Appendix D

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List of Acronyms

AMSF	Aircraft Maintenance and Storage Facility Area
BRAC	Base Realignment and Closure
BTEX	benzene, toluene, ethylbenzene, and xylenes
cm/sec	centimeter(s) per second
ESI	Engineering-Science, Inc.
ft	foot (feet)
IT	IT Corporation
mg/L	milligram(s) per liter
msl	mean sea level
ONSFL	Onshore Fuel Line
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbon
TRPH	total recoverable petroleum hydrocarbon
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound
WCFS	Woodward-Clyde Federal Services
µg/L	microgram(s) per liter

1.0 Introduction

The purpose of this appendix is to describe the hydrogeologic conditions at the Base Realignment and Closure (BRAC) Property and summarize the previous investigative groundwater results. The majority of groundwater data generated for the BRAC Property are from previous investigations presented in the following three reports:

- Final Environmental Investigation Report, Hamilton Army Airfield, Volumes I and II (ESI, 1993)
- Additional Environmental Investigation of BRAC Property, Final Report, Hamilton Army Airfield (WCFS, 1996)
- Comprehensive Remedial Investigation Report for the BRAC Property, Hamilton Army Airfield (IT, 1999).

This appendix is organized into the following sections:

- Section 1.0 – Introduction
- Section 2.0 – Hydrogeologic Conditions
- Section 3.0 – Previous Investigation Activities
- Section 4.0 – Groundwater Analytical Results
- Section 5.0 – References

This appendix only summarizes the key findings of the previous investigations; however, further details regarding the hydrogeologic and groundwater analytical data can be referenced from the three reports listed above.

2.0 Hydrogeologic Conditions

There are three shallow hydrogeologic units that occur within the BRAC Property airfield parcel: fill, desiccated Bay Mud, and soft Bay Mud. Measurement data for key properties of the fill material and Bay Mud, compiled during previous investigations for all BRAC Property parcels including outparcels and cantonment tracts that are not a part of the airfield, are presented in Table 2-1 (ESI, 1993; WCFS, 1996; USACE, 1994; and IT, 1999). Each hydrogeologic unit is described in the subsections below followed by a discussion of the typical groundwater parameters for key areas.

2.1 Artificial Fill

Artificial Fill present on the BRAC Property originates from two sources. The vast majority of the fill was placed during construction on the BRAC Property beginning with late nineteenth century reclamation of San Francisco Bay margin wetlands for agriculture. Its clay-rich composition closely resembles the Bay Mud (described below) from which it was largely derived by dredging. Reclamation fill is distributed widely throughout the shallow subsurface of the airfield portion of the BRAC Property. Its thickness typically ranges from 0 to 3 feet (ft). Greater depths of fill are present in topographic low areas. Although the fill was likely unstratified when originally placed, the fill now exhibits horizontal and vertical anisotropy acquired by compaction and subsidence over the last 80 to 100 years. Reclamation fill horizontal groundwater conductivities range widely from 10^{-5} to 10^{-8} centimeters per second (cm/s) (ESI, 1993). The corresponding vertical conductivities fall in the narrower range from 10^{-7} to 10^{-8} cm/s (WCFS, 1996; IT, 1999). A second type of fill are materials placed for engineering purposes, such as structural bridging material to support building foundations, road metal, and bedding material for underground conduits such as some sewers and presumably the Onshore Fuel Line (ONSFL). These fill materials, which are typically well graded (poorly sorted) but unstratified, range in size from gravel to clay and have moderate to low permeabilities in the range of 10^{-4} to 10^{-8} cm/s (ESI, 1993). The engineering fill is limited in aerial extent, being confined primarily to areas formerly occupied by airfield buildings in the portions of the aircraft maintenance area or westernmost BRAC Property parcels now protected by the New Hamilton Partnership levee.

TABLE 2-1
Properties of Fill and Bay Mud on Base Realignment and Closure Property

Property	Fill	Desiccated Bay Mud	Soft Bay Mud	Reference
pH (standard units)	NM[a]	4	8	WCFS, 1996[b]
Liquidity Index (%)	NM	NM	1	WCFS, 1996
Plasticity Index (%)	NM	NM	40 - 50.1	WCFS, 1996
Organic Content (%)	NM	11 - 11.4	10.67 - 14.18	WCFS, 1996
Specific Gravity	2.66 - 2.70	2.62 - 2.71	2.64 - 2.74	WCFS, 1996
	2.45 - 2.71		2.39 - 2.67	IT, 1999[c]
Wet Bulk Density (%)	1.46 - 2.07	1.38 - 1.55	1.41 - 1.73	WCFS, 1996
Dry Density (pcf[d])	59.1 - 128.9	NM	44.9 - 63.4	IT, 1999
Water Content (%)	14 - 47	65 - 96	54 - 99	WCFS, 1996
	13.3 - 71.4		62.6 - 88.0	IT, 1999
Porosity (%)	33.5 - 55	58.3 - 66.1	60 - 73	WCFS, 1996
Hydraulic Conductivity (cm/sec[e])				
Horizontal	$3.7x10^{-8}$ - $1.5x10^{-3}$	$1x10^{-7}$ - $9.3x10^{-2}$ [f]	$2.9x10^{-8}$ - $3.1x10^{-4}$	slug tests, USACE, 1994[g]
	NM	$8.2x10^{-8}$	$3.4x10^{-8}$ - $2.2x10^{-6}$	lab tests, ESI, 1993[h]
Vertical	$2.3x10^{-8}$ - $2.2x10^{-6}$	NM	NM	lab tests, ESI, 1993
	$3.6x10^{-8}$ - $3.7x10^{-7}$	NM	$5.5x10^{-8}$ - $1.2x10^{-7}$	lab tests, IT, 1999

a Not measured.
b Woodward-Clyde Federal Services (WCFS), 1996, Additional Environmental Investigation of BRAC Property, Hamilton Army Airfield, Oakland, California.
c IT Corporation (IT), 1999, Comprehensive Remedial Investigation Report, BRAC Property, Hamilton Army Airfield, Novato, California, Martinez, California.
d Pounds per cubic foot.
e Centimeters per second.
f Described as "Desiccated Bay Mud/Soft Bay Mud."
g U.S. Army Corps of Engineers (USACE), 1994, Supplemental to the Final Environmental Investigation Report, Hamilton Army Airfield, Sacramento, California.
h Engineering-Science, Inc. (ESI), 1993, Final Environmental Investigation Report, Hamilton Army Airfield, Alameda, California.

2.2 Bay Mud

The Bay Mud typically consists of semi-consolidated to unconsolidated, highly plastic, silty clays containing variable amounts of organic material and numerous small shell fragments (WCFS, 1996). The Bay Mud is soft and plastic when it is wet, and shrinks, hardens, and becomes brittle when it dries. The desiccated Bay Mud corresponds to the seasonal influenced, partially desaturated to desiccated near-surface deposits. The soft Bay Mud corresponds to the underlying saturated deposits. The soft Bay Mud acts as an aquitard. Airfield wells penetrating soft Bay Mud exhibit slug test conductivities in the typical range of 10^{-6} to 10^{-8} cm/s. Vertical conductivities of soft Bay Mud range from 10^{-7} to 10^{-8} cm/s in the same areas (WCFS, 1996 and IT, 1999).

The desiccated Bay Mud has low matrix permeability, but may have some fracture permeability extending from the surface to depths of a few to several centimeters. Preferential flow is probably vertical through desiccation cracks. Slug tests of airfield wells within the desiccated Bay Mud indicated horizontal hydraulic conductivities of 10^{-4} to 10^{-7} cm/sec. Laboratory measurements of desiccated Bay Mud vertical conductivities fall within the 10^{-6} to 10^{-8} range which is consistent with silty clay matrix (IT, 1999 and WCFS, 1996).

2.3. Groundwater

The groundwater at the BRAC Property is considered part of the Novato Creek Basin, which has several potential beneficial uses as defined by the Water Quality Control Plan for the San Francisco Bay (RWQCB, 1995). These uses, within the basin, include agricultural, industrial service, industrial process, and municipal and domestic water supply. The groundwater within the BRAC Property, however, is unsuitable as a drinking water source (human beneficial use) because of the elevated total dissolved solids content in excess of the drinking water threshold of 3,000 milligrams per liter (mg/L). The total dissolved solid concentrations on the BRAC Property ranged from 819 to 18,270 mg/L as shown on Table 2-2 (IT, 1999). Furthermore, the groundwater is not a likely source of industrial groundwater because of its very low sustainable yield in the impermeable Bay Mud. An evaluation of the beneficial use of the shallow groundwater beneath the general lowland site areas was performed during studies for the adjacent General Services Administration Phase I Sale Area in 1995. This study (WCFS, 1995) indicated that the groundwater should not be considered a source for domestic or municipal water supplies.

The depth to groundwater ranges from approximately 2 to 10 ft below grade in the fill and Bay Mud (WCFS, 1996). Based on data from 1996 and 1997, groundwater was encountered in the monitoring wells at depths from 3.6 ft above mean sea level (msl) to 13.4 ft below msl. The depth varies seasonally because of high evapotranspiration rates in the summer and fall and recharge during winter and spring.

TABLE 2-2
Total Dissolved Solids in Groundwater

Well Number	Well Purpose	Conductivity[a] μS/cm[b]	TDS[c], mg/L[d]	TDS, ppt[e]
BKG-MW1	background	8,200	5,166	5
BKG-MW2	background	29,000	18,270	18
BKG-MW4	background	2,050	1,292	1
BKG-MW5	background	4,200	2,646	3
JFL-MW1	characterization	1,500	945	1
JFL-MW3	characterization	13,500	8,505	9
PSA-MW1	characterization	5,990	3,774	4
PSA-MW2	characterization	3,920	2,470	2
PSA-MW3	characterization	11,000	6,930	7
PSA-MW4	characterization	1,300	819	1
RVT-MW1	characterization	2,350	1,481	1
RVT-MW2	characterization	1,600	1,008	1
RVT-MW3	characterization	2,500	1,575	2
AM-MW-101[f]	characterization	11,400	7,182	7
TP-MW-101[f]	characterization	18,100	11,403	11
Average		7,036	4,898	5
Minimum		1,300	819	1
Maximum		29,000	18,270	18
Standard Deviation		7,543	4,920	5
Geometric Mean of All Wells Listed		4,521	3,124	3
Geometric Mean of Background Wells		6,701	4,238	4
Geometric Mean of Characterization Wells		6,651	2,797	3

[a] Conductivity data taken from field purge records; lowest measurement used.
[b] Microsiemens per centimeter.
[c] Total dissolved solids, calculated as TDS = 0.63x(electrical conductivity); equation developed from correlation of electrical conductivity with total dissolved solids (IT, 1999).
[d] Milligrams per liter.
[e] Parts per thousand, calculated as milligrams per liter x 0.001. [f] Sampled by IT Corporation in July 1997; all others sampled by Woodward-Clyde Federal Services in April 1995

2.4 Potential Preferred Groundwater Pathways

Diverse hydrogeologic units and site factors combine to present a number of potential preferential groundwater migration paths. Preferential migration pathways are a concern with regard to contaminant transport because of the possibility that contamination breakthrough, the point at which groundwater contamination exceeds levels of acceptable risk, will occur sooner than predicted. Of particular concern at Hamilton Army Airfield (HAAF) is any potential threat to future wetlands receptors from contamination conveyed by groundwater to exposure points at excavated or eroded channels or in the existing coastal salt marsh or San Pablo Bay.

Preferential pathways can be divided into two general groups, those that short circuit expected transport routes, and those through which transport occurs at an accelerated rate. Examples of first group at HAAF are fissures in desiccated clay soils, bedrock fractures, and open conduits, such as drain lines. Desiccation cracks or fissures tend to short-circuit the normal pathway through the porous matrix only for short distances at the exposed surface of the unit. Desiccation cracks tend to anneal at depth due to normal hydrostatic pressures and the difficulty of maintaining unsupported void space at depth. It is possible that fissures may be filled with non-matrix soil material, but even if such material is relatively permeable, the fissures themselves are discontinuous and do not form, interconnected networks for distances much greater than several centimeters. Bedrock units are not a factor for the Hamilton airfield although fractured bedrock is a consideration for a BRAC Property outparcel. Bedrock plunges from outcrop areas to the west of the airfield too many meters deep beneath the airfield. Fractures, if present at depth, are separated from potential receptors of the shallower zones by several meters of soft Bay Mud and other fine grained units.

More problematic than naturally occurring voids are the existing storm water drainage system conduits. These pipes range in size from less than 1 ft to as much as 54-inches in diameter. In general, the lines are distributed in three areas. One network drains the mid-airfield just north of the revetment area. Another network drains the revetment area itself, while a third drains the aircraft maintenance area to the west of the revetments. The revetment area network is of special interest because it is the most likely to intersect with tidal channels that will be excavated or that may erode as part of the HAAF wetlands. The component lines in each network span various distances and lie at various depths, usually no deeper than 3 to 5 ft below current grade. One cannot rule out the possibility of groundwater seepage into the drain lines through gaps, joints, or other breaks in the lines. Fortunately, in the case of the mid-airfield and revetment area networks, the drains themselves do not approach closely to any known sites with quantities of buried contamination to serve as a source to groundwater. The drains in the Aircraft Maintenance and Storage Facility Area (AMSF) pass through some areas where inorganic chemicals of concern are encountered in the subsurface. However, these drain lines convey water to discharge into the perimeter drainage ditch to the west of the central portion of the airfield. Hence, they do not pose a potential threat to future critical habitat areas subject to channel formation. Additionally, recent monitoring of wells in this area indicates that groundwater is relatively free of contamination. More discussion about groundwater quality in this area is contained in Section 4.2.

The second type of preferred pathway may include interbeds of relatively permeable units, such as sand or gravel lenses within otherwise fine-grained units, engineering fill materials, or organic rich, peat layers. Engineering fill may have extended along the ONSFL and possibly beneath airfield drains or other buried conduits. However, during the period of construction of the airfield, modern filter fabrics and other siltation controls were not widely used. It is likely that gravel or other material used for bedding or drainage silted up as early as within a few to several months after placement depending on soil moisture conditions. In the specific case of the ONSFL, any potential longitudinal preferred pathway for groundwater migration was removed or otherwise interrupted in 1995 when the pipeline itself and over 6,000 cubic yards of inline and proximal contaminated soils were removed (ATG, 1995). A potential concern might be raised over near subsurface road metal and pavement underlayment. For example, the paved revetments appear to lie upon gravel bedding. While this bedding is potentially a preferred pathway for horizontal transport, the practical observation is that revetments with known, shallow subsurface contamination at their centers typically do not exhibit elevated levels in perimeter samples. Either migration under transient saturated conditions (infiltration of rainwater) does not appear to take place, or the gravel itself contains enough fine matrix to block transport. A coarse grained bridging layer underlies portions of the AMSF in the vicinity of Building 82. However, an open excavation created to remove residual soil contamination penetrated the layer at approximately 7-ft below ground surface. The coarser material, which appears to be distributed in surrounding areas as well, only produced water for about one day. Beyond that point, the water level in the open excavation began to decline, indicating the bridging layer is likely a perched zone with limited permeability extent.

Along with engineering fill of various origins, naturally occurring zones of increased permeability are known to exist at HAAF. The Bay Mud contains interbedded fluvial deposits of sand and silt ranging in thickness from 1 inch to 3 ft. These deposits are more characteristic of the Bay Mud where it lies near the flanks of upland areas such as Petroleum, Oil, and Lubricant Hill, Ammo Hill, or the Coast Guard housing area. The interbedded units are lenseatic in nature and do not form through going aquifers. The origin for the sediment contained in the lenses is likely the adjacent bedrock. The zone containing fluvial sediments interfingers with bay sediments as distance from the upland sources increases (WCFS, 1996). In a vertical sense, the depth zone containing medium to coarse-grained interbeds plunges along with the bedrock surface beneath the shallower, exclusively fine grained units encountered in airfield borings, excavations, and wells. Under these considerations the presence of high permeability, coarse grained units as preferred pathways for groundwater is very unlikely for extended distances. Another consideration is the potential presence of peat or other organic rich permeable layers. While such features are an important component of the airfield's Reyes-type soils, they too form discontinuous lenses, particularly in the reclamation fill. Hence, it is concluded that through going, high permeability units, either naturally occurring or of man-made origin do not form preferred pathways for groundwater contaminant migration beneath the Hamilton airfield.

2.5 Conditions for Horizontal Groundwater Transport of Contamination.

Groundwater gradients were found to vary from 0.001 beneath the revetment area to 0.051 near the Pump Station Area and east levee, which are closer to tidal influences from San Pablo Bay. Groundwater elevations, contours, and inferred flows generally agree with those found during previous investigations (WCFS, 1996). The recent historic flow direction is generally from the north and western areas toward a low null point in the east-central portion of the airfield (IT, 1999).

The null point is a region where the gradient becomes flat, a flow stagnation point. It was concluded in the previous section that there are no continuous aquifer units beneath the Hamilton airfield. The absence of an aquifer does not preclude advective flow. However, the low conductivities, even in the horizontal dimension, coupled with the small natural gradient culminating in a stagnation point result in very slow rates of movement. An estimate of the Darcy velocity is derived from the following revetment area parameters:

$$Vd = k\ i = 10^{-4} \times 0.0014 = 1.4 \times 10^{-7}\ cm/s$$

Assuming the soils have only 20 percent porosity (low for clay-rich units that might be twice that number), the rate of groundwater movement is on the order of 22 centimeters per year. This calculation is based upon the assumption that historic gradients will be sustained. The gradient condition should persist up to the point when the site is restored to wetlands habitat. For a brief period of years during construction, transient conditions will exist during which the primary transport mechanism will be vertically downward as dredge materials dewater and infiltration processes proceed. As placement cells are loaded, the water table may rise a negligible amount toward the infiltration front a negligible amount due to incremental increases in pore pressure. After the transition period, the airfield will ultimately be saturated by San Pablo Bay water. The horizontal flow regime after inundation may follow the same direction as the current one; however, the gradient will not likely change magnitude in a significant way because the airfield will still be essentially flat. The existing unsaturated zone will eventually disappear. Once Bay water infiltrating from the surface merges with groundwater, a standard hydrostatic condition of uniform pressure increase with depth will exist everywhere in the saturated subsurface. At that point, diffusion will be the only mechanism for contaminant transport in the vertical direction (USACE, 2001), and depending on the position and extent of stagnation, it may also become the primary mechanism for horizontal transport.

In summary, HAAF may contain limited areas of contamination in-place and hence pose a theoretical threat to groundwater. But consideration of the impermeable hydrogeologic units and small gradients, the limited extent of areas at risk for preferential flow, and the flat lying nature of Bay plane areas, it is concluded that groundwater is not a potential threat to a restored wetlands or existing habitats.

3.0 Previous Investigation Activities

Although numerous environmental investigations dating back to 1985 have been conducted on the BRAC Property, the majority of the groundwater investigations were conducted under three major efforts in 1993 (ESI, 1993), 1996 (WCFS, 1996), and 1998 (IT, 1999). The following sections describe the groundwater investigation activities conducted under each investigation.

3.1 Environmental Investigation

The investigation by Engineering-Sciences, Inc. (ESI) in 1993 defined the distribution, type, and concentrations of contaminants at the Base and assessed the risk associated with the contaminants (1993). The investigation included installation and sample collection of 19 groundwater monitoring wells at six sites (the revetment area, Revetment 10 firefighter training area, AMSF, pump station area, former sewage treatment plant, and the east levee construction debris disposal area). Groundwater samples from the ESI investigation were analyzed for volatile organic compounds (VOC); benzene, toluene, ethylbenzene, and xylenes (BTEX); semivolatile organic compounds (SVOC); total recoverable petroleum hydrocarbons (TRPH); metals; pesticides/polychlorinated biphenyls (PCB); and general chemistry parameters. In general, the study found no contamination from organic chemicals in groundwater.

3.2 Additional Environmental Investigation

The investigation conducted by Woodward-Clyde Federal Services (WCFS) in 1995 and 1996 provided additional environmental investigation data for the BRAC Property. The additional investigation report described the investigation for several areas of the BRAC Property and summarized information from previous investigations (WCFS, 1996). There were 17 groundwater monitoring wells installed at five sites (revetment area, jet [onshore] fuel lines, pump station area, AMSF, and background locations). The five background wells were installed at locations away from known artificial or natural drainage features to evaluate the background groundwater quality on the BRAC Property. Groundwater samples were collected and analyzed for VOCs, SVOCs, polynuclear aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPH) (measured as gasoline, diesel, and JP-4), BTEX, metals, pesticides, herbicides, oil and grease, and total organic carbon. Organic chemicals were detected at low levels. Most wells detected a number of metals on par with the corresponding values observed in the background wells.

3.3 Remedial Investigation

The Remedial Investigation conducted by IT Corporation (IT) in 1997 and 1998 evaluated conditions at specific sites within the BRAC Property. Data from previous investigations were evaluated during the Remedial Investigation and additional samples were collected at specific sites and analyzed to aid in characterizing and determining background chemical conditions.

Groundwater samples were collected from five sites (Building 15, Building 20, Building 86, Building 84, Building 90, and Former Sewage Treatment Plant Sludge Drying Beds) during the Remedial Investigation. The groundwater samples were analyzed for TPH (measured as gasoline, diesel, and JP-4), VOCs, BTEX, PAHs, metals, PCBs, pesticides, and dissolved organic carbon.

Both organic and inorganic chemicals were detected at low levels.

The results of these investigations are summarized further on a site-specific basis in the following section.

4.0 Groundwater Analytical Results

The groundwater results from the various investigations indicated that groundwater does not appear to be significantly impacted by site activities. In general, detections in groundwater well samples appear to be limited to the vicinity of a single well and are not representative of general site conditions or as part of a contaminant plume.

Maximum values for metals detected in the BRAC Property airfield parcel groundwater samples collected during previous investigations are listed in Table 4-1. Fourteen metals occurred in some or all of the groundwater samples from previous investigations by ESI (1993) and WCFS (1996).

The maximum concentrations of organic analytes detected in the BRAC Property airfield parcel groundwater samples collected during previous investigations are listed in Table 4-2. Three of the detected compounds (acetone, methylene chloride, and butyl benzyl phthalate), each common laboratory contaminants, were detected sporadically at low levels and were interpreted in the Remedial Investigation (IT, 1999) to be investigation-related contaminants rather than related to *in situ* groundwater conditions. Pesticides and PCBs were not detected in any groundwater samples in which they were analyzed for. Benzyl alcohol and butyl benzyl phthalate were detected in the background monitoring well samples.

The Remedial Investigation (IT, 1999) summarized the previous investigative results for groundwater by dividing the inboard BRAC Property into five areas: the AMSF, the Former Sewage Treatment Plant, the Pump Station Area, the Revetment Area, and the ONSFL. In addition, five background wells, which were installed as part of the Additional Investigation conducted in 1995, were evaluated. A discussion of the analytical results for the background groundwater wells and inboard BRAC Property monitoring wells excerpted from the Remedial Investigation is presented in the subsections below.

4.1 Background Monitoring Wells

The five background monitoring wells (BKG-MW1 through BKG-MW5) were placed throughout the inboard BRAC Property as part of the site wide groundwater investigation conducted for the Additional Investigation in 1995. One background well, monitoring well BKG-MW1 was located on the northern end of the BRAC Property on the runway panhandle. The other four background wells were located on both sides of the runway south of the Revetment Area.

Total metals (in unfiltered samples) were detected in all five background wells. The maximum concentrations of metals are shown on Table 4-1. The only organic constituents detected (Table 4-2) were benzyl alcohol (at a concentration of 32 micrograms per liter [µg/L]) and butyl benzyl phthalate (at a concentration of 44 µg/L) in groundwater recovered from well BKG-MW1. These constituents were judged to be laboratory contaminants. Volatile organic compounds, oil and grease, PAHs, and TPH measured as diesel and JP-4 were not detected in any of the wells. Total petroleum hydrocarbon measured as gasoline was not analyzed. The lack of organic chemical detections and the persistent detections of metals in all wells is consistent with the interpretation of these wells as representative of background.

TABLE 4-1
Metals Detected in Groundwater

Site/Area	Source	Maximum Detections of Metals[a] Detected in Groundwater Samples, μg/L[b]													
		Sb	As	Ba	Be	B	Cr	Co	Cu	Pb	Mn	Hg	Ni	V	Zn
Surface Water Criteria	RWQCB, 2000[c]	30	36	3.9	5.1	1.6	180	3.0	2.4	3.2		0.012	8.2	19	23
Background	WCFS, 1996[d]		13	47	2.7	2000	120	160	49	15	10300	0.24	880	98	210
Aircraft Maintenance and Storage Facility	ESI, 1993[e]	86.3	29.6	170	20	2380	52.4		60.9	11.6	13200		40.5		90.9
	WCFS, 1996					550	28	23		3.8	3100		79	20	57
	IT, 1999[f]			100		1500	18			13	1170				37.3
Former Sewage Treatment Plant	ESI, 1993	101	15.6	144	1.8							0.338	57.6		26.8
	IT, 1999		33	120		390	5.3					0.72			
Pump Station Area	ESI, 1993			109			32.5				4360		38.6		35.8
	WCFS, 1996		28	180	2.1	2800	290	53	130	24	3800	0.27	290	250	310
	IT, 1999		44	120		2200	18			11			170		
Revetment Area	ESI, 1993		7.28	70.5					30.9	9.13	1050				
	WCFS, 1996		6.8			850	66	24	32	7.7	2200		110	57	93
ONSFL[g]	WCFS, 1996		21			3700	20	15	21		2400			13	110

[a] Metals listed are antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), boron (B), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn).
[b] Micrograms per liter.
[c] Regional Water Quality Control Board (RWQCB), 2000, *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater*, Interim Final, August, San Francisco, California.
[d] Woodward-Clyde Federal Services (WCFS), 1996, *Additional Environmental Investigation of BRAC Property*, Oakland, California.
[e] Engineering-Science, Inc. (ESI), 1993, *Final Environmental Investigation Report, Hamilton Army Airfield*, Alameda, California.
[f] IT Corporation (IT), 1999, *Comprehensive Remedial Investigation Report, BRAC Property, Hamilton Army Airfield, Novato, California,* Martinez, California.
[g] Onshore fuel line (referred to as "jet fuel line" in WCFS 1996 report).

TABLE 4-2
Organic Chemicals Detected in Groundwater

Site	Analyte	Maximum Detection (μg/L)[a], by Investigation					Surface Water Criteria (μg/L)
		1991[b]	1992[c]	1994[d]	1995[e]	1997/ 1998[f]	RWQCB, 2000[g]
Background Wells	Benzyl alcohol				32		
	Butyl benzyl phthalate				44		
	Unknown Hydrocarbon				False Positive		640
Aircraft Maintenance and Storage Facility	1,2-Dichloroethylene	5.4					590
	Benzene	1.2					46
	Chloromethane		8.5				6,400
	Naphthalene		2.0				24
	Unknown Hydrocarbon (diesel)					190	640
Former Sewage Treatment Plant	1,3-Dimethylbenzene	2.8					
	1,4-Dichlorobenzene	15		11.6		13	15
	2-Methylnaphthalene	3.7					2.1
	4-Methylphenol	22					
	Acetone	200					1,500
	Benzene	1.4				1.8	46
	Chlorobenzene	20		15.5		15	50
	Dichlorobenzene (non-specific)	13					14
	Methyl ethyl ketone	76					
	Methyl isobutyl ketone	11					14,000
	Methylene chloride			17.1			170
	Naphthalene	5.2					2,200
	Phenol	230		58.4			24
	Pyrene			58.4			2,560
	Toluene	1.7					0.40
	Xylenes (total)	3.2		2.4		1.1	130
	Gasoline					3.3	13
	Unknown Hydrocarbon (diesel)					180	500
						360	640
Pump Station Area	Cyanide	18.5					1.0
	Methyl ethyl ketone	32					14,000
	Methylene chloride			102			2,200
	Toluene				0.55		130
	Unknown Hydrocarbon (diesel)					94	640
Revetment Area	Cyanide	12.6					1.0
Revetment 10 (Burn Pit)	Methyl ethyl ketone	30					14,000

TABLE 4-2
Organic Chemicals Detected in Groundwater

Site	Analyte	Maximum Detection (μg/L)[a], by Investigation					Surface Water Criteria (μg/L)
		1991[b]	1992[c]	1994[d]	1995[e]	1997/ 1998[f]	RWQCB, 2000[g]
Jet Fuel Pipeline	Benzyl alcohol				27		
	Butyl benzyl phthalate				130		
	Unknown Hydrocarbon (unspecified)				620		640

[a] Micrograms per liter.
[b] Woodward-Clyde Federal Services (WCFS) (1987), *Confirmation Study for Hazardous Waste, Hamilton AFB, Novato, California, Final Report*, Omaha, Nebraska.
[c] Engineering-Science, Inc. (ESI) (1993), *Final Environmental Investigation Report, Hamilton Army Airfield*, Alameda, California.
[d] U.S. Army Corps of Engineers (USACE) (1994), *Supplement to the Final Environmental Investigation Report, Hamilton Army Airfield, California*, Sacramento, California.
[e] Woodward-Clyde Federal Services (WCFS) (1996), *Additional Environmental Investigation of BRAC Property*, Oakland, California.
[f] IT Corporation (IT) (1999), *Comprehensive Remedial Investigation Report, BRAC Property, Hamilton Army Airfield, Novato, California*, Martinez, California.
[g] Regional Water Quality Control Board (RWQCB), 2000, *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater*, Interim Final, August, San Francisco, California

4.2 Aircraft Maintenance and Storage Facility (includes the Building 82/87/92/94 Area and Building 86)

As part of a previous investigation, ESI installed four groundwater monitoring wells (1993) in the former Aircraft Maintenance and Storage Facility located on the south end of the runway. Wells AM-MW-101, -102, and -103 were located on the northwest and southwest sides of Building 86, and Monitoring Well AM-MW-104 was placed alongside Building 87. Groundwater samples collected from the four monitoring wells were filtered through 45-micron filters in the field and analyzed for VOCs, SVOCs, and metals. Thirteen metals were detected in some or all of the four wells (Table 4-1). Five organic compounds were reported since 1991, including 1,2-dichloroethene (5.4 μg/L), benzene (1.2 μg/L), chloromethane (8.5 μg/L), naphthalene (2.0 μg/L), and degraded diesel (190 μg/L) (Table 4-2).

In 1995, WCFS installed monitoring wells AMA-MW1 and -MW2 alongside Perimeter Road, east of Building 87 and ESI's well AM-MW-104. Groundwater samples from the two new wells were analyzed for metals; PAHs, oil and grease, BTEX, and TPH measured as gasoline, diesel, and JP-4. Analytical results showed trace or background detections of eight metals, four of which had previously been reported in AM-MW-104 (Table 4-1). No organic compounds were detected in the WCFS wells (1996) nor were any reported for AM-MW-104 (ESI, 1993).

During the Remedial Investigation, IT collected a groundwater sample from existing Monitoring Well AM-MW-101 and analyzed the sample for TPH measured as gasoline, diesel, motor oil, and JP-4, VOCs, BTEX, PAHs, pesticides, PCBs, and metals. The groundwater sample did not contain any detections of organic compounds, with the exception of unknown extractable petroleum hydrocarbons at 190 μg/L, well below the lowest aquatic life protection value of 640 μg/L. The sample also contained five metals, four of which had previously been reported in groundwater from this well as shown on Table 4-1. It should be noted that samples in general have not been filtered before analysis, suggesting values might be substantially lower if particulates were removed from the water samples.

4.3 Building 84/90

During the Remedial Investigation, five soil borings were drilled at Building 90. Soil boring SB-AM90-002 was drilled near a small sump at the southern end of the building. The sump was the receiving structure for a floor drain inside the southern shed of Building 90. Soil borings SB-AM90-001 and SB-AM90-003 through SB-AM90-005 were drilled west of the building, adjacent to the edge of the wash racks. Only one boring, SBAM90-001, had sufficient groundwater yield for sample collection; the groundwater from this boring was sampled and analyzed for TPH measured as gasoline, diesel, motor oil, and JP-4, BTEX, VOCs, PAHs, and lead. Again, none of the organic analytes were detected; lead was the only constituent detected in the groundwater sample at a concentration of 13 μg/L which is less than the background wells.

4.4 Former Sewage Treatment Plant

The groundwater in the vicinity of the Former Sewage Treatment Plant was initially characterized by a monitoring well located to the south of the former drying beds. Monitoring well TP-MW-101 was installed in December 1990 (ESI, 1993), approximately 50 ft south of the former sludge drying beds and midway between the East Levee and Perimeter Road. The well was screened within the Bay Mud from 4.8 to 14.8 ft below ground surface. Water-level measurements by ESI (1993) indicated artesian conditions, and two seeps were reported in the area. Groundwater elevation measurements from TP-MW-101 and other wells indicated that shallow groundwater flows on a very steep gradient from the coastal salt marsh into the airfield in this vicinity.

A groundwater sample was collected from TP-MW-101 by ESI (1993) and analyzed for VOCs, SVOCs, metals, and general chemistry parameters. The well was found to be saline (8,000 mg/L of chloride) and high in dissolved ions. Nine VOCs and five SVOCs were also detected in the groundwater sample as shown on Table 4-2. All values for volatiles were below the chronic and acute surface water criteria except for 2-Methylnapthalene at 3.7 μg/L compared to the published value of 2.1 μg/L and Pyrene at 58.4 μg/L as compared to 0.40 μg/L.

In 1994, the U.S. Army Corps of Engineers (USACE) further evaluated the TP-MW-101 area and installed and sampled four temporary groundwater wells. Three wells were placed hydraulically downgradient (west) of the former sludge drying beds. One was placed next to a seep southwest of monitoring well TP-MW-101. Groundwater in well TP-MW-101 was also resampled. The samples were analyzed for VOCs, SVOCs, TRPH, TPH measured as diesel, and lead. Methylene chloride was detected in all of the samples although evaluation of the results indicated that this detection was probably associated with sample collection practices or, more likely, with laboratory contamination. The groundwater sample from TP-MW-101 also contained chlorobenzene, xylenes, 4-dichlorobenzene, and phenol as shown on Table 4-2.

In 1997 and 1998, as part of the Remedial Investigation, two additional samples were collected from Monitoring Well TP-MW-101 to provide more recent groundwater quality data and assess conditions in saturated portions of the fill and Bay Mud. One sample was collected on June 27, 1997 and the other sample was collected on October 23, 1998. The samples were analyzed for TPH measured as gasoline, diesel, motor oil, and JP-4, BTEX, PAHs, VOCs, PCBs, pesticides, and metals (total and dissolved). The groundwater results from both sampling events indicated the presence of gasoline (maximum concentration of 180 μg/L), unknown hydrocarbons (360 μg/L), benzene (1.8 μg/L), toluene (1.1 μg/L), xylenes (3.3 μg/L), 1,4-dichlorobenzene (13 μg/L), chlorobenzene (15 μg/L), and metals. The concentrations of organic constituents were comparable for both sampling events as shown in Table 4-3.

Monitoring Well TP-MW-101 was abandoned in 1998 in preparation for the interim removal actions conducted at the Former Sewage Treatment Plant.

4.5 Pump Station Area (includes Buildings 35/39 and Building 41)

The Pump Station Area located in the northeast portion of the BRAC Property has been monitored as part of the initial Environmental Investigation conducted in 1993 and again in 1997 and 1998 as part of the Remedial Investigation. The Pump Station Area consists of several buildings that house the pumps used to dewater the BRAC Property, including Building 35/39 and Building 41 Areas.

TABLE 4-3
Comparison of Detected Concentrations at Monitoring Well TP-MW-101 *(Concentrations in micrograms per liter)*
Former Sewage Treatment Plant

Parameter	27-Jun-97	23-Oct-98
Benzene	1.8	ND[a]
Toluene	1.1	ND
Xylene (total)	3.3	ND
Unknown hydrocarbon	340	360
Gasoline	180	140
1,4-dichlorobenzene	13	10
Chlorobenzene	15	11
Arsenic – dissolved	28	32
Arsenic – total	31	33
Barium – dissolved	120	84
Barium – total	120	90
Boron – dissolved	290	390
Boron – total	340	390
Chromium – dissolved	5.3	ND
Iron – total	1100	ND
Mercury – dissolved	0.68	ND
Mercury – total	0.72	0.5

[a] Not detected.

During the Environmental Investigation, ESI (1993) collected a groundwater sample from Monitoring Well PS-MW-101 installed to the northeast of Building 35. The groundwater was analyzed it for TRPH, VOCs, SVOCs, and metals. Five metals were detected as shown on Table 4-1. The only organic analyte detected was methyl ethyl ketone, a common laboratory contaminant as shown on Table 4-2. The well was resampled during the USACE supplemental investigation (1994). Methylene chloride, a common laboratory contaminant, was the only organic constituent detected in that investigation (Table 4-2). No metals were analyzed except lead, which was not detected.

During the Remedial Investigation in 1997, IT collected a groundwater sample from Monitoring Well PS-MW-101 and analyzed for TPH measured as gasoline, diesel, motor oil, and JP-4, metals, and VOCs. Only metals were detected in the sample (IT, 1999) as shown on Table 4-1. In general, the metal detections were consistent with background wells.

Four monitoring wells, PSA-MW1 through PSA-MW4, were installed by WCFS (1996) in the vicinity of Building 41. Groundwater samples from the wells were analyzed for TPH measured as gasoline, diesel, motor oil, and JP-4, BTEX, herbicides, pesticides, oil and grease, SVOCs, and metals; only toluene (in one sample at 0.55 μg/L) and 13 metals were detected (Tables 4-1 and 4-2).

In 1998, an additional groundwater sample was collected from Monitoring Well PSA-MW3 located southwest of Building 41. The sample was analyzed for TPH measured as gasoline, diesel, motor oil, and JP-4, pesticides, VOCs, PAHs, and metals. The results indicated the presence of UHE (0.094 mg/L), barium (0.11 mg/L), and boron (2.2 mg/L) (IT, 1999). The organic chemical detections fall below aquatic life protection levels and the inorganic detections are consistent with background wells.

4.6 Revetment Area

Features of groundwater in the revetment area have been evaluated in the Environmental Investigation (ESI, 1993) and for the Additional Environmental Investigation (WCFS, 1996). One well (RV-MW-101) was installed near Revetment 6 (the former engine test pad) in 1990 by an earlier contractor and two monitoring wells were installed by ESI at Revetment 20 (RV MW-103) and Revetment 26 (RV-MW-102). Well RV-MW-102 could not be sampled because recharge was insufficient; however, two rounds of groundwater samples from wells RV-MW-101 and RV-MW-103 were analyzed for TRPH, BTEX, and lead. Detections included five metals, but no organic compounds as shown on Tables 4-1 and 4-2. Metal detections were on par with background wells.

In addition to these Revetment Area wells, four monitoring wells (BP-MW-101 through BP-MW-104) were installed by ESI (1993) around the edge of the Revetment 10, which had previously been used as a firefighter training area. Groundwater samples from the wells were analyzed for VOCs, SVOCs, TRPH (using U.S. Environmental Protection Agency Method 418.1), and lead. Methyl ethyl ketone (a common laboratory contaminant) and lead were the only analytes detected. The lead level was consistent with lead in background wells.

Additional groundwater samples were collected in the Revetment Area as part of the Additional Environmental Investigation conducted in 1996. Eight temporary monitoring wells (RVT-TW1 through RVT-TW8) were installed in direct-push borings placed throughout the

Revetment Area (WCFS, 1996). Groundwater samples were collected from each temporary well and analyzed for TPH (measured as gasoline, diesel, and JP-4), BTEX, and PAHs. Only xylenes were detected at Revetments 9 and 12. Ethylbenzene was detected at Revetment 12.

Woodward-Clyde Federal Services (1996) also installed three monitoring wells (RVT-MW1 through RVT-MW3) around a catch basin next to Revetment 5. The samples were analyzed for TPH (measured as gasoline, diesel, and JP-4), oil and grease, PAHs, VOCs, BTEX, pesticides, herbicides, and metals. Detections included 10 metals as presented on Table 4-1 but no organic constituents were found. All metals were in the range of background wells.

4.7 Onshore Fuel Line

The ONSFL was investigated as part of the Additional Environmental Investigations conducted by WCFS (1996). Three groundwater monitoring wells (JFL-MW1, JFL-MW2, and JFL-MW3) were installed by WCFS near a 90-degree bend in the 54-inch storm drain line that contained the north perimeter fuel line. Groundwater samples collected from these wells were analyzed for BTEX, PAHs, TPH as diesel and JP-4, oil and grease, and lead. All three wells had what were termed false positive detections of unknown hydrocarbons at concentrations of 140, 290, and 620 μg/L. Additionally, common laboratory contaminants benzyl alcohol at a concentration of 27 μg/L and butyl benzyl phthalate at a concentration of 130 μg/L were measured in Monitoring Well JFL-MW1. Several metals were also detected in the three wells, including arsenic, boron, chromium, cobalt, copper, manganese, vanadium, and zinc. Of these only cobalt and zinc were found at concentrations above the surface water criteria. Maximum concentrations detected are shown on Table 4-1.

5.0 Groundwater Assessment

The U.S. Army in consultation with the San Francisco Regional Water Quality Control Board selected six wells on the Hamilton Inboard Area for review of groundwater quality and comparison to selected surface water quality objectives. The wells were selected based on their proximity to areas of potential scour within channels of the future wetland proposed for the Inboard Area of the Hamilton BRAC property. The locations of these channels and scour areas have been determined by mathematical modeling. The intent of the groundwater quality review was to compare groundwater quality to selected surface water quality objectives in areas where groundwater might come in contact with surface water in the development and maturation of the wetland. The surface water quality objectives that were used for comparison include the "4 day average continuous concentration for salt water aquatic life protection in enclosed bays and estuaries" as specified in the California Water Quality Goals document by Jon Marshack of the California Regional Water Quality Control Board and the Regional Monitoring Program values provided by the San Francisco Estuary Institute. The goal of the comparison is to determine whether groundwater is expected to pose a potential risk to aquatic receptors if the groundwater should combine with surface water in the development and maturation of the wetland.

One of the six, selected wells, RV-MW-102, had no data available other than a notation in a report (ESI, July 1993) that the results of a soil sample collected from the well boring was non-detect. It is reasoned that groundwater was not collected from this well due to the lack of a source of contamination in the overlying soil. In a second well, RV-MW-103, only a simple volatile organic compound (VOC) analysis (for benzene, ethyl benzene, toluene, and xylenes (BTEX)) of the water sample was performed. No VOCs were detected. Due to the lack of analyses, these two wells were not included in the groundwater quality review. The data from a cluster of three other wells located in the general vicinity of the two wells were substituted. The water sample data presented in Table 5-1 include the following wells:

- BKG-MW-2, BKG-MW-4, BKG-MW-5
- RV-MW-101
- RVT-MW1, RVT-MW2, RVT-MW3

Review of the data (Table 5-1) indicates that metals were detected at concentrations at, or below the ambient metals concentrations in soil (see the Human Health and Ecological Risk Assessment, U.S. Army 2001). The table indicates although concentrations of copper, lead, nickel, and zinc exceed the values for "4 day average continuous concentration for salt water aquatic life protection in enclosed bays and estuaries", the concentrations detected are consistent with ambient conditions. All reported data for volatile and semi-volatile organic compounds, pesticides, herbicides, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and petroleum hydrocarbons indicate these analytes were not detected. A reasonable conclusion is that since there is no groundwater contamination at the wells reviewed, no groundwater contamination could be contributed if or when surface water contacts groundwater as the wetland develops. Therefore, the groundwater does not pose a threat to surface water or aquatic receptors.