APPENDIX F

HYDROLOGY AND WATER QUALITY REPORTS

BENCHMARK RESOURCES

APPENDIX F-1

HYDRAULIC DESIGN STUDY

BENCHMARK RESOURCES

Hydraulic Design Study

Prepared for
CEMEX Eliot Facility
CA Mine ID No. 91-01-0009
Alameda County, California
December 17, 2018
(Revised March 4, 2020)

Nathan H. Foged
California Civil Engineer License: C66395
Expiration: June 2020
Engineer in Responsible Charge

William K. Faisst
California Civil Engineer License: C29146
Expiration: March 2019
Senior Review

Brown AND Caldwell

1390 Market Street, Suite 1025
San Francisco, CA 94102
Phone: 415.552.5849

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List of Abbreviations

ADV	Arroyo del Valle
Agreement	The existing agreement between Zone 7 and RMC Lonestar (a predecessor to CEMEX) dated March 29, 1988
AMA	Alameda Creek Alliance
AVL	Arroyo del Valle at Livermore
AVP	Arroyo del Valle at Pleasanton
Balance	Balance Hydrologics, Inc.
BC	Brown and Caldwell
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
CEMEX	CEMEX Construction Materials Pacific, LLC.
CEQA	California Environmental Quality Act
cfs	cubic foot/feet per second
CL	clay
cm/s	centimeters per second
County	Alameda County
EIR	environmental impact report
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
ft	foot/feet
ft/ft	foot/feet vertical per 1 foot horizontal
ft/s	foot/feet per second
ft^2	square foot/feet
GC	clayey gravel
GIS	geographic information system
GW-GC	well-graded gravel with silt, clay, and sand
H:V	horizontal:vertical
HDPE	high-density polyethylene
IACWD	Interagency Advisory Committee on Water Data
Helix	Helix Environmental Planning, Inc.
LiDAR	light detecting and ranging
mm	millimeter(s)
msl	mean sea level
NED	National Elevation Dataset
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
O&M	operations and maintenance
pcf	pounds per cubic feet
PG&E	Pacific Gas and Electric
Project	Proposed conditions under the RPA
Project Site	Approximately 920 acres of land, bounded by Stanley Boulevard to the north and Vineyard Avenue to the south
PVC	polyvinyl chloride
RCP	reinforced concrete pipe
RSP	rock slope protection
RPA	Reclamation Plan Amendment
RWQCB	Regional Water Quality Control Board
SC	clayey sand with gravel
SFEI	San Francisco Estuary Institute
SFPUC	San Francisco Public Utilities Commission
SMP	Surface Mining Permit
Specific Plan	Alameda County Specific Plan for Livermore-Amador Valley Quarry Area Reclamation
Spinardi	Associates
SR 84	State Route 84
Study Reach	ADV channel and floodplain from approximately 1,000 feet downstream of Bernal Avenue to approximately 4,500 feet upstream of Vallecitos Road
SW-SM	well-graded sand with gravel
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
Valley	Livermore-Amador Valley
Zone 7	Zone 7 Water Agency

Executive Summary

CEMEX Construction Materials Pacific, LLC. ("CEMEX") owns and operates the Eliot Quarry, a ±920-acre sand and gravel mining facility, located between the cities of Livermore and Pleasanton, at 1544 Stanley Boulevard in unincorporated Alameda County. CEMEX and its predecessors-in-interest have been continuously mining for sand and gravel at the Eliot Quarry since at least 1906. In addition to mining and reclamation, existing permitted and accessory uses at the Eliot Quarry include aggregate, asphalt and ready-mix concrete processing, as well as ancillary uses such as aggregate stockpiling, load-out, sales, construction materials recycling, and equipment storage and maintenance. CEMEX's mining operations at the site are vested per pre-1957 mining activities and Alameda County Quarry Permits Q-1 (1957), Q-4 (1957), and Q-76 (1969). Surface mining reclamation activities at the site are currently conducted pursuant to Surface Mining Permit and Reclamation Plan No. SMP-23 ("SMP-23"), approved in 1987.

Under the Eliot Quarry SMP-23 Reclamation Plan Amendment Project ("Project"), CEMEX proposes a revised Reclamation Plan that serves to adjust reclamation boundaries and contours, enhance drainage and water conveyance facilities, incorporate a pedestrian and bike trail, and achieve current surface mining reclamation standards. The planned post-mining end uses are water management, open space, and agriculture (non-prime).

Consistent with prior approvals, the Project will develop Lake A and Lake B, which are the first two lakes in the Chain of Lakes pursuant to the Alameda County Specific Plan for Livermore-Amador Valley Quarry Area Reclamation adopted in 1981 ("Specific Plan"). Upon reclamation, Lake A and Lake B, along with their appurtenant water conveyance facilities, will be dedicated to the Zone 7 Water Agency ("Zone 7") for purposes of water storage, conveyance and recharge management.

Lake A reclamation will include installation of a surface water diversion from the Arroyo del Valle ("ADV") to Lake A; conversion of a berm that crosses the west side of the lake to a small island to allow water to flow across the lake; installation of a water conveyance pipeline from Lake A to future Lake C (located off-site to the northwest); and an overflow outlet to allow water to flow back into ADV when Lake A water levels are high to prevent flooding in the localized area. The final surface area of Lake A will be 81 acres as compared to 208 acres in SMP-23. No further mining will occur in Lake A.

Lake B reclamation will include installation of a pipeline turn-out from Lake A, a water pipeline conduit to future Lake C, and an overflow outlet to allow water to flow back into ADV when Lake B water levels are high. The final bottom elevation of Lake B is proposed at 150 feet above mean sea level ("msl"), in order to maximize the available aggregate resource. The final surface area of Lake B will be 208 acres as compared to 243 acres in SMP-23.

To facilitate the southerly progression of Lake B, the Project includes realignment and restoration of a ±5,800 linear foot reach of ADV. The proposed ADV realignment will result in an enhanced riparian corridor that flows around, rather than through (as currently anticipated in SMP-23), Lake B. The ADV realignment was contemplated in the Specific Plan and subject to environmental review in 1981.

Outside of Lake A and Lake B, reclamation treatment for other disturbed areas, including the Lake J excavation (not part of the Chain of Lakes), processing plant sites, and process water ponds will involve backfills and/or grading for a return to open space and/or agriculture.

The Project is a modification of an approved project. Except as outlined above, CEMEX proposes no change to any fundamental element of the existing operation (e.g., mining methods, processing operations, production levels, truck traffic, or hours of operation). A more complete description of the proposed Project is contained in CEMEX's Project Description, Revised Reclamation Plan, and other application materials provided to the County.

CEMEX retained Brown and Caldwell (BC) to perform hydrologic and hydraulic analyses to evaluate water diversion, conveyance, and flooding in support of the RPA. The objectives of this study include:

- Develop a design concept and demonstrate that the elements of the Reclamation Plan designed to address diversion and conveyance into the Chain of Lakes can be feasibly constructed in compliance with known regulatory requirements
- Conduct technical analyses to demonstrate that the realigned ADV channel will remain stable, and that neither the channel modification nor the diversion structure will increase flood risk to neighboring properties and infrastructure

ES.1 Baseline Conditions

Baseline conditions for purposes of subsequent environmental analysis of the RPA pursuant to the California Environmental Quality Act (CEQA) (Cal. Pub. Res. Code § 21166) consist of the existing physical conditions at the Project Site and vicinity as of approximately 2018. Figure ES-1 shows recent aerial photography of Lake A, Lake B, and ADV.

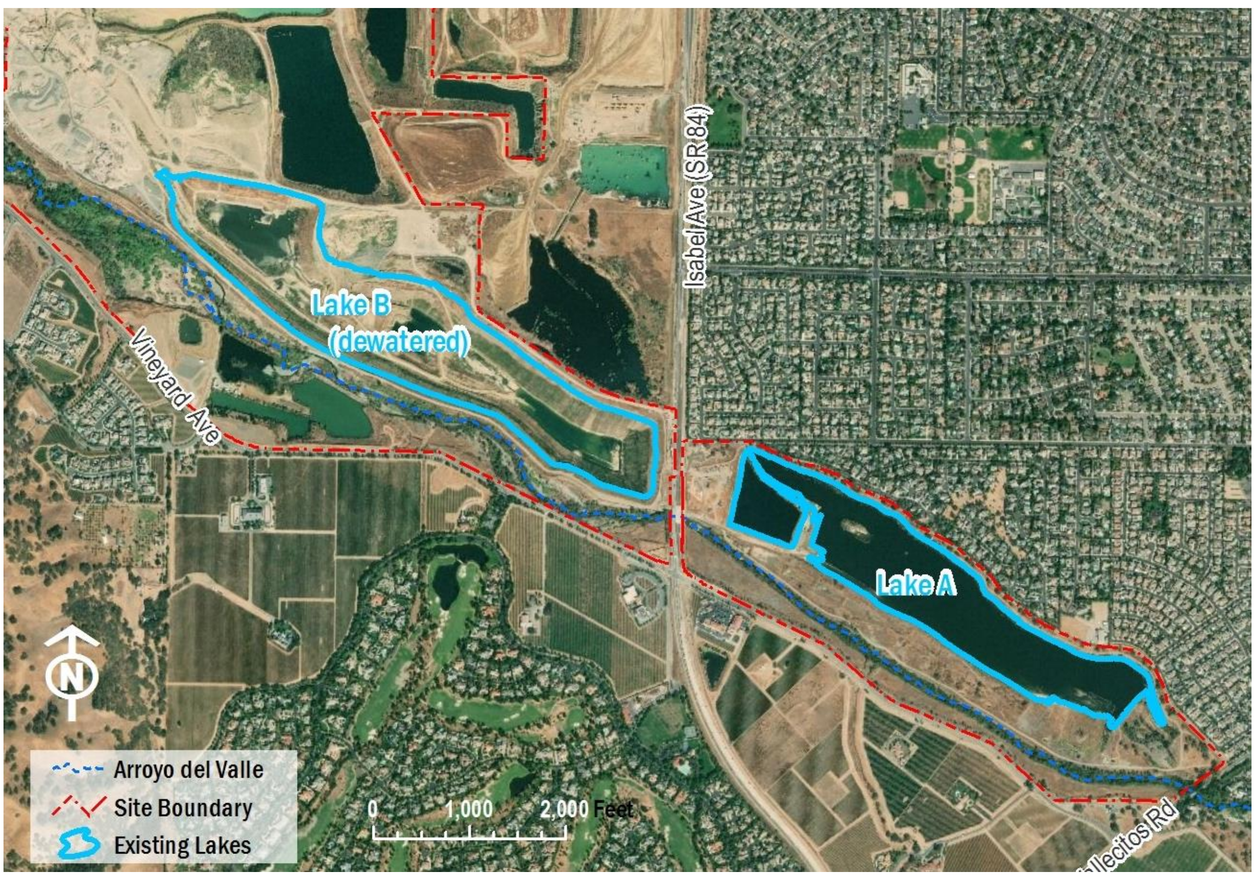

Figure ES-1. Aerial view of Lake A and Lake B baseline conditions at Project Site

Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community (ESRI 2018)

Under existing conditions, ADV flows east to west along the south edge of the Project Site. ADV enters the Project Site at the eastern boundary after it flows under Vallecitos Road and then flows parallel to Lake A. ADV then flows under an existing highway bridge for State Route 84 (SR 84) (Isabel Avenue) and continues parallel to Lake B. ADV continues west into Island Pond (outside of the proposed RPA boundary) and then exits the Project Site at the western boundary where it discharges into Boris Lake. Information pertaining to the existing hydrologic and geomorphic conditions of ADV can be found in Sections 3 and 4, respectively.

With an average water surface elevation of 373 ft msl, the existing baseline water surface area at Lake B, if pumping has stopped and the lake is not dewatered, covers approximately 121 acres. Existing topographic elevations within the footprint of Lake B range from 265 feet msl to approximately 422 feet msl at the east side of Lake B. Under SMP-23, the County assumed excavation in Lake B would reach a depth of 340 feet msl. On April 15, 2013, the County administratively approved a minor amendment to SMP-23 adjusting the depth of the existing footprint of Lake B from 340 feet msl to 250 feet msl, with a CEQA categorical exemption. The existing water surface area of Lake A covers approximately 77 acres with a water surface elevation of 415 ft msl.

ES.2 Proposed Project

The proposed project for the RPA will include diversion and conveyance facilities constructed to divert water into and between the proposed Lakes A and B, as well as future Lake C (in the SMP-16 area, which is controlled by others), as can be seen in Figure ES-2. CEMEX will construct a diversion structure at Lake A, and a new conduit will connect Lake A to Lake C, with an optional turnout to Lake B. In addition, a conduit will connect Lake B and Lake C. The conduits to and from Lake C will be stubbed and capped at CEMEX's property lines until such time that future Lake C is developed. CEMEX will realign ADV with a new constructed channel and floodplain corridor south of Lake B along Vineyard Avenue. New outlets on Lake A and Lake B will allow flow back into ADV when water levels are high. The following paragraphs describe each of these facilities.

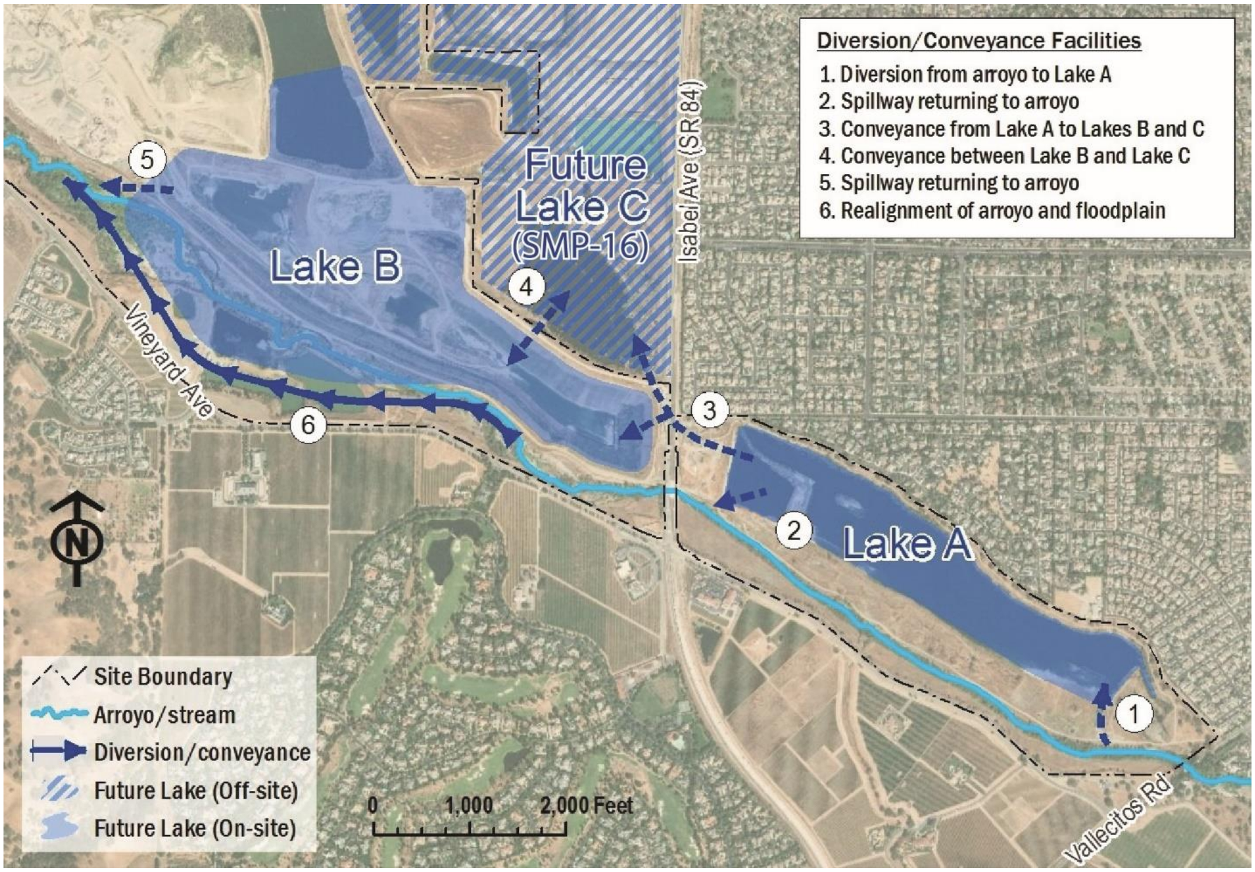

Figure ES-2. Surface flows related to ADV and proposed Lakes A, B, and C

Lake A Diversion. The diversion from ADV to Lake A will consist of an intake and fish screen, a low-head diversion dam to control water levels in the channel, a bypass structure for fish passage, a flow control structure, and a conduit into Lake A. The diversion will feature an infiltration bed concept that includes a 100-foot-wide (extending in the horizontal direction perpendicular to the stream bank) by 200-foot-long gravel infiltration bed to be constructed along the north bank of ADV. To meet the objectives of the Specific Plan and requirements of the Zone 7 Agreement, the diversion structure will convey up to 500 cfs through an 84-inch-diameter pipe into Lake A.

Lake Conduits. As described in the Specific Plan, future Lake C will be located west of Isabel Avenue and generally north of Lake B (County 1981). Conduits will be constructed between Lake A and Lake C and Lake B and Lake C, consistent with the approved SMP-23 Reclamation Plan and Zone 7 Agreement (Lone Star Industries, Inc. 1987; Zone 7 1988). In addition, CEMEX has agreed to provide a turnout from Lake A into Lake B as part of the Lake A to Lake C conveyance structure. To meet the objectives of the Specific Plan and requirements of the Zone 7 Agreement, the pipeline from Lake A to Lake C will be 84 in diameter to provide a conveyance capacity of 500 cfs. The Lake B to Lake C conduit will be a 30-inch-diameter pipe placed at an elevation that allows gravity flow between the two lakes.

Lake A Outlet. CEMEX proposes to construct an overflow outlet at the southwest end of Lake A to allow water to flow back into ADV. The outlet will consist of a 270-ft wide shallow spillway lined with pit run gravel that slopes south toward ADV at 3 horizontal to 1 vertical (personal communication with Karen Spinardi, civil engineer with Spinardi Associates, Oct., 2018).

Lake B Outlet. CEMEX proposes to construct an outlet on Lake B to allow water to flow back into ADV through a controlled and stable pathway. The outlet will be located at the west end of Lake B and will consist of an armored trapezoidal weir and chute, with an armored outlet apron. The outlet crest will be 60 feet (ft) wide perpendicular to the flow with 4 (horizontal)-to-1 (vertical) side slopes, and the trapezoid will be at least 5 ft deep, thus resulting in a top width of 60 ft for the trapezoidal section. The outlet crest is 120 ft wide in the direction of the flow. The outlet flow path will be lined with rock riprap to mitigate the potential for erosion to occur.

Arroyo Realignment. CEMEX will move the arroyo closer to Vineyard Avenue in a realigned stream channel and floodplain, creating an enhanced riparian and aquatic habitat. A total corridor width of 260 ft will set aside 30-foot-wide sections for access roads on either side. The corridor is approximately 5,800 ft long. The upstream end of the corridor is roughly 390 ft above mean sea level (msl) and the downstream end is roughly 360 ft above msl; the resulting channel slope is equal to approximately 0.56 percent.

ES.3 Impact Evaluations

BC performed modeling and mapping analyses for existing conditions (as of 2018) and proposed conditions (the proposed RPA) to evaluate potential impacts to ADV channel stability and flooding. BC developed a hydraulic model of the ADV channel and floodplain from approximately 1,000 ft downstream of Bernal Avenue to approximately 4,500 ft upstream of Vallecitos Road (Study Reach[1]) using Hydrologic Engineering Centers River Analysis System (HEC-RAS) software (Version 5.0, 2016). BC reviewed existing hydraulic modeling data, 2014 LiDAR data received from Zone 7, and topographic data from a 2018 topographic survey of the Project Area to develop an up-to-date existing-conditions model of ADV. BC then modified that model to reflect the conditions of the proposed project.

ES.3.1 Channel Stability

During field assessments Balance identified that signs of degradation and instability still occur at some points along ADV, suggesting that the channel has not finished adjusting to anthropogenic changes in the watershed. However, given that the dam was constructed more than 45 years ago and that in-channel gravel mining has ceased, it is reasonable to assume that the rate of degradation has considerably decreased in recent years. Inspection reports for the SR 84 (Isabel Avenue) bridge corroborate this assumption, stating that the channel under Isabel Avenue degraded 6 ft between 1983 and 1999, but then stabilized.

Given these findings, BC designed the realigned channel to maintain a quasi-equilibrium state by maintaining sediment continuity with upstream reaches. BC evaluated average annual sediment loads for four reaches of ADV: (1) upstream of the Project Site in Sycamore Grove Park (SGP), (2) along Lake A, (3) along Lake B, and (4) downstream of the Project Site along Shadow Cliffs.

BC performed the hydraulic design evaluations in parallel with the sediment continuity calculations to compare the average annual sediment load for the new realigned reach (i.e., proposed conditions) with the sediment loads transported from upstream reaches under existing (i.e., baseline) conditions. Hydraulic design parameters, such as cross-sectional dimensions and channel sinuosity/slope, were adjusted to nearly match the sediment loads, thus creating a realigned stream channel that balances or maintains sediment continuity with upstream reaches (Figure ES-3). According to Lane's Principle, maintaining such continuity reduces the potential long-term aggradation or degradation, and thus the proposed channel and floodplain configuration is expected to be stable and persist.

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[1] A map showing the extent of the Study Reach is provided with the hydraulic modeling results in Appendix I.

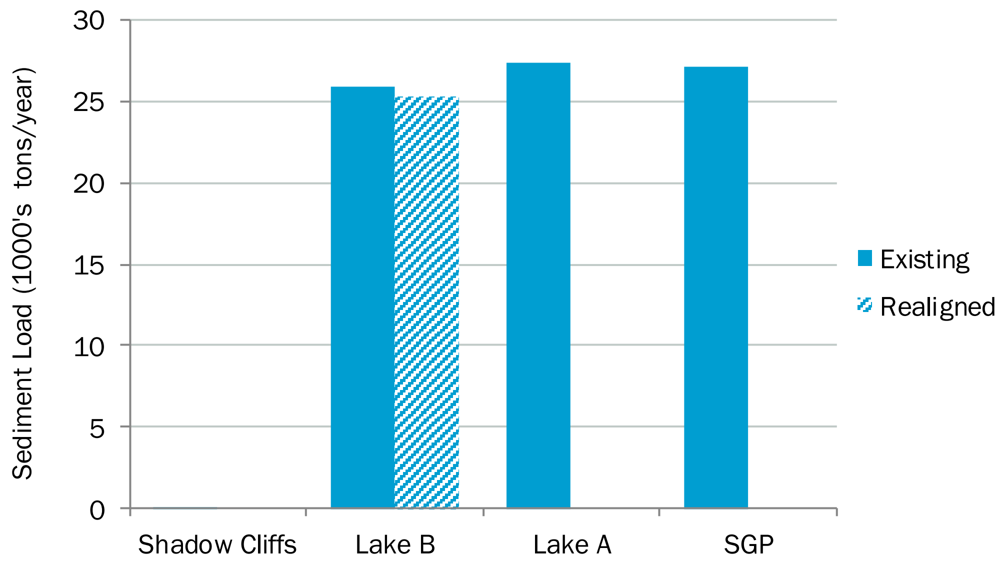

Figure ES-3. Average annual sediment load transported through ADV reaches

Sediment loads calculated for the post-dam period of record were converted to average annual values.
Sediment loads transported through Shadow Cliffs are nearly zero because water is impounded, and velocities are low.

Long-term Stability. The Isabel Avenue bridge has been widened and modified as part of the SR 84 Expressway Widening project. This bridge widening exists under both baseline and proposed conditions. According to the *Initial Study with Negative Declaration/Environmental Assessment with Finding of No Significant Impact* for that project, the California Department of Transportation (Caltrans) has widened the bridge by 53 ft, expanding to the east, and constructed a parallel pedestrian/bicycle trail bridge to the east of the expanded highway bridge (Caltrans 2008). In 2009, the engineering firm WRECO prepared a *Bridge Design Hydraulic Study Report* for the SR 84 Expressway Widening project that included a scour analysis for the Isabel Avenue bridge (WRECO 2009). In that report, WRECO concluded that the ADV channel is generally stable.

Localized Scour. Although long-term stability will remain unchanged, potential always exists for transient scour to occur during high flows. Both contraction scour and local scour are common at bridges where water must flow through a bridge opening that is narrower than the upstream floodplain, and structural components (e.g., piers and abutments) can obstruct flow.

According to WRECO, Caltrans coordinated extensively with its consultant design team to evaluate countermeasures to mitigate the potential for local scour to occur at the Isabel Avenue bridge abutments and piers (WRECO 2009). Caltrans concluded that piers of the widened section of the highway bridge and the new trail bridge, as well as abutments for the new trail bridge, should be supported by piles driven as deep as the estimated maximum depth of scour at each location. In addition, the existing rock slope protection (RSP) at the Isabel Avenue bridge has been upgraded.

The above findings suggest that the ADV channel near the Isabel Avenue bridge is generally stable in its current configuration (i.e., baseline condition), and will continue to be under future (i.e., proposed project) conditions. Because Caltrans has implemented measures to address the potential for bridge scour at the upstream structures, further actions are not required related to bridge scour as part of the RPA for SMP-23.

ES.3.2 Flood Impacts

FEMA has developed flood hazard mapping for ADV as part of the Flood Insurance Study (FIS) for the County. BC obtained technical data from FEMA as a basis for this study; however, BC found that significant changes have occurred along the Project Site since the original FEMA study. Therefore, new and updated analyses were needed to obtain an accurate depiction of flooding potential under existing baseline conditions.

BC evaluated flood hazard impacts by performing steady-state hydraulic simulations of the 100-year flood to calculate peak water surface elevations, and then delineated potentially inundated areas using geographic information system (GIS) tools. BC performed additional steady-state hydraulic simulations using the proposed-conditions (i.e., implementation of reclamation pursuant to the RPA) geometric model. BC compared the 100-year water surface profiles for existing (i.e. baseline) and proposed conditions along the Project Site (Figure ES-4). The results indicate that water surface elevations along the realigned corridor increase by an average of approximately 2.2 ft. At the Lake A diversion dam, the 100-year water surface elevation increases by approximately 2.2 ft at the diversion dam, but the increase diminishes rapidly in the upstream direction and is negligible approximately 500 ft upstream of the diversion.

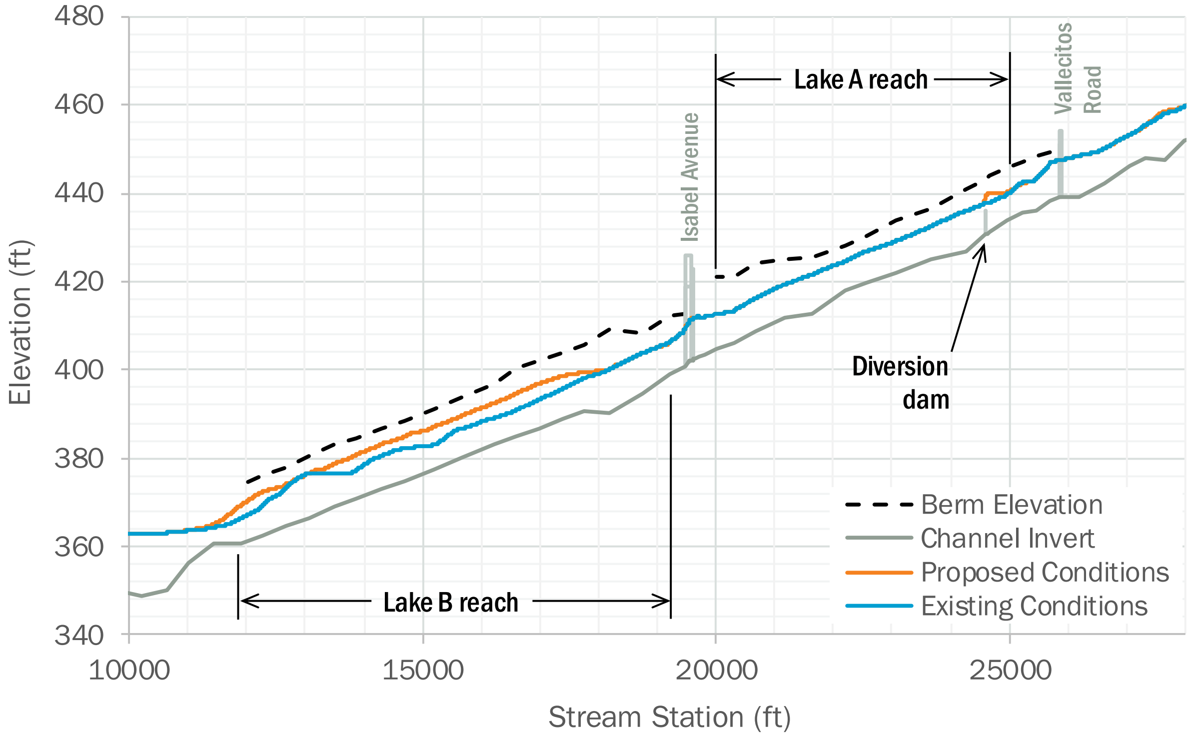

Figure ES-4. 100-year water surface profiles for existing and proposed conditions

Berm elevations based on proposed ADV realignment, existing ground, and raised berm elevations as proposed for RPA

Given the potential increases in 100-year water surface elevations as compared to existing conditions, BC examined potential flood inundation impacts at each location. Figure ES-5 shows a direct comparison of the estimated inundation areas under existing and proposed conditions along Lake B. Proposed changes along Lake B do not increase flood inundation areas outside of the realigned corridor or cause any new offsite flood impacts because the realigned corridor will be designed to contain flood waters.

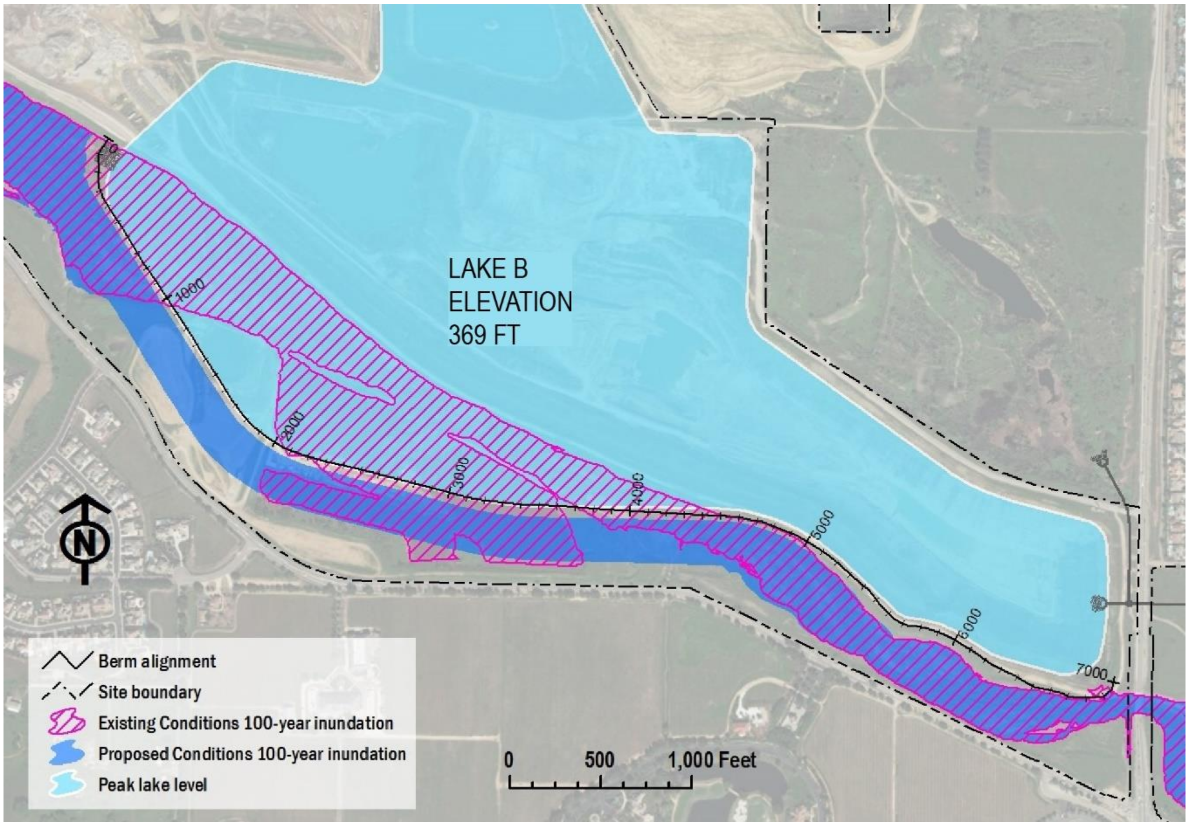

Figure ES-5. 100-year water surface profiles for existing and proposed conditions at Lake B

BC also compared the 100-year flood inundation areas along Lake A (Figure ES-6) and found that the Lake A diversion structure increases the inundated area just upstream of the diversion dam by approximately 1.9 acres. However, this area is confined to the CEMEX property and does not affect any roadways or structures.

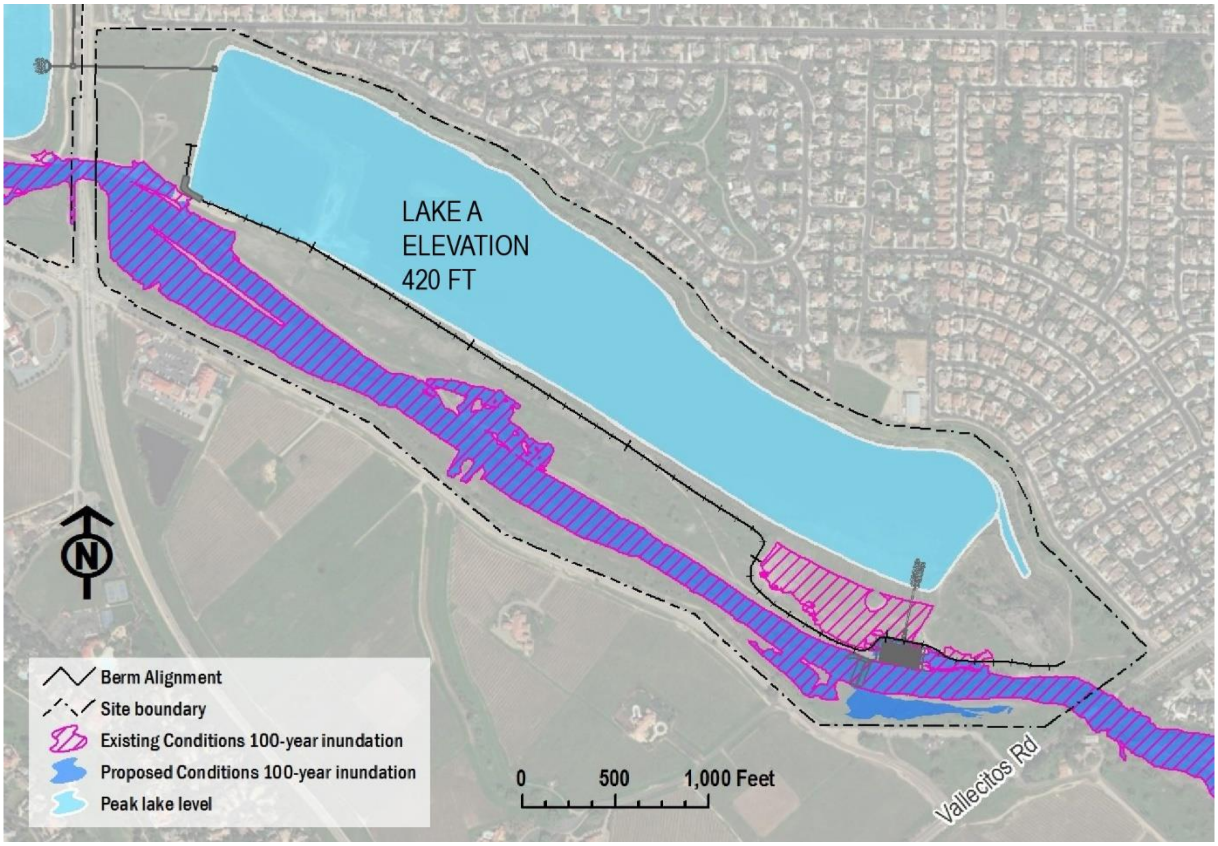

Figure ES-6. 100-year flood inundation areas for existing and proposed conditions at Lake A

ES.3.3 Berm Elevations

Berms will be located between Lake A and ADV and Lake B and ADV, as can be seen in Figure ES-5 and ES-6. The grade along the existing berm alignments will be raised where necessary to prevent overtopping during the 100-year flood. Under the proposed project for the RPA, new berms are to be constructed with a factor of safety above the estimated water surface elevations for the 100-year ADV flood event to provide a factor of safety in design following Alameda County's Hydrology and Hydraulics Manual, Code of Federal Regulations, Title 44, Section 65.10(b) Chapter I (10–1–2002 edition). This includes the following freeboard requirement:

> *(1) Freeboard. (i) Riverine levees must provide a minimum freeboard of three feet above the water surface level of the base flood. An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted. An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.*

It is important to note that the berms are not intended to be a flood protection levee as defined by 44 CFR 65.10, and will not be designed to protect developed areas with permanent structures. Moreover, the berms will not remove areas from the Special Flood Hazard Area (SFHA) as shown on Alameda County's adopted Flood Insurance Rate Maps. The purpose of the berms is to reduce the potential for ADV to overtop and for flood waters to flow into Lakes A and B during reclamation operations and in future reclaimed conditions.

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Section 1

Introduction

CEMEX Construction Materials Pacific, LLC. ("CEMEX") owns and operates the Eliot Quarry, a ±920-acre sand and gravel mining facility, located between the cities of Livermore and Pleasanton, at 1544 Stanley Boulevard in unincorporated Alameda County. CEMEX and its predecessors-in-interest have been continuously mining for sand and gravel at the Eliot Quarry since at least 1906. In addition to mining and reclamation, existing permitted and accessory uses at the Eliot Quarry include aggregate, asphalt and ready-mix concrete processing, as well as ancillary uses such as aggregate stockpiling, load-out, sales, construction materials recycling, and equipment storage and maintenance. CEMEX's mining operations at the site are vested per pre-1957 mining activities and Alameda County Quarry Permits Q-1 (1957), Q-4 (1957), and Q-76 (1969). Surface mining reclamation activities at the site are currently conducted pursuant to Surface Mining Permit and Reclamation Plan No. SMP-23 ("SMP-23"), approved in 1987.

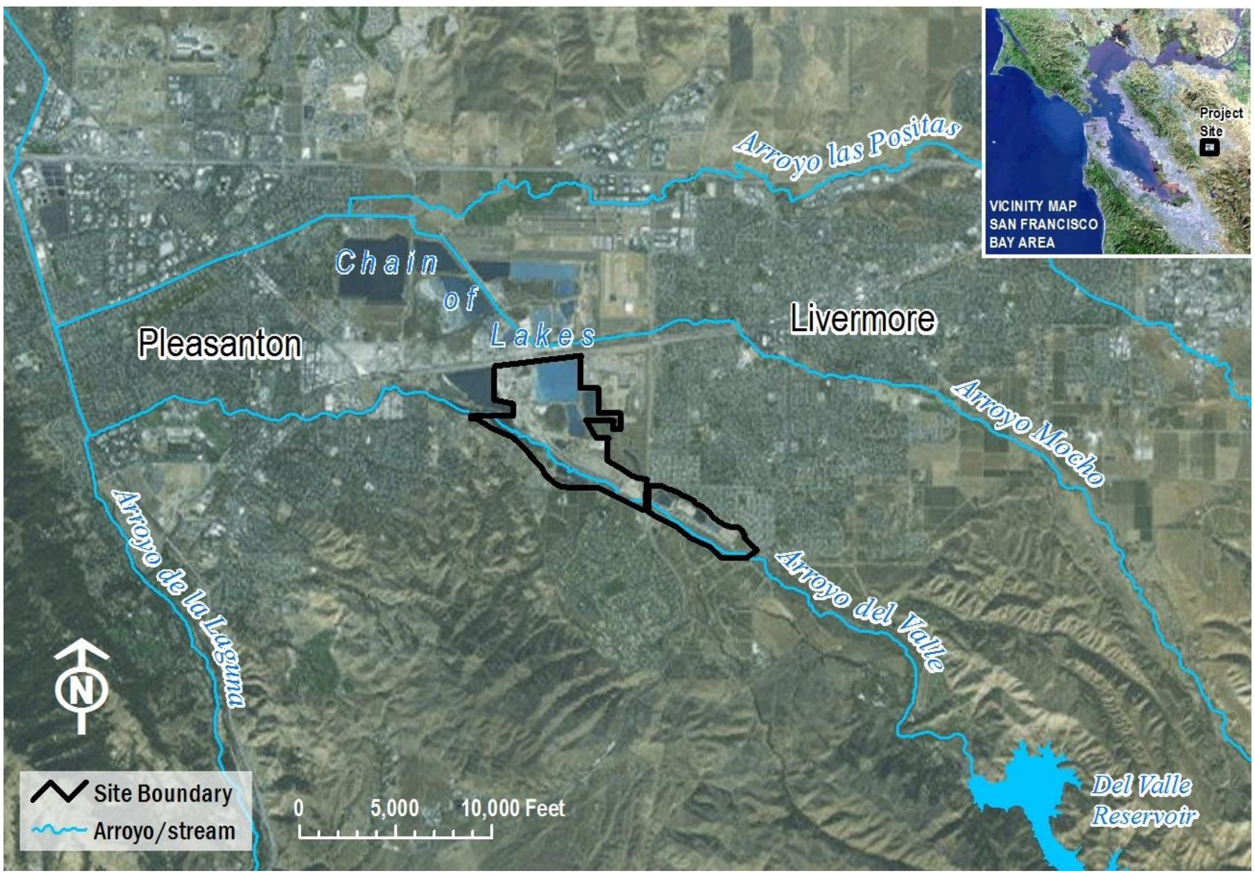

Figure 1-1. Vicinity and location of Project Site

1.1 Reclamation of the Project Site

Under the Eliot Quarry SMP-23 Reclamation Plan Amendment Project ("Project"), CEMEX proposes a revised Reclamation Plan that serves to adjust reclamation boundaries and contours, enhance drainage and water conveyance facilities, incorporate a pedestrian and bike trail, and achieve current surface mining reclamation standards. The planned post-mining end uses are water management, open space, and agriculture (non-prime).

Consistent with prior approvals, the Project will develop Lake A and Lake B, which are the first two lakes in the Chain of Lakes pursuant to the *Alameda County Specific Plan for Livermore-Amador Valley Quarry Area Reclamation* adopted in 1981 ("Specific Plan"). Upon reclamation, Lake A and Lake B, along with their appurtenant water conveyance facilities, will be dedicated to the Zone 7 Water Agency ("Zone 7") for purposes of water storage, conveyance and recharge management.

Lake A reclamation will include installation of a surface water diversion from the Arroyo del Valle ("ADV") to Lake A; conversion of a berm that crosses the west side of the lake to a small island to allow water to flow across the lake; installation of a water conveyance pipeline from Lake A to future Lake C (located off-site to the northwest); and an overflow outlet to allow water to flow back into ADV when Lake A water levels are high to prevent flooding in the localized area. The final surface area of Lake A will be 81 acres as compared to 208 acres in SMP-23. No further mining will occur in Lake A.

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Outside of Lake A and Lake B, reclamation treatment for other disturbed areas, including the Lake J excavation (not part of the Chain of Lakes), processing plant sites, and process water ponds will involve backfills and/or grading for a return to open space and/or agriculture.

The Project is a modification of an approved project. Except as outlined above, CEMEX proposes no change to any fundamental element of the existing operation (e.g., mining methods, processing operations, production levels, truck traffic, or hours of operation). A more complete description of the proposed Project is contained in CEMEX's Project Description, Revised Reclamation Plan, and other application materials provided to the County.

1.2 Technical Objectives

CEMEX retained Brown and Caldwell (BC) to perform hydrologic and hydraulic analyses to evaluate water diversion, conveyance, and flooding in support of the RPA. The objectives of this study include:

- Develop a design concept and demonstrate that the elements of the Reclamation Plan designed to address diversion and conveyance into the Chain of Lakes can be feasibly constructed in compliance with known regulatory requirements
- Conduct technical analyses to demonstrate that the realigned ADV channel will remain stable, and that neither the channel modification nor the diversion structure will increase flood risk to neighboring properties and infrastructure

1.3 Document Organization

This report is organized into the following sections:

1. Introduction: brief overview and technical objectives of this study
2. Background: general discussion of the site, baseline conditions, and proposed project
3. Hydrology: summary of hydrologic conditions including statistical analyses of arroyo discharges
4. Geomorphology: summary of geomorphic conditions, including field observations
5. Proposed Project: design concepts for water management features
6. Impact Evaluations: discussion on channel stability and flood conveyance and inundation for the proposed project

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Section 2

Background

The Livermore-Amador Valley (Valley) is a wide depression in the Diablo Range, bounded by the East Bay Hills to the west and the Altamont Hills to the east. The western portion is the Amador Valley, and it includes the city of Pleasanton; the eastern portion is the Livermore Valley, and it includes the city of Livermore. The two valleys together form the Valley.

According to the San Francisco Estuary Institute (SFEI), the Valley was formed by geological processes and provides a wide space for streams to spread and sink. Numerous streams that drain out of the surrounding hills have deposited sediments over thousands of years and filled the Valley (SFEI 2013).

Arroyo Mocho and ADV are two major streams draining into the southern portion of the Valley. Historically, these were wide and braided streams that deposited large amounts of coarse sediment transported from their headwaters in the Diablo Range (SFEI 2013). Sand and gravel mining has occurred along the Arroyo Mocho and ADV alluvial formations since the late 1800s, including the areas around the Eliot Quarry. Over the years, mining and development activities have rerouted and channelized much of the lower reaches of Arroyo Mocho and ADV. ADV's existing channel flows along the southern portion of the Project Site, as shown in Figure 1-1.

2.1 Arroyo del Valle

ADV is in the northern Alameda Creek watershed. The arroyo[2] drains an area of approximately 172 square miles before it discharges to Arroyo de la Laguna west of Pleasanton. Arroyo de la Laguna flows south and discharges into Alameda Creek near the town of Sunol. Alameda Creek then flows west through the East Bay Hills before discharging into San Francisco Bay.

Approximately 85 percent (i.e., 146 square miles) of the ADV basin is located upstream of Del Valle Reservoir, constructed in 1968 to serve as off-channel storage for water delivered through the South Bay Aqueduct (part of the California State Water project) and for flood control. Zone 7 is one of three water agencies served by the South Bay Aqueduct. Table 1 shows the annual entitlements for each agency. Zone 7 also uses a small portion of Del Valle Reservoir capacity to store runoff from the local watershed (Zone 7 2017). Although Del Valle Reservoir serves primarily as water supply storage, a portion of its 77,100-acre-foot capacity is normally reserved for flood control.

2 An arroyo is a stream or a watercourse and is generally characterized by steep terrain and intermittent or ephemeral flow; arroyos are typically associated with arid regions such as the southwestern United States. The terms arroyo and stream are used interchangeably throughout this report.

Table 2-1. Water Agencies Served by the South Bay Aqueduct

Water Agency	Annual Entitlement (acre-ft)
Zone 7	80,619
Alameda County Water District	42,000
Santa Clara Valley Water District	100,000
Total	**188,000**

Source: CDWR 1968, 2001; Zone 7 2015.

Del Valle Reservoir altered the hydrologic flow regime in the lower reaches of ADV (Kamman 2009). Peak flows decreased and large-magnitude flood flows were virtually eliminated. Managed releases during the dry season resulted in perennial flow conditions along the valley floor, rather than the historical intermittent flow conditions when the arroyo was dry in the summertime (Kamman 2009). Altered flows also contributed to changes in the ADV channel, the once actively braided channel network along the valley floor now has shifted to a more defined central channel system (Kamman 2009).

Directly downstream of the dam, ADV flows through a narrow, sinuous canyon until it reaches the valley floor about 1 mile downstream, near the Veterans Administration Hospital upstream of the Project Site. At this point, the channel and floodplain become wider and, in the past, was more active and braided. Sycamore Grove Park is an important community park that preserves mature western sycamore trees along this reach of the historical ADV floodplain. This park stretches approximately 2 miles from the hospital to Vallecitos Road.

The Project Site is just downstream of Sycamore Grove Park. ADV flows along the southern portion of the Project Site and then through two small lakes along the south side of the Shadow Cliffs Regional Recreation Area, before continuing west through the city of Pleasanton. Several small streams drain into ADV between the dam and its confluence with Arroyo de la Laguna.

Additional discussions regarding ADV hydrology and geomorphology are provided in Sections 3 and 4, respectively.

2.2 Chain of Lakes

In 1987, Lone Star Industries developed the SMP-23 Reclamation Plan in accordance with the Specific Plan, which was adopted by the County in November 1981. The Specific Plan describes a Chain of Lakes reclamation concept (Figure 2-1), where excavated gravel quarries will be converted into a series of open lakes and used for storage and groundwater recharge (County 1981). After mining is complete and the quarry sites are reclaimed, the Chain of Lakes will be dedicated to Zone 7. Per the SMP-23 Reclamation Plan, and consistent with the Specific Plan, mining at the Eliot Quarry will result in the formation of two of these lakes (Lone Star Industries, Inc. 1987):

- Lake A will be located north of Vineyard Avenue, between Isabel Avenue (State Route [SR] 84) and Vallecitos Road
- Lake B will be located north of Vineyard Avenue, between Isabel Avenue (SR 84) and the Shadow Cliffs Regional Recreation Area

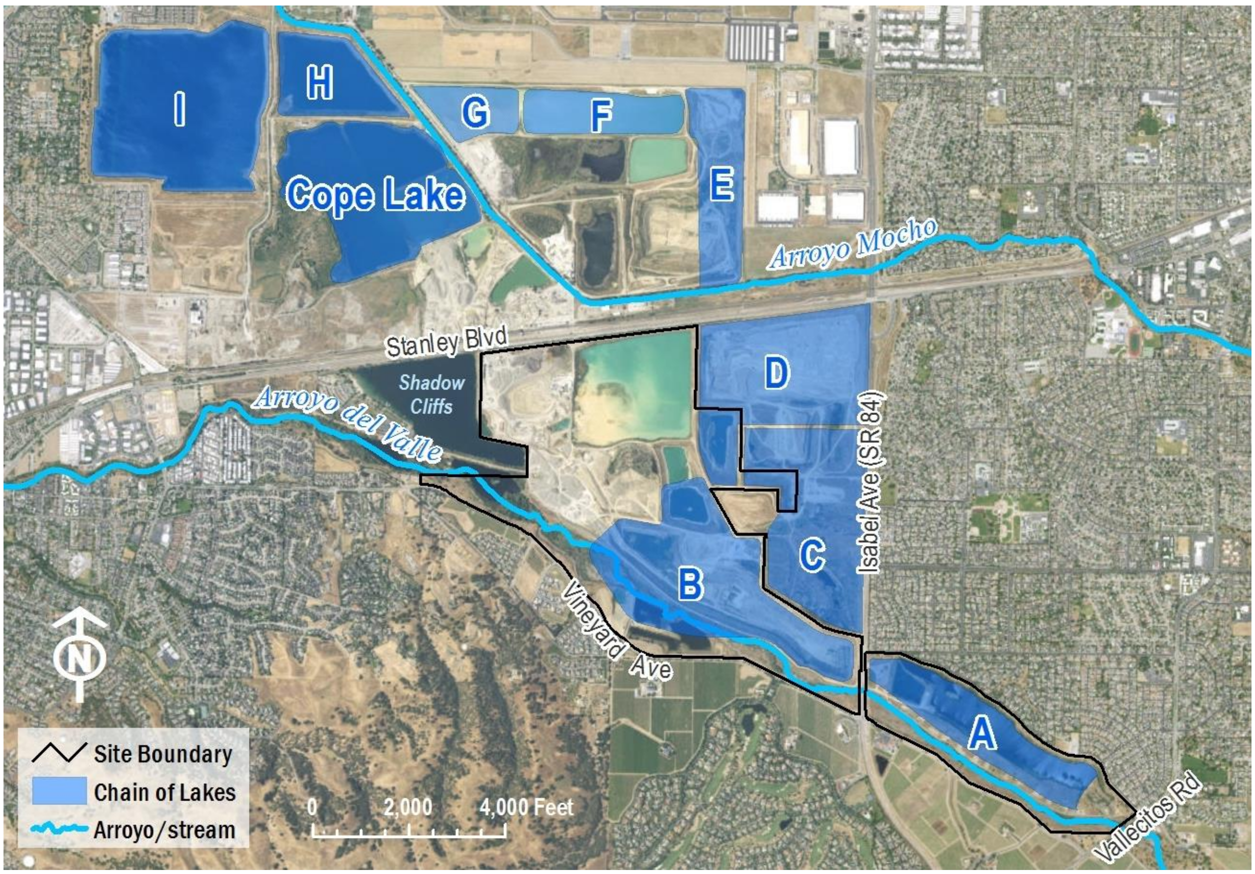

Figure 2-1. Chain of Lakes reclamation concept

Source: Zone 7 2014

The existing SMP-23 Reclamation Plan indicates that excavation at Lake A and Lake B would extend as far south as Vineyard Avenue, and that ADV will flow into and through the pits during active mining operations (Figure 2-2) (Lone Star Industries, Inc. 1987).

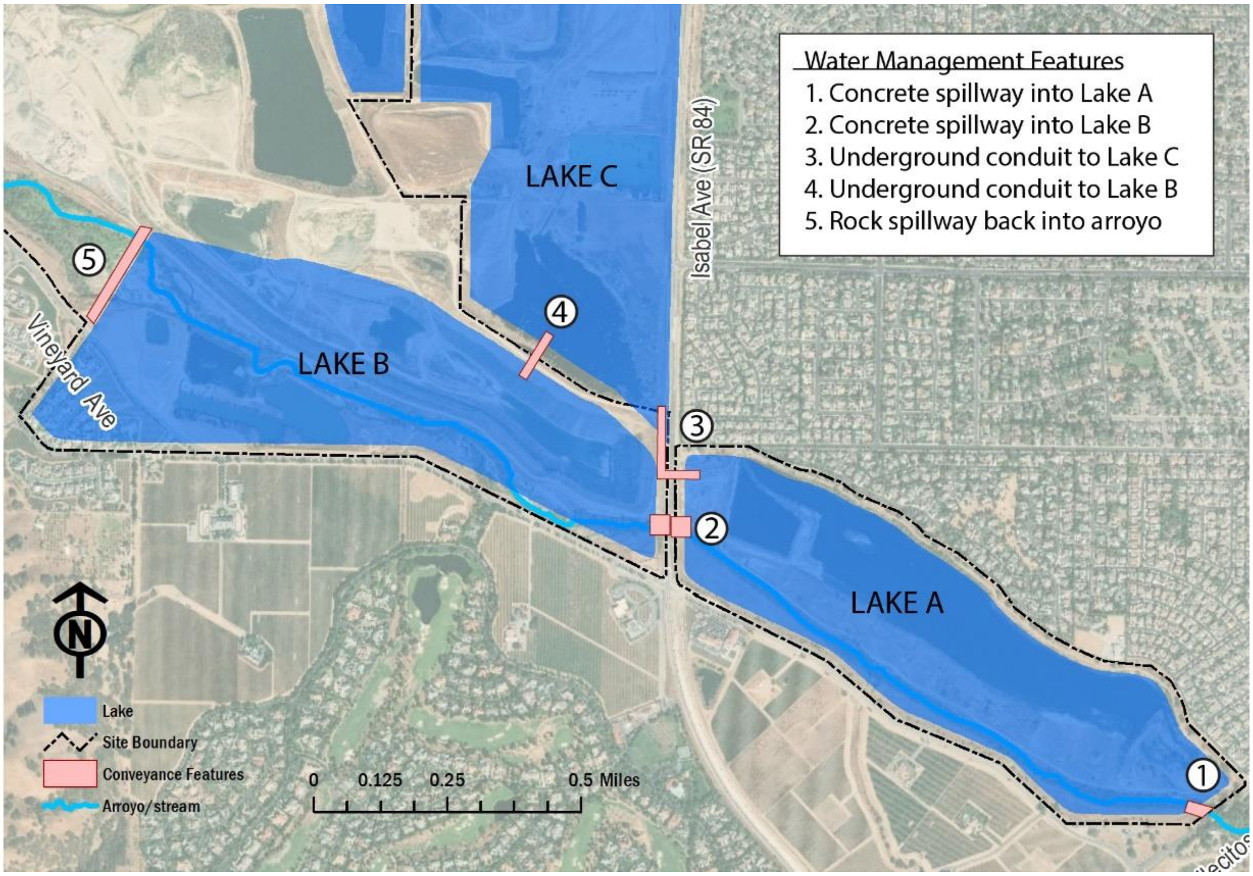

Figure 2-2. Lakes and water management features for SMP-23 (Lone Star Industries, Inc. 1987)

The RPA proposes to reconfigure the footprints of both Lake A and Lake B to keep the channel of ADV separate from them (Figure 2-3). Lake A will no longer be excavated as far south as Vineyard Avenue; as such, the existing ADV channel can remain separate. Lake B still will extend south through the currently disturbed ADV channel alignment, but CEMEX will construct a new channel alignment closer to Vineyard Avenue and enhance the initial hydraulic and biological function of the arroyo in this reach.

2.3 Baseline Conditions

For purposes of this Project, baseline conditions for purposes of subsequent environmental analysis of the RPA pursuant to the California Environmental Quality Act (CEQA) (Cal. Pub. Res. Code § 21166) will conservatively consist of the existing physical conditions at the Project Site and vicinity as of approximately 2018. Figure 2-4 shows recent aerial photography of Lake A, Lake B, and ADV.

Figure 2-4. Aeial view of Lake A and Lake B baseline conditions at Project Site

Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community (ESRI 2018)

Under existing conditions, ADV flows east to west along the south edge of the Project Site. ADV enters the Project Site at the eastern boundary after it flows under Vallecitos Road and then flows parallel to Lake A. ADV then flows under an existing highway bridge for State Route 84 (SR 84) (Isabel Avenue) and continues parallel to Lake B. ADV continues west into Island Pond (outside of the proposed RPA boundary) and then exits the Project Site at the western boundary where it discharges into Boris Lake. Information pertaining to the existing hydrologic and geomorphic conditions of ADV can be found in Sections 3 and 4, respectively.

With an average water surface elevation of 373 ft msl, the existing baseline water surface area at Lake B, if pumping has stopped and the lake is not dewatered, covers approximately 121 acres. Existing topographic elevations within the footprint of Lake B range from 265 feet msl to approximately 422 feet msl at the east side of Lake B. Under SMP-23, the County assumed excavation in Lake B would reach a depth of 340 feet msl. On April 15, 2013, the County administratively approved a minor amendment to SMP-23 adjusting the depth of the existing footprint of Lake B from 340 feet msl to 250 feet msl, with a CEQA categorical exemption. The existing water surface area of Lake A covers approximately 77 acres with a water surface elevation of 415 ft msl.

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Section 3

Hydrology

ADV is in the northern Alameda Creek watershed. The arroyo drains an area of approximately 172 square miles before it discharges to Arroyo de la Laguna west of Pleasanton. Arroyo de la Laguna flows south and discharges into Alameda Creek near the town of Sunol. Alameda Creek then flows west through the East Bay Hills before discharging into San Francisco Bay.

3.1 Watershed Description

Approximately 85 percent (146 square miles) of the ADV basin is located upstream of Del Valle Reservoir. The watershed above Del Valle Dam includes steep-sloped canyons comprising primarily hard sedimentary and metasedimentary rocks with small areas of basic igneous rocks (Welch et al. 1966).

In 1968 the State of California Department of Water Resources constructed the dam with a reservoir capacity of approximately 77,100 acre-feet; the reservoir serves as off-channel storage for water delivered through the South Bay Aqueduct (part of the California State Water project) and provides some flood control storage. Zone 7—one of three water agencies served by the South Bay Aqueduct—uses Del Valle Reservoir for water supply storage and reserves a small portion of its capacity to store runoff from the local watershed.

Del Valle Reservoir altered the hydrologic flow regime in the lower reaches of ADV (Kamman 2009). Peak flows decreased and large-magnitude floods were virtually eliminated. Managed releases during the dry season resulted in perennial flow conditions along the valley floor, rather than the historical intermittent flow conditions when the arroyo was dry in the summertime (Kamman 2009). Altered flows have also contributed to changes in the ADV channel, the once actively braided channel network along the valley floor now has shifted to a more defined central channel system (Kamman 2009).

Directly downstream of the dam, ADV flows through a narrow, sinuous canyon until it reaches the valley floor about 1 mile downstream, near the Veterans Administration Hospital upstream of the Project Site. From there, ADV flows approximately 2 miles through Sycamore Grove Park, which is an important community park that preserves mature western sycamore trees along this reach of the historical ADV floodplain.

CEMEX's Eliot Facility is northwest of Sycamore Grove Park, just downstream from the Vallecitos Road crossing. ADV flows along the southern portion of the Eliot Facility site adjacent to the Lake A and Lake B mining areas. The arroyo flows through the site for approximately 3 miles before flowing into Island Pond at the northwest edge. The arroyo flows through Boris Lake along the south side of the Shadow Cliffs Regional Recreation Area, and then continues west through the city of Pleasanton.

3.2 Streamflow Analysis

Streamflow data records are available for two U.S. Geological Survey (USGS) stream-gauging stations on ADV:

- **USGS 11176500 Arroyo del Valle at Livermore (AVL):** average daily discharge available from 1912 to present, located just downstream of Del Valle Reservoir and upstream of the Study Reach
- **USGS 11176600 Arroyo del Valle at Pleasanton (AVP):** average daily discharge available from 1957–86, located just downstream of Main Street in the city of Pleasanton and downstream of the Study Reach

Figure 3-1 shows a correlation comparison of the average daily discharge data for each of the USGS stream gauges. Construction of Del Valle Reservoir in 1968 substantially altered the hydrologic flow regime (i.e., frequency and duration of stream flows) in ADV; therefore, BC used streamflow data from only 1968 onward for this analysis (Kamman 2009). Concurrent data ranging from 1968–85 show a high level of correlation (i.e., R-squared = 0.96), likely because of the dominance of regulated flow releases from the Del Valle Reservoir. Given the close correlation of data from the two gauges, BC narrowed the hydrologic analyses to just data from the AVL gauge, which has a substantially longer period of record and data available through the present.

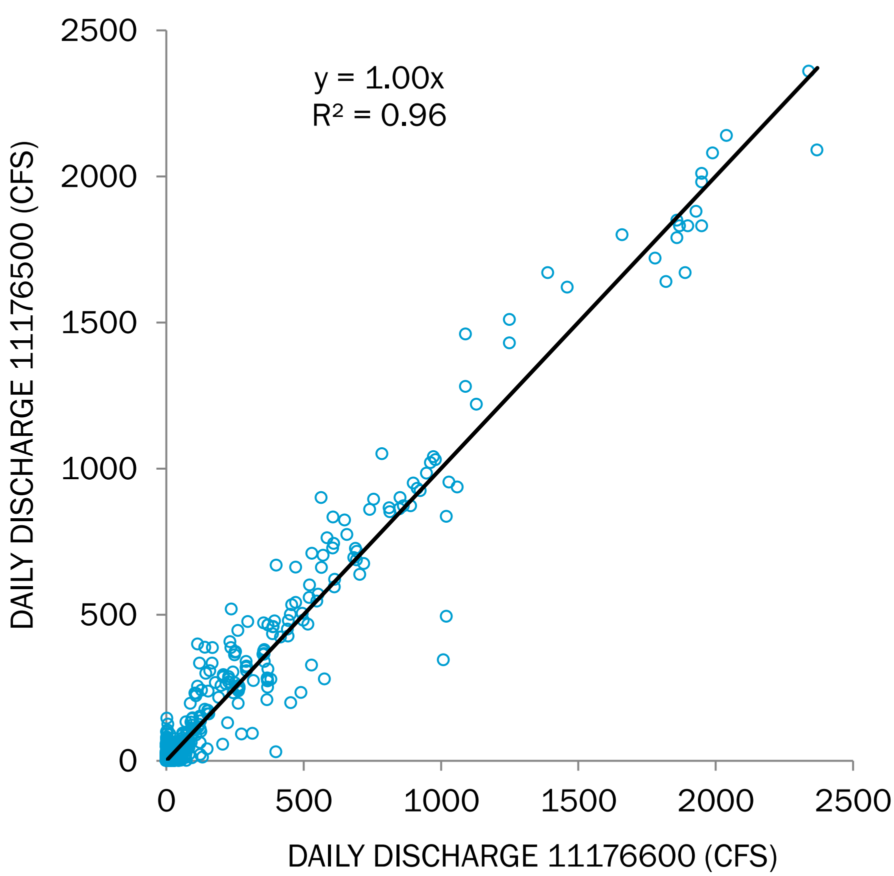

Figure 3-1. Correlation of average daily discharge data at USGS gauges 11176500 (AVL) and 11176600 (AVP)

The correlation shown is a simple comparison; BC only used recent data from 11176500 (AVL) for flow frequency and duration analyses (see the following section).

3.2.1 Flow Duration and Distribution

BC divided the mean daily discharge time series for AVL into two periods:

- **Pre-dam data** (i.e., before the construction of Del Valle Reservoir in 1968) span from 1912–67; however, records are unavailable from 1930–57, so the time series covers 28 water years
- **Post-dam data** span from 1969 to 2017 for a period covering 48 water years

BC calculated flow duration curves using the mean daily flow data for the pre-dam and post-dam periods (Figure 3-2).

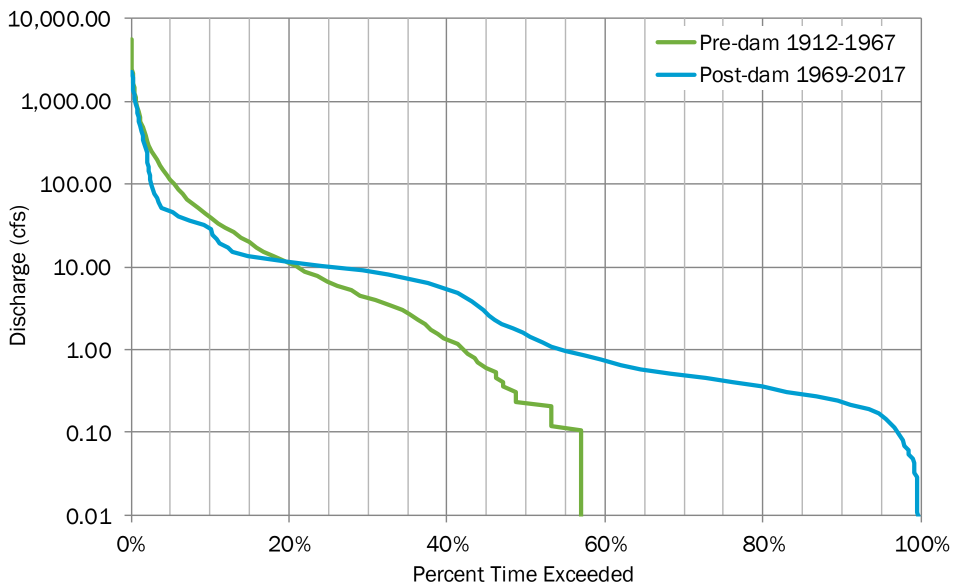

Figure 3-2. Pre-dam and post-dam flow duration curves calculated using average daily flows at AVL

Data from 1968 were not included in this analysis because that was the year the dam was under construction. The minimum recorded flow is 0.01 cfs; therefore, the percentage of time for which there is no flow in the arroyo is assumed to be one minus the percent of time exceeded for the minimum value. More specifically, before the dam was constructed (1912-1967) the arroyo was dry approximately 43 percent of the time. After the dam was constructed (1969-2017), the arroyo was dry less than 1 percent of the time.

Figure 3-2 indicates that the construction of Del Valle Reservoir resulted in a reduction in high flows and an increase in low flows, as would be expected for a regulated system. Moreover, a comparison of flow duration curves shows that ADV shifted from intermittent to perennial flow conditions. Table 3-1 lists specific flow exceedances for percentiles of interest, based on commonly used criteria for fish passage evaluations (Taylor and Love 2010).

Table 3-1. Exceedance Flows for ADV

Percent Time Exceeded	Stream Flow (cfs)	
	Pre-dam (1912–67)	Post-dam (1969–2015)
1	678	548
5	104	45
10	37	27
50	0.20	1.4
90	– [a]	0.22
95	– [a]	0.15

a. Pre-dam streamflow data at AVL indicate that the arroyo was dry 43% of the time.

Another way to analyze streamflow data is to create a distribution histogram. BC used 100 logarithmically distributed flow bins to generate flow distribution histograms for pre-dam and post-dam conditions (Figure 3-3).

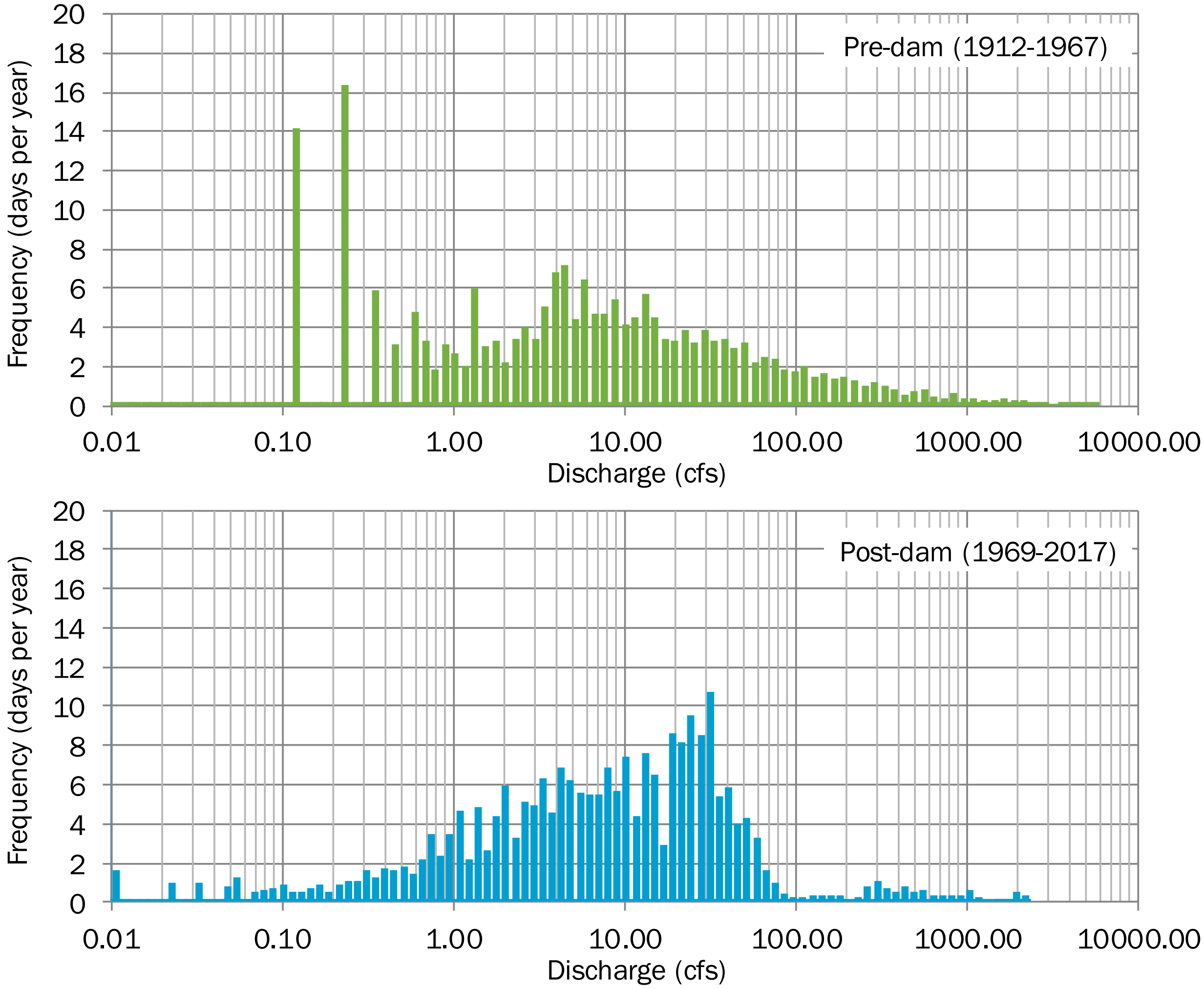

Figure 3-3. Flow frequency histogram for AVL daily discharges

Figure 3-3 indicates that, with the construction of Del Valle Reservoir, flows in ADV shifted to a bimodal distribution with two distinct peaks, relating to the seasonal discharges at the dam. BC visually examined the post-dam average daily discharge data for the AVL gauge and found that the 16 most recent water years—2002 through 2017—exhibit a reasonably consistent pattern of seasonal flow releases (Figure 3-4). BC then calculated the mean and median flows by day of the year for the period of record spanning from 2002–17 (Figure 3-5).

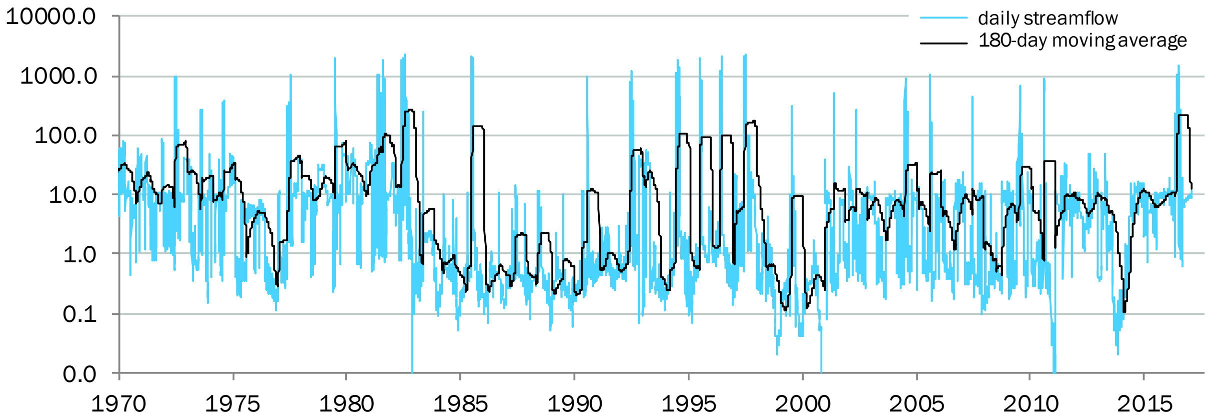

Figure 3-4. Average daily discharge data for AVL after the construction of Del Valle Reservoir

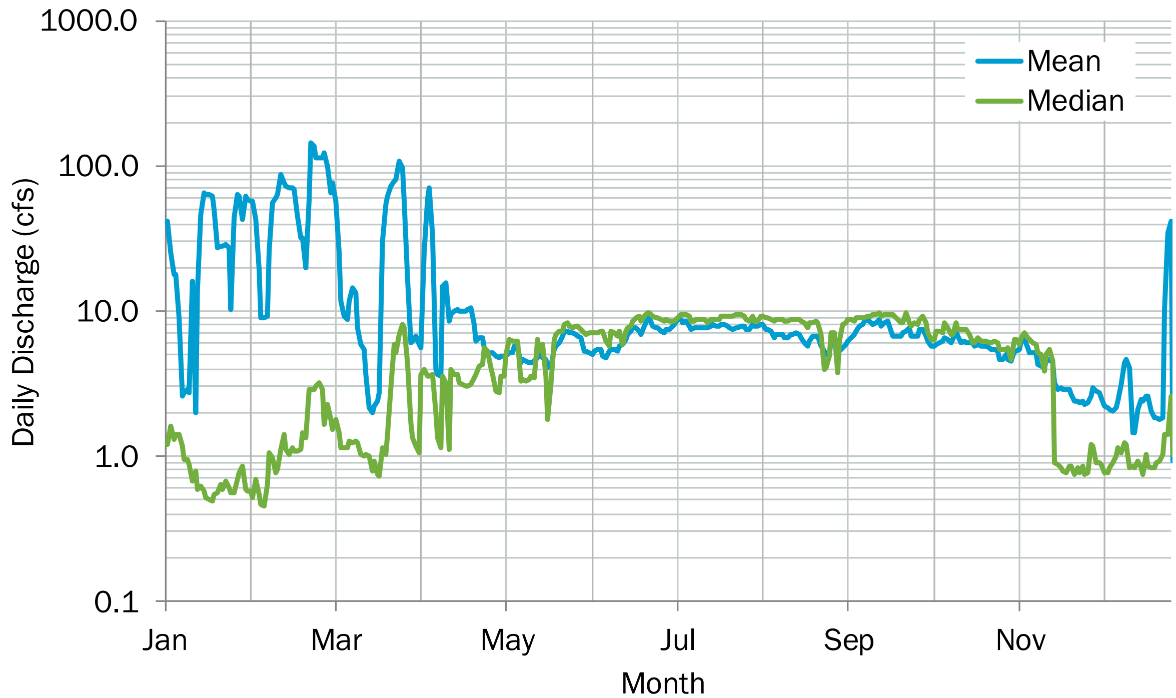

Figure 3-5. Mean and median daily flows in ADV by day of year

Figure 3-5 shows a marked seasonal pattern, where median daily flow rates in the range of 0.5 to 3.0 cubic foot per second (cfs) occur in the wet season (i.e., November through April), while higher median daily flow rates in the range of 5 to 10 cfs occur in the dry season (i.e., May through October). This pattern suggests that dry season flows are predominantly due to controlled releases from upstream facilities.

3.2.2 Peak Flow Frequency

BC used the peak annual discharge data for AVL to perform a statistical regression analysis using the standard Bulletin 17B method recommended by the Interagency Advisory Committee on Water Data (IACWD) (IACWD 1982). Appendix A provides details regarding the Bulletin 17B method and BC's assumptions. Table 3-2 lists the estimated peak discharges for a range of annual probabilities. Figure 3-6 presents the peak discharge frequency results.

Table 3-2. Peak Discharge Summary					
Recurrence Interval (years)	Annual Chance of Exceedance (percent)	Peak Discharges from Analysis of USGS Streamflow Records (cfs)[a]		Peak Discharges from FEMA Flood Insurance Study[b]	Peak Discharges with Regulation at Del Valle Reservoir[c]
		Pre-dam	Post-dam		
1.5	66.7	547	87	– [d]	– [d]
2.0	50.0	1,413	198	– [d]	– [d]
5.0	20.0	6,434	898	– [d]	– [d]
10.0	10.0	12,087	1,891	1,860	2,200
25.0	4.0	21,198	4,042	– [d]	3,500
50.0	2.0	28,818	6,483	4,150	4,500
100.0	1.0	36,695[e]	9,797[e]	7,000[f]	4,500
200.0	0.5	44,565[e]	14,153[e]	– [d]	7,000[g]
500.0	0.2	54,617[e]	21,831[e]	9,080	20,000[h]

Notes:

a. *Peak discharges calculated using Bulletin 17B methodology (see Appendix A); analysis performed using peak annual discharge records from USGS 11176500 (pre-dam, 1912–67) and (post-dam, 1969–2017).*

b. *Peak discharges obtained from effective FIS for Alameda County (FEMA 2009); the 100-year (i.e., base flood) peak discharge corresponds with managed releases plus spill at Del Valle Reservoir during the standard project flood (see next footnote).*

c. *Discharges estimated from Plate 3 of "Report on Reservoir Regulation" by the U.S. Army Corp of Engineers (USACE 1978). Flood control operations described by USACE (1978) as follows: "When the reservoir water surface is between 701.7 and 742.0 feet (39,000 and 74,000 acre-feet of storage, respectively), releases will be restricted to a maximum of 4,500 cfs, the estimated discharge when bank erosion begins on Arroyo Valle. When the reservoir water surface is between 742.0 and 749.0 (81,400 acre-feet of storage including 4,400 acre-feet of surcharge storage) releases will be made to restrict releases plus spill to a maximum of 7,000 cfs during floods up to the standard project flood magnitude. Inundation on Arroyo Valle is estimated to begin when discharge exceeds 7,000 cfs. When reservoir water surface is above elevation 749.0 no releases will be made."*

d. *Data not available at specified recurrence interval.*

e. *Recurrence intervals of 100, 200, and 500 years are greater than the available period of record and are therefore considered extrapolations; post-dam estimates do not account for flood control operations at Del Valle Reservoir and should not be relied upon for floodplain management.*

f. *Base Flood for floodplain management.*

g. *Standard Project Flood for Del Valle Reservoir (USACE 1978).*

h. *The peak discharge for the 500-year is large relative to the other discharges in the table; this is likely due to the rapid increase in discharge expected at the spillway.*

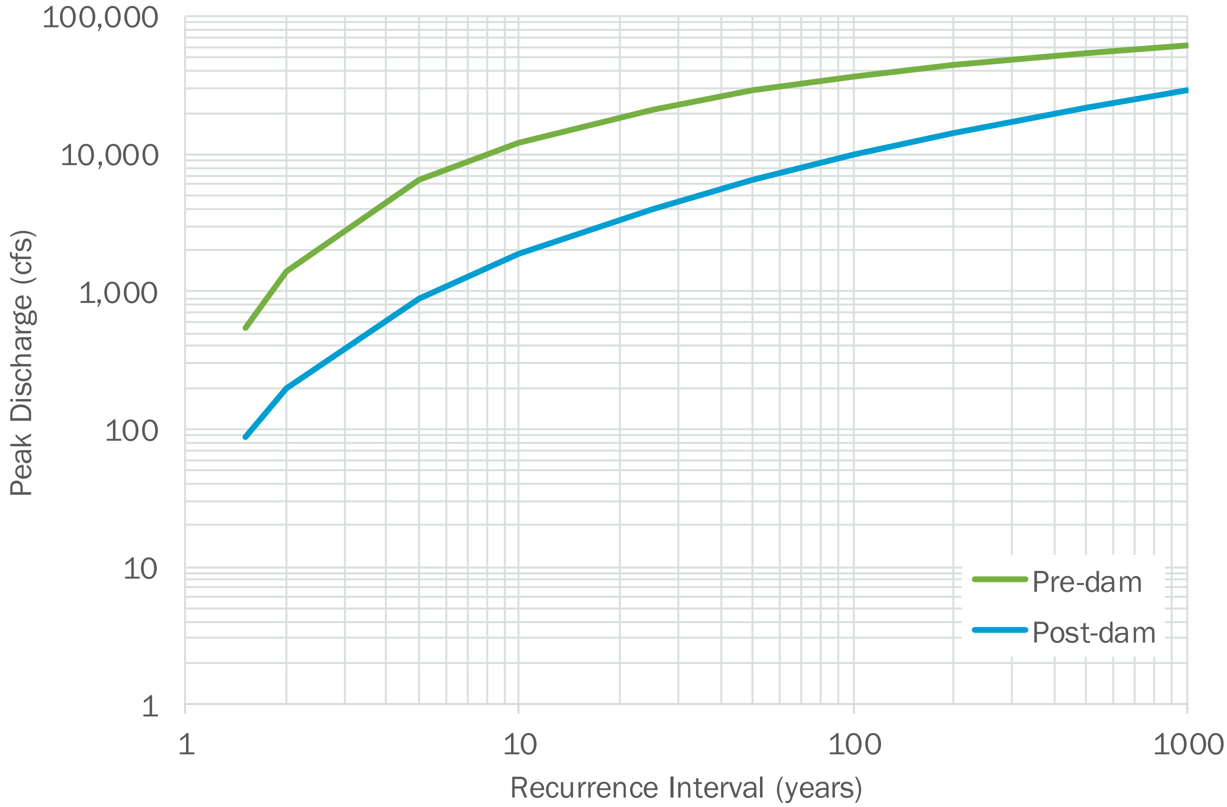

Figure 3-6. Peak flow frequency curves for ADV from regression analysis

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Section 4

Geomorphology

ADV was once a wide and braided stream that transported large amounts of coarse sediment from the mountains of the Diablo Range to the Valley (SFEI 2013) where it was deposited across the valley floor and alluvial fan. Sand and gravel mining has occurred within these alluvial formations for well over 100 years. The following sections describe the geomorphologic conditions of ADV including a summary of anthropogenic changes and observations from field assessments.

4.1 Pre-Developed Conditions

The *Alameda Creek Watershed Historical Ecology Study* published by SFEI synthesizes historical information from numerous sources to describe conditions in the Alameda Creek watershed prior to significant Euro-American modification (SFEI 2013). The section on ADV describes an alluvial system along the Valley that transitioned from a narrow-confined channel as it exits the upper canyon, to a wide-braided system along the valley floor, and then back to a single thread channel before dividing into multiple distributary channels as it enters the Pleasanton Marsh complex. The following excerpt from the SFEI study describes the observed geomorphology:

> Del Valle began to split into multiple channels shortly after entering the valley, approximately where the Veteran's Hospital is located today. Historical maps show Arroyo del Valle broadening to develop a braided pattern, with clearly depicted islands between the multiple channels of the creek (Boardman 1870, Duerr 1872a, Allardt 1874, Gibbes 1878, Thompson and West 1878, USGS 1906) [. . .] In the braided reach of the creek, the riparian corridor may have been up to 1,500 feet wide. In some places, even wider outer relic floodplain terraces are still visible in the LiDAR survey and historical aerials, extending the potential corridor width up to 3,000 feet [. . .] In contrast to the braided reach, the portion of Del Valle in the vicinity of Pleasanton was a single-thread meandering channel (Boardman 1870, Allardt 1874, Thompson and West 1878, USGS 1906). Historically, this lower reach began in what is now Shadow Cliffs Regional Recreational Area, where the dominant substrate shifted from gravel to clay (mapped as fine-grained Livermore silty fine sandy loam; Westover and Van Duyne 1910). By this point, the stream had dropped its load of coarse gravels on its fan and lost most surface flow (SFEI 2013).

The SFEI study goes on to describe ADV as a historically intermittent stream. As the stream lost power, coarse gravels deposited across the alluvial fan (vertically and horizontally) and surface flow percolated into the coarse sediments (SFEI 2013). The following excerpt from the SFEI study describes the coarse material formations and loss of surface flows:

> This braided form corresponded with a coarse gravelly substrate and large sediment load; through much of Livermore Valley the strip of soil underlying the creek was characterized in the historical soil survey by "numerous abandoned channels," an underlying "bed of coarse gravel many feet in thickness," and in the contemporary soil survey as "porous sandy soil," or "riverwash" (Westover and Van Duyne 1910:35, Welch et al. 1966). Water sank through these gravels, so that much of the flow of the creek continued subsurface [. . .] Through this reach, Del Valle shifted from a perennial to an intermittent stream. At the edge of the valley, a mile downstream of the reservoir,

> Sherman Day noted “a fine stream of water, running over a dam of sandstone rocks” in August 1853 (Day 1853:289). Another mile and a half downstream, in Sycamore Grove Park, he described water “in pools.” As water continued to sink through the gravels, he found “no water in summer” at Isabel Avenue, another two miles further downstream (1853). The pools were part of the gradual transition as water sank further below the surface (SFEI 2013).

4.2 Anthropogenic Changes

Human disturbances in a watershed and floodplain development can affect flow, conveyance, and the balance of sediment supply, which often leads to fluvial disturbances that result in channel degradation (Schum et al. 1984; Simon and Rinaldi 2006). ADV is a highly modified system because of nearly two centuries of development (i.e., grazing, agriculture, urbanization, floodplain channelization, and gravel mining) and the construction of Del Valle Reservoir in 1968.

4.2.1 Watershed and Floodplain Development

This section summarizes types of watershed and floodplain development in the Valley.

Grazing. Settlers in the early to mid-1800s began modifying the land by grazing cattle, clearing trees for firewood, and diverting water for irrigation and drainage. By the mid-1800s cattle and sheep grazing was widespread and a likely factor in changing the ecological and morphological processes within the watershed (SFEI 2013). Grazing not only changes vegetative cover, but also compacts soil, hastens erosion, and contributes to stream degradation and channel widening (Meehan and Platts 1978; Evans 1998; Bilotta et al. 2007).

Agriculture. The Valley began to shift from ranching to agriculture in the middle to late 1800s. Although grains were the primary crop in the Valley, settlers also planted grapes, orchard trees, and some row crops (SFEI 2013). Around the turn of the century and into the mid-1900s, agricultural lands shifted from primarily dryland wheat farming to more irrigated farming with orchards, vineyards, and row crops (Clark 1915; McCann and Hinkel 1937; SFEI 2013). With an increasing need for irrigation and drainage in the Valley, many streams were rerouted, straightened, channelized, and connected.

Urbanization. In the middle to late 20th century the Valley experienced rapid population growth and is now home to more than 200,000 people. Extensive urbanization in and around the cities of Livermore and Pleasanton replaced open lands with residential and commercial developments and new roadways. Most of the large valley wetlands have been drained, and floodplains have continued to narrow and channelize. In many areas, species composition of the remaining grasslands and riparian corridors has shifted toward non-native plant species (SFEI 2013). Runoff from newly paved (i.e., impermeable) surfaces increases stormwater flows, which contribute to stream degradation and channel incision (Booth 1990; Bledsoe and Watson 2001).

Mining. The coarse gravelly formations underlying Arroyo Mocho and ADV have supported gravel mining and development in the region for nearly 150 years. There is evidence that—in addition to grazing and agriculture—gravel mining in the middle to late 1800s began to cause a shift in the course of ADV. SFEI compares historical maps from the 1870s to a USGS topographic quadrangle map from 1906, showing how the channel appears to narrow and straighten over time (SFEI 2013). In-channel mining throughout much the 20th century continued to alter the channel and floodplain. Collins and Dunne examined several in-channel gravel mining case studies and found that mining activities considerably alter river morphology and habitat, and often interrupt the supply of gravel to downstream reaches (Collins and Dunne 1990).

4.2.2 Construction of Del Valle Reservoir

As discussed in Section 3, construction of Del Valle Reservoir had a substantial impact on the flow regime of ADV below the dam; peak flood flows decreased dramatically, and the duration of low flows increased such that the stream shifted from intermittent to perennial. The dam also has had a tremendous impact on the sediment regime in ADV by disrupting natural sediment transport from the upper watershed to the Valley. Using a standard relationship developed by Brune, BC estimated that the dam will trap roughly 97 percent of sediment flowing into Del Valle Reservoir (Brune 1953)—though it is important to note that 100 percent of upstream bedload will be trapped. Trapping and removing sediment supply creates a clear water or sediment-starved condition downstream from the dam, which leads to channel degradation, bank erosion, and bed-coarsening (Williams and Wolman 1984; Kondolf and Matthews 1991). Williams and Wolman found that riparian vegetation commonly increased in reaches downstream from the dams, likely due to the reduction in peak flows that would typically scour the riparian corridor (Williams and Wolman 1984).

In a study of Sycamore Grove Park, Kamman found that after 1968, sedimentation inputs to the park reach were “likely derived solely from the reworking of [existing] channel [materials] between the Park and dam and inputs from the Dry Creek drainage, which enters the central portion of the Park from the north” (Kamman 2009). Kamman describes how the reduced sediment supply diminished gravel bar formation, lessened topographic variation, and coarsened/armored the channel bed to the point that it became dominated by gravel- and cobble-size material (Kamman 2009). Per Kamman, aerial photographs indicate an active braided-channel system as late as 1963, followed by photographs from the 1970s–90s showing a drastic reduction in secondary channels and areas of floodplain disturbance, accompanied by vegetation encroachment across the floodplain and along the channel (Kamman 2009). Figure 4-1 shows a similar comparison, including current baseline conditions in 2018 for comparison.

1958	2012	2018
(10 years before construction of Del Valle Reservoir)	*(44 years after construction of Del Valle Reservoir)*	*(50 years after construction of Del Valle Reservoir)*

Figure 4-1. Aerial photographs of ADV in Sycamore Grove Park

4.3 Assessment of Existing Conditions

In October 2015, geomorphologists from Balance Hydrologics, Inc. (Balance) conducted three site visits and collected data to assist with its geomorphic assessment of ADV. The investigations focused on three reaches of ADV:

- Adjacent to Lake B from the west end of the Eliot Facility site to Isabel Avenue
- Adjacent to Lake A from Isabel Avenue to Vallecitos Road
- Sycamore Grove Park

The Balance team (Bill Christner, Chelsea Neill, and Eric Donaldson) measured channel substrate and constructed particle-size distributions from data collected at locations along Lake B, using standard Wolman pebble count methods and a reach-averaged procedure taken within the active channel. Balance measured approximate channel dimensions along Lake A and Lake B using field tape measurements. Balance used a laser level to take channel geometry measurements in Sycamore Grove Park. Balance also estimated bankfull dimensions at each location based on channel morphology. Section 4.5 presents additional discussion on bankfull channel dimensions.

Sections 4.3.1 through 4.3.3 contain observations and geomorphic descriptions from Balance's assessments as summarized by Bill Christner (Balance 2016). While sediment characteristics, geomorphic features, and remnant formations can vary significantly over space and time, field work and data collection activities focused on existing conditions and channel processes within the project area reaches of Arroyo del Valle. The data collected helped to establish a conceptual understanding of present-day conditions, channel hydraulics, and sediment transport potential as these pertain to channel restoration and design. Interpretations of the data were viewed within this context.

4.3.1 Arroyo del Valle at Lake B

The riparian corridor along ADV near Lake B has thick non-native vegetation that limits access to, and encroaches well into, the active channel. In many areas, this vegetation is a dominant factor for channel roughness. Vegetation encroachment is likely caused by sustained summer releases from Del Valle Reservoir and releases from South Bay Aqueduct in Sycamore Grove Park. These releases, combined with a lack of high flows that scour vegetation, result in a shift from a well-defined channel with riparian vegetation along the banks, to a channel chocked with riparian vegetation and limited sediment transport capacity. Balance made observations at three sites along this reach (see observation points 1, 2, and 3 in Figure 4-2).

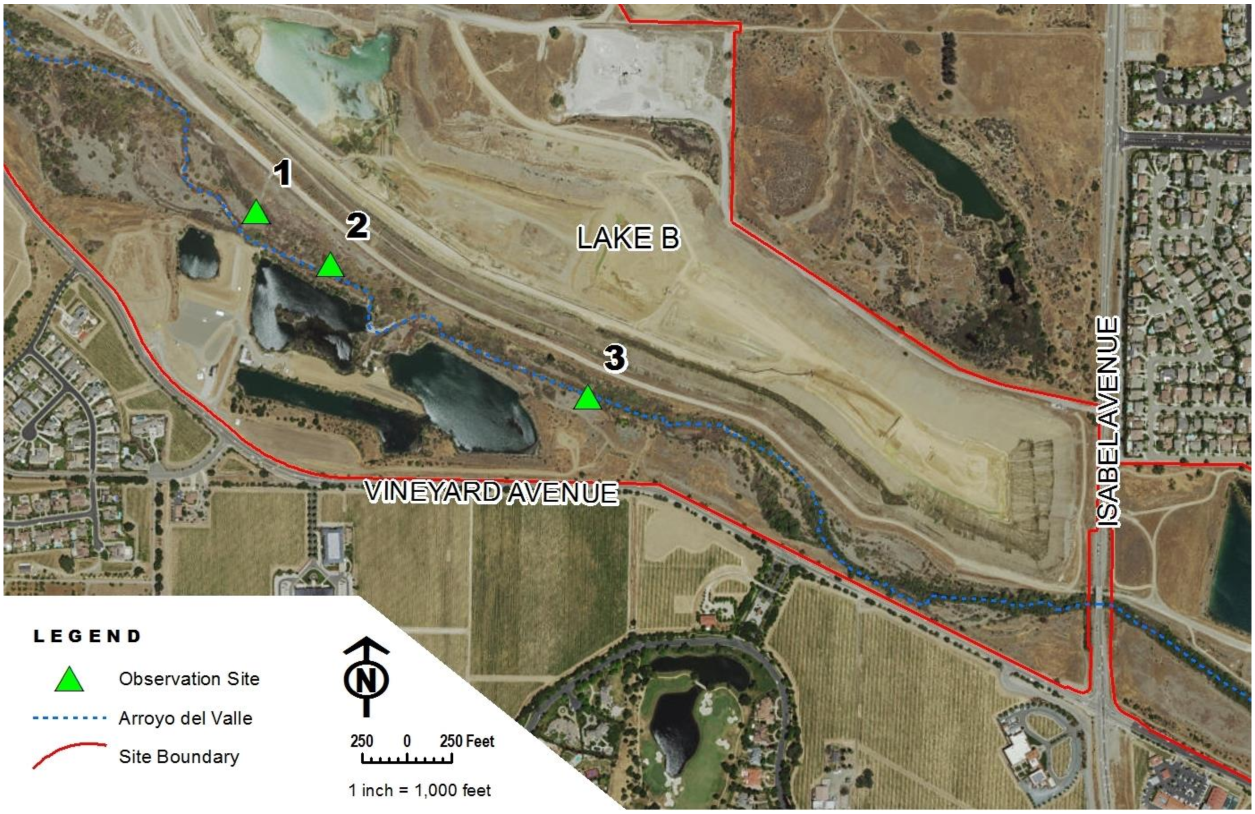

Figure 4-2. Geomorphic observations along ADV at Lake B

Channel substrates at observation points 1 and 3 consisted of large cobbles and gravels covered with a veneer of fine silts and sands mixed with organics. Observation point 2 is located off-channel north of the main channel and is interpreted as a relict/abandoned channel that likely formed under pre-dam hydrologic conditions. Channel substrate at observation point 2 comprised sands, gravels, and cobbles. Appendix B contains pebble count data for observation point 2 and gradation curves from bulk sediment samples for observation points 1 and 3, along with cross-section plots showing estimated bankfull widths.

4.3.2 Arroyo del Valle at Lake A

The ADV channel running along Lake A is also thickly vegetated but provides areas of channel access. As seen in the Lake B reach, riparian vegetation encroaches well into the active channel throughout the Lake A reach. This reach is highly altered; Balance investigated it at a cursory level for the purposes of this geomorphic assessment to assess the current sediment transport ability of the reach.

Balance made observations and measurements at three locations along the Lake A reach (see observation points 4, 5, and 6 in Figure 4-3). Although channel substrate was not measured directly, it was visually assessed and consisted of coarse sand to medium gravels in the area of active channel flow, and fine silts and sands along the channel margins where vegetation encroachment in the channel slows channel velocities and reduces sediment transport. While no pebble counts were taken, the field team estimated cross-section dimensions with field tapes and noted the extent of vegetative encroachment (see Appendix C). Pebble count data were collected upstream, in Sycamore Grove Park. Bulk sample sediment data were collected both upstream and downstream in Sycamore Grove Park and along Lake B to assess erosion and sediment supply.

Figure 4-3. Geomorphic observations along ADV at Lake A

4.3.3 Arroyo del Valle at Sycamore Grove Park

Sycamore Grove Park is immediately upstream of the Eliot Facility on the southeast side of Vallecitos Road. Walking trails within the park are set back from ADV on both banks; however, the park trail system has a footbridge and two wet crossings. The footbridge is approximately 2,000 feet upstream of Vallecitos Road. The Olivina Trail Crossing is located about 1.0 mile upstream of Vallecitos Road, and Kingfisher Crossing is nearly 1.5 miles upstream of Vallecitos Road. A South Bay Aqueduct outfall pipe is on the left bank (facing downstream) immediately downstream of the Kingfisher Crossing. Balance estimated a discharge of 10 cfs from the pipe, which during the visit appeared to be the sole source of flow in ADV.

Sycamore Grove Park contains relict, braided-channel morphology, attributed to geomorphic processes that operated prior to Del Valle Dam construction. While Sycamore Grove Park has multiple channels, flows are presently restricted to a single thread. Channel access was not inhibited by vegetation, and vegetation did not appear to influence channel roughness and morphology as it did along ADV at the Eliot Facility. The Livermore Area Recreation and Park District and community volunteers actively manage vegetation within Sycamore Grove Park and remove invasive species (verbal communication with local Parks staff). After performing an initial visual survey of ADV in Sycamore Grove Park, Balance identified four sites for data collection (Figure 4-4).

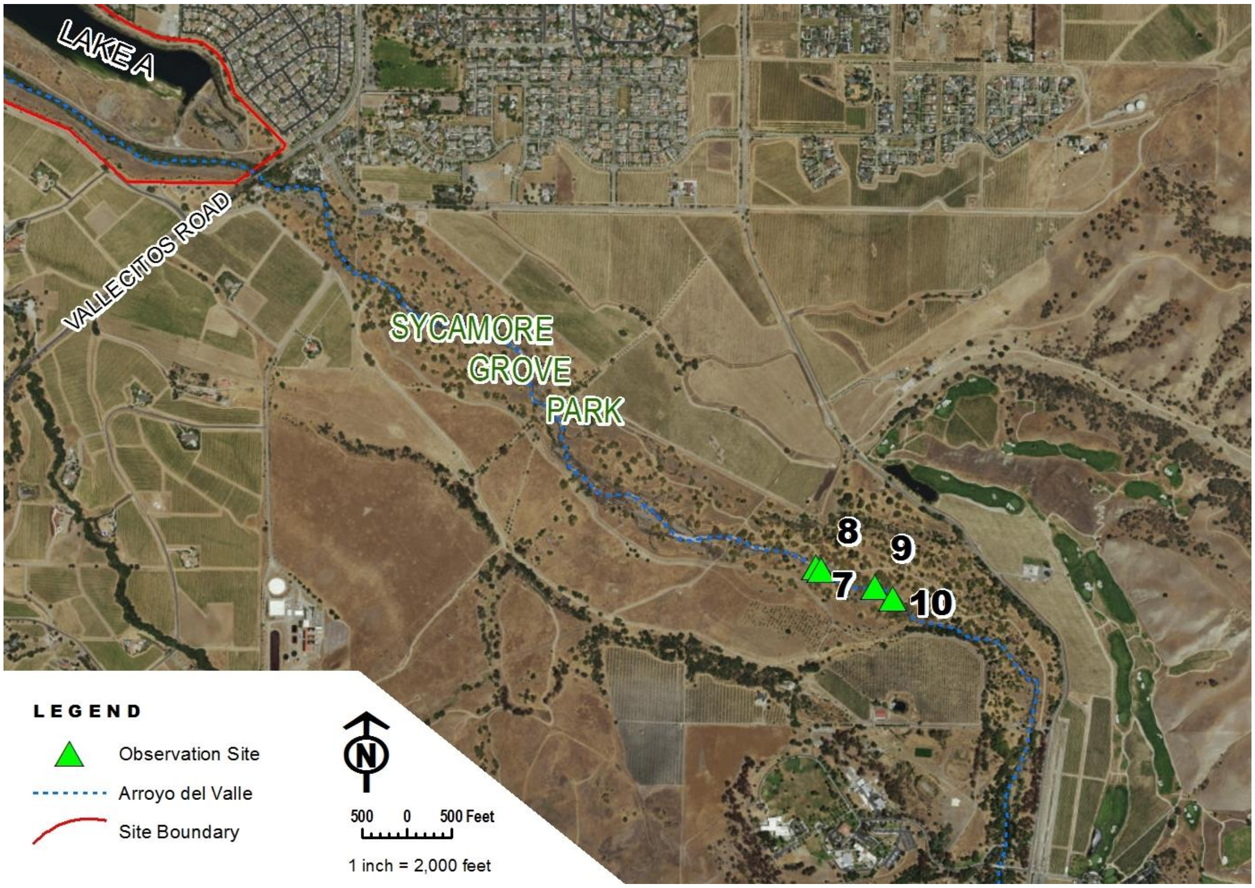

Figure 4-4. Geomorphic observations along ADV in Sycamore Grove Park

Observation points 7 and 8 were located at riffles, while observation points 9 and 10 were collected at pools. Appendix B contains pebble counts and gradation curves from bulk sediment samples for observation points 7 through 10 together with field-surveyed cross-section plots showing estimated bankfull widths at each location, contained in Appendix C.

4.3.4 Signs of Degradation and Instability

As discussed in Section 4.2, development and disturbance within the ADV watershed likely have destabilized and degraded the stream system over time. Simon and Hupp developed a channel evolution model to describe how destabilized and degrading streams change over time (Simon and Hupp 1986). As degrading streams become deeper and more incised, the main channel becomes disconnected from the floodplain and banks become steep and unstable. As flows undermine steep banks, mass wasting occurs, which begins to widen the channel. As degradation continues to migrate upstream, the now-flatter bed slope cannot transport the incoming sediment, and secondary aggradation begins to fill in the channel, leading to meandering and further widening.

During the site visit in October 2015, Balance observed some continuing signs of instability along the Sycamore Grove Park reach of ADV. Specifically, it found a high right bank with vertical exposure of roughly 12 to 15 feet near the lower pedestrian bridge in Sycamore Grove Park, just south of the parking lot off Wetmore Road. The impacted reach begins approximately 120 feet downstream of the pedestrian bridge and continues for roughly 450 feet to just upstream of the pedestrian bridge. Such areas of channel destabilization may indicate that the channel is in a state of disequilibrium, and that it still may be adjusting to changes in the watershed (Balance 2016).

Balance also examined the Isabel Avenue crossing, which the California Department of Transportation (Caltrans) has recently graded and armored with riprap, forming a convex channel slope as it flows under the bridge. Construction recently removed vegetation throughout the area, including several small- to medium-sized trees along the channel banks, allowing easy access to the channel on both banks. The riprap blanket covers approximately 420 feet of channel bank-to-bank (Balance 2016).

These modifications are countermeasures to protect the bridge from scour. A report by the engineering firm WRECO described the bridge as "scour critical" because of past channel degradation that has reduced the cover over pier and abutment footings (WRECO 2009). Note that the scour analysis by WRECO assumes the channel has stabilized, and that future bed degradation will be negligible (WRECO 2009).

WRECO's assumptions are based on bridge inspections conducted by Caltrans. Caltrans inspected the Isabel Avenue/SR 84 bridge at ADV on September 17, 2008. According to the *Bridge Inspection Report*, the channel degraded 6 feet between 1983 and 1999, but then stabilized (Caltrans 2008). Although the *Bridge Inspection Report* attributed the degradation to in-stream gravel mining (Caltrans 2008), it seems likely that multiple factors contributed to the degradation, and it is possible that ADV is still adjusting to the construction of Del Valle Dam. In a study of 21 dams constructed on alluvial rivers, Williams and Wolman found that most degradation occurred during the first one to two decades after a dam was completed (Williams and Wolman 1984). For ADV, the upstream Del Valle Dam has been in existence for 4.5 decades.

4.4 Sediment Analysis and Review of Aerial Photographs

In February 2017, Balance completed an analysis of sediment samples collected along Reach-A and Reach-B, and an aerial photograph review of Reach-A and Reach-B on ADV (Appendix D), see Figure 4-5. The purpose of this analysis was to assess how sediment transport on ADV has changed since the construction of Del Valle Reservoir, and to gain a better understanding of the geomorphic processes that have affected evolution of the channel reach along Lake A.

Results from the analysis of sediments along Lake A and Lake B suggest that the sediment composition in both reaches has been impacted due to the construction of Del Valle Dam (Balance 2017). Particle size distributions analyzed by Balance indicate winnowing[3] in the fine-sediment fraction in reaches downstream of the dam, and channel sediment coarsening within the active channel (Balance 2017). Such processes are caused by dam releases that are sediment-deficient, in other words, discharges that have the capacity to transport sediment, yet carry little to no sediment when released. ADV has adjusted to the reduced sediment load by harvesting and mobilizing (i.e., eroding) sediment from its channel bed and banks. Finer sediment fractions are selectively removed from the active channel because they are more easily mobilized. This process continues until the channel bed is armored[4] (Brandt 2000).

3 Winnowing is the natural removal of fine material from a coarser sediment by wind or flowing water. Once a sediment has been deposited, subsequent changes in the speed or direction of wind or flowing water can agitate the sediment grains and allow the preferential removal of the finer grains. This action can increase the mean grain size of a sediment after it has been deposited (Compton 1962).

4 Channel armor is a veneer underlain by remnant, or un-winnowed channel materials (Williams and Wolman 1984).

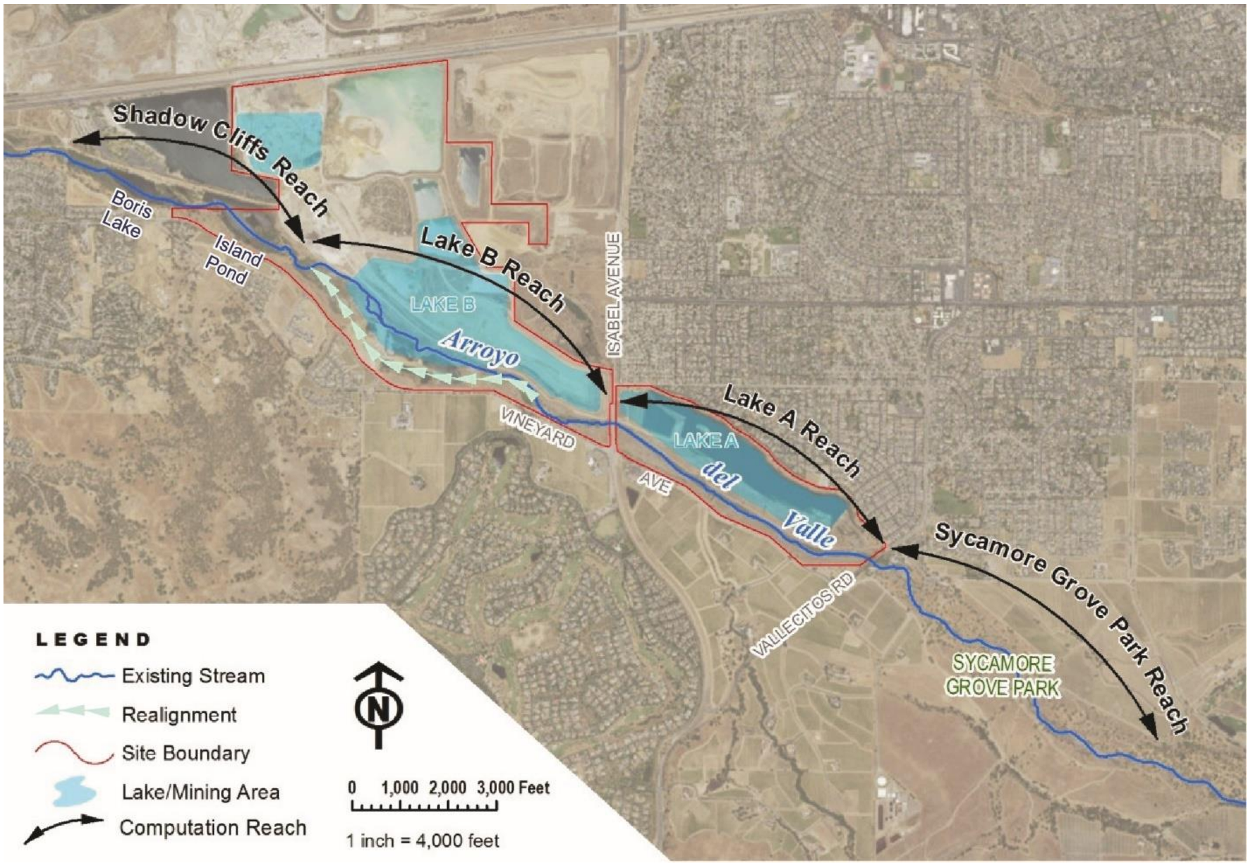

Figure 4-5. Reaches of ADV used for sediment continuity analysis

Balance reviewed aerial photographs spanning the past 34 years and observed a change in channel form on ADV from a sinuous, multi-thread braided channel network that actively meanders and erodes its channel banks, to a single thread channel with low sinuosity, and thick riparian vegetation. Williams and Wolman, who examined downstream changes in streams at 21 dam sites across the United States, found that braided channel systems often evolve into single thread channels with increased riparian vegetation following dam construction (Williams and Wolman 1984).

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Section 5

Proposed Project

CEMEX proposes to keep ADV separate from Lake A and Lake B under reclaimed conditions. The proposed project for the RPA will include diversion and conveyance facilities constructed to divert water into and between the planned Lakes A, B and C of the Chain of Lakes (Figure 5-1). CEMEX will construct a diversion structure at Lake A. A new conduit will connect from Lake A to future Lake C, with an optional turnout to Lake B. In addition, a conduit will connect Lake B and Lake C. Until such time that the future Lake C is developed, the conduits to and from Lake C will be stubbed and capped at CEMEX's property lines. A damage-resistant marker detectable by metal detectors will be placed at the surface of the stub and cap location to demarcate the location of the pipe. CEMEX will realign ADV and construct a new channel and floodplain corridor south of Lake B along Vineyard Avenue. New outlets on Lake A and Lake B will allow flow back into ADV when water levels are high. The following sections discuss conceptual design criteria for each of these facilities.

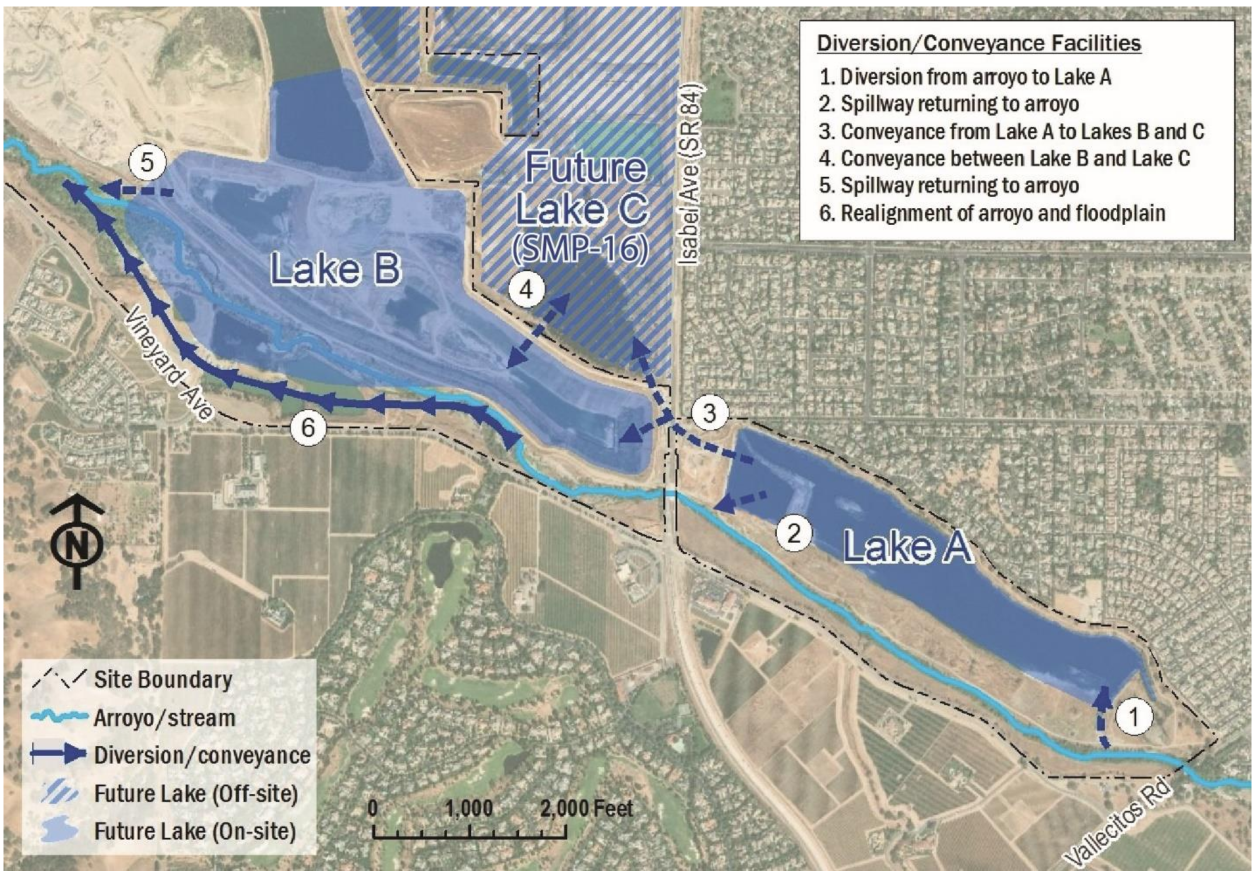

Figure 5-1. Surface flows related to ADV and the Chain of Lakes

5.1 Lake A Diversion

After the Project Site is reclaimed, CEMEX will dedicate Lake A, Lake B, and all appurtenant diversion and conveyance structures to Zone 7 for use in water management. According to a memorandum provided by Zone 7 (August 16, 2013), it plans to use these facilities to divert water from ADV into the Chain of Lakes to "replace loss of water through evaporation, mitigate the concentrations of salts in the water due to evaporation, recharge the groundwater basin, and enhance regional flood protection," consistent with the objectives of the Specific Plan (Zone 7 2013).

The Specific Plan states that "the diversion structure from ADV within Lake A into Lake C will be capable of diverting at least the first 500 cubic feet per second of flow from the Arroyo" (County 1981). The Specific Plan does not, however, explicitly discuss water diversion from ADV to Lake A. This lack of clarity was not an issue for the 1987 Reclamation Plan because ADV would have continued to flow directly into Lake A after the site was reclaimed. However, the proposed project will now keep the ADV channel separate from Lake A; therefore, direct transfer of surface water from ADV to the Chain of Lakes requires a diversion structure.

The existing agreement between Zone 7 and RMC Lonestar (a predecessor to CEMEX) dated March 29, 1988 (Agreement), was developed based on the 1987 Reclamation Plan, which assumed that ADV would flow through Lake A and called for a diversion structure from Lake A to Lake C that would divert at least the first 500 cfs (Lone Star Industries, Inc. 1987). Given the changes described above, CEMEX discussed new design options with Zone 7 assuming that the diversion will occur from the ADV channel. In an email from Colleen Winey, geologist at Zone 7 to Nathan Foged, engineer at BC, dated August 16, 2013, Zone 7 provided a document containing draft performance criteria for the new diversion structure. The document included the following specific criteria relating to diversion and bypass flow rates:

- Divert the first 500 cfs of water from ADV into the Chain of Lakes in an environmentally sensitive manner, specifically:
  - Provide the ability to control diverted flow rates in increments of 20 to 25 cfs up to the first 250 cfs
  - Provide the ability to control diverted flow rates in increments of 50 to 100 cfs between 250 and 500 cfs
  - Divert up to 500 cfs during flood releases greater than 1,000 cfs from Del Valle Reservoir, without any dams or other obstructions in place
- Provide for controlled bypass flows as follows:
  - 1 to 40 cfs in winter/spring
  - 6 to 15 cfs in summer/fall

BC evaluated alternatives for a diversion structure at Lake A and developed a design concept that can be feasibly constructed in compliance with the known regulatory requirements. More specifically, BC performed the following:

- Investigated options for key project components and concerns (e.g., fish exclusion, hydraulic grade controls, environmental impacts, visual impacts, and fish passage), performed an initial screening of options, and developed several conceptual design alternatives
- Evaluated design requirements and feasibility for diversion and conveyance facilities at Lake A, including the above performance criteria requested by Zone 7
- Analyzed several design alternatives with respect to feasibility, cost, and ability to meet key performance criteria, and identified a preferred alternative

- Developed conceptual design sketches and prepared a preliminary construction cost estimate for the preferred alternative

It is important to note that for the Lake A to Lake C pipeline, after it is constructed, the 500-cfs design discharge capacity should be verified by desktop analysis using as-built dimensions; field testing will not be possible because water cannot be run through the pipeline until Lake C is excavated. Therefore, BC recommends a hydraulic analysis be conducted to confirm the pipeline dimensions, invert elevations, water surface elevations, lateral flow conveyance, and assumptions regarding losses.

Section 5.1.1 discusses the need for fish passage and screening requirements, including the associated additional design criteria. Section 5.1.2 describes development of the concept design and evaluation of key design criteria.

5.1.1 Fish Passage and Exclusion

The California Department of Fish and Wildlife (CDFW) requires fish passage and fish screening for diversions located within salmon- or steelhead-bearing waters of the state. The National Oceanic and Atmospheric Administration (NOAA) also consults on projects impacting fish habitat where federally listed species (e.g., steelhead) are present.

ADV is a tributary stream to Alameda Creek, which has historically been a spawning area for fish species, including central California coastal rainbow trout/steelhead (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) (SFEI 2013). Fish barriers currently exist on ADV downstream of the Project Site; however, in recent years numerous fish passage projects were constructed on Alameda Creek and its tributaries to remove barriers to, and encourage anadromous fish migration into, the upper creek system. For example, San Francisco Public Utilities Commission (SFPUC) has worked on fish passage and screening improvements for its diversion dam on upper Alameda Creek, a channel reach identified as having suitable habitat for steelhead.

Hanson investigated the current and historical occurrence of steelhead in the Valley for Zone 7. The report provided the following findings (Hanson 2004):

- Historically, steelhead passage in ADV occurred infrequently, in response to high flow events that provided suitable surface water connectivity between ADV and lower Alameda Creek
- It is unlikely that the ADV watershed historically provided consistent suitable habitat conditions for steelhead passage, spawning, and/or juvenile rearing to support self-sustaining populations
- Suitable habitat exists for steelhead spawning and rearing in the reach immediately downstream of Del Valle Reservoir; however, management actions are required to achieve these benefits

BC contacted CDFW regarding permitting requirements for a water diversion structure on ADV. Based on personal communication between Michelle Lester of CDFW and Aren Hanson of BC on January 23, 2014, it is too early now to conclude that CDFW will require fish screens or passage given the uncertainties regarding the quantity and size of the diversion, as well as uncertainty regarding the suitability of the habitat.

Fish habitat studies are ongoing, and new information will be available in the coming years. Per CDFW, Zone 7 recently commissioned a study titled, ADV and Arroyo de la Laguna Steelhead Habitat Assessment (Cardno Entrix 2013); however, this study has not yet been finalized. In a related effort, the Alameda Creek Alliance (ACA) is working with Zone 7 and several other agencies to assess instream flows for migratory fish in ADV. According to the ACA website:

> The Alameda Creek Alliance is working with 16 agencies conducting studies and modeling to determine the range, timing, duration, frequency, and location of the water flows needed to restore the steelhead fishery in Alameda Creek. The Alameda County

Water District is negotiating with regulatory agencies to determine appropriate bypass flows for future fish ladders in the lower watershed. In the northern watershed, the Alameda Creek Alliance has prompted Zone 7 Water Agency to begin assessing instream flows for migratory fish in Arroyo Mocho, Arroyo del Valle and Arroyo de la Laguna through Livermore and Pleasanton (ACA 2017).

Notwithstanding the uncertainties discussed above, for this study BC assumes that a diversion structure on ADV must meet requirements for anadromous fish passage and screening. Specific criteria include:

- **Fish passage:** Cross-channel structures should include a passable flow bypass structure, and off-channel flow diversions should include return flow channels to avoid trapping.
- **Bypass flows:** Zone 7 requested that the ADV diversion allow for controlled diversion bypass flows of up to 40 cfs in winter/spring and 15 cfs in summer/fall (email from Colleen Winey, geologist at Zone 7 to Nathan Foged, engineer at BC dated August 16, 2013).
- **Fish screening:** CDFW criteria require fish screens to be sized such that the approach velocity entering the screen does not exceed 0.33 foot per second (ft/s) for all self-cleaning screens located in on-stream installations. For screens without automatic cleaning, the approach velocity is limited to one-fourth of the self-cleaning screens. Fish screens are typically sized by dividing the desired diversion flow (e.g., 500 cfs) and the limiting approach velocity (e.g., 0.33 ft/s), which results in the minimum area of fish screen required. For example, a 500 cfs diversion limited to 0.33 ft/s approach velocity would require at least 1,515 square feet (ft^2) of fish screen. The U.S. Bureau of Reclamation (USBR) recommends the use of a 10 percent safety factor, which would increase the required area in this example to 1,667 ft^2 (USBR 2006).

During detailed design, the designer should revisit these criteria as part of consultation with CDFW. It may be feasible to request a variance from CDFW for the approach velocity restrictions during certain times of year when fish fry are not present. For example, with such a variance, a diversion structure designed to screen 210 cfs at 0.33 ft/s approach velocity during periods when fry may be present may also be used to screen 500 cfs at 0.8 ft/s (maximum velocity allowed by CDFW) during periods of the year when anadromous fish fry are not present (e.g., likely during summer and fall).

5.1.2 Concept Design Development

The ADV diversion system will consist of several interrelated components. The schematic representation shown in Figure 5-2 identifies six major components, as follows:

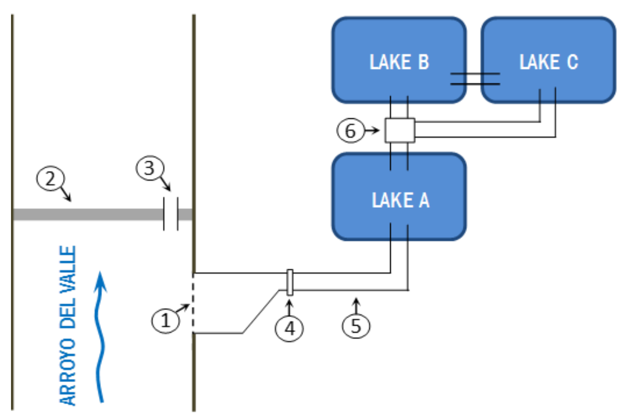

Figure 5-2. Schematic representation of diversion system

1. Intake and fish exclusion: This component diverts water away from the ADV channel through an intake structure that incorporates a device (e.g., screen) to prevent fish capture or trapping.
2. Hydraulic grade control: This component raises upstream water levels to create the hydraulic head required for lateral diversions, and to limit bypass flows in ADV.
3. Fish passage and/or bypass: This component allows fish to move upstream past any physical barriers created by the hydraulic grade control structure, and includes structures that will measure and control bypass flows that continue downstream in ADV.

4. Diverted flow control structure: This structure controls flow through the intake, and will include a device to adjust release rates, and a device to measure the diverted discharge.
5. Conduit into Lake A: This component consists of a pipe to convey diverted water into Lake A.
6. Conduit from Lake A to Lake C: This component consists of a pipeline to convey water from Lake A to Lake C, and allows for an optional turnout to Lake B.

BC investigated several options for diversion, screening, and conveyance and evaluated potential options with respect to feasibility, cost, and performance. BC found that the fish exclusion mechanism is the key differentiating feature among the alternatives because that component is the primary driver for the diversion system size, flow capacity, and construction and maintenance costs. The selected alternative uses a wide gravel bed with an infiltration gallery to meet fish screening requirements.

Figure 5-3 shows a schematic of proposed design for the Lake A diversion.

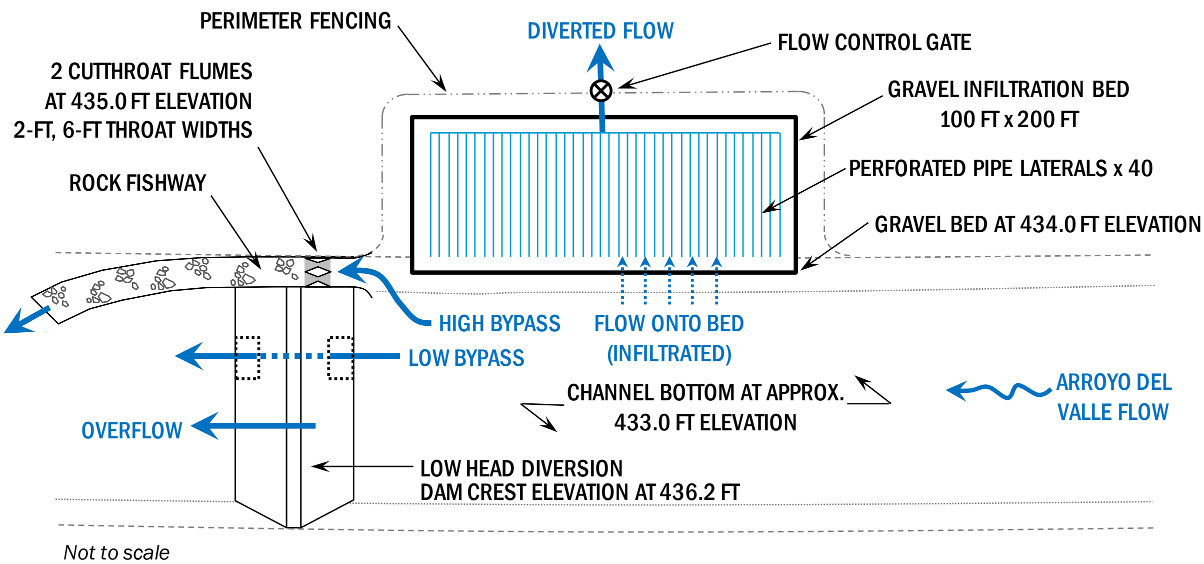

Figure 5-3. Schematic of the proposed Lake A diversion

As shown in Figure 5-3, the infiltration bed concept includes a 100-foot-wide (extending in the horizontal direction perpendicular to the stream bank) by 200-foot-long gravel infiltration bed to be constructed along the north bank of ADV. The infiltration bed consists of approximately 4 feet of coarse gravel (e.g., pea gravel) with a gallery of 40 100-foot-long perforated horizontal drain pipes (i.e., laterals) buried at a depth of 2 to 3 feet (1 percent slope).

The edge of the infiltration bed nearest to the arroyo will be set at an elevation of 434 feet, or approximately 1 foot above the channel bottom to allow for sedimentation. The top surface of the gravel infiltration bed will be sloped at 0.5 percent, sloping down toward ADV so that fish will move back toward the main stream channel as water levels drop. A clay cutoff wall installed along the infiltration bed edge closest to the ADV channel will prevent horizontal subsurface flow from the channel from draining into the laterals at elevations less than 434 feet.

Diverting Water into Lake A. When the main flow control gate is open, water ponded above the infiltration bed will infiltrate through the gravel and into the drainage laterals, which are sloped away from ADV toward a pipe manifold. The manifold then connects to an 84-inch main conduit/trunk that drains by gravity toward Lake A. A concrete vault with a stainless-steel slide gate will be constructed on the main conduit so that operators will be able to raise or lower the slide gate to different levels to control diversions. Riprap will be installed at the outfall to Lake A, extending to approximately elevation 400 feet, or just below the lowest anticipated operating level in Lake A.

The elevation drop from the ADV channel to Lake A is adequate for drainage and conveyance pipes to be sloped to allow for gravity flow, substantially reducing operation and maintenance (O&M) requirements.

Diversion Dam. A low-head diversion dam will be constructed across the main channel of ADV to impound water and create a wide pool that inundates the infiltration bed at higher flows. BC recommends a simple low-head diversion dam with a concrete core as the preferred method for hydraulic grade control given the flexibility of the design, low maintenance, potential for incorporating natural rock features on the slopes, and moderate cost. A small bypass channel with a rock fishway will be incorporated into the dam design to provide fish passage and preserve the natural riparian conditions of the stream. In addition, a low-level gate will be added to manage bypass flows when the diversion is not operating. This low-level gate will also facilitate regular and periodic sluicing of sediments that could build up behind the diversion dam.

Preliminary fishway sizing indicates that a channel roughly 2 feet deep and 10 feet wide with an average longitudinal slope of approximately 2 percent is adequate to convey bypass discharges. Two gated flumes will be installed near the entrance to the fishway to control and measure bypass discharges. A small flume will measure low flow rates, while a second, larger flume will measure higher bypass flow rates. Preliminary sizing calculations determined that a cutthroat flume with a throat width of 2 feet will pass up to approximately 8 cfs with 1 foot of hydraulic head. A second, larger cutthroat flume (placed in parallel) with a throat width of 6.0 feet can be used in combination with the first flume to pass a total flow of approximately 40 cfs with 1.2 feet of hydraulic head, complying with Zone 7's request for controlled diversion bypass flows of up to 40 cfs in winter/spring and 15 cfs in summer/fall. Bypass flows in excess of 40 cfs will flow over the diversion dam.

Given that 1.0 foot of ponding is required over the infiltration bed and an additional 1.2 feet of head are required to discharge 40 cfs into the fish bypass, the minimum elevation of the dam crest is estimated to be 436.2 feet. At that elevation, the crest of the dam will span roughly 140 to 160 feet across the channel.

Power and Signal. Electrical power from the local utility will be needed for operating the flow control diversion gate. It is assumed that electrical power is available at the east boundary of the Project Site from a pole or manhole. Electrical power will be provided for the following loads: (a) actuator for the 84-inch slide gate, and (b) flow measurement and/or water level instruments. Controls for the diversion will consist of simple buttons and indicators; there will not need to be a control panel that provides functions such as automatic control or remote control via telemetry. All electrical and control equipment will be suitable for outdoor and mounted on a rack that is raised to an elevation above the 100-year flood level.

Appendix E contains concept-level design drawings for the proposed diversion structure.

5.1.3 Hydraulic Design

Infiltration galleries are commonly used in riverbeds or lakebeds for low-flow applications, but can be expanded beyond typical applications by adding more laterals and increasing the area over which water is drawn. Preliminary sizing calculations were performed using an equation from USBR (1995):

$$L = \frac{Q ln\left(\frac{2d}{r}\right)}{2\pi KH}$$

where: *L* is the computed length of screen to yield desired discharge (feet)
Q is the desired discharge (cfs)
r is the radius of the drainage pipe
K is the permeability coefficient for the gravel fill (ft/s)
H is the depth of water over the gravel fill (feet)
d is the distance from the ground surface to the center of the drain pipe (feet)

A maximum diversion flow rate of 500 cfs can be achieved with a coarse aggregate and using 40 parallel drainage pipes that are each 100 feet long (as described previously).

BC analyzed pipe capacities to calculate the sizes needed to convey water by gravity through the laterals, pipe manifold, and trunk pipeline. The lateral pipes can be 12 inches diameter for 30 feet, but must expand to 18 inches diameter for the remaining 70 feet. Table 5-1 provides a summary of the pipe sizing calculations.

Table 5-1. Summary of Pipe Sizing

Component	Material	Slope (percent)	Sizing		
			Number	Diameter (inches)	Total Length (ft)
Laterals	PVC	1	40	12	1,200
	PVC	1	40	18	2,800
Manifold	PVC	1	2	36	60
	RCP	1	2	48	80
	RCP	1	2	60	60
Main Conduit	RCP	2	1	84	400

Note: HDPE pipe might be a suitable substitute for PVC.

If the lateral drain pipes are placed approximately 5 feet apart, the surface area of the infiltration bed will be approximately 20,000 ft^2. A diversion rate of 500 cfs over an area of 20,000 ft^2 will result in an inflow velocity of approximately 0.025 ft/s across the surface of the infiltration bed, and a pore velocity of 0.08 ft/s, assuming a porosity of 0.3 for the gravel in the bed. This estimated approach velocity is much less than the 0.33 ft/s limit required for fish screens.

5.1.4 Maintenance

The infiltration bed proposed for the diversion would function similar to a modified slow sand filter, the general concepts for which are firmly established within the water industry. The maintenance plan for the infiltration bed will need to be adaptive; i.e., the methods and frequency of removing debris and fine sediments will need to be adjusted over time based on the system's response to its environment. Preliminary maintenance activities are likely to include the following:

- Remove vegetation on and around the filter bed and adjacent berms up to three times per year: late March during early vegetation emergence, early June at the transition from spring to summer, and mid-August to catch late emerging vegetation.
- Perform infiltration bed coring and sampling every five years using filter maintenance techniques established by the American Water Works Association to check for clogging. If clogging occurs, either remove and replace the upper-most layer of gravel, or remove, wash and reinstall the gravel layer.
- Monitor the integrity of the perimeter fencing several times a year and repair as needed.

- Monitor, test, and repair instrumentation, meters, and flow control gates as needed.

The low-head diversion dam could trap bedload sediments that accumulate over time. A small bed-level gate could be installed in the dam to facilitate periodic sluicing of sediments.

5.2 Lake Conduits

As described in the Specific Plan, future Lake C will be located west of Isabel Avenue and generally north of Lake B (County 1981). Conduits will be constructed between Lake A and Lake C and Lake B and Lake C, consistent with the approved SMP-23 Reclamation Plan and Zone 7 Agreement (Lone Star Industries, Inc. 1987; Zone 7 1988). The conduits to and from Lake C will be stubbed and capped at CEMEX's property lines until such time that future Lake C is developed. In addition, CEMEX has agreed to provide a turnout from Lake A into Lake B as part of the Lake A to Lake C conveyance structure. Figure 5-4 shows a schematic of the proposed conduits.

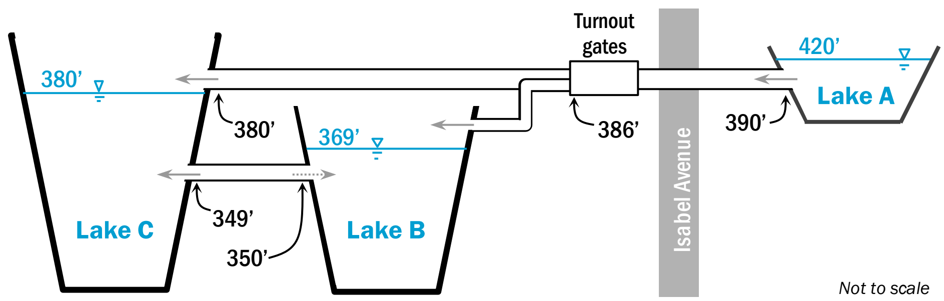

Figure 5-4. Schematic representation of proposed lake conduits and approximate elevations

Invert elevations for proposed conduits labeled in black. Predicted median lake levels shown in blue for Lakes A and B based on a technical memorandum by EMKO (2018). Historical median water level shown in blue for Lake C based on report by Zone 7 (2014).

To meet the objectives of the Specific Plan and requirements of the Zone 7 Agreement, the Lake A to Lake C pipeline will have a conveyance capacity of 500 cfs. The Lake B to Lake C conduit will be a 30-inch-diameter pipe placed at an elevation that allows gravity flow between two lakes.

5.2.1 Lake A to Lake C Pipeline

A pipeline capable of conveying 500 cfs will be constructed under Isabel Avenue from Lake A to Lake C. The pipeline alignment will be approximately 1,580 feet long, including 150 feet through a bore-and-jack crossing under Isabel Avenue. The bore-and-jack section will include an installed casing that conforms to Caltrans standards. Pipe installation east of Isabel Avenue will use cut-and-cover construction. Pipe installation west of the Isabel Avenue right-of-way (ROW) will use shoring and shielding.

Vault 1 will be located at the pipeline's upstream (Lake A) end, which will have two submerged stainless-steel slide gates. One slide gate allows flow to enter the vault from Lake A, and the other allows flow to exit the vault into an 84-inch-diameter conduit. These gates will control the flow and allow pipeline shutdown for inspection and maintenance. These slide gates will require an operating platform that is elevated above the maximum water surface elevation.

Flow exits Vault 1 via a slide gate into an 84-inch-diameter steel reinforced high-density polyethylene (HDPE) pipe material that conveys flow under Isabel Avenue. Downstream (west) of Isabel Avenue flow enters another vault (Vault 2) that diverts flow via slide gates to either Lake B directly or to Lake C through another 84-inch-diameter HDPE conduit. Construction details will conform to Caltrans standards (that are in effect) during final design. Figure 5-5 shows the alignment of the vaults and slide gates.

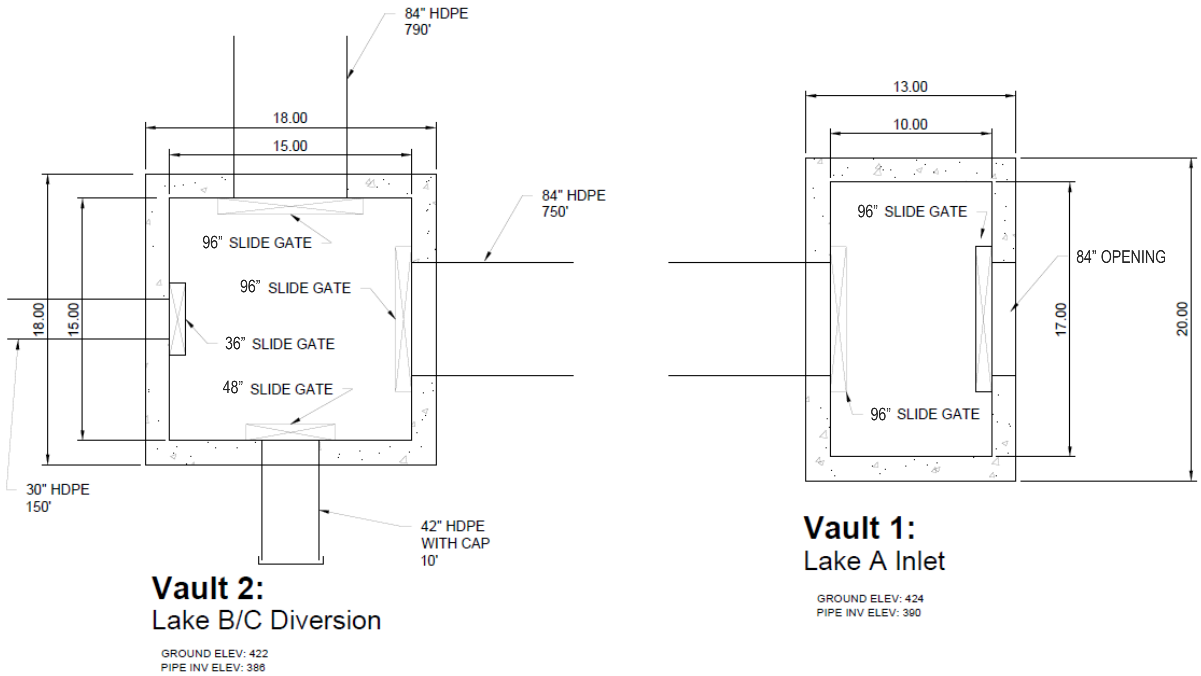

Figure 5-5. Plan views of Vault 1 and Vault 2 for the Lake A–Lake C pipeline

The pipeline will consist of the following major components:

- **Vault 1, Lake A inlet controls**: Vault 1 will be at the pipeline's upstream (Lake A) end, and will have two 96-inch-high by 96-inch-wide submerged stainless-steel slide gates. One slide gate allows flow to enter the vault from Lake A, and the other allows flow to exit the vault into an 84-inch-diameter conduit. The inlet will have an invert elevation at approximately 390 feet msl. This gate is to be completely submerged below the expected minimum surface water elevation of 408.7 feet msl (EMKO 2018). The slide gates in Vault 1 will be installed to control flow and allow for pipeline shutdown for inspection and maintenance. These slide gates will require an operating platform elevated above the maximum water surface elevation of 420 feet msl. The top of the vault and operating platform should be placed above grade, or roughly 424 feet msl.
- **Conduit from Vault 1 to Isabel Avenue:** Approximately 640 linear feet of 84-inch-diameter HDPE pipe will be installed from the west bank of Lake A to Isabel Avenue. Pipe installation in this section will use traditional cut-and-cover construction with an average pipe depth of 27 feet.
- **Jack-and-bore section under Isabel Avenue:** Approximately 150 linear feet of the pipeline will be installed under Isabel Avenue and parallel to a Pacific Gas and Electric (PG&E) utility line using jack-and-bore construction. This section will include an 84-inch-diameter HDPE pipe encased in a 108-inch-diameter welded-steel jack-and-bore installed casing, as required by Caltrans.
- **Vault 2, Lake B/C diversion:** Pipe installation west of the Isabel Avenue ROW will use shoring and shielding to continue installation of the 84-inch-diameter HDPE pipe from the jack-and-bore section to Vault 2. Flow enters Vault 2 downstream of Isabel Avenue via a 96-inch wide by 96-inch -high slide gate. Vault 2 serves as a diversion structure to convey flow either to Lake B or Lake C. Flow may be diverted to Lake B via a 36-inch-wide by 36-inch-high slide gate with 30-inch-diameter pipe to the Lake B outfall. Flow may be diverted to Lake C via a 96-inch-wide by 96-inch-high slide gate with 84-inch-diameter HDPE conveyance pipe to the Lake C outfall. An additional 48-inch-wide by 48-inch-high slide gate with stub outlet is also included in Vault 2 for future use by Zone 7.

- **Conduit from Vault 2 to Lake C**: In its final design, approximately 800 linear feet of 84-inch-diameter HDPE pipe will be installed from Vault 2 to the outlet at Lake C, where flow will discharge onto a riprap apron at Lake C with an outlet elevation of 380 feet msl. This section of pipe will be installed using standard shoring, sheeting, and shielding techniques with an average pipe depth of 27 feet. However, until future Lake C is developed, approximately 550 linear feet of conduit from Vault 2 to CEMEX's property line will be stubbed and capped at both ends. A damage-resistant marker detectable by metal detectors will be placed at the surface of the stub and cap location to demarcate the location of the pipe.

BC performed a hydraulic evaluation of the proposed Lake A to Lake C pipeline to confirm that the system would have sufficient hydraulic head in Lake A to meet the 500 cfs requirement. BC used PC-Storm Water Management Model (SWMM) 5.1 software to simulate pipeline hydraulics assuming the following conditions:

- A conservative roughness value (i.e., Manning's n) of 0.013 is used for all HDPE pipes
- Gates are modeled with discharge coefficients (C_d) of 0.5, 0.6, and 0.7 to capture a likely range[5]
- At Vault 2 velocity reduces to zero, which is a conservative assumption in estimating headloss across the line of conveyance from Lake A to Lake C
- Slide gates for the 84-inch-diameter pipe conveyance are a minimum of 7 feet wide by 7 feet high
- The 36-inch and 48-inch slide gates are closed when conveying water to Lake C
- Water levels in Lake C always below the pipeline outfall (i.e., free discharge conditions)

Groundwater levels in the vicinity of the Project Site tend to fluctuate based on rainfall patterns and groundwater pumping. The actual water level in Lake A will vary depending on climatic conditions and diverting water into and out of the lake. Under normal conditions, Lake A would operate with a water level of approximately 420 feet msl. The water surface elevation in Lake A is anticipated to be above 409 feet msl for most diversion operations (EMKO 2018).

To demonstrate the proposed pipeline is capable of conveying 500 cfs, BC conducted a series of hydraulic modeling simulations using water surface elevations at Lake A varying from 395 feet msl to 420 feet msl, based on the available information regarding potential Lake A water levels. BC also evaluated multiple discharge loss coefficients (C_d) to account for potential variations in minor losses within the system. The results from these simulations indicate that Lake A water levels of roughly 405 feet msl and above will have sufficient capacity to convey water to Lake C at a rate of 500 cfs (Figure 5-6). With Lake A water levels planned for 420 msl, the Lake A to Lake C pipeline will have more than sufficient hydraulic head to convey the desired 500 cfs specified in the Specific Plan and by the Zone 7 Agreement. Concept-level design drawings for the proposed pipeline are provided in Appendix E.

[5] A recent study by Navid Nasehi Oskuyi and Farzin Salmasi (2012) found that C_d values can be calculated using gate opening depth and water elevations on the inlet and outlet side of the gate. Using this methodology, BC found that a range of 0.5 to 0.7 will capture all likely values of C_d for the gates in this pipeline design.

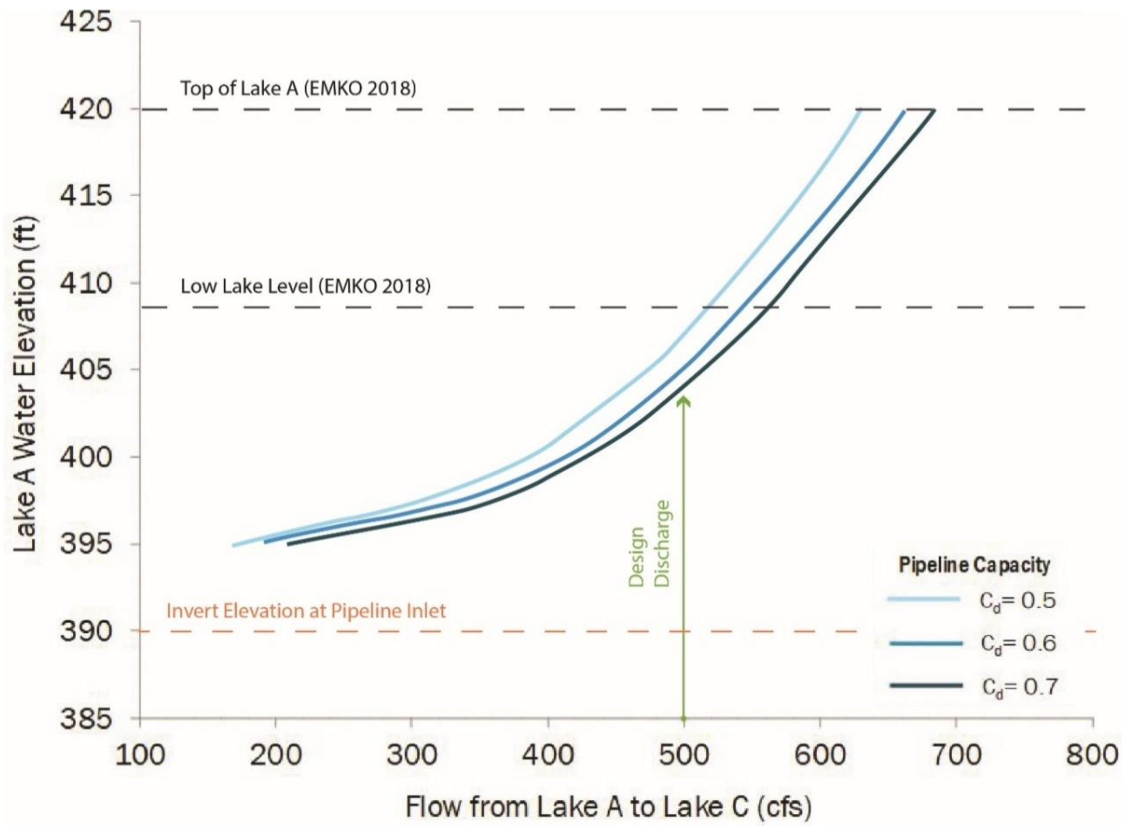

Figure 5-6. Calculated capacities for the proposed pipeline from Lake A–Lake C

After the pipeline is constructed, the 500-cfs design discharge capacity should be verified by desktop analysis using as-built dimensions; field testing will not be possible because water cannot be run through the pipeline until Lake C is excavated. Therefore, BC recommends a similar hydraulic analysis be conducted including confirming the pipeline dimensions, invert elevations, water surface elevations, and assumptions regarding losses.

5.2.2 Lake B and Lake C Conduit

The embankment between Lake B and Lake C is natural and will not be mined or reconstructed. CEMEX will install a 30-inch-diameter pipe in the unmined berm between Lake B and Lake C. The invert elevation for the pipe will be approximately 350 feet msl at Lake B, and approximately 349 feet msl at Lake C, providing a slope of 0.0030 foot vertical per 1 foot horizontal (ft/ft). Appropriate gates or other devices will be installed to control the transfer of water from one lake to another, as required by the Zone 7 Agreement (Zone 7 1988). Flow between the lakes will occur by gravity, based on the head differences between Lake B and Lake C, and mechanical pumping facilities will not be installed. Depending on the head difference between the two lakes, water may flow from Lake B to Lake C or from Lake C to Lake B when the control gates are open.

The conveyance between Lake B and Lake C will be constructed in generally the same location, depth, and manner as that required in the Zone 7 Agreement and shown in the SMP-23 Reclamation Plan (Zone 7 1988; Lone Star Industries, Inc. 1987). However, until future Lake C is constructed, the conduit will require stubbing and capping with backfill over it. A damage-resistant marker detectable by metal detectors will be placed at the surface of the stub and cap location to demarcate the location of the pipe.

5.3 Lake Outlets

Lake A. CEMEX proposes to construct an overflow outlet at the southwest end of Lake A to allow water to flow back into ADV. The outlet will consist of a 270-ft wide shallow spillway lined with pit run gravel at elevation 420 ft msl that slopes south toward ADV at 3 horizontal to 1 vertical (personal communication with Karen Spinardi, civil engineer with Spinardi Associates, October 2018).

Lake B. CEMEX proposes to construct an outlet on Lake B to allow water to flow back into ADV through a controlled and stable pathway. The outlet will be located at the west end of Lake B and will consist of an armored trapezoidal weir and chute, with an armored outlet apron as shown in Figure 5-7.

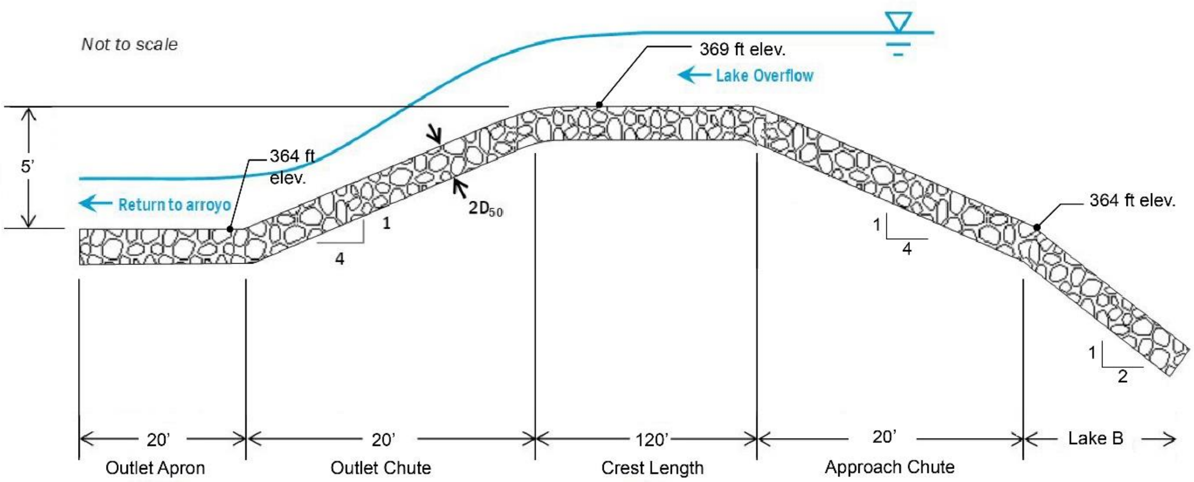

Figure 5-7. Conceptual sketch for Lake B outlet

The outlet crest will be 120 ft long in the direction of flow. The outlet crest is 60 ft wide perpendicular to the flow, with 4(horizontal):1(vertical) side slope on the southern side, 2:1 side slope on the northern side and the depth of the trapezoid will be 5 feet. The outlet flow path will be lined with rock riprap to mitigate the potential for erosion to occur. Riprap should be a well-graded mixture with a median stone diameter (D_{50}) of approximately 15 inches or a median stone weight of 200 pounds. Standard riprap gradation classes are found in the *California Bank and Shore Rock Slope Protection Design Manual* (Racin 2000) and guidance from the Federal Highway Administration (USDOT 2009). BC recommends the use of either of the following riprap slope protection classes:

- “Light” riprap as specified by the *California Bank and Shore Rock Slope Protection Design Manual* (Racin 2000)
- “Class IV” as specified by the Federal Highway Administration (USDOT 2009)

The thickness of the riprap blanket should be approximately 2 times the median stone diameter, which is roughly 30 inches if one of the above-specified riprap classes is used.

Table 5-2. Conceptual Design Parameters for Lake B Outlet	
Parameter	Design Sizing
Weir crest width (ft)	60
Weir crest length (ft)	120
Minimum depth of trapezoidal weir section (ft)	5
Side slope of trapezoidal section (H:V)	2:1 and 4:1
Slope of chute (H:V)	4:1
Median rock diameter for armoring, D_{50} (inches)	15
Minimum thickness of rock armoring, $2D_{50}$ (inches)	30
Length of inlet (ft)	20
Length of outlet, $30D_{50}$ (ft)	40

5.4 Arroyo Realignment

In order to develop the sand and gravel resources on the South side of Lake B, CEMEX will move ADV closer to Vineyard Avenue in a realigned channel and floodplain, creating an enhanced riparian and aquatic habitat, as shown in Figure 5-8. A total corridor width of 260 feet will allow for 30-foot-wide easements for access roads on either side and will still provide adequate space to tie in to the existing grade (Figure 5-8).

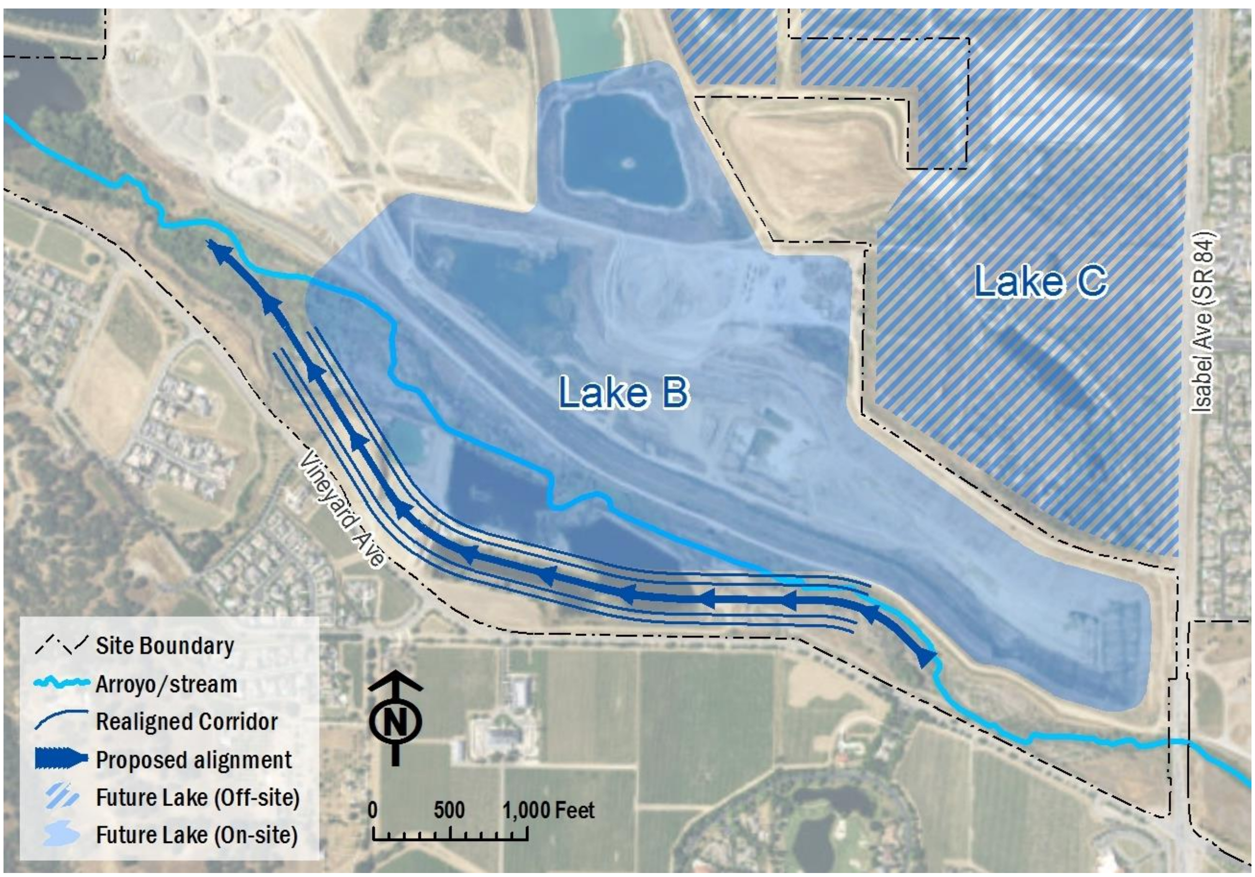

Figure 5-8. Proposed expansion of Lake B and new arroyo alignment

The corridor shown in Figure 5-8 is approximately 5,800 feet long. The upstream end of the corridor is roughly 390 feet above msl and the downstream end is roughly 360 feet above msl; the resulting channel slope is equal to approximately 0.56 percent.

Given the site constraints and findings from the preliminary geomorphic assessment, BC performed hydraulic design calculations to develop channel dimensions and design parameters (Section 5.1). BC then performed a detailed stability analysis based on sediment continuity and the magnitude and frequency of stream flows (Section 5.2). The overall process was iterative, because feedback from the stability analysis helped to inform dimensioning the channel and floodplain. Finally, BC formulated a design (Section 5.3) and prepared drawings (Appendix E).

Geomorphic investigations conducted by Balance suggest that a single-thread channel with low-flow, bankfull, and flood stages is appropriate for restoring ADV along the new alignment (see Section 4). The following sub-sections describe the development of design parameters for the restored reach (i.e., channel and floodplain) including typical cross-section dimensions, sinuosity and meander patterns, and local variations at bends.

5.4.1 Geomorphic Design

ADV is a highly modified fluvial system that has been altered and channelized, and the hydrologic and sediment regimes dramatically changed by the construction of Del Valle Reservoir and land use changes within the watershed. It is likely that the stream is still adjusting to these impacts and continued land use changes. While the degradation caused by the dam has likely diminished, there is still a risk of instability and continued channel evolution. In addition, channels adjust naturally to episodic events such as watershed-scale wildfires and floods (Balance 2016).

Given this dynamic setting, there is no single absolute size and configuration for a restored reach of ADV. Therefore, BC and Balance used multiple lines of evidence and assessments, along with engineering and scientific judgement to develop the design. The design concept was not based on any single method, and all interpretations were made within the greater context of the Arroyo del Valle system. Accordingly, channel restoration design efforts for ADV focus on establishing a suitable range of channel geometries that will allow for some adjustment over time to accommodate the flow and sediment regime that it will experience.

5.4.1.1 Pattern and Planform

Geomorphic investigations conducted by Balance suggest that a single-thread morphology is suitable for restoring the ADV channel along the new alignment (Balance 2016, 2017). Balance further recommends that the single-thread design include elements that promote stability and channel complexity, while also providing fish passage (Balance 2017).

While there are some indicators suggesting that the arroyo can also function as a braided system, the historical flow regime and sediment loads have been dramatically altered by the construction of the Del Valle Dam, and the trend appears to be that ADV is shifting from a braided system to a single-thread form in the reaches downstream of the dam (Balance 2016, 2017). Moreover, the project will be constructed through a developed area where spatial constraints limit flexibility of the design to incorporate a wider, more complex pattern. Thus, BC has developed the design of the realigned ADV that is predominantly based on a single-thread channel configuration. However, additional features, native vegetation, and channel complexity are incorporated into the design to allow for natural evolution of the landscape, a diverse riparian ecosystem, and improved aquatic habitat.

Figure 5-9 illustrates the basic single-thread morphology as a compound-channel design with a low-flow channel, intermediate or bankfull channel, and a floodplain corridor.

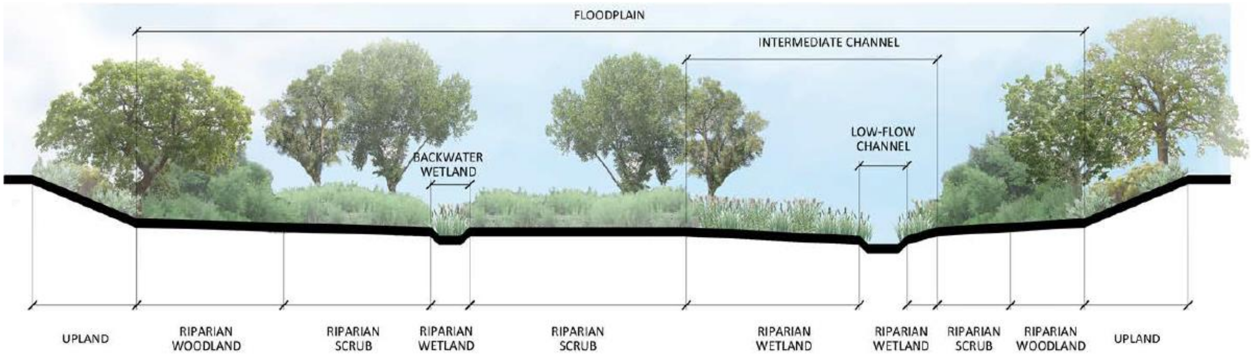

Figure 5-9. Sketch of a compound single-thread channel with low-flow, bankfull, and flood sections

Vegetation shown in this figure is for simple illustration; a detailed planting plan will be developed prior to issuance of regulatory permits by USACE and others.

5.4.1.2 Design Discharges

Design discharges are needed to size the low-flow, bankfull, and flood sections of the realigned ADV corridor. The hydrologic analyses described in Section 3 were used to inform the selection of design discharges, as follows:

- **Low flow:** A low-flow channel was designed to provide a stream channel to support aquatic habitat and maintain flow depths and velocities for fish passage during critical periods when discharges may be low. Typical dry season (i.e., May through October) flows in ADV are around 8 to 10 cfs based on streamflow records from 2002–17 (see Section 3.2.1). Therefore, the low-flow channel was designed to convey a discharge of around 8 to 10 cfs.
- **Bankfull:** In alluvial streams, the term bankfull refers to the stage or flow at which a stream begins to overtop its banks (i.e., the point of incipient flooding). The bankfull discharge is often used as a surrogate for the channel-forming discharge because it is considered to be the morphologic transition between the active stream channel, floodplain, and flow that defines channel shape and size in most stable reaches (Leopold et al. 1964). Bankfull or channel-forming flows are generally associated with the 1.5- to 2.3-year recurrence interval (Dunne and Leopold 1978). The bankfull channel has been designed to convey the 2-year peak discharge of approximately 200 cfs, which was calculated based on a regression of post-dam annual peak discharges (see Section 3.2.2).
- **Flood:** In Alameda County, floodplains are defined and managed according to the area inundated by the 100-year flood event, or the flood that has a 1 percent annual chance of occurrence. Per the Federal Emergency Management Agency's (FEMA) current Flood Insurance Study (FIS) for the County, the peak 100-year discharge for ADV is 7,000 cfs (FEMA 2009). As noted previously, flood flows in ADV are highly regulated by Del Valle Reservoir. The 100-year flood flow of 7,000 cfs corresponds to a managed flood release from the dam, which differs from the estimated 100-year peak discharge listed in Section 3.2.2 (USACE 1978). The former is regarded as a better estimate because it accounts for the flood storage at Del Valle Reservoir.

5.4.1.3 Hydraulic Geometry

Hydraulic geometry is used to describe the natural stream channel form resulting from the interaction of many environmental factors including climate, land development, sediment sources and transport, bank stability, and riparian assemblage. More simply, the size and shape of a naturally formed stream channel can be related to the frequency and magnitude of the driving forces—particularly discharge.

Balance conducted field investigations that were an important source of information for determining the preliminary hydraulic geometry for the restored channel. As described in Section 4.3.3, Balance surveyed the channel geometry of ADV at four locations in Sycamore Grove Park and measured the associated channel substrate via pebble counts and bulk sediment samples. Sycamore Grove Park is unique in that it is less altered by urban encroachments and historical mining operations, which makes it a good reference reach for how the system has responded to the post-dam hydrologic regime. Bankfull flow depths and widths were calculated using the estimated 2-year discharge and standard Manning-Strickler uniform flow equations. The results are shown in Table 5-3.

Table 5-3. Bankfull Dimensions Calculated for Cross-Sections in Sycamore Grove Park

Observation Point	Morphologic Feature	Bankfull dimensions			
		Top Width (ft)	Mean Depth (ft)	Cross-sectional Area (ft^2)	Width-to-Depth Ratio
7	Riffle	31	1.6	48	20
8	Riffle	34	1.5	49	23
9	Pool	49	1.2	59	40
10	Pool	44	1.3	56	35

Leopold and Maddock advanced the theory of hydraulic geometry by developing quantitative relationships between the shape of natural channels and discharge using simple power functions (Leopold and Maddock 1953). Dunne and Leopold promulgated the theory by developing several regional curves that relate bankfull channel dimensions (e.g., mean depth, width, and cross-sectional area) to drainage area (Dunne and Leopold 1978).

Building on the work by Dunne and Leopold, Balance developed its own modified regional curves for bankfull channel dimensions based on data collected in the Bay Area (Dunne and Leopold 1978; Hecht, Senter, and Strudley 2013). These curves were developed for areas with higher annual precipitation, so they are only used here as a secondary method for estimating bankfull dimensions. Rather than using the full watershed area, only the drainage area downstream of the dam was considered because the upper watershed is not expected to significantly contribute to channel-forming discharges. The following dimensions were estimated from the Balance regional curves based on an assumed drainage area of approximately 17 square miles:

- Cross-sectional area of 72.1 ft^2
- Channel width of 27.9 feet
- Mean channel depth of 2.1 feet

Bankfull relations must be applied loosely, with due deference for the changes that come with time in an evolving landscape—particularly those heavily affected by anthropogenic modifications. BC has used above-estimated values to help inform design of the restored channel by providing reasonable target ranges.

5.4.1.4 Slope and Sinuosity

Historic and current topography and aerial photographs were used to evaluate the slope and sinuosity of the proposed ADV realignment as needed to design a stable stream. While baseline conditions are 2018, BC used data from 2006 and 2012. During hydraulic modeling analyses, BC performed checks at several cross sections and confirmed that the channel inverts from the 2006 and 2012 data showed minimal change when compared with 2018 data, and thus, would not change the proposed slope or sinuosity for the realigned channel.

BC used aerial photography from 2012 to delineate the primary flow path of ADV, starting from Arroyo de la Laguna and ending at the base of Del Valle Dam. Elevations along most of the stream course were obtained from 2006 light detecting and ranging (LiDAR) data provided by Zone 7. Elevations outside of the available LiDAR data were obtained from USGS's National Elevation Dataset (NED), which is available at a 3-meter resolution, nearly matching the LiDAR data. In addition, historical USGS 7.5-minute quadrangle maps from 1953 were used to approximate the pre-dam profile along ADV for the same reach. The resultant stream profiles, as seen in Figure 5-10, show three distinct reaches:

- ADV below Bernal Avenue has an average slope of approximately 0.35 percent. This reach flows through Pleasanton and was substantially altered from its historical condition when the area was covered by the Pleasanton Marsh complex, and ADV bifurcated into multiple channels.
- ADV between Bernal Avenue and the Eliot Facility has little slope as it flows through Boris Lake and Island Pond near the Shadow Cliffs Recreation Area. This reach was also substantially altered from its historical conditions, largely because of past gravel mining.
- ADV from Island Pond to the base of Del Valle Dam has an average slope of approximately 0.56 percent. This reach has likely degraded from its historical elevation because of gravel mining and construction of the Del Valle Reservoir; however, the 1953 topography does not indicate a substantial decline. The most notable change from 1953 to 2006 appears to be degradation near Lake B and Isabel Avenue, which may suggest continued degradation from past in-channel mining activities.

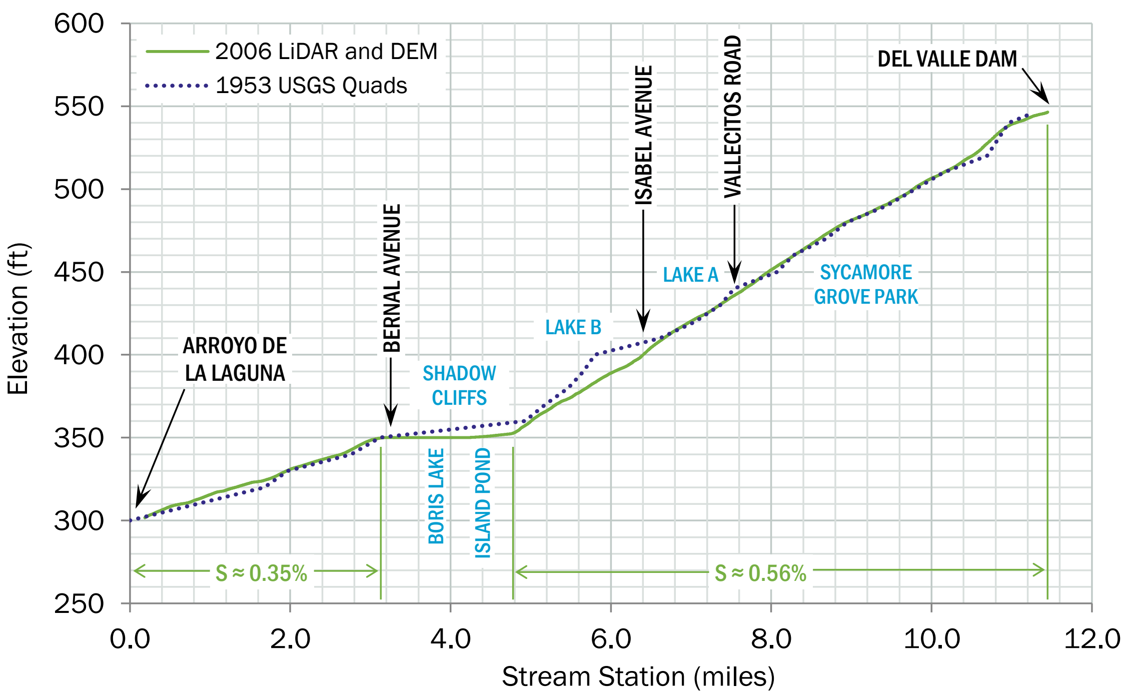

Figure 5-10. ADV stream profiles and slope estimates

The stream course delineated from 2012 aerial photography was used to estimate channel sinuosity at incremental lengths along the reach between Island Pond and the mouth of the canyon near Del Valle Dam. The sinuosity of this reach ranges between about 1.05 and 1.15 ft/ft, with an average sinuosity of 1.14 ft/ft. The estimated sinuosity of the existing channel within Sycamore Grove Park is approximately 1.13 ft/ft. The design sinuosity for the restored channel has been designed for a similar range as those observed on aerial photography; however, the final sinuosity will depend upon the hydraulic characteristics of the channel and stream power required for the anticipated sediment supply.

5.4.2 On-site Soils and Alluvial Material

ADV and the Eliot Facility overlie the Livermore Formation, which is alluvium comprising unconsolidated gravel, sand, silt, and clay deposited during the Pliocene, Pleistocene, and Holocene geologic epochs (EMKO 2013). The Livermore Formation is generally divided into three units: (1) Lower Livermore, (2) Upper Livermore, and (3) Quaternary Alluvium. The Eliot Facility is mining Holocene deposits from the Quaternary Alluvium, and possibly some Pleistocene deposits from Upper Livermore. A significant amount of the Quaternary Alluvium consists of eroded and transported Upper Livermore sediment, which makes it difficult to differentiate between the two.

GEOCON (2019) conducted geotechnical investigations within borrow areas and found that deposits from aggregate processing "generally consist of a heterogeneous mixture of sandy lean clay (CL) with gravel and some small cobble…Gravel and small cobble is typically rounded and consists of maximum particle sizes of approximately 4 inches or less. The fractions of sand, silt, clay, and gravel varies significantly throughout the deposit." GEOCON performed laboratory testing of a composite sample and found the barrow material to consist of approximately 55 percent fines (clay/silt), 25 percent sand, and 20 percent gravel.

GEOCON (2019) also investigated the on-site alluvium and found a mixture of gravel deposits, as well as some clay deposits. The gravel deposits generally consist of gravel and small cobble (less than 4 inches in diameter) in a sand/silt/clay matrix. The relative fractions of sand, silt, and clay tend to vary throughout the deposits. USCS classifications include: clayey gravel (GC), well-graded gravel with silt, clay, and sand (GW-GC), clayey sand with gravel (SC), and well-graded sand with gravel (SW-SM). The clay deposits generally consist of sandy lean clay (CL) with little gravel.

GEOCON (2019) performed seepage and slope stability analyses for embankment fill along the ADV realignment. GEOCON concluded that excavated soils generated from cut operations along the ADV realignment are "suitable for use as engineered fill/embankment construction provided they do not contain deleterious matter, organic material, or rock/cementations larger than 6 inches in maximum dimension." Based on their investigations, GEOCON anticipates that the majority of the cut materials along the alignment will consist of gravel deposits (GEOCON 2019). GEOCON further identified borrow materials ("clay" and "silt") as also acceptable for use as fill; however, soil conditions throughout the borrow areas are likely to be highly variable. Therefore, GEOCON recommends periodic sampling and laboratory testing to verify that fill materials meet the properties listed in Table 5-4.

Table 5-4. Recommended Properties for Fill Materials (GEOCON 2019)	
Property / Parameter	**Requirement**
Percent Gravel (lager than No. 4 Sieve)	---
Percent Sand (between No. 4 and No. 200 Sieves)	25 percent minimum
Percent Fines (Silt/Clay) (Finer than No. 200 Sieve)	10 percent minimum
Liquid Limit	50 maximum
Plasticity Index	7 minimum, 25 maximum
Acceptable USCS Soil Classifications	CL, SC, SC-SM, GC, GW-GC
Total Unit Weight (at 90% relative compaction)	120 pcf minimum
Effective Cohesion, C	150 pcf
Effective Friction Angle, f	23
Saturated Hydraulic Conductivity	1 x 10-4 cm/s (or slower)

pcf: pounds per cubic feet

cm/s: centimeters per second

The coarse alluvial fan deposits along ADV are important groundwater recharge areas for the Valley (EMKO 2013). Surficial soils at the Project Site are classified as Yolo-Pleasanton association, comprising a mixture of fine-loamy alluvium (i.e., Yolo soils) and gravelly fine sandy loam (i.e., Pleasanton soils) (Welch et al. 1966). These are well-drained soils with low-to-medium runoff potential, and moderately slow-to-moderate permeability (Welch et al. 1966).

Balance and EMKO performed infiltration testing at the proposed ADV realignment site to compare properties of the native soils with onsite spoil materials and evaluate their suitability as a construction material for the realigned channel and floodplain (Appendix F). The realigned corridor will require cut, fill, and compaction of the spoil soil material present at the site. Thus, existing spoil soil material around the proposed realignment is considered representative of the soil that will compose the substrate under the realigned channel.

Results from field testing indicate that infiltration rates for the spoil material are less (i.e., slower) than those observed in native soil materials, indicating that stream channel seepage rates along the restored channel are likely to be less than current rates. Given these results, Balance and EMKO concluded the following:

> [. . .] infiltration of water through the realigned channel of Arroyo del Valle would not steepen the groundwater gradient toward the south edge of Lake B, would not increase the groundwater elevation at the south edge of Lake B, and would not increase the rate of seepage into the south face of Lake B. As such, realignment of Reach-B would not alter the hydrologic conditions along the south side of Lake B in a manner that would be inconsistent with the existing geotechnical slope stability analysis (Balance and EMKO 2016).

The realigned channel and floodplain corridor will be constructed with on-site cut material, which generally consists of sands and gravels, with a mixture of some fines. Material placed in the low-flow channel will not be compacted, and if necessary, the graded soils could be ripped where unavoidable or inadvertent compaction occurs.

5.4.3 Design Criteria

The primary goals of the project are: (1) to facilitate the southerly progression of Lake B mining, while (2) enhancing the riparian and aquatic habitat along ADV. Given these goals, BC defined the following design objectives for the proposed project:

- **Realignment:** establish a new stream corridor (i.e., channel and floodplain) outside of Lake B mining operations
- **Transitions:** conform to existing grade at upstream and downstream tie-in points using gradual and stable transitions
- **Flood conveyance:** avoid adverse flooding impacts and/or substantive increases in flood risk to adjacent properties and infrastructure
- **Erosion and bank stability:** minimize the risk of channel migration/avulsion that can threaten adjacent structures or cause the stream to be captured by Lake B, or flow into adjacent areas
- **Long-term channel stability:** minimize the risk of long-term channel degradation that can result in channel incision, bank steepening/failures, substantial downstream sediment deposition, and/or upstream instability
- **Geomorphic function:** create a fluvial stream system that generates natural geomorphic conditions and maintains a stable yet dynamic equilibrium within the context of overall watershed conditions
- **Riparian and aquatic habitat:** create new habitat areas as part of a natural ecosystem that supports native flora and fauna
- **Fish passage:** avoid barriers to fish migration and create fluvial formations and natural habitat features that allow for fish passage

Table 5-5 lists the design objectives along with corresponding design criteria for the project.

Table 5-5. ADV Realignment Design Criteria and Objectives		
Issue	**Design Objective**	**Design Criterion**
Spatial constraints	Establish a new stream corridor (channel and floodplain) outside of Lake B mining operations	Preliminary grading by Spinardi suggests that a corridor width of approximately 260 ft can be created between Lake B and Vineyard Avenue. [a]
	Conform to existing grade at upstream and downstream tie-in points using gradual and stable transitions	Ensure that the channel bed elevation matches the existing upstream and downstream tie-in locations; the average longitudinal slope of the corridor should be equal to the predominant valley slope of approximately 0.56%.
Flood conveyance	Avoid adverse flooding impacts and/or substantive increases in flood risk to adjacent properties and infrastructure	The regulatory flood hazard area as defined by FEMA is based on the area inundated by the 1% annual chance event, or the 100-year flood event. Per the current effective FIS, the 100-year peak discharge on ADV downstream of Del Valle Dam is 7,000 cfs.
		Ensure that the new stream corridor contains the 100-year flood without increasing upstream inundation areas. Given the uncertainty in peak discharge estimates and floodplain hydraulics, a minimum freeboard height of 3 ft is assumed for preliminary design as a factor of safety, which is consistent with federal requirements for riverine levees.
Channel stability	Minimize the risk of channel migration/avulsion that could threaten adjacent structures or cause the stream to be captured by Lake B, or flow into adjacent areas	Ensure that water surface elevations corresponding to a 100-year peak discharge plus 3 ft of freeboard do not exceed lateral roadway/berm elevations, thereby preventing water from flowing directly from the floodplain into Lake B or other adjacent depressions.
	Minimize the risk of long-term channel degradation that could result in channel incision, bank steepening/failures, substantial downstream sediment deposition, and/or upstream instability	Develop a channel configuration (e.g., dimensions, pattern, and profile) that maintains a balanced sediment transport regime through the study reach.
		Incorporate a compound channel design to convey typical low flows, bankfull, or channel-forming flows, and flood flows while maintaining connectivity between the channel and floodplain.
		Ensure that flood flows more than the channel-forming discharge spill into a floodplain, such that the flow is unconfined, resulting in lower overbank velocities and shear stresses.
Geomorphic function	Create a fluvial stream system that generates natural geomorphic conditions and maintains a stable yet dynamic equilibrium within the context of the overall watershed	Design the dimension, pattern, and profile of the restored channel to transport sediment at rates that create a long-term balance with the inflowing sediment load.
		Use fill materials to construct the channel and floodplain that are comparable to the existing stream bed material with a bed competence and composition sufficient to limit degradation.
Biological resources	Create new riparian and aquatic habitat areas as part of a natural ecosystem that supports native flora and fauna	Construct a low-flow channel that can be used to create habitat areas such as freshwater marsh, a perennial stream, and intermittent stream.
		Construct an intermediate, frequently flooded channel that can be used to create habitat areas, such as riparian scrub and riparian wetland.
		Construct a floodplain that can be used to create riparian habitat areas that are flooded only occasionally.
	Avoid barriers to fish migration and create fluvial formations and natural habitat features that allow for fish passage	Configure the low-flow channel to maintain targeted flow depths and velocity ranges for identified fish species and life stages.
		Do not create in-channel obstructions or depth/velocity conditions that exceed specified criteria for identified fish species and life stages.

a. *Source: Compass Land Group 2018 and Spinardi 2018*

Preliminary investigations were performed to evaluate project design criteria and support design development. These investigations can be broadly divided into four categories: (1) civil/site design, (2) hydrology, (3) geomorphology, and (4) biology. The flow chart in Figure 5-11 describes the major steps and illustrates how these investigations feed into the overall conceptual design development. This report focuses mostly on the hydrologic and geomorphic investigations supporting the design (see Sections 3 and 4, respectively). This section describes development of the design, including hydraulic design and stability analyses.

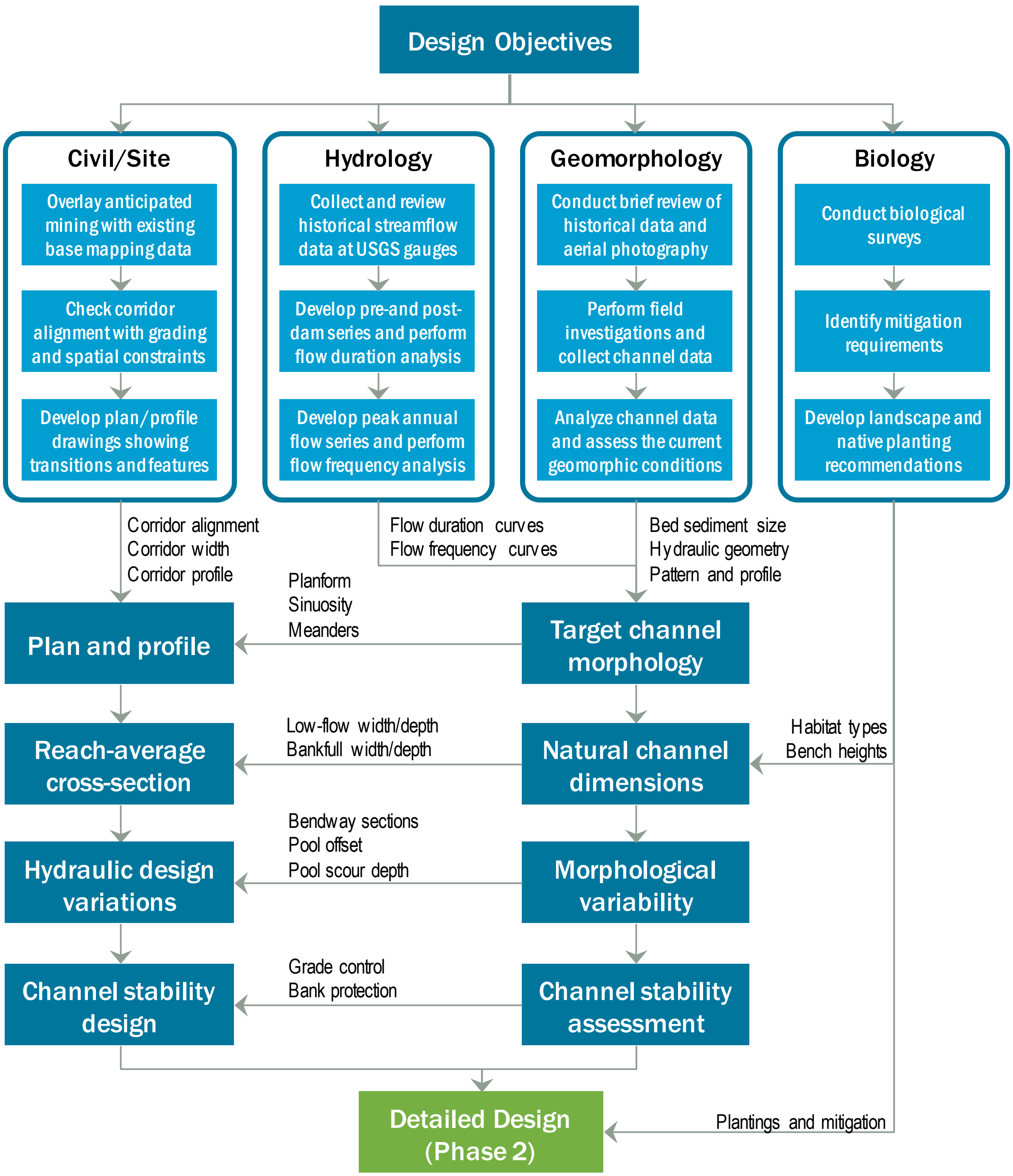

Figure 5-11. ADV Realignment conceptual design development process

5.4.4 Cross-Section

A general, or reach-averaged cross-section for the compound channel and floodplain was developed based on spatial constraints, geomorphic recommendations, and recognized hydraulic design methodologies. Channel stability analyses (Section 5.2) were performed in parallel to establish a slope and geometry that maintain sediment continuity through the restored reach. The size and configuration of the resultant reach-averaged cross-section are:

- **Low-flow channel:** The low-flow channel was designed to convey 9 cfs, which is based on the average daily discharge and is roughly equivalent to the typical dry season flow releases in ADV. The basic trapezoidal shape has a bottom width of 8 feet and side slopes at 2 to 1 horizontal to vertical (H:V). An assumed low-flow channel depth of 6 inches provides enough flow capacity, while also providing a bench less than 1 foot above the thalweg that can be used for freshwater marsh and stream habitats. The top width of the low-flow channel is 10 feet.
- **Bankfull channel:** The bankfull channel will contain the low-flow channel, but will also include a second stage sized to convey the estimated bankfull discharge of approximately 200 cfs. Observations in Sycamore Grove Park indicate that the bankfull channel width for ADV is likely around 31 to 34 feet at riffles, and 44 to 49 feet at pools. This is slightly wider than the 28 feet predicted by hydraulic geometry equations for the region, but is considered reasonable; a slightly wider channel is required to accommodate the compound channel configuration. Assuming a top width of 36.0 feet and 2 to 1 H:V side slopes, the depth of the bankfull channel must be 2.1 feet to convey the bankfull discharge, which matches the depth predicted by hydraulic geometry equations for the region.
- **Floodplain:** The stream corridor will widen considerably above the bankfull depth to provide a floodplain area for dispersing high flows, reducing velocities, and providing space for riparian habitat. Assuming a maximum top width of 260 feet and 3 to 1 H:V side slopes, the floodplain terrace will be approximately 215 feet wide. The floodplain terrace will generally be between 2.1 and 2.5 feet above the thalweg, with a gradual slope back toward the bankfull channel. The total depth of the floodplain corridor will depend on the final grading for the project, but will be around 10 feet above the thalweg. Preliminary hydraulic modeling indicates that there will be more than 3 feet of freeboard between the 100-year water surface (based on the FEMA discharge of 7,000 cfs) and the top of the realigned corridor.

Figure 5-12 shows the general cross-section for the realigned corridor with a compound channel and floodplain, including simulated water surface elevations for each of the design discharges. The actual position of the bankfull and low-flow channels will vary laterally across the floodplain because of meandering. Similarly, the depth and width of the bankfull channel will have localized variations when features such as bends, riffles, and pools are added to the design.

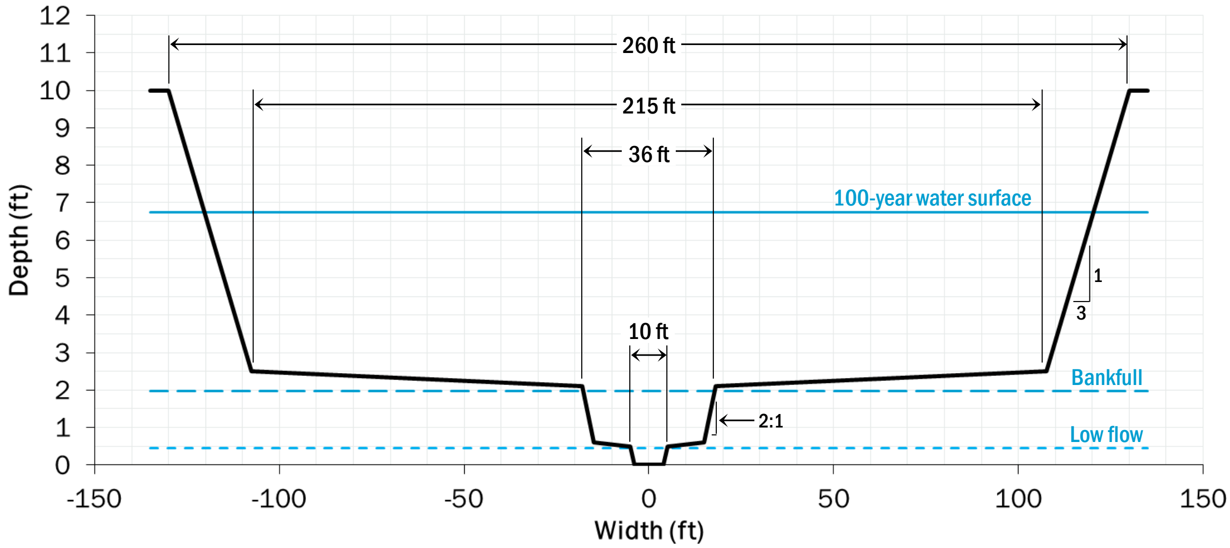

Figure 5-12. Reach-averaged cross-section widths for compound channel design

5.4.5 Channel Pattern

Nearly all natural stream channels have some sinuosity; Leopold and Wolman note that it is unusual for a stream channel to be straight for more than about 10 channel widths (Leopold and Wolman 1960). In fact, according to Leopold and Langbein: "[scientists] have found that meanders are not mere accidents of nature but the form in which a river does the least work in turning, and hence are the most probable form a river can take" (Leopold and Langbein 1966).

For engineering purposes, meanders can be viewed as wave patterns where the distance between two consecutive bends is the wavelength, λ, and the lateral spread between two bends is the amplitude, or the width of the meander belt, W_{belt}. Building on their least work concept, Langbein and Leopold developed an analytical approach for determining planform meanders based on the theory of minimum variance, which asserts that streams seek the path that provides the minimum variance of bed shear stress and friction, and that this path closely resembles a sine-generated curve (Langbein and Leopold 1966). Figure 5-13 illustrates how wave parameters can be used to define channel meanders.

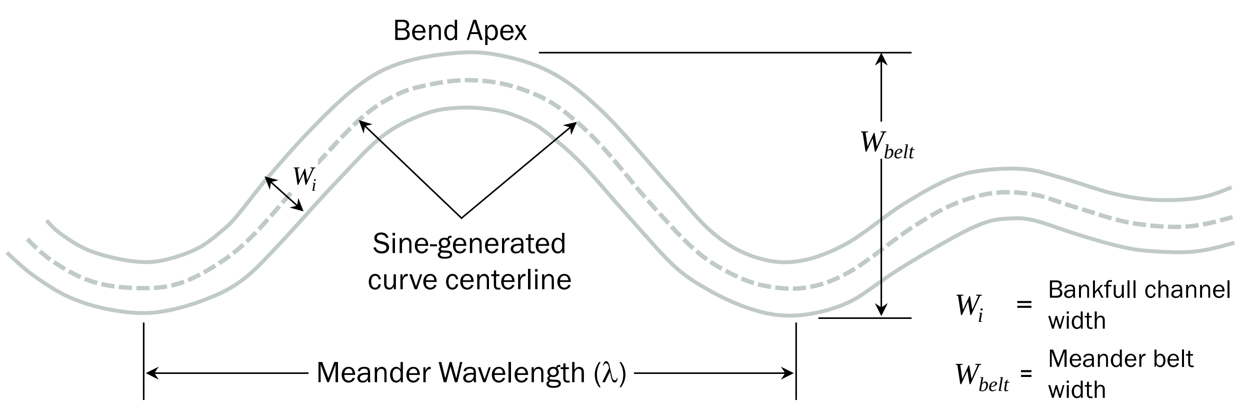

Figure 5-13. Meander and bend parameter definitions

Copeland et al. present hydraulic design methodologies for stream restoration projects, including discussions on planform and meander development (Copeland et al. 2001). The equation for a sine-generated meander curve is given as:

$$\phi = \omega \sin\left(\frac{2\pi s}{\lambda K}\right)$$

Where, ☐ = angle of meander path with the mean longitudinal axis

ω = maximum angle a path makes with the mean longitudinal axis in radians

s = the curvilinear coordinate along the meander path

λ = wavelength

K = sinuosity

Note that λK is often replaced my M, which is the meander arc length.

The angle of the meander path, ϕ, can be calculated from the curvilinear coordinate along the meander path, s, if all other variables are known. The ordinates of the meander centerline can then be determined by numeric integration, or by approximate methods.

5.4.5.1 Wavelength

Copeland et al. discusses several relationships for estimating meander wavelength, λ, based on channel width, W, including the following equation developed by Leopold and Wolman (Copeland et al. 2001; Leopold and Wolman 1960):

$$\lambda = 10.9W^{1.01}$$

Formation of meanders in natural streams is driven primarily by stream flow dynamics rather than by sediment or debris loads (Leopold and Wolman 1960; Leopold et al. 1964). Leopold and Wolman describe how meander formation relates to the same flow mechanisms that lead to variation in bed forms, noting that the meander wavelength closely resembles riffle and pool spacing (Leopold and Wolman 1960). Hey found that the distance between successive riffles (or pools) equates to roughly 2π times the channel width ($2\pi W$), which produces similar results to the wavelength equation presented above (Hey 1976). Thus, using a bankfull width of 36 feet, the design meander wavelength for the restored channel was estimated to be 407 feet using Leopold and Wolman and 452 feet using the Hey relationship (Leopold and Wolman 1960; Hey 1976).

5.4.5.2 Sinuosity

As described in Section 4.4.3, ADV currently exhibits a relatively low sinuosity, K, in the range of 1.05 to 1.15 ft/ft. The existing channel through Sycamore Grove Park—which has shifted to a single-thread form since the construction of Del Valle Dam—has an average sinuosity of approximately 1.13 ft/ft. BC targeted a similar sinuosity for the realigned channel by incorporating gradual meanders and bends into the new alignment.

5.4.5.3 Maximum Angle

The maximum angle of the meander path, ω, can be approximated from the sinuosity as given by Mecklenburg and Jayakaran (2012):

$$\omega = 2\sqrt{2}\sqrt{1 - \frac{1}{\sqrt{K}}}$$

5.4.5.4 Meander Computations

Once wavelength and sinuosity are found, meander calculations can proceed for a series of plotted ordinates. For example, if we assume a wavelength of 407 feet and a sinuosity of 1.13, a meander angle curve can be plotted for a complete wavelength (Figure 5-14[a]). Then, the ordinates of the meander centerline can be determined by approximate methods (Figure 5-14[b]).

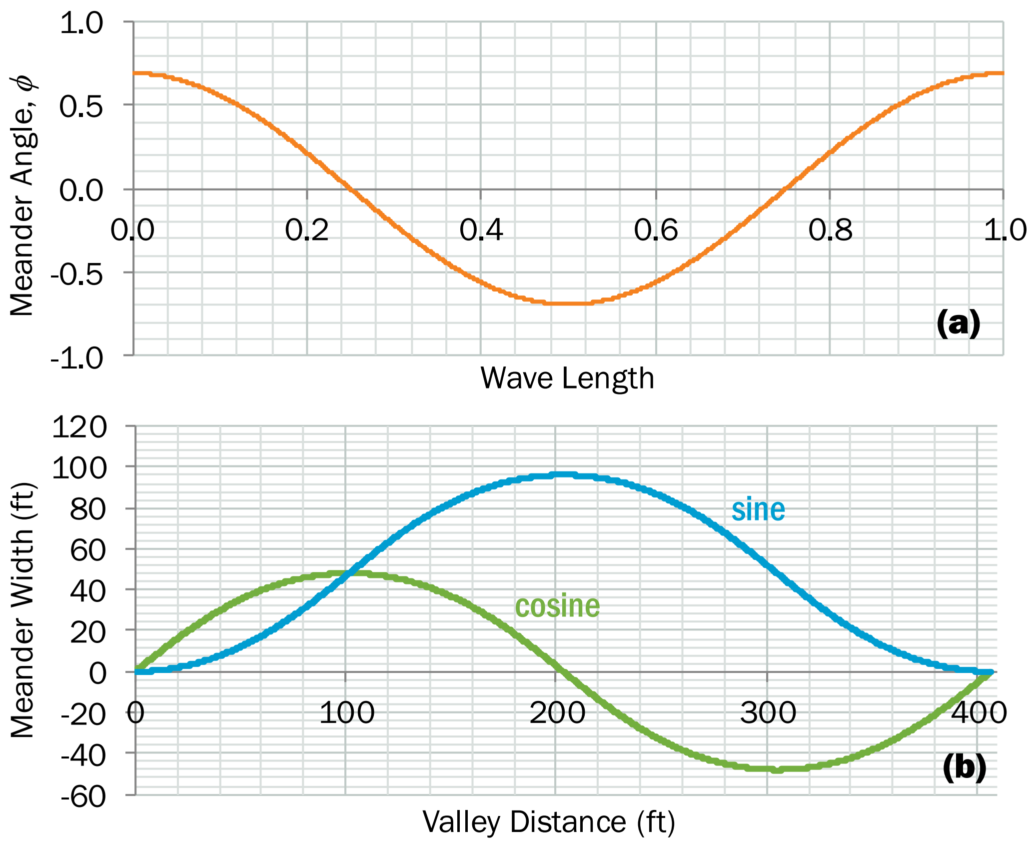

Figure 5-14. Example of a sine-generated meander pattern for λ = 407 and *K* = 1.13

BC developed a meander pattern for the realigned reach of ADV by applying the sine-generated curve template to a series of meander curves. BC utilized the uncertainty around the wavelength and sinuosity parameter estimation to introduce more of a naturalistic variation to the planform, while still maintaining a stable geometry that is consistent with conditions along existing and upstream reaches. Sinuosity was allowed to vary randomly between 1.0 and 1.2, and wavelength was allowed to vary randomly between 350 and 550 feet. Each sinuosity wavelength parameter set was applied for four-thirds of the wavelength (4λ/3) before transitioning to the next parameter set. Figure 5-15 shows the simulated meander pattern for the entire reach. While the stream corridor is approximately 5,800 linear ft, the plot in Figure 5-15 shows a slightly shorter length, allowing space to accommodate gradual transitions between the realigned reach and the existing reaches at the upstream and downstream tie-in locations (see Section 5.4.7).

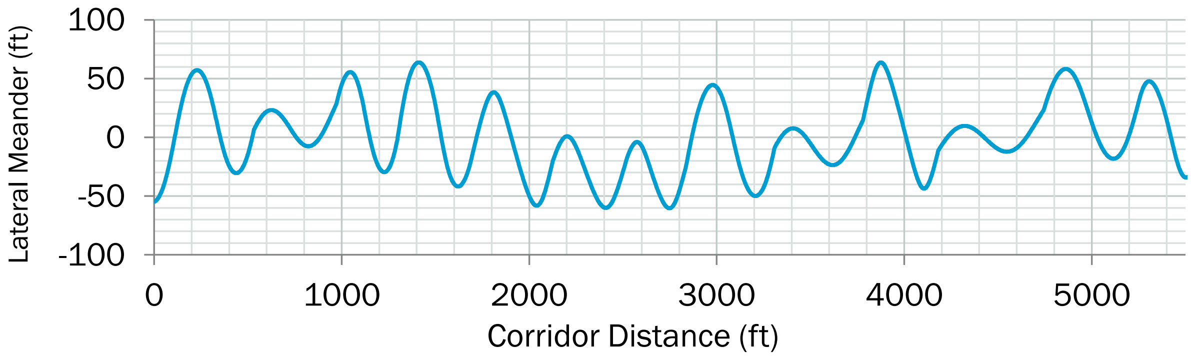

Figure 5-15. Meander pattern for bankfull channel

The lateral offsets defined by the above meander pattern were applied to the centerline of the realigned corridor (rather than an x-axis) to spatially translate the data and generate real-world geospatial coordinates for the bankfull channel centerline. Left and right bank lines were then generated in ArcGIS by creating parallel lines offset by 18 feet ($W/2$) on either side of the bankfull channel centerline.

5.4.6 Bed and Bend Variation

Although the geometry of a stream channel can be described in terms of a reach-averaged cross-section, the actual geometry of the stream will naturally vary along its course. Variations in the width and depth of the channel tend to correlate with bends, as does the formation of pools and riffles. Pools generally form in bends where the channel becomes wider and deeper due to accelerations along the outside of the bend that erode material. Conversely, riffles tend to form in areas between bends; channel widths are typically narrower and depths are shallower than those found in pools.

Leopold and Wolman describe how bends generally produce a circular motion that forms helical or spiral flow through meanders, first observed by Thomsen (Leopold and Wolman 1960; Thomsen 1879). Centrifugal force causes superelevation on the outside of a bend, flow is forced downward toward the bed, and increased shear stress on the concave bank causes erosion. As the water moves downstream through the curve, it rotates inward toward the convex bank, velocity decreases, and entrained sediment deposits (see Figure 5-16).

This basic erosional and depositional pattern through the bend creates a deeper pool toward the outside of the bend and a shallower point bar formation on the inside of the bend (Leopold et al. 1964). Riffles form between pools and are generally located near the cross-over, or point of inflection between meander bends (Leopold and Wolman 1960). Riffle sections exhibit shallow, rapid flow with bed sediments that are coarser than those of the pool sections. Figure 5-17 illustrates typical bend morphology and shows the general variations in flow depths and cross-section widths.

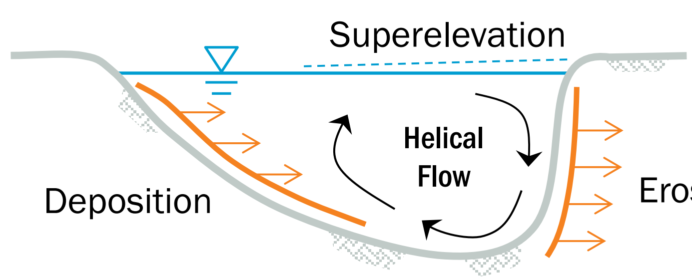

Figure 5-16. Cross-section showing secondary flow in bends

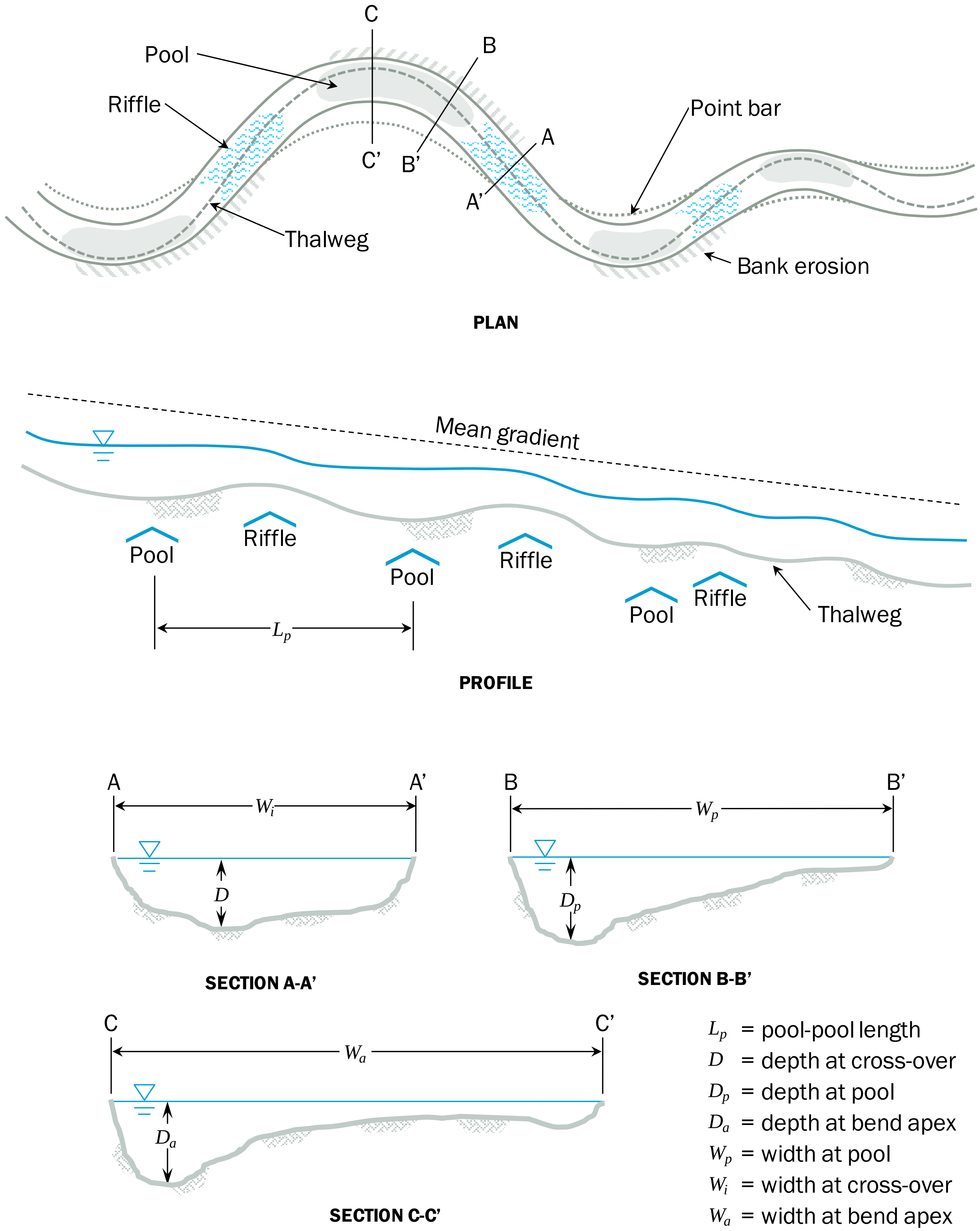

Figure 5-17. Typical morphological variations and bed forms within bends

Source: Adapted from Copeland 2001; Harmon et al. 2012.

Not drawn to scale.

Channel cross-sections within riffles, or the approximate inflection point of the meander, most closely resemble the reach-averaged cross-section described in Section 5.1.1. However, the width and depth of the cross-section tend to increase through the bends as shown in Figure 5-17.

Copeland presents morphological relationships for width ratios; however, these are applicable to moderate-to-high sinuosity streams (i.e., sinuosity greater than approximately 1.2) (Copeland et al. 2001). Alternately, BC used the observed widths in the Sycamore Grove Park reach of ADV to estimate the ratio between the maximum width at the bend apex (i.e., pools) and the width at the inflection point (i.e., riffles). Top widths presented in Table 5-3 indicated that bankfull channel widths in bends are approximately 1.43 times greater than bankfull channel widths at riffles. Therefore, for design purposes, the widths will vary from approximately 36 feet between bends to approximately 52 feet at the apex of bends.

In natural streams, the deepest pool is usually located just downstream of the bend apex. Copeland recommends that restored streams mimic this attribute using a pool-offset ratio, which is the distance from the bend apex to the deepest part of the scour hole divided by the distance from the bend apex to the next downstream inflection point (Copeland et al. 2001). Empirical data presented by Copeland indicate an average pool-offset ratio of 0.36 (Copeland et al. 2001). Thus, the deepest part of the scour hole in a bend should be roughly one-third of the distance between the apex of the bend and the inflection point downstream.

Copeland also provides the following design equation for estimating maximum pool depth based on the mean depth at the inflection point (Copeland et al. 2001):

$$D_{max} = D_m \left(1.5 + 4.5 \left(\frac{R_c}{W_i}\right)^{-1}\right)$$

Where, D_{max} = maximum depth of the scour pool, feet

D_m = mean depth at the inflection point between bends, feet

R_c = radius of curvature of the bend, feet

W_i = width of the channel at the inflection point

The width of the channel at the inflection point is equivalent to the bankfull channel width of 36 feet. The mean depth for the bankfull channel described in Section 5.1.1 is 1.56 feet. The radius of curvature for a sine-generated curve varies; however, a fit can be approximated using an equation presented by Mecklenburg and Jayakaran (Mecklenburg and Jayakaran 2012):

$$R_c = \frac{\lambda K^{1.5}}{13(K-1)^{0.5}}$$

Given the ranges of sinuosity, K, and wavelength, λ, described in Section 5.1.2, the radius of curvature for the bends varies between roughly 100 and 400 feet. Consequently, the maximum depth of the bankfull channel will vary between approximately 2.7 and 4.0 feet in pools just downstream of the designed meander bends.

The hydraulic design parameters developed in Section 5.1 were applied to the site to form a complete design concept. Figure 5-18 provides an overview of the proposed realigned channel. Appendix E provides additional maps of the proposed alignment.

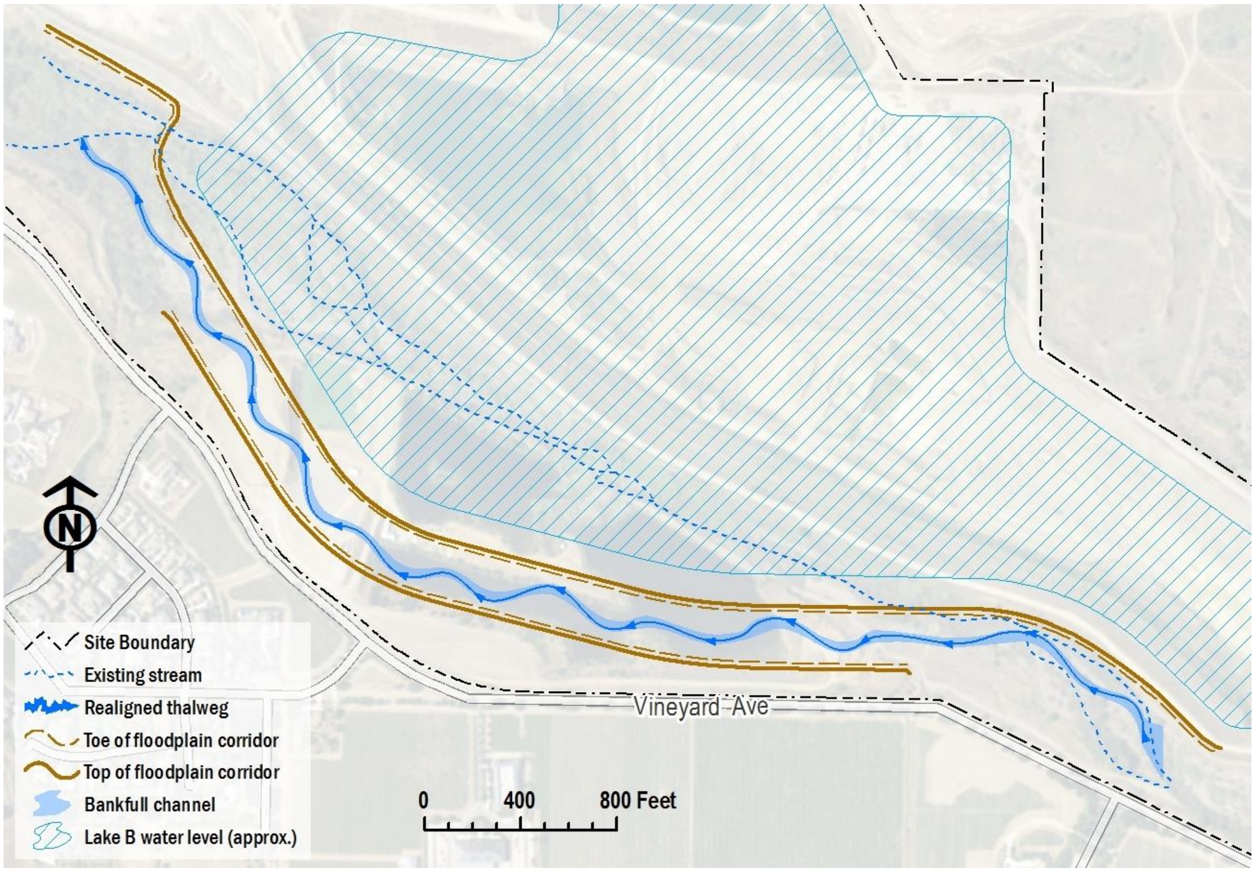

Figure 5-18. Design overview for realigned bankfull channel and floodplain corridor

The realigned channel begins about 1,600 feet downstream of Isabel Avenue at an elevation of roughly 393 feet above msl. The new alignment briefly parallels the existing channel and then shifts southwest closer to Vineyard Avenue. Construction of the new channel and floodplain corridor will eliminate an existing remnant quarry pond at the southern edge of the site and restore an uninterrupted stream channel. The downstream end of the realigned channel will tie back into the existing channel several hundred feet northwest of the future extent of Lake B at an elevation of roughly 358 feet above msl. The realigned corridor extends roughly 5,800 linear feet and the realigned bankfull channel within the floodplain extends approximately 6,200 linear feet.

5.4.7 Additional Complexity and Habitat

BC incorporated additional features into the design of the realigned corridor to increase channel complexity and diversity of habitat. Stream channel complexity generally refers to the heterogeneity of stream geometry or habitat and plays a critical role in maintaining stream ecosystem structure and function (Livers and Wohl 2016; Laub et al. 2012). Johnson et al. (2019) describes the importance of connecting streams with healthy ecosystems as part of stream restoration. Johnson et al. (2019) further emphasize the influence of biology on maintaining natural stream functions and processes.

With this in mind, Balance (2017) recommended that the realigned ADV include additional elements such as overflow channels within the floodplain, off-channel wetlands, and vegetated mid-channel bars (Balance 2017). BC worked closely with Balance and team biologists to develop several options for adding complexity and habitat features to the basin channel design. Table 5-6 lists the types of features and associated design criteria.

Table 5-6. Geomorphic Diversity and Habitat Features				
ID	Description	Objective	Function/Benefit	Design Criterion
1	Flow-through wetland	Create off-channel willow riparian wetland habitat that allows surface water to flow through and inundate areas for a prolonged period (at least 14 days) during the growing season.	Supports willow riparian wetland habitat and provides area for wetland mitigation.	• Wetland will be inundated by overflow from stream channel a minimum of 14 days per year in and average year, based on historical post-dam stream flow frequency. • Wetland should not have enclosed depressions greater than approximately 12 inches; however, microtopography will be created (field fit) with roughly 6–12 inches of variation to slow flow. • Entry and exit angles should be relaxed to avoid acute bends and sharp changes in flow direction.
2	Backwater wetland	Create off-channel willow riparian wetland that that is inundated by intermediate flows through a backwater channel, occurring about once a year on average.	Supports willow riparian wetland habitat and provides area for wetland mitigation.	• Wetland will be inundated by overflow from stream channel a minimum of 14 days per year in and average year, based on historical post-dam stream flow frequency. • Wetland should not have enclosed depressions greater than approximately 12 inches; however, microtopography will be created (field fit) with roughly 6–12 inches of variation to slow flow.
3	Tributary wetland	Create willow riparian wetland areas near tributary confluences utilizing tributary flows where possible.	Supports willow riparian wetland habitat and provides area for wetland mitigation.	• Wetland will be inundated by overflow from stream channel a minimum of 14 days per year in and average year, based on historical post-dam stream flow frequency. • Wetland should not have enclosed depressions greater than approximately 12 inches; however, microtopography will be created (field fit) with roughly 6–12 inches of variation to slow flow. • Entry and exit angles should be relaxed to avoid acute bends and sharp changes in flow direction.
4	Channel bifurcation	Increase stream channel complexity by creating a bifurcated section where a secondary channel can be activated by a wide range of flows.	Allows for a more dynamic and active fluvial system while still maintaining a controlled and relatively stable condition.	• Secondary channel should have similar geometry to bankfull channel such that it could become the preferred flow path at a future time. • Low-flow channel will be directed preferentially into the main channel by design.

BC worked with Balance to delineate and design various features along the realigned reach to increase the geomorphic diversity, support natural vegetation, and promote healthy habitats and ecosystems. Figure 5-19 shows the proposed realigned channel and floodplain with locations of the additional habitat features.

Vegetation will play a crucial role in creating a healthy and stable stream system. In particular, healthy vegetation will need to be established along the bankfull and low flow channel sections to maintain strong and stable banks. To address these needs, Helix Environmental Planning Inc.[6] (Helix) will prepare a *Woodland Riparian Restoration Plan* for the project. This document will provide a detailed planting plan, as well as describe near-term activities and requirements for establishing native vegetation along the channel, within the added habitat features, and across upper floodplain areas. The document will also outline on-going activities for long-term adaptive management of vegetation.

[6] Formerly Foothill Associates

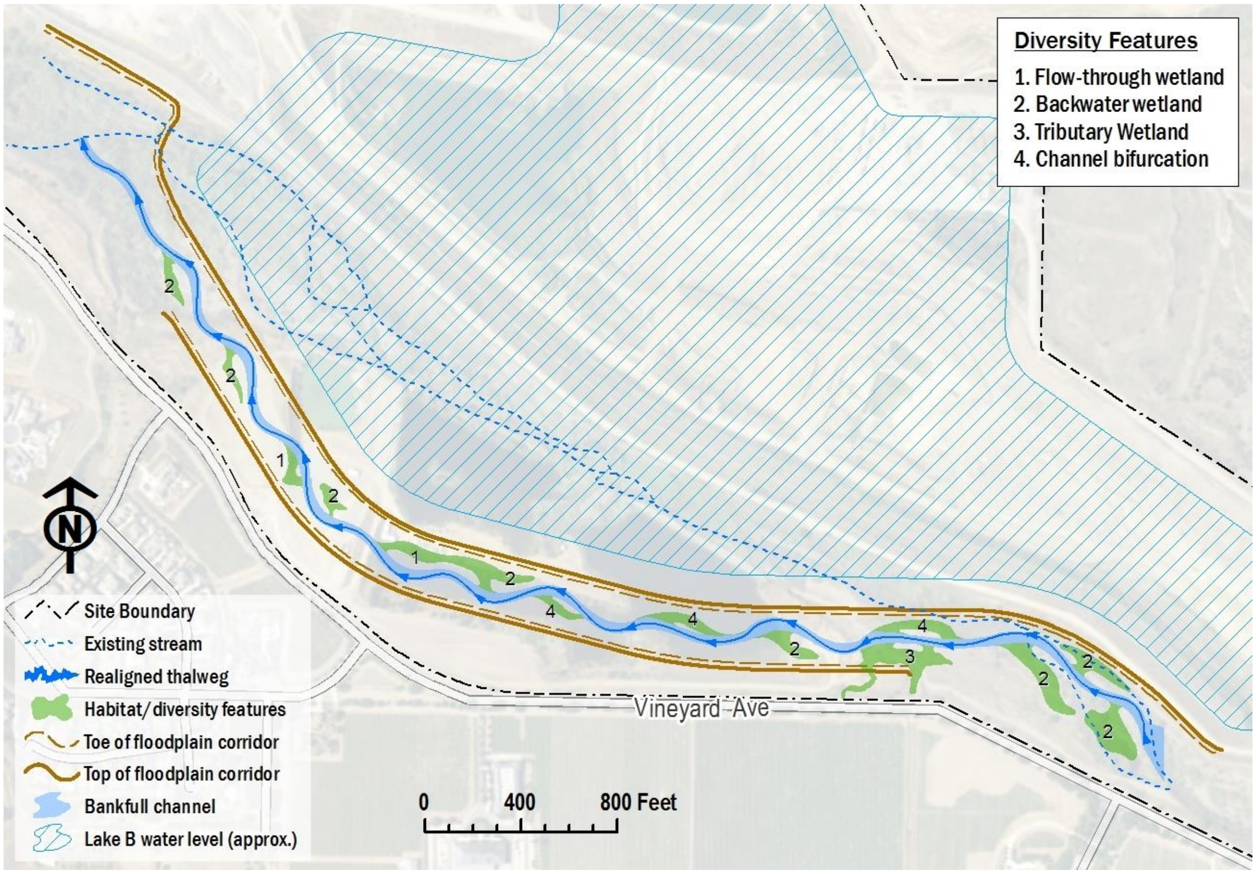

Figure 5-19. Proposed realigned channel and floodplain with habitat and diversity features

5.4.8 Additional Stability Considerations

Transitions at the upstream and downstream ends of the realignment will be graded to provide smooth and gradual connections between the designed channel and the existing geometry. For example, the banks of the new bankfull channel will be extended upstream and tied into the outer slopes of the existing floodplain to intercept flow from a wider area and minimize the potential for ADV to shift channels upstream and flank the transition point. This concept is illustrated in Figure 5-19. The transition at the downstream end of the realignment can flow more freely but will still be graded to provide a smooth gradual change in channel geometry.

Several tributary drainages flow into ADV between the proposed upstream and downstream tie-in points. The tributaries are typically dry with intermittent flow from stormwater runoff; drainage areas range between about 0.5 to 2.0 square miles. Each tributary originates from the south and crosses Vineyard Avenue via an existing culvert. These existing culverts will be extended and connected to maintenance holes and new pipes where stormwater runoff will be dropped to a lower elevation and conveyed to the realigned floodplain. The drop structures will reduce the discharge velocities at the outfalls; however, riprap aprons will also be constructed at the outfall to ADV to reduce the potential for erosion.

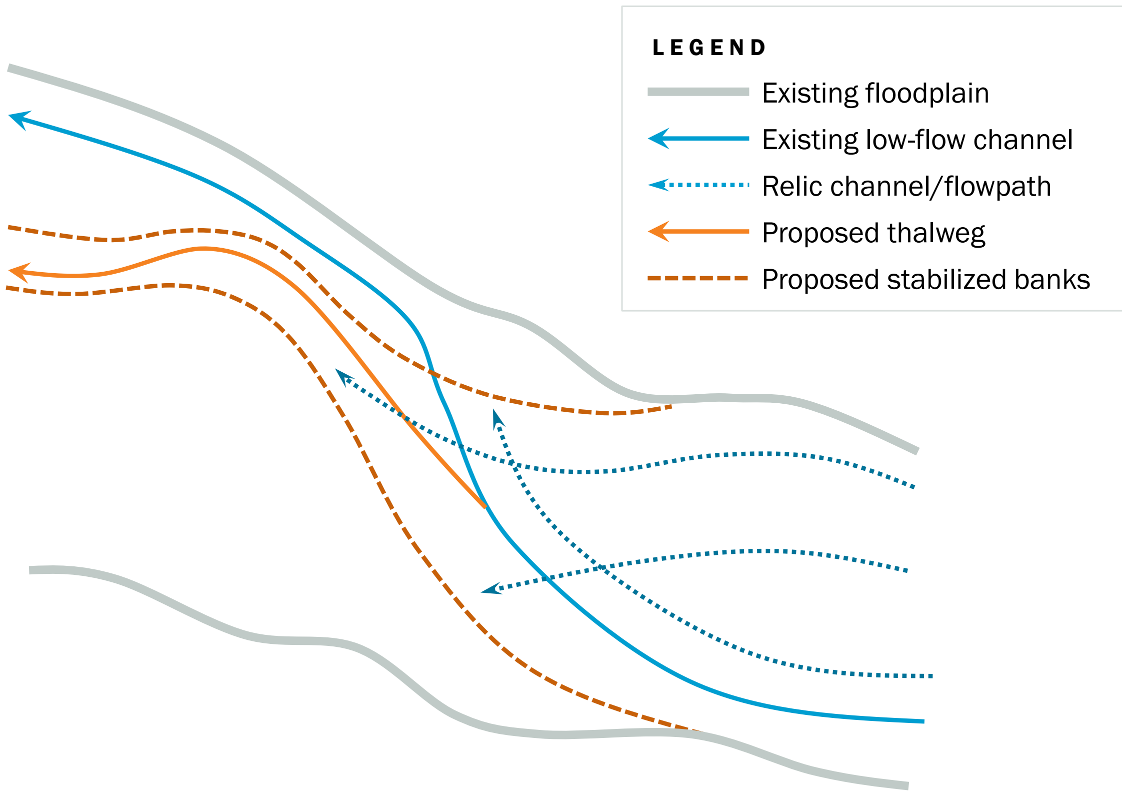

Figure 5-19. Schematic of bank tie-in at upstream transition

Given the considerable uncertainty associated with transient and highly variable phenomena such as sediment loads, transport rates, and equilibrium dynamics, BC designed additional stability features to mitigate the potential for channel migration and floodplain widening that could impact Lake B or adjacent properties and infrastructure. Rock barbs will be installed along the outer bends of the floodplain. These barbs will function like vanes, designed to reduce velocities along the outside edges of the floodplain and direct flow away from the outer slopes of the floodplain corridor.

Rocks used to construct the stone barbs should have a median stone diameter of at least 24 inches to remain stable under 100-year flood conditions[7]. BC recommends using rock material that meets Caltrans standard specifications for “1/2-ton” riprap with “Method B” placement (Racin 200). Riprap should be composed of well-graded angular rocks to allow for interlocking and include a mixture of smaller rocks to fill interstices.

[7]BC evaluated stable rock sizes using a combination of standard methods including methods described in the USACE Engineering Manual, *Hydraulic Design of Flood Control Channels* (USACE 1994) and the *California Bank and Shore Rock Slope Protection Design Manual* (Racin 2000). BC applied an additional safety factor to the calculated median rock size to address the potential for impinging flow.

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Section 6

Impact Evaluations

BC performed modeling and mapping analyses for existing and proposed conditions to evaluate potential impacts to ADV channel stability and flooding. Section 6.1 describes the development of a hydraulic model of the arroyo. Section 6.2 describes BC's evaluation of long-term channel stability, including a discussion of the potential for localized scour. Section 6.3 describes BC's evaluation of flood levels and inundation areas.

6.1 Hydraulic Modeling

BC developed a hydraulic model of ADV from approximately 1,000 feet downstream of Bernal Avenue to approximately 4,500 feet upstream of Vallecitos Road (Study Reach) using Hydrologic Engineering Centers River Analysis System (HEC-RAS) software (Version 5.0, 2016). HEC-RAS is a 1-dimensional step backwater flow model developed by USACE HEC. Standard hydraulic simulations require two types of input data: (1) geometric data comprising cross-sections, stream reach lengths, and bridge/culvert dimensions; and (2) flow data comprising flow rates and boundary conditions.

BC reviewed existing hydraulic modeling data as well as new topographic data from 2018 to develop an up-to-date existing-conditions (i.e. baseline conditions) model of ADV. BC then modified that model to reflect the conditions of the proposed project (i.e. proposed conditions). The hydraulic model developed for this analysis will be used not only to evaluate proposed project impacts, but also likely for future design and permitting. Therefore, it is important that this modeling effort use existing data sources, and that the modeling methodology be in accordance with accepted modeling guidelines.

6.1.1 FEMA Flood Modeling

BC collected and reviewed flood hazard information from FEMA, which administers the National Flood Insurance Program (NFIP)[8]. BC purchased the effective FIS for the County, effective Flood Insurance Rate Maps (FIRMs) covering the Study Reach, and the associated Digital Flood Insurance Rate Map (DFIRM) data from FEMA's Map Services Center (FEMA 2009, 2017a).

Exhibit 1 (Appendix G) shows the effective flood hazard mapping for ADV based on the DFIRM data. The entire reach of ADV from Arroyo de la Laguna to Del Valle Dam is mapped as a Special Flood Hazard Area (SFHA). The area shown to be within the SFHA is equivalent to the area that can be inundated by the base flood.[9] The SFHA along ADV is divided into the following two flood hazard designations:

- **Zone AE** is a riverine flooding hazard with established base flood elevations; the delineated areas and flood profiles are based on detailed hydraulic modeling.
- **Zone A** is a riverine flooding hazard with no base flood elevations; these areas are delineated by approximate methods that may not have included any detailed modeling.

[8] FEMA provides flood insurance to the residents of communities participating in the NFIP, provided that each community adopts and enforces floodplain regulations that meet or exceed FEMA minimum requirements (http://www.fema.gov/national-flood-insurance-program). Alameda County, the City of Pleasanton, and the City of Livermore are each participating community.

[9] The base flood is a flooding event with a 1 percent annual chance of exceedance, or a 100-year flood.

Two reaches of ADV are shown as Zone AE. The first reach begins at the confluence with Arroyo de la Laguna and ends approximately 1,300 feet upstream of Bernal Avenue. The second reach begins at Isabel Avenue and ends at Del Valle Dam. The connecting Zone A reach covers approximately 3 miles, including areas adjacent to Shadow Cliffs Regional Recreation Area and Lake B of the Eliot Facility. BC compared the SFHA delineations with the existing topography at the Project Site and found that significant changes have occurred since the original FEMA study. Therefore, new and updated analyses are needed to obtain an accurate depiction of flooding potential under existing conditions.

BC submitted an official data request to the FEMA Engineering Library to obtain supporting technical data for the two detailed studies along ADV (FEMA 2017b). FEMA provided images of the HEC-2[10] modeling files for the lower reach (i.e., the reach from Arroyo de la Laguna to just upstream of Bernal Avenue). FEMA developed the HEC-2 model as part of the original FIS for the City of Pleasanton in 1983. The HEC-2 input data include cross-sections and basic bridge configurations (most notably at Bernal Avenue). FEMA could not locate any information for the reach upstream of Isabel Avenue.

6.1.2 Model Development

Zone 7 is responsible for flood control along ADV and has conducted several studies along the ADV corridor. BC met with Zone 7 on August 1, 2013, to discuss its modeling activities and availability of modeling data[11]. Zone 7 provided BC with a preliminary HEC-RAS model covering approximately 7.5 miles of ADV from the confluence with Arroyo de la Laguna[12] to Vallecitos Avenue on October 8, 2013. Zone 7 also provided BC with the supporting topographic data in the form of a digital terrain model (DTM), as well as aerial imagery from the 2006 LiDAR survey. Existing 2018 topography from the site was also received from Compass Land Group.

Zone 7 labeled its HEC-RAS model a work in progress, subject to change as Zone 7 continues to develop the model. BC reviewed Zone 7's preliminary hydraulic model and found that it was insufficient for design and permitting evaluations without significant modification. We documented several issues when we received that the information:

- No documentation was available related to model development or data sources
- The Zone 7 model did not extend upstream of Vallecitos Road; modeling would require additional cross-sections to evaluate potential flooding impacts in Sycamore Grove Park.
- In some locations, the Zone 7 model sections did not extend far enough laterally to include all the ADV floodplain.
- The bridge data were extremely coarse, which suggests that they were based on limited information rather than surveys or as-built drawings.
- The 100-year flow data in the Zone 7 model did not match the data in the County FIS; the information provided no citation as to the source of the 100-year flow data and no information as to why the flow deviates from the current FEMA study (FEMA 2009).
- Manning's roughness values appeared to be too low for some highly-vegetated channel areas.

10 HEC-2 is the predecessor to the HEC-RAS model; HEC no longer supports HEC-2.

11 BC also contacted the City of Livermore floodplain coordinator regarding the availability of hydraulic modeling data for Arroyo del Valle. The floodplain coordinator passed the inquiry on to one City of Livermore engineering contractors, Schaaf & Wheeler, which recently conducted a flood study on portions of Arroyo Mocho, Arroyo Las Positas, and Arroyo del Valle. However, that study covered only a few thousand feet of Arroyo del Valle near the confluence with Arroyo de la Laguna. BC did not use these data because they are located downstream of the relevant Study Reach.

12 Zone 7 is only responsible for portions of Arroyo del Valle, primarily west of Bernal Avenue near Vineyard Avenue.

CEMEX directed BC to rebuild the HEC-RAS model of ADV from earlier versions using the 2018 topography. In 2014, BC completed the model and then conducted preliminary hydraulic modeling analyses. In August 2017 Zone 7 provided BC with a new set of topographic data developed from a LiDAR survey conducted in 2014. Then, in April of 2018 BC received an updated topographic model of the existing site conditions to be able to model the baseline conditions for the site. The 2018 topography only included the Project Site, not the Study Reach, so the 2018 topography was merged with the 2014 LiDAR to create a model that extended throughout the Study Reach and was the most up-to-date. BC used this topography to update the HEC-RAS model to reflect the 2018 conditions.

BC used a geographic information system (GIS)-based toolbox called HEC-GeoRAS to assist with extracting geometric data for import to HEC-RAS (USACE 2017). We manually digitized geometric data features such as a stream centerline, cross-section cut-lines, overbank flow paths, and bank stations in ArcGIS using topographic data and aerial imagery (ESRI 2018). BC created a HEC-GeoRAS export file using the terrain data, digitized geometries, and land use data described above and imported the export file directly into HEC-RAS as new geometric data files. After importing the data, BC made the following adjustments:

- Cross-section identifiers (IDs) (based on stream profile stations) were rounded to the nearest integer.
- Cross-section ordinates were filtered to remove superfluous points and reduce the number of ordinates to less than 500 per cross-section
- Bank stations were set on each cross-section by visually approximating the main flow channel.
- Ineffective flow areas were set in off-channel depressions to confine conveyance to the main channel for all cross-sections (unless overtopping occurs).
- Ineffective flow areas were set on the cross-sections upstream and downstream of the bridges by approximating the flow lines into and out of the bridge openings.
- Expansion and contraction coefficients were increased from the default values (0.1 for contraction and 0.3 for expansion) to 0.3 and 0.5 for cross-sections near bridges and abrupt transitions per HEC-RAS guidance.

HEC-RAS uses Manning's roughness coefficients to compute flow resistance in channels. Manning's roughness values for natural channels depend on bed material, geometric irregularities, variation in cross-section, vegetation, obstructions, and meandering (Chow 1959). A straight earthen channel could have a Manning's roughness as low as 0.020, while a highly irregular channel with dense woody vegetation could be as high as 0.090. BC estimated Manning's roughness values for the ADV channel and floodplain using standard factors presented in *Open-Channel Hydraulics* (Chow 1959) and based on observations made during field reconnaissance and review of aerial photographs. Manning's roughness values for the main channel ranged between 0.035 and 0.055. Manning's roughness values for overbank (i.e., floodplain) areas ranged between 0.030 and 0.085.

BC developed geometric data inputs to incorporate the bridges located at Bernal Avenue, Isabel Avenue, and Vallecitos Road. Table 6-1 lists the sources and summarizes the input data for each bridge.

Table 6-1. Bridge Input Data		
Bridge	**Source**	**Input Data Summary**
Bernal Avenue	HEC-2 model from City of Pleasanton FIS [b]	• Top of roadway elevation of 367.9 ft NAVD88 [a] • Low chord of bridge elevation of 360.2 ft NAVD88 [a] • Total width of obstructions = 7.0 ft (assumed to be 2 3.5 ft piers) • Drag coefficient for pier loss = 2.00 • Abutments were placed 185 ft apart and centered over the channel • The longitudinal width of the deck/roadway was assumed to be 100 ft based on aerial images • The channel geometry through the bridge was based on upstream and downstream cross-sections cut from the 2018 survey
Isabel Avenue	Existing and Proposed conditions: Widened bridge [c]	• Top of roadway elevation of roughly 426 ft NAVD88 • An additional 2 ft were added to the top of the bridge deck to represent the concrete barrier • Low chord of bridge elevation of roughly 419 ft NAVD88 • A 1.5-ft-wide pier was added at mid-span • Abutments were placed 121 ft apart and centered over the channel • The longitudinal width of the deck/roadway was set to 93.5 ft • The channel geometry through the bridge was based on upstream and downstream cross-sections cut from the 2018 topography described previously
Trail bridge at Isabel Avenue	Existing and Proposed conditions: Widened bridge [c]	• Top of trail surface elevation of roughly 421 ft NAVD88 • An additional 2 ft were added to the top of the bridge deck to represent the concrete barrier • Low chord of bridge elevation of roughly 416 ft NAVD88 • A 4-ft-wide pier was added at mid-span • Abutments were placed 162 ft apart and centered over the channel • The longitudinal width of the deck/roadway was set to 18.5 ft • The channel geometry through the bridge was based on upstream and downstream cross-sections cut from the 2018 topography described previously
Vallecitos Road	Preliminary HEC-RAS model developed by Zone 7 [d]	• Top of roadway elevation of 454 ft NAVD88 • Low chord of bridge elevation of 451 ft NAVD88 • The channel geometry through the bridge was based on upstream and downstream cross-sections cut from the 2018 topography described previously • Abutments were placed 230 ft apart, roughly equivalent to the top width of the channel shown in the 2018 topography described previously • The longitudinal width of the deck/roadway was assumed to be 40 ft based on aerial images

a. *Original data with elevations based on the NGVD29 were converted to NAVD88 using a +2.69 ft conversion factor obtained from http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl.*

b. *Source: Federal Emergency Management Agency 1983.*

c. *Source: Caltrans 2010.*

d. *Source: Zone 7 2013.*

6.1.3 Proposed Project Conditions

BC modified the existing-conditions HEC-RAS model to reflect the proposed project changes to the ADV channel and floodplain, including the diversion structure at Lake A, the realigned corridor and Lake B. The following sub-sections describe the model modifications.

6.1.3.1 Lake A Diversion

The RPA calls for the construction of a diversion structure on ADV near the upstream end of Lake A to divert water from ADV into the Chain of Lakes (see Section 5.1). The structure will divert water from the main channel into a conduit that will flow by gravity into Lake A. In addition to the lateral diversion facilities (e.g., infiltration bed, piping, conduits, etc.), the Lake A diversion will include a low-head dam within the channel to generate controlled hydraulic head for the diversion system. BC modified the HEC-RAS model geometry data by adding an in-line (i.e., in-channel) weir with a crest elevation of 436.2 feet (see Figure 6-1).

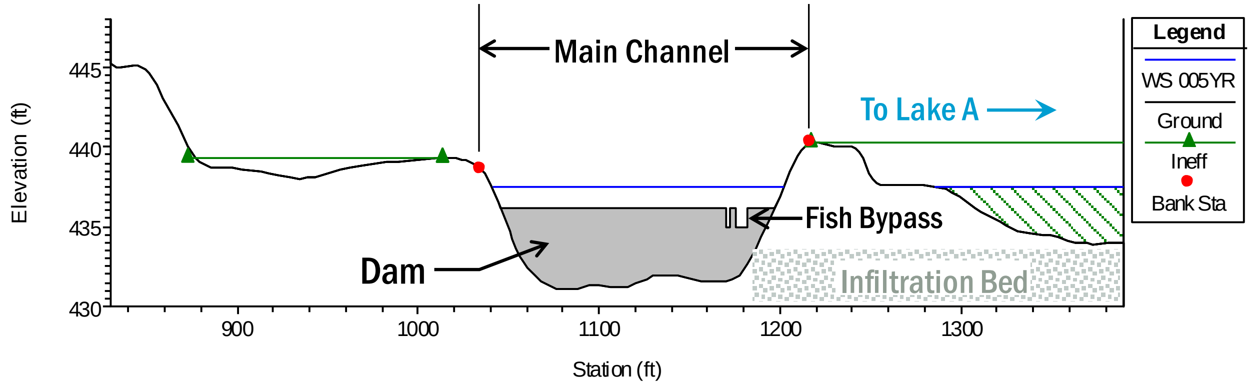

Figure 6-1. HEC-RAS cross-section showing proposed diversion dam at Lake A

Infiltration bed shown for reference; not explicitly modeled in HEC-RAS

A lateral structure was added immediately upstream of the in-line weir to allow flow diversion away from the main channel and into a storage node representing Lake A. However, we did not simulate the infiltration bed and diversion conduit structural features explicitly. The infiltration bed, diversion conduit, and other appurtenant structures will be constructed off the main channel and below the existing ground surface. Such modifications would not affect the conveyance capacity of the channel or floodplain, and thus were not modeled.

6.1.3.2 Realigned Channel and Floodplain

BC used AutoCAD Civil 3D software to create a 3-dimensional terrain model of the proposed configuration of the realigned ADV (Figure 6-2) (AUTODESK Inc. 2017). The terrain model incorporated the single-thread cross-section (Section 5.4.3) with the meander pattern (Section 5.4.4) and bend variations (Section 5.4.5). BC modified the terrain model to reflect tributary streams (Section 5.4.6) and smooth channel transitions at the upstream and downstream tie-in points (Section 5.4.7). The terrain model does not reflect minor topographic variations (i.e., microtopography) associated with the added diversity and habitat features described in Section 5.4.8. These variations are small, affect only short ADV reaches, and in most cases, do not affect the conveyance capacity of the channel and floodplain substantially. BC considers not incorporating these minor features to be a reasonable simplification for floodplain mapping and reach-scale channel stability analyses.

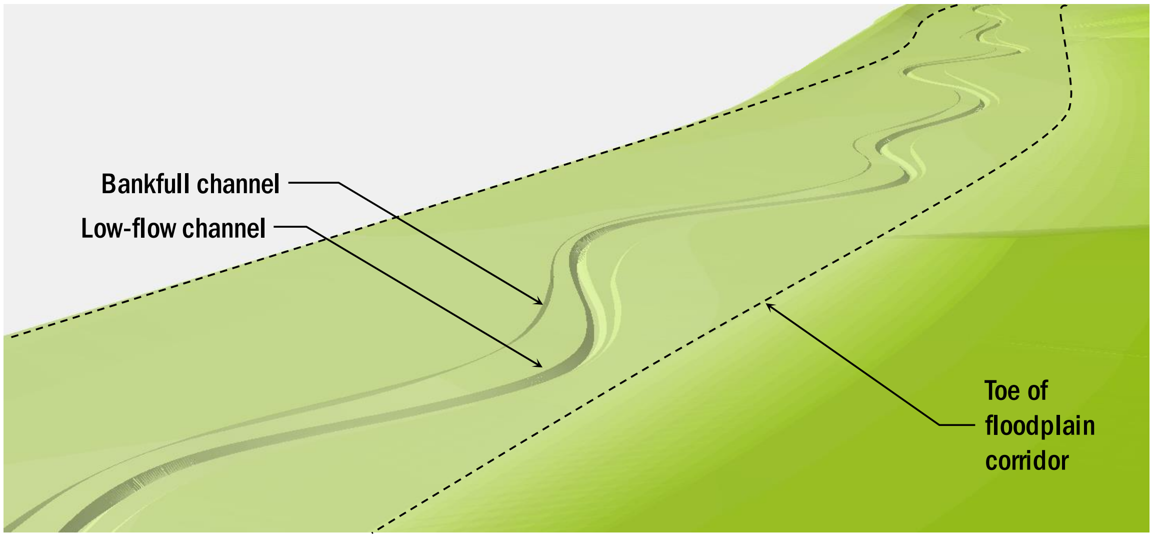

Figure 6-2. Three-dimensional terrain model of realigned corridor with bend variations

The outer embankments along the floodplain of the realigned corridor were raised at a slope of 3 to 1 (H:V) until the top elevations were high enough to provide 3 feet of freeboard. BC merged the terrain model of the realigned ADV with the proposed topography of Lake B, and then extracted new cross-section input data for HEC-RAS, representing proposed conditions after reclamation.

6.2 Channel Stability

Alluvial channels form and continually shift in response to temporal sequences of flow rate and sediment supply. Over many years, channels adjust to flow and sediment regimes through changes in geometry (e.g., planform, channel dimensions, and longitudinal slope). Given a period with a relatively constant flow regime and sediment supply, a channel approaches a stable geometry and is in dynamic equilibrium. This conclusion is not to say that the channel is static, but rather morphological responses to extreme events are only temporary, and that a more stable morphology is continually restored over time by the long-term formative conditions of the system. This geomorphic concept of disturbance, channel adjustment, and dynamic equilibrium is qualitatively represented by Lane's Principle (Lane 1955):

$$Q_s \, D_{50} \propto Q_w \, S$$

Where, Q_s = sediment load
D_{50} = the 50th percentile of the sediment grain size distribution
Q_w = the stream discharge
S = the channel slope

While Lane's Principle is not a perfect representation of sediment transport in complex alluvial systems, it does provide a useful conceptual model. The relationship represented by Lane's Principle suggests that a long-term shift in any of these factors will destabilize the system and initiate a compensatory response in one or more of the other factors as the system attempts to restore equilibrium. For example, Lane's Principle suggests that if sediment supply decreases while stream discharges and grain size distribution remain constant, the channel slope must decrease to restore equilibrium. In other words, the stream channel would need to degrade until a new equilibrium slope is reached. This process is essentially what happened in 1968 when the construction of Del Valle Dam effectively eliminated the sediment supply from the upper watershed (see Section 4.2.2).

As discussed in Section 4.3.4, field work identified signs of degradation and instability still occur at some points along ADV, suggesting that the channel has not finished adjusting to anthropogenic changes in the watershed. However, given that the dam was constructed more than 45 years ago and that in-channel gravel mining has ceased, it is reasonable to assume that the rate of degradation near Lake B has considerably decreased in recent years. Inspection reports for the SR 84 (Isabel Avenue) bridge corroborate this assumption, stating that the channel under Isabel Avenue degraded 6 feet between 1983 and 1999, but then stabilized. Given these findings, BC designed the realigned channel to maintain a quasi-equilibrium state by maintaining sediment continuity with upstream reaches.

Applying Lane's Principle at a reach scale, we can evaluate channel stability by comparing the incoming sediment load (i.e., supply) to the stream power available to transport that sediment through the reach (i.e., capacity). If the sediment supply exceeds the transport capacity, then deposition occurs and the reach is expected to aggrade. Conversely, if the transport capacity exceeds the sediment supply, erosion occurs and the reach is expected to degrade. When the sediment supply and transport capacity are in balance, the reach is expected to maintain a state of dynamic equilibrium. This reach-scale balance of supply and transport is sometimes referred to as sediment continuity.

6.2.1 Calculating Sediment Loads

BC calculated long-term sediment loads using a magnitude-frequency analysis, where sediment transport capacities are estimated for a full range of stream discharges and then multiplied by the frequency of occurrence. The magnitude-frequency concept stems from a theory developed by Wolman and Miller describing how the geomorphic evolution of landscapes is strongly influenced by the amount of work done by the forces acting on the system—in this case, shear forces caused by flowing water (Wolman and Miller 1960). Figure 6-3 is a graphical representation of the magnitude-frequency concept where the relative amount of work done depends on both the magnitude of the force and frequency of occurrence.

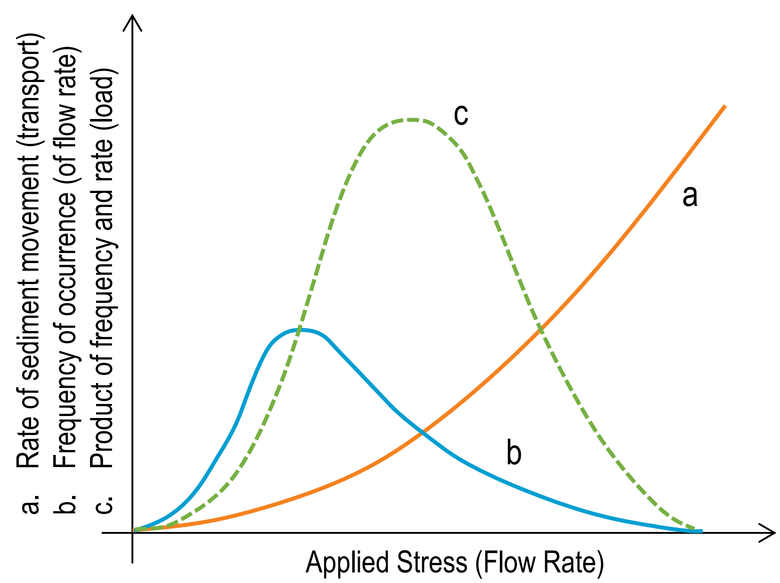

Figure 6-3. Relation between applied stress and frequency of occurrence in geomorphic processes

The frequency of occurrence is log-normally distributed and the magnitude of the influencing force increases per a power function. The product of the frequency of the occurrences and the magnitude of the influencing force results in an effective work curve. Source: Wolman and Miller 1960

For an alluvial system, the frequency of flows multiplied by the sediment transport capacity results in a sediment loading curve. The integral of the sediment loading curve is the total sediment load. If the frequency of occurrence is based on a finite time frame, such as a year, then the calculated sediment load represents the periodic average (or in the case of a year, the average annual transported sediment load).

Flow Frequency Curve. BC analyzed long-term measured streamflow data for ADV during both pre- and post-dam conditions (see Section 3.2.1). The historical flow frequency histogram was developed using USGS streamflow data at AVL (Station 11176500) based on post-dam records ranging from 1969 through 2017. The histogram data shown in Figure 3-3 effectively to approximate the flow frequency curve (curve b in Figure 6-3).

Sediment Transport Curve. Wilcock and Crowe (2003) developed a surface-based relation for transport of bed material in streams with sand-gravel mixtures. The transport function accounts for the interplay of sand and gravel components and incorporates a hiding function where smaller particles tend to be sheltered from the forces of flow by larger particles. The transport model developed by Wilcock and Crowe (2003) uses a dimensionless similarity collapse over a specified fraction of sediment within a bedload mixture, described by the following equation:

$$W_i^* = \frac{(s-1)gq_{bi}}{F_i u_*^3}$$

where: W^*_i = dimensionless bedload transport for the i^{th} fraction of the sediment mixture

s = ratio of sediment density to water density

g = gravitational constant (ft/s^2)

q_{bi} = volumetric transport rate per unit width for sediment size fraction i (cfs/ft)

F_i = fractional proportion of sediment size i

u_* = shear velocity (ft/s) = $\sqrt{\tau/\rho}$

τ = shear stress (lb/ft^2)

ρ = water density (lb/ft^3)

Wilcock and Crowe (2003) estimated dimensionless bedload transport by fitting the following function to observed transport data:

$$W_i^* = \begin{cases} 0.002\phi^{7.5} & , \quad \phi < 1.35 \\ 14\left(1 - \dfrac{0.894}{\phi^{0.5}}\right)^{4.5} & , \quad \phi \geq 1.35 \end{cases}$$

where: $\phi = \tau/\tau_{ri}$ = ratio of shear stress to a reference shear stress, τ_{ri}

τ_{ri} = shear stress at which W^*_i is equal to a value of 0.002 (Parker et al. 1982)

The reference shear stress for any sediment size fraction, i, can be determined from a hiding function of the form:

$$\tau_{ri} = \tau_{rm}\left(\frac{D_i}{D_{sm}}\right)^b$$

$$b = \frac{0.67}{1 + e^{\left(1.5 - \frac{D_i}{D_{sm}}\right)}}$$

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where: D_i = diameter of the sediment fraction, i

D_{sm} = geometric mean diameter of the sediment mixture

τ_{rm} = reference shear stress for the mean of the sediment mixture

The reference shear stress for the sediment mixture can be determined using the following equations:

$$\tau_{rm} = \tau_{rm}^{*}(s-1)\rho g D_{sm}$$

$$\tau_{rm}^{*} = 0.021 + 0.015e^{-20F_s}$$

where: F_i = fraction of sand-sized sediments within the mixture

Once the volumetric transport rate per unit width for each size fraction is calculated, the total sediment transport per unit width can then be obtained from the sum of the transport rates for all size fractions:

$$q_T = \sum_{i=1}^{n} q_{bi}$$

where: q_T = volumetric sediment transport rate per unit width

Using the equations from Wilcock and Crowe (2003), BC calculated sediment transport capacity in ADV for the range of discharges indicated by the post-dam flow frequency distribution. BC performed uniform-flow hydraulic computations to estimate the hydraulic depths, velocities, and shear stresses associated with each flow bin. BC selected cross-sections that represented the typical geometry of each reach for existing conditions (see Section 6.1.2 for a discussion of topographic data). For the proposed project condition, BC used the reach-averaged cross-section (see Figure 5-12), which corresponds to a riffle section.

BC estimated Manning's roughness values using the methodology described by Chow (1959) based on bed material, geometric irregularities, variation in cross-section, vegetation, obstructions, and meandering. Calculated roughness values varied horizontally and with depth, resulting in weighted cross-section roughness values that generally ranged between 0.025 and 0.055.

The grain size distribution used to represent the bed material was based on a composite of the bulk samples taken by Balance (2015). Due to the variability, sensitivity, and uncertainty associated with sediment parameters, the same sediment sizes were used consistently for all reaches, assuming these data are generally representative of the sediments moving through the system.

Appendix H provides additional information on the magnitude-frequency approach, as well as the computational methods and assumptions used to determine sediment loads.

6.2.2 Balancing Sediment Loads

BC evaluated average annual sediment loads for four reaches of ADV, as shown in Figure 6-4 and described below:

- **Shadow Cliffs Reach:** downstream of the proposed realignment where ADV flows through Island Pond and Boris Lake
- **Lake B Reach:** adjacent to Lake B from just upstream of Island Pond to Isabelle Avenue
- **Lake A Reach:** adjacent to Lake A from Isabelle Avenue to Vallecitos Road
- **Sycamore Grove Park Reach:** upstream of Vallecitos Road through Sycamore Grove Park

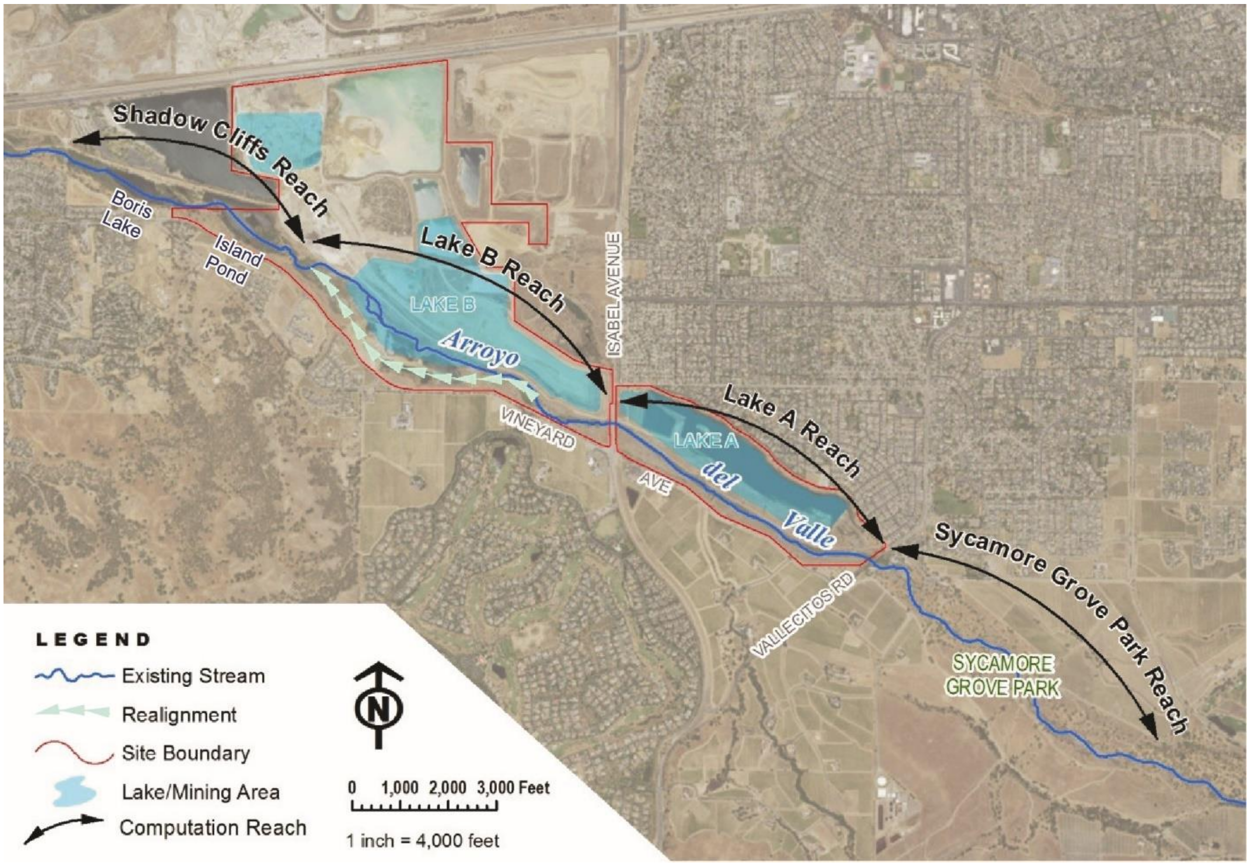

Figure 6-4. Reaches of ADV used for sediment continuity analysis

BC began by calculating average annual sediment loads for each of the four reaches under existing conditions and found that the reaches along Lake B, Lake A, and Sycamore Grove Park transport roughly equivalent sediment loads—in the range of 100,000 to 120,000 tons per year—while the Shadow Cliffs Reach transports considerably less at around 5,000 tons per year (Figure 6-5). This latter difference was expected, because the impoundments (Island Pond and Boris Lake) appear to trap sediments. The low-energy gradient created by the impounded water reduces stream power and tends to create highly depositional conditions.

BC performed the hydraulic design evaluations described in Section 5.1 in parallel with the sediment continuity calculations so that one can compare the average annual sediment load for the new realigned reach with the sediment loads transported from upstream reaches under existing conditions. Hydraulic design parameters such as cross-sectional dimensions and channel sinuosity/slope were adjusted to nearly match the sediment loads, thus creating a realigned stream channel that balances or maintains sediment continuity with upstream reaches (Figure 6-5).

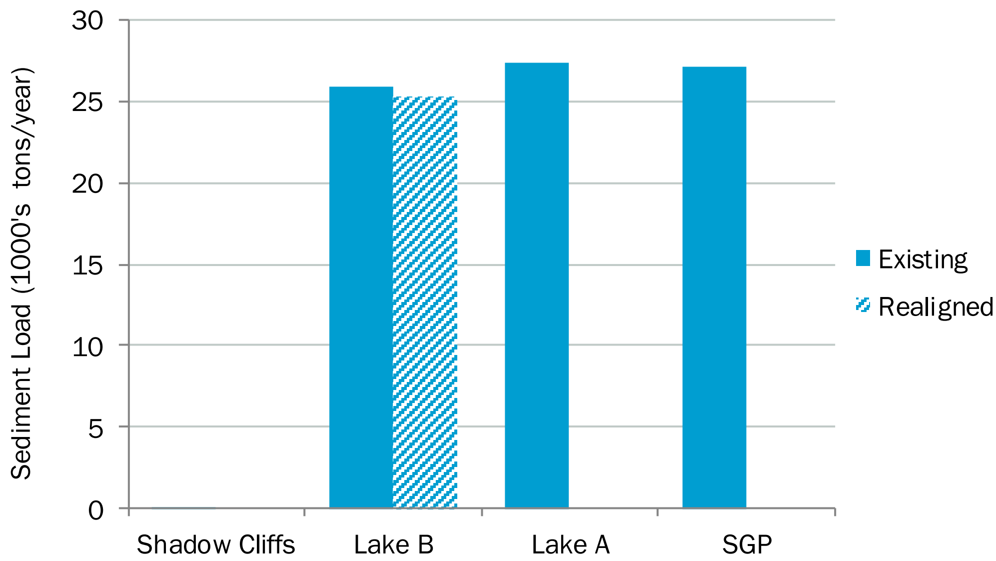

Figure 6-5. Average annual sediment load transported through ADV reaches

Reaches defined in Figure 6-4; sediment loads calculated for the post-dam period of record were converted to average annual values. Sediment loads transported through Shadow Cliffs are nearly zero because water is impounded, and velocities are low.

In addition to comparing the total sediment load estimates, BC examined the sediment loading curve and sediment load distribution (i.e., the discharge ranges predicted to transport the most sediment). We plotted cumulative sediment loadings for the realigned reach and two upstream reaches, Lake A and Sycamore Grove Park (Figure 6-6). The cumulative distribution of sediment loads shown in Figure 6-6 exhibit similar patterns, which suggests that the realigned channel will transport comparable sediment loads over similar discharge ranges.

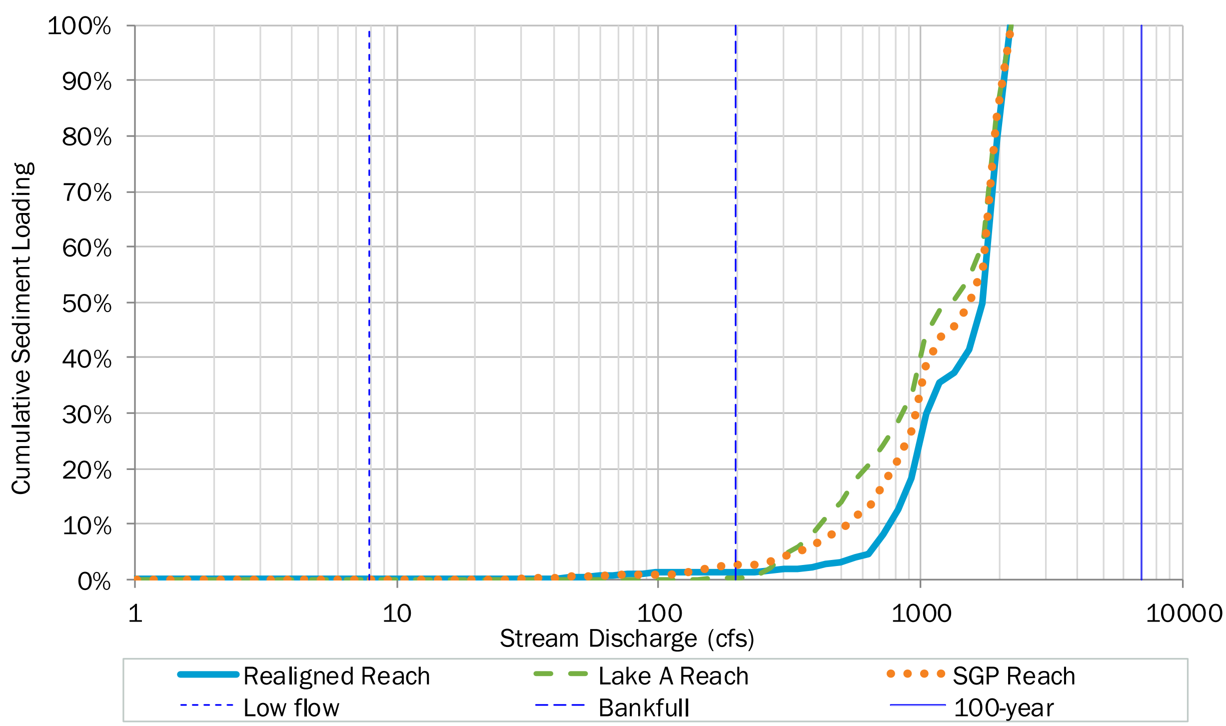

Figure 6-6. Cumulative sediment loading curves

Note that sediment continuity analyses, such as those presented in this section, are inherently uncertain and require careful consideration of the assumptions and limitations of the available data. Two important limitations include:

- **Extreme events are not included in the historical record:** The post-dam streamflow data used for this analysis do not include extreme events such as the 100-year flood. The low frequency of such events reduces their long-term significance; however, it is possible that a large flood event will cause a substantial—even if only temporary—disturbance to the geomorphic balance of the stream system under either existing or proposed conditions.
- **Sediment yield to ADV downstream of the Del Valle Dam is unknown:** As mentioned previously, Del Valle Dam traps most of the sediment load that used to come from the upper reaches of ADV. In fact, nearly all bedload sediment (comprised of sands and gravels) will be trapped behind the dam. BC performed some preliminary calculations to estimate sediment yields to ADV reaches downstream of the Del Valle Dam, and found that inflowing sediment yields could be less than half of the sediment loads calculated for the Lake B, Lake A, and Sycamore Grove Park reaches. This finding suggests that sediment loads originating from Sycamore Grove Park could be largely due to the reworking of alluvial material immediately downstream of the Del Valle Dam and in Sycamore Grove Park. Therefore, even though data show some evidence that ADV has stabilized, the potential still exists for degradation and reduced sediment loads in those upstream reaches.

6.2.3 Evaluation of Long-term Stability

For background, under the implementation of the current SMP-23 Reclamation Plan, CEMEX would mine the ADV channel and floodplain from the east end of Lake A to the west end of Lake B. ADV would flow into Lake A through a concrete spillway located immediately downstream of Vallecitos Road. Then water would flow from Lake A to Lake B through a second spillway beneath Isabel Avenue (i.e., SR 84). The stream would return eventually to its natural channel at the west end of Lake B by flowing over a 750-foot-wide (north to south) concrete and riprap buttress acting as a weir structure.

The engineering plans provided in the existing SMP-23 Reclamation Plan indicate that the existing Isabel Avenue bridge would remain in place with no changes to the bridge height or channel width (Lone Star Industries, Inc. 1987). A spillway would be constructed beneath the existing bridge consisting of riprap and concrete-lined portions. The channel section approaching Isabel Avenue from the east would be lined with riprap, extending halfway under the existing bridge. From that point, the channel would be concrete-lined with riprap-lined sides, extending west into Lake B.

Human disturbances in a watershed and floodplain development can affect flow, conveyance, and the balance of sediment supply, which can often lead to fluvial disturbances that result in channel degradation (Schum et al. 1984; Simon and Rinaldi 2006). ADV is a highly modified system because of nearly two centuries of development (i.e., grazing, agriculture, urbanization, floodplain channelization, and gravel mining) and the construction of Del Valle Reservoir in 1968. Due to the dam, the once actively braided channel network along the valley floor now has shifted to a more defined central channel system (Kamman 2009), peak flood flows decreased dramatically, and the duration of low flows increased such that the stream shifted from intermittent to perennial. The dam also has had a tremendous impact on the sediment regime in ADV by disrupting natural sediment transport from the upper watershed to the Valley.

Under current conditions, BC estimated that the dam will trap roughly 97 percent of sediment flowing into Del Valle Reservoir (Brune 1953). Trapping and removing sediment supply creates a clear water or sediment-starved condition downstream from the dam, which leads to channel degradation, bank erosion, and bed-coarsening (Williams and Wolman 1984; Kondolf and Matthews 1991). The reduced sediment supply diminished gravel bar formation, lessened topographic variation, and coarsened/armored the channel bed to the point that it became dominated by gravel- and cobble-size material (Kamman 2009). ADV has adjusted to the reduced sediment load by harvesting and mobilizing (i.e., eroding) sediment from its channel bed and banks. Finer sediment fractions are selectively removed from the active channel because they are more easily mobilized. This process continues until the channel bed is armored (Brandt 2000). Degradation due to the construction of Del Valle Dam is likely to diminish after the first one to two decades, and there is some evidence suggesting that ADV has stabilized. However, it is likely that the stream is still adjusting to these impacts and continued land use changes. Given the dynamic nature of the alluvial system, it is difficult to discern minor or localized changes from long-term trends. While the degradation caused by the dam has likely diminished, there is still a risk of instability and continued channel evolution.

Further field work by Balance identified signs of degradation and instability still occur at some points along ADV, suggesting that the channel has not finished adjusting to anthropogenic changes in the watershed. However, given that the dam was constructed more than 45 years ago, and that in-channel gravel mining has ceased, it can be assumed that the rate of degradation near Lake B has considerably decreased in recent years. Inspection reports for the SR 84 (Isabel Avenue) bridge corroborate this assumption, stating that the channel under Isabel Avenue degraded, but then stabilized.

As part of the baseline conditions, the Isabel Avenue bridge has been modified as part of the SR 84 Expressway Widening project. According to the *Initial Study with Negative Declaration/Environmental Assessment with Finding of No Significant Impact* for that project, Caltrans has widened the bridge by 53 feet, expanding to the east, and constructed a parallel pedestrian/bicycle trail bridge to the east of the expanded highway bridge (Caltrans 2008). In 2009, WRECO prepared a *Bridge Design Hydraulic Study Report* for the SR 84 Expressway Widening project that included a scour analysis for the Isabel Avenue bridge (WRECO 2009). In that report, WRECO concluded that the ADV channel is generally stable: “According to the Bridge Inspection Report for Bridge Number 33-0710 at Arroyo del Valle (3/2/06), ‘there was 5.9 [feet] (1.8 m) of channel degradation between 1983 and 1999; this was attributed to in-stream gravel mining.’ Since then the channel has stabilized and we have assumed the long-term bed change to be negligible” (WRECO 2009). Although the *Bridge Inspection Report* attributed the degradation to in-stream gravel mining, it seems likely that multiple factors contributed to the degradation. WRECO’s assumptions are based on bridge inspections conducted by Caltrans. Caltrans inspected the Isabel Avenue/SR 84 bridge at ADV on September 17, 2008. Although the *Bridge Inspection Report* attributed the 5.9 ft of degradation to in-stream gravel mining, it seems likely that multiple factors contributed to the degradation, and that ADV still may be adjusting to construction of Del Valle Dam.

It is also important to note that even though some data shows evidence that ADV has stabilized, the potential still exists for degradation and reduced sediment loads in upstream reaches of ADV. BC performed some preliminary calculations to estimate sediment yields to ADV reaches downstream of the Del Valle Dam, and found that inflowing sediment yields could be less than half of the sediment loads calculated for the Lake B, Lake A, and Sycamore Grove Park reaches. This finding suggests that sediment loads originating from Sycamore Grove Park could be largely due to the reworking of alluvial material immediately downstream of the Del Valle Dam and in Sycamore Grove Park.

The proposed conditions for the ADV realignment has been designed by BC to maintain a quasi-equilibrium state by maintaining sediment continuity with upstream reaches. Geomorphic investigations conducted by Balance suggest that a single-thread channel with low-flow, bankfull, and flood stages is appropriate for restoring ADV along the new alignment. Balance further recommends that the single-thread design include elements that promote stability and channel complexity, while also providing fish passage (Balance 2017). Thus, BC has developed the design of the realigned ADV that is predominantly based on a single-thread channel configuration. However, additional features and channel complexity are incorporated into the design to allow for natural evolution of the landscape.

In order to design a stable channel that minimizes the risk of long-term channel degradation, BC developed a channel configuration (e.g., dimensions, pattern, and profile) that maintains a balanced sediment transport regime through the study reach; incorporated a compound channel design to convey typical low flows, bankfull, or channel-forming flows, and flood flows while maintaining connectivity between the channel and floodplain; and ensured that flood flows more than the channel-forming discharge spill into a floodplain, such that the flow is unconfined, resulting in lower overbank velocities and shear stresses. By maintaining continuity of sediment loads with upstream reaches along Lake A and within Sycamore Grove Park (see Figures 6-5 and 6-6), according to Lane's Principle, such continuity reduces the potential long-term aggradation or degradation, and thus the proposed channel and floodplain configuration is expected to be stable and persist.

Channel restoration design efforts for ADV focused on establishing a suitable range of channel geometries that will allow for some adjustment over time to accommodate the flow and sediment regime that it will experience. The bankfull discharge is often used as a surrogate for the channel-forming discharge because it defines channel shape and size in most stable reaches (Leopold et al. 1964). Bankfull or channel-forming flows are generally associated with the 1.5- to 2.3-year recurrence interval (Dunne and Leopold 1978). The bankfull channel has been designed to convey the 2-year peak discharge of approximately 200 cfs, which was calculated based on a regression of post-dam annual peak discharges. A general, or reach-averaged cross-section for the compound channel and floodplain was developed based on spatial constraints, geomorphic recommendations, and recognized hydraulic design methodologies. Channel stability analyses (Section 5.2) were performed in parallel to establish a slope and geometry that maintain sediment continuity through the restored reach. The overall process was iterative, because feedback from the stability analysis helped to inform dimensioning the channel and floodplain.

Given the considerable uncertainty associated with transient and highly variable phenomena such as sediment loads, transport rates, and equilibrium dynamics, BC added additional features to the design to help mitigate disturbances that could lead to severe degradation or channel widening—particularly to vulnerable areas such as the outsides of bends. These features consist of rock barbs designed to reduce velocities and direct water away from the outer slopes. These types of features offer a dual purpose by both promoting a stable channel configuration and providing a more reliable platform for ecological restoration as plant communities are established and fish-passable features are created.

It is important to note that it is possible that a large flood event will cause a substantial—even if only temporary—disturbance to the geomorphic balance of the stream system under either existing or proposed conditions.

6.2.4 Localized Scour

Although long-term stability will remain unchanged, potential always exists for transient scour to occur during high flows when water is funneled through narrow constrictions (i.e., contraction scour), and at obstructions where swiftly moving water can create erosive vortices around a structure (i.e., local scour). Both contraction scour and local scour are common at bridges where water must flow through a bridge opening that is narrower than the upstream floodplain, and structural components (e.g., piers and abutments) can obstruct flow.

The scour analysis conducted by WRECO found that the baseline and proposed conditions for the 100-year flood event may result in (WRECO 2009):

- 1.2 feet of contraction scour at the widened Isabel Avenue bridge
- 2.9 feet of contraction scour at the trail bridge
- 7.5 to 13.9 feet of total scour (i.e., contraction plus local) at the abutments of the widened Isabel Avenue bridge
- Up to 14.5 feet of total scour along the pier of the widened Isabel Avenue bridge
- Roughly 25.0 feet total scour at the piers and abutments of the new trail bridge

According to WRECO, Caltrans coordinated extensively with its consultant design team to evaluate countermeasures to mitigate the potential for local scour to occur at the Isabel Avenue bridge abutments and piers (WRECO 2009). That work investigated gabions, pre-cast concrete blocks, concrete lining, sheet piling, and riprap (see Table 6-2).

Table 6-2. Scour Countermeasures Evaluated by Caltrans

Measure	Outcome
Gabions	Eliminated: vandalism concerns
Interlocking concrete blocks	Eliminated: not appropriate for steep slopes
Concrete pavement	Eliminated: environmental permitting challenges
Sheet piling	Eliminated: difficult to drive into gravels
Riprap/RSP	Preferred, but not sufficient as a standalone measure

Source: WRECO 2009.

Caltrans ultimately concluded that piers of the widened section of the highway bridge and the trail bridge, as well as abutments for the trail bridge, should be supported by piles driven as deep as the estimated maximum depth of scour at each location. In addition, the existing rock slope protection (RSP) at the Isabel Avenue bridge was upgraded. According to WRECO, RSP is the most common type of bridge scour countermeasure due to its general availability, ease of installation, and relatively low cost (WRECO 2009).

The potential bridge scour identified by WRECO occurs at the structures that were installed in the channel by Caltrans in 2018. Note that the widening of the highway bridge and construction of the trail bridge has increased the extent and magnitude of the scour that can occur at the Isabel Avenue crossing during a large flow event. Specifically:

- The length of the constricted channel section has increased by as much as 100 feet due to the wider abutments and addition of a second bridge structure
- The maximum scour depth has increased because the total scour at the trail bridge is more than 10 feet deeper than the total scour at the roadway bridge

This additional scour potential currently exists and would not occur in the RPA without the Caltrans SR 84 Expressway Widening project.

The above findings suggest that the ADV channel near the Isabel Avenue bridge is generally stable in its current and proposed configuration; however, scour may occur during an extreme condition such as the 100-year flood event. Estimated scour depths are nearly 15 feet at the widened roadway bridge and roughly 25 feet at the trail bridge. The scour associated with these depths may occur at structures located upstream of the concrete spillway proposed in the SMP-23 Reclamation Plan and would therefore be unaffected by the proposed amendments that eliminate the need for a spillway. Because Caltrans has implemented measures to address the potential for bridge scour at the upstream structures, no need for further actions are needed related to bridge scour as part of the RPA for SMP-23.

6.3 Flood Impacts

As described in Section 6.1.1, FEMA has completed flood hazard mapping for ADV, including a detailed study of the reach upstream of Isabel Avenue. However, conditions have changed since the original FEMA study was completed and supporting technical data, such as the current effective hydraulic model, are not available. Therefore, BC evaluated flood hazard impacts by developing an updated model and performing new steady-state hydraulic simulations for the 10-, 50-, 100-, and 500-year floods.

BC used the peak discharges from the current FIS to develop the data inputs for the HEC-RAS model as shown in Table 6-3 (FEMA 2009). According to FEMA's current FIS for the County, the peak 100-year discharge of 7,000 cfs, which corresponds to a managed flood release from the dam (FEMA 2009; USACE 1978).

Table 6-3. ADV Peak Discharge Frequency

HEC-RAS Profile No.	Recurrence Interval (years)	Peak Discharge (cfs)
1	10	1,860
2	50	4,150
3	100	7,000
4	500	9,080

Note: At confluence with Arroyo de la Laguna. Source: (FEMA 2009).

BC set up the HEC-RAS model to automatically calculate upstream and downstream water surface boundaries using normal depth calculations using channel slope. BC's analyses estimated the upstream slope for the normal depth calculation to be 0.6 percent, and the downstream slope to be 0.5 percent. If this model is later used for FEMA flood hazard map revisions, the upstream and downstream boundary conditions may need to be adjusted to tie into the effective base flood elevations at each boundary. However, the model boundaries are located well upstream and downstream of the Project Site; thus, small changes to boundary conditions are unlikely to affect flood modeling results at the Project Site.

BC calculated hydraulic profiles (e.g., peak water surface elevations) along the Study Reach using the existing-conditions geometric model described in Section 6.1.2. Figure 6-7 shows an overview of the calculated water surface profiles for the 10-, 50-, 100-, and 500-year floods. Appendix I contains detailed output tables.

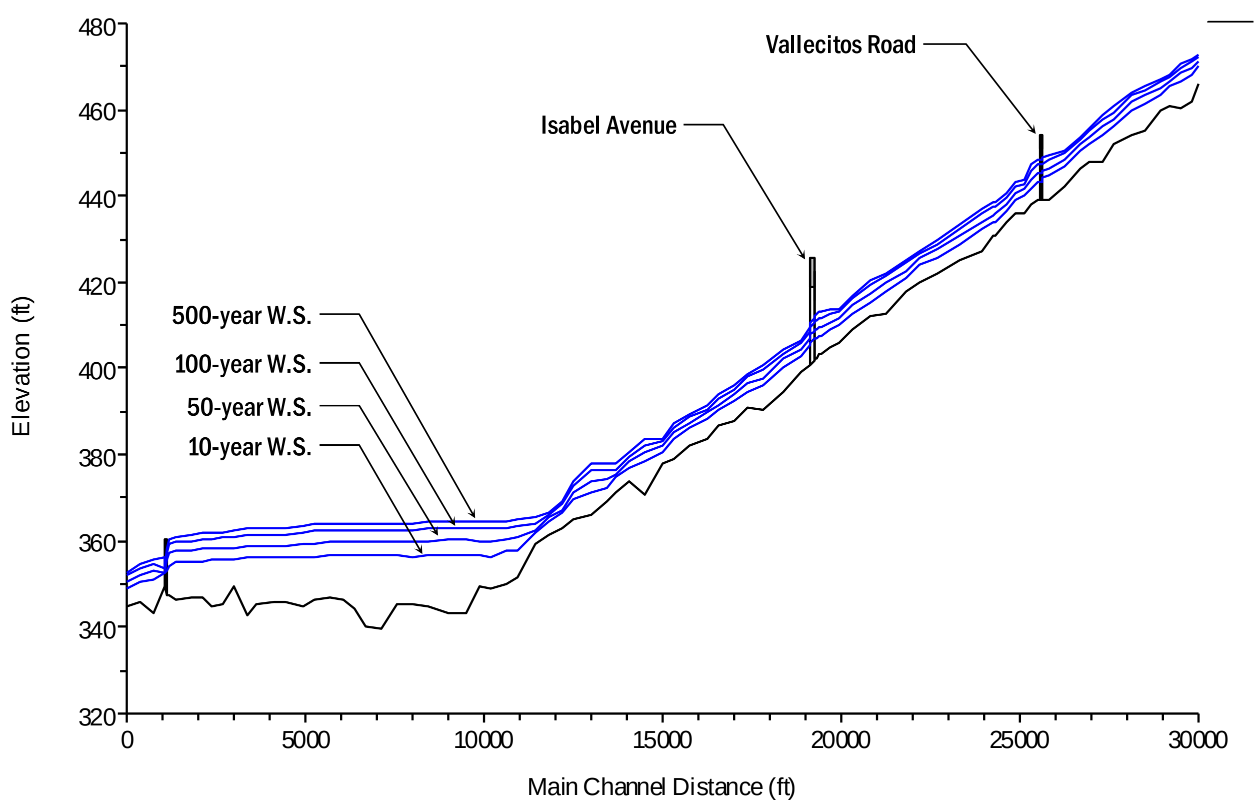

Figure 6-7. Overview of HEC-RAS water surface profiles for ADV under existing conditions

As discussed in Section 6.1.1, FEMA uses the 100-year flood as its base flood. Local communities typically use the 100-year flood for the management and regulation of floodplains. Therefore, BC used the 100-year flood scenario to perform inundation mapping and evaluate flood impacts. BC developed existing-conditions flood inundation mapping using the following steps:

1. Export the HEC-RAS results from the existing 100-year scenario to ArcGIS using HEC-GeoRAS, which attributes water surface elevations to modeled cross-section transects
2. Convert the cross-section transects in a three-dimensional triangulated irregular network (TIN) surface representing the hydraulic profile along ADV, then convert to a gridded raster surface with 5-foot resolution
3. Convert the 2018 topography data into a raster surface representing existing terrain topography on the same 5-foot grid as the water surface raster
4. Convert the 2014 LiDAR survey data into a raster surface representing existing terrain topography on the same 5-foot grid as the water surface raster
5. Merge the 2014 and 2018 topography data to get a raster surface of the entire Project Site reach
6. Subtract the terrain surface from the water surface grid to obtain an elevation difference raster where the positive values represent the potential inundation depth
7. Examine potentially inundated areas for connectivity with the main channel, then remove areas not directly connected

Figure 6-8 shows the existing 100-year flood inundation area for the Study Reach.

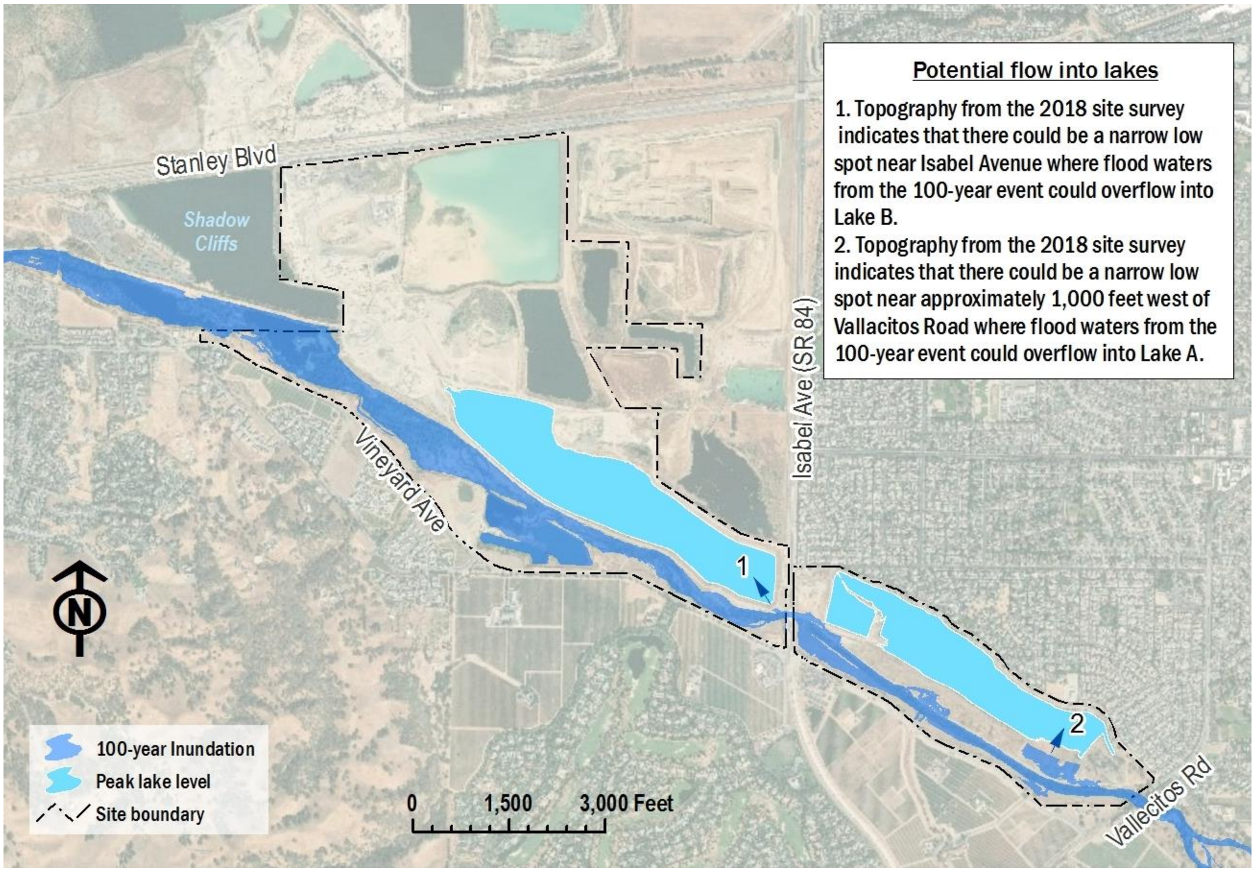

Figure 6-8. 100-year flood inundation based on existing conditions hydraulic modeling

BC's inundation mapping analysis found that the estimated water surface elevations in ADV are high enough to indicate that water could potentially flow into Lake A and/or Lake B at two low spots, as noted in Figure 6-8. These will be addressed by the proposed project through the addition of berms. In addition to the modifications described in Section 5, CEMEX proposes to use these modeling results to raise the berms between ADV and Lakes A and B to prevent overtopping during a 100-year flood event. Additional modifications to the berms outside of the ADV realignment and the Lake A diversion were not explicitly modeled because such modifications are located outside of portion of the floodplain that actively conveys flood flows. In other words, minor modifications to the berms outside of the floodplain or at the two overtopping areas noted in Figure 6-8 would have a negligible impact on ADV flood flow conveyance.

BC performed additional steady-state hydraulic simulations using the proposed-conditions (i.e., implementation of reclamation pursuant to the RPA) geometric model, which included modifications representing the Lake A diversion structure and the realigned ADV corridor as described in Section 6.1.3. Figure 6-9 shows the 100-year flood inundation area under proposed conditions. Figure 6-9 also shows the inundated areas of Lakes A and B at maximum water surface elevations of 420 feet and 369 feet, respectively (EMKO 2018).

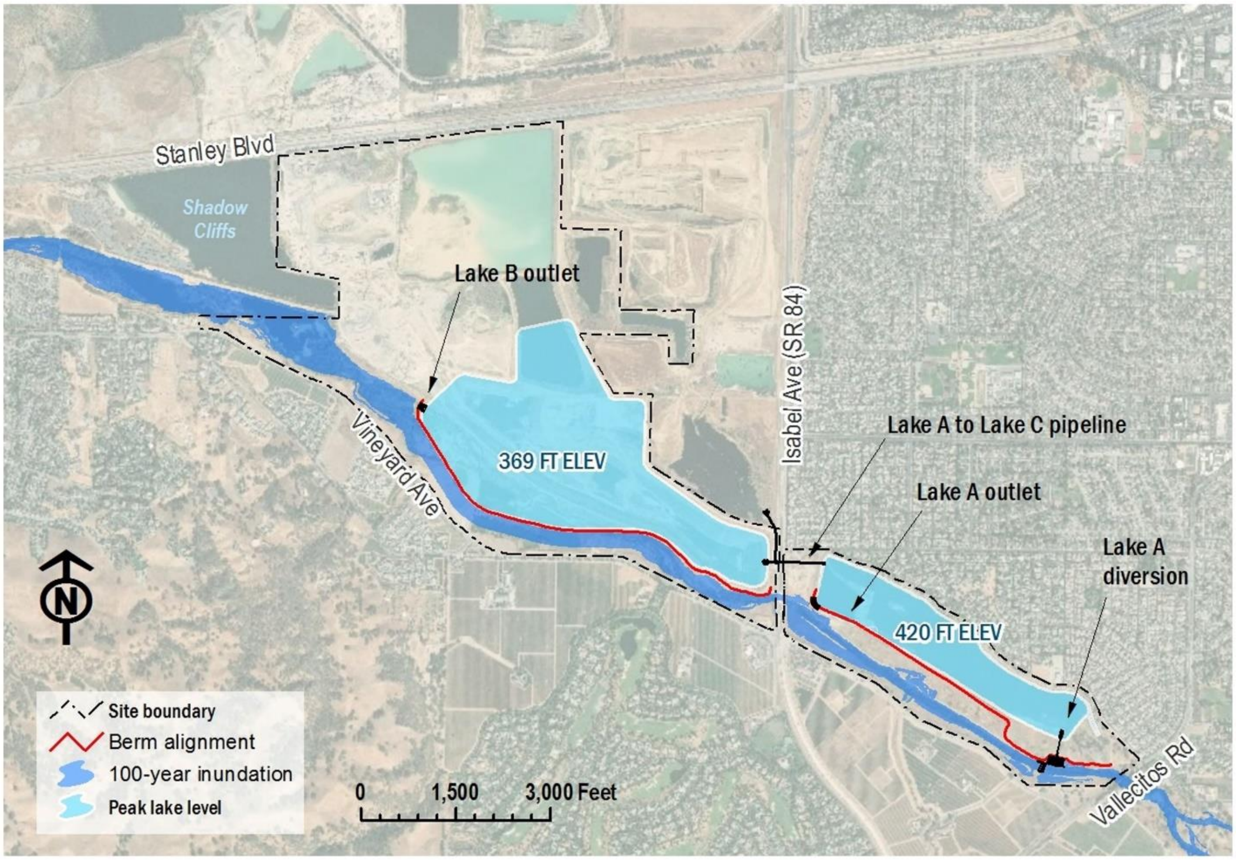

Figure 6-9. 100-year flood inundation based on proposed conditions hydraulic modeling

BC compared the 100-year water surface profiles and flood inundation areas for existing and proposed conditions. Water surface profiles and inundation areas for the reach adjacent to Lake B are shown in Figure 6-10 and Figure 6-11, respectively. Water surface profiles and inundation areas for the reach adjacent to Lake A are shown in Figure 6-12 and Figure 6-13, respectively.

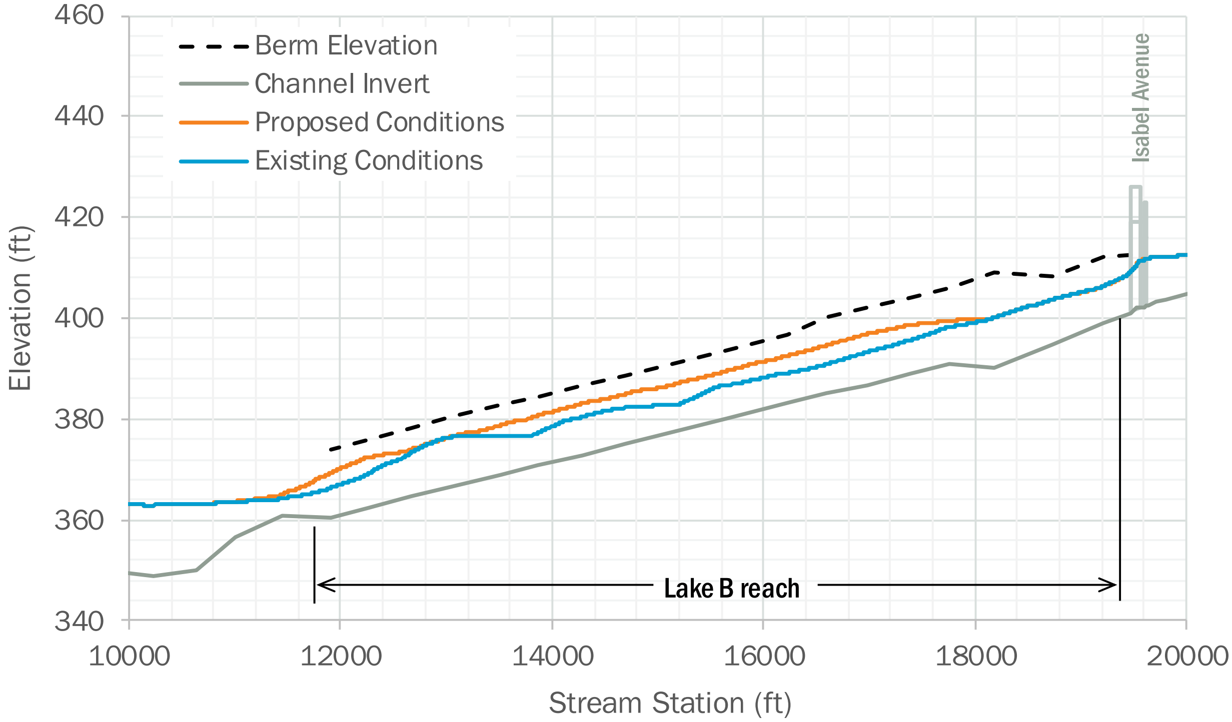

Figure 6-10. 100-year water surface profiles for existing and proposed conditions at Lake B

Berm elevations based on proposed ADV realignment, existing ground, and raised berm elevations as proposed for RPA

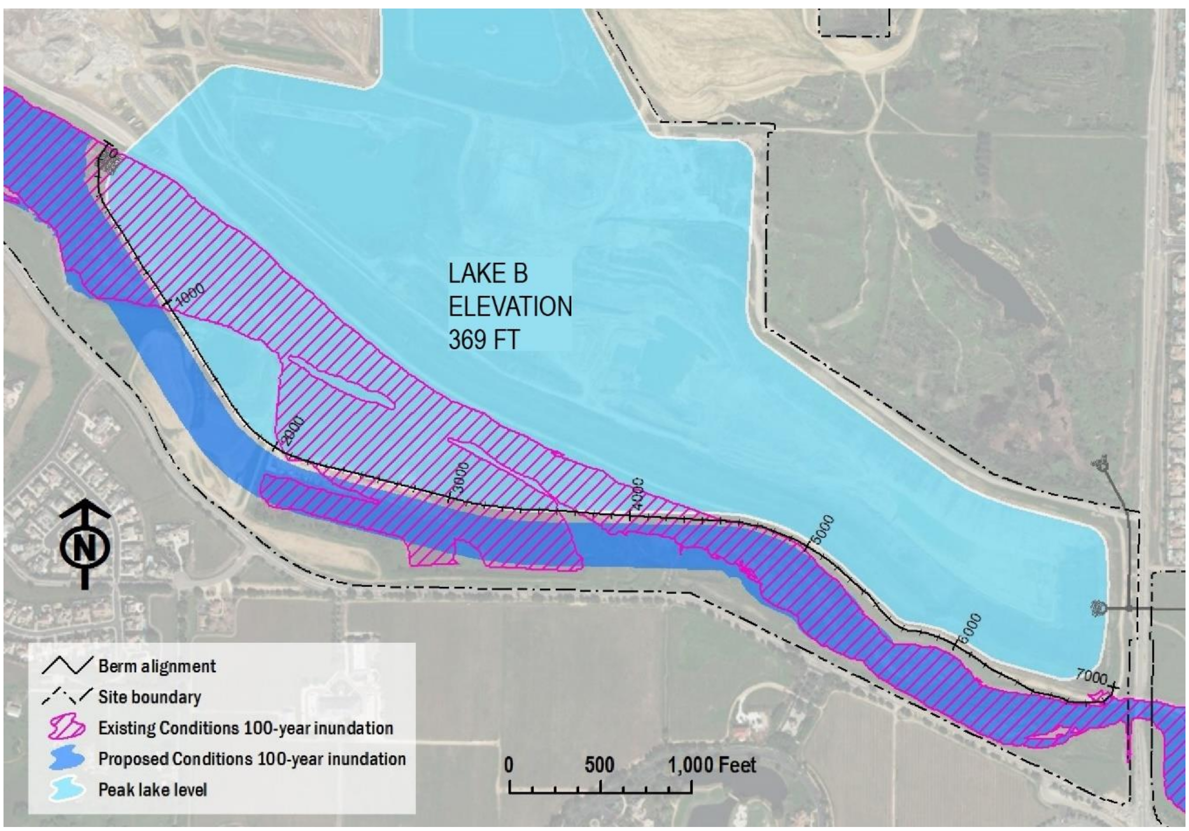

Figure 6-11. 100-year water surface profiles for existing and proposed conditions at Lake B

Brown AND Caldwell

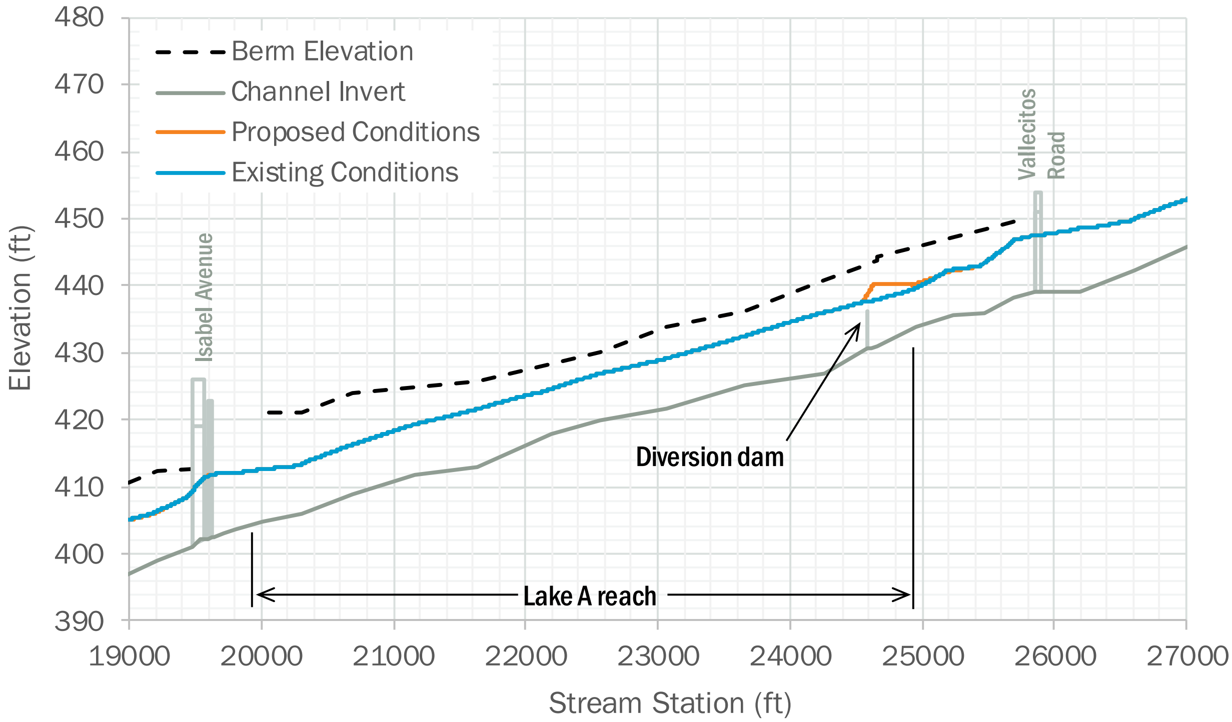

Figure 6-12. 100-year water surface profiles for existing and proposed conditions at Lake A

Berm elevations based on proposed ADV realignment, existing ground, and raised berm elevations as proposed for RPA

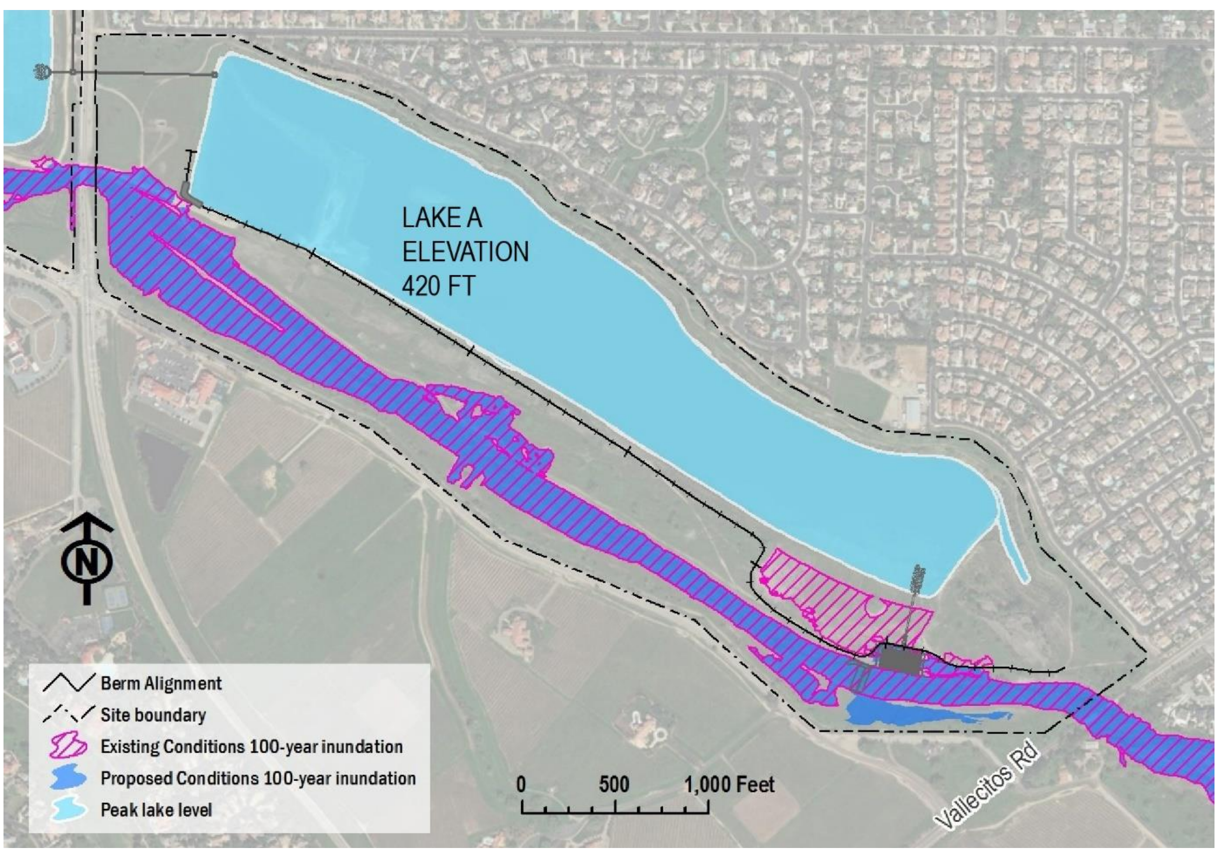

Figure 6-13. 100-year flood inundation areas for existing and proposed conditions at Lake A

The results indicate that water surface elevations along the realigned ADV corridor increase by an average of approximately 2.2 feet. Proposed changes along Lake B do not increase flood inundation areas outside of the realigned corridor or cause any new offsite flood impacts because the realigned corridor will be designed to contain flood waters.

At the Lake A diversion dam, the 100-year water surface elevation increases by approximately 2.2 feet at the diversion dam, but the increase diminishes rapidly in the upstream direction and is negligible approximately 500 feet upstream of the diversion. BC found that the Lake A diversion structure increases the inundated area just upstream of the diversion dam by approximately 1.9 acres. However, this area is confined to the CEMEX property and does not affect any roadways or structures.

6.4 Berm Elevations

The grade along the berm alignments noted in Figure 6-10 and Figure 6-12 will be raised where necessary to prevent overtopping during the 100-year flood and reduce the potential for breaching or avulsion. As described for the realigned corridor, new berms are proposed to be constructed to a height that is greater than the estimated water surface elevations for the 100-year ADV flood event to provide a factor of safety in design that compensates for the uncertainty associated with many of the factors that contribute to flood heights that could result in water surface elevations that are greater than those calculated using a hydraulic model.

FEMA recommends that communities include freeboard standards in their floodplain management code. Alameda County's Hydrology and Hydraulics Manual requires major flood control facilities[13] that protect developed areas to provide freeboard in accordance with Code of Federal Regulations, Title 44, Section 65.10(b) Chapter I (10–1–2002 edition). This includes the following freeboard requirement:

> *(1) Freeboard. (i) Riverine levees must provide a minimum freeboard of three feet above the water surface level of the base flood. An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted. An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.*

BC recommends that the berms along the ADV floodplain be constructed to heights that meet the freeboard requirements described above. However, it is important to note that ***the berms are not intended to be a flood protection levee as defined by 44 CFR 65.10***, and will not be designed to protect developed areas with permanent structures. Moreover, the berms will not remove areas from the Special Flood Hazard Area (SFHA) as shown on Alameda County's adopted Flood Insurance Rate Maps. The purpose of the berms is to reduce the potential for ADV to overtop and for flood waters to flow into Lakes A and B during reclamation operations and in future reclaimed conditions. While the berms may remain in place after reclamation, areas protected by the berms will still be subject to the County's requirements for development within a floodplain.

GEOCON (2019) evaluated slope stability for the proposed ADV realignment and recommended that embankment fill slopes and adjacent Lake B mining slopes be constructed at an inclination of 2H:1V or flatter. GEOCON added that, for slopes exceeding 50 feet high, a bench should be constructed at approximately mid-height to provide access for maintenance operations. If the specified criteria are met, GEOCON concludes that the potential for pit capture is low, as long as the berm/embankment

[13] Alameda County defines "major facilities" as flood control facilities serving drainage areas 25 square miles or greater. Arroyo del Valle meets this criterion.

is not overtopped by floodwaters. As an extra factor of safety, the proposed project will use 3H:1V interior (to ADV) side slopes along the realigned floodplain corridor.

As described in Section 5.3, spillway outlets will be constructed on Lakes A and B to allow water to spill back into ADV. While it is possible for the water levels in Lake A and Lake B to rise to these spillway elevations—which are greater than the adjacent floodplain elevations—the berms between the lakes and the arroyo are not designed to impound water and should not be viewed as engineered impoundment structures.

The spillway crest and maximum water surface elevation in Lake B of 369 feet is approximately 5.5 feet higher than the lowest ground surface at the toe of the Lake B berm in the realigned ADV. If these elevations hold true, Lake B cannot impound water more than 6 feet above the ADV floodplain, thereby avoiding the creation of a jurisdictional dam according to California Water Code14. A jurisdictional dam would be subject to regulation by California Department of Water Resources, Division of Safety of Dams.

[14] In California, any dam that is 6-feet or greater in height is considered jurisdictional and subject to regulation by the Division of Safety of Dams (see *http://www.water.ca.gov/damsafety/jurischart/index.cfm*).

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Section 7

Limitations

This document was prepared solely for CEMEX in accordance with professional standards at the time the services were performed and in accordance with the contract between CEMEX and Brown and Caldwell dated November 18, 2015. This document is governed by the specific scope of work authorized by CEMEX; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by CEMEX and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 8

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Appendix A: Bulletin 17B Approach

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Appendix A

Bulletin 17B Approach

Frequency Analysis Using Bulletin 17B Approach (IACWD 1982)

Statistical parameters such as mean values, standard deviations, and skewness are used to fit the peak discharge data to a log-Pearson Type III (LP3) distribution that can be used to estimate the likelihood of various discharges as a function of recurrence interval, or exceedance probability. The advantage of this technique is that extrapolation can be used to estimate values for events with return periods beyond the period of record. The LP3 distribution is calculated using the following general equation:

$$\log x = \overline{\log x} + K\sigma_{\log x}$$

Equation A-1

where x is the discharge value of some specified probability, $\overline{\log x}$ is the average of the log x discharge values, K is a frequency factor, and $\sigma_{\log x}$ is the standard deviation of the log x values. The frequency factor K is a function of the skewness coefficient and recurrence interval and can be approximated using the following formula (Kite 1977; Chow et al. 1988):

$$K = z + (z^2 - 1)k + \frac{1}{3}(z^3 - 6z)k^2 - (z^2 - 1)k^3 + zk^4 + \frac{1}{3}k^5$$

Equation A-2

where z is the standard normal variable and k is equal to the coefficient of skewness (C_s) divided by 6. The coefficient of skewness is calculated as follows:

$$C_s = \frac{n\sum\left(\log x - \overline{\log x}\right)^3}{(n-1)(n-2)\left(\sigma_{\log x}\right)^3}$$

Equation A-3

where n is the number of values in the data set. The skewness estimate (C_s) computed using Equation 6 is referred to as the station skew because it is based solely on data from the station of interest. Error and bias in the skewness estimate increase as the number of data values (n) decrease. Bulletin 17B recommends the use of a weighted coefficient of skewness (C_w) that not only accounts for the station skew, but also incorporates a generalized estimate of the coefficient of skewness (C_m) developed from data observed at other sites within the region:

$$C_w = \frac{V(C_m)C_s + V(C_s)C_m}{V(C_m) + V(C_s)}$$

Equation A-4

where $V(C_m)$ is the variance of the generalized skew and $V(C_s)$ is variance of the station skew. BC estimated the generalized skew (C_m) to be -0.6 and the variance of the generalized skew, $V(C_m)$, was assumed to be 0.14 based the regional study for California prepared by Parrett (Parrett et al. 2011).

The variance of the station skew, $V(C_s)$, for LP3 random variables can be obtained from the results of Monte Carlo experiments by Wallis, which showed that (Wallis et al. 1974):

$$V(C_s) = 10^{A-B\log\left(n/_{10}\right)}$$

Equation A-5

where $A = -0.33 + 0.08\ |C_s|$ if $|C_s| \leq 0.90$ or $A = -0.52 + 0.30\ |C_s|$ if $|C_s| > 0.90$; and $B = 0.94 - 0.26\ |C_s|$ if $|C_s| \leq 1.50$ or $B = 0.55$ if $|C_s| > 1.50$. Note that $|C_s|$ is the absolute value of the station skew.

Appendix A References

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Appendix B: Sediment Data

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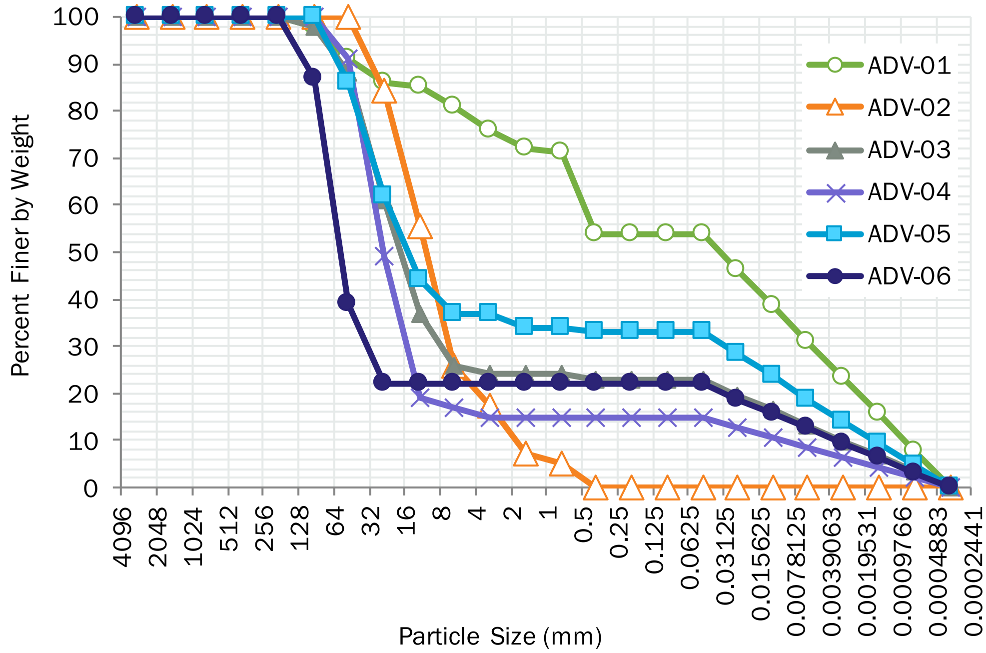

Figure B-1. Bed gradation curves based on Wolman pebble counts

Note: the distribution of fines was not measured; values for silt and clay were interpolated for use in quantitative analyses and computations.

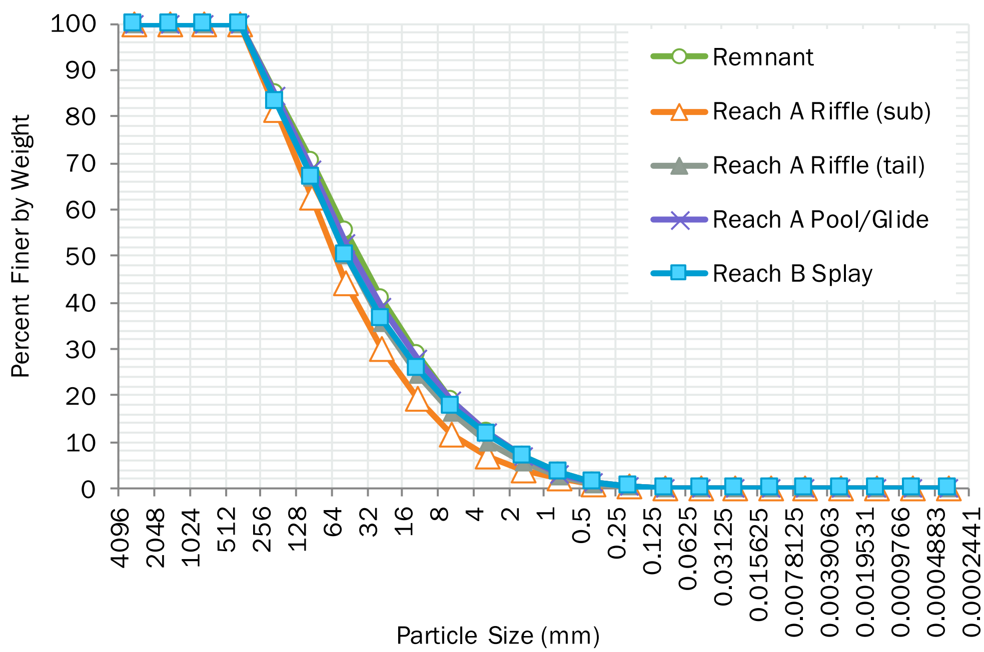

Figure B-2. Bed gradation curves based on bulk sediment samples

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Appendix C: Bankfull Channel Measurements

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Appendix C

Bankfull Channel Measurements

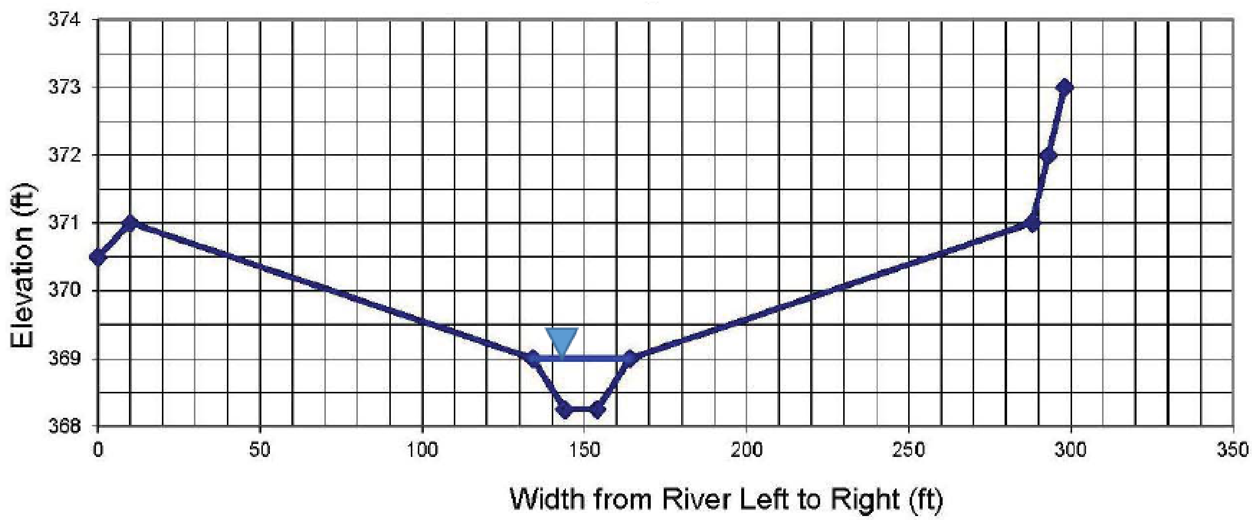

Figure C-1. Cross-section and bankfull estimate for observation point 1

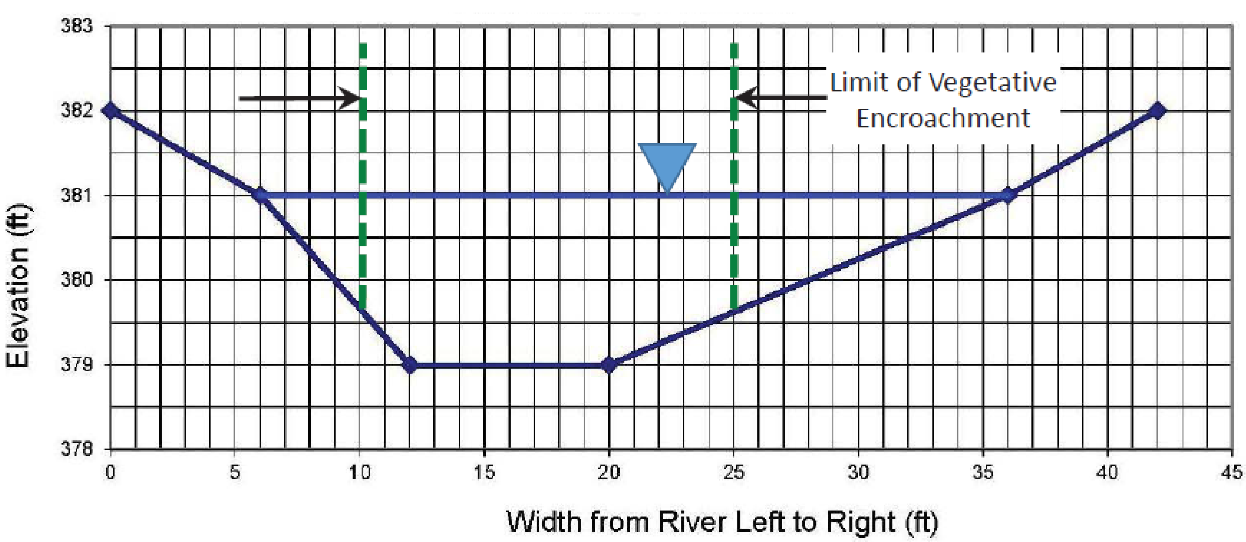

Figure C-2. Cross-section and bankfull estimate for observation point 3

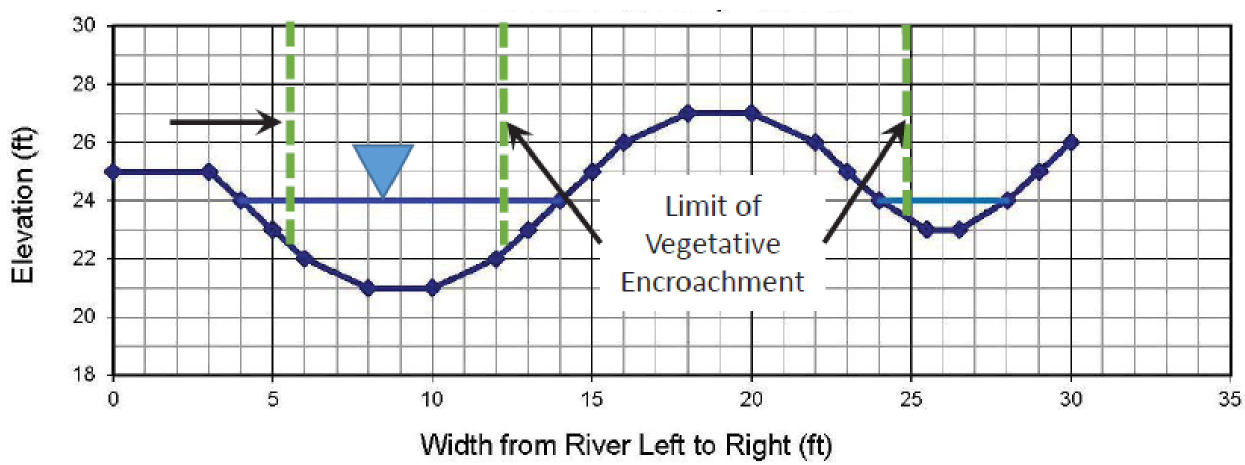

Figure C-3. Cross-section and bankfull estimate for observation point 4

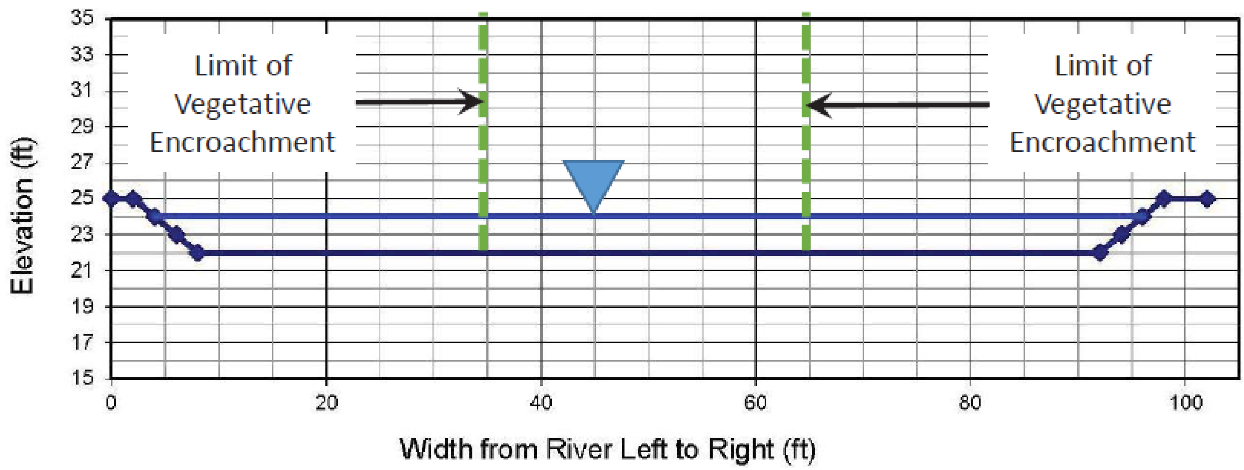

Figure C-4. Cross-section and bankfull estimate for observation point 5

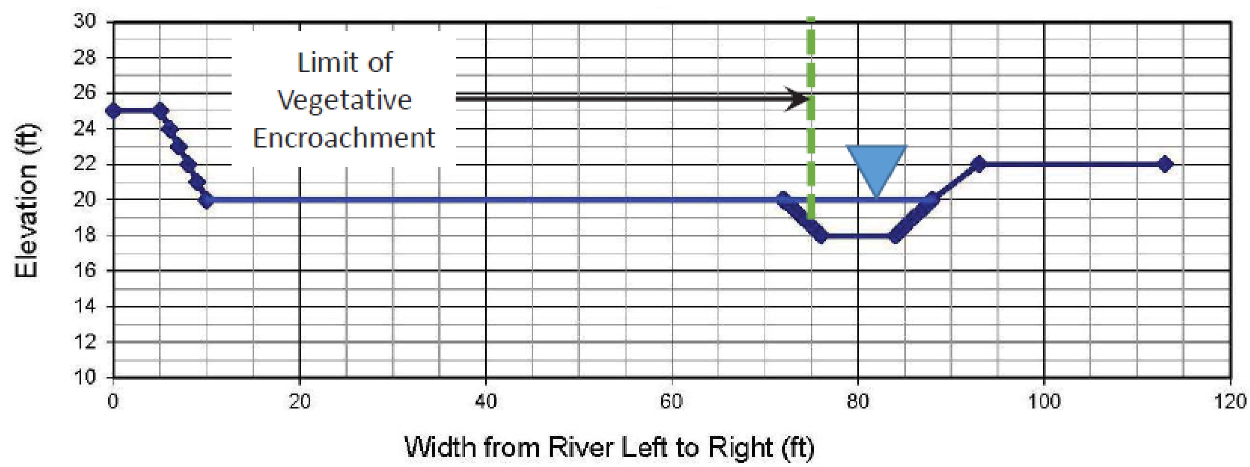

Figure C-5. Cross-section and bankfull estimate for observation point 6

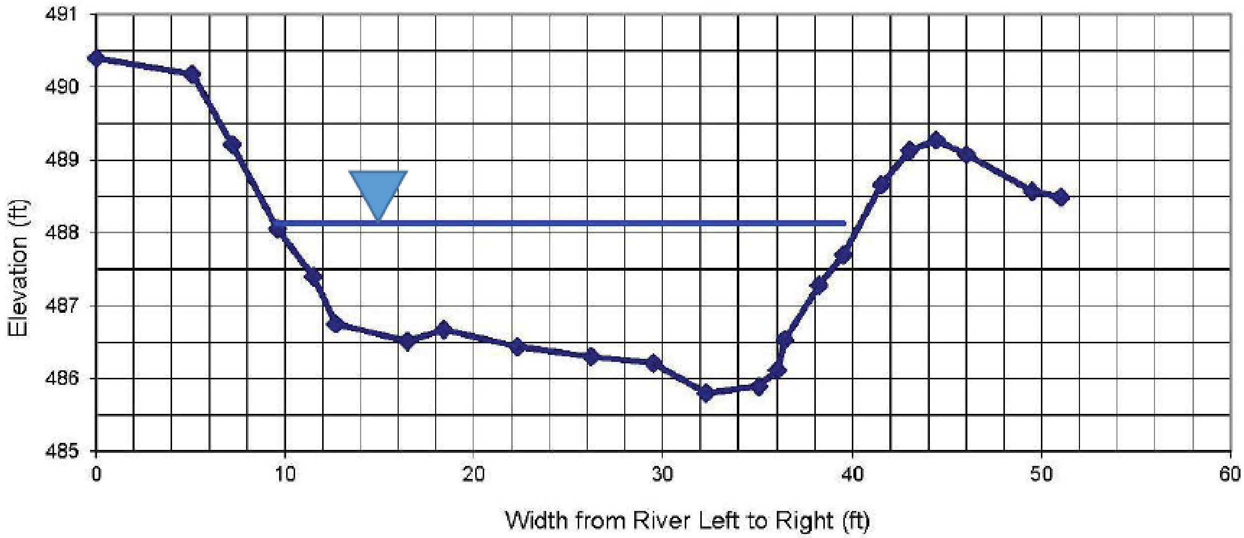

Figure C-6. Cross-section and bankfull estimate for observation point 7

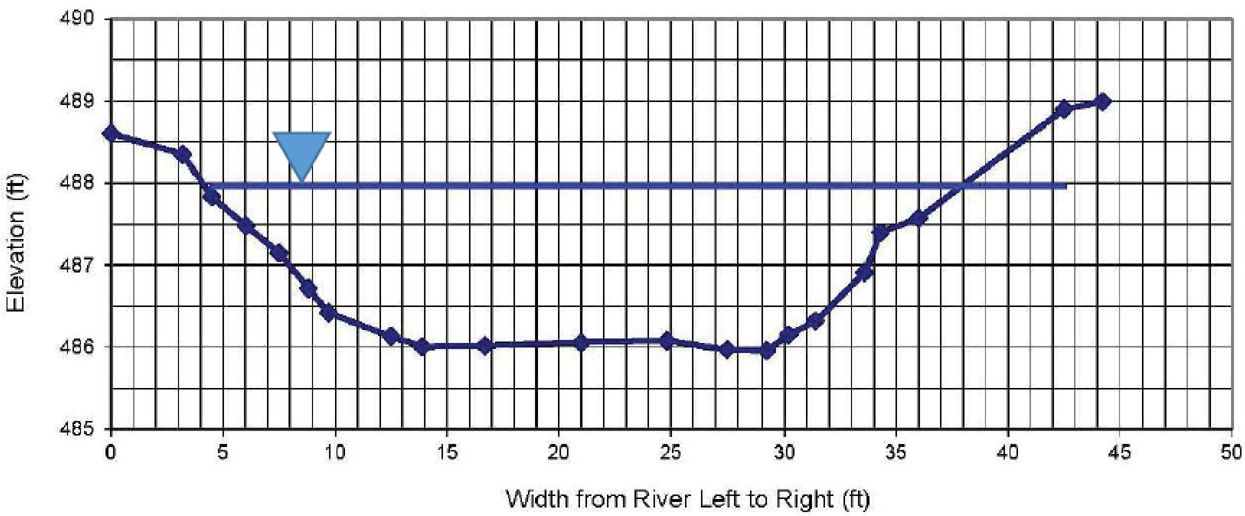

Figure C-7. Cross-section and bankfull estimate for observation point 8

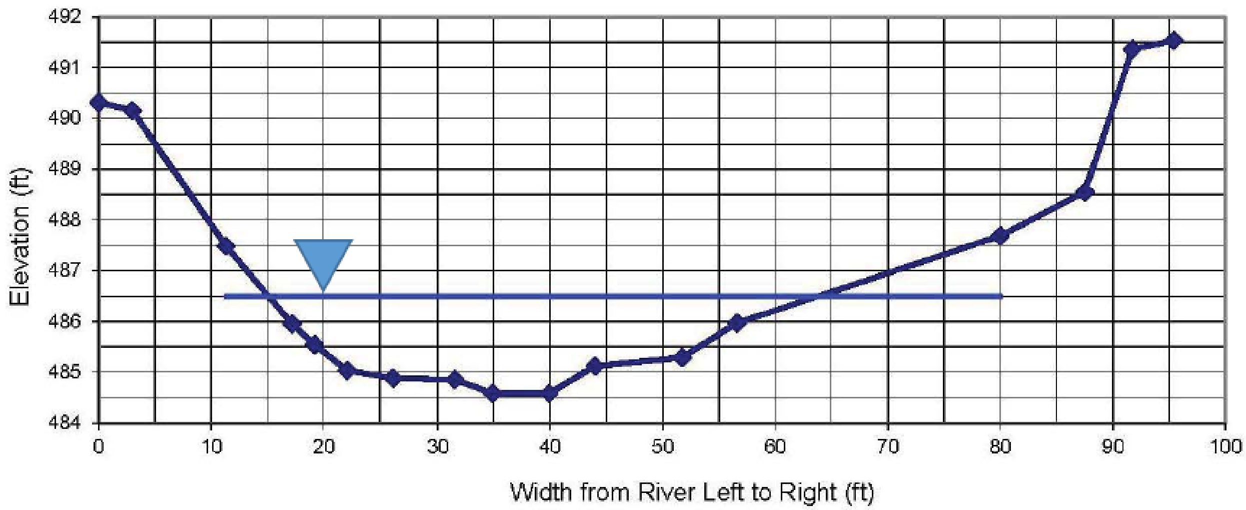

Figure C-8. Cross-section and bankfull estimate for observation point 9

Figure C-9. Cross-section and bankfull estimate for observation point 10

Appendix D: Geomorphic Assessment

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SEDIMENT ANALYSIS AND AERIAL PHOTO REVIEW ALONG REACH-A AND REACH-B, ARROYO DEL VALLE, CEMEX ELIOT FACILITY ALAMEDA COUNTY, CALIFORNIA

Report prepared for:
Brown and Caldwell

Prepared by:
Bill Christner
Eric Donaldson
Barry Hecht

Balance Hydrologics, Inc.

February 2017

A report prepared for:

Nathan Foged, P.E.
Project Manager
Brown and Caldwell
701 Pike Street, Suite 1200
Seattle, Washington 98101

Sediment Analysis and Aerial Photo Review Along Reach-A and Reach-B, Arroyo Del Valle, CEMEX Eliot Facility, Alameda County, California

 Project Assignment: 215101

by

Bill Christner, Ph.D.
Project Geomorphologist - Project Manager

Eric Donaldson, P.G.
Project Geomorphologist

Barry Hecht, C.E.G., C.Hg.
Senior Principal

Balance Hydrologics, Inc.®

800 Bancroft Way, Suite 101
Berkeley, California 94710
(510) 704-1000
office@balancehydro.com

February 6, 2017

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PROJECT BACKGROUND

This report presents the results of Balance Hydrologics' analysis of sediment samples collected along Reach-A and Reach-B, and an aerial photo review of Reach-A and Reach-B on Arroyo del Valle at the CEMEX Construction Materials, Inc. (CEMEX) Eliot Facility located between the cities of Pleasanton and Livermore within the unincorporated area of Alameda County, California. CEMEX is seeking the approval of an amendment to its existing Reclamation Plan, which was originally approved in 1987 under Surface Mining Permit 23 (SMP-23).

Alameda County issued a Notice of Preparation of a Draft Environmental Impact Report in 2015 for the Reclamation Plan Amendment in accordance with the California Environmental Quality Act (CEQA). CEMEX developed a team of technical experts to assist in developing the CEQA analysis. Initial entitlement discussions with agency representatives have prompted CEMEX to conduct investigations and prepare a draft conceptual design document in support of the proposed realignment of Reach-B on Arroyo del Valle. Reach-B on Arroyo del Valle extends from the Isabel Road overpass downstream (west) approximately 4,450 feet. It is bounded by Vineyard Avenue on the south, Isabel Avenue on the east, and the levee for Lake B on the north.

The closure of Del Valle Dam has disrupted the natural hydrologic and sediment transport regimes in Arroyo del Valle and their associated geomorphic processes. Changes in the geomorphic processes on Arroyo del Valle need to be considered as the channel design for the restoration of Reach-B is developed because steady-state assumptions are not likely valid.

Previous work performed by Balance in support of the restoration design for Reach-B focused on the current and historical channel geometry on Arroyo del Valle, and infiltration rates of native and spoil soil material that may be used to construct the restored channel. These analyses included field data collected on Arroyo del Valle along Reach-B, Reach-A, and upstream in Sycamore Grove Park. Historical maps were reviewed to assess flow patterns and channel slope prior to the construction of Del Valle Dam. Peak flow estimates for a range of recurrence intervals were also reviewed. Results from these analyses were utilized to inform the proposed restoration design for Reach-B. The work also identified the need for additional fieldwork to assess the evolution of the current single-thread channel pattern on Arroyo del Valle in Reach-A, and to assess the characteristics of potential sediment mobilization and transport of the restored channel.

To assess the characteristics of potential sediment mobilization and transport, Balance sampled and sieved sediment from active and remnant (former) channel sites. Sediment analysis of active and remnant sites on Arroyo del Valle will provide insight to past and present sediment transport characteristics. This will constrain potential channel erosion and assist with establishing channel design criteria.

To assess the evolution of the single-thread channel pattern on Arroyo del Valle in Reach-A, Balance reviewed historical aerial photography. Aerial photo review will provide insight to the channel evolution of Reach-A and the potential future trajectory of the restored channel in Reach-B. Results from these analyses are expected to provide insight to the channel processes operating in Reach-B following realignment. Additionally, particle-size analysis can provide insight into the hydraulic properties of soil materials that may be used for channel reconstruction. Balance visited the site on August 26, 2016 to perform the required field work for the analyses. This report describes the methods and analyses performed to evaluate the bed-material characteristics of Arroyo del Valle, and assess the channel evolution of Reach-A following realignment. The analysis provides recommendations for the composition of the material to be used for reconstruction of Arroyo del Valle in Reach-B, along with robust geomorphic design recommendations to meet the stated project objectives (Foged, 2016), as part of the 90% channel design for Reach-B on Arroyo del Valle.

1. GOALS AND OBJECTIVES

The goal of the current work effort is to assess the applicability of a braided and single-thread channel design for the realignment of Reach-B on Arroyo del Valle. To achieve this goal, two evaluations(tasks) were performed. The first was an assessment of the particle-size distributions of active and remnant channels on Arroyo del Valle. The second was an aerial photo review of Reach-A. One element of the particle-size analysis was to obtain sediment samples from both active and remnant channel sites on Arroyo del Valle and assess how sediment transport on Arroyo del Valle has changed over time based on the particle-size distributions from these sites. This will provide historical insight into the sediment transport potential of the proposed design based on the particle-size distribution of the materials utilized for construction of the restored channel in Reach-B.

The goal of the aerial photo review is to develop a better understanding of the geomorphic processes that have affected the evolution of Reach-A following channel realignment associated with mining activities at the Eliot facility at Lake A. Results from these analyses will provide insight to:

- The evolution of the present-day channel flow pattern on Reach-A, and
- The establishment of riparian vegetation within Reach-A.

Additionally, results from these analyses will assist in the refinement of our guidance with the channel design for Reach-B on Arroyo del Valle.

2. HISTORICAL SETTING

Prior to the completion of Del Valle Dam, Arroyo del Valle was a braided, intermittent stream (SFEI, 2013) in the reaches where it currently flows through Reach-A and Reach-B on the CEMEX Eliot site (**Figure 1**). As the stream exited the confines of the mountains onto the broad valley floor, it lost stream power and dropped its sediment load forming an alluvial fan with a braided channel network (SFEI, 2013; Foged, 2016). The braided channel network included broad, nearly level, terraces and floodplains.

Historical accounts describe the alluvial valley as "river wash" and characterize the streambeds as very porous material, underlain by a bed of coarse gravel several feet thick (Westover and Van Duyne, 1910; Welch et al., 1966). Infiltration rates of the coarse channel material often allowed surface flows to percolate into the streambed at a rate such that channel flow was intermittent and discontinuous[1] (SFEI, 2013).

Today Arroyo del Valle is a highly disturbed and modified channel due to urban development, gravel extraction, and operations of Del Valle Dam. Combined, these land-use changes have altered the hydrology, geomorphology, and ecology of Arroyo del Valle. These changes are well documented in prior work:

- San Francisco Estuary Institute (SFEI), 2013, Alameda Creek watershed historical ecology study.
- Kamman Hydrology & Environmental Engineering, 2009, Phase 2 Technical report, Sycamore Grove Recovery Program, Sycamore Grove Park, Livermore, California. Prepared for Livermore Area Recreation and Park District and the Zone 7 Water Agency.
- Balance Hydrologics and EMKO Environmental, 2016, Infiltration Tests of Native and Spoil Soil Material Along Reach-B, Arroyo del Valle, CEMEX Eliot Facility.
- Balance Hyrdologics, 2016, DRAFT Technical Memorandum: Initial Geomorphic Assessment and Conceptual Design for Reach B, Arroyo del Valle on the CEMEX Eliot Facility, Alameda County, California.

[1] Discontinuous stream flow in this context is described as flow that may disappear into the streambed and then reappear further downstream. The pattern may repeat several times depending upon the composition of channel bed materials and depth to groundwater.

- Brown and Caldwell,2014, Hydraulic modeling of Arroyo del Valle: Technical memorandum 1, prepared for CEMEX Construction Materials, Inc. February 12, 2014.
- Brown and Caldwell, 2014, Arroyo del Valle diversion and conveyance feasibility. Technical memorandum 2, prepared for CEMEX Construction Materials, Inc. March 7, 2014.
- Kane GeoTech, Inc, 2013, CEMEX Eliot Quarry, Lakes A and B slope stability investigation, Alameda County, California. Project No. GT13-16. Consulting report prepared for CEMEX Construction Materials.
- EMKO Environmental, 2013, Hydrology and water-quality analysis report, Lake A and Lake B expansion, CEMEX Eliot Quarry – SMP-23. Consulting report prepared for CEMEX Construction Materials.
- Spinardi Associates, 2013, Reclamation plan amendment, CEMEX application for a Reclamation Plan Amendment, Eliot Facility – SMP-23, California Mine 91-01-0009.

Balance's previous geomorphic assessment combined field surveys of the channel geometry on Arroyo del Valle, pebble counts of the bed surface in the active channel and a remnant, off-channel site, and discharge estimates for a range of recurrence intervals based on USGS regional equations. Results from the geomorphic assessment provided channel design parameters for a single-thread channel geometry of the restored channel following completion of gravel-mining activities. However, the design parameters were preliminary and identified the need for these additional analyses.

3. GENERAL TECHNICAL APPROACH AND WORK CONDUCTED

3.1 Sediment Sampling

Senior Geomorphologist Bill Christner, PhD and Geomorphologist Eric Donaldson MS visited Reach-A and Reach-B on the project site (**Figure 1**) on Sept-26, 2016 to observe channel conditions and collect sediment samples from active and remnant sites on Arroyo del Valle. A site walk was also performed to assess channel conditions on the upper section of Arroyo del Valle just above Reach-A.

To evaluate sediment transport characteristics of Arroyo del Valle, bulk sediment samples were collected from five (5) sites (**Figure 2** and **Figure 3**). Sampling targeted active and remnant channel sites including:

- three (3) from the active[2] channel in Reach-A,
- one (1) splay[3] deposit in Reach-B, and
- one (1) remnant[4] channel deposit at the east end of Lake-A area.

The active channel sites on Reach-A represent the sediment-transport characteristics currently operating in Arroyo del Valle through the CEMEX Eliot site. The remnant channel site is thought to represent the bed-sediment characteristics of the historic Arroyo del Valle when it functioned as a braided system prior to the construction of Del Valle Dam in 1968. The remnant channel site is located on the eastern end of the Lake A site in an unmined area where Arroyo del Valle flowed as a braided system prior to the construction of Del Valle Dam. The splay deposit site in Reach-B is thought to represent depositional conditions during an episodic event on Reach-B under post-dam hydrologic conditions. Aerial photos indicated the size of the splay has remained relatively constant over time, suggesting the splay was created during a single event.

Sediment samples from all sites were obtained using a shovel technique (Bunte and Abt, 2001). The shovel technique has been shown to provide reliable results compared with other bulk sampling methods (Schuett-Hames and others.,1996). Sediment samples were obtained from the observed thalweg within the active channel. Individual subsample weights varied from 3,874.9 g to 5,912.7 g. Sample volumes required bulk

[2] Active bed sites are those sampled from the present-day channel.

[3] A splay deposit is a sedimentary fluvial deposit which forms when a stream breaks through its natural or artificial levee(s) and deposits sediment on the adjacent land area.

[4] The remnant site is sampled from the former (remnant) braided channel network.

samples to be subdivided and sieved separately in order to not exceed individual sieve capacity. Sediment samples were oven-dried at 105 degrees C, and mechanically sieved in Balance's laboratory utilizing ten (10) sieve sizes: 3", 2" 1.5", 1.0", 0.75", 0.375", #4, #10, #40, and #200. Final sediment results represent the total dry mass for each sample. Results are reported as the percent of the total sample mass retained on each sieve (**Appendix A**). Particle-size distributions are reported for each sample in both tabular and graphical format.

3.2 Aerial Photo Review

Balance acquired and reviewed a series of historical aerial photos of Reach-A on Arroyo del Valle spanning a 33-year period (1982 - 2015) to assess the evolution of Reach-A following mining activities and its realignment to the southern border parallel to Vineyard Avenue. The assessment focused on lateral channel migration, interaction with and influence of vegetation on channel geomorphic processes, and channel evolutionary processes following realignment. Balance reviewed six (6) aerial photos of Reach-B spanning a 22-year period (1993 – 2015) to assess the evolution of Reach-B and the splay deposit during this period.

Balance obtained a series of historical aerial photographs of Arroyo del Valle and the surrounding area from the USGS and Google Earth. The images selected for analysis are of reasonably high resolution, which allowed for the identification of geomorphic features and to document spatial and temporal changes.

The 33-year period used to evaluate Reach A represents most of the larger flow events since the dam was closed in 1968 (**Figure 4**). This extended period allowed us to assess channel adjustments to the suppressed flows and curtailed bedload delivery which now affect the stream. The shorter period used for Reach B provided the opportunity for a more detailed consideration of bed mobility and how the channel behaves under the current set of geomorphic and hydrogeologic conditions.

Seven (7) images on Reach-A were selected for analysis:

- July 5, 1982, NAHP image
- July 2, 1987, NAPP image
- June 11, 1993, NAPP image
- 1996, USGS image (exact date unknown)

- August 22, 1998, NAPP image,
- September 30, 2002, USGS image
- October 30, 2015, USGS image

Six (6) images of Reach-B were selected for analysis:

- June 11, 1993, USGS image
- September 30, 2002, USGS image
- August 31, 2008, USGS image
- September 2010, USGS image (exact date unknown)
- June 1, 2013, image source unknown
- October 30, 2015, image source unknown

4. FINDINGS

4.1 Sediment Analysis

Particle-size distributions for all bed-sampling sites[5] are presented in **Table 1**. The data reflect the morphological feature where the sample was collected, and their relative location within the project site. Morphologically, the riffle was coarser than the pool-glide, and the riffle subsurface sample was the coarsest. This is an expected outcome as riffles represent higher energy environments than a pool or glide. Channel substrate also coarsened in a downstream direction with the splay deposit in Reach-B coarser than the riffle deposit in Reach-A (D_{50} of 17.0 mm and 16.0 mm respectively). The coarsening of channel material is evident and more pronounced at the D_{84} and D_{95} values. The D_{84} of the splay deposit and riffle are 67.0 mm and 56.4 mm respectively, and the D_{95} are 104.6 mm and 96.6 mm respectively. Active channel sites were also coarser than the remnant channel site (**Table 1**). The coarsening of channel substrate following dam construction is a well-documented impact of new dams on downstream reaches (Brandt, 2000; Ligon and others, 1995; Williams and Wolman, 1984). Del Valle Dam has altered the natural hydrologic regime (**Figure 4**) and dramatically reduced the sediment load in Arroyo del Valle (Foged, 2016; SFEI, 2013). This in turn has created "hungry" water conditions in Arroyo del Valle. Releases from Del Valle Dam are sediment deficient, and as such, have the capacity to transport sediment, yet little to no sediment accompanies these discharges. Arroyo del Valle has adjusted to the reduced sediment load by harvesting and mobilizing (eroding) sediment from its channel bed and banks. The flows selectively remove the finer sediment fraction from the active channel as displayed in the particle-size distributions (**Figure 5**). This process proceeds until the channel bed becomes armored (Brandt, 2000). Channel armor is a veneer underlain by remnant, or un-winnowed channel materials (Williams and Wolman, 1984).

The average particle size (D_{50}) in the active channel sites on Arroyo del Valle is 17.1 mm. The D_{50} of the remnant site on Arroyo del Valle is 9.1 mm. This represents an 87 percent increase in the D_{50} of the active channel sites compared to the remnant channel site. This coarsening pattern continues through the D_{84} and D_{95} with average particle sizes of 64.2 mm and 101.2 mm, representing a 77 and 75 percent increase respectively compared to the remnant channel site values of 36.3 mm (D_{84}) and 57.8mm (D_{95}).

[5] Sieve data for all five (5) sites are presented in **Appendix A**.

Table 1. Particle size distribution for bulk sediment samples on Arroyo del Valle.

Percentile Sediment Finer Than	ADV Remnant Channel Bed-surface (mm)	Reach-A Riffle Subsurface (mm)	Reach-A Riffle Tail Bed-surface (mm)	Reach-A Pool/Glide Bed-surface (mm)	Reach-B Splay Deposit Bed-surface (mm)
D_{16}	1.1	4.0	1.8	1.3	1.4
D_{25}	2.2	7.7	3.6	2.3	3.2
D_{50}	9.1	24.4	16.0	10.8	17.0
D_{84}	36.3	80.6	56.4	52.9	67.0
D_{95}	57.8	110.8	96.6	92.6	104.6

The splay deposit sample is thought to represent hydraulic conditions associated with an episodic event. Aerial photos indicate the size of the splay has remained relatively constant over time suggesting that it was formed during a single event sometime between June-993 and September2002. The sample was collected along the left bed of an active channel that flows through the deposit (**Figure 3**). Sieve analysis indicates the sediment in the sample is coarse (relative to the other samples) with a D_{50} of 17.0 mm and a range in materials from 1.4 mm up to 104.6 mm. The splay deposit is interpreted as the re-working of remnant materials initially deposited prior to construction of Del Valle Dam and may be related to activities associated with the realignment of Arroyo del Valle in Reach-A. Reach-A was realigned to the south between June-1993 and 1996. The realignment of Arroyo del Valle to the south disturbed material along Reach-A. This newly disturbed material would have been easily mobilized during bankfull events, especially since the channel pattern also shifted from a multi-channel, braided system to a single-thread channel. The single thread channel would concentrate flows that previously were dispersed through multiple channels across a broad area. The concentrated flows may have mobilized the newly disturbed material and then deposited the material in Reach-B when the channel was breached.

4.2 Site Walk of Upper Portion on Reach-A

Two headcuts were observed during the site walk on Arroyo del Valle immediately upstream of the Vallecitos Road bridge (**Figure 6**). The first headcut is located below a concrete drainage channel connected to Vallecitos Road (**Figure 7**). The drainage channel connects to Arroyo del Valle on the east side of the Vallecitos Road bridge through an open concrete culvert. Storm runoff funnels down the concrete drainage and has created a 4-ft headcut below the concrete apron.

The second headcut is located on Arroyo del Valle approximately 150 ft upstream of the Vallecitos Road bridge. The headcut is approximately three feet in height over a series of large boulders (**Figure 8**). It is uncertain if the boulders have arrested the upstream progression of the headcut.

The existence of headcuts on Arroyo del Valle is not unexpected. Arroyo del Valle may still be adjusting to hydrologic changes and/or land-use changes within the watershed including: the operations of Del Valle Dam, urbanization, and gravel mining activities. Runoff from newly paved (impermeable) surfaces has been shown to increase stormwater flows, which contribute to stream degradation and channel incision (Booth 1990; Bledsoe and Watson, 2001) particularly in channels where the bed-material sizes were formed by more moderate non-urbanized peaks. Additionally, a March-2006 bridge inspection report by Caltrans noted that Arroyo del Valle, between Reach-A and Reach-B, had degraded (incised) 5.9-feet from 1983 to 1999 (Caltrans, 2006, in Liang, 2009). While the report noted the incision was due to in-stream gravel mining; Caltrans noted that since 1999 the channel had stabilized and they assumed the long-term channel bed incision to be negligible.

4.3 Aerial Photo Review

4.3.1 Reach-A

Balance acquired and reviewed thirteen (13) historical aerial photos of Arroyo del Valle and its surrounding area. The aerial photos were reviewed to evaluate the current channel geometry of Arroyo del Valle in Reach-A and Reach-B, with a focused review of the evolutionary processes that have occurred on Arroyo del Valle since mining activities began in Area-A. The review focused on lateral channel migration, meander and curvature patterns, the influence of vegetation on channel geomorphic processes, and how these influenced the channel evolutionary processes on Arroyo del Valle through Reach-A and Reach-B

July-1982, **Figure 9**. After 10 years of subdued flows following dam closure, peak flows of 2160 cfs and 1940 cfs were recorded in 1980 and 1982 respectively (**Figure 4**). These higher flow events had the capacity to act on the bed and banks of Arroyo del Valle and mobilize sediment. Arroyo del Valle enters Reach-A along the southeast border at Vallecitos Road and flows in a northwest direction through the first one-third of Reach-A. Multiple channels are present in this section with limited riparian vegetation, as might be expected following the largest storms since the dam was closed. These higher flows have the ability to scour away the riparian vegetation leaving fresh sediment deposits.

The arroyo then turns southwest and flows through a short section of thick vegetation and emerges into a section of multiple channels with limited riparian vegetation. The arroyo flows to the southern border along E. Vineyard Avenue and then turns and flows northwest before exiting Reach-A at the western end under Isabel Avenue. Multiple channels are present in this section with mid-channel bars and limited riparian vegetation. The riparian corridor is thinly vegetated and the channel exhibits areas of lateral scour with fresh sediment deposition in the western portion where it parallels E. Vineyard Avenue. No mining activity is present.

July – 1987, **Figure 10**. Despite some of highest peaks on record following closure of Del Valle Dam, flow patterns on Arroyo del Valle have changed little since 1982. The arroyo enters and exits in the same general locations and channel flow patterns appear similar. Channel width has narrowed and riparian vegetation has increased since 1982 with a single-thread flow pattern emerging. A section of multiple channels is present in the west end of Reach-A that are well vegetated and lack signs of channel migration. The system seems to be in a state of disequilibrium and responding to changes in the hydrologic and sediment regimes following the closure of Del Valle Dam. It is shifting from a sediment-rich, multi-channel, braided system, to a sediment starved, single-thread channel following the closure of Dell Valle Dam. The channel is no longer flowing over large, un-vegetated gravel bars (surficial scour), nor is it building new gravel bars. The channel does exhibit evidence of limited, lateral migration (scour) as it establishes its new, single-thread, dimension, pattern and profile (dynamic equilibrium). There appears to be some deposition of new (fine) sediment on outside meander bends where the channel has narrowed. This is most probably due to mobilization of fines from upstream sources (Sycamore Grove Park). No mining activity is present.

June – 1993, **Figure 11**. Flow patterns on Arroyo del Valle remain similar to those present in 1982 and 1987 with some meander migration in the western end. During these years, very little flow was measured at the gage, with peak flows ≤ 23 cfs in five of the six years, therefore little adjustment in channel pattern would be expected. However, the channel exhibits evidence of migration with channel braids with un-vegetated mid-channel bars present through the middle and western sections of Reach-A, along with evidence of fresh sediment deposition. This may be due to the peak flows of 1560 cfs in 1991(6^{th} highest since dam closure in 1968), and 1460 cfs in 1993 that mobilized sediment from upstream sources and deposited it in Reach-A. No mining activity is present.

1996, **Figure 12**. Mining activity has begun in the northwest section of the property and the flow pattern on Arroyo del Valle has been realigned to the south and straightened. Arroyo del Valle now flows southwest towards E. Vineyard Avenue after entering the property. The arroyo then turns northwest and parallels the southern boundary along E. Vineyard Avenue. Multiple peak flows exceeding 2000 cfs were recorded from 1995 through 1998 (**Figure 4**). Mid-channel bars are present along the southeast, middle and western sections, but they are small and narrow compared to previous years. The development of mid-channel bars suggests an increased sediment supply. This may be the result of 1) mobilization of unconsolidated sediment in Reach-A following channel disturbance associated with reconfiguration, and/or 2) mobilization of sediment from upstream by high flows. The riparian corridor has narrowed and meander belt width[6] and channel sinuosity have been reduced. The newly realigned channel lacks vegetation within the riparian corridor and the associated benefits riparian vegetation provides in terms of bank protection. Channel banks will be more susceptible to erosion until the riparian vegetation is established.

August – 1998, **Figure 13**. The mining area has expanded to the southeast. Channel flow pattern is similar to 1996 and exhibits areas with mid-channel bars and recent sediment deposition. The riparian corridor and meander belt width have narrowed.

September – 2002, **Figure 14**. The mining area has expanded further to the southeast and earlier mine areas are now filled with water. Channel flow pattern is similar to 1998. The riparian corridor is narrow and fully vegetated. Meander belt width is narrow, channel sinuosity is further reduced, and no lateral channel migration or surficial channel scour is evident. A section of channel around a mid-channel bar has been abandoned. No signs of new sediment deposition or lateral channel migration.

October – 2015, **Figure 15**. Mining activities in the area have ceased and the former mine area is full of water. Channel flow pattern is similar to 2002. The riparian corridor remains narrow with low sinuosity (k = 1.02), and is fully vegetated with no signs of channel migration, sediment deposition, and/or gravel bar development.

4.3.2 Reach-B

June – 1993, **Figure 16**. Arroyo del Valle enters Reach-B on the southeast from Reach-A and flows in a northwest direction through the property. A former mine site is present in

[6] Meander belt width is the distance between lines drawn tangential to the extreme limits of fully developed meanders.

the south-central portion of Reach-B and consists of three (3) small lakes filled with water. Channel morphology exhibits a braided pattern with multiple flow paths, mid-channel bars, and lateral channel migration. The riparian corridor is open with little vegetation. Meander belt width and channel sinuosity are relatively high. The downstream portion is well vegetated, possibly due to backwater effects from Island Pond and Lake Boris located immediately downstream of the project site to the northwest.

September – 2002, **Figure 16**. Flows on Arroyo del Valle have exceeded 2000 cfs on four consecutive years from 1995 – 1998. Active mining is occurring immediately to the north of Arroyo del Valle. Arroyo del Valle is a well-vegetated, multi-channel system with reduced channel migration and meander belt width. A splay deposit is visible in the largest lake and effectively splits the lake in half. When the splay occurred is unknown, but the presence of vegetation on the deposit indicates it is at least a year old. The origin of the splay deposit is unknown but may be related to channel disturbances on Arroyo del Valle in Reach-A during realignment associated with mining activities. Reach-A was realigned prior to the development of the splay deposit. The realignment of Arroyo del Valle to the south disturbed a substantial amount of material along Reach-A. This newly disturbed material would have been easily mobilized during bankfull events, especially since the channel pattern also shifted from a multi-channel, braided system to a single-thread channel. The single thread channel would concentrate flows that previously were dispersed through multiple channels across Reach-A. The concentrated flows may have mobilized the newly disturbed material and then deposited the material in Reach-B when the channel was breached. The splay enters the lake in an open section (breach) of a ridge (**Figure 17**) that runs parallel to Arroyo del Valle between the arroyo and the lake. The ridge is interpreted as a remnant terrace and is composed of coarse sand, gravel and cobble embedded in fine matrix which appears undisturbed (**Figure 18**). The elevation of the ridge top aligns well with the elevation of the stream terrace to the south. The ridge is also composed of consolidated materials with a side-wall angle of 49 degrees, which is well beyond the maximum 45-degree angle of repose for irregularly shaped gravels (Great Britain Ministry of Defense, 1976). The breach in the ridge was present in 1993 and Arroyo del Valle flowed into and out of the lake; but no sediment deposition was present in 1993. The splay deposit spans the lake, cutting it in half. Arroyo del Valle flows into the upper half of the lake, cuts through the splay, and exits the lake at the western end of the splay back into the arroyo.

September – 2008 and September - 2010, **Figure 19**. Channel and meander patterns remain similar to that in 2002. Riparian vegetation has increased adding to roughness along the riparian corridor both in and out of the active channel. As the vegetation matures it becomes more permanent. This combined with the lower peak flows on Arroyo del Valle have the effect of fixing the channel flow pattern. There is little evidence of new channel migration.

June – 2013 and October – 2015, **Figure 20**. Channel flow patterns and sinuosity in both photos mimic that seen in previous years. Riparian vegetation continues to increase and fix the channel flow pattern. There is no indication of active channel migration in either photo.

5. DISCUSSION

The results of the sediment analyses have documented the selective removal of the finer fraction of particles (winnowing) through the active reaches on Arroyo del Valle. Sediment data from the remnant sites indicate they are composed of a larger portion of fine sediment sizes (coarse sands) than active channel sites. This has resulted in a coarsening of the active channel through the removal of the fine sediment fraction.

The effects dams on reaches immediately downstream regarding sediment transport and sediment composition are well documented (Brandt, 2000; Williams and Wolman, 1984). Results from the sediment analysis of Reach-A and Reach-B indicate that the sediment composition in both reaches has been impacted due to the construction of Del Valle Dam. Particle size distributions indicate a winnowing[7] of the fine sediment fraction on the active channel sites (**Figure 5**). The removal of the fine sediment fraction is the result of hungry waters (Ligon and others, 1995; Brandt, 2000) released from Del Valle Dam and has resulted in a coarser channel with less fines. As noted in **Figure 5**, the active channel sites are coarser than the remnant channel site. The remnant channel site reflects pre-dam conditions with un-regulated flows. Prior to the construction of del Valle Dam, Arroyo del Valle was an ephemeral, multi-channel, braided system in the area of Reach-A and Reach-B (SFEI, 2013). Today Arroyo del Valle is a perennial, single thread channel with thick riparian vegetation that has aggressively encroached into the active channel (**Figure 21**). Perennial flows in Arroyo del Valle are controlled by Del Valle Dam and Zone 7 releases for deliveries to the South Bay Aqueduct. The operation of Del Valle Dam has the greatest impact on the present-day morphology in Arroyo del Valle.

Sediment data from Sycamore Grove Park also indicate a winnowing effect due to Del Valle Dam (Christner and others, 2015). Particle size distributions from four (4) sites in Sycamore Grove Park indicate all sites are coarser than the remnant channel site in Reach-A with D_{50} values ranging from 18.1 mm at ADV SGP-03, to 63.9 mm at SDV SGP-04 (**Table 2**). While these sites are closer to the canyon outlet on Arroyo del Valle, and are therefore expected to be coarser, they represent a 99 percent increase and 602 percent increase in size respectively over the remnant channel D_{50} of 9.1 mm.

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[7] Winnowing is the natural removal of fine material from a coarser sediment by wind or flowing water. Once a sediment has been deposited, subsequent changes in the speed or direction of wind or flowing water can agitate the sediment grains and allow the preferential removal of the finer grains. This action can increase the mean grain size of a sediment after it has been deposited (Compton, 1962).

Table 2. Particle-size distributions for pebble count data on Arroyo del Valle at four (4) sites in Sycamore Grove Park and sieved data from the remnant channel site on Reach-A.

Sediment Size Class	ADV SGP-01 (mm)	ADV SGP-02 (mm)	ADV SGP-03 (mm)	ADV SGP-04 (mm)	ADV Reach-A Remnant Channel (mm)
D_{16}	3.1	5.0	0.5	13.1	1.1
D_{35}	12.6	21.4	1.9	49.7	2.2
D_{50}	20.1	27.4	18.1	63.9	9.1
D_{84}	49.3	47.2	51.7	104.4	36.3
D_{95}	84.0	63.5	77.0	143.7	57.8

The splay deposit site is relatively close to the location of sample site ADV-01a, a remnant channel deposit on Reach-B we sampled during previous field work (**Figure 3**). Pebble count data from ADV-01a resulted in a D_{50} of 28.9 mm with a range of 11.7 mm to 65.8 mm in these sediment-size metrics (Christner and others, 2015). Sieve analysis of the splay deposit resulted in a D_{50} of 17.0 mm and a range of 1.4 mm up to 104.6 mm in the size metrics. Both ADV-01a and the splay deposit are coarser than the remnant channel site sampled in Reach-A. The splay deposit is interpreted as the re-working of materials initially deposited prior to construction of Del Valle Dam.

Sediment material in the splay deposit sample is highly variable in size, ranging from 1.4 mm (D_{16}) up to 104.6 mm (D_{95}). Only two (2) other sites have greater variability, the subsurface sample in Reach-A, and ADV SGP-04 sampled in Sycamore Grove Park. The coarse material in the splay deposit is interpreted as material transported from Reach-A following the channel realignment of Arroyo del Valle to the south. The splay deposit does not develop until after the realignment of Reach-A (**Figure 11** and **Figure 12**). Channel realignment activities would have required a new channel to be cut through existing sediment that was deposited prior to the construction of Del Valle Dam. This would have resulted in an area of highly disturbed and unconsolidated material with a high degree of variability. Additionally, the realigned channel would have little to no riparian vegetation to protect against erosion, and the channel material would be readily/easily mobilized.

Additionally, the new cut channel reduced channel length 916 feet through Reach-A, from 7,072 feet to 6,156 feet and channel sinuosity from 1.17 to 1.02. The reduction in channel length increased channel slope through Reach-A resulting in higher stream power. The combination of freshly disturbed, unconsolidated sediment, with increased slope and stream power created the ideal conditions to mobilize sediment.

Site ADV-01a was originally thought to be a remnant channel deposit of Arroyo del Valle developed prior to the construction of Del Valle Dam. However, the lack of fines at ADV-01a, coupled with its position on the active floodplain, suggests the site may be post-dam deposit reworked by Arroyo del Valle *after* the construction of Del Valle Dam.

The remnant ridge deposit was not sampled, but visual observations indicate the deposit is consolidated. The clasts consist of coarse sands, gravels, cobbles and small boulders, held together by a consolidated and apparently in-situ matrix of fine sand, silt, and clay (**Figure 18**). The deposit is interpreted as a terrace on Arroyo del Valle deposited prior to construction of Del Valle Dam and not a man-made berm. The elevation of the ridge top aligns well with the stream terrace to the south, and the 49-degree side-slope angle is greater than the angle of repose for mixed gravels (Azam and others, 2009). Furthermore. a man-made deposit would lack consolidation. While no samples were collected at the ridge site, the presence of an abundant amount of sands in the deposit suggest the composition of the ridge reflects the composition observed at the remnant site in Reach-A.

5.1.1 Braided to Single Tread

Aerial photo review documents the change in channel form on Arroyo del Valle over the past thirty-four (34) years, from a sinuous, multi-thread, braided channel network that actively meanders and erodes its channel banks; to a single thread channel, with low sinuosity, and thick riparian vegetation.

Arroyo del Valle was a multi-channel, braided system prior to the construction of Del Valle Dam (SFEI, 2013). The construction and closure of Del Valle Dam dramatically altered the hydrologic regime and reduced sediment loads in Arroyo del Valle downstream of the dam (see also, Kamman, 2009). Braided systems require an abundant supply of sediment and a highly variable discharge (Ashmore, 1991; Gran and Paola, 2001). While neither of these conditions exist today on Arroyo del Valle, remnant artifacts of the former braided system are present in Sycamore Grove Park, and portions of Reach A and B. The remnant channels may become hydrologically active during times of high runoff volumes, but the abundant sediment supply and transport processes required for a braided system to form are absent. Williams and Wolman (1984) documented the downstream changes in streams at twenty-one (21) sites across the United States. Their work illustrates how braided channel systems evolved into single thread channels with increased riparian vegetation following dam construction.

Aerial photos indicate that except for anthropogenic alterations, the meander pattern and flow path of Arroyo del Valle have changed very little since the construction of Del Valle Dam which has reduced both the frequency and magnitude of flood flows on Arroyo del Valle. Prior to the construction of Del Valle Dam, Arroyo del Valle had the capacity to transport large volumes of sediment ranging in size from silt/sand size particles (0.05 – 2.0 mm) up to very large cobbles[8] (256 mm) and small boulders. This capacity resulted in a dynamic, braided channel pattern that was constantly adjusting to these geomorphic events. The closure of Del Valle Dam changed the hydrology of the system, reducing the magnitude and frequency of flood flows, and the sediment load. Present-day flows on Arroyo del Valle have a reduced competence[9] and capacity to transport sediment, especially for the largest-size particles deposited during pre-dam conditions.

The operation of Del Valle Dam also changed the timing of flows on Arroyo del Valle, allowing for development of a wooded geomorphic floodplain and riparian corridor. Prior to the completion of Del Valle Dam, Arroyo del Valle was an ephemeral system with little to no flow during summer months (SFEI, 2013). Today, operations of Del Valle Dam result in year-round flow. This perennial flow pattern has altered the vegetative community of the riparian corridor and assisted the establishment and propagation of riparian vegetation compared to pre-dam conditions. The reduced geomorphic events combined with perennial flows on Arroyo del Valle have allowed the riparian vegetation to encroach within the active channel and effectively lock-in the meander pattern on Arroyo del Valle through three (3) processes. First, riparian vegetation provides protection to the channel banks against erosive forces. Second, as the vegetation encroaches into the active channel it reduces in-stream velocities by increasing channel roughness. And third, increased riparian vegetation results in additional water losses via evapotranspiration (Williams and Scott, 2009; Naglera, 2005). Combined, these have effectively reduced the arroyo's stream power, resulting in a channel with decreased in-stream velocities which limits the arroyo's sediment transport

[8] Size estimates based on particle size distributions of remnant channel site in Reach-A.

[9] Capacity is a measure of a stream's ability to transport volumes of sediment; competence is a measure of the largest sizes that the stream can transport.

capacity and ability to erode its channel banks and/or bed, two conditions necessary to sustaining a braided system (Ashmore, 1991; Gran and Paola, 2001).

Braided systems require abundant bedload, a lack of capacity to transport the entire sediment load, a lack of competence to transport all sediment sizes, erodible channel banks, and a highly variable discharge (Ashmore,1991, Gran and Paola, 2001). Braided channel patterns develop when geomorphic processes shift from a system dominated by sediment transport to a system dominated by sediment deposition. This is how the historic braided channel pattern on Arroyo del Valle formed prior to the construction of Del Valle Dam. As Arroyo del Valle exited the confines of the canyon the channel was no longer confined, and flowed freely across the broad Livermore Valley forming a network of braided channels. These geomorphic conditions no longer exist on Arroyo del Valle due to the presence of Del Valle Dam. Today Arroyo del Valle flows in a single-thread channel that is a combination of the remnant braided system (Sycamore Grove Park), and man-made channels (Reach-A). The change in geomorphic processes on Arroyo del Valle due to the closure of Del Valle Dam, requires a corresponding change in the channel forming processes. Understanding the change in geomorphic processes is vital to developing a sound and robust channel design for restoration of Reach-B on Arroyo del Valle.

Bankfull discharge is universally recognized as a key geomorphic flow in channels (Leopold and Wolman, 1957, Leopold, Wolman and Miller, 1964, Dunne and Leopold, 1978, Williams, 1978, Emmett and Wolman, 2001); as such, it forms the basis for developing a sound and robust channel design for stream restoration. The volume associated with bankfull flows varies with watershed conditions and watershed size. All things being equal, larger watersheds produce larger bankfull discharges than smaller watersheds. The closure of Del Valle Dam reduced the effective watershed size on Arroyo del Valle to approximately 17 sq.-mi. The smaller watershed is the primary source of flow for the bankfull discharge in Arroyo del Valle below Del Valle Dam. Flow releases from Del Valle Dam are not thought to contribute significantly to bankfull flows in Arroyo del Valle due to the dam's capacity. Del Valle Dam has a capacity of 77,100 acre-feet (AF), with an average storage of 25,000 to 40,000 AF (Zone 7, 2017). The average annual volume on Arroyo del Valle is 20,500 AF, which is 1.8x more than the maximum 40,000 AF storage. Therefore, little to no contributions are expected from Del Valle Dam to bankfull flows, and all channel design metrics should be based on the smaller 17 sq.-mi. watershed below Del Valle Dam.

6. CONCLUSIONS AND SUGGESTIONS FOR DESIGN

Results from the sediment and aerial photo analyses suggest the restoration design for Arroyo del Valle on Reach-B in the CEMEX facility would be best served by a single-thread channel design that incorporates elements which both promote stability and increase channel complexity, while also providing fish passage. Stream channel complexity generally refers to the heterogeneity of stream geometry or habitat (Livers and Wohl, 2016), and plays a critical role in maintaining stream ecosystem structure and function (Laub et al., 2012). Furthermore, research has shown that the lack of channel complexity can lead to reduced habitat diversity and lower fish and macroinvertebrate populations (Muotka and Syrja¨nen, 2007, Jungwirth, Moog, and Muhar, 1993).

The restoration channel design for Reach-B on Arroyo del Valle may benefit from, but is not limited to, the inclusion of the following elements:

- a dedicated overflow channel on the floodplain,
- on-channel and off-channel wetlands, and
- vegetated mid-channel bars.

A dedicated overflow channel provides relief for the more frequent (low return interval) flood events. This allows flood flows to spread out across the floodplain, lowering the erosive velocity of the flood flow.

On-channel and off-channel wetlands provide passage habitat for aquatic species and also help attenuate flows from the more frequent flood events.

Vegetated mid-channel bars provide a sediment buffer for the channel. The mid-channel bar will be a sediment source during times of low sediment supply, while also providing sediment storage during times of excessive sediment inputs. This will enhance channel stability in the highly regulated system.

Del Valle Dam has altered the hydrology and sediment transport characteristics on Arroyo del Valle. Peak flows and sediment loads downstream of the dam have been dramatically reduced. Combined, this has resulted in a channel that has a diminished ability to mobilize sediment associated with geomorphic channel-forming processes. The channel’s ability to mobilize and transport sediment is directly related to the particle-size distribution of the material to be utilized for channel construction.

The composition of substrate material that the re-aligned channel will be constructed from is of critical consideration for channel design in terms of channel erosion and long-term channel stability. Existing spoil material in the area of the proposed realignment is representative of soil conditions that may be part of the substrate under the realigned channel (Balance and EMKO, 2016). The realigned channel segment will require cut, fill, and compaction of the spoil soil material that are currently present in the areas sampled. Matching the hydraulic properties of the spoil material to the hydraulic properties of the realigned channel is critical to the development of a stable channel design. Therefore, careful consideration should be given to the composition of the restoration material so that the threshold grain size of the restored channel would not result in excessive erosion and/or channel degradation.

A review of the proposed channel design for Reach-B on Arroyo del Valle shows a compound channel design that incorporates a smaller low-flow channel inside a larger bankfull channel (Foged, 2016). Analysis of the bankfull channel hydraulics[10] at the bankfull discharge of 216 cfs, indicates a mean velocity of 3.86 fps with a shear stress of 0.50 lbs/ft^2 on the channel bed and banks. The 0.50 lbs/ft^2 shear stress results in a threshold grain size[11] of 31 mm. This is equivalent to a coarse gravel and indicates that sediment particles ≤ 31 mm may be mobilized during the bankfull discharge of 216 cfs depending upon channel conditions. Since several factors influence sediment mobilization including particle orientation, sediment matrix, hiding effects of larger particles, and the presence of vegetation; the actual threshold grain size is anticipated to be smaller.

A review of the bankfull channel hydraulics at the active channel sites surveyed on Arroyo del Valle in Sycamore Grove Park indicate the estimated threshold grain size of the proposed channel design[12] is similar to threshold grain size values at other active

[10] Cross-sectional area = 56 sq ft, channel width = 36 ft, channel slope = 0.0053, Manning's roughness = 0.037.

[11] Threshold grain size is the size of the particle at the incipient of motion at the specified discharge. It is predicted from the Shields curve which is a plot of the critical shear stress required to initiate movement of grains. The threshold grain size estimate does not account for any stabilizing influence of bed forms, "hiding" effects of larger particles, submerged logs, and/or riparian vegetation. Because only a fraction of the threshold grain-size particles may be mobilized during a bankfull event, this estimate is considered conservative.

[12] Threshold grain size estimates based on a design discharge of 216 cfs and Manning's n of 0.037-0.038.

channel sites (**Table 3**). The average threshold grain size of the four active channel sites at a discharge of 216 cfs is 31 mm with an average size class of D_{47}.

Table 3. Predicted threshold grain sizes and their associated size class at a discharge of 216 cfs for surveyed cross-sections from active sites on Arroyo del Valle in Sycamore Grove Park.

Site	ADV SGP-01	ADV SGP-02	ADVSGP-03	ADVSGP-04
Threshold Grain Size (mm)	35	33	27	28
Sediment Size Class	D_{64}	D_{35}	D_{65}	D_{23}

Source materials for the construction of the realigned channel through Reach-B may be derived from one of two sources; native, un-mined materials, or spoil materials. Currently two gravel harvesting approaches (options) are under consideration. Option one is to mine the area in Reach-B and use the spoil material to construct the channel. Option two is to mine up to the location of the proposed restoration corridor in Reach-B but not in the actual restoration corridor, and construct the channel from native, un-mined material. The material used for channel reconstruction (native or spoil) should take into account the potential in-channel shear stresses and threshold grain size at the bankfull discharge. The analysis indicates the bankfull discharge is capable of mobilizing material ≤ 31mm. This corresponds to the D_{83} in the remnant deposit and the D_{65} in the splay deposit (**Figure 22**). The higher value in the remnant deposit reflects the larger composition of fine sediment compared to the active channel values in Reach-A and Reach-B.

While no sediment analysis was performed on spoil material, it is reasonable to assume the particle-size distribution for spoil material would be finer than native soil material due to mining activities that selectively remove coarser material. Finer sediments, such as spoil material, would be expected to have a higher percentage of material ≤ 31 mm, and therefore a higher percent available for mobilization at the bankfull discharge.

Sediment mobility plays an important role in the stability of the reconstructed channel on Reach-B of Arroyo del Valle. Natural sediment transport processes on Arroyo del Valle have been severely modified due to the effects of Del Valle Dam on the hydrology and sediment loads in Arroyo del Valle.

Results from the sediment analysis indicate a winnowing of the fine fraction of sediment in the active reaches sampled on Arroyo del Valle. This suggests that while Reaches A and B on Arroyo del Valle have the capability to mobilize and transport a range of sediment sizes, the managed hydrology due to operations of Del Valle Dam limits sediment transport to the fine sediment fraction. Materials selected for the channel reconstruction of Reach-B on Arroyo del Valle should have the appropriate range of particle sizes to accommodate the desired bed mobility without inducing adverse effects on channel stability. Therefore, it is recommended that channel materials used for the restoration of Reach-B on Arroyo del Valle would be best served using native channel materials due to their higher concentration of coarse material.

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FIGURES

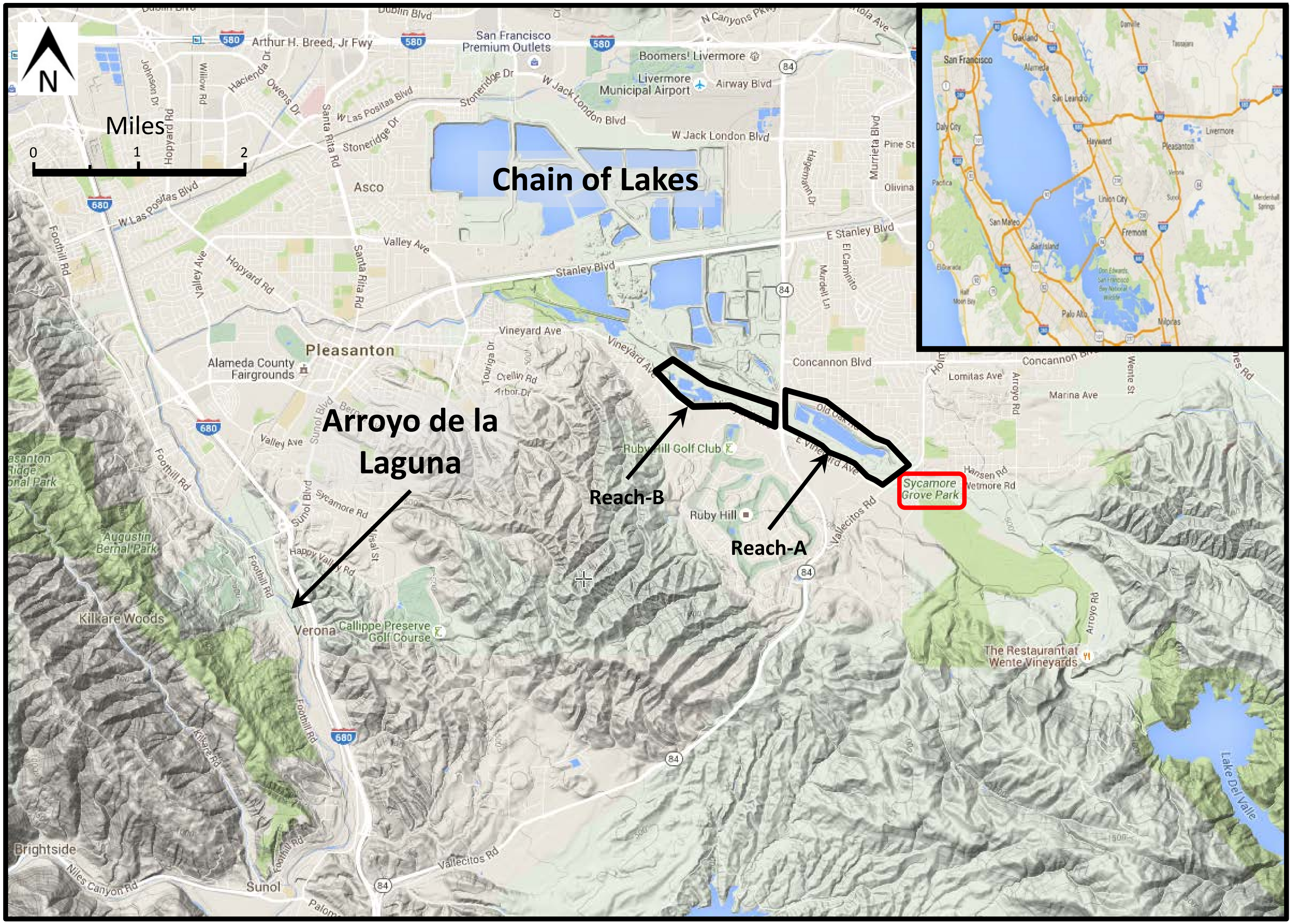

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Figure 1. **Location of Reach-B and Reach-A on Arroyo del Valle, CEMEX Eliot Facility, Pleasanton, California.**

215101 Sediment_Memo_Lndscp-Figs.pptx

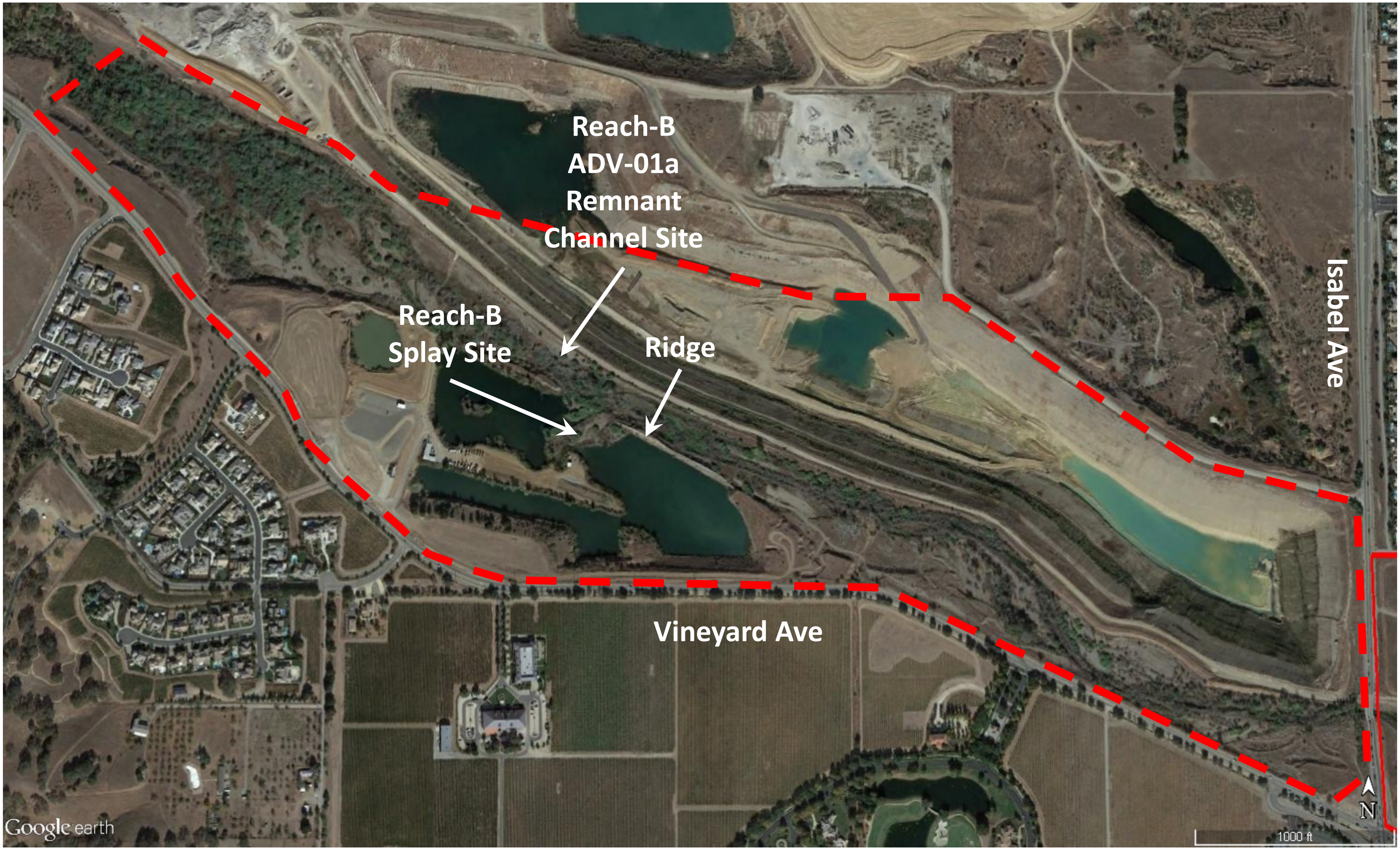
Source: ACME Maps

Balance Hydrologics, Inc.

215101 Sediment_Memo_Lndscp-Figs.pptx

Figure 2. **Reach-A on Arroyo del Valle (dashed red line), CEMEX Eliot Facility, Pleasanton, California indicating the location of bulk sediment sampling sites on the remnant channel and active channel (Sites 1-2-3) of Arroyo del Valle, CEMEX Eliot Facility, Pleasanton, California.**

Source: Google Earth, Oct-2015



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215101 Sediment_Memo_Lndscp-Figs.pptx

Figure 3. **Reach-B on Arroyo del Valle (dashed red line) indicating the location the bulk sediment sample collected from the splay deposit, the erosional ridge deposit, and the remnant channel site on Reach-B, CEMEX Eliot Facility, Pleasanton, California.**

Source: Google Earth

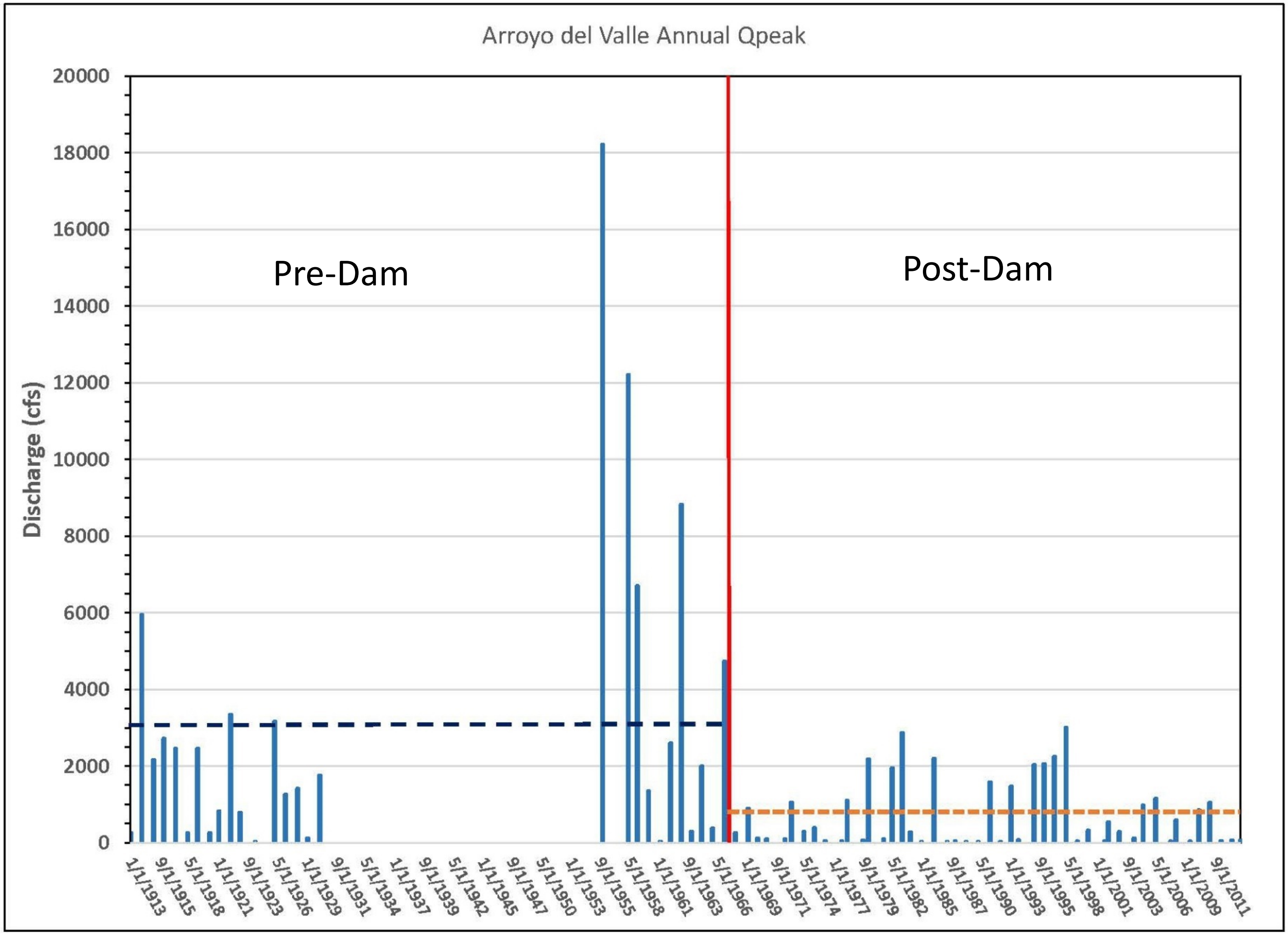

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Figure 4. **Annual peak discharge for Arroyo del Valle as measured at USGS gage #11176500, Livermore, California. Red line represents the closure of Del Valle Dam in 1968. Blue dashed line is the mean peak discharge pre-dam (3,075 cfs). Brown dashed line is the mean peak discharge post-dam (685 cfs).**

215101 Sediment_Memo_Lndscp-Figs.pptx

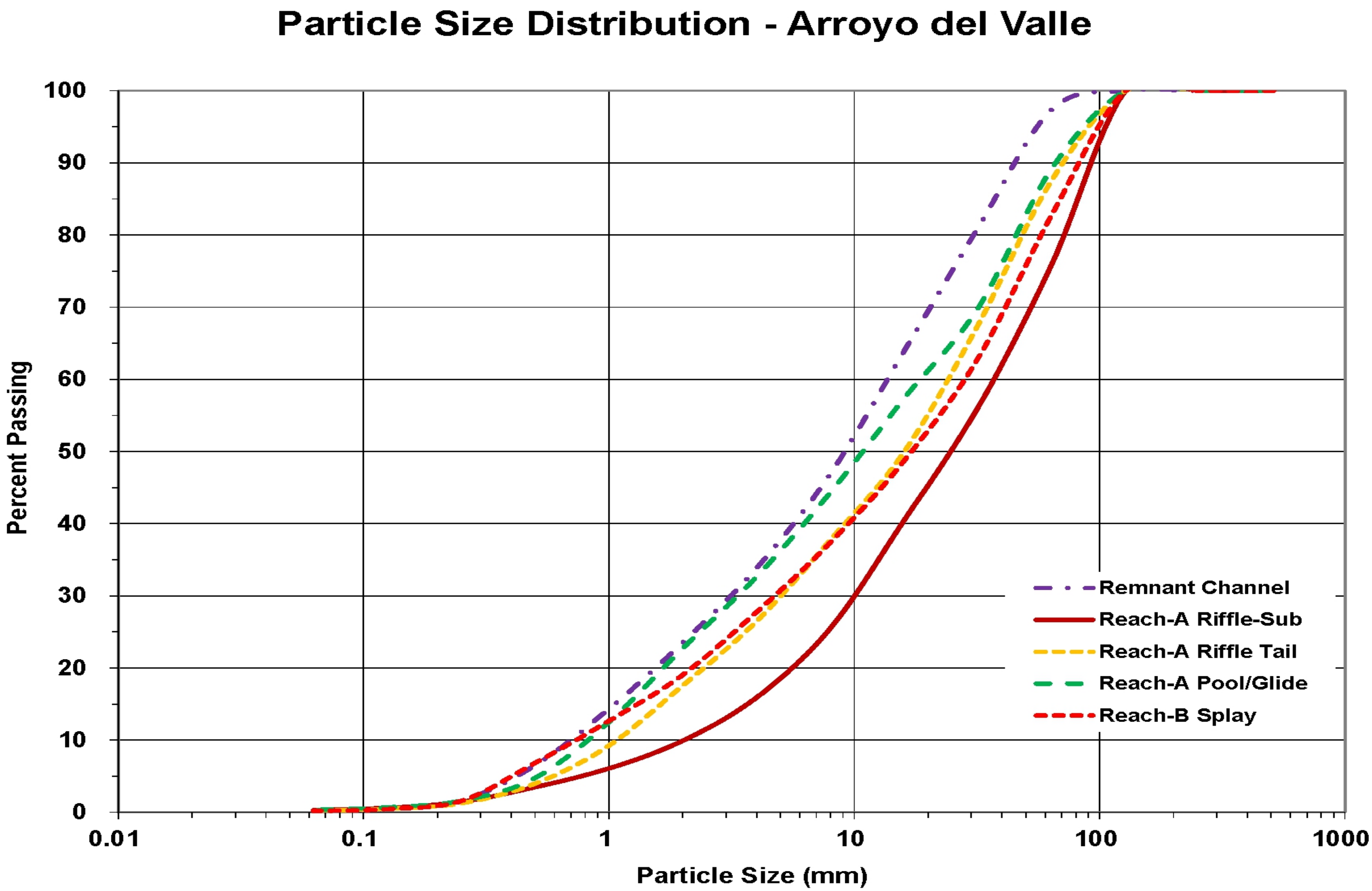

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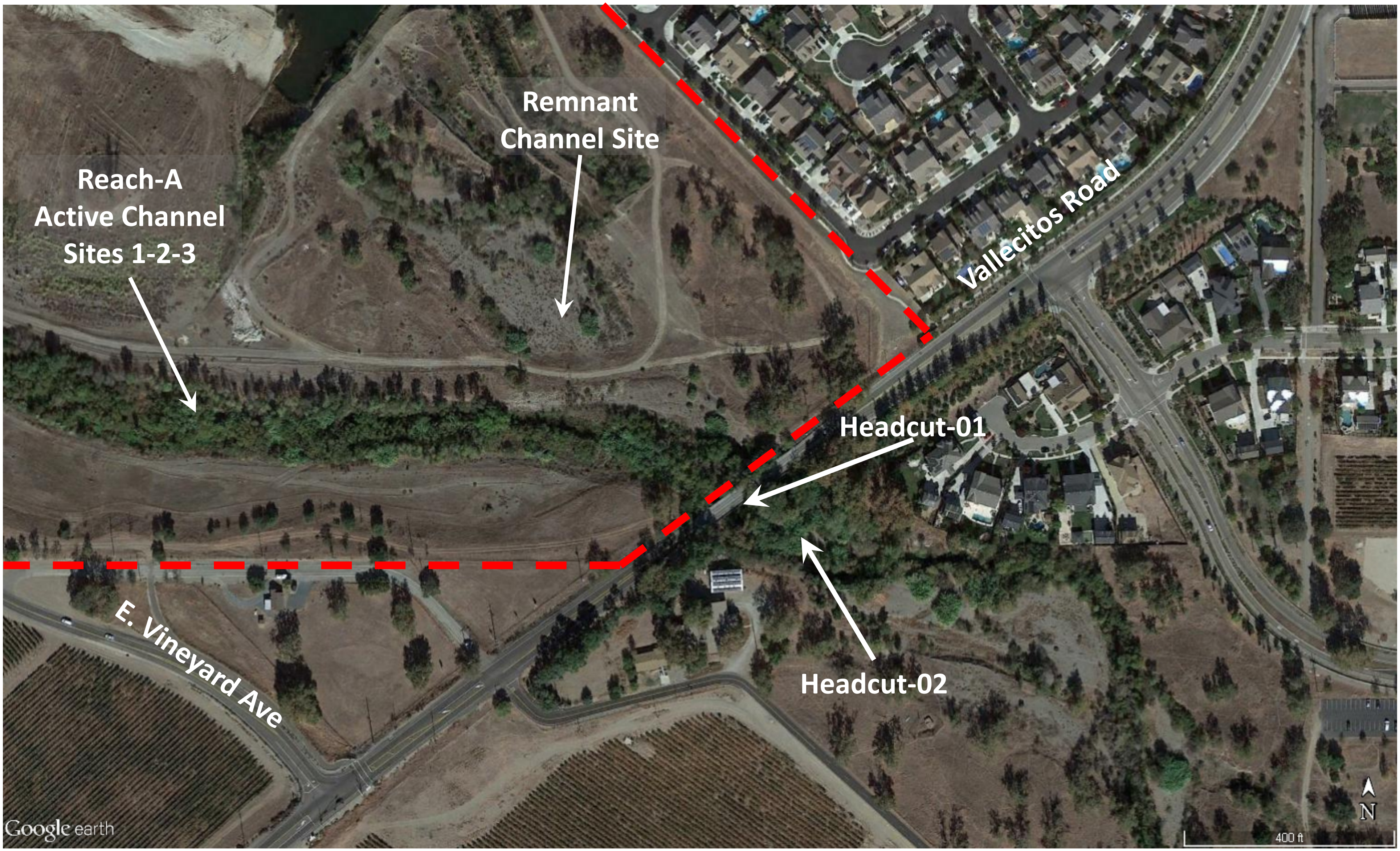
Figure 5. **Particle size distribution for five (5) bulk sediment samples on Arroyo del Valle, CEMEX Eliot Facility, Pleasanton, California.**

215101 Sediment_Memo_Lndscp-Figs.pptx



Balance Hydrologics, Inc.

215101 Sediment_Memo_Lndscp-Figs.pptx

Figure 6. **Location of two (2) headcuts on Arroyo del Valle in relation to the active and remnant sediment sample sites in Reach-A (dashed yellow line). Headcuts are immediately east of the Vallectios Road bridge, and west of Sycamore Grove Park, Pleasanton, California.**

Source: Google Earth

Balance Hydrologics, Inc.

Figure 7. **Photo of Headcut-01 on a road drainage associated with the Vallecitos Road bridge, that is tributary to Arroyo del Valle. Dashed red line indicates height of headcut, Arroyo del Valle, Pleasanton, California.**

Balance Hydrologics, Inc.

Figure 8. **Photo of Headcut-02 on Arroyo del Valle just upstream of Headcut-01. Dashed red line indicates height of headcut. Pleasanton, California,**

215101 Sediment_Memo_Lndscp-Figs.pptx

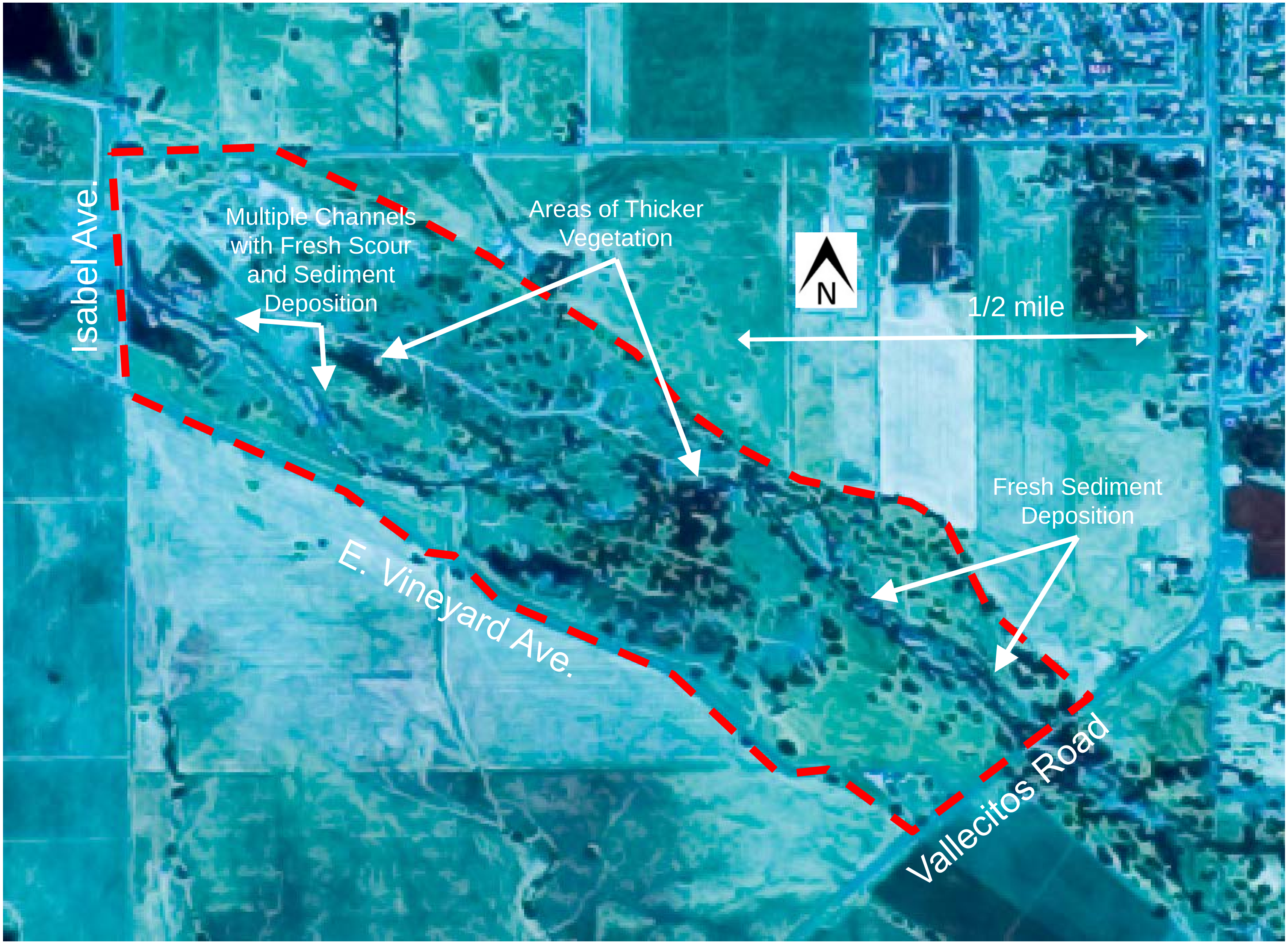


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Figure 9. Reach-A, Arroyo Del Valle (dashed red line), July 1982. Arroyo del Valle is a braided system with multiple channels, active sediment deposition, lateral channel migration, and surficial scouring.

Source: NAHP image, USGS Earth Explorer

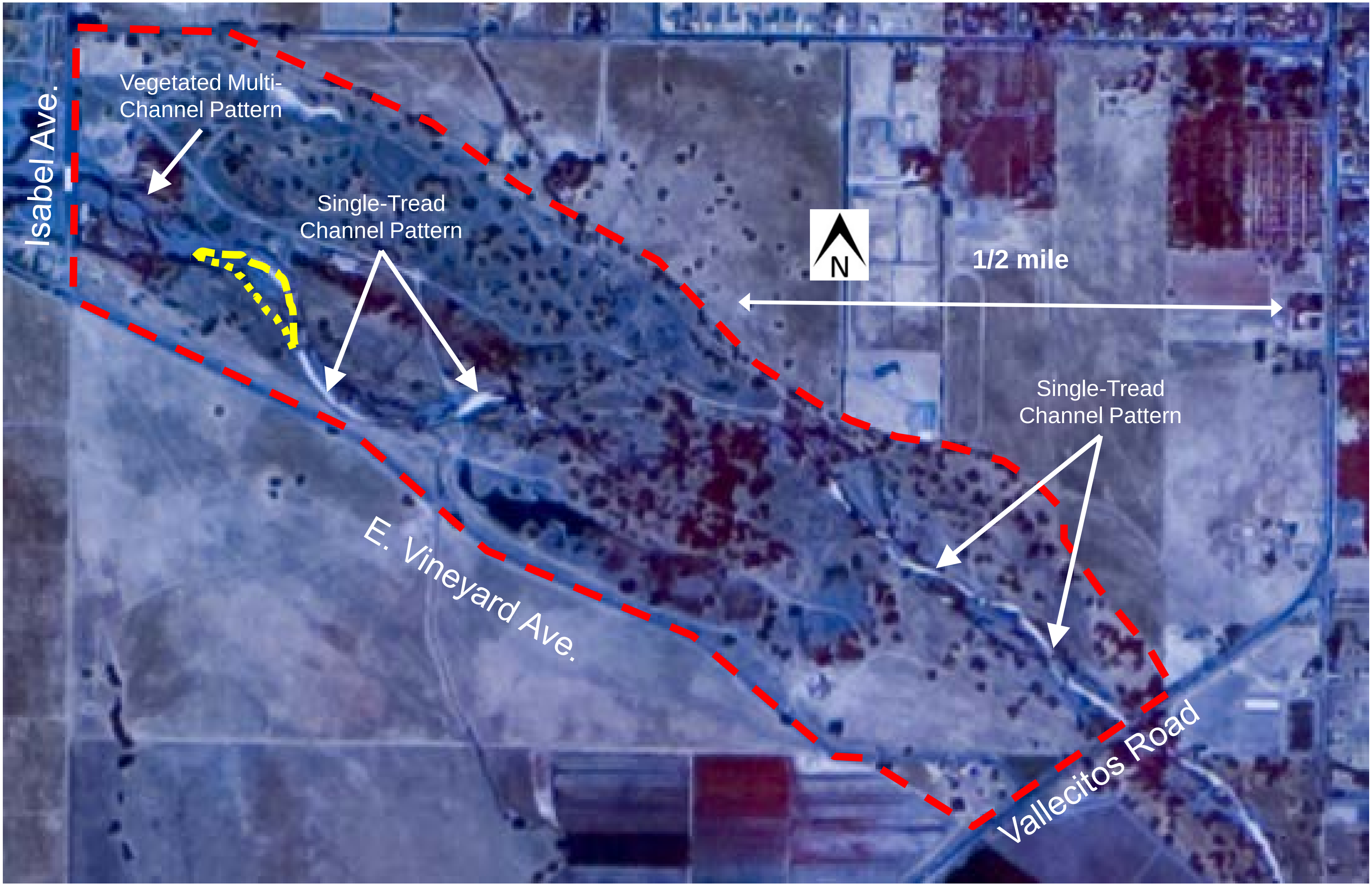

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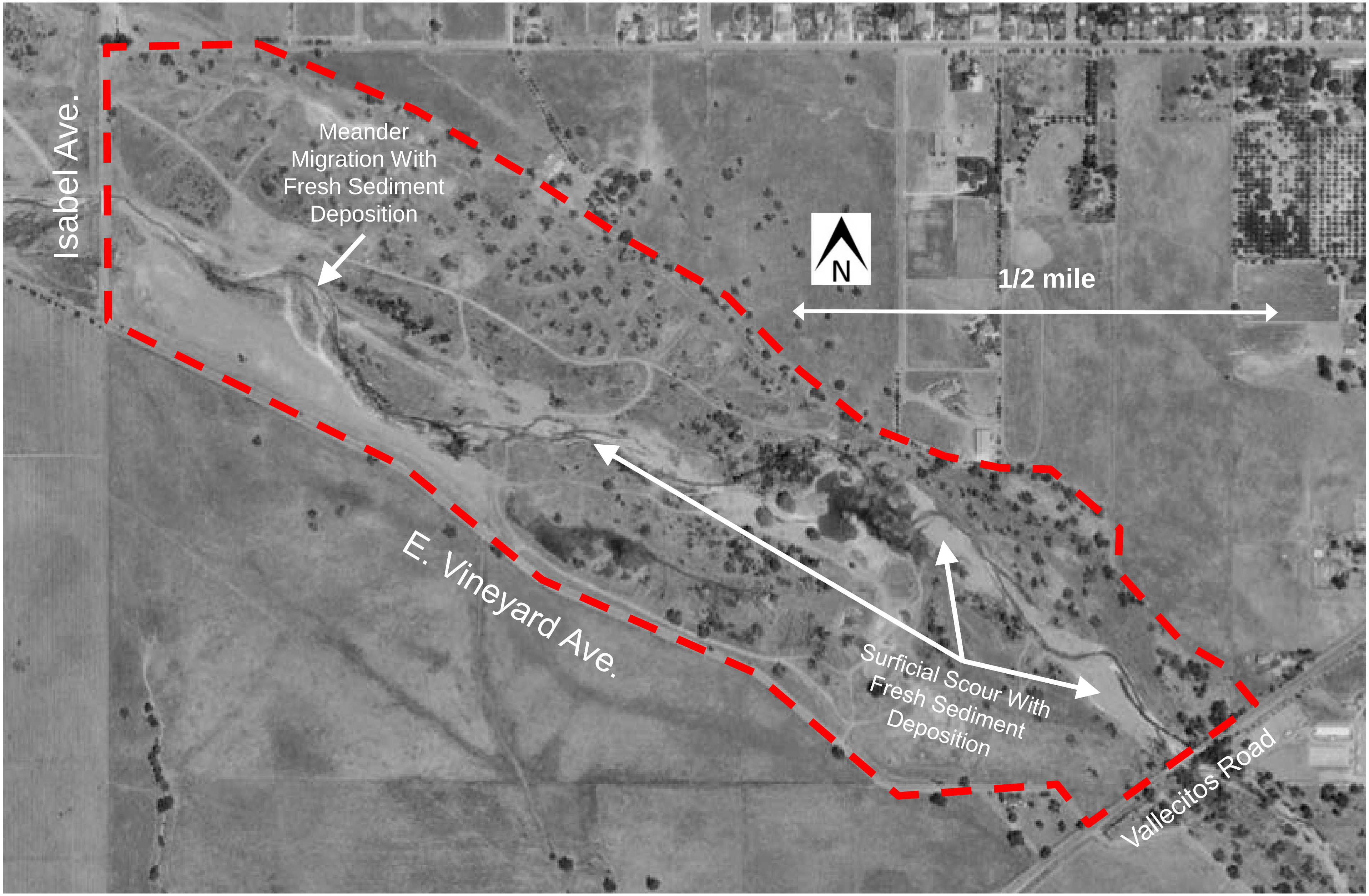
Figure 10. **Reach-A, Arroyo Del Valle (dashed red line), July 1987. Arroyo del Valle is free-flowing with multiple channels and un-vegetated channel bars. A single-thread channel pattern is emerging as indicated by the light grey color of the channel. There is little evidence of channel bar growth or migration with the exception of increased channel length from 1982 (dotted yellow line) to 1987 (dashed yellow line).**

Source: NAPP image, USGS Earth Explorer



Balance Hydrologics, Inc.

Figure 11. **Reach-A, Arroyo Del Valle (dashed red line), June 11, 1993. Arroyo del Valle exhibits multiple channels with meander migration, surficial channel scour, and fresh sediment deposition.**

215101 Aerial images.pptx

Source: NAPP image, USGS Earth Explorer

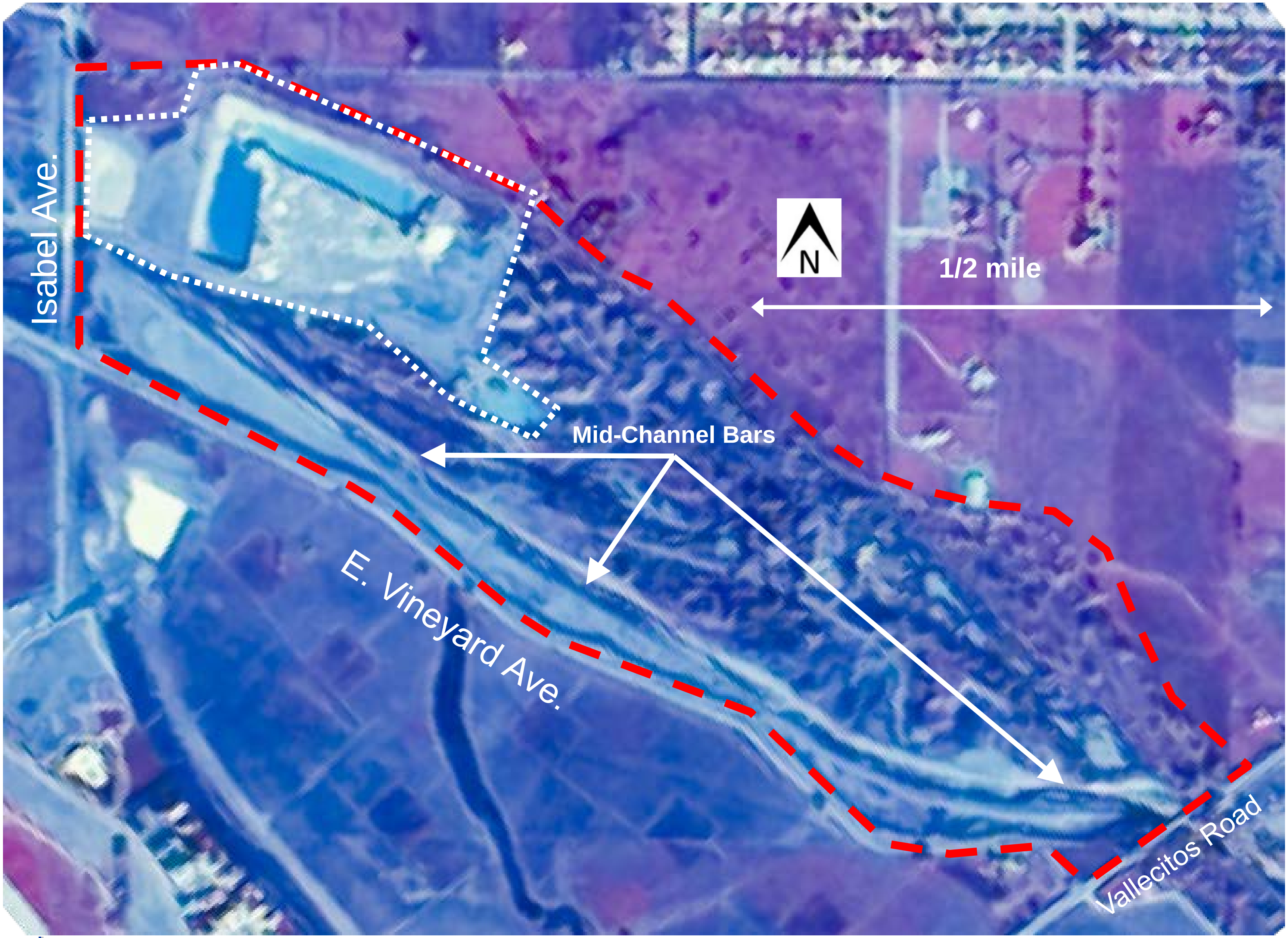


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Figure 12. **Reach-A, Arroyo Del Valle (dashed red line), 1996. White dotted line is the active mine boundary. Arroyo del Valle has been realigned to the south and flows parallel to E. Vineyard Ave. Channel sinuosity and complexity have been reduced due to realignment to the south. Mid-channel bars have developed which may be the result of channel disturbance due to realignment, or mobilization of upstream sediments.**

Source: Aerial photo single frame, USGS Earth Explorer

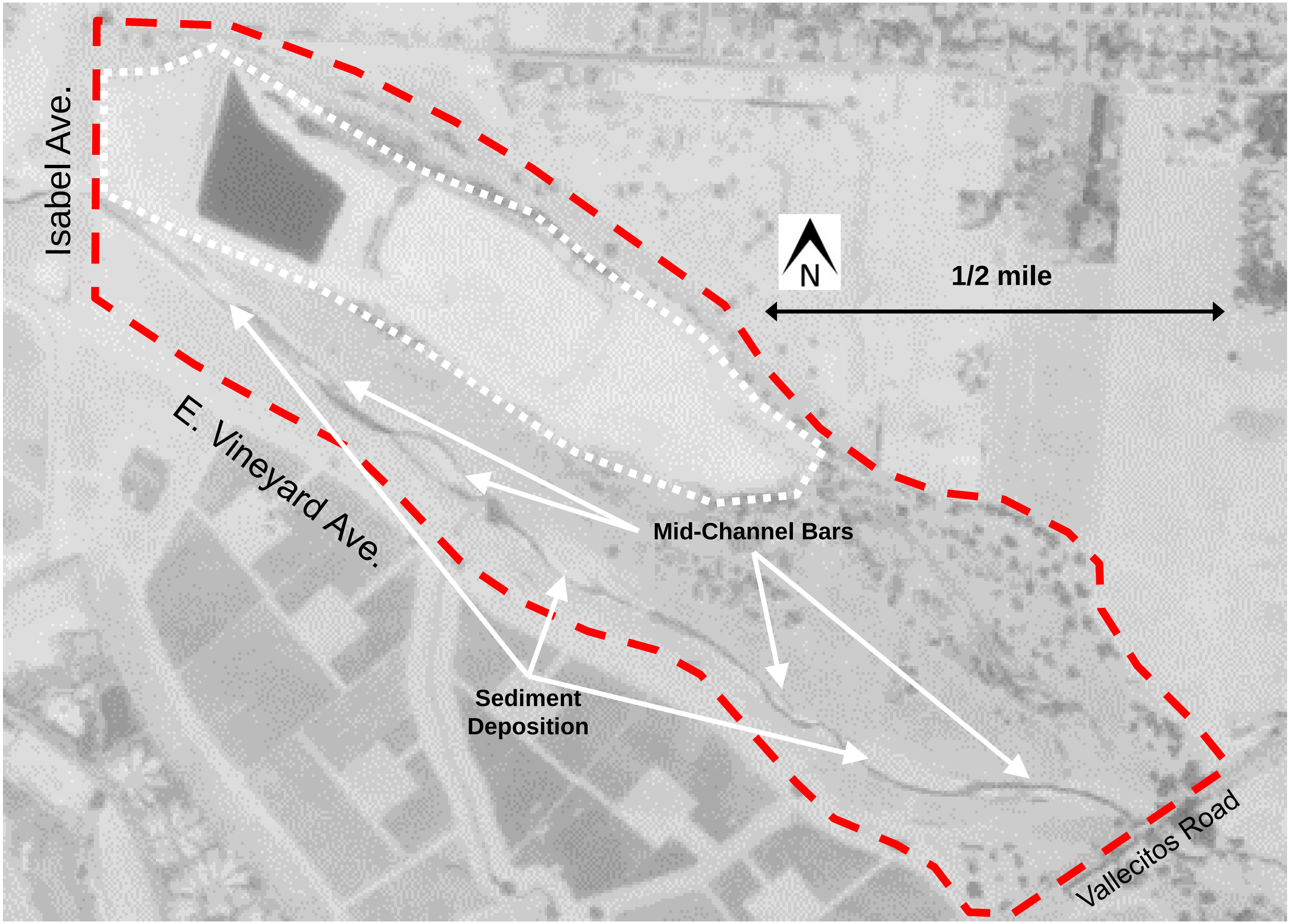

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Figure 13. **Reach-A, Arroyo Del Valle (dashed red line) , August 1998. White dotted line delineates the active mine site. Arroyo del Valle is predominately a single thread channel through Reach-A. The mining area has expanded to the southeast. Channel flow pattern is similar to 1996 and exhibits areas with mid-channel bars and recent sediment deposition. The riparian corridor and meander belt width have narrowed.**

Source: Aerial photo single frame, USGS Earth Explorer

Balance Hydrologics, Inc.

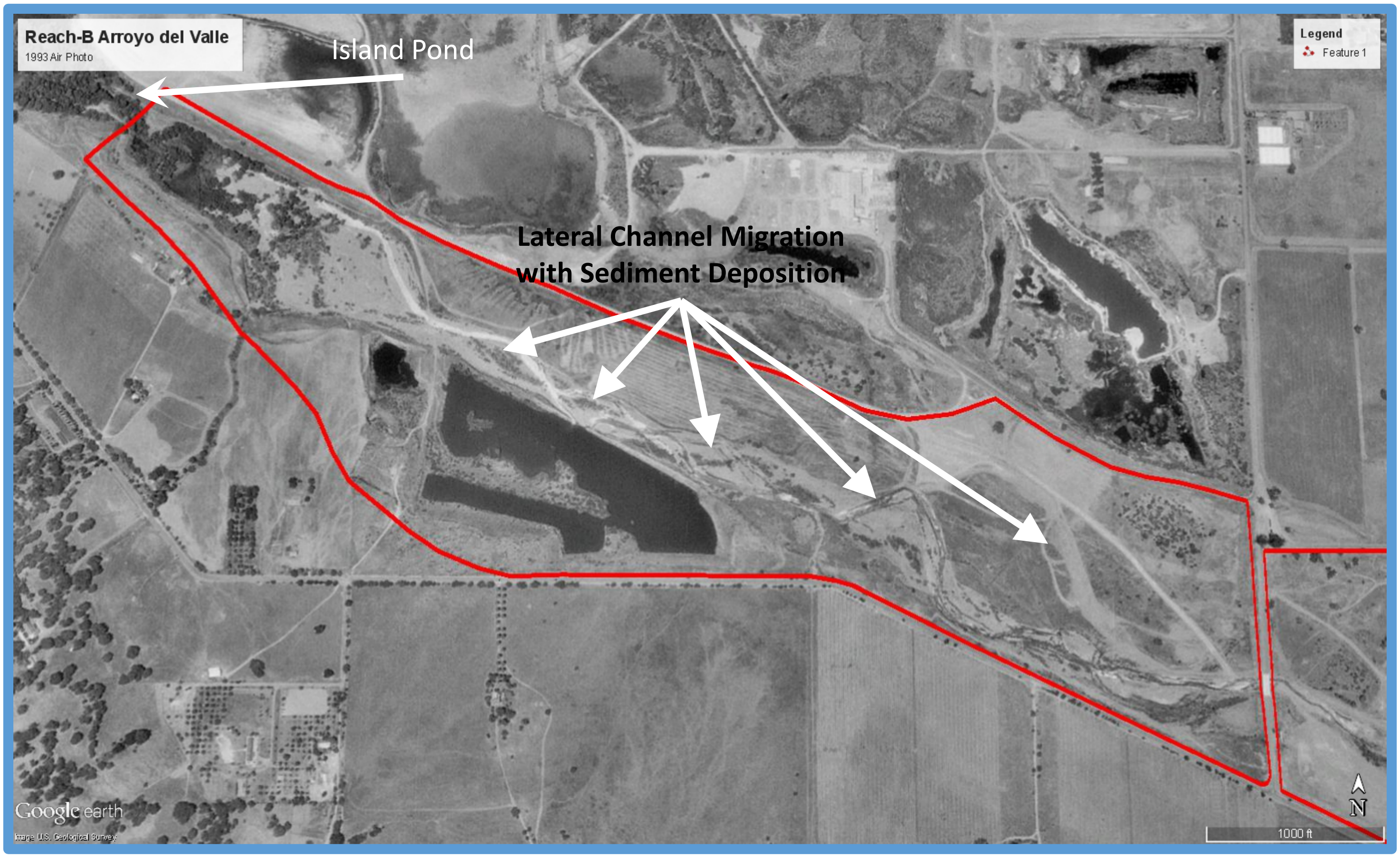
Figure 14. **Reach-A, Arroyo Del Valle (dashed red line), September 2002. White dotted line delineates the active mine site. Meander belt width has decreased since 1998 as has channel sinuosity. A section of channel around a mid-channel bar has been abandoned, The riparian corridor on Arroyo del Valle has narrowed more and is fully vegetated. No signs of new sediment deposition or lateral channel migration.**

Source: Google Earth

Balance Hydrologics, Inc.

Figure 15. **Reach-A on Arroyo del Valle (dashed red line), October 2015. White dotted line delineates the mine site. Riparian corridor on Arroyo del Valle is fully vegetated with no signs of channel migration, sediment deposition, and/or gravel bar development. CEMEX Eliot Facility, Pleasanton, California.**

Source: Google Earth



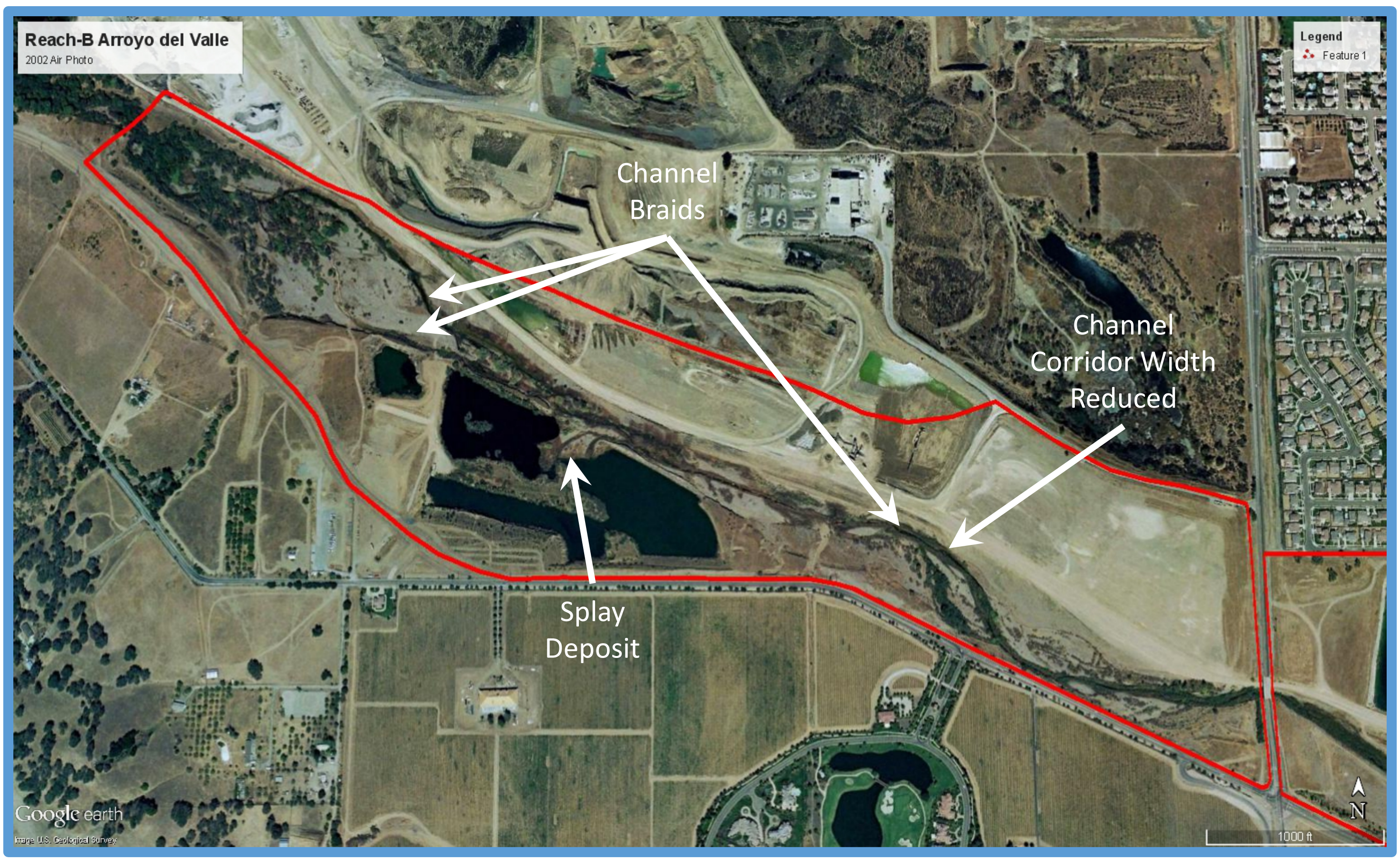


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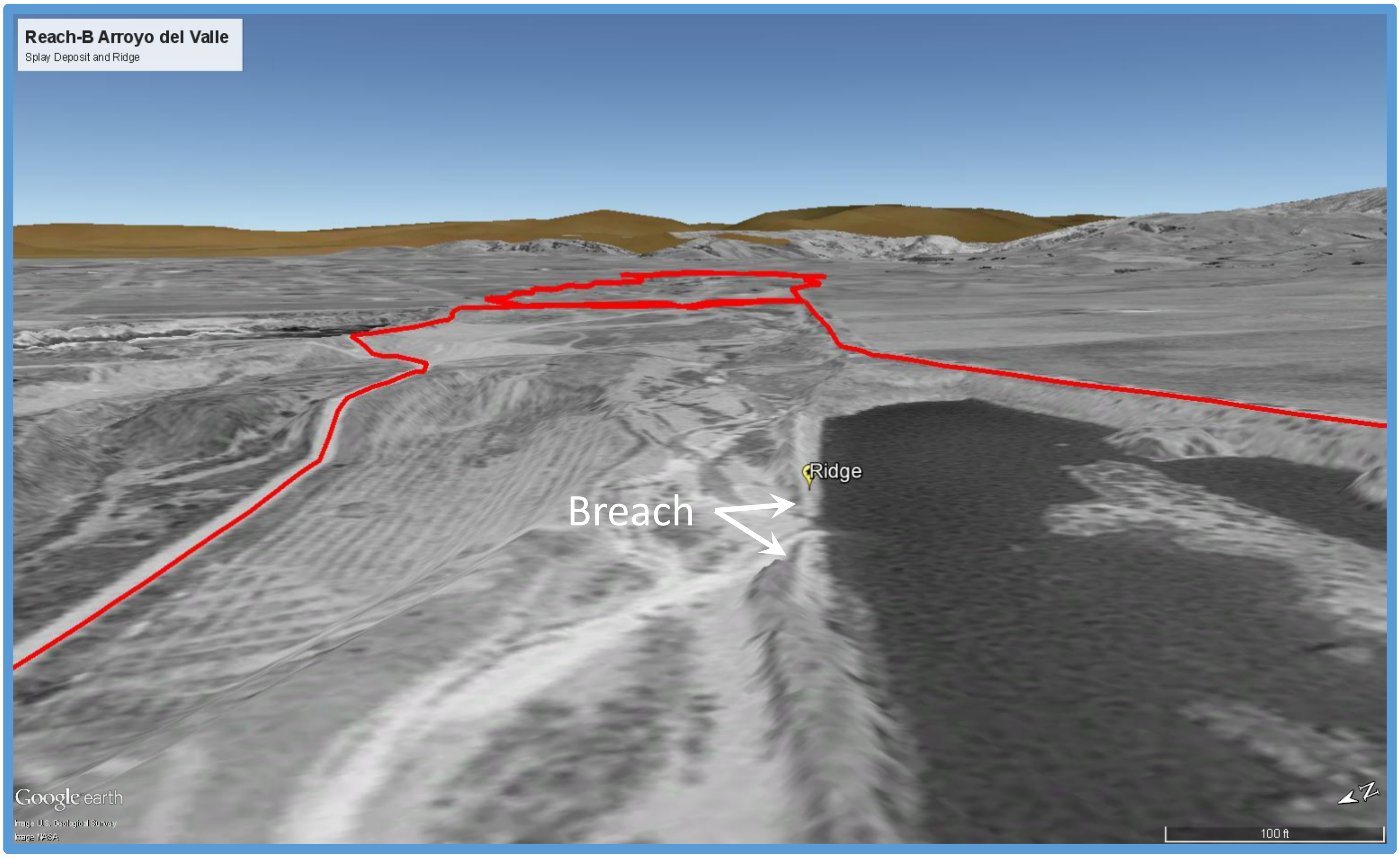
Figure 16. **Reach-B on Arroyo del Valle in June-1993 (top) and September-2002 (bottom). Channel morphology shifts from a braided system with active lateral channel migration, recent sediment deposition, and little vegetation in 1993, to a well-vegetated multi-channel system with reduced channel migration in 2002. CEMEX, Eliot Facility, Pleasanton, California.**

Source: Google Maps



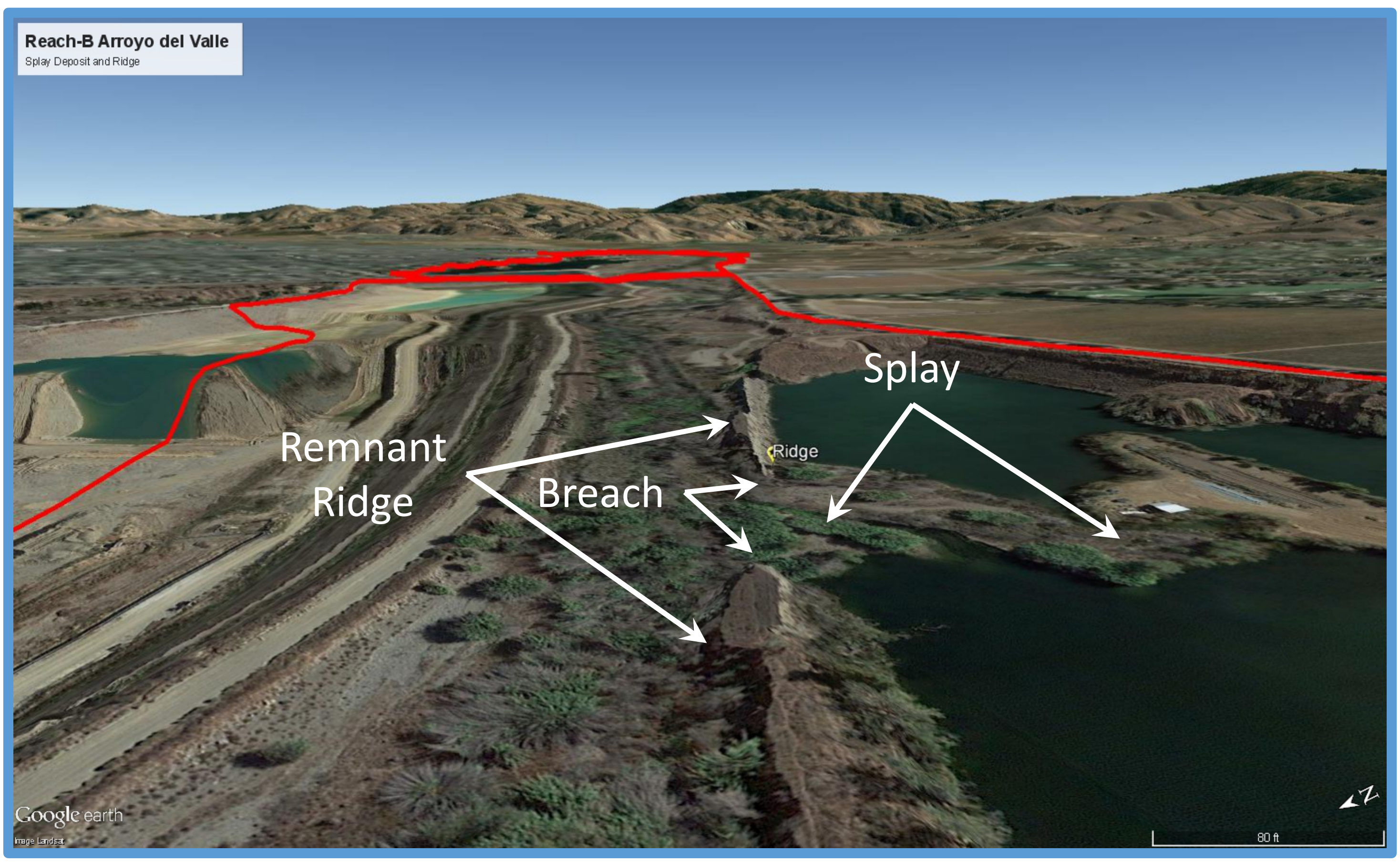


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Figure 17. **Reach-B on Arroyo del Valle in 1993 (top) and 2002 (bottom) illustrating the location of the ridge photo, the breach in the remnant depositional ridge, and the development and location of the splay deposit. CEMEX, Eliot Facility, Pleasanton, California.**

Source: Google Maps

Balance Hydrologics, Inc.

Figure 18. **Composition of the "Ridge" above Reach-B on Arroyo del Valle. Notice the presence of coarse sand, gravels, cobbles and small boulders. Deposit is interpreted as a remnant terrace deposit of Arroyo del Valle that has been eroded away and/or mined. CEMEX, Eliot Facility, Pleasanton, California.**

Balance Hydrologics, Inc.

Figure 19. **Reach-B on Arroyo del Valle in August-2008 (top) and September-2010 (bottom). Channel complexity shows little change since 2002. Riparian vegetation has increased with little evidence of lateral channel migration or new sediment deposition. Channel flow patterns in both photos mimic those present in 2002. CEMEX, Eliot Facility, Pleasanton, California.**

Source: Google Maps

Balance Hydrologics, Inc.

Figure 20. **Reach-B on Arroyo del Valle in June-2013 (top) and October-2015 (bottom). Increased riparian vegetation with no signs of active channel migration or new sediment deposition. Channel flow patterns in both photos mimic previous years. CEMEX, Eliot Facility, Pleasanton, California.**

Source: Google Maps

Balance Hydrologics, Inc.

Figure 21. **Photo of Arroyo del Valle on Reach-A illustrating the thick, riparian vegetation that has encroached into the active channel. Channel is actively flowing through the vegetation on both sides of the open channel beyond the view shown in the photo. CEMEX, Eliot Facility, Pleasanton, California,**

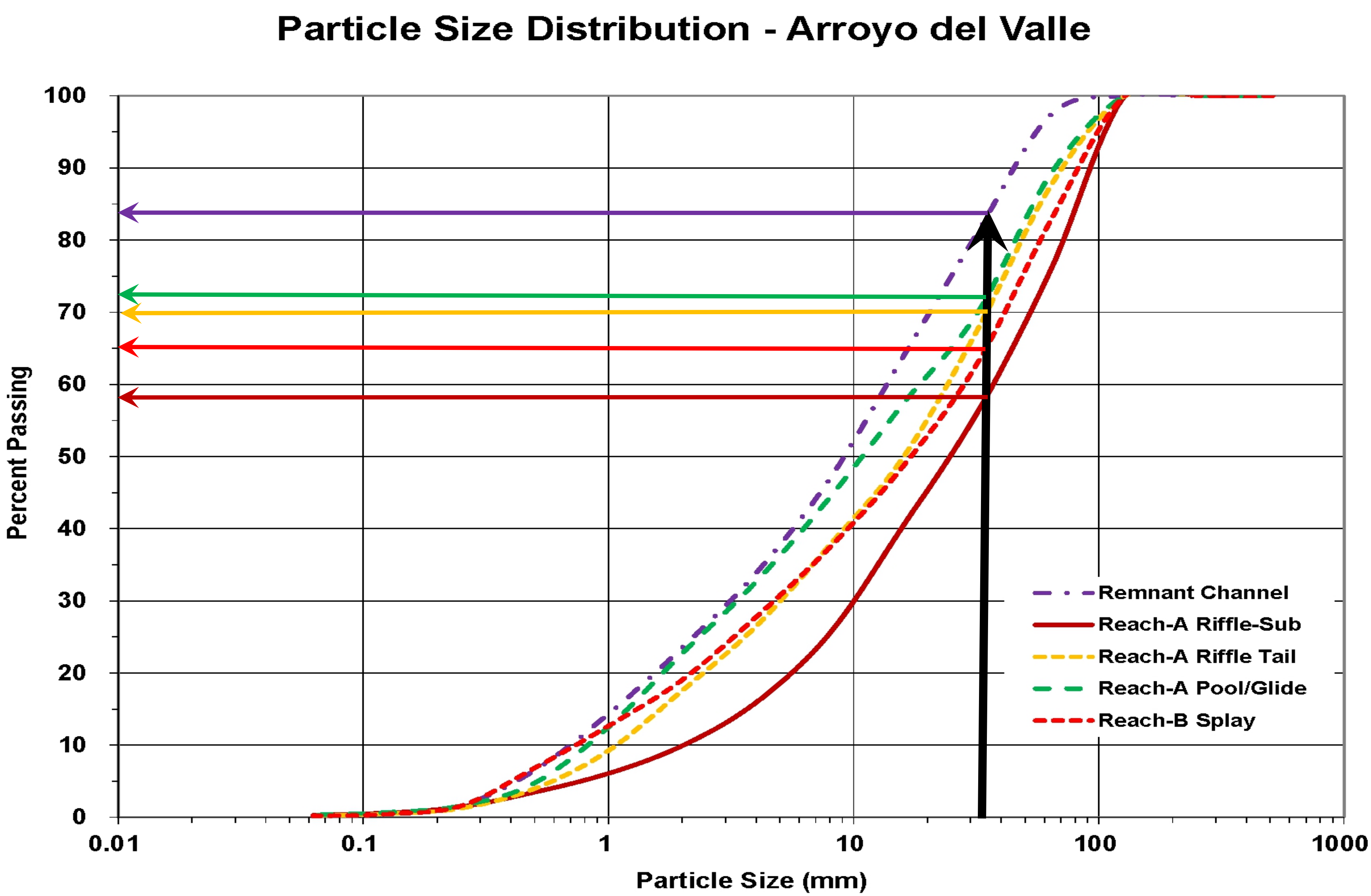

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Figure 22. **Particle size distribution for five (5) bulk sediment samples on Arroyo del Valle, CEMEX Eliot Facility, Pleasanton, California. Solid black line represents the 31 mm threshold grain size at the bankfull discharge of 216 cfs. Intersection of black line with each particle size distribution represents the potential percent mobile for each sediment sample at the bankfull discharge.**

APPENDIX A

Sieve Data for Bulk Sediment Samples, Reach-A and Reach-B, Arroyo del Valle

Appendix A2. Size-Class Analysis

GENERAL INFORMATION

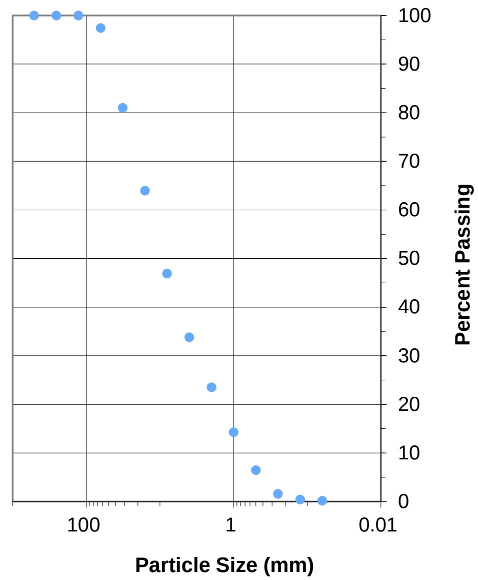
Stream: Arroyo del Valle
Location: Stop 2 - Reach A, surface sample abandoned braided network to n of channel
Date: 9/26/16 0:00
Observer: BC, ED
Weighed by: KS

Tare weight (g): 0.0

SIEVE ANALYSIS

Weight Retained Sample + Tare (g)	Weight Retained Sample - Tare (g)	Class	Sieve Opening (mm)	Phi	Weight Retained (g)	Weight Passing (g)	Cumulative Percent Finer by Weight (% passing)
	0.0	boulder	512	-9	0	17663.7	100.00
	0.0	boulder	256	-8	0	17663.7	100.00
	0.0	cobble	128	-7	0	17663.7	100.00
455.8	455.8	cobble	64	-6	455.8	17207.9	97.42
2893.7	2893.7	gravel	32	-5	2893.7	14314.2	81.04
3017.1	3017.1	gravel	16	-4	3017.1	11297.1	63.96
3006.4	3006.4	gravel	8	-3	3006.4	8290.7	46.94
2313.5	2313.5	gravel	4	-2	2313.5	5977.2	33.84
1821.6	1821.6	sand	2	-1	1821.6	4155.6	23.53
1629	1629.0	sand	1	0	1629	2526.6	14.30
1378.3	1378.3	sand	0.5	1	1378.3	1148.3	6.50
868.5	868.5	sand	0.25	2	868.5	279.8	1.58
198.9	198.9	sand	0.125	3	198.9	80.9	0.46
44.2	44.2	sand	0.0625	4	44.2	36.7	0.21
36.7	36.7		pan	> 4	36.7	0	0.00
Total	17663.7						

loss 0.419%



CHARACTERISTIC SIZES (mm)

D-1	0.1
D-5	0.4
D-10:	0.7
D-16:	1.1
D-25	2.2
D-50:	9.1
D-60	13.6
D-75	25.0
D-84:	36.3
D-90:	46.8
D-95	57.8

WEIGHT CHECK

Initial weight of bulk sample (g):	17738.0	17738
End weight of bulk sample (g):	17663.7	17663.7
Net Loss (g):		74.3
% Loss:		0.42%
Remarks :		

D-Max: enter data
D16/D84 0.027240359

Appendix A2. Size-Class Analysis

GENERAL INFORMATION

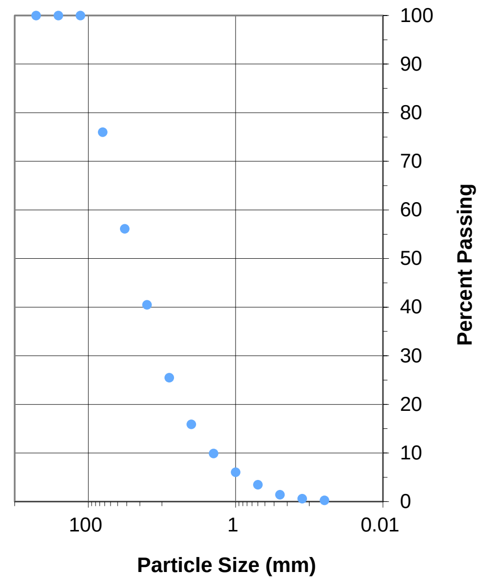
Stream: Arroyo del Valle
Location: Sample A-1 (IA sub-surface from riffle
Date: 9/26/16 0:00
Observer: BC, ED
Weighed by: KS

Tare weight (g): 0.0

SIEVE ANALYSIS

Weight Retained Sample + Tare (g)	Weight Retained Sample - Tare (g)	Class	Sieve Opening (mm)	Phi	Weight Retained (g)	Weight Passing (g)	Cumulative Percent Finer by Weight (% passing)
	0.0	boulder	512	-9	0	3874.9	100.00
	0.0	boulder	256	-8	0	3874.9	100.00
	0.0	cobble	128	-7	0	3874.9	100.00
928.8	928.8	cobble	64	-6	928.8	2946.1	76.03
770.2	770.2	gravel	32	-5	770.2	2175.9	56.15
606	606.0	gravel	16	-4	606	1569.9	40.51
581	581.0	gravel	8	-3	581	988.9	25.52
372.3	372.3	gravel	4	-2	372.3	616.6	15.91
232.5	232.5	sand	2	-1	232.5	384.1	9.91
148.5	148.5	sand	1	0	148.5	235.6	6.08
100.8	100.8	sand	0.5	1	100.8	134.8	3.48
78.9	78.9	sand	0.25	2	78.9	55.9	1.44
32	32.0	sand	0.125	3	32	23.9	0.62
12.6	12.6	sand	0.0625	4	12.6	11.3	0.29
11.3	11.3		pan	> 4	11.3	0	0.00
Total	3874.9						

loss 1.125%



CHARACTERISTIC SIZES (mm)

D-1 0.1
D-5 0.7
D-10: 2.0
D-16: 4.0
D-25 7.7
D-50: 24.4
D-60 36.6
D-75 61.7
D-84: 80.6
D-90: 95.9
D-95 110.8

WEIGHT CHECK

Initial weight of bulk sample (g):	3919.0	3919
End weight of bulk sample (g):	3874.9	3874.9
Net Loss (g):		44.1
% Loss:		1.13%
Remarks :		

D-Max: enter data
D16/D84 0.032722297

Appendix A2. Size-Class Analysis

GENERAL INFORMATION

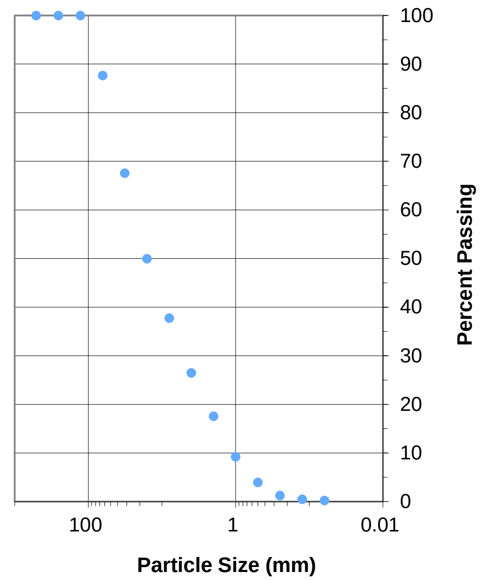
Stream: Arroyo del Valle
Location: Sample A-2 (2a tail end of same riffle as 1a, riffle tail)
Date: 9/26/16 0:00
Observer: BC, ED
Weighed by: KS

Tare weight (g): 0.0

SIEVE ANALYSIS

Weight Retained Sample + Tare (g)	Weight Retained Sample - Tare (g)	Class	Sieve Opening (mm)	Phi	Weight Retained (g)	Weight Passing (g)	Cumulative Percent Finer by Weight (% passing)
	0.0	boulder	512	-9	0	4184.2	100.00
	0.0	boulder	256	-8	0	4184.2	100.00
	0.0	cobble	128	-7	0	4184.2	100.00
516	516.0	cobble	64	-6	516	3668.2	87.67
840.7	840.7	gravel	32	-5	840.7	2827.5	67.58
736.1	736.1	gravel	16	-4	736.1	2091.4	49.98
511.7	511.7	gravel	8	-3	511.7	1579.7	37.75
471.9	471.9	gravel	4	-2	471.9	1107.8	26.48
372.2	372.2	sand	2	-1	372.2	735.6	17.58
349.3	349.3	sand	1	0	349.3	386.3	9.23
219.8	219.8	sand	0.5	1	219.8	166.5	3.98
114.2	114.2	sand	0.25	2	114.2	52.3	1.25
32.2	32.2	sand	0.125	3	32.2	20.1	0.48
10.8	10.8	sand	0.0625	4	10.8	9.3	0.22
9.3	9.3		pan	> 4	9.3	0	0.00
Total	4184.2						

loss 1.370%



CHARACTERISTIC SIZES (mm)

D-1	0.1
D-5	0.6
D-10:	1.1
D-16:	1.8
D-25	3.6
D-50:	16.0
D-60	23.7
D-75	41.3
D-84:	56.4
D-90:	73.0
D-95	96.6

WEIGHT CHECK

Initial weight of bulk sample (g):	4242.3	4242.3
End weight of bulk sample (g):	4184.2	4184.2
Net Loss (g):		58.1
% Loss:		1.37%
Remarks :		

D-Max: enter data
D16/D84 0.025780818

Appendix A2. Size-Class Analysis

GENERAL INFORMATION

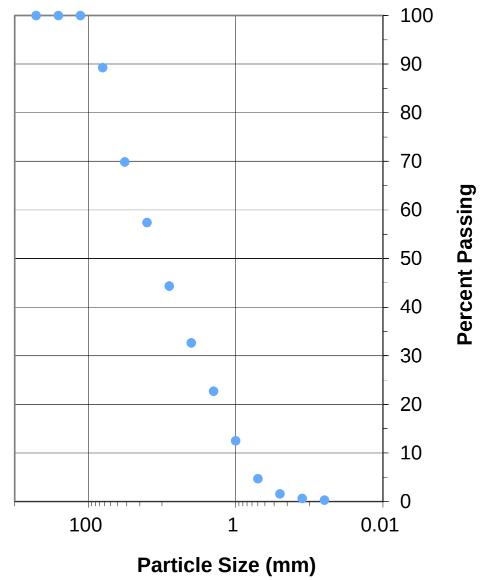
Stream: Arroyo del Valle
Location: Sample A-3(3a pool infill)
Date: 9/26/16 0:00
Observer: BC, ED
Weighed by: KS

Tare weight (g): 0.0

SIEVE ANALYSIS

Weight Retained Sample + Tare (g)	Weight Retained Sample - Tare (g)		Sieve Opening (mm)	Phi	Weight Retained (g)	Weight Passing (g)	Cumulative Percent Finer by Weight (% passing)
	0.0	boulder	512	-9	0	3902.4	100.00
	0.0	boulder	256	-8	0	3902.4	100.00
	0.0	cobble	128	-7	0	3902.4	100.00
418.2	418.2	cobble	64	-6	418.2	3484.2	89.28
756.2	756.2	gravel	32	-5	756.2	2728	69.91
487.7	487.7	gravel	16	-4	487.7	2240.3	57.41
509.9	509.9	gravel	8	-3	509.9	1730.4	44.34
456.3	456.3	gravel	4	-2	456.3	1274.1	32.65
387.2	387.2	sand	2	-1	387.2	886.9	22.73
398.6	398.6	sand	1	0	398.6	488.3	12.51
303	303.0	sand	0.5	1	303	185.3	4.75
123.3	123.3	sand	0.25	2	123.3	62	1.59
35.5	35.5	sand	0.125	3	35.5	26.5	0.68
14.1	14.1	sand	0.0625	4	14.1	12.4	0.32
12.4	12.4		pan	> 4	12.4	0	0.00
Total	3902.4						

loss 1.140%



CHARACTERISTIC SIZES (mm)

D-1 0.13
D-5 0.51
D-10: 0.80
D-16: 1.27
D-25 2.34
D-50: 10.80
D-60 18.47
D-75 38.40
D-84: 52.98
D-90: 67.04
D-95 92.63

WEIGHT CHECK

Initial weight of bulk sample (g):	3947.4	3947.4
End weight of bulk sample (g):	3902.4	3902.4
Net Loss (g):		45.0
% Loss:		1.14%
Remarks :		

D-Max: enter data
D16/D84 0.0208108

Appendix A2. Size-Class Analysis

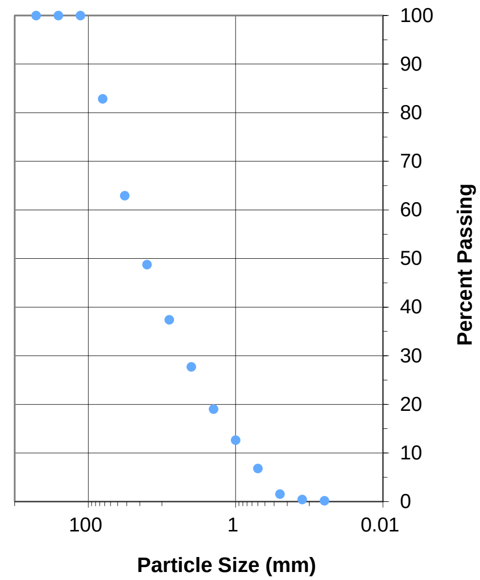
GENERAL INFORMATION

Stream: Arroyo del Valle
Location: Splay #1 (on channel as it flows into western pond)
Date: 9/26/16 0:00
Observer: BC, ED
Weighed by: KS

Tare weight (g): 0.0

SIEVE ANALYSIS

Weight Retained Sample + Tare (g)	Weight Retained Sample - Tare (g)	Class	Sieve Opening (mm)	Phi	Weight Retained (g)	Weight Passing (g)	Cumulative Percent Finer by Weight (% passing)
	0.0	boulder	512	-9	0	5443.6	100.00
	0.0	boulder	256	-8	0	5443.6	100.00
	0.0	cobble	128	-7	0	5443.6	100.00
932.9	932.9	cobble	64	-6	932.9	4510.7	82.86
1084.4	1084.4	gravel	32	-5	1084.4	3426.3	62.94
772.3	772.3	gravel	16	-4	772.3	2654	48.75
617.8	617.8	gravel	8	-3	617.8	2036.2	37.41
525.9	525.9	gravel	4	-2	525.9	1510.3	27.74
473.6	473.6	sand	2	-1	473.6	1036.7	19.04
347.6	347.6	sand	1	0	347.6	689.1	12.66
317.2	317.2	sand	0.5	1	317.2	371.9	6.83
286.3	286.3	sand	0.25	2	286.3	85.6	1.57
62.1	62.1	sand	0.125	3	62.1	23.5	0.43
14	14.0	sand	0.0625	4	14	9.5	0.17
9.5	9.5		pan	> 4	9.5	0	0.00
Total	5443.6						
loss	1.246%						



CHARACTERISTIC SIZES (mm)

D-1	0.13
D-5	0.39
D-10:	0.73
D-16:	1.44
D-25	3.21
D-50:	17.00
D-60	27.72
D-75	48.68
D-84:	67.01
D-90:	85.42
D-95	104.56

WEIGHT CHECK

Initial weight of bulk sample (g):	5512.3	5512.3
End weight of bulk sample (g):	5443.6	5443.6
Net Loss (g):		68.7
% Loss:		1.25%
Remarks :		

D-Max: enter data
D16/D84 0.014971713

Appendix E: Design Drawings

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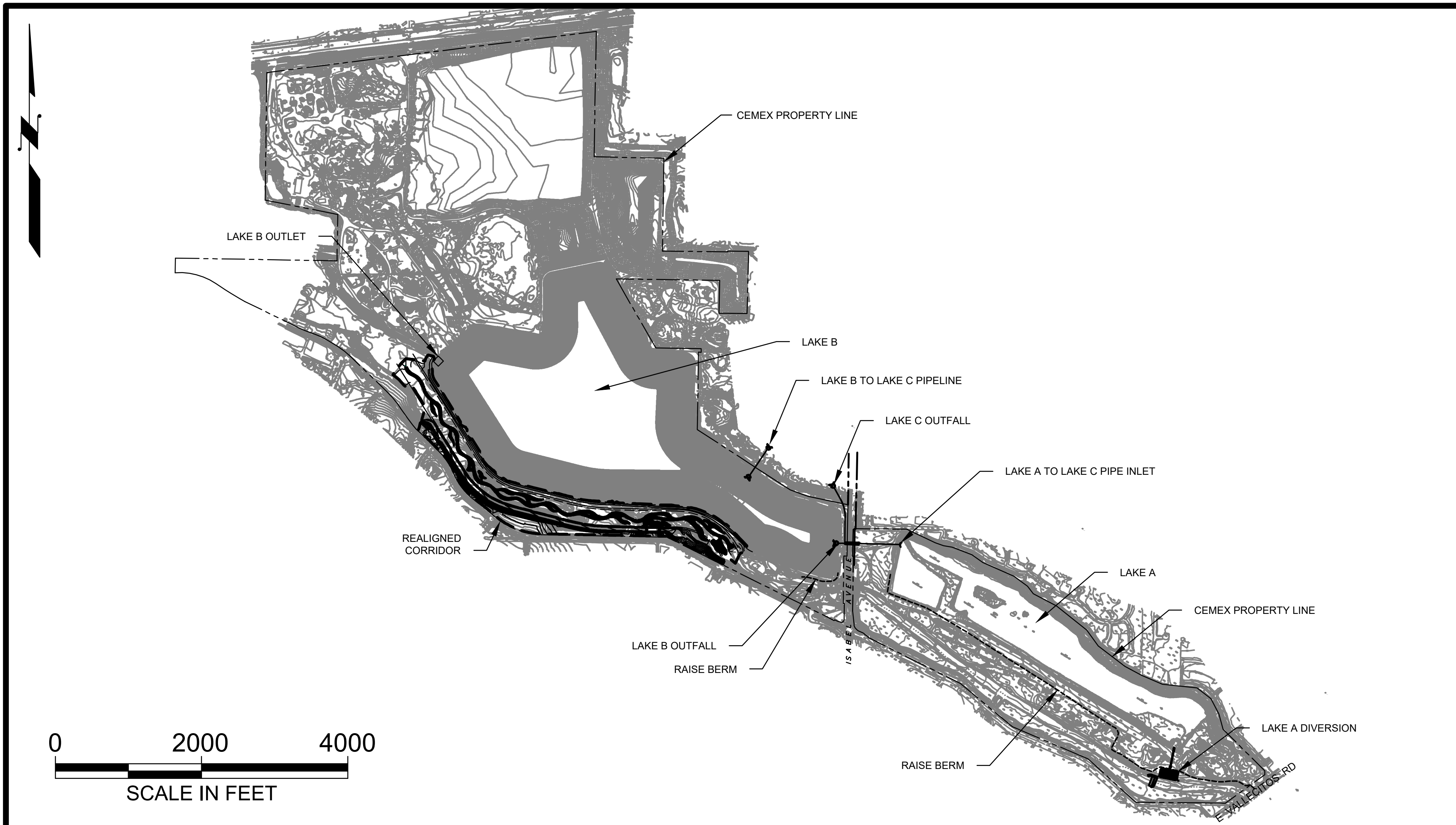


Brown AND Caldwell
701 PIKE STREET
SUITE 1200
SEATTLE, WA 98101

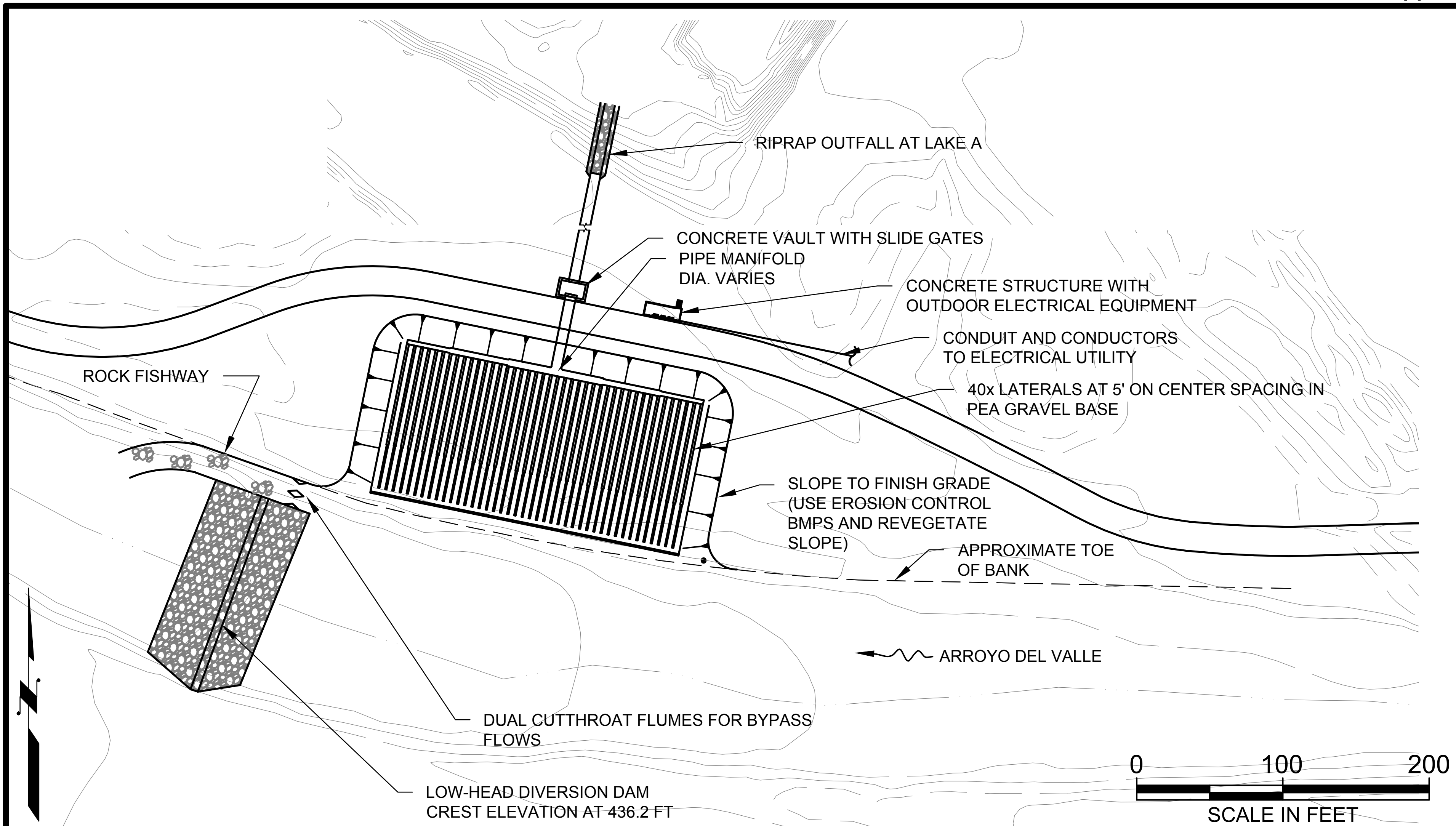
CEMEX
2365 IRON POINT ROAD
SUITE 120
FOLSOM, CA 95630

ELIOT QUARRY
RECLAMATION PLAN AMENDMENT
HYDRAULIC DESIGN
1544 STANLEY BOULEVARD
PLEASANTON, CA 94566
CA MINE ID NO: 91-01-0009

FIGURE E-1

OVERALL SITE PLAN FOR PROPOSED PROJECT

Path: \\BCSEAFP01\PROJECTS\CEMEX\149951 ARROYO DEL VALLE REALIGNMENT\CAD\0-PROJECT\FIGURES FILENAME: FIGURE-E-2.DWG PLOT DATE: 12/15/2017 10:17 AM CAD USER: KEITH TOLLE [C]



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SEATTLE, WA 98101

CEMEX
5180 GOLDEN FOOTHILLS
PARKWAY
EL DORADO HILLS, CA 95762

ELIOT QUARRY
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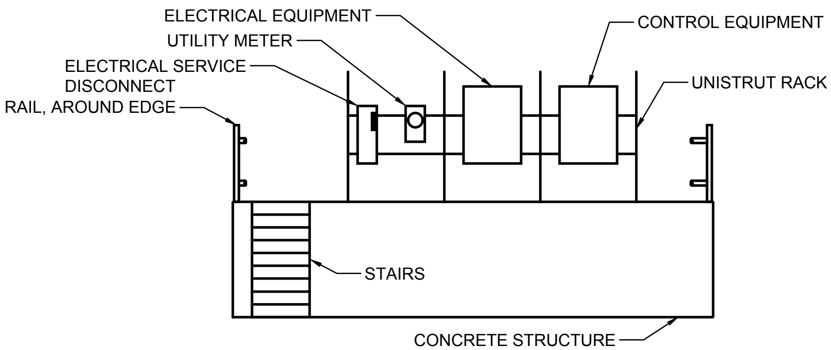
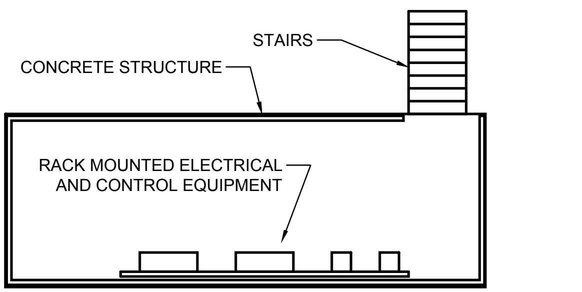
HYDRAULIC DESIGN
1544 STANLEY BOULEVARD
PLEASANTON, CA 94566
CA MINE ID NO: 91-01-0009

FIGURE E-2

PROPOSED LAKE A
DIVERSION PLAN

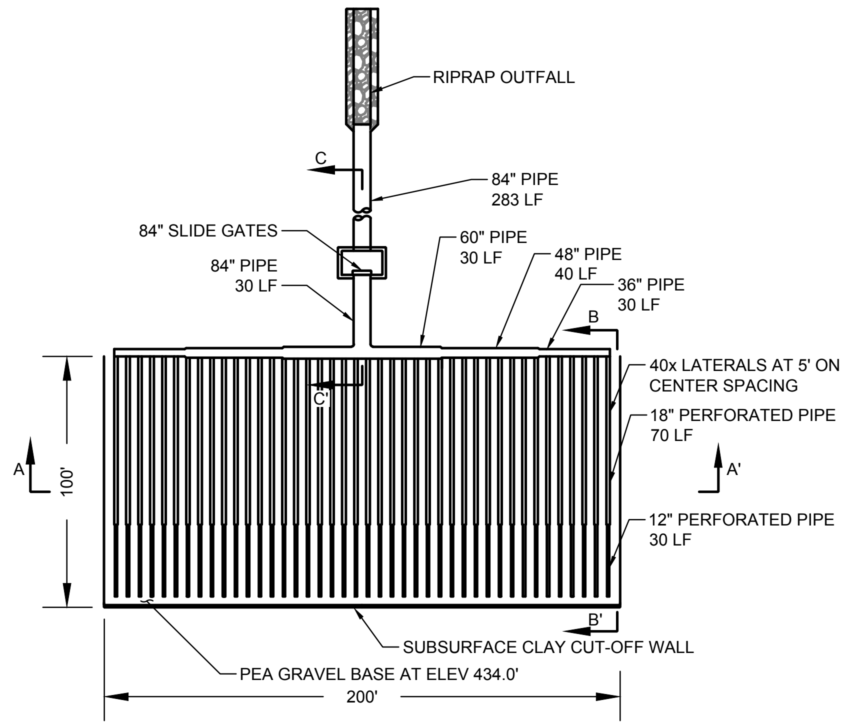


ELECTRICAL FRONT ELEVATION



ELECTRICAL PLAN VIEW

0 10 20
SCALE IN FEET



0 80 160
SCALE IN FEET

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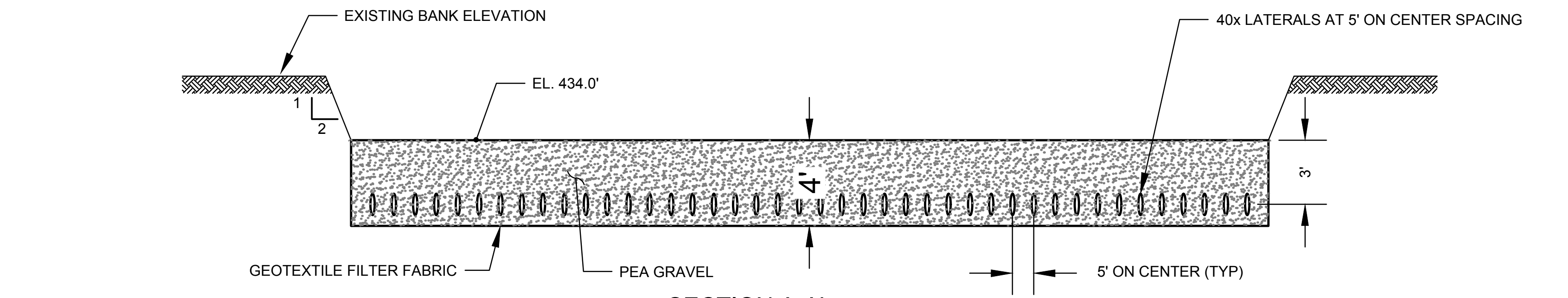
CA MINE ID NO: 91-01-0009

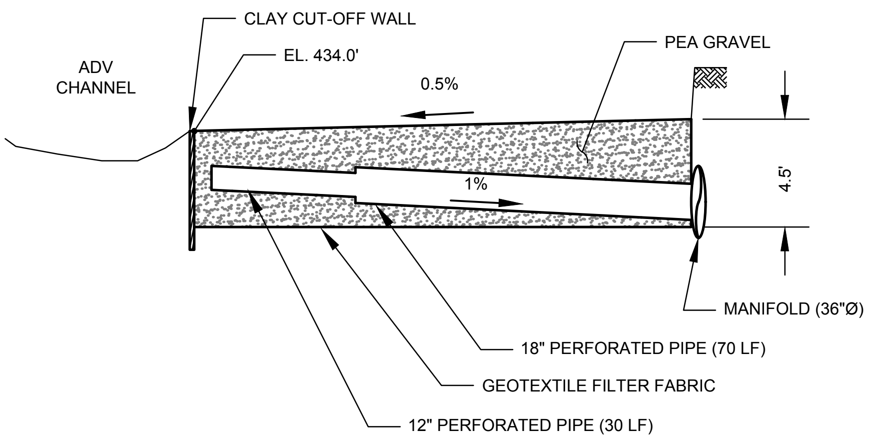
FIGURE E-3

PROPOSED LAKE A DIVERSION DETAILS

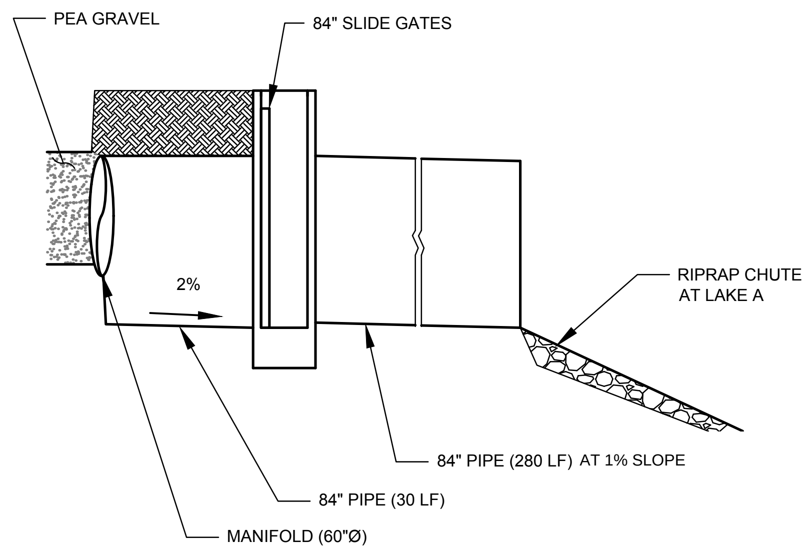
Path: \\BCSEAFP01\PROJECTS\CEMEX\149951 ARROYO DEL VALLE REALIGNMENT\CAD\0-PROJECT\FIGURES FILENAME: FIGURE-E-4.DWG PLOT DATE: 12/15/2017 10:21 AM CAD USER: KEITH TOLLE [C]



SECTION A-A'



SECTION B-B'



SECTION C-C'

HZ 1"=40'-0"
VT 1"=8'-0"

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1544 STANLEY BOULEVARD
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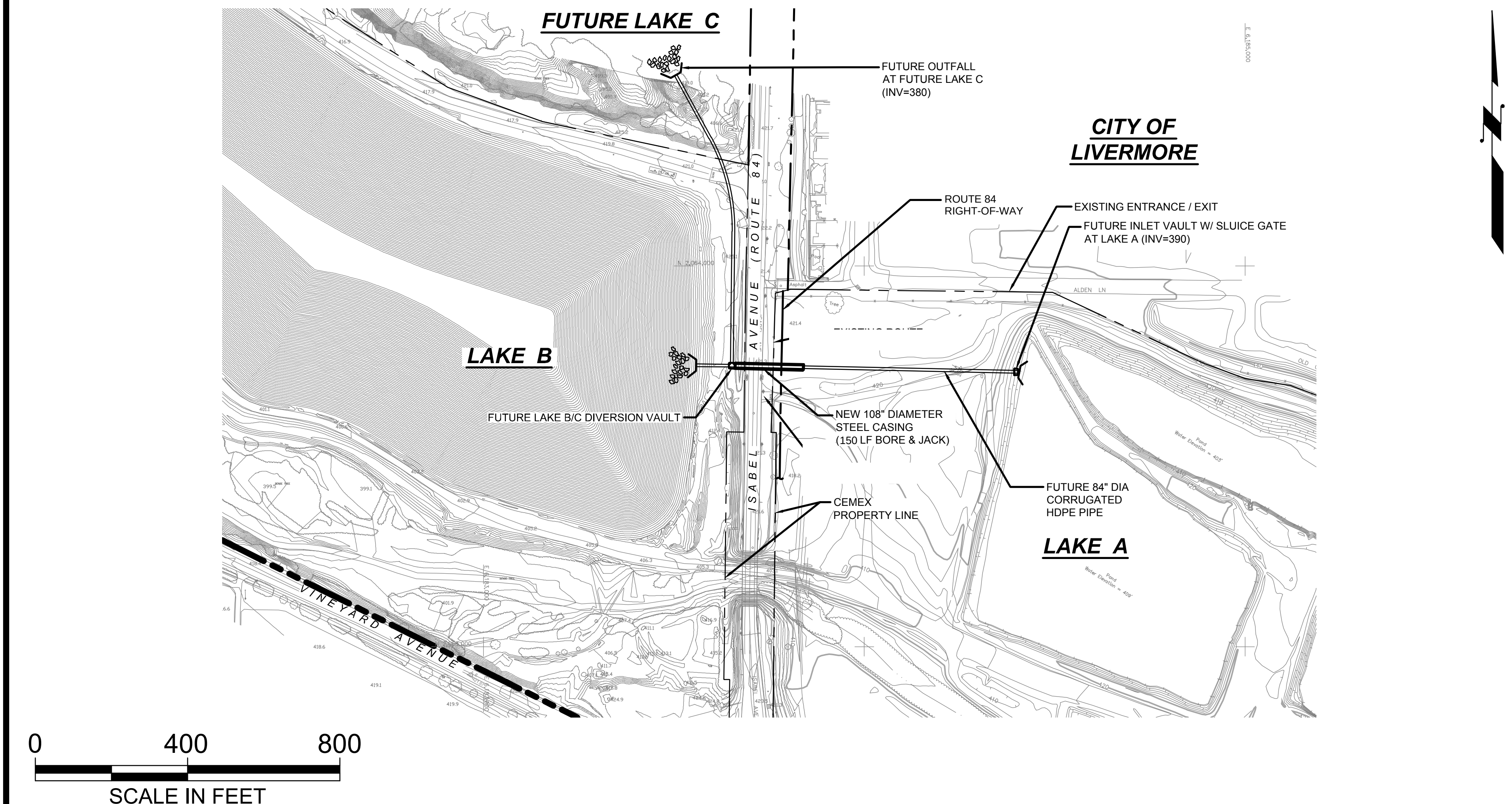
FIGURE E-4

PROPOSED INFILTRATION BED SECTIONS



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HYDRAULIC DESIGN
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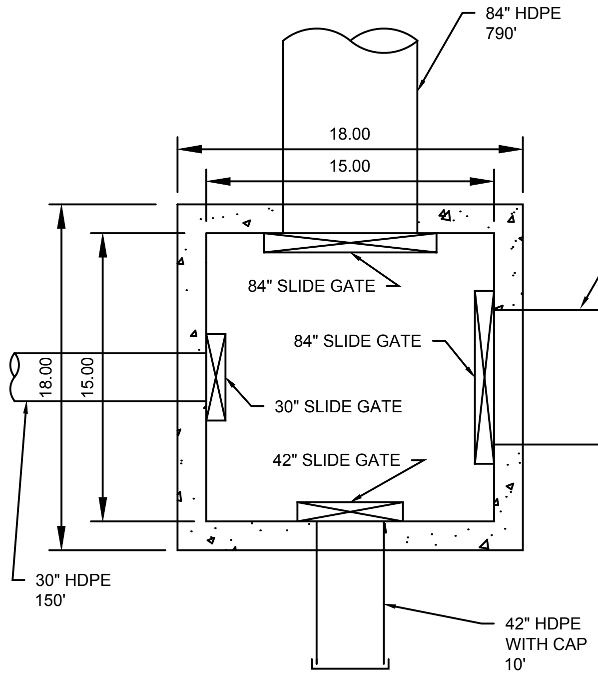
CA MINE ID NO: 91-01-0009

FIGURE E-5

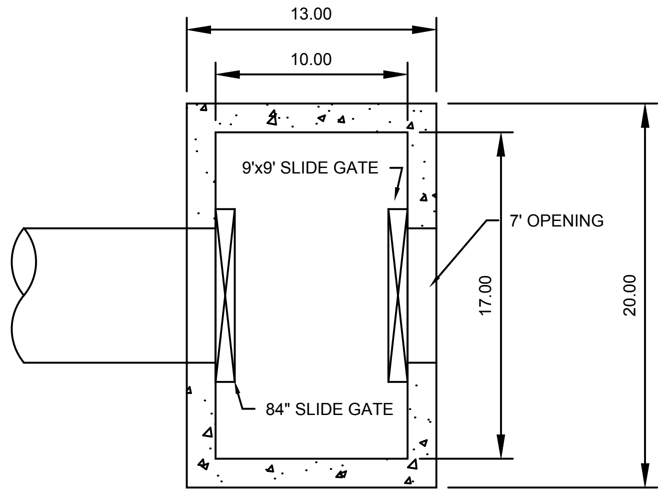
PROPOSED LAKE A TO LAKE C CONDUIT

Path: \\BCSEAFP01\PROJECTS\CEMEX\149951 ARROYO DEL VALLE REALIGNMENT\CAD\0-PROJECT\FIGURES FILENAME: FIGURE-E-6.DWG PLOT DATE: 11/3/2017 10:46 AM CAD USER: KEITH TOLLE [C]



LAKE B/C DIVERSION

GROUND ELEV: 422
PIPE INV ELEV: 386



LAKE A INLET

GROUND ELEV: 424
PIPE INV ELEV: 390

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HYDRAULIC DESIGN
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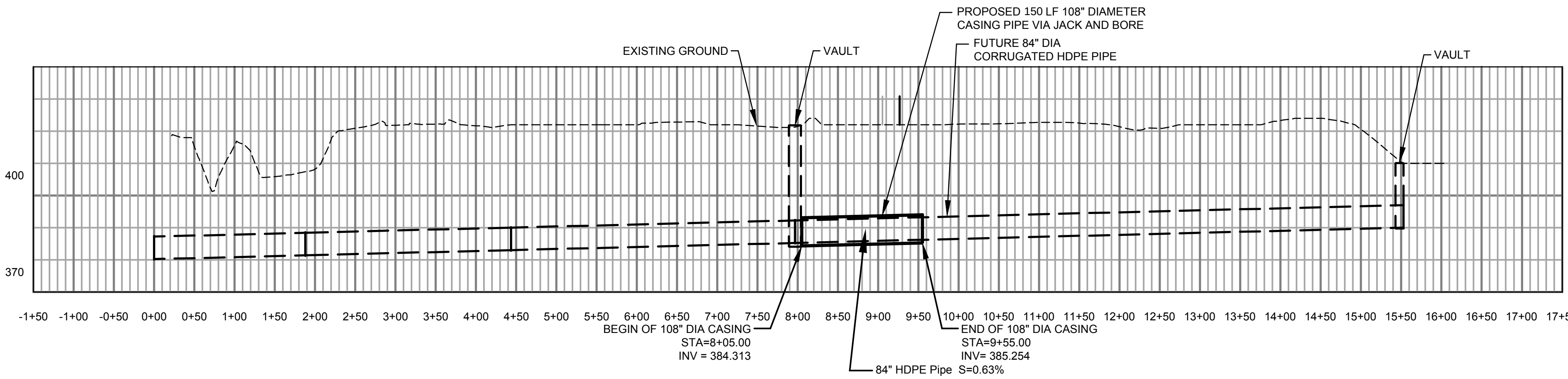
PLEASANTON, CA 94566
CA MINE ID NO: 91-01-0009

FIGURE E-6

PROPOSED 108" DIA CASING VAULT DETAIL

Path: \\BCSEAFP01\PROJECTS\CEMEX\149951 ARROYO DEL VALLE REALIGNMENT\CAD\0-PROJECT\FIGURES FILENAME: FIGURE-E-7.DWG PLOT DATE: 12/15/2017 10:52 AM CAD USER: KEITH TOLLE [C]



PROFILE

SCALE H: 1" = 200'
V: 1" = 50'

0 50 (V)

0 200 (H)

SCALE IN FEET

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SEATTLE, WA 98101

CEMEX

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RECLAMATION PLAN AMENDMENT
HYDRAULIC DESIGN
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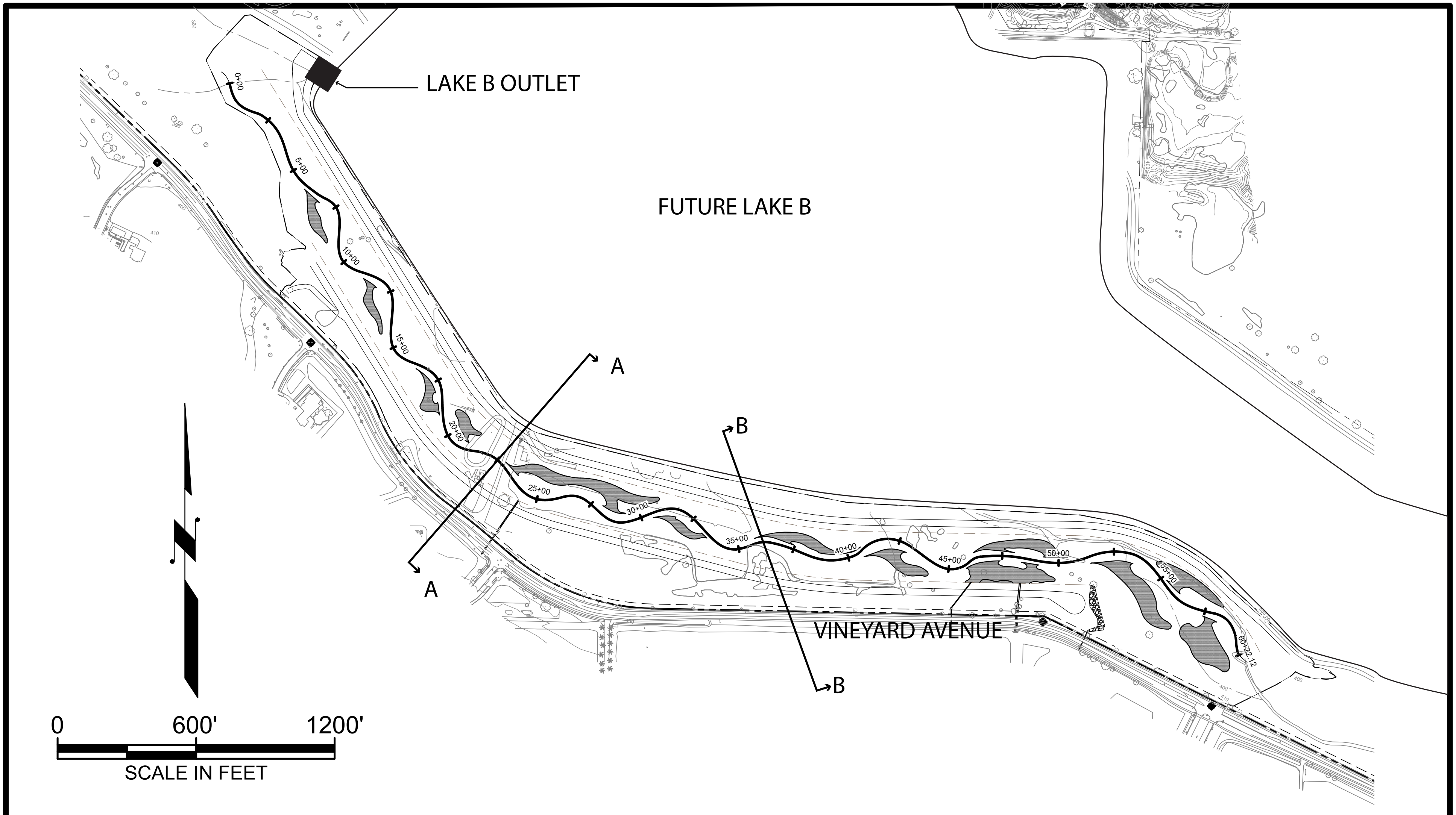
CA MINE ID NO: 91-01-0009

FIGURE E-7

PROPOSED
LAKE A TO LAKE C
PIPELINE PROFILE

Path: \\BCSEAFP01\PROJECTS\CEMEX\149951 ARROYO DEL VALLE REALIGNMENT\CAD\0-PROJECT\FIGURES FILENAME: FIGURE-E-8.DWG PLOT DATE: 8/16/2018 CAD USER: SAMANTHA COHEN



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SEATTLE, WA 98101

CEMEX

2365 IRON POINT ROAD
SUITE 120
FOLSOM, CA 95630

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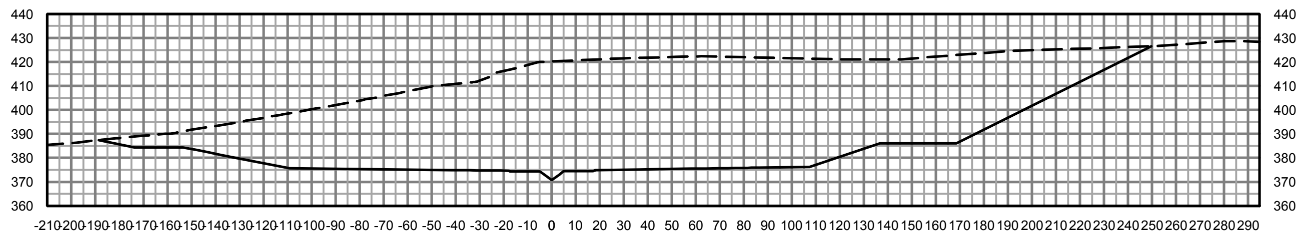
RECLAMATION PLAN AMENDMENT
HYDRAULIC DESIGN
1544 STANLEY BOULEVARD
PLEASANTON, CA 94566
CA MINE ID NO: 91-01-0009

FIGURE E-8

PROPOSED
ARROYO DEL VALLE
REALIGNMENT PLAN

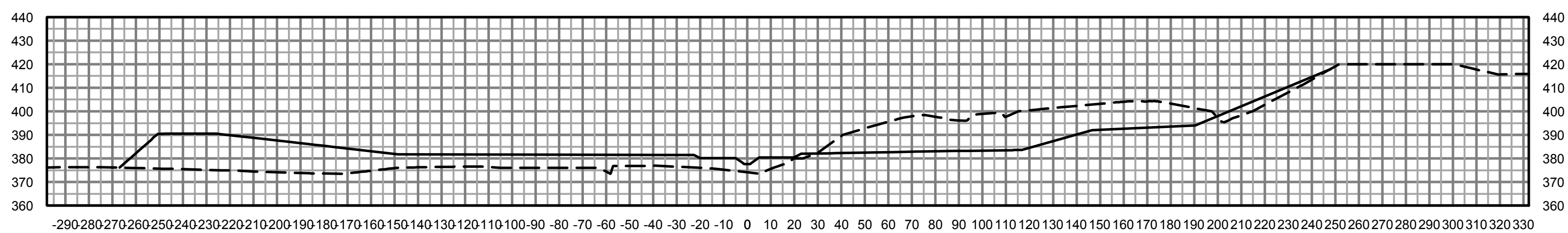
Path: \\BCSEAFP01\PROJECTS\CEMEX\149951 ARROYO DEL VALLE REALIGNMENT\CAD\0-PROJECT\FIGURES FILENAME: FIGURE-E-9.DWG PLOT DATE: 12/15/2017 11:49 AM CAD USER: KEITH TOLLE [C]



TYPICAL POND CROSS SECTION

DETAIL A-A TYP

SCALE: 1" = 80'



TYPICAL RIFFLE CROSS SECTION

DETAIL B-B TYP

SCALE: 1" = 80'

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SUITE 1200
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EL DORADO HILLS, CA 95762

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FIGURE E-9

PROPOSED ARROYO DEL VELLE REALIGNMENT CROSS-SECTIONS

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Appendix F: Infiltration Testing

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MEMO

To: Ron Wilson, CEMEX

From: Bill Christner (Balance Hydrologics, Inc.) and Andy Kopania (EMKO Environmental, Inc.)

Date: May 13, 2016

Subject: Infiltration Tests of Native and Spoil Soil Material Along Reach-B, Arroyo del Valle, CEMEX Eliot Facility

This memo presents the results of Balance Hydrologics' and EMKO's infiltration tests and analysis of the native and spoil soil material along Reach-B, of Arroyo del Valle on the CEMEX Construction Materials, Inc. (CEMEX) Eliot Facility located between the cities of Pleasanton and Livermore within the unincorporated area of Alameda County, California. CEMEX is seeking the approval of an amendment to its existing Reclamation Plan, which was originally approved in 1987 under Surface Mining Permit 23 (SMP-23).

Alameda County issued a Notice of Preparation of a Draft Environmental Impact Report in 2015 for the Reclamation Plan Amendment in accordance with the California Environmental Quality Act (CEQA). Initial entitlement discussions with agency representatives have prompted CEMEX to conduct investigations and prepare a draft conceptual design document in support of the proposed realignment of Reach-B on Arroyo del Valle.

Preliminary design meetings identified the need for infiltration data on native and spoil soil material. Infiltration data will provide insight into the hydrologic properties of soil materials that may be used for channel reconstruction. Balance and EMKO visited the site on March 28, 2016 to perform the desired tests. This memo describes the test methods and analysis carried out to evaluate the infiltration rates of the native and spoil soil materials.

Goals and Objectives

The goal of the infiltration investigation is to evaluate the infiltration rates of native and spoil soil material in terms of their suitability for use as a construction material of the reconstructed channel on Arroyo del Valle. A secondary objective is to provide a quantitative assessment of the potential change in the rate of percolation from the existing stream bed compared to the realigned stream bed, and the qualitative implications for seepage and slope stability along the south slope of the Lake B mining pit.

General Technical Approach and Work Conducted

To evaluate the infiltration rates of the soils, field tests were conducted utilizing a dual-ring infiltrometer and methods described by the United States Geological Society (USGS, 1963). Two metal rings are driven into the soil surface (Figure 1) and water is then introduced into both cylinders. Water depths are measured at specified time intervals until a relatively constant rate is achieved. The constant rate of water surface decline (drawdown) in the rings reflects the steady-state infiltration rate.

Infiltration rates are affected by many variables including but not limited to the: soil texture and structure, surface soil condition (compacted), antecedent soil moisture, head of the applied water, depth to ground water, length of time water is applied, biological activity, and atmospheric pressure (Brady and Weil, 1999).

Infiltration tests were performed at four (4) sites, two (2) in native soil material along the riparian corridor of Reach-B, and two (2) on spoil soil material (Figure 2). Native soil test sites represent infiltration rates under existing conditions along Reach-B of Arroyo del Valle. Spoil soil material test sites are intended to be representative of infiltration rates that would occur through the realigned channel bed[1]. Test times ranged from 20 minutes at the N1 site, to 30 minutes at N2, S1, and S2 sites. Soil antecedent moisture conditions were relatively moist as indicated from nearby precipitation gages. Rainfall totals from two nearby precipitation gages indicate the area received between 0.3 and 0.6 inches of precipitation (Figure 3) in the week prior to the infiltration tests (2016, CDE). Precipitation totals for water year 2016 (WY-2016) vary between 11.40 inches and 15.75 inches since the beginning of the water year (October 1, 2015).

Setting

Historically, Arroyo del Valle was an intermittent stream (SEFI, 2013). As the stream exited the confines of the mountains onto the broad valley floor, it lost power and dropped its sediment load forming an alluvial fan with a braided channel network. The braided channel network included broad, nearly level, terraces and floodplains.

[1] The realigned channel segment will require cut, fill, and compaction of the spoil soil material present in the areas tested. Thus, existing spoil soil material in the area of the proposed realignment is representative of the soil conditions that will exist as part of the substrate under the realigned channel.

Soils across the Livermore Valley are dominated by the Yolo-Pleasanton association (Westover and Van Duyne, 1910; Welch et al., 1966). Yolo soils are entisols formed in fine-loamy alluvium derived from sedimentary formations. Entisols are soils defined by the absence or near absence of horizons, or layers that clearly reflect soil-forming processes. They are found on nearly level to moderately sloping alluvial fans (Soil Survey Staff, 2016). They tend to be well-drained with slow to medium runoff and moderate permeability.

Pleasanton soils are gravelly fine sandy loam alfisols, and occur on nearly level to gently sloping alluvial fans and terraces. Alfisols typically exhibit well-developed, contrasting soil horizons or layers. They are well-drained soils with slow to medium runoff, and moderately slow permeability (Soil Survey Staff, 2016).

Historical accounts describe the alluvial soils as “river wash” and characterize the streambeds as very porous material, underlain by a bed of coarse gravel several feet thick (Westover and Van Duyne 1910; Welch et al. 1966). Infiltration rates of the coarse channel material often allowed surface flows to percolate into the sediments at a rate such that channel flow was intermittent (SEFI, 2013).

Findings

Surface Infiltration Rates

Infiltration data for all four (4) sites are presented in Attachment A. Infiltration rates are similar for most sites except the N1 site (Figure 4). Infiltration rates at N1 were much higher than infiltration rates measured at the other sites. Initial infiltration at N1 was 60.0 in/hr and quickly fell to 21.0 in/hr after 8.5 minutes (510 seconds). These rates are significantly higher than infiltration rates observed at the other three (3) sites. Initial infiltration rates at sites N2, S1, and S2 were 15.0 in/hr, 6.0 in/hr, and 15.0 in/hr respectively. These rates fell quickly and stabilized at 3.4 in/hr, 0.59 in/hr, and 1.9 in/hr respectively after 20 minutes (1200 s). Predictive equations for infiltration rates were developed from the field data based on best-fit lines. These equations indicate infiltration rates continue to decline at each site through time (Table 1).

Table 1. Infiltration rates (in/hr) for sites N1, N2, S1, and S2 from 20 minutes through 12 hours times.

Site	Infiltration Rate (in/hr)			
	20 (mins)	30 (mins)	1 (hr)	12 (hr)
	1200 (sec)	1800 (sec)	2600 (sec)	43,200 (sec)
N1	13.47	11.40	8.58	3.09
N2	3.43	3.11	2.62	1.43
S1	0.59	0.46	0.31	0.07
S2	1.91	1.61	1.20	0.42

Conclusions and Implications for Design

Concerns were raised about the potential for high water seepage rates through the soils used to reconstruct Reach-B on Arroyo del Valle. Infiltration tests were performed at four (4) sites along Reach-B, two (2) on native soil material, and two (2) on spoil soil material. Field test results indicate infiltration rates for the spoil soil material are less (slower) then those observed in native soil materials. Results from this field investigation indicate that infiltration rates following channel reconstruction should be similar to or slower than current rates. Therefore, infiltration of water through the realigned channel of Arroyo del Valle would not steepen the groundwater gradient toward the south edge of Lake B, would not increase the groundwater elevation at the south edge of Lake B, and would not increase the rate of seepage into the south face of Lake B. As such, realignment of Reach-B would not alter the hydrologic conditions along the south side of Lake B in a manner that would be inconsistent with the existing geotechnical slope stability analysis (Kane GeoTech, 2015).

Limitations

This report was prepared in general accordance with the accepted standard of practice in surface-water and groundwater hydrology existing in Northern California for projects of similar scale at the time the investigations were performed. No other warranties, expressed or implied, are made.

As is customary, we note that readers should recognize that interpretation and evaluation of subsurface conditions and physical factors affecting the hydrologic context of any site is a difficult and inexact art. Judgments leading to conclusions and recommendations are generally made with an incomplete knowledge of the conditions present. More extensive or extended studies, including additional hydrologic baseline monitoring, can reduce the inherent uncertainties associated with such studies. We note, in particular, that many factors affect local and regional groundwater levels, and soil composition varies both spatially and temporally. If the client wishes to further reduce the uncertainty beyond the level associated with this study, Balance should be notified for additional consultation.

We have used standard environmental information such as rainfall, topographic mapping, and soil mapping, in our analyses and approaches without verification or modification, in conformance with local custom. New information or changes in regulatory guidance could influence the plans or recommendations, perhaps fundamentally. As updated information becomes available, the interpretations and recommendations contained in this memo may warrant change. To aid in revisions, we ask that readers or reviewers advise us of new plans, conditions, or data when they become available.

Concepts, findings and interpretations contained in this report are intended for the exclusive use of CEMEX, under the conditions presently prevailing except where noted otherwise. Their use beyond the boundaries of the site could lead to environmental or structural damage, and/or to noncompliance with water-quality policies, regulations or permits. Data developed or used in this report were collected and interpreted solely for developing an understanding of the hydrologic context at the site as an aid to conceptual planning and channel and wetland restoration design. They should not be used for other purposes without great care, updating, review of sampling and analytical methods used, and consultation with Balance staff familiar with the site. In particular, Balance Hydrologics, Inc. should be consulted prior to applying the contents of this report to geotechnical or facility design, routine wetland management, sale or exchange of land, or for other purposes not specifically cited in this report.

Finally, we ask once again that readers who have additional pertinent information, who observed changed conditions, or who may note material errors should contact us with their findings at the earliest possible date, so that timely changes may be made.

References

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Westover, H.L., and Van Duyne, C., 1910. Soil survey of the Livermore area, California. United States Department of Agriculture, Soil Conservation Service.

Attachments

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FIGURES

Figure 1. **Photos of the dual-ring infiltrometer set-up at site S1 on the CEMEX Eliot Facility, Alameda County, California, March 28, 2016.**

Balance Hydrologics, Inc.

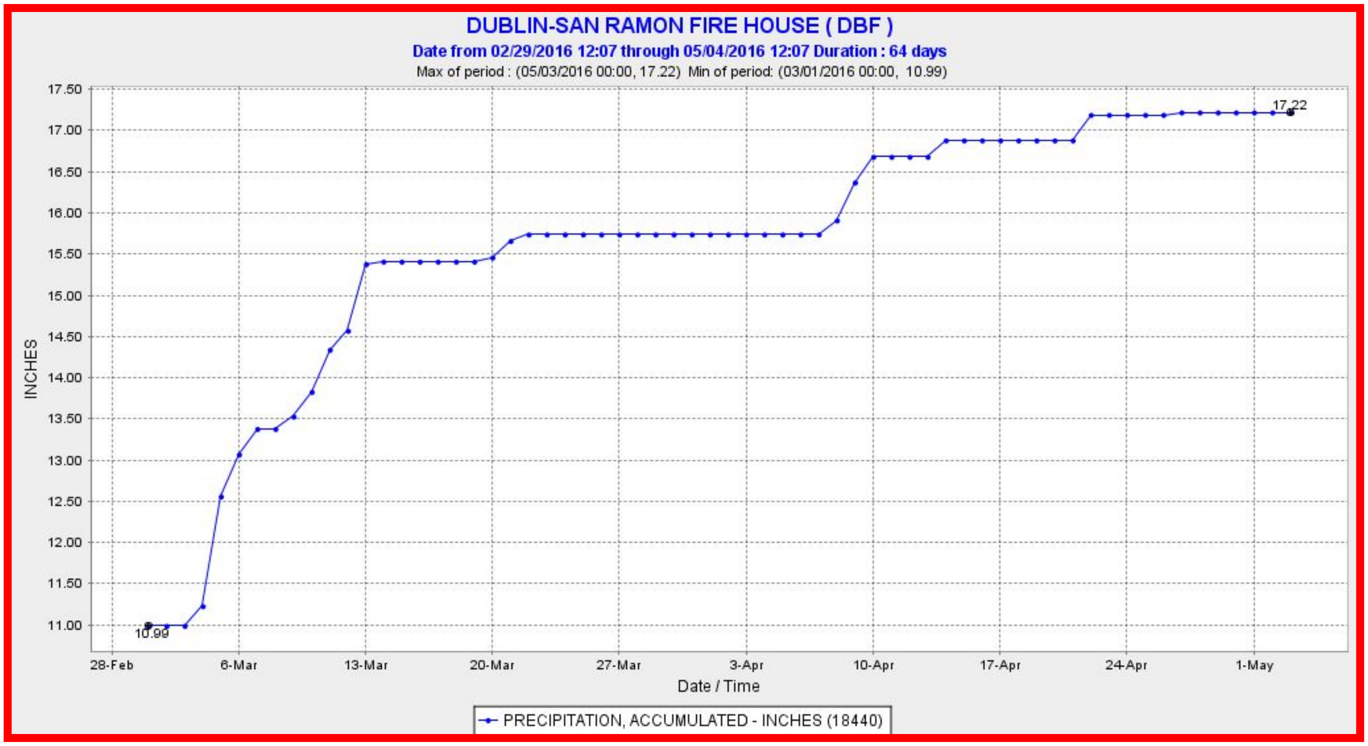
215184 Protrait_Figs-2.pptx

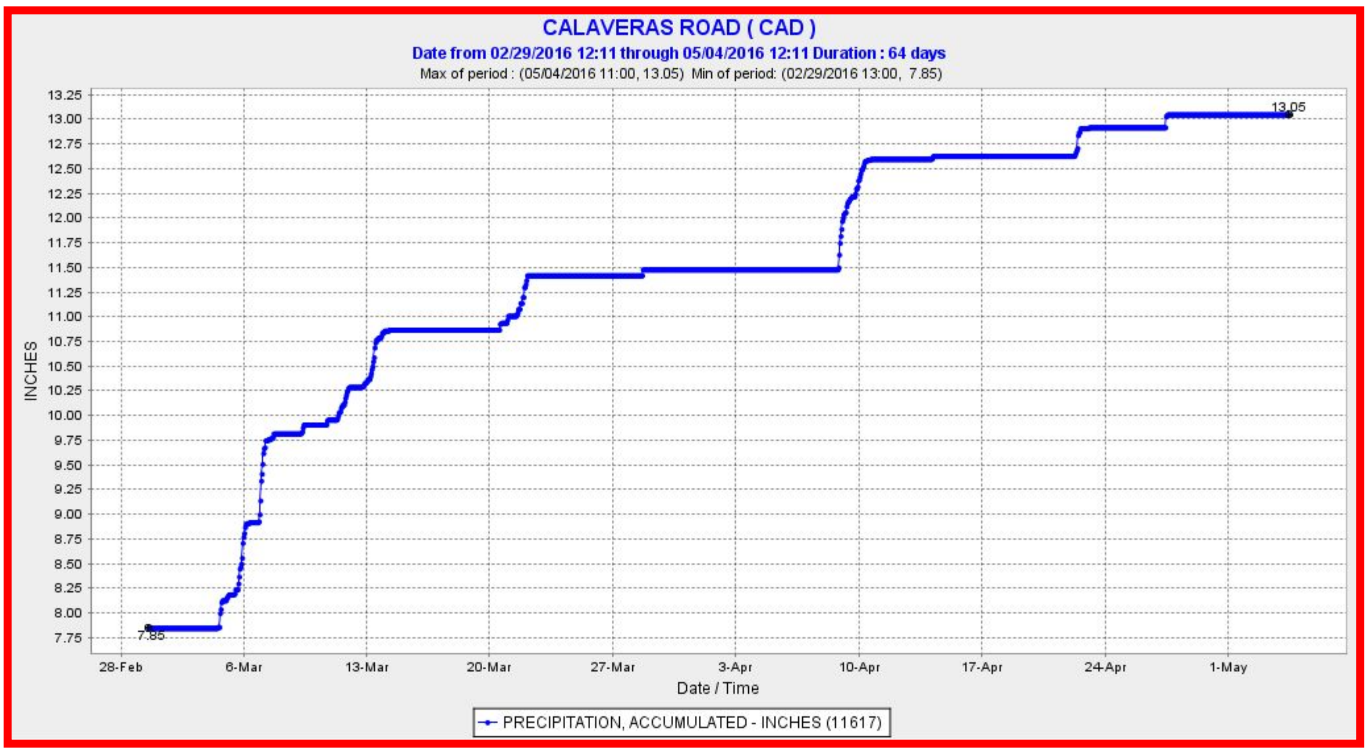
Balance Hydrologics, Inc.

216034_Lndscp-Figs.pptx

Figure 2. **Location of infiltration sites on Reach-B along Arroyo del Valle (dashed blue line), CEMEX Eliot Facility, Alameda County, California, March 28, 2016. South test sites (S1 and S2) reflect spoil soil material, north test sites (N1 and N2) reflect native soil material.**

Source: Google Maps

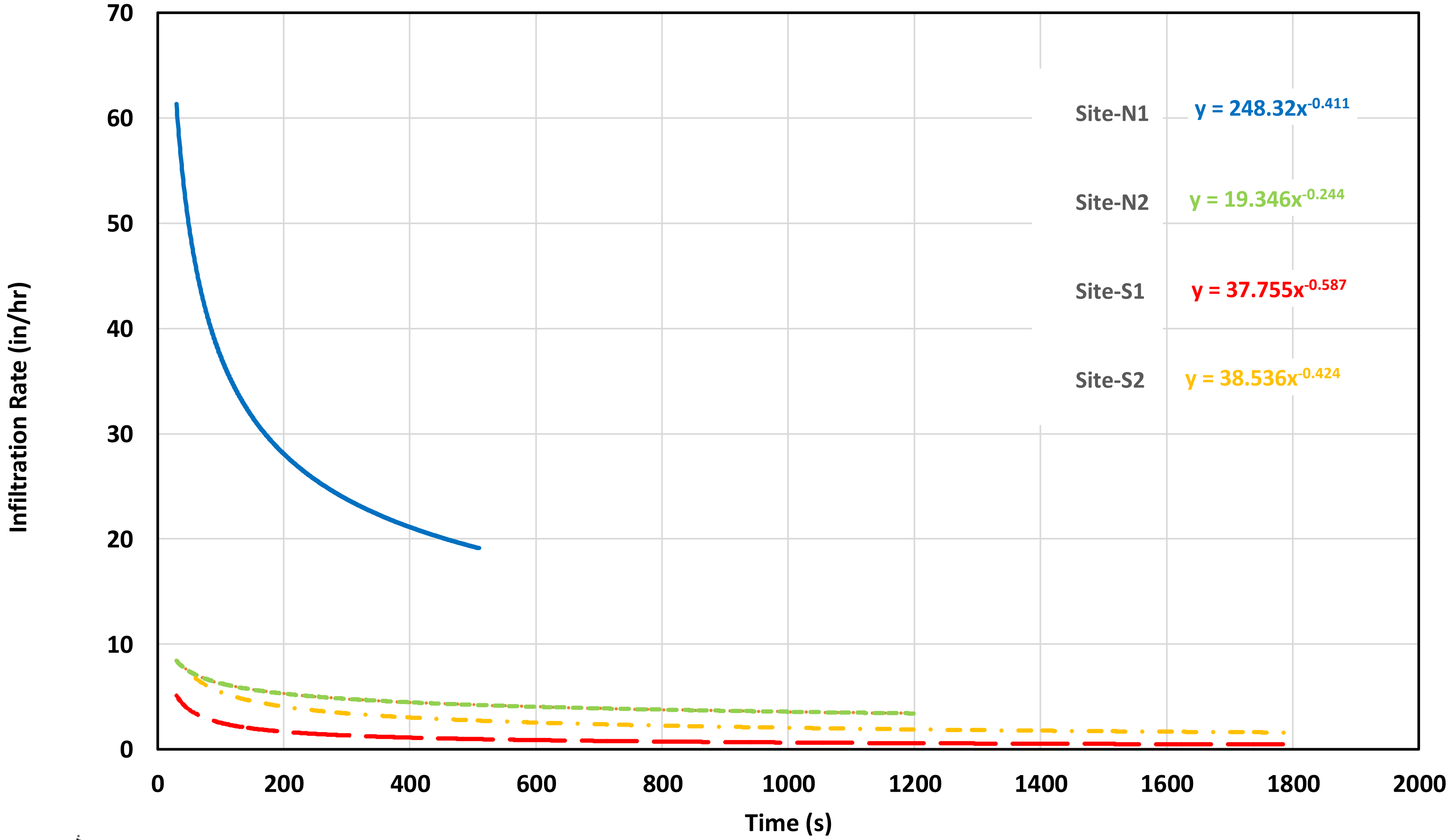




Balance Hydrologics, Inc.

215184 Protrait_Figs-2.pptx

Figure 3. **Charts illustrating the accumulated precipitation for the Dublin-San Ramon Fire House (DBF) gage (top) and the Calaveras Road (CAD) gage (bottom) from March 1, 2016 through May 4, 2016. Data obtained from the California Department of Water Resources Data Exchange Center (CDEC). Both gages located within 10 miles of the project site.**



Balance Hydrologics, Inc.

Figure 4 **Infiltration rates at four (4) sites: N1 (solid blue line), N2 (dotted green line), S1 (short dashed gold line), and S2 (long dashed red line) along Reach-B on Arroyo del Valle at the CEMEX Eliot Facility, Alameda County, California.**

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APPENDIX A

Summary of Infiltration Tests for Sites: N1, N2, S1, and S2

Appendix A. Summary of infiltration tests for sites: N1, N2, S1, and S2. CEMEX Eliot Facility, Arroyo del Valle, Alameda County, California

Project Number/Name: **216034_Arroyo del Valle Infiltration**
Location: **Site-N1**
Date: **28-Mar-16**

Observation	Time (sec)	Depth (in)	Rate (in/hr)
0	0	7.00	NA
1	30	6.50	60.0
2	60	6.10	48.0
3	90	5.80	36.0
4	120	5.50	36.0
5	150	5.25	30.0
6	180	5.00	30.0
7	210	4.75	30.0
8	240	4.50	30.0
9	270	4.30	24.0
10	300	4.10	24.0
11	330	3.90	24.0
12	360	3.75	18.0
13	390	3.55	24.0
14	420	3.40	18.0
15	450	3.25	18.0
16	480	3.10	18.0
17	510	2.90	24.0
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Time (sec)	Depth (cm)	Rate (cm/hr)
0	17.780	NA
30	16.510	152.4
60	15.494	121.9
90	14.732	91.4
120	13.970	91.4
150	13.335	76.2
180	12.700	76.2
210	12.065	76.2
240	11.430	76.2
270	10.922	61.0
300	10.414	61.0
330	9.906	61.0
360	9.525	45.7
390	9.017	61.0
420	8.636	45.7
450	8.255	45.7
480	7.874	45.7
510	7.366	61.0

Time (sec)	Depth (inch)	Rate (in/hr)
0	7.00	NA
30	6.50	60.0
60	6.10	48.0
90	5.80	36.0
120	5.50	36.0
150	5.25	30.0
180	5.00	30.0
210	4.75	30.0
240	4.50	30.0
270	4.30	24.0
300	4.10	24.0
330	3.90	24.0
360	3.75	18.0
390	3.55	24.0
420	3.40	18.0
450	3.25	18.0
480	3.10	18.0
510	2.90	24.0

Location: **Site-N2**
Date: **28-Mar-16**

Observation	Time (sec)	Depth (in)	Rate (in/hr)	Time (sec)	Depth (cm)	Rate (cm/hr)
0	0	7.10	NA	0	18.0	NA
1	30	6.98	15.00	30	17.7	38.10
2	60	6.90	9.00	60	17.5	22.86
3	90	6.81	10.80	90	17.3	27.43
4	120	6.80	1.20	120	17.3	3.05
5	150	6.75	6.00	150	17.1	15.24
6	180	6.70	6.00	180	17.0	15.24
7	240	6.65	3.00	240	16.9	7.62
8	300	6.55	6.00	300	16.6	15.24
9	360	6.52	1.80	360	16.6	4.57
10	420	6.40	7.20	420	16.3	18.29
11	480	6.31	5.40	480	16.0	13.72
12	540	6.21	6.00	540	15.8	15.24
13	600	6.15	3.60	600	15.6	9.14
14	660	6.05	6.00	660	15.4	15.24
15	720	6.00	3.00	720	15.2	7.62
16	780	5.92	4.80	780	15.0	12.19
17	840	5.90	1.20	840	15.0	3.05
18	900	5.80	6.00	900	14.7	15.24
19	960	5.75	3.00	960	14.6	7.62
20	1020	5.69	3.60	1020	14.5	9.14
21	1080	5.60	5.40	1080	14.2	13.72
22	1140	5.53	4.20	1140	14.0	10.67
23	1200	5.46	4.20	1200	13.9	10.67
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Location: Site-S1
Date: 28-Mar-16

Observation	Time (sec)	Depth (in)	Rate (in/hr)		Time (sec)	Depth (cm)	Rate (cm/hr)
0	0	1.00	NA		0	2.5	NA
1	30	0.95	6.00		30	2.4	15.24
2	60	0.93	2.40		60	2.4	6.10
3	90	0.91	2.40		90	2.3	6.10
4	120	0.90	1.20		120	2.3	3.05
5	180	0.85	3.00		180	2.2	7.62
6	240	0.80	3.00		240	2.0	7.62
7	300	0.78	1.20		300	2.0	3.05
8	360	0.73	3.00		360	1.9	7.62
9	420	0.71	1.20		420	1.8	3.05
10	480	0.70	0.60		480	1.8	1.52
11	540	0.69	0.60		540	1.8	1.52
12	600	0.68	0.60		600	1.7	1.52
13	720	0.61	2.10		720	1.5	5.33
14	840	0.60	0.30		840	1.5	0.76
15	960	0.58	0.60		960	1.5	1.52
16	1080	0.52	1.80		1080	1.3	4.57
17	1200	0.51	0.30		1200	1.3	0.76
18	1500	0.49	0.24		1500	1.2	0.61
19	1800	0.42	0.84		1800	1.1	2.13
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Location: Site-S2

Date: 28-Mar-16

Observation	Time (sec)	Depth (in)	Rate (in/hr)	Time (sec)	Depth (cm)	Rate (cm/hr)
0	0	2.00	NA	0	5.08	NA
1	60	1.75	15.00	60	4.45	38.10
2	120	1.63	7.20	120	4.14	18.29
3	180	1.59	2.40	180	4.04	6.10
4	240	1.51	4.80	240	3.84	12.19
5	300	1.48	1.80	300	3.76	4.57
6	360	1.42	3.60	360	3.61	9.14
7	420	1.40	1.20	420	3.56	3.05
8	480	1.35	3.00	480	3.43	7.62
9	540	1.31	2.40	540	3.33	6.10
10	600	1.29	1.20	600	3.28	3.05
11	660	1.23	3.60	660	3.12	9.14
12	720	1.20	1.80	720	3.05	4.57
13	840	1.11	2.70	840	2.82	6.86
14	900	1.08	1.80	900	2.74	4.57
15	1200	0.90	2.16	1200	2.29	5.49
16	1500	0.68	2.64	1500	1.73	6.71
17	1800	0.41	3.24	1800	1.04	8.23
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Appendix G: Arroyo del Valle Maps

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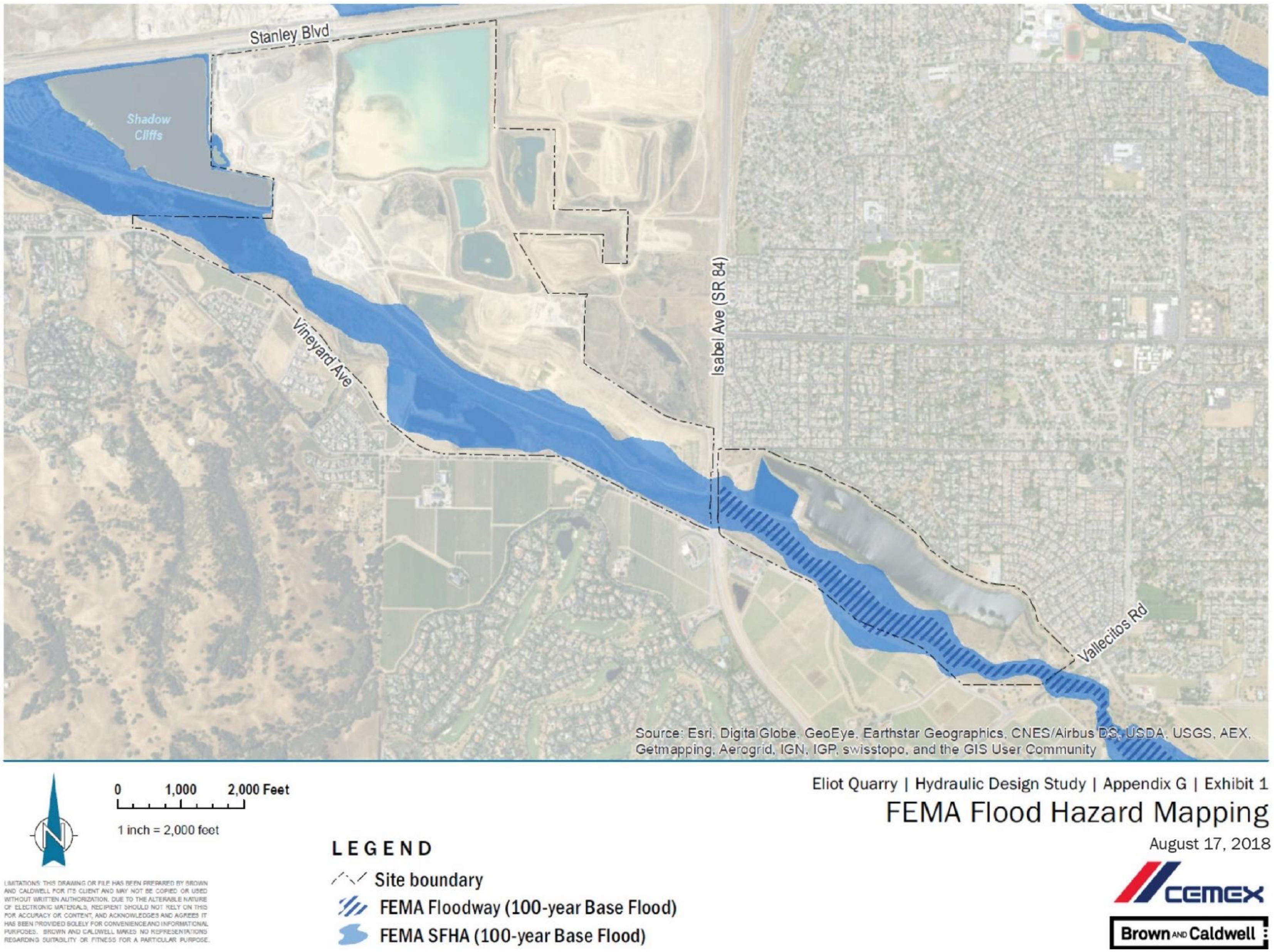
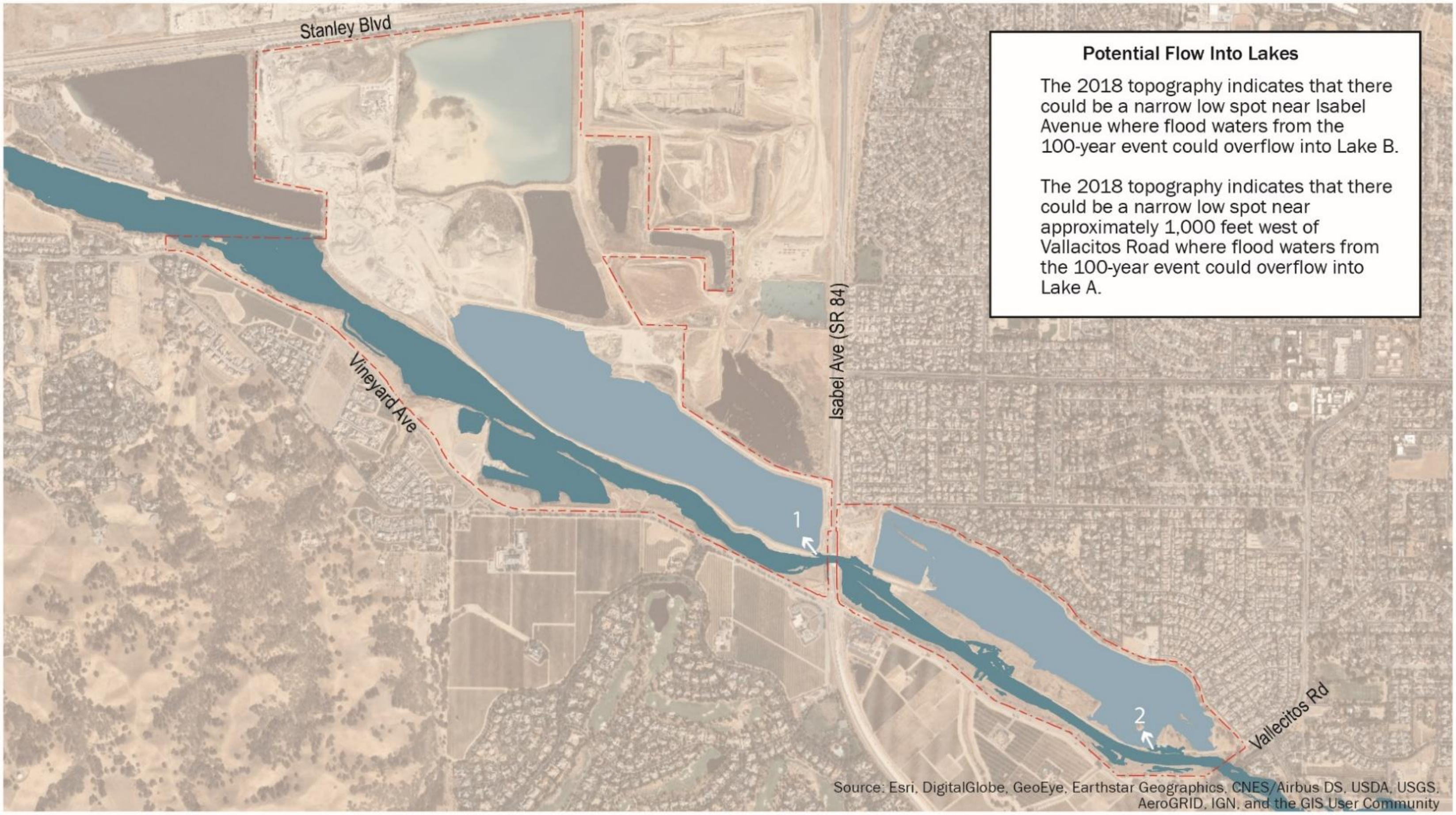

Stanley Blvd
Shadow Cliffs
Vineyard Ave
Isabel Ave (SR 84)
Vallecitos Rd
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
0 1,000 2,000 Feet
1 inch = 2,000 feet
LIMITATIONS: THIS DRAWING OR FILE HAS BEEN PREPARED BY BROWN AND CALDWELL FOR ITS CLIENT AND MAY NOT BE COPIED OR USED WITHOUT WRITTEN AUTHORIZATION. DUE TO THE ALTERABLE NATURE OF ELECTRONIC MATERIALS, RECIPIENT SHOULD NOT RELY ON THIS FOR ACCURACY OR CONTENT, AND ACKNOWLEDGES AND AGREES IT HAS BEEN PROVIDED SOLELY FOR CONVENIENCE AND INFORMATIONAL PURPOSES. BROWN AND CALDWELL MAKES NO REPRESENTATIONS REGARDING SUITABILITY OR FITNESS FOR A PARTICULAR PURPOSE.
LEGEND
Site boundary
FEMA Floodway (100-year Base Flood)
FEMA SFHA (100-year Base Flood)
Eliot Quarry | Hydraulic Design Study | Appendix G | Exhibit 1
FEMA Flood Hazard Mapping
August 17, 2018



0' 1,200 2,400 ft

LEGEND

- Site boundary
- 100-year inundation
- Peak lake level

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Existing Conditions Inundation Mapping

August 17, 2018

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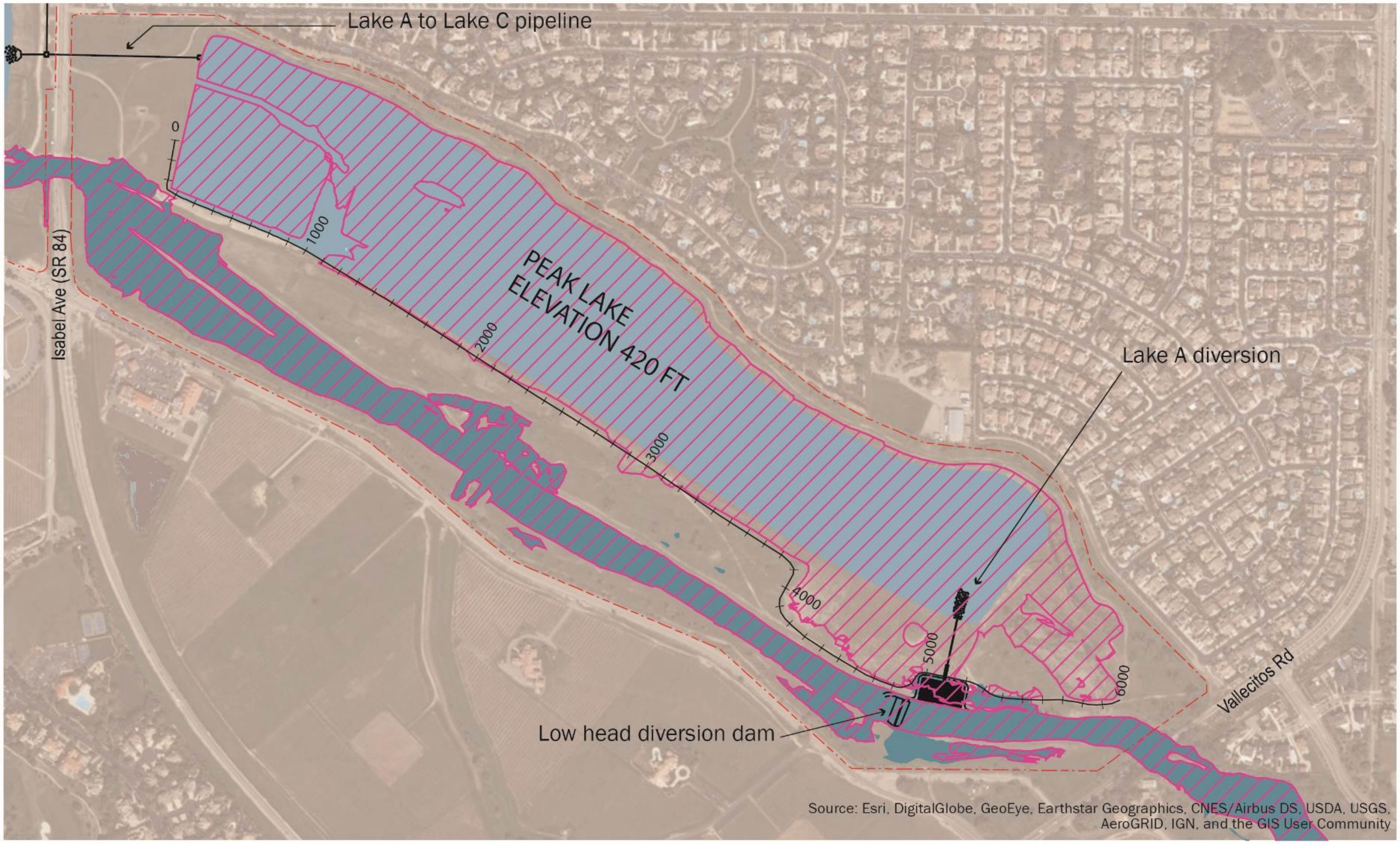
Proposed Conditions Inundation Mapping

August 17, 2018

0' 1,200 2,400 ft

LEGEND

- Site boundary
- Berm alignment
- 100-year inundation
- Peak lake level



Eliot Quarry | Hydraulic Design Study | Appendix G | Exhibit 4

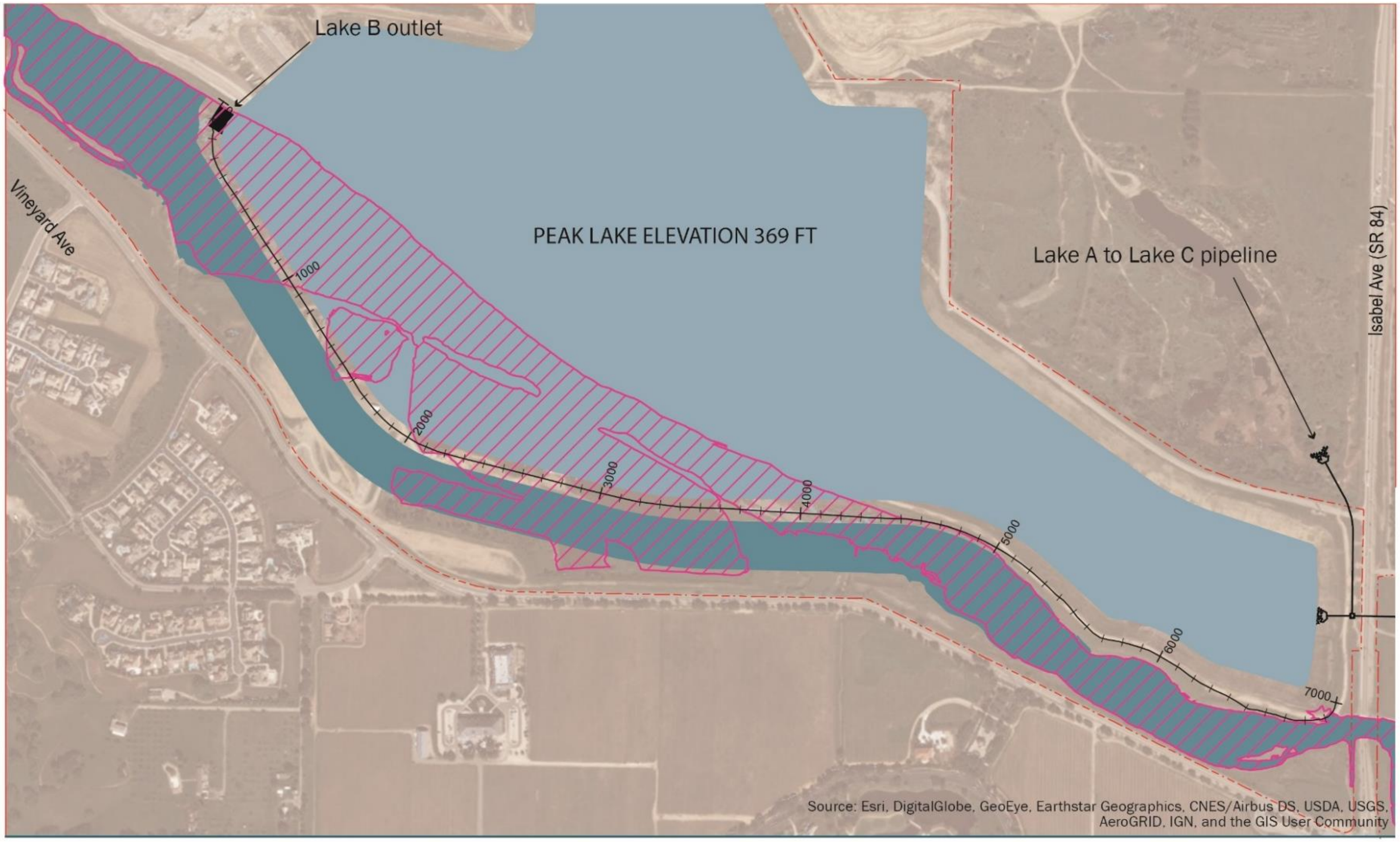
Proposed Conditions Inundation Mapping at Lake A

August 17, 2018

0 500 1,000 FT

LEGEND

- Site Boundary
- Berm Alignment
- Existing Conditions 100-year Inundation
- Proposed Conditions 100-year Inundation
- Proposed Conditions Peak Lake Level



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Proposed Conditions Inundation Mapping at Lake B

August 17, 2018

LEGEND

- Site Boundary
- Berm Alignment
- Existing Conditions 100-year Inundation
- Proposed Conditions 100-year Inundation
- Proposed Conditions Peak Lake Level

CEMEX

Brown AND Caldwell

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Appendix H: Magnitude-Frequency Analysis

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Appendix H

A Model for Geomorphic Evolution

Although observations from catastrophic events often suggest that infrequent events of immense magnitude tend to drive geomorphic processes such as stream channel formation, this is typically not the case. Wolman and Miller described how the geomorphic evolution of landscapes is strongly influenced by the amount of “work” done by forces acting on the system (e.g., shear forces caused by flowing water), and that the relative amount of work done depends not only on the magnitude of the force, but also on the frequency of occurrence (Wolman and Miller 1960).

Figure D-1 is a graphical representation of the “work done” concept, where the frequency of occurrence is log-normally distributed and the magnitude of the influencing force (i.e., applied stress) increases in accordance with a mathematical power function. The product of the frequency of the occurrences and the magnitude of the influencing force is referred to as the “effective work” curve (noted “c” in Figure D-2). The relationship shown in Figure D-2 illustrates how frequent mid-range events do more effective work than extremely large, relatively rare events.

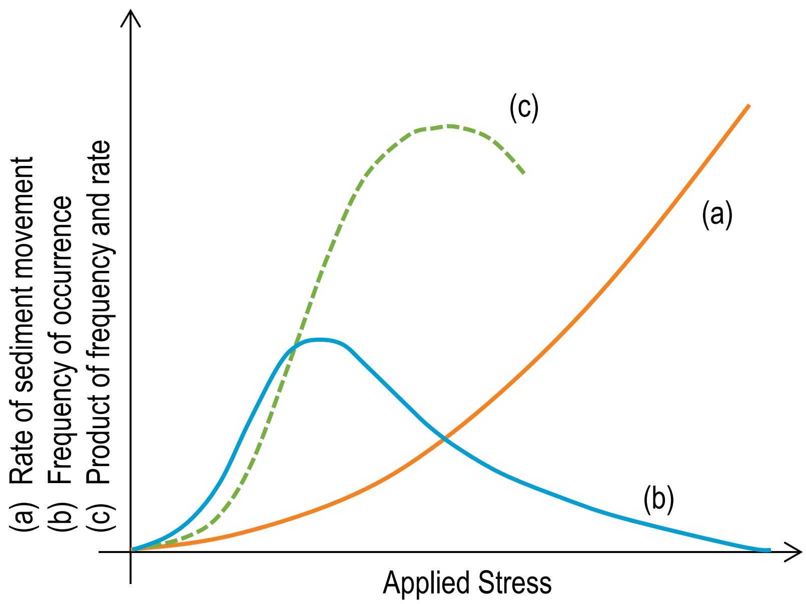

Figure G-1. Relation between applied stress and frequency of occurrence in geomorphic processes

Adapted from Wolman and Miller (1960).

Magnitude-Frequency Analysis

Practical application of the effective work concept is sometimes referred to as magnitude-frequency analysis (MFA) (Soar and Thorne 2001). Bledsoe et al. describe MFA as a fundamental tool for fluvial stream assessment (Bledsoe et al. 2007). MFA can be used to define the “effective discharge” for a stream, which is the flow rate corresponding to the maximum work on the effectiveness curve (Bledsoe et al. 2007). The effective discharge is roughly equivalent to the channel-forming (or bankfull) discharge as defined by Leopold et al. (Leopold et al. 1964).

MFA can also be used to define geomorphically significant flows, or the range of flow rates over which a substantial portion of the channel-forming work is done. Leopold et al. describe geomorphically significant flows as the range of flow rates occurring between a lower limit of competence (critical stress necessary for grain movement) and an upper limit at which flow is no longer confined to the channel (i.e., greater than bankfull discharge) (Leopold et al. 1964). Figure D-2 shows a modified version of the effective work graphic where MFA is used to define geomorphic parameters such as effective discharge and a range of geomorphically significant flows for a stream.

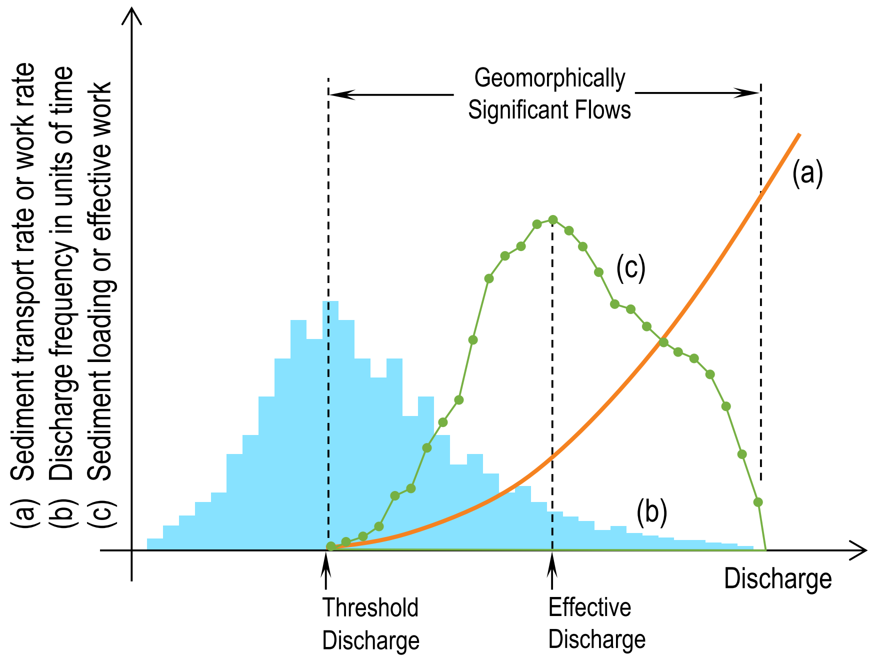

Figure G-2. Schematic representation of MFA results used to define geomorphic parameters

Note that the discharge frequency distribution for a stream (curve “b” in Figure D-1) is developed using a series of discrete discharge bins. The value at each point in the discharge frequency curve represents the amount of time (e.g., hours per year) stream discharges fall within the specified bin range. The size of the bins can be variable as long as the distribution of discharges is adequately represented.

The rate-of-movement curve (curve “a” in Figure D-1) can be calculated by either a sediment transport function or an equivalent work rate function. In either case, the curve represents the rate at which sediment is mobilized for any given stream discharge (higher discharge rates result in greater mobilization for the particle sizes evaluated). Multiplying stream discharge rates by sediment transport rates (or effective work rates) provides results in terms of total sediment load or total effective work (units of mass mobilized or units of work per year). This is represented by curve “c” on Figure D-1.

Computational Considerations

The development of flow frequency distribution data requires careful attention because the methods used to prepare these data are of critical importance to MFA evaluations. Flow hydrographs were processed into flow distribution histograms by summing the number of time steps for which stream flow values fall within specified ranges of flows, or discrete flow “bins.” Soar and Thorne provide a detailed discussion on how the number and distribution of flow bins can greatly influence MFA results, thus requiring careful selection, and possibly sensitivity testing, to determine the most appropriate method (Soar and Thorne 2001).

Logarithmically distributed flow bins have an advantage over arithmetically distributed (i.e., evenly spaced) flow bins in that stream flows tend to be log-normally distributed, and a larger number of flow bins in the low flow ranges can great improve the resolution of the distribution. However, logarithmically distributed flow bins can introduce bias to the estimation of parameters such as effective discharge, as described by Soar and Thorne:

> If the discharge interval systematically increases, as in a logarithmic scale, then the resultant sample frequency distribution is incorrectly skewed in the negative direction (or misrepresented by exaggeration). As a direct result, the product of sediment load and frequency will tend to follow a similar trend. This is intuitive because in MFA, the sediment load transported by the mean discharge of a class is multiplied by a frequency corresponding to the probability of falling within that class. This probability increases with class size. With logarithmic class intervals, the systematic increase in the size of class interval with increasing discharge will overestimate the effective discharge. (Soar and Thorne 2001)

However, additional investigations and sensitivity testing found that logarithmically distributed flow bins produced satisfactory results due to the following conditions:

- *Discharges in Arroyo del Valle and tributaries are fairly stable, which minimizes the potential error.* Soar and Thorne’s exploration of the “misrepresentation error” resulting from the above-described bias found that potential errors are greatest for streams with highly variable flow regimes and least for more stable flow regimes (Soar and Thorne 2001). Examining the standard deviation of the natural logarithm of discharges found that stream flows downstream of Del Valle Reservoir are moderately stable.
- *A large number of bins (i.e., 200) could be used while still maintaining a well-defined distribution curve, which reduces approximation error.* Increasing the number of flow bins decreases the bin size, improves resolution, and provides improved estimates of geomorphic parameters such as effective discharge. However, if bin sizes are too small, there could be bins with zero records. Soar and Thorne recommends that flow bins be large enough to avoid zero values and maintain a continuous flow distribution curve (Soar and Thorne 2001).
- *Arithmetic bins resulted in poor resolution at low discharges.* Even with as many as 200 arithmetically distributed flow bins, a substantial portion of flow distribution curves tended to fall within the first one or two bins. Logarithmically distributed flow bins provided additional detail that can be used to examine relative differences resulting from small changes in flow regime.

Appendix H References

Bledsoe, B.P. and C.C. Watson. April 2001. “Effects of Urbanization on Channel Stability.” Journal of the American Water Resources Association; Vol. 37, No. 2, p. 255–270.

Chow, V.T. 1959. *Open-channel Hydraulics*. New York: McGraw-Hill. p108-114.

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Soar, P.J. and C.R. Thorne. 2001. *Channel Restoration Design for Meandering Rivers*. ERDC/CHL CR-01-1, 416, Engineer Research and Development Center, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

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Appendix I: HEC-RAS Model Results

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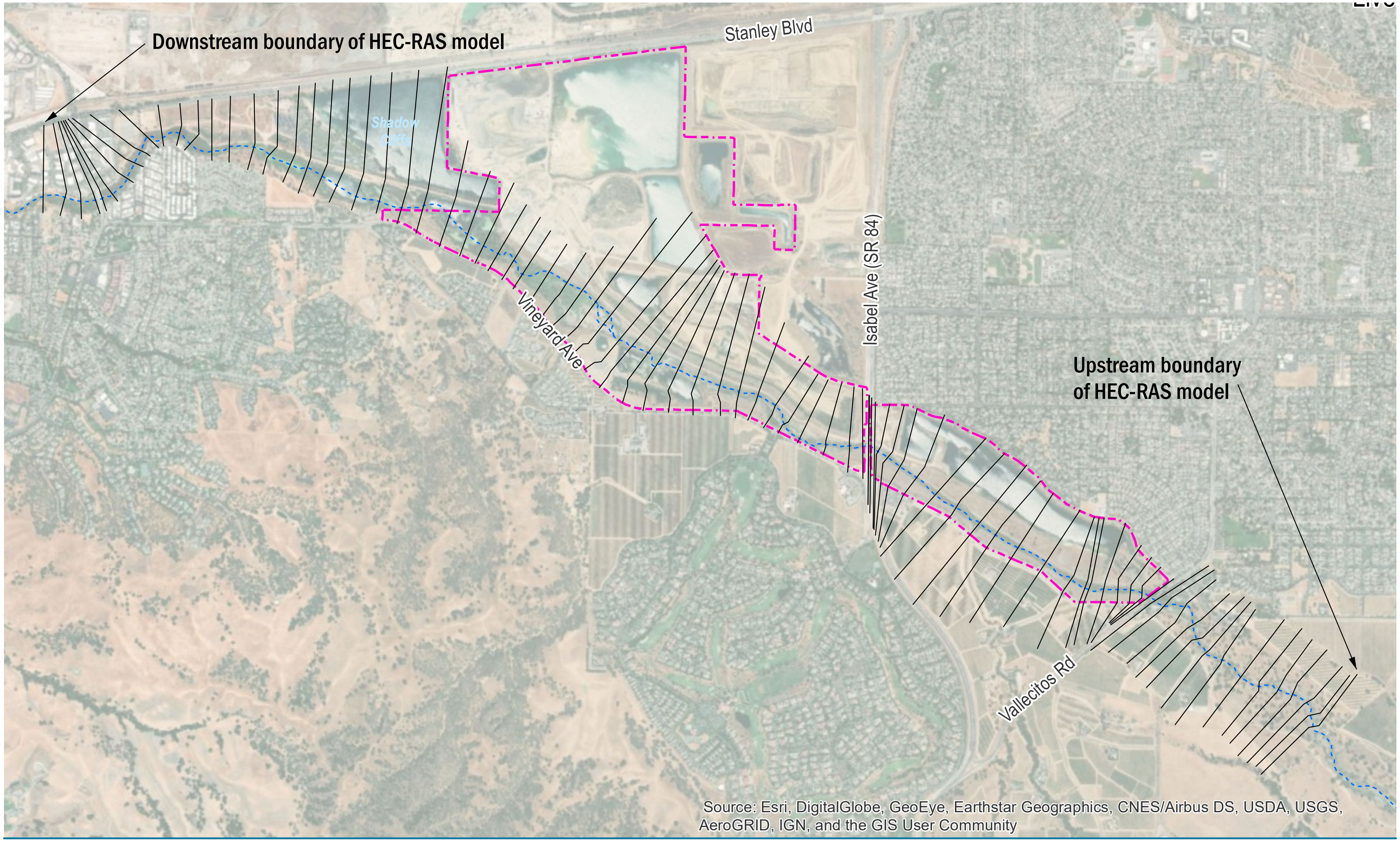

0 0.5 Miles

1 inch = 0.5 miles

LEGEND

- Cross-sections
- Site boundary
- Existing Stream

Eliot Quarry | Hydraulic Design Study | Appendix I | Exhibit 1

Cross-section Locations and HEC-RAS Model Extent

August 17, 2018

CEMEX

Brown AND Caldwell

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Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30040	010YR	1860	1761.08	466.44	0.02100	470.02	470.89	0.01347	1.95	1.94	118.18	229.55	0.97	7.67	12.54	1.63
main	29819	010YR	1860	1859.93	461.78	0.00620	467.94	468.56	0.00518	3.03	2.96	99.68	295.20	0.64	6.30	6.03	0.96
main	29546	010YR	1860	1851.70	460.08	-0.00170	466.68	467.28	0.00424	3.45	3.40	87.20	296.39	0.59	6.25	5.62	0.90
main	29236	010YR	1860	1539.13	460.61	0.00290	465.39	465.82	0.00450	2.88	2.85	94.48	268.97	0.59	5.72	4.58	0.80
main	28946	010YR	1860	1767.36	459.76	0.01150	463.30	463.95	0.00990	1.96	1.95	137.98	268.45	0.83	6.58	7.92	1.20
main	28559	010YR	1860	1817.71	455.32	0.00250	461.37	461.84	0.00335	3.43	3.39	96.86	328.11	0.53	5.54	3.92	0.71
main	28162	010YR	1860	1704.88	454.33	0.00480	460.00	460.44	0.00373	3.16	3.12	98.76	308.08	0.55	5.53	4.02	0.73
main	27666	010YR	1860	1856.22	451.96	0.01220	455.95	457.21	0.01301	2.57	2.55	80.68	205.51	0.99	9.03	18.69	2.07
main	27322	010YR	1860	1858.83	447.74	-0.00100	454.17	454.62	0.00313	3.47	3.42	100.96	345.13	0.51	5.39	3.59	0.67
main	26994	010YR	1860	1845.29	448.07	0.00690	452.05	452.94	0.00910	2.59	2.57	94.46	242.80	0.83	7.60	11.10	1.46
main	26712	010YR	1860	1660.75	446.12	0.00880	450.44	450.99	0.00497	3.08	3.05	86.30	263.54	0.63	6.30	5.97	0.95
main	26291	010YR	1860	1667.82	442.40	0.00760	446.89	447.90	0.01201	2.49	2.46	79.88	196.61	0.95	8.48	15.66	1.85
main	25868	010YR	1860	1860.00	439.19	0.00080	444.93	445.19	0.00202	3.16	3.14	144.44	454.16	0.41	4.10	1.62	0.40
main	25665	010YR	1860	1860.00	439.02	0.00000	444.22	444.60	0.00404	2.49	2.47	153.12	377.67	0.55	4.92	3.06	0.62
main	25597		Bridge														
main	25528	010YR	1860	1860.00	438.99	0.00480	443.42	443.67	0.00217	2.91	2.90	159.53	462.32	0.42	4.02	1.58	0.39
main	25373	010YR	1860	1860.00	438.25	0.00960	441.97	442.84	0.01067	2.26	2.23	111.04	248.13	0.88	7.50	11.16	1.49
main	25145	010YR	1860	1860.00	436.05	0.00120	440.33	441.01	0.00569	2.99	2.96	95.16	281.68	0.67	6.60	6.95	1.05
main	24905	010YR	1860	1860.00	435.76	0.00710	439.27	439.71	0.00460	2.52	2.51	138.88	349.19	0.59	5.33	3.85	0.72
main	24632	010YR	1860	1860.00	433.84	0.00950	436.65	437.62	0.01437	1.95	1.94	121.10	234.97	1.00	7.92	13.77	1.74
main	24337	010YR	1860	1860.00	431.03	0.00400	434.08	434.61	0.00606	2.35	2.34	136.32	319.18	0.67	5.83	5.16	0.89
main	24257	010YR	1860	1860.00	430.71	0.01190	433.72	434.16	0.00455	2.57	2.55	136.18	347.74	0.59	5.35	3.88	0.73
main	23941	010YR	1860	1860.00	426.97	0.00310	432.16	432.71	0.00456	3.02	2.99	104.59	312.63	0.60	5.95	5.06	0.85
main	23337	010YR	1860	1860.00	425.11	0.00560	428.89	429.53	0.00609	2.73	2.72	106.19	288.47	0.69	6.45	6.65	1.03
main	22741	010YR	1860	1860.00	421.76	0.00400	425.72	426.24	0.00494	2.75	2.73	116.89	319.20	0.62	5.83	4.90	0.84
main	22245	010YR	1860	1860.00	419.78	0.00490	423.86	424.23	0.00324	2.88	2.86	133.18	381.42	0.51	4.88	2.83	0.58
main	21864	010YR	1860	1860.00	417.92	0.00920	420.93	421.91	0.01419	1.98	1.97	119.00	234.20	1.00	7.94	13.85	1.74
main	21309	010YR	1860	1860.00	412.81	0.00190	417.91	418.35	0.00339	3.19	3.17	110.25	349.00	0.53	5.33	3.57	0.67
main	20841	010YR	1860	1860.00	411.91	0.00630	415.41	416.14	0.00682	2.74	2.73	99.58	271.73	0.73	6.85	7.95	1.16
main	20357	010YR	1860	1860.00	408.84	0.00780	412.84	413.40	0.00463	3.01	2.99	103.66	310.18	0.61	6.00	5.18	0.86
main	19981	010YR	1860	1860.00	405.92	0.00400	409.94	410.85	0.01049	2.34	2.33	104.61	243.54	0.88	7.64	11.64	1.52
main	19692	010YR	1860	1860.00	404.76	0.00560	408.88	409.23	0.00295	2.95	2.94	133.62	392.91	0.49	4.73	2.56	0.54
main	19474	010YR	1860	1860.00	403.53	0.00490	407.62	408.28	0.00647	2.65	2.63	108.58	285.73	0.71	6.51	6.92	1.06
main	19394	010YR	1860	1860.00	403.14	0.00890	407.57	407.86	0.00246	2.93	2.92	148.32	432.46	0.44	4.30	1.93	0.45
main	19319	010YR	1860	1860.00	402.47	0.00000	407.28	407.64	0.00295	3.00	2.98	130.43	389.19	0.49	4.78	2.63	0.55
main	19299		Bridge														
main	19279	010YR	1860	1860.00	402.11	0.01000	407.06	407.46	0.00334	2.98	2.97	123.76	367.03	0.52	5.07	3.14	0.62
main	19274	010YR	1860	1860.00	402.06	0.00000	407.04	407.44	0.00339	2.98	2.96	123.05	364.56	0.52	5.10	3.20	0.63
main	19220		Bridge														
main	19150	010YR	1860	1860.00	400.96	0.00740	405.46	406.58	0.01432	2.18	2.16	101.17	218.89	1.02	8.50	16.43	1.93
main	18884	010YR	1860	1860.00	398.98	0.00920	402.81	403.55	0.00733	2.64	2.61	103.16	269.71	0.75	6.90	8.25	1.20
main	18420	010YR	1860	1860.00	394.72	0.00790	400.19	400.81	0.00469	3.22	3.19	92.63	295.42	0.62	6.30	5.87	0.93
main	17851	010YR	1860	1860.00	390.20	-0.00130	396.30	397.29	0.00836	3.00	2.93	79.98	234.11	0.81	7.94	12.14	1.53
main	17432	010YR	1860	1773.74	390.76	0.00760	394.66	395.03	0.00328	2.97	2.96	119.80	354.12	0.51	5.01	3.03	0.61
main	17028	010YR	1860	1855.32	387.70	0.00190	392.64	393.31	0.00558	3.03	2.99	94.35	282.03	0.67	6.58	6.85	1.04
main	16619	010YR	1860	1847.37	386.94	0.00900	390.34	390.86	0.00623	2.27	2.26	141.41	319.89	0.68	5.78	5.08	0.88
main	16273	010YR	1860	1860.00	383.84	0.00330	388.50	388.89	0.00502	2.17	2.17	170.68	369.56	0.60	5.03	3.41	0.68
main	15808	010YR	1860	1860.00	382.29	0.00670	386.09	386.42	0.00556	1.76	1.76	229.92	403.74	0.61	4.61	2.81	0.61
main	15358	010YR	1860	1860.00	379.27	0.00460	383.80	384.16	0.00454	2.19	2.18	177.51	386.94	0.57	4.81	2.97	0.62
main	15023	010YR	1860	1860.00	377.74	0.01320	380.75	381.55	0.01552	1.59	1.58	163.41	258.83	1.00	7.19	11.03	1.53

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	14502	010YR	1860	1689.66	370.87	-0.00710	378.57	378.63	0.00051	3.12	3.10	266.88	827.13	0.20	2.04	0.20	0.10
main	14067	010YR	1860	1860.00	373.94	0.00800	377.02	377.93	0.01248	2.08	2.05	118.44	242.94	0.94	7.66	12.23	1.60
main	13722	010YR	1860	1860.00	371.18	0.00660	374.93	375.19	0.00487	1.64	1.63	277.68	453.01	0.57	4.11	2.04	0.50
main	13445	010YR	1860	1860.00	369.36	0.00770	372.28	372.84	0.01752	1.10	1.10	283.40	311.06	1.01	5.98	7.18	1.20
main	13042	010YR	1860	1583.52	366.24	0.00290	371.50	371.61	0.00090	3.24	3.23	176.22	569.54	0.27	2.78	0.50	0.18
main	12550	010YR	1860	1860.00	364.83	0.00590	369.70	370.59	0.00705	3.16	3.10	79.13	245.40	0.75	7.58	10.34	1.36
main	12210	010YR	1860	1860.00	362.84	0.00440	366.36	367.07	0.01614	1.41	1.40	196.77	275.53	1.00	6.75	9.52	1.41
main	11840	010YR	1860	1535.83	361.22	0.00500	364.35	364.54	0.00317	2.04	2.04	196.10	399.76	0.47	3.84	1.55	0.40
main	11439	010YR	1860	1579.63	359.22	0.01760	361.71	362.19	0.01444	1.28	1.28	206.25	263.21	0.94	6.00	6.90	1.15
main	10998	010YR	1860	1858.83	351.45	0.00400	358.02	358.45	0.00314	3.37	3.34	104.85	349.88	0.51	5.31	3.48	0.65
main	10636	010YR	1860	1860.00	349.99	0.00240	357.59	357.81	0.00097	4.85	4.76	104.37	496.41	0.30	3.75	1.08	0.29
main	10222	010YR	1860	1829.04	349.00	-0.00190	356.60	357.09	0.00349	3.47	3.41	94.56	322.18	0.54	5.68	4.21	0.74
main	9912	010YR	1860	1206.85	349.60	0.01720	356.83	356.85	0.00011	5.36	5.34	164.45	878.34	0.10	1.37	0.05	0.04
main	9542	010YR	1860	1800.10	343.24	0.00010	356.84	356.84	0.00000	11.97	11.96	724.50	8665.26	0.01	0.21	0.00	0.00
main	9056	010YR	1860	1859.77	343.21	-0.00290	356.84	356.84	0.00000	11.78	11.71	609.24	7135.57	0.01	0.26	0.00	0.00
main	8465	010YR	1860	1810.11	344.90	-0.00100	356.83	356.84	0.00001	11.07	10.88	215.15	2341.13	0.04	0.77	0.01	0.01
main	8046	010YR	1860	1860.00	345.34	0.00010	356.55	356.80	0.00065	7.57	6.95	67.69	470.52	0.25	3.95	1.12	0.28
main	7601	010YR	1860	1666.20	345.30	0.01220	356.67	356.69	0.00003	9.72	9.66	153.15	1478.70	0.06	1.13	0.02	0.02
main	7146	010YR	1860	1847.56	339.73	-0.00090	356.68	356.68	0.00000	15.00	14.95	432.47	6464.14	0.01	0.29	0.00	0.00
main	6727	010YR	1860	1858.74	340.12	-0.01330	356.68	356.68	0.00000	14.12	13.99	423.29	5920.48	0.01	0.31	0.00	0.00
main	6395	010YR	1860	1826.17	344.54	-0.00500	356.67	356.68	0.00001	11.13	11.01	268.61	2956.80	0.03	0.62	0.00	0.01
main	6072	010YR	1860	1735.08	346.15	-0.00180	356.63	356.67	0.00014	5.57	5.52	201.58	1111.72	0.12	1.56	0.07	0.05
main	5737	010YR	1860	1517.12	346.76	0.00110	356.62	356.64	0.00005	8.64	8.57	135.27	1158.68	0.08	1.31	0.04	0.03
main	5292	010YR	1860	1626.26	346.28	0.00360	356.52	356.59	0.00020	8.02	7.87	87.66	689.54	0.15	2.36	0.23	0.10
main	4956	010YR	1860	1854.00	345.07	-0.00220	356.39	356.51	0.00030	7.44	7.20	94.79	682.25	0.18	2.72	0.36	0.13
main	4489	010YR	1860	1834.69	346.10	0.00030	356.14	356.32	0.00052	6.76	6.55	82.47	540.04	0.23	3.40	0.73	0.21
main	4125	010YR	1860	1802.04	346.00	0.00100	356.16	356.21	0.00011	8.48	8.43	114.72	966.55	0.11	1.86	0.11	0.06
main	3664	010YR	1860	1685.42	345.56	0.00920	356.10	356.15	0.00012	8.29	8.16	107.58	877.86	0.12	1.92	0.12	0.06
main	3386	010YR	1860	1819.54	343.00	-0.01720	356.12	356.13	0.00001	11.38	11.29	218.96	2471.68	0.04	0.74	0.01	0.01
main	3010	010YR	1860	1822.29	349.45	0.01320	355.73	356.08	0.00274	3.22	3.19	118.90	378.93	0.47	4.81	2.62	0.54
main	2714	010YR	1860	1707.94	345.54	0.00290	355.74	355.83	0.00025	7.11	6.98	99.68	695.92	0.16	2.45	0.27	0.11
main	2423	010YR	1860	1782.03	344.70	-0.00920	355.67	355.76	0.00021	8.10	7.94	91.44	726.34	0.15	2.45	0.26	0.10
main	2164	010YR	1860	1681.82	347.09	0.00030	355.60	355.70	0.00030	6.65	6.58	98.72	649.35	0.18	2.59	0.32	0.12
main	1833	010YR	1860	1839.39	346.99	0.00090	355.46	355.58	0.00038	6.41	6.24	104.70	653.04	0.20	2.82	0.42	0.15
main	1422	010YR	1860	1381.96	346.60	-0.00350	355.21	355.37	0.00074	5.75	5.62	67.36	378.50	0.27	3.65	0.95	0.26
main	1198	010YR	1860	1658.07	347.39	0.00000	354.42	354.98	0.00243	5.44	5.29	49.39	261.14	0.48	6.35	5.09	0.80
main	1133		Bridge														
main	1068	010YR	1860	1641.25	349.56	0.02080	352.37	353.15	0.01119	2.18	2.18	100.05	217.65	0.90	7.54	11.46	1.52
main	764	010YR	1860	1716.45	343.22	-0.00820	351.06	351.26	0.00155	3.30	3.25	143.97	467.85	0.36	3.67	1.15	0.31
main	427	010YR	1860	1597.78	345.99	0.00310	350.35	350.62	0.00224	3.25	3.25	111.77	362.89	0.43	4.40	2.00	0.45
main	31	010YR	1860	1628.92	344.77		348.81	349.31	0.00500	2.87	2.86	94.10	269.23	0.63	6.05	5.40	0.89

Reach	River Sta	Profile	Q Total (cfs)	Q Channel (cfs)	Min Ch El (ft)	Invert Slope	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Hydr Depth C (ft)	Hydr Radius C (ft)	W.P. Channel (ft)	Flow Area Ch (sq ft)	Froude # Chl	Vel Chnl (ft/s)	Power Chan (lb/ft s)	Shear Chan (lb/sq ft)
main	30040	050YR	4150	3560.69	466.44	0.02100	471.26	472.44	0.01094	3.06	3.05	125.33	381.66	0.94	9.33	19.41	2.08
main	29819	050YR	4150	3968.51	461.78	0.00620	469.90	470.73	0.00502	3.98	3.91	136.22	532.15	0.66	7.46	9.12	1.22
main	29546	050YR	4150	3780.07	460.08	-0.00170	468.45	469.36	0.00500	4.44	4.38	107.37	470.33	0.67	8.04	10.99	1.37
main	29236	050YR	4150	3230.04	460.61	0.00290	466.67	467.50	0.00648	3.72	3.67	108.05	396.95	0.74	8.14	12.09	1.49
main	28946	050YR	4150	3707.76	459.76	0.01150	465.06	465.78	0.00539	3.54	3.50	147.62	516.43	0.67	7.18	8.44	1.18
main	28559	050YR	4150	3818.18	455.32	0.00250	463.26	463.98	0.00417	4.18	4.14	130.55	540.26	0.61	7.07	7.62	1.08
main	28162	050YR	4150	3344.37	454.33	0.00480	461.99	462.40	0.00343	3.45	3.42	173.62	593.04	0.54	5.64	4.12	0.73
main	27666	050YR	4150	3957.26	451.96	0.01220	457.89	459.58	0.00976	4.12	4.06	91.26	370.62	0.93	10.68	26.43	2.48
main	27322	050YR	4150	3923.78	447.74	-0.00100	456.10	456.86	0.00342	5.01	4.91	111.39	546.83	0.56	7.18	7.53	1.05
main	26994	050YR	4150	3946.76	448.07	0.00690	453.65	455.10	0.00888	3.94	3.89	102.63	399.04	0.88	9.89	21.31	2.15
main	26712	050YR	4150	3455.93	446.12	0.00880	451.85	452.89	0.00631	4.32	4.29	90.54	388.21	0.75	8.90	15.04	1.69
main	26291	050YR	4150	3275.33	442.40	0.00760	448.35	449.68	0.01010	3.80	3.75	84.85	318.15	0.93	10.29	24.33	2.36
main	25868	050YR	4150	4150.00	439.19	0.00080	446.69	447.19	0.00257	4.33	4.30	169.85	729.86	0.48	5.69	3.92	0.69
main	25665	050YR	4150	4150.00	439.02	0.00000	445.81	446.49	0.00407	3.87	3.82	164.52	627.82	0.59	6.61	6.40	0.97
main	25597		Bridge														
main	25528	050YR	4150	4150.00	438.99	0.00480	445.35	445.78	0.00210	4.55	4.52	172.82	780.31	0.44	5.32	3.15	0.59
main	25373	050YR	4150	4150.00	438.25	0.00960	443.97	445.06	0.00669	3.79	3.74	132.87	496.37	0.76	8.36	13.05	1.56
main	25145	050YR	4150	4150.00	436.05	0.00120	441.80	443.28	0.00797	4.18	4.12	103.33	425.99	0.84	9.74	19.97	2.05
main	24905	050YR	4150	4128.13	435.76	0.00710	440.85	441.64	0.00462	3.89	3.87	149.61	579.70	0.64	7.12	7.96	1.12
main	24632	050YR	4150	4150.00	433.84	0.00950	438.06	439.63	0.01231	3.13	3.11	133.07	413.68	1.00	10.03	23.96	2.39
main	24337	050YR	4150	4150.00	431.03	0.00400	435.95	436.73	0.00453	3.92	3.89	150.77	586.75	0.63	7.07	7.79	1.10
main	24257	050YR	4150	4150.00	430.71	0.01190	435.70	436.38	0.00354	4.25	4.21	149.34	629.37	0.56	6.59	6.15	0.93
main	23941	050YR	4150	4150.00	426.97	0.00310	434.11	435.06	0.00474	4.43	4.38	121.23	530.70	0.66	7.82	10.12	1.29
main	23337	050YR	4150	4150.00	425.11	0.00560	430.65	431.80	0.00617	4.18	4.14	116.68	482.73	0.74	8.60	13.71	1.59
main	22741	050YR	4150	4150.00	421.76	0.00400	427.49	428.42	0.00504	4.14	4.10	130.98	537.32	0.67	7.72	9.97	1.29
main	22245	050YR	4150	4135.97	419.78	0.00490	425.46	426.19	0.00382	4.30	4.27	140.52	599.44	0.59	6.90	7.02	1.02
main	21864	050YR	4150	4150.00	417.92	0.00920	422.65	423.95	0.00961	3.27	3.25	139.61	454.13	0.89	9.14	17.84	1.95
main	21309	050YR	4150	4150.00	412.81	0.00190	419.97	420.73	0.00357	4.62	4.58	129.76	593.71	0.57	6.99	7.13	1.02
main	20841	050YR	4150	4150.00	411.91	0.00630	417.35	418.50	0.00640	4.08	4.05	118.89	481.12	0.75	8.63	13.95	1.62
main	20357	050YR	4150	4150.00	408.84	0.00780	414.62	415.68	0.00521	4.48	4.42	113.60	502.54	0.69	8.26	11.88	1.44
main	19981	050YR	4150	4150.00	405.92	0.00400	411.63	413.08	0.00926	3.67	3.64	117.95	429.29	0.89	9.67	20.34	2.10
main	19692	050YR	4150	4150.00	404.76	0.00560	410.89	411.48	0.00279	4.57	4.53	149.08	675.72	0.51	6.14	4.85	0.79
main	19474	050YR	4150	4146.21	403.53	0.00490	409.64	410.62	0.00522	4.23	4.19	124.10	520.17	0.68	7.97	10.88	1.36
main	19394	050YR	4150	4064.22	403.14	0.00890	409.80	410.22	0.00182	4.97	4.94	156.50	773.21	0.42	5.26	2.95	0.56
main	19319	050YR	4150	4150.00	402.47	0.00000	409.45	410.02	0.00259	4.71	4.67	147.13	687.43	0.49	6.04	4.56	0.76
main	19299		Bridge														
main	19279	050YR	4150	4150.00	402.11	0.01000	409.17	409.83	0.00299	4.72	4.67	137.06	640.26	0.53	6.48	5.64	0.87
main	19274	050YR	4150	4150.00	402.06	0.00000	409.14	409.81	0.00303	4.72	4.67	136.14	635.67	0.53	6.53	5.77	0.88
main	19220		Bridge														
main	19150	050YR	4150	4150.00	400.96	0.00740	407.07	408.83	0.01194	3.52	3.48	111.76	389.28	1.00	10.66	27.68	2.60
main	18884	050YR	4150	4150.00	398.98	0.00920	404.55	405.76	0.00744	3.78	3.73	126.43	471.42	0.80	8.80	15.24	1.73
main	18420	050YR	4150	3880.40	394.72	0.00790	402.49	403.30	0.00344	5.25	5.19	100.17	519.96	0.57	7.46	8.31	1.11
main	17851	050YR	4150	4150.00	390.20	-0.00130	397.83	399.89	0.01174	4.09	3.97	90.71	359.90	1.00	11.53	33.54	2.91
main	17432	050YR	4150	3661.32	390.76	0.00760	396.63	397.16	0.00256	4.91	4.89	120.95	591.25	0.49	6.19	4.85	0.78
main	17028	050YR	4150	3995.85	387.70	0.00190	393.98	395.42	0.00772	4.34	4.27	95.48	407.23	0.83	9.81	20.18	2.06
main	16619	050YR	4150	3877.98	386.94	0.00900	391.70	392.54	0.00574	3.63	3.62	141.41	511.71	0.70	7.58	9.82	1.30
main	16273	050YR	4150	4150.00	383.84	0.00330	389.64	390.47	0.00629	3.21	3.19	177.90	568.37	0.72	7.30	9.15	1.25
main	15808	050YR	4150	4150.00	382.29	0.00670	387.39	387.91	0.00456	2.89	2.88	249.07	716.08	0.60	5.80	4.74	0.82
main	15358	050YR	4150	4150.00	379.27	0.00460	385.14	385.79	0.00484	3.25	3.22	199.64	643.80	0.63	6.45	6.28	0.97
main	15023	050YR	4150	4150.00	377.74	0.01320	381.89	383.22	0.01302	2.65	2.63	170.54	449.16	1.00	9.24	19.78	2.14

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	14502	050YR	4150	3446.58	370.87	-0.00710	380.50	380.59	0.00043	5.06	5.02	266.88	1339.38	0.20	2.57	0.34	0.13
main	14067	050YR	4150	4150.00	373.94	0.00800	378.75	379.98	0.00906	3.34	3.28	142.22	465.78	0.86	8.91	16.50	1.85
main	13722	050YR	4150	4150.00	371.18	0.00660	375.28	376.15	0.01301	1.94	1.93	285.84	552.36	0.95	7.51	11.79	1.57
main	13445	050YR	4150	4150.00	369.36	0.00770	374.19	374.49	0.00293	2.59	2.58	371.51	959.72	0.47	4.32	2.04	0.47
main	13042	050YR	4150	2988.17	366.24	0.00290	373.93	374.03	0.00050	5.66	5.65	176.22	995.48	0.22	3.00	0.53	0.18
main	12550	050YR	4150	4150.00	364.83	0.00590	371.04	373.19	0.01144	4.27	4.17	84.72	352.96	1.00	11.76	34.99	2.98
main	12210	050YR	4150	4150.00	362.84	0.00440	367.35	368.55	0.01384	2.34	2.32	203.99	473.77	1.01	8.76	17.58	2.01
main	11840	050YR	4150	3107.74	361.22	0.00500	365.35	365.68	0.00342	3.04	3.04	196.10	596.56	0.53	5.21	3.38	0.65
main	11439	050YR	4150	3247.11	359.22	0.01760	362.40	363.21	0.01439	1.97	1.97	206.25	405.94	1.00	8.00	14.15	1.77
main	10998	050YR	4150	3418.38	351.45	0.00400	360.85	361.22	0.00138	6.20	6.15	104.85	644.75	0.38	5.30	2.82	0.53
main	10636	050YR	4150	3977.96	349.99	0.00240	360.44	360.81	0.00097	7.43	7.28	110.22	802.69	0.32	4.96	2.17	0.44
main	10222	050YR	4150	3136.24	349.00	-0.00190	360.12	360.39	0.00097	6.83	6.72	98.95	664.78	0.32	4.72	1.93	0.41
main	9912	050YR	4150	2265.31	349.60	0.01720	360.23	360.26	0.00008	8.77	8.74	164.45	1436.69	0.09	1.58	0.07	0.04
main	9542	050YR	4150	3991.27	343.24	0.00010	360.25	360.25	0.00000	15.38	15.37	724.50	11132.29	0.02	0.36	0.00	0.00
main	9056	050YR	4150	4145.17	343.21	-0.00290	360.24	360.25	0.00000	15.19	15.10	609.24	9198.85	0.02	0.45	0.00	0.00
main	8465	050YR	4150	3931.34	344.90	-0.00100	360.22	360.24	0.00003	14.46	14.21	215.15	3058.16	0.06	1.29	0.03	0.02
main	8046	050YR	4150	3655.85	345.34	0.00010	359.80	360.18	0.00083	9.48	8.78	79.73	700.27	0.30	5.22	2.39	0.46
main	7601	050YR	4150	3481.46	345.30	0.01220	359.97	360.01	0.00006	13.02	12.93	153.15	1980.90	0.09	1.76	0.08	0.05
main	7146	050YR	4150	4082.56	339.73	-0.00090	359.99	360.00	0.00000	18.32	18.25	432.47	7891.27	0.02	0.52	0.00	0.00
main	6727	050YR	4150	4120.60	340.12	-0.01330	359.99	360.00	0.00000	17.43	17.27	423.29	7309.07	0.02	0.56	0.00	0.00
main	6395	050YR	4150	3897.41	344.54	-0.00500	359.98	359.99	0.00002	14.43	14.27	268.61	3834.32	0.05	1.02	0.01	0.01
main	6072	050YR	4150	3394.02	346.15	-0.00180	359.93	359.98	0.00011	8.86	8.78	201.58	1770.12	0.11	1.92	0.12	0.06
main	5737	050YR	4150	3037.90	346.76	0.00110	359.90	359.95	0.00007	11.93	11.83	135.27	1599.64	0.10	1.90	0.10	0.05
main	5292	050YR	4150	3291.97	346.28	0.00360	359.73	359.88	0.00026	11.24	11.02	87.66	966.36	0.18	3.41	0.62	0.18
main	4956	050YR	4150	4021.03	345.07	-0.00220	359.49	359.76	0.00043	10.54	10.20	94.79	966.76	0.23	4.16	1.15	0.28
main	4489	050YR	4150	3828.75	346.10	0.00030	359.15	359.50	0.00067	9.77	9.46	82.47	780.54	0.28	4.91	1.93	0.39
main	4125	050YR	4150	3924.42	346.00	0.00100	359.19	359.32	0.00019	11.51	11.44	114.72	1311.83	0.16	2.99	0.41	0.14
main	3664	050YR	4150	3399.41	345.56	0.00920	359.12	359.23	0.00018	11.31	11.13	107.58	1197.60	0.15	2.84	0.35	0.12
main	3386	050YR	4150	4008.18	343.00	-0.01720	359.16	359.19	0.00003	14.42	14.30	218.96	3131.05	0.06	1.28	0.03	0.02
main	3010	050YR	4150	3766.11	349.45	0.01320	358.75	359.12	0.00129	6.24	6.17	118.90	734.01	0.36	5.13	2.55	0.50
main	2714	050YR	4150	3488.80	345.54	0.00290	358.73	358.89	0.00033	10.09	9.91	99.68	987.77	0.20	3.53	0.71	0.20
main	2423	050YR	4150	3832.54	344.70	-0.00920	358.57	358.79	0.00035	11.00	10.78	91.44	985.97	0.21	3.89	0.92	0.24
main	2164	050YR	4150	3439.06	347.09	0.00030	358.50	358.68	0.00038	9.55	9.45	98.72	932.80	0.21	3.69	0.82	0.22
main	1833	050YR	4150	3911.00	346.99	0.00090	358.27	358.53	0.00052	9.22	8.98	104.70	939.74	0.24	4.16	1.20	0.29
main	1422	050YR	4150	2741.49	346.60	-0.00350	358.02	358.28	0.00077	8.56	8.37	67.36	563.62	0.29	4.86	1.96	0.40
main	1198	050YR	4150	2761.69	347.39	0.00000	357.50	357.98	0.00151	8.52	8.28	49.39	408.94	0.41	6.75	5.27	0.78
main	1133		Bridge														
main	1068	050YR	4150	3275.10	349.56	0.02080	353.50	354.73	0.01103	3.31	3.31	100.05	330.91	0.96	9.90	22.54	2.28
main	764	050YR	4150	3660.32	343.22	-0.00820	352.91	353.26	0.00161	5.14	5.07	143.97	729.19	0.39	5.02	2.55	0.51
main	427	050YR	4150	3324.85	345.99	0.00310	352.15	352.59	0.00224	5.05	5.04	111.77	563.33	0.46	5.90	4.15	0.70
main	31	050YR	4150	3409.41	344.77		350.41	351.27	0.00500	4.46	4.46	94.10	419.33	0.68	8.13	11.31	1.39

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30040	100YR	7000	5489.96	466.44	0.02100	472.42	473.77	0.00890	4.22	4.20	125.33	526.58	0.90	10.43	24.33	2.33
main	29819	100YR	7000	6097.01	461.78	0.00620	470.96	472.07	0.00541	5.04	4.94	136.22	673.19	0.71	9.06	15.11	1.67
main	29546	100YR	7000	5436.31	460.08	-0.00170	469.78	470.74	0.00431	5.77	5.70	107.37	611.74	0.65	8.89	13.61	1.53
main	29236	100YR	7000	5157.41	460.61	0.00290	467.75	468.93	0.00747	4.53	4.48	115.67	517.71	0.83	9.96	20.78	2.09
main	28946	100YR	7000	5565.29	459.76	0.01150	466.53	467.25	0.00406	4.72	4.66	158.60	738.36	0.61	7.54	8.88	1.18
main	28559	100YR	7000	6005.66	455.32	0.00250	464.65	465.52	0.00512	4.35	4.31	172.99	746.13	0.68	8.05	11.10	1.38
main	28162	100YR	7000	5415.20	454.33	0.00480	463.39	463.90	0.00303	4.59	4.55	185.49	844.25	0.53	6.41	5.52	0.86
main	27666	100YR	7000	6123.53	451.96	0.01220	459.49	461.38	0.00864	5.22	5.13	101.85	522.05	0.90	11.73	32.42	2.76
main	27322	100YR	7000	6082.82	447.74	-0.00100	457.83	458.74	0.00332	6.29	6.13	121.17	742.89	0.58	8.19	10.39	1.27
main	26994	100YR	7000	6391.04	448.07	0.00690	455.15	457.03	0.00859	5.08	4.99	111.51	556.30	0.90	11.49	30.74	2.68
main	26712	100YR	7000	5639.48	446.12	0.00880	452.93	454.67	0.00798	5.40	5.36	90.54	485.38	0.88	11.62	31.04	2.67
main	26291	100YR	7000	5065.04	442.40	0.00760	449.76	451.34	0.00847	5.20	5.13	84.85	435.59	0.90	11.63	31.57	2.71
main	25868	100YR	7000	7000.00	439.19	0.00080	448.50	449.17	0.00285	4.95	4.91	217.56	1068.62	0.52	6.55	5.73	0.87
main	25665	100YR	7000	7000.00	439.02	0.00000	447.76	448.52	0.00333	4.87	4.81	208.61	1002.74	0.56	6.98	6.98	1.00
main	25597		Bridge														
main	25528	100YR	7000	7000.00	438.99	0.00480	447.41	447.99	0.00184	6.19	6.12	187.59	1148.44	0.43	6.10	4.29	0.70
main	25373	100YR	7000	7000.00	438.25	0.00960	446.24	447.39	0.00437	5.50	5.40	149.98	810.36	0.65	8.64	12.72	1.47
main	25145	100YR	7000	7000.00	436.05	0.00120	442.96	445.50	0.01064	5.07	4.99	109.83	547.67	1.00	12.78	42.33	3.31
main	24905	100YR	7000	6780.08	435.76	0.00710	442.37	443.42	0.00433	5.22	5.20	155.73	809.13	0.65	8.38	11.77	1.40
main	24632	100YR	7000	7000.00	433.84	0.00950	439.43	441.52	0.01139	4.12	4.09	147.51	603.76	1.01	11.59	33.75	2.91
main	24337	100YR	7000	7000.00	431.03	0.00400	437.80	438.79	0.00383	5.36	5.31	164.89	875.57	0.61	7.99	10.15	1.27
main	24257	100YR	7000	7000.00	430.71	0.01190	437.58	438.48	0.00319	5.72	5.66	162.36	918.83	0.56	7.62	8.59	1.13
main	23941	100YR	7000	6980.85	426.97	0.00310	435.95	437.23	0.00470	5.59	5.52	139.14	768.07	0.68	9.09	14.71	1.62
main	23337	100YR	7000	7000.00	425.11	0.00560	432.34	433.95	0.00622	5.38	5.31	129.37	686.98	0.77	10.19	21.00	2.06
main	22741	100YR	7000	6980.69	421.76	0.00400	429.00	430.37	0.00560	5.13	5.09	146.02	742.83	0.73	9.40	16.71	1.78
main	22245	100YR	7000	6726.85	419.78	0.00490	426.80	427.89	0.00419	5.51	5.45	144.82	789.92	0.64	8.52	12.15	1.43
main	21864	100YR	7000	6931.99	417.92	0.00920	424.36	425.76	0.00760	4.14	4.12	177.01	729.03	0.82	9.51	18.58	1.95
main	21309	100YR	7000	6929.95	412.81	0.00190	421.43	422.62	0.00423	5.74	5.69	138.52	787.87	0.65	8.80	13.20	1.50
main	20841	100YR	7000	6636.20	411.91	0.00630	419.17	420.48	0.00490	5.69	5.63	125.25	705.57	0.70	9.41	16.20	1.72
main	20357	100YR	7000	7000.00	408.84	0.00780	416.05	417.76	0.00632	5.57	5.48	121.75	667.33	0.78	10.49	22.67	2.16
main	19981	100YR	7000	6838.95	405.92	0.00400	413.15	415.03	0.00826	4.95	4.89	125.63	614.95	0.88	11.12	28.06	2.52
main	19692	100YR	7000	6899.48	404.76	0.00560	412.56	413.39	0.00292	5.83	5.77	161.82	934.26	0.54	7.38	7.78	1.05
main	19474	100YR	7000	6174.79	403.53	0.00490	411.98	412.77	0.00268	6.49	6.44	126.22	812.26	0.53	7.60	8.18	1.08
main	19394	100YR	7000	6420.33	403.14	0.00890	412.06	412.52	0.00134	7.08	7.01	161.08	1128.45	0.38	5.69	3.33	0.59
main	19319	100YR	7000	6885.67	402.47	0.00000	411.62	412.32	0.00209	6.63	6.55	154.59	1013.32	0.47	6.80	5.81	0.85
main	19299		Bridge														
main	19279	100YR	7000	6994.05	402.11	0.01000	411.24	412.11	0.00273	6.29	6.20	150.81	935.10	0.53	7.48	7.89	1.05
main	19274	100YR	7000	6998.33	402.06	0.00000	411.20	412.09	0.00283	6.20	6.11	151.86	927.63	0.53	7.54	8.14	1.08
main	19220		Bridge														
main	19150	100YR	7000	7000.00	400.96	0.00740	408.60	410.98	0.01085	4.76	4.68	120.79	565.61	1.00	12.38	39.24	3.17
main	18884	100YR	7000	7000.00	398.98	0.00920	406.02	407.77	0.00742	5.03	4.95	133.33	659.49	0.83	10.61	24.31	2.29
main	18420	100YR	7000	6132.38	394.72	0.00790	403.61	404.91	0.00449	6.37	6.30	100.17	631.50	0.68	9.71	17.17	1.77
main	17851	100YR	7000	6251.45	390.20	-0.00130	399.83	401.69	0.00729	5.90	5.68	95.31	541.51	0.84	11.54	29.87	2.59
main	17432	100YR	7000	5875.92	390.76	0.00760	398.07	398.86	0.00280	6.35	6.33	120.95	765.19	0.54	7.68	8.48	1.10
main	17028	100YR	7000	6068.09	387.70	0.00190	395.29	397.07	0.00736	5.65	5.56	95.48	530.96	0.85	11.43	29.18	2.55
main	16619	100YR	7000	6277.23	386.94	0.00900	393.03	394.16	0.00533	4.95	4.94	141.41	698.28	0.71	8.99	14.78	1.64
main	16273	100YR	7000	6999.03	383.84	0.00330	390.67	392.01	0.00728	4.14	4.12	182.78	752.28	0.81	9.30	17.41	1.87
main	15808	100YR	7000	6997.20	382.29	0.00670	388.61	389.33	0.00411	3.99	3.97	258.10	1025.15	0.60	6.83	6.95	1.02
main	15358	100YR	7000	6984.54	379.27	0.00460	386.38	387.33	0.00471	4.45	4.41	201.91	890.91	0.65	7.84	10.18	1.30
main	15023	100YR	7000	7000.00	377.74	0.01320	383.00	384.86	0.01190	3.67	3.64	175.62	638.88	1.01	10.96	29.62	2.70

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	14502	100YR	7000	5100.68	370.87	-0.00710	382.32	382.41	0.00034	6.88	6.82	266.88	1820.21	0.19	2.80	0.40	0.14
main	14067	100YR	7000	7000.00	373.94	0.00800	379.73	381.80	0.01159	4.11	4.00	151.82	607.53	1.00	11.52	33.37	2.90
main	13722	100YR	7000	7000.00	371.18	0.00660	376.63	377.49	0.00646	3.22	3.20	294.86	944.32	0.73	7.41	9.57	1.29
main	13445	100YR	7000	6638.41	369.36	0.00770	376.59	376.78	0.00084	4.92	4.91	379.99	1865.81	0.28	3.56	0.92	0.26
main	13042	100YR	7000	4675.26	366.24	0.00290	376.44	376.55	0.00036	8.17	8.15	176.22	1436.34	0.20	3.25	0.59	0.18
main	12550	100YR	7000	7000.00	364.83	0.00590	372.91	375.80	0.01043	5.77	5.57	92.16	513.60	1.00	13.63	49.46	3.63
main	12210	100YR	7000	6730.27	362.84	0.00440	368.77	369.92	0.00761	3.68	3.66	209.46	765.73	0.81	8.79	15.27	1.74
main	11840	100YR	7000	5078.75	361.22	0.00500	365.91	366.52	0.00520	3.60	3.60	196.10	706.14	0.67	7.19	8.41	1.17
main	11439	100YR	7000	5051.95	359.22	0.01760	364.10	364.63	0.00441	3.67	3.66	206.25	754.80	0.62	6.69	6.74	1.01
main	10998	100YR	7000	4932.81	351.45	0.00400	363.53	363.85	0.00087	8.88	8.80	104.85	922.50	0.32	5.35	2.57	0.48
main	10636	100YR	7000	6277.29	349.99	0.00240	363.06	363.53	0.00088	10.05	9.85	110.22	1085.22	0.32	5.78	3.13	0.54
main	10222	100YR	7000	4546.84	349.00	-0.00190	362.92	363.17	0.00065	9.62	9.47	98.95	936.62	0.28	4.85	1.87	0.39
main	9912	100YR	7000	3568.72	349.60	0.01720	363.01	363.05	0.00008	11.55	11.51	164.45	1892.25	0.10	1.89	0.10	0.05
main	9542	100YR	7000	6705.45	343.24	0.00010	363.03	363.03	0.00000	18.16	18.15	724.50	13147.44	0.02	0.51	0.00	0.00
main	9056	100YR	7000	6983.63	343.21	-0.00290	363.03	363.03	0.00001	17.97	17.86	609.24	10883.68	0.03	0.64	0.00	0.01
main	8465	100YR	7000	6506.07	344.90	-0.00100	362.98	363.02	0.00004	17.22	16.93	215.15	3641.68	0.08	1.79	0.08	0.04
main	8046	100YR	7000	4740.12	345.34	0.00010	362.66	362.96	0.00058	12.35	11.43	79.73	911.71	0.26	5.20	2.16	0.42
main	7601	100YR	7000	5552.63	345.30	0.01220	362.75	362.82	0.00008	15.80	15.69	153.15	2403.56	0.10	2.31	0.17	0.07
main	7146	100YR	7000	6815.30	339.73	-0.00090	362.78	362.79	0.00001	21.11	21.03	432.47	9093.60	0.03	0.75	0.01	0.01
main	6727	100YR	7000	6897.55	340.12	-0.01330	362.78	362.79	0.00001	20.22	20.03	423.29	8478.63	0.03	0.81	0.01	0.01
main	6395	100YR	7000	6359.28	344.54	-0.00500	362.76	362.78	0.00003	17.21	17.02	268.61	4572.71	0.06	1.39	0.04	0.03
main	6072	100YR	7000	5368.78	346.15	-0.00180	362.70	362.77	0.00011	11.63	11.53	201.58	2323.36	0.12	2.31	0.19	0.08
main	5737	100YR	7000	4812.19	346.76	0.00110	362.66	362.73	0.00009	14.69	14.56	135.27	1969.91	0.11	2.44	0.21	0.08
main	5292	100YR	7000	5228.95	346.28	0.00360	362.42	362.65	0.00032	13.92	13.66	87.66	1197.15	0.21	4.37	1.21	0.28
main	4956	100YR	7000	6673.91	345.07	-0.00220	362.02	362.48	0.00059	13.07	12.64	94.79	1198.07	0.27	5.57	2.57	0.46
main	4489	100YR	7000	6141.88	346.10	0.00030	361.61	362.15	0.00081	12.22	11.84	82.47	976.65	0.32	6.29	3.78	0.60
main	4125	100YR	7000	6499.93	346.00	0.00100	361.66	361.90	0.00028	13.99	13.89	114.72	1593.73	0.19	4.08	0.98	0.24
main	3664	100YR	7000	5406.28	345.56	0.00920	361.60	361.77	0.00024	13.79	13.57	107.58	1459.70	0.18	3.70	0.74	0.20
main	3386	100YR	7000	6702.53	343.00	-0.01720	361.66	361.71	0.00004	16.92	16.77	218.96	3672.72	0.08	1.82	0.08	0.05
main	3010	100YR	7000	6139.79	349.45	0.01320	361.11	361.61	0.00118	8.59	8.51	118.90	1011.73	0.36	6.07	3.79	0.62
main	2714	100YR	7000	5620.07	345.54	0.00290	361.08	361.35	0.00042	12.45	12.22	99.68	1218.34	0.23	4.61	1.48	0.32
main	2423	100YR	7000	6325.62	344.70	-0.00920	360.80	361.20	0.00052	13.23	12.97	91.44	1186.13	0.26	5.33	2.24	0.42
main	2164	100YR	7000	5544.84	347.09	0.00030	360.75	361.04	0.00049	11.79	11.67	98.72	1152.36	0.25	4.81	1.70	0.35
main	1833	100YR	7000	6400.44	346.99	0.00090	360.40	360.84	0.00069	11.35	11.04	104.70	1156.28	0.29	5.54	2.64	0.48
main	1422	100YR	7000	4355.06	346.60	-0.00350	360.11	360.51	0.00094	10.64	10.40	67.36	700.84	0.34	6.21	3.81	0.61
main	1198	100YR	7000	4054.90	347.39	0.00000	359.59	360.19	0.00157	10.61	10.31	49.39	509.18	0.43	7.96	8.04	1.01
main	1133		Bridge														
main	1068	100YR	7000	5064.73	349.56	0.02080	355.20	356.40	0.00663	5.01	5.00	100.05	500.71	0.80	10.12	20.96	2.07
main	764	100YR	7000	5995.79	343.22	-0.00820	354.65	355.16	0.00163	6.88	6.78	143.97	976.47	0.41	6.14	4.24	0.69
main	427	100YR	7000	5373.27	345.99	0.00310	353.87	354.49	0.00220	6.77	6.76	111.77	755.12	0.48	7.12	6.60	0.93
main	31	100YR	7000	5549.02	344.77		351.92	353.16	0.00500	5.98	5.97	94.10	561.59	0.71	9.88	18.42	1.86

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30040	500YR	9080	6783.15	466.44	0.02100	473.00	474.51	0.00886	4.79	4.78	125.33	598.50	0.91	11.33	29.94	2.64
main	29819	500YR	9080	7428.85	461.78	0.00620	471.49	472.77	0.00575	5.57	5.46	136.22	743.95	0.75	9.99	19.58	1.96
main	29546	500YR	9080	6136.96	460.08	-0.00170	470.67	471.48	0.00341	6.66	6.57	107.37	705.63	0.59	8.70	12.16	1.40
main	29236	500YR	9080	6559.46	460.61	0.00290	468.28	469.78	0.00831	5.07	5.01	115.67	579.24	0.89	11.32	29.40	2.60
main	28946	500YR	9080	6780.67	459.76	0.01150	467.23	467.99	0.00387	5.33	5.26	161.31	848.48	0.61	7.99	10.16	1.27
main	28559	500YR	9080	7532.64	455.32	0.00250	465.29	466.30	0.00519	4.89	4.85	177.19	859.42	0.70	8.76	13.78	1.57
main	28162	500YR	9080	6809.64	454.33	0.00480	464.05	464.64	0.00305	5.26	5.21	185.49	966.58	0.54	7.05	6.99	0.99
main	27666	500YR	9080	7393.60	451.96	0.01220	460.58	462.32	0.00708	5.99	5.87	108.25	635.69	0.84	11.63	30.21	2.60
main	27322	500YR	9080	7485.57	447.74	-0.00100	458.93	459.87	0.00316	6.95	6.78	129.33	876.41	0.57	8.54	11.40	1.34
main	26994	500YR	9080	8104.23	448.07	0.00690	455.87	458.13	0.00947	5.50	5.40	118.18	637.58	0.96	12.71	40.56	3.19
main	26712	500YR	9080	7164.76	446.12	0.00880	453.58	455.78	0.00883	6.05	6.00	90.54	543.67	0.94	13.18	43.61	3.31
main	26291	500YR	9080	6315.52	442.40	0.00760	450.75	452.43	0.00736	6.19	6.11	84.85	518.58	0.86	12.18	34.22	2.81
main	25868	500YR	9080	9080.00	439.19	0.00080	449.73	450.42	0.00265	5.36	5.32	256.64	1364.84	0.51	6.65	5.84	0.88
main	25665	500YR	9080	9080.00	439.02	0.00000	449.07	449.85	0.00266	5.92	5.84	218.97	1279.15	0.51	7.10	6.88	0.97
main	25597		Bridge														
main	25528	500YR	9080	9080.00	438.99	0.00480	448.78	449.40	0.00196	6.25	6.18	231.82	1432.98	0.45	6.34	4.80	0.76
main	25373	500YR	9080	9080.00	438.25	0.00960	447.54	448.79	0.00399	6.24	6.12	165.31	1012.08	0.63	8.97	13.67	1.52
main	25145	500YR	9080	9080.00	436.05	0.00120	444.01	446.92	0.01021	5.81	5.70	116.39	663.48	1.00	13.69	49.70	3.63
main	24905	500YR	9080	8659.54	435.76	0.00710	443.18	444.45	0.00449	5.89	5.86	159.75	936.14	0.67	9.25	15.21	1.64
main	24632	500YR	9080	9045.44	433.84	0.00950	440.47	442.65	0.00941	4.93	4.90	155.48	761.50	0.94	11.88	34.18	2.88
main	24337	500YR	9080	9079.96	431.03	0.00400	438.79	439.97	0.00387	6.04	5.99	174.24	1043.01	0.62	8.71	12.59	1.45
main	24257	500YR	9080	9055.44	430.71	0.01190	438.57	439.66	0.00328	6.46	6.38	169.49	1081.73	0.58	8.37	10.95	1.31
main	23941	500YR	9080	8824.78	426.97	0.00310	437.08	438.45	0.00424	6.48	6.40	144.67	925.90	0.66	9.53	16.15	1.69
main	23337	500YR	9080	9080.00	425.11	0.00560	433.35	435.22	0.00674	5.65	5.58	148.54	828.37	0.81	10.96	25.72	2.35
main	22741	500YR	9080	8918.34	421.76	0.00400	429.87	431.47	0.00565	5.78	5.73	152.34	872.87	0.75	10.22	20.65	2.02
main	22245	500YR	9080	8551.52	419.78	0.00490	427.35	428.77	0.00503	5.97	5.91	146.90	868.57	0.71	9.85	18.28	1.86
main	21864	500YR	9080	8618.73	417.92	0.00920	425.25	426.65	0.00617	5.03	5.00	177.01	884.46	0.77	9.74	18.75	1.92
main	21309	500YR	9080	8911.96	412.81	0.00190	422.23	423.73	0.00451	6.55	6.49	138.52	898.48	0.68	9.92	18.12	1.83
main	20841	500YR	9080	8256.93	411.91	0.00630	420.34	421.68	0.00406	6.85	6.79	125.25	850.68	0.65	9.71	16.72	1.72
main	20357	500YR	9080	9080.00	408.84	0.00780	416.86	419.04	0.00717	6.08	5.98	128.21	766.79	0.85	11.84	31.68	2.68
main	19981	500YR	9080	8685.44	405.92	0.00400	413.98	416.15	0.00817	5.65	5.59	128.61	718.79	0.90	12.08	34.43	2.85
main	19692	500YR	9080	8304.29	404.76	0.00560	413.87	414.62	0.00223	6.93	6.86	167.41	1148.59	0.48	7.23	6.89	0.95
main	19474	500YR	9080	6964.39	403.53	0.00490	413.58	414.15	0.00163	8.10	8.03	126.22	1013.43	0.43	6.87	5.61	0.82
main	19394	500YR	9080	7750.72	403.14	0.00890	413.58	414.01	0.00104	8.46	8.35	164.45	1373.58	0.34	5.64	3.07	0.54
main	19319	500YR	9080	8579.07	402.47	0.00000	413.13	413.83	0.00168	7.98	7.87	158.51	1247.18	0.43	6.88	5.67	0.82
main	19299		Bridge														
main	19279	500YR	9080	8940.46	402.11	0.01000	412.62	413.56	0.00236	7.50	7.39	154.58	1142.11	0.50	7.83	8.53	1.09
main	19274	500YR	9080	8971.53	402.06	0.00000	412.57	413.53	0.00245	7.41	7.29	155.66	1135.04	0.51	7.90	8.82	1.12
main	19220		Bridge														
main	19150	500YR	9080	9080.00	400.96	0.00740	409.56	412.32	0.01040	5.50	5.40	126.15	681.31	1.00	13.33	46.73	3.51
main	18884	500YR	9080	9080.00	398.98	0.00920	406.85	409.01	0.00776	5.71	5.60	137.32	769.42	0.87	11.80	32.05	2.72
main	18420	500YR	9080	7626.41	394.72	0.00790	404.48	405.98	0.00454	7.24	7.16	100.17	717.61	0.70	10.63	21.57	2.03
main	17851	500YR	9080	7722.11	390.20	-0.00130	400.60	402.72	0.00746	6.65	6.39	95.68	611.60	0.86	12.63	37.57	2.98
main	17432	500YR	9080	7455.29	390.76	0.00760	398.95	399.90	0.00293	7.23	7.20	120.95	870.49	0.56	8.56	11.27	1.32
main	17028	500YR	9080	7493.52	387.70	0.00190	396.01	398.05	0.00752	6.37	6.27	95.48	598.70	0.87	12.52	36.83	2.94
main	16619	500YR	9080	7995.09	386.94	0.00900	393.87	395.19	0.00513	5.79	5.78	141.41	816.74	0.72	9.79	18.11	1.85
main	16273	500YR	9080	9069.85	383.84	0.00330	391.25	392.98	0.00798	4.69	4.65	184.37	858.06	0.86	10.57	24.50	2.32
main	15808	500YR	9080	9052.67	382.29	0.00670	389.38	390.23	0.00384	4.75	4.72	258.93	1222.97	0.60	7.40	8.37	1.13
main	15358	500YR	9080	9029.37	379.27	0.00460	387.14	388.30	0.00464	5.22	5.17	201.91	1044.17	0.67	8.65	12.95	1.50
main	15023	500YR	9080	9080.00	377.74	0.01320	383.73	385.91	0.01111	4.35	4.30	178.62	767.57	1.00	11.83	35.27	2.98

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	14502	500YR	9080	6263.00	370.87	-0.00710	383.45	383.55	0.00031	8.01	7.95	266.88	2121.32	0.18	2.95	0.45	0.15
main	14067	500YR	9080	9080.00	373.94	0.00800	380.57	382.95	0.01109	4.74	4.60	159.68	734.30	1.00	12.37	39.38	3.18
main	13722	500YR	9080	9080.00	371.18	0.00660	378.09	378.76	0.00320	4.59	4.56	301.84	1375.95	0.54	6.60	6.00	0.91
main	13445	500YR	9080	8114.95	369.36	0.00770	378.17	378.32	0.00050	6.50	6.48	379.99	2462.71	0.23	3.30	0.66	0.20
main	13042	500YR	9080	5896.02	366.24	0.00290	378.03	378.16	0.00031	9.77	9.74	176.22	1716.93	0.19	3.43	0.66	0.19
main	12550	500YR	9080	9080.00	364.83	0.00590	374.07	377.42	0.01004	6.67	6.41	96.56	618.74	1.00	14.67	58.93	4.02
main	12210	500YR	9080	8177.45	362.84	0.00440	369.32	370.53	0.00707	4.23	4.20	209.46	879.80	0.80	9.29	17.24	1.85
main	11840	500YR	9080	6362.73	361.22	0.00500	366.63	367.28	0.00444	4.32	4.32	196.10	847.39	0.64	7.51	9.00	1.20
main	11439	500YR	9080	6365.23	359.22	0.01760	365.60	366.01	0.00223	5.17	5.16	206.25	1063.70	0.46	5.98	4.30	0.72
main	10998	500YR	9080	6013.60	351.45	0.00400	365.15	365.48	0.00074	10.50	10.41	104.85	1091.34	0.30	5.51	2.65	0.48
main	10636	500YR	9080	7888.02	349.99	0.00240	364.64	365.18	0.00085	11.63	11.40	110.22	1256.26	0.32	6.28	3.81	0.61
main	10222	500YR	9080	5572.83	349.00	-0.00190	364.56	364.83	0.00058	11.27	11.09	98.95	1097.02	0.27	5.08	2.04	0.40
main	9912	500YR	9080	4505.43	349.60	0.01720	364.67	364.71	0.00008	13.20	13.15	164.45	2163.09	0.10	2.08	0.13	0.06
main	9542	500YR	9080	8680.44	343.24	0.00010	364.69	364.69	0.00000	19.82	19.80	724.50	14345.92	0.02	0.61	0.00	0.00
main	9056	500YR	9080	9034.54	343.21	-0.00290	364.68	364.69	0.00001	19.62	19.51	609.24	11885.49	0.03	0.76	0.01	0.01
main	8465	500YR	9080	8357.07	344.90	-0.00100	364.61	364.68	0.00005	18.85	18.54	215.15	3987.89	0.09	2.10	0.12	0.06
main	8046	500YR	9080	5398.18	345.34	0.00010	364.35	364.61	0.00049	14.03	12.99	79.73	1035.94	0.25	5.21	2.08	0.40
main	7601	500YR	9080	6934.05	345.30	0.01220	364.40	364.48	0.00008	17.44	17.33	153.15	2654.32	0.11	2.61	0.24	0.09
main	7146	500YR	9080	8788.66	339.73	-0.00090	364.44	364.45	0.00001	22.76	22.68	432.47	9806.70	0.03	0.90	0.01	0.01
main	6727	500YR	9080	8903.59	340.12	-0.01330	364.43	364.45	0.00001	21.87	21.67	423.29	9172.17	0.04	0.97	0.01	0.01
main	6395	500YR	9080	8110.95	344.54	-0.00500	364.40	364.44	0.00003	18.86	18.65	268.61	5010.32	0.07	1.62	0.06	0.03
main	6072	500YR	9080	6745.54	346.15	-0.00180	364.34	364.42	0.00012	13.27	13.15	201.58	2651.42	0.12	2.54	0.24	0.09
main	5737	500YR	9080	6061.30	346.76	0.00110	364.30	364.38	0.00010	16.32	16.18	135.27	2189.13	0.12	2.77	0.29	0.10
main	5292	500YR	9080	6586.49	346.28	0.00360	364.00	364.28	0.00036	15.50	15.21	87.66	1333.33	0.22	4.94	1.69	0.34
main	4956	500YR	9080	8215.09	345.07	-0.00220	363.58	364.11	0.00061	14.62	14.15	94.79	1340.98	0.28	6.13	3.29	0.54
main	4489	500YR	9080	7730.97	346.10	0.00030	363.09	363.75	0.00088	13.70	13.28	82.47	1094.96	0.34	7.06	5.15	0.73
main	4125	500YR	9080	8353.15	346.00	0.00100	363.15	363.47	0.00033	15.48	15.37	114.72	1763.19	0.21	4.74	1.48	0.31
main	3664	500YR	9080	6819.48	345.56	0.00920	363.09	363.31	0.00027	15.28	15.04	107.58	1618.10	0.19	4.21	1.05	0.25
main	3386	500YR	9080	8653.43	343.00	-0.01720	363.16	363.23	0.00005	18.42	18.27	218.96	4000.21	0.09	2.16	0.13	0.06
main	3010	500YR	9080	7805.26	349.45	0.01320	362.53	363.13	0.00114	10.02	9.92	118.90	1179.75	0.37	6.62	4.67	0.71
main	2714	500YR	9080	7289.06	345.54	0.00290	362.48	362.85	0.00049	13.85	13.60	99.68	1355.57	0.25	5.38	2.26	0.42
main	2423	500YR	9080	8035.91	344.70	-0.00920	362.15	362.68	0.00060	14.58	14.30	91.44	1307.12	0.28	6.15	3.32	0.54
main	2164	500YR	9080	7041.86	347.09	0.00030	362.11	362.48	0.00054	13.15	13.02	98.72	1285.34	0.27	5.48	2.42	0.44
main	1833	500YR	9080	8189.97	346.99	0.00090	361.68	362.25	0.00079	12.63	12.29	104.70	1286.25	0.32	6.37	3.88	0.61
main	1422	500YR	9080	5498.42	346.60	-0.00350	361.37	361.87	0.00104	11.91	11.64	67.36	783.89	0.36	7.01	5.27	0.75
main	1198	500YR	9080	4942.45	347.39	0.00000	360.86	361.54	0.00160	11.89	11.55	49.39	570.35	0.44	8.67	9.97	1.15
main	1133		Bridge														
main	1068	500YR	9080	6363.65	349.56	0.02080	356.26	357.52	0.00552	6.07	6.06	100.05	606.62	0.75	10.49	21.93	2.09
main	764	500YR	9080	7669.48	343.22	-0.00820	355.74	356.35	0.00163	7.97	7.86	143.97	1131.29	0.42	6.78	5.43	0.80
main	427	500YR	9080	6839.22	345.99	0.00310	354.94	355.69	0.00218	7.84	7.83	111.77	875.25	0.49	7.81	8.32	1.06
main	31	500YR	9080	7078.61	344.77		352.87	354.35	0.00500	6.92	6.91	94.10	650.04	0.73	10.89	23.49	2.16

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30366	010YR	1860	1761.10	466.44	0.02100	470.02	470.89	0.01348	1.95	1.94	118.17	229.52	0.97	7.67	12.54	1.63
main	30144	010YR	1860	1859.93	461.78	0.00620	467.94	468.56	0.00518	3.03	2.96	99.68	295.20	0.64	6.30	6.03	0.96
main	29871	010YR	1860	1851.70	460.08	-0.00170	466.68	467.28	0.00424	3.45	3.40	87.20	296.39	0.59	6.25	5.62	0.90
main	29561	010YR	1860	1539.13	460.61	0.00290	465.39	465.82	0.00450	2.88	2.85	94.48	268.97	0.59	5.72	4.58	0.80
main	29271	010YR	1860	1767.36	459.76	0.01150	463.30	463.95	0.00990	1.96	1.95	137.98	268.46	0.83	6.58	7.92	1.20
main	28884	010YR	1860	1817.72	455.32	0.00250	461.37	461.84	0.00335	3.43	3.39	96.86	328.10	0.53	5.54	3.92	0.71
main	28487	010YR	1860	1705.82	454.33	0.00480	459.99	460.43	0.00376	3.15	3.12	98.67	307.38	0.55	5.55	4.05	0.73
main	27991	010YR	1860	1855.98	451.96	0.01220	455.96	457.21	0.01280	2.58	2.56	80.77	206.62	0.99	8.98	18.35	2.04
main	27647	010YR	1860	1858.55	447.74	-0.00100	454.19	454.63	0.00307	3.49	3.44	101.07	347.27	0.51	5.35	3.52	0.66
main	27319	010YR	1860	1860.00	448.07	0.00690	452.05	452.96	0.00927	2.59	2.57	94.45	242.63	0.84	7.67	11.39	1.49
main	27038	010YR	1860	1660.72	446.12	0.00880	450.44	450.99	0.00497	3.08	3.05	86.30	263.52	0.63	6.30	5.98	0.95
main	26616	010YR	1860	1667.91	442.40	0.00760	446.89	447.90	0.01201	2.49	2.46	79.86	196.61	0.95	8.48	15.66	1.85
main	26193	010YR	1860	1860.00	439.19	0.00080	444.93	445.19	0.00202	3.16	3.14	144.45	454.15	0.41	4.10	1.62	0.40
main	25990	010YR	1860	1860.00	439.02	0.00000	444.22	444.60	0.00404	2.49	2.47	153.12	377.64	0.55	4.93	3.06	0.62
main	25922		Bridge														
main	25853	010YR	1860	1860.00	438.99	0.00480	443.42	443.67	0.00217	2.91	2.90	159.54	462.42	0.42	4.02	1.58	0.39
main	25698	010YR	1860	1860.00	438.25	0.00960	441.97	442.84	0.01071	2.26	2.23	110.96	247.79	0.88	7.51	11.21	1.49
main	25470	010YR	1860	1860.00	436.05	0.00120	440.35	441.02	0.00559	3.00	2.97	95.26	283.29	0.67	6.57	6.82	1.04
main	25230	010YR	1860	1860.00	435.76	0.00710	439.00	439.55	0.00637	2.33	2.33	134.18	312.40	0.69	5.95	5.52	0.93
main	24958	010YR	1860	1860.00	433.84	0.00950	438.32	438.59	0.00195	3.32	3.30	135.59	447.78	0.40	4.15	1.67	0.40
main	24663		Lat Struct														
main	24662	010YR	1860	1860.00	431.03	0.00400	438.33	438.39	0.00020	5.73	5.67	169.91	963.52	0.14	1.93	0.14	0.07
main	24622		Inl Struct														
main	24582	010YR	1860	1860.00	430.71	0.01190	433.72	434.16	0.00455	2.57	2.55	136.18	347.74	0.59	5.35	3.88	0.73
main	24266	010YR	1860	1860.00	426.97	0.00310	432.16	432.71	0.00456	3.02	2.99	104.58	312.61	0.60	5.95	5.06	0.85
main	23662	010YR	1860	1860.00	425.11	0.00560	428.89	429.53	0.00609	2.73	2.72	106.19	288.48	0.69	6.45	6.65	1.03
main	23066	010YR	1860	1860.00	421.76	0.00400	425.72	426.24	0.00494	2.75	2.73	116.89	319.21	0.62	5.83	4.90	0.84
main	22570	010YR	1860	1860.00	419.78	0.00490	423.86	424.23	0.00325	2.88	2.86	133.18	381.37	0.51	4.88	2.83	0.58
main	22189	010YR	1860	1860.00	417.92	0.00920	420.93	421.91	0.01418	1.98	1.97	119.00	234.22	1.00	7.94	13.84	1.74
main	21634	010YR	1860	1860.00	412.81	0.00190	417.91	418.35	0.00339	3.19	3.17	110.25	349.00	0.53	5.33	3.57	0.67
main	21166	010YR	1860	1860.00	411.91	0.00630	415.41	416.14	0.00682	2.74	2.73	99.58	271.70	0.73	6.85	7.95	1.16
main	20682	010YR	1860	1860.00	408.84	0.00780	412.84	413.40	0.00462	3.01	2.99	103.67	310.25	0.61	6.00	5.18	0.86
main	20306	010YR	1860	1860.00	405.92	0.00400	409.94	410.85	0.01050	2.34	2.33	104.61	243.46	0.88	7.64	11.65	1.53
main	20017	010YR	1860	1860.00	404.76	0.00560	408.88	409.23	0.00295	2.95	2.94	133.62	392.96	0.49	4.73	2.56	0.54
main	19799	010YR	1860	1860.00	403.53	0.00490	407.62	408.28	0.00644	2.65	2.63	108.66	286.17	0.70	6.50	6.89	1.06
main	19719	010YR	1860	1860.00	403.14	0.00790	407.58	407.87	0.00245	2.93	2.92	148.37	433.19	0.44	4.29	1.92	0.45
main	19644	010YR	1860	1860.00	402.55	0.00000	407.30	407.65	0.00289	2.98	2.97	133.23	395.05	0.48	4.71	2.52	0.53
main	19624		Bridge														
main	19604	010YR	1860	1860.00	402.24	0.00800	407.07	407.47	0.00339	2.95	2.94	124.79	366.85	0.52	5.07	3.15	0.62
main	19599	010YR	1860	1860.00	402.20	0.00000	407.04	407.45	0.00346	2.95	2.94	123.68	363.30	0.53	5.12	3.25	0.63
main	19537		Bridge														
main	19475	010YR	1860	1860.00	400.96	0.00740	405.48	406.58	0.01391	2.19	2.18	101.33	220.93	1.00	8.42	15.94	1.89
main	19209	010YR	1860	1860.00	398.98	0.00920	402.81	403.55	0.00736	2.64	2.61	103.13	269.28	0.75	6.91	8.29	1.20
main	18745	010YR	1860	1848.40	394.72	0.00790	400.17	400.79	0.00472	3.21	3.17	92.43	293.44	0.62	6.30	5.89	0.94
main	18176	010YR	1860	1860.00	390.20	-0.00130	396.34	397.30	0.00809	3.03	2.95	80.19	236.69	0.80	7.86	11.72	1.49
main	17757	010YR	1860	1601.82	390.76	0.00470	396.30	396.41	0.00062	4.58	4.56	120.95	551.27	0.24	2.91	0.51	0.18
main	17383	010YR	1860	1207.18	389.00	0.00540	395.35	395.89	0.00426	4.42	4.18	40.22	167.93	0.60	7.19	7.99	1.11
main	16980	010YR	1860	1143.81	386.81	0.00480	393.64	394.08	0.00470	3.61	3.43	50.42	172.90	0.61	6.62	6.65	1.01
main	16590	010YR	1860	990.44	384.94	0.00530	391.32	391.87	0.00738	3.30	3.10	41.10	127.61	0.75	7.76	11.10	1.43
main	16231	010YR	1860	1136.16	383.04	0.00520	389.29	389.77	0.00450	4.01	3.81	43.01	163.72	0.61	6.94	7.41	1.07

Reach	River Sta	Profile	Q Total (cfs)	Q Channel (cfs)	Min Ch El (ft)	Invert Slope	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Hydr Depth C (ft)	Hydr Radius C (ft)	W.P. Channel (ft)	Flow Area Ch (sq ft)	Froude # Chl	Vel Chnl (ft/s)	Power Chan (lb/ft s)	Shear Chan (lb/sq ft)
main	15652	010YR	1860	1178.56	380.02	0.00540	386.16	386.83	0.00641	3.90	3.68	39.61	145.56	0.72	8.10	11.91	1.47
main	15205	010YR	1860	1216.62	377.62	0.00520	383.86	384.38	0.00468	3.94	3.75	46.39	173.74	0.62	7.00	7.66	1.09
main	14694	010YR	1860	1053.88	374.95	0.00500	381.49	381.98	0.00506	3.91	3.67	39.95	146.64	0.64	7.19	8.34	1.16
main	14297	010YR	1860	960.43	372.97	0.00520	379.75	380.15	0.00469	3.79	3.55	39.92	141.89	0.61	6.77	7.04	1.04
main	13870	010YR	1860	954.69	370.73	0.00510	377.43	377.92	0.00634	3.53	3.30	38.68	127.50	0.70	7.49	9.77	1.30
main	13510	010YR	1860	1198.01	368.88	0.00520	375.27	375.90	0.00543	4.20	3.94	38.94	153.51	0.67	7.80	10.42	1.34
main	13053	010YR	1860	1102.43	366.52	0.00500	373.19	373.67	0.00454	4.13	3.89	40.09	155.86	0.61	7.07	7.80	1.10
main	12660	010YR	1860	1260.70	364.55	0.00530	370.76	371.51	0.00715	3.71	3.51	43.39	152.14	0.76	8.29	12.97	1.57
main	12256	010YR	1860	1073.78	362.43	0.00530	369.19	369.58	0.00328	4.64	4.36	37.98	165.58	0.53	6.49	5.78	0.89
main	11904	010YR	1860	1154.54	360.55	-0.00070	366.90	367.68	0.00966	3.27	3.07	42.56	130.87	0.86	8.82	16.36	1.85
main	11439	010YR	1860	1621.30	360.87	0.01000	362.87	363.06	0.00442	1.54	1.53	281.22	431.67	0.53	3.76	1.59	0.42
main	10998	010YR	1860	1431.74	356.48	0.01790	359.27	359.99	0.01252	2.07	2.06	90.04	185.89	0.94	7.70	12.43	1.61
main	10636	010YR	1860	1860.00	349.99	0.00240	357.59	357.81	0.00097	4.85	4.76	104.36	496.41	0.30	3.75	1.08	0.29
main	10222	010YR	1860	1829.03	349.00	-0.00190	356.60	357.09	0.00349	3.47	3.41	94.56	322.20	0.54	5.68	4.21	0.74
main	9912	010YR	1860	1206.88	349.60	0.01720	356.83	356.85	0.00011	5.36	5.34	164.45	878.37	0.10	1.37	0.05	0.04
main	9542	010YR	1860	1800.10	343.24	0.00010	356.84	356.84	0.00000	11.97	11.96	724.50	8665.26	0.01	0.21	0.00	0.00
main	9056	010YR	1860	1859.77	343.21	-0.00290	356.84	356.84	0.00000	11.78	11.71	609.24	7135.58	0.01	0.26	0.00	0.00
main	8465	010YR	1860	1810.11	344.90	-0.00100	356.83	356.84	0.00001	11.07	10.88	215.15	2341.13	0.04	0.77	0.01	0.01
main	8046	010YR	1860	1860.00	345.34	0.00010	356.55	356.80	0.00065	7.57	6.95	67.69	470.52	0.25	3.95	1.12	0.28
main	7601	010YR	1860	1666.20	345.30	0.01220	356.67	356.69	0.00003	9.72	9.66	153.15	1478.70	0.06	1.13	0.02	0.02
main	7146	010YR	1860	1847.56	339.73	-0.00090	356.68	356.68	0.00000	15.00	14.95	432.47	6464.14	0.01	0.29	0.00	0.00
main	6727	010YR	1860	1858.74	340.12	-0.01330	356.68	356.68	0.00000	14.12	13.99	423.29	5920.48	0.01	0.31	0.00	0.00
main	6395	010YR	1860	1826.17	344.54	-0.00500	356.67	356.68	0.00001	11.13	11.01	268.62	2956.82	0.03	0.62	0.00	0.01
main	6072	010YR	1860	1735.09	346.15	-0.00180	356.63	356.67	0.00014	5.57	5.52	201.58	1111.79	0.12	1.56	0.07	0.05
main	5737	010YR	1860	1517.10	346.76	0.00110	356.62	356.64	0.00005	8.64	8.57	135.27	1158.65	0.08	1.31	0.04	0.03
main	5292	010YR	1860	1626.27	346.28	0.00360	356.52	356.59	0.00020	8.02	7.87	87.66	689.51	0.15	2.36	0.23	0.10
main	4956	010YR	1860	1854.00	345.07	-0.00220	356.39	356.51	0.00030	7.44	7.20	94.79	682.25	0.18	2.72	0.36	0.13
main	4489	010YR	1860	1834.69	346.10	0.00030	356.14	356.32	0.00052	6.76	6.55	82.47	540.03	0.23	3.40	0.73	0.21
main	4125	010YR	1860	1802.04	346.00	0.00100	356.15	356.21	0.00011	8.48	8.43	114.72	966.55	0.11	1.86	0.11	0.06
main	3664	010YR	1860	1685.42	345.56	0.00920	356.10	356.15	0.00012	8.29	8.16	107.58	877.86	0.12	1.92	0.12	0.06
main	3386	010YR	1860	1819.54	343.00	-0.01720	356.12	356.13	0.00001	11.38	11.29	218.96	2471.67	0.04	0.74	0.01	0.01
main	3010	010YR	1860	1822.29	349.45	0.01320	355.73	356.08	0.00274	3.22	3.19	118.90	378.94	0.47	4.81	2.62	0.54
main	2714	010YR	1860	1707.94	345.54	0.00290	355.74	355.83	0.00025	7.11	6.98	99.68	695.92	0.16	2.45	0.27	0.11
main	2423	010YR	1860	1782.03	344.70	-0.00920	355.67	355.76	0.00021	8.10	7.94	91.44	726.33	0.15	2.45	0.26	0.10
main	2164	010YR	1860	1681.82	347.09	0.00030	355.60	355.70	0.00030	6.65	6.58	98.72	649.35	0.18	2.59	0.32	0.12
main	1833	010YR	1860	1839.39	346.99	0.00090	355.46	355.58	0.00038	6.41	6.24	104.70	653.04	0.20	2.82	0.42	0.15
main	1422	010YR	1860	1381.96	346.60	-0.00350	355.21	355.37	0.00074	5.75	5.62	67.36	378.50	0.27	3.65	0.95	0.26
main	1198	010YR	1860	1658.06	347.39	0.00000	354.42	354.98	0.00243	5.44	5.29	49.39	261.15	0.48	6.35	5.09	0.80
main	1133		Bridge														
main	1068	010YR	1860	1641.25	349.56	0.02080	352.37	353.15	0.01120	2.18	2.18	100.05	217.63	0.90	7.54	11.47	1.52
main	764	010YR	1860	1716.43	343.22	-0.00820	351.06	351.26	0.00155	3.30	3.25	143.97	467.83	0.36	3.67	1.15	0.31
main	427	010YR	1860	1597.78	345.99	0.00310	350.35	350.62	0.00224	3.25	3.25	111.77	362.87	0.43	4.40	2.00	0.45
main	31	010YR	1860	1628.94	344.77		348.81	349.31	0.00500	2.87	2.86	94.10	269.23	0.63	6.05	5.40	0.89

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30366	050YR	4150	3560.74	466.44	0.02100	471.26	472.44	0.01094	3.06	3.04	125.33	381.64	0.94	9.33	19.41	2.08
main	30144	050YR	4150	3968.51	461.78	0.00620	469.90	470.73	0.00502	3.98	3.91	136.22	532.15	0.66	7.46	9.12	1.22
main	29871	050YR	4150	3780.07	460.08	-0.00170	468.45	469.36	0.00500	4.44	4.38	107.37	470.33	0.67	8.04	10.99	1.37
main	29561	050YR	4150	3230.04	460.61	0.00290	466.67	467.50	0.00648	3.72	3.67	108.05	396.95	0.74	8.14	12.09	1.49
main	29271	050YR	4150	3707.76	459.76	0.01150	465.06	465.78	0.00539	3.54	3.50	147.62	516.43	0.67	7.18	8.44	1.18
main	28884	050YR	4150	3818.20	455.32	0.00250	463.26	463.98	0.00417	4.18	4.14	130.55	540.24	0.61	7.07	7.62	1.08
main	28487	050YR	4150	3344.51	454.33	0.00480	461.99	462.40	0.00344	3.44	3.41	173.60	592.74	0.54	5.64	4.13	0.73
main	27991	050YR	4150	3956.73	451.96	0.01220	457.89	459.58	0.00974	4.12	4.06	91.27	370.83	0.93	10.67	26.37	2.47
main	27647	050YR	4150	3875.57	447.74	-0.00100	456.37	457.03	0.00286	5.22	5.11	112.83	576.02	0.52	6.73	6.13	0.91
main	27319	050YR	4150	4150.00	448.07	0.00690	453.60	455.33	0.01026	3.90	3.84	102.34	393.36	0.94	10.55	25.97	2.46
main	27038	050YR	4150	3455.90	446.12	0.00880	451.85	452.89	0.00631	4.32	4.29	90.54	388.19	0.75	8.90	15.04	1.69
main	26616	050YR	4150	3275.44	442.40	0.00760	448.35	449.68	0.01010	3.80	3.75	84.85	318.16	0.93	10.29	24.33	2.36
main	26193	050YR	4150	4150.00	439.19	0.00080	446.69	447.19	0.00257	4.33	4.30	169.85	729.89	0.48	5.69	3.92	0.69
main	25990	050YR	4150	4150.00	439.02	0.00000	445.81	446.49	0.00407	3.87	3.82	164.52	627.78	0.59	6.61	6.40	0.97
main	25922		Bridge														
main	25853	050YR	4150	4150.00	438.99	0.00480	445.34	445.78	0.00210	4.55	4.51	172.82	780.22	0.44	5.32	3.15	0.59
main	25698	050YR	4150	4150.00	438.25	0.00960	443.96	445.05	0.00672	3.78	3.73	132.84	495.73	0.76	8.37	13.10	1.56
main	25470	050YR	4150	4150.00	436.05	0.00120	441.81	443.28	0.00791	4.19	4.13	103.38	426.96	0.84	9.72	19.82	2.04
main	25230	050YR	4150	4137.77	435.76	0.00710	440.65	441.53	0.00554	3.70	3.69	148.78	548.70	0.69	7.54	9.61	1.27
main	24958	050YR	4150	4150.00	433.84	0.00950	439.58	440.26	0.00361	4.22	4.19	149.54	626.28	0.57	6.63	6.25	0.94
main	24663		Lat Struct														
main	24662	050YR	4150	4140.89	431.03	0.00400	439.59	439.78	0.00054	6.72	6.65	177.83	1182.42	0.24	3.50	0.79	0.23
main	24622		Inl Struct														
main	24582	050YR	4150	4150.00	430.71	0.01190	435.70	436.38	0.00354	4.25	4.21	149.34	629.37	0.56	6.59	6.15	0.93
main	24266	050YR	4150	4150.00	426.97	0.00310	434.11	435.06	0.00474	4.43	4.38	121.22	530.67	0.66	7.82	10.13	1.29
main	23662	050YR	4150	4150.00	425.11	0.00560	430.65	431.80	0.00617	4.18	4.14	116.68	482.75	0.74	8.60	13.71	1.59
main	23066	050YR	4150	4150.00	421.76	0.00400	427.49	428.42	0.00504	4.14	4.10	130.98	537.33	0.67	7.72	9.97	1.29
main	22570	050YR	4150	4136.04	419.78	0.00490	425.46	426.19	0.00382	4.30	4.27	140.52	599.35	0.59	6.90	7.02	1.02
main	22189	050YR	4150	4150.00	417.92	0.00920	422.65	423.95	0.00961	3.28	3.26	139.37	453.92	0.89	9.14	17.86	1.95
main	21634	050YR	4150	4150.00	412.81	0.00190	419.97	420.73	0.00357	4.62	4.58	129.76	593.71	0.57	6.99	7.13	1.02
main	21166	050YR	4150	4150.00	411.91	0.00630	417.35	418.50	0.00640	4.08	4.05	118.89	481.11	0.75	8.63	13.95	1.62
main	20682	050YR	4150	4150.00	408.84	0.00780	414.62	415.68	0.00521	4.48	4.42	113.60	502.58	0.69	8.26	11.88	1.44
main	20306	050YR	4150	4150.00	405.92	0.00400	411.63	413.08	0.00926	3.68	3.65	117.67	428.94	0.89	9.68	20.38	2.11
main	20017	050YR	4150	4150.00	404.76	0.00560	410.89	411.48	0.00279	4.57	4.53	149.09	675.71	0.51	6.14	4.85	0.79
main	19799	050YR	4150	4146.25	403.53	0.00490	409.64	410.62	0.00522	4.23	4.19	124.10	519.94	0.68	7.97	10.90	1.37
main	19719	050YR	4150	4064.38	403.14	0.00790	409.80	410.22	0.00182	4.97	4.94	156.49	772.97	0.42	5.26	2.96	0.56
main	19644	050YR	4150	4148.68	402.55	0.00000	409.49	410.03	0.00244	4.75	4.71	149.43	703.88	0.48	5.89	4.23	0.72
main	19624		Bridge														
main	19604	050YR	4150	4150.00	402.24	0.00800	409.21	409.84	0.00296	4.62	4.58	142.19	651.30	0.52	6.37	5.40	0.85
main	19599	050YR	4150	4150.00	402.20	0.00000	409.18	409.82	0.00303	4.61	4.57	141.08	645.15	0.53	6.43	5.55	0.86
main	19537		Bridge														
main	19475	050YR	4150	4150.00	400.96	0.00740	407.04	408.83	0.01220	3.50	3.46	111.61	386.55	1.01	10.74	28.33	2.64
main	19209	050YR	4150	4150.00	398.98	0.00920	404.48	405.73	0.00791	3.71	3.67	126.01	462.10	0.82	8.98	16.27	1.81
main	18745	050YR	4150	3775.35	394.72	0.00790	402.46	403.22	0.00331	5.22	5.17	100.17	517.40	0.56	7.30	7.78	1.07
main	18176	050YR	4150	4150.00	390.20	-0.00130	397.78	399.92	0.01148	4.27	4.14	85.56	354.03	1.00	11.72	34.75	2.96
main	17757	050YR	4150	3379.58	390.76	0.00470	397.99	398.25	0.00096	6.28	6.25	120.95	755.75	0.31	4.47	1.68	0.38
main	17383	050YR	4150	1987.04	389.00	0.00540	396.99	397.59	0.00405	6.06	5.72	40.22	229.91	0.62	8.64	12.50	1.45
main	16980	050YR	4150	2115.71	386.81	0.00480	395.21	395.84	0.00484	5.18	4.92	50.42	247.84	0.66	8.54	12.67	1.48
main	16590	050YR	4150	1845.99	384.94	0.00530	392.93	393.68	0.00686	4.91	4.61	41.10	189.55	0.78	9.74	19.22	1.97
main	16231	050YR	4150	2062.99	383.04	0.00520	390.92	391.60	0.00476	5.64	5.35	43.01	230.26	0.67	8.96	14.24	1.59

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	15652	050YR	4150	2082.97	380.02	0.00540	387.81	388.67	0.00620	5.55	5.23	39.61	206.98	0.75	10.06	20.34	2.02
main	15205	050YR	4150	2208.72	377.62	0.00520	385.49	386.22	0.00487	5.57	5.29	46.39	245.56	0.67	8.99	14.46	1.61
main	14694	050YR	4150	1879.99	374.95	0.00500	383.19	383.82	0.00484	5.60	5.26	39.95	210.27	0.67	8.94	14.23	1.59
main	14297	050YR	4150	1796.72	372.97	0.00520	381.43	382.02	0.00482	5.47	5.13	39.92	204.85	0.66	8.77	13.55	1.54
main	13870	050YR	4150	1783.90	370.73	0.00510	379.02	379.75	0.00642	5.12	4.78	38.68	184.81	0.75	9.65	18.49	1.92
main	13510	050YR	4150	2081.14	368.88	0.00520	376.98	377.77	0.00525	5.90	5.55	38.94	215.96	0.70	9.64	17.51	1.82
main	13053	050YR	4150	1994.71	366.52	0.00500	374.82	375.52	0.00489	5.77	5.43	40.09	217.54	0.67	9.17	15.20	1.66
main	12660	050YR	4150	2248.47	364.55	0.00530	372.32	373.30	0.00708	5.26	4.98	43.39	215.98	0.80	10.41	22.89	2.20
main	12256	050YR	4150	1821.03	362.43	0.00530	370.80	371.30	0.00348	6.26	5.88	37.98	223.16	0.57	8.16	10.43	1.28
main	11904	050YR	4150	2060.71	360.55	-0.00070	368.00	369.17	0.01175	4.36	4.10	42.56	174.69	1.00	11.80	35.51	3.01
main	11439	050YR	4150	3512.24	360.87	0.01000	363.62	364.02	0.00553	2.28	2.28	281.22	641.84	0.64	5.47	4.31	0.79
main	10998	050YR	4150	2614.74	356.48	0.01790	360.94	361.57	0.00580	3.74	3.73	90.04	336.05	0.71	7.78	10.52	1.35
main	10636	050YR	4150	3977.97	349.99	0.00240	360.44	360.81	0.00097	7.43	7.28	110.22	802.69	0.32	4.96	2.17	0.44
main	10222	050YR	4150	3136.26	349.00	-0.00190	360.12	360.39	0.00097	6.83	6.72	98.95	664.80	0.32	4.72	1.93	0.41
main	9912	050YR	4150	2265.36	349.60	0.01720	360.23	360.26	0.00008	8.77	8.74	164.45	1436.73	0.09	1.58	0.07	0.04
main	9542	050YR	4150	3991.27	343.24	0.00010	360.25	360.25	0.00000	15.38	15.37	724.50	11132.29	0.02	0.36	0.00	0.00
main	9056	050YR	4150	4145.17	343.21	-0.00290	360.24	360.25	0.00000	15.19	15.10	609.24	9198.86	0.02	0.45	0.00	0.00
main	8465	050YR	4150	3931.35	344.90	-0.00100	360.22	360.24	0.00003	14.46	14.21	215.15	3058.15	0.06	1.29	0.03	0.02
main	8046	050YR	4150	3655.87	345.34	0.00010	359.80	360.18	0.00083	9.48	8.78	79.73	700.27	0.30	5.22	2.39	0.46
main	7601	050YR	4150	3481.46	345.30	0.01220	359.97	360.01	0.00006	13.02	12.93	153.15	1980.90	0.09	1.76	0.08	0.05
main	7146	050YR	4150	4082.56	339.73	-0.00090	359.99	360.00	0.00000	18.32	18.25	432.47	7891.27	0.02	0.52	0.00	0.00
main	6727	050YR	4150	4120.60	340.12	-0.01330	359.99	360.00	0.00000	17.43	17.27	423.29	7309.07	0.02	0.56	0.00	0.00
main	6395	050YR	4150	3897.41	344.54	-0.00500	359.98	359.99	0.00002	14.43	14.27	268.62	3834.35	0.05	1.02	0.01	0.01
main	6072	050YR	4150	3394.05	346.15	-0.00180	359.93	359.98	0.00011	8.86	8.78	201.58	1770.18	0.11	1.92	0.12	0.06
main	5737	050YR	4150	3037.87	346.76	0.00110	359.90	359.95	0.00007	11.93	11.83	135.27	1599.60	0.10	1.90	0.10	0.05
main	5292	050YR	4150	3291.96	346.28	0.00360	359.73	359.88	0.00026	11.24	11.02	87.66	966.33	0.18	3.41	0.62	0.18
main	4956	050YR	4150	4021.03	345.07	-0.00220	359.49	359.76	0.00043	10.54	10.20	94.79	966.76	0.23	4.16	1.15	0.28
main	4489	050YR	4150	3828.75	346.10	0.00030	359.15	359.50	0.00067	9.77	9.46	82.47	780.54	0.28	4.91	1.93	0.39
main	4125	050YR	4150	3924.42	346.00	0.00100	359.19	359.32	0.00019	11.51	11.44	114.72	1311.83	0.16	2.99	0.41	0.14
main	3664	050YR	4150	3399.41	345.56	0.00920	359.12	359.23	0.00018	11.31	11.13	107.58	1197.60	0.15	2.84	0.35	0.12
main	3386	050YR	4150	4008.18	343.00	-0.01720	359.16	359.19	0.00003	14.42	14.30	218.96	3131.05	0.06	1.28	0.03	0.02
main	3010	050YR	4150	3766.11	349.45	0.01320	358.75	359.12	0.00129	6.24	6.17	118.90	734.01	0.36	5.13	2.55	0.50
main	2714	050YR	4150	3488.80	345.54	0.00290	358.73	358.89	0.00033	10.09	9.91	99.68	987.77	0.20	3.53	0.71	0.20
main	2423	050YR	4150	3832.53	344.70	-0.00920	358.57	358.79	0.00035	11.00	10.78	91.44	985.97	0.21	3.89	0.92	0.24
main	2164	050YR	4150	3439.07	347.09	0.00030	358.50	358.68	0.00038	9.55	9.45	98.72	932.80	0.21	3.69	0.82	0.22
main	1833	050YR	4150	3911.00	346.99	0.00090	358.27	358.53	0.00052	9.22	8.98	104.70	939.74	0.24	4.16	1.20	0.29
main	1422	050YR	4150	2741.49	346.60	-0.00350	358.02	358.28	0.00077	8.56	8.37	67.36	563.62	0.29	4.86	1.96	0.40
main	1198	050YR	4150	2761.69	347.39	0.00000	357.50	357.98	0.00151	8.52	8.28	49.39	408.94	0.41	6.75	5.27	0.78
main	1133		Bridge														
main	1068	050YR	4150	3275.01	349.56	0.02080	353.50	354.73	0.01103	3.31	3.31	100.05	330.91	0.96	9.90	22.54	2.28
main	764	050YR	4150	3660.28	343.22	-0.00820	352.91	353.26	0.00161	5.14	5.06	143.97	729.17	0.39	5.02	2.55	0.51
main	427	050YR	4150	3324.85	345.99	0.00310	352.15	352.59	0.00224	5.05	5.04	111.77	563.32	0.46	5.90	4.15	0.70
main	31	050YR	4150	3409.45	344.77		350.41	351.27	0.00500	4.46	4.46	94.10	419.34	0.68	8.13	11.31	1.39

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30366	100YR	7000	5492.48	466.44	0.02100	472.42	473.78	0.00893	4.21	4.20	125.33	526.15	0.90	10.44	24.42	2.34
main	30144	100YR	7000	6097.01	461.78	0.00620	470.96	472.07	0.00541	5.04	4.94	136.22	673.19	0.71	9.06	15.11	1.67
main	29871	100YR	7000	5436.28	460.08	-0.00170	469.78	470.74	0.00431	5.77	5.70	107.37	611.74	0.65	8.89	13.61	1.53
main	29561	100YR	7000	5157.42	460.61	0.00290	467.75	468.93	0.00747	4.53	4.48	115.67	517.72	0.83	9.96	20.78	2.09
main	29271	100YR	7000	5565.22	459.76	0.01150	466.53	467.25	0.00405	4.72	4.66	158.60	738.37	0.61	7.54	8.88	1.18
main	28884	100YR	7000	6005.93	455.32	0.00250	464.65	465.52	0.00512	4.35	4.31	172.97	746.01	0.68	8.05	11.10	1.38
main	28487	100YR	7000	5418.41	454.33	0.00480	463.38	463.89	0.00306	4.58	4.54	185.49	842.20	0.53	6.43	5.57	0.87
main	27991	100YR	7000	6111.71	451.96	0.01220	459.53	461.38	0.00847	5.24	5.14	102.26	525.36	0.90	11.63	31.60	2.72
main	27647	100YR	7000	5910.29	447.74	-0.00100	458.51	459.19	0.00232	6.73	6.56	125.80	825.27	0.49	7.16	6.80	0.95
main	27319	100YR	7000	7000.00	448.07	0.00690	455.06	457.61	0.01085	5.02	4.93	110.85	546.47	1.01	12.81	42.77	3.34
main	27038	100YR	7000	5639.51	446.12	0.00880	452.93	454.67	0.00798	5.40	5.36	90.54	485.36	0.88	11.62	31.04	2.67
main	26616	100YR	7000	5065.19	442.40	0.00760	449.75	451.34	0.00847	5.20	5.13	84.85	435.58	0.90	11.63	31.57	2.72
main	26193	100YR	7000	7000.00	439.19	0.00080	448.50	449.17	0.00285	4.95	4.91	217.56	1068.68	0.52	6.55	5.73	0.87
main	25990	100YR	7000	7000.00	439.02	0.00000	447.76	448.52	0.00333	4.87	4.81	208.61	1002.76	0.56	6.98	6.98	1.00
main	25922		Bridge														
main	25853	100YR	7000	7000.00	438.99	0.00480	447.41	447.99	0.00184	6.19	6.12	187.59	1148.45	0.43	6.10	4.29	0.70
main	25698	100YR	7000	7000.00	438.25	0.00960	446.24	447.39	0.00437	5.50	5.40	149.98	810.37	0.65	8.64	12.72	1.47
main	25470	100YR	7000	7000.00	436.05	0.00120	442.96	445.50	0.01064	5.07	4.99	109.83	547.67	1.00	12.78	42.33	3.31
main	25230	100YR	7000	6813.90	435.76	0.00710	442.12	443.30	0.00509	5.01	4.98	154.62	770.68	0.70	8.84	14.01	1.59
main	24958	100YR	7000	6998.31	433.84	0.00950	440.13	441.64	0.00713	4.60	4.56	155.48	709.64	0.81	9.86	20.03	2.03
main	24663		Lat Struct														
main	24662	100YR	7000	6919.49	431.03	0.00400	440.17	440.61	0.00119	7.12	7.05	182.23	1284.24	0.36	5.39	2.83	0.52
main	24622		Inl Struct														
main	24582	100YR	7000	7000.00	430.71	0.01190	437.58	438.48	0.00319	5.72	5.66	162.36	918.88	0.56	7.62	8.59	1.13
main	24266	100YR	7000	6980.86	426.97	0.00310	435.95	437.23	0.00470	5.59	5.52	139.14	768.00	0.68	9.09	14.72	1.62
main	23662	100YR	7000	7000.00	425.11	0.00560	432.34	433.95	0.00622	5.38	5.31	129.37	686.99	0.77	10.19	21.00	2.06
main	23066	100YR	7000	6980.68	421.76	0.00400	429.00	430.37	0.00560	5.13	5.09	146.02	742.84	0.73	9.40	16.71	1.78
main	22570	100YR	7000	6726.96	419.78	0.00490	426.80	427.89	0.00419	5.51	5.45	144.82	789.92	0.64	8.52	12.15	1.43
main	22189	100YR	7000	6932.01	417.92	0.00920	424.36	425.76	0.00760	4.14	4.12	177.01	729.03	0.82	9.51	18.58	1.95
main	21634	100YR	7000	6929.94	412.81	0.00190	421.43	422.62	0.00423	5.74	5.69	138.52	787.89	0.65	8.80	13.20	1.50
main	21166	100YR	7000	6636.37	411.91	0.00630	419.17	420.48	0.00490	5.68	5.63	125.25	705.48	0.70	9.41	16.20	1.72
main	20682	100YR	7000	7000.00	408.84	0.00780	416.05	417.76	0.00631	5.57	5.48	121.77	667.64	0.78	10.48	22.64	2.16
main	20306	100YR	7000	6838.94	405.92	0.00400	413.15	415.03	0.00827	4.95	4.89	125.63	614.71	0.88	11.13	28.09	2.53
main	20017	100YR	7000	6899.64	404.76	0.00560	412.56	413.39	0.00292	5.83	5.77	161.81	934.17	0.54	7.39	7.78	1.05
main	19799	100YR	7000	6175.44	403.53	0.00490	411.97	412.77	0.00268	6.49	6.43	126.22	812.09	0.53	7.60	8.19	1.08
main	19719	100YR	7000	6420.72	403.14	0.00790	412.06	412.52	0.00134	7.08	7.00	161.08	1128.28	0.38	5.69	3.34	0.59
main	19644	100YR	7000	6849.08	402.55	0.00000	411.67	412.34	0.00194	6.76	6.69	154.27	1031.73	0.45	6.64	5.38	0.81
main	19624		Bridge														
main	19604	100YR	7000	6959.37	402.24	0.00800	411.31	412.13	0.00248	6.44	6.37	150.44	958.34	0.50	7.26	7.16	0.99
main	19599	100YR	7000	6964.27	402.20	0.00000	411.28	412.11	0.00254	6.41	6.34	149.99	950.67	0.51	7.33	7.36	1.00
main	19537		Bridge														
main	19475	100YR	7000	7000.00	400.96	0.00740	408.60	410.98	0.01086	4.75	4.68	120.77	565.35	1.00	12.38	39.30	3.17
main	19209	100YR	7000	6999.96	398.98	0.00920	405.92	407.74	0.00789	4.95	4.87	132.88	646.56	0.86	10.83	25.94	2.40
main	18745	100YR	7000	5964.67	394.72	0.00790	403.62	404.82	0.00423	6.38	6.31	100.17	632.45	0.66	9.43	15.72	1.67
main	18176	100YR	7000	6231.64	390.20	-0.00130	399.86	401.71	0.00727	5.90	5.68	95.35	541.23	0.84	11.51	29.64	2.57
main	17757	100YR	7000	5538.12	390.76	0.00470	399.53	399.97	0.00125	7.81	7.78	120.95	940.41	0.37	5.89	3.57	0.61
main	17383	100YR	7000	2835.63	389.00	0.00540	398.52	399.21	0.00390	7.59	7.16	40.22	288.02	0.63	9.85	17.15	1.74
main	16980	100YR	7000	3193.19	386.81	0.00480	396.72	397.52	0.00469	6.69	6.35	50.42	320.19	0.68	9.97	18.55	1.86
main	16590	100YR	7000	2846.33	384.94	0.00530	394.40	395.41	0.00678	6.38	6.00	41.10	246.65	0.81	11.54	29.29	2.54
main	16231	100YR	7000	3089.25	383.04	0.00520	392.44	393.31	0.00481	7.16	6.80	43.01	292.39	0.70	10.57	21.57	2.04

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	15652	100YR	7000	3098.13	380.02	0.00540	389.32	390.40	0.00613	7.06	6.65	39.61	263.55	0.78	11.76	29.92	2.54
main	15205	100YR	7000	3321.07	377.62	0.00520	387.02	387.95	0.00490	7.10	6.75	46.39	313.00	0.70	10.61	21.90	2.06
main	14694	100YR	7000	2818.39	374.95	0.00500	384.78	385.58	0.00473	7.19	6.76	39.95	269.95	0.69	10.44	20.85	2.00
main	14297	100YR	7000	2763.89	372.97	0.00520	382.99	383.80	0.00493	7.03	6.60	39.92	263.52	0.70	10.49	21.30	2.03
main	13870	100YR	7000	2744.49	370.73	0.00510	380.53	381.50	0.00643	6.63	6.19	38.68	239.30	0.79	11.47	28.46	2.48
main	13510	100YR	7000	3080.03	368.88	0.00520	378.55	379.54	0.00523	7.48	7.03	38.94	273.58	0.73	11.26	25.81	2.29
main	13053	100YR	7000	3004.40	366.52	0.00500	376.37	377.28	0.00503	7.31	6.88	40.09	275.77	0.71	10.89	23.55	2.16
main	12660	100YR	7000	3386.08	364.55	0.00530	373.67	374.97	0.00751	6.61	6.25	43.39	271.26	0.86	12.48	36.57	2.93
main	12256	100YR	7000	2604.87	362.43	0.00530	372.22	372.84	0.00360	7.68	7.21	37.98	273.85	0.61	9.51	15.43	1.62
main	11904	100YR	7000	3060.19	360.55	-0.00070	369.00	370.56	0.01300	5.36	5.05	42.56	214.84	1.08	14.24	58.36	4.10
main	11439	100YR	7000	5802.27	360.87	0.01000	364.71	365.21	0.00408	3.38	3.38	281.22	950.52	0.59	6.10	5.25	0.86
main	10998	100YR	7000	3794.28	356.48	0.01790	363.57	363.98	0.00207	6.37	6.36	90.04	572.47	0.46	6.63	5.44	0.82
main	10636	100YR	7000	6277.30	349.99	0.00240	363.06	363.53	0.00088	10.05	9.85	110.22	1085.22	0.32	5.78	3.13	0.54
main	10222	100YR	7000	4546.88	349.00	-0.00190	362.92	363.17	0.00065	9.62	9.47	98.95	936.64	0.28	4.85	1.87	0.39
main	9912	100YR	7000	3568.78	349.60	0.01720	363.01	363.05	0.00008	11.55	11.51	164.45	1892.30	0.10	1.89	0.10	0.05
main	9542	100YR	7000	6705.45	343.24	0.00010	363.03	363.03	0.00000	18.16	18.15	724.50	13147.46	0.02	0.51	0.00	0.00
main	9056	100YR	7000	6983.63	343.21	-0.00290	363.03	363.03	0.00001	17.97	17.86	609.24	10883.70	0.03	0.64	0.00	0.01
main	8465	100YR	7000	6506.07	344.90	-0.00100	362.98	363.02	0.00004	17.22	16.93	215.15	3641.68	0.08	1.79	0.08	0.04
main	8046	100YR	7000	4740.14	345.34	0.00010	362.66	362.96	0.00058	12.35	11.43	79.73	911.71	0.26	5.20	2.16	0.42
main	7601	100YR	7000	5552.62	345.30	0.01220	362.75	362.82	0.00008	15.80	15.69	153.15	2403.56	0.10	2.31	0.17	0.07
main	7146	100YR	7000	6815.30	339.73	-0.00090	362.78	362.79	0.00001	21.11	21.03	432.47	9093.61	0.03	0.75	0.01	0.01
main	6727	100YR	7000	6897.55	340.12	-0.01330	362.78	362.79	0.00001	20.22	20.03	423.29	8478.64	0.03	0.81	0.01	0.01
main	6395	100YR	7000	6359.28	344.54	-0.00500	362.76	362.78	0.00003	17.21	17.02	268.62	4572.74	0.06	1.39	0.04	0.03
main	6072	100YR	7000	5368.84	346.15	-0.00180	362.70	362.77	0.00011	11.63	11.53	201.58	2323.44	0.12	2.31	0.19	0.08
main	5737	100YR	7000	4812.14	346.76	0.00110	362.66	362.73	0.00009	14.69	14.56	135.27	1969.88	0.11	2.44	0.21	0.08
main	5292	100YR	7000	5228.96	346.28	0.00360	362.42	362.65	0.00032	13.92	13.66	87.66	1197.12	0.21	4.37	1.21	0.28
main	4956	100YR	7000	6673.92	345.07	-0.00220	362.02	362.48	0.00059	13.07	12.64	94.79	1198.07	0.27	5.57	2.57	0.46
main	4489	100YR	7000	6141.88	346.10	0.00030	361.61	362.15	0.00081	12.22	11.84	82.47	976.65	0.32	6.29	3.78	0.60
main	4125	100YR	7000	6499.93	346.00	0.00100	361.66	361.90	0.00028	13.99	13.89	114.72	1593.73	0.19	4.08	0.98	0.24
main	3664	100YR	7000	5406.27	345.56	0.00920	361.60	361.77	0.00024	13.79	13.57	107.58	1459.70	0.18	3.70	0.74	0.20
main	3386	100YR	7000	6702.53	343.00	-0.01720	361.66	361.71	0.00004	16.92	16.77	218.96	3672.72	0.08	1.82	0.08	0.05
main	3010	100YR	7000	6139.79	349.45	0.01320	361.11	361.61	0.00118	8.59	8.51	118.90	1011.73	0.36	6.07	3.79	0.62
main	2714	100YR	7000	5620.07	345.54	0.00290	361.08	361.35	0.00042	12.45	12.22	99.68	1218.34	0.23	4.61	1.48	0.32
main	2423	100YR	7000	6325.62	344.70	-0.00920	360.80	361.20	0.00052	13.23	12.97	91.44	1186.12	0.26	5.33	2.24	0.42
main	2164	100YR	7000	5544.85	347.09	0.00030	360.75	361.04	0.00049	11.79	11.67	98.72	1152.36	0.25	4.81	1.70	0.35
main	1833	100YR	7000	6400.44	346.99	0.00090	360.40	360.84	0.00069	11.35	11.04	104.70	1156.28	0.29	5.54	2.64	0.48
main	1422	100YR	7000	4355.07	346.60	-0.00350	360.11	360.51	0.00094	10.64	10.40	67.36	700.84	0.34	6.21	3.81	0.61
main	1198	100YR	7000	4054.90	347.39	0.00000	359.59	360.19	0.00157	10.61	10.31	49.39	509.18	0.43	7.96	8.04	1.01
main	1133		Bridge														
main	1068	100YR	7000	5064.71	349.56	0.02080	355.20	356.40	0.00663	5.01	5.00	100.05	500.68	0.80	10.12	20.96	2.07
main	764	100YR	7000	5995.76	343.22	-0.00820	354.65	355.16	0.00163	6.88	6.78	143.97	976.42	0.41	6.14	4.24	0.69
main	427	100YR	7000	5373.31	345.99	0.00310	353.87	354.49	0.00220	6.77	6.76	111.77	755.05	0.48	7.12	6.60	0.93
main	31	100YR	7000	5549.06	344.77		351.92	353.16	0.00500	5.98	5.97	94.10	561.59	0.71	9.88	18.42	1.86

Reach	River Sta	Profile	Q Total	Q Channel	Min Ch El	Invert Slope	W.S. Elev	E.G. Elev	E.G. Slope	Hydr Depth C	Hydr Radius C	W.P. Channel	Flow Area Ch	Froude # Chl	Vel Chnl	Power Chan	Shear Chan
			(cfs)	(cfs)	(ft)		(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)	(sq ft)		(ft/s)	(lb/ft s)	(lb/sq ft)
main	30366	500YR	9080	6783.99	466.44	0.02100	473.00	474.51	0.00887	4.79	4.77	125.33	598.41	0.91	11.34	29.97	2.64
main	30144	500YR	9080	7428.88	461.78	0.00620	471.49	472.77	0.00575	5.57	5.46	136.22	743.95	0.75	9.99	19.58	1.96
main	29871	500YR	9080	6136.94	460.08	-0.00170	470.67	471.48	0.00341	6.66	6.57	107.37	705.63	0.59	8.70	12.16	1.40
main	29561	500YR	9080	6559.49	460.61	0.00290	468.28	469.78	0.00831	5.07	5.01	115.67	579.24	0.89	11.32	29.40	2.60
main	29271	500YR	9080	6780.69	459.76	0.01150	467.23	467.99	0.00387	5.33	5.26	161.30	848.47	0.61	7.99	10.17	1.27
main	28884	500YR	9080	7532.63	455.32	0.00250	465.29	466.30	0.00519	4.89	4.85	177.19	859.41	0.70	8.76	13.78	1.57
main	28487	500YR	9080	6809.59	454.33	0.00480	464.05	464.64	0.00305	5.26	5.21	185.49	966.59	0.54	7.04	6.99	0.99
main	27991	500YR	9080	7393.18	451.96	0.01220	460.58	462.32	0.00708	5.99	5.87	108.25	635.67	0.84	11.63	30.20	2.60
main	27647	500YR	9080	6945.72	447.74	-0.00100	459.85	460.43	0.00206	7.03	6.87	145.38	998.28	0.46	6.96	6.14	0.88
main	27319	500YR	9080	9068.56	448.07	0.00690	456.29	459.00	0.00944	5.84	5.73	119.90	686.78	0.96	13.20	44.57	3.38
main	27038	500YR	9080	7164.85	446.12	0.00880	453.58	455.78	0.00883	6.05	6.00	90.54	543.64	0.94	13.18	43.62	3.31
main	26616	500YR	9080	6315.65	442.40	0.00760	450.75	452.43	0.00736	6.20	6.11	84.85	518.59	0.86	12.18	34.22	2.81
main	26193	500YR	9080	9080.00	439.19	0.00080	449.73	450.42	0.00265	5.36	5.32	256.64	1364.90	0.51	6.65	5.84	0.88
main	25990	500YR	9080	9080.00	439.02	0.00000	449.07	449.85	0.00266	5.92	5.84	218.97	1279.17	0.51	7.10	6.88	0.97
main	25922		Bridge														
main	25853	500YR	9080	9080.00	438.99	0.00480	448.78	449.40	0.00196	6.25	6.18	231.82	1432.99	0.45	6.34	4.80	0.76
main	25698	500YR	9080	9080.00	438.25	0.00960	447.54	448.79	0.00399	6.24	6.12	165.31	1012.09	0.63	8.97	13.67	1.52
main	25470	500YR	9080	9080.00	436.05	0.00120	444.01	446.92	0.01021	5.81	5.70	116.39	663.48	1.00	13.69	49.70	3.63
main	25230	500YR	9080	8659.41	435.76	0.00710	443.18	444.45	0.00449	5.89	5.86	159.76	936.45	0.67	9.25	15.19	1.64
main	24958	500YR	9080	9045.74	433.84	0.00950	440.46	442.65	0.00943	4.93	4.90	155.48	761.11	0.94	11.88	34.25	2.88
main	24663		Lat Struct														
main	24662	500YR	9080	8979.30	431.03	0.00400	440.15	440.90	0.00202	7.11	7.04	181.97	1280.47	0.46	7.01	6.23	0.89
main	24622		Inl Struct														
main	24582	500YR	9080	9055.41	430.71	0.01190	438.57	439.66	0.00328	6.46	6.38	169.49	1081.77	0.58	8.37	10.95	1.31
main	24266	500YR	9080	8824.78	426.97	0.00310	437.08	438.45	0.00424	6.48	6.40	144.67	925.82	0.66	9.53	16.16	1.70
main	23662	500YR	9080	9080.00	425.11	0.00560	433.35	435.22	0.00674	5.65	5.58	148.54	828.38	0.81	10.96	25.72	2.35
main	23066	500YR	9080	8918.31	421.76	0.00400	429.87	431.47	0.00565	5.78	5.73	152.34	872.89	0.75	10.22	20.64	2.02
main	22570	500YR	9080	8551.69	419.78	0.00490	427.35	428.77	0.00503	5.97	5.91	146.90	868.56	0.71	9.85	18.28	1.86
main	22189	500YR	9080	8618.70	417.92	0.00920	425.25	426.65	0.00617	5.03	5.00	177.01	884.48	0.77	9.74	18.75	1.92
main	21634	500YR	9080	8911.96	412.81	0.00190	422.23	423.73	0.00451	6.55	6.49	138.52	898.48	0.68	9.92	18.12	1.83
main	21166	500YR	9080	8256.91	411.91	0.00630	420.34	421.68	0.00406	6.85	6.79	125.25	850.69	0.65	9.71	16.72	1.72
main	20682	500YR	9080	9080.00	408.84	0.00780	416.86	419.04	0.00717	6.08	5.98	128.21	766.74	0.85	11.84	31.69	2.68
main	20306	500YR	9080	8684.55	405.92	0.00400	413.98	416.16	0.00816	5.65	5.59	128.62	719.02	0.90	12.08	34.39	2.85
main	20017	500YR	9080	8301.08	404.76	0.00560	413.88	414.62	0.00222	6.93	6.86	167.46	1149.63	0.48	7.22	6.86	0.95
main	19799	500YR	9080	6960.30	403.53	0.00490	413.59	414.16	0.00162	8.11	8.04	126.22	1014.31	0.42	6.86	5.59	0.81
main	19719	500YR	9080	7748.21	403.14	0.00790	413.59	414.01	0.00104	8.46	8.36	164.48	1374.72	0.34	5.64	3.06	0.54
main	19644	500YR	9080	8520.79	402.55	0.00000	413.18	413.85	0.00157	8.11	8.01	158.09	1265.76	0.42	6.73	5.28	0.78
main	19624		Bridge														
main	19604	500YR	9080	8876.94	402.24	0.00800	412.69	413.57	0.00217	7.66	7.56	154.04	1165.10	0.49	7.62	7.80	1.02
main	19599	500YR	9080	8904.16	402.20	0.00000	412.65	413.55	0.00223	7.62	7.53	153.60	1155.93	0.49	7.70	8.08	1.05
main	19537		Bridge														
main	19475	500YR	9080	9080.00	400.96	0.00740	409.56	412.32	0.01041	5.50	5.40	126.15	681.21	1.00	13.33	46.76	3.51
main	19209	500YR	9080	9079.99	398.98	0.00920	405.84	409.01	0.01394	4.88	4.80	132.52	636.42	1.14	14.27	59.62	4.18
main	18745	500YR	9080	7435.54	394.72	0.00790	404.49	405.88	0.00430	7.25	7.17	100.17	718.35	0.68	10.35	19.92	1.92
main	18176	500YR	9080	7691.50	390.20	-0.00130	400.64	402.74	0.00735	6.66	6.40	95.68	612.65	0.86	12.55	36.91	2.94
main	17757	500YR	9080	7081.57	390.76	0.00470	400.46	401.03	0.00140	8.74	8.70	120.95	1052.70	0.40	6.73	5.13	0.76
main	17383	500YR	9080	3417.41	389.00	0.00540	399.47	400.23	0.00381	8.54	8.06	40.22	324.33	0.64	10.54	20.21	1.92
main	16980	500YR	9080	3942.77	386.81	0.00480	397.66	398.57	0.00461	7.64	7.25	50.42	365.41	0.69	10.79	22.48	2.08
main	16590	500YR	9080	3549.45	384.94	0.00530	395.32	396.48	0.00675	7.30	6.86	41.10	281.97	0.82	12.59	36.36	2.89
main	16231	500YR	9080	3806.78	383.04	0.00520	393.38	394.38	0.00485	8.10	7.69	43.01	330.63	0.71	11.51	26.79	2.33

Reach	River Sta	Profile	Q Total (cfs)	Q Channel (cfs)	Min Ch El (ft)	Invert Slope	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Hydr Depth C (ft)	Hydr Radius C (ft)	W.P. Channel (ft)	Flow Area Ch (sq ft)	Froude # Chl	Vel Chnl (ft/s)	Power Chan (lb/ft s)	Shear Chan (lb/sq ft)
main	15652	500YR	9080	3798.96	380.02	0.00540	390.25	391.47	0.00609	7.99	7.53	39.61	298.35	0.79	12.73	36.48	2.86
main	15205	500YR	9080	4089.19	377.62	0.00520	387.98	389.03	0.00488	8.06	7.65	46.39	355.09	0.72	11.52	26.84	2.33
main	14694	500YR	9080	3470.42	374.95	0.00500	385.77	386.68	0.00466	8.18	7.69	39.95	307.23	0.70	11.30	25.29	2.24
main	14297	500YR	9080	3441.47	372.97	0.00520	383.96	384.90	0.00496	8.00	7.51	39.92	299.91	0.72	11.47	26.72	2.33
main	13870	500YR	9080	3419.87	370.73	0.00510	381.47	382.59	0.00642	7.57	7.06	38.68	273.13	0.80	12.52	35.44	2.83
main	13510	500YR	9080	3774.18	368.88	0.00520	379.52	380.64	0.00523	8.44	7.93	38.94	308.98	0.74	12.21	31.65	2.59
main	13053	500YR	9080	3709.48	366.52	0.00500	377.31	378.36	0.00512	8.25	7.76	40.09	311.30	0.73	11.92	29.60	2.48
main	12660	500YR	9080	4177.06	364.55	0.00530	374.48	376.00	0.00775	7.42	7.02	43.39	304.73	0.89	13.71	46.58	3.40
main	12256	500YR	9080	3145.62	362.43	0.00530	373.09	373.78	0.00368	8.55	8.02	37.98	304.71	0.62	10.32	19.03	1.84
main	11904	500YR	9080	3745.23	360.55	-0.00070	369.62	371.42	0.01351	5.98	5.63	42.56	239.72	1.13	15.62	74.24	4.75
main	11439	500YR	9080	7435.93	360.87	0.01000	365.94	366.38	0.00238	4.61	4.61	281.22	1296.80	0.47	5.73	3.92	0.68
main	10998	500YR	9080	4685.35	356.48	0.01790	365.19	365.57	0.00148	7.99	7.98	90.04	718.27	0.41	6.52	4.81	0.74
main	10636	500YR	9080	7888.04	349.99	0.00240	364.64	365.18	0.00085	11.63	11.40	110.22	1256.26	0.32	6.28	3.81	0.61
main	10222	500YR	9080	5572.87	349.00	-0.00190	364.56	364.83	0.00058	11.27	11.09	98.95	1097.04	0.27	5.08	2.04	0.40
main	9912	500YR	9080	4505.49	349.60	0.01720	364.67	364.71	0.00008	13.20	13.15	164.45	2163.13	0.10	2.08	0.13	0.06
main	9542	500YR	9080	8680.44	343.24	0.00010	364.69	364.69	0.00000	19.82	19.80	724.50	14345.94	0.02	0.61	0.00	0.00
main	9056	500YR	9080	9034.54	343.21	-0.00290	364.68	364.69	0.00001	19.62	19.51	609.24	11885.52	0.03	0.76	0.01	0.01
main	8465	500YR	9080	8357.09	344.90	-0.00100	364.61	364.68	0.00005	18.85	18.54	215.15	3987.90	0.09	2.10	0.12	0.06
main	8046	500YR	9080	5398.19	345.34	0.00010	364.35	364.61	0.00049	14.03	12.99	79.73	1035.94	0.25	5.21	2.08	0.40
main	7601	500YR	9080	6934.04	345.30	0.01220	364.40	364.48	0.00008	17.44	17.33	153.15	2654.32	0.11	2.61	0.24	0.09
main	7146	500YR	9080	8788.66	339.73	-0.00090	364.44	364.45	0.00001	22.76	22.68	432.47	9806.71	0.03	0.90	0.01	0.01
main	6727	500YR	9080	8903.59	340.12	-0.01330	364.43	364.45	0.00001	21.87	21.67	423.29	9172.18	0.04	0.97	0.01	0.01
main	6395	500YR	9080	8110.95	344.54	-0.00500	364.40	364.44	0.00003	18.86	18.65	268.62	5010.35	0.07	1.62	0.06	0.03
main	6072	500YR	9080	6745.60	346.15	-0.00180	364.34	364.42	0.00012	13.27	13.15	201.58	2651.50	0.12	2.54	0.24	0.09
main	5737	500YR	9080	6061.24	346.76	0.00110	364.30	364.38	0.00010	16.32	16.18	135.27	2189.10	0.12	2.77	0.29	0.10
main	5292	500YR	9080	6586.49	346.28	0.00360	364.00	364.28	0.00036	15.50	15.21	87.66	1333.30	0.22	4.94	1.69	0.34
main	4956	500YR	9080	8215.10	345.07	-0.00220	363.58	364.11	0.00061	14.62	14.15	94.79	1340.99	0.28	6.13	3.29	0.54
main	4489	500YR	9080	7730.97	346.10	0.00030	363.09	363.75	0.00088	13.70	13.28	82.47	1094.96	0.34	7.06	5.15	0.73
main	4125	500YR	9080	8353.15	346.00	0.00100	363.15	363.47	0.00033	15.48	15.37	114.72	1763.19	0.21	4.74	1.48	0.31
main	3664	500YR	9080	6819.47	345.56	0.00920	363.09	363.31	0.00027	15.28	15.04	107.58	1618.10	0.19	4.21	1.05	0.25
main	3386	500YR	9080	8653.43	343.00	-0.01720	363.16	363.23	0.00005	18.42	18.27	218.96	4000.21	0.09	2.16	0.13	0.06
main	3010	500YR	9080	7805.26	349.45	0.01320	362.53	363.13	0.00114	10.02	9.92	118.90	1179.75	0.37	6.62	4.67	0.71
main	2714	500YR	9080	7289.05	345.54	0.00290	362.48	362.85	0.00049	13.85	13.60	99.68	1355.58	0.25	5.38	2.26	0.42
main	2423	500YR	9080	8035.90	344.70	-0.00920	362.15	362.68	0.00060	14.58	14.30	91.44	1307.12	0.28	6.15	3.32	0.54
main	2164	500YR	9080	7041.88	347.09	0.00030	362.11	362.48	0.00054	13.15	13.02	98.72	1285.34	0.27	5.48	2.42	0.44
main	1833	500YR	9080	8189.99	346.99	0.00090	361.68	362.25	0.00079	12.63	12.29	104.70	1286.25	0.32	6.37	3.88	0.61
main	1422	500YR	9080	5498.42	346.60	-0.00350	361.37	361.87	0.00104	11.91	11.64	67.36	783.89	0.36	7.01	5.27	0.75
main	1198	500YR	9080	4942.45	347.39	0.00000	360.86	361.54	0.00160	11.89	11.55	49.39	570.35	0.44	8.67	9.97	1.15
main	1133		Bridge														
main	1068	500YR	9080	6363.52	349.56	0.02080	356.26	357.52	0.00552	6.07	6.06	100.05	606.57	0.75	10.49	21.93	2.09
main	764	500YR	9080	7669.49	343.22	-0.00820	355.74	356.35	0.00163	7.97	7.86	143.97	1131.18	0.42	6.78	5.43	0.80
main	427	500YR	9080	6839.31	345.99	0.00310	354.94	355.69	0.00218	7.84	7.83	111.77	875.14	0.49	7.82	8.33	1.07
main	31	500YR	9080	7078.65	344.77		352.87	354.35	0.00500	6.92	6.91	94.10	650.04	0.73	10.89	23.49	2.16