APPENDIX M
GEOLOGY, SOILS, AND SEISMICITY RESOURCES

This appendix contains supporting documentation for the assessment of Geology, Soils, and Seismicity Resources for the Environmental Impact Statement and Environmental Impact Report.

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September 8, 2009
Project: 92158-1906

Ms. Sara Hassert
Mr. Rob Adams
Landrum and Brown
8755 W. Higgins Road, Suite 850
Chicago, IL 60631

Subject: Geology, Soils and Seismicity Subsection
Gnoss Field Airport EIS/EIR
Novato, California

Dear Ms. Hassert and Mr. Adams:

Kleinfelder is pleased to provide the enclosed revised Geology, Soils, and Seismicity section for your review, comment, and use. As requested, Alternative C has been deleted from consideration. Based on the tasking sequence, we understand this text may be used for the appropriate sections of both the EIS and EIR documents, which we understand will be separate stand-alone documents. These subsections were prepared entirely by Kleinfelder. Once finalized, we understand you will fold all of the subsections from the various consultants together. At this time, we didn't include supporting appendix material, other than Plates 1, 2, and 3, with this submittal. We understand that as you review and assemble the EIS and EIR documents, you will decide what supporting material will need to accompany the EIS and/or EIR documents. We will provide copies of whatever supporting reports you select for inclusion.

Plate 1 – Regional Geologic Map- General Study Area, is currently provided in a 17- by 22-inch format to provide the maximum amount of information. The information can be split into two 11- by 17-inch plates, if you decide that publishing needs require the smaller format.

The text and plates are being provided in a PDF format. The text is also being provided in an MS Word format to enable you to make your edits in track changes mode and copy sections of text directly into the appropriate locations in the EIS and EIR. Once the final plate information is agreed upon, the information on the plates is also available in GIS.

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We trust that this submittal provides you with the information needed at this time. If you have any questions, or would like to discuss the submittal, please contact us at (707) 571-1883.

Respectfully submitted,

KLEINFELDER WEST, INC.

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MGB\WVM\kdw

Enclosure: Draft Text – Geology, Soils, and Seismicity
Plates 1, 2, and 3

Subtask 19.6 Geology, Soils, and Seismicity

SITE DESCRIPTION

The existing Gnoss Field Airport and proposed runway extension areas are located within the Petaluma River/San Pablo Bay estuarine plain in Northern Marin County, California. Review of historical topographic maps and aerial photographs indicate the current northwest-southeast airport runway configuration has existed since at least 1968. Previously, the airport runway was oriented generally east-west from at least 1952 to 1965. The airport facility is surrounded by agricultural fields. The Northwest Pacific rail line parallels Highway 101 approximately 1,200 feet to the west of the existing airfield. The airfield and surrounding fields are located on tidal marshes reclaimed through levee and drainage channel construction. Levee fills surrounding and in the vicinity of the airfield were generally constructed at approximately 2H:1V (Horizontal:Vertical), apparently utilizing both on-site marsh deposits and more granular imported soil. Drainage channels range from less than 1 foot deep within secondary channels up to approximately 5 feet deep in the main channels. Channel banks are generally gently sloping within existing natural channels, while artificial channel banks were typically constructed near-vertical.

The proposed northwest runway extension area is traversed by two main east-flowing channels that collect drainage from east of the rail line. Localized denuded 0.5 to 1 foot deep depressions similiar to salt pannes exist throughout the area. Outside of the channels and depressions, the northwest extension area is essentially flat and supports a moderate growth of wild grasses. The area is currently utilized for livestock grazing.

The proposed mixed northwest and southeast runway extension alternative areas also extend southeast across an undeveloped open field filled predominantly with star thistle and grasses. Vegetation within the fields and low areas adjacent to the improvements generally consists of wild grasses.

As discussed, topography at the airfield is essentially flat, aside from the levees and airfield improvements. Elevations range between 3 feet below to approximately 7 feet above mean sea level.

DATA SOURCES

Various published geologic reports and maps cited in the References section were reviewed to evaluate the local and regional geology. In addition to published geologic

reports and maps, reports prepared by private consultants for Gnoss Field and sites in the vicinity where also reviewed, through the cooperation and assistance of Marin County Department of Public Works. The following reports were particularly relevant to the proposed runway extension:

- Cooper Clark & Associates, December 26, 1975, Report: Soil Investigation: Proposed Del Pantano Industrial Park, Marin County, California
- Cortright & Siebold, October 2, 1987, Airport Master Plan and Environmental Impact Report for Marin County (Gnoss Field) Airport; Working Paper 3, Environmental Impact Assessment
- Environmental Science Associates, May 1985, Environmental Assessment, Gnoss Field Expansion, Marin County, California
- Environmental Science Associates, December 2002, Administrative Draft, Redwood Landfill Solid Waste Facilities, Permit Revision, Subsequent Environmental Impact Report

Pertinent data compiled from the above sources has been considered and incorporated into this geologic assessment, where applicable.

SITE RECONNAISSANCE

Geologic reconnaissance was conducted by our Certified Engineering Geologist on May 19 and 20, 2009. The reconnaissance included the identification of existing and potential areas of slope instability and erosion on, and in the vicinity of, the proposed northwest and southeast runway extensions. Quaternary age surficial deposits were delineated; no bedrock outcrops were encountered within the limits of detailed mapping. Geologic mapping was completed on a 2007 aerial photo base acquired from the County of Marin Global Information Systems (GIS) website (http://mmgis.marinmap.org/OrthoGrid/viewer.htm). The results of our detailed mapping are presented on Plate 2, Geologic Map, Detailed Study Area North, and Plate 3: Geologic Map, Detailed Study Area South. A map depicting the regional geology of the General Study Area and surrounding vicinity is presented on Plate 1, Regional Geologic Map: General Study Area.

In addition to our geologic reconnaissance, the assessment included interpretation of aerial photo stereo pairs from the March 21, 2000, flight at 1:24,000 scale in color. These photos were scrutinized by our Certified Engineering Geologist to identify terrain features indicative of landslides, erosion, general slope instability, and faulting. Features identified on or in close proximity to the detailed study area were investigated

during the geologic reconnaissance. Results of the aerial photo interpretation are presented on Plates 2 and 3 have been incorporated into this assessment as applicable.

GEOLOGIC SETTING

Regional and Site Geology

Gnoss Field Airport is located on the Petaluma River tidal flat, in Northern Marin County, within the Coast Range Geomorphic Province of Northern California. This province is generally characterized by northwest-trending mountain ranges and intervening valleys, which are a reflection of the dominant northwest structural trend of the bedrock in the region. The basement rock in the northern portion of this province consists of the Great Valley Sequence, a Jurassic volcanic ophiolite sequence with associated Cretaceous to Jurassic sedimentary rocks, and the Franciscan Complex, a subduction complex of diverse groups of igneous, sedimentary, and metamorphic rocks of Upper Jurassic to Cretaceous age (140 to 65 million years old). The Great Valley Sequence was tectonically juxtaposed with the Franciscan Complex most likely during subduction accretion of the Franciscan, and these ancient fault boundaries are truncated by a modern right-lateral fault system that includes the San Andreas, Healdsburg-Rodgers Creek, and Hayward faults. The San Andreas fault defines the westernmost boundary of the local bedrock, approximately 14 miles southwest of the study area. In the site vicinity, the Great Valley Sequence and Franciscan Complex are unconformably overlain by Tertiary age continental and marine sedimentary and volcanic rocks. These Tertiary age rocks are locally overlain by younger Quaternary alluvial, colluvial, and landslide deposits.

The geology of the detailed study area has been mapped by Wagner et al. (*2006*), Wagner et al. (*2002*); Blake et al. (*2000*); and Rice (*1975*). Wagner et al. (*2002, 2006*) indicate the existing airfield is underlain by artificial fill placed over Bay Mud, with levee fill around the northern perimeter of the runway. Additional levees identified by Wagner et al. (*2002, 2006*) separate the airfield from an artificial section of Black John Slough, and also extend east and west of the airport facility. The areas proposed for runway extension (northwest and southeast of the airfield) and surrounding vicinity are shown to be underlain by Holocene (<11,000 years old) Bay Mud, consisting of silt, clay, peat, and fine sand. West of the airfield, Wagner et al. (*2002, 2006*) indicate sections of the Northwestern Pacific rail line are underlain by artificial fill placed over Bay Mud, with localized areas of Bay Mud extending west of the rail line. Holocene fan deposits

comprised of moderately sorted and bedded sand, gravel, silt and clay are mapped along the base of the hills west of the airfield, generally incorporate Highway 101, and generally mark the west margin of the Bay Mud deposits.

Rice (*1975*) also indicates the airfield, as well as areas west of the runway, are underlain by artificial fill over Quaternary age (<1.8 million years old) Bay Mud. The composition and degree of compaction of the fill is described as highly variable, while the Bay Mud consists of highly compressible silty clay, peat, and sand deposits, typically located at or below sea level. The areas proposed for the runway extension are mapped as being underlain by Bay Mud.

The Blake et al. (*2000*) publication is mapped at a significantly smaller scale, prohibiting the mapped detail achieved by both Wagner et al. (*2002, 2006*) and Rice (*1975*). This publication is in general accordance with the other authors, and shows the airfield and surrounding vicinity as underlain by artificial fill placed over Quaternary age marine and marsh deposits, with Quaternary alluvium mapped along the base of the hills to the west.

The three publications identify large landslide features encompassing the low hills west of Highway 101, and extending up to or in close proximity to the margin of the tidal flat on which the airfield is located. Rice (*1975*) shows the features, characterized as either block slump or debris flow landslides, extending beyond (east) of the highway, locally, and at their closest point, within approximately 200 feet of the northern end of the detailed study area and runway extension.

Soil

Soil units at the site and surrounding vicinity have been mapped by the U.S. Soil Conservation Service. Soil unit distribution and data were accessed on the United States Department of Agriculture (USDA) Natural Resources Conservation Service Web Soil Survey page, located at: http://websoilsurvey.nrcs.usda.gov/app/. There are three (3) soil units found within the detailed study area. Two of the soil units have been classified as urban land and fill Xerorthents, and comprise the airfield fill and general fill area to the west. The physical properties of the two Xerorthent units were not provided by the USDA, likely due to their characteristic variability. The third soil unit is the Reyes Clay, which underlies both the southeast and northwest runway expansion areas. Pertinent physical and engineering characteristics of this soil unit are summarized in Tables 1 and 2, below.

TABLE 1
Physical Properties: Reyes Clay Soil Unit

USDA Classification	USCS Classification	Percent Passing #200 sieve	Liquid Limit	Plasticity Index	Erodibility Factor
clay, silty clay, silty clay loam	MH	85-95	50-70	20-30	K=0.2 to 0.32

The survey indicates the Reyes Clay has moderate erodibility, based on the Universal Soil Loss Equation (USLE) K-Factor which accounts for soil type, structure, permeability, and local runoff. For the purposes of this report, soil units with a K-Factor between 0.05 to 0.2 are considered to have low erodibility potential, between 0.2 and 0.4 moderate erodibility potential, and those greater than 0.4 to have high erodibility potential.

In addition, the Survey identifies roadway construction limitations for which the Reyes Clay soil unit received the highest negative rating:

- Low strength
- Saturation <12" depth
- High shrink-swell potential
- Potential subsidence greater than 12"

The fill and urban fill Xerorthents have not been assigned any limitations by the USDA, likely due to their characteristic variability.

Faulting and Seismicity

The site is located within the seismically active North Bay/North Coast region of California and is subject to seismically-induced ground shaking from nearby and distant faults. Several faults have been mapped in the general site vicinity. The San Andreas fault zone, located southwest of the site, is the boundary between two tectonic plates; the Pacific Plate (west of the fault), and the North American Plate (east of the fault). At this boundary, the Pacific Plate is moving north relative to the North American Plate. In the North Coast region of California, this movement is distributed across a complex system of predominantly strike-slip, right-lateral, parallel, and sub-parallel faults that include the San Andreas, Hayward-Rodgers Creek, and Maacama among others.

The site is not located within an Earthquake Fault Zone, as defined by the California Geological Survey (CGS) in accordance with the Alquist-Priolo Earthquake Fault Zone Act of 1972 (*CGS, 2000*). The nearest known sufficiently-active fault is the Hayward-Rodgers Creek fault, located approximately 6 miles northeast of the site. The Hayward-Rodgers Creek is capable of producing a maximum moment magnitude event of 7.2; as such, moderate to major earthquakes generated on the Hayward-Rodgers Creek fault can be expected to cause strong ground shaking at the site. Strong ground shaking can also be expected from moderate to major earthquakes generated on other faults in the region such as the Maacama fault (located 31 miles north), the West Napa fault (located 15 miles east/northeast), the Concord-Green Valley fault (located 22 miles east/northeast) and the San Andreas fault (located 14 miles southwest).

In addition to the active faults discussed above, the U.S. Geological Survey (USGS) (Quaternary Fault and Fold Database: http://earthquake.usgs.gov/regional/qfaults/) identifies a Quaternary (<1.6 million years old) fault known as the Burdell Mountain fault, which crosses the southwest corner of the airfield property and is located within 200 feet of the southeast runway extension at its closest point. Rice (*1975*) shows the fault in the same approximate location as "concealed" (i.e. buried and has not ruptured the Bay Mud surface), while Wagner et al. (*2002*) terminates the fault at Highway 101, west of the airfield. The Burdell Mountain fault is not mapped by Blake et al. (*2000*). Based on the Quaternary designation, the Burdell Mountain fault may be considered "potentially active". A generally accepted definition of "potentially active" is a fault showing evidence of displacement that is older than 11,000 years (Holocene age) and younger than 1.7 million years (Pleistocene age). However, "potentially active" is no longer used as criteria for zoning by the CGS.

A number of large earthquakes have occurred within this region in the historic past. Some of the significant nearby events include two 1969 Santa Rosa earthquakes (M5.6, 5.7), the 2000 Yountville earthquake (M5.2), the 1868 Hayward earthquake (M6.8) and the 1906 San Francisco earthquake (M8+). Future seismic events in this region can be expected to produce strong seismic ground shaking at this site. The intensity of future shaking will depend on the distance from the site to the earthquake focus, magnitude of the earthquake, and the response of the underlying soil and bedrock.

The table below presents the significant faults in the area and corresponding parameters.

TABLE 2
Fault Parameters

Fault Name	Closest Distance to Site (miles)	Maximum Earthquake Magnitude*	Slip Rate (mm/yr)
Hayward-Rodgers Creek	6	7.2	9
San Andreas	14	7.9	17-24
West Napa	15	6.9	1
Concord-Green Valley	22	6.7	4-5
Maacama-Garberville	31	7.5	9
Burdell Mountain	<0.1	-	<0.2

* *Moment magnitude*: An estimate of an earthquake's magnitude based on the seismic moment (measure of an earthquake's size utilizing rock rigidity, amount of slip, and area of rupture). Maximum earthquake magnitude shown may assume multiple rupture scenarios on combined segments of the fault indicated.

Based upon the National Seismic Hazard Mapping Project (NSHMP) Probabilistic Seismic Hazards Assessment (PSHA) Deaggregation, return period of 2% in 50 years, a preliminary peak horizontal ground acceleration of approximately 0.75g may be assumed for the site.

GEOLOGIC HAZARDS AND ASSOCIATED IMPACTS

Geologic/seismic surface/near-surface conditions in the site vicinity described in this report are based on existing available geologic maps and literature as well as a preliminary site reconnaissance. On the basis of those conditions, the potential for adverse geologic hazards that may influence the study area and the impacts on the proposed project are discussed below.

Hazard: Shallow Groundwater/Tidal Influence
The areas proposed for runway expansion are located at or slightly above sea level, within a partially-drained tidal marsh, currently protected from inundation by levees. While the natural and artificial channels, coupled with levee protection, have generated

a relatively firm ground surface, apparent static groundwater was observed as shallow as 2 to 3 feet in depth during our reconnaissance. Shallow groundwater (within 5 feet of the surface) should be anticipated within the areas proposed for runway expansion.

Impact:
Shallow groundwater will potentially hinder access and operation of equipment during construction of the proposed runway extension(s). Utility trench excavations extending down to or below the static groundwater table may also experience loss of trench wall stability and require dewatering for utility installation. Shallow groundwater may have other impacts on the future performance of any improvements, particularly in the presence of compressible and liquefiable soils (see the following discussion) and heavy surface loads, if not mitigated during construction.

Hazard: Expansive Soils
Expansive soils have the capacity to undergo large volume changes with changes in moisture content and typically are associated with high plasticity clays. Expansive soils were observed throughout the areas proposed for runway extension during our reconnaissance, evidenced by surface dessication cracks and mud cracks.

Impact:
If not properly mitigated, the cyclic volume changes capable of expansive soils (i.e. shrink-swell) can cause distress and failure of shallow founded structures, pavements, slabs on grade, and other surfaces. In the case of paved surfaces and slabs on grade, the effects of heave occur particularly along (but not limited to) the margins, where surface water may infiltrate immediately adjacent to the improvement, whereas the remainder is effectively impermeable. The increased moisture content creates a differential or “edge” condition, where soils along the margin of the improvement expand to a greater magnitude than those underlying the impermeable area beneath the improvement, and beyond the zone of influence of the edge, causing uplift cracking and other forms of distress.

Standard mitigative solutions for the detrimental effects of expansive soils acting on surface improvements and structures include, but are not limited to the following:

- chemical treatment of the expansive soil within the zone (depth) of influence to reduce its plasticity and expansion potential to an acceptable level.
- removal of the expansive soil within the zone of influence, and replacement with non-expansive import soil.

- construction of subsurface moisture barriers along the perimeter of improvements, which extend to depths below the zone of influence.
- construction of foundation elements which inherently resist the differential uplift pressures of expansive soils, such as post-tensioned slabs, cast in place pier foundations, and driven pile foundations.

Hazard: Compressible Soils

Compressible soils are typically fine-grained soils that possess low density and are incapable of supporting significant vertical loads without excessive settlement. Compressible soils tend to coincide with younger, Holocene age deposits that have not had sufficient time to densify. The tidal marsh on which the existing airfield and proposed extension areas are located are underlain by Bay Mud deposits (*Wagner [2002], Blake [2000], and Rice [1975]*). Anticipated thickness of the Bay Mud is generally <50 feet below the ground surface, and potentially deeper, locally (*ESA, 2002*). As such, it is our opinion that the existence of variable thickness compressible soils should be anticipated within the areas proposed for the runway extension.

Impact

When loaded by fill placement and/or building pressures, compressible soil (and Bay Mud in particular) undergoes settlement, due to consolidation of the soil, and may potentially experience both vertical and lateral displacement due to plastic deformation. Rarely is this settlement uniform, due to the variability in thickness and composition of the deposit, which, in the case of Bay Mud, may include lenses of peat. Differential settlement at the airfield facility has necessitated frequent pavement rehabilitation throughout the field's existence; settlement actually rendered the runway inoperable approximately 30 years ago (*Personal Communication, Ken Robbins, 2009*). As such, improvements constructed on un-remediated compressible soil can be subject to differential settlement which can approach 5 feet or more, occurring over 100 to 200 years, depending upon the thickness of the Bay Mud and the vertical load placed upon it (*Rice, 1975*). In the case of the runway extension(s), this would result in an irregular runway surface and progressive damage to any subsurface utilities requiring substantial future maintenance and repair, comparable to that experienced at the existing facility.

Standard mitigative solutions for the detrimental effects of compressible soils on surface improvements and structures include, but are not limited to the following:

- installation of wick drain system and placement of fill surcharge along and in the vicinity of the proposed runway extension, engineered for anticipated loads.
- deep soil mixing of compressible soils with cement or lime for their full depth.
- construction of proposed runway extension and related structures on deep foundation elements, such as driven piling or equivalent.

Hazard: Earthquake Ground Motions
Data presented by the Working Group on California Earthquake Probabilities (*2007*) suggests the likelihood of a Magnitude 6.7 or greater seismic event to occur within in the San Francisco Bay region in the next 30 years is approximately 63 percent. Within the San Francisco Bay Region, the Hayward-Rodgers Creek fault has the highest probability at 31%, with the San Andreas fault at 21%. As such, the site is expected to experience strong seismic ground shaking resulting from future earthquakes on the Hayward-Rodgers Creek, San Andreas, and other active faults in the region during the lifetime of construction at this site. Time, location, and magnitude of earthquakes are not accurately predictable with existing technology. It is, however, generally agreed that the intensity of ground shaking from future earthquakes will depend on several factors including the distance from the site to the earthquake focus, the magnitude and duration of the earthquake, and the response of the underlying soil and bedrock.

Impact:
Structures not engineered or constructed per the above described and accepted standards are likely to suffer distress and or collapse. As the proposed project location is underlain by Bay Mud deposits, the impact is compounded, in that 1) shaking is typically amplified in areas of relatively thick unconsolidated sediments, and 2) settlement of the Bay Mud occurs at an irregular and accelerated rate, particularly when under vertical load. It will be necessary to design any proposed structures in accordance with the earthquake-resistant provisions of ASCE/SEI 31-03, Seismic Evaluation of Existing Buildings, published by American Society of Civil Engineers (ASCE) and the Structural Engineering Institute, or by an appropriate standard, in combination with a site-specific geotechnical investigation.

Hazard: Ground Surface Rupture
The nearest known active fault is the Hayward-Rodgers Creek fault, located approximately 6 miles northeast of the site. The Burdell Mountain fault is located within approximately 200 feet of the proposed southeast runway extension. Rice (*1975*) cites relatively young geomorphic features and alignment of low level seismic event epicenters as evidence for recent activity along the Burdell Mountain fault, and

recommends additional investigation of the fault should construction of “large public structures” be considered in close proximity to it. In general, this fault has recognized activity in the Quaternary and may be considered “potentially active”, but has not been zoned as “sufficiently active” or “well defined” by the CGS.

Impact:
No impact on the proposed project due to fault ground surface rupture is anticipated.

Hazard: Liquefaction and Cyclic Softening
Soil liquefaction cyclic softening are conditions where saturated soil undergoes substantial loss of strength due to pore pressure increase resulting from cyclic stress application induced by earthquakes. In the process, the soil acquires mobility sufficient to permit both horizontal and vertical movements if the soil mass is not confined. Soil most susceptible to liquefaction are saturated, loose, clean, uniformly graded sand deposits. Soft, saturated, unconsolidated clay and high plasticity silt, which typically comprise Bay Mud deposits, are most susceptible to cyclic softening. If either ground effect occurs, improvements resting on or within the effected layers may undergo settlements. Sowers et al. (*1998*) indicate the site is underlain by Holocene age estuarine deposits with very high susceptibility to liquefaction. Based on this limited data, it is our opinion the potential for liquefaction and cyclic softening to occur within the areas proposed for runway extension is high.

Impact:
If left unmitigated at the site, the existing soils will be subject to differential settlement due to the previously discussed ground effects during a seismic event, particularly under load of the proposed runway extension(s). The effects of the seismically induced differential settlement will be comparable to those incurred from settlement of compressible soils (i.e. pavement distress, cracking, subsurface utility damage). However, the effects are likely to be immediate, potentially posing a threat to air traffic utilizing the runway.

The detrimental effects of liquefaction on the proposed runway extension may be mitigated utilizing the deep soil mixing and/or structural solutions described for compressible soils.

Hazard: Lateral Spreading and Lurching
Lateral spreading and lurching are potential secondary seismic effects commonly associated with liquefaction where extensional ground cracking and settlement occur as

a response to lateral migration of liquefiable material. These phenomena typically occur adjacent to free faces such as steep slopes and creek channels.

Impact:

While the areas proposed for runway extension are located within a flat estuarine plain, the plain is traversed by several natural and artificial channels with near vertical sides which approach approximately 5 feet in depth. Should liquefiable layers exist at or above the flow line elevation of a channel, lateral spreading and/or lurching could potentially occur during a seismic event, causing immediate damage to the proposed runway extension, subsurface utilities, and any structures if not remediated during construction. Likewise, a seismically induced levee breech or failure in areas where significant elevation changes exist across the levee, combined with and/or caused by liquefaction and lateral spreading of the material contained by the levee, could result in the inundation/flooding of proposed improvements, locally. A condition similar to the one described exists at the southeast end of the existing airfield in the area proposed for extension.

The hazard posed by secondary seismic ground effects to the proposed runway extension may be mitigated utilizing the deep soil mixing and/or structural solutions described for liquefiable soils, particularly given the shallow incision depth of the existing channels. It is anticipated similar methods could be utilized for mitigation of existing levees after their individual assessment.

Hazard: Landsides and Slope Instability

The site is located on an effectively estuarine plain, traversed by artificial and natural drainage channels ranging in depth from 1 to 5 feet below the ground surface. In deeper channels with near vertical banks, shallow slumping of the banks is conceivable on a local level, particularly during periods of saturation, rapid draw down, and/or seismic events. Levees surround the existing airfield and agricultural field in the vicinity of the site. In general, the levees were constructed at approximately 2H:1V (Horizontal:Vertical), and slightly steeper, locally. Shallow erosion and severe bioturbation of the levees was observed during our reconnaissance. The fact that evidence of mass landsliding or levee instability was not apparent does not preclude the possibility of occurrence, due to secondary ground effects during seismic events.

It is assumed the proposed runway extensions will require construction of fill slopes. If not designed and constructed to maintain integrity under static conditions and/or during a seismic event, failure of the slope may occur in the form of raveling and/or shallow landslides.

In addition, the geologic publications reviewed for the project all identify large landslide features west of the detailed study area, the closest of which is located approximately 200 feet west of the proposed runway extension, according to Rice (*1975*). Our aerial photo interpretation identified several large landslides in the vicinity of those mapped on the publications. The features appear to terminate west of Highway 101, or immediately at the roadway; in some cases, the existing geomorphology of the features has been altered by original construction, suggesting the landslide possibly extended beyond (east of) the roadway. The feature located within 200 feet of the proposed northwest runway extension which Rice (*1975*) identifies as a landslide, however, we interpreted to be an alluvial fan, as did Wagner (*2006, 2002*) and Blake et al. (*2000*). If this interpretation is considered, the closest landslide deposit to either the northwest or southeast runway extension is approximately 1,000 feet to the west.

Impact:
Shallow failure of drainage channel banks, levees, and/or fill slopes could impact the proposed extension(s) if not taken into account during design and construction. Channel blockage and levee breach due to localized failure could potentially result in flood inundation. Failure of fill slopes could conceivably damage newly constructed pavements, depending upon fill slope height and the proximity of the improvements to the slope face.

The large landslide features west of the airfield appear to underlie Highway 101 locally, and may extend as far east as the rail line. Distress or damage to the roadway pavement or rail line due to movement of the landslides, or geomorphology suggestive of landsliding in the vicinity of the proposed extensions was not apparent during our reconnaissance. As such, it is our opinion that the potential impact of the large (apparently dormant) landslides along Highway 101 should not be significant, provided any proposed construction does not alter the current topography in the vicinity of the landslide toe.

Hazard: Tsunami and Seiche
Tsunamis are oceanic waves that are generated by earthquakes, submarine volcanic eruptions, or large submarine landslides. The waves are generally formed in groups that may have very long wavelengths (several miles to more than 100 miles), but only a few feet high. As a tsunami enters shallow water near coastlines, the wave velocity diminishes and the wave height increases. If the trough of the wave reaches land first, the arrival of a tsunami is preceded by recession of coastal waters; if the crest of the wave reaches land first, there would be a rise in water level. The large waves that

follow can crest at heights of more than 50 feet and strike with devastating force. However, since the study area is more than 4 miles from San Pablo Bay and 17 miles from the nearest coastline, the potential for this condition is considered low.

Seiche is a standing wave condition whereby large bodies of water, when subjected to seismic accelerations, can generate significant waves that overtop the basin boundaries. The nearest large body of water to the study area is 4 miles to the southeast (San Pablo Bay). Therefore, the potential for a seiche hazard within the study area is also considered low.

Impact:
No impact on the proposed project due to tsunami or seiche inundation is anticipated.

RECOMMENDED INVESTIGATION

Given the geologic hazards present at the site, performance of a geologic and geotechnical subsurface investigation of the site is recommended in order to more accurately characterize the potential geologic and geotechnical impacts anticipated. The investigation should include subsurface investigation of the areas proposed for runway extension, laboratory testing, and engineering analysis. A typical investigation would determine the following at a minimum, in order to provide options for mitigation of existing geologic hazards during construction:

- Depth to static groundwater table
- Thickness of Bay Mud deposits
- Existence and thickness of peat lenses, if encountered
- Depth to and thickness of alluvial deposits underlying Bay Mud, if encountered
- Depth and lithology of bedrock underlying Bay Mud and alluvial deposits
- Laboratory test results
- Analysis of the potential for liquefaction, cyclic softening, lateral spreading, and settlement given proposed loads

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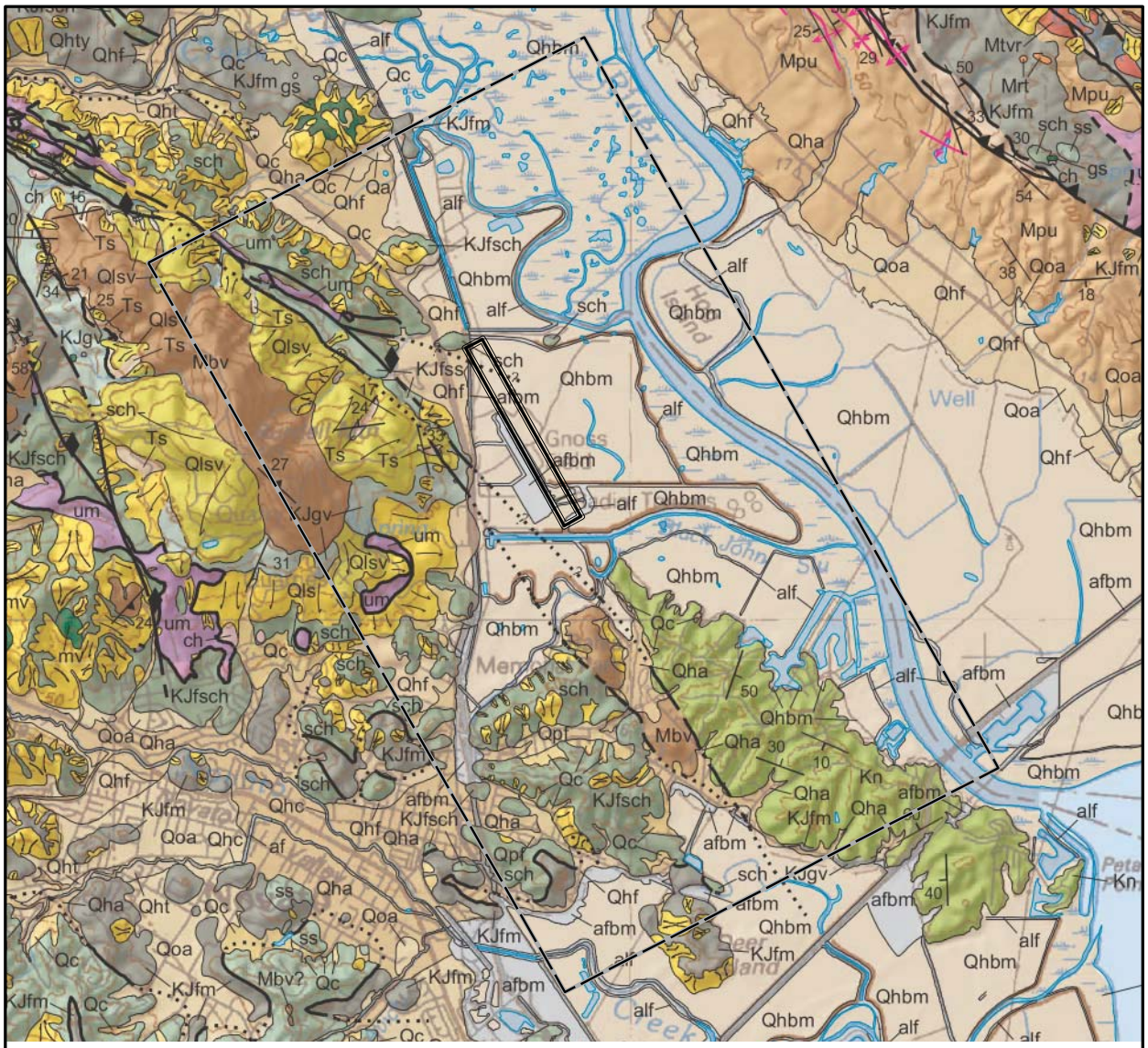

Explanation of Geologic Units

Holocene

- afbm — Artificial fill placed over bay mud
- alf — Artificial levee fill
- Qhbm — Holocene estuarine deposits (bay mud)
- Qha — Holocene alluvium (undivided)
- Qhf — Holocene alluvial fan deposits
- Qa — Alluvium (undivided)

Pleistocene

- Qls — Landslide deposits
- Qlsv — Landslide deposits (volcanic)
- Qc — Colluvium
- Qpf — Alluvial fan deposits

Miocene

- Mbv — Burdell Mountain volcanics
- Ts — Unnamed tuffaceous sediment

Cretaceous

- KJgv — Great Valley Sequence (Great Valley Sequence)
- Kn — Novato Conglomerate (Great Valley Sequence)

Jurassic

Franciscan Complex

- KJfss, KJfsch, KJfm

KJfsch - Schist and semischist
KJfss - Sandstone and shale
KJfm - Melange

Blocks within the Franciscan Melange

- sch, um

sch - Schist and semischist
♦ - Blueschist blocks

Geologic Map Symbols

Contact between map units - Solid where accurately located, dashed where approximately located; short dash where inferred; dotted where concealed; queried where uncertain.

Fault - Solid where accurately located, dashed where approximately located; short dash where inferred; dotted where concealed, queried where uncertain. U = upthrown block, D = downthrown block. Arrow and number indicate direction and angle of dip of fault plane.

Strike and dip of sedimentary beds:

Inclined bedding

Strike and dip of foliation

Landslide - arrow indicates principal direction of movement, queried where existence is questionable (some geologic features are drawn within questionable landslides); hachured where headscarp is mappable

Study Area Explanation

- Detailed Study Area
- General Study Area

N

0 0.5 1 1.5 2 Miles

Source: Wagner et al., 2006
Projection: NAD 1983 StatePlane California III, FIPS 0403, Feet

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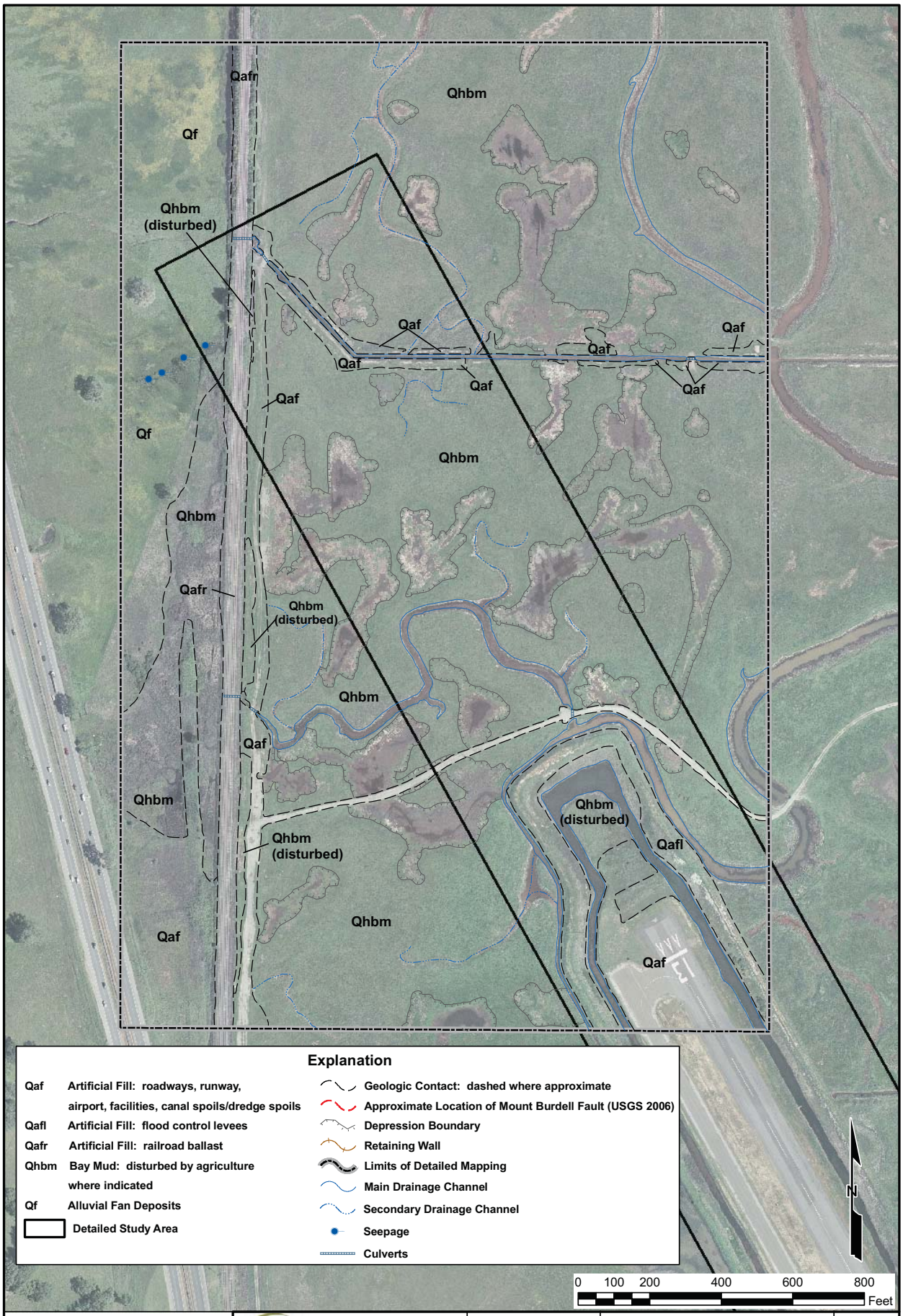
REGIONAL GEOLOGIC MAP
GENERAL STUDY AREA

GNOSS FIELD AIRPORT
EIS/EIR
NOVATO, CALIFORNIA

PLATE **1**



Source of Base: County of Marin, 2007
Projection: NAD 1983, StatePlane, California III, FIPS 0403, Feet

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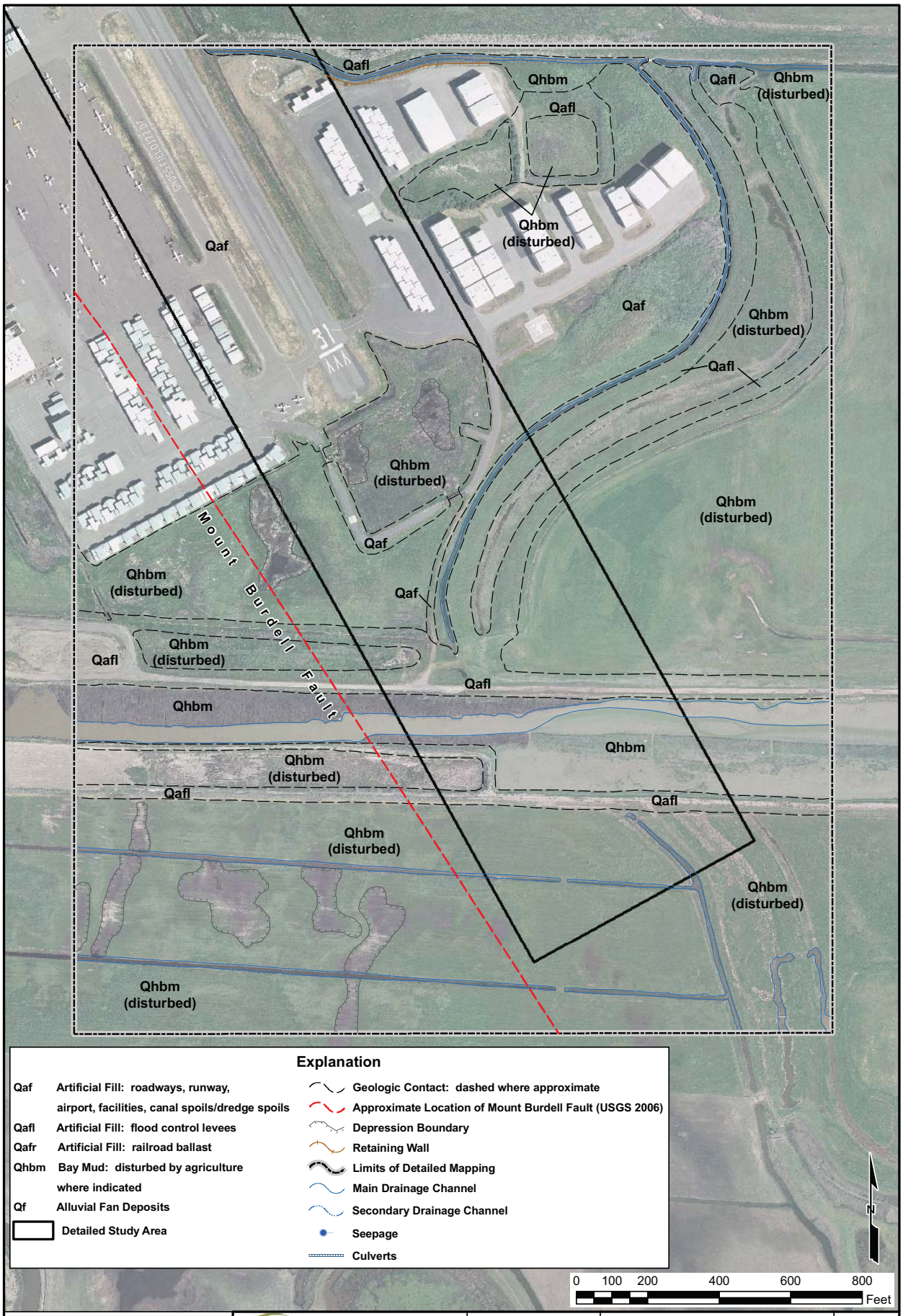
GEOLOGIC MAP
DETAILED STUDY AREA, NORTH

GNOSS FIELD AIRPORT
EIS/EIR
NOVATO, CALIFORNIA

PLATE
2



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Projection: NAD 1983, StatePlane, California III, FIPS 0403, Feet

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GEOLOGIC MAP
DETAILED STUDY AREA, SOUTH

GNOSS FIELD AIRPORT
EIS/EIR
NOVATO, CALIFORNIA

PLATE
3