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APPENDIX G
POST- CONSTRUCTION STORM WATER CONTROL ANALYSIS

for

Laboratory for Energy-related Health Research/ Old Campus Landfill Superfund Site University of California, Davis

prepared for

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ACRONYMS AND ABBREVIATIONS

ASCE	American Society of Civil Engineers
BMP	best management practice
CASQA	California Stormwater Quality Association
cfs	cubic feet per second
CGP	*2009-0009-DWQ Construction General Permit*
CIMIS	California Irrigation Management Information System
CVRWQCB	Central Valley Regional Water Quality Control Board
FS – Volume 1	*Final Feasibility Study for the University of California, Davis Areas Volume 1: Soil/Solid Waste and Soil Gas*
LEHR	Laboratory for Energy-related Health Research
LFU	landfill unit
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OCL	Old Campus Landfill
RAO	remedial action objective
RI	*Final Remedial Investigation Report*
Site	Laboratory for Energy-related Health Research/Old Campus Landfill Superfund Site
SWMP	storm water management plan
SWRCB	State Water Resources Control Board
UC Davis	University of California, Davis
URQM	Urban Runoff Quality Management
USDA	United States Department of Agriculture
WBH	Waste Burial Holes

WDR	waste discharge requirement
WEF	Water Environment Federation

G1. Purpose and Background

This appendix presents a preliminary, feasibility-level evaluation of post-construction storm water control requirements for implementation of remediation alternatives outlined in the *Final Feasibility Study for the University of California, Davis Areas Volume 1: Soil/Solid Waste and Soil Gas (FS – Volume 1)* at the University of California, Davis (UC Davis) Laboratory for Energy-related Health Research (LEHR)/Old Campus Landfill (OCL) Superfund Site (Site). This appendix includes a summary of anticipated regulatory requirements, estimation of storm water treatment volumes and rates, and identification of assumed best management practices (BMP) that would be required in the implementation of each remedial alternative. Because the final design parameters for the remedy are not established, and due to evolving storm water engineering practice and regulations, the BMPs used for the final remedy may be substantially different than those presented in this appendix.

The landfill areas are predominantly covered by grass and surface soils, with some buildings and concrete pavement. Surface soils primarily consist of silt and clay, with varying amounts of sand. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) classifies Site soils as Reiff fine sandy loam, which is described as a well-drained soil (USDA, 2007). The USDA estimates that the loam has a moderate available water capacity (about 8.6 inches), and the capacity of the most limiting layer to transmit water is high (1.98 to 5.95 inches per hour) (USDA, 2007). The infiltration potential of these soils is likely medium to high (Geomatrix, 2004; USDA, 1977). Most precipitation collects in puddles and evaporates or infiltrates to the subsurface. Site discharge to Putah Creek is estimated to be a very small fraction of Putah Creek flow, especially during the moderate to heavy precipitation events that generate Site runoff.

Site-generated storm water discharge was evaluated during the 2004 *Final Remedial Investigation Report* (RI) (Geomatrix, 2004). During peak rainfall events, typically during moderate to heavy winter storms, storm water runoff from the Site may discharge at three locations, each of which eventually flows to Putah Creek. Figure G-1 shows storm water catchment areas, discharge locations, and other Site features. Storm water runoff from Landfill Unit (LFU) No. 1 and most of LFU-2 and the Waste Burial Holes (WBH) discharges into Putah Creek through a culvert beneath Levee Road at location LF-01; this area is referred to as the LF-01 catchment. Storm water runoff from the western portion of LFU-2 and the WBH, as well as the Department of Energy remediation areas, discharges to a pump station at location LS-01 (western edge of the Site), where it enters a drainage ditch and eventually discharges to Putah Creek. Storm water runoff from LFU-3 discharges through a culvert at location LF-03 into a concrete-lined drainage ditch, herein referred to as the LF-03 catchment.

The discharge rate for Site-generated storm water was calculated in the RI using the standard NRCS model for runoff (Geomatrix, 2004). Calculations demonstrate that runoff from LFU-1 and the eastern portions of LFU-2 and the WBH discharges into location LF-01 an average of eight days per year (Geomatrix, 2004). Discharge at LF-03 was not considered due to intermittent and less frequent flows from this drainage basin (Geomatrix, 2004).

G2. Regulatory Requirements for Post-Construction Storm Water Controls

In order to meet the remedial action objectives (RAOs) of the FS – Volume 1, Alternatives SW-3 through SW-10 proposed various surface disturbances that would trigger applicable or relevant

and appropriate requirements related to storm water. These surface disturbances are intended, in part, to meet the RAO of preventing the contact of surface water or storm water with residual landfill waste or impacted soil. This section summarizes requirements for storm water treatment, referred to as "post-construction controls," that could be applicable to storm water runoff from the remedial alternatives proposed in the FS – Volume 1.

G2.1. Phase II Municipal Separate Storm Sewer System

UC Davis is a non-traditional Phase II Municipal Separate Storm Sewer System (MS4) covered by the 2003 MS4 Permit (CVRWQCB, 2003). In 2010, UC Davis prepared a *Stormwater Management Plan* (SWMP) (Larry Walker Associates, 2010) that was approved by the Central Valley Regional Water Quality Control Board (CVRWQCB). With regard to post-construction controls, the SWMP specifies that the project must incorporate "a storm water management plan that prevents the post-development peak discharge rate and quantity from exceeding the pre-development peak discharge rate and quantity for the one- and two-year 24-hour design storms."

G2.2. Storm Water Construction General Permit

Construction activities resulting in land disturbance greater than one acre must comply with the *2009-0009-DWQ Construction General Permit* (CGP) (SWRCB, 2010). Among other requirements, the CGP includes post-construction controls (Section XIII.A) for projects that are not covered under an active Phase I or II MS4 permit with an approved SWMP. Although not applicable to UC Davis, which has an approved SWMP, the CGP requires dischargers to "use non-structural and structural measures to replicate the pre-project water balance for the smallest storms up to the 85th percentile storm event." The pre-project water balance is defined as the volume of rainfall that ends up as runoff.

G2.3. Draft 2011 MS4 Permit

In June 2011, the California State Water Resources Control Board (SWCRB) published for comment the *Draft Waste Discharge Requirements (WDRs) for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) (General Permit)* ("Draft 2011 MS4 Permit") (SWRCB, 2011). This permit will ultimately replace the 2003 MS4 Permit and will likely establish new storm water requirements applicable to UC Davis. The current draft states that the Permittee shall "… capture, infiltrate, and evapotranspire the runoff from the 85th percentile storm event to the maximum extent practicable. Runoff from the 85th percentile storm that cannot be captured, infiltrated, and evapotranspired must be treated via a flow-through device designed to treat runoff at a flow rate produced by a rain event equal to at least two times the 85th percentile hourly rainfall intensity for the applicable area, based on historical records of hourly rainfall depths" (Section E.12.b.3., Water Quality Runoff Standards).

For this preliminary, feasibility-level evaluation, post-construction control requirements enumerated in the Draft 2011 MS4 Permit were used to calculate the water quality treatment volume and flow rate. These requirements are consistent with the CGP and other MS4 permits in place in California and will likely be adopted by the SWRCB before the remedial action commences. Post-construction control requirements in effect at the time of the remedial action will be used during final design.

G3. Estimation of Stormwater Treatment Volumes and Rates

To estimate treatment volumes and flow rates, the 85th percentile, one-hour and 24-hour storm events were estimated using daily and hourly precipitation datasets from historical records. Daily rainfall data for 1908 to 2011 from the Davis WSW Exp Farm meteorological station, maintained by the U.S. National Oceanographic and Atmospheric Administration (Station #CA042294), were used to calculate an 85th percentile, 24-hour storm event of 0.66 inches/day. Hourly rainfall data from 1980 to 2012 from the California Irrigation Management Information System (CIMIS) station in Davis were used to calculate an 85th percentile, one-hour storm event of 0.12 inches/hour.

G3.1. Water Quality Treatment Volume

Table G-1 presents post-construction storm water treatment volume estimates for each remedial alternative. Treatment volumes were calculated using the Urban Runoff Quality Management (URQM) method (WEF/ASCE, 1998), which estimates the required treatment volume that corresponds to the "maximized" volume (i.e., the point at which rapidly diminishing returns in the number of runoff events captured begins to occur.) The 85th percentile, 24-hour storm event was used to calculate the maximized volume to treat runoff that could be generated within the surface extents of the surface covers/caps at the LF-01 and LF-02 catchments. Watershed runoff coefficients were developed for each alternative. Since Alternatives SW-1 and SW-2 do not involve land disturbance, and Alternative SW-9 and SW-10 involve the removal of most buried waste and replacement by clean fill, no post-construction storm water controls are needed for these alternatives.

The URQM method calculates the maximized detention volume, "P_0" (watershed inches), with the following equation:

$$P_0 = a \cdot C \cdot P_6$$

where "a" is a regression constant from least-squared analysis, "C" is the watershed runoff coefficient, and "P_6" is the mean storm precipitation volume (inches). The value of "a" was selected for the volume-capture ratio that corresponds to an extended detention basin drain time of 48 hours.

The watershed runoff coefficient, "C", can be computed from the following third-order regression equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

where "i" is the watershed impervious ratio estimated from Site data (percent total imperviousness divided by 100). This approach was used to calculate the watershed runoff coefficient for Alternative SW-5, which includes impervious asphalt caps. The graded covers (Alternative SW-3), evapotranspiration caps (Alternative SW-4), and multiple-layer caps (Alternatives SW-6 through SW-8) are designed to be impermeable, but the presence of soil and vegetative cover above the impermeable geomembrane liner would effectively reduce the watershed runoff coefficient. In order to better capture these effects, the watershed runoff coefficient was computed using the technique specified in Caltrans (2006) for the Rational Method. Site conditions and assumed surface cap conditions were used to estimate runoff coefficients for relief, soil infiltration, vegetation cover, and surface storage. A conservative approach was taken to select the

higher value in the coefficient range for each applicable category, as this value will result in a higher total treatment volume.

G3.2. Water Quality Treatment Flow Rate

Table G-2 presents post-construction storm water treatment flow rate estimates for each remedial alternative. Treatment flow rates were calculated using the Rational Formula (Caltrans, 2006). Similar to the volume calculations, treatment flow rates were calculated based on the surface extents of the surface covers/caps using watershed runoff coefficients that were developed for each alternative. These calculations were used to estimate the required minimum cross-sectional area of a conveyance swale. Treatment flow rates were estimated for Alternatives SW-3 through SW-8 in the LF-01 catchment. The treatment flow rate for the LF-03 catchment is low compared to the LF-01 catchment; no swale would be required to convey water from the volume-based post-construction control to the discharge point.

The Rational Formula predicts flow rate, *Q* (cubic feet per second [cfs]), based on rainfall intensity and drainage area characteristics, with the following equation:

$$Q = CiA$$

where "*C*" is the watershed runoff coefficient, as calculated above for the URQM approach; "*i*" is a uniform rainfall intensity in inches per hour, corresponding to two times the rainfall resulting from the 85th percentile, one-hour storm event; and "*A*" is the drainage area in acres, considered to be the surface extent of the surface covers/caps.

G4. Post-Construction Storm Water Controls

Table G-3 contains a matrix of BMPs for post-construction control applicability for each FS – Volume 1 alternative. For this evaluation, it is assumed the each alternative would generally mimic the existing drainage, where LFU-1, LFU-2, and the WBH areas drain to Putah Creek at location LF-01, and LFU-3 drains to the concrete-lined drainage channel via a culvert at location LF-03 or a new culvert to the south of the current location of LF-03 (Figure G-1). At this location, it is likely that compliance with post-construction control requirements would be achieved by volume-based treatment (i.e., extended detention basins). At the LF-01 catchment, it is assumed for the purposes of the FS – Volume 1 that both a volume-based treatment (i.e., an extended detention basin) and a flow-based treatment (i.e., vegetated swale) would be used.

G4.1. Evapotranspiration

Evapotranspiration, a combination of evaporation of water from the surface and soil and transpiration of water from plants, reduces the volume of water that infiltrates or is discharged to Putah Creek. Physical soil properties, slope gradients, weather conditions, and vegetation type(s) can affect the rate of evapotranspiration. During remedial design, plant species for the engineered surface covers/caps would be selected to maximize evapotranspiration and reduce storm water runoff volumes that would be treated by other BMPs.

G4.2. Drainage Collection and Conveyance

Drainage collection and conveyance structures are a means to limit the infiltration component of the water balance by capturing runoff for remedial actions where waste will remain on-Site. Small drainage depressions would be installed across the sloped landfill surface to direct water to a collection system for conveyance away from the landfill area. Collected water would then be pumped (if necessary) to the post-construction controls and discharged at locations LF-01 or LF-03. Erosion controls would be installed as needed through the entire drainage system. Final design of this BMP would include hydrologic and hydraulic analysis to properly locate and size the drainage system.

G4.3. Volume-Based Post-Construction Controls

Volume-based post-construction control, consisting of an extended detention basin, may be necessary for some remedial action alternatives in order to "capture, infiltrate, and evapotranspire the runoff from the 85th percentile storm event to the maximum extent practicable" (SWRCB, 2011). The goals of this BMP are to improve water quality by reducing sediment discharge, to reduce the peak discharge rate by retaining water on-Site, and to reduce discharge volume by encouraging evapotranspiration at the basin.

An extended detention basin (or basins) would be designed and constructed in accordance with BMP TC-22, contained in the California *Stormwater Best Management Practice Handbook, New Development and Redevelopment* by the California Stormwater Quality Association (CASQA, 2003). In addition, the basin(s) would include an impermeable liner beneath the basin to minimize or prevent infiltration. Final design of this BMP would include development of a storm hydrograph, layout of features within the basin to encourage evapotranspiration, capture sediment, and minimize potentially deleterious effects that can be associated with basins (e.g., vector problems, invasive species, and excessive maintenance). An operation and maintenance plan would be required to ensure acceptable performance of the basin over the long term.

Table G-4 shows the estimated extended detention basin size necessary to capture the water quality treatment volume calculated above for each remedial alternative (Table G-1). The water quality treatment volume is increased by 20 percent to account for sediment accumulation (WEF/ASCE, 1998). Basin size was estimated by specifying dimensions of a trapezoid-shaped basin; the required volume was estimated by the following equation:

$$V = \frac{L \cdot h(b_1 + b_2)}{2}$$

where "V" is the storage volume equal to the treatment volume plus an additional 20 percent to account for sedimentation; "b_1" is the bottom width; "b_2" is the top width, based on approximately 3:1 (horizontal:vertical) side slopes; "L" is the basin length, sized to be approximately two times the top width (b_2); and "h" is the storage depth.

G4.4. Flow-Based Post-Construction Controls

Flow-based post-construction controls, such as a vegetated swale, may be necessary for the LF-01 catchment in some remedial action alternatives in order to "treat runoff at a flow rate produced

by a rain event equal to at least two times the 85th percentile hourly rainfall intensity" (SWRCB, 2011). The goal of this BMP is to treat water that is not evapotranspired within the detention basin and to improve water quality by reducing sediment loading.

Vegetated swale(s) would be designed and constructed in accordance with BMP TC-30 (CASQA, 2003). Final design of this BMP would include hydraulic calculations to estimate swale dimensions and development of erosion controls.

Table G-5 shows estimated vegetated swale sizes for each of the remedial alternatives based on the water quality treatment flow rate (Table G-2). A vegetated drainage swale was not calculated for the eastern edge of LFU-1 under Alternative SW-3 due to space constraints (Buildings X-1 through X-5 are not proposed for demolition under this alternative, resulting in limited space to install a swale). For Alternatives SW-4 through SW-8, the cross-sectional area of vegetated, open channel, trapezoidal-shaped channels was estimated by solving the following uniform flow section factor equation, derived from Manning's equation (Mays, 2005):

$$AR^{2/3} = \frac{Qn}{KS^{1/2}}$$

where "*A*" is the cross-sectional area of flow in square feet; "*R*" is the hydraulic radius in feet; "*Q*" is the design discharge in cfs; "*n*" is the dimensionless Manning's roughness coefficient; "*K*" is a dimensionless units factor of 1.49 for U.S. customary units; and "*S*" is the dimensionless channel slope, set to a minimum of one percent. For a trapezoidal channel:

$$AR^{2/3} = \left[\frac{(b+zy)^5 y^5}{(b+2y\sqrt{1+z^2})^2}\right]^{1/3} = \frac{Qn}{KS^{1/2}}$$

where "*b*" is the bottom width in feet; "*z*" is the horizontal component of the side slopes in feet; and "*y*" is the flow depth in feet. Based on recommendations for vegetated swales (CASQA, 2003), the design flow depth "*y*" was set at 0.33 feet, Manning's "*n*" was set at 0.25, and the "*z*" value was set at 3 to correspond to 3:1 (horizontal:vertical) side slopes.

G5. Summary

To comply with the Draft 2011 MS4 Permit requirements, storm water drainage enhancements, including the installation of extended detention basins and vegetated swales, were estimated for Alternatives SW-3 through SW-8. A schematic of what this drainage system might look like is presented on Figure G-2, using Alternative SW-6 - VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring. This alternative would include the installation of extended detention basins to the north of LFU-2 and LFU-3, as well as a vegetated swale along the eastern edge of LFU-1. A drainage collection and conveyance system would be constructed around the cap perimeter to collect and gravity drain storm water to a lift station for pumping to the extended detention basins. Once water leaves the LFU-2 extended detention basin, it would flow through a discharge pipe to the vegetated drainage swale. Water that is not evapotranspired or does not infiltrate through the swale would be discharged to Putah Creek through the Levee Road culvert. Water that passes through the LFU-3 extended detention basin would enter

the vegetated drainage channel and eventually enter the concrete-lined drainage channel before discharging to Putah Creek. In addition to these drainage enhancements, the existing storm water drainage ditch across LFU-3 would be relocated to accommodate the LFU-3 surface cap.

G6. Limitations

This memorandum provides a basis for cost comparison of alternatives as it relates to storm water post-construction control requirements. It is not meant to convey a conceptual design for the preferred alternative. A design for drainage and post-construction storm water controls will be completed for the selected alternative.

G7. References

California Stormwater Quality Association (CASQA), 2003. *Stormwater Best Management Practice Handbook, New Development and Redevelopment*, January.

Caltrans, 2006. *Highway Design Manual*, Chapter 810: Hydrology, California Department of Transportation, September 1, Updated in July 1, 2008 and October 4, 2010.

Central Valley Regional Water Quality Control Board (CVRWQCB), 2003. *General Permit/WDRs for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems*, California Water Resource Control Board, WQ Order No. 2003-0005-DWQ. National Pollutant Discharge Elimination System (NPDES) Permit NO CAS000004.

Geomatrix, 2004. *Final Remedial Investigation Report, LEHR/SCDS Environmental Restoration, University of California Davis*, December 29.

Larry Walker Associates, 2010. *University of California, Davis Stormwater Management Plan (SWMP).* Non-Traditional Phase II Municipal Separate Storm Sewer System, WQ Order No. 2003-0005-DWQ, NPDES General Permit No. CAS000004, May.

Mays, Larry W., 2005. *Water Resources Engineering*, 2005 Edition, John Wiley and Sons, Inc.

State Water Resources Control Board (SWRCB), 2010. *2009-0009-DWQ Construction General Permit* (Effective July 1).

SWRCB, 2011. *Draft Waste Discharge Requirements (WDRs) for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) (General Permit)*, retrieved from http://www.swrcb.ca.gov/water_issues/programs/stormwater/docs/phsii2011/draft_order.pdf, June.

United States Department of Agriculture (USDA), 1977. *Soil Survey of Solano County, California*.

USDA, 2007. *Map Unit Description: Reiff Fine Sandy Loam - Solano County, California*,Version 5: Dec 12, 2007, http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx, Accessed February 13, 2012.

Water Environment Federation and American Society of Civil Engineers (WEF/ASCE), 1998. *Urban Runoff Quality Management*, WEF Manual of Practice No. 23/ ASCE Manual of Practice No. 87.

FIGURES

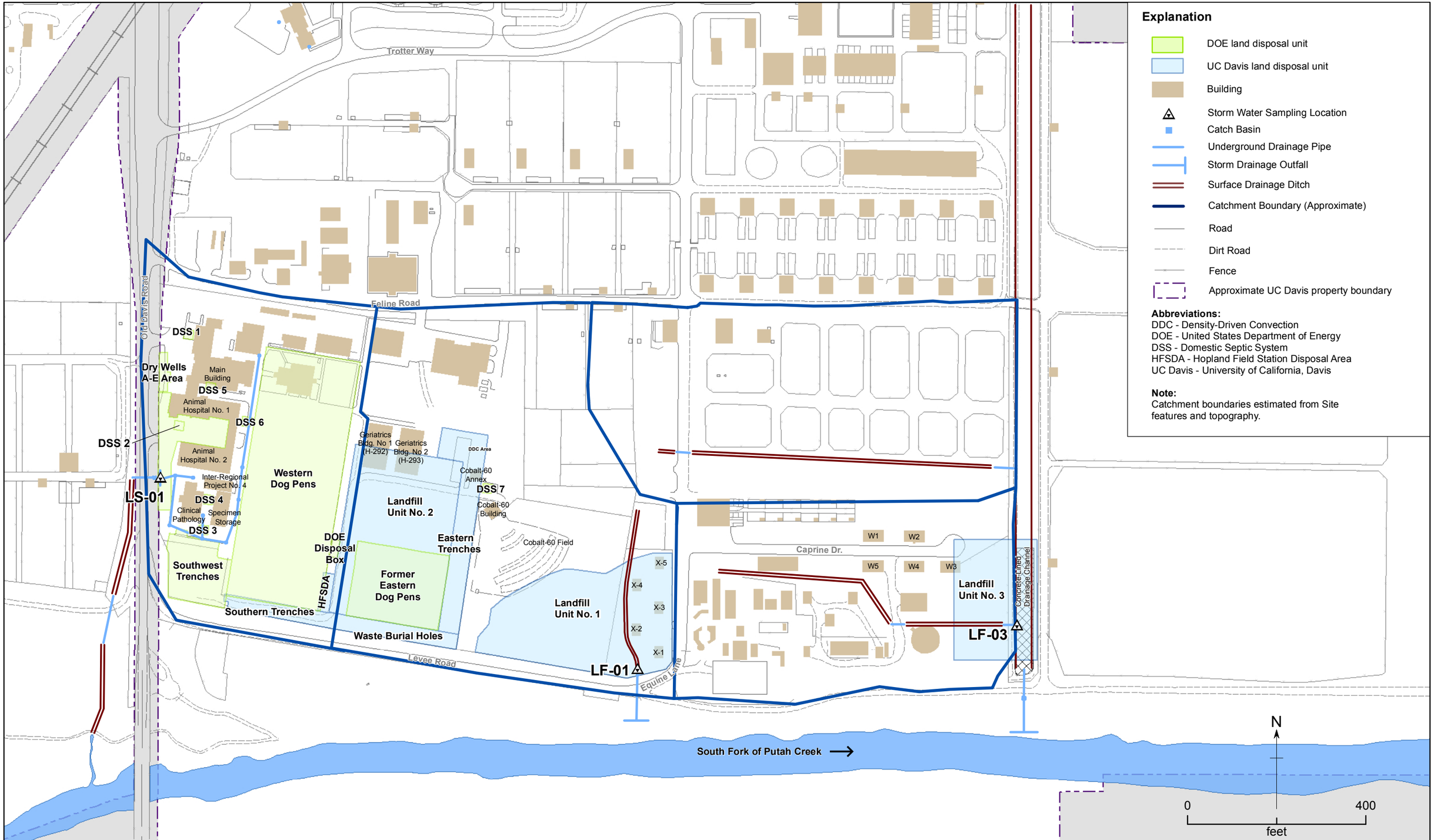


Figure G-1. Site Features and Existing Drainage Controls - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

EXPLANATION

Proposed features of Alternative

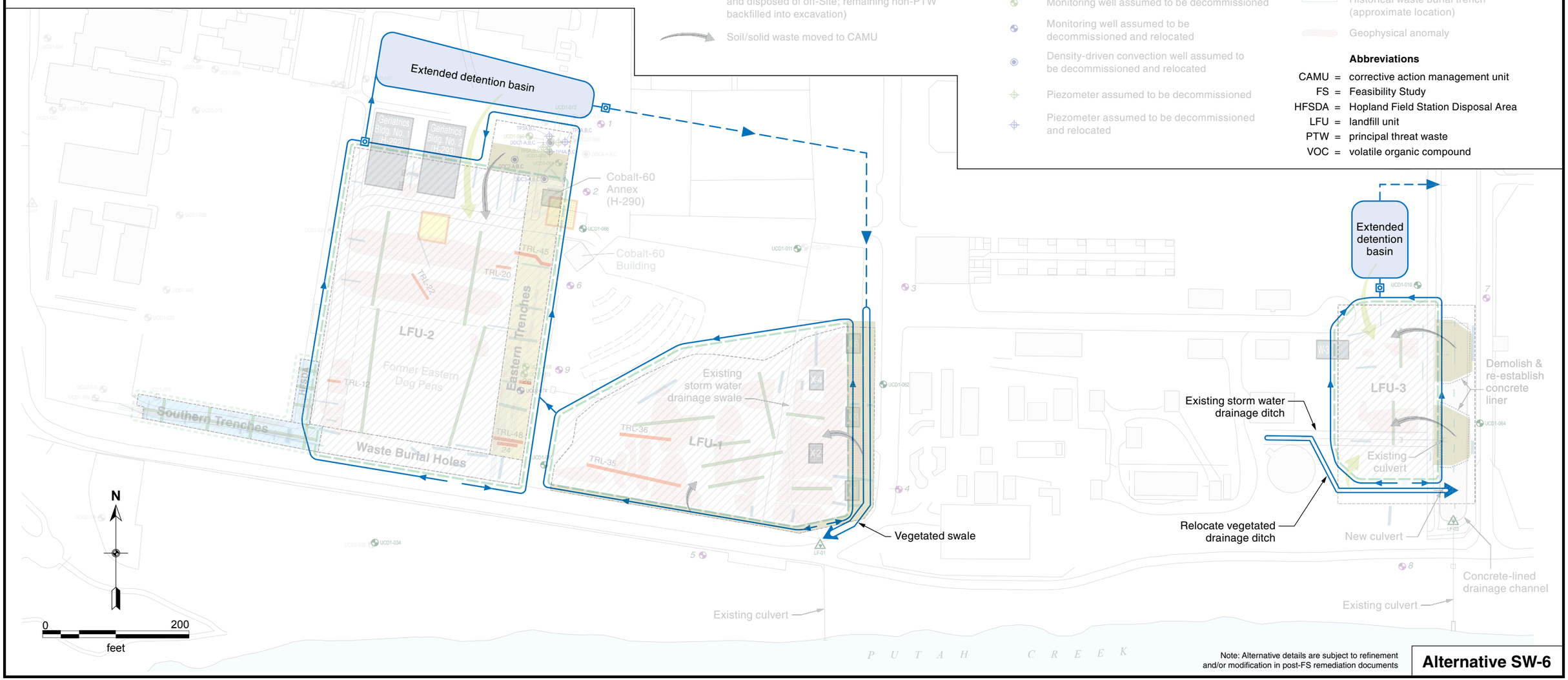
- Soil/solid waste excavation area; PTW segregated and disposed of off-Site; confirmation soil samples collected; remaining soil/solid waste moved to an on-Site capped area; excavated area backfilled with clean fill
- Soil/solid waste excavation area; PTW segregated and disposed of off-Site; remaining soil/solid waste placed back into excavation area within capped unit
- Investigation via trenching to assess if inclusion in Alternative is required
- VOC "hot spot" excavation and removal of soil to 20 feet below ground surface; hazardous material disposed of off-Site; remaining material backfilled within capped unit
- VOC "hot spot" excavation and removal of soil to 20 feet below ground surface; hazardous material disposed of off-Site; area backfilled with clean fill
- H-292 — Building to be demolished and non-hazardous debris recycled or disposed of in on-Site CAMU
- Multiple-layer cap covering CAMU, unlined
- Multiple-layer cap extension contingent upon results of sampling
- TRL-20 — Previously investigated exploratory trench with PTW (excavated and PTW disposed of off-Site; remaining non-PTW backfilled into excavation)
- Proposed exploratory trench (PTW excavated and disposed of off-Site; remaining non-PTW backfilled into excavation)
- Soil/solid waste moved to CAMU
- Clean material used as backfill
- Underground drainage collection pipe
- Underground discharge pipe
- Storm water lift station
- 1 — New designated LFU monitoring well
- Storm water sample location designated for monitoring
- Existing designated LFU monitoring well
- Monitoring well assumed to be decommissioned
- Monitoring well assumed to be decommissioned and relocated
- Density-driven convection well assumed to be decommissioned and relocated
- Piezometer assumed to be decommissioned
- Piezometer assumed to be decommissioned and relocated

Existing features

- LFU-1 — Land disposal unit
- Building
- Existing monitoring well
- Density-driven convection well
- Storm water sample location
- Previously investigated exploratory trench (no PTW)
- Historical waste burial trench (approximate location)
- Geophysical anomaly

Abbreviations

CAMU = corrective action management unit
FS = Feasibility Study
HFSDA = Hopland Field Station Disposal Area
LFU = landfill unit
PTW = principal threat waste
VOC = volatile organic compound



Note: Alternative details are subject to refinement and/or modification in post-FS remediation documents

Alternative SW-6

Figure G-2. Conceptual Drainage Plan — Alternative SW-6: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

TABLES

Table G-1. Post-Construction Storm Water Treatment Volume Estimate - Post-Construction Storm Water Control Analysis, UC Davis LEHR/OCL

Alternative	Units	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Summary of Alternative		**No Action/No Further Action**	**Institutional Controls and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**
LFU-1 and LFU-2 Drainage Area (LF-01 Catchment)											
LFU-1 Cover/Cap Area	acres	---	---	2.0	2.0	2.0	2.0	2.0	---	---	---
LFU-2 Cover/Cap Area	acres	---	---	3.5	3.5	3.5	3.5	3.5	---	---	---
Total Area Post-Construction Disturbance	acres	0.0	0.0	5.5	5.5	5.5	5.5	5.5	6.7	0.0	0.0
(i) Watershed Impervious Ratio[a]	unitless	---	---	---	---	1.0	---	---	---	---	---
(C) Watershed Runoff Coefficient [b,c]	unitless	---	---	0.44	0.34	0.89	0.34	0.34	0.34	---	---
(P_6) Mean Storm Precipitation Volume[d]	inches	---	---	0.66	0.66	0.66	0.66	0.66	0.66	---	---
(a) Regression Coefficient[e]	unitless	---	---	1.963	1.963	1.963	1.963	1.963	1.963	---	---
(P_0) Maximized Detention Volume	inches	---	---	0.57	0.44	1.16	0.44	0.44	0.44	---	---
Water Quality Treatment Volume	cf	---	---	11,381	8,743	23,073	8,743	8,743	10,650	---	---
LFU-3 Drainage Area (LF-03 Catchment)											
Total Area LFU-3 Post-Construction Disturbance	acres	0.0	0.0	0.7	0.7	0.7	0.7	0.0	0.0	0.0	0.0
(i) Watershed Impervious Ratio[a]	unitless	---	---	---	---	1.0	---	---	---	---	---
(C) Watershed Runoff Coefficient [b,c]	unitless	---	---	0.44	0.34	0.89	0.34	---	---	---	---
(P_6) Mean Storm Precipitation Volume[d]	inches	---	---	0.66	0.66	0.66	0.66	---	---	---	---
(a) Regression Coefficient[e]	unitless	---	---	1.963	1.963	1.963	1.963	---	---	---	---
(P_0) Maximized Detention Volume	inches	---	---	0.57	0.44	1.16	0.44	---	---	---	---
Water Quality Treatment Volume	cf	---	---	1,428	1,135	2,978	1,135	---	---	---	---
Total Site Water Quality Treatment Volume		---	---	12,809	9,878	26,051	9,878	---	---	---	---

Notes:

Water Quality Treatment Volume calculations based on the 85th percentile, 24-hour runoff event from the formula recommended in WEF/ASCE (1998)

[a] Watershed impervious ratio calculated for asphalt caps; all other covers/caps assumed to be pervious

[b] Assumed asphalt caps (SW-5) to be impervious surfaces and estimated watershed runoff coefficient using the regression equation in WEF/ASCE (1998) (page 175).

[c] Estimated watershed runoff coefficient for graded covers, evapotranspiration caps, and multiple-layer caps from the method in Caltrans (2006) Figure 819.2A; corroborated by Fenn et al. (1975). The evapotranspiration and multiple-layer cap coefficients assumed low relief (0.098; interpolated for 1.5% slope), normal soil infiltration (0.08), low vegetal cover (0.06), and high surface storage(0.10). The graded cover coefficient assumed low relief (0.098; interpolated for 1.5% slope), high soil infiltration (0.12), high vegetal cover (0.12), and high surface storage (0.10).

[d] 85th percentile, 24-hour precipitation event calculated from historical records at NOAA Station Id: CA042294; Davis WSW Exp Farm; Latitude: 38°32'06N Longitude: 121°46'34W; Elevation: 60

[e] Regression coefficient "a" taken as the volume capture ratio for a drain time of capture volume equal to 48 hours; from Table 5.4 in WEF/ASCE (1998) (page 177)

Acronyms/Abbreviations:

ASCE - American Society of Civil Engineers
cf - cubic feet
LFU - landfill unit
NOAA - National Oceanic and Atmospheric Administration
VOC - volatile organic compound
WEF - Water Environment Federation
--- - not applicable

References:

Caltrans, 2006. *Highway Design Manual*, Chapter 810: Hydrology, California Department of Transportation, September 1, Updated in July 1, 2008 and October 4, 2010.

Fenn, Dennis G., Keith J. Hanley, and Truett V. DeGeare, 1975. *Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites* , United States Environmental Protection Agency Report SW-168.

Water Environment Federation and American Society of Civil Engineers (WEF/ASCE), 1998. *Urban Runoff Quality Management*, WEF Manual of Practice No. 23, ASCE Manual of Practice No. 87.

Table G-2. Post-Construction Storm Water Treatment Rate Estimate - Post-Construction Storm Water Control Analysis, UC Davis LEHR/OCL

Alternative	Units	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Summary of Alternative		**No Action/No Further Action**	**Institutional Controls and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**
LFU-1 and LFU-2 Drainage Area (LF-01 Catchment)											
LFU-1 Cover/Cap Area	acres	---	---	2.0	2.0	2.0	2.0	2.0	---	---	---
LFU-2 Cover/Cap Area	acres	---	---	3.5	3.5	3.5	3.5	3.5	---	---	---
Total Area Post-Construction Disturbance	acres	0.0	0.0	5.5	5.5	5.5	5.5	5.5	6.7	0.0	0.0
(C) Watershed Runoff Coefficient [a,b]	unitless	---	---	0.44	0.34	0.89	0.34	0.34	0.34	---	---
Rainfall intensity [c]	inches/hour	---	---	0.24	0.24	0.24	0.24	0.24	0.24	---	---
Discharge	cfs	0.0	0.0	0.58	0.45	1.18	0.45	0.45	0.54	0.0	0.0
Total Water Quality Treatment Rate	**cfs**	**0.00**	**0.00**	**0.58**	**0.45**	**1.18**	**0.45**	**0.45**	**0.54**	**0.00**	**0.00**

Notes:

Capture discharge rate calculations based on two times the 85 th percentile, one-hour precipitation event, as calculated using the Rational Method (Caltrans, 2006)

Runoff from LFU-3 is very low (less than 0.15 cfs), and it is likely that compliance with post-construction control requirements will be achieved by volume-based treatment (i.e., extended detention basins)

[a] Assumed asphalt caps (SW-5) to be impervious surfaces and estimated watershed runoff coefficient using the regression equation in WEF/ASCE (1998) (page 175) and an impervious ratio of 1.0

[b] Estimated watershed runoff coefficient for graded covers, evapotranspiration caps, and multiple-layer caps from the method in Caltrans (2006) Figure 819.2A; corroborated by Fenn et al. (1975). The evapotranspiration and multiple-layer cap coefficients assumed low relief (0.098; interpolated for 1.5% slope), normal soil infiltration (0.08), low vegetal cover (0.06), and high surface storage(0.10). The graded cover coefficient assumed low relief (0.098; interpolated for 1.5% slope), high soil infiltration (0.12), high vegetal cover (0.12), and high surface storage (0.10).

[c] 85th percentile, one-hour precipitation event calculated from historical records at CIMIS Station 6: Davis; Latitude: 38°32'08N Longitude: 121°46'35W

Acronyms/Abbreviations:

ASCE - American Society of Civil Engineers
cfs - cubic feet per second
CIMIS - California Irrigation Management Information System
LFU - landfill unit
VOC - volatile organic compound
WEF - Water Environment Federation
--- - not applicable

References:

Caltrans, 2006. *Highway Design Manual*, Chapter 810: Hydrology, California Department of Transportation, September 1, Updated in July 1, 2008 and October 4, 2010.

Fenn, Dennis G., Keith J. Hanley, and Truett V. DeGeare, 1975. *Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites* , United States Environmental Protection Agency Report SW-168.

Water Environment Federation and American Society of Civil Engineers (WEF/ASCE), 1998. *Urban Runoff Quality Management*, WEF Manual of Practice No. 23, ASCE Manual of Practice No. 87.

Table G-3. Summary of Best Management Practices for Post-Construction Storm Water Control – Post-Construction Storm Water Control Analysis, UC Davis LEHR/OCL

Alternative	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Summary of Alternative	**No Action/ No Further Action**	**Institutional Controls and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**
Evapotranspiration: selection of vegetation and cover material to encourage evapotranspiration			●	●	●	●	●	●	●	●
Drainage collection and conveyance, installation of a storm water collection and conveyance system			●	●	●	●	●	●		
Volume-based post-construction controls, installation of extended detention basin(s) to improve water quality and reduce discharge rate and volume			●	●	●	●	●	●		
Flow-based post-construction controls, installation of vegetated swale(s) to improve water quality				●	●	●	●	●		

Acronym/Abbreviation:
VOC - volatile organic compound

Table G-4. Estimated Extended Detention Basin Size - Post-Construction Storm Water Control Analysis, UC Davis LEHR/OCL

Alternative	Units	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Summary of Alternative		**No Action/ No Further Action**	**Institutional Controls and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**
LFU-1 and LFU-2 Drainage Area (LF-01 Catchment)											
Water Quality Treatment Volume	cf	---	---	11,381	8,743	23,073	8,743	8,743	10,650	---	---
Sediment Accumulation Volume (20%)	cf	---	---	2,276	1,749	4,615	1,749	1,749	2,130	---	---
Storage Volume (treatment volume + sediment accumulation volume)	cf	---	---	13,657	10,491	27,687	10,491	10,491	12,780	---	---
Required Basin Dimensions[a]											
(h) Depth	feet	---	---	4	4	4	4	4	4	---	---
(L) Length[b]	feet	---	---	100	85	135	85	85	100	---	---
(b_1) Bottom Width	feet	---	---	20	20	40	20	20	20	---	---
(b_2) Top Width[c]	feet	---	---	50	45	65	45	45	45	---	---
LFU-3 Drainage Area (LF-03 Catchment)											
Water Quality Treatment Volume	cf	---	---	1,428	1,135	2,978	1,135	---	---	---	---
Sediment Accumulation Volume (20%)	cf	---	---	286	227	596	227	---	---	---	---
Storage Volume (treatment volume + sediment accumulation volume)	cf	---	---	1,713	1,362	3,574	1,362	---	---	---	---
Required Basin Dimensions[a]											
(h) Depth	feet	---	---	3	3	3	3	---	---	---	---
(L) Length[b]	feet	---	---	50	40	60	40	---	---	---	---
(b_1) Bottom Width	feet	---	---	5	3	10	3	---	---	---	---
(b_2) Top Width[c]	feet	---	---	25	20	30	20	---	---	---	---

Notes:

Extended detention basin design and sizing criteria from guidelines recommended in CASQA (2003) (Best Management Practice TC-22)

[a] Basin dimension approximated based on trapezoidal cross-section and length required to capture treatment volume

[b] Ratio of flowpath length to width from the inlet to the outlet is approximately 2:1 (length:width ratio)

[c] Side slopes are approximately 3:1 (horizontal:vertical ratio)

Acronyms/Abbreviations:

CASQA - California Stormwater Quality Association
cf - cubic feet
LFU - landfill unit
VOC - volatile organic compound
--- - not applicable

Reference:

California Stormwater Quality Association (CASQA), 2003. *Stormwater Best Management Practice Handbook: New Development and Redevelopment*, January.

Table G-5. Estimated Vegetated Swale Size - Post-Construction Storm Water Control Analysis, UC Davis LEHR/OCL

Alternative	Units	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Summary of Alternative		**No Action/No Further Action**	**Institutional Controls and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**	**Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring**
LFU-1 and LFU-2 Drainage Area (LF-01 Catchment)											
Water Quality Treatment Rate	cfs	---	---	---	0.45	1.18	0.45	0.45	0.54	---	---
(n) Manning's n[a]	unitless	---	---	---	0.25	0.25	0.25	0.25	0.25	---	---
(S) Longitudinal Slope[b]	unitless	---	---	---	0.01	0.01	0.01	0.01	0.01	---	---
(z) Side Slope[c]	unitless	---	---	---	3	3	3	3	3	---	---
(y) Flow Depth[d]	feet	---	---	---	0.33	0.33	0.33	0.33	0.33	---	---
(b) Bottom Width[e]	feet	---	---	---	4.3	12.0	4.3	4.3	5.3	---	---

Notes:

Vegetated swale calculations were performed using the Manning's equation-derived uniform flow section factor, as described in Mays (2005), Section 15.3 (Stormwater Drainage Channels)

[a] Vegetated swale design and sizing criteria from guidelines recommended in CASQA (2003) (Best Management Practice TC-30)

[b] Slope estimated from Site conditions; CASQA (2003) recommends slope be below 2.5 percent for vegetated swale

[c] The side slopes should not be steeper than 3:1 (horizontal:vertical ratio) (CASQA, 2003)

[d] Design flow depth should not exceed 2/3 the height of the grass or four inches, whichever is less (CASQA, 2003)

[e] Estimated using Manning's equation for a trapezoidal channel

Acronyms/Abbreviations:

CASQA - California Stormwater Quality Association
cfs - cubic feet per second
LFU - landfill unit
VOC - volatile organic compound

References:

California Stormwater Quality Association (CASQA), 2003. *Stormwater Best Management Practice Handbook: New Development and Redevelopment*, January.
Mays, Larry W., 2005. *Water Resources Engineering*, 2005 Edition, John Wiley & Sons, Inc.