APPENDIX J

HYDROLOGY AND WATER QUALITY

J-1 Technical Report on Airport Drainage, Northern Sector – Airport and Ordinance Creek Watershed / Preliminary Creek Constructed Natural Channel Culvert
J-2 Preliminary Stormwater Mitigation Plan / SUSMP Assessment
J-3 Technical Report on Airport Drainage, Northern Sector – Airport and Ordinance Creek Watershed, Airport Creek Hydrologic Models

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APPENDIX J-1

Technical Report on Airport Drainage, Northern Sector – Airport and Ordinance Creek Watershed / Preliminary Creek Constructed Natural Channel Culvert

Technical Report on Airport Drainage

Appendix J-1: Northern Sector – Airport and Ordinance Creek Watershed

Preliminary Design – Airport Creek Constructed Natural Channel and Culvert

Introduction

The proposed project includes extension of runway 14-32 to the northwest, which will include the construction of fill over the existing Airport Creek natural channel (as well as a ditch interconnecting Airport Creek with Ordinance Creek), with fill extending as far as 1000 feet to the north of the existing creek channel. The normal design event for Airport Creek in this location is the 25-year event, based on an upstream tributary area of approximately 2 square miles, which places it in the category of a secondary waterway. However the proposed improvements (fill for the runway extension) combined with high existing grade elevations north of the realigned Airport Creek channel will not allow overland relief of 100-year event runoff, therefore per Sonoma County Flood Control Design Criteria, the design event for the evaluation of these improvements is the 100-year storm. The project proposal includes realignment of Airport Creek and the creation of approximately 700 feet of constructed natural channel leading into a culvert of approximately 650 feet in length under the runway extension fill. The constructed channel and culvert, with a connection at each end into the existing Airport Creek channel, are proposed to replace the portion of the existing creek channel that will be covered over by the runway extension project. The portion of the creek channel to be rerouted also includes a replacement of the interconnection ditch leading to (west) Ordinance Creek that will need to be reestablished as a part of the final design of the Airport Creek channel improvements, in order to continue to maintain existing drainage flow patterns in Ordinance Creek west of the runways. The proposed project includes a second, smaller culvert to interconnect Airport and Ordinance Creek for this purpose.

Based upon the project description, the replacement channel/culvert will realign and connect Airport Creek from HEC-RAS River Stations 1.428± to 1.145±, meaning approximately 1,500 feet of natural channel length will be replaced by a combined 1,350 feet of constructed natural channel and underground culvert beneath the runway extension fill.

The proposed constructed natural channel configuration is a trapezoidal channel with a bottom width of 30 feet and 4:1 side slopes. Ultimately, the final design for the channel will also include provisions for low-flow conditions, however for the purposes of this report the preliminary calculations provided herein do not include this minor effect on the overall geometry of the channel. The proposed channel is required to satisfy Sonoma County Water Agency (SCWA) Flood Control Design Criteria (SCWA, 1983) with a minimum freeboard requirement (vertical distance from the design water surface to top of bank) of 1.5 feet or 0.2 of the specific energy ($v^2/2g$) of the design flow, whichever is greater. The required minimum radius of the "reverse curve" configuration of the channel realignment is three times the top width (width of water surface for the design event) of the channel.

The proposed constructed natural channel has been assigned a Manning's "n" value of 0.08, which is consistent with design values typically applied in the Windsor/Airport locale for natural creek riparian zones, representing a vegetation matrix that has theoretically been allowed to evolve naturally and is fully developed. It is also consistent with field observations of the dense understory

vegetation to be found within the existing natural channel along the local reach of Airport Creek. We understand there are restrictions as to the height of vegetation that can remain unmaintained beneath the airspace restrictions of the runway, implying that a certain degree of creek channel maintenance can be expected over time. However for the purposes of this report, a conservative "n" value of 0.08 has been applied to the constructed natural channel for the backwater calculations and to evaluate channel conveyance capacity.

The proposed design for a culvert to convey Airport Creek flow beneath the runway extension fill is a multi-barrel reinforced box culvert. Headwalls and wing walls will be provided to resolve the grade discontinuities at the culvert entrances. Debris walls – downward-slope angled walls projecting from intermediate culvert support walls - will be included at the culvert inlet to minimize obstruction of the culvert entrance. Local turbulence which may cause scour at the culvert outfall would be prevented by providing suitable channel stabilization materials at the outfall. This may be in the form of an apron of graded rock rip-rap as well as a prism of channel soils stabilized by one or more alternative materials and methods now available to the designer, or even in combination, to result in an acceptable installation that will minimize local channel erosion. In accordance with the requirements of the Sonoma County Water Agency ("SCWA"), this culvert is required to be adequately sized not only to convey the 100-year event but must also do so with at least one foot of freeboard between the water surface and the soffit of the culvert. In addition the design must consider debris obstruction at the entrance. The SCWA standard is to assume 1 foot either side of the intermediate box culvert support walls. (Note: Use of 2:1 sloped debris walls extending out from the intermediate box culvert support walls at the culvert entrance allows for limiting the zone of potential debris blockage to the upper two feet of the culvert opening.)

The ability of the culvert to structurally support potential loading must also be considered as a part of the culvert design. The proposed culvert alignment does not run beneath the actual paved runway, but beneath fill in the safety zone at the end of the runway. It is conceivable that at some point in the future the culvert may be subject to airport runway live loads in addition to the dead load of the fill, and because replacing such a facility is potentially very difficult and costly, it would be prudent to assume such loading in the subsequent engineered structural design of the culvert elements.

Preliminary Hydraulic Calculations – Reinforced Box Culvert

Design Storm Event = 100-year flow: Q_{100} = 955.5 cfs (318.5 cfs/barrel)

Downstream Channel Depth of Flow = 9.6 feet

Allowable Downstream Tailwater Depth = 7 feet (assuming an 8 foot culvert height dimension)

Downstream Channel Flowline Elevation = +81.0*

Downstream Culvert Invert Elevation = +83.6*

Culvert Invert Slope s = 0.15% (0.0015 ft/ft)

Upstream Culvert Invert Elevation = +84.6*
(*all elevations shown based on NGVD 1929 vertical datum)

BOX CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

May 13, 2011

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Span (ft)	10.0
Culvert Rise (ft)	8.0
FHWA Chart Number	8
FHWA Scale Number (Type of Culvert Entrance)	1
Manning's Roughness Coefficient (n-value)	0.012
Entrance Loss Coefficient of Culvert Opening	0.5
Culvert Length (ft)	650.0
Invert Elevation at Downstream end of Culvert (ft)	83.6
Invert Elevation at Upstream end of Culvert (ft)	84.6
Culvert Slope (ft/ft)	0.0015
Starting Flow Rate (cfs)	318.5
Incremental Flow Rate (cfs)	0.0
Ending Flow Rate (cfs)	318.5
Starting Tailwater Depth (ft)	7.0
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	7.0

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
318.5	7.0	5.03	6.78	3.89	3.16	7.0	4.55

Preliminary Hydraulic Calculations – Ordinance Creek Crossover Flow Conduit

The HEC-RAS model of the existing conditions in Airport Creek includes a crossover ditch that transfers a part of the flow in Airport Creek to (west) Ordinance Creek when Airport Creek is flowing at a sufficient depth to spill over into the crossover ditch. This ditch will be filled as a part of the proposed project. In order to preserve this flow contribution to the upstream reach of (west) Ordinance Creek a second, smaller culvert approximately 600 feet in length is proposed beneath the runway extension fill that is to be designed to provide an equivalent amount of flow transfer. Preliminary sizing of this crossover culvert assuming 100-year conditions results indicates that a single 8' wide x 4' high reinforced box culvert will provide the needed flow capacity and backwater profile to induce the crossover flow to leave the main Airport Creek channel and flow into Ordinance Creek. The amount of flow transferred by the existing crossover ditch is shown in the HEC-RAS model for the following distinct storm events:

Storm Event	Crossover Flow
2-year	57.4 cfs
10-year	83.2 cfs
25-year	107.1 cfs
100-year	115.0 cfs

The previous calculations for the primary box culvert assumes that capacity of the crossover culvert will accommodate the 100-year flow of 115 cfs and that it will be constructed at an elevation that will hydraulically allow 115 cfs to separate out of the main creek flow, i.e. the upstream energy grade line (EGL = HGL + $v^2/2g$) the crossover culvert is no higher than that of the main culvert at the point where the crossover culvert connects into Airport Creek.

Design Storm Event = 100-year flow: Q_{100} = 115 cfs

Downstream Channel Depth of Flow = 9.6 feet

Downstream Tailwater Depth = 4.74 feet (W.S. Elevation = +91.74* @ "Crossover" R.S. 0.0286)

Downstream Channel Flowline Elevation = +87.0 (Note: existing crossover ditch will require lowering by approximately two feet from the connection to Ordinance Creek to the crossover culvert outlet)

Proposed Downstream Culvert Invert Elevation = +87.0*

Culvert Invert Slope s = 0.17% (0.0017 ft/ft)

Proposed Crossover Culvert Length = 600 feet

Upstream Culvert Invert Elevation = +88.0*
(*all elevations shown based on NGVD 1929 vertical datum)

BOX CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

May 13, 2011

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Span (ft)	8.0
Culvert Rise (ft)	4.0
FHWA Chart Number	8
FHWA Scale Number (Type of Culvert Entrance)	1
Manning's Roughness Coefficient (n-value)	0.012
Entrance Loss Coefficient of Culvert Opening	0.5
Culvert Length (ft)	600.0
Invert Elevation at Downstream end of Culvert (ft)	87.0
Invert Elevation at Upstream end of Culvert (ft)	88.0
Culvert Slope (ft/ft)	0.0017
Starting Flow Rate (cfs)	115.0
Incremental Flow Rate (cfs)	0.0
Ending Flow Rate (cfs)	115.0
Starting Tailwater Depth (ft)	3.9
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	3.9

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
115.0	3.9	2.97	3.58	2.24	1.86	3.9	3.69

Preliminary Hydraulic Calculations - Constructed Natural Channel

The constructed natural channel connecting the culvert inlet back into the natural channel of Airport Creek will be constructed through elevated ground north of the existing natural channel. The design alignment is a reverse curve to route flow first to the north out of the existing channel alignment, then turning east to flow directly into the culvert entrance. Hydraulic analysis of the proposed channel dimensions indicate that the maximum depth of flow in the constructed channel will be less than 8 feet. If one assumes this depth of flow in the proposed trapezoidal channel cross section geometry with 4:1 side slopes and a 30' wide channel bottom, the top width of flow would be 2 x (8' x 4) + 30' = 92 feet. Therefore, the proposed minimum centerline radius of the curved portions of the constructed natural channel shall be equal to or greater than 3 x 92' or 276 feet.

From the results of the calculations for the culvert, the downstream tailwater depth of flow for the constructed channel during a peak 100-year event is approximately 7 feet. At the upstream end of the constructed natural channel, assuming a Manning's "n" value of 0.08, the water surface profile calculations show that the 100-year hydraulic grade line (HGL) of +93.1 will be lower than calculated for the existing channel (+94.6) at the location where the constructed natural channel rejoins the existing channel of Airport Creek at River Station 1.428. This would be expected as the replacement culvert/constructed natural channel has higher nominal conveyance capacity exhibits lower hydraulic losses from friction, and is also about 150 feet shorter in physical length than the existing (slightly meandering) natural channel that is proposed to be replaced as a result of the project. Flow velocity in the constructed channel is less than 3 ft/second for the 100-year flow. Water surface elevations will range from +91.6 to +93.1, requiring a minimum elevation of the constructed channel top of bank to range from +93.1 to +94.6 to provide at least 1.5 feet of freeboard.

TRAPEZOIDAL CHANNEL ANALYSIS
STANDARD STEP WATER SURFACE PROFILE COMPUTATION

May 13, 2011

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Flow Rate (cfs)	1,070.7
Channel Bottom Slope (ft/ft)	0.0013
Manning's Roughness Coefficient (n-value)	0.08
Channel Left Side Slope (horizontal/vertical)	4.0
Channel Right Side Slope (horizontal/vertical)	4.0
Channel Bottom Width (ft)	30.0
Flow-Line Elevation at Starting Station (ft)	84.6
Water Surface Elevation at Starting Station (ft)	91.6
Starting Channel Station (ft)	0.0
Ending Channel station (ft)	700.0
Channel Length (ft)	50.0

COMPUTATION RESULTS

Normal Depth (ft)	8.3
Critical Depth (ft)	2.97

Channel Station (ft)	Flow-Line Elevation (ft)	WS Elevation (ft)	Channel Depth (ft)	Flow Area (sq ft)	Flow Velocity (fps)	Velocity Head (ft)	EGL Slope (ft/ft)
0.0	84.6	91.6	7.0	406.0	2.64	0.108	0.002614
50.0	84.66	91.73	7.07	411.71	2.6	0.105	0.002516
100.0	84.73	91.86	7.13	417.02	2.57	0.102	0.002429
150.0	84.79	91.98	7.18	421.98	2.54	0.1	0.002351
200.0	84.86	92.1	7.24	426.62	2.51	0.098	0.002282
250.0	84.92	92.21	7.29	430.98	2.48	0.096	0.002219
300.0	84.99	92.32	7.33	435.07	2.46	0.094	0.002163
350.0	85.05	92.43	7.38	438.93	2.44	0.092	0.002111
400.0	85.12	92.54	7.42	442.57	2.42	0.091	0.002064
450.0	85.18	92.64	7.46	446.0	2.4	0.09	0.002021
500.0	85.25	92.74	7.49	449.26	2.38	0.088	0.001981
550.0	85.31	92.84	7.53	452.35	2.37	0.087	0.001944
600.0	85.38	92.94	7.56	455.27	2.35	0.086	0.00191
650.0	85.44	93.03	7.59	458.05	2.34	0.085	0.001879
700.0	85.51	93.13	7.62	460.7	2.32	0.084	0.001849

Summary of Results

The proposed culvert configurations use standard box culvert sizes and will meet the requirements of the Sonoma County Water Agency Flood Control Criteria based on the parameters described in the calculations. The proposed configuration of the major culvert conveying Airport Creek under the runway improvements is a triple box culvert made up of three 10' wide x 8' high conduits. The calculation results show that there is adequate flow capacity and freeboard provided by this configuration. Outlet velocity is within an acceptable range of less than 5 feet per second for the 100-year event. If it is desired to reserve the first one or two feet culvert bottom for channel bottom gravel material enhancement, the actual box culvert vertical dimension should be increased accordingly.

The proposed cross connection culvert is an 8' wide by 4' wide box culvert. Because the Ordinance Creek channel is at higher flowline elevations than the Airport Creek channel, there is a very limited window of elevation differential that can be used to redirect a portion of the Airport Creek flow into Ordinance Creek. The existing ditch from the cross connection outfall to Ordinance Creek (a distance of approximately 150 feet as the outfall is depicted on the maps accompanying the project description) will need to be excavated down about 2 feet to permit enough hydraulic grade in the cross connection culvert to do this. The calculations for the configuration provided in this report show that specifically for the 100-year event, the theoretical cross-connection flow is maintained.

The calculations for the constructed natural channel indicate that the proposed cross section will adequately convey the 100-year event, provided that finished top of bank is at least 1.5 feet higher than the calculated 100-year water surface elevation along the length of the new channel. The channel realignment trends north into an area of higher elevation than adjacent to the existing Airport Creek channel to be replaced, so this requirement should be easily met by the finish grade, except for the transition zone at the point where the channel connects into Airport Creek. However, overbank flow in this area will not impact any existing buildings or facilities in the flood plain, and would qualify for an exception to freeboard requirements for existing conditions as described in the SCWA Flood Control Design Criteria manual.

Finally, the hydraulic improvement realized by the construction of the box culvert and realigned constructed natural channel will result in no increased water surface elevations upstream of the point where the constructed natural channel connects back into the existing Airport Creek channel. This also means that Redwood Creek, which has a confluence with Airport Creek a short distance upstream from the proposed channel realignment, will not be hydraulically impacted by the project. By the same token the location where Airport Creek crosses the limits of the Sonoma County Airport parcel, even further upstream, will also not be hydraulically impacted by the project.