Further, the number of days when river flows equaled or exceeded the dominant discharges computed at each of the three long-term stream gaging stations was greatest during WYs 2010, 2011, and 2013. Thus, the potential for geomorphic change between WY 2009 and 2014 has been mostly limited to these three years. There was virtually no potential for geomorphic change occurring during WYs 2009, 2012, and 2014.
- Sediment transport remains quite active in the Lower Alexander Valley and Middle reaches despite influences of various land-use activities having the potential to alter run-off and sediment delivery processes (see Section 2.1.5). Total annual suspended-sediment load (*i.e.*, sand, silt, and clay) at the Gueneville have been independently estimated to be 1,000,000 tons. Total annual bedload likely represents a tenth of the suspended-sediment load, based on the annual gravel replenishment evaluations conducted in support of the ARM Plan.
- Evaluation of nine channel cross-sections of the Lower Alexander Valley Reach from 2009–2014 and 27 cross-sections of the Middle Reach monitoring reaches from 2009–2013 reveals substantial spatial and temporal variability in the estimated changes in cross-sectional area due to local erosion and deposition (see Tables 7 and 8). The 2009–2014 reach-wide average change in the Lower Alexander Valley Reach was only +18 ft^2, whereas the cumulative change in area was about +800 ft^2. During 2009–2013, the Middle Reach experienced a reach-wide average change in area of +28 ft^2, and a cumulative change of about +3,600 ft^2. These results indicate that most monitored cross-sections experienced net sediment accumulation as a combination of thalweg and/or bar deposition.
- Evaluation of thalweg profiles of the two reaches reveals similar patterns of annual readjustments in bed elevation during 2009–2013/2014. Comparison of thalweg elevations along the cross-sections found that both reaches have experienced a cumulative decrease, or lowering, over time; a net decrease of about -1 ft has occurred since 2008 (see Tables 9 and 10). In the Lower Alexander Valley Reach, the upstream portion has lowered while the downstream portion has risen between 1994 and 2014.In the Middle Reach between 1994 and 2013, the downstream portion has risen while the bed positions in the upstream portion have fluctuated about the 1994 level. These results suggest that the reaches have experienced a net loss of sediment over time.

- A longer-term, but spatially limited, evaluation of changes to thalweg elevations revealed a similar pattern of net sediment loss in the two reaches (see Tables 12 and 13). In the Lower Alexander Valley Reach, the average change from the six long-term thalweg points was -2.3 ft between 1982 and 1994, and -4.6 ft between 1982 and 2014. In the Middle Reach, the average change from the three long-term thalweg points was -5.0 ft between 1982 and 1994, and -3.6 ft between 1982 and 2013.

- The reach-average water surface elevations (WSELs) in both reaches experienced virtually no change between 2008–2013/2014 compared with the 1997 reference WSEL (see Tables 14 and 15). Since 2009, however, there has been a steady, albeit low-magnitude, decline in WSELs through to 2013/2014 in both reaches. While these declines are small, they do suggest that the river bed has generally lowered during this time period due to net sediment loss, which agrees with the thalweg change results from the same time period.

- Evaluation of lateral changes at the cross-sections found that both reaches generally experienced greater bank retreat than bank/bar accretion during the 2009–2013/2014 period. In the Lower Alexander Valley Reach the greatest amount of left-bank and right-bank retreat occurred at cross-sections 47+2800 (159 ft) and 52+0000 (223 ft), respectively, while the reach-average left-bank and right-bank retreat over the 2009–2014 period was 31 and 32 ft, respectively. The greatest reach-average retreat of both banks in the Lower Alexander Valley Reach occurred between 2010 and 2011. In the Middle Reach bank retreat was greatest on river left of cross-section 30+0000 (86 ft) and on river right of cross-section II (138 ft). The reach average retreat on both banks between 2009 and 2013 was only 1 ft, which indicates a closer balance between total bank retreat and bank/bar accretion despite the annual variability observed at most cross-sections.

- Volumetric changes in sediment storage as derived by the standard "Average End Area Method," or AEA method, using the changes in cross-sectional area over the distance between paired cross-sections revealed that the cumulative change for 2008–2014 in the Lower Alexander Valley Reach was about +321,000 yd^3, which equates to an average annual recharge rate of +53,500 yd^3/yr—less than the average annual recharge rate of +78,900 yd^3/yr determined for 1994–2008 (see Table 18). The AEA method also found a net sediment accumulation in the Middle Reach between 2008 and 2013, amounting to approximately +103,000 yd^3 (see Table 19). The corresponding average annual recharge rate in this reach is +20,600 yd^3/yr, which is substantially less than the 1994–2008 average rate of +147,500 yd^3 (inclusive of gravel mined).

- Evaluation of volumetric changes in sediment storage using the "Surface Elevation Differencing Method," or SED method, that analyzes spatially discrete zones of erosion and deposition by overlapping DTMs of different years, found the cumulative changes in both reaches to differ substantially from volumetric changes estimated using the AEA method. Use of the SED method found that the Lower Alexander Valley Reach experienced alternating patterns of net erosion and deposition, with a cumulative change during the entire 2009–2014 period of -13,000 yd^3, indicating net sediment loss (see Table 20). The Middle Reach experienced similar oscillations in sediment storage and overall net sediment loss during 2009–2013; the cumulative change in sediment volume was -125,000 yd^3 (see Table 21). In both reaches, the greatest net sediment losses occurred during the wetter years of 2010 and 2011, while the greatest net sediment gains occurred the following year (*i.e.*, 2011–2012).

- Application of the SED method to the ~2.3-mi. portion of the Lower Alexander Valley Reach upstream of station 52+0000 determined the cumulative change in sediment storage during 2009–2014 was +32,000 yd^3, indicating an overall aggregation trend (see Table 22). Adding this amount to the volumetric change estimated for the reach portion between stations 52+0000 and 46+0000 results in a combined volumetric change of +19,000 yd^3, indicating net sediment gain over this longer extent of the Lower Alexander Valley Reach.

- In summary, the overall trends of aggradation and/or deposition in the two monitoring reaches vary considerably depending on the spatial and temporal extents that each data source represents, *and* on the particular evaluation method employed. The SED method seemingly presents the most detailed and comprehensive account of geomorphic changes occurring since 2008. Within those portions of the two monitoring reaches that were monitored during 2009–2013/2014, the overall finding is that they experienced net sediment loss on the order of -10,000 to -100,000 yd^3 (using the SED method), with attendant lowering of the thalweg elevation and greater bank retreat.
- Finally, the numerical uncertainty, or error, associated with each analysis remains unknown due to the absence of technical documentation for the various data-collection methods employed by the gravel operators and/or their contractors. Thus, we cannot yet determine whether the numerical values reported above are sufficiently outside of the margin of error inherent in each computation, or whether the reported results are too small to be significant.

3.2 Recommendations

3.2.1 Establish mining and non-mining baseline

Future ARM monitoring reports should document conditions separately in the proposed mining and non-mining areas to establish a baseline in each before mining recommences, to the extent feasible. Establishing a baseline in the mining and non-mining subreaches of the Lower Alexander Valley Reach will require that Syar extend their DTM coverage across the entire reach extent (i.e., RMs 46.0–56.2) and establish additional repeat cross-sections in the upstream end of the mining subreach and in the upstream non-mining subreach, based on the reasons provided below. The exact number and placement of new cross-sections should be discussed by the PRMD, Syar, and SRC. Additional repeat cross-sections may also be needed in the downstream non-mining subreach if a higher density of cross-sections is desired for all subreaches. Establishing a baseline in the Middle Reach may be irrelevant in the short time because there are no current plans to conduct instream mining.

For the present report, we did not separate the mining and non-mining sub-reaches within the Lower Alexander Valley Reach in our findings because of two reasons. The first is that the precise locations of the future mining remain uncertain until Syar has secured necessary Federal permits. The second reason is because of a seemingly lack of data in portions of the potential subreaches. To illustrate this point further, we have included a graphical plot below that depicts of the extents of the Lower Alexander Valley Reach, proposed mining subreach, and existing DTM coverage (Figure 14). We understand that the entire Lower Alexander Valley, as described in the ARM Plan encompasses RMs 45.9 to 56.2 (10.3 river miles). The proposed mining subreach with its 15 gravel bars would encompass about 6.5 river miles, between RMs 47.5 to 54.0, as indicated in Syar's Alexander Valley Draft EIR (AECOM 2010). Thus, the upstream non-mining subreach would encompass 2.2-miles in total length, extending from RMs 54.0 to 56.2 and, the downstream non-mining subreach would be about 1.5-miles in total length, extending from RMs 46.0 to 47.5. Since 2009, Syar has been generating DTMs that encompass the active river corridor from RMs 46.0 to 55.0. Within the DTM extent, Syar has routinely extracted nine repeat cross-sections that lie between RMs 46.0 and 52.0. We evaluated the DTM surfaces and repeat cross-sections in the above sections. As one can see in the graphical depiction below, the DTM covers most of the Lower Alexander Valley Reach, except for about 1.2 river miles at the upstream end. Of the nine repeat cross-sections, only two would be present in the downstream non-mining subreach, seven would lie in the mining subreach, and zero in the upstream non-mining reach. Thus, establishing a baseline in the mining and non-mining subreaches of the Lower Alexander Valley Reach will require that Syar extend their DTM coverage across the entire reach extent (i.e., RMs 46.0–56.2) and establish additional repeat cross-sections in the upstream end of the mining subreach and in the upstream non-mining subreach.

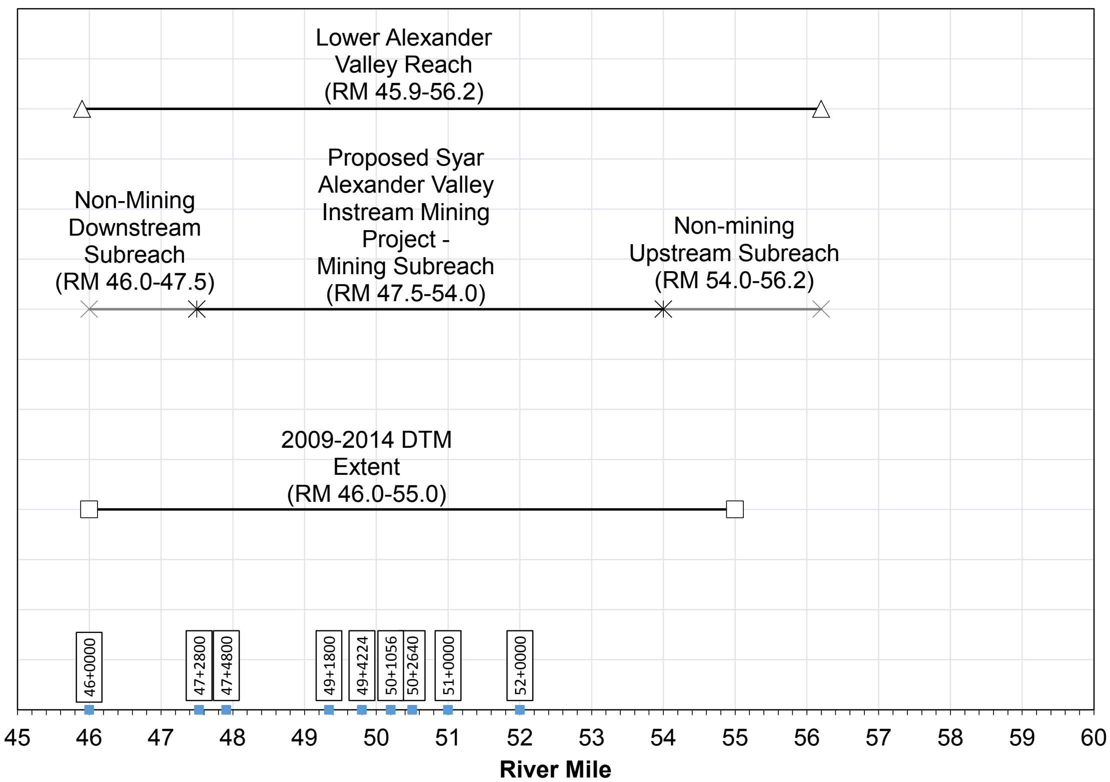


Figure 14. Extents of the Lower Alexander Valley Reach, proposed mining subreaches, and existing DTM coverage.

3.2.2 Evaluate effects during mining years

Future ARM monitoring reports documenting geomorphic changes during mining years should evaluate whether gravel extraction has been conducted on a sustained basis. Further, evaluation should be undertaken that considers the effectiveness of existing mining methods, mitigations, and standards at each instream mining site at avoiding or minimizing adverse impacts, meeting the ARM Plan and site-specific objectives, complying with mining standards, and site-specific performance standards adopted with the permit approvals within each reach, as appropriate. And, recommendations should be developed, as appropriate, for continuing existing mining methodologies, mitigations, and standards or revising them to better achieve the goal of adverse environmental impacts while meeting ARM Plan and permit objectives.

3.2.3 Continuation of data collection and assessment activities

We recommend the continued collection of high-resolution aerial photography and their topography-surface products shall continue on an annual basis, and cover the same spatial extent of the Lower Alexander Valley Reach as surveyed during 2009–2014. This spatial extent should be expanded if the PRMD wishes the SRC to evaluate baseline conditions of mining and non-mining subreaches, based on the rationale described above. Direct collection of high-resolution topographic surfaces via LiDAR technology and bathymetric survey equipment could be collected in place of the producing the photogrammetry-derived DTMs. Future annual monitoring reports should evaluate the same cross-sections evaluated herein during non-mining years. During mining years, at least the 48 cross-sections proposed for this reach by the 2008 Monitoring Report should be evaluated in future monitoring reports.

Aerial photography, topographic surfaces, and cross-sections should be collected in the Middle Reach prior to and following re-commencement of gravel mining. During mining years, at least the 43 cross-sections proposed for this reach by the 2008 Monitoring Report should be evaluated in future monitoring reports.

Future monitoring reports should continue to evaluate changes of cross-sectional areas, thalweg elevation, bank erosion, and sediment storage. Further, evaluating changes in sediment storage should only employ the SED method, not the AEA method, as they do not appear to be comparable. It will still be possible and cost-effective for the SRC to calculate the average end area in specific locations if it is necessary to compare results to pre-DTM monitoring reports.

Evaluation of aquatic and riparian habitat monitoring data should resume when such information becomes available for the purposes of evaluating potential effects from past and present gravel mining activities in the ARM Plan reaches.

3.2.4 Evaluate additional channel features

Future ARM monitoring reports should assess changes to more localized features, such as pool depth, channel width, bar area, and vertical channel stability, to the extent that future data collected may support. Such an assessment would be most useful in those areas of the river channel adjacent to specific bars planned for mining and those that could serve as non-mining comparisons. Our recommendation is in line with Syar's draft EIR (AECOM 2010) proposed mitigation measure 3.2-5 to include monitoring of several of channel features, including pool depth, channel width, and bar area. This information collected as part of the mitigation measure could be utilized in future ARM monitoring reports.

These features could not be evaluated in this annual report because the only data provided to us in advance of preparing the present annual report were DTM-derived surfaces and cross-section profiles representing river conditions between 2009 and 2014 for the Lower Alexander Valley Reach and between 2009 and 2013 for the Middle Reach; we were not provided with data specific to spatially discrete pool, bar, or bank features. In past monitoring reports, information on these features has been included with annual assessment(s) of aquatic and riparian habitat (see Section 4.0 in the 2008 Monitoring Report [Entrix 2010]). We are not aware of any aquatic and riparian assessments being completed since 2008.

3.2.5 Document data collection methods

The results presented herein are based on datasets that did not include technical information documenting specific collection and processing methods. As such, it is currently not possible to quantify the potential error associated with each numerical value presented above. Because some of the reported values are relatively small, it is possible that their implications for geomorphic change are not statistically significant and, therefore, should be discarded. For example, the inherent error of the annual DTM datasets, which is presently unknown, may be great enough to overwhelm our computed volumetric changes in sediment storage of -10,000 to -100,000 yd^3 using the SED method. All datasets provided to the SRC for evaluation in future annual monitoring reports should include the basic information listed below to assist with an uncertainty analysis recommended for inclusion in each future monitoring report. The uncertainty analysis will provide needed confidence to the computed changes in channel morphology. The monitoring datasets should include the following information:

- The methods used to acquire orthographic, cross-sectional, and thalweg survey data to generate the DTMs, including the date and time, surveyor, equipment used, published methodology, QA/QC procedures, coordinate systems, horizontal and vertical datums, and other limitations.
- The river discharge associated with the WSEs polyline provided on the AutoCAD model *or* the date of the WSEs measurement to enable subsequent reference to USGS gaging station flow records for that day.
- The locations (GIS .shp files) of all cross-sections surveyed since the monitoring program began in order to cut new cross-sections from the Syar-provided DTM surfaces. This should include accurate 2008 cross-section endpoints in order to compare historic and present-year cross-sectional data.
- Spatially discrete quantities of gravel actually extracted at each bar during any future mining operation. Currently, only the total, annual volume of gravel removed in each reach is known along with the list of designated bars in each reach where some quantity of gravel was mined.

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Appendix A

Comparisons of Annual Cross-Sectional Areas: 2009–2013/2014

Table A-1. Summary of annual cross-sectional areas and differences for the Lower Alexander Valley Reach.

Cross-Section	Section Width (ft)	Section Base Elev. (ft)	Cross-sectional Area (ft^2)						Added Area Above 0-ft Elev. (ft^2)	Total Cross-section Area used in Change Analysis (ft^2)							Change in Cross-sectional Area (ft^2)					
			2009	2010	2011	2012	2013	2014		2008 [A]	2009	2010	2011	2012	2013	2014	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
52+0000	750	170	21,281	21,190	20,879	20,935	20,595	20,584	127,500	148,668	148,781	148,690	148,379	148,435	148,095	148,084	N/A[B]	-91	-311	56	-340	-11
51+0000	600	170	11,690	11,680	11,386	11,427	11,238	11,613	102,000	114,080	113,690	113,680	113,386	113,427	113,238	113,613	N/A[B]	-10	-294	41	-189	375
50+2640	950	165	20,160	20,524	19,970	20,368	20,054	20,291	156,750	178,092	176,910	177,274	176,720	177,118	176,804	177,041	N/A[B]	364	-554	398	-314	237
50+1056	1,010	165	22,189	22,057	22,047	22,219	21,821	22,120	166,650	191,534	188,839	188,707	188,697	188,869	188,471	188,770	N/A[B]	-132	-10	172	-398	299
49+4224	1,389	160	31,781	31,855	31,804	31,829	32,052	32,234	222,240	253,183	254,021	254,095	254,044	254,069	254,292	254,474	838	74	-51	25	223	182
49+1800	833	155	19,155	19,814	19,960	20,198	19,685	19,677	129,115	148,016	148,270	148,929	149,075	149,313	148,800	148,792	254	659	146	238	-513	-8
47+4800	624	140	18,404	18,616	18,642	18,559	18,685	18,923	87,360	105,442	105,764	105,976	106,002	105,919	106,045	106,283	322	212	26	-83	126	238
47+2800	756	140	21,686	21,690	21,732	22,016	21,848	21,786	105,840	126,940	127,526	127,530	127,572	127,856	127,688	127,626	586	4	42	284	-168	-62
46+0000	560	130	16,475	16,604	16,405	16,650	16,330	16,382	72,800	85,614	89,275	89,404	89,205	89,450	89,130	89,182	N/A[B]	129	-199	245	-320	52

Table footnotes:
[A] Data source from the 2008 Monitoring Report (Entrix 2010).
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Table A-2. Summary of annual cross-sectional areas and differences for the Middle Reach.

Cross-Section	Section Width (ft)	Section Base Elev. (ft)	Cross-sectional Area (ft^2)						Added Area Above 0-ft Elev. (ft^2)	Total Cross-section Area used in Change Analysis (ft^2)							Change in Cross-sectional Area (ft^2)					
			2009	2010	2011	2012	2013	2014 [A]		2008 [B]	2009	2010	2011	2012	2013	2014 [A]	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
J	321	70	3,965	3,652	3,492	3,832	3,690	---	22,470	26,152	26,435	26,122	25,962	26,302	26,160	---	283	-313	-160	340	-142	---
I	560	65	10,892	10,962	10,723	10,912	10,745	---	36,400	47,334	47,292	47,362	47,123	47,312	47,145	---	-42	70	-239	189	-167	---
H	760	55	21,087	21,287	21,209	21,415	21,034	---	41,800	62,510	62,887	63,087	63,009	63,215	62,834	---	377	200	-78	206	-381	---
G	438	60	9,017	9,140	8,913	9,090	8,931	---	26,280	35,169	35,297	35,420	35,193	35,370	35,211	---	128	123	-227	177	-159	---
F	723	60	16,631	16,865	16,726	16,714	16,700	---	43,380	60,060	60,011	60,245	60,106	60,094	60,080	---	-49	234	-139	-12	-14	---
E1	799	60	15,523	15,739	15,878	15,903	15,939	---	47,940	63,263	63,463	63,679	63,818	63,843	63,879	---	200	216	139	25	36	---
E	470	60	10,248	10,248	10,428	10,352	10,440	---	28,200	38,418	38,448	38,448	38,628	38,552	38,640	---	30	0	180	-76	88	---
D	398	60	7,351	7,445	7,208	7,269	7,320	---	23,880	31,063	31,231	31,325	31,088	31,149	31,200	---	168	94	-237	61	51	---
C	495	55	7,439	7,605	7,512	7,244	7,356	---	27,225	34,636	34,664	34,830	34,737	34,469	34,581	---	28	166	-93	-268	112	---
31+1700	488	45	13,321	13,301	13,340	13,265	13,300	---	21,960	35,323	35,281	35,261	35,300	35,225	35,260	---	-42	-20	39	-75	35	---
B	485	45	13,283	13,306	13,377	13,279	13,469	---	21,825	34,961	35,108	35,131	35,202	35,104	35,294	---	147	23	71	-98	190	---
A	663	45	18,065	18,090	17,946	17,993	18,138	---	29,835	47,642	47,900	47,925	47,781	47,828	47,973	---	258	25	-144	47	145	---
AA	731	40	22,097	22,292	22,192	22,139	22,121	---	29,240	51,316	51,337	51,532	51,432	51,379	51,361	---	21	195	-100	-53	-18	---
BB	588	40	14,083	13,965	14,156	14,036	13,969	---	23,520	37,459	37,603	37,485	37,676	37,556	37,489	---	144	-118	191	-120	-67	---
30+0000	605	40	16,631	16,247	16,241	15,495	16,191	---	24,200	40,724	40,831	40,447	40,441	39,695	40,391	---	107	-384	-6	-746	696	---

Cross-Section	Section Width (ft)	Section Base Elev. (ft)	Cross-sectional Area (ft^2)						Added Area Above 0-ft Elev. (ft^2)	Total Cross-section Area used in Change Analysis (ft^2)							Change in Cross-sectional Area (ft^2)					
			2009	2010	2011	2012	2013	2014 [A]		2008 [B]	2009	2010	2011	2012	2013	2014 [A]	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
BB1	453	45	9,116	9,260	9,153	9,257	9,420	---	20,385	29,549	29,501	29,645	29,538	29,642	29,805	---	-48	144	-107	104	163	---
CC	533	40	14,309	14,139	14,416	14,313	14,266	---	21,320	35,576	35,629	35,459	35,736	35,633	35,586	---	53	-170	277	-103	-47	---
DD	512	40	12,384	12,400	12,545	12,538	12,561	---	20,480	32,719	32,864	32,880	33,025	33,018	33,041	---	145	16	145	-7	23	---
EE	500	35	13,147	13,228	13,484	13,460	13,253	---	17,500	30,284	30,647	30,728	30,984	30,960	30,753	---	363	81	256	-24	-207	---
FF	667	35	17,796	17,761	18,151	18,245	18,419	---	23,345	41,060	41,141	41,106	41,496	41,590	41,764	---	81	-35	390	94	174	---
GG	711	35	21,194	20,955	20,960	20,999	21,106	---	24,885	45,912	46,079	45,840	45,845	45,884	45,991	---	167	-239	5	39	107	---
GG1A	1,387	35	42,204	41,873	41,951	42,042	41,942	---	48,545	90,829	90,749	90,418	90,496	90,587	90,487	---	-80	-331	78	91	-100	---
28+3900	1,287	30	46,792	46,878	46,880	47,055	47,508	---	38,610	85,364	85,402	85,488	85,490	85,665	86,118	---	38	86	2	175	453	---
HH	1,214	35	38,446	38,382	38,580	38,582	38,414	---	42,490	80,737	80,936	80,872	81,070	81,072	80,904	---	199	-64	198	2	-168	---
II	853	30	26,713	26,075	26,546	26,086	26,180	---	25,590	52,006	52,303	51,665	52,136	51,676	51,770	---	297	-638	471	-460	94	---
JJ	660	35	17,229	17,111	17,208	17,163	17,106	---	23,100	40,131	40,329	40,211	40,308	40,263	40,206	---	198	-118	97	-45	-57	---
28+0900	663	35	17,806	17,591	17,617	17,636	17,702	---	23,205	43,867	41,011	40,796	40,822	40,841	40,907	---	N/A [C]	-215	26	19	66	---

Table footnotes:
[A] --- = no data provided by PRMD.
[B] Data source from the 2008 Monitoring Report (Entrix 2010).
[C] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Appendix B

Cross-section Comparison Plots: 2009–2013/2014

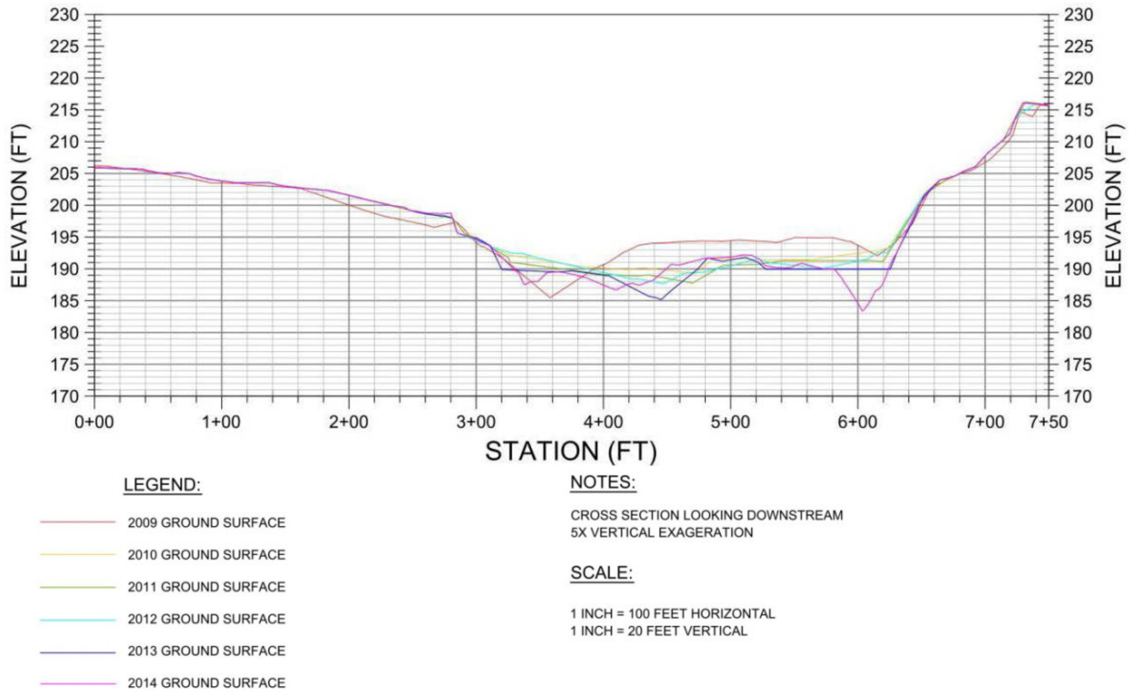

Figure B-1. Comparison of 2009–2014 annual cross-sections at station 52+0000 in the Lower Alexander Valley Reach.

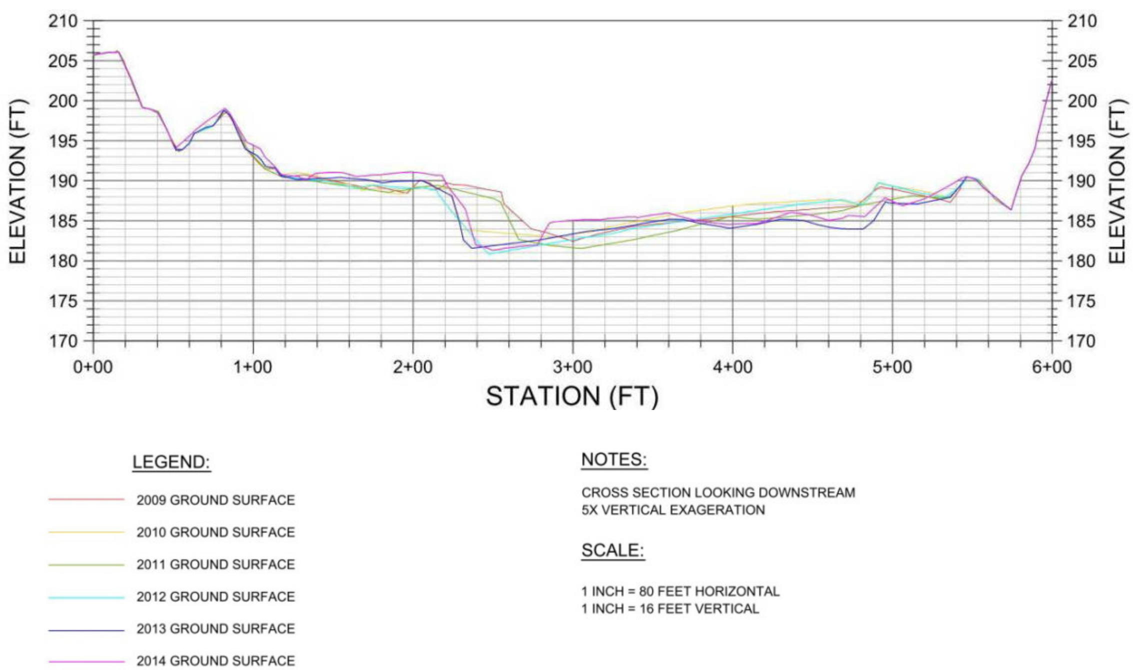

Figure B-2. Comparison of 2009–2014 annual cross-sections at station 51+0000 in the Lower Alexander Valley Reach.

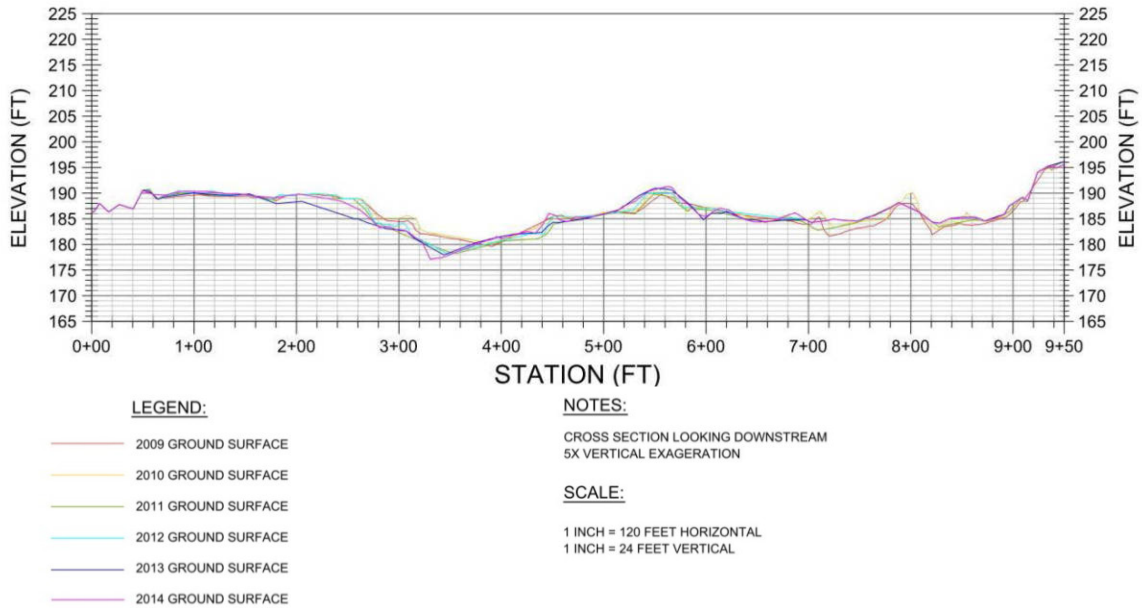

Figure B-3. Comparison of 2009–2014 annual cross-sections at station 50+2640 in the Lower Alexander Valley Reach.

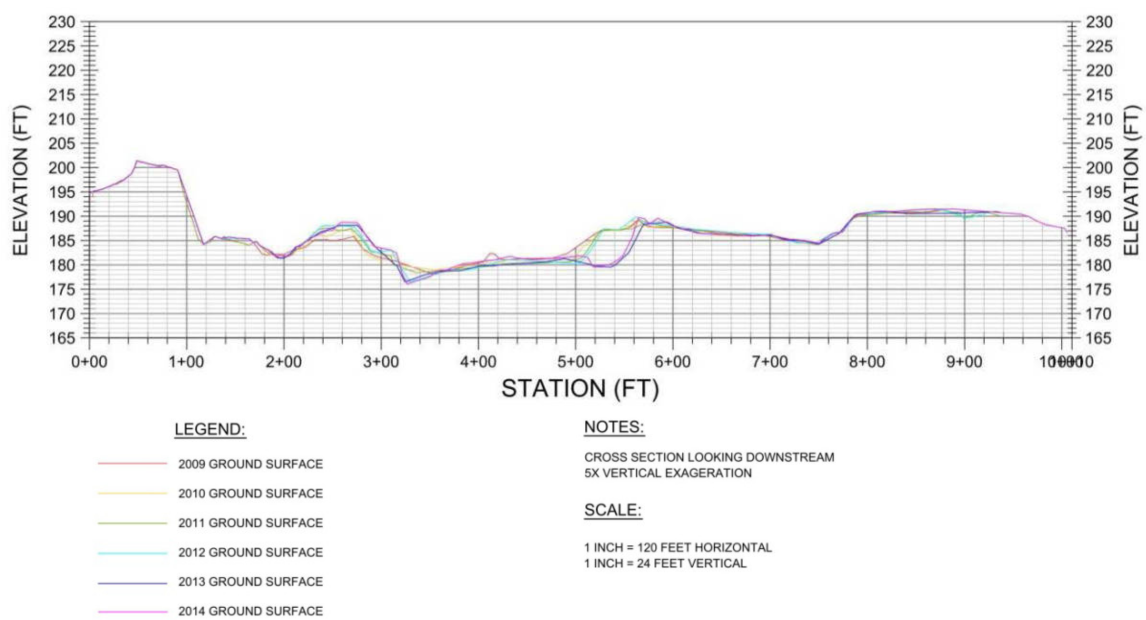

Figure B-4. Comparison of 2009–2014 annual cross-sections at station 50+1056 in the Lower Alexander Valley Reach.

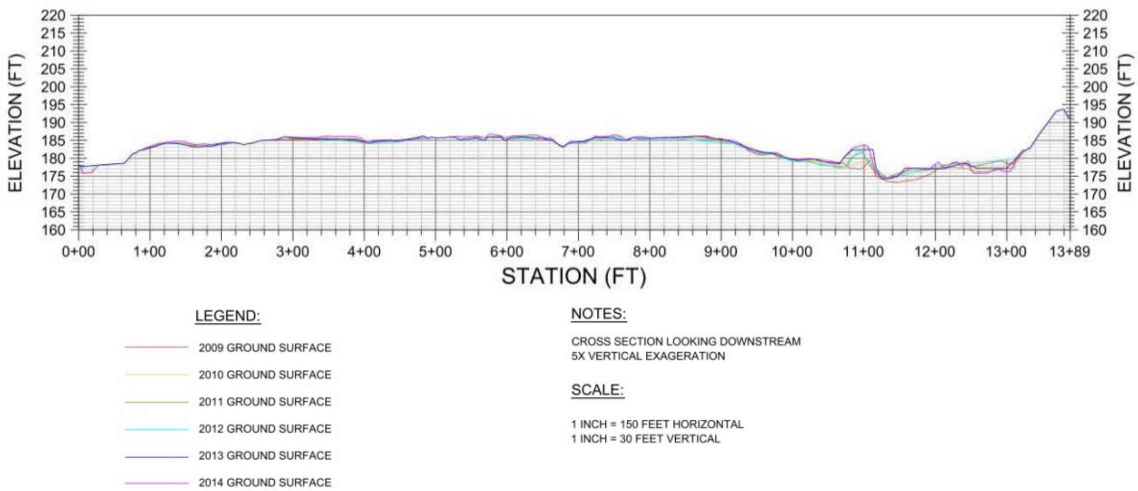

Figure B-5. Comparison of 2009–2014 annual cross-sections at station 49+4224 in the Lower Alexander Valley Reach.

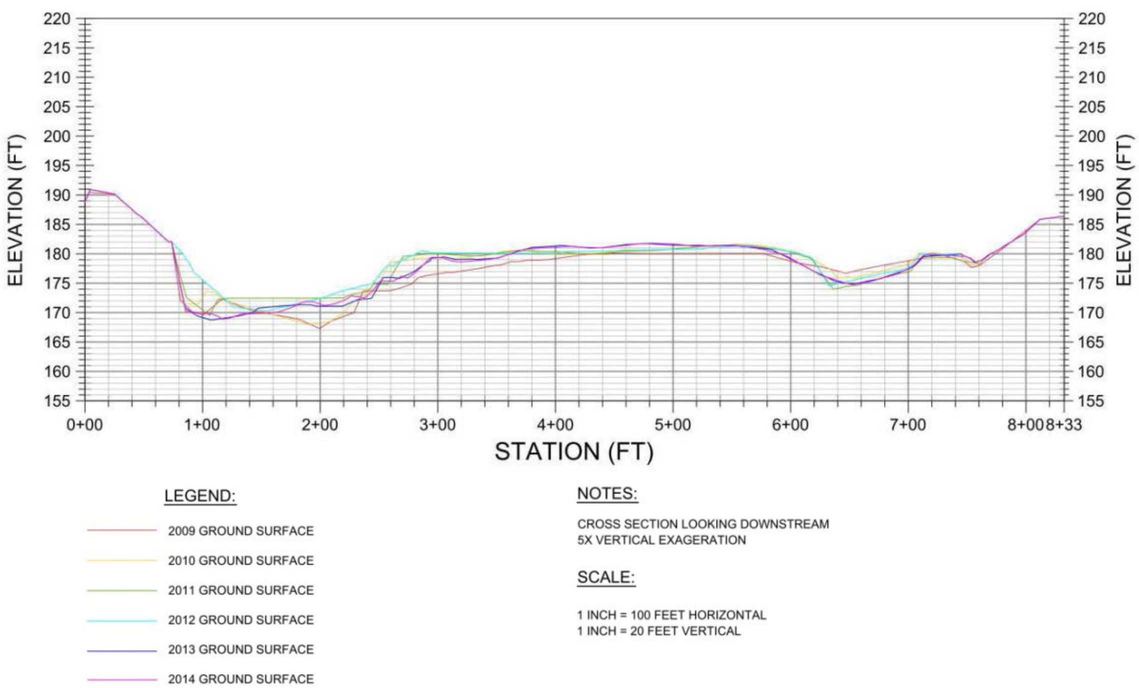

Figure B-6. Comparison of 2009–2014 annual cross-sections at station 49+1800 in the Lower Alexander Valley Reach.

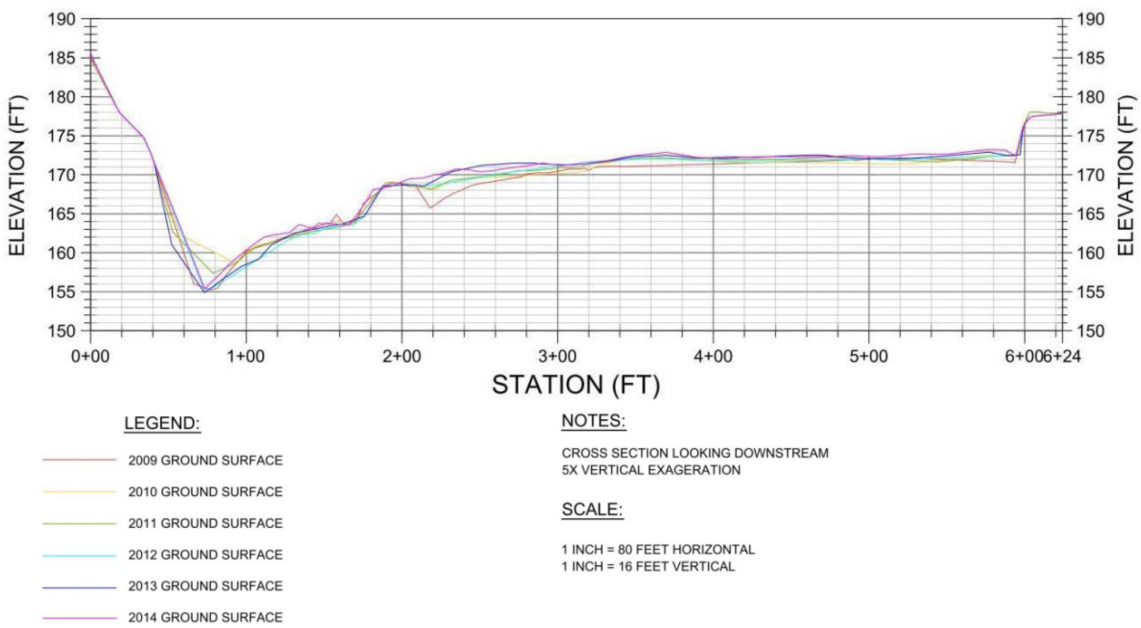

Figure B-7. Comparison of 2009–2014 annual cross-sections at station 47+4800 in the Lower Alexander Valley Reach.

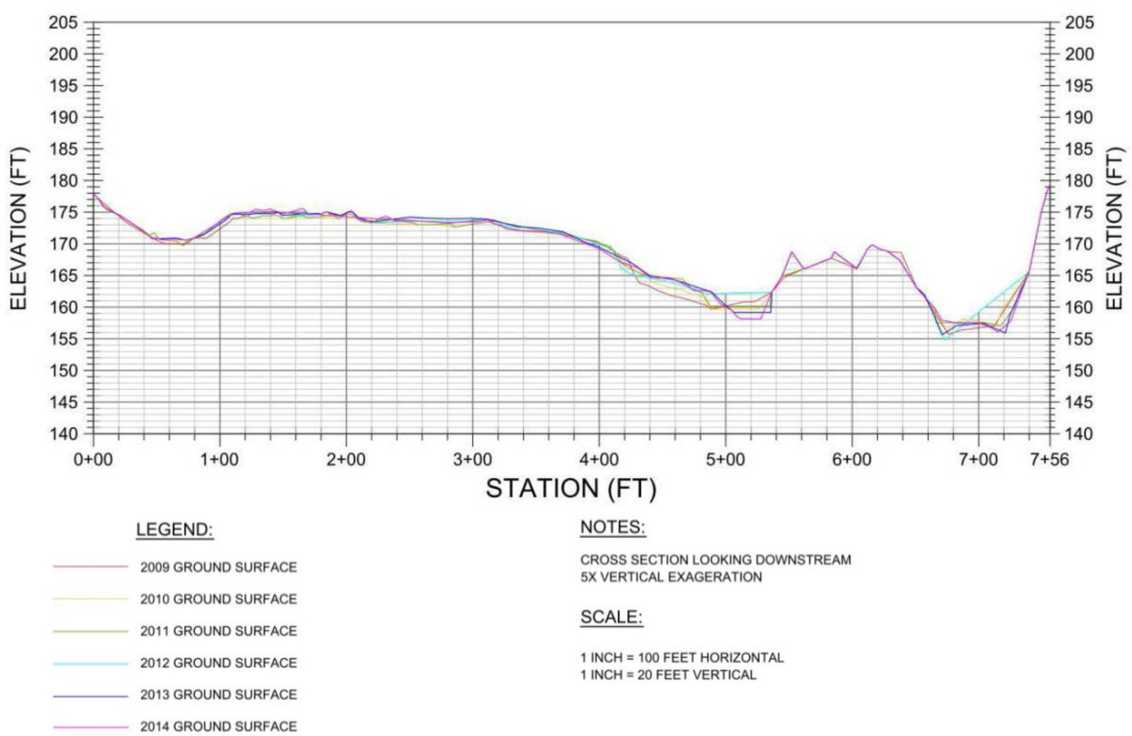

Figure B-8. Comparison of 2009–2014 annual cross-sections at station 47+2800 in the Lower Alexander Valley Reach.

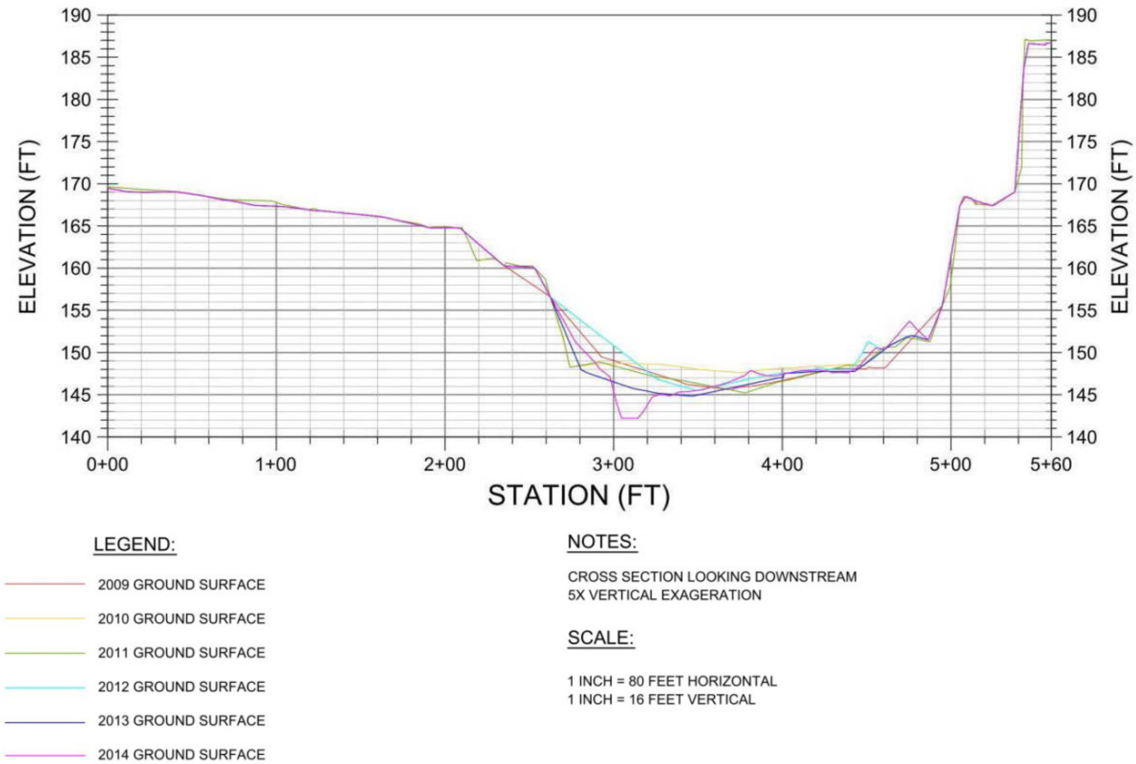

Figure B-9. Comparison of 2009–2014 annual cross-sections at station 46+0000 in the Lower Alexander Valley Reach.

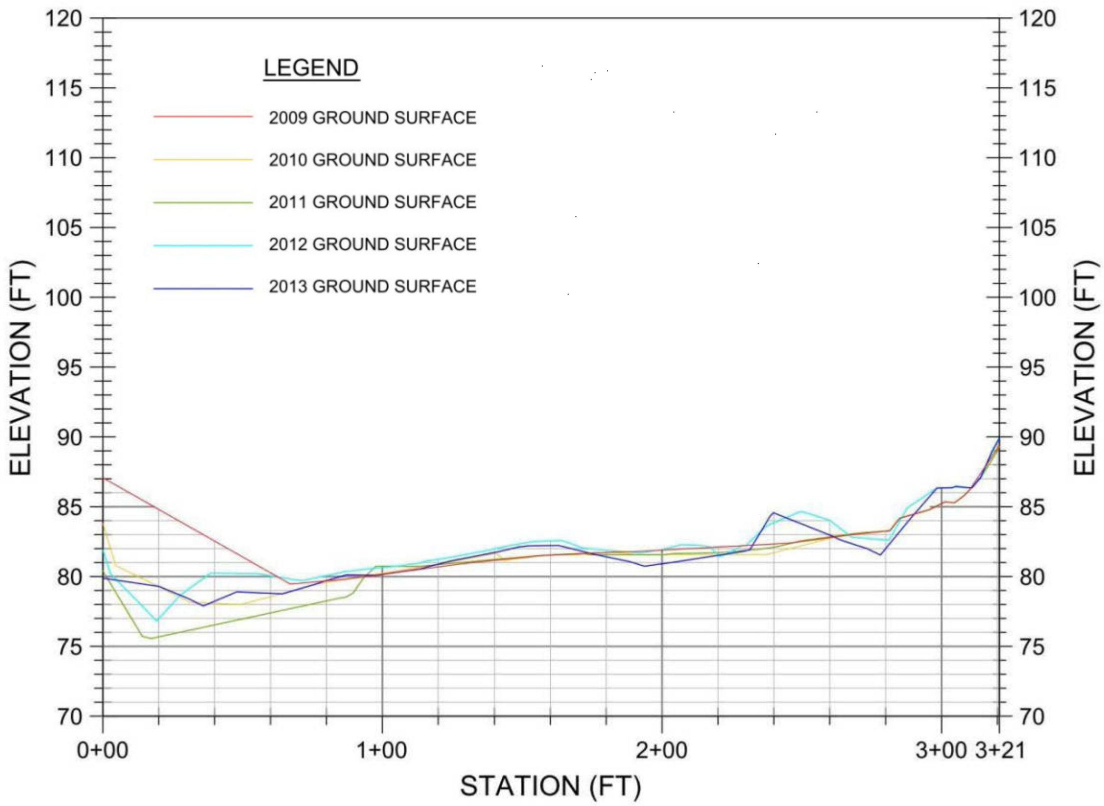

Figure B-10. Comparison of 2009–2013 annual cross-sections at station J in the Middle Reach.

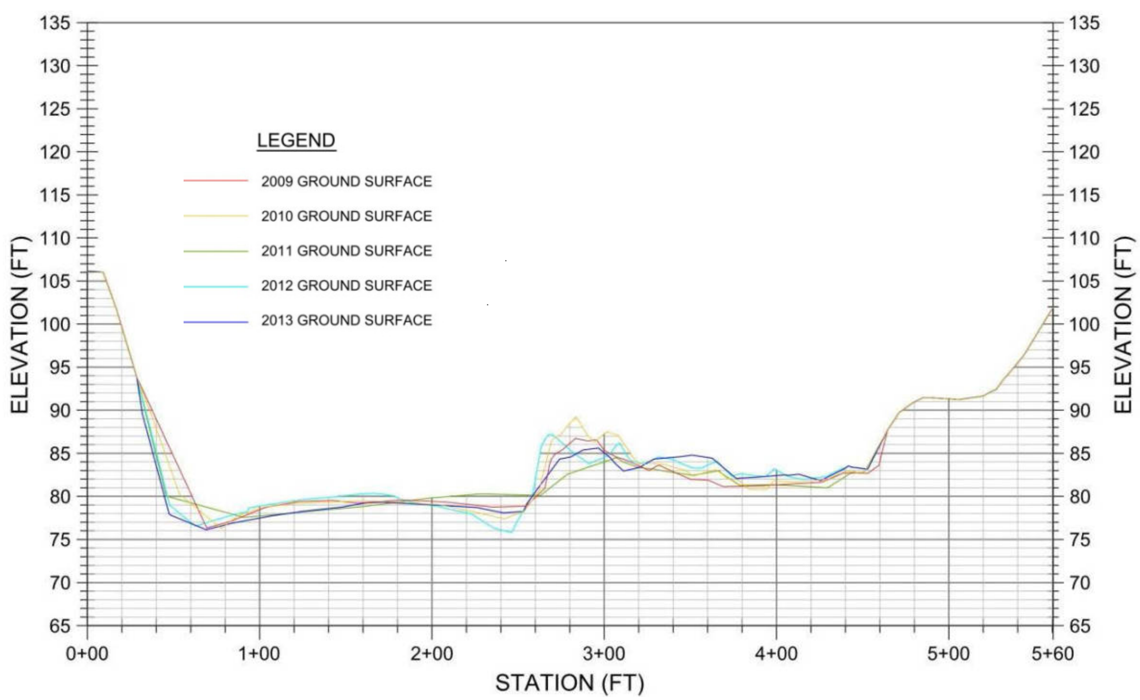

Figure B-11. Comparison of 2009–2013 annual cross-sections at station I in the Middle Reach.

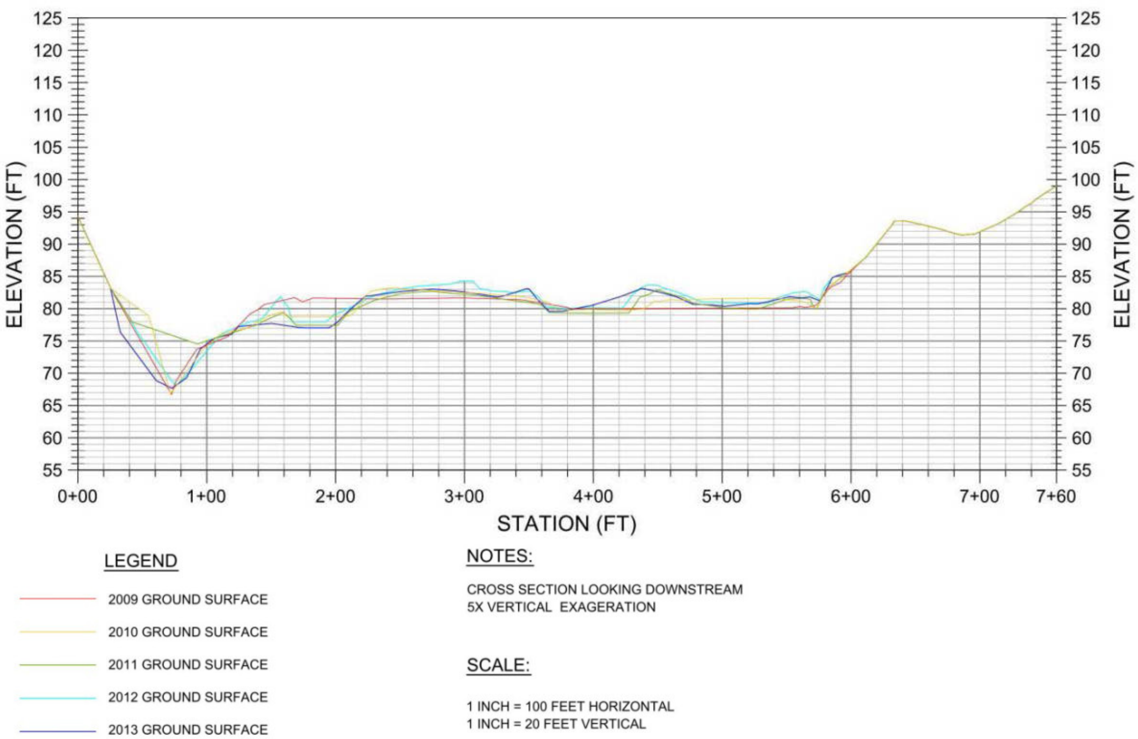

Figure B-12. Comparison of 2009–2013 annual cross-sections at station H in the Middle Reach.

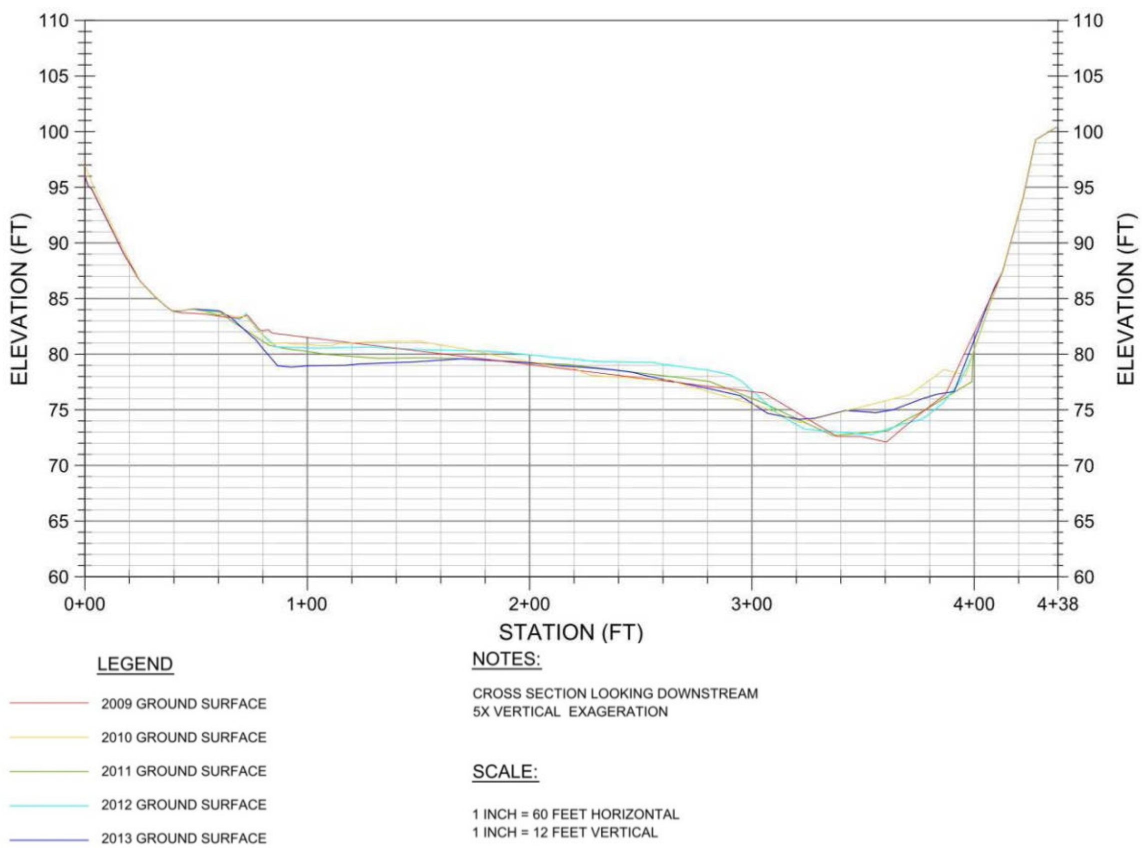

Figure B-13. Comparison of 2009–2013 annual cross-sections at station G in the Middle Reach.

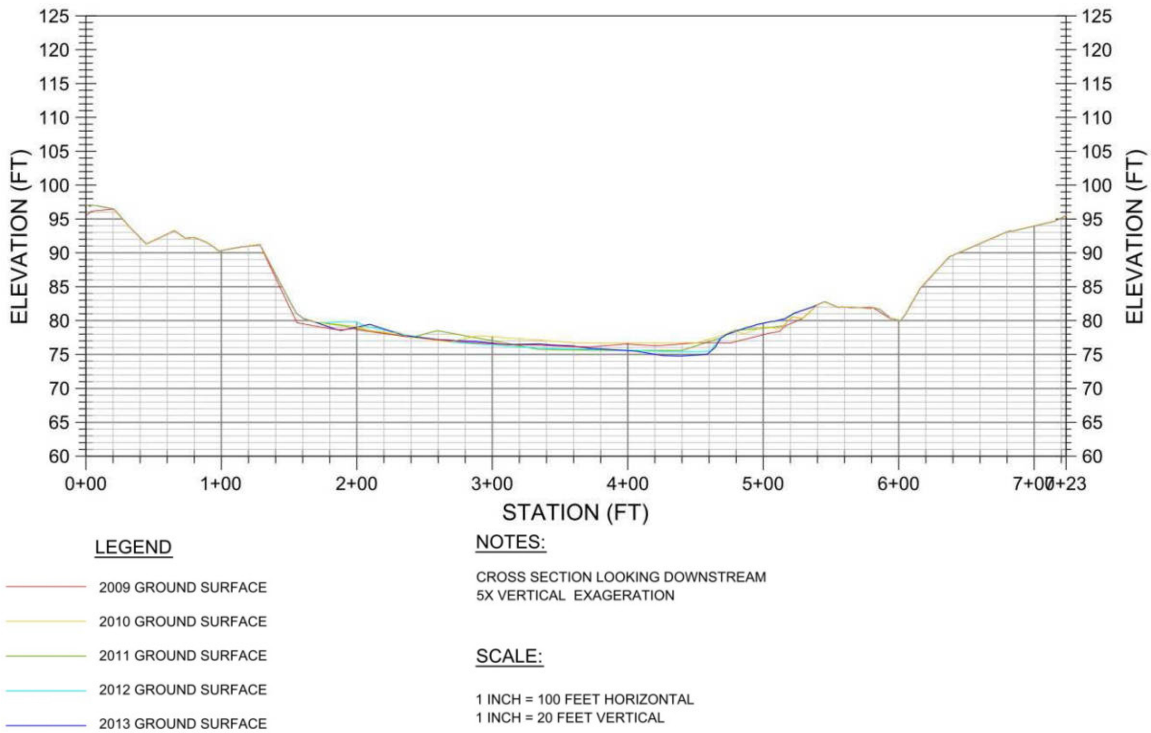

Figure B-14. Comparison of 2009–2013 annual cross-sections at station F in the Middle Reach.

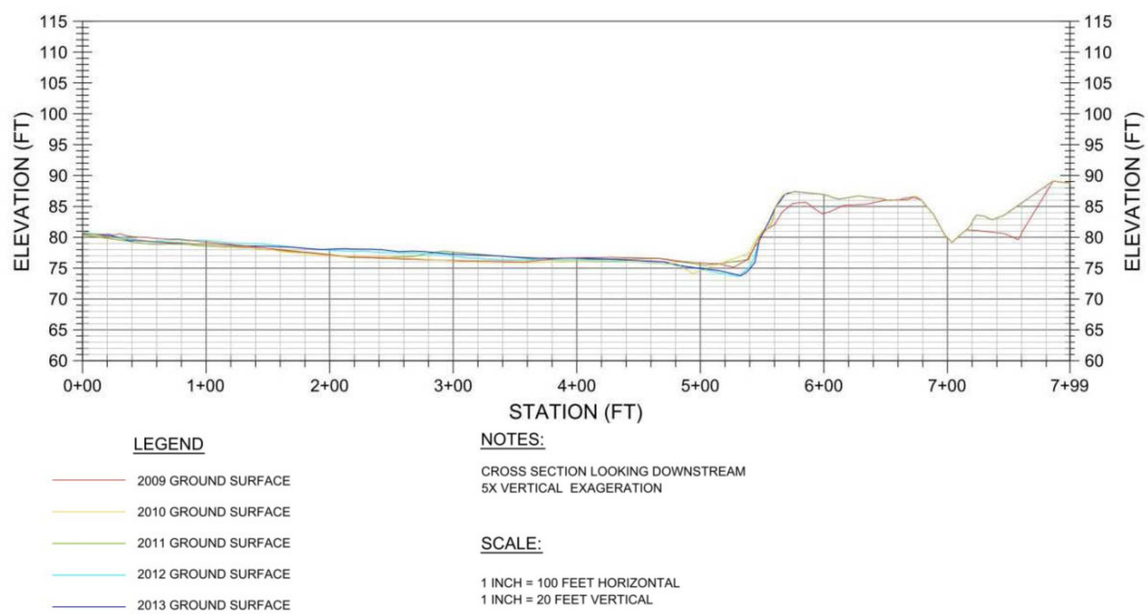

Figure B-15. Comparison of 2009–2013 annual cross-sections at station E1 in the Middle Reach.

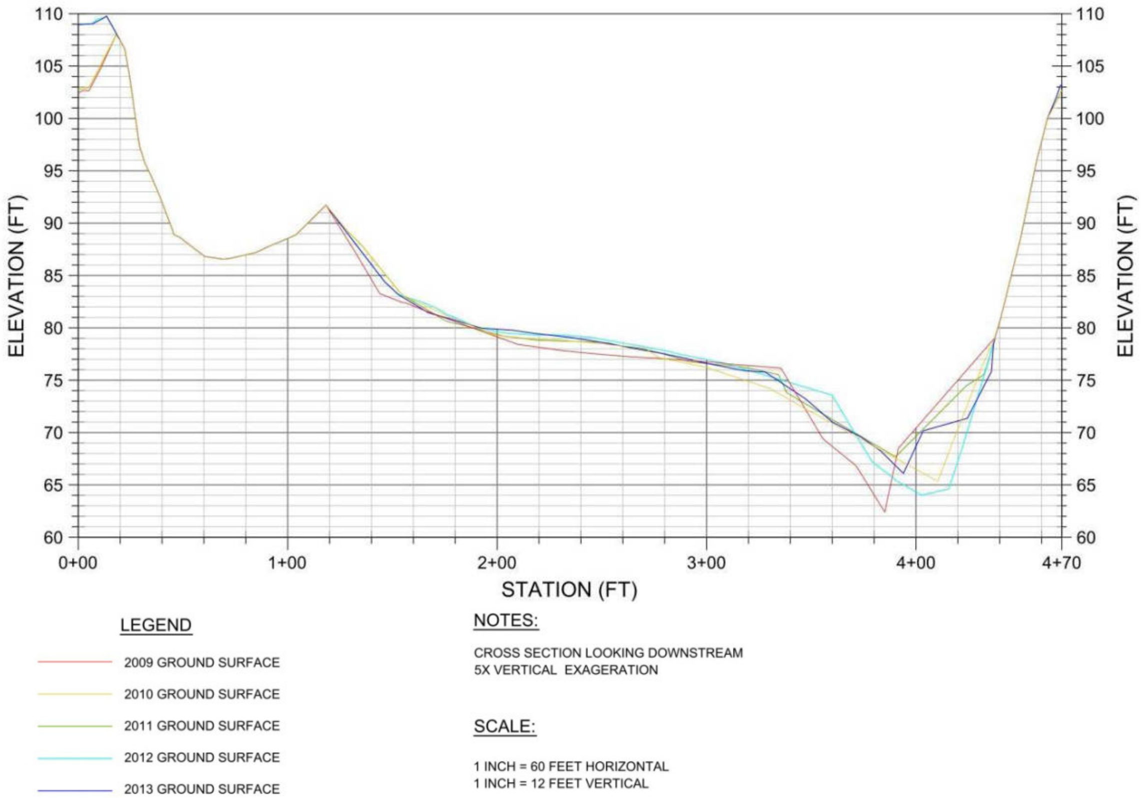

Figure B-16. Comparison of 2009–2013 annual cross-sections at station E in the Middle Reach.

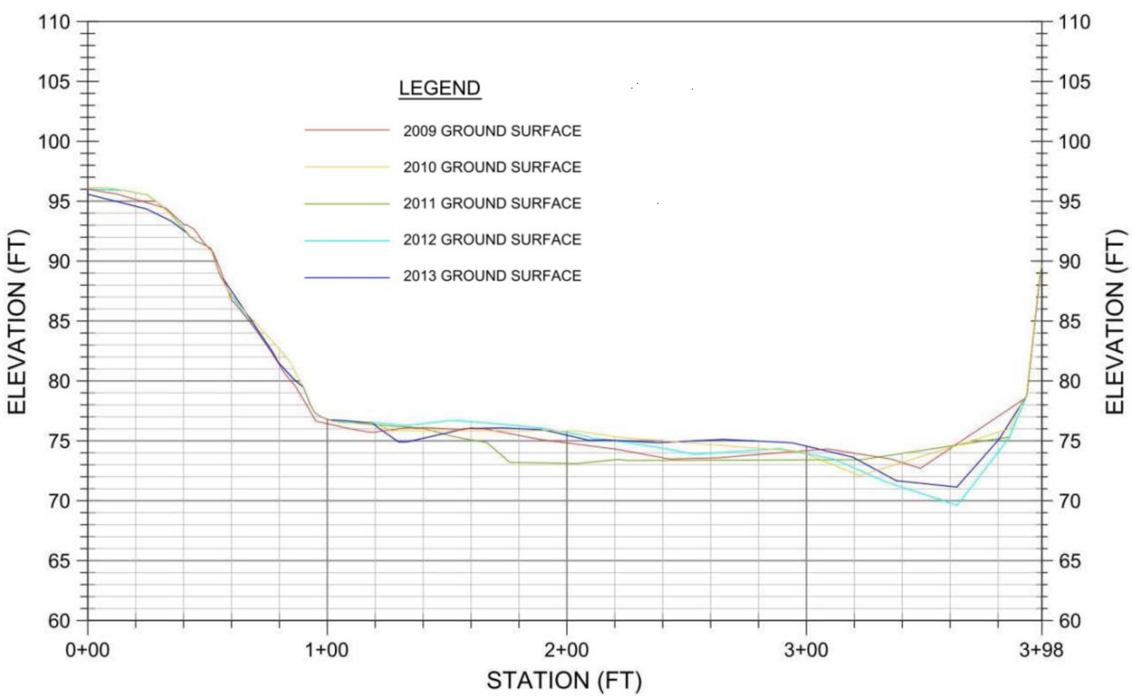

Figure B-17. Comparison of 2009–2013 annual cross-sections at station D in the Middle Reach.

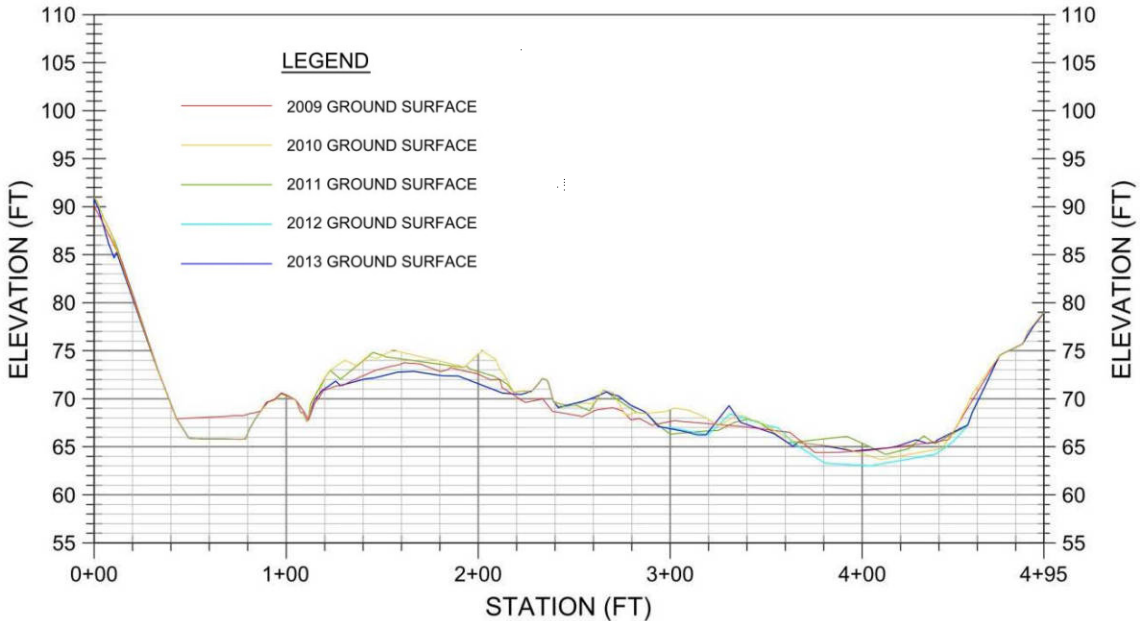

Figure B-18. Comparison of 2009–2013 annual cross-sections at station C in the Middle Reach.

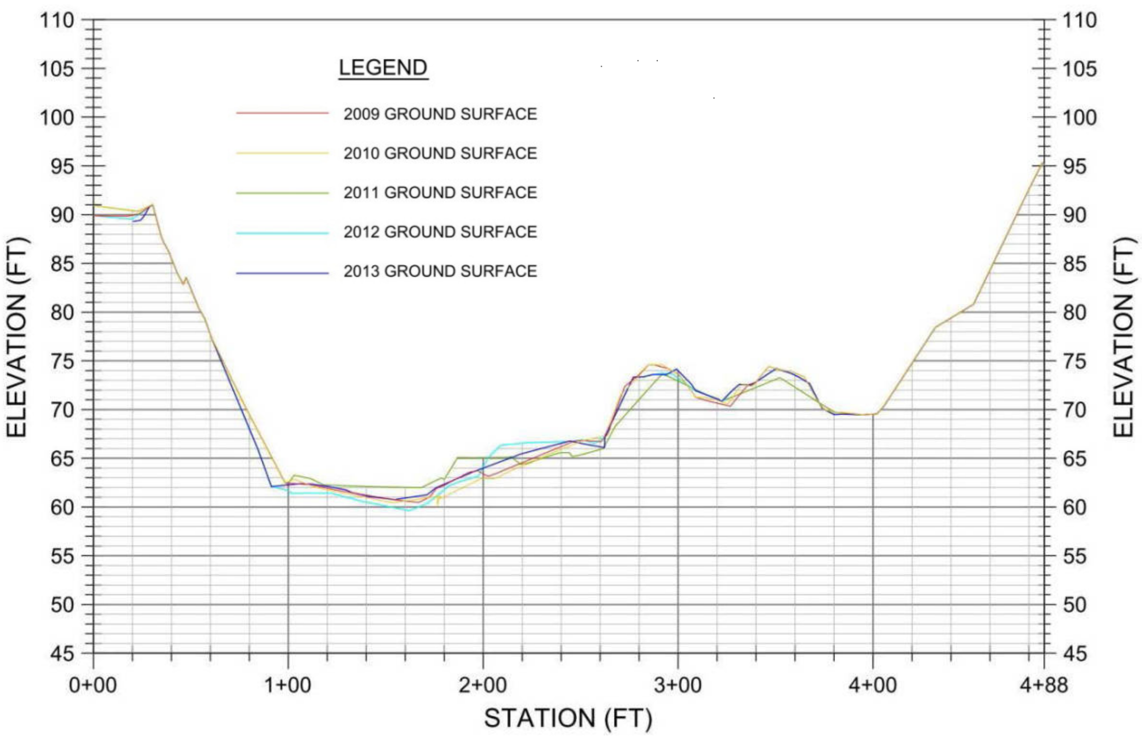

Figure B-19. Comparison of 2009–2013 annual cross-sections at station 31+1700 in the Middle Reach.

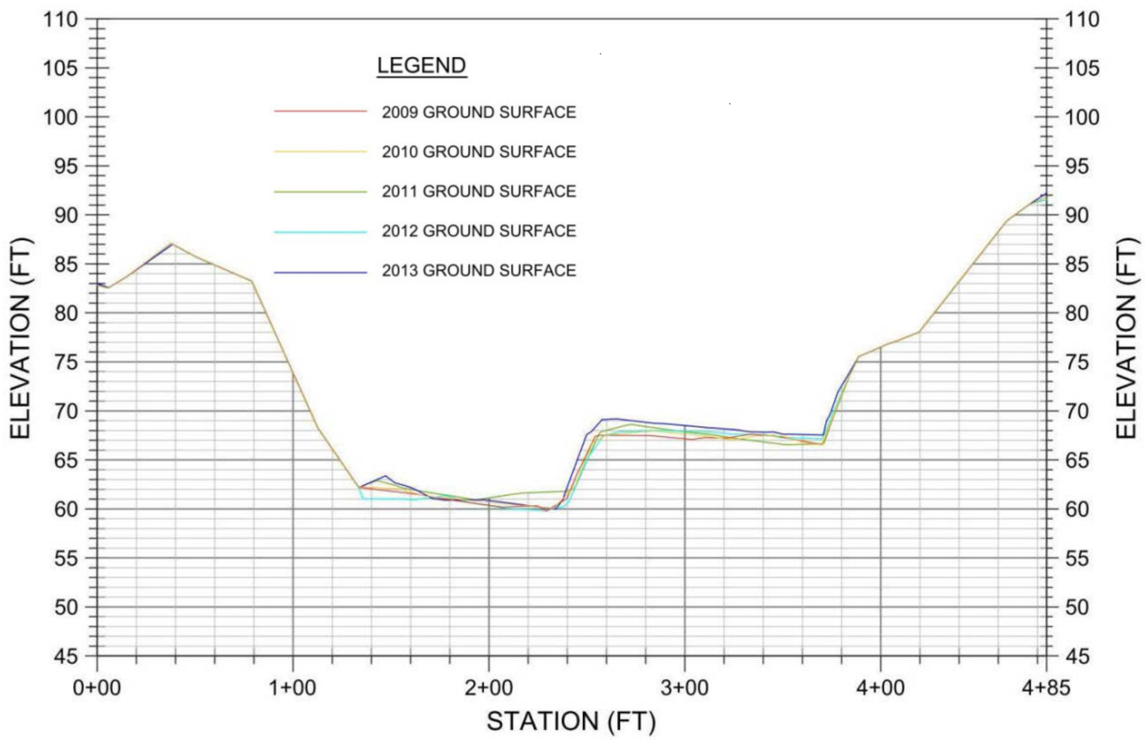

Figure B-20. Comparison of 2009–2013 annual cross-sections at station B in the Middle Reach.

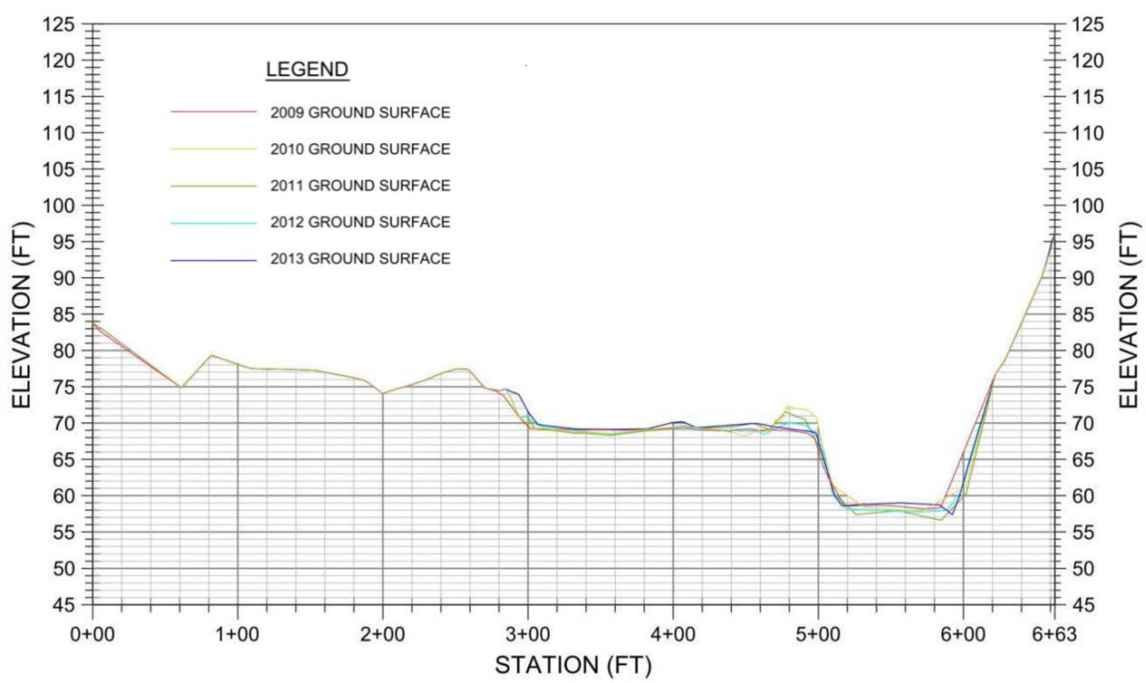

Figure B-21. Comparison of 2009–2013 annual cross-sections at station A in the Middle Reach.

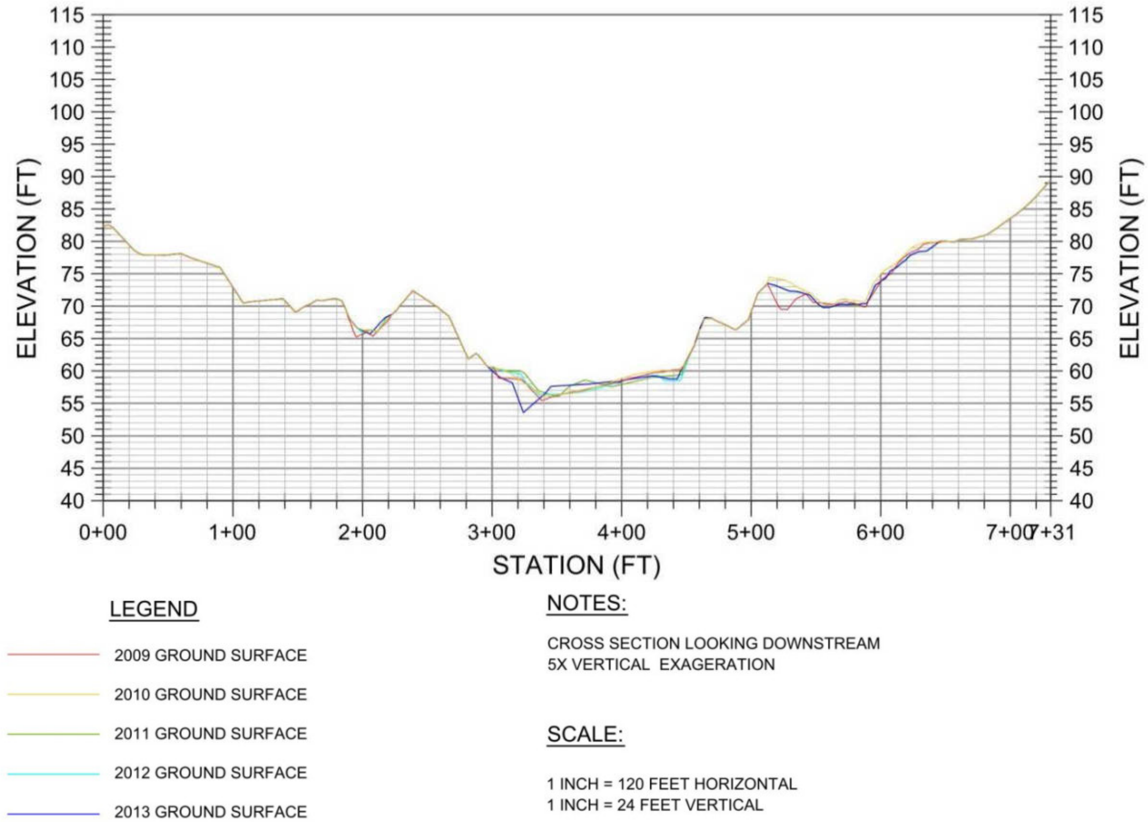

Figure B-22. Comparison of 2009–2013 annual cross-sections at station AA in the Middle Reach.

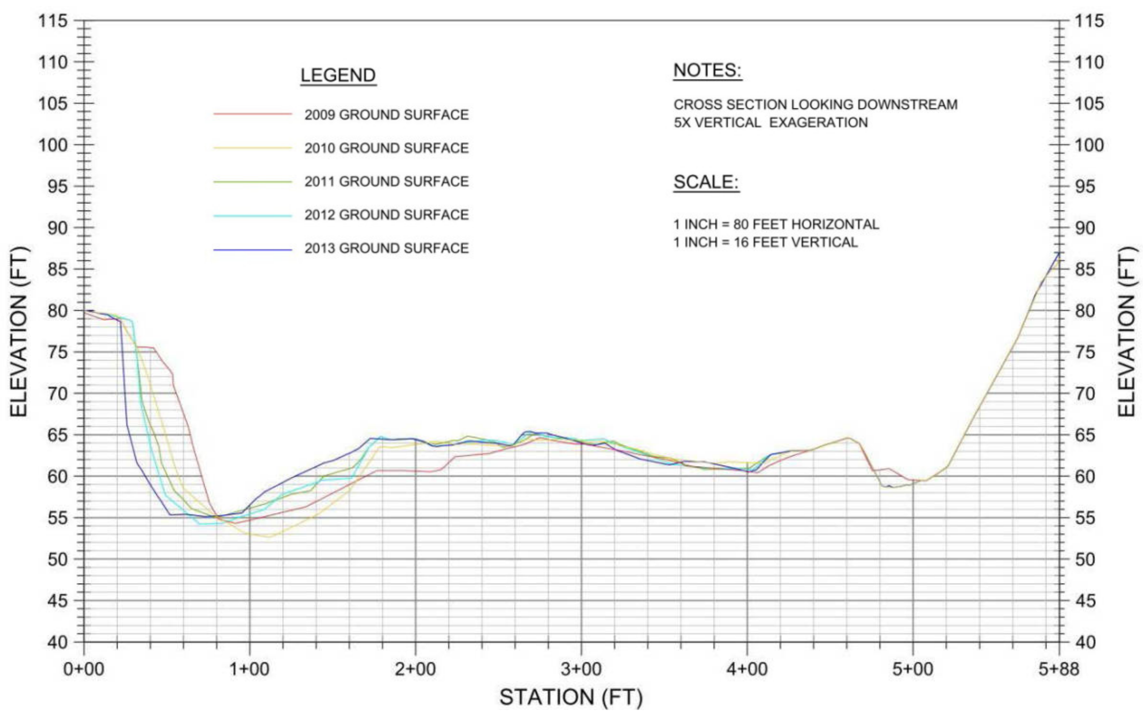

Figure B-23. Comparison of 2009–2013 annual cross-sections at station BB in the Middle Reach.

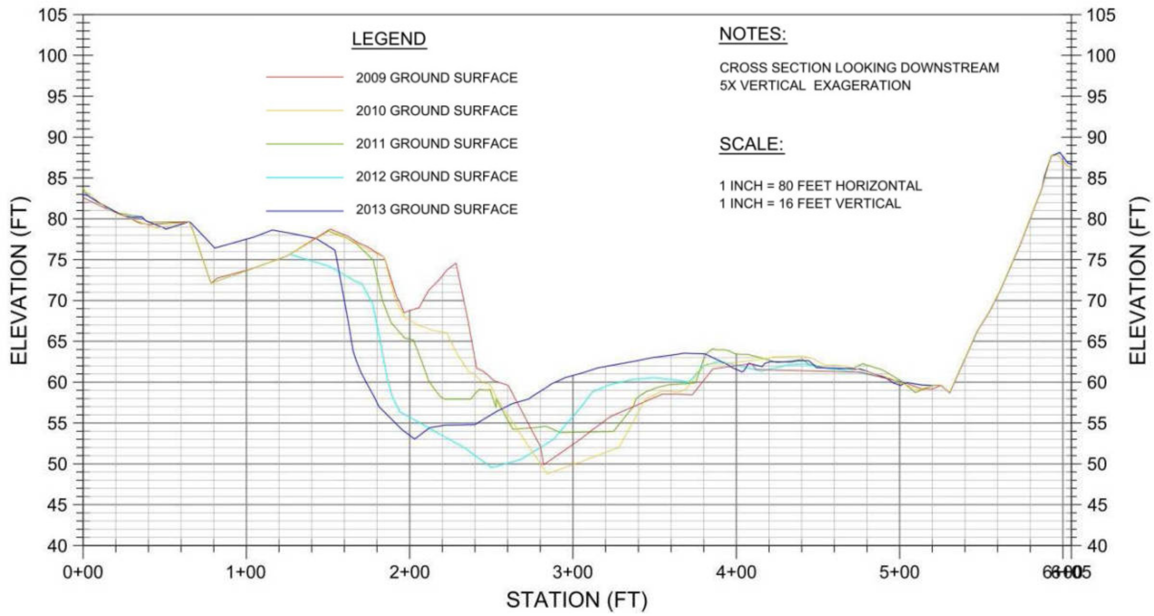

Figure B-24. Comparison of 2009–2013 annual cross-sections at station 30+0000 in the Middle Reach.

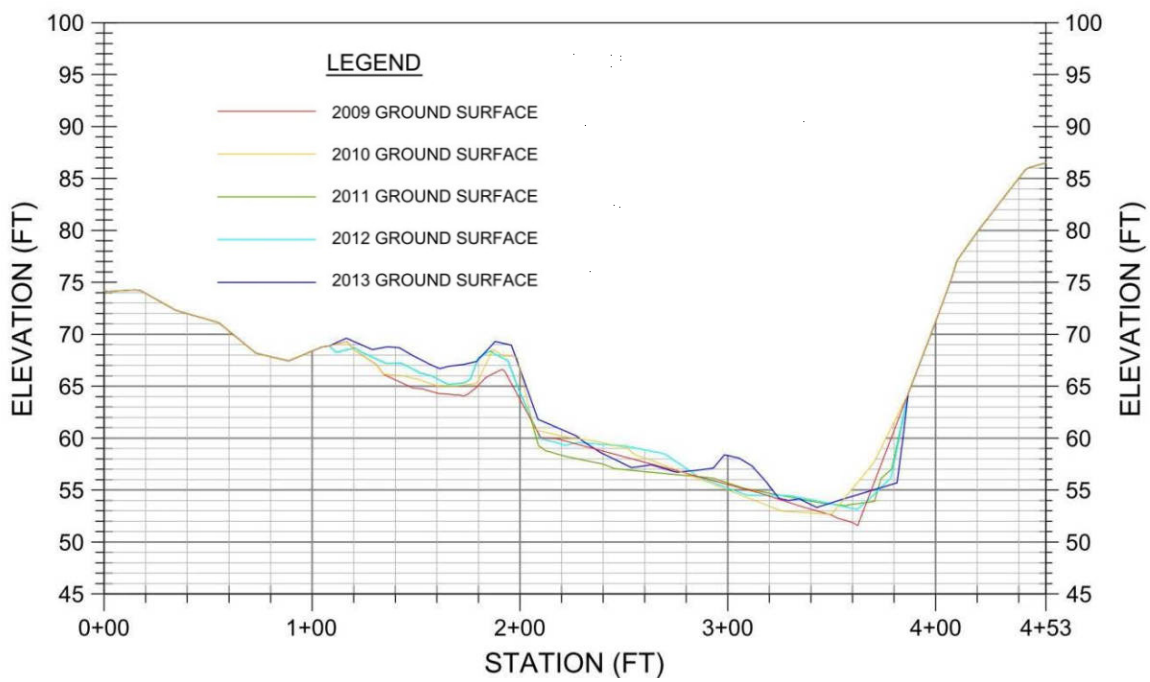

Figure B-25. Comparison of 2009–2013 annual cross-sections at station BB1 in the Middle Reach.

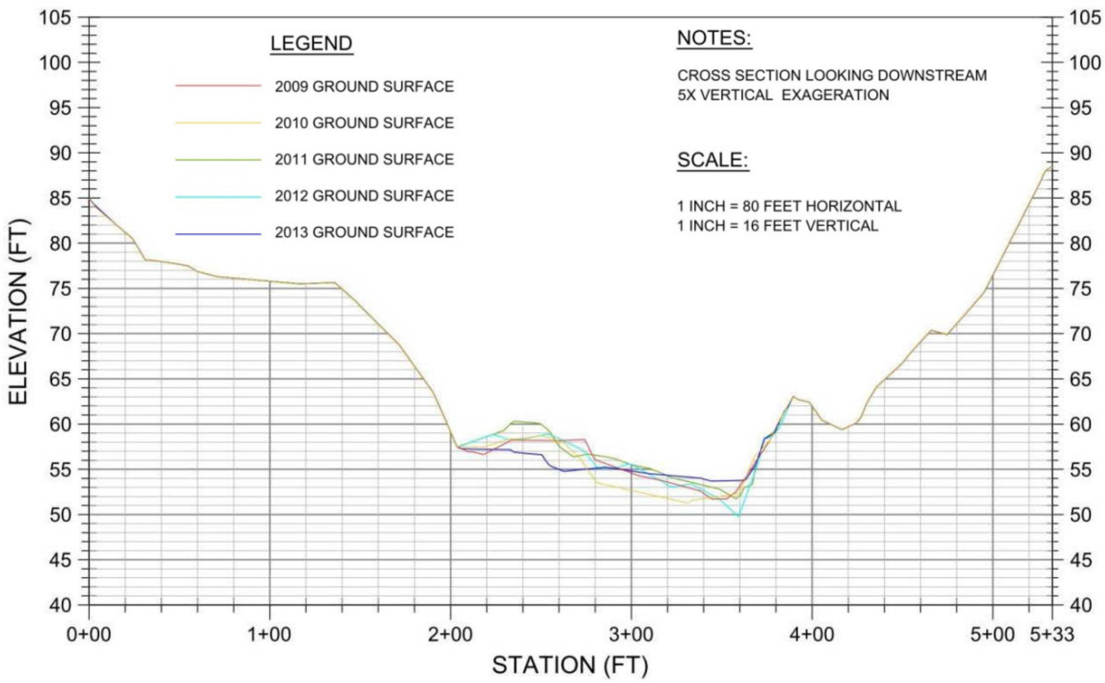

Figure B-26. Comparison of 2009–2013 annual cross-sections at station CC in the Middle Reach.

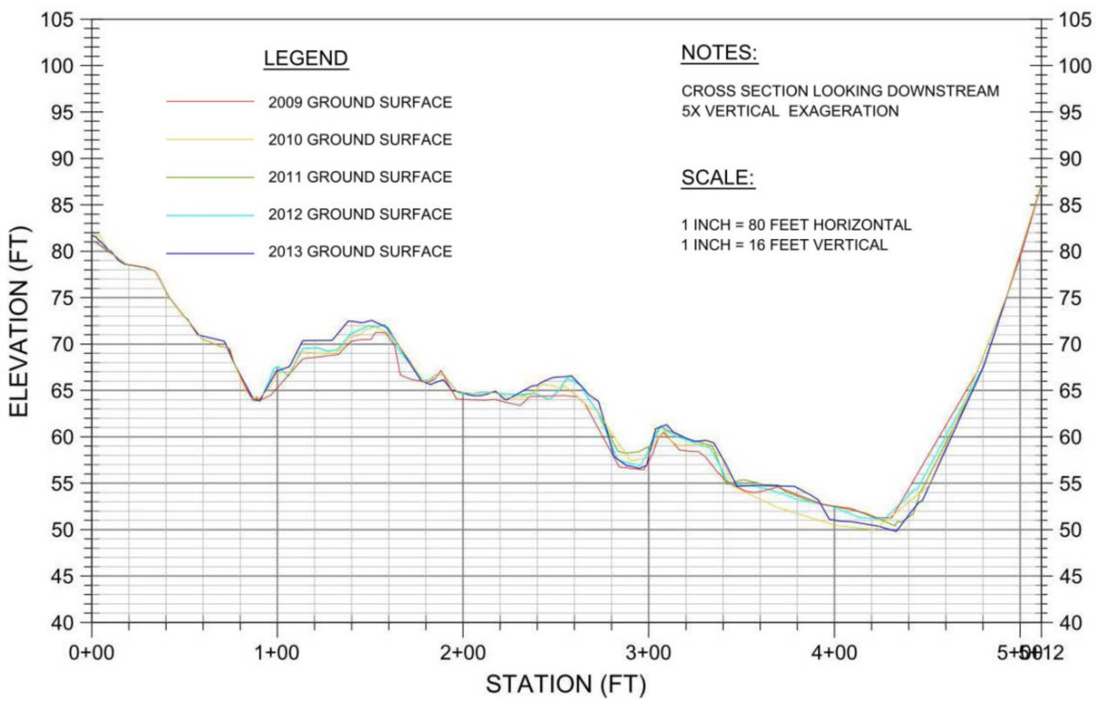

Figure B-27. Comparison of 2009–2013 annual cross-sections at station DD in the Middle Reach.

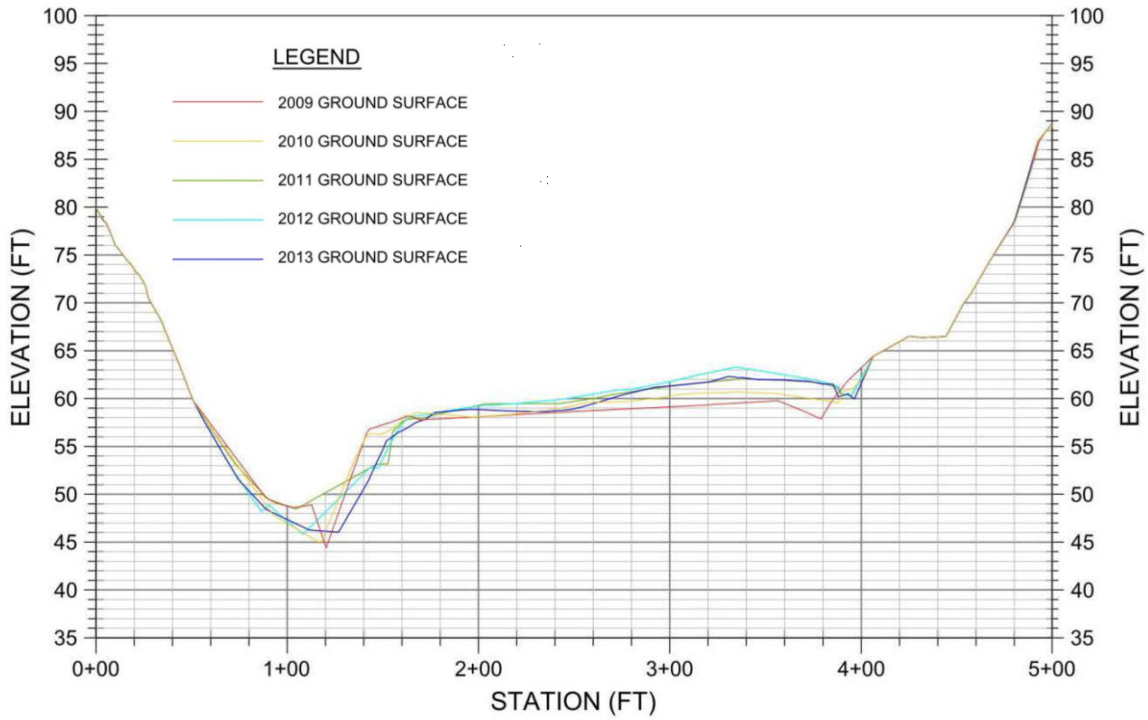

Figure B-28. Comparison of 2009–2013 annual cross-sections at station EE in the Middle Reach.

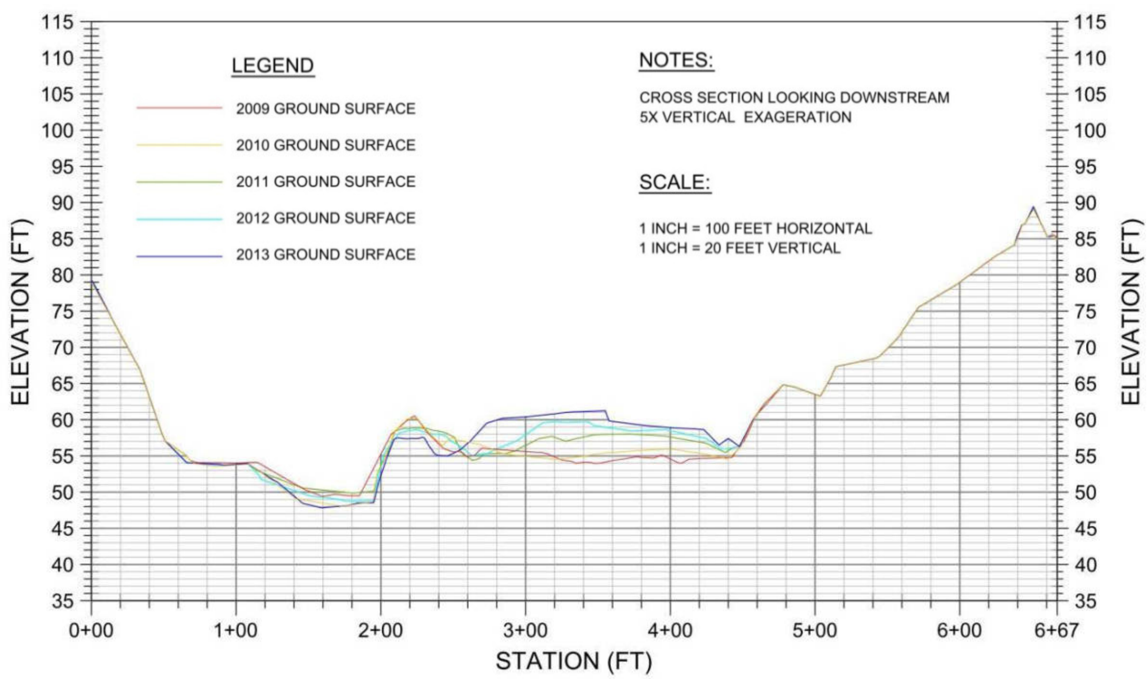

Figure B-29. Comparison of 2009–2013 annual cross-sections at station FF in the Middle Reach.

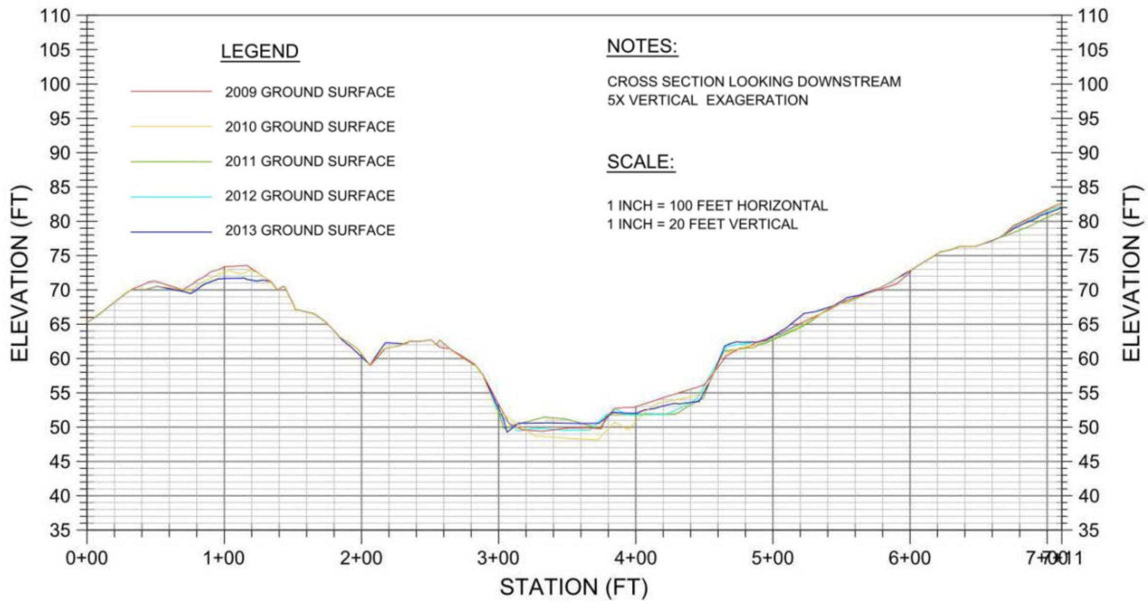

Figure B-30. Comparison of 2009–2013 annual cross-sections at station GG in the Middle Reach.

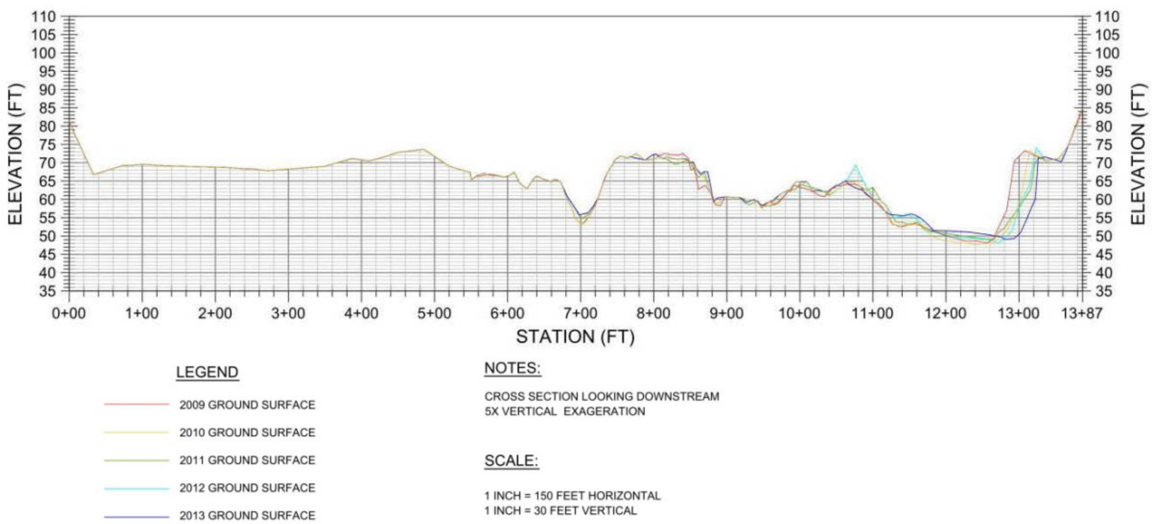

Figure B-31. Comparison of 2009–2013 annual cross-sections at station GG1A in the Middle Reach.

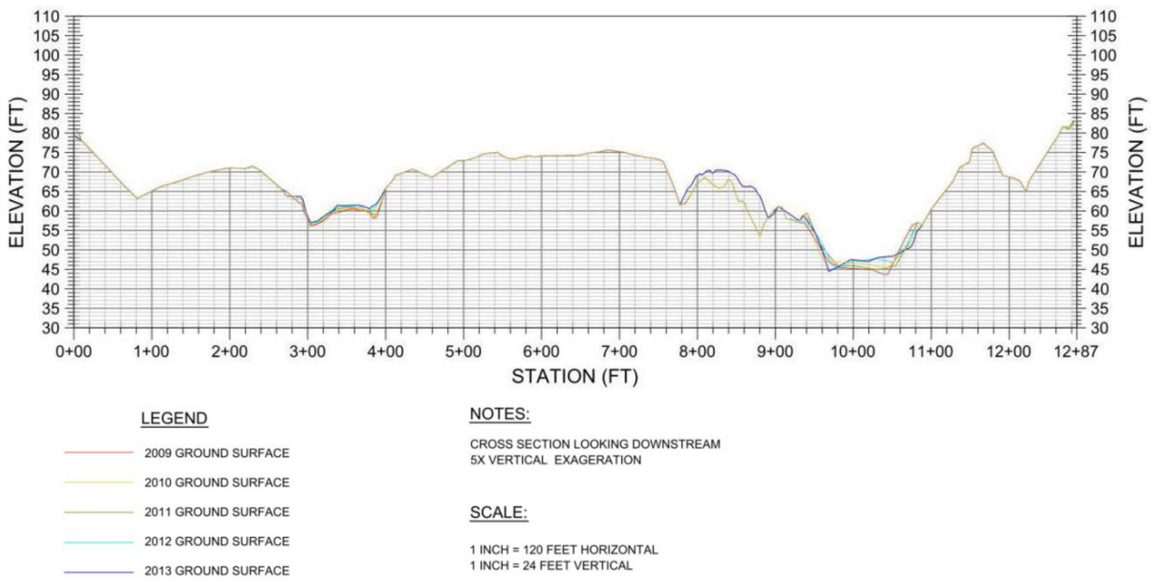

Figure B-32. Comparison of 2009–2013 annual cross-sections at station 28+3900 in the Middle Reach.

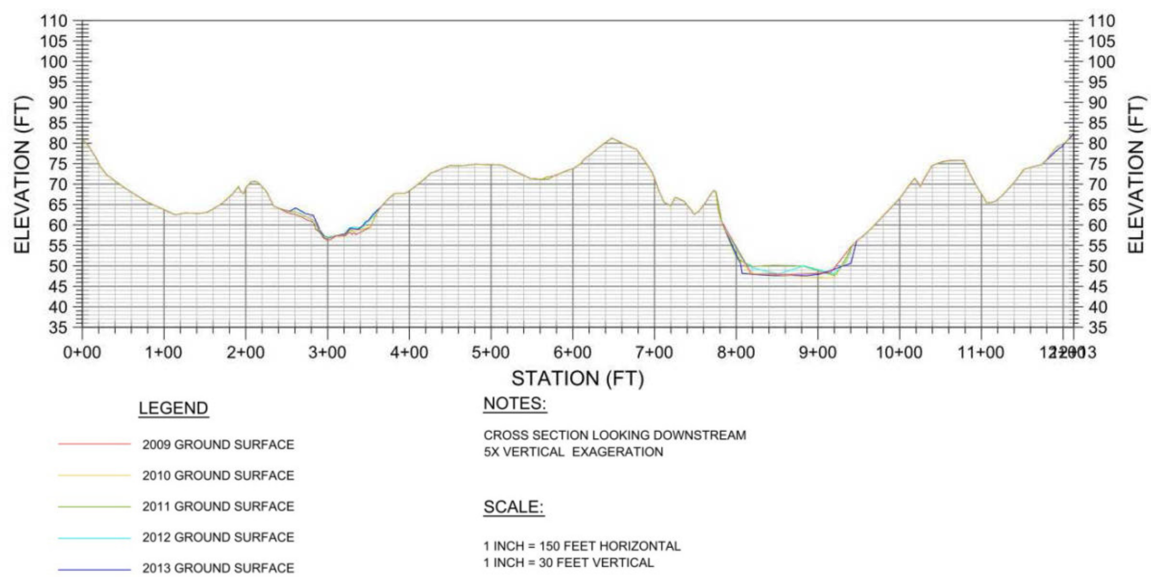

Figure B-33. Comparison of 2009–2013 annual cross-sections at station HH in the Middle Reach.

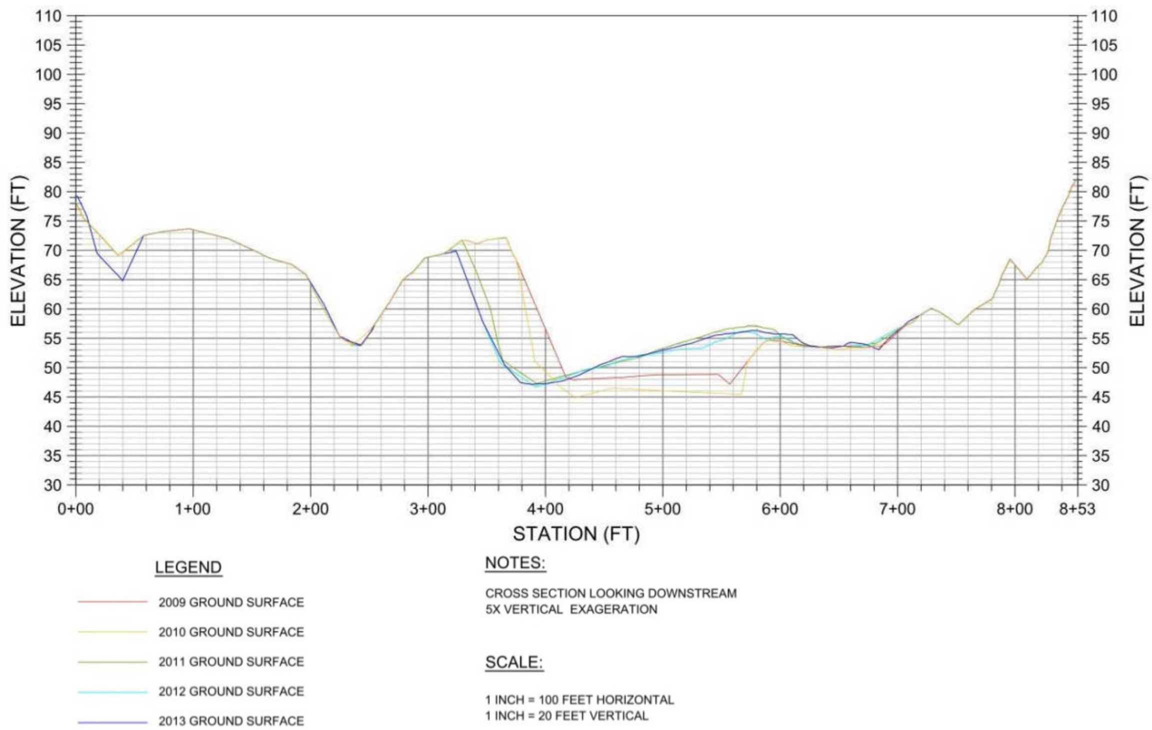

Figure B-34. Comparison of 2009–2013 annual cross-sections at station II in the Middle Reach.

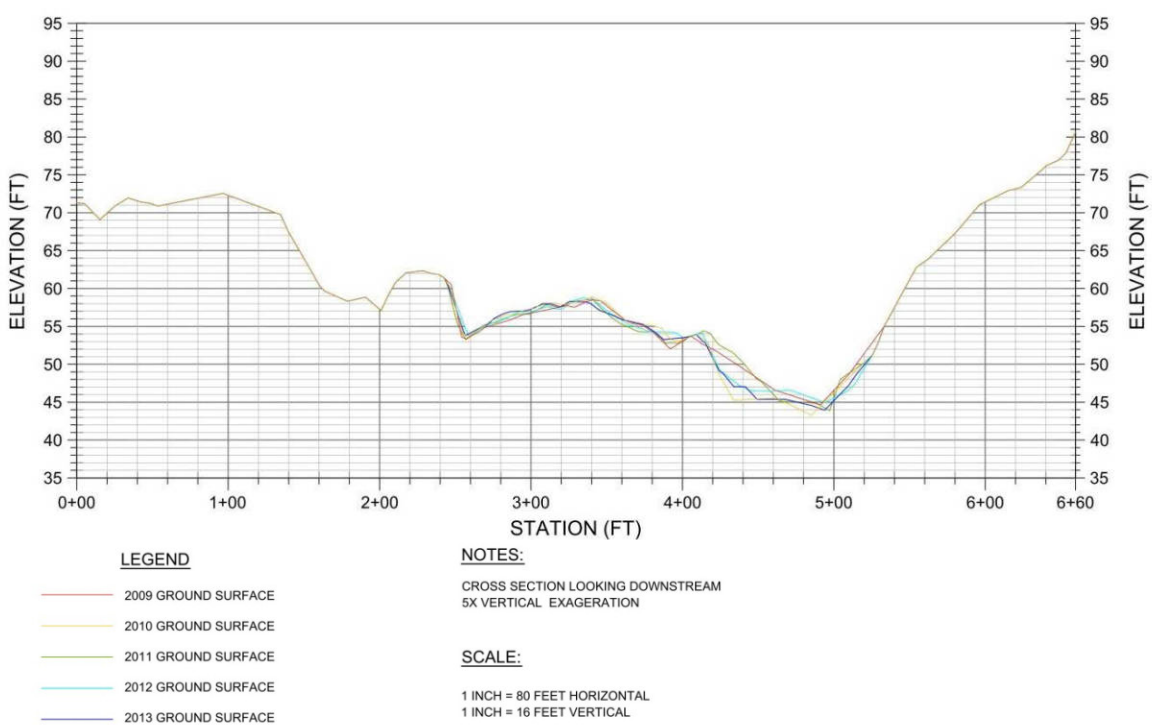

Figure B-35. Comparison of 2009–2013 annual cross-sections at station JJ in the Middle Reach.

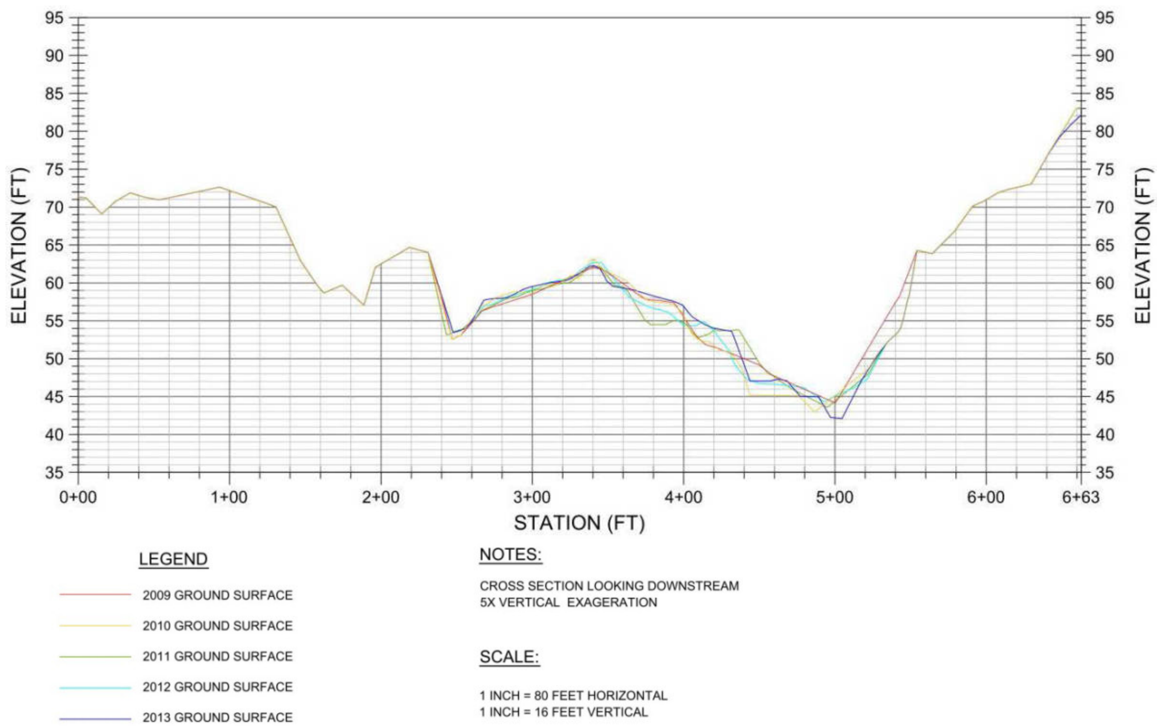

Figure B-36. Comparison of 2009–2013 annual cross-sections at station 28+0900 in the Middle Reach.

Appendix C

Comparisons of Annual Thalweg Elevations: 1994–2013/2014

Table C-1. Summary of annual thalweg elevations and differences for the Lower Alexander Valley Reach.

Cross-section Intercept along Thalweg	Thalweg Elevation per Year (ft above referenced datum)																						
	1994 [A, B]	1994 [A, C]	1995 [A, B]	1996 [A, B]	1997 [A, B]	1998 [A, B]	1999 [A, B]	1999 [A, C]	2000 [A, C]	2001 [A, C]	2002 [A, C]	2003 [A, C]	2004 [A, C]	2005 [A, C]	2006 [A, C]	2007 [A, C]	2008 [A, C]	2009 [C]	2010 [C]	2011 [C]	2012 [C]	2013 [C]	2014 [C]
AV 52+0000	190.0	192.8	188.7	189.1	185.8	186.9	185.9	185.9	189.8	189.8	189.1	188.3	187.8	188.4	N/A [D]	187.5	185.3	185.5	189.3	187.8	187.7	185.2	183.4
AV 51+0000	181.3	184.1	179.4	180.6	181.8	180.6	N/A [D]	N/A [D]	183.0	182.9	182.6	183.4	181.1	184.0	183.0	182.6	182.2	182.4	182.9	181.5	180.8	181.6	181.3
AV 50+2640	176.4	179.2	174.6	177.8	179.0	175.7	N/A [D]	N/A [D]	179.8	181.0	180.6	179.9	180.0	179.6	180.5	180.4	180.5	179.6	180.3	178.2	178.0	178.0	177.1
AV 50+1056	173.1	175.9	173.4	174.4	173.6	171.3	N/A [D]	N/A [D]	178.1	177.7	177.9	177.6	181.5	179.5	178.3	179.4	179.0	178.1	179.0	178.5	176.5	176.5	176.1
AV 49+4224	173.0	175.8	172.2	171.7	172.4	168.2	N/A [D]	N/A [D]	171.4	172.1	173.6	172.5	172.5	170.1	174.5	173.9	173.9	173.2	N/A [D]	174.8	174.2	174.4	174.3
AV 49+1800	164.6	167.4	166.2	166.5	167.6	165.8	165.5	165.5	166.5	166.9	167.8	165.5	167.5	167.2	168.4	168.8	167.7	167.3	168.0	169.5	170.3	168.7	168.9
AV 47+4800	154.4	157.2	153.7	152.8	152.4	153.1	153.1	155.9	155.5	155.7	157.1	156.9	153.5	156.2	154.2	156.2	155.6	155.2	158.6	157.4	155.0	154.9	155.4
AV 47+2800	153.8	156.6	153.7	153.0	148.6	153.9	153.6	156.4	156.0	156.9	156.1	153.8	154.9	154.6	155.6	155.6	155.9	155.7	156.5	157.1	154.8	155.6	156.1
AV 46+0000	137.2	140.0	138.3	141.3	139.5	138.3	N/A [D]	N/A [D]	N/A [D]	141.7	142.4	143.1	142.4	141.4	142.5	142.4	141.7	144.9	147.6	145.2	145.5	144.8	142.2

Change in Thalweg Elevation (ft)

Cross-section Intercept along Thalweg	1993–1994 [A]		1994–1995 [A]	1995–1996 [A]	1996–1997 [A]	1997–1998 [A]	1998–1999 [A]		1999–2000 [A]	2000–2001 [A]	2001–2002 [A]	2002–2003 [A]	2003–2004 [A]	2004–2005 [A]	2005–2006 [A]	2006–2007 [A]	2007–2008 [A]	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
AV 52+0000	-0.10		-1.30	0.40	-3.30	1.10	-1.00		3.90	0.00	-0.70	-0.80	-0.50	0.60	N/A [D]	-0.90	-2.24	0.17	3.80	-1.50	-0.10	-2.51	-1.81
AV 51+0000	0.10		-1.90	1.20	1.20	-1.20	N/A [D]		N/A [D]	-0.10	-0.30	0.80	-2.40	3.00	-1.00	-0.40	-0.36	0.23	0.48	-1.37	-0.70	0.71	-0.27
AV 50+2640	-0.10		-1.80	3.20	1.20	-3.30	N/A [D]		N/A [D]	1.20	-0.40	-0.70	0.10	-0.40	0.80	-0.10	0.06	-0.90	0.73	-2.10	-0.21	-0.05	-0.84
AV 50+1056	-0.3		0.3	1.0	-0.8	-2.3	N/A [D]		N/A [D]	-0.4	0.2	-0.3	3.9	-2.1	-1.2	1.2	-0.4	-0.89	0.86	-0.50	-1.96	0.01	-0.44
AV 49+4224	1.50		-0.80	-0.50	0.70	-4.20	N/A [D]		N/A [D]	0.70	1.50	-1.10	0.00	-2.40	4.40	-0.60	-0.01	-0.67	N/A [D]	N/A [D]	-0.57	0.18	-0.05
AV 49+1800	N/A [D]		1.60	0.30	1.10	-1.80	-0.30		1.00	0.40	0.90	-2.30	1.90	-0.20	1.20	0.30	-1.06	-0.40	0.65	1.57	0.74	-1.53	0.17
AV 47+4800	N/A [D]		-0.70	-0.90	-0.40	0.70	0.00		-0.50	0.20	1.40	-0.20	-3.40	2.80	-2.00	2.00	-0.1	-0.40	3.39	-1.24	-2.38	-0.06	0.46
AV 47+2800	0.30		-0.10	-0.70	-4.40	5.40	-0.40		-0.40	0.90	-0.80	-2.30	1.10	-0.40	1.00	0.00	0.31	-0.20	0.80	0.57	-2.29	0.83	0.44
AV 46+0000	-0.50		1.10	3.00	-1.80	-1.20	N/A [D]		N/A [D]	N/A [D]	0.70	0.60	-0.60	-1.00	1.00	-0.10	-0.74	3.24	2.66	-2.38	0.28	-0.66	-2.64

Summary of Changes

Average Change in Thalweg Elevation (ft)	0.13		-0.40	0.78	-0.72	-0.76	-0.43		1.00	0.36	0.28	-0.70	0.01	-0.01	0.47	0.16	-0.50	0.02	1.67	-0.87	-0.80	-0.34	-0.55
Number of Thalweg-Change Points	7.0		9.0	9.0	9.0	9.0	4.0		4.0	8.0	9.0	9.0	9.0	9.0	8.0	9.0	9.0	9.0	8.0	8.0	9.0	9.0	9.0
Number of Thalweg Points with Increased Elevations	3.0		3.0	6.0	4.0	3.0	1.0		2.0	6.0	5.0	2.0	5.0	3.0	5.0	4.0	2.0	3.0	8.0	2.0	2.0	4.0	3.0
Number of Thalweg Points with Decreased Elevations	4.0		6.0	3.0	5.0	6.0	3.0		2.0	2.0	4.0	7.0	4.0	6.0	3.0	5.0	7.0	6.0	0.0	6.0	7.0	5.0	6.0

Table footnotes:

[A] Data from the 2008 Monitoring Report (Entrix 2010).
[B] Elevations referenced to National Geodetic Vertical Datum of 1929 (NGVD29).
[C] Elevations referenced to North American Vertical Datum of 1988 (NAVD88).
[D] N/A = Not surveyed of no data available for year-to-year comparison.

Table C-2. Summary of annual thalweg elevations and differences for the Middle Reach.

Cross-section Intercept along Thalweg	Thalweg Elevation per Year (ft above referenced datum)																						
	1994 [A, B]	1994 [A, C]	1995 [A, B]	1996 [A, B]	1997 [A, B]	1998 [A, B]	1999 [A, B]	1999 [A, C]	2000 [A, C]	2001 [A, C]	2002 [A, C]	2003 [A, C]	2004 [A, C]	2005 [A, C]	2006 [A, C]	2007 [A, C]	2008 [A, C]	2009 [C]	2010 [C]	2011 [C]	2012 [C]	2013 [C]	2014 [E]
J	76.7	79.5	75.7	76.2	76.4	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	77.1	81.7	79.9	77.7	79.6	78.32	79.26	79.46	78	75.56	76.79	77.9	---
I	72.5	75.3	74.6	73.5	73.9	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	75.4	76.2	76.8	76.7	76.6	75.60	76.65	76.33	76.28	77.56	75.8	76.13	---
H	67.3	70.1	69.2	73.2	67.2	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	73.9	72.7	72.2	67.9	69.3	67.90	65.30	66.7	66.82	74.52	68.25	67.66	---
G	70.7	73.5	71.8	70.5	69.8	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	72.5	72.7	72.6	72.5	73.3	72.70	73.10	72.1	73.86	72.69	72.77	74.15	---
F	70.4	73.2	70.5	69.7	70.3	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	75.0	76.3	76.9	76.3	76.7	76.44	76.35	76.12	76.71	75.57	75.42	74.79	---
E1	70.9	73.7	70.4	70.1	71.6	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	74.0	74.2	74.5	74.8	74.9	75.36	75.93	75.13	74.15	75.46	73.66	73.76	---
E	63.1	65.9	60.6	60.8	61.2	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	62.1	74.3	65.0	67.2	64.9	66.90	69.50	62.4	65.34	67.68	64.03	66.11	---
D	66.7	69.5	67.4	69.8	65.7	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	70.0	74.5	69.3	68.8	71.8	71.19	70.95	72.72	72.09	73.12	69.62	71.15	---
C	59.3	62.1	59.7	59.8	60.1	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	63.6	66.4	64.7	62.6	63.4	64.50	64.96	64.4	63.68	64.22	63.05	64.56	---
31+1700	55.2	58.0	56.7	57.3	59.3	59.3	58.1	60.9	60.5	60.8	60.4	60.4	60.7	59.2	60.1	59.60	60.45	60.46	60.19	61.98	59.61	60.74	---
B	55.0	57.8	56.4	56.7	57.9	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	60.4	59.5	60.6	59.7	59.8	59.56	60.29	59.77	60.02	60.91	59.82	59.99	---
A	52.4	55.2	54.8	53.5	55.5	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	58.2	58.2	56.4	56.4	58.7	56.30	57.43	58.19	57.89	56.61	57.74	57.39	---
AA	50.2	53.0	50.5	51.3	52.6	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	54.1	56.8	55.1	56.5	55.9	56.30	56.59	55.4	56	56.02	56.35	53.59	---
BB	47.2	50.0	47.4	47.0	49.6	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	54.2	55.2	55.6	53.9	55.4	54.20	54.61	54.3	52.61	55	54.23	55.14	---
30+0000	50.5	53.3	50.3	48.4	49.7	50.3	49.5	52.3	51.5	52.3	52.1	51.0	50.4	52.8	55.1	54.90	49.90	49.9	48.78	53.8	49.53	53.03	---
BB1	48.4	51.2	48.8	51.8	52.2	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	53.7	55.6	53.3	53.6	52.9	52.10	50.70	51.6	52.68	53.49	53.14	53.33	---
CC	49.3	52.1	49.6	49.8	48.7	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	51.4	52.5	52.4	50.3	52.0	52.00	51.30	51.7	51.27	51.76	49.77	53.69	---
DD	48.0	50.8	47.3	47.7	46.8	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	51.7	51.7	51.2	50.2	51.5	51.70	50.68	51.27	50	50.4	51.08	49.82	---
EE	45.8	48.6	46.7	46.6	46.4	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	48.9	50.1	49.5	48.2	49.2	48.70	49.10	44.4	44.86	48.46	45.81	46.05	---
FF	46.3	49.1	46.5	45.8	45.6	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	49.7	48.9	49.4	48.5	49.0	49.10	49.50	49.4	48.04	49.87	48.75	47.85	---
GG	46.1	48.9	46.2	45.3	45.4	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	48.5	48.9	48.4	48.1	48.6	48.40	49.20	49.38	48.14	49.72	49.44	49.25	---
GG1A	43.9	46.7	41.9	43.1	43.4	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	47.4	45.8	46.4	46.3	47.2	47.40	48.01	48.1	47.6	49.09	48.03	49.1	---
28+3900	40.8	43.6	43.3	43.7	43.9	44.7	44.3	47.1	47.1	44.9	45.3	46.3	44.4	45.4	43.3	46.00	43.50	43.7	45.2	44.89	45.08	44.47	---
HH	41.2	44.0	41.4	43.2	43.3	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	47.5	46.4	47.2	47.1	46.9	48.40	47.10	47.9	47.01	47.64	48	47.62	---
II	41.1	43.9	40.4	40.3	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	49.4	46.1	47.3	45.9	46.3	47.00	46.28	47.17	44.87	47.27	46.72	47.16	---
JJ	38.8	41.6	38.6	38.0	40.2	N/A [D]	N/A [D]	N/A [D]	N/A [D]	N/A [D]	44.3	44.8	45.1	43.4	45.6	44.20	43.90	44.64	43.28	43.86	44.94	43.95	---
28+0900	38.8	41.6	38.2	38.6	39.8	40.9	39.5	42.4	43.0	43.8	43.1	41.7	42.2	42.1	45.2	43.06	42.69	44.16	42.94	43.58	44.32	42.11	---

Change in Thalweg Elevation (ft)

Cross-section Intercept along Thalweg	1993–1994 [A]		1994–1995 [A]	1995–1996 [A]	1996–1997 [A]	1997–1998 [A]	1998–1999 [A]		1999–2000 [A]	2000–2001 [A]	2001–2002 [A]	2002–2003 [A]	2003–2004 [A]	2004–2005 [A]	2005–2006 [A]	2006–2007 [A]	2007–2008 [A]	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014 [E]
J	0.4		-1.0	0.5	0.1	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	4.6	-1.8	-2.2	1.8	-1.2	0.94	0.20	-1.46	-2.44	1.23	1.11	---
I	-1.4		2.1	-1.1	0.4	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.9	0.6	-0.1	-0.1	-1.0	1.05	-0.32	-0.05	1.28	-1.76	0.33	---
H	0.8		1.9	4.0	-6.0	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	-1.2	-0.4	-4.3	1.4	-1.4	-2.60	1.40	0.12	7.70	-6.27	-0.59	---
G	-0.1		1.1	-1.3	-0.7	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.2	-0.1	-0.1	0.8	-0.6	0.40	-1.00	1.76	-1.17	0.08	1.38	---
F	0.6		0.1	-0.8	0.5	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	1.3	0.6	-0.6	0.4	-0.3	-0.09	-0.23	0.59	-1.14	-0.15	-0.63	---
E1	0.1		-0.5	-0.3	1.5	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.2	0.3	0.4	0.1	0.5	0.57	-0.80	-0.98	1.31	-1.80	0.10	---
E	2.5		-2.5	0.1	0.4	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	12.2	-9.3	2.2	-2.3	2.0	2.60	-7.10	2.94	2.34	-3.65	2.08	---
D	0.4		0.7	2.4	-4.1	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	4.5	-5.2	-0.5	3.0	-0.6	-0.24	1.77	-0.63	1.03	-3.50	1.53	---
C	-0.8		0.4	0.1	0.3	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	2.8	-1.7	-2.1	0.8	1.1	0.46	-0.56	-0.72	0.54	-1.17	1.51	---
31+1700	-0.7		1.5	0.5	2.0	0.0	-1.2		-0.4	0.3	-0.4	0.0	0.3	-1.5	0.9	-0.5	0.85	0.01	-0.27	1.79	-2.37	1.13	---
B	0.1		1.4	0.2	1.2	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	-0.9	1.1	-0.9	0.1	-0.2	0.73	-0.52	0.25	0.89	-1.09	0.17	---
A	-1.4		2.4	-1.3	2.1	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.1	-1.8	0.0	2.3	-2.4	1.13	0.76	-0.30	-1.28	1.13	-0.35	---
AA	-1.5		0.3	0.8	1.3	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	2.7	-1.7	1.4	-0.6	0.4	0.29	-1.19	0.60	0.02	0.33	-2.76	---
BB	1.1		0.2	-0.4	2.6	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	1.0	0.4	-1.7	1.5	-1.2	0.41	-0.31	-1.69	2.39	-0.77	0.91	---
30+0000	N/A [D]		-0.2	-2.0	1.3	0.6	-0.8		-0.9	0.8	-0.1	-1.2	-0.6	2.4	2.3	-0.2	-5.00	0.00	-1.12	5.02	-4.27	3.50	---
BB1	0.5		0.4	3.0	0.4	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	1.8	-2.3	0.3	-0.7	-0.8	-1.40	0.90	1.08	0.81	-0.35	0.19	---
CC	0.6		0.3	0.3	-1.1	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	1.1	0.0	-2.1	1.7	0.0	-0.70	0.40	-0.43	0.49	-1.99	3.92	---
DD	0.3		-0.7	0.4	-1.0	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.1	-0.5	-1.0	1.3	0.3	-1.02	0.59	-1.27	0.40	0.68	-1.26	---
EE	0.0		0.9	-0.1	-0.1	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	1.2	-0.6	-1.3	1.0	-0.5	0.40	-4.70	0.46	3.60	-2.65	0.24	---

FF	0.4		0.2	-0.7	-0.2	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	-0.7	0.5	-0.9	0.5	0.1	0.40	-0.10	-1.36	1.83	-1.12	-0.90	---
GG	-0.1		0.1	-0.9	0.1	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.5	-0.5	-0.3	0.6	-0.2	0.80	0.18	-1.24	1.58	-0.28	-0.19	---
GG1A	0.6		-2.0	1.2	0.3	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	-1.6	0.6	-0.1	0.9	0.3	0.61	0.09	-0.50	1.49	-1.06	1.07	---
28+3900	-2.5		2.5	0.4	0.2	0.8	-0.5		0.0	-2.2	0.4	1.0	-1.9	1.0	-2.1	2.7	-2.50	0.20	1.50	-0.31	0.19	-0.61	---
HH	-2.1		0.2	1.8	0.8	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	-1.1	0.8	-0.1	-0.2	1.5	-1.30	0.80	-0.89	0.63	0.36	-0.38	---
II	-0.8		-0.7	-0.1	N/A [D]	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	-3.3	1.2	-1.4	0.4	0.7	-0.72	0.89	-2.30	2.40	-0.55	0.44	---
JJ	-0.7		-0.2	-0.7	2.3	N/A [D]	N/A [D]		N/A [D]	N/A [D]	N/A [D]	0.5	0.3	-1.7	2.2	-1.4	-0.30	0.74	-1.36	0.58	1.08	-0.99	---
28+0900	1.1		-0.6	0.4	1.3	1.0	-1.3		0.6	0.8	-0.7	-1.4	0.4	-0.1	3.2	-2.2	-0.37	1.47	-1.22	0.64	0.74	-2.21	---

Summary of Changes

Average Change in Thalweg Elevation (ft)	-0.10		0.31	0.24	0.23	0.60	-0.95		-0.18	-0.08	-0.20	0.94	-0.79	-0.57	0.79	-0.19	-0.17	-0.24	-0.31	1.20	-1.07	0.32	---
Number of Thalweg-Change Points	26.0		27.0	27.0	26.0	4.0	4.0		4.0	4.0	4.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	---
Number of Thalweg Points with Increased Elevations	15.0		18.0	15.0	19.0	4.0	0.0		2.0	3.0	1.0	19.0	13.0	7.0	21.0	11.0	15.0	16.0	9.0	22.0	9.0	16.0	---
Number of Thalweg Points with Decreased Elevations	11.0		9.0	12.0	7.0	0.0	4.0		2.0	1.0	3.0	8.0	14.0	20.0	6.0	16.0	12.0	11.0	18.0	5.0	18.0	11.0	---

Table footnotes:
[A] Data from the 2008 Monitoring Report (Entrix 2010).
[B] Elevations referenced to National Geodetic Vertical Datum of 1929 (NGVD29).
[C] Elevations referenced to North American Vertical Datum of 1988 (NAVD88).
[D] N/A = Not surveyed of no data available for year-to-year comparison.
[E] --- = no data provided by PRMD.

Appendix D

Thalweg Elevation Comparison Plots: 2009–2013/2014

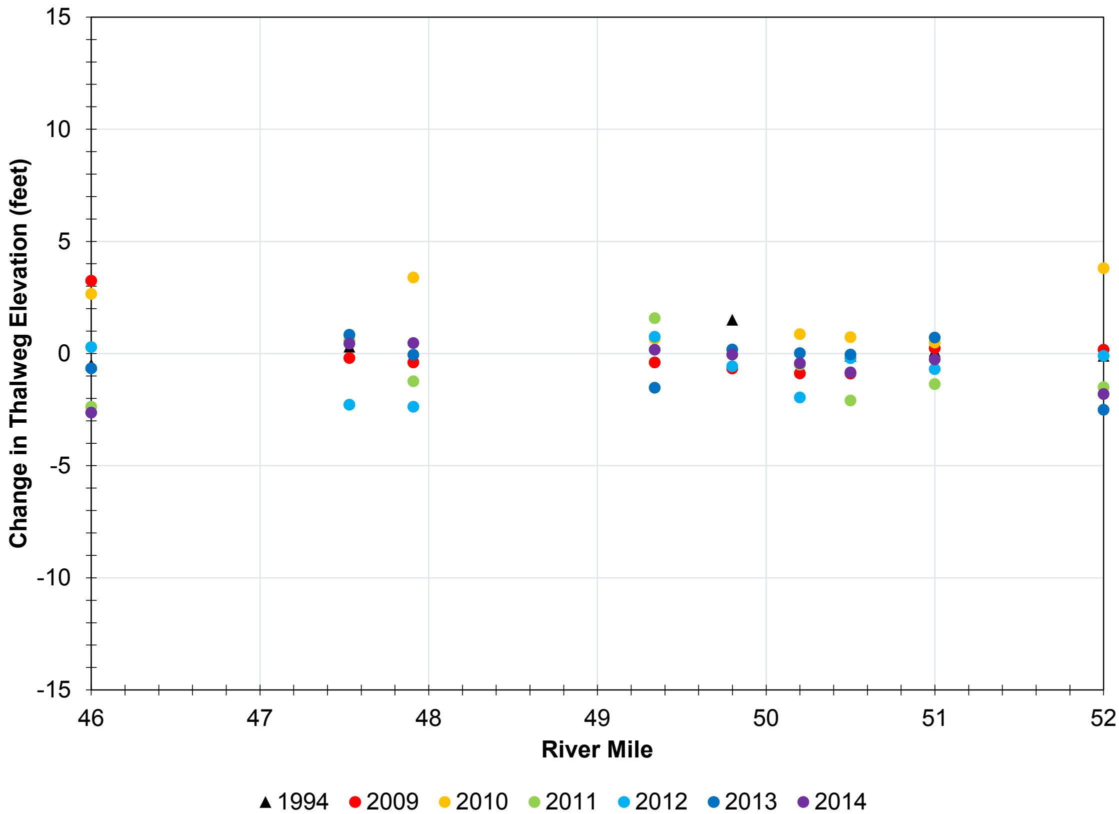

Figure D-1. Change in thalweg elevations in 1994 and 2009-2014 at the nine cross-sections in the Lower Alexander Valley Reach.

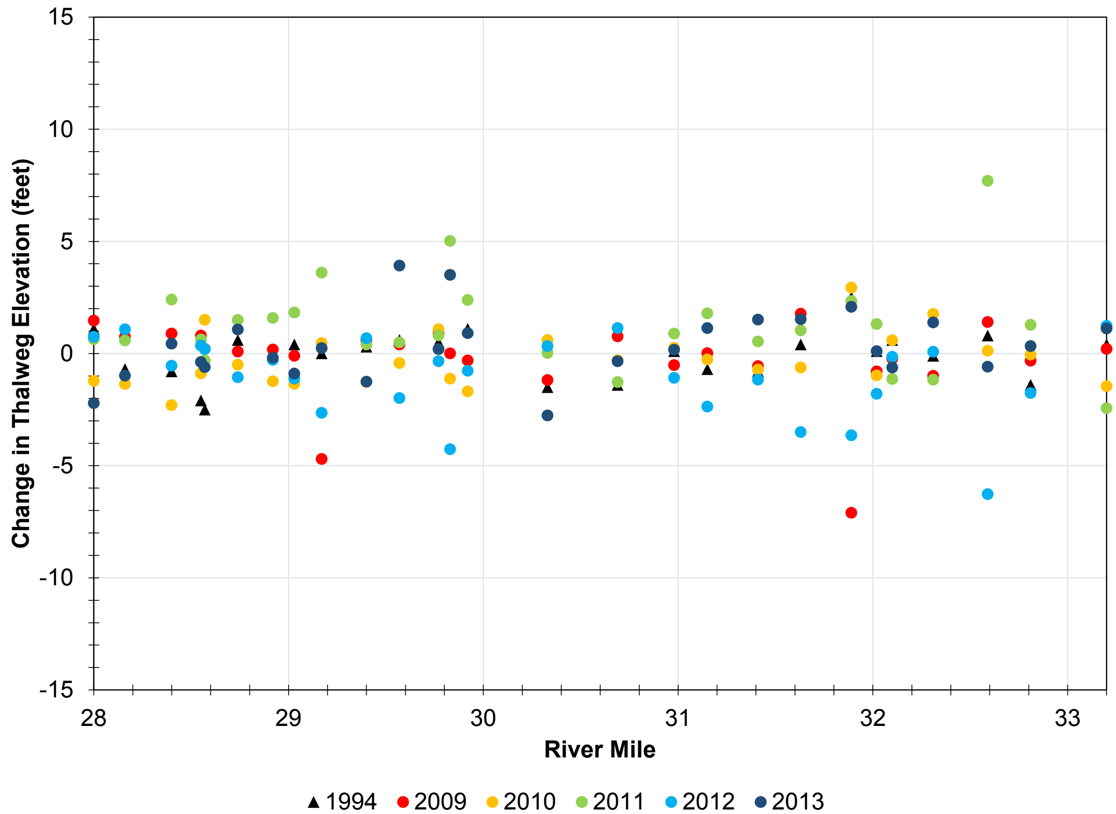

Figure D-2. Change in thalweg elevations in 1994 and 2009-2013 at the 27 cross-sections in the Middle Reach.

Appendix E

Comparisons of Riverbank Positions: 2009–2013/2014

Table E-1. Summary of annual riverbank positions and changes for the Lower Alexander Valley Reach.

Cross-Section	Mean WSEL from 2009–2014 (ft) [A]	Left Bank Station along Cross-section (ft) [B]						Right Bank Station along Cross-section (ft) [B]						Change in Left Bank Station (ft) [C]					Change in Right Bank Station (ft) [D]					Notes
		2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2010–2009	2011–2010	2012–2011	2013–2012	2014–2013	2010–2009	2011–2010	2012–2011	2013–2012	2014–2013	
52+0000	190.9	325.6	365.7	331.4	366.8	317.7	324.9	402.7	481.9	528.5	592.5	627.3	626.0	40.1 accrete	-34.3 retreat	35.5 accrete	-49.1 retreat	7.1 accrete	79.3 retreat	46.5 retreat	64.0 retreat	34.8 retreat	-1.2 accrete	Section shows scour at bridge at right bank and lateral shift to right bank with greatest scour in 2014
51+0000	182.9	293.0	287.2	265.6	238.3	231.2	237.8	308.0	287.2	343.9	307.3	287.7	280.3	-5.8 retreat	-21.6 retreat	-27.3 retreat	-7.1 retreat	6.6 accrete	-20.8 accrete	56.7 retreat	-36.6 accrete	-19.6 accrete	-7.4 accrete	Left bank has eroded laterally: 2010 thalweg station is assumed to be equal to bank station because average elevation line does not quite intercept profile line
50+2640	181.3	348.5	359.8	312.5	317.1	314.7	316.3	408.5	406.8	437.5	412.3	395.1	402.6	11.3 accrete	-47.2 retreat	4.6 accrete	-2.4 retreat	1.6 accrete	-1.7 accrete	30.7 retreat	-25.2 accrete	-17.2 accrete	7.5 retreat	Channel erodes laterally toward left bank
50+1056	179.5	333.8	336.1	321.3	320.6	317.0	319.9	381.7	374.5	396.8	399.9	394.8	374.0	2.3 accrete	-14.8 retreat	-0.8 retreat	-3.6 retreat	2.9 accrete	-7.2 accrete	22.4 retreat	3.1 retreat	-5.1 accrete	-20.8 accrete	Channel eroding lateral towards left bank
49+4224	176.8	1,113	1,117	1,113	1,119	1,118	1,115	1,202	1,194	1,288	1,186	1,156	1,307	3.4 accrete	-3.5 retreat	5.5 accrete	-0.6 retreat	-3.1 retreat	-8.1 accrete	93.6 retreat	-101.8 accrete	-30.1 accrete	150.7 retreat	Channel is relatively stable
49+1800	171.6	81.1	83.3	88.7	119.8	83.8	83.7	233.6	231.4	113.2	195.0	232.5	221.2	2.2 accrete	5.3 accrete	31.1 accrete	-36.0 retreat	-0.1 retreat	-2.2 accrete	-118.2 accrete	81.8 retreat	37.5 retreat	-11.4 accrete	Left bank is very steep and eroding, sections show annual pattern of both degradation and aggradation
47+4800	161.5	57.9	68.4	59.8	61.2	52.0	61.8	113.6	113.1	115.0	123.4	118.0	105.6	10.5 accrete	-8.6 retreat	1.4 accrete	-9.2 retreat	9.8 accrete	-0.5 accrete	1.9 retreat	8.4 retreat	-5.3 accrete	-12.4 accrete	Channel is incised and relatively stable with aggradation in 2010
47+2800	159.1	665.8	666.7	666.1	664.4	664.3	507.3	718.3	717.7	724.6	698.3	725.2	727.5	0.9 accrete	-0.6 retreat	-1.7 retreat	-0.1 retreat	-157.0 retreat	-0.6 accrete	6.8 retreat	-26.3 accrete	26.9 retreat	2.3 retreat	Channel appears to have split; 2014 is the only location where channel at new split falls below WSEL reference but all profiles reflect left bank erosion
46+0000	147.9	318.1	356.6	310.0	319.0	281.3	292.9	426.1	386.8	426.8	416.7	444.0	441.7	38.5 accrete	-46.6 retreat	8.9 accrete	-37.6 retreat	11.6 accrete	-39.3 accrete	39.9 retreat	-10.0 accrete	27.3 retreat	-2.3 accrete	Channel migrates toward left bank
Average Change in Lateral Movement (ft)														11.5 accrete	-19.1 retreat	6.4 accrete	-16.2 retreat	-13.4 retreat	-0.1 accrete	20.0 retreat	-4.7 accrete	5.5 retreat	11.7 retreat	
Number of Bank-position Comparisons with Lateral Movement Toward Left Bank (retreat)														1	8	3	9	3						
Number of Bank-position Comparisons with Lateral Movement Toward Right Bank (retreat)																			1	8	4	4	3	

Table footnotes:
[A] WSEL = water surface elevation based on an assumed vertical datum of NAVD88.
[B] Stationing along cross-sections began on the left bank side and increased towards the right bank.
[C] Positive values in the left bank columns indicate bank-position movement toward the river's centerline and away from the floodplain (i.e., bank and/or bar accretion), while negative values indicate bank movement away from the river's centerline and toward the floodplain (i.e., bank retreat).
[D] Positive values in the right bank columns indicate bank-position movement away from the river's centerline and toward the floodplain (i.e., bank retreat), while negative values indicate bank movement toward from the river's centerline and away from the floodplain (i.e., bank and/or bar accretion).

Table E-2. Summary of annual riverbank positions and changes for the Middle Reach.

Cross-Section	Mean WSEL from 2009–2014 (ft) [A]	Left Bank Station along Cross-section (ft) [B]						Right Bank Station along Cross-section (ft) [B]						Change in Left Bank Station (ft) [C]					Change in Right Bank Station (ft) [D]					Notes
		2009	2010	2011	2012	2013	2014 [E]	2009	2010	2011	2012	2013	2014 [E]	2010–2009	2011–2010	2012–2011	2013–2012	2014–2013	2010–2009	2011–2010	2012–2011	2013–2012	2014–2013	
J	81.0	74.6	26.7	21.3	24.0	14.9	---	164.6	168.1	161.3	141.8	232.5	---	-47.8 retreat	-5.4 retreat	2.7 accrete	-9.1 retreat	---	3.5 retreat	-6.8 accrete	-19.5 accrete	90.7 retreat	---	Channel migrates towards left bank
I	80.0	63.4	61.8	66.5	48.1	46.2	---	254.8	255.8	163.4	254.5	254.7	---	-1.6 retreat	4.8 accrete	-18.4 retreat	-1.9 retreat	---	1.0 retreat	-92.5 accrete	91.2 retreat	0.1 retreat	---	Island forms section; confirmed in aerial photo review
H	77.8	39.1	55.7	40.7	40.7	30.7	---	129.9	144.2	205.5	195.2	203.9	---	16.6 accrete	-15.1 retreat	0.0	-10.0 retreat	---	14.3 retreat	61.3 retreat	-10.3 accrete	8.7 retreat	---	Channel incises; relatively stable except for aggradation in 2011
G	77.3	231.7	225.0	250.4	286.7	247.5	---	391.5	396.6	399.1	395.6	394.2	---	-6.7 retreat	25.4 accrete	36.3 accrete	-39.2 retreat	---	5.0 retreat	2.6 retreat	-3.5 accrete	-1.4 accrete	---	Channel relatively stable with aggradation in 2010 and 2013
F	77.2	258.5	255.0	257.6	261.0	295.4	---	485.6	459.2	464.7	467.4	468.1	---	-3.4 retreat	2.6 accrete	3.4 accrete	34.4 accrete	---	-26.4 accrete	5.4 retreat	2.8 retreat	0.7 retreat	---	Channel relatively stable with consistent but minor scouring from 2009–2013
E1	76.5	253.7	269.9	364.1	324.4	418.9	---	538.4	527.0	539.4	543.3	544.8	---	16.2 accrete	94.2 accrete	-39.7 retreat	94.5 accrete	---	-11.4 accrete	12.4 retreat	4.0 retreat	1.5 retreat	---	Slight lateral movement and incision towards right bank
E	75.9	290.1	283.6	289.7	301.7	293.4	---	428.2	432.9	434.6	434.7	436.4	---	-6.5 retreat	6.2 accrete	12.0 accrete	-8.3 retreat	---	4.6 retreat	1.7 retreat	0.1 retreat	1.7 retreat	---	Channel incises and shows patterns of annual degradation and aggradation
D	75.4	105.2	122.7	129.9	183.0	120.6	---	373.7	385.2	386.5	386.5	383.8	---	17.4 accrete	7.2 accrete	53.1 accrete	-62.4 retreat	---	11.5 retreat	1.3 retreat	0.0	-2.8 accrete	---	Channel incises and laterally moves toward right bank
C	65.9	286.5	321.4	291.7	291.2	291.2	---	451.0	450.8	455.8	455.8	455.8	---	34.9 accrete	-29.8 retreat	-0.5 retreat	0.0	---	-0.1 accrete	4.9 retreat	0.0	0.0	---	Channel relatively stable except for 2009 that shows aggradation; right-most bank sections ignored (assumed a pit in floodplain and too far away and consistent to be an island forming)
31+1700	62.2	91.0	91.0	91.0	85.6	85.6	---	229.1	232.5	248.7	203.9	217.7	---	0.0	0.0	-5.4 retreat	0.0	---	3.4 retreat	16.2 retreat	-44.8 accrete	13.8 retreat	---	Channel relatively stable with aggradation in 2011
B	61.4	129.3	129.3	129.3	129.3	129.3	---	244.5	246.1	246.6	246.5	242.2	---	0.0	0.0	0.0	0.0	---	1.6 retreat	0.5 retreat	-0.2 accrete	-4.3 accrete	---	Channel relatively stable with slight aggradation in 2011
A	60.5	511.8	514.3	509.3	509.8	510.1	---	589.3	597.7	602.4	598.6	598.4	---	2.5 accrete	-5.0	0.5 accrete	0.3 accrete	---	8.3 retreat	4.7 retreat	-3.8 accrete	-0.2 accrete	---	Channel incises and relatively stable
AA	58.9	304.1	316.4	326.7	322.9	304.4	---	415.9	407.0	439.8	446.8	444.2	---	12.4 accrete	10.3 accrete	-3.8 retreat	-18.5 retreat	---	-8.8 accrete	32.8 retreat	7.0 retreat	-2.6 accrete	---	Channel relatively stable; 2013 channel migrates towards left bank
BB	57.8	74.8	66.5	58.9	51.0	45.2	---	144.5	154.5	119.3	117.0	104.7	---	-8.3 retreat	-7.6 retreat	-7.9 retreat	-5.8 retreat	---	9.9 retreat	-35.1 accrete	-2.3 accrete	-12.3 accrete	---	Channel laterally migrates towards right bank

Cross-Section	Mean WSEL from 2009–2014 (ft) [A]	Left Bank Station along Cross-section (ft) [B]						Right Bank Station along Cross-section (ft) [B]						Change in Left Bank Station (ft) [C]					Change in Right Bank Station (ft) [D]					Notes
		2009	2010	2011	2012	2013	2014 [E]	2009	2010	2011	2012	2013	2014 [E]	2010–2009	2011–2010	2012–2011	2013–2012	2014–2013	2010–2009	2011–2010	2012–2011	2013–2012	2014–2013	
30+0000	57.3	267.0	256.5	252.6	192.2	180.9	---	338.1	342.1	337.0	305.4	260.1	---	-10.5 retreat	-3.9 retreat	-60.4 retreat	-11.3 retreat	---	3.9 retreat	-5.1 accrete	-31.6 accrete	-45.3 accrete	---	Channel significantly migrates toward left bank
BB1	56.6	265.4	269.4	241.3	277.8	251.4	---	373.6	369.3	379.3	379.8	382.6	---	4.0 accrete	-28.1 retreat	36.6 accrete	-26.4 retreat	---	-4.3 accrete	10.0 retreat	0.5 retreat	2.8 retreat	---	Channel relatively stable
CC	55.7	286.1	273.7	298.3	279.4	254.0	---	368.0	366.5	369.0	370.1	369.0	---	-12.5 retreat	24.6 accrete	-18.9 retreat	-25.5 retreat	---	-1.5 accrete	2.5 retreat	1.1 retreat	-1.1 accrete	---	Channel relatively stable with scouring in 2010 and aggradation in 2013
DD	53.9	356.3	352.5	374.9	369.8	384.6	---	438.8	446.4	445.9	441.6	449.3	---	-3.8 retreat	22.4 accrete	-5.0 retreat	14.8 accrete	---	7.6 retreat	-0.5 accrete	-4.3 accrete	7.7 retreat	---	Channel relatively stable with slight lateral movement to right bank
EE	52.8	80.6	78.4	79.1	74.0	73.6	---	133.4	131.5	134.9	138.4	143.3	---	-2.3 retreat	0.7 accrete	-5.1 retreat	-0.4 retreat	---	-1.9 accrete	3.3 retreat	3.5 retreat	4.8 retreat	---	Channel incises and relatively stable with aggradation in 2011
FF	52.4	136.5	124.8	132.5	119.6	126.6	---	190.7	197.0	196.8	197.8	198.9	---	-11.7 retreat	7.7 accrete	-12.9 retreat	7.0 accrete	---	6.3 retreat	-0.2 accrete	1.0 retreat	1.1 retreat	---	Channel relatively stable with slight consistent scouring trend
GG	51.9	305.8	308.5	301.6	304.5	303.4	---	378.8	402.1	377.6	375.3	377.2	---	2.8 accrete	-6.9 retreat	2.9 accrete	-1.1 retreat	---	23.3 retreat	-24.5 accrete	-2.2 accrete	1.8 retreat	---	Channel relatively stable
GG1A	51.3	1207.7	1183.8	1233.9	1215.2	1275.2	---	1265.6	1273.5	1267.9	1281.0	1295.4	---	-23.9 retreat	50.1 accrete	-18.7 retreat	60.0 accrete	---	7.9 retreat	-5.5 accrete	13.1 retreat	14.3 retreat	---	Channel migrates towards right bank with erosion of steep right bank
28+3900	51.0	961.0	956.4	964.9	965.0	960.5	---	1057.9	1064.0	1064.7	1062.1	1062.2	---	-4.6 retreat	8.5 accrete	0.1 accrete	-4.5 retreat	---	6.0 retreat	0.7 retreat	-2.6 accrete	0.1 retreat	---	Channel relatively stable with slight but consistent aggradation trend
HH	51.0	814.8	812.7	889.9	820.5	806.2	---	920.0	928.0	927.2	927.3	924.0	---	-2.1 retreat	77.3 accrete	-69.4 retreat	-14.3 retreat	---	8.1 retreat	-0.8 accrete	0.1 retreat	-3.3 accrete	---	Channel relatively stable
II	50.7	417.3	404.4	384.3	379.3	374.3	---	561.8	569.8	412.0	416.9	424.0	---	-12.9 retreat	-20.2 retreat	-4.9 retreat	-5.0 retreat	---	8.0 retreat	-157.8 accrete	4.9 retreat	7.1 retreat	---	Channel migrates toward left bank
JJ	47.9	451.3	426.3	450.6	433.1	430.6	---	506.3	508.4	504.1	515.5	512.1	---	-25.0 retreat	24.2 accrete	-17.5 retreat	-2.5 retreat	---	2.1 retreat	-4.3 accrete	11.4 retreat	-3.3 accrete	---	Channel migrates toward left bank
28+0900	47.9	458.0	439.7	457.5	439.2	442.4	---	511.5	517.4	521.6	523.0	520.0	---	-18.2 retreat	17.8 accrete	-18.3 retreat	3.3 accrete	---	5.9 retreat	4.2 retreat	1.4 retreat	-2.9 accrete	---	Channel migrates toward right bank
Average Change in Lateral Movement (ft)														-3.5 retreat	9.7 accrete	-5.9 retreat	-1.2 retreat	---	3.3 retreat	-6.2 accrete	0.6 retreat	2.9 retreat	---	
Number of Bank-position Comparisons with Lateral Movement Toward Left Bank (retreat)														17	9	16	17	---						
Number of Bank-position Comparisons with Lateral Movement Toward Right Bank (retreat)																			20	16	14	15	---	

Table footnotes:
[A] WSEL = water surface elevation based on an assumed vertical datum of NAVD88.
[B] Stationing along cross-sections began on the left bank side and increased towards the right bank.
[C] Positive values in the left bank columns indicate bank-position movement toward the river's centerline and away from the floodplain (i.e., bank and/or bar accretion), while negative values indicate bank movement away from the river's centerline and toward the floodplain (i.e., bank retreat).
[D] Positive values in the right bank columns indicate bank-position movement away from the river's centerline and toward the floodplain (i.e., bank retreat), while negative values indicate bank movement toward from the river's centerline and away from the floodplain (i.e., bank and/or bar accretion).
[E] --- = no data provided by PRMD.

Appendix F

Comparisons of Annual Sediment Storage Using the AEA (1993–2013/2014) and SED Methods (2009–2013/2014)

Table F-1. Summary of annual changes in cross-sectional area and sediment storage during 2008-2014 in the Lower Alexander Valley Reach.

Cross-Section	River Mile	Change in 2008–2009 [A]		Change in 2009–2010		Change in 2010–2011		Change in 2011–2012		Change in 2012–2013		Change in 2013–2014	
		Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)
52+0000	52.00	N/A [B]		-91		-311		56		-340		-11	
			N/A		-9,876		-59,160		9,485		-51,729		35,594
51+0000	51.00	N/A [B]		-10		-294		41		-189		375	
			N/A		17,308		-41,461		21,464		-24,593		29,922
50+2640	50.50	N/A [B]		364		-554		398		-314		237	
			N/A		6,806		-16,545		16,721		-20,887		15,724
50+1056	50.20	N/A [B]		-132		-10		172		-398		299	
			N/A		-2,269		-2,386		7,706		-6,845		18,814
49+4224	49.80	838		74		-51		25		223		182	
			49,120		32,971		4,273		11,830		-13,045		7,827
49+1800	49.34	254		659		146		238		-513		-8	
			80,544		121,795		24,051		21,674		-54,116		32,162
47+4800	47.91	322		212		26		-83		126		238	
			33,740		8,026		2,527		7,469		-1,561		6,540
47+2800	47.53	586		4		42		284		-168		-62	
			NA [B]		19,898		-23,489		79,145		-73,011		-1,496
46+0000	46.00	N/A [B]		129		-199		245		-320		52	
Reach-wide Total			***163,404***		***194,660***		***-112,190***		***175,494***		***-245,785***		***145,086***

Table footnotes:
[A] 2008 data source from the 2008 Monitoring Report (Entrix 2010).
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Table F-2. Summary of annual changes in cross-sectional area and sediment storage during 2008-2013 in the Middle Reach.

Cross-Section	River Mile	Change in 2008–2009 [A]		Change in 2009–2010		Change in 2010–2011		Change in 2011–2012		Change in 2012–2013	
		Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)	Change in Cross-Sectional Volume (yd^3)	Change in Cross-Sectional Area (ft^2)
J	33.37	283		-313		-160		340		-142	
			9,191		-9,267		-15,216		20,174		-11,784
I	32.98	-42		70		-239		189		-167	
			7,207		5,808		-6,820		8,498		-11,789
H	32.76	377		200		-78		206		-381	
			13,827		8,844		-8,351		10,487		-14,785
G	32.48	128		123		-227		177		-159	
			1,622		7,331		-7,516		3,388		-3,553
F	32.27	-49		234		-139		-12		-14	
			1,181		3,520		0		102		172
E1	32.19	200		216		139		25		36	
			2,924		2,746		4,055		-648		1,576
E	32.06	30		0		180		-76		88	
			5,034		2,390		-1,449		-381		3,534
D	31.80	168		94		-237		61		51	
			4,217		5,593		-7,099		-4,453		3,507
C	31.58	28		166		-93		-268		112	
			-356		3,712		-1,373		-8,721		3,737
31+1700	31.32	-42		-20		39		-75		35	
			1,745		50		1,829		-2,876		3,740
B	31.15	147		23		71		-98		190	
			11,485		1,361		-2,070		-1,446		9,500
A	30.86	258		25		-144		47		145	
			9,822		7,745		-8,589		-211		4,471
AA	30.50	21		195		-100		-53		-18	
			1,129		527		623		-1,184		-582
BB	30.43	144		-118		191		-120		-67	
			10,554		-21,108		7,779		-36,413		26,448
30+0000	30.00	107		-384		-6		-746		696	
			346		-1,408		-663		-3,767		5,040
BB1	29.94	-48		144		-107		104		163	
			98		-508		3,325		20		2,269
CC	29.74	53		-170		277		-103		-47	
			3,291		-2,560		7,015		-1,829		-399
DD	29.57	145		16		145		-7		23	
			11,425		2,182		9,019		-697		-4,138
EE	29.34	363		81		256		-24		-207	
			6,078		630		8,844		958		-452
FF	29.20	81		-35		390		94		174	
			2,668		-2,947		4,249		1,431		3,023
GG	29.09	167		-239		5		39		107	
			1,531		-10,033		1,461		2,288		123
GG1A	28.91	-80		-331		78		91		-100	

Cross-Section	**River Mile**	**Change in 2008–2009** [A]		**Change in 2009–2010**		**Change in 2010–2011**		**Change in 2011–2012**		**Change in 2012–2013**	
		Change in Cross-Sectional Area (ft^2)	**Change in Cross-Sectional Volume (yd^3)**	**Change in Cross-Sectional Area (ft^2)**	**Change in Cross-Sectional Volume (yd^3)**	**Change in Cross-Sectional Area (ft^2)**	**Change in Cross-Sectional Area (ft^2)**	**Change in Cross-Sectional Volume (yd^3)**	**Change in Cross-Sectional Area (ft^2)**	**Change in Cross-Sectional Volume (yd^3)**	**Change in Cross-Sectional Area (ft^2)**
			-698		-4,073		1,330		4,422		5,868
28+3900	28.74	38		86		2		175		453	
			464		43		391		346		557
HH	28.72	199		-64		198		2		-168	
			7,275		-10,297		9,813		-6,718		-1,085
II	28.57	297		-638		471		-460		94	
			11,617		-17,742		13,330		-11,852		868
JJ	28.33	198		-118		97		-45		-57	
			N/A [B]		-5,210		1,924		-407		141
28+0900	28.17	N/A [B]		-215		26		19		66	
Reach-wide Total			***123,677***		***-32,672***		***15,839***		***-29,490***		***26,007***

Table footnotes:
[A] 2008 data source from the 2008 Monitoring Report (Entrix 2010).
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Table F-3. Summary of annual changes in sediment storage during 1993-2014 in the Lower Alexander Valley Reach.

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]																				
	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
Geyserville Bridge - 52+0000																					
	42,142	-30,663	-353	-807	-26	-227	-116	-494	-253	-54	-112	249	-4,397	882	102	N/A [B]	-9,876	-59,160	9,485	-51,729	35,594
Geyserville Bridge - 51+5230																					
			-4,250	-32,924	-21,319	-5,870	12,279	2,091	-3,840	21,554	-12,825	15,679	-27,247	4,183	6,005						
Above Miller Creek - 51+1600																					
		-44,880	-5,104	-2,288	7,275	6,884	-87,609	5,941	9,709	3,582	8,378	-5,122	-4,374	4,195	-2,347						
1500' U/S from Smith's Levee - 51+0000																					
	49,280	-122,516	-5,182	31,191	36,667				15,950	-81,257	26,792	-12,696	-9,900	2,298	1,760	N/A [B]	17,308	-41,461	21,464	-24,593	29,922
300' U/S from Smith's Levee - 50+2640																					
	8,096	-37,840	-16,632	-1,115	23,349				3,334	-49,756	11,704	-4,724	9,640	-3,403	557	N/A [B]	6,806	-16,545	16,721	-20,887	15,724
Smith's Levee - 50+1056																					
	-8,917	126,916	-13,415	-82,212	-30,272				37,391	-25,543	52,089	-22,027	42,705	-10,052	-26,400	N/A [B]	-2,269	-2,386	7,706	-6,845	18,814
800' D/S from Smith's Levee- 49+4224																					
	-71,692	173,344	3,868	-78,261	-9553				86,935	20	67,287	-13,512	37,781	-3,058	-28,741	49,120	32,971	4,273	11,830	-13,045	7,827
A-A - DeWitt Gravel																					
					1,238	1,015	-5,095			774											
B-B - DeWitt Gravel																					
					-1,051	2,019	-4,366			-3,192											
C-C - DeWitt Gravel																					
					-4,605	836	1,168			-1,604											
D-D - DeWitt Gravel																					
					-3,353	-141	546			-980											
E-E - DeWitt Gravel																					
					-8,583	1,061	-5,072			-5,373											
F-F - DeWitt Gravel																					
					-7,166	472	-6,023			-705											
G-G - DeWitt Gravel																					
					3,954	-804	710			3,743											
DeWitt Gravel - 49+1800																					
		85,137	-30,131	12,390	29,146	-5,757	-6,927	11,452	89,934	29,550	44,040	38,062	64,406	-375	8,730	80,544	121,795	24,051	21,674	-54,116	32,162
H-H - DeWitt Gravel																					
					-13,798	2,640	-14,538			5,515											
I-I - DeWitt Gravel																					
					-10,294	2,697	-11,608			4,613											
J-J - DeWitt Gravel																					
					-1,857	1,065	-8,325			5,762											
K-K - DeWitt Gravel																					
					16,521	1,140	2,710														

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]																				
	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
DeWitt Gravel - 48+2000																					
										-4,848											
M-M - DeWitt Gravel																					
		10,248	2,987	-60,983	96,553		17,601	2,619	4,247	-10,959	52,435	-3,910	7,819	1,287	9,972						
N-N - DeWitt Gravel						3,139															
										-1,697											
Gird Creek - 47+4800																					
					17,668		-10,325			5,681											
O-O - DeWitt Gravel																					
										3,508											
P-P - DeWitt Gravel																					
		48,748	20,956	-36,004	-2,112	3,852	-19,125	-111	-32,742	-360	56,508	-23,179	-9,438	12,559	-16,831	33,740	8,026	2,527	7,469	-1,561	6,540
Q-Q - DeWitt Gravel																					
										1,095											
R-R - DeWitt Gravel																					
					18,343	5,069	1,932			4,161											
SCPD - 47+2800																					
										4,725											
S-S - DeWitt Gravel	-37,151	126,994	21,609	108,377	62,333	140,042	13,048	-6,566	-81,457		63,400	-19,372	31,005	17,620	-42,470						
										-8,919											
SCPD - 46+3590																					
			14,292			89,886	13,583	-18,544	13,878							N/A [B]	19,898	-23,489	79,145	-73,011	-1,496
Jimtown Bridge - 46+0400				31,537	13,643					-9,617	14,057	11,775	25,193	-6,503	10,455						
	13,364	60,970	1,798			1,065	343	-1,403	1,274												
Jimtown Bridge - 46+0150																					
			1,492	-179	679				136	1,134	-515	1,015	201	-197	145						
Jimtown Bridge - 46+0000																					
Reach-wide Total	***-4,878***	***396,458***	***-8,065***	***-111,278***	***213,380***	***250,083***	***-115,209***	***-5,015***	***144,496***	***-109,447***	***383,238***	***-37,762***	***163,394***	***19,436***	***-79,063***	***163,404***	***194,660***	***-112,190***	***175,494***	***-245,785***	***145,086***

Table footnotes:
[A] 1993–2008 data source from the 2008 Monitoring Report (Entrix 2010); AEA method = average-end-area method used to compute change in sediment volume using cross-sectional area.
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Table F-4. Summary of annual changes in sediment storage during 1993-2013 in the Middle Reach.

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd³) [A]																			
	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Yolano J - 176170 – Yolano I - 174130	419	4,767	-2,517	11,669	-7,287	55,851	4,850	70,713	-37,556	6,586	3,259	-3,383	5,148	801	-3,432	9,191	-9,267	-15,216	20,174	-11,784
Yolano I - 174130 – Yolano H - 172960	280	12,175	-2,560	22,544						-25,722	32,179	-19,761	7,830	5,464	-20,285	7,207	5,808	-6,820	8,498	-11,789
Yolano H - 172960 – Yolano G - 171490	-1,205	14,264	903	19,028						-35,584	31,957	-18,933	13,552	1,095	-26,912	13,827	8,844	-8,351	10,487	-14,785
Yolano G - 171490 – Yolano F - 170410	-4,107	4,846	4,209	513						-5,074	10,432	1,505	1,889	-4,394	534	1,622	7,331	-7,516	3,388	-3,553
Yolano F - 170410 – Healdsburg Bendway - 32+1200	-634	-1,678	966	417						143	8,071	1,102	2,214	-1,596	696	1,181	3,520	0	102	172
Healdsburg Bendway - 32+1200 – Yolano E1 - 169960	55	-888	-896	1,532	24,575	1,439	-1,142	634												
Yolano E1 - 169960 – Healdsburg Bendway - 32+0800	-98	2,163	30,511	8,504						5,256	8,005	-1,722	6,775	-4,220	203	2,924	2,746	4,055	-648	1,576
Healdsburg Bendway - 32+0800 – Yolano E - 169270	1,918	4,180	68,746			8,453	-7,666	23,129												
Yolano E - 169270 – Healdsburg Bridge - 31+4685	7,627	5,466	2,847	-3,262						24,016	-7,516	-6,523	10,245	0	-6,635	5,034	2,390	-1,449	-381	3,534
Healdsburg Bridge - 31+4685 – Yolano D - 167910	0	0	0	0	---	11,733	-4,553													
Yolano D - 167910 – Yolano C - 166730	-5,055	17,037	3,635	-3,162						15,717	3,601	-3,732	5,249	6,496	-5,571	4,217	5,593	-7,099	-4,453	3,507
Yolano C - 166730 – Below Healdsburg Dam	-1,971	13,622	2,024	13,420	19,374					17,718	32,057	-21,950	3,737	4,271	-1,602	-356	3,712	-1,373	-8,721	3,737
Below Healdsburg Dam – Below Hwy. 101 Bridge - 31+1700	485	4,678	-23	8,534	-2,050	-227														
Below Hwy. 101 Bridge - 31+1700 – Yolano B - 164460	898	20,429	-1,828	18,641	21,479	2,622	-3,322	43,532	-31,578	11,191	17,717	-14,166	1,496	100	199	1,745	50	1,829	-2,876	3,740
Yolano B - 164460 – Yolano A - 162940	-25,662	49,367	8,025	43,242						16,551	10,015	-11,241	5,926	1,021	-8,195	11,485	1,361	-2,070	-1,446	9,500
Yolano A - 162940 – Yolano AA - 161040	-29,779	48,576	8,554	54,595						13,311	18,454	-19,236	1,866	14,643	-12,637	9,822	7,745	-8,589	-211	4,471
Yolano AA - 161040 – Below Dry Creek - 30+2250	188	3,459	-311	6,276						1,420	4,842	-2,067	-375	3,755	1,382	1,129	527	623	-1,184	-582
Below Dry Creek - 30+2250 – Yolano BB - 158860	3,482	7,556	2,924	13,746	27,240	-6,415	4,790	-2,208	-20,720	12,929	23,323	-15,350	2,666	5,224	-2,267					
Yolano BB - 158860 – Basalt Pit - 30+0000	-235	1,514	3,423	3,722						-197	9,444	-8,038	1,056	-299	-6,107	10,554	-21,108	7,779	-36,413	26,448
Basalt Pit - 30+0000 – Yolano BB1 - 158070		3,098	2,399	3,578	26,874	-31,744	715	-8,073	217,693	-412	2,214	-1,061	1,760	522	-2,540	346	-1,408	-663	-3,767	5,040
Yolano BB1 - 158070 – Yolano CC - 157020	-5,241	22,137	3,148	12,907						4,116	5,054	4,082	-15,703	3,872	-3,227	98	-508	3,325	20	2,269
Yolano CC - 157020 – Phase II Pit - 29+3000	-1,064	15,741	-632	7,890						5,637	8,894	-2,351	-12,450	-1,446	-3,092	3,291	-2,560	7,015	-1,829	-399

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]																			
	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
	0	0	0	0																
Yolano DD - 156120					4,652	-1,523	334	1,635												
		9,865	4,496	3,558																
Phase III Pit - 29+2000	1,102									-6,949	25,849	-12,144	6,882	1,979	-20,285	11,425	2,182	9,019	-697	-4,138
		1,345	876	1,519																
Yolano EE - 154920																				
	1,205	21,615	3,012	10,212						-30,031	30,246	-12,280	13,470	2,615	-30,458	6,078	630	8,844	958	-452
Yolano FF - 154200																				
	-1,387	20,242	312	19,306	22,977	50,500	-14,518	21,214		-18,828	21,822	-22,227	13,165	968	-14,455	2,668	-2,947	4,249	1,431	3,023
Yolano GG - 153570																				
	-634	47,133	-1,478	39,160						11,148	31,505	-47,054	19,466	2,922	-7,990	1,531	-10,033	1,461	2,288	123
Yolano GG1A - 152620																				
	15,193	43,035	3,191	23,311						17,032	26,113	-47,329	11,203	8,943	-12,816	-698	-4,073	1,330	4,422	5,868
SCPD - 28+3900																				
	1,330	2,358	712	2,672						1,538	-2,020	-3,436	-125	1,361	-796	464	43	391	346	557
Yolano HH - 151690																				
	-2,728	18,685	5,104	15,444						7,626	-9,972	-6,099	-4,943	5,324	-5,148	7,275	-10,297	9,813	-6,718	-1,085
Yolano II - 150870					30,441	40,964	-13,599	11,035	120,701											
	-1,948	16,075	1,737	6,266						4,693	39,940	-13,420	-7,392	2,675	-6,547	11,617	-17,742	13,330	-11,852	868
Yolano JJ - 149570																				
	798	4,693	-3,755	8,119						2,703	13,966	-3,989	6,884	-907	-329	N/A [B]	-5,210	1,924	-407	141
SCPD - 28+0900																				
Reach-wide Total	***-46,768***	***437,555***	***147,754***	***373,901***	***168,275***	***131,653***	***-34,111***	***161,611***	***248,540***	***56,534***	***399,451***	***-310,803***	***101,491***	***61,189***	***-198,312***	***123,677***	***-32,672***	***15,839***	***-29,490***	***26,007***

Table footnotes:
[A] 1993–2008 data source from the 2008 Monitoring Report (Entrix 2010); AEA method = average-end-area method used to compute change in sediment volume using cross-sectional area.
[B] N/A = cross-section end-point coordinates from 2008 dataset are unknown and cannot be compared to cross-sections from 2009 or later.

Table F-5. Comparison of annual changes in sediment storage using the AEA and SED methods during 2009-2014 in the Lower Alexander Valley Reach.

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]					Change in Volume between Cross-sections Using the SED Method (yd^3) [B]				
	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
Geyserville Bridge - 52+0000										
Geyserville Bridge - 51+5230	-9,876	-59,160	9,485	-51,729	35,594	50,942	-94,760	-7,185	-26,677	27,542
Above Miller Creek - 51+1600										
1500' U/S from Smith's Levee - 51+0000										
	17,308	-41,461	21,464	-24,593	29,922	26,938	-24,857	17,644	-8,402	4,012
300' U/S from Smith's Levee - 50+2640										
	6,806	-16,545	16,721	-20,887	15,724	6,316	-9,629	13,877	-9,588	3,731
Smith's Levee - 50+1056										
	-2,269	-2,386	7,706	-6,845	18,814	-6,785	-4,055	10,334	-2,010	24,667
800' D/S from Smith's Levee- 49+4224										
A-A - DeWitt Gravel										
B-B - DeWitt Gravel										
C-C - DeWitt Gravel										
D-D - DeWitt Gravel	32,971	4,273	11,830	-13,045	7,827	-76	-27,244	36,808	-5,561	-10,961
E-E - DeWitt Gravel										
F-F - DeWitt Gravel										
G-G - DeWitt Gravel										
DeWitt Gravel - 49+1800										
H-H - DeWitt Gravel										
I-I - DeWitt Gravel										
J-J - DeWitt Gravel										
K-K - DeWitt Gravel	121,795	24,051	21,674	-54,116	32,162	6,340	-22,116	52,443	-42,598	44,413
DeWitt Gravel - 48+2000										
M-M - DeWitt Gravel										
N-N - DeWitt Gravel										
Gird Creek - 47+4800										

Cross-Section	**Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]**					**Change in Volume between Cross-sections Using the SED Method (yd^3) [B]**				
	2009–2010	**2010–2011**	**2011–2012**	**2012–2013**	**2013–2014**	**2009–2010**	**2010–2011**	**2011–2012**	**2012–2013**	**2013–2014**
O-O - DeWitt Gravel										
P-P - DeWitt Gravel										
Q-Q - DeWitt Gravel	8,026	2,527	7,469	-1,561	6,540	-4,920	-2,923	7,213	5,995	-4,191
R-R - DeWitt Gravel										
SCPD - 47+2800										
S-S - DeWitt Gravel										
SCPD - 46+3590										
Jimtown Bridge - 46+0400	19,898	-23,489	79,145	-73,011	-1,496	8,945	-71,851	93,213	-40,946	-27,421
Jimtown Bridge - 46+0150										
Jimtown Bridge - 46+0000										
Reach-wide Total	***194,660***	***-112,190***	***175,494***	***-245,785***	***145,086***	***87,699***	***-257,436***	***224,349***	***-129,786***	***61,792***

Table footnotes:
[A] AEA method = average-end-area method used to compute volumetric change in sediment storage using cross-sectional areas and distances between the paired cross-sections, both derived from digital topographic surfaces.
[B] SED method = surface-elevation-differencing method used to compute volumetric change in sediment storage using digital topographic surfaces.

Table F-6. Comparison of annual changes in sediment storage using the AEA and SED methods during 2009-2013 in the Middle Reach.

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]				Change in Volume between Cross-sections Using the SED Method (yd^3) [B]			
	2009-2010	2010-2011	2011-2012	2012-2013	2009-2010	2010-2011	2011-2012	2012-2013
Yolano J - 176170								
	-9,267	-15,216	20,174	-11,784	-20,495	-13,088	3,582	-8,333
Yolano I - 174130								
	5,808	-6,820	8,498	-11,789	12,056	-9,115	12,824	-9,114
Yolano H - 172960								
	8,844	-8,351	10,487	-14,785	3,808	-4,899	3,821	-16,444
Yolano G - 171490								
	7,331	-7,516	3,388	-3,553	2,998	-11,468	9,139	-9,802
Yolano F - 170410								
Healdsburg Bendway - 32+1200	3,520	0	102	172	-946	-1,060	423	-79
Yolano E1 - 169960								
Healdsburg Bendway - 32+0800	2,746	4,055	-648	1,576	-2,821	-390	2,453	-864
Yolano E - 169270								
Healdsburg Bridge - 31+4685	2,390	-1,449	-381	3,534	5,704	-19,425	17,269	-12,692
Yolano D - 167910								
	5,593	-7,099	-4,453	3,507	3,261	-2,404	-1,782	2,957
Yolano C - 166730								
Below Healdsburg Dam	3,712	-1,373	-8,721	3,737	864	-438	-4,330	3,718
Below Hwy. 101 Bridge - 31+1700								
	50	1,829	-2,876	3,740	-5,886	549	-3,613	5,729
Yolano B - 164460								
	1,361	-2,070	-1,446	9,500	-4,726	-372	-3,508	6,826
Yolano A - 162940								
	7,745	-8,589	-211	4,471	-15,511	-12,424	7,052	-1,217
Yolano AA - 161040								
Below Dry Creek - 30+2250	527	623	-1,184	-582	8,698	5,461	-1,141	-6,253
Yolano BB - 158860								
	-21,108	7,779	-36,413	26,448	-6,328	911	-3,718	1,361
Basalt Pit - 30+0000								
	-1,408	-663	-3,767	5,040	-740	-2,836	-882	-1,825
Yolano BB1 - 158070								
	-508	3,325	20	2,269	2,152	1,999	-1,676	842
Yolano CC - 157020								
	-2,560	7,015	-1,829	-399	-1,169	105	386	-1,744
Phase II Pit - 29+3000								

Cross-Section	Change in Volume between Cross-sections Using the AEA Method (yd^3) [A]				Change in Volume between Cross-sections Using the SED Method (yd^3) [B]			
	2009-2010	**2010-2011**	**2011-2012**	**2012-2013**	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**
Yolano DD - 156120								
Phase III Pit - 29+2000	2,182	9,019	-697	-4,138	-2,356	1,360	1,172	-4,901
Yolano EE - 154920								
	630	8,844	958	-452	-254	12,566	-1,319	3,130
Yolano FF - 154200								
	-2,947	4,249	1,431	3,023	-5,281	200	1,694	934
Yolano GG - 153570								
	-10,033	1,461	2,288	123	-3,176	-4,787	4,821	-725
Yolano GG1A - 152620								
	-4,073	1,330	4,422	5,868	-2,224	-3,759	1,031	1,885
SCPD - 28+3900								
	43	391	346	557	-2,015	926	-113	-337
Yolano HH - 151690								
	-10,297	9,813	-6,718	-1,085	-3,528	3,713	-4,391	3,159
Yolano II - 150870								
	-17,742	13,330	-11,852	868	-7,430	-8,579	-10,705	3,333
Yolano JJ - 149570								
	-5,210	1,924	-407	141	-298	98	6	-20
SCPD - 28+0900								
Reach-wide Total	***-32,672***	***15,839***	***-29,490***	***26,007***	***-45,644***	***-67,158***	***28,496***	***-40,473***

Table footnotes:
[A] AEA method = average-end-area method used to compute volumetric change in sediment storage using cross-sectional areas and distances between the paired cross-sections, both derived from digital topographic surfaces.
[B] SED method = surface-elevation-differencing method used to compute volumetric change in sediment storage using digital topographic surfaces.

Appendix G

Surface Elevation Differencing Maps: 2009–2013/2014

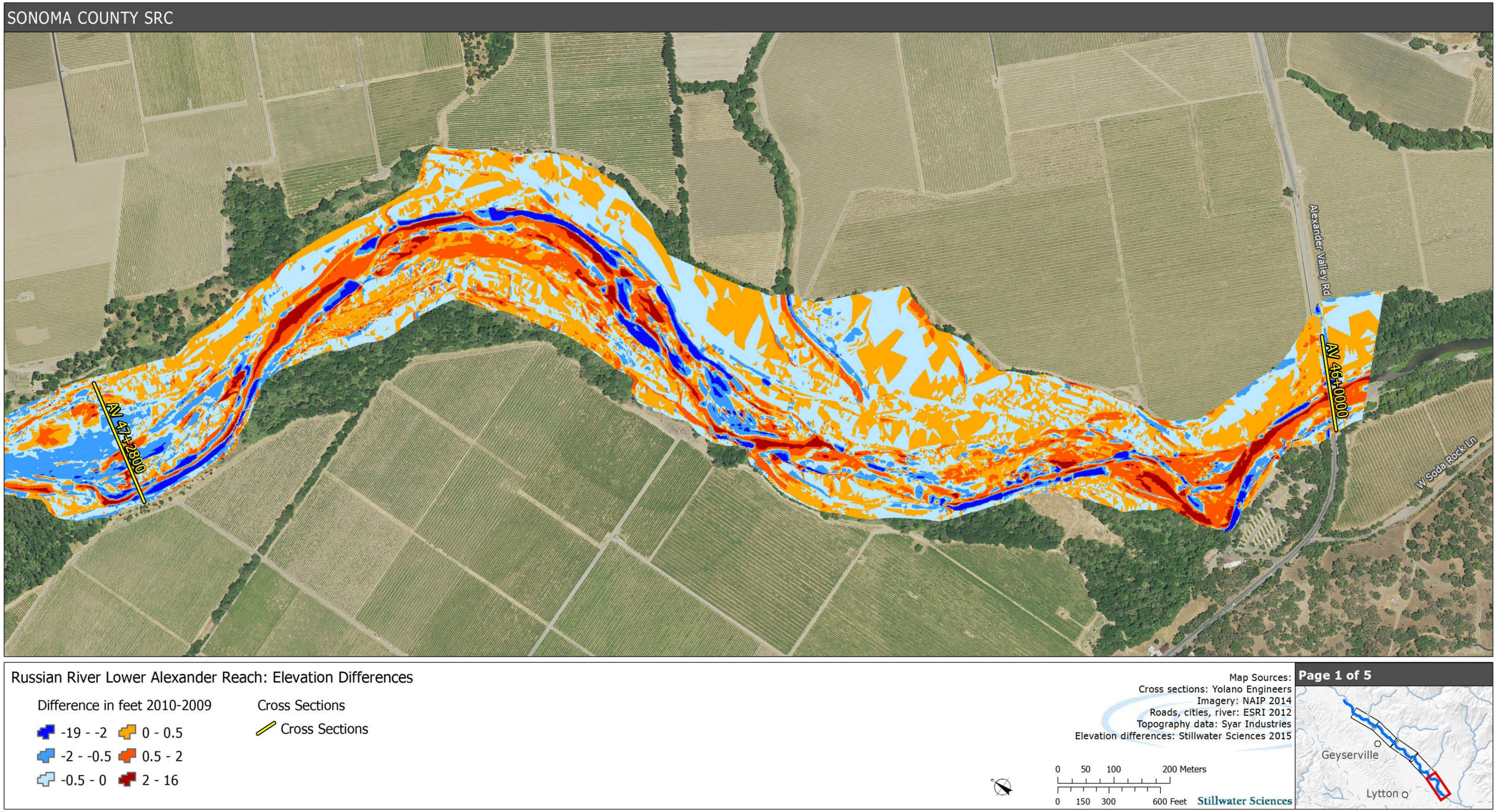

Figure G-1. Map of surface-elevation differencing for 2009-2010 in the Lower Alexander Valley Reach (map tile 1 of 5, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

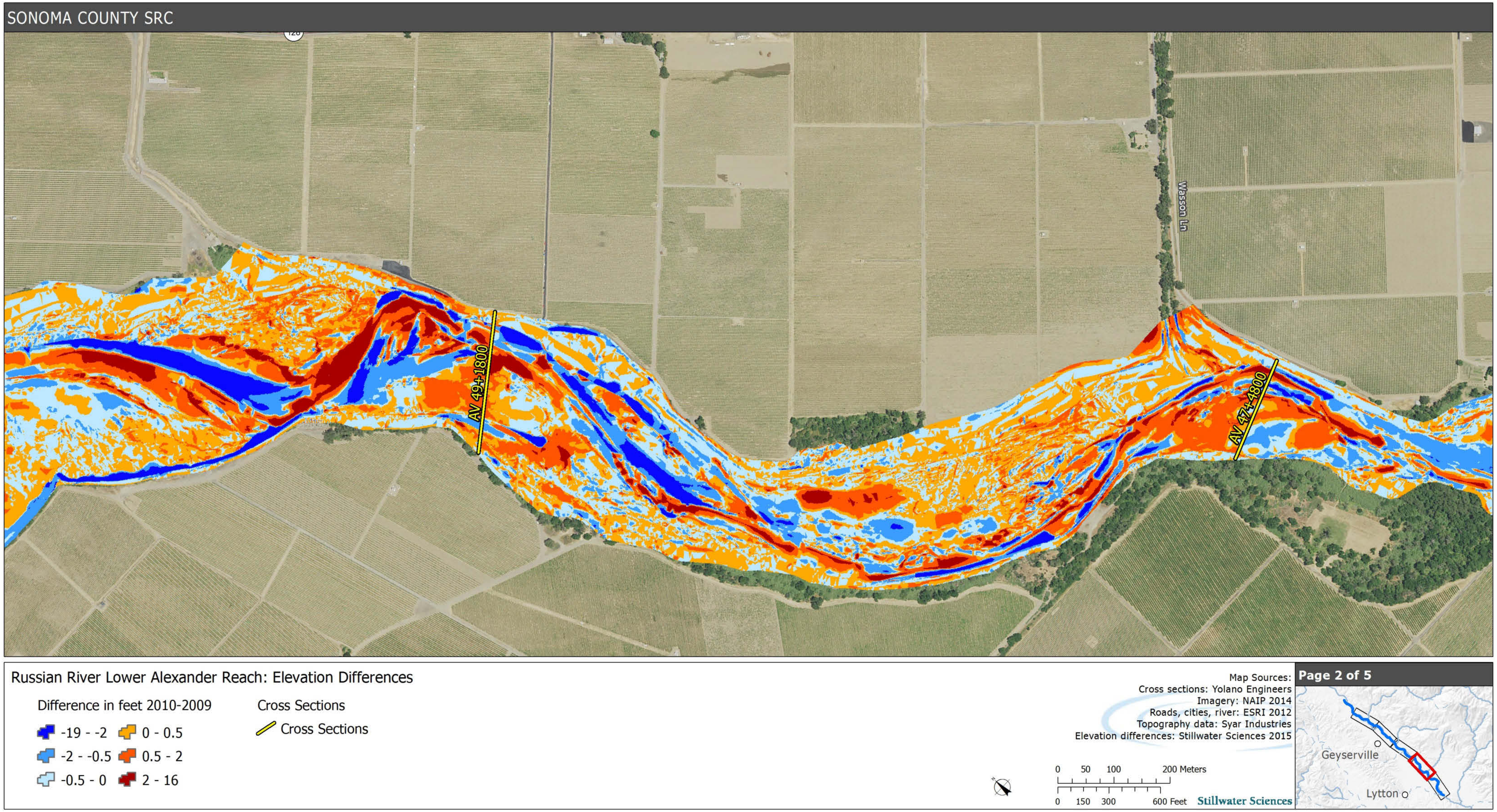

Figure G-2. Map of surface-elevation differencing for 2009-2010 in the Lower Alexander Valley Reach (map tile 2 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

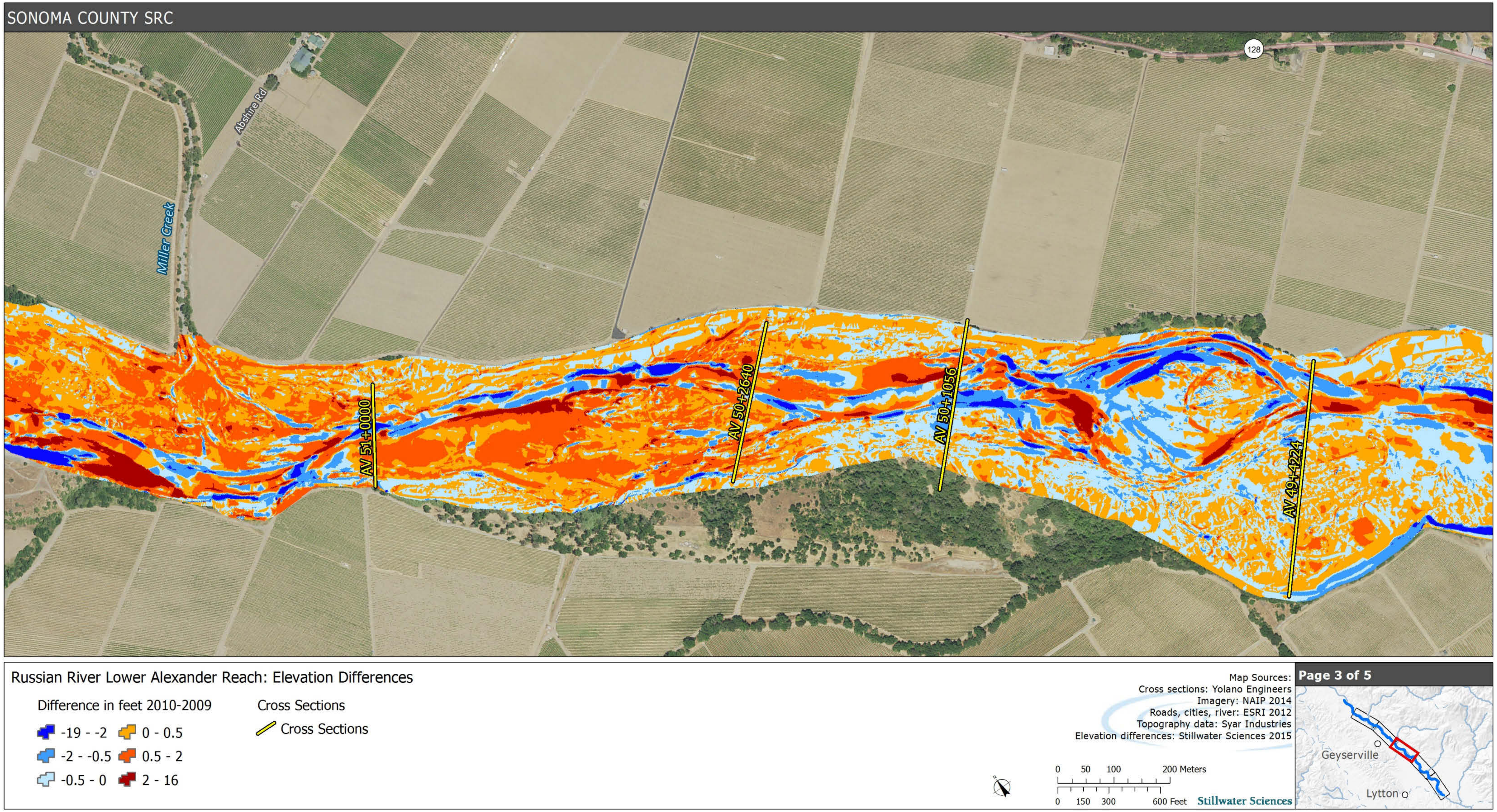

Figure G-3. Map of surface-elevation differencing for 2009-2010 in the Lower Alexander Valley Reach (map tile 3 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

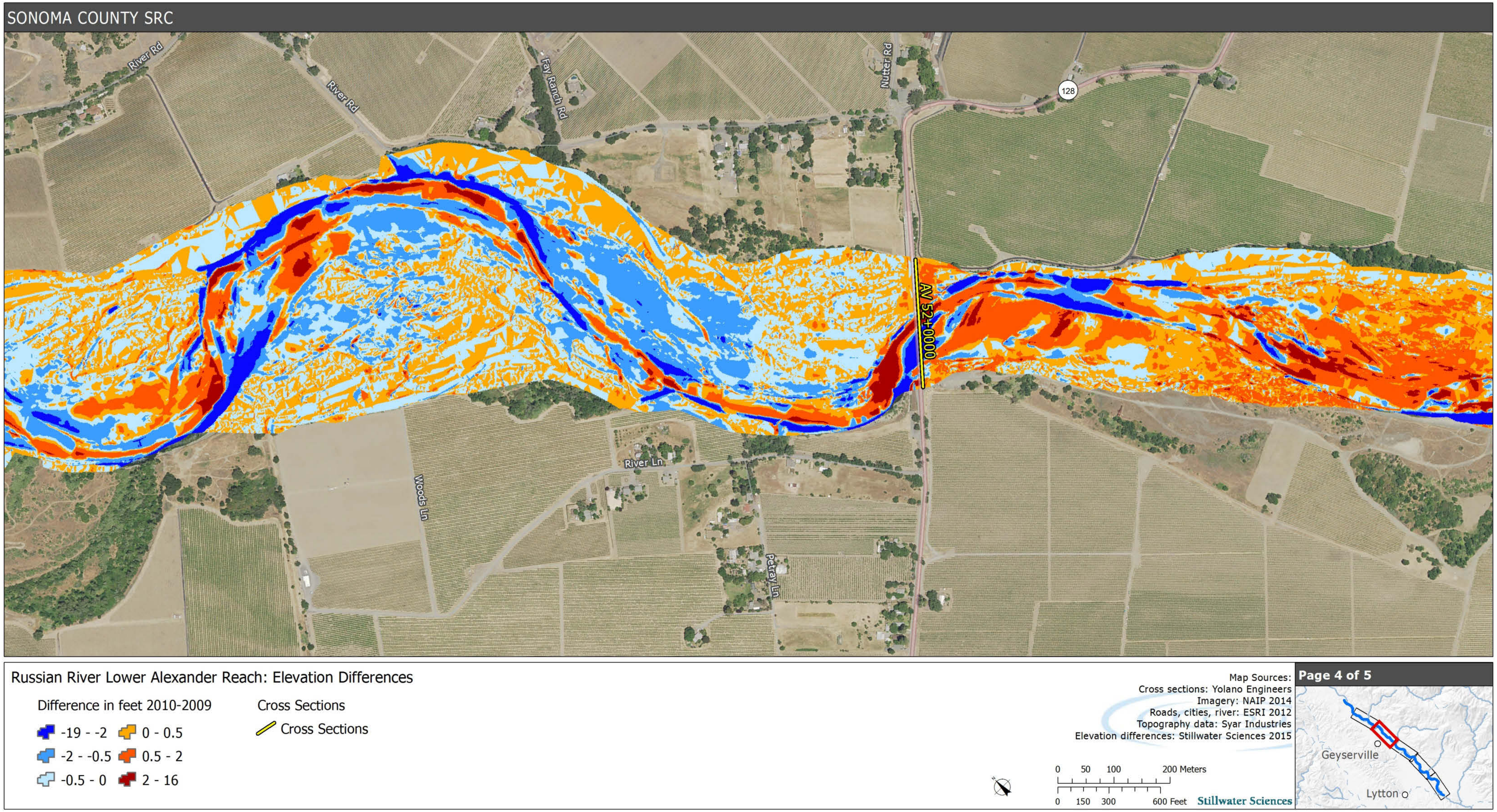

Figure G-4. Map of surface-elevation differencing for 2009-2010 in the Lower Alexander Valley Reach (map tile 4 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

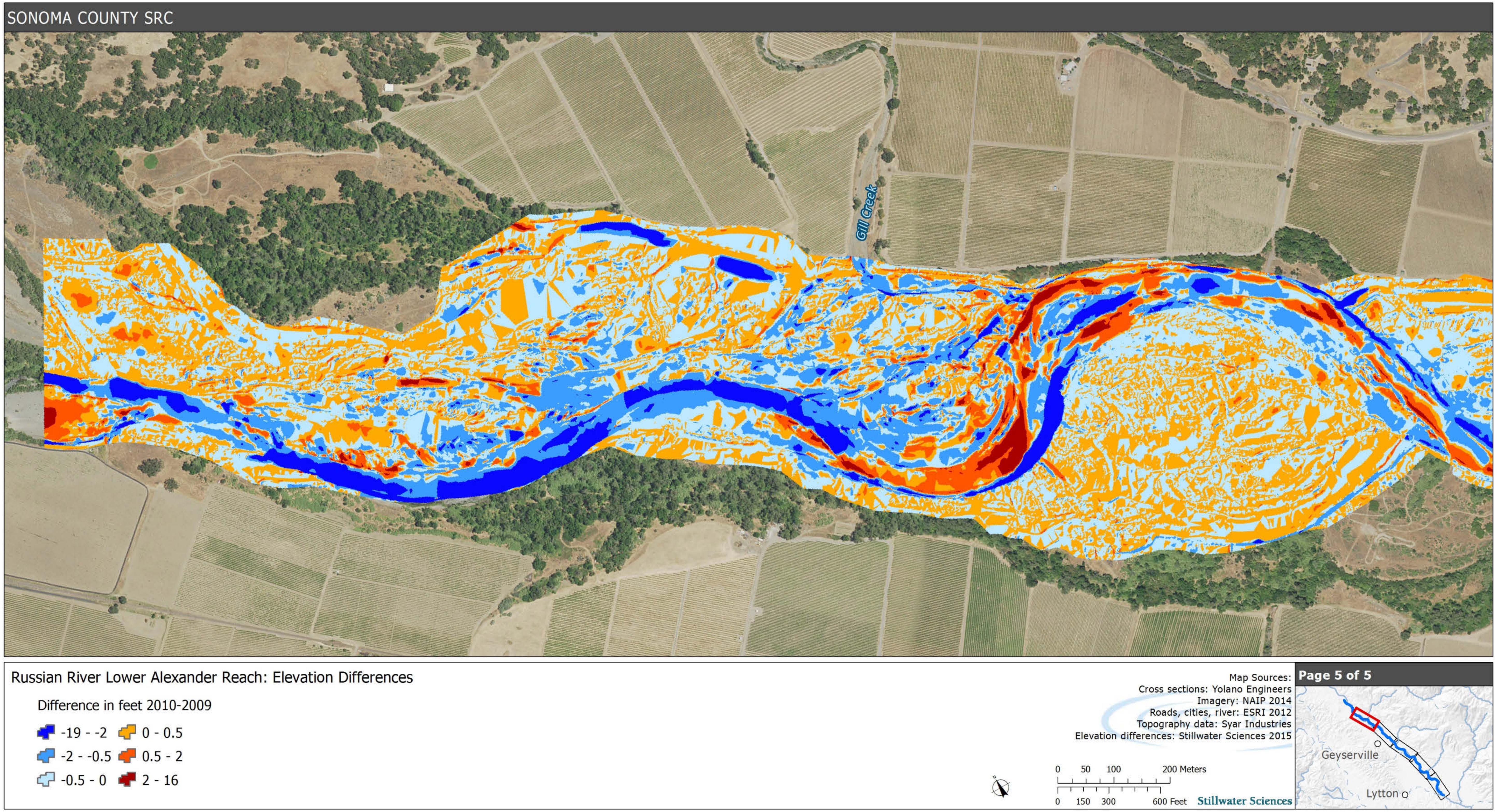

Figure G-5. Map of surface-elevation differencing for 2009-2010 in the Lower Alexander Valley Reach (map tile 5 of 5, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

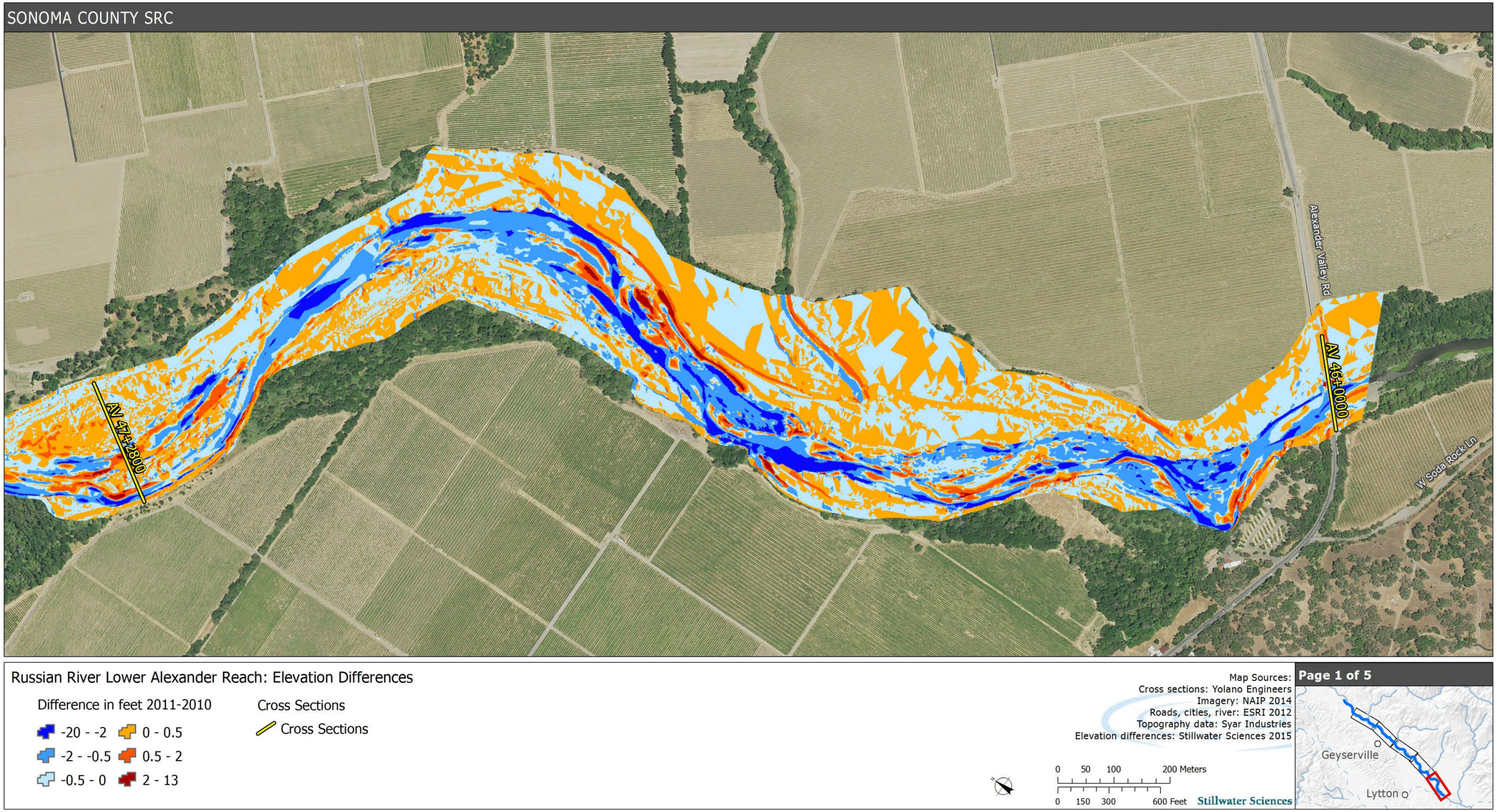

Figure G-6. Map of surface-elevation differencing for 2010-2011 in the Lower Alexander Valley Reach (map tile 1 of 5, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

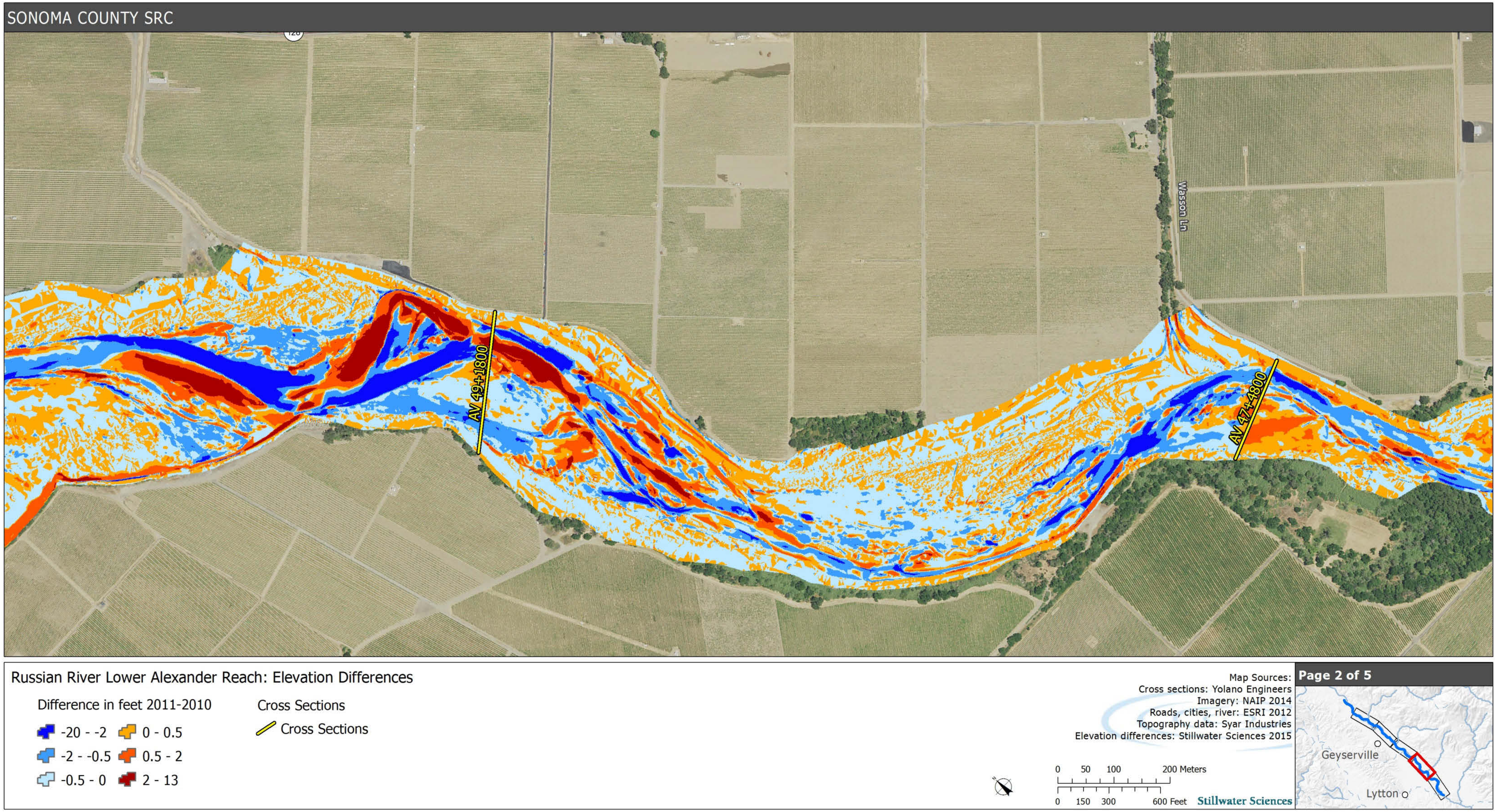

Figure G-7. Map of surface-elevation differencing for 2010-2011 in the Lower Alexander Valley Reach (map tile 2 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

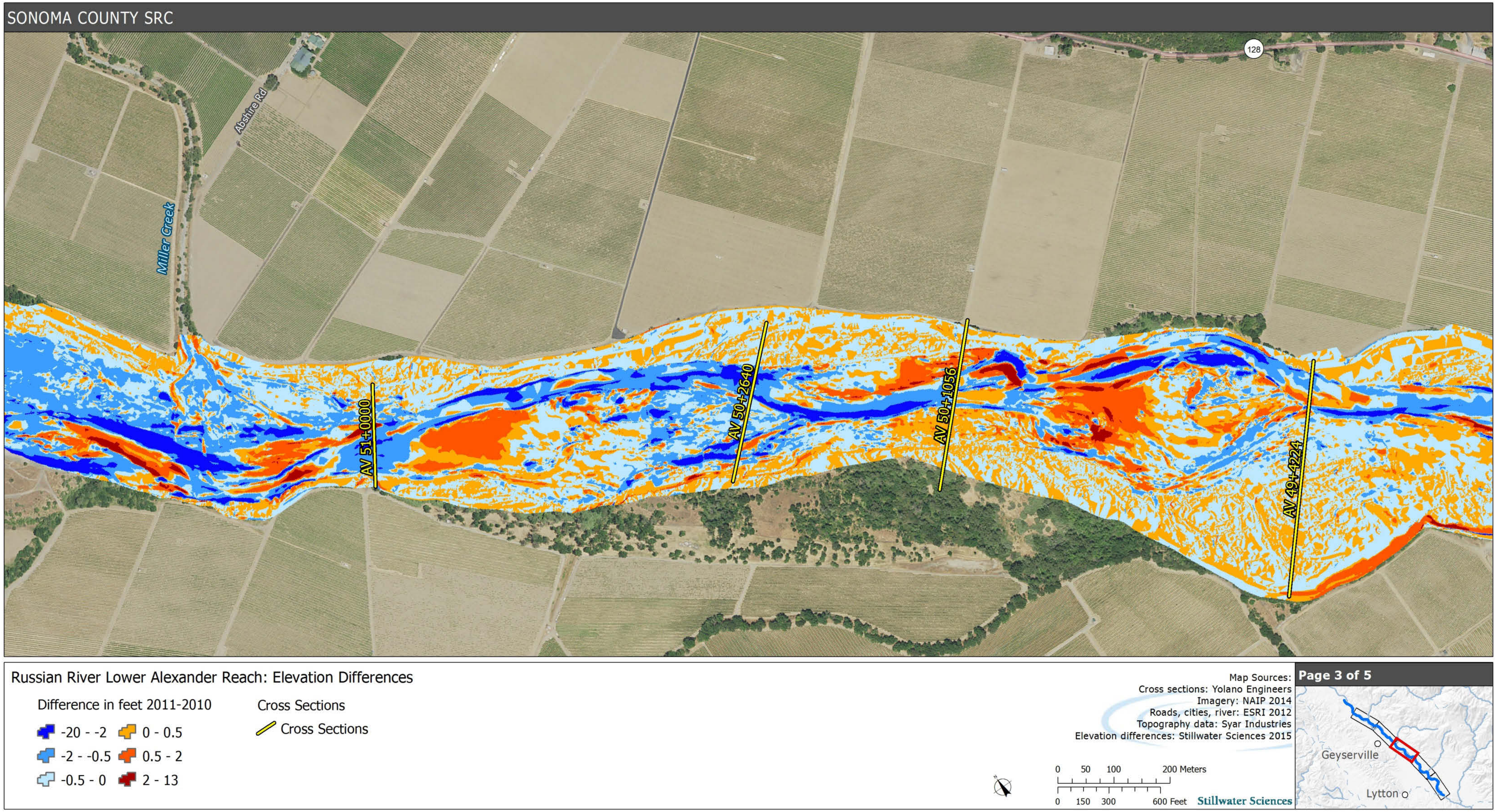

Figure G-8. Map of surface-elevation differencing for 2010-2011 in the Lower Alexander Valley Reach (map tile 3 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

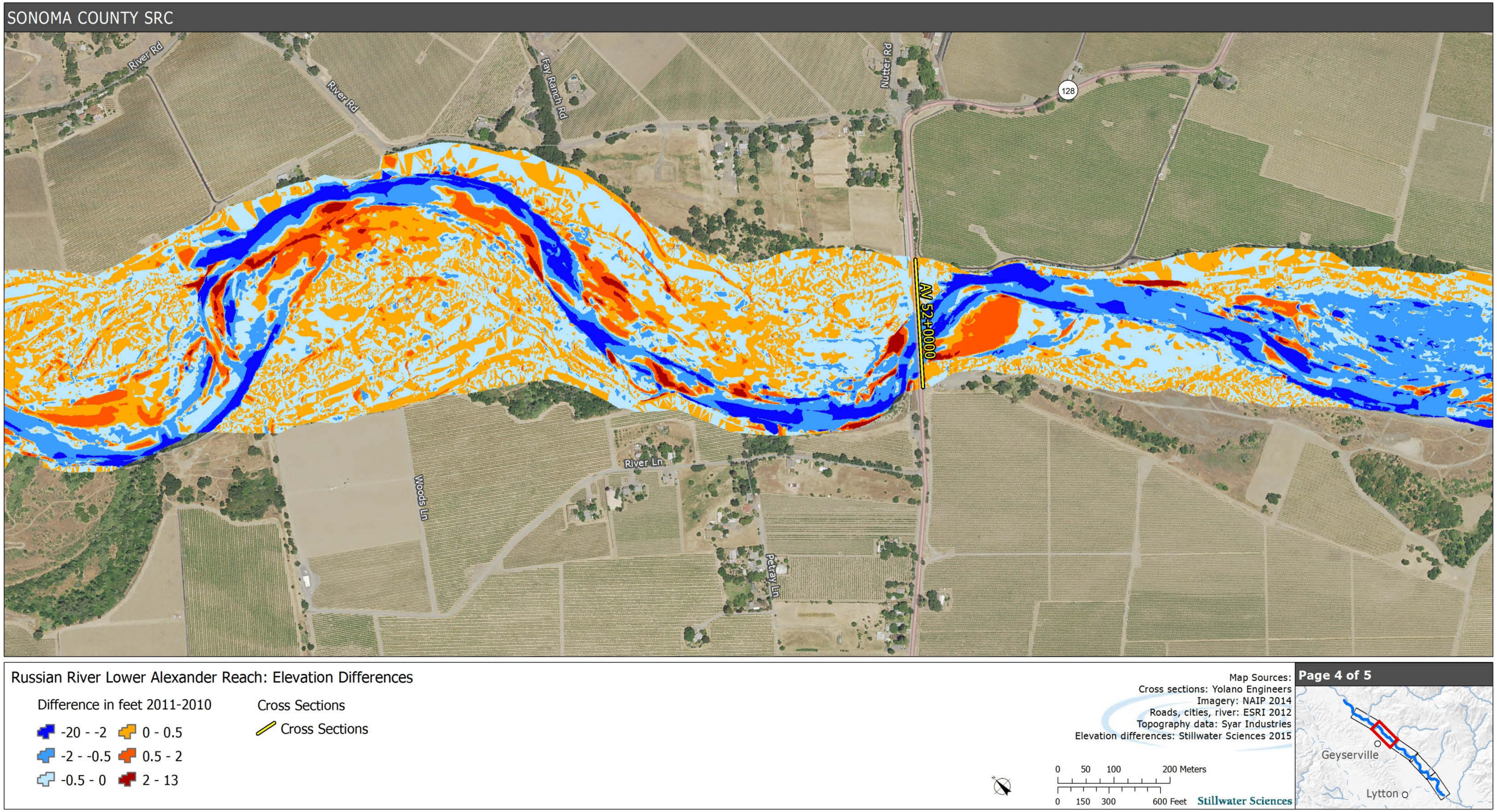

Figure G-9. Map of surface-elevation differencing for 2010-2011 in the Lower Alexander Valley Reach (map tile 4 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

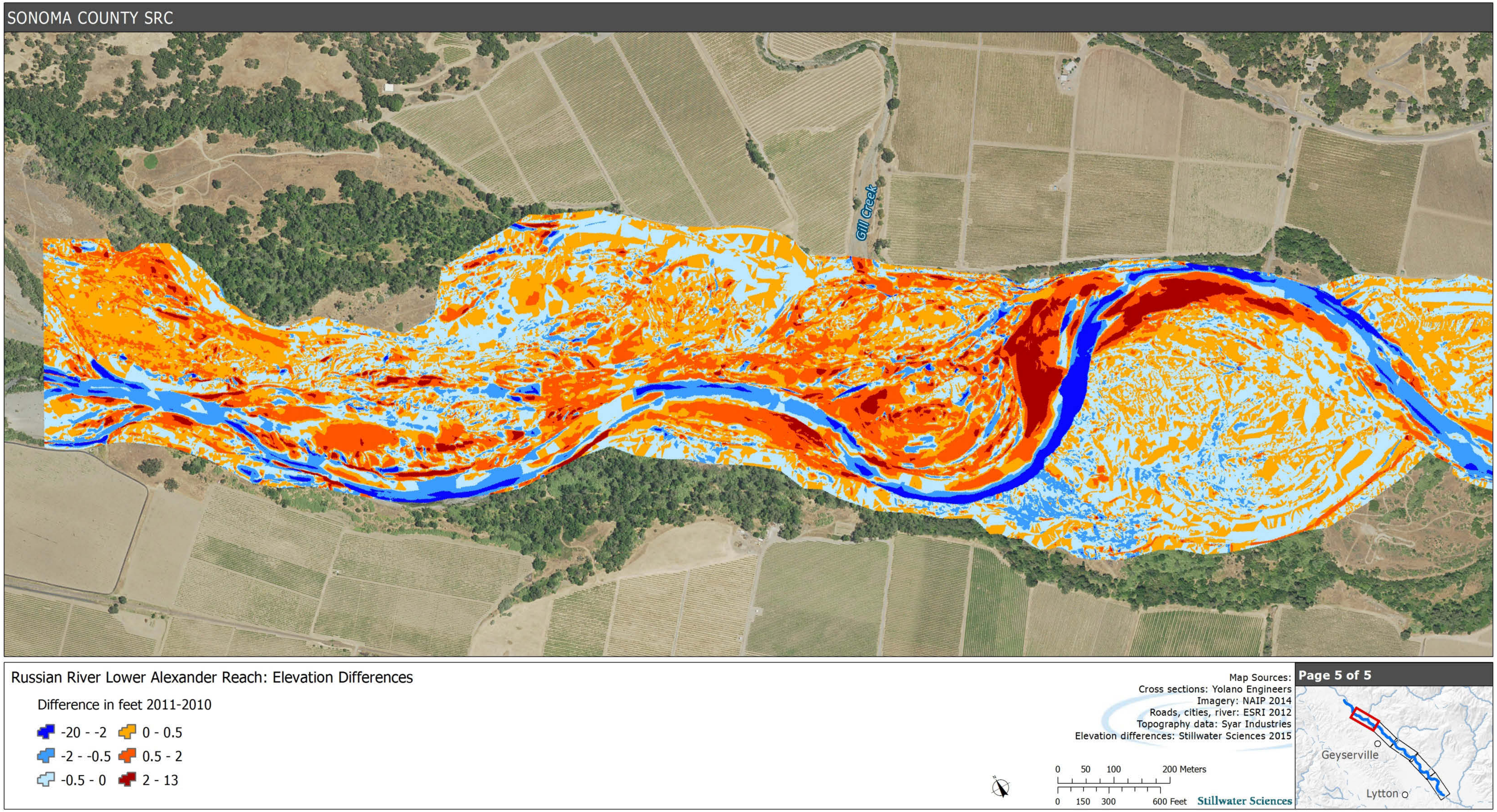

Figure G-10. Map of surface-elevation differencing for 2010–2011 in the Lower Alexander Valley Reach (map tile 5 of 5, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

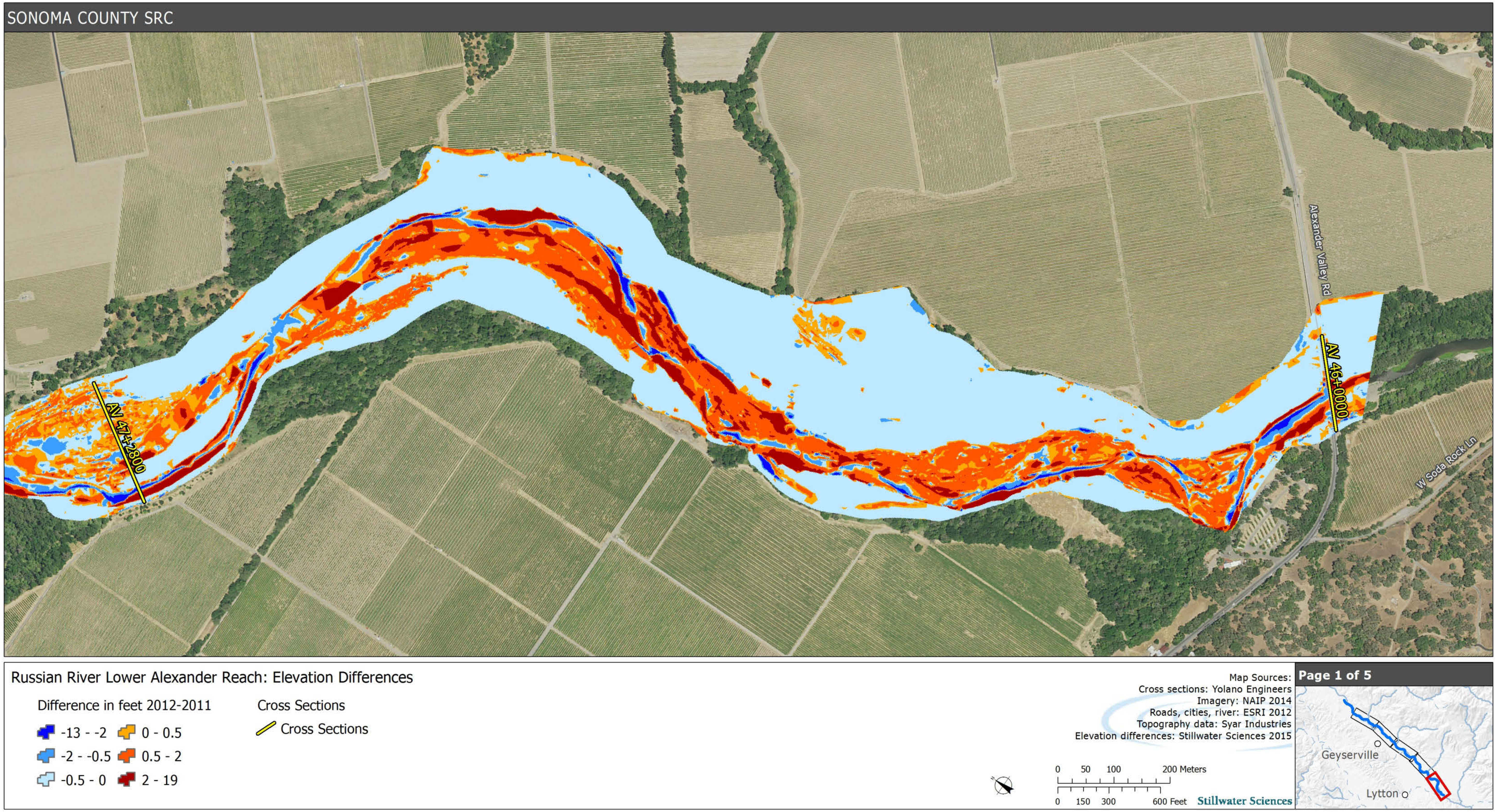

Figure G-11. Map of surface-elevation differencing for 2011-2012 in the Lower Alexander Valley Reach (map tile 1 of 5, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

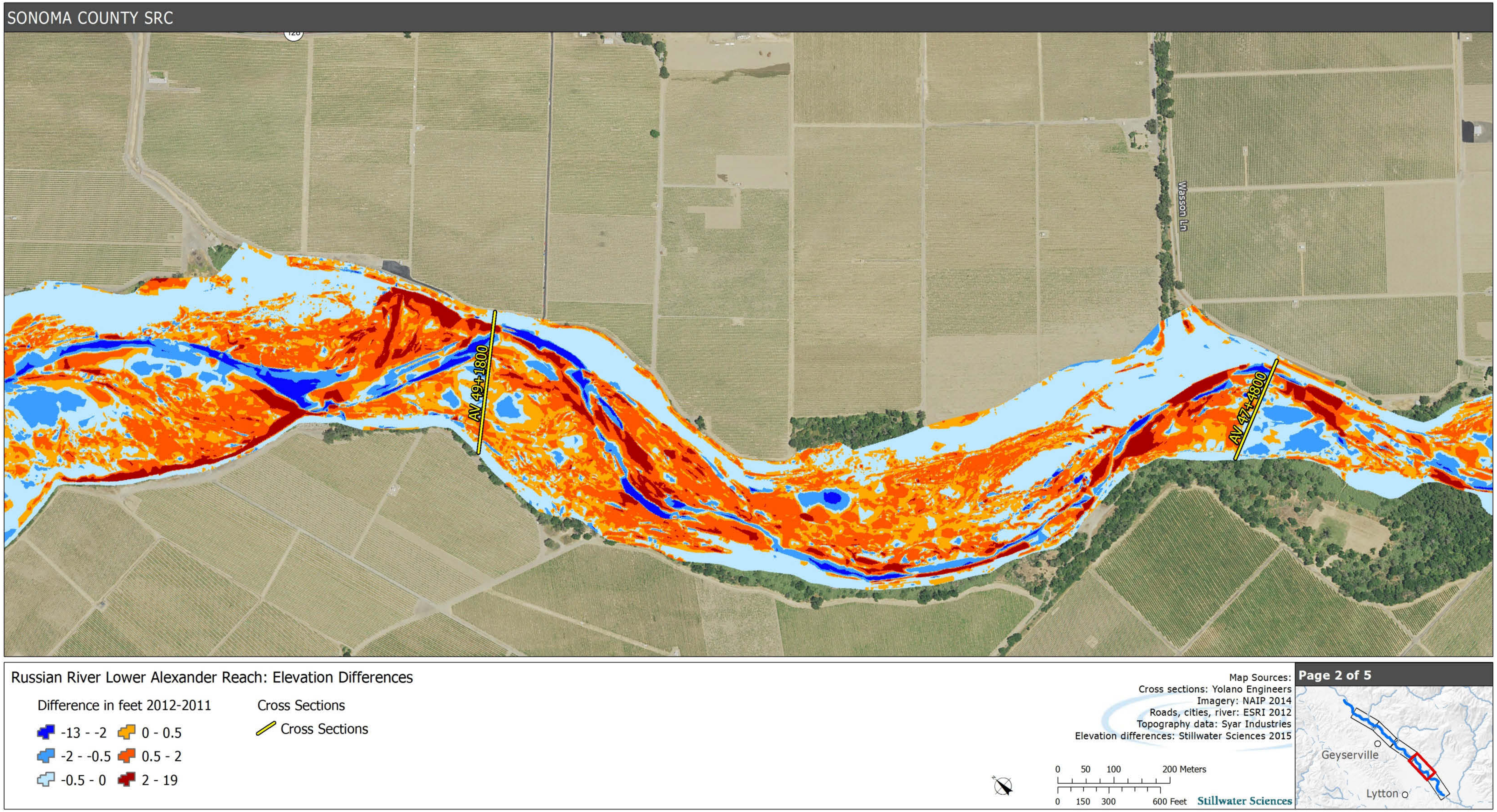

Figure G-12. Map of surface-elevation differencing for 2011-2012 in the Lower Alexander Valley Reach (map tile 2 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

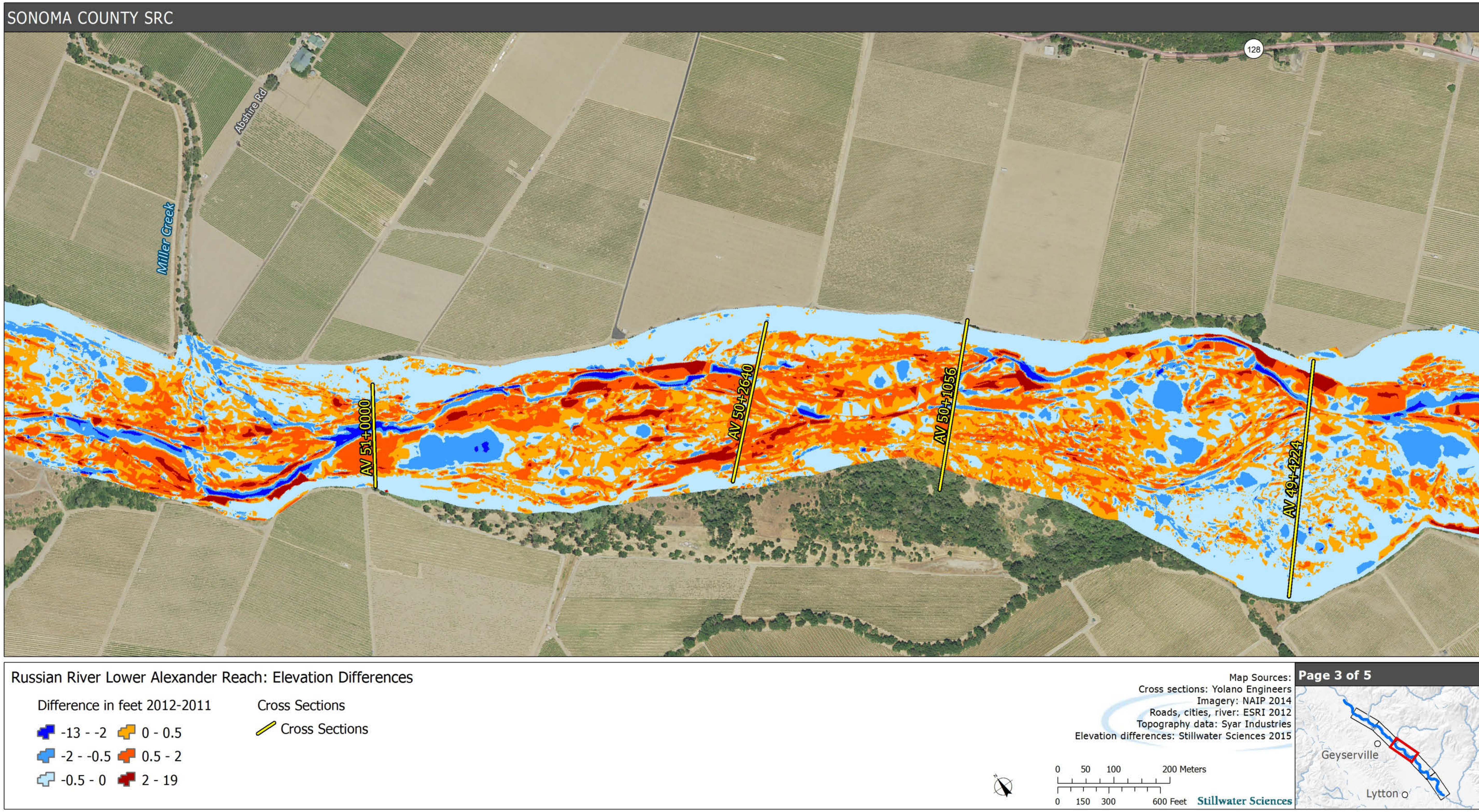

Figure G-13. Map of surface-elevation differencing for 2011-2012 in the Lower Alexander Valley Reach (map tile 3 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

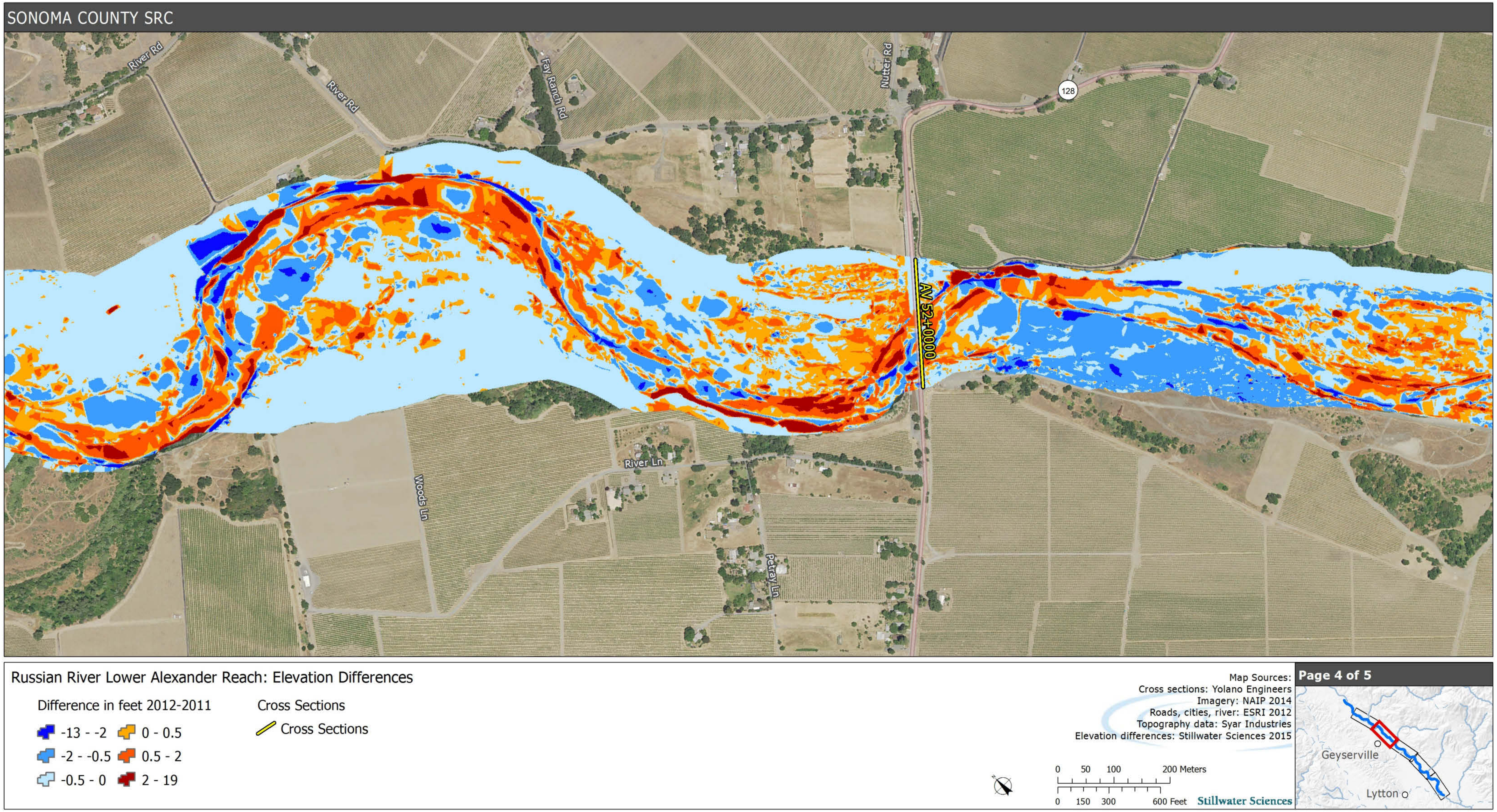

Figure G-14. Map of surface-elevation differencing for 2011-2012 in the Lower Alexander Valley Reach (map tile 4 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

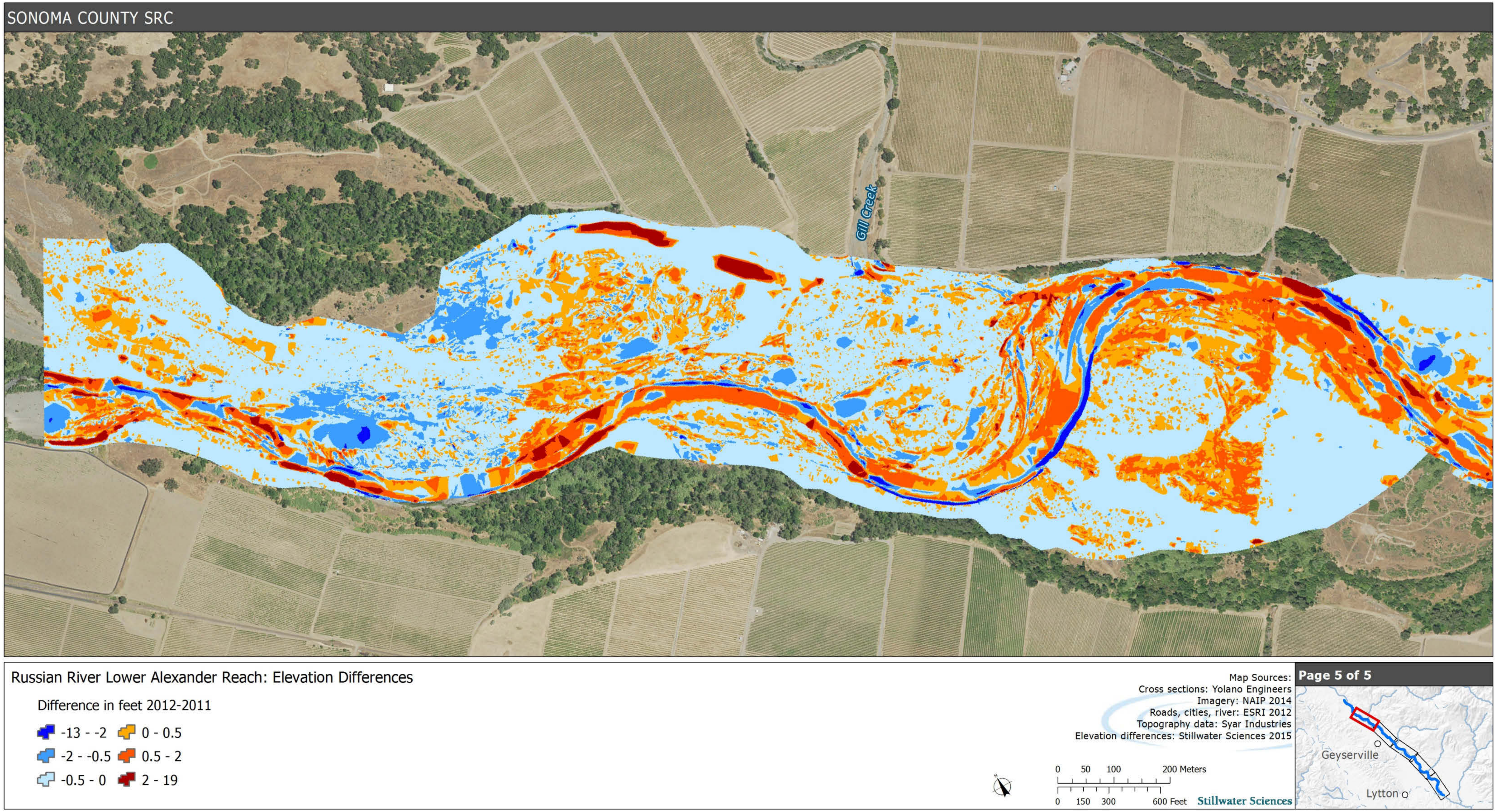

Figure G-15. Map of surface-elevation differencing for 2011-2012 in the Lower Alexander Valley Reach (map tile 5 of 5, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

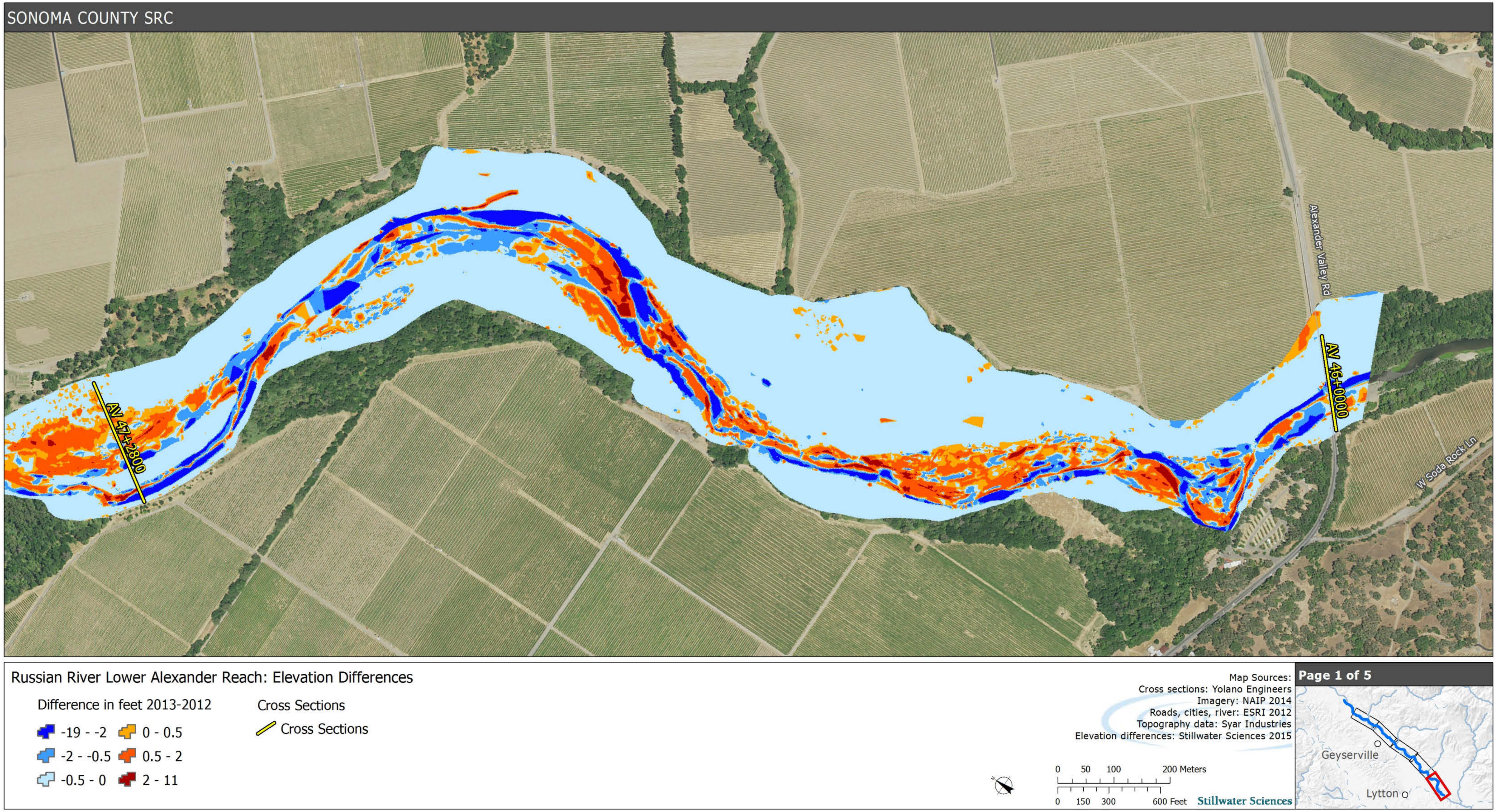

Figure G-16. Map of surface-elevation differencing for 2012-2013 in the Lower Alexander Valley Reach (map tile 1 of 5, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

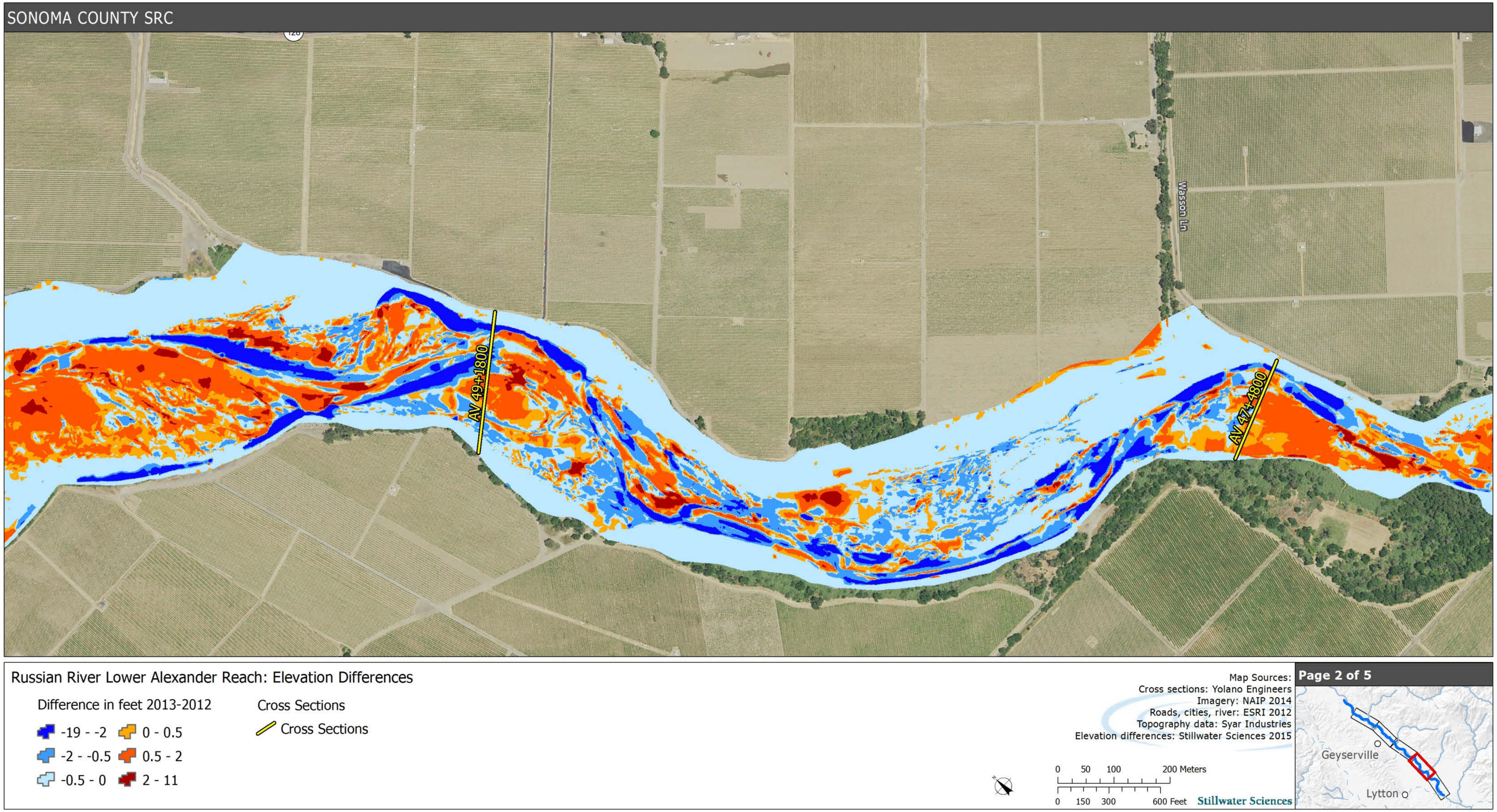

Figure G-17. Map of surface-elevation differencing for 2012-2013 in the Lower Alexander Valley Reach (map tile 2 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

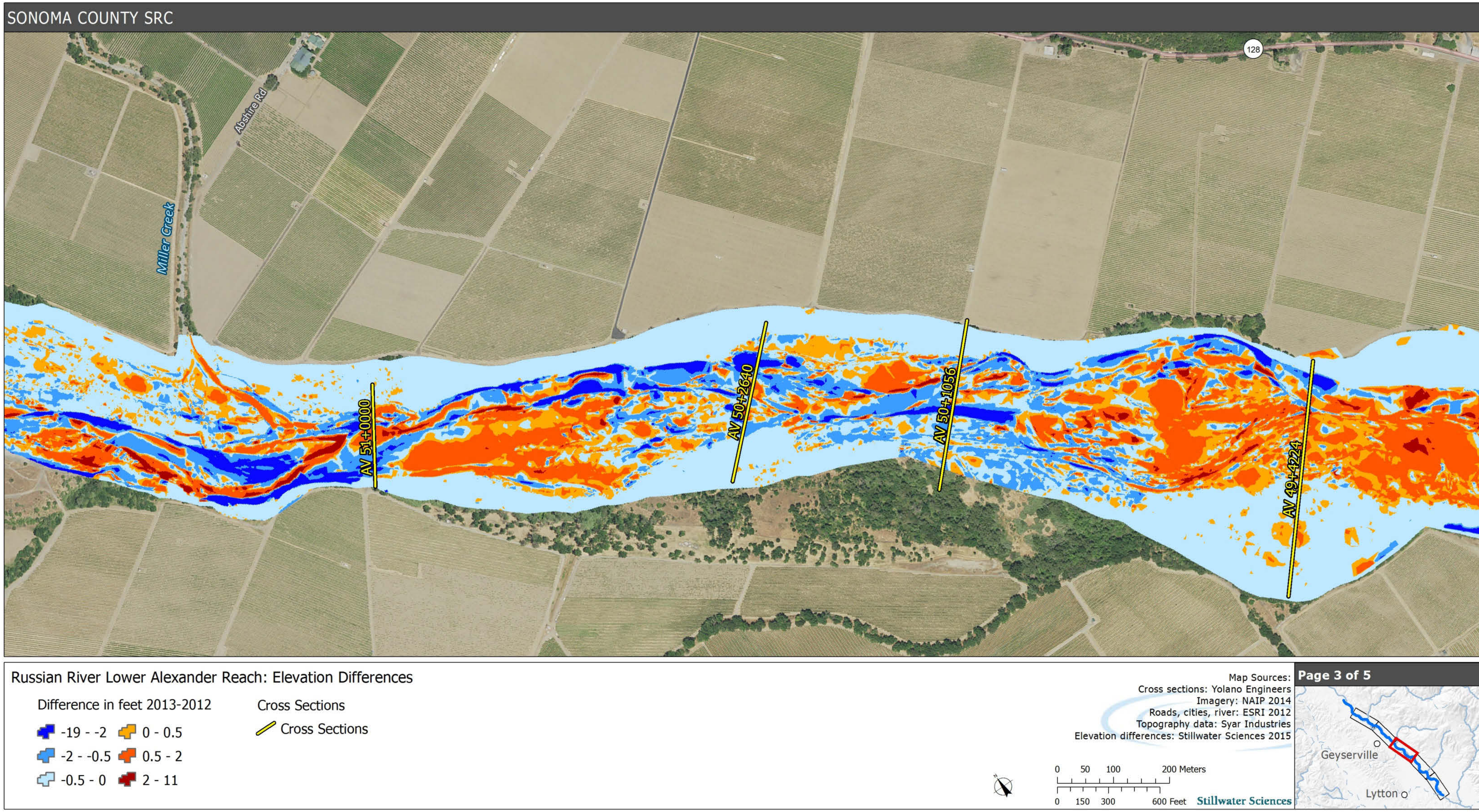

Figure G-18. Map of surface-elevation differencing for 2012-2013 in the Lower Alexander Valley Reach (map tile 3 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

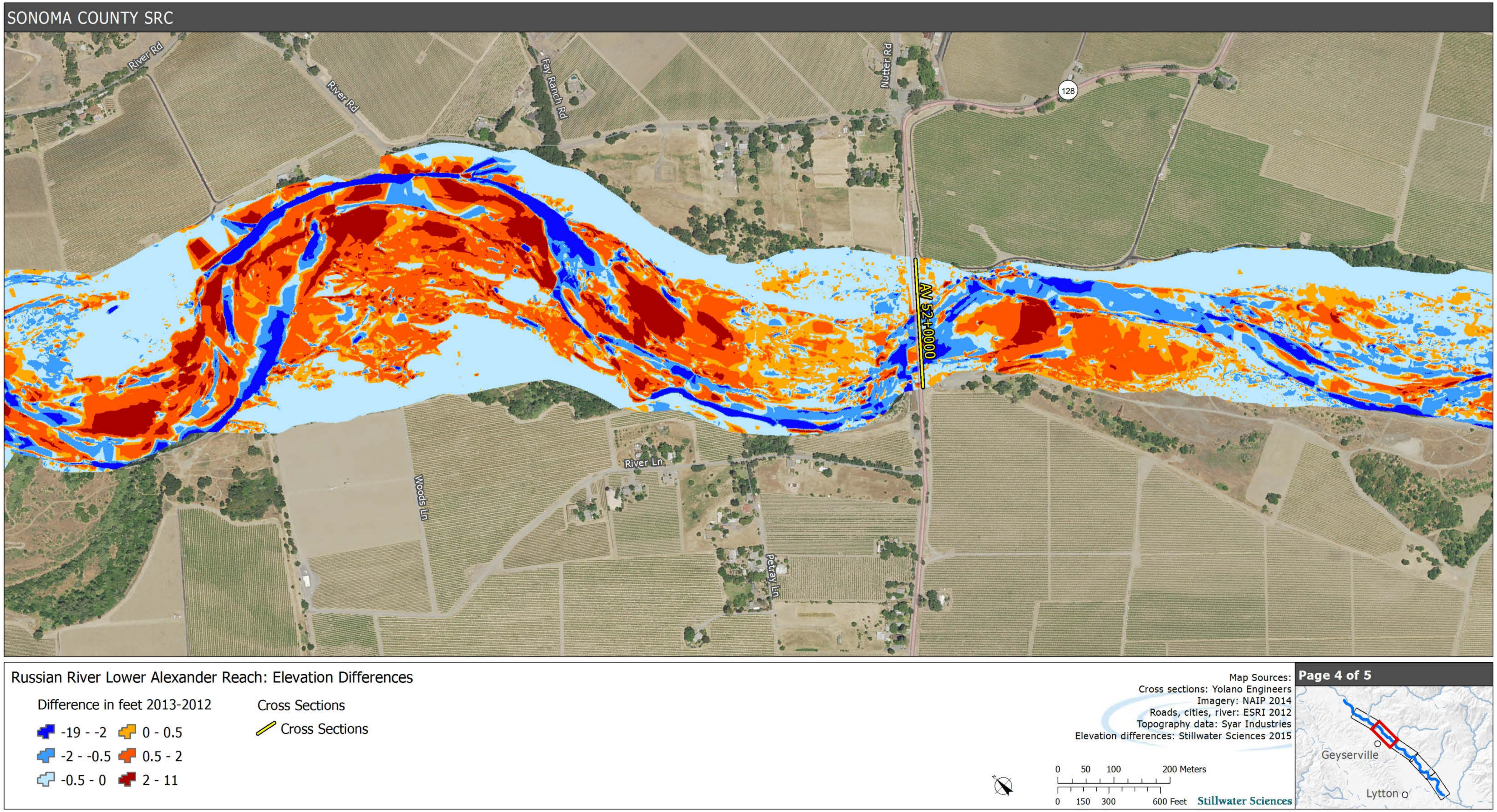

Figure G-19. Map of surface-elevation differencing for 2012-2013 in the Lower Alexander Valley Reach (map tile 4 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

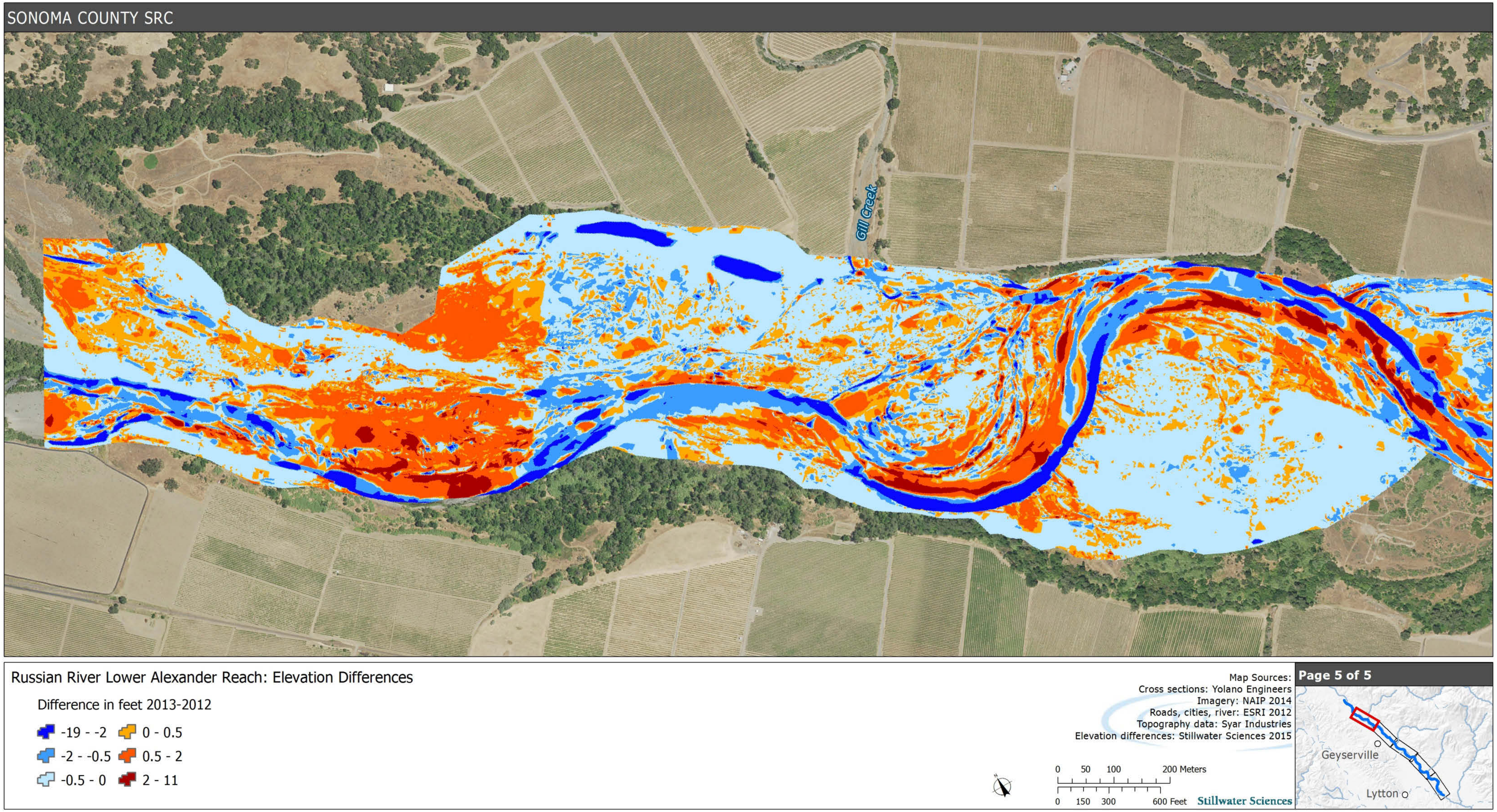

Figure G-20. Map of surface-elevation differencing for 2012-2013 in the Lower Alexander Valley Reach (map tile 5 of 5, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

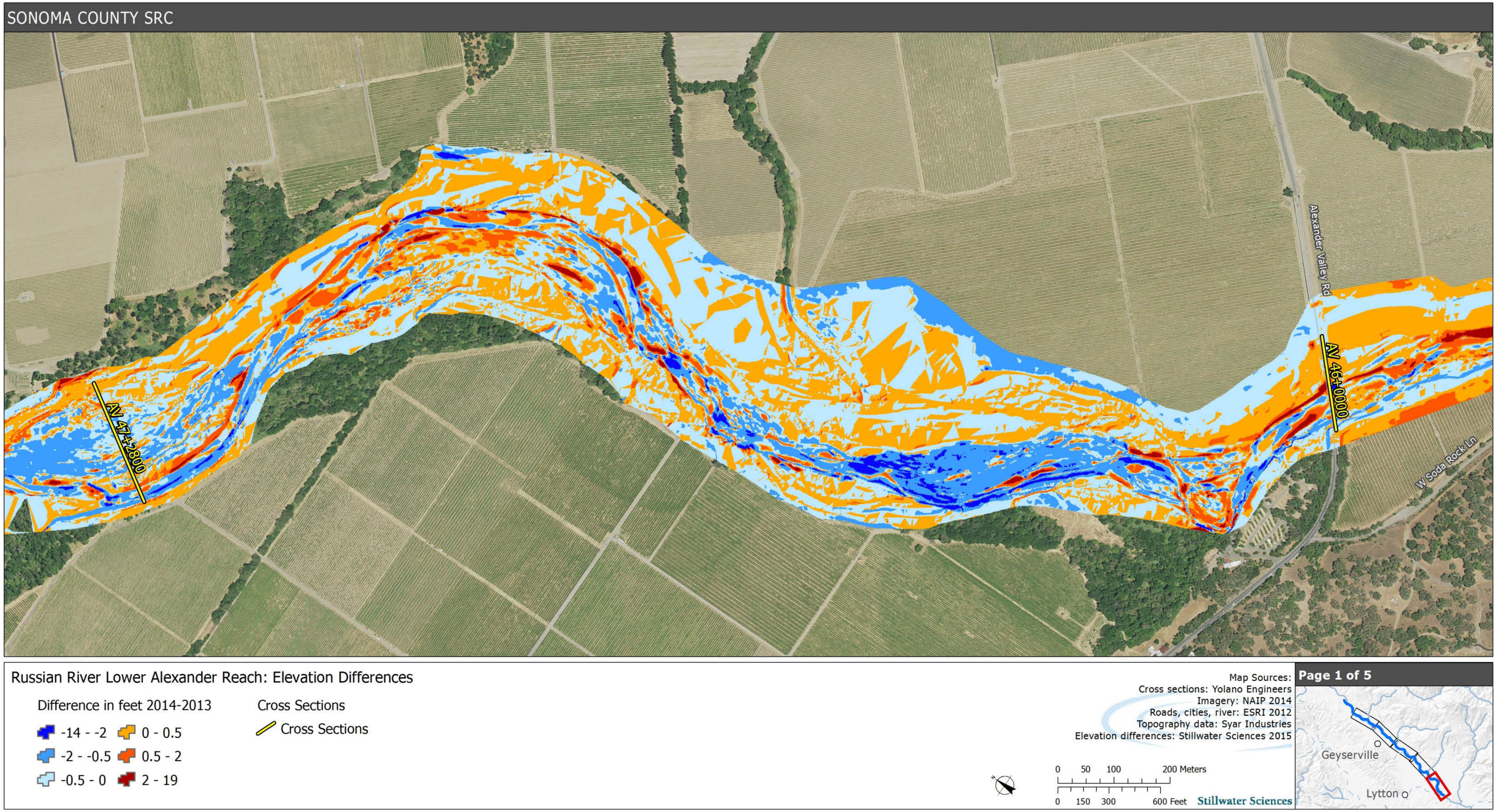

Figure G-21. Map of surface-elevation differencing for 2013-2014 in the Lower Alexander Valley Reach (map tile 1 of 5, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

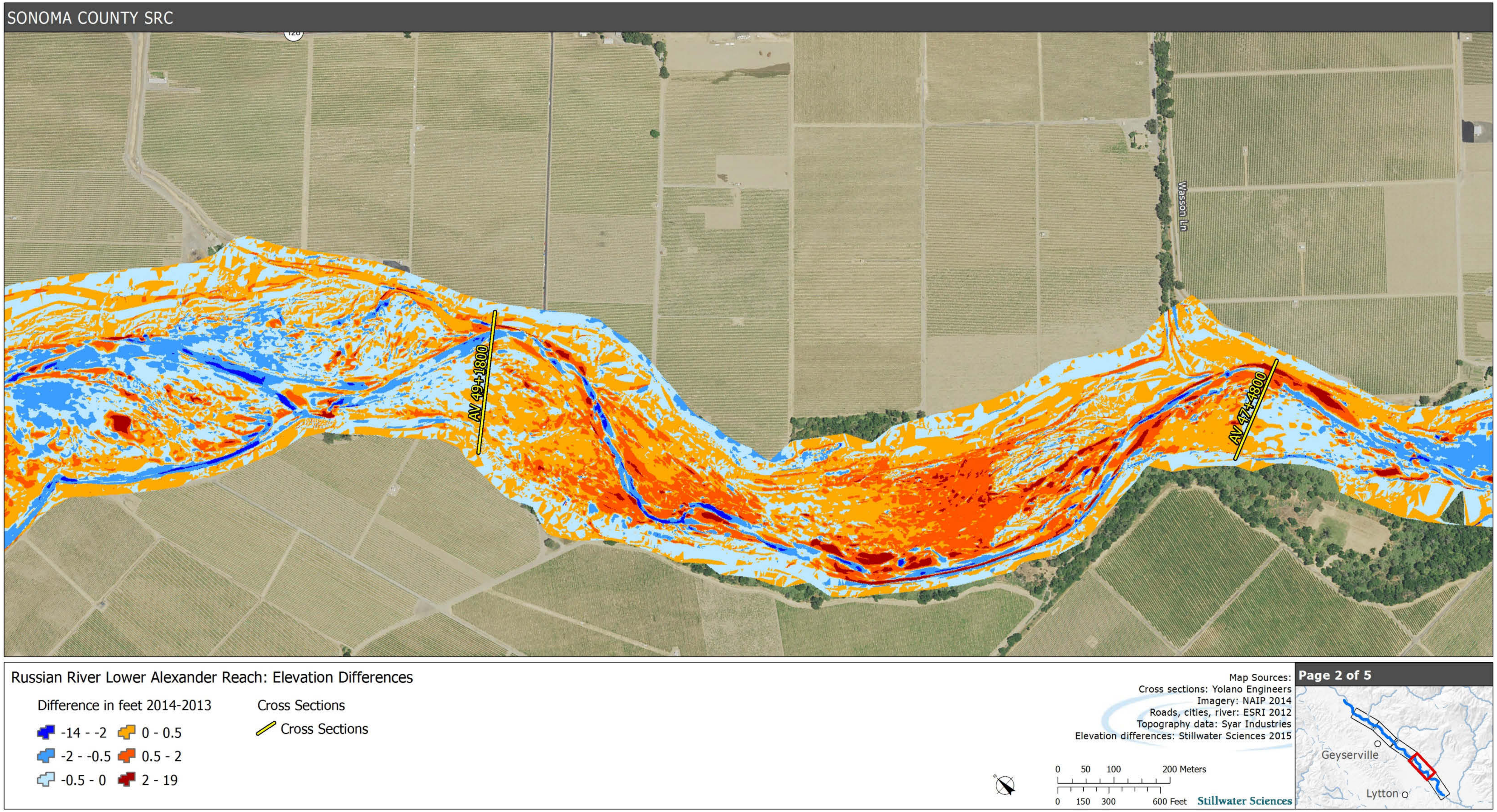

Figure G-22. Map of surface-elevation differencing for 2013-2014 in the Lower Alexander Valley Reach (map tile 2 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

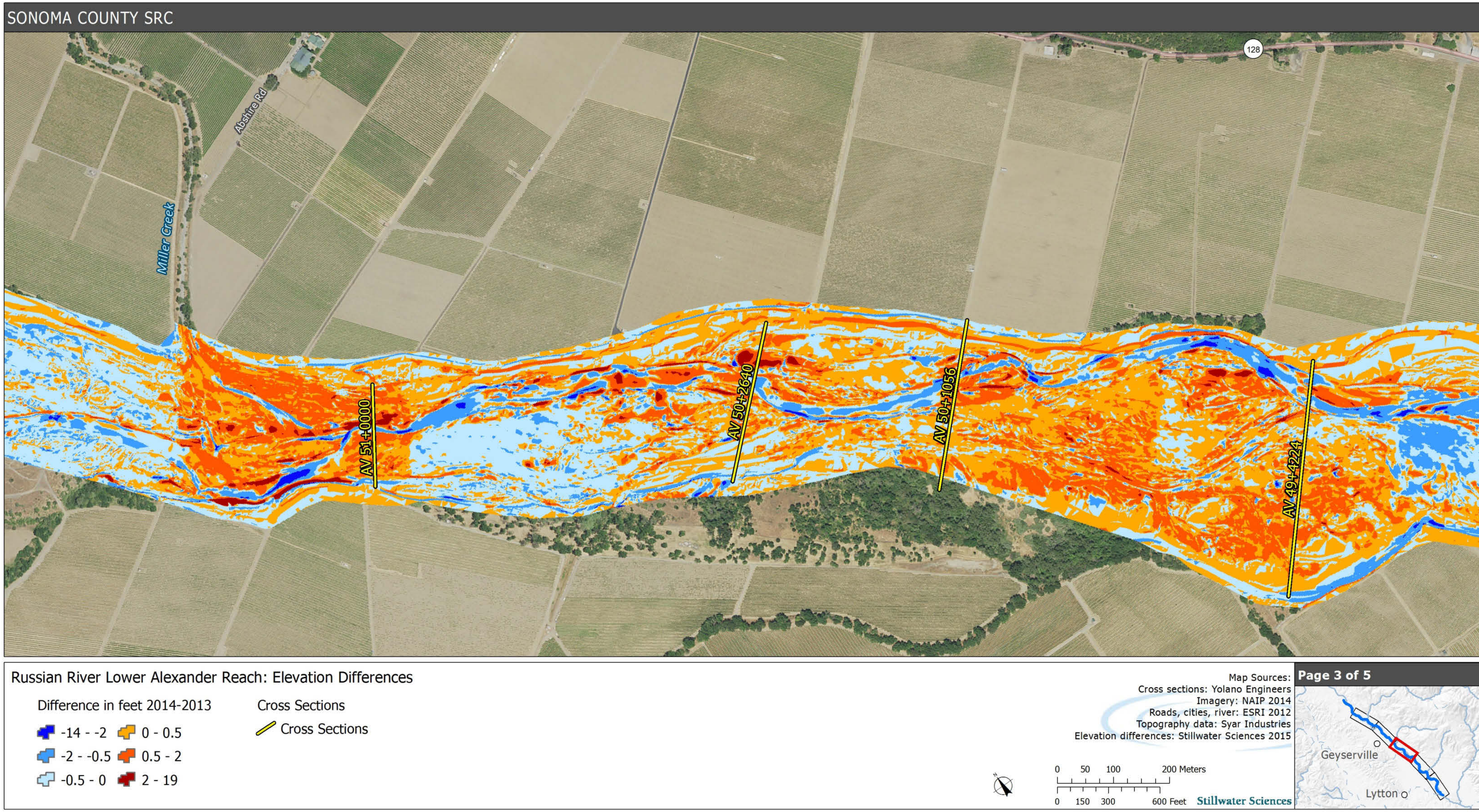

Figure G-23. Map of surface-elevation differencing for 2013-2014 in the Lower Alexander Valley Reach (map tile 3 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

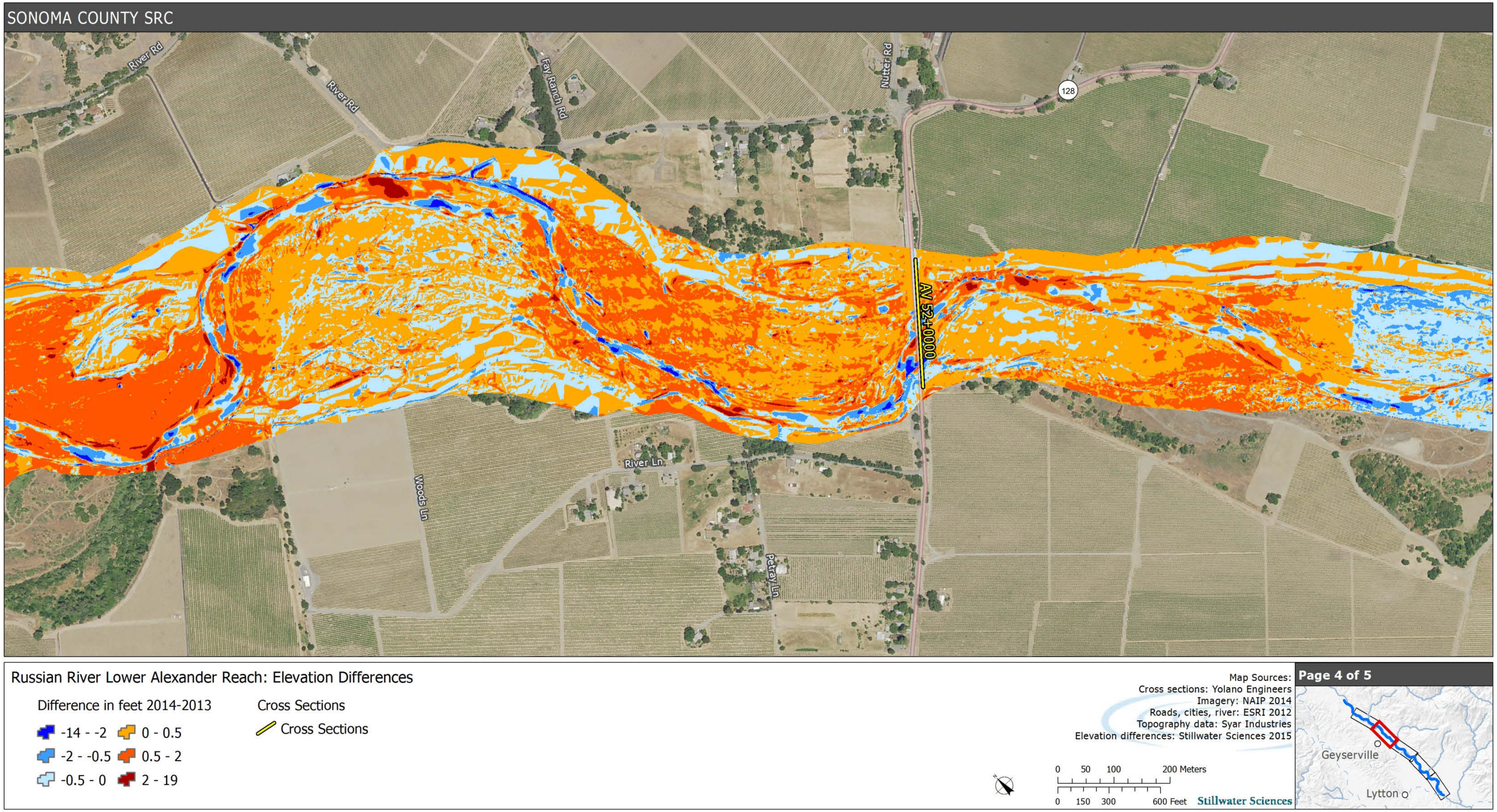

Figure G-24. Map of surface-elevation differencing for 2013-2014 in the Lower Alexander Valley Reach (map tile 4 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

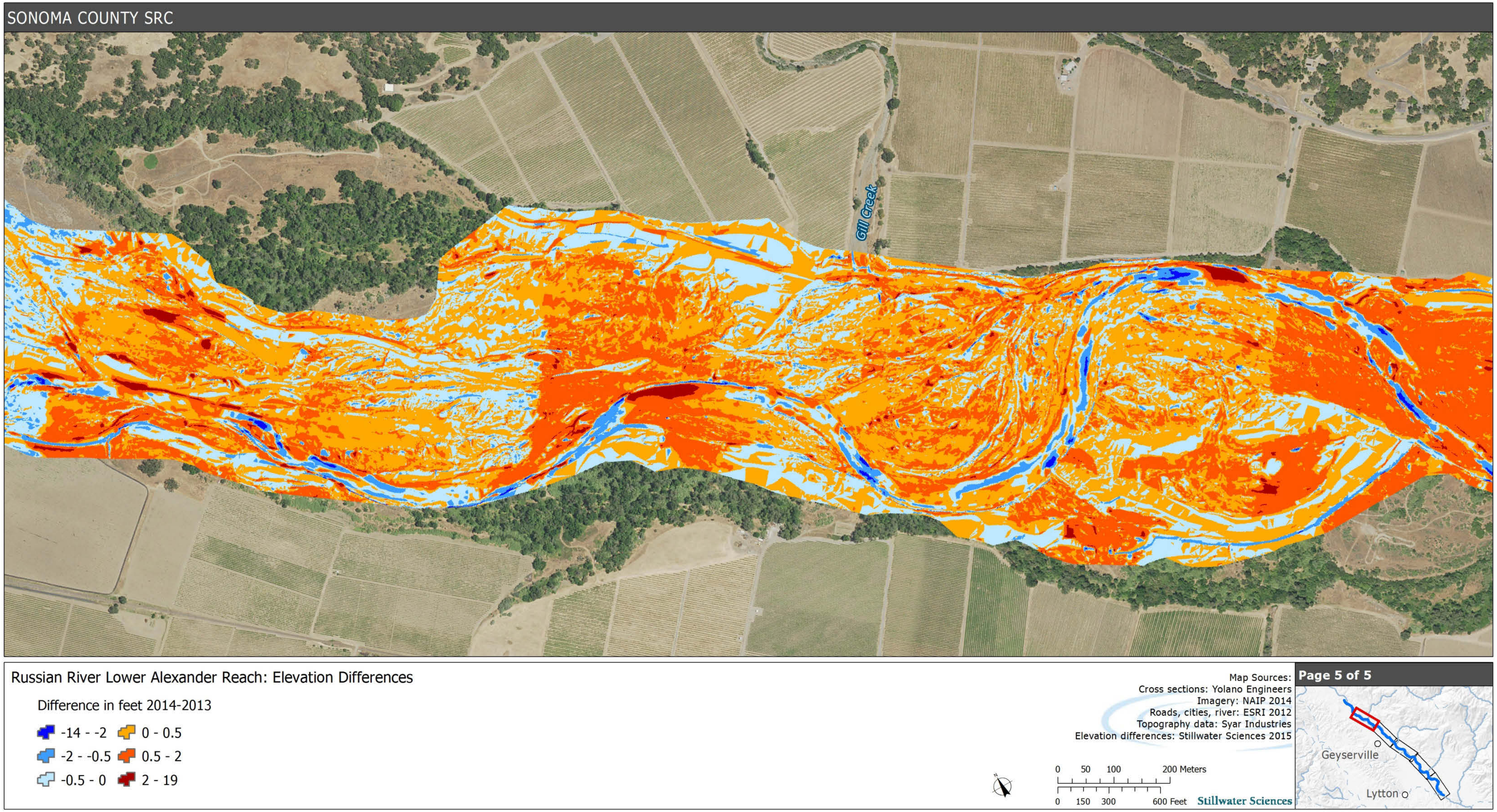

Figure G-25. Map of surface-elevation differencing for 2013-2014 in the Lower Alexander Valley Reach (map tile 5 of 5, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

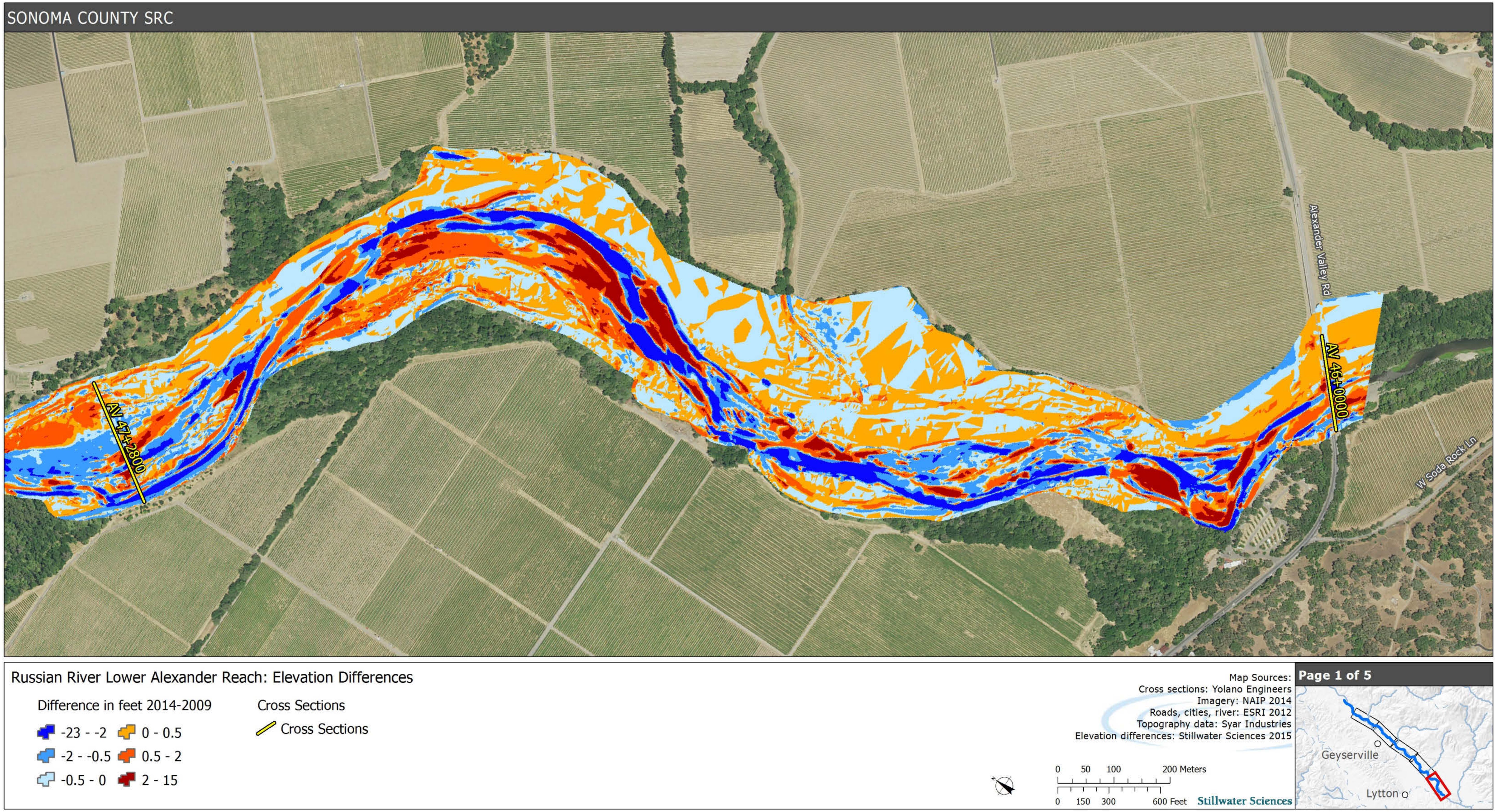

Figure G-26. Map of surface-elevation differencing for 2009-2014 in the Lower Alexander Valley Reach (map tile 1 of 5, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

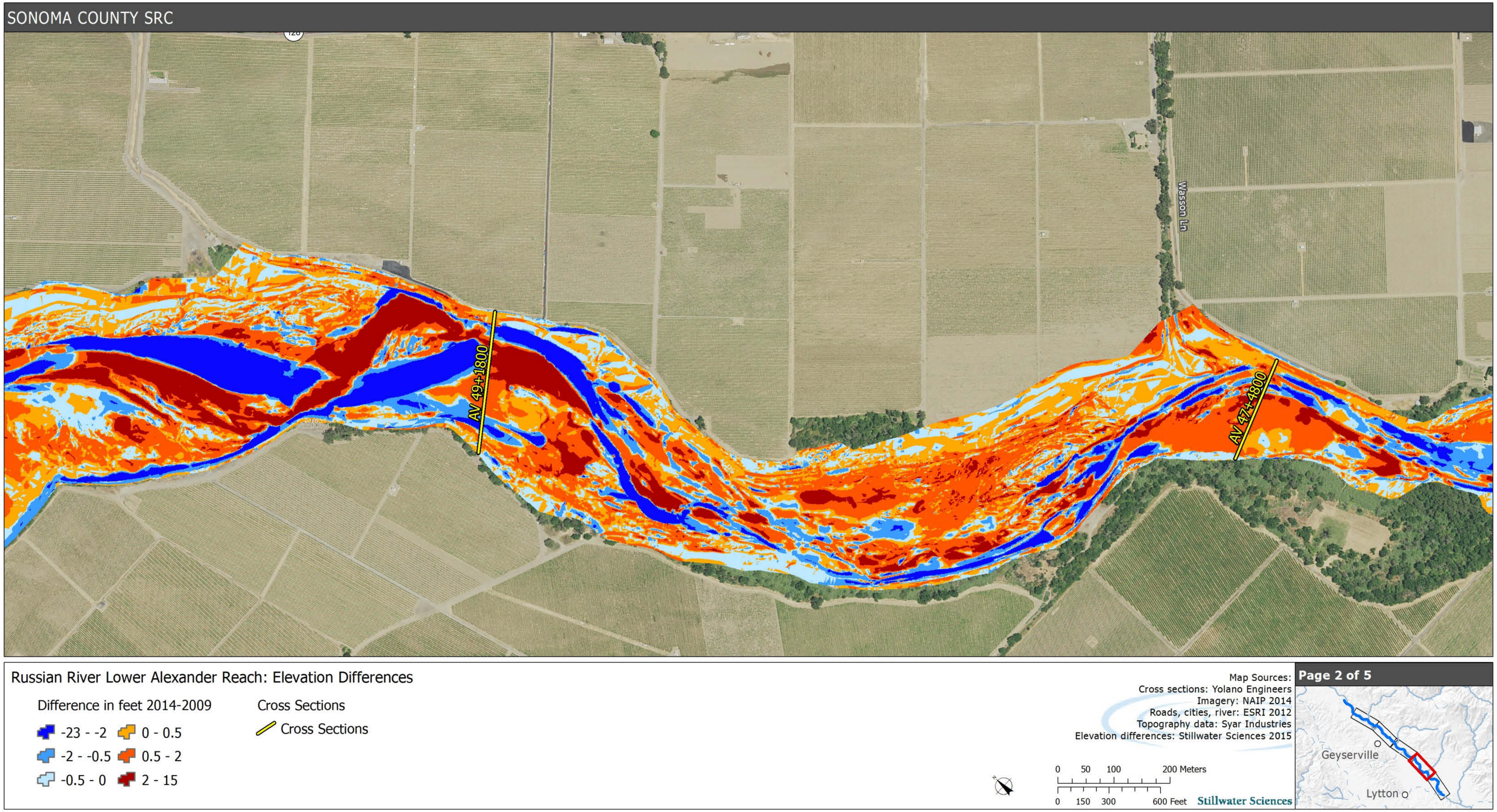

Figure G-27. Map of surface-elevation differencing for 2009-2014 in the Lower Alexander Valley Reach (map tile 2 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

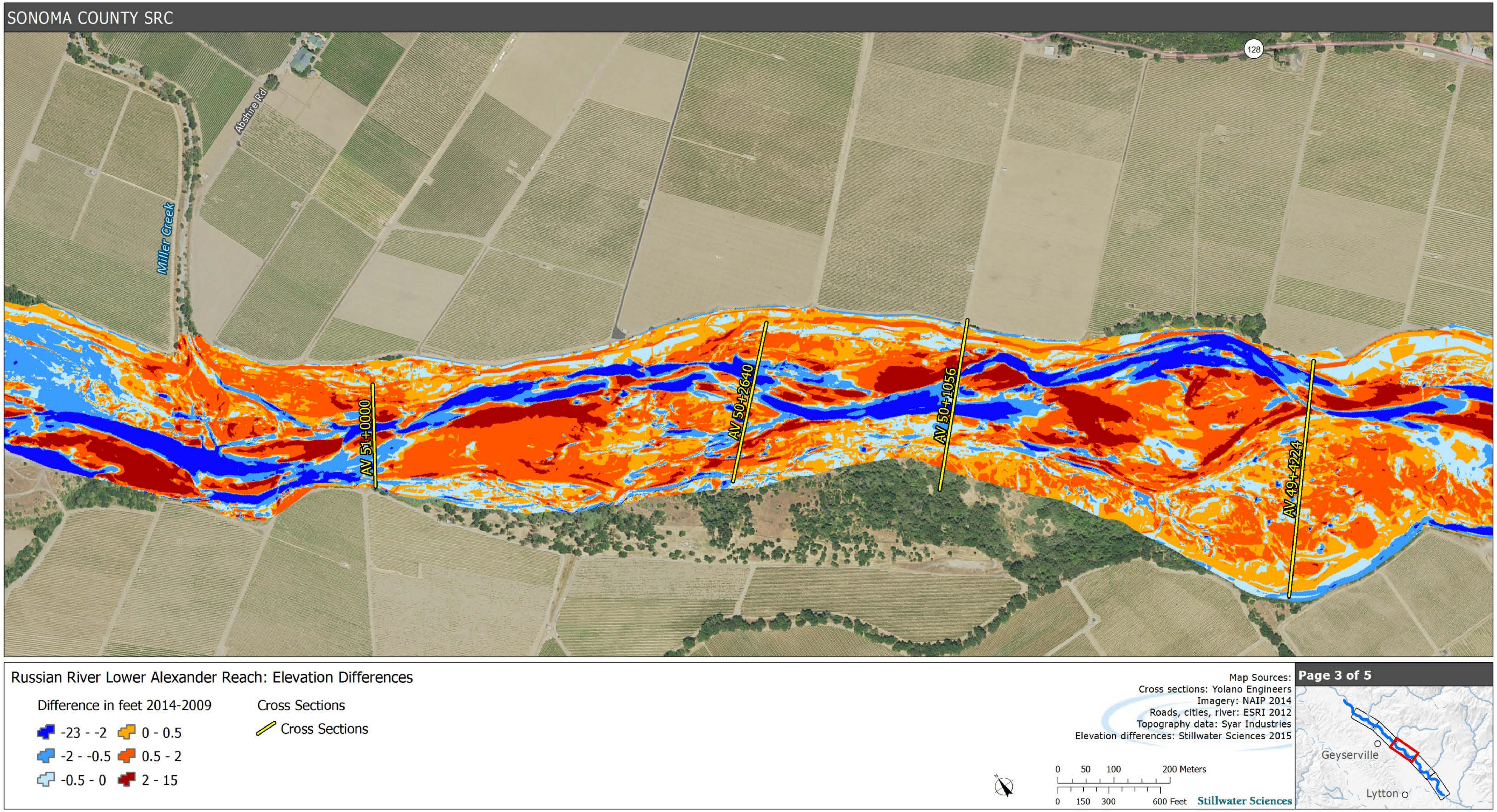

Figure G-28. Map of surface-elevation differencing for 2009-2014 in the Lower Alexander Valley Reach (map tile 3 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

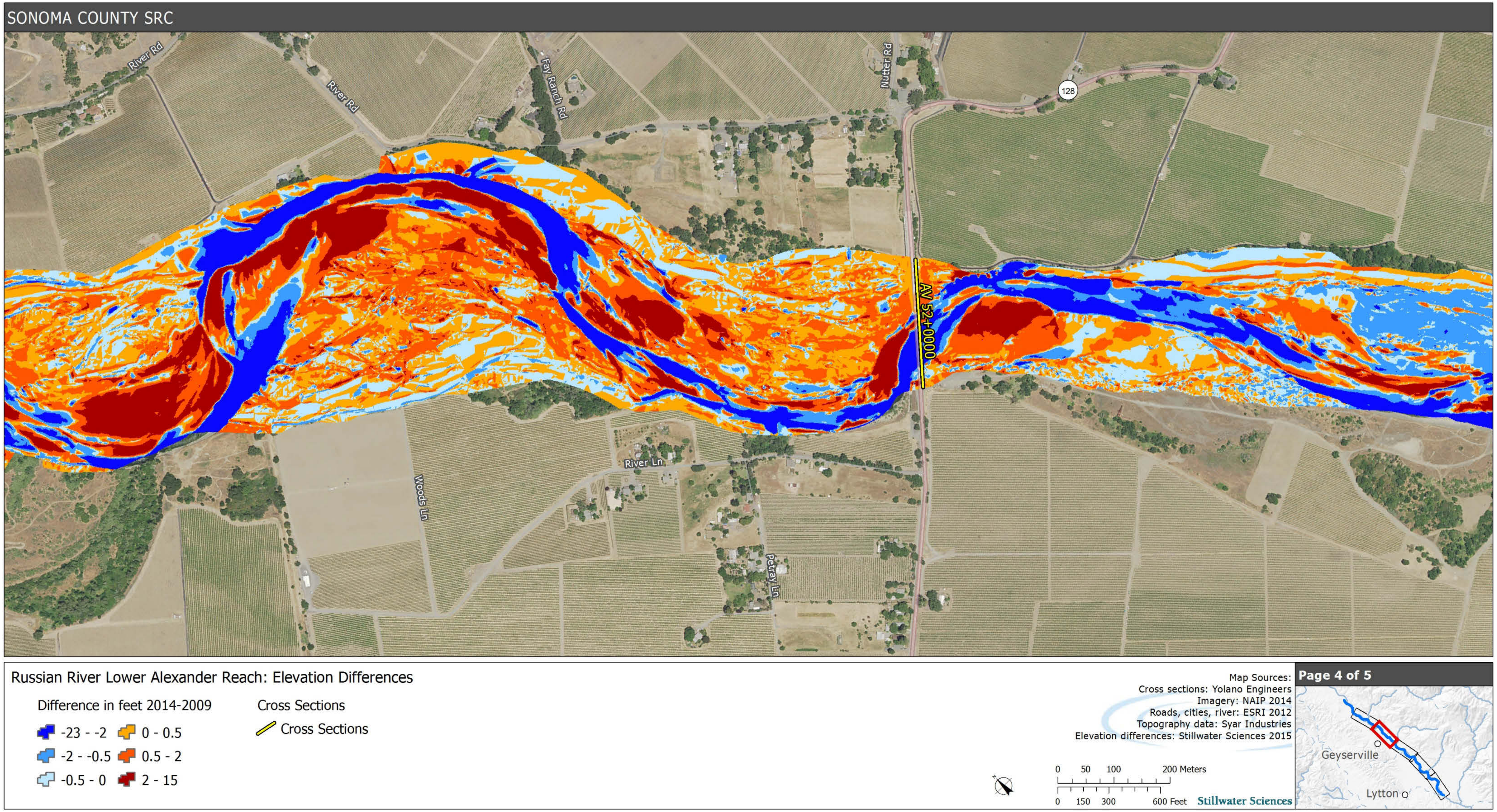

Figure G-29. Map of surface-elevation differencing for 2009-2014 in the Lower Alexander Valley Reach (map tile 4 of 5). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

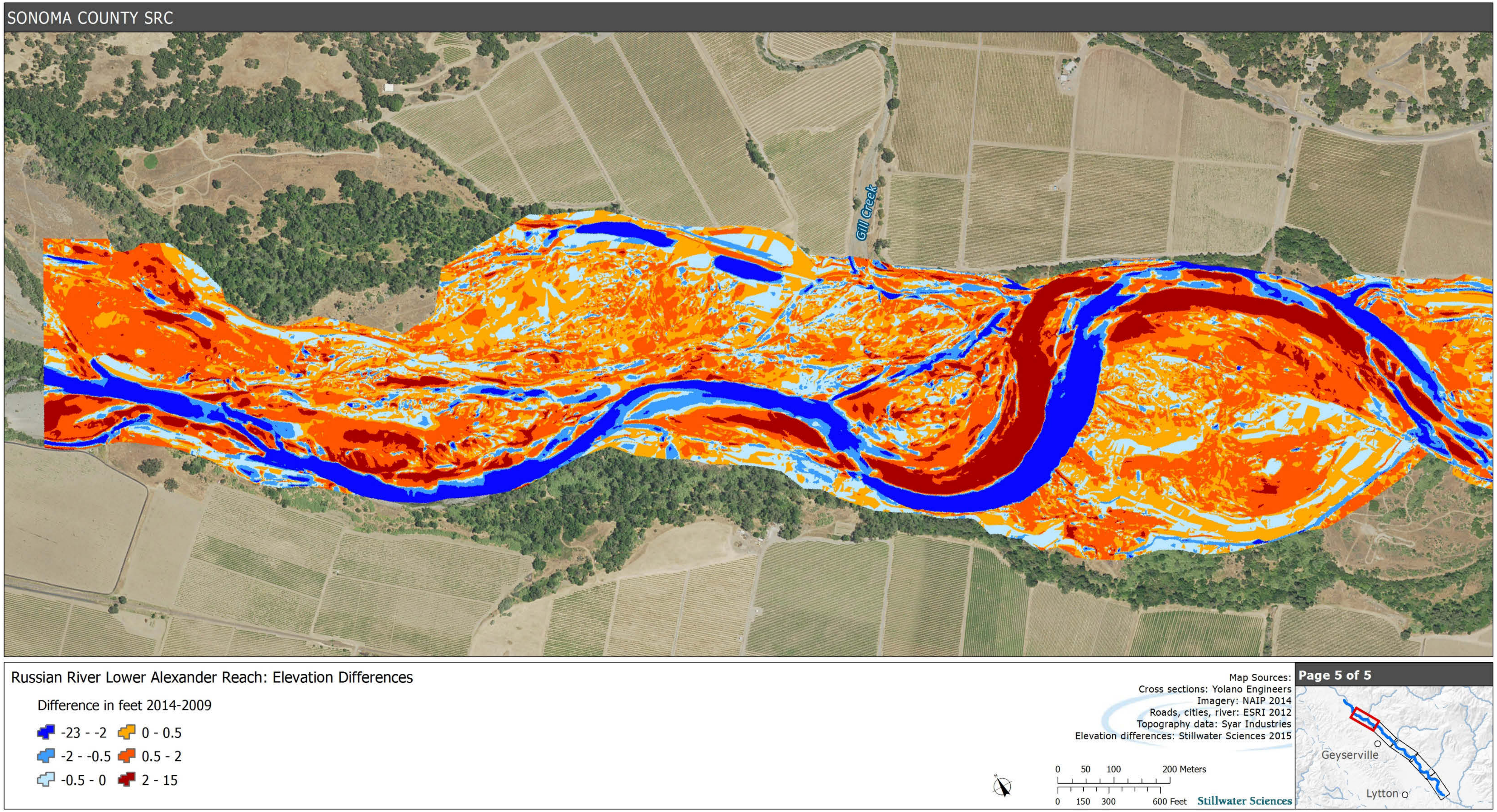

Figure G-30. Map of surface-elevation differencing for 2009-2014 in the Lower Alexander Valley Reach (map tile 5 of 5, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

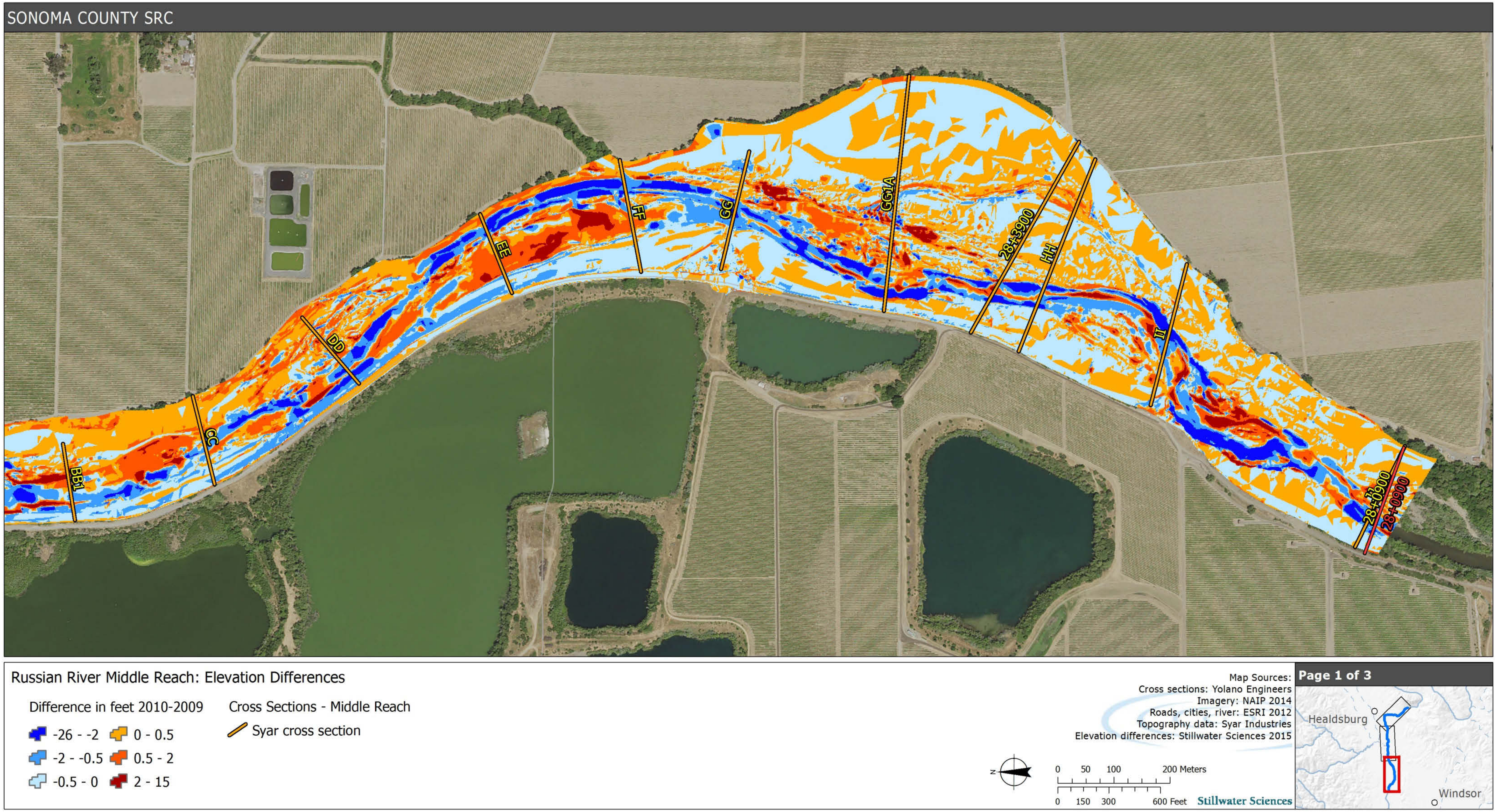

Figure G-31. Map of surface-elevation differencing for 2009-2010 in the Middle Reach (map tile 1 of 3, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

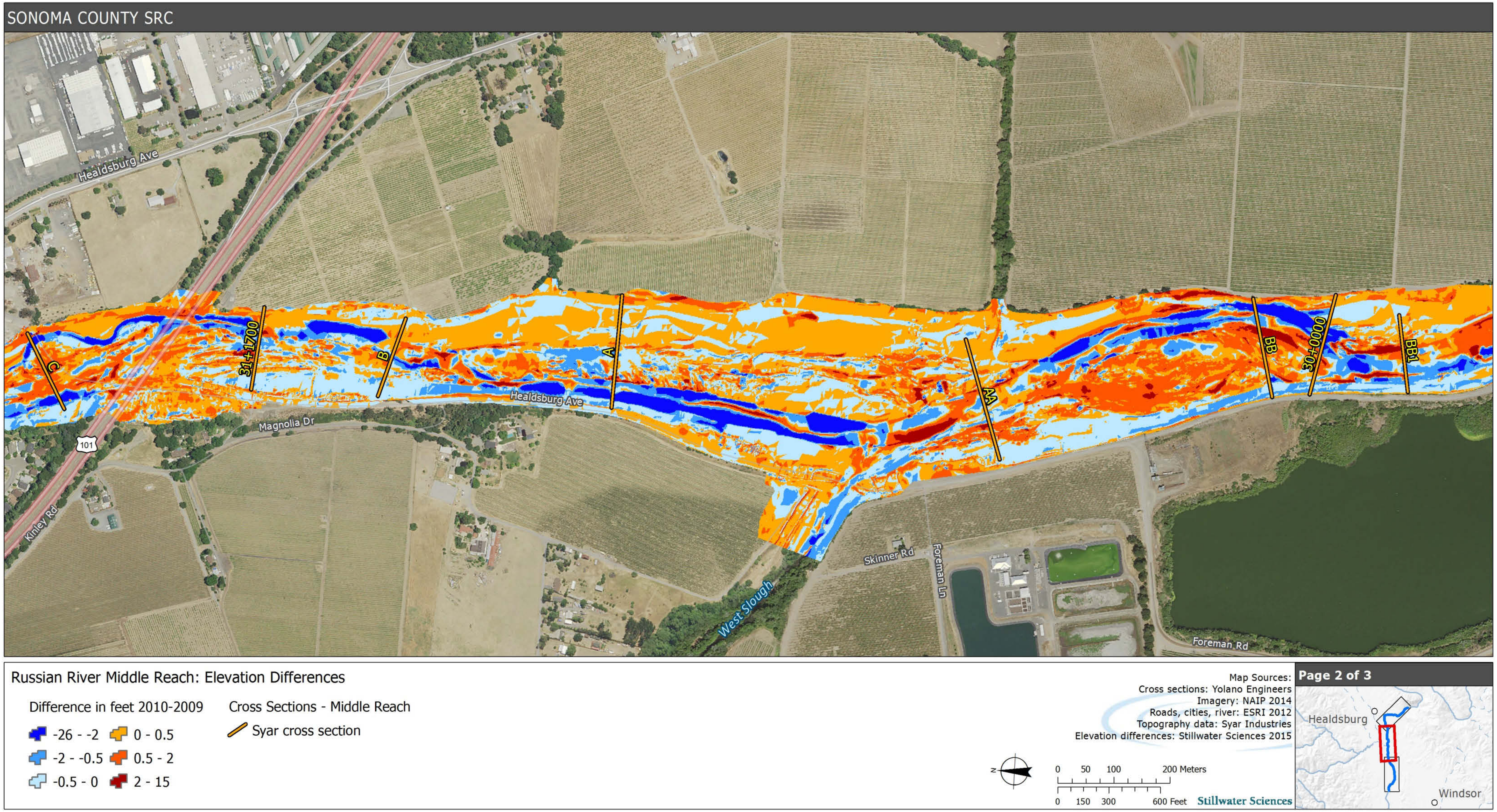

Figure G-32. Map of surface-elevation differencing for 2009-2010 in the Middle Reach (map tile 2 of 3). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

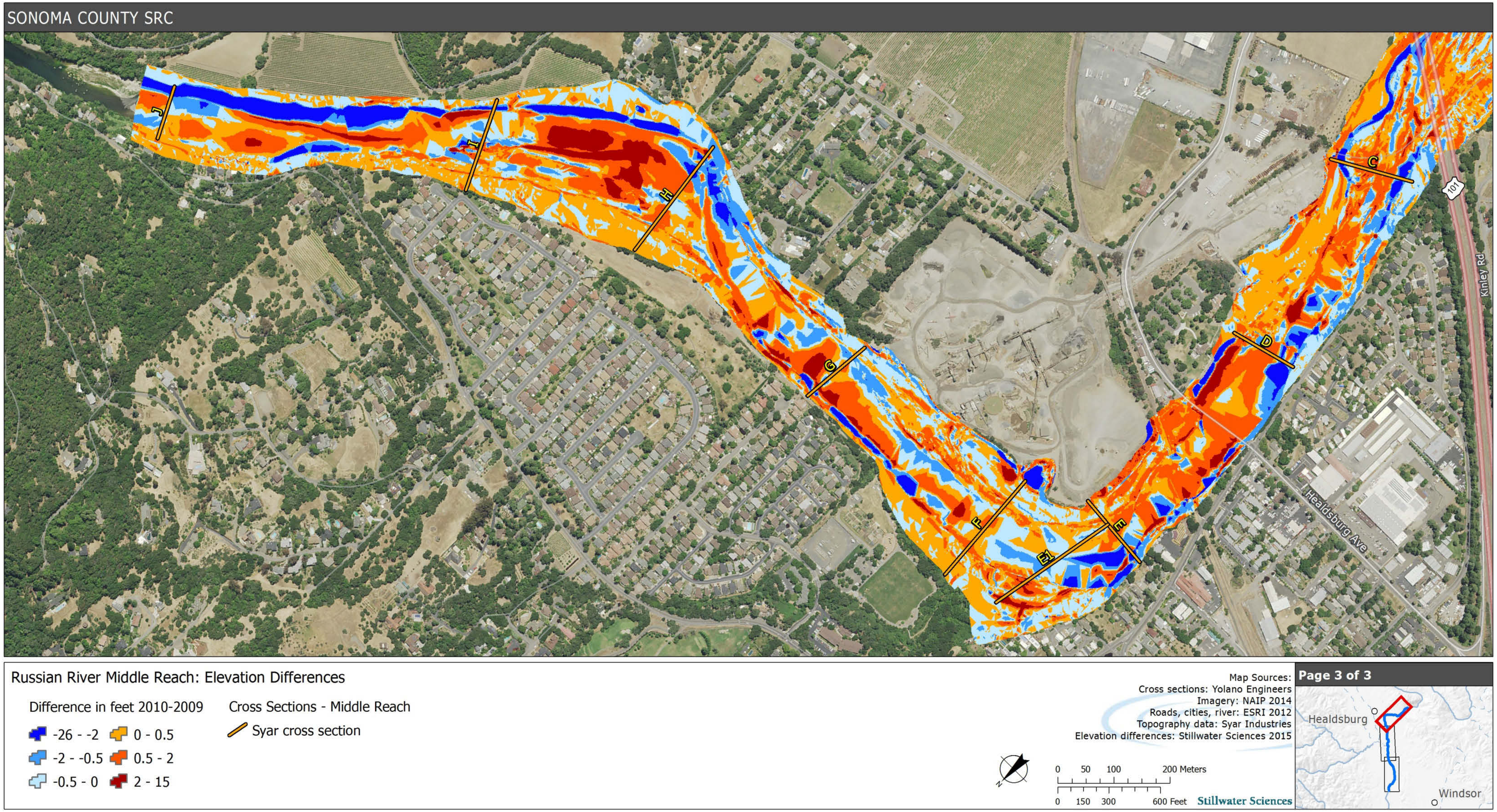

Figure G-33. Map of surface-elevation differencing for 2009-2010 in the Middle Reach (map tile 3 of 3, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

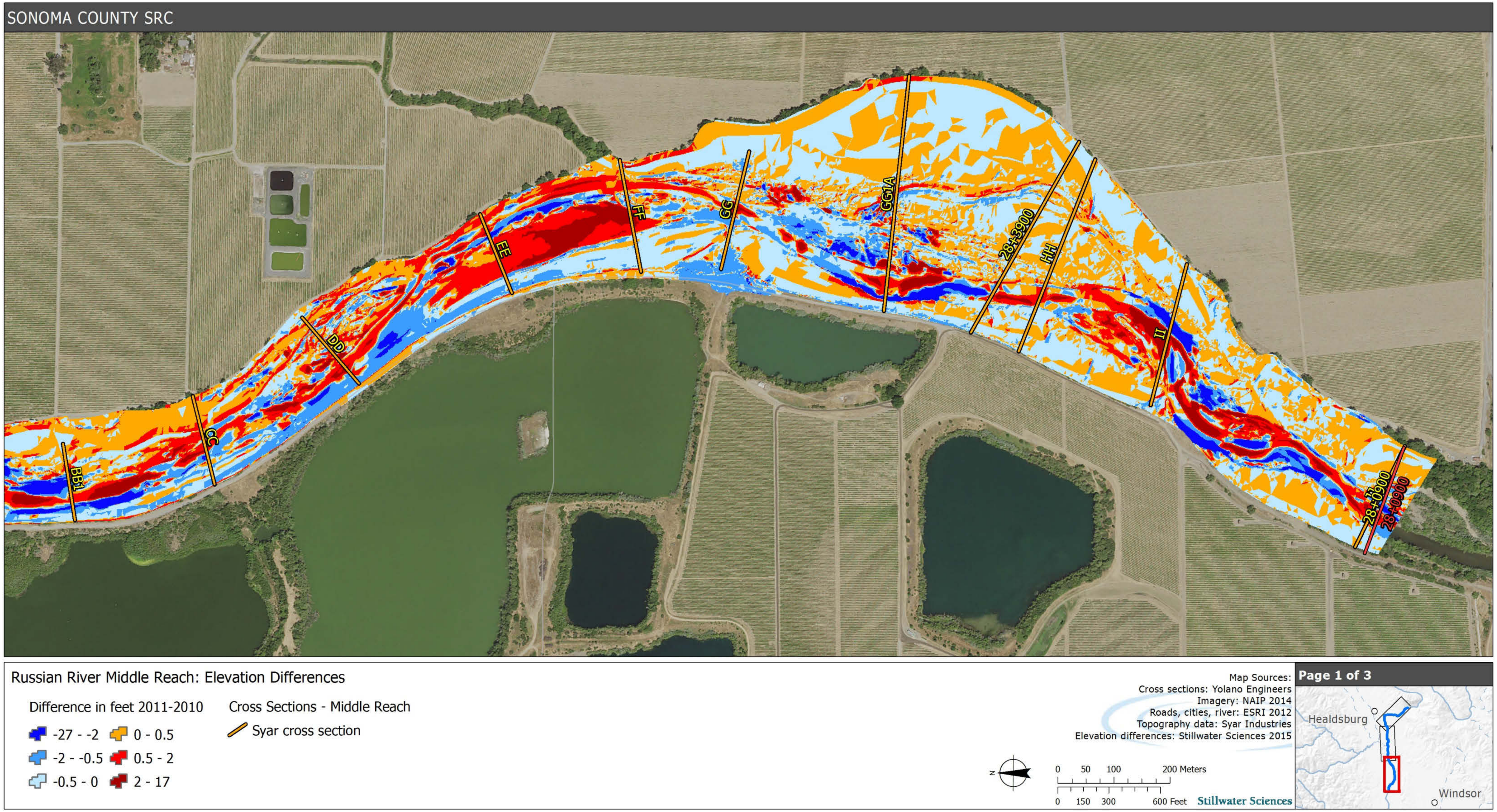

Figure G-34. Map of surface-elevation differencing for 2010-2011 in the Middle Reach (map tile 1 of 3, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

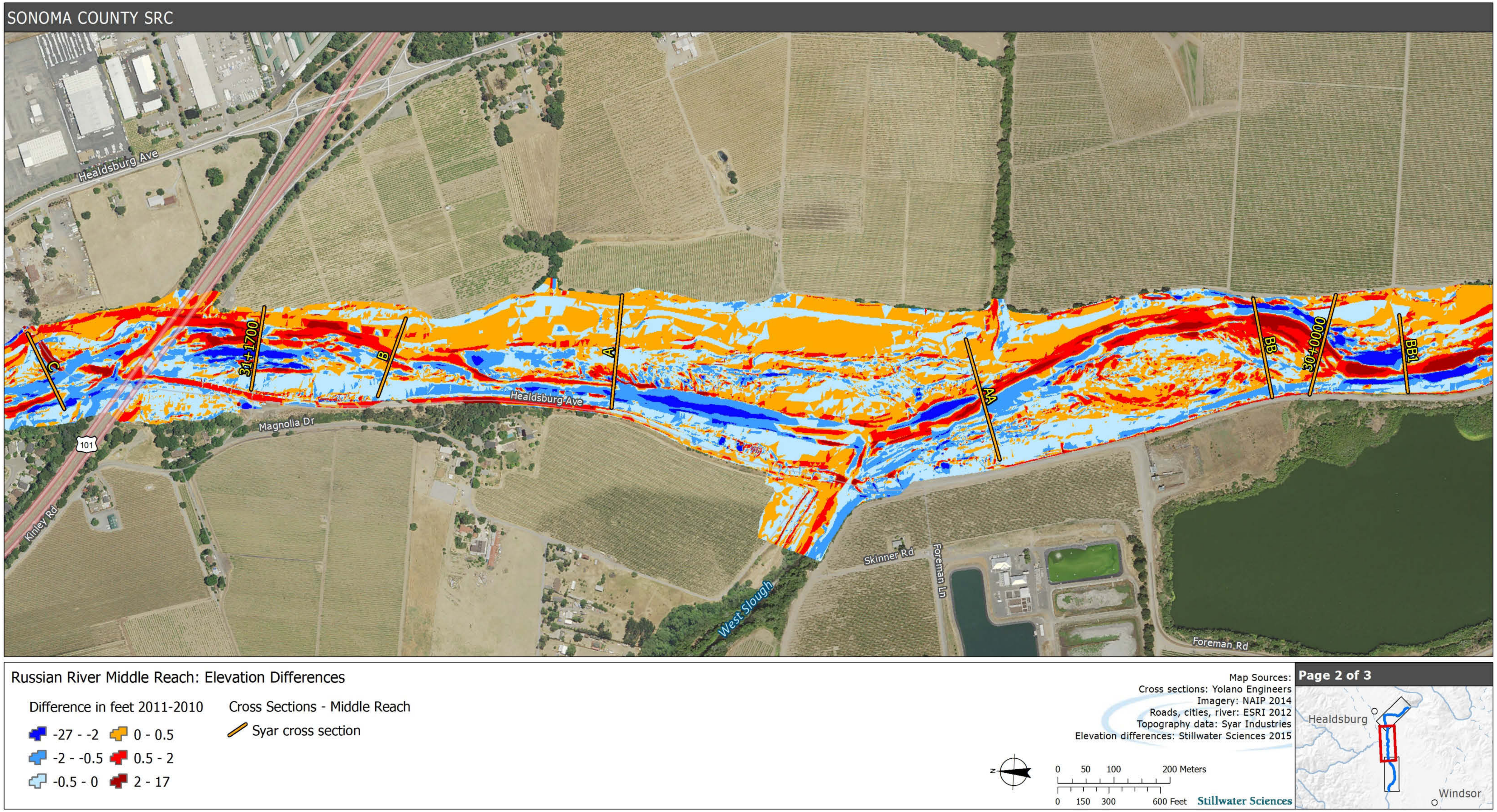

Figure G-35. Map of surface-elevation differencing for 2010-2011 in the Middle Reach (map tile 2 of 3). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

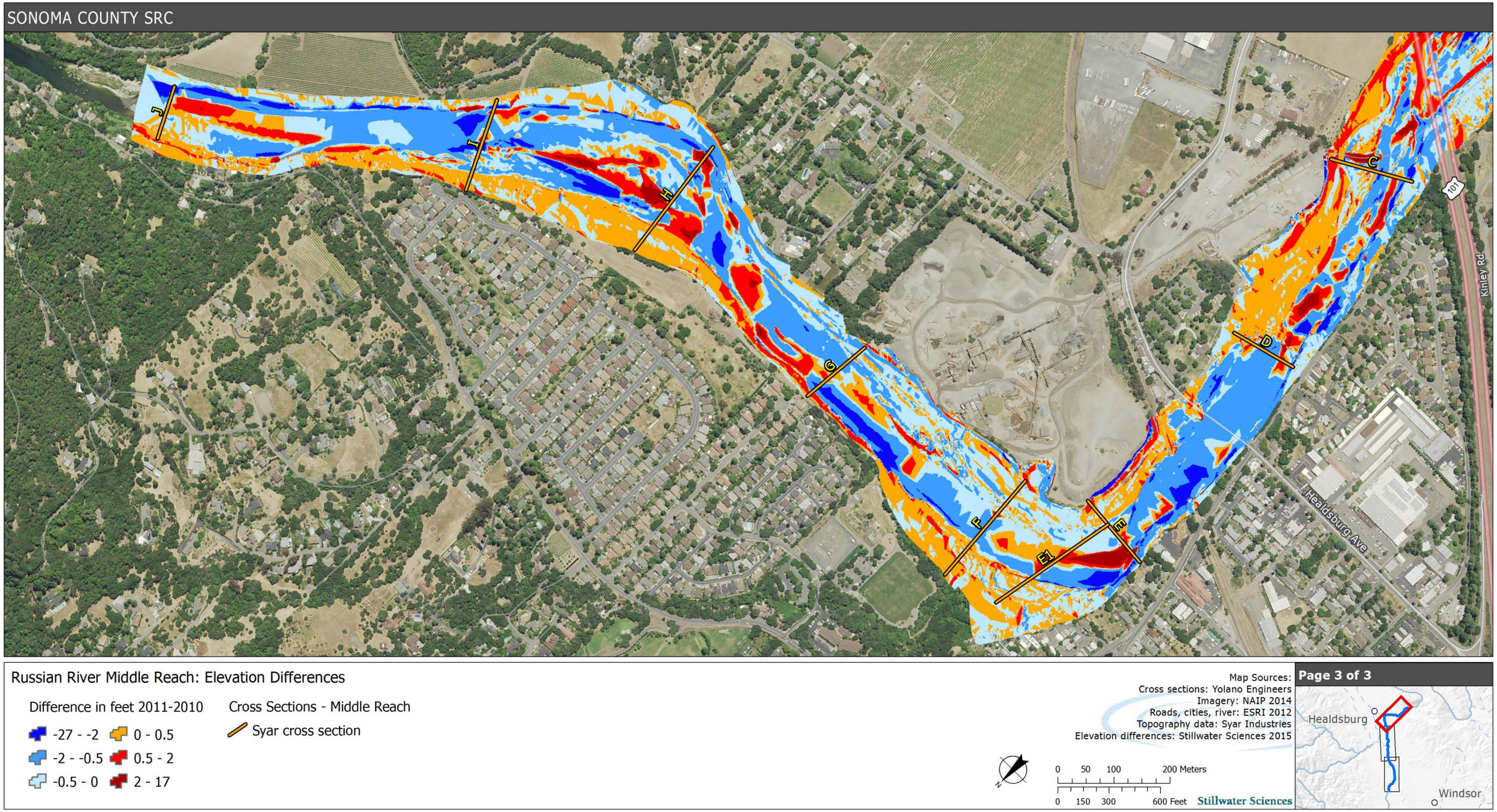

Figure G-36. Map of surface-elevation differencing for 2010–2011 in the Middle Reach (map tile 3 of 3, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

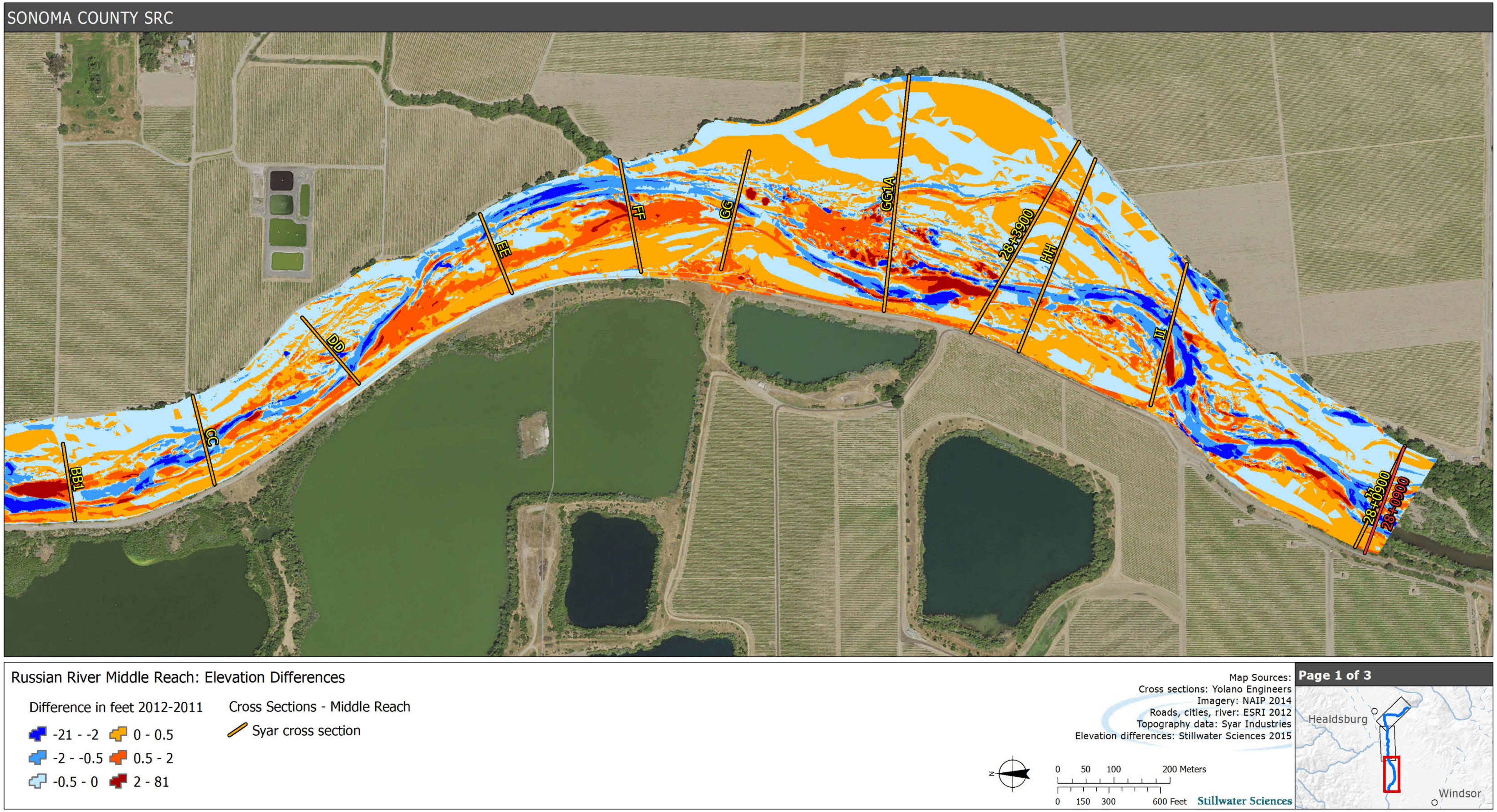

Figure G-37. Map of surface-elevation differencing for 2011-2012 in the Middle Reach (map tile 1 of 3, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

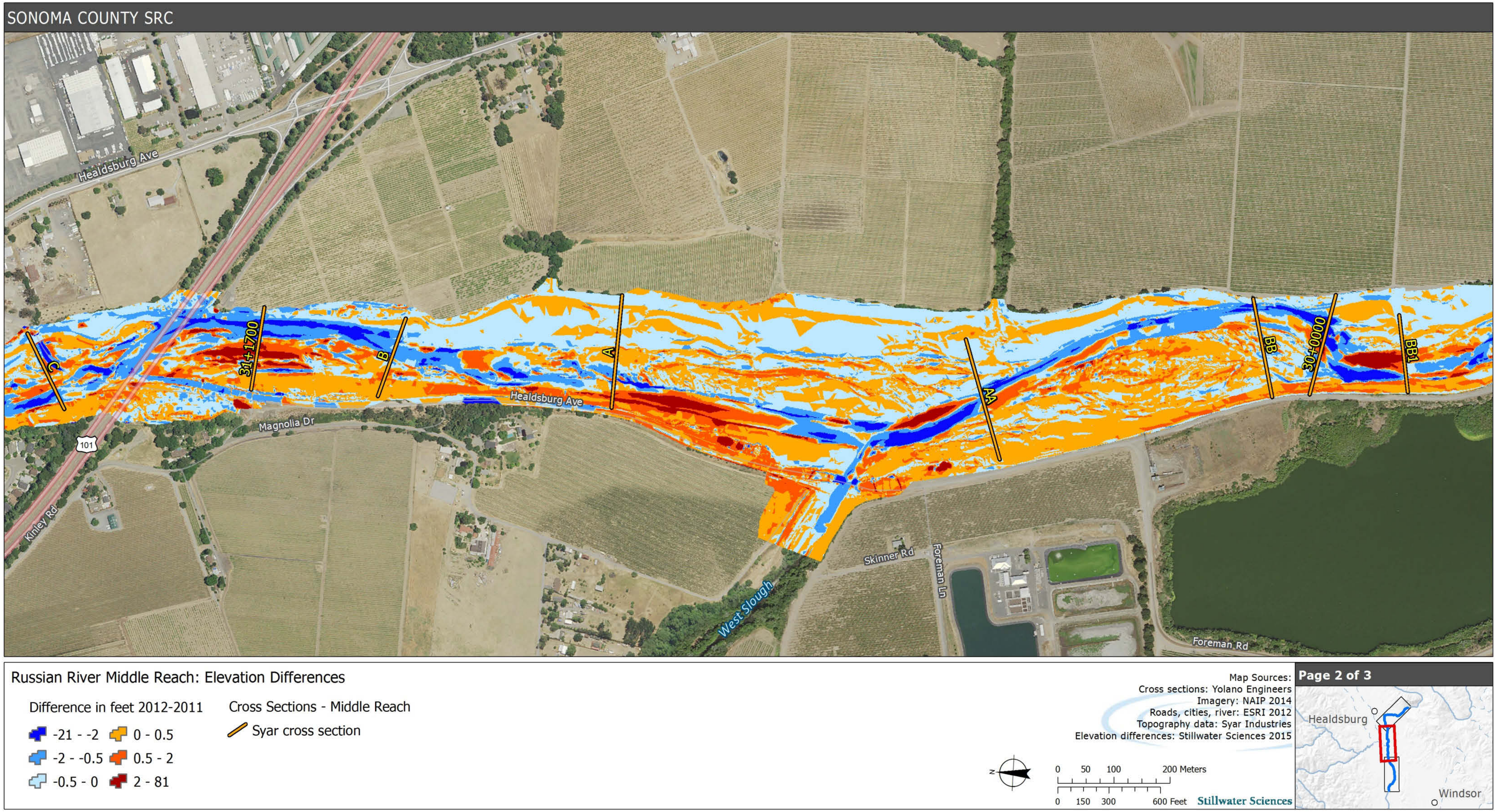

Figure G-38. Map of surface-elevation differencing for 2011-2012 in the Middle Reach (map tile 2 of 3). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

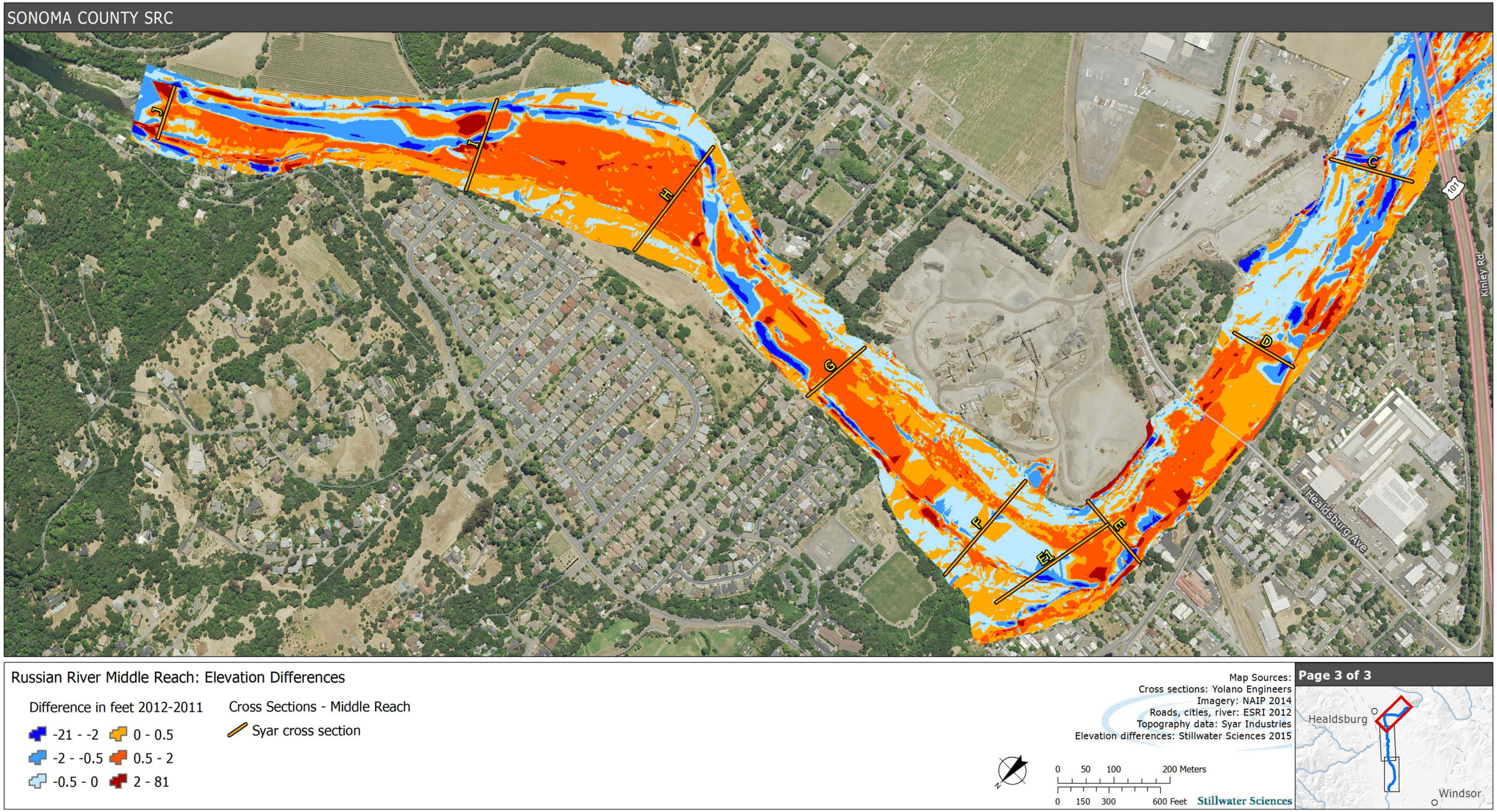

Figure G-39. Map of surface-elevation differencing for 2011-2012 in the Middle Reach (map tile 3 of 3, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

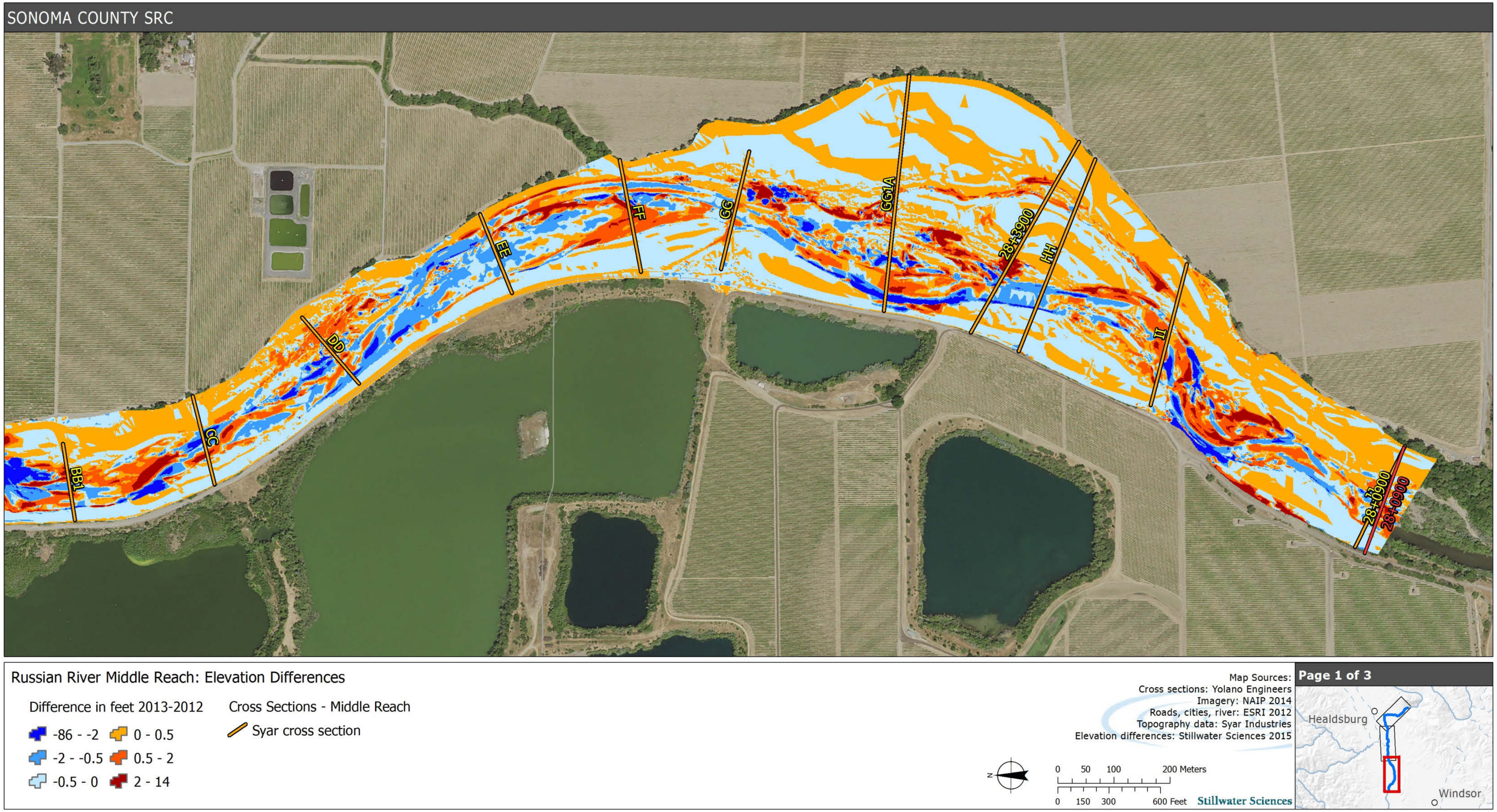

Figure G-40. Map of surface-elevation differencing for 2012-2013 in the Middle Reach (map tile 1 of 3, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

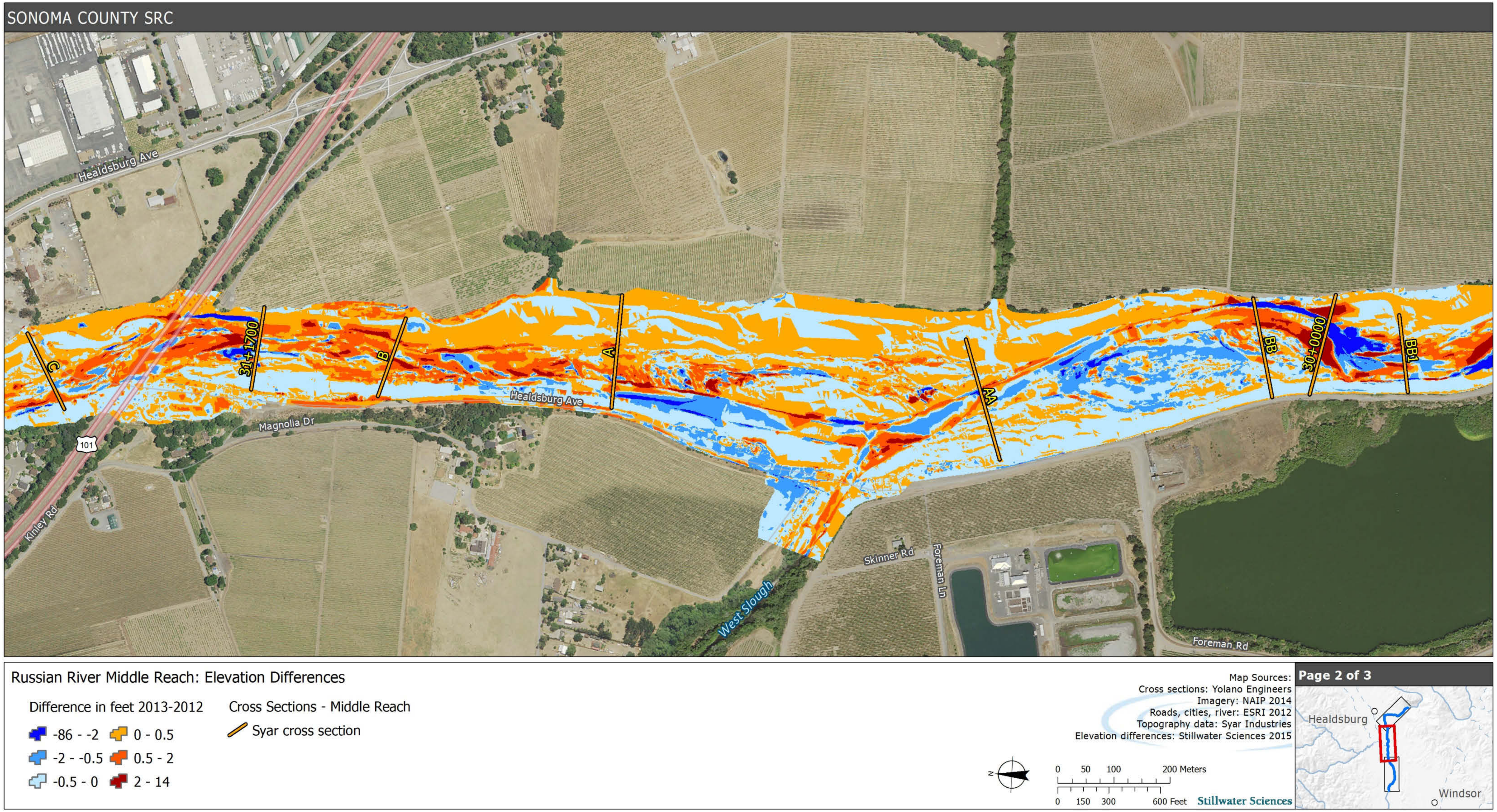

Figure G-41. Map of surface-elevation differencing for 2012-2013 in the Middle Reach (map tile 2 of 3). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

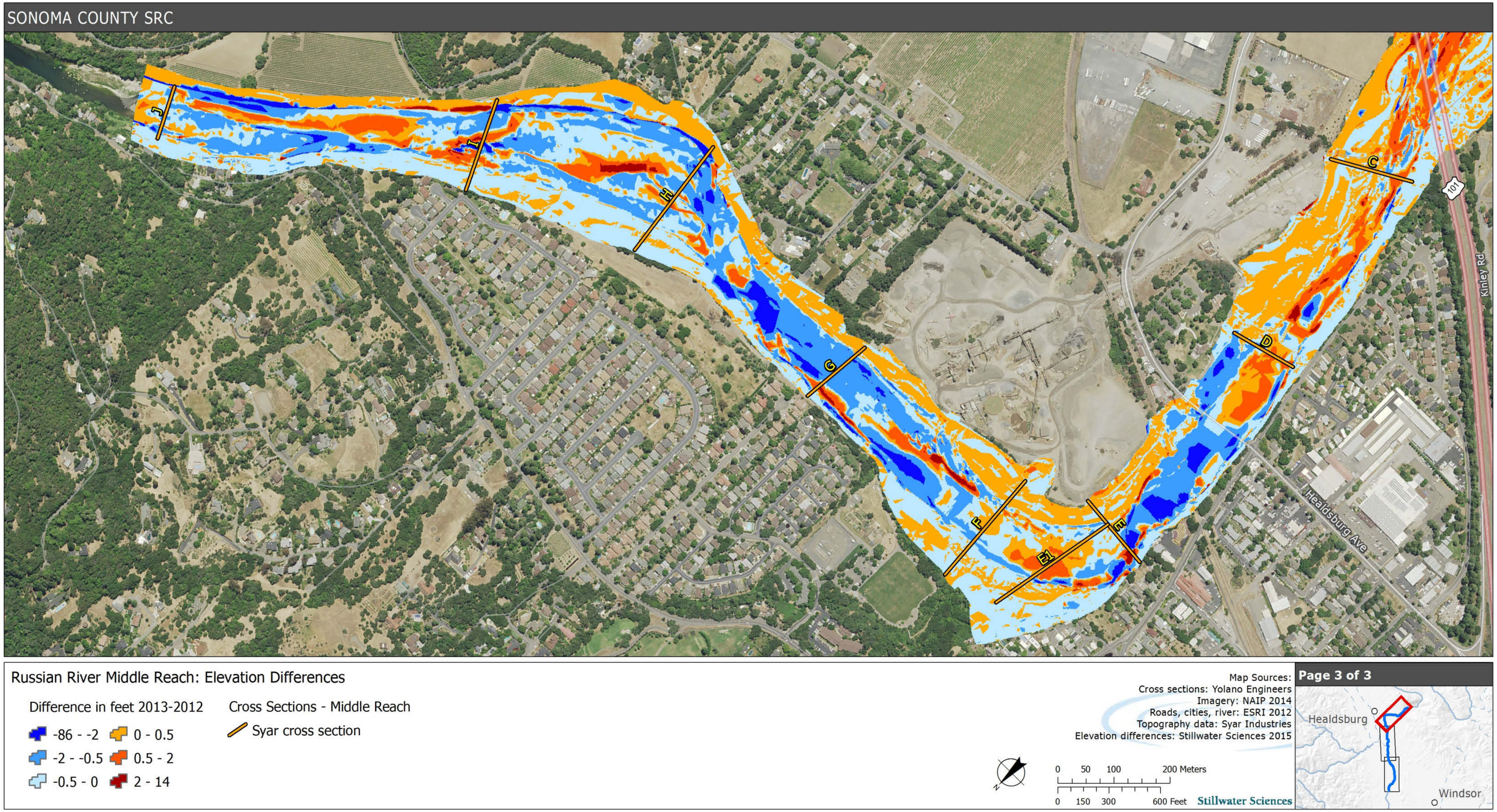

Figure G-42. Map of surface-elevation differencing for 2012-2013 in the Middle Reach (map tile 3 of 3, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

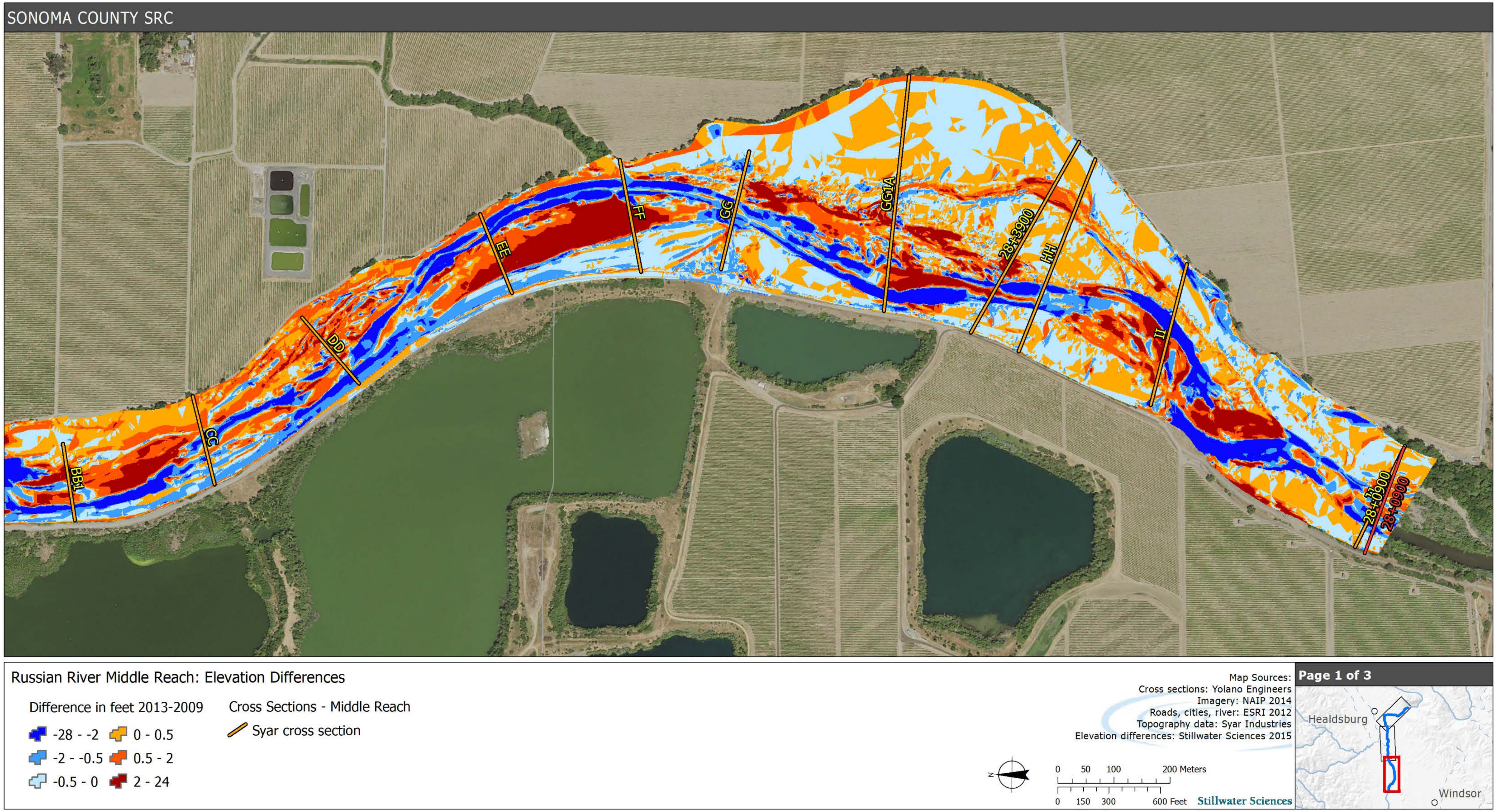

Figure G-43. Map of surface-elevation differencing for 2009–2013 in the Middle Reach (map tile 1 of 3, downstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

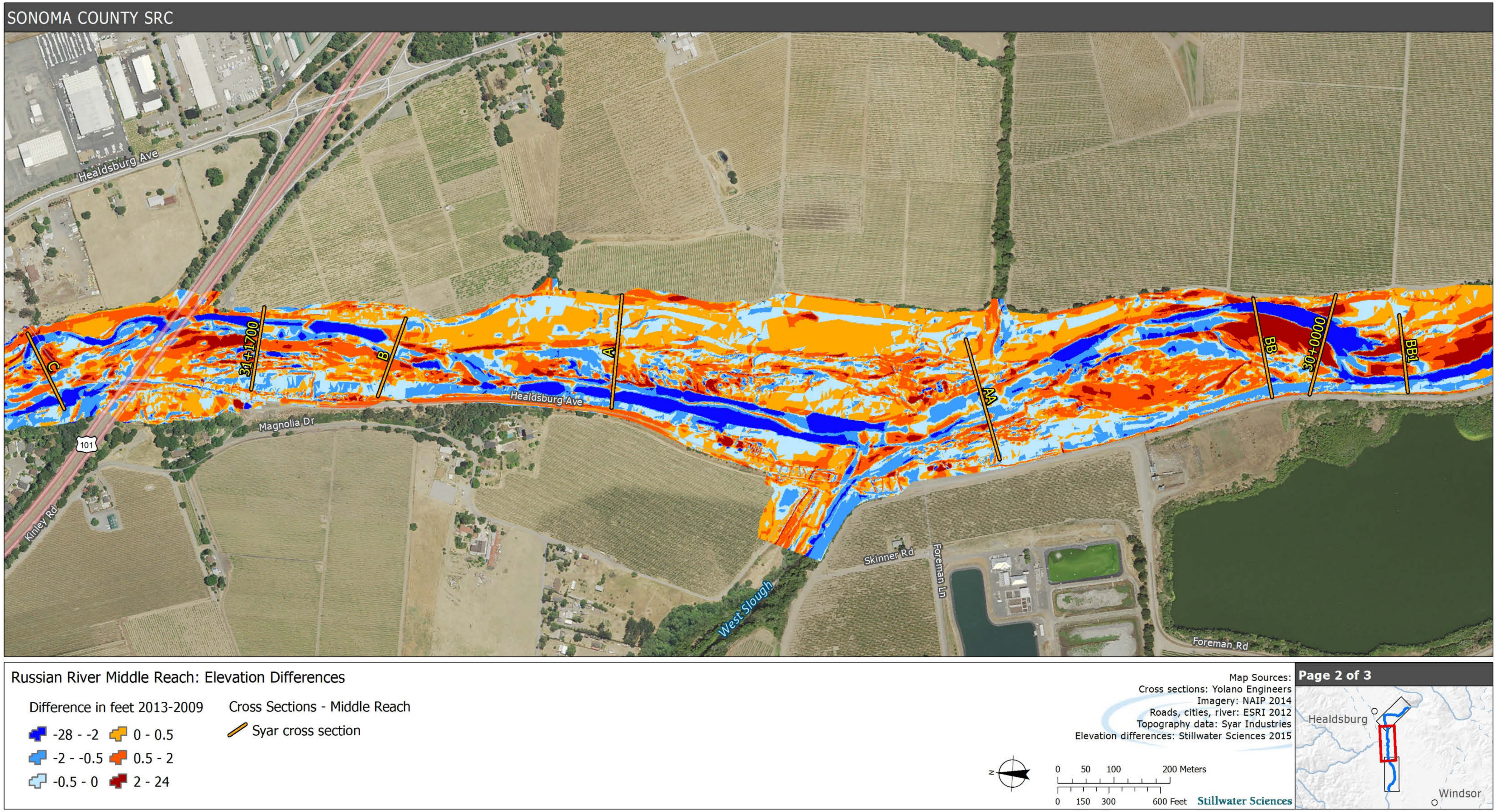

Figure G-44. Map of surface-elevation differencing for 2009-2013 in the Middle Reach (map tile 2 of 3). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).

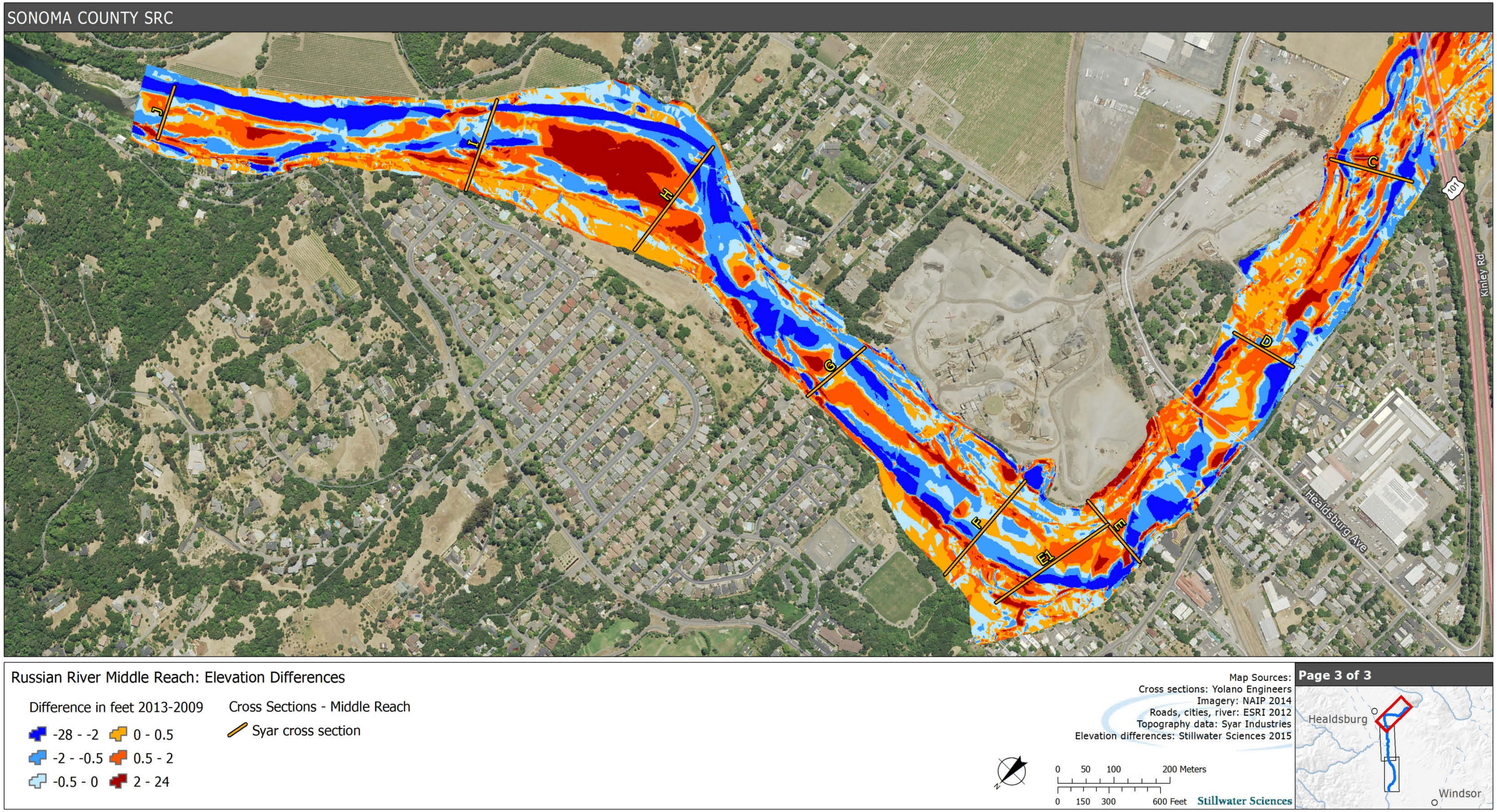

Figure G-45. Map of surface-elevation differencing for 2009-2013 in the Middle Reach (map tile 3 of 3, upstream end). Red-colored contours represent areas of aggradation (deposition) and blue-colored contours represent areas of degradation (erosion).